Executive Summary

The City of Waukesha provides water to its customers primarily from deep wells, constructed to depths of 2,100 feet and withdrawing water from 800 to 1,000 feet below ground. The extraction of groundwater from the deep aquifer has decreased the water level 500 to 600 feet in little over a century, and it continues to decrease 5 to 9 feet annually. Existing groundwater levels require that the City use very large well pumps to extract the groundwater. Pumping water from extreme depths is energy-intensive and costly, and increases the carbon footprint of the water utility. Furthermore, as water is pumped from greater and greater depths, the quality of the source water declines. Radium and other dissolved solids are present in increasingly higher concentrations and require removal to meet drinking water standards. The City is under a court order to comply with radium standards by June 30, 2018.

In certain areas of the region, precipitation helps to recharge the deep aquifer, but in the Waukesha area, a hard layer of shale above the aquifer limits groundwater recharge. Also, the water the City uses does not recharge the aquifer. After use and treatment, the water is discharged to the Fox River, ultimately finding its way to the Mississippi River and the Gulf of Mexico. The precious freshwater resource is not returned to its source—the Great Lakes and Mississippi River groundwatersheds. It is sent to the ocean.

The City obtains less than 13 percent of its water supply from shallow wells in the Troy Bedrock Valley aquifer. Increased pumping of the shallow aquifer has adverse environmental impacts on surface water resources, including reduced baseflows (groundwater contributions) to local streams and wetlands. The City's vision for the future is to provide and use efficiently an adequate supply of healthful water to its citizens for the long term (50 to 100 years), without overburdening the region's water resources.

In 2006, the City implemented a Water Conservation and Protection Plan that has accomplished significant water savings through water sprinkling restrictions, conservation water rates, plumbing fixture replacement, public education, regional water conservation collaboration, and strategic alliances with national water conservation agencies. Total water use by City customers has dropped 31 percent from 1988 to 2008, despite an 18 percent population increase.[1] Some of the decline in water use is attributed to industry leaving the area and the recent economic recession, but some can be attributed to the City's water conservation and protection plan. However, while the City's water conservation efforts have been and will continue to be successful, water conservation measures alone cannot offset the projected need for an alternative water supply.[2] Conservation of existing groundwater supplies cannot avoid the need for a Lake Michigan supply.

Continued and increased withdrawal from the deep and shallow groundwaters to meet present and future demands, at the cost of adverse environmental impact to water resources and ecosystems, is not a sustainable solution, nor the best way to protect public health. The City of Waukesha needs a new long-term water supply. Based on extensive water supply planning, the City of Waukesha is submitting a proposal to withdraw up to an annual average of 10.9 million gallons per day from Lake Michigan. The proposed amount will serve the public water system needs of the City of Waukesha for the ultimate water supply service area population of 97,400, projected to be reached sometime after 2035.

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[1] Waukesha Water Utility operating data, 1988 through 2008.

[2] AECOM. 2009. *Summary of Water Requirements, Waukesha, Wisconsin, Final Draft Technical Memorandum.*

The City and the Southeastern Wisconsin Regional Planning Commission evaluated numerous water supply alternatives, such as increased withdrawal from the shallow aquifer, local river supplies, local lake supplies, continued use of the deep and shallow aquifers, and wastewater reuse. This application presents a review of the water supply alternatives that have been studied for many years. The four most feasible alternatives are presented in detail:

- Continued use of the deep and shallow aquifer
- Use of shallow aquifer resources alone
- Use of Lake Michigan water and the shallow aquifer, with return flow to Lake Michigan
- Use of Lake Michigan water, and return of flow to Lake Michigan

The most feasible alternatives have been developed and compared with four evaluation criteria consistent with Wisconsin Department of Natural Resources requirements: environmental impact, long-term sustainability, public health, and implementability. The evaluation is summarized below.

Water Supply Alternatives Evaluation Summary

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementa-bility
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●
Lake Michigan and shallow aquifers	●	◎	⊙	●
Lake Michigan	○	○	⊙	◎

○ No adverse impact
⊙ Minor adverse impact
◎ Moderate adverse impact
● Significant adverse impact

The groundwater in the deep aquifer is severely depleted and does not provide reliable quantity or quality over the long term. The quantity of water in the shallow aquifer is limited, the water is less protected from contamination, and increased withdrawal would have an adverse environmental impact on sensitive streams, brooks, and wetlands. Using a combination of shallow aquifer and Lake Michigan water does not eliminate the adverse environmental impacts of shallow aquifer use, and increases the amount of out-of-basin water returned to the waters of the Lake Michigan basin. Use of Lake Michigan as the City's water supply is fully sustainable with sound management of return flow. It has the least environmental impact and provides the greatest protection of public health. A Lake Michigan water supply also has the lowest cost.

The only reasonable water supply for the City is a Lake Michigan supply with continued water conservation and return flow, in accordance with the requirements of the Compact. This is the only water supply that balances the inherent social, environmental and economic development benefits of a reliable source of drinking water with stewardship of environmental resources for future generations. A Lake Michigan supply for the City is sustainable, protective of public health, and results in more effective management, and improvement, of the waters and water dependent natural resources of the Great Lakes Basin.

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C Waukesha Water Utility: Future Water Supply Study

D Water Supply Service Area Plan for the City of Waukesha

E Waukesha Wastewater Facility Plan Amendment: Return Flow

*F Sanitary Service Area Reports

G Technical Memorandum: Underwood Creek Effluent Return Evaluation, July 23, 2009

H Water Quality Model of Proposed Discharge to Underwood Creek

*I A Regional Water Supply Plan for Southeastern Wisconsin

*J Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds

K Final Draft Technical Memorandum: Summary of Water Requirements

L Return Flow Effects on Habitat in Underwood Creek and Menomonee River

M Cost Estimates Update

N Environmental Report

* Not on the compact disk; available for purchase from the Southeastern Wisconsin Regional Planning Commission.

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SECTION 1
Introduction

This application is prepared and submitted in accordance with the Great Lakes–St. Lawrence River Basin Water Resources Compact (the Compact) and the Wisconsin Compact implementing statute (§ 281.346 and 281.348, Wis. Stats.). Throughout this Application the City has provided in the various Sections, extensive documentation as to why its proposal is consistent with the Compact, satisfies all of the required conditions for the diversion, as well as meets or exceeds the standard of review. The Application provides historic evidence, future water resources planning, and scientific data that support the conclusion that a Lake Michigan water supply with return flow is the only reasonable and environmentally beneficial water supply for the City of Waukesha. A Lake Michigan supply would end the City's use of the deep St. Peter sandstone aquifer and provide environmental benefits to groundwaters and surface waters throughout the region while meeting the reasonable needs and protecting the public health of water utility customers.

The appendixes contain technical references in support of this application.

Eligibility to Apply

A proposal by a community within a straddling county to divert Great Lakes water is excepted from the prohibition against diversions, provided that the proposal satisfies all of the requirements of the Compact and Wis. Stat. § 281.346(4). Reference: Compact Article 4, Section 4.9.3; Wis. Stat. § 281.346(4).

A community within a straddling county is defined as "any city, village or town that is not a straddling community and that is located outside the Great Lakes basin but wholly within a county that lies partly within the Great Lakes basin." Wis. Stat. § 281.346(1)(d); See also Compact Article 1.

City of Waukesha Background

The City of Waukesha is a historic community in southeastern Wisconsin, 18 miles west of Lake Michigan. Redevelopment has been central to the City's strategic plan for the community. For example, extensive revitalization of Waukesha's historic downtown has created a thriving commercial and arts district. Investments made in the downtown area have spurred the development of community resources, including local small businesses, galleries, and museums. The City looks forward to a future with well-managed growth that involves continued urban redevelopment; increased use of green infrastructure in the community; and effective management of water resources to sustain water and the natural environment for future generations.

EXHIBIT 1-1
Wisconsin Counties Within Great Lakes Basin



The City of Waukesha is located in the Mississippi River Basin. It is outside the Great Lakes Basin but wholly within a county that lies partly within the Great Lakes Basin (see Exhibit 1-1). It is 1.5 miles west of the Great Lakes watershed surface water

divide but 17.4 miles east of the Great Lakes groundwater divide, well within the Great Lakes groundwatershed. The City of Waukesha is eligible for a Lake Michigan diversion if the conditions of the Compact are met, including:

- The diverted water would be used solely for the City's public water supply because the City is without adequate supplies of potable water.
- The portion of diverted water that is returned to the Waters of Basin is maximized, and the portion of the returned water that is from the Mississippi River Basin is minimized.
- The City demonstrates it does not have a reasonable water supply alternative within the Mississippi River Basin, including conservation of existing groundwater supplies.
- The diversion with return flow does not endanger the integrity of the Basin ecosystem.
- The proposed diversion with return flow is reviewed and approved by the Council of Great Lakes Governors.

Waukesha is the first community within a county that straddles the surface water divide to apply for a Great Lakes diversion for a public water supply under the terms in the Compact. Waukesha's application follows the New Berlin, Wisconsin application, which was approved under the straddling community provision of the Compact and Wis. Stat. §281.346 and §281.348.

A proposal for a diversion may be made only by an entity operating a public water supply system that would receive water from the diversion. Reference: Wis. Stat. § 281.346(4)(b)2.

The applicant for the diversion is the City of Waukesha. The City operates a public water supply system through its water utility. The Waukesha Water Utility is a public water supplier governed by Chapter 196, Wisconsin Statutes. The water utility is regulated by the WDNR and the Wisconsin Public Service Commission.

Need for a New Water Supply

The City obtains more than 87 percent of its water supply from the deep St. Peter Sandstone Aquifer. Near and beyond the City of Waukesha, the aquifer is confined by a geological feature—the Maquoketa shale layer—that limits natural recharge of the aquifer. Continued use of the aquifer by the City and by numerous other communities in Wisconsin and Illinois since the 19th century, combined with the limited recharge, has contributed to the 500- to 600-foot decline in aquifer water levels.[1] Water levels continue to drop 5 to 9 feet per year.[2] Reduced groundwater levels in southeastern Wisconsin have in turn affected regional surface waters, which now receive about 18 percent[3] less groundwater contribution as water is drawn toward the deep aquifer wells. As the aquifer level drops, water quality degrades and concentrations of radionuclides and salts increase. Radionuclides (radium-226, radium-228, and gross alpha) are naturally occurring elements that pose increased risk of cancer. To provide safe drinking water, the City treats some deep aquifer water to remove radium and blends some untreated deep aquifer water with radium-compliant water from the shallow aquifer. Increasing concentrations of total dissolved solids (TDS), also referred to as salts, is another serious water quality concern with the current deep aquifer supply. Excessive levels of TDS have prompted the City to partially plug certain screen areas of some deep aquifer wells.

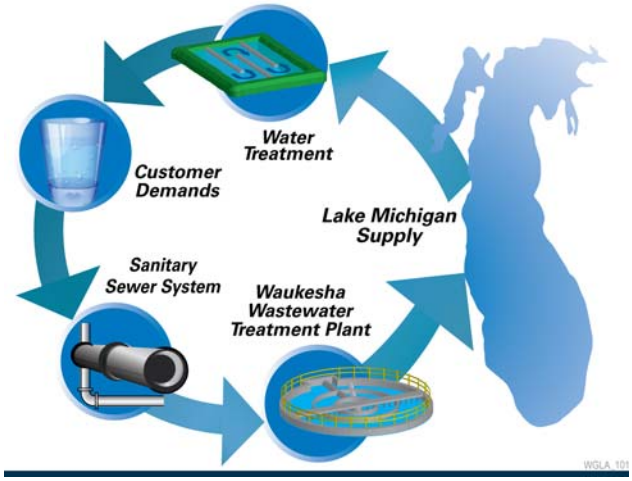
[1] SEWRPC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, pp.102–103.

[2] Waukesha Water Utility operating data 2009.

[3] USGS and WGNHS, *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*, March, 2007

The City obtains less than 13 percent of its water supply from the shallow aquifer. Pumping the shallow aquifer withdraws groundwater baseflows that would otherwise naturally feed local streams and wetlands.[4] Increasing withdrawal from the Troy Bedrock Valley shallow aquifer to meet the City's needs was simulated with groundwater modeling. Even with wells spaced so as to minimize drawdown impacts on sensitive environmental resources, shallow aquifer drawdown is estimated to be between 50 and 100 feet with baseflow reductions to wetlands and brooks, between 50 and 340 percent.[5] Additional pumping of the shallow aquifer to provide long-term water supply for the City would dramatically reduce or eliminate groundwater flows to surface waters and water dependent sources. Drawdown also reduces the ability of water for private wells and might draw contaminants from private septic tems into the public water supply.

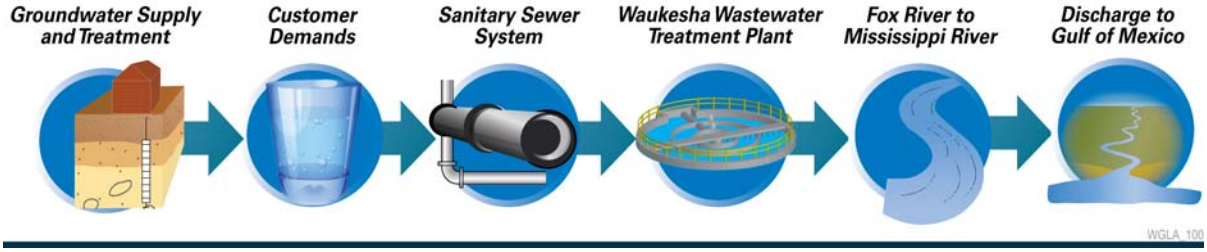
EXHIBIT 1-2
Proposed Supply, Treatment, and Discharge System



Physical evidence, scientific research, groundwater modeling, and land use planning form the basis of a comprehensive regional water supply plan that concluded that the City of Waukesha is without an adequate supply of potable water and that no water supply alternative is as sustainable and protective of public health and natural water resources as a Great Lakes water supply.

A Great Lakes supply that recycles fresh water is sustainable (Exhibit 1-2), compared to the City's current water management strategy in which fresh water is withdrawn from local aquifers in excess of natural recharge, used, treated, and ultimately discharged the Gulf of Mexico (Exhibit 1-3).

EXHIBIT 1-3
Existing Waukesha Water System Overview



The City seeks to divert 10.9 million gallons per day (mgd) from Lake Michigan and to return the flow to meet the average day demand of the City's projected water supply service area at build-out. The City's planned Water Service Area was delineated by the regional planning authority, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in accordance with Chapter NR 121, Wisconsin Administrative Code.

[4] SEWPRC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, pp. 8–14.

[5] RJN Environmental Services, LLC. March 2010. *Results of Groundwater Modeling Study Shallow Aquifer Groundwater Source—Fox River & Vernon Marsh Area, Waukesha Water Utility.*

Long-term water supply planning studies were conducted for both the City and the region to evaluate the water supply alternatives. These studies addressed the continued use of the deep and shallow aquifer, the increased withdrawal from the shallow aquifer, local river supplies, lake supplies and wastewater reuse.

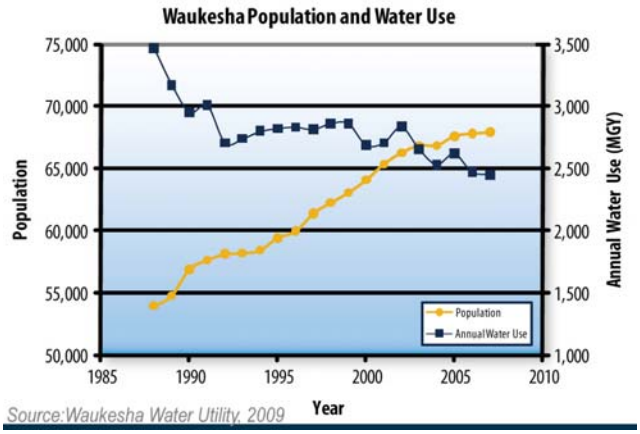
A Lake Michigan potable water supply has fewer adverse environmental impacts and is more sustainable and protective of the public health than any of the alternatives considered. A Lake Michigan water supply would do the following:

- It manages water resources so they are available for future generations.
- It contributes to the recovery of groundwater and surface waters, including waters of the Great Lakes Basin.
- It ensures a long-term adequate supply of potable water.
- It provides environmental benefits to the Great Lakes ecosystem by increasing flows in Underwood Creek, to restore aquatic and wildlife habitat in the watercourse that returns flow to Lake Michigan.
- It reduces energy usage and greenhouse gas emissions associated with the water supply.
- It eliminates the amount of salt, used to soften hard groundwater, that is released to the environment.
- It reduces the release of radium to the environment.

Water Conservation Leadership

In 2006, the City launched an aggressive water conservation plan. Over the past 3 years, the City accomplished reductions in water used through a ban on daytime water sprinkling, rate structures that promote water conservation, a high efficiency toilet rebate program, and educational outreach. The success of the water conservation measures has helped the City to reliably provide radium-compliant drinking water on an interim basis. Water conservation contributes to the City's water use trend, summarized in Exhibit 1-4. Between 1988 and 2008, water use decreased 31 percent, despite a corresponding 26 percent increase in population during the same period. Other leading factors in Waukesha's reduced water use is loss of local industry and decline in new development in a weak economy. Water conservation is only a partial solution to the City's water supply needs. Alone, water conservation cannot save enough water to offset the projected future water demand.

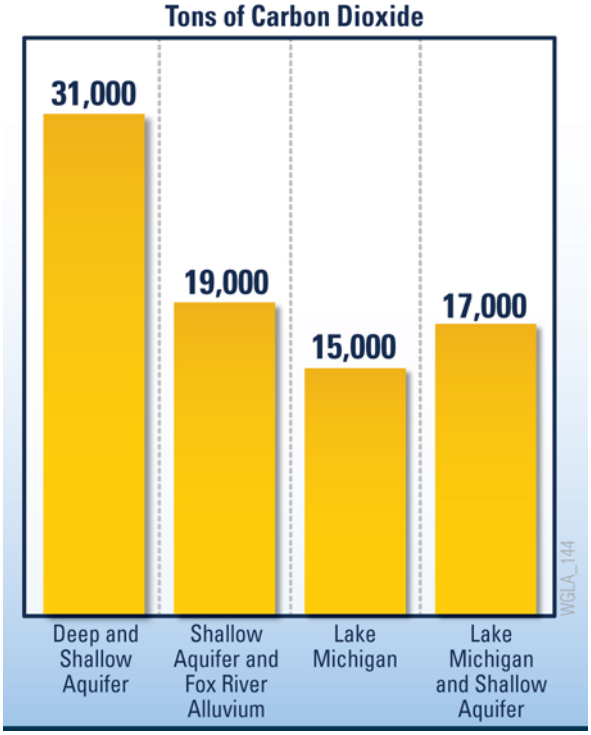
EXHIBIT 1-4
Waukesha Population and Water Use



Regional Benefits

The regional environmental benefits of ceasing deep aquifer pumping for the City's water supply, and instead using Lake Michigan water with return flow, include deep aquifer recovery and increase of groundwater flows to surface water resources in both the Great Lakes Basin and the Mississippi River Basin. The proposed return flow strategy would provide flow beneficial to habitat restoration in Underwood Creek and the Menomonee River, which supports the environmental goals for the watercourses, particularly during dry periods. Use of Lake Michigan water also reduces the need to soften groundwater to remove natural hardness. Salts used in water softening pass through conventional wastewater treatment processes and are discharged to the environment. Customers of the Waukesha Water Utility currently use nearly 5,000 tons of salt annually to soften groundwater.[6] Another significant regional environmental benefit of using Lake Michigan water is reduced energy consumption. Energy use and greenhouse gas emissions are less with a Great Lakes water supply than they are for withdrawing and treating groundwater supplies (Exhibit 1-5).

EXHIBIT 1-5
Annual Greenhouse Gas Emissions



[6] CH2M HILL and Ruekert-Mielke. 2002. *Future Water Supply Report,* p. 6-3.

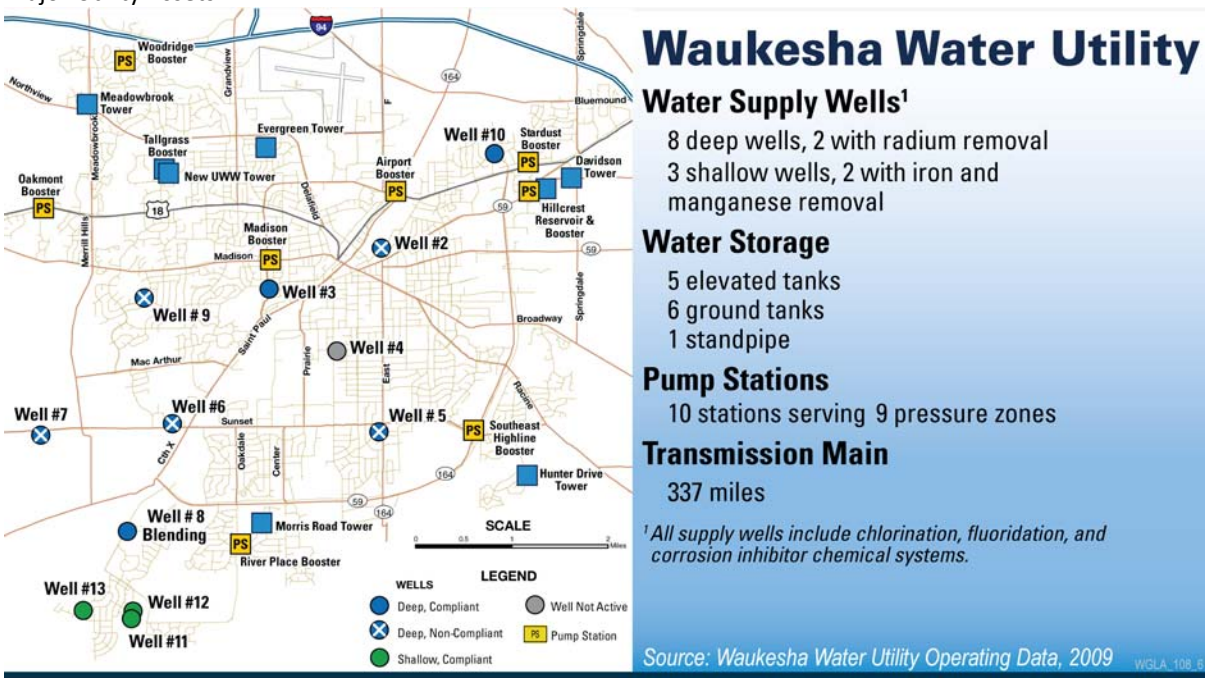
City of Waukesha Water System

Diverted water will be used solely for public water supply purposes by a community within a straddling county. Reference: Compact Article 4, Section 4.9.3.a.; Wis. Stat. § 281.346(4)(e)1.

"Public water supply" means "water distributed to the public through a physically connected system of treatment, storage, and distribution facilities that serve a group of largely residential customers and that may also serve industrial, commercial and other institutional customers." Reference: Wis. Stat. § 281.346(1)(pm).

The City of Waukesha water system comprises groundwater supply, treatment, storage, and conveyance assets (Exhibit 2-1). The City's system is a "public water supply"—a means of distributing water to the public through a physically connected system of supply, treatment, storage, and distribution facilities that serve a group of largely residential customers, and that also serves industrial, commercial and public customers. The City also maintains a water utility administration building with offices for customer service, billing, supervisory control and data acquisition system control, meter testing, fleet storage, and equipment storage. Appendix D, Water Supply Service Area Plan, contains additional water infrastructure information. The diverted water will be used solely for public water supply purposes by the City of Waukesha.

EXHIBIT 2-1
Major Utility Assets



Water Supply Service Area

For the purposes of applying the application requirements, the Wisconsin Department of Natural Resources shall use, as appropriate, the current or planned service area of the public water supply system receiving water under this proposal. The planned service area is the service area of the sys-

tem at the end of any planning period authorized by the Wisconsin Department of Natural Resources in the approved water supply service area plan that covers the public water supply system. Reference: Wis. Stat. § 281.346(4)(bg)2.

To prepare a long-term water supply plan, the City studied historic water utility performance, investigated regional water quality and quantity data, undertook aggressive water conservation practices, and developed water supply projections to meet the estimated needs of its water vice area. The City of Waukesha's public water supply system service area was delineated by SEWRPC pursuant to its authority under Chapter NR121 Wis. Admin. Code. Exhibit 2-2 shows the planned water service area. Eighty-five percent of the planned water service area is already developed or designated as natural and environmentally sensitive areas to be preserved in a manner consistent with the regional land use plan.[1] Fifteen percent of the planned water vice area would be available for future development.

Although there are minor differences between the City of Waukesha water and wastewater service areas, SEWRPC considers the two areas to be essentially the same.[2] The minor differences are quantified in Appendix E, Waukesha Wastewater Facility Plan Amendment, Return Flow.

Water Service Area Population Projections and Water Demand Forecasts

An approved diversion shall be limited to quantities that are reasonable for the purposes for which it is proposed. Reference: Compact Article 4, Section 4.9.4.b. Wis. Stat. §§ 281.346(4)(f)2.

The Wisconsin Department of Natural Resources shall specify a diversion amount equal to the quantity of water that is reasonable for the purposes for which the diversion is proposed when granting an approval for a diversion. Reference: Wis. Stat. § 281.346(4)(i).

As part of its regional water supply plan, SEWRPC prepared population projections for the City of Waukesha water supply service area.[3, 4] To account for economic uncertainty, SEWRPC prepared regional population projections assuming low, intermediate, and high growth scenarios. SEWRPC estimated a Waukesha water supply service area population of 88,500 in 2035 under an intermediate growth scenario. This is equivalent to less than 1 percent annual increase in population.

The estimated "ultimate population" for the water supply service area is 97,400. The ultimate population projection represents a condition beyond the SEWRPC 2035 planning horizon. It occurs when all land available for development has been developed in a manner consistent with the regional land use plan. For water supply planning purposes, the City assumed the ultimate population will be reached in 2050. Exhibit 2-3 shows the population projections. The interpolated projections for the 20-year planning period (2010–2030) required under the state's new water supply plan statute (§ 281.348(3) Wis. Stats.) are also depicted.

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1 SEWRPC. 2008. Preliminary Draft, *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Chapter I, p. 5-6.

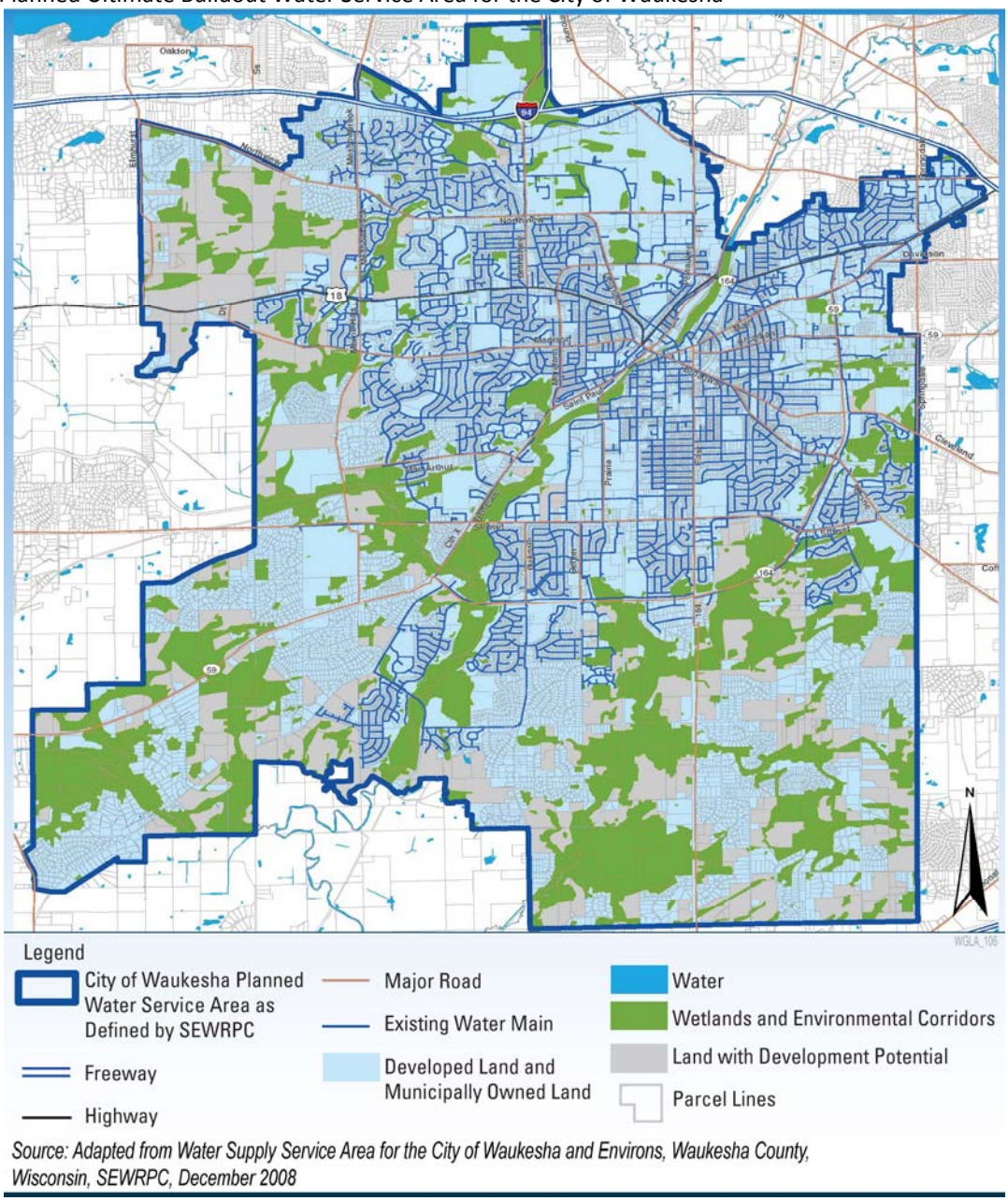
2 SEWRPC/Philip Evenson, Executive Director. December 23, 2008. Letter to Waukesha Water Utility/Daniel S. Duchniak, P.E., General Manager. Attachment, p. 1.

3 Ibid. Chapter IV, p. 52.

4 SEWRPC/Executive Director Kenneth R. Yunker, P.E. March 17, 2009. Letter to Steven Crandall Community Development Director, City of Waukesha.

EXHIBIT 2-2

Planned Ultimate Buildout Water Service Area for the City of Waukesha



Source: Adapted from Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin, SEWRPC, December 2008

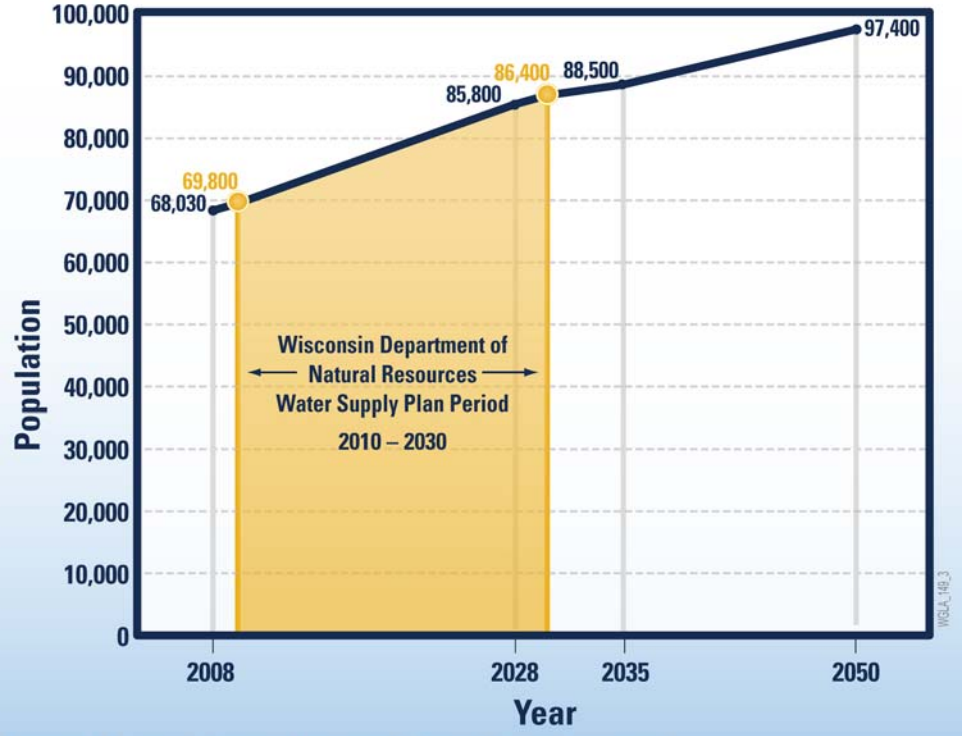
SEWRPC prepared future water demand forecasts based on intermediate population projections. The demand forecasts considered water service area demographics, land use plans, and water use data from 2000, 2004, and 2005.[5] For the SEWRPC planning period ending in 2035, water demand forecasts were prepared using multiple factors including implementation of water conservation practices. Water conservation measures were estimated to result in 4 to 10 percent average day demand water savings, depending on the type of water supply.[6] For the Waukesha water service area, a 10 percent average day demand reduction was factored into the water de-

[5] Preliminary Draft, *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, 2008, Chapter IV, p.7.

[6] Ibid., Chapter IV, p. 39.

mand forecasts. The reduction accomplished through conservation represents an increase over and above the current levels of water conservation. Exhibit 2-4 summarizes the SEWRPC 2035 water demand forecasts.

EXHIBIT 2-3
City of Waukesha Water Supply Service Area Population Projections



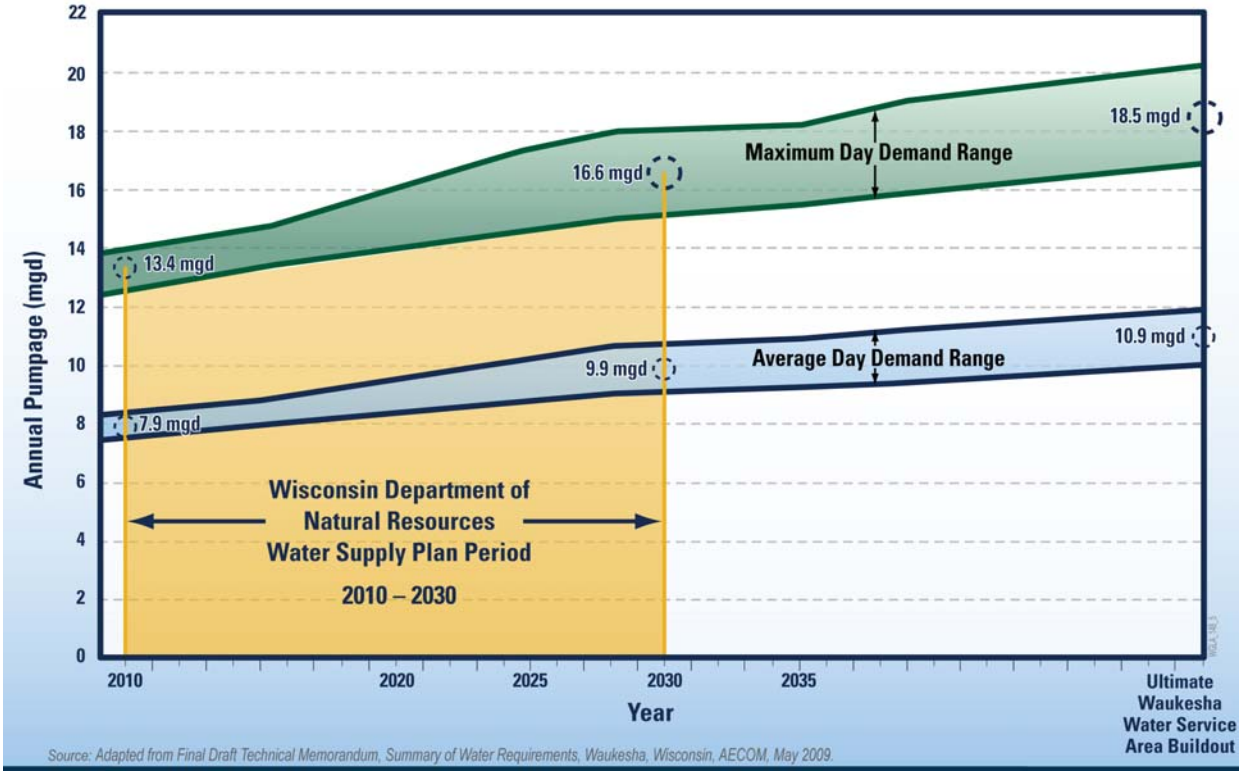
Adapted from Final Draft Technical Memorandum, Summary of Water Requirements, Waukesha, Wisconsin, AECOM, May 2009.

EXHIBIT 2-4
2035 Water Demand Forecasts

Water Use	Value
2035 Average Daily Pumpage Including 5 percent allowance for fire fighting flow and unaccounted for water and 10 percent additional water conservation	9.8 mgd
2035 Average Daily Demand Including 10 percent additional water conservation	9.3 mgd
2035 Average Daily Demand Without water conservation	10.2 mgd
2035 Maximum Day Demand Based on 1.37 peaking factor and including 10 percent additional water conservation	13.7 mgd
2035 Per Capita Water Use Based on 2035 Population of 88,500	111 gallons/capita/day

Preliminary draft *Planning Report on Regional Water Supply Plant for Southeastern Wisconsin*, Chapter IV, pp. 52, 53, 72.

EXHIBIT 2-5
City of Waukesha Water Supply Service Area Demand Projections



The City used the SEWRPC projections, 38 years of Waukesha water system operating data, the water service area plan, and the City's water conservation and protection plan to further refine water demand forecasts for the ultimate water service area population of 97,400. Ranges of average- and maximum-day demands, developed by considering greater variability in population and water conservation effectiveness, were prepared (Exhibit 2-5). The interpolated demand forecasts for the 20-year planning period (2010–2030) required under the state's new water supply plan statute (§ 281.348(3) Wis. Stats.) are also depicted.

Two water demand factors vary between the SEWRPC and City forecasts. First, the City's amount of unaccounted-for water and fire fighting flow historically equals 4 to 7 percent of total water pumpage. For long-range planning, the City used a realistic, but conservative value of 7 percent, in lieu of the 5 percent value used in the SEWRPC plan on the basis of Waukesha's performance in 2000, 2004, and 2005 only.

Second, the City used a more conservative peaking factor to estimate maximum day demand. A peaking factor a 1.68 was used after consideration of several decades of Waukesha system performance and the inherent uncertainty of very long-range water supply plans that need to address potential impacts of climate change, including drought. The peaking factor of 1.37 used in the SEWRPC plan was based on peak flows in 2000, 2004, and 2005 only. The demand values shown are tabulated in Exhibit 2-6.

The amount of the requested diversion is based upon the proposed quantity of water needed to supply the projected City of Waukesha water service area population as delineated by SEWRPC. Under Chapter NR 121, Wis. Admin. Code, SEWRPC is the area-wide water quality planning agency designated by the State to delineate proposed water supply services for all public water

EXHIBIT 2-6
Ultimate Water Service Supply Area Water Demand Forecasts

Water Use	Value
Ultimate Average Daily Including 7 percent allowance for firefighting flow and unaccounted for water and continued water conservation	10.9 mgd
Ultimate Average Daily Demand Without water conservation	12.0 mgd
Ultimate Maximum Day Demand Based on 1.68 peaking factor and including continued water conservation	18.5 mgd
Ultimate Per Capita Water Use Based on Ultimate Population of 97,400	112 gallons/capita/day

Final Draft Technical Memorandum, Summary of Water Requirements, Waukesha, Wisconsin, AECOM, May 2009.

supply systems in the southeastern Wisconsin planning area. The delineated water supply service area for the City of Waukesha (See Exhibit 2-2) is consistent with the SEWRPC 2008 regional water supply study.

For the projected buildout of the City of Waukesha water service area (beyond 2035), as delineated by SEWRPC, the annual average day capacity of the proposed supply is 10,900,000 gallons per day; the water supply infrastructure will be sized to supply a proposed maximum day demand of 18,500,000 gallons per day.[7] For the WDNR 20-year planning period (2010–2030) for the City of Waukesha water service area, the maximum day capacity of the proposed supply is 9,900,000 gallons per day and the proposed maximum day demand is 16,600,000 gallons per day. See Section 2: Water Supply Service Area Population Projections and Water Demand Forecasts.[8]

Combined Lake Michigan and Groundwater Supply

To limit the Great Lakes diversion to the smallest reasonable quantity, a combination of Lake Michigan water and shallow aquifer water was evaluated by the City.

Under the shallow aquifer/Lake Michigan supply alternative, also discussed in Section 4, return flow to the Great Lakes Basin would consist of both Lake Michigan water and Mississippi River Basin groundwater. This alternative does not meet the intent of the Compact to protect the Basin ecosystem by minimizing the return of water from outside the Great Lakes Basin.

An alternative with deep aquifer water and Lake Michigan water was not developed or analyzed. The primary reasons for not evaluating this combination of supplies are the operating challenge of continuously meeting regulatory standards with source waters of widely varied water quality and meeting distribution system pressure requirements with distributed ground water supplies and a central Lake Michigan supply. Also, this combination was not developed because Illinois and Wisconsin are supportive of the goal of eliminating the use of the deep St. Peter Sandstone aquifer. See also *State of Wisconsin, et al v. State of Illinois, et al, 449 U.S. 48, 101 S.Ct. 557, 66 L.Ed.2d 253*.

Based on extensive water supply planning, the City of Waukesha is submitting a proposal to withdraw up to an average of 10.9 mgd from Lake Michigan. The proposed amount will serve

[7] AECOM. 2009. *Summary of Water Requirements, City of Waukesha, Wisconsin Technical Memorandum.*
[8] Ibid.

the public water system needs of the City of Waukesha for the ultimate water supply service area population of 97,400, projected to be reached sometime after 2035.

Waukesha Water Conservation and Efficiency

The need for the proposed diversion cannot be reasonably be avoided through the efficient use and conservation of existing water supplies. Reference: Compact Article 4, Section 4.9.4.a.; Wis. Stat. §§ 281.346(4)(f)1. and 281.346(4)(g).

Conservation of existing water supplies cannot avoid the need for a Lake Michigan supply. In 2006, the City implemented a Water Conservation and Protection Plan that has accomplished significant water savings through water sprinkling restrictions, conservation water rates, plumbing fixture replacement, public education, regional water conservation collaboration, and strategic alliances with national water conservation agencies. Total water use by City customers has dropped 31 percent from 1988 to 2008, despite an 26 percent population increase.[9] Some of the decline in water use is attributed to industry leaving the area and the recent economic recession, but some of the decline can be attributed to the City's water conservation and protection plan. However, while the City's water conservation efforts have been and will continue to be successful, water conservation measures alone cannot offset the projected need for an alternative water supply.[10] See Exhibit 2-5.

Accounting for Water

Measuring all water used is essential to ensuring wise water use. The City of Waukesha meters all water customers and monitors water use with accurate automatic flow meters that can be read remotely. The City describes water use on customer bills in terms of gallons rather than cubic feet. This small detail helps customers understand how water use relates to behavior. Also, with automatic meters, City staff routinely monitor meter records. If a dramatic change in water use is observed, the City contacts a customer to promptly address potential water waste issues.

All water utilities, including the Waukesha Water Utility have unavoidable water loss. This water loss, called unaccounted-for water, is used for fighting fires and flushing mains, or is lost through leaks in water pipes. To minimize unaccounted-for water, the City monitors the system for leaks and estimates water used for routine system flushing. Historically, the City averages 4 to 7 percent unaccounted-for water,[11] which is below the American Water Works Association-recommended benchmark of 10 percent.[12]

The proposed Great Lakes withdrawal will be planned in a way that provides for the efficient use of the water and will avoid and minimize the waste of water.

Water Conservation Measures

The proposal will be implemented so as to incorporate environmentally sound and economically feasible water conservation measures to minimize water withdrawals and consumptive use. Reference: Compact Article 4, Section 4.9.4.e.; see also Wis. Stat. § 281.346(4)(f)6.

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9 Waukesha Water Utility operating data, 1988 through 2008.

10 AECOM. 2009. *Summary of Water Requirements, Waukesha, Wisconsin, Final Draft Technical Memorandum.*

11 Waukesha Water Utility annual operating data submitted to Wisconsin Public Service Commission.

12 AWWA Leak Detection and Accountability Committee. 1991.

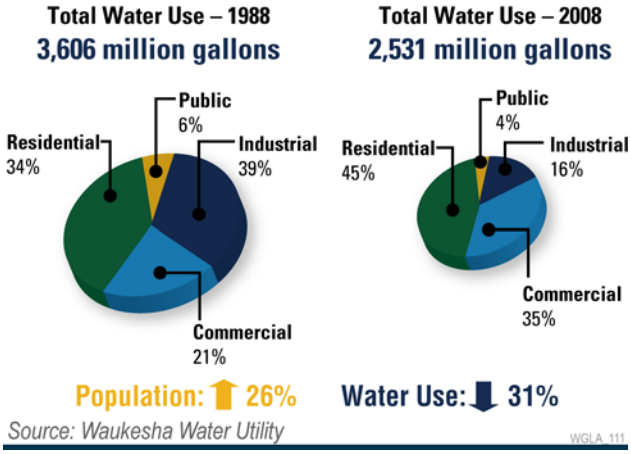
"Environmentally sound and economically feasible water conservation measures" is defined as "those measures, methods, or technologies for efficient water use and for reducing water loss and waste or for reducing the amount of a withdrawal, consumptive use, or diversion that are, taking into account environmental impact, the age and nature of equipment and facilities involved, the processes employed, the energy impacts, and other appropriate factors, all of the following: 1. Environmentally sound. 2. Reflective of best practices applicable to the water use section. 3. Technically feasible and available. 4. Economically feasible and cost-effective based on an analysis that considers direct and avoided economic and environmental costs." Wis. Stat. § 281.346(1)(i); See also Compact Article 1.

An applicant shall document the water conservation planning and analysis used to identify the water conservation and efficiency measures that the applicant determined were feasible. Reference: Wis. Stat. § 281.346(4)(g).

The City has implemented and will continue to set forth environmentally sound and economically feasible water conservation measures.

Total water use by City customers has dropped 31 percent from 1988 to 2008, despite a 26 percent population increase (Exhibit 2-7). Some of this decline in water use is attributed to industry leaving the area and the recent economic recession, but some can be attributed to the City's water conservation and protection plan. In 2006, the City implemented a comprehensive water conservation plan that successfully reduced water use. Water conservation efforts will be continued and monitored to determine which measures are the most effective. Exhibit 2-8 presents highlights of the City's plan for continued investment in water conservation.

EXHIBIT 2-7
City of Waukesha Population and Water Use 1988–2008



Outdoor Sprinkling Restrictions

The first conservation initiative implemented in 2006 was adoption of a sprinkling ordinance that affected all customer classes. The ordinance was targeted at reducing peak demand and reducing overall average day demand with a ban daytime sprinkling and restricted evening sprinkling.

Water bill inserts, refrigerator magnets, and press releases were used to educate the public regarding the ordinance. In 2007, street signs with sprinkler ordinance information were installed. These actions were successful in reducing the average and maximum day water demand. Comparisons show a 15 percent reduction in summer watering season water use from 2005 to 2008 (Exhibit 2-9). The baseline year of 2005 was chosen because it is the year before implementation of the conservation plan.

EXHIBIT 2-8

City of Waukesha Water Conservation and Protection Plan Goals

Relative Water Savings Benefit Scale: = Minimal = Moderate = Major

Short-term Goals

Provide Public Education on Web Site – Teach the public why they should conserve water and how they can help, mentioning the resulting time and cost savings. Provide information on rain gardens and rain barrels.	
Continue Student Water Education – Teach Waukesha students about the water level in the aquifer, the importance of conservation, and practices their families can implement.	
Develop Outdoor Water Use Ordinance – Create and implement an ordinance that sets limits on sprinkling times to reduce peak water use and costs for customers.	
Communicate Monetary Benefits of Water Conservation – Place water conservation cost savings information in customer bills.	
Accelerate Water Main and Lateral Replacement – Continue to replace outdated mains and service laterals, helping to ensure a reduction in leaks.	
Promote Water Conservation – Create brochures, magnets, signage, and a public service announcement; attend events to promote conservation.	
Implement Conservation Water Rates – Develop with the Public Service Commission a water pricing structure that encourages conservation.	
Loop Water Mains – Have contractors loop the water mains to reduce hydrant flushing water requirements.	
Organize Regional Stakeholder Groups – Create stakeholder groups to promote regional water conservation through residential contests, commercial and industrial customer groups, regional water utility collaboration, and educational events for conservation.	
Recycle Filtered Backwash Water – Implement a recycling process for Wells 8, 11, and 12.	
Audit Water Use in City Buildings – Starting with City Hall, audit all city buildings to identify ways to reduce water use.	
Develop Incentives/Rebates Programs – Continue to work with the Public Service Commission to determine the feasibility and potential success of rebate programs.	
Implement Rain Barrel Program – Work with the Coalition to provide rain barrels for landscaping maintenance water supply.	
Become a Member of WaterSense – Gain current information on tested products to meet performance standards of plumbing fixtures for our rebate programs.	
Join Alliance for Water Efficiency – Acquire and implement best management practices for water conservation.	
Initiate Restaurant Table Tents and Other Water-saving Ideas – Work with the Coalition and Wisconsin Conference for Restaurants to develop "table tents" that explain water conservation at restaurants.	

Mid-term Goals

Continue Student Water Education Programs – Update curriculum.	
Continue Public Outreach Program – Provide press releases, and update brochures and materials. Update Utility Web site.	
Maintain Water System Leak Detection Program – Update Utility leak detection to identify priority areas in the system to reduce large leaks and reduce unaccounted-for flow.	
Implement City Water Audit – Install water-saving fixtures throughout Utility facilities.	
Evaluate Indoor Incentives/Rebates Programs – Evaluate rebate programs for targeted water-using appliances and fixtures.	
Evaluate Outdoor Incentives/Rebates Programs – Evaluate rebates for outdoor water use equipment (timers, sprayers).	
Evaluate Residential Audit Feasibility – Determine the feasibility of coordinating a residential water audit program with a water meter change-out program that would link to an incentive/rebate program.	
Review Water Use Restriction Ordinances – Review plumbing requirements in ordinances for new construction, remodeling, and retrofits, and study potential for requiring plumbing updates at time of property sale.	
Enhance Outreach to Commercial Sector – Provide commercial businesses (i.e., car washes, laundromats, hair salons) and retailers with information for customers about the benefits of updating indoor fixtures and outdoor watering devices.	
Reduce City Departments and Schools Outdoor Water Use – Identify opportunities for reduced outdoor sprinkling in parks and school fields.	
Evaluate Sewer Credit Meters – Investigate the phase-out of residential sewer credit meters to further encourage reductions in outdoor water use.	
Pilot Low-impact Development on City Properties – Add green infrastructure, such as rain gardens and permeable pavement, to City properties.	
Work with Housing Authority to Update Public Housing Plumbing – Work with Waukesha Housing Authority to update water fixtures in Waukesha public housing.	
Replace Plumbing Fixtures with Efficient Devices – Work with the Wisconsin Focus on Energy Program to update shower heads at hotels and hand sprayers at restaurants.	
Form Regional Source Water Protection Planning Committee – Work with surrounding utilities to better coordinate source water protection.	
Communicate Monetary Benefits of Water Conservation – Place individual account water use information on the internet and on water bills.	
Fix a Leak Week in March – Get involved with EPA's Fix a Leak Week by including dye tablets and a brochure in all water bills.	

Long-term Goals

Implement Unidirectional Flushing – Update the flushing program to maximize velocities in the main for flushing, thereby reducing the amount of water needed to clean the water mains.	
Implement Smart Growth Land Use Planning and Zoning – Work with other entities (surrounding communities, developers, businesses) to develop Low-impact Development Practices to prevent pollution from entering the Fox River. Consider revision of Comprehensive Plan and zoning ordinances to encourage infiltration of stormwater into the ground.	
Audit Commercial and Industrial Sectors Water Use – Work with commercial and industrial customers to identify areas to reduce water use and save customers' money.	
Evaluate Gray Water Systems – Investigate reuse of the City's wastewater after it is returned to the Lake Michigan watershed. Reuse may involve "gray" water separation or redirection of treated wastewater for regional aquifer recharge.	

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Conservation Water Rates

Waukesha adopted a conservation (inclining) rate structure for residential customers in 2007, becoming the first city in the state to charge customers more per gallon as water use increases. The City recently strengthened and expanded the conservation water rate model to include increasing the cost in each rate tier and reducing the amount of water allowed before reaching the next tier. Exhibit 2-10 summarizes the single-family residential rates before and since water conservation rates were implemented.

The Utility has focused on residential users because they represent the largest customer class with the most significant fluctuations in water use. Water rates for commercial and industrial customers have increased by larger percentages than for residential customers. To date, nonresidential customers have realized major water use reductions through individual conservation efforts and collaboration with City officials. Because 20 percent of the industry and commercial business class uses 80 percent of the water,[13] a few key changes with a small number major water users has resulted in significant water savings.

Water Conservation Education in Public Schools

The hallmark of the City's water conservation public outreach program is its contribution to the environmental education curriculum in the City of Waukesha. Fifth- and ninth-grade students are taught about water conservation by Waukesha Water Utility staff. By visiting water facilities, operating tabletop groundwater models, and collaborating with teachers, the City has introduced water conservation to more than 17,000 students.[14]

EXHIBIT 2-9
Water Reduction Following Water Conservation Measures

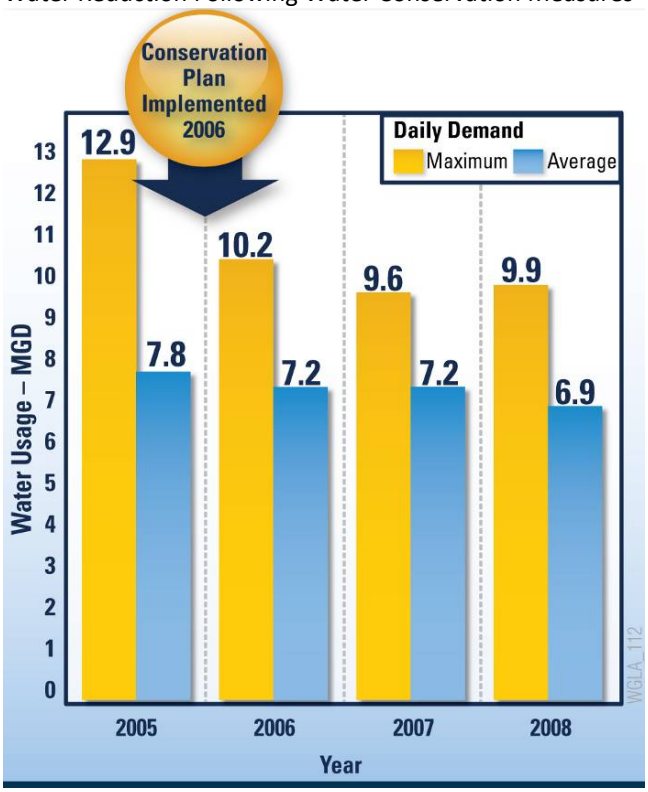


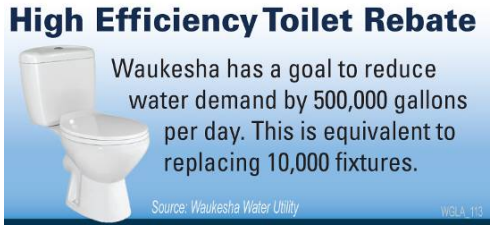
EXHIBIT 2-10
City of Waukesha Water Conservation Rates

Quarterly Use (gal.)	Current Rate ($ / 1,000 gal.)
Tier 1: 0 to 10,000	2.05
Tier 2: 10,001–30,000	2.65
Tier 3: over 30,000	3.40
Quarterly Use (gal.)	**2007 Rate ($ / 1,000 gal.)**
Tier 1: 0 to 30,000	1.95
Tier 2: 30,001–40,000	2.20
Tier 3: over 40,000	2.70
Quarterly Use (gal.)	**Pre-conservation Rate ($ / 1,000 gal.)**
Tier 1: 0 to 40,000	1.69
Tier 2: 75,000–1,425,000	1.14
Tier 3: over 1,425,000	1.02

[13] Waukesha Water Utility annual operating data. 2009.
[14] Waukesha Water Utility. 2009. Annual educational program data.

Toilet Rebate Program

After the City's measurable success with outdoor water use reduction, more attention was focused on indoor water use. Toilets are the largest user of residential water, accounting for 26.7 percent of the water used in an average home.[15] Toilet replacement is one the most effective ways to reduce indoor water use. The toilet rebate program was launched in October 2008, with a goal of saving 500,000 gallons per day by replacing old high-flow toilets with new high-efficiency toilets.



Regional Conservation Coalition

In 2006, leaders from the City of Waukesha and Waukesha County created the Waukesha County Water Conservation Coalition. Water supply is a regional issue and cooperation among the area's water users will improve the results of conservation initiatives. The coalition of business, government, education, and local stakeholder groups, collaborated on countywide messages on water conservation.

Waukesha County Water Conservation Coalition:

- Initiated rain barrel distribution to increase outdoor use of stormwater instead of drinking water
- Created restaurant table tents that say, "Water served upon request. By reducing water waste and washing chemical use, our restaurant is protecting the environment. Thank you for your cooperation and helping us do the right thing."
- Sponsored a residential water conservation contest with prizes going to greatest water use reductions

Active Member of Water Conservation Advocacy Organizations

The Utility is a member of leading national advocacy organizations to promote best water management strategies. Associations with the following key partners have enabled the City to bring innovative water conservation best practices to their customers:

WaterSense, a partnership program sponsored by the U.S. Environmental Protection Agency, makes it easy for all Americans to save water and protect the environment. The Utility is a partner of the program that promotes water efficiency and enhances the market for water-efficient products. The WaterSense label denotes quality, water-efficient products, the same way EnergyStar promotes energy-efficient appliances.

Alliance for Water Efficiency serves as a national voice on water efficiency, and the Utility is a sponsor. Headquartered in Chicago, the Alliance for Water Efficiency promotes the efficient and sustainable use of water.

Continued Water Conservation Practices

Water savings from conservation is an important element in the City's long-range water supply plan. Based on the effectiveness of current water conservation measures and projected water use across various customer classes over the water supply planning period, and beyond, it is estimated that another 10 percent water savings may be gained through conservation, but that additional volume resulting from increased conservation efforts—about 1 mgd—would not be sufficient to offset the need for a new adequate supply of potable water.

[15] Amy Vickers. 2001. *Handbook of Water Use and Conservation*.

Waukesha Water Consumptive Use

"Consumptive use" means a use of water that results in the loss of or failure to return some or all of the water to the basin from which the water is withdrawn because of evaporation, incorporation into products, or other processes. (§ 281.346(1)(e), Wis. Stats.). Public water suppliers can calculate their consumptive use coefficients following the USGS Winter Base-Rate Method.[16] Based on water utility data over the past 10 years, the City of Waukesha annual average consumptive use is 8 percent (Exhibit 2-11). By comparison, the USGS found consumptive use in the Great Lakes can range as high as 74 percent for the domestic and public sector, with an average between 12 to 15 percent.[17, 18]

EXHIBIT 2-11
Waukesha Water Utility Seasonal and Annual Consumptive-Use Coefficients Computed Using the Winter-Base-Rate Method

Year	Spring	Summer	Fall	Annual
1999	8	18	6	9
2000	6	12	2	5
2001	6	22	5	9
2002	6	24	8	10
2003	3	20	7	8
2004	5	16	10	8
2005	5	26	11	12
2006	5	16	3	6
2007	8	19	6	9
2008	5	14	3	6
2009	4	14	3	5
25th percentile	5	15	3	6
Median	6	17	6	8
75th percentile	6	21	7	9
Average (1999–2009)	6	18	6	8

Note: The consumptive-use coefficient is a percentage, rounded to the whole number.

[16] USGS, Kimberly H. Shaffer. 2009. Scientific Investigations Report: 2009-5096.

[17] USGS. 2008. Consumptive Water Use in the Great Lakes Basin. Fact Sheet 2008-3032, page 3.

[18] USGS. 2007. *Consumptive Water Use Coefficients for the Great Lakes Basin and Climatically Similar Areas.* Scientific Investigations Report 2007-5197, page 25.

Existing Water Supply Sources

The City of Waukesha's current source of water supply is groundwater. The City of Waukesha has 11 functional wells, 8 in the deep aquifer and 3 in the shallow aquifer (Exhibit 3-1). Approximately 87 percent of Waukesha's supply is from the deep St. Peter Sandstone aquifer, which has severely declining water levels and significant water quality issues. About 13 percent of Waukesha's supply is from the shallow Troy Bedrock Valley aquifer, which feeds sensitive surface water resources and also has water quality issues.

EXHIBIT 3-1
Waukesha Water Utility Supply Wells

Well No.	Well Depth (ft)	Capacity (mgd)
1	Abandoned because of contamination	N/A
2	1,835	1.15
3	1,995	1.40
4	Abandoned because of contamination	N/A
5	2,120	1.44
6	2,075	2.59
7	1,658	1.08
8	2,024	2.16
9	1,730 (backup service only)	1.94
10	2,145	3.74
11	127	0.47
12	149	0.90
13	105	1.01

Waukesha's Water Supply Linkage to the Great Lakes Basin

In determining whether to approve a proposal under this paragraph, the department shall give substantive consideration to whether the applicant provides sufficient scientifically based evidence that the existing water supply is derived from groundwater that is hydrologically interconnected to waters of the Great Lakes basin. The department may not use a lack of hydrological connection to the waters of the Great Lakes basin as a reason to disapprove a proposal. Wis. Stat. 281.346(4)(e)2.

Waukesha's existing groundwater supply is hydrologically interconnected to the waters of the Great Lakes Basin.[1]

The drawdown of the deep sandstone aquifer and continued pumping are also having a measurable impact on the Great Lakes Basin. The U.S. Geological Survey (USGS), the Wisconsin Geological and Natural History Survey (WGNHS), and other leading researchers in Wisconsin and Illinois have conducted extensive modeling and studies of the deep sandstone aquifer. USGS recently determined that most of water withdrawn from southeastern Wisconsin over the last 136 years was not derived from groundwater storage but rather from captured baseflow.[2] Baseflow is groundwater that under natural conditions would discharge to streams and lakes, including Lake Michigan. Because of pumping, groundwater has been diverted to wells instead of supplying water to surface water resources.

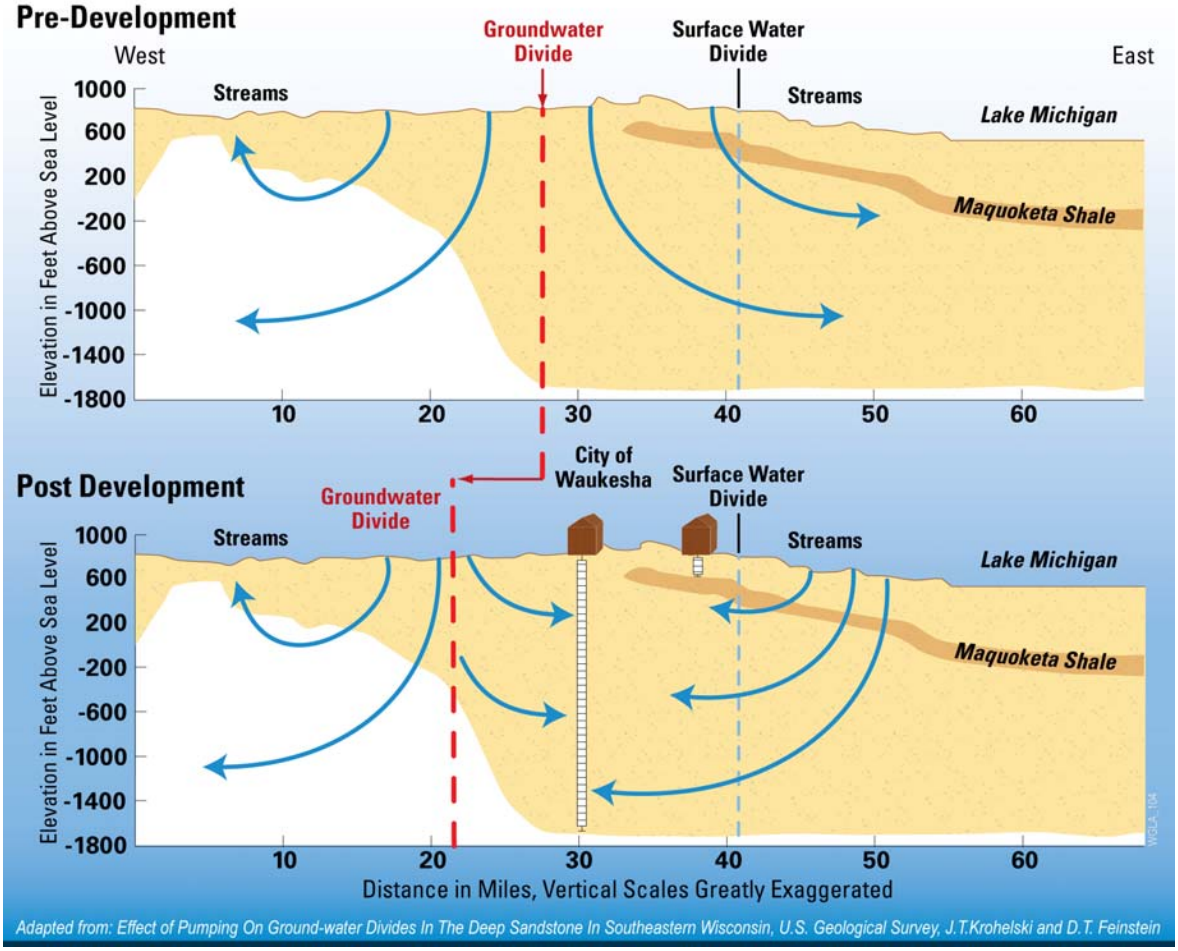
Historically, the deep sandstone aquifer flowed east to Lake Michigan. Currently, groundwater flows from Lake Michigan west to the City of Waukesha.

[1] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*; D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*; CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[2] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin.*

Groundwater pumping has also moved the groundwater divide—the boundary that defines the flow of groundwater toward Lake Michigan or to the Mississippi River—farther to the west (Exhibit 3-2). The natural hydrogeology has been altered so that the deep aquifer, which historically fed the Lake Michigan Basin with groundwater, now draws water from the Lake Michigan Basin.

EXHIBIT 3-2
Flow of Groundwater in the St. Peter Sandstone Aquifer



Even though the City's wells are outside the Great Lakes surface water divide, they withdraw water from both the Mississippi River Basin and the Great Lakes Basin. The USGS estimates that 30 percent of the 33 mgd of water pumped by the deep aquifer wells in southeastern Wisconsin originates from inside the Lake Michigan Basin.[3]

Reducing or eliminating pumping of the deep sandstone aquifer would have a significant positive effect on groundwater levels. In 2006, City of Waukesha pumping accounted for 22 percent of the 33 mgd annual withdrawal from the deep aquifer beneath southeastern Wisconsin. The Great Lakes Basin can be better preserved and more effectively managed, if more communities that pump from the deep aquifer reduce or eliminate future pumping. Measurements taken after other communities have replaced deep aquifer groundwater supplies with a Lake Michigan supply indicate recovery of the aquifer. In areas of northeastern Illinois, where groundwater withdrawal has

[3] D. T. Feinstein, USGS. October 2006.*Where do the deep wells in southeastern Wisconsin get their water?*

ceased because communities have converted from the deep St. Peter Sandstone aquifer to a Lake Michigan supply, groundwater levels at former pumping centers recovered more than 100 feet.[4] For southeastern Wisconsin, the USGS estimated that if all pumping of the deep aquifer ceased in year 2000, the aquifer would similarly recover over this century. Specifically, USGS estimates that:[5]

- To replace 50 percent of the water drawn out of storage, it would take 13 years for the shallow portion and 9 years for the deep portion of the aquifer to recover.
- To replace 90 percent of the water drawn out of storage, it would take 100 years for the shallow portion and 70 years for the deep portion of the aquifer to recover.

Based upon the available scientific evidence, it has been shown that the City's groundwater supply is derived in part from groundwater that is interconnected hydrologically to the Lake Michigan Basin. Ceasing groundwater pumping of the deep aquifer will reduce amount of groundwater withdrawn from the Lake Michigan Basin. [6]

A community within a straddling county applying for a diversion must be without adequate supplies of potable water. Reference: Compact Article 4, Section 4.9.3.a.; Wis. Stat. 281.346(4)(e)1.a.

"Without adequate supplies of potable water" is defined as "lacking a water supply that is economically and environmentally sustainable in the long term to meet reasonable demands for a water supply in the quantity and quality that complies with applicable drinking water standards, is protective of public health, is available at a reasonable cost, and does not have adverse environmental impacts greater than those likely to result from the proposed new or increased diversion" Reference: Wis. Stat. Sec. 281.346(1)zm.

With the passage of the Great Lakes–St. Lawrence River Basin Water Resources Compact, Lake Michigan became a potential source of water supply for the City of Waukesha. Because the City lies wholly within a county that is partially in the Basin, the City may apply to withdraw Lake Michigan water for public water service and return treated water to the Great Lakes Basin.

To understand why the City is without adequate supplies of potable water, the potential sources of supply are discussed below. Specific water supply alternatives to meet the City's needs are presented and evaluated in Section 4.

Deep St. Peter Sandstone Aquifer

The City's deep aquifer wells are constructed to depths of greater than 2,100 feet and withdraw water from 800 to 1,000 feet below ground. Since the 1840s, the aquifer has served as a source of water supply for many communities in Wisconsin and Illinois. Today deep aquifer water supply pumping in southeastern Wisconsin results in additional groundwater level declines of 5 to 9 feet per year.[7]

[4] S. L. Burch. 2002. *A Comparison of Potentiometric Surfaces for the Cambrian-Ordovician Aquifers of Northeastern Illinois, 1995 and 2000.* Illinois State Water Survey Data/Case Study 2002-02.

[5] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin.*

[6] Ibid.

[7] Waukesha Water Utility operating data.

The dramatic drawdown of the aquifer (an estimated 500 to 600 feet in the confined aquifer since the nineteenth century[8]) is in part attributed to the Maquoketa shale confining layer, a geological feature that limits the recharge of the aquifer by rain and snow (Exhibit 3-3).

Not all of the St. Peter Sandstone aquifer is confined. Parts of the aquifer are unconfined but located outside the jurisdiction of the City. In the unconfined part of the aquifer in southeastern Wisconsin, groundwater levels have declined more than 100 feet. The largest capacity wells in that area supply the City of Oconomowoc and had an average annual flow of 1.8 mgd.[9, 10] (Exhibit 3-4).

In addition to significant drawdown and associated adverse environmental impacts, the installation of more wells located outside the City's jurisdiction will undoubtedly result in legal challenges because Wisconsin law protects against municipal withdrawal of large amounts of water from a particular area and transporting that water to other locations for its use. Installation of high capacity wells in the unconfined aquifer would interfere with other communities' and land owners' beneficial use of the water and would expose the City to numerous damage claims from other municipalities and homeowner associations.[11]

EXHIBIT 3-3
Hydrogeology of Southeastern Wisconsin

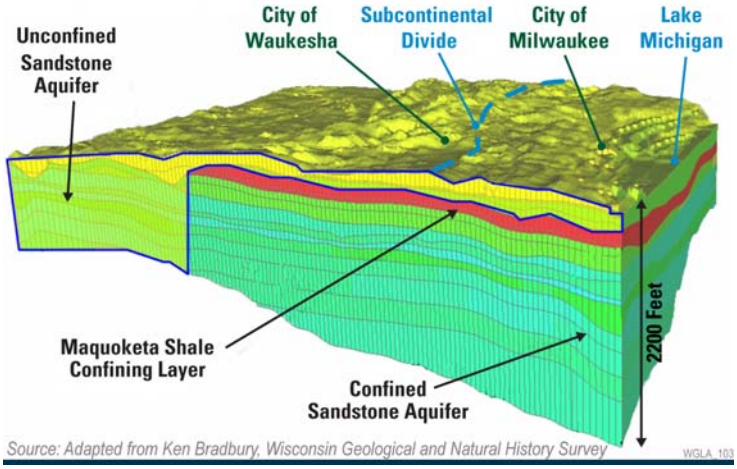
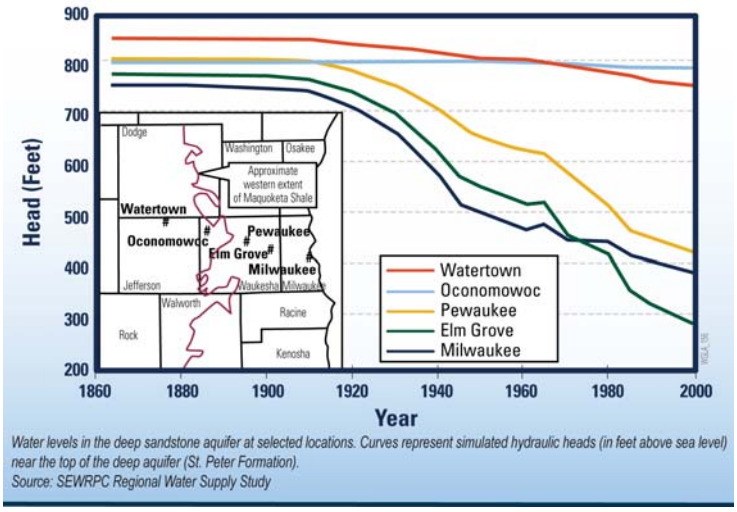


EXHIBIT 3-4
Deep Aquifer Groundwater Levels in Several Locations



The deep aquifer is not an environmentally sustainable source of supply for the City because pumping exceeds the rate at which the aquifer can be renewed. The quantity of available groundwater is decreasing. The deep aquifer is not a reliable, reasonable source of supply for the future.

Deep Aquifer Groundwater Quality

As water is pumped from greater depths, naturally occurring contaminants, primarily radium and total dissolved solids (TDS), are present in progressively higher concentrations. These con-

8 SEWRPC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* p.102–103.

9 SEWRPC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Chapter II, p. 107

10 Utility operating data, City of Oconomowoc. 2009.

11 State v. Michaels Pipeline Construction Inc., 63 Wis.2d 278, 292 (1974).

taminants require removal to meet drinking water standards. The City's groundwater supply has radium levels up to three times the United States Environmental Protection Agency's (USEPA's) drinking water maximum contaminant level (MCL) of 5 picocuries per liter (piC/L). The naturally occurring radioactive isotopes radium-226 and radium-228 are present in the aquifer because of parent elements in the sandstone. The radioactive isotopes are known to be carcinogenic. The concentration of radium in the City's groundwater supply is as high as 15 piC/L; the radium levels in the City's supply are among the highest concentrations in the country for a potable water supply.

To provide drinking water that meets the radium standard on a weighted average basis, the City treats some deep aquifer water to remove radium and blends some untreated deep aquifer water with radium-compliant water from the shallow aquifer. The City has until 2018 to complete the capital investments needed to meet the radium standard at all times at each entry point to the water system. Treatment for radium removal, in conjunction with deep aquifer pumping, is costly. Also, the radium removal process creates a highly concentrated radium waste stream. WDNR requires the waste stream radium concentration to be minimized prior to disposal to the wastewater treatment plant. Radium levels are also regulated in the wastewater treatment plant residual sludge.

USEPA regulates TDS as a secondary drinking water standard of 500 mg/L. For the City of Waukesha, continued use of the deep aquifer eventually may require treatment to remove TDS. TDS concentrations in the City's wells range from 300 to 1,000 mg/L. To mitigate the high TDS concentrations, wells can be partially blocked, but plugging reduces well capacity by as much as 35 percent.[12] TDS can be removed by desalination treatment. Desalination is an expensive and energy-intensive process that may be necessary for the long-term continued use of the deep wells. Desalination produces a waste stream with a high concentration of salts. These salts ultimately pass through the wastewater treatment plant and are released to the environment.

In addition to naturally occurring contaminants, deep aquifer wells are susceptible to pollution. Two of the City's deep wells are no longer in service because they are contaminated by a local landfill. Removing contaminants, such as radium and salts, from the deep aquifer water to protect public health is technically feasible, but the significant investment in pumping and treatment is not reasonable because the quantity of available water is declining and will be more limited in the future. Further, as water levels in the deep aquifer drop as a result of continued pumping, the public health is compromised, because the lower the aquifer level, the higher the levels of contaminants such as radium and TDS. See 4-14. The relative costs of water supply alternatives are defined and compared in Section 4.

Deep Aquifer Supply Environmental Impacts

The City's deep aquifer pumping contributes to the following cumulative environmental impacts:

- Continued significant decline of groundwater levels
- Baseflow reduction of 12 percent to surface water resources, as water is drawn toward deep wells[13]

[12] Waukesha Water Utility operating data for Well 9, 2000 and 2006.

[13] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case of Southeastern Wisconsin*

- Reversal of the natural flow system causing more than 10 times the water that once flowed east toward Lake Michigan through the deep aquifer in southeastern Wisconsin to now converge from all directions on pumping centers[14]
- Diversion of as much as 30 percent of the water replenishing the deep aquifer from the Great Lakes Basin[15]
- Ultimate discharge of water from the Great Lakes Basin to the Mississippi River Basin, which will adversely affect the environment by reducing the amount of water available to the waters and water dependent resources of the Great Lakes Basin

Shallow Troy Bedrock Valley Aquifer

The City draws about 13 percent of its water supply from the shallow aquifer (Troy Bedrock Valley formation) overlying the Maquoketa shale. That formation contains up to 500 feet of glacial deposits in its deepest parts.[16] It is a source of water supply for the Village of Mukwonago, the Village of East Troy, the City of Waukesha and the City of Muskego. It is also hydraulically connected to sensitive environmental resources including the Vernon Marsh Wildlife Area, Pebble Brook (a Class II trout stream), and Pebble Creek. Because of quantity and quality concerns with the deep aquifer, the City and other neighboring communities consider the shallow aquifer a potential source of additional water supply. However, the shallow aquifer is partially located in Waukesha County, which is a state-designated groundwater management area.[17][18] Given aquifer conditions and the presence of Vernon Marsh Wildlife Area and Pebble Brook, it would be a challenge to locate high capacity shallow wells in a manner that does not impair other wells or affect the environment adversely.

To estimate the impacts of the City significantly increasing its withdrawal from the shallow aquifer, hydrogeologic modeling was conducted with the Troy Bedrock Valley Aquifer Model.[19] The model predicted groundwater level drawdown and the baseflow reduction index if additional City wells are put into service. Baseflow is groundwater that discharges to, or feeds, surface water bodies. The groundwater discharge is the inflow that keeps surface waters flowing during dry periods. Estimating the loss of baseflow from groundwater pumping is critical to understanding whether the shallow aquifer is a sustainable water supply. To quantify impacts on baseflow, a baseflow reduction index was used in regional water supply planning studies.[20, 21]

$$\text{baseflow reduction index} = [(\text{net baseflow}_{2005} - \text{net baseflow}_{1900})/\text{net baseflow}_{1900}] \times 100$$

where net baseflow is $\text{surface water flow}_{out} - \text{surface water flow}_{in}$.

Although the wells needed to meet the City's demands in the model were spread over an extensive area and located at least 1,300 feet from sensitive water resources, additional shallow aquifer withdrawal resulted in severe drawdown at the wells of up to 50 to 100 feet. Additional City

14 D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*
15 Ibid.
16 SEWRPC. January 2010. *Southeastern Wisconsin Regional Planning Commission Report No.188*
17 Wis. Stat. § 281.34(9)
18 Ibid.
19 Ibid.
20 SEWRPC. *A Regional Water Supply Plan for Southeastern Wisconsin,* pp 38–50.
21 Cherkauer, p. 11.

wells would also reduce baseflow to surface waters ranging from 17 to 340 percent.[22] This reduction is severe and not environmentally sustainable given the historical reference baseflow reduction index for Waukesha County from 1920 to 2000 of less than 10 percent.[23] As presented in Section 4, the infrastructure cost of expanding the City's shallow aquifer supply is significant because a large number of small capacity wells located over a large area are needed to minimize aquifer drawdown and baseflow reduction.

Shallow Aquifer Groundwater Quality

Groundwater from the shallow aquifer requires treatment to meet secondary drinking water standards of 0.3 mg/L for iron, 0.05 mg/L for manganese, and primary standard of 10 ppb for arsenic. Given the results of the Troy Bedrock Valley aquifer modeling, there is also evidence that both the Fox River water and groundwater could be impacted by contaminants from septic waste disposal systems that would be drawn into shallow wells. To remove these contaminants from the shallow aquifer supply and meet applicable drinking water standards, conventional surface water treatment, including coagulation, flocculation, sedimentation, filtration and disinfection is needed.

As with continued use of the deep aquifer, continued pumping of the shallow aquifer will tend to diminish the protection to public health. By its very nature, the shallow aquifer is more susceptible to contamination than deep confined aquifers and large surface water bodies such as Lake Michigan.

As evaluated in Section 4, the costs to expand the shallow aquifer supply are significant, particularly when considered in balance with the anticipated adverse environmental impacts.

Shallow Aquifer Supply Environmental Impacts

Additional shallow aquifer pumping by the City would contribute to the following cumulative environmental impacts:

- Significant decline of groundwater levels
- Baseflow reduction indices ranging from 17 to 340 percent will have a devastating effect on surface waters including the Vernon Marsh Wildlife Area and the Pebble Brook Class II trout stream
- Over 400 existing private wells could be impacted by the City pumping as little at 6.4 mgd from the shallow aquifer to meet the public water system demand[24]
- The shallow aquifer supply cannot be expanded to meet future demands sustainably because additional withdrawal causes severe adverse impacts to local surface water resources.

Comparison of the Adverse Environmental Impacts of Continued Use of the Deep and Shallow Aquifers versus a Lake Michigan Diversion

Section 4 of this application sets forth a comprehensive comparative analysis of the water supply alternatives. Part of the analysis includes comparisons between the adverse environmental impacts of the City's available water supply with adverse environmental impacts result-

[22] *Results of Groundwater Modeling Study Shallow Aquifer Groundwater Source, Fox River & Vernon Marsh Area, Waukesha Water Utility,* RJN Environmental Services, April 2010.

[23] Cherkauer, p. 13.

[24] RJN Environmental Services.

ing from a proposed diversion. Scientific evidence and studies reveal that the adverse environmental impacts of the City's deep and shallow aquifer pumping are greater than the impacts likely to result from the proposed Great Lakes diversion. See 4-2 Future Water Supply Study; 4-4 Evaluation of Water Supply Alternatives by SEWRPC; 4-7 Water Supply Alternatives tion; 4-28 An Analysis of Environmental Impacts of a Lake Michigan diversion.

The comparative analysis shows that eliminating the pumping of the deep and shallow aquifer would discontinue a number of cumulative adverse environmental impacts and improve groundwater resources of the Great Lakes Basin. It would assist the recovery of both surface and groundwater resources; assist in the restoration of the natural flow system wherein the deep aquifer feeds the Waters of the Great Lakes; benefit habitat restoration of Underwood Creek and the Menomonee River through the return flow; and eliminate the diversion of water from the Lake Michigan groundwatershed to the Mississippi River Basin. Continued pumping of the deep aquifer would create poor quality water with resulting higher concentrations of radium and TDS.

Switching from groundwater to a Lake Michigan supply will have cumulative impacts that will result in a positive net benefit to the environment versus continued adverse impacts resulting from the City's continued use of its existing groundwater supplies:

- Assist in the recovery of both surface water and groundwater resources.
- Assist in the restoration of the natural flow system wherein the deep aquifer feeds the Waters of the Great Lakes.
- Eliminate the diversion of water from the Lake Michigan groundwatershed to the Mississippi River Basin.
- Result in no impact on Lake Michigan water level for the proposed diversion of 10.9 mgd with return flow.
- Prevent radium in wastewater treatment plant sludge from being discharged into the environment.
- Reduce the release of salts used to soften hard groundwater into the environment.

Waukesha Does Not Have Adequate Supplies of Potable Water

The foregoing discussion along with analysis of alternative water supplies in Section 4 and the return flow discussion in Section 5 support the diversion exception criterion: that the City of Waukesha lacks an adequate supply of potable water. The groundwater supply in the deep aquifer is severely depleted and is not a reliable source to meet future needs. The quantity of water that can be withdrawn from the shallow aquifer for potable water supply is limited because increased pumping would severely reduce the quantity of water available for local streams, brooks, and wetlands.

The City lacks a water supply that is economically and environmentally sustainable in the long term to meet reasonable demands for a water supply in the quantity and quality that complies with applicable drinking water standards, is protective of public health, is available at a reasonable cost, and does not have adverse environmental impacts greater than those likely to result from the proposed new Great Lakes diversion.

The only reasonable water supply for the City is a Lake Michigan supply with continued water conservation and return flow, in accordance with the requirements of the Compact. This is the only water supply that balances the inherent social and economic development benefits of a reliable source of drinking water with stewardship of environmental resources for future generations. A Lake Michigan supply for the City is sustainable, protective of public health, and results in more effective management and improvement, of the waters and water-dependent natural resources of the Great Lakes Basin.

A community within a straddling county applying for a diversion must have no reasonable water supply alternative within the basin in which the community is located, including conservation of existing water supplies. Reference: Compact Article 4, Section 4.9.3.d.; Wis. Stat. §§ 281.346(4)(e)1.d. and 281.346(4)(e)1.g.

"Reasonable water supply alternative" is defined as "a water supply alternative that is similar in cost to, and as environmentally sustainable and protective of public health as, the proposed new or increased diversion and that does not have greater adverse environmental impacts than the proposed new or increased diversion." Reference: Wis. Stat. § 281.346(1)(ps).

Introduction

The City and others have studied extensively the water resources in the Waukesha area.[1, 2, 3] The evaluations and recommendations from the various studies are summarized in this application.

As stated above, the Compact (Section 4.9.3(d)) requires a community in a straddling county applying for a diversion to show that: "There is no reasonable water supply alternative within the basin in which the community is located, including conservation of existing water supplies." Further, Wisconsin Statute § 281.346(1)(ps) states:

> "Reasonable water supply alternative" means a water supply alternative that is similar in cost to, and as environmentally sustainable and protective of public health as, the proposed new or increased diversion and that does not have greater adverse environmental impacts than the proposed new or increased diversion.

In this application, water supply alternatives have been evaluated based on the following criteria:

- Environmental impact
- Long-term sustainability to provide the public with adequate supplies of potable water
- Protection of public health
- Implementability

Costs of the alternatives were also estimated.

This evaluation determined the water supply alternative that would best protect, conserve, restore and improve waters and water dependent natural resources of the Great Lakes Basin.

Previous Studies of Water Supply Alternatives

Extensive studies have investigated various water supply alternatives for the City of Waukesha. The results and conclusions from a few of those studies are summarized in this Section. These studies helped identify the alternatives analyzed in this application.

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[1] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*

[2] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.

[3] Douglas S. Cherkauer. 2009. *Groundwater Budget Indices and their Use in Assessing Water Supply Plans for Southeastern Wisconsin,* Technical Report 46, Preliminary Draft. Department of Geosciences, University of Wisconsin—Milwaukee.

Future Water Supply Study

In March 2002, the City of Waukesha water utility completed a future water supply study.[4] Stakeholders in this study included representatives from the water utility, City of Waukesha, WDNR, SEWRPC, USGS, the WGNHS, and the University of Wisconsin–Madison. The study looked at the following 14 water supply sources and combinations of them:

- Deep aquifer near Waukesha (confined)
- Deep aquifer west of Waukesha (unconfined)
- Shallow groundwater south of Waukesha
- Shallow groundwater west of Waukesha
- Dolomite aquifer
- Fox River
- Rock River
- Lake Michigan
- Dam on the Fox or Rock River
- Waukesha quarry
- Waukesha springs
- Pewaukee Lake
- Milwaukee River
- Wastewater reuse

The study eliminated nine water supply sources for the primary reasons listed in Exhibit 4-1. Additional detail can be found in the Future Water Supply Study report, Appendix C.[5]

EXHIBIT 4-1
Water Supply Alternatives Eliminated

Potential Water Supply Source	Primary Reason for Not Being a Reasonable Alternative
Dolomite Aquifer	Insufficient water in the aquifer to meet the needs of the City of Waukesha.
Fox River	Inability to provide a reliable supply during dry periods, when public water supply is most needed.
Rock River	Inability to provide a reliable supply during dry periods, when public water supply is most needed.
Dam on the Fox or Rock River	Environmental impacts, regulatory issues, and public/property concerns.
Waukesha Quarry	Inadequate supply, water quality contamination potential, used for other purposes.
Waukesha Springs	Insufficient water in the aquifer to meet the needs of the City of Waukesha.
Pewaukee Lake	Insufficient water to meet the needs of the City of Waukesha, adverse environmental impacts, property owner concerns.
Milwaukee River	Poor quality, environmental impacts.
Wastewater Reuse	Public health and perception, water quality concerns, treatment requirements, limited supply, seasonal demand, regulatory issues.

The water supply alternatives that passed the initial screening process included:

- Deep confined aquifer
- Deep unconfined aquifer
- Shallow groundwater near Waukesha
- Shallow groundwater and deep confined aquifer
- Lake Michigan

These remaining alternatives, and combinations of them, were evaluated by a broad group of stakeholders using the following criteria:

- Sustainability and reliability as a long-term, high-quality water supply

[4] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*
[5] Ibid.

- Regulations, environmental impacts, and land and legal requirements
- Political issues and public acceptance
- Operational and maintenance requirements
- Schedule for implementation
- Infrastructure requirements

A brief summary of the results follows. Refer to the Future Water Supply report,[6] Appendix C, for details.

Continued use of the deep confined aquifer (current water supply for Waukesha) was ranked lowest because:

- It is not sustainable over the long term due to drastically declining water levels and water quality requiring extensive treatment (radium and total dissolved solids removal)
- Adverse environmental impacts to the deep aquifer, shallow aquifers, surface water and hydrologically connected waters of the Great Lakes Basin
- Potential negative public health impacts from radium and high dissolved solids in the water
- It also had the highest cost for facilities and long term operations and maintenance

The deep unconfined aquifer alternative, far west of Waukesha, also was ranked low because:

- Adverse impacts to the surrounding groundwater and surface water environment due to groundwater table drawdown and water budget depletion
- Adverse impacts to other water users currently using this source
- Poor public acceptance and potential lawsuits
- Extensive infrastructure requirements due to the distance from Waukesha
- High costs for facilities and long term operations and maintenance

With the deep aquifer alternatives ranking lowest, the Future Water Supply Study report recommended further evaluation of the highest ranked alternatives:

- Lake Michigan
- Shallow aquifer sources

Key recommendations relating to the Lake Michigan potable water supply included evaluating diversion permit requirements and identifying a Lake Michigan water provider. The alternatives analysis noted that the Lake Michigan alternative provided the most reliable and highest quality source of water for Waukesha, a reasonable water supply.

For the shallow aquifer alternatives, the report recommended evaluating sustainable capacities from the aquifers, environmental impacts of extracting additional shallow groundwater, land issues, and impacts on other shallow aquifer users. Evaluation of these items was not in the scope of the Future Water Supply study. However, subsequent reports addressed these issues.[7]

[6] Ibid.

[7] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.

Evaluation of Water Supply Alternatives by SEWRPC

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is the official regional planning agency for the seven-county Southeastern Wisconsin Region, including Waukesha County. SEWRPC is charged by law with making and adopting a comprehensive plan for the physical development of the region. In 2008, SEWRPC released a draft report titled, *A Regional Water Supply Plan for Southeastern Wisconsin* (Appendix I). This plan is an extensive evaluation of water supply alternatives for the seven-county area, including the City of Waukesha, to the year 2035.

Water supply alternatives were evaluated on the basis of five overall objectives:

1. Support of existing land use patterns
2. Conservation and wise use of the surface water and groundwater supplies
3. Protection of public health, safety, and welfare
4. Economical and efficient systems
5. Responsive and adaptable plans

Each objective had several sub-objectives or standards. Two key standards under Objective 2 were as follows:

- Manage the use of the deep and shallow aquifers so as to minimize ecological impacts on the surface water system of the region.
- Use groundwater and surface water for water supply purposes in a manner that minimizes adverse impacts to the water resources, including lakes, streams, springs, and wetlands.

Similar to the Future Water Supply Study, the SEWRPC study screened alternative water supplies and ultimately identified similar water supply alternatives. The water supply alternatives evaluated for the region included the following:

- Lake Michigan
- Shallow aquifers
- Deep aquifer
- Shallow aquifers and artificial recharge using rainwater and wastewater treatment plant effluent
- Deep aquifer and artificial recharge using treated Lake Michigan water
- Combinations of these alternatives

Extensive groundwater and surface water modeling was conducted in the evaluation of these alternatives. Major findings include the following:

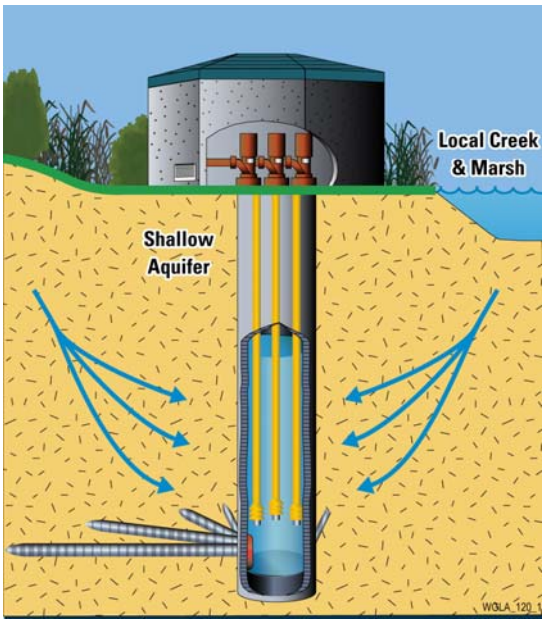
- Continued increased pumping of the deep aquifer would continue to draw down groundwater levels, create poorer water quality (higher concentrations of radium and TDS), increases adverse impacts on surface waters and hydrologically connected waters of the Great Lakes Basin, and increase the water budget deficits.
- Increased pumping of the shallow aquifer would reduce baseflows to surface waters, produce water budget deficits, and have adverse environmental impacts on sensitive surface water ecosystems, such as Vernon Marsh, Pebble Brook, and Pebble Creek (a high quality trout stream)[8] near Waukesha.
- Shallow aquifer recharge with rainfall or treated wastewater infiltration would increase baseflows, but would create land use concerns and public health concerns due to contami-

[8] WDNR, Wisconsin Trout Streams, PUB-FH-306, 2002.

nation, and require overcoming regulatory hurdles along with constructing extensive, costly facilities.

- A Lake Michigan supply to some straddling communities and counties west of the sub-continental divide (with return flow) would reduce the ecological stress on the deep aquifer, shallow aquifer, and associated waters and water dependent natural resources of the Great Lakes Basin compared to the other alternatives.
- The amount of chlorides and sodium discharged into the environment by home water-softening devices would increase greatly under any groundwater alternative. The SEWRPC report estimated that eliminating groundwater softening by providing Lake Michigan water to some communities east and west of the divide (including Waukesha) would eliminate 5.2 million pounds of chlorides discharged to the Cedar Creek, Milwaukee River, and Lake Michigan environments.[9]

EXHIBIT 4-2
A Shallow Aquifer Water Supply Affects Surface Waters and Groundwaters



- Shallow groundwater supplies are more susceptible to contamination than a Lake Michigan supply. This could result in an increased risk to public health and the need for advanced water treatment facilities that would increase costs, energy use, and greenhouse gas emissions.

Comparing alternatives under which the City of Waukesha obtains a Lake Michigan water supply with return flow to alternatives using current or new groundwater supplies (deep and shallow aquifers), **SEWRPC concluded that the Lake Michigan alternative "offers advantages related to a greater improvement in the deep aquifer long-term sustainability, reductions in chloride discharges to the surface waters, and improvement in groundwater-derived baseflow inputs to the surface water system." On that basis, SEWRPC issued a draft recommendation for the City of Waukesha to change to a Lake Michigan water supply.** This recommendation was reviewed, and 32 experts with a variety of interests and perspectives in the region concurred.[10]

A 2009 study provided further groundwater/surface water modeling of the SEWRPC alternatives, with projections to 2035.[11] The study evaluated alternatives for the City of Waukesha similar to those in the SEWRPC Regional Water Supply Plan. The analysis showed that a Lake Michigan water supply for the City of Waukesha would improve the deep aquifer water levels and reduce its adverse impacts on the shallow aquifer and surface water baseflow reductions in the whole region. **A Lake Michigan supply to Waukesha would also increase deep aquifer flows to the Lake Michigan Basin, since they are hydrologically connected.**[12, 13, 14] The study issued cau-

[9] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.
[10] http://www.sewrpc.org/SEWRPC/DataResources/CommissionAdvisoryCommittees/RegionalWaterSupplyPlanningAdv.htm
[11] Cherkauer. 2009.
[12] USGS. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*, March, 2007.
[13] D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*

tions against Waukesha's or other similarly situated communities reliance on a future groundwater supply west of the divide, noting that groundwater levels and environmental impacts would worsen.[15]

These studies evaluated alternatives up to 2035, only 25 years from now.[16, 17] This is a relatively limited planning period, given that water supply planning typically looks out 50 years and more. A community water supply must be sustainable in the long term, or the capital, operations, and environmental costs of development are too high to make it reasonable. Developing a short-term water supply puts communities at risk of paying twice for the large capital costs involved.

Water Supply Alternatives Studied, But Not Pursued

Artificial Recharge

Some of the SEWRPC groundwater alternatives assume that the shallow aquifer will be artificially recharged with rainwater infiltration facilities, or that treated wastewater effluent will be artificially recharged into the shallow aquifer. By artificially increasing the amount of water infiltrating into the shallow aquifer, surface water baseflow reduction can be decreased. However, SEWRPC noted several issues and concerns:

- WDNR regulations do not allow using treated wastewater effluent to recharge a potable drinking water aquifer. A high level of treatment would be required for this to be considered. Capital and operating costs would be very high. SEWRPC estimates capital costs of advanced wastewater treatment alone would be $12.6 million for 1 mgd.[18] Transmission mains from the Waukesha wastewater plant to recharge areas would add another $4 million.
- Large land areas are required for artificial recharge, with significant costs and public concerns. An important issue is who owns and controls the use on these lands. SEWRPC estimated more than 100 acres would be needed for Waukesha to implement artificial recharge, even if it relies on the deep aquifer for more than half of its water supply.[19]
- Water which is artificially recharged is more vulnerable to contamination, which might increase the cost of treatment and risk to public health.
- The long-term feasibility of artificial recharge is unknown. Long-term soil permeability for effective recharge might be compromised in the long term. Plugging of the aquifer would reduce effectiveness over time. Restoration or decommissioning of facilities would add to costs.
- Rainfall recharge will be subject to drought constraints.

Because of the issues above, artificial groundwater recharge was not considered in this application.

Unconfined Deep Aquifer

The Future Water Supply Study evaluated a deep unconfined aquifer alternative west of Waukesha, but the SEWRPC did not. SEWRPC assumed that groundwater supplies will be located

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14 CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

15 Cherkauer. 2009.

16 SEWRPC. 2008.*Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

17 Cherkauer. 2009.

18 SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

19 Ibid.

within 1 mile of the 2035 utility service area to minimize public concerns and municipal boundary issues.[20]

Installing high capacity wells in the unconfined aquifer west of the Maquoketa shale presents not only logistical but also definite legal problems. Installation of high capacity wells in an unconfined aquifer could result in legal challenges and expose the City to numerous damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. Under Wisconsin law, the City could be liable if its withdrawal of water caused unreasonable harm through lowering the water table for residential and municipal wells in the area (State v. Michels Pipeline Construction, Inc., 63 Wis.2d 278, 217 N.W.2d 339). The City could be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels). Damages could include the cost of new wells, deepening existing wells, the cost of water treatment as water quality declines and replacement of well pumps. Additionally, groundwater protection legislation has been recently introduced (on March 12, 2010), which would require environmental review of proposed high capacity wells located in a groundwater management area, even before WDNR approves or develops a groundwater management plan for the area. For these and other reasons detailed in the Future Water Study, the unconfined deep aquifer west of the Maquoketa shale was screened out as a reasonable water supply.

As discussed previously, two significant reasons that the deep unconfined aquifer was ranked low in the Future Water Supply study is adverse impact to the groundwater and surface water environment and negative impacts on other water communities using the same aquifer. Near Oconomowoc, the deep unconfined aquifer has dropped about 100 feet in the last 100 years.[21] This has occurred with the small pumping demands of Oconomowoc of around 1 to 2 mgd. Increasing the water pumped out of that aquifer by a factor of 5 to 10 or more will have significant impacts not only on the aquifer drawdown and surrounding water ecosystems, but on municipal and private wells in the area.

Water Supply Alternatives Evaluation

Extensive evaluations of water supply alternatives for the City of Waukesha and the region have previously been conducted. This application requests the use of Lake Michigan water. To be eligible for Lake Michigan water, the City must show that there is no reasonable water supply alternative within the basin the City is located in. For this application, the City compared its Lake Michigan request to the top ranked water supply alternatives. The water supply alternatives were chosen based on the screening done in previous studies.[22] Exhibit 4-3 summarizes the alternatives screening.

The water supply alternatives include:

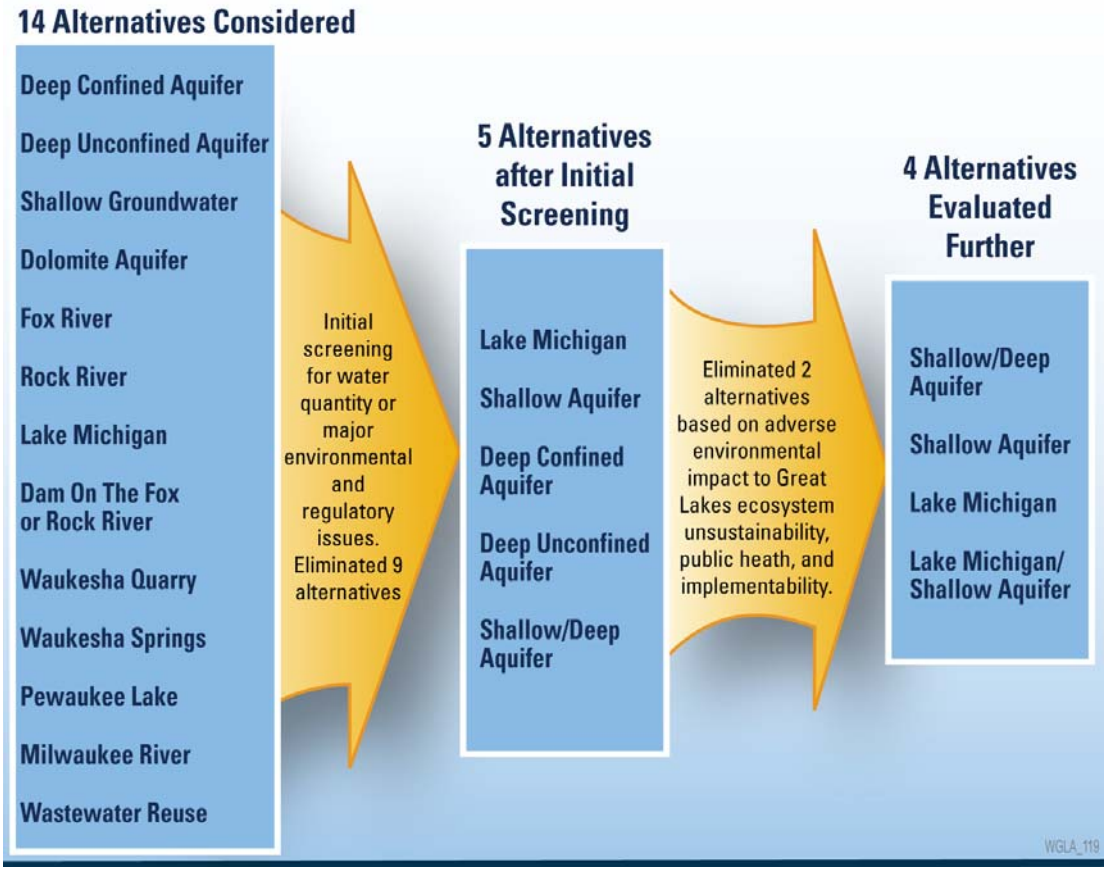
- Deep and shallow aquifer
- Shallow aquifer and Fox River alluvium
- Lake Michigan and shallow aquifer
- Lake Michigan

[20] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.

[21] SEWRPC. 2008, Figure 7.

[22] SEWRPC. 2008; CH2M HILL et al. 2002.

EXHIBIT 4-3
Water Supply Alternative Screening



A general description of each alternative is provided, along with comparisons to the following evaluation criteria:

- **Environmental Impacts**
  - Impact on ground and surface waters of the Great Lakes Basin
  - Impact on ecosystem flora and fauna environmental sustainability
  - Greenhouse gas emissions
- **Long-Term Sustainability**
  - Reliability during droughts and infrastructure failures
  - Ability to provide adequate supplies of potable water to the public for generations without adverse environmental impacts
- **Public Health**
  - Quality of the water for human consumption to protect public health
  - Potential for contamination
- **Implementability**
  - Infrastructure requirements
  - Operation and maintenance requirements
  - Land requirements, legal issues, easements, public impact

Each alternative was rated by the following categories:

- ○ No adverse impact
- ⦿ Minor adverse impact
- ◉ Moderate adverse impact
- ● Significant adverse impact

Water Supply Alternative 1: Continued Use of Deep and Shallow Aquifers

Alternative 1 consists of continued use of the deep aquifer (St. Peter sandstone) and shallow aquifer south of Waukesha (Troy Bedrock Valley). The future average annual water usage would be 10.9 mgd based on water demand projections (Section 2).

To meet a future maximum day demand of 18.5 mgd, infrastructure would be in place for 7.6 mgd firm capacity from the deep wells and 10.9 mgd from the shallow wells. The maximum capacity from shallow wells would be achieved by relying upon the current 1.2 mgd firm capacity from existing wells 11,12,13, plus developing an additional 9.7 mgd firm capacity (capacity with the largest well out of operation) by installing 14 new wells south of Waukesha near Vernon Marsh in the Troy Bedrock Valley aquifer.

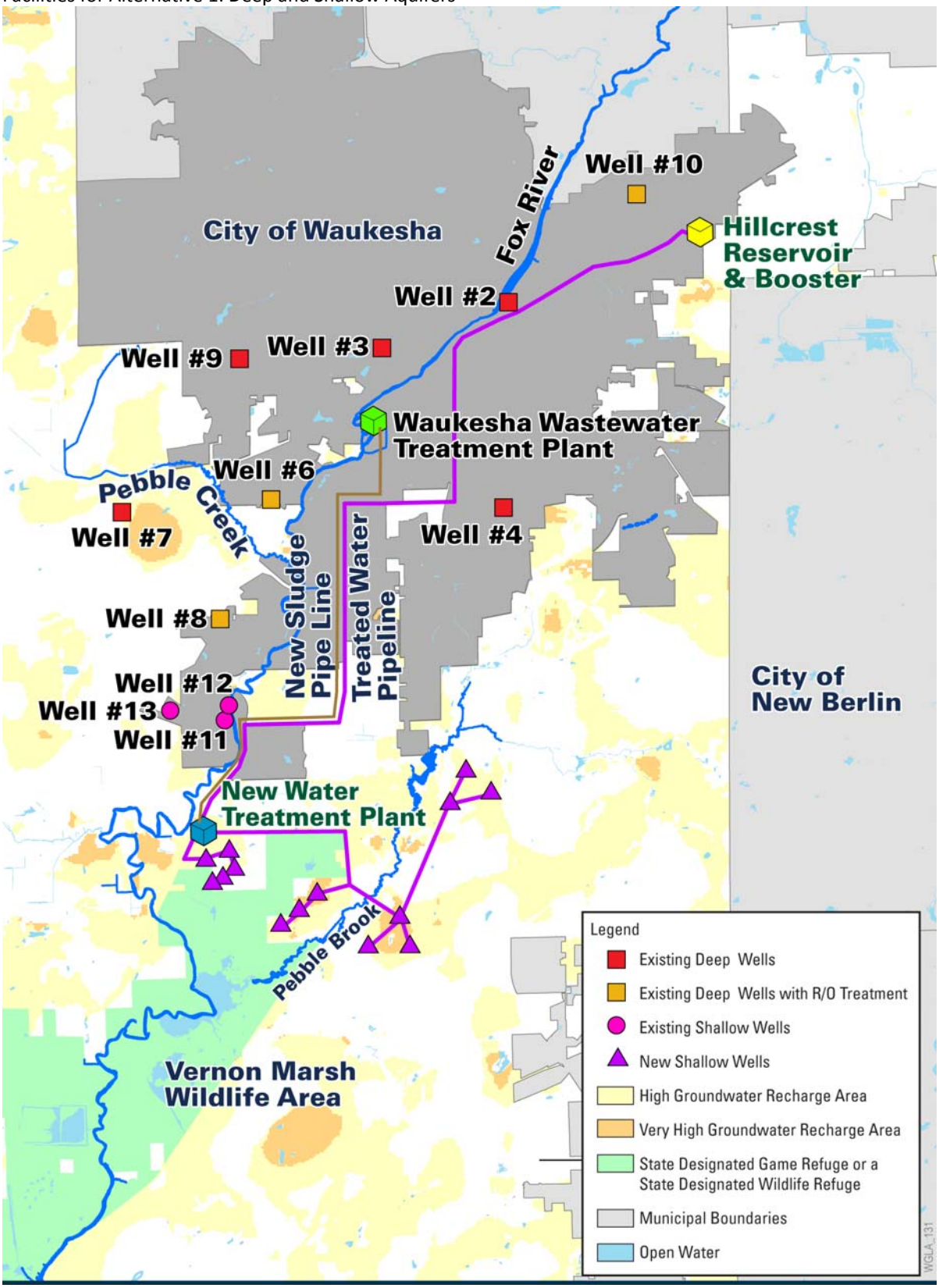
Water from the shallow wells would need to undergo treatment for iron, manganese and microorganism removal. The recent discovery of arsenic in the shallow aquifer at future well sites means arsenic treatment would be required as well. The shallow well water would be pumped from the wells to a new treatment plant. A new pump station would convey treated water to the City of Waukesha and connect with the water distribution system and Hillcrest reservoir, the largest reservoir in Waukesha used as a point to deliver water to the City.

Exhibit 4-4 shows the facilities for Alternative 1. For the purposes of this alternative, the capacity of the City's deep wells was estimated to decrease 30 percent in the future. Waukesha's deep wells vary in age from 30 to 75 years. Several wells have been abandoned because of contamination and decreasing capacity. One well had TDS concentrations greater than 1,000 mg/L and was rehabilitated to reduce the TDS (blocking off part of the well hole). In doing so, the well capacity was reduced over 35 percent. The Future Water Supply Study warned that many of the wells were not constructed to current well codes and could experience physical failures such as casing leaks or borehole collapse, which would require extensive rehabilitation or replacement.[23]

Capacity is also expected to decrease from the deep wells because the groundwater elevation continues to drop. Currently it is over 600 feet below predevelopment levels. This declining water level causes water quality problems (increased TDS, radium, and gross alpha levels). As a result, treatment would be installed at the three largest deep wells (No. 6, 8, 10) to reduce TDS and radium. Since the deep wells are on small lots, adjacent residential property would need to be purchased and homes demolished to make room for the additional treatment facilities. It was assumed that the three deep wells will have their own treatment facility, and that water from the remaining deep wells and shallow wells will be blended at the Hillcrest reservoir. Treatment to remove TDS would produce a concentrated salt waste stream equal to about 7.5 percent of the water pumped (assuming 25 percent bypass). The lost capacity would be made up with shallow wells. This is consistent with the Future Water Supply Study.[24]

[23] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*
[24] Ibid.

EXHIBIT 4-4
Facilities for Alternative 1: Deep and Shallow Aquifers



Environmental Impacts

Deep Aquifer

Studies have shown that the deep aquifer is hydrologically connected to the waters of the Lake Michigan Basin.[25] Before development, the deep groundwater below southeast Wisconsin flowed toward Lake Michigan. Pumping water from the deep aquifer reduces the amount of water that would flow to the waters of the Lake Michigan Basin, and actually reverses the flow so that it is away from Lake Michigan.[26] The USGS estimates that 30 percent of the 33 mgd of water currently pumped by the deep aquifer wells in Southeast Wisconsin originates from inside the Lake Michigan Basin.[27] The largest pumping center with the highest drawdown is in Waukesha County.[28]

Reducing the amount of water that would have flowed into the Lake Michigan Basin by deep aquifer pumping has adverse environmental impacts on the waters of the Lake Michigan Basin. By stopping deep aquifer pumping in Waukesha alone, an improvement in the hydrology and hydrogeology of the waters of the Lake Michigan Basin can be realized.[29]

In addition, water pumped from the deep aquifer removes water that would otherwise be available to local surface water resources. The USGS and WGNHS indicate that 70 percent of water pumped from the deep aquifer would have gone to inland surface waters. The remaining 30 percent originates from inside the Lake Michigan Basin and 4 percent of that is contributed by Lake Michigan.[30] Reducing natural flows to surface waters by pumping the deep aquifer has adverse environmental impacts both inside and outside the Lake Michigan Basin.

Adverse environmental impacts are also occurring because of the depletion of the deep aquifer. Recharge is limited for the deep aquifer near Waukesha because of the shale confining layer, causing continued depletion of the aquifer along with increasing TDS and radionuclides. In addition, dropping groundwater levels can expose sulfide minerals to oxygen and increase arsenic levels. This oxygen can also provide conditions for growth of pathogenic microorganisms in wells, which as occurred in a number of deep wells.[31] Changing the physical and biological nature of the aquifer creates adverse environmental impacts and is not environmentally sustainable.

Shallow Aquifer

Pumping the shallow aquifer can cause adverse environmental impacts on ground and surface water resources. SEWRPC estimates that about 85 percent of water extracted from the shallow aquifer is diverted or extracted from surface waters.[32] This would negatively affect sensitive and valuable environmental areas near Waukesha, such as Pebble Brook, Pebble Creek (a trout stream), and Vernon Marsh. SEWRPC estimated parts of Vernon Marsh and Pebble Creek could see the baseflow decrease more than 25 percent if the City of Waukesha continues using a combination of deep and shallow groundwater, with artificial recharge.[33] A subsequent study estimated signifi-

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[25] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*; D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*; CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[26] D.T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?* http://wi.water.usgs.gov/glpf/index.html

[27] Ibid.

[28] Ibid.

[29] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[30] D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?* http://wi.water.usgs.gov/glpf/index.html

[31] CH2M HILL with Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*

[32] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

[33] Ibid.

cant baseflow reductions would occur near Waukesha even if only 3.9 mgd of shallow groundwater was pumped and artificial recharge was used.[34] Under Alternative 1, Waukesha would need a maximum of 10.9 mgd of shallow aquifer water without artificial recharge, so the adverse impacts to baseflow reduction and groundwater/surface water ecosystems would be much greater.

For this application, the recently completed Troy Bedrock Valley groundwater model[35] was used to simulate shallow aquifer groundwater drawdown and baseflow reduction for Alternative 1. Although a maximum day pumpage of 10.9 mgd may need to be extracted from the shallow aquifer, an annual average well pumpage of 6.4 mgd was the withdrawal amount modeled.

The results on groundwater drawdown are shown in Exhibit 4-5.[36] The results show significant shallow aquifer drawdown (about 50 feet) near the wells. Water levels would also be lower in a large portion of the Vernon Marsh and near Pebble Brook. A groundwater drawdown of 1 foot is significant in a wetland as it may affect root structures of aquatic plants. In addition, there are many private wells in the drawdown area that could be affected, along with potential contamination from associated septic tanks.

Water extracted from the ground reduces the water that would naturally flow to wetlands, lakes and streams (base flow). The model estimated that base flow would be reduced as shown below with this alternative.[37] This baseflow reduction can have significant adverse environmental impacts to the water ecosystems. Not only would groundwater be intercepted and not reach surface waters, under this scenario water also would be drawn from the Fox River. Appendix N, Environmental Report, contains additional information on the environmental impacts.

Resource	Baseflow Reduction (%) from pumping 17 shallow wells for a total of 6.4 mgd
Fox River	142
Pebble Brook	61
Vernon Marsh	7
Mill Brook	29
Pebble Creek	9

Water transmission mains extending from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha, would have environmental impacts during construction. Appendix N contains additional information on environmental impacts.

Deep and Shallow Aquifers Combined

Water is not returned to its source when deep or shallow groundwater is pumped and discharged to surface water. Water is transferred out of the Great Lakes and Mississippi river ecosystem and eventually to the ocean (Exhibit 4-6). This results in less water in the Great Lakes and Mississippi river watersheds and associated adverse environmental impacts. One of the decision making standards of the Compact (4.11.1) states "All Water withdrawn shall be returned, either naturally or after use to the Source watershed less allowance for Consumptive Use." Since the deep aquifer and the waters of the Lake Michigan Basin are hydrologically connected, pumping the deep aquifer and discharging the water into the Fox River does not comply with this Compact decision-making standard.

[34] Cherkauer. 2009.

[35] Troy Bedrock Valley Aquifer Model. Memorandum Report Number 188. Prepared by Ruekert & Mielke for SEWRPC. Reviewed by Dr. Kenneth R. Bradbury – Wisconsin Geological and Natural History Survey. January 2010.

[36] RJN Environmental Services, LLC. March, 2010. Results of Groundwater Modeling Study Shallow Groundwater Source, Fox River & Vernon Marsh Area. Reviewed by Dr. Kenneth R. Bradbury – Wisconsin Geological and Natural History Survey.

[37] Ibid.

EXHIBIT 4-5

Groundwater Drawdown: Alternative 1 with 17 wells pumping, total 6.4 mgd

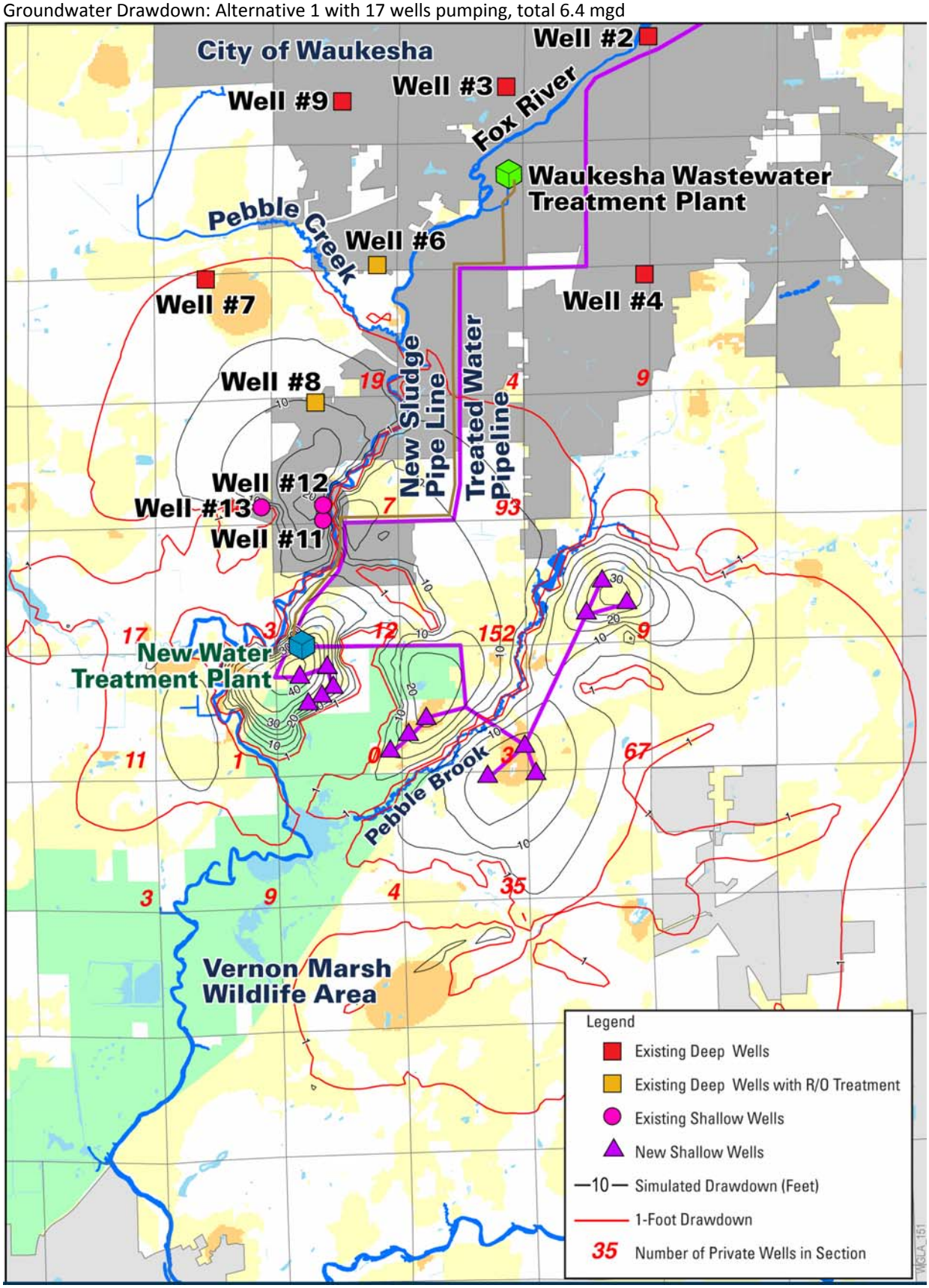
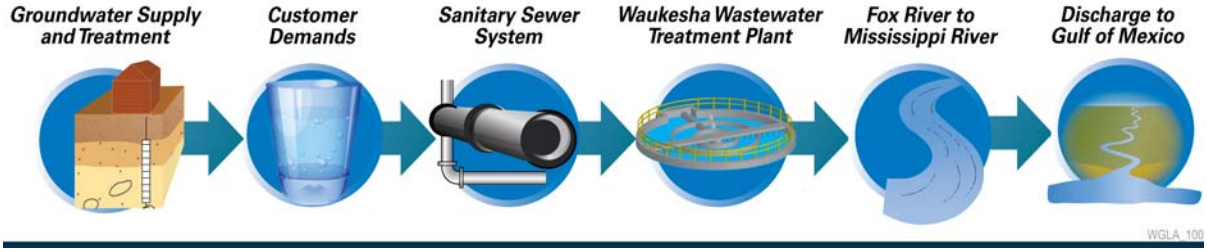


EXHIBIT 4-6
Groundwater Supply Water Cycle



Both the deep and shallow groundwaters are hard, requiring use of home water softeners. Continued and expanded use of water softeners increases salt discharge into the environment. It is estimated that Waukesha discharges 7.4 million pounds of salt into the Fox River each year from home water softeners. Water use also increases with the use of home water softeners. It is estimated that each household water softener produces 40 gallons of salty wastewater per regeneration. TDS removal treatment concentrates salts that also are discharged into the environment and increases wastewater volumes. Continued use of hard groundwater would increase water and energy use while degrading conservation efforts. Finally, it is estimated that Alternative 1 would discharge 31,000 tons of greenhouse gases per year (carbon dioxide equivalent) through pumping from aquifers, water treatment, and pumping from the wellfield to Waukesha. That is equivalent to powering about 3,000 homes for a year.[38]

Considering the environmental impacts of Alternative 1, a rating of "significant adverse impact" was applied. The continued use of deep and shallow aquifers has greater adverse environmental impacts than the proposed diversion.

Long-Term Sustainability

The City seeks Lake Michigan water because its current water source is not sustainable.

The deep aquifer water levels are very low and dropping. Water quality is degrading and radium and TDS levels are increasing. Two wells have recently been abandoned due to contamination from outside sources. Capacity in some wells is decreasing due to the ever increasing depth that water needs to be pumped from (over 600 feet from the surface now and dropping 5 to 9 feet per year). In order to continue withdrawing water, the existing pumps may need to be replaced with larger and different type (submersible) pumps to draw water from lower levels. This will increase costs and energy.

The deep wells are 30 to 75 years old and have some of the largest pumps of their kind which have to be custom built. If a failure occurs with the pumping equipment, it could be many months before repairs can be made. This situation has occurred on Waukesha's well 10 recently. This situation reduces reliability and sustainability of the water supply.

Current deep aquifer pumping could be reduced by using more shallow groundwater. That would slow the drawdown but may not eliminate it. The amount of deep aquifer pumping by other communities, which accounts for approximately 75 percent of the total deep aquifer usage in southeastern Wisconsin, would also greatly affect drawdown.

Using the shallow groundwater as a replacement for the deep aquifer pumping would not be sustainable. As described above, pumping for average day water demands result in significant

[38] US Energy Information Administration. http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home

groundwater drawdowns and baseflow reduction, causing adverse environmental impacts to wetlands, streams, lakes and rivers. This adverse impact will increase during drought periods and when water demands are higher. As the shallow aquifer depends on rainwater for recharge, it is less reliable during drought conditions, when water supply is needed most. It is unlikely that the shallow aquifer could provide adequate water for maximum day demands during a drought, and even less likely if it could do so without severe adverse impacts to the environment.

The deep aquifer is not significantly affected by drought, since the shale confining layer above the aquifer limits recharge near Waukesha. Having two sources of water is more reliable than having only one.

It should also be noted that treatment requirements for the deep and shallow aquifers would require more water to be pumped because the treatment process itself uses water. This would require more water to be pumped out of the ground to meet demand and thus decrease water efficiency. Treatment of all the water supply in multiple treatment plants is required. This would increase operation and maintenance efforts and costs, plus produce a salty liquid waste stream.

Considering the long-term sustainability of Alternative 1, a rating of "significant adverse impact" was applied.

Public Health

The deep aquifer exceeds the radium and gross alpha regulations. While drinking water regulations can be met with proper treatment, if there is a malfunction in the treatment process or if new contaminants appear, the public may be exposed to these contaminants. One of Waukesha's deep wells has already been contaminated from outside sources in recent years and shut down, and another deep well has been shut down due to potential contamination from a nearby landfill. Similar contamination may occur in the future requiring abandoning the wells or installing expensive treatment. The deep wells are mainly located within City limits, so there are numerous sources of contamination present.

In addition, the deep groundwater is high in TDS, mainly from calcium, magnesium, carbonates, chlorides and sulfate. Home softening takes out calcium and magnesium, but adds sodium. Sodium has been identified as an item to limit if you have certain health conditions such as heart disease. The shallow groundwater is also high in TDS.

Shallow aquifers are more susceptible to contamination than deep confined aquifers and large surface water bodies. Without a confining layer, the porous sand and gravel of shallow aquifers can quickly pass contaminants into the drinking water. Preventing a potential source of contamination (i.e., industry, gas station) from locating near the wellfield is difficult, particularly when the wellfield is located outside of a municipality's borders. The proposed shallow wellfield here will be located outside of the City limits, and, as a result, the City would have limited zoning control to enforce a wellhead protection ordinance to protect the well. A wellhead protection program is required by WDNR to protect municipal wells from contamination. Buying large tracts of land or trying to influence land use zoning around the wellfield is possible, but costly and the effectiveness is uncertain.

Arsenic was recently detected in a future shallow aquifer wellfield site near Waukesha. The future shallow wells may exceed arsenic regulations and would require treatment. In addition, City pumping of wells located in the shallow could impact private wells. Private wells may run dry or encounter water quality problems due to additional shallow aquifer pumping. If this should occur, new wells or deeper wells would be needed. Exhibit 4-5 shows the number of pri-

vate wells that may be affected by a shallow wellfield. Private wells are often located near septic systems. These septic systems could be another source of contamination such as pathogenic microorganisms or nitrate, in situations where groundwater pumping pulls the contaminants towards the well.

With the Lake Michigan proposal, the deep aquifer would no longer be used and the potential public exposure to radionuclide and other contaminants would be eliminated. In addition, water resources, private wells and municipalities on groundwater near Waukesha would not be affected if Waukesha obtains a Lake Michigan water supply. Home softening would no longer be needed, and the water would contain much less sodium and TDS than a groundwater supply, making it healthier to consume. A Lake Michigan potable water supply is more protective of public health than the current water supply.

Considering the public health impacts of Alternative 1, a rating of "moderate adverse impact" was applied.

Implementability

The City's ability to implement Alternative 1, which requires the installation of 14 new shallow wells, would be difficult for several reasons.

First, Waukesha is part of a groundwater management area, and as a result, more requirements and restrictions could be placed on groundwater development. Additionally, groundwater protection legislation has been recently introduced (on March 12, 2010). The legislation would require environmental review of proposed high capacity wells located in a groundwater management area before WDNR approves or develops a groundwater management plan for the area.

Second, the shallow aquifer wellfield would be installed outside the City's boundaries. Significant land purchase/lease and controls outside the city limits would be required. Residents near the shallow aquifer wellfield have opposed high-capacity wells because of concerns about adequate water supply and impacts to wetlands, private wells, and other environmental resources.

Installation of wells in the unconfined aquifer may create legal challenges and expose the City to numerous damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. The City, for example, could be liable if its withdrawal of water causes unreasonable harm through lowering the water table for residential and municipal wells in the area. The City could also be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels).

If new wells need to be installed in the future because of declining water levels in existing wells or the need to locate wells farther from surface water resources, wells may need to be located a greater distance from Waukesha. Locating wells further from Waukesha would increase costs, energy usage, and legal/public concerns. The environmental and legal impacts described above would become more severe.

If the new shallow wells can be built, a new water treatment plant would be required to remove iron, manganese, arsenic and microorganisms. If new contaminants are discovered, additional treatment would need to be constructed. A new pump station and transmission pipes are required to convey the treated water to the Hillcrest reservoir in Waukesha and throughout the City. The water treatment plant would be located outside the City limits and require land purchase or lease. The new wells, water plant, and pump station would require ongoing operation and maintenance.

Water transmission mains would need to be constructed from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha. This would require easements, and construction through rural and urban conditions.

Additional treatment for the water still pumped from the deep aquifer would result in significantly increased operation and maintenance requirements. If TDS is removed with reverse osmosis (RO) treatment, it would consist of pretreatment to condition the water, RO treatment with membranes, aeration to remove dissolved gases, and chemical addition for corrosion control and disinfection. It is assumed that the concentrated waste brine and chemical cleaning waste solution can be discharged to the sewer. This may cause TDS increases in the wastewater plant influent. In addition, residential housing would need to be bought and demolished to make room for the treatment facilities at the three well sites. This may require legal condemnation procedures.

Some of the deep aquifer water supply would be softened by RO, but the shallow aquifer supply would still be hard. Blending the different waters before distribution would be required to mitigate water quality issues (red water, corrosion) that could lead to customer complaints. However, this requires additional piping in the water distribution system to blend waters from different sources.

Considering the implementability of Alternative 1, a rating of "significant adverse impact" was applied. Exhibit 4-7 summarizes the criteria for Alternative 1.

EXHIBIT 4-7
Water Supply Evaluation: Alternative 1

Water Supply Alternative	Environmental Impact	Long-term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◉	●

○ No adverse impact
⊙ Minor adverse impact
◉ Moderate adverse impact
● Significant adverse impact

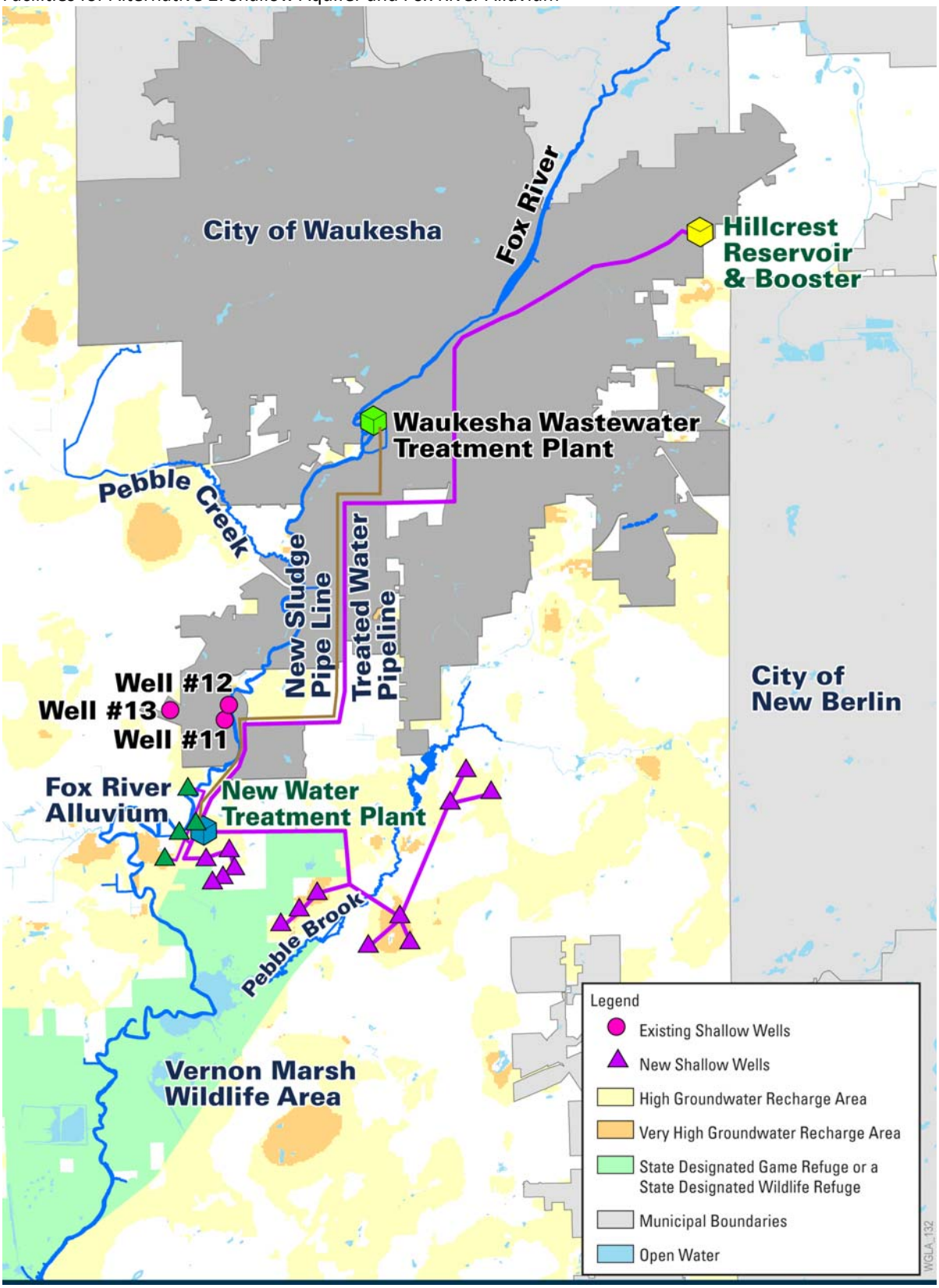
Water Supply Alternative 2: Shallow Aquifer and Fox River Alluvium

Alternative 2 uses the shallow aquifer south of Waukesha for Waukesha's entire water supply. The future average annual water usage would be 10.9 mgd based on water demand projections (Section 3). To meet a future maximum day demand of 18.5 mgd, infrastructure would be built for 4.5 mgd of firm capacity through 4 new wells along the Fox River south of Waukesha, in what is called the Fox River alluvium. Another 12.8 mgd firm capacity would be obtained through 14 new wells in the Troy Bedrock Valley south of Waukesha and adjacent to Vernon Marsh. The remaining 1.2 mgd firm capacity would be obtained from Waukesha's existing shallow wells 11 through 13.

The wells would pump water to a central treatment plant south of Waukesha. The water would be treated for iron, manganese, arsenic and microorganism removal. A pump station and pipelines would convey treated water to the Hillcrest reservoir in Waukesha and through the distribution system. Exhibit 4-8 shows the facilities for Alternative 2.

EXHIBIT 4-8

Facilities for Alternative 2: Shallow Aquifer and Fox River Alluvium



Environmental Impacts

Pumping the shallow aquifer can cause adverse environmental impacts on groundwater and surface water resources (see Alternative 1 discussion). Alternative 2 would have greater adverse environmental impacts than Alternative 1, since almost twice the amount of shallow groundwater would be pumped. The Troy Bedrock Valley aquifer south of Waukesha has several sensitive environmental areas (Vernon Marsh, Pebble Creek). Appendix N, Environmental Report, contains additional information on environmental impacts.

For this application, the recently completed Troy Bedrock Valley groundwater model[39] was used to simulate shallow aquifer groundwater drawdown and baseflow reduction for Alternative 2. Although the City may need to extract a maximum day pumpage of 18.5 mgd from the shallow aquifer occasionally, only the annual average well pumpage of 10.9 mgd was modeled to simulate a future average day water demand. The results on groundwater drawdown are shown in Exhibit 4-9.[40] The results show significant shallow aquifer drawdown (105 feet) near the wells. Water levels would also be lowered in a large portion of the Vernon Marsh and near Pebble Brook. A groundwater drawdown of 1 foot is significant in a wetland as it may affect root structures of aquatic plants. The model estimated that base flow would be reduced 346 percent to the Fox River and 58 percent to Pebble Brook in this alternative. This would have very significant adverse environmental impacts to the water ecosystems and is not sustainable.

Drawdown in the shallow aquifer can be reduced by spreading more wells out over a larger area and reducing the capacity of each well. Exhibit 4-10 shows the groundwater drawdown if the number of shallow wells increases from 12 to 28 and the wellfield land area is nearly doubled.

Although this reduces the drawdown from a maximum of 105 to 55 feet, there is a larger area affected by reduced groundwater levels. Base flow reduction decreases from 346 percent to 156 percent in the Fox River, but increases in the other resources as shown below.[41] Spreading the wells over a larger area and reducing the pumping from each well still would have a very significant adverse impact on the baseflow to sensitive wetlands and streams.

Resource	Baseflow Reduction (%) from pumping 28 shallow wells for a total of 10.9 mgd
Fox River	156
Pebble Brook	82
Vernon Marsh	51
Mill Brook	94
Pebble Creek	10

This modeling of the shallow aquifer shows that development of a wellfield for a City the size of Waukesha would be very difficult from an environmental impacts standpoint.

[39] Ruekert & Mielke, for SEWRPC. January 2010. Troy Bedrock Valley Aquifer Model. Memorandum Report Number 188. Reviewed by Dr. Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey.

[40] RJN Environmental Services, LLC. Results of Groundwater Modeling Study Shallow Groundwater Source, Fox River & Vernon Marsh Area. March, 2010. Reviewed by Dr. Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey.

[41] Ibid.

EXHIBIT 4-9

Groundwater Drawdown: Alternative 2 with 12 Wells Pumping, 10.9 mgd

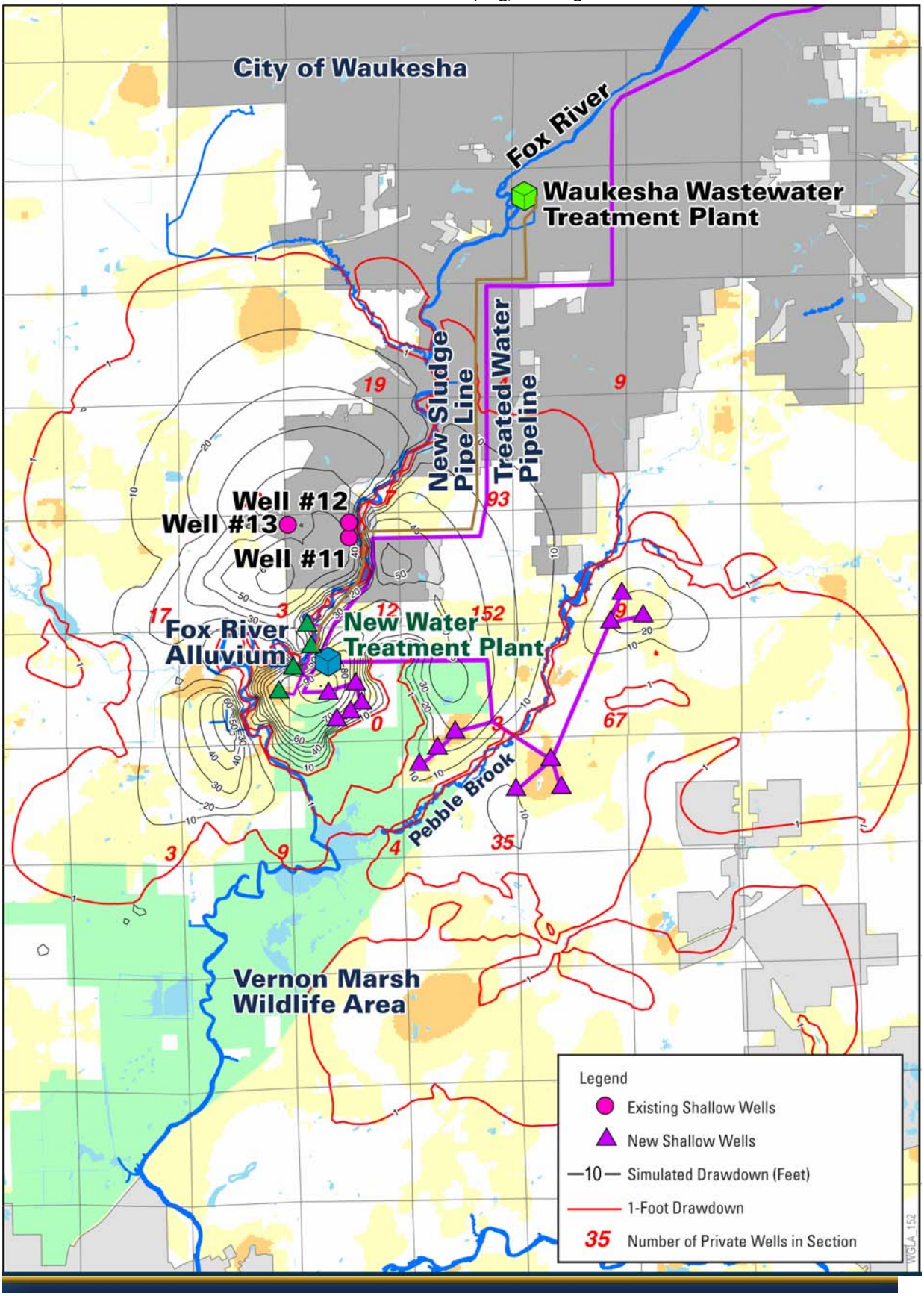
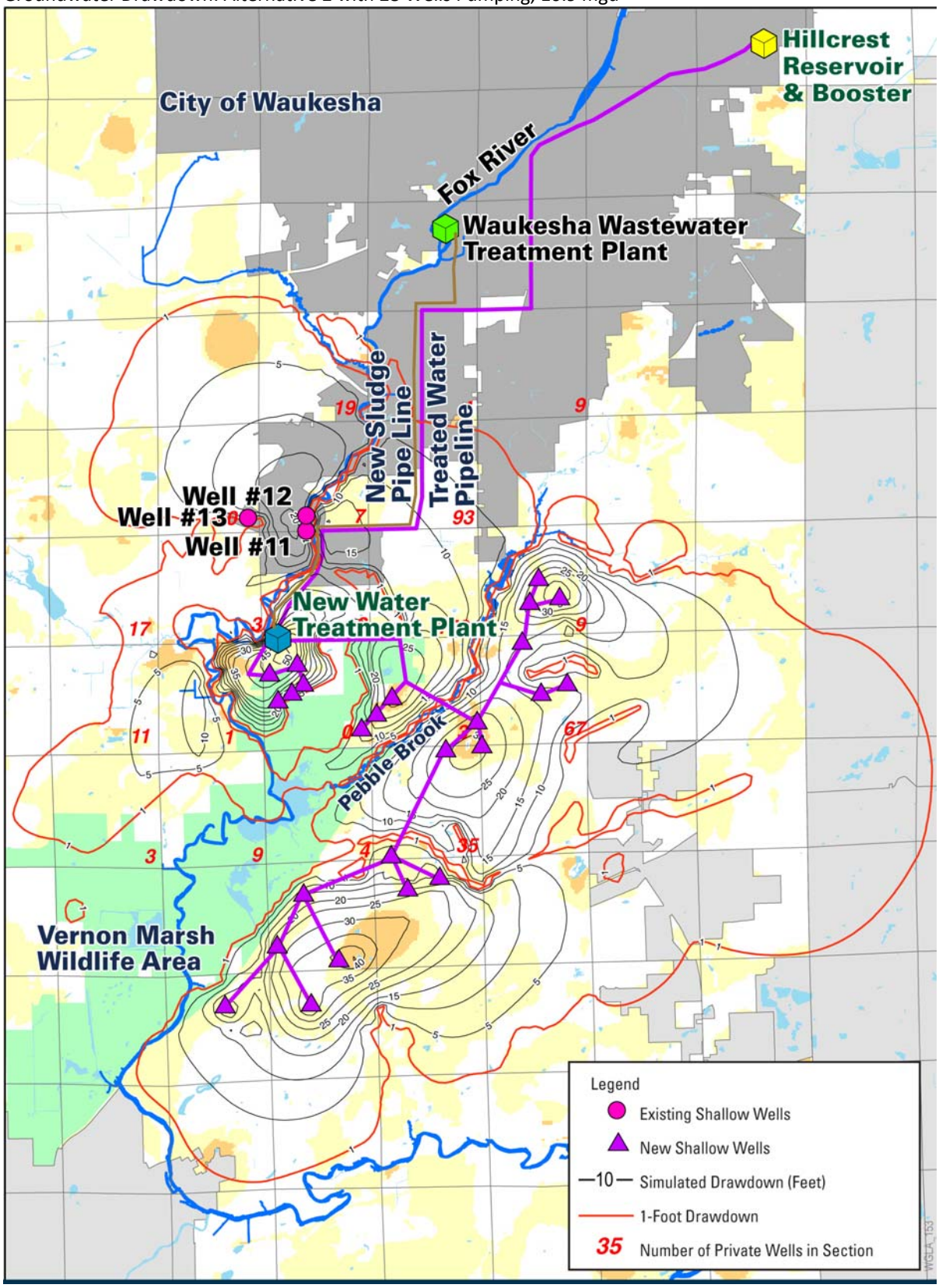


EXHIBIT 4-10

Groundwater Drawdown: Alternative 2 with 28 Wells Pumping, 10.9 mgd



On a much smaller scale, the Village of Mukwonago installed a single shallow groundwater well in the southern area of the Vernon Marsh wildlife area and monitored the effects to a nearby marsh and calcareous fen, a rare Wisconsin wetland. According to the WDNR, the well appears to have created a cone of depression that is affecting the fens, along with the endangered plant species that depend on the groundwater supply.[42, 43] The long-term impacts of pumping this well are being evaluated by WDNR.

A benefit of Alternative 2 is that Waukesha's deep aquifer pumpage would be eliminated, and therefore deep aquifer water levels would increase under Waukesha. The amount of the actual increase in water levels in the deep aquifer would depend on how many other communities continue to use it. If enough communities reduce deep aquifer pumping, increasing deep aquifer levels would have an environmental benefit.[44, 45, 46]

If shallow groundwater is used as the City's water source, return flow would not remain in the region. Instead, treated wastewater would be discharged to the Fox River and transferred out of the Great Lakes and Mississippi River ecosystem, eventually discharging to the ocean (Exhibit 4-6). This would result in less water in the Great Lakes and Mississippi River watersheds and associated adverse environmental impacts.

If shallow groundwater is used, customers would continue to use home water softeners as shallow groundwater is hard. Adverse environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) are similar to those under Alternative 1.

In order to use the shallow aquifer wellfield, the City would be required to construct water transmission mains from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha. This construction would have environmental impacts as discussed in Appendix N.

Alternative 2 would discharge 19,000 tons of greenhouse gases (carbon dioxide equivalent) annually through pumping from aquifers, water treatment, and pumping from the wellfield to Waukesha.

Considering the environmental impacts of Alternative 2, a rating of "significant adverse impact" was applied. Water supply Alternative 2, Shallow Aquifer and Fox River Alluvium, has greater adverse environmental impacts than the proposed diversion.

Long-Term Sustainability

This alternative relies on multiple wells spread out over a large area. All wells would draw from the same aquifer. Relying upon one aquifer is less reliable than relying upon two aquifers as Alternative 1 does.

The shallow aquifer is dependent on rainwater for recharge and is less reliable during drought conditions, when water supply is needed most. Given the modeling of the shallow aquifer con-

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42 Letter to City of Waukesha Common Council from Brian Glenzinski, Vernon Marsh Wildlife Area Property Manager, WDNR. July 18, 2006.

43 Lisa Gaummitz, T. Asplund, and M. R. Matthews. June 2004. "A Growing Thirst of Groundwater." Wisconsin Natural Resources.

44 http://wi.water.usgs.gov/glpf/cs_pmp_src.html.

45 SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

46 Douglas Cherkauer. 2009. *Groundwater Budget Indices and their Use in Assessing Water Supply Plans for Southeastern Wisconsin,* Technical Report 46, Preliminary Draft. Department of Geosciences, University of Wisconsin—Milwaukee.

ducted at average day conditions, it is unlikely that this shallow aquifer could provide the City's maximum water demand during a drought. Furthermore, the adverse impacts of groundwater drawdown and baseflow reduction at average day water demand conditions as demonstrated by the model would be worse in a drought situation. Pumping the shallow aquifer for the City's maximum water demand during a drought could result in severe adverse impacts to the environment.

Treatment requirements for the shallow aquifers would also reduce the amount of water available to customers because the treatment requirements would require water and produce waste streams. However, the waste streams would only be about 2 to 3 percent of pumped water, much less than the TDS removal treatment in Alternative 1. Treatment of all the water supply in one treatment plant would reduce operation and maintenance efforts and costs compared to the multiple treatment plants in Alternative 1, but reduce reliability because there is only one treatment plant.

Considering the long-term sustainability of Alternative 2, a rating of "significant adverse impact" was applied.

Public Health

Shallow aquifers are more susceptible to contamination than deep confined aquifers and large surface water bodies. Contaminants may be undetected for some time, exposing the public to health risks. Proper drinking water treatment can meet regulations as long as new contaminants are known before the water treatment plant is designed. If new contaminants are undetected or there is a malfunction in the treatment process, contaminants may be exposed to the public.

In addition, the Fox River alluvium may have exposure to additional contaminants from the Fox River. The Fox River is listed as impaired for PCBs[47] and is known to contain compounds that may be regulated in the future such as endocrine disrupters.

WDNR requires a wellhead protection program to protect municipal wells from contamination. Waukesha would have no zoning control to enforce the wellhead protection ordinance because the shallow wellfield is outside the City limits. Preventing a potential source of contamination such as a gas station or industry from locating near the wellfield will be difficult without owning the land. Buying large tracts of land or influencing land use and zoning on surrounding properties is possible, but costly and the effectiveness is uncertain.

Other wells in the influence of the new wellfield may run dry or encounter water quality problems due to additional shallow aquifer pumping. Exhibit 4-10 shows the number of private wells that may be affected by a shallow wellfield. Private wells are associated with septic systems as well. These septic systems under the influence of a wellfield cone of depression could be sources of contamination such as pathogenic microorganisms or nitrate.

Groundwater is high in TDS, mainly from calcium, magnesium, carbonates, chlorides and sulfate. Home softening takes out calcium and magnesium, but adds sodium. Sodium has been identified as an item to limit if people have certain health conditions such as heart disease.

Under Alternative 2, the deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants would be eliminated.

Considering the public health impacts of Alternative 2, a rating of "moderate adverse impact" was applied.

[47] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html

Implementability

For the Troy Bedrock Valley and Fox River alluvium wellfields, significant land purchase/lease and controls outside the city limits would be required. Local residents have opposed high-capacity wells because of concerns about adequate water supply and impacts to wetlands, private wells, and other environmental resources. Installation of wells an unconfined aquifer may create legal challenges and expose the City to damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. The City, for example, could be liable if its withdrawal of water causes unreasonable harm through lowering the water table for residential and municipal wells in the area. The City could also be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels).

Because the Waukesha area is part of a groundwater management area, more requirements and restrictions could be placed on groundwater development. Additionally, groundwater protection legislation has been recently introduced in Wisconsin by the relevant committee chairs (on March 12, 2010). The legislation would require environmental review of proposed high capacity wells in a groundwater management area before WDNR approves or develops a groundwater management plan for the area.

The legal issues with siting new wells and impacting other entities discussed in Alternative 1 would be much greater in Alternative 2 because the City would be installing nearly twice as many wells and they would cover a larger land area. This land is outside the Waukesha municipal boundaries. A new water treatment plant, pump station, and transmission pipes would be required to convey the treated water to the Hillcrest reservoir in Waukesha and through the distribution system. The treatment plant would be located outside the City limits and require land purchase or lease. The new wells, water plant, and pump station would require additional operations and maintenance. Water transmission mains from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha would require, easements, and construction through rural and urban conditions.

Treatment of all the water supply in one treatment plant would reduce operation and maintenance efforts and costs compared to the multiple treatment plants in Alternative 1, but reduce reliability because there is only one treatment plant.

If well capacity decreases due to declining water levels or wells need to be located a greater distance from surface water resources, wells may need to be located a greater distance from Waukesha, which would increase costs, energy, and public concerns. The environmental and legal impacts described above would still be present, and may increase.

Considering the implementability of Alternative 2, a rating of "significant adverse impact" was applied. Exhibit 4-11 summarizes the criteria for water supply Alternatives 1 and 2.

EXHIBIT 4-11
Water Supply Evaluation: Alternatives 1 and 2

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●

○ No adverse impact
⊙ Minor adverse impact
◎ Moderate adverse impact
● Significant adverse impact

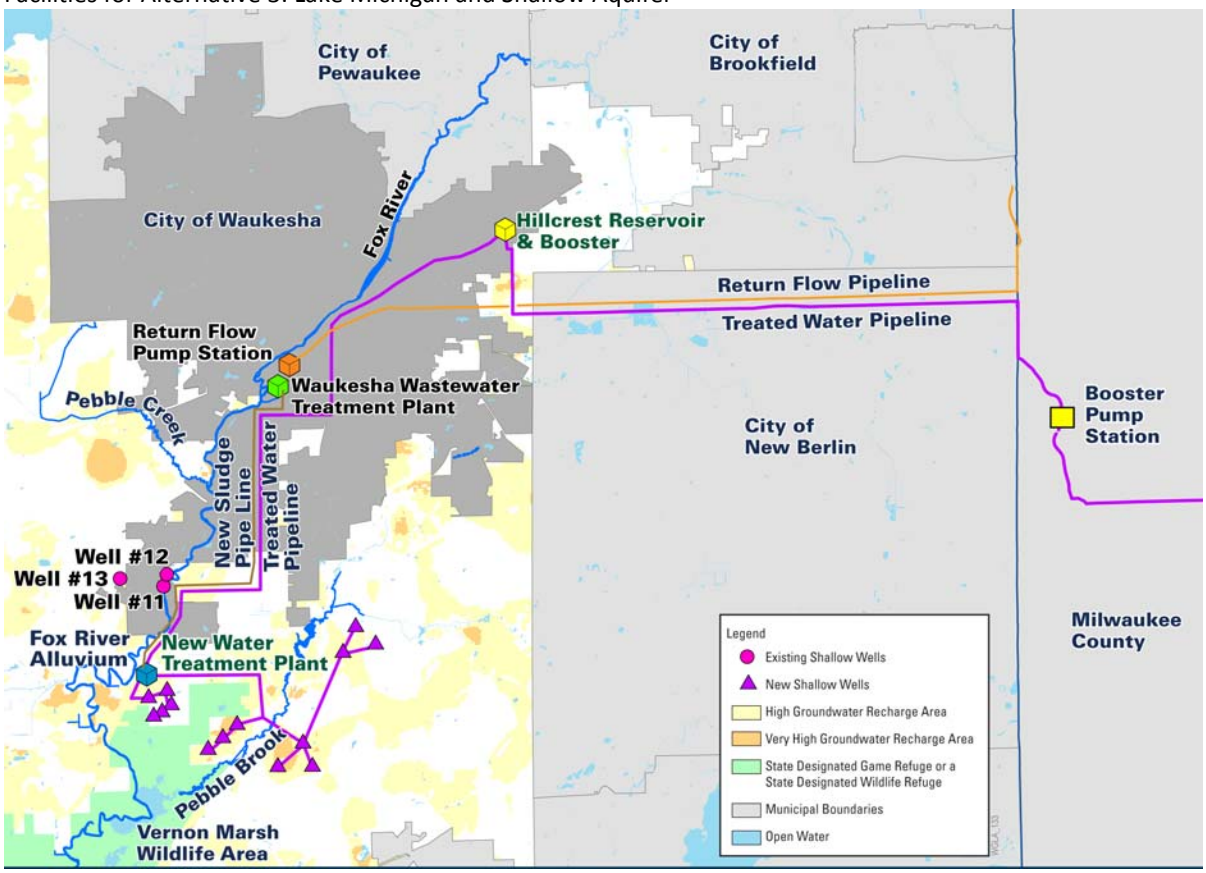
Water Supply Alternative 3: Lake Michigan and Shallow Aquifer

Alternative 3 consists of obtaining about 40 percent the City's required potable water (4.5 mgd average day demand, 7.6 mgd maximum day demand) from a Lake Michigan water utility and the other 60 percent (6.4 mgd average day demand, 10.9 mgd maximum day demand) from the shallow aquifer in the Mississippi River Basin. The shallow aquifer supply quantity is the same as in Alternative 1. This amount of shallow aquifer water caused significant adverse environmental impacts on water resources, so using a higher amount of shallow aquifer water and less Lake Michigan water was not deemed reasonable for the purposes of this alternative. A slightly higher or lower amount of shallow aquifer water would not significantly change the results of this alternative analysis.

The Lake Michigan supply would be conveyed to Waukesha through a transmission pipeline and booster pump station to the Hillcrest reservoir in Waukesha. Additional distribution system piping would convey water through the City. Water used by Waukesha would be returned to the Lake Michigan watershed via Underwood Creek.

The supply from the shallow aquifer would be provided by existing and new wells. Existing shallow wells 11 through 13 would provide firm capacity for 1.2 mgd. The remaining 9.7 mgd would come from 14 wells in the Troy Bedrock Valley south of Waukesha. These wells would be combined into a central water treatment plant and the treated water pumped to the Hillcrest reservoir in Waukesha for blending with Lake Michigan water. The facilities are shown in Exhibit 4-12.

EXHIBIT 4-12
Facilities for Alternative 3: Lake Michigan and Shallow Aquifer



Environmental Impacts

Current and future adverse environmental impacts of pumping the shallow aquifer would be the same as Alternative 1. Groundwater drawdown would negatively affect sensitive and valuable environmental areas such as Pebble Brook, Pebble Creek, and Vernon Marsh, and the reduction in baseflow to these water resources would negatively impact ecosystems.

Home water softening would continue because shallow groundwater is two to three times as hard as Lake Michigan water. Blending the two waters will reduce the hardness, but hardness will still be relatively high and a significant reduction in home softener use is not anticipated. The adverse environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) would remain.

It is estimated that Alternative 3 would discharge 17,000 tons of greenhouse gases per year (carbon dioxide equivalent). Greenhouse gases would be produced by the pumping needed to convey water from and back to Lake Michigan. In addition, pumping from the shallow aquifer, treating the water and pumping the water to Waukesha uses energy and produces greenhouse gases. This alternative produces more greenhouse gases than the Lake Michigan Alternative 4 (see Exhibit 4-14).

Water transmission mains from a Lake Michigan supplier to Waukesha, the booster pump stations, and return flow pipelines from the Waukesha wastewater plant to Underwood creek would have environmental impacts during construction (see Appendix N). Existing utility corridors would be used for pipeline routing where possible to minimize environmental impacts. Developing the shallow aquifer wellfield, pipelines, treatment plant and pump station would also have environmental impacts during construction.

Considering the environmental impacts of Alternative 3, a rating of “significant adverse impact” was applied. Water Supply Alternative 3, Lake Michigan and Shallow Aquifer, has greater adverse environmental impacts that the proposed diversion.

Long-Term Sustainability

Lake Michigan as a drinking water source for Waukesha provides adequate quantity, high-quality, and long-term reliability indefinitely by allowing water to be recycled to its source. Alternative 3 also restores the hydrologic conditions and functions of the source watershed by stopping deep aquifer pumping and restoring flow toward, rather than away from Lake Michigan.

Lake Michigan water is much more resistant to drought conditions than groundwater. During a drought Waukesha could rely more on Lake Michigan and less on the shallow aquifer, increasing reliability. The infrastructure needed to provide Lake Michigan water is similar to Alternative 4, with the main difference being a smaller pipe. In addition, a shallow aquifer wellfield, treatment plant, pump station and pipeline are needed. Waukesha would have to maintain not only the Lake Michigan supply, but also the shallow aquifer supply. Blending the two waters would require attention to water chemistry so customers are receiving consistent water quality and distribution system corrosion is minimized.

Considering the long-term sustainability of Alternative 3, a rating of “moderate adverse impact” was applied.

Public Health

Treated Lake Michigan water is high quality and safe. Millions of people are provided with drinking water from Lake Michigan. Contamination is possible, as with all supplies, but the large

size and high quality of Lake Michigan makes this a rare occurrence. Lake Michigan water suppliers have some of the most stringent water quality programs and advanced treatment processes to assure high quality water.

The deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants is eliminated.

The contamination and wellhead protection issues with the shallow aquifer remain (see Alternative 1). Private wells will be affected by the shallow aquifer pumping and septic systems may contribute contaminants into the water supply. However, if a contamination issue should occur, Waukesha could rely more on the Lake Michigan water supply.

Home softening would still be needed, so the increased sodium and TDS would still be present.

Considering the public health impacts of Alternative 3, a rating of "minor adverse impact" was applied.

Implementability

Alternative 3 still requires an agreement with a Lake Michigan water supplier to provide water, and approval from the Governors of the Great Lakes states under the terms of the Compact. Since a large portion of Waukesha's water supply would come from shallow groundwater and be blended with Lake Michigan water, minimizing out of Basin return water to comply with section 4.9.3(b) of the Compact would not be possible. This would apply even if a much smaller amount of groundwater were used with a Lake Michigan water supply.

A Lake Michigan supply will have the same issues and requirements of pipeline routing studies, easements, land purchase and construction through rural and urban conditions.

Land purchase and easement requirements for the shallow aquifer supply would be similar to Alternative 1. Land use and legal issues for wellhead protection, well and treatment plant siting remain. Public concerns over impacts to groundwater levels and long-term wetland impacts are also still present.

In Alternative 3, Waukesha would operate and maintain the Lake Michigan supply in addition to the shallow aquifer wellfield, treatment plant and pumping/pipelines. This will make operation and maintenance of the water utility more complex than that of a Lake Michigan alternative.

Considering the implementability of Alternative 3, a rating of "significant adverse impact" was applied. Exhibit 4-13 summarizes the criteria for water supply Alternatives 1, 2, and 3.

EXHIBIT 4-13

Water Supply Evaluation: Alternatives 1, 2, and 3

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●
Lake Michigan and shallow aquifers	●	◎	⊙	●

○ No adverse impact
⊙ Minor adverse impact
◎ Moderate adverse impact
● Significant adverse impact

Using the deep aquifer with Lake Michigan water instead of the shallow aquifer will have similar results and impacts. However, since the deep aquifer will continue to be pumped, the benefit of increasing water levels and restoration of the natural groundwater flow toward Lake Michigan will not be realized. In addition, the old deep wells are less reliable. The wells are 30 to 75 years old and have some of the largest pumps of their kind which have to be custom built. If a failure occurs with the pumping equipment, it could be many months before repairs can be made. This situation has occurred on Waukesha's well 10 recently. The deep wells also have more water quality issues than new shallow wells with treatment. Radium treatment facilities will be over half their expected life when a Lake Michigan supply is finished, and will require replacement in the near future. Additional treatment for TDS removal in the future will be a large expense in both capital and operating costs (See Alternative 1). Other issues with using the deep aquifer for a portion of Waukesha's water supply are explained in the Alternative 1 description. For these reasons, a Lake Michigan and deep aquifer supply alternative was not developed in detail.

Combinations of Water Supply Sources

In general, water utilities rarely have more than two primary water supply sources. A main principal of public drinking water supply is to obtain the water supply source with the highest quality and most reliability. If this water supply does not have adequate quantity, the next highest quality water supply source is obtained. Using multiple sources of water is possible when necessary, but increases costs along with operational and maintenance complexity. Impacts to the environment can increase if unsustainable sources are tapped, and public health protection can decrease if lower quality water sources are used.

For example, a quarry north of Waukesha was evaluated as a potential water source, but screened out due to inadequate capacity (2 mgd) and contamination concerns.[48] Using this 2 mgd quarry capacity to supplement a deep and shallow aquifer supply instead of obtaining an additional 2 mgd from the shallow aquifer would actually increase the capital cost significantly because of the addition of a new water intake, treatment plant and piping. Under this example, having three sources of water (deep aquifer, shallow aquifer, quarry) instead of two (deep and shallow aquifer) would increase costs and operational complexity, and also increase risk to public health by using a poorer quality water source.

Water Supply Alternative 4: Proposal to Use Lake Michigan Water

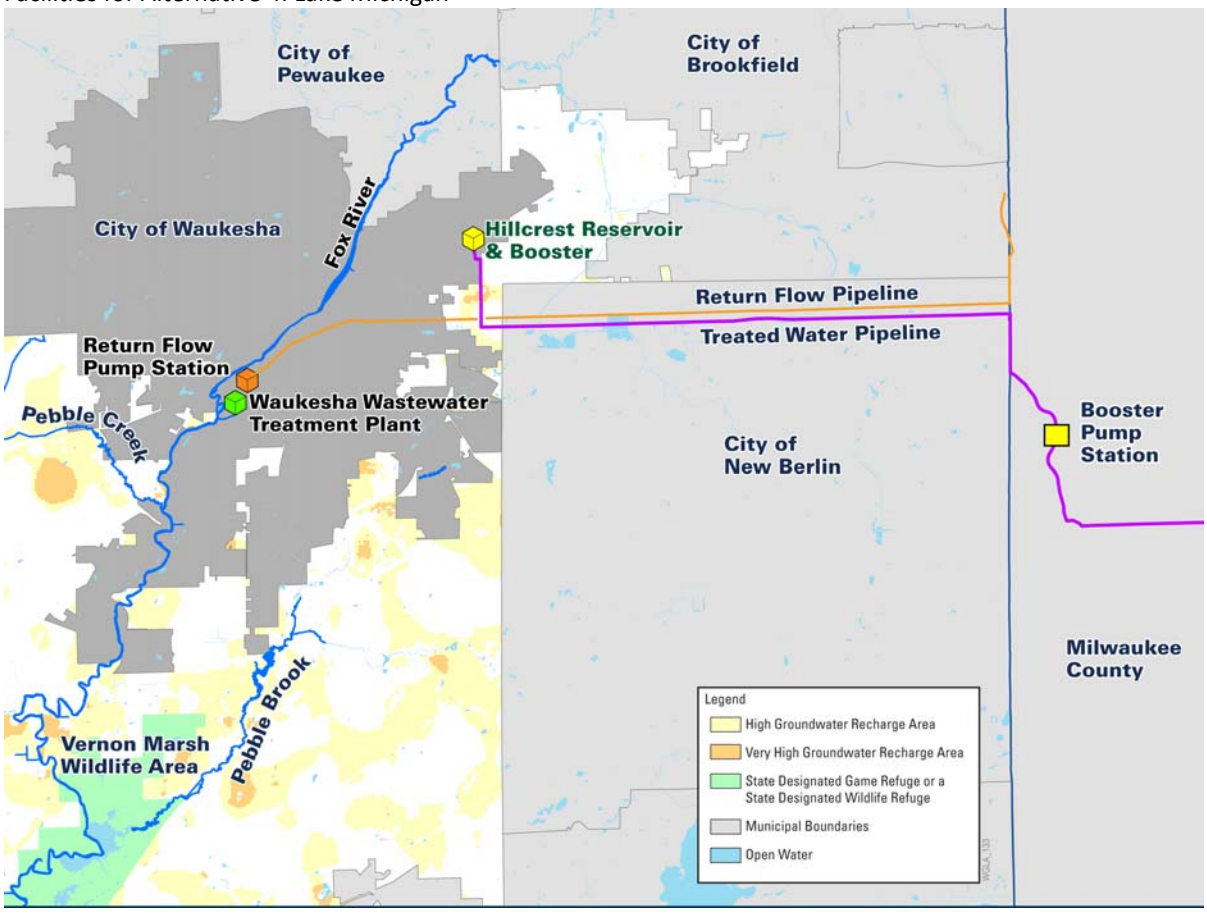
"If a person who applies under subd. 1 will not directly withdraw the water proposed to be diverted, the person shall identify any entities that may withdraw the water and provide evidence of support from each of those entities in the form of a letter or resolution." Wis. Stat. § 281.346(4)(b)4m.

The City is discussing the purchase of potable water from Lake Michigan with the City of Milwaukee, the City of Oak Creek, and the City of Racine. Milwaukee, Oak Creek and Racine are all located within the Great Lakes Basin, and they all operate public water utilities that withdraw water from Lake Michigan. All three have submitted letters or resolutions indicating a willingness to negotiate an agreement for the sale of water. See Appendix P.

"The diversion will result in no significant adverse individual impacts or cumulative impacts to the quantity or quality of the waters of the Great Lakes basin or to water dependent natural resources, including cumulative impacts that might result due to any precedent-setting aspects of the proposed diversion, based upon a determination that the proposed diversion will not have any signifi-

[48] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*

EXHIBIT 4-14
Facilities for Alternative 4: Lake Michigan



cant adverse impacts on the sustainable management of the waters of the Great Lakes basin." Wis. Stat. 281.346(4)(f)5.

This application seeks authority to obtain water supply from Lake Michigan. The City seeks to obtain treated potable drinking water from a Lake Michigan water utility, and convey it to Waukesha through a transmission pipeline and booster pump station to the Hillcrest reservoir in Waukesha (Exhibit 4-14). This application seeks to withdraw 10.9 mgd of water on a future average day, and 18.5 mgd on a future maximum day; the same as the other alternatives. Water used by Waukesha would be returned to the Lake Michigan watershed.

To estimate infrastructure requirements and costs, Alternative 4 assumes connection to Milwaukee's water system at a large transmission main near 60th Street and Howard Avenue. Milwaukee is the closest Lake Michigan water utility to Waukesha and has excess capacity to provide water. Other options for a Lake Michigan water supply include the Cities of Oak Creek or Racine. The Lake Michigan water supplier would be determined after negotiations with the various cities.

There are several options for a return flow pipeline, all starting at the Waukesha wastewater treatment plant with a pump station. Discharge location options include Underwood Creek, Root River, and Lake Michigan through an outfall. The Underwood Creek location has the shortest distance and is the preferred alternative.

Environmental Impacts

"The proposal will not endanger the integrity of the Great Lakes basin ecosystem based upon a determination that the proposal will have no significant adverse impact on the Great Lakes basin ecosystem." Wis. Stat. § 281.346(4)(e)1.e.

If Lake Michigan water is obtained, the City would cease pumping the deep aquifer and groundwater levels would begin to increase. Using the Southeastern Wisconsin Regional Groundwater Model and assuming Waukesha stops pumping from the deep aquifer, the deep aquifer cone of depression may recover 100 feet over time.[49] SEWRPC estimates deep aquifer water levels could rise as much as 270 feet if deep aquifer pumping ceased in several communities, including Waukesha.[50] Ceasing deep aquifer pumping in northeastern Illinois allowed water levels to rise 300 feet between 1980 and 2000 at Villa Park and Elmhurst, Illinois.[51] Similar aquifer recovery is becoming evident near Green Bay, Wisconsin, where Brown County water utilities stopped pumping the deep aquifer and started using Lake Michigan water.

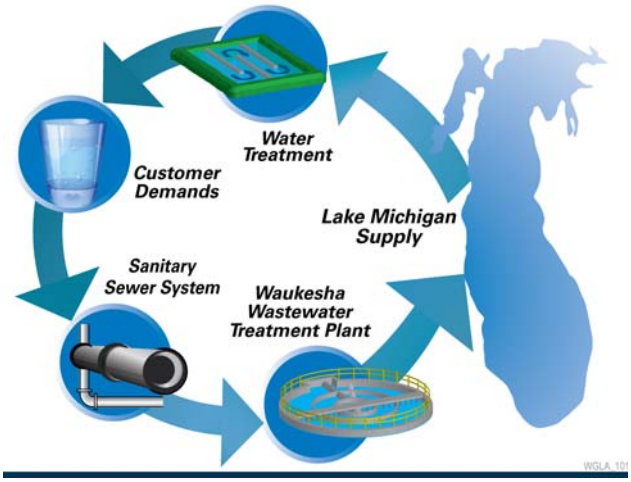
Increasing deep aquifer water levels would result in an environmental benefit because more water would be provided to the waters and water dependant natural resources of the Lake Michigan Basin.[52] A 2003 study concluded that ceasing groundwater pumping from Waukesha's deep wells would have a beneficial effect on streams and wetlands and help restore the natural flow regimes toward, rather than away from Lake Michigan.[53] This has a significant benefit to the waters and water dependent natural resources of the Lake Michigan Basin. Another conclusion was that withdrawing the amount of water Waukesha needs from Lake Michigan would have an unmeasurable effect on the ecosystem.

In addition, water sent to Waukesha is returned to Lake Michigan (Exhibit 4-15). This preserves the waters and water dependent natural resources of the Lake Michigan Basin and protects the integrity of the Great Lakes ecosystem. There is no measurable impact on Lake Michigan water quantity.[54]

In contrast, a groundwater supply alternative diverts water from the region.

Current and future adverse environmental impacts of pumping deep and shallow groundwater and reducing baseflows would be eliminated, thus protecting sensitive and valuable environmental areas such as Pebble Brook, Pebble Creek, and Vernon Marsh.

EXHIBIT 4-15
Lake Michigan Water Cycle



[49] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[50] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

[51] S. L. Burch. 2002. *A Comparison of Potentiometric Surfaces for the Cambrian-Ordovician Aquifers of Northeastern Illinois, 1995 and 2000.* Illinois State Water Survey Data/Case Study 2002-02.

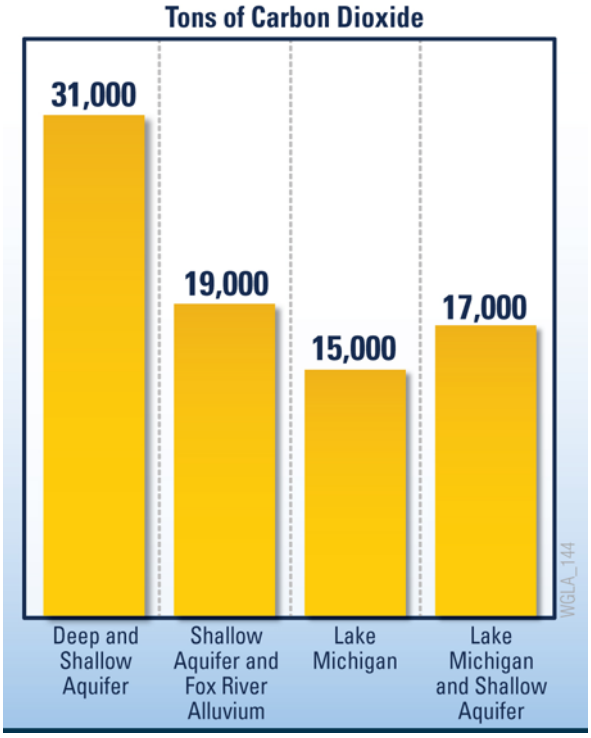
[52] D.T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?* http://wi.water.usgs.gov/glpf/index.html

[53] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply*.

[54] Ibid.

Another benefit of using Lake Michigan water is that it is two to three times softer than groundwater and customers do not need home water softeners. The adverse environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) could be eliminated under Alternative 4.

EXHIBIT 4-16
Greenhouse Gas Emissions from Water Supply Alternatives



It is estimated that Alternative 4 would discharge 15,000 tons of greenhouse gases per year (carbon dioxide equivalent) through pumping from Milwaukee and returning the water to the Great Lakes Basin. This is less than the deep and shallow aquifer alternatives (Exhibit 4-16). Using the Lake Michigan alternative would save enough electricity to power about 1,600 homes for a year compared to the current water supply sources (Alternative 1).[55]

Water transmission mains from a Lake Michigan supplier to Waukesha, the booster pump stations, and return flow pipelines from the Waukesha wastewater plant to Underwood Creek would have environmental impacts during construction (see Appendix N, Environmental Report). However, existing utility corridors would be used for pipeline routing where possible to minimize environmental impacts.

A diversion must be implemented so as to ensure that it will result in no significant adverse individual impacts or cumulative impacts to the quantity or quality of the waters and water dependent natural resources of the basin, including cumulative impacts that might result due to any precedent-setting aspects of the proposal, based upon a determination that the proposal will not have any significant adverse impacts on the sustainable management of the waters of the Great Lakes basin. Reference: Compact Article 4, Section 4.9.4.d.; Wis. Stat. §§ 281.346(4)(f)5.

"Cumulative impacts" is defined as "the impacts on the Great Lakes basin ecosystem that result from incremental effects of all aspects of a withdrawal, diversion, or consumptive use in addition to other past, present, and reasonably foreseeable future withdrawals, diversions, and consumptive uses regardless of who undertakes the other withdrawals, diversions, and consumptive uses, including individually minor but collectively significant withdrawals, diversions, and consumptive uses taking place over a period of time. Wis. Stat. § 281.346(1)(g); See also Compact, Article 1.

The proposed diversion as implemented will have individual or cumulative impacts on the quantity or quality of the waters and water dependent natural resources of the Basin. However, the proposed diversion is anticipated to have a significant positive impact on the quantity and quality of the waters and water dependent natural resources.

The City proposes to use Lake Michigan for its water supply source. After use and treatment, the City would return the water to the basin. As a result of switching to a Lake Michigan source of

[55] US Energy Information Administration. http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home

water, the City would discontinue its use of groundwater from the deep aquifer. Discontinuing the use of groundwater would stop the cumulative adverse impacts identified in the other water supply alternatives discussed in this Section. In preparation for the passage of the Great Lakes Compact, the City participated in a case study that arrived at several critical conclusions about a potential diversion for the City.[56] Chief among these was that changing sources from the current groundwater supply to a withdrawal from Lake Michigan was found to provide an improvement to the groundwater resources of the Great Lakes Basin through ceasing groundwater pumping from the deep aquifer. Further, a Lake Michigan withdrawal has no measureable effect on the Basin ecosystem.[57]

Switching to a Lake Michigan water supply and discontinuing the withdrawal of groundwater from the deep aquifer would benefit the waters of the basin. It would assist in the recovery of both surface water and groundwater resources; assist in the restoration of the natural flow system wherein the deep aquifer feeds the water of the Great Lakes; result in no impact on Lake Michigan water level for the proposed diversion of 10.9 mgd with return flow.

Historically, water from the deep aquifer flowed to Lake Michigan. After groundwater pumping of the deep aquifer began, water from the deep aquifer was drawn down and was not available to feed Lake Michigan. As pumping increased, the flow of groundwater was actually reversed and water that would have otherwise fed Lake Michigan was drawn to the groundwater wells. Now with current pumping practices, waters of the Great Lakes Basin are flowing into the deep aquifer rather than recharging the Lake Michigan Basin. The USGS estimates that 30 percent of the 33 mgd of water currently pumped by the deep aquifer wells in southeastern Wisconsin originates from inside the Lake Michigan Basin.[58] See Section 3, Need for New Water Supply: Deep St. Peter Sandstone Aquifer. Switching from the groundwater supply to a Lake Michigan surface water supply would contribute to aquifer recovery and reduce the diversion of water from the Lake Michigan groundwatershed to the Mississippi River watershed.[59]

Pumping the deep aquifer also pulls down water from the overlaying shallow aquifer to the deep aquifer. It is estimated that 18 percent of shallow aquifer baseflows are diverted toward deep wells and away from surface water resources[60] If pumping of the deep aquifer is stopped, water will no longer be pulled from the shallow aquifer to the deep aquifer, and as a result critical baseflows to surface water resources including wetlands, streams, and lakes, will be restored.

The City's use of Lake Michigan water will also not result in a significant adverse cumulative impact to the water dependent industries of the Great Lakes such as shipping or hydropower generation. The City proposes a goal of providing 100 percent return flow to the basin. On individual days the amount of return flow may be slightly greater than or less than the amount of the withdrawal (the range of flow rates are discussed in Section 5), but over the management period, the City has a goal that the amount of return flow will equal the amount of the withdrawal. By providing 100 percent return flow, there will be no volume change to the Great Lakes Basin and no significant cumulative impact to the water dependent industries of the Great Lakes.

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56 CH2M HILL, Ruekert & Mielke, et al. 2003. *Case Study Report—Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply*, p. ES-5.

57 Ibid.

58 Ibid.

59 S. L. Burch. 2002. *A Comparison of Potentiometric Surfaces for the Cambrian-Ordovician Aquifers of Northeastern Illinois, 1995 and 2000.* Illinois State Water Survey Data/Case Study 2002-02.

60 USGS. Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin

Further, it would prevent radium in wastewater treatment plant sludge from being discharged into the environment, as well as reduce the release of salts used to soften hard groundwater into the environment. Also see Section 5 "Return Flow."

In summary, switching from a groundwater to a Lake Michigan supply would have the following cumulative impacts:

- Assist in the recovery of both surface water and groundwater resources.
- Assist in the restoration of the natural flow system wherein the deep aquifer feeds the Waters of the Great Lakes.
- Eliminate the diversion of water from the Lake Michigan groundwatershed to the Mississippi River Basin.
- Result in no impact on Lake Michigan water level for the proposed diversion of 10.9 mgd with return flow.
- Prevent radium in wastewater treatment plant sludge from being discharged into the environment
- Reduce the release of salts, used to soften hard groundwater, into the environment.

Overall, the City believes a Lake Michigan water supply results in a net environmental benefit compared to using a groundwater supply. This is consistent with SEWRPC's conclusion that the Lake Michigan alternative "offers advantages related to a greater improvement in the deep aquifer long-term sustainability, reductions in chloride discharges to the surface waters, and improvement in groundwater-derived baseflow inputs to the surface water system."[61] The net environmental benefit would therefore not endanger the integrity of the Great Lakes basin ecosystem. Also see further discussion on Return Flow in Section 5.

Considering the environmental impacts of Alternative 4, a rating of "no adverse impact" was applied. There is actually an environmental benefit to the waters and water dependent natural resources of the Lake Michigan Basin because groundwater pumping would be eliminated, and as a result baseflow to surface waters would increase. In addition, there would be less of a need for water softening and salt discharge into the environment would decrease.

Long-Term Sustainability

Lake Michigan would provide Waukesha with an adequate quantity of high-quality water. The water source would provide long-term sustainability indefinitely because the water used would be recycled to its source. Lake Michigan is also a reliable water source because it is much more resistant to drought conditions than groundwater.

Using a Lake Michigan water supply also restores the hydrologic conditions and functions of the source watershed by stopping deep aquifer pumping and restoring flow toward, rather than away from Lake Michigan. This improves the long-term reliability and sustainability of the water resources in the region.

The infrastructure needed to provide Lake Michigan water is less than that for groundwater because no additional treatment or wellfields are needed. Existing treatment and pumping infrastructure from a Lake Michigan suppler would be used. In addition, long term operation and

61 SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Preliminary Draft.

maintenance of pipelines and pump stations are simpler and less expensive than those of wellfields and water treatment plants.

Waukesha would maintain its shallow wells as an emergency backup to the Lake Michigan supply. This will increase reliability.

Considering the long-term sustainability of Alternative 4, a rating of "no adverse impact" was applied.

Public Health

Treated Lake Michigan water is high quality and safe. Millions of people are provided with drinking water from Lake Michigan. Contamination is possible, as with all supplies, but the large size and high quality of Lake Michigan water makes this a rare occurrence. Lake Michigan water suppliers have some of the most stringent water quality programs and advanced treatment processes to assure high quality water.

The deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants is eliminated. Private wells and municipalities on groundwater near Waukesha would not be adversely affected if Waukesha obtains a Lake Michigan water supply because Waukesha would no longer be pumping groundwater. Home softening would no longer be needed, and the water would contain much less sodium and TDS than a groundwater supply, making it healthier to consume. A Lake Michigan potable water supply for Waukesha would be more protective of public health than the groundwater alternatives.

Considering the public health impacts of Alternative 4, a rating of "minor adverse impact" was applied.

Implementability

Alternative 4 requires an agreement with a Lake Michigan water supplier to provide water. Waukesha has letters from three Lake Michigan water utilities willing to negotiate a contract. It would also require approval from the Governors of the Great Lakes States under the terms of the Compact.

Land purchase requirements would be less than a groundwater alternative, because no treatment plant or wellfield are required. Land use issues for wellhead protection, well and treatment plant siting are eliminated. Public concerns over impacts to groundwater levels and long-term wetland impacts are also eliminated.

A new pump station and transmission pipe would be required to convey the treated drinking water to the Hillcrest reservoir in Waukesha. A new pump station and transmission pipe would be required to convey treated wastewater from the wastewater treatment plant to Underwood Creek. The drinking water pump station would be located outside the City limits and require land purchase or lease. Water transmission mains to and from Waukesha would require routing studies, easements, and construction through rural and urban conditions. There are no treatment plants or wellfields for Waukesha to operate with Alternative 3, making operation and maintenance of the water utility much simpler than that of a groundwater alternative.

Considering the implementability of Alternative 4, a rating of "moderate adverse impact" was applied.

Summary of Water Supply Alternatives

Major studies previously conducted by the City of Waukesha[62] and others[63, 64] thoroughly evaluated the water supply alternatives for the City of Waukesha. Through these studies, potential-

[62] Ibid.

ly feasible water supply options were identified. This application analyzes four alternatives for Waukesha's water supply:

- Deep and shallow aquifers
- Shallow aquifer and Fox river alluvium
- Lake Michigan and shallow aquifer
- Lake Michigan

Each alternative was evaluated against four criteria:

- Environmental impact
- Long-term sustainability
- Public health
- Implementability

Exhibit 4-17 summarizes the water supply alternatives evaluation results. The results show the Lake Michigan alternative (Alternative 4) has the most environmental benefit for the waters and water dependent natural resources of the Lake Michigan Basin, is the most reliable and environmentally sustainable in the long term, provides the most public health protection, and is implementable. A Lake Michigan water supply also provides higher quality potable water to consumers.

EXHIBIT 4-17
Water Supply Alternatives Evaluation Summary

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●
Lake Michigan and shallow aquifers	●	◎	⊙	●
Lake Michigan	○	○	⊙	◎

○ No adverse impact
⊙ Minor adverse impact
◎ Moderate adverse impact
● Significant adverse impact

The much lower total dissolved solids content in the Lake Michigan water supply (Exhibit 4-18) not only eliminates the need for home softening; it also is healthier for consumers and the environment, and better for many industrial and commercial uses.

Estimated costs for each alternative are summarized in Exhibit 4-19. These cost estimates were prepared for guidance in comparing alternatives based on information available at the time of the estimate. Detailed engineering design has not been done. The final cost estimate of any project will depend on market conditions, site conditions, final project scope, schedule, and other variable factors. As a result, final project costs may vary from the estimates presented here.

The cost comparison of the alternatives shows that the Lake Michigan water supply is the most cost-effective in the long term. There is no cost advantage of a groundwater supply or combination groundwater/Lake Michigan supply over a Lake Michigan supply. The combination of a Lake Michigan and groundwater supply (Alternative 3) is the most expensive. The lake Michi-

63 SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.
64 Cherkauer. 2009.

gan supply is also the simplest to operate and maintain. Capital, operation, and maintenance cost details are in Appendix M, Cost Estimates Update.

The groundwater supply alternatives are not reasonable water supply alternatives under the Wisconsin Compact implementing statute (§281.346(4)(e)1.d., Wis. Stats.). Under Wisconsin law, "a reasonable water supply alternative means a water supply alternative that is similar in cost to, and as environmentally sustainable and protective of public health as, the proposed new or increased diversion and that does not have greater adverse environmental impacts than the proposed new or increased diversion." Compared to a Lake Michigan water supply, the groundwater supply alternatives create greater adverse environmental impacts, are less sustainable, less protective of public health and are more expensive.

Exhibit 4-20 compares the water supply alternatives to some of the Great Lakes Compact criteria.

EXHIBIT 4-18
Water Quality Comparison between Water Supply Alternatives

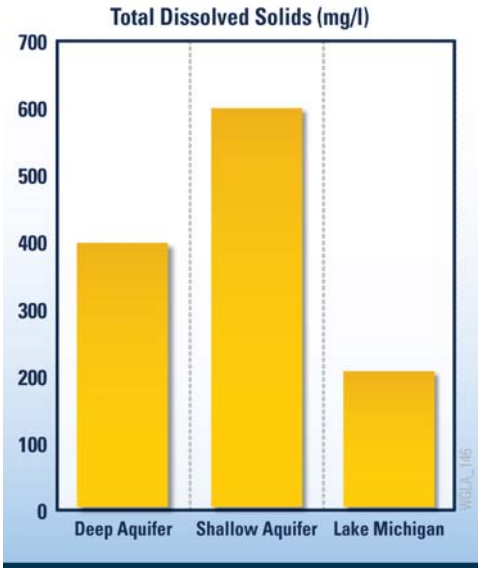


EXHIBIT 4-19
Water Supply Alternative Cost Estimates

Water Supply Alternative	Capital Cost[a] ($ million)	Annual Operation/Maintenance Cost ($ million)	20 yr. Present Worth Cost ($ million, 6%)	50 yr. Present Worth Cost ($ million, 6%)
Deep and shallow aquifers	189	7.2	272	302
Shallow aquifer and Fox River alluvium	184	7.4	269	301
Lake Michigan and shallow aquifer	238	7.5	324	356
Lake Michigan with return flow to Underwood Creek	164	6.2	235	262

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

Summary

An analysis of Waukesha's water supply alternatives demonstrates that a Lake Michigan water supply is the only reasonable solution for the Waukesha Water Utility (Exhibit 4-21). It provides the most reliable, cost-effective, and high quality drinking water for the future. It protects the integrity of the Great Lakes Basin ecosystem. A Lake Michigan water supply will result in termination of deep aquifer pumping which will restore the natural flow regime of the groundwater towards the Lake Michigan Basin instead of away from it. This will eliminate adverse environmental impacts of using groundwater and improve the Great Lakes water and water-related ecosystems.

This analysis also demonstrates that that there is no reasonable water supply alternative to a Lake Michigan supply within the basin in which Waukesha is located. The groundwater water supply options have much greater adverse environmental impacts than using Lake Michigan, are not sustainable long-term and are not as protective of public health.

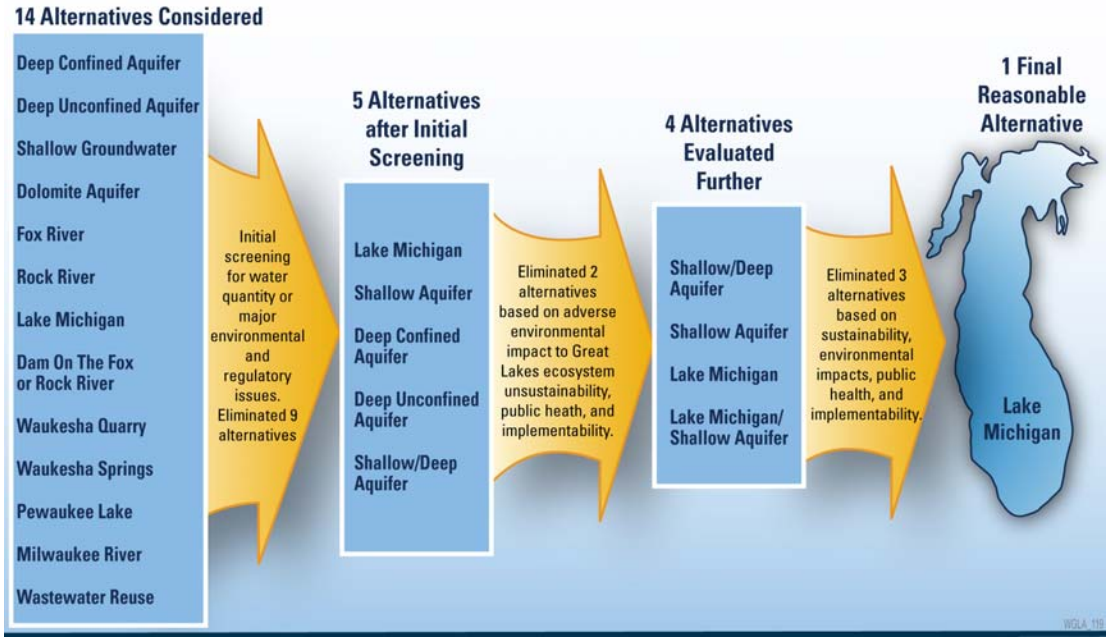
EXHIBIT 4- 20

Great Lakes Compact Requirements and Water Supply Alternatives

	Lake Michigan with Return Flow to Underwood Creek	Shallow Aquifer	Shallow / Deep Confined Aquifer
All water withdrawn shall be returned to the Source watershed, minus consumptive use (4.11.1)	✓		
No significant individual or cumulative adverse impact to the quantity or quality of the waters and water dependent natural resources and the applicable source watershed (4.11.2)	✓		
Environmentally sound and economically feasible water conservation measures (4.11.3)	✓	✓	✓
The supply potential of the water source, considering quantity, quality, reliability and safe yield of hydrologically interconnected water sources (4.11.5(d))	✓		
Not endanger the integrity of the Basin Ecosystem (4.9.3(e))	✓		
Restoration of hydrologic conditions and functions of the Source Watershed (4.11.5(f))	✓		
In compliance with all applicable laws and agreements (4.11.4)	✓	✓	✓
Protection of the integrity of the Great Lakes (4.5.1(d))	✓		
Protect, conserve, restore, improve and effectively manage the Waters and Water dependent natural resources of the Basin (1.3.1(f) and 1.3.2(a))	✓		

EXHIBIT 4-21

Final Water Supply Alternative Selection



SECTION 5
Return Flow

The Compact and Wisconsin State Statutes § 281.346 place a number of requirements on the return flow to the source watershed. The City of Waukesha has developed a return flow management plan to meet those requirements. The management plan has the goal of exceeding the requirements of the Compact, and Wisconsin Statutes by returning 100 percent of the withdrawn water over a management period. The return flow management plan will provide environmental benefits to the source watershed by returning flow to a Lake Michigan tributary that is flow-limited during baseflow and low flow periods. The return flow management plan will allow 100 percent return of the withdrawn water volume or less for an allowance for consumptive use.

*The applicant is to return the water withdrawn to the Great Lakes basin. If it will not, the applicant shall identify any entities that may return the water and provide evidence of support from each of those entities in the form of a letter or resolution. Reference: Wis. Stat. § 281.346(4)(b)4p.*The City will be responsible for returning the water withdrawn to the Great Lakes Basin.

As first discussed on 4-28, the proposal addressed that it will not endanger the integrity of the Great Lakes basin ecosystem based on the fact that the proposal will have no significant adverse impacts on the Great Lakes basin ecosystem. See § 281.346(4)(e)1.e. Section 5 will offer further support of the proposal meeting this requirement and discussion of the return flow alternatives.

The City will, at a minimum, return the amount of water withdrawn from Lake Michigan, less consumptive use, to the source watershed by managing return flow as discussed under Return Flow Management Plan. The source watershed is the Lake Michigan watershed because the water is to be withdrawn from Lake Michigan. As the Compact and Wis. Stat. § 281.346(1)(r) provides in relevant part, "[i]f water is withdrawn directly from a Great Lake, then the source watershed is the watershed of that Great Lake."

The Compact and state law require that an amount of water equal to the amount of water withdrawn from the Great Lakes Basin will be returned to the source watershed, less consumptive use. The City's goal is to exceed the Compact requirements by returning 100 percent of the withdrawn water over a management period. See "Return Flow Management Plan" below.

This section will also discuss how the City will minimize out-of-basin water in the return flow, see "Return Flow Management Plan: Minimizing Out-of-Basin Water in Return Flow" later in this Section.

Return Flow Management Plan

"An amount of water equal to the amount of water withdrawn from the Great Lakes basin will be returned to the source watershed, less an allowance for consumptive use." Wis. Stat. § 281.346(4)(f)3.

"Consumptive use" is defined as "a use of water that results in the loss of or failure to return some or all of the water to the basin from which the water is withdrawn due to evaporation, incorporation into products, or other processes. Wis. Stat. § 281.346(1)(e).

"The proposal maximizes the amount of water withdrawn from the Great Lakes basin that will be returned to the source watershed and minimizes the amount of water from outside the Great Lakes basin that will be returned to the source watershed." Wis. Stat. § 281.346(4)(e)1.c.

The City of Waukesha will meet these requirements by returning the volume of water withdrawn from Lake Michigan, less consumptive use (Compact Section 4.9(4)c, Wisconsin Statute Section 281.346(4)(f)3). The proposal will also maximize the amount of water withdrawn that will be returned to the source watershed as the City of Waukesha also has a goal of returning 100 percent of the water supplied from Lake Michigan to ensure that its withdrawal will not individually or cumulatively create an adverse impact to the water quantity within Lake Michigan (Compact Section 4.9(4)d, Wisconsin Statute Section 281.346(4)(f)5).

"Source watershed" is defined as "the watershed from which a withdrawal originates." If water is withdrawn directly from a Great Lake, then the source watershed is the watershed of that Great Lake. If water is withdrawn from the watershed of a stream that is a direct tributary to a Great Lake, then the source watershed is the watershed of that Great Lake. Wis. Stat. Sec. 281.346(1)(r)

To accomplish the 100 percent return flow goal, a management plan has been developed using an innovative precedent of using treated wastewater as an environmental resource to balance the return and withdrawal volumes, and for supporting flow restoration and other watershed goals for the Lake Michigan tributary.

The return flow will come from the City of Waukesha Wastewater Treatment Plant (WWTP). The WWTP is an advanced facility with primary, secondary, and tertiary treatment (dual media sand filters), and ultraviolet light disinfection processes. It produces a high quality effluent that is discharged to the Fox River, in the Mississippi watershed. The Fox River has a small watershed area at the City of Waukesha, and the WWTP provides a significant contribution to the flow in the Fox River during periods of low river flow. The WWTP maintains high quality treatment standards to protect the river water quality. The City of Waukesha will continue to use the treatment facility and at least maintain its high-quality treatment standards for future return flow.

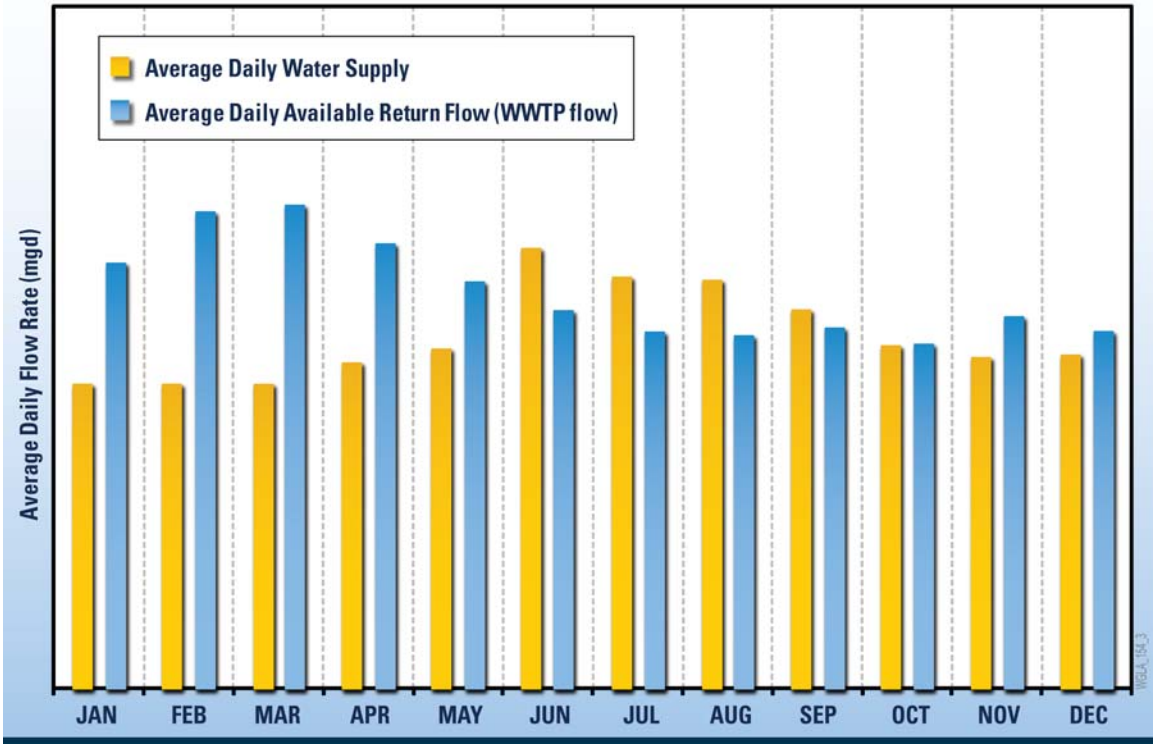
The City of Waukesha's goal is to return 100 percent of the water withdrawn from Lake Michigan.

Water supply rates change throughout the year because of changes in demand, with the greatest water usage generally occurring during hot and dry periods. For example, water consumption is greater during the summer, when the temperatures are high and precipitation is low, than it is in the winter. Return flow from the WWTP also varies throughout the year, but it does not always follow the same variation as the water supply. During periods of high water demand (e.g., July and August), return flow from the WWTP often is less than the water supply. Exhibit 5-1 shows how the water supply and an available return flow (from the WWTP) would have varied seasonally during 2005. Year 2005 was used to demonstrate this because it was a year when there were several months when the water supply was greater than the available return flow.

Return Flow Rates

To achieve 100 percent return volume and to balance the periods when the water withdrawal is greater than the available return flow, the return flow management plan will use a period of time to track water withdrawal and return volumes. The return flow will at least meet the Compact requirement of returning the withdrawn water, less consumptive use. To account for summer days when water withdrawal is greater than the available return flow, slightly more water will be returned during spring, fall, and winter when the available return volume typically is greater than the demand (Exhibit 5-1). This will provide a total water balance of 100 percent return over a management period.

EXHIBIT 5-1
Example of Variability between a Water Supply and Available Return Flow Volume for Example Year 2005



As required by the Compact Section 4.9(4)(c) and Wisconsin Statute Section 281.346(4)(f)3, the *minimum* daily return flow rate will be the water withdrawn less consumptive use, which at some times (summer) is the available flow rate from the WWTP. As discussed in Section 2 *Waukesha Water Consumptive Use*, page 2-12, the City of Waukesha has an average consumptive use of about 8 percent. The *maximum* daily return flow rate will not exceed 115 percent of the average water withdrawal; that is the maximum daily return flow rate will not be more than 15 percent more than the average withdrawal. With return flow not exceeding 115 percent of the average daily withdrawal, the City of Waukesha will balance the amount of return flow with the amount of water withdrawn, allowing the City to provide a return flow rate very close to the withdrawal rate. This approach will provide a uniform return flow rate that will prevent large fluctuations in the return volume and excessive "banking" of volume during the management period. Exhibit 5-2 demonstrates the range of return flow rates following the management plan for 2005. As shown, the managed return flow provides a relatively uniform return flow rate throughout the year.

The return flow will meet the Compact requirement of returning the withdrawn water, less consumptive use.

When the available return flow rate (WWTP flow) exceeds 115 percent of the water withdrawal rate, the excess flow from the WWTP will be conveyed through the existing outfall to the Fox River. Exhibit 5-3 summarizes the management plan.

To demonstrate how the management plan would provide return flow, the water supply and available return flows (WWTP flows) were modeled for the most recent period of record, between years 2002 and 2009. Over this period the management plan provided 100 percent return of the withdrawn volume each year, including 2005 when there were several months when the water

EXHIBIT 5-2
Return Flow in Example Year 2005: Following the Management Plan for Controlling the Minimum and Maximum Return Flow Rates

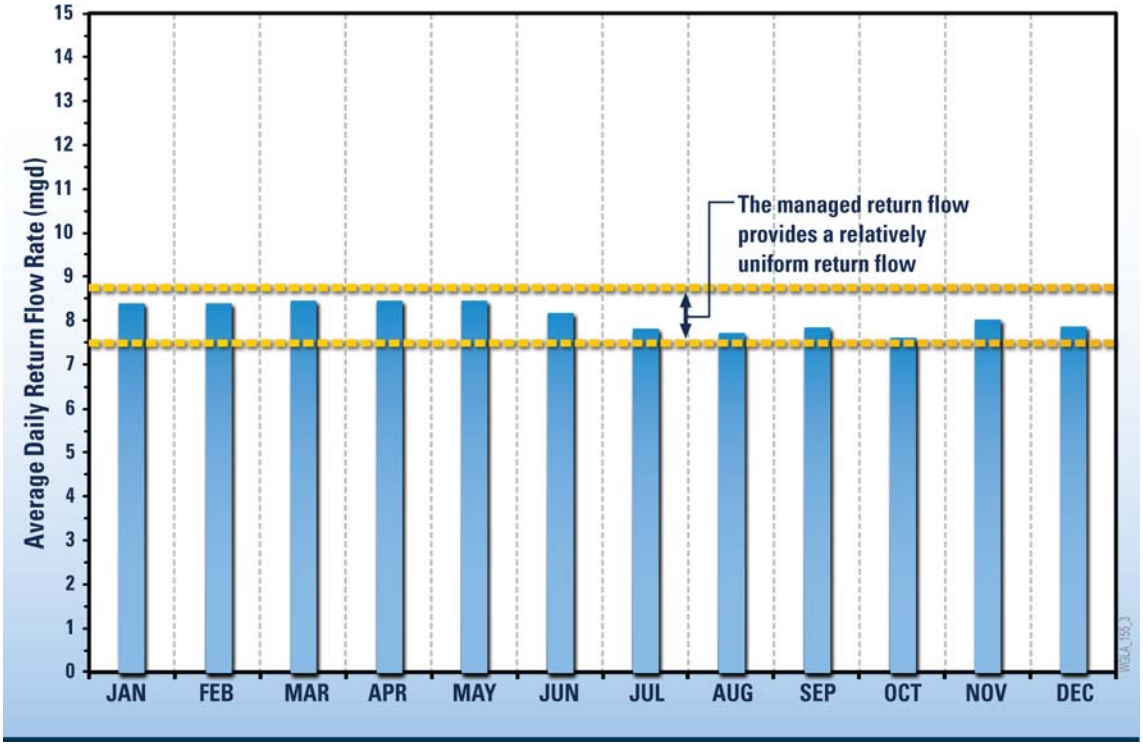


EXHIBIT 5-3
Summary of the Return Flow Management Plan

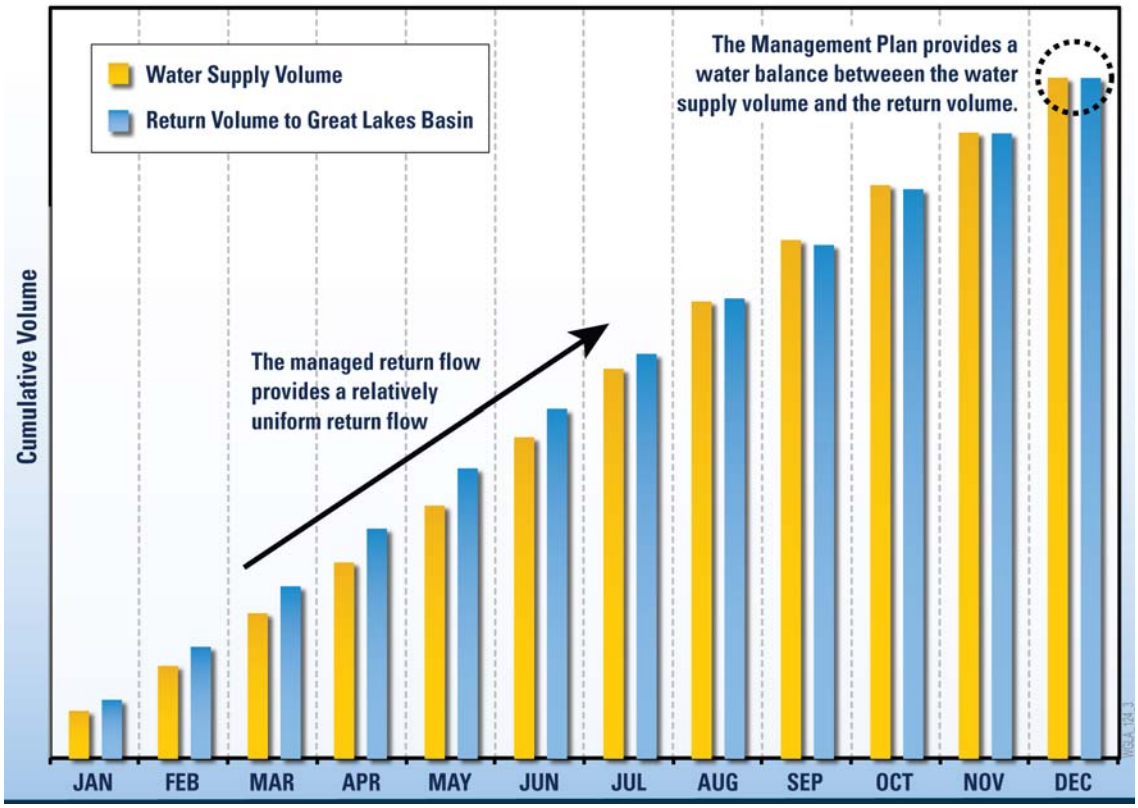
Average Daily Return Flow to Lake Michigan Source Watershed		Receiving Water Body for Return Flow Exceeding the Maximum
Minimum Return Flow	Maximum Return Flow	
Available flow from the WWTP (water withdrawal, less consumptive use)	Average daily water withdrawal + 15%	Fox River

supply was greater than the available return volume (i.e., a year when obtaining 100 percent return flow would be more difficult). As shown in Exhibit 5-4, the return and withdrawal volumes fluctuate throughout example year 2005, and at the end of the year there is a water balance between the withdrawal and return volumes (i.e. at the end of the year, the cumulative water withdrawn is equal to the return volume). Because the management plan allows the return flow rate to be relatively uniform (Exhibit 5-2) and very close to the withdrawal volume (Exhibit 5-4), the average daily variations between the withdrawal and return flow rates will be limited. This uninterrupted flow will allow the return flow to be used as a resource to enhance the fisheries and aquatic habitat in a Lake Michigan tributary while protecting the streambed geomorphic stability.

Management Plan Period

The City of Waukesha will monitor the withdrawal and return flow rates on a daily basis to ensure that the minimum requirement of the Compact is met: returning the withdrawn water, less consumptive use. The City also proposes using a 5-year rolling average to track water withdrawal and return flow rates to achieve its goal of 100 percent return flow. The 5-year man-

EXHIBIT 5-4
Example of 100 Percent Return during Example Year 2005



agement period will be used to provide 100 percent return flow because there could be periods in the future with extended drought, when available return flow from the WWTP is less than the water withdrawal (when only the minimum Compact requirement of returning the withdrawn water, less consumptive use, is achieved). By using the 5-year rolling average, drought periods can be balanced with wet or normal precipitation periods, to provide a 100 percent return flow and a water balance between the withdrawal and the return volumes. As noted, because the average return flow rate is similar to the average withdrawal flow rate, the management plan will minimize daily variations between the two and will prevent "banking" excessive volume to account for days when available return flow is much less than the withdrawal.

Minimizing Out-of-Basin Water in Return Flow

"No water from outside the Great Lakes basin will be returned to the source watershed unless all of the following apply:

a. The returned water is from a water supply or wastewater treatment system that combines water from inside and outside the Great Lakes basin.

b. The returned water will be treated to meet applicable permit requirements under § 283.31 and to prevent the introduction of invasive species into the Great Lakes basin and the department has approved the permit under § 283.31.

c. If the water is returned through a structure on the bed of a navigable water, the structure is designed and will be operated to meet the applicable permit requirements under Sec. 30.12 and the department has approved the permit under Sec. 30.12." Wis. Stat. 281.346(4)(f)4.a.-c.

The City of Waukesha operates a separate sanitary sewer collection system that conveys wastewater from the sanitary sewer service area (Appendix E) to the WWTP. The City will continue to operate this system for the proposed Lake Michigan water supply and return flow. As required by the Compact Section 4.9(4)(c)i and Wisconsin Statute Section 281.346(4)(f)4a, the return flow will consist only of flow from the WWTP that originates within the sanitary sewer service area (Appendix E) served by the City of Waukesha WWTP. Sources of return flow outside that area will not be used for return flow.

The City of Waukesha has been implementing an aggressive infiltration and inflow (I&I) reduction program to reduce the amount of clear water entering the sanitary sewer collection system (Waukesha has only a separate sanitary sewer system). As in all communities with sanitary sewer collection systems, some I&I is observed in the City of Waukesha during wet periods and storms. The I&I contributes to the collection system flows during those times, and subsequently receives the same treatment at the WWTP as the sanitary flow. The City's collection system and WWTP have adequate conveyance and treatment capacity to treat the I&I, but the City has continued the I&I reduction program to minimize treatment costs and to minimize the I&I that could be part of the return flow.

Over the past several years, projects that have contributed to reducing I&I include televising, smoke testing, and dye tracing of sewer pipes and structures; replacing sewer laterals, cracked pipes, and manholes; lining and sealing manholes and sewers; and identifying and correcting sump pump and foundation drain connections to the sanitary sewer. The City continues to investigate I&I throughout the collection system to prioritize projects that provide the most efficient I&I reduction.[1] Those efforts include sewer system modeling, in-pipe flow monitoring, sewer televising and smoke testing, and conducting a sewer system evaluation survey. The I&I reduction program will contribute to minimizing out-of-basin water in the return flow.

The return flow management plan will also contribute to minimizing out-of-basin water in the return flow Because I&I contributes to WWTP flows that are greater than the withdrawn water, the maximum return flow rate will not include the WWTP flows where I&I have the greatest contribution. Instead, the return flow rate will not exceed 15 percent more than the average withdrawal (as discussed under "Return Flow Management Plan"). By limiting the return flow rate, I&I contributions above that amount will not contribute to return flow, and the out-of-basin water (I&I) will be minimized. The WWTP flows exceeding the maximum return flow will continue to the Fox River, which is within the surface watershed where the I&I occurs.

By using the City of Waukesha sanitary sewer system, the I&I reduction program, and the return flow management plan as discussed above, the Compact Sections 4.9(3)b and Wisconsin Statute Sections 281.346(4)(e)1c and 281.346(4)(f)4a requirements are met for minimizing the amount of water from outside the Great Lakes Basin that will be returned.

Prevention of Invasive Species

In compliance with the requirement of Wis. State. Sec. 281.346(4)(f)4.b., the return flow will prevent the introduction of invasive species by only returning treated wastewater conveyed in a pipe directly from the WWTP to the return flow location. The applicable permits and associated operating requirements for the discharge (Wis. Stat. § 30.12 or § 30.12.4m) will be obtained before the return flow outfall is constructed.

[1] Donohue & Associates. (2010; in press). *Sanitary Sewer Master Plan—Phase I.*

Return Flow Alternatives

Five alternatives were considered for return flow to the Lake Michigan source watershed. The alternatives include return flow to:

- Underwood Creek, a tributary to the Menomonee River that flows to Lake Michigan
- Root River, a tributary to Lake Michigan
- Direct to Lake Michigan
- The Milwaukee Metropolitan Sewerage District (MMSD) sewer system and water reclamation facility, which would then return flow to Lake Michigan. Two subalternatives were considered for return flow to MMSD.

The Compact Section 4.9(4)d and Wisconsin Statute Section 281.346(4)(f)5 requires that the return flow result in no significant adverse individual or cumulative impacts to the quantity or quality of the Great Lakes Basin. Each alternative includes a corridor for the return flow pipeline and associated infrastructure along the pipeline alignment (e.g., pump station, service manholes). Therefore, the pipeline corridors and the return flow discharge locations were selected to protect public health and safety, to provide long-term and sustainable return flow, to minimize environmental impacts, to provide feasible implementation (an alignment that is constructible), to use previously disturbed areas and existing utility corridors, to be consistent with the SEWRPC alignments, to allow the return flow to be used as an environmental resource to the Lake Michigan Basin, and to minimize cost.

The return flow alignments selected follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands. The alignments are discussed below for each return flow alternative. The alignments were developed to a limited level of detail that allows for screening and comparison of alternatives. The concepts do not include the details that will be identified and evaluated in subsequent engineering design phases for the actual project.

Similar infrastructure (a pump station and a pipeline of varying length depending on the alternative) was included for each alternative. Based on the above criteria, return flow to Underwood Creek is the preferred alternative because it protects public health, it has the least environmental impact, it occurs exclusively in previously disturbed areas, it is consistent with SEWRPC's recommended alignment, it will allow the return flow to provide an environmental resource benefit within Underwood Creek, and it is the least costly alignment.

Regardless of the return flow discharge location, the return flow will meet the Compact Section 4.9(4)c and Wisconsin Statute Section 281.346(4)(f)4b requirements of preventing introduction of invasive species into the Great Lakes Basin. This will be accomplished because the City of Waukesha WWTP will prevent invasive species from entering the return flow pipeline, and because the pipeline is only proposed to be connected to only the WWTP and the return flow discharge location.

Each alternative is discussed below with additional information and evaluation details included in Appendixes E and N. Because Underwood Creek is the preferred return flow location, it is discussed in detail.

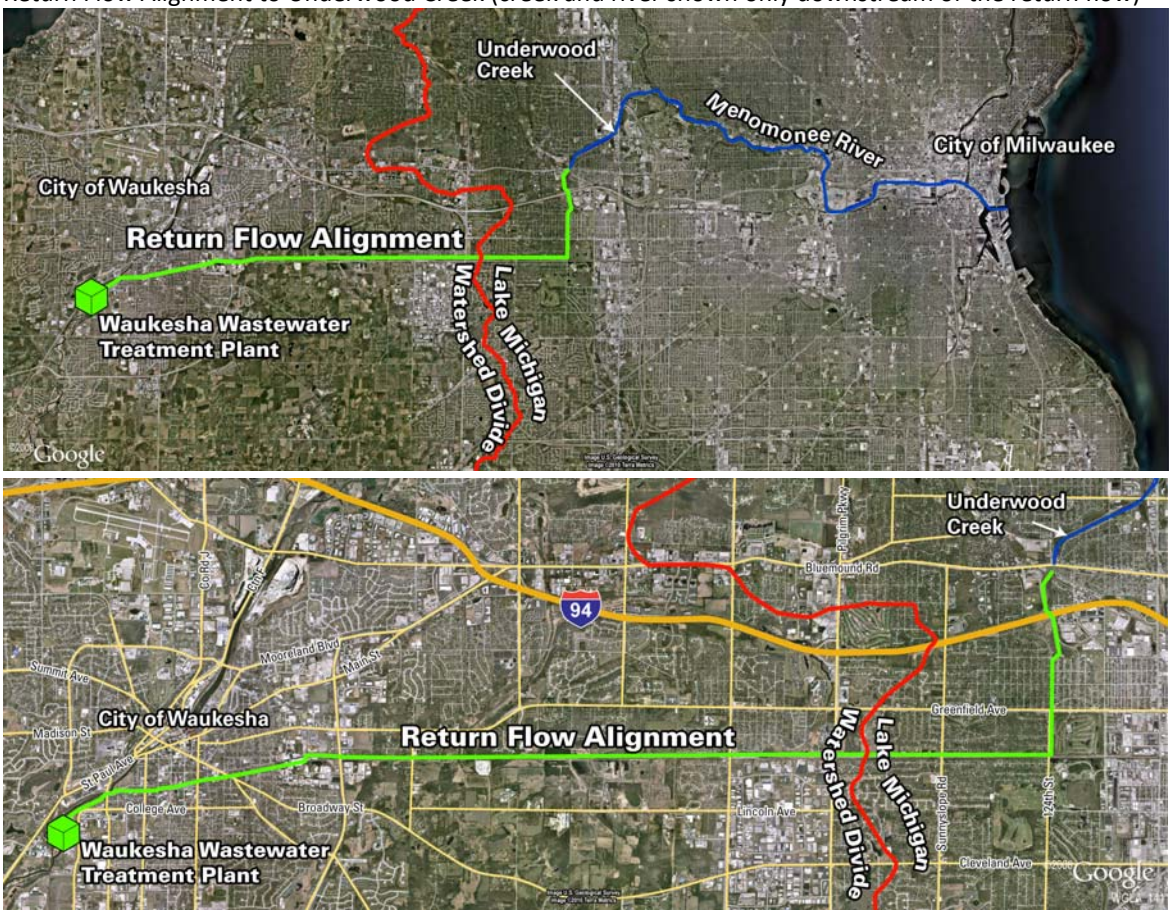
Return Flow to Underwood Creek

Return flow to Underwood Creek is expected to occur in Waukesha County, near the crossing of Underwood Creek and Bluemound Road. At that location, Underwood Creek flows about

2.6 river miles to its confluence with the Menomonee River in Wauwatosa before flowing another 10 river miles to Lake Michigan in the City of Milwaukee.

A screening level layout was developed for the return flow pipeline (Exhibit 5-5). It begins at the City of Waukesha WWTP, and proceeds north and east through a City park and along an alley and minor streets for about 1.3 miles. The pipeline continues east for another 1.3 miles following an abandoned railroad corridor planned for a future recreational trail, where it joins with an utility corridor and bike trail and runs for another 7 miles. The pipeline continues north 1.9 miles along a street and bike path until it ends near the confluence of the north and south branch of Underwood Creek. The return flow discharge elevation is expected to be located at an elevation similar to the bed elevation of Underwood Creek, where the detailed design of the structure will meet the requirements of Wisconsin Statute Section 281.346(4)(f)4c.

EXHIBIT 5-5
Return Flow Alignment to Underwood Creek (creek and river shown only downstream of the return flow)



Environmental Resources

The return flow pipeline follows corridors that are previously disturbed, and it avoids environmental resources, such as wetlands, stream crossings, and other similar land use categories as much as possible. Some areas of the alignment will have temporary (short-term) impacts to these resources because of the construction-related activities associated with building the pipeline, but there will be no significant adverse short-term impacts. There will also be no long-term significant adverse impacts because the return flow alignment follows an alignment previously disturbed with existing development (e.g. bike path, utility corridor). The impacts to environmental resources (Appendix N)

were analyzed for the return flow pipeline corridor, and the Underwood Creek return flow had the least impact of all alternatives. A 75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare impacts between alternatives. Exhibit 5-6 summarizes the impacts for the corridor.

EXHIBIT 5-6
Summary of Potential Environmental Impacts for an Underwood Creek Return Flow

Resource Type	Potential Temporary Impact of Pipeline Corridor
Stream crossings	17
Water body crossings	8
Water body crossing (acres)	0.15
Wetlands (acres)	9.4[a]

[a]For an outfall near Bluemound Road. The impacts are about 5.0 acres for a discharge 0.9 mile upstream.

The estimated total temporary wetland impacts related to construction are 9.4 acres within the pipeline corridor between the City of Waukesha WWTP and the outfall to Underwood Creek. Most of the impacts occur in the last 0.9 mile of the alignment, where about 5.3 acres of land are classified as wetlands. This area has been disturbed in the past when the creek was lined with concrete and when a pedestrian trail was recently constructed. The pipeline corridor is located along the pedestrian trail to minimize wetland impacts, but some temporary impacts are estimated for a return flow outfall near Bluemound Road. To reduce these impacts, the outfall could be located upstream of Bluemound Road 0.9 mile. This would reduce the total potential temporary construction impacts from 9.4 acres to about 5.0 acres.

The return flow *discharge* will not adversely impact the environmental resources along the pipeline corridor, but the discharge was analyzed for potential effects on resources within Underwood Creek, Menomonee River, and Lake Michigan. These effects are summarized below.

Flow, Geomorphology, and Habitat

Wisconsin law requires that, if water will be returned to the source watershed through a stream tributary to one of the Great Lakes, the applicant shall provide documentation of how the physical, chemical, and biological integrity of the receiving water will be protected and sustained, considering the state of the receiving water before the proposal is implemented and considering potential adverse impacts due to changes in temperature and nutrient loadings. If the receiving water is a surface water body that is tributary to one of the Great Lakes, the applicant shall include a description of the flow of the receiving water before the proposal is implemented, considering both low and high flow conditions. Reference: Wis. Stat. § 281.346(4)(b)4s, and § 281.346(4)(f)4m.

Downstream of the return flow outfall, Underwood Creek is mostly concrete-lined, but in 2009 a 2,400-foot-long segment of lining was removed and rehabilitated with natural channel design features.[2] The rehabilitated creek provides improved habitat because the bottom substrate is coarse grained sediments (gravel and cobbles); it provides various habitat features such as riffles, runs, pools, and glides; it meanders and includes other habitat features like rock boulders; the vegetation will overhang the channel once it is mature; and the creek is reconnected with its floodplain. A preliminary design for rehabilitating an additional 4,400-foot section of creek is complete.[3] When construction is completed it is expected to provide similar environmental resource benefits.

[2] MMSD. 2008. "Watercourse: Underwood Creek Rehabilitation and Flood Management—Phase 1." Designed by Short Elliott Hendrickson, Inc. (SEH).

[3] SEH. 2009. "Underwood Creek Effluent Return Evaluation." Technical memorandum dated July 23, 2009, page 2.

The Underwood Creek design engineers conducted a hydraulic and geomorphic analysis for a City of Waukesha return flow. This analysis used a 20-cfs (12.9-mgd) return flow rate, which provides a conservatively high estimate because it is about 18 percent more than the future average day water demand. The analysis assessed the impacts of return flow to the creek geomorphic stability and concluded that the return flow will have a negligible effect on the geomorphic stability of the rehabilitated creek.[4]

The Underwood Creek watershed is a predominantly urban area. Flow in the creek fluctuates from no flow during dry periods and winter, to high flows during rain events. With the addition of return flow, the return flow would subsequently fluctuate between all the flow in Underwood Creek (e.g., during dry periods) to providing a very small portion of flow during storms. For example, a 20-cfs return flow is only 1.5 to 2.0 percent of the 2-year creek flow (for locations in the creek downstream of the potential return flow location) and 0.29 to 0.76 percent of the 100-year flow.[5]

Return flow effects on the flow in the Menomonee River are similar to Underwood Creek. The Menomonee River is downstream of Underwood Creek, and therefore the river has a much larger watershed and flow rate. Because of this, the return flow is even less of a fraction of the river flow and similar to Underwood Creek, the return flow is also expected not to affect the geomorphic stability of the river. Comparing the same frequency storm events for the river, a 20-cfs return flow is only 0.30 to 0.59 percent of the 2-year flow (for locations in the river downstream of the potential return flow location) and 0.11 to 0.21 percent of the 100-year flow.[6]

A habitat assessment was also completed for Underwood Creek and Menomonee River to determine the changes in habitat that could result from return flow to Underwood Creek. The return flow increases the average velocity, cross sectional flow area, shear stress, and the wetted perimeter in the creek and river. The increases are not expected to have a significant effect on the in-stream habitat, but they are expected to benefit the habitat within the creek by reducing the potential for fine sediments to fill the coarse sediment substrate (embeddedness), providing deeper pools and riffles for more functional fish passage, and providing more wetted perimeter to support a greater benthic macroinvertebrate community. Return flow will provide the greatest benefit to in-stream habitat during periods when Underwood Creek has low or no flow. Return flow will eliminate the no flow conditions, and will augment low baseflow flow to provide improved habitat. The return flow is expected to have similar but less significant benefits for the Menomonee River, because the river flow is greater than the creek flow. Appendix L contains additional details of the habitat analysis that was completed for this Application.

Based on the above analysis, the physical integrity of Underwood Creek or Menomonee River will be protected and sustained (as required by the Compact Section 4.9(4)d and Wisconsin Statute Sections 281.346(4)(f)4m and 281.346(4)(f)5).

Fisheries

Fisheries data for the Menomonee River watershed show an apparent net gain of fish species within the watershed. For example, 10 new species have been identified since 1986, and the most recent fishery surveys conducted by the USGS in 2004 and 2007 identified that 12 of the 20 species found in the Menomonee River watershed occurred within Underwood Creek.[7] Un-

[4] SEH. 2009. "Underwood Creek Effluent Return Evaluation," pages 2, 5.

[5] SEH. 2009. Underwood Creek HEC-RAS Model. Underwood Creek Rehabilitation and Flood Management Project.

[6] MMSD. 2001. Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Modified for newer HEC-RAS model v3.1.3.

[7] SEWRPC. 2007. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.* Planning Report No. 50. pp. 200–14. Data compilation from MMSD, USGS, and WDNR.

derwood Creek is predominantly a concrete channel with little habitat for fish, but the creek provides minimal substrate for macroinvertebrates. The part of the concrete channel removed in 2009 and rehabilitated to a meandering stream channel has numerous pools and riffles, and a substrate composed of gravel, sand, and silt.

Underwood Creek, along with most streams in the Menomonee River watershed, is a warm-water habitat, with an imbalance of number and type of species indicative of a poor quality fishery. Although macroinvertebrate communities within the watershed improved substantially since 1993, the USGS macroinvertebrate data collected in 2007 concluded that Underwood Creek and the Menomonee River range from fairly poor to fair to good, in terms of relative quality based on the presence of specific macroinvertebrates.

With the potential presence of two state-listed threatened fish species in the Menomonee River watershed, there appear to be areas of good river quality within limited parts of the watershed. The poor quality of the fish communities in the watershed is caused mostly by habitat loss. The rehabilitated channel of Underwood Creek contains habitat features that fish and macroinvertebrates can use. Although habitat conditions in Underwood Creek are limiting for the fish and benthic communities, those conditions could be improved by providing more or higher quality habitat. Because return flow is expected to improve habitat, the fish and macroinvertebrate communities would also be expected to improve.

One example of improving fisheries with effluent flow from a WWTP is in southeast Michigan, where the Ypsilanti Community Utilities Authority (YCUA) WWTP uses wastewater effluent as an environmental resource. In 1995, the Lower Rouge River near Detroit began receiving flow augmentation from YCUA effluent. Since then, the Lower Rouge River has been able to support an improved fishery, with the potential for up to 29 species and angling opportunities for 7. Baseflow enhancement has dramatically increased the fishery potential of the Lower Rouge, where the YCUA flow augmentation demonstrates that baseflow enhancement to low flow systems may be a particularly useful tool to enhance sport fish populations.[8] Following a similar precedence for the City of Waukesha, return flow could provide similar opportunities to improve public and natural resources, and provide benefits beyond just maintaining a water balance in Lake Michigan. Underwood Creek experiences extended periods of very low flows and periods of no flow (i.e., a dry creek). Flow augmentation with return flow would eliminate dry periods and could enhance the baseflow in Underwood Creek and Menomonee River to support an improved fishery. Return flow to the creek provides natural resource benefits as it flows on the surface towards Lake Michigan. In contrast, when conveyed in a pipe (e.g., return flow direct to Lake Michigan), the flow does not have an opportunity to provide an environmental benefit.

Based on the above analysis, the biological integrity of Underwood Creek or Menomonee River will be protected and sustained, and invasive species will be prevented in the return flow.

Flooding

The City of Waukesha will manage the return flow to meet regulatory floodplain management requirements and not to cause additional flood damage downstream of the return flow discharge. The Underwood Creek and Menomonee River watersheds in the Milwaukee area are highly developed with existing residential and commercial buildings very near, and sometimes within, the 100-year flood plain. During a flood in the watershed, floodwaters rise and then subside quickly. To

[8] Michael Wiley, P. Seelbach, and S. Bowler. 1998. *Ecological Targets for Rehabilitation of the Rouge River.* School of Natural Resources and Environment. University of Michigan. Final Report, April 30. Page 7, 13, and 18.

protect downstream properties, conveying floodwaters to the Milwaukee County Grounds floodwater management facility is estimated to last only 6 hours for the 100-year return period storm.[9]

To protect public and private property, there have been significant and ongoing investment in flood control projects. For example, downstream of the return flow location, the MMSD has invested $48 million in the Hart Park flood control project, completed in 2007,[10] and $99 million in the County Grounds flood control project, to be completed in 2010.[11] Other projects have been completed or are planned elsewhere in the watershed. Each project contributes to providing flood protection to neighboring and downstream residents. Although return flow is a very small percentage of flow during a flood, if an extreme flood condition threatens personal property or public investments, return flow would be temporarily paused. This will not affect the City of Waukesha's goal of providing 100 percent return flow because based on the duration of flooding events, the paused return flow is not anticipated to be significant.

Water Quality

Wisconsin law requires that, if water will be returned to the source watershed through a stream tributary to one of the Great Lakes, the applicant shall provide documentation of how the physical, chemical, and biological integrity of the receiving water will be protected and sustained, considering the state of the receiving water before the proposal is implemented and considering potential adverse impacts due to changes in temperature and nutrient loadings. If the receiving water is a surface water body that is tributary to one of the Great Lakes, the applicant shall include a description of the flow of the receiving water before the proposal is implemented, considering both low and high flow conditions. Reference: Wis. Stat. § 281.346(4)(b)42. and § 281.346(4)(f)4m.

The City of Waukesha will provide return flow with water quality that not only meets but also exceeds the discharge requirements stipulated by the Wisconsin Pollutant Discharge Elimination System (WPDES). The City of Waukesha will also meet future water quality effluent standards that are at least as stringent as those currently imposed.

The WDNR has provided the City of Waukesha with proposed effluent limits for discharge to a Lake Michigan tributary.[12] Effluent limits for two other in-basin municipal dischargers to Lake Michigan tributaries were obtained for comparison purposes. The WDNR-proposed effluent limits for the City of Waukesha are more stringent than the other Lake Michigan tributary dischargers (Exhibit 5-7). Because the City is committed to maintaining high quality effluent from their WWTP, the return flow will meet WPDES requirements with any alternative return flow location.

The City of Waukesha WWTP has water quality limits for several other parameters, including chlorides, which the WDNR has indicated would continue to be regulated.[13] As noted in Section 4, a Lake Michigan water supply will eliminate the need for Utility customers to soften water with salt. As a result, the chloride concentration from WWTP-treated return flow is expected to decrease in the future.

The temperature of the WWTP discharge varies seasonally, with the warmest month of August averaging 70°F (21.3°C) and the coolest month of February averaging 53°F (11.5°C). This type of seasonal variation is typical at municipal WWTPs. The current discharge to the Fox River

9 HNTB. 2006. *Environmental Assessment Milwaukee County Grounds Floodwater Management Facility and Underwood Creek Rehabilitation Projects.*

10 MMSD. http://v3.mmsd.com/hartparkproject.aspx. Accessed January 13, 2010.

11 MMSD. http://v3.mmsd.com/milwaukeecogrounds.aspx. Accessed January 13, 2010.

12 WDNR letter from Duane Schuettpelz. October 16, 2008.

13 Ibid.

EXHIBIT 5-7
Comparison of WDNR-Proposed WPDES Limits to
Historical WWTP Performance and Other Lake Michigan Tributary Dischargers

Water Quality Parameter	City of Waukesha Potential Return Flow		Lake Michigan Tributary WWTP Discharger #1[b]	Lake Michigan Tributary WWTP Discharger #2[c]
	WDNR-Proposed Limit for Lake Michigan Tributary Return	Waukesha Historic Average[a]		
Biological oxygen demand, mg/L	≤ 5.0 to ≤ 10.0	1.8	≤ 10.0 to ≤ 15	≤ 30.0 monthly avg.
Total suspended solids, mg/L	≤ 5.0 to ≤ 10.0	1.2	≤15.0	≤ 30.0 monthly avg.
Dissolved oxygen, mg/L	≥ 7.0	9.2	≥ 6.0	≥ 6.0
Phosphorus, mg/L	≤ 1.0	0.16	≤ 1.0	≤ 1.0
Ammonia (NH_3-N), mg/L	Likely lower than current range of 2.0 to 6.0	< 1.0	3.3 to 6.4 monthly avg.	6.3 to 12.0 monthly avg.

[a]October 1, 2002, to August 31, 2009.
[b]WPDES Permit No. WI-0020222-08-0
[c]WPDES Permit No. WI-0020184-08-0

meets temperature requirements and consequently, return flow temperatures will meet temperature requirements (Wisconsin Statute Section 281.346(4)(f)4m).

Underwood Creek and Menomonee River Water Quality

Underwood Creek is classified as a warm water fishery under the WDNR fish and aquatic life standards, but it has a variance in Milwaukee County for dissolved oxygen and fecal coliform.[14] The Menomonee River downstream of Underwood Creek is also classified as a warm water fishery under the WDNR fish and aquatic life standards, but it has the same dissolved oxygen and fecal coliform variances from Honey Creek to the mouth of the river (about 5 miles downstream of the proposed return flow location).[15]

A reach of Underwood Creek in Waukesha County, upstream of the proposed return flow discharge location, is proposed to be included on the 2010 303(d) list for fecal coliform as a recreational restriction.[16] Similarly, the last 2.67 miles of the Menomonee River is proposed to be included on the 2010 303(d) list for fecal coliform as recreational restrictions. The Menomonee River is currently on the 303(d) list in the same stretch of river for PCBs from contaminated sediment, *E. coli* bacteria for recreational restrictions, total phosphorus for low dissolved oxygen, and unspecified for chronic aquatic toxicity. These listings were all made in 1998.[17] More recently, SEWRPC completed a detailed analysis of water quality in the Menomonee River and found that the dissolved oxygen variance standard was always met for the 11-year period of record analyzed.[18]

Water quality in Underwood Creek and the Menomonee River was extensively studied in SEWRPC's *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*. Findings for the 11-year period of record under SEWRPC's existing condition scenario are summarized below for three points closest to the proposed return flow location. Additional wa-

[14] NR 104.06(2) Water Quality Standards for Wisconsin Surface Waters.
[15] Ibid.
[16] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html accessed January 19, 2010.
[17] Ibid.
[18] SEWRPC. 2007. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, Appendix N, Planning Report Number 50.

ter quality analysis was completed for the current conditions in Underwood Creek and Menomonee River, and for conditions with return flow (Appendix H).

Fecal Coliform. Underwood Creek and Menomonee River sometimes meet fecal coliform standards during the summer recreational season. The overall compliance for the single sample standard is met 67 to 86 percent of the time. The geometric mean fecal coliform concentration for the summer season ranges from 351 to 496 cells/100 mL.[19]

The historical performance at the City of Waukesha WWTP for the summer recreation season (May through October) had geometric mean fecal coliform concentration ranging from 2 to 49 cells/100 mL. Because the return flow fecal coliform concentration is much lower than the existing conditions and water quality standards in Underwood Creek and Menomonee River, the average fecal coliform concentration with return flow will improve. To provide this improvement with return flow, and because portions of Underwood Creek and Menomonee River are proposed to be listed on the 303(d) list for fecal coliform, the City of Waukesha is proposing to disinfect the return flow to protect (and improve) the chemical and biological integrity of Underwood Creek, Menomonee River, and Lake Michigan.

Dissolved Oxygen. The SEWRPC study predicted that Underwood Creek and Menomonee River comply with the standards of maintaining 5 mg/L of dissolved oxygen (2 mg/L for variance standard). The City of Waukesha WWTP historical performance for average dissolved oxygen concentration ranges from 7.9 to 10.5 mg/L. Because the return flow concentration is greater and has a very low concentration of biological oxygen demand, the average dissolved oxygen concentration in Underwood Creek and the Menomonee River would be expected to continue to meet water quality standards.

Total Phosphorus. Underwood Creek and Menomonee River meet the SEWRPC planning level goal of 0.1 mg/L 66 to 84 percent of the time. The City of Waukesha WWTP historical performance for monthly average phosphorus concentration ranges from 0.10 to 0.24 mg/L. Phosphorus concentration in Underwood Creek and the Menomonee River is expected to increase as a result of return flow, but the effect of the increased concentration is expected to be minimal as described below in "Return Flow Water Quality Modeling" and in Appendix H.

Total Suspended Solids. The average total suspended solids in Underwood Creek and the Menomonee River are always less than the total suspended solids reference background concentration of 17.2 mg/L used in the SEWRPC modeling. The City of Waukesha WWTP historical performance for total suspended solids concentration ranges from 0.9 to 1.8 mg/L. Because the return flow total suspended solids are much lower than the background concentration, the average total suspended solids concentration is expected to improve in Underwood Creek and the Menomonee River as a result of return flow.

The return flow will protect and sustain the physical, chemical, and biological integrity of Underwood Creek and the Menomonee River, and for some parameters, the return flow will have a beneficial improvement on these systems.

Return Flow Water Quality Modeling

Underwood Creek Water Quality. Water quality modeling was conducted for the Underwood Creek return flow alternative. Modeling included existing conditions in Underwood Creek with expected Waukesha return flow concentration and also a "worse case" scenario having high

[19] Ibid.

flows and higher concentrations in the discharge (but still within permit limits). Appendix H contains the detailed water quality modeling conclusions and also the detailed findings.

The water quality modeling found that average water quality improved or continued to meet water quality standards or background reference concentrations for three of four water quality parameters (fecal coliform, dissolved oxygen, and total suspended solids). For the fourth water quality parameter (phosphorus), concentrations increased and were more frequently higher than the planning level goal used in the SEWRPC modeling (0.1 mg/L). However, the modeling results indicate that with return flow, nuisance algae growth will decrease in Underwood Creek and Menomonee River. The WDNR is developing new phosphorus standards that are intended to prevent in-stream algae and plant growth to the extent that is detrimental to fish and aquatic life as determined by intensive field studies.[20] The proposed standards would further reduce the phosphorus discharge concentration in the return flow. The WDNR is hosting public comment hearings for the new standard in April 2010, with the intent of finalizing the standard in 2010. The City of Waukesha will provide return flow with water quality that meets effluent requirements, regardless of the discharge location.

Lake Michigan Water Quality. The return flow is ultimately conveyed to Lake Michigan. Consequently, water quality information was reviewed for overall water quality parameter loadings from the greater Milwaukee watersheds tributary to Lake Michigan. SEWRPC compiled total annual water quality parameter loadings for all the greater Milwaukee watersheds.[21] The contribution of the City of Waukesha return flow loadings was calculated using the information from the water quality modeling documented in Appendix H and then compared to the SEWRPC annual average load findings. The analysis indicates the following:

- Fecal coliform contribution in the return flow under very conservative "worst case" conditions is only 0.20 percent of all fecal coliform loading from the greater Milwaukee watersheds.
- Total suspended solids contribution in the return flow under very conservative "worst case" conditions is only 0.21 percent of all total suspended solids loading from the greater Milwaukee watersheds.
- Phosphorus contribution in the return flow is only 1.23 percent of all phosphorus loading even under "worst case" conditions and only 0.62 percent of all phosphorus loading when considering the City of Waukesha's WWTP historic performance. These contributions could be even less because the WDNR is considering new phosphorus regulations that could require more stringent phosphorus discharge limitations.

As required by the Compact Section 4.9(4)d and Wisconsin Statute Sections 281.346(4)(f)4m and 281.346(4)(f)5, the return flow water quality will not have a significant adverse impact on the Lake Michigan Basin. For some parameters, such as Fecal Coliform, the return flow will allow Underwood Creek and Menomonee River to meet their water quality standards more often.

Thus, the return flow will not have any significant adverse impacts on the waters or water dependent natural resources of the Great Lakes basin.

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[20] http://www.dnr.wi.gov/org/nrboard/2010/March/03-10-3A5.pdf. Page 2. Accessed March 12, 2010.

[21] SEWRPC. 2007. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, Tables 54–56. Planning Report Number 50,

Cost Estimate

Exhibit 5-8 summarizes the screening-level cost estimate, based on return flow to the creek through a pump station at the City of Waukesha WWTP, a pipeline, and an outfall to the creek. Appendixes E and M contain additional information. These cost estimates were prepared for guidance in comparing alternatives based on information available at the time of the estimate. Detailed engineering design has not been completed. The final cost estimate of any project will depend on market conditions, site conditions, final project scope, schedule, and other variable factors. As a result, final project costs may vary from the estimates presented here.

EXHIBIT 5-8
Screening Level Cost Estimate for Return Flow to Underwood Creek

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
Underwood Creek	$56,174,000	$119,000	$57,539,000	$58,050,000

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

Return Flow to Root River

The Root River flows through parts of Milwaukee and Racine counties, and into Lake Michigan at Racine, Wisconsin. The river has more natural channel (e.g., natural bottom substrate and vegetated river banks) than does Underwood Creek, and it has a mixture of land uses between its headwaters and Lake Michigan. The headwaters of the Root River are heavily urbanized, the middle reaches are primarily agriculture and lower density development, and the lower parts of the watershed near Lake Michigan are heavily urbanized.

The conceptual pipeline alignment for return flow to the Root River is the same as the pipeline for Underwood Creek for about the first 9.6 miles. Where the Underwood Creek pipeline heads north toward Underwood Creek, the Root River pipeline would head southeast for 6 miles toward the Root River (Exhibit 5-9) following streets, a parkway, and a bike trail.

The outfall location is farther downstream than the location considered by SEWRPC.[22] This downstream location was chosen to allow for a watershed size and river flow rate similar to that of the Underwood Creek outfall location (i.e., the SEWRPC outfall location was farther upstream on the Root River, where the watershed was smaller). Having similar watershed areas allows the Root River and Underwood Creek return flow locations to be more readily compared for a resulting return flow discharge.

Environmental Resources

Similar to the Underwood Creek alignment, the Root River alignment follows corridors that are previously disturbed and avoids such environmental resources as wetlands and stream crossings as much as possible. Some areas of the alignment will have temporary (short-term) impacts to these resources because of construction activities associated with building the pipeline, but there will be no long-term significant adverse impacts.

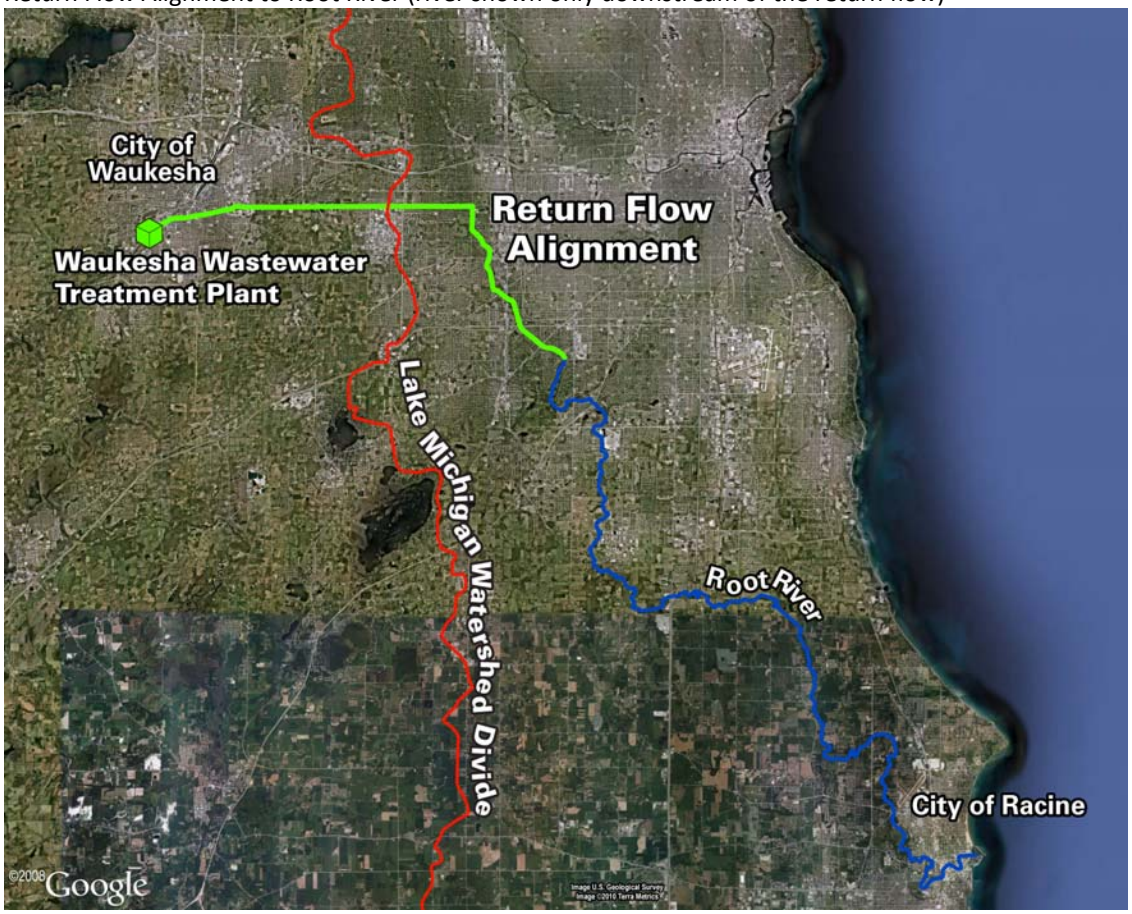
Impacts to environmental resources were analyzed for the return flow pipeline corridor (Appendix N). The Root River alignment has greater environmental impacts than does the Under-

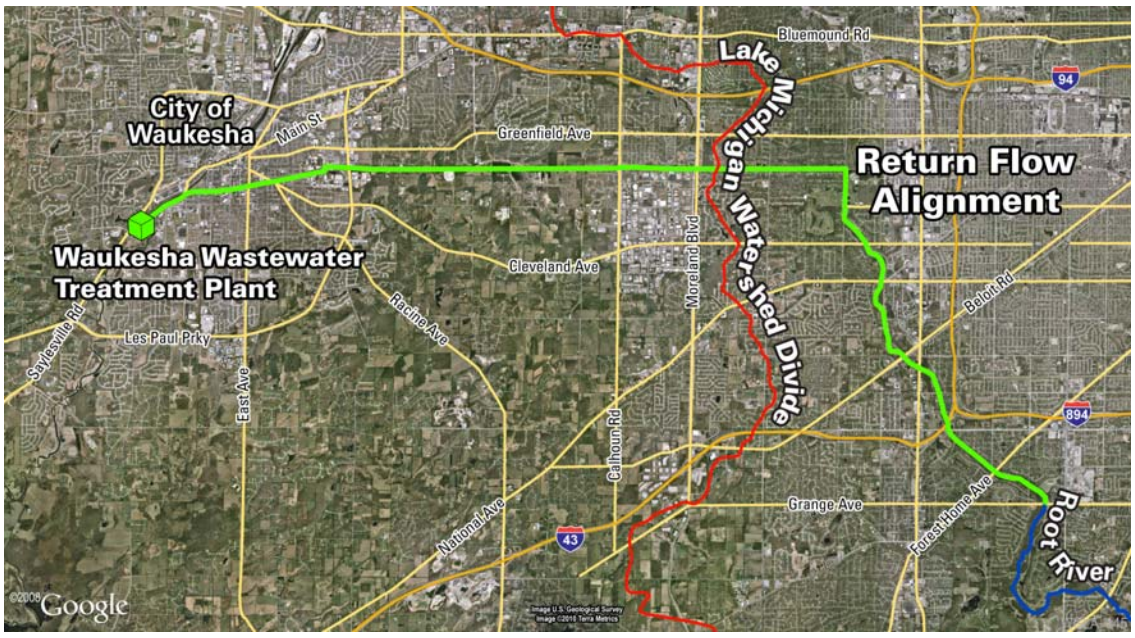
22 SEWRPC. 2008. *A Regional Water Supply Plan for Southeastern Wisconsin*, Chapter 9, Map IX-8. Planning Report No. 52.

wood Creek alignment, primarily because the Root River is a more natural channel than Underwood Creek, which results in more environmental resources are near the Root River.

EXHIBIT 5-9

Return Flow Alignment to Root River (river shown only downstream of the return flow)





A 75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare impacts between alternatives. Exhibit 5-10 summarizes the impacts for the corridor. The return flow discharge will not negatively impact the environmental resources along the pipeline corridor. Instead, the discharge was analyzed for its impact on resources within the Root River.

EXHIBIT 5-10
Summary of Potential Environmental Impacts for a Root River Return Flow

Resource Type	Potential Temporary Impact of Pipeline Corridor
Stream crossings	24
Water body crossings	9
Water body crossings (acres)	0.34
Wetlands (acres)	12.4

Flow, Geomorphology, and Habitat

The Milwaukee Metropolitan Sewerage District completed a comprehensive study of the Root River in 2007 within MMSDs jurisdiction. The primary purposes of the study were to baseline the existing channel stability in the North Branch of the river and provide hydrologic, hydraulic and sediment transport predictions on the vertical and lateral stability of the river and tributary channels.[23] The study area included the location where return flow is proposed. The results of the study were used, in part, to evaluate the effect of a return flow discharge on the flow, geomorphology, and habitat within the Root River. The flow, geomorphology, and habitat impacts from a Root River return flow were also evaluated in comparison to Underwood Creek. A general comparison can be made because the watersheds border each other and they have similar size, land use, and urbanization at the discharge location.

The Root River has a more natural channel than does Underwood Creek, and it is longer from the discharge location to the confluence with Lake Michigan. With the greater length, there is a greater opportunity for habitat enhancements by augmenting the flow in the Root River with return flow. Similar to Underwood Creek, flow in the Root River sometimes is very low, and the functional habitat in the river is limited by the river flow. Augmentation of the return flow would eliminate the very low flow periods. Because the return flow rate is small compared to the higher flows in the river, return flow is not expected to adversely impact the geomorphic stability of the river. For example, a 20-cfs return flow is about 5 percent of the 2-year river flow in the reach at the discharge location, and about 2.2 percent at the next reach about 1.3 miles downstream of the return flow outfall location.[24] For a 100-year river flow at the two locations, the return flow is about 0.5 and 0.8 percent. These are similar to the Underwood Creek flow, where a detailed evaluation concluded that the return flow would not adversely impact the geomorphic stability of the rehabilitated parts of the creek. In addition, the MMSD sediment transport study of the Root River concluded that the river stability is relatively insensitive to changes in flows because of the erosion resistance of the channel boundary materials, the relatively flat channel gradient, and the presence of a functional floodplain.[25] Consequently, the return flow is not expected to adversely impact the Root River.

Beneficial habitat effects in the Root River are expected to be similar to those for Underwood Creek and Menomonee River. Because the Root River is longer and has more natural channel (compared to concrete in Underwood Creek) downstream of the return flow location, more habitat benefits are expected. However, because the return flow is a small part of the river flow as

[23] MMSD. May 4, 2007. *Root River Sediment Transport Planning Study.*

[24] MMSD. May 4, 2007. *Root River Sediment Transport Planning Study.* Hydraulics Technical Memorandum 3. HEC-RAS model from enclosed CD.

[25] MMSD. May 4, 2007. *Root River Sediment Transport Planning Study.* Hydraulics Technical Memorandum 6. Page 1.

the river continues downstream, the habitat benefits are not expected to be significant, similar to Underwood Creek and the Menomonee River.

Fisheries

Fishery data for in the Root River watershed show that 10 new species have been identified, but 10 of 64 recorded species have not been observed since 1986.[26] The most recent fishery surveys, conducted in 2004 and 2007 by the USGS, identified 17 species in the Root River near the proposed return flow location. Some of the new species were observed in reaches of the Root River between the confluence with Lake Michigan and the first dam, suggesting that Lake Michigan's fish community may be influencing the fish community of the lower reaches of the watershed. The Root River is a warmwater habitat, where the balance of fish species indicates a fair quality fishery overall in the watershed that is higher in quality than that of the Menomonee River watershed. Macroinvertebrate data collected within the Root River watershed suggest that the river is dominated by species tolerant of a low quality habitat. Most species within the fish and macroinvertebrate communities generally indicate fair habitat quality.

With the potential presence of one state-listed endangered and three state-listed threatened fish species, there appear to be areas of good quality within parts of the watershed, but there is also impairment because of the agricultural and urban development. The Root River watershed has relatively few streambed and bank modifications, with less than 1 percent of the stream channel observed being in conduit and none lined with concrete. Although habitat conditions in the Root River are fair to good, habitat could be improved by providing more or higher quality habitat. Because return flow would be expected to improvement habitat somewhat, the fish and macroinvertebrate communities could also be expected to improve.

Flooding

Similar to the managed return flow to Underwood Creek, flow would be returned to the Root River in a manner that meets regulatory floodplain management requirements and without causing additional flood damage.

Water Quality

The Root River is classified as a warm water fishery under the WDNR fish and aquatic life standards. The Root River at the potential return flow discharge location is on the 303(d) list for low dissolved oxygen with reported causes from sediment and phosphorus.[27] In addition, the last roughly 6-miles of the Root River upstream of Lake Michigan is on the 303(d) list for PCBs. These listings were all made in 1998.[28] More recently, SEWRPC modeled water quality in the Root River in great detail and found that dissolved oxygen predictions met the standard between 95 and 100 percent of the time for the 11-year period of record analyzed.[29] The water quality findings for SEWRPC's existing condition scenario are summarized below for three points closest to the proposed return flow location.

Fecal Coliform. The Root River sometimes meets fecal coliform standards during the summer recreational season, where the compliance for the single sample standard is met 58 to 66 per-

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[26] SEWRPC. 2007. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.* Planning Report No. 50. pp. 200–14. Data compilation from MMSD, USGS, and WDNR.

[27] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html accessed January 19, 2010.

[28] Ibid.

[29] SEWRPC. 2007. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, Appendix N. Planning Report Number 50.

cent of the time. The geometric mean fecal coliform concentration for the summer season ranges from 603 to 770 cells/100 mL.[30] The historical performance at the City of Waukesha WWTP for the summer recreation season (May through October) had geometric mean fecal coliform concentration ranges from 2 to 49 cells/100 mL. Because the return flow fecal coliform concentration is much lower than the existing conditions and water quality standards in the Root River, the average fecal coliform concentration with return flow will improve.

Dissolved Oxygen. The SEWRPC study predicted that the Root River would comply with the standards of maintaining 5 mg/L of dissolved oxygen 95 to 100 percent of the time. The City of Waukesha WWTP historical performance for average dissolved oxygen concentration ranges from 7.9 to 10.5 mg/L. Because the return flow concentration is greater and has a very low concentration of biological oxygen demand, the average dissolved oxygen concentration in the Root River could improve compliance with water quality standards.

Total Phosphorus. The Root River meets with the SEWRPC planning level goal of 0.1 mg/L 73 to 84 percent of the time. The City of Waukesha WWTP historical performance for monthly average phosphorus concentration ranges from 0.10 to 0.24 mg/L. Phosphorus concentration in the Root River is expected to increase as a result of return flow. However, the environmental change with an increase in phosphorus could be limited, as described in the Underwood Creek water quality modeling conclusions.

Total Suspended Solids. The average total suspended solids in the Root River ranges from 10.3 to 19.4 mg/L. The historical performance of the City of Waukesha WWTP for total suspended solids concentration ranges from 0.9 to 1.8 mg/L. Because the return flow total suspended solids are much lower than the current concentration, the average total suspended solids concentration is expected to improve in Underwood Creek and the Menomonee River as a result of return flow.

Lake Michigan. Return flow under all alternatives is ultimately to Lake Michigan. The comparison of the return flow water quality loading to that of the greater Milwaukee watersheds is the same as that summarized in the Underwood Creek alternative.

Cost Estimate

Exhibit 5-11 summarizes the screening-level cost estimate for this alternative. The costs were based on return flow to the river through a pump station at the City of Waukesha WWTP, a pipeline, and an outfall to the river. Appendixes E and M contain additional information.

EXHIBIT 5-11
Screening Level Cost Estimate for Return Flow to Root River

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
Root River	$75,963,000	$145,000	$77,627,000	$78,249,000

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

[30] Ibid.

EXHIBIT 5-12
Return Flow Alignment Direct to Lake Michigan



Return Flow Directly to Lake Michigan

A screening-level alignment for return flow directly to Lake Michigan was developed to evaluate the environmental effects and costs (Exhibit 5-12). The conceptual pipeline alignment is the same as that for Underwood Creek and Root River for about the first 9.6 miles. Where the two pipelines diverge, the Lake Michigan alignment continues east about 11.2 miles parallel to a railroad corridor. As the alignment nears Lake Michigan, it continues east about 1.2 miles along a city street where it intersects with the lake. The alignment extends into Lake Michigan about 0.5 mile to provide an offshore outfall.

The alignment is that developed by SEWRPC, except the last segment of is a few city blocks to the north. The city street used for the last segment is larger and the shoreline at Lake Michigan has been previously disturbed and is undeveloped compared to the SEWRPC alignment. This alignment appears to have slightly less constructability challenges and is shorter in distance than the alignment developed by SEWRPC.

Environmental Resources

Similar to the Underwood Creek and Root River alignments, the alignment follows corridors that are previously disturbed and avoids environmental resources such as wetlands, stream crossings, and other similar land uses as much as possible. Some areas of the alignment will have temporary (short-term) impacts to these resources because of construction activities associated with building the pipeline. A minor adverse impact may occur in this alternative where the outfall is constructed within Lake Michigan for an offshore discharge.

EXHIBIT 5-13
Summary of Potential Environmental Impacts for Return Flow Direct to Lake Michigan

Resource Type	Potential Impact of Pipeline Corridor
Stream crossings	19
Water body crossings	8
Water body crossings (acres)	6.5
Wetlands (acres)	5.4

The impacts to environmental resources were analyzed (Appendix N) for the return flow pipeline corridor. The alignment has greater environmental impacts than the other two, primarily because it is much longer and includes construction an outfall within Lake Michigan. A 75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare

impacts between alternatives. Exhibit 5-13 summarizes the environmental impacts along the corridor.

The return flow discharge will not adversely impact the environmental resources along the pipeline corridor. Instead, a direct discharge was analyzed for the potential impacts on resources in Lake Michigan.

Flow, Geomorphology, and Habitat

The same as the Underwood Creek and Root River alternatives, return flow directly to Lake Michigan does not cause significant adverse impacts to the flow, geomorphology, or habitat in the lake. As discussed under "Return Flow Alternatives," for discharges to Underwood Creek or Root River, the return flow is able to provide a resource benefit by providing additional flow in the creek and river during periods when little or no flow is naturally present. The return flow to a Lake Michigan tributary could provide benefits to habitat with flow augmentation while not adversely affecting geomorphic stability. In contrast, return flow directly to Lake Michigan would have no environmental benefit because the return flow would be conveyed in a pipe, instead of through a surface water where the additional flow could benefit the water dependent natural resources in the Great Lakes Basin. Consequently, return flow directly to Lake Michigan is the least preferred alternative because the return flow is not able to be used as a resource.

Fisheries

Return flow directly to Lake Michigan will not have a significant adverse impact to fisheries in Lake Michigan. The outfall construction would have a minor adverse impact upon Lake Michigan substrate and the return flow water quality loading is small as described above. Consequently, there will be no significant adverse impact on Lake Michigan fisheries.

Water Quality

Under all alternatives, flow ultimately is returned to Lake Michigan. The comparison of water quality loading to that of the greater Milwaukee watersheds is the same as that summarized in the Underwood Creek alternative.

Cost Estimate

Exhibit 5-14 summarizes the screening-level cost estimate for this alternative. Costs were based on return flow to Lake Michigan through a pump station at the City of Waukesha WWTP, a pipeline, and an outfall to the lake. Appendixes E and M contain additional information.

EXHIBIT 5-14

Screening Level Cost Estimate for Return Flow Direct to Lake Michigan

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
Direct to Lake Michigan	$109,848,000	$159,000	$111,672,000	$112,355,000

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

Return Flow through the Milwaukee Metropolitan Sewerage District

The MMSD operates regional sewage collection and water reclamation systems for most communities within the Lake Michigan Basin in the Milwaukee metropolitan area. Under this return

flow alternative, the City of Waukesha sanitary sewer system would collect flow from its sanitary sewer service area and convey return flow to MMSD for treatment and discharge to Lake Michigan. There are two subalternatives for return flow to MMSD:

- Sanitary sewer flow treated at the City of Waukesha WWTP with return flow to MMSD
- Sanitary sewer and return flow conveyed to MMSD without treatment at the Waukesha WWTP

For either option, a new pump station would be located at the WWTP, and a pipeline alignment would be selected to provide return flow while minimizing impacts to environmental resources and other land uses. The City would continue to operate a WWTP, even for the subalternative where the City would return untreated sanitary sewer flow to the MMSD. Continued WWTP operation would occur because there are periods when sanitary sewer flow exceeds the water withdrawal. To prevent returning more than 100 percent of the withdrawn water, discharge to the Fox River for the additional sanitary sewer flow would continue. This intermittent operation of the WWTP would not be possible without significant modification of the existing WWTP processes.

For either subalternative, improvements to the MMSD collection system and treatment plants are likely required. The MMSD system is capacity-limited during wet weather, so any flow returned to MMSD would likely require additional conveyance and treatment capacity equivalent to the return flow.

As with returning flow directly to Lake Michigan, returning flow to MMSD does not allow the return flow to be used as a resource, because the flow would not be in a Lake Michigan tributary. For the subalternative with treatment of return flow at the City of Waukesha WWTP and MMSD, the return flow would be inefficiently using resources by providing double-treatment with no significant improvement in return flow water quality.

SEWRPC included the MMSD alternative in its evaluation of return flow alternatives, but the MMSD alternative was not recommended because the cost exceeded that of return flow directly to Lake Michigan and to a Lake Michigan tributary.[31] Consequently, this alternative was not evaluated further for these reasons, and for those discussed above.

Preferred Return Flow Alternative

The City of Waukesha is committed to providing return flow for the withdrawn water, with a goal of returning 100 percent of it as discussed under "Return Flow Management Plan." Returning flow through Underwood Creek or Root River, or directly to Lake Michigan, can be achieved, but return flow through Underwood Creek is preferred because it has the least environmental impact, it maximizes use of existing utility corridors and previously disturbed areas, and the discharge can be used as an environmental resource by improving the habitat and fisheries in Underwood Creek and the Menomonee River. Exhibit 5-15 summarizes the environmental impacts for the return flow alternatives for a 75-foot-wide corridor along the pipeline alignments.

Return flow to Underwood Creek also will protect public health by providing return flow with water quality that meets or exceeds the effluent limits proposed by the WDNR (as required by Compact Section 4.9(4)c). The WDNR proposed return flow effluent limits would be a higher standard than that from other Lake Michigan tributary dischargers.

[31] SEWRPC. 2008. *A Regional Water Supply Plan for Southeastern Wisconsin*, Chapter 9, Page 37. Planning Report No. 52.

EXHIBIT 5-15
Summary of Potential Environmental Impacts for the Pipeline Alignment Alternatives

Return Flow Alternative	Stream Crossings	Water Body Crossings	Water Body Crossings (acres)	Wetlands (acres)
Underwood Creek	17	8	0.15	9.4[a]
Root River	24	9	0.34	12.4
Direct to Lake Michigan	19	8	6.5	5.4

[a]For an outfall near Bluemound Road. The impacts are about 5.0 acres for a discharge 0.9 mile upstream.

Return flow through Underwood Creek is also significantly less costly than the other alternatives. Because return flow to Underwood Creek and Root River has similar benefits, the additional cost and additional impacts further support Underwood Creek as the preferred alternative. Exhibit 5-16 summarizes the cost estimates for return flow under the three alternatives studied. Flow returned directly to Lake Michigan is least preferred because it does not allow the discharge to provide an environmental resource, and it is the highest cost. A cost estimate for return flow to MMSD was not made, because the alternative is not being considered further.

EXHIBIT 5-16
Cost Comparison for Return Flow Alternatives

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
Underwood Creek	$56,174,000	$119,000	$57,539,000	$58,050,000
Root River	$75,963,000	$145,000	$77,627,000	$78,249,000
Direct to Lake Michigan	$109,848,000	$159,000	$111,672,000	$112,355,000

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

Wisconsin law requires that the place at which the water is returned to the source watershed be as close as practicable to the place at which the water is withdrawn, unless the applicant demonstrates that returning the water at that place is one of the following: (a) not cost-effective; (b) not environmentally sound; or (c) not in the interest of public health. Reference: Wis. Stat. § 281.346(4)(f)3m.

The proposed return flow to Underwood Creek complies with Sec. 281.346(4)(f)3m of providing the return flow to the source watershed as close as practicable to the withdrawal location. Comparing the Underwood Creek return flow location to a return flow direct to Lake Michigan location, Underwood Creek is more economically feasible, environmentally sound, and protective of human health for the following reasons:

- The location where the return flow is conveyed to Lake Michigan is the same as the withdrawal area. The water withdrawal will be from Lake Michigan in the Milwaukee area (Section 4) and return flow is proposed to be conveyed to Lake Michigan through Underwood Creek and Menomonee River in Milwaukee.
- A return flow directly to Lake Michigan is about double the cost ($53.7 million more) than a return flow to Underwood Creek. A return flow direct to Lake Michigan is not fiscally responsible when providing less of an environmental benefit compared to return flow to a Lake Michigan tributary and is not economically feasible.

- A return flow direct to Lake Michigan provides a water balance in the basin, but it has more environmental impacts compared to discharge to Underwood Creek. The outfall construction in Lake Michigan has a pipeline that is longer than any other alternative and subsequently has more environmental impacts. A return flow to Underwood Creek provides a water balance in the basin and it has more environmental benefits. Because a return flow to Underwood Creek has more environmental benefits, a return flow direct to Lake Michigan is not environmentally sound.

- Underwood Creek and Menomonee River often do not meet water quality standards for fecal coliform bacteria, but return flow will improve the water quality by allowing the creek and river to meet their water quality standards more often. This is accomplished because the City of Waukesha's WWTP produces a very high quality treated water that will provide high quality return flow. The return flow increases the time that Underwood Creek and Menomonee River meets its water quality standards, which is in the interest of public health. A return flow direct to Lake Michigan does not provide this public health benefit to Underwood Creek or Menomonee River.

The proposed return flow to Underwood Creek complies with the Compact Section 4.9(4)d and Wisconsin Statute Section 281.346(4)(f)5 of providing the return flow with no significant individual or cumulative adverse impact. Return flow will be implemented to ensure that no significant individual or cumulative adverse impacts result to the quantity and quality of the waters and water dependent natural resources of the basin. The Application proposal maintains, and in some cases improves, the chemical, physical, and biological integrity of the Great Lakes Basin as discussed above regarding Underwood Creek under "Return Flow Alternatives."

The return flow management plan has met the Compact and Wisconsin requirements for return flow with no exceptions and it sets a high standard for obtaining a Great Lakes water supply because the Application exceeds the requirements in the following ways:

- The City of Waukesha has a return flow goal that is greater than water supply less consumptive use. The return flow goal has been set at 100 percent, which is higher than the Compact requirement.

- Return flow will be used as a resource to benefit habitat, fisheries, and water quality in a Lake Michigan tributary.

- Return flow water quality is more stringent than other Lake Michigan tributary dischargers and will improve the water quality in Underwood Creek by allowing the creek to meet water quality standards more often.

Any future application by others must follow the Compact requirements and will be evaluated at that time on its own merit. The Compact was developed to regulate Great Lakes diversions. Because the return flow management plan meets all the requirements without exception and exceeds some requirements, it would create a high standard if it were to be used as a precedent in the future. By proposing to exceed the Compact and Wisconsin requirements, the City of Waukesha has set a precedent beyond that which is required.

SECTION 6

Application Compact Compliance Summary

This section provides a summary of the preceding five sections of this application as to why the proposal satisfies the conditions for an exception to the prohibition against a diversion and meets the exception standard criteria.

The conditions for a diversion and exception standard criteria of the Great Lakes-St. Lawrence River Basin Water Resources Compact and the Wisconsin Compact implementing § 281.346 and § 281.348 Wis. Stats. will be highlighted separately followed by a summary and/or reference to the appropriate section of this proposal on how the proposal satisfies the exception for a diversion and meets the exception standard criteria.

Eligibility to Apply

A proposal by a community within a straddling county to divert Great Lakes water is excepted from the prohibition against diversions, provided that the proposal satisfies all of the requirements of the Compact and Wis. Stat. § 281.346(4). Reference: Compact Article 4, Section 4.9.3; Wis. Stat. § 281.346(4).

A community within a straddling county is defined as "any city, village or town that is not a straddling community and that is located outside the Great Lakes basin but wholly within a county that lies partly within the Great Lakes basin." Wis. Stat. § 281.346(1)(d); See also Compact Article 1.

The City of Waukesha is a community within a straddling county. While the City is located only 18 miles west of Lake Michigan, it is located 1.5 miles west of the Great Lakes watershed surface water divide, and is outside of the Great Lakes Basin. See Exhibit 1.1.

The City, however, is located wholly within Waukesha County, Wisconsin. Waukesha County lies partly within the Great Lakes Basin, and therefore is a straddling county. As a community within a straddling county, the City is eligible to submit this application for Lake Michigan water.

A proposal for a diversion may be made only by an entity operating a public water supply system that would receive water from the diversion. Reference: Wis. Stat. § 281.346(4)(b)2.

The applicant for the diversion is the City of Waukesha. The City operates a public water supply system through its water utility. The Waukesha Water Utility is a public water supplier governed by Chapter 196, Wisconsin Statutes. The water utility is regulated by the WDNR and the Wisconsin Public Service Commission.

Demonstration of Need

A community within a straddling county applying for a diversion must be without adequate supplies of potable water. Reference: Compact Article 4, Section 4.9.3.a.; Wis. Stat. § 281.346(4)(e)1.a.

"Without adequate supplies of potable water" is defined as "lacking a water supply that is economically and environmentally sustainable in the long term to meet reasonable demands for a water supply in the quantity and quality that complies with applicable drinking water standards, is protective of public health, is available at a reasonable cost, and does not have adverse environmental impacts greater than those likely to result from the proposed new or increased diversion." Reference: Wis. Stat. § 281.346(1)(zm).

The City withdraws about 87 percent of its water supply from the deep St. Peter Sandstone aquifer. The deep aquifer is not an adequate source of supply for the long term because the aquifer has been drawn down 500 to 600 feet and continues to decline at a rate of 5 to 9 feet per year.[1] Pumped withdrawals from the deep aquifer continue to exceed the rate at which the aquifer can be recharged. The groundwater mining that is taking place cannot be sustained indefinitely and does not maintain a reliable source of supply for the near future.

Continued use of the deep aquifer is also not environmentally sustainable. As discussed in Section 4, Water Supply Alternatives: Water Supply Alternative 1: Continued Use of Deep and Shallow Aquifers. Continued deep aquifer pumping contributes to the following cumulative environmental impacts:

- Groundwater level decline
- Reduced baseflows to surface water resources, as water is drawn toward deep wells
- Reversal of the natural flow system as groundwater once flowed east toward Lake Michigan through the deep aquifer in southeastern Wisconsin and now it is drawn to the groundwater pumping centers west of the surface water divide
- Diversion of as much as 30 percent of the water replenishing the deep aquifer from the Waters of the Basin
- Discharge of water from the Great Lakes Basin to the Mississippi River Basin

These impacts illustrate that the waters of the Great Lakes Basin would be better preserved and more effectively managed if regional deep aquifer pumping was reduced. See Section 3, Need for a New Water Supply: Deep St. Peter Sandstone Aquifer.

The City also draws about 13 percent of its current water supply from the shallow aquifer As discussed in Section 3, Need for a New Water Supply: Shallow Troy Bedrock Valley Aquifer, that formation is the source of water supply for Village of Mukwonago, the Village of East Troy, the City of Waukesha and the City of Muskego; it is also the home of sensitive environmental resources including the Vernon Marsh Wildlife Area, Pebble Brook (a Class II trout stream), and Pebble Creek.

Continued use of the shallow aquifer to meet the City's needs would not be environmentally sustainable. The estimated cumulative impacts of increased shallow aquifer pumping include groundwater drawdown at the wells of up to 50 to 100 feet and reduction of baseflow to surface waters ranging from 17 to 340 percent.[2] Also, over 400 existing private wells may be impacted if the City increases pumping to as little as 6.4 mgd from the shallow aquifer. See also Section 4, Water Supply Alternatives: Water Supply Alternative 1: Continued Use of Deep and Shallow Aquifers.

Expansion of the Troy Bedrock Valley aquifer supply to meet the City's needs is not a reasonable water source because withdrawing the quantity of water needed by the City would have a devastating impact on extensive, rare water resources that are designated for protection by the state and the regional water quality and land use planning authority.

The physical evidence and scientific studies demonstrate that the City of Waukesha is without an adequate supply of potable water. The City's supply of deep aquifer groundwater is not economically and environmentally sustainable because pumping exceeds the rate at which the aquifer can

[1] *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* SEWRPC, 2008, p.102–103.

[2] *Results of Groundwater Modeling Study Shallow Aquifer Source – Fox River & Vernon Marsh Area, Waukesha Water Utility*, RJN Environmental Services, April 2010.

be renewed and the quantity of available groundwater is decreasing. The deep aquifer is not a reliable long-term source of supply. Further, the City's continued pumping of the deep aquifer withdraws groundwater from the Great Lakes Basin and diverts it to the ocean. This diversion adversely impacts the environment by reducing the amount of water available to the waters and water dependent resources of the Great Lakes Basin. The City's shallow aquifer supply cannot be expanded to meet future demands sustainably because additional withdrawal causes severe adverse environmental impacts to local surface water resources. The City's groundwater supplies can be treated to remove contaminants and meet applicable drinking water standards. However, the cost of groundwater pumping and treatment is greater than the cost of the proposed new Great Lakes diversion with return flow. It is possible that either the groundwater or Lake Michigan sources of potable water supply could be contaminated. Because groundwater contamination such as found in stormwater runoff, chemical spills, septic systems, or landfills is more likely, the proposed Lake Michigan supply is more protective of public health.

A community within a straddling county applying for a diversion must have no reasonable water supply alternative within the basin in which the community is located, including conservation of existing water supplies. Reference: Compact Article 4, Section 4.9.3.d.; Wis. Stat. §§ 281.346(4)(e)1.d. and 281.346(4)(e)1.g.

"Reasonable water supply alternative" is defined as "a water supply alternative that is similar in cost to, and as environmentally sustainable and protective of public health as, the proposed new or increased diversion and that does not have greater adverse environmental impacts than the proposed new or increased diversion." Reference: Wis. Stat. § 281.346(1)(ps).

The body of previously developed scientific work and the analysis of water supply alternatives for the City presented in Section 4 conclude that the City has no reasonable water supply alternative within the Mississippi River Basin that is as environmentally sustainable, protective of public health, and cost effective as the use of Lake Michigan water. See Exhibits 4-18 and 4-20. This conclusion is based on the adverse environmental impacts of continued pumping of the deep aquifer and expanded pumping of the shallow aquifer. It is also based on a comparison of the alternatives' relative costs and ability to protect public health. A Lake Michigan water supply with continued water conservation and return flow, in accordance with the requirements of the Compact, is the only water supply that balances the inherent social and economic development benefits of a reliable source of drinking water with stewardship of environmental resources for future generations. A Lake Michigan supply for the City is sustainable, protective of public health, and results in more effective management, or improvement, of the waters and water dependent resources of the Great Lakes Basin.

The decision-making standard requires that the proposed use of the water be reasonable., § 281.346(6)(e). This is based on consideration of factors that include the balancing of the effects of the proposed withdrawal and use and other existing or planned withdrawals and water uses from the water source on economic development, social development and environmental protection, § 281.346(6)(e)3.

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has undertaken the task of conducting a socio-economic impact analysis to SEWRPC's regional water supply plan to address this factor. The results of this socio-economic impact analysis will be incorporated into and made a part of this proposal when completed.

Allowable Use

Diverted water will be used solely for public water supply purposes by a community within a straddling county. Reference: Compact Article 4, Section 4.9.3.a.; Wis. Stat. § 281.346(4)(e)1.

"Public water supply" means "water distributed to the public through a physically connected system of treatment, storage, and distribution facilities that serve a group of largely residential customers and that may also serve industrial, commercial and other institutional customers." Reference: Wis. Stat. § 281.346(1)(pm).

The City requests the use of Lake Michigan water solely to serve the City's public water system within the water supply service area determined by the regional water quality planning agency under the provisions of state's water supply plan law, Wis. Stat. § 281.348(2)(cm). See Section 2, Water System Overview: Water Supply Service Area. Currently the City provides water service to the following customer classes: residential (45 percent), commercial (35 percent), industrial (16 percent) and public (4 percent).

Source of Water

If an applicant will not directly withdraw the water proposed to be diverted, the applicant shall identify any entities that may withdraw the water and provide evidence of support from each of those entities in the form of a letter or resolution. Reference: Wis. Stat. § 281.346(4)(b)4m.

The City is discussing the purchase of potable water from Lake Michigan with the City of Milwaukee, the City of Oak Creek, and the City of Racine. Milwaukee, Oak Creek and Racine are located within the Great Lakes Basin and they operate public water utilities that withdraw water from Lake Michigan. All three potential water suppliers have submitted letters or resolutions indicating a willingness to negotiate an agreement for the sale of water. See Appendix P.

In determining whether to approve a proposal for a community within a straddling county, the DNR shall give substantive consideration to whether the applicant provides sufficient scientifically based evidence that the existing water supply is derived from groundwater that is hydrologically interconnected to waters of the Great Lakes basin, although the DNR may not use a lack of hydrological connection to the waters of the Great Lakes basin as a reason to disapprove a proposal. Reference: Wis. Stat. § 281.346(4)(e)2; See also Compact Article 4, Section 4.3.

Based on available scientific evidence, it has been shown that the City's groundwater supply is derived in part from groundwater that is interconnected hydrologically to the Lake Michigan basin.[3] Also see Section 3, "Waukesha's Water Supply Linkage to Great Lakes Basin."

Amount of Request

An approved diversion shall be limited to quantities that are reasonable for the purposes for which it is proposed. Reference: Compact Article 4, Section 4.9.4.b. Wis. Stat. §§ 281.346(4)(f)2.

The Wisconsin Department of Natural Resources shall specify a diversion amount equal to the quantity of water that is reasonable for the purposes for which the diversion is proposed when granting an approval for a diversion. Reference: Wis. Stat. § 281.346(4)(i).

[3] D.T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*

Based on extensive water supply planning, the City of Waukesha is submitting a proposal to withdraw up to an average of 10.9 mgd from Lake Michigan. The proposed amount will serve the public water system needs of the City of Waukesha for the ultimate water supply service area population of 97,400, projected to be reached sometime after 2035. See Section 2, Water System Overview. The City of Waukesha is requesting that the WDNR approve this water supply service area plan as part of the Great Lakes application process.

At the end of the 20-year planning period (2010–2030), the City has estimated its water needs to be 9.9 mgd from Lake Michigan with return flow. This proposed amount will serve the public water system needs of the City of Waukesha through 2030. (§ 281.348 (4)(a), Wis. Stat.) This amount is less than the City's application request of 10.9 mgd because the City's request is based upon ultimate build out of the water supply service area which is expected to occur after 2035.

For the purposes of applying the application requirements, the Wisconsin Department of Natural Resources shall use, as appropriate, the current or planned service area of the public water supply system receiving water under this proposal. The planned service area is the service area of the system at the end of any planning period authorized by the Wisconsin Department of Natural Resources in the approved water supply service area plan that covers the public water supply system. Reference: Wis. Stat. § 281.346(4)(bg)2.

The amount of the requested diversion is based upon the proposed quantity of water needed to supply the projected City of Waukesha water service area population as delineated by SEWRPC. Under Chapter NR 121, Wis. Admin. Code, SEWRPC is the agency designated by the State to delineate proposed water supply service areas for all public water supply systems in the southeastern Wisconsin planning area. The delineated water supply service area for the City of Waukesha (See Exhibit 2-2) is consistent with the SEWRPC 2008 regional water supply study.

For the projected buildout of the City of Waukesha water service area (beyond 2035), the annual average day capacity of the proposed supply is 10,900,000 gallons per day; the water supply infrastructure will be sized to supply a proposed maximum day demand of 18,500,000 gallons per day.[4] For the WDNR 20-year planning period (2010–2030) for the City of Waukesha water service area, the maximum day capacity of the proposed supply is 9,900,000 gallons per day and the proposed maximum day demand is 16,600,000 gallons per day. See Section 2: Water Supply Service Area Population Projections and Water Demand Forecasts.[5]

An alternative with deep aquifer water and Lake Michigan water was not developed or analyzed. The primary reasons for not evaluating this combination of supplies are the operating challenge of continuously meeting regulatory standards with source waters of widely varied water quality and meeting distribution system pressure requirements with distributed ground water supplies and a central Lake Michigan supply. Also, this combination was not developed because Illinois and Wisconsin are supportive of the goal of eliminating the use of the deep St. Peter Sandstone aquifer. See also *State of Wisconsin, et al v. State of Illinois, et al, 449 U.S. 48, 101 S.Ct. 557, 66 L.Ed.2d 253*.

[4] AECOM. 2009. *Summary of Water Requirements, City of Waukesha, Wisconsin Technical Memorandum.*
[5] Ibid.

Conservation of Existing Supplies

An applicant cannot reasonably avoid through the efficient use and conservation of existing water supplies the need for all or part of the proposed diversion. Reference: Compact Article 4, Section 4.9.4.a. Wis. Stat. §§ 281.346(4)(f)1. and 281.346(4)(g).

The City cannot reasonably avoid the need for the proposed diversion through the efficient use and conservation of existing water supplies. The requested diversion amount assumes the City will continue and expand its water conservation measures. Water savings from conservation is an important element in the City's long-range water supply plan. Based on the effectiveness of current water conservation measures and projected water use across various customer classes over the water supply planning period, and beyond, it is estimated that another 10 percent water savings may be gained through conservation, but that volume—about 1 mgd—is not sufficient to offset the need for a new adequate supply of potable water.

An applicant shall demonstrate the efficient use and conservation of existing water supplies in accordance with Wisconsin Department of Natural Resources requirements. Wis. Stat.§ 281.346(4)(g).

The City has demonstrated its commitment to the efficient use and conservation of existing water supplies. The City's conservation program is described in Section 2, Water System Overview: Waukesha Water Conservation and Efficiency. The City's water conservation plan (Appendix A) has been referred to by the Wisconsin Public Service Commission as a model for conservation planning in the state. It identifies practical near-term, mid-term, and long-term goals and actions to be evaluated and implemented. The effectiveness of the conservation practices being used is measured so that the City can adapt the plan and target investment to maximize water savings.

Commitment to Conservation of Lake Michigan Water

The proposal will be implemented so as to incorporate environmentally sound and economically feasible water conservation measures to minimize water withdrawals and consumptive use. Reference: Compact Article 4, Section 4.9.4.e.; see also Wis. Stat. § 281.346(4)(f)6.

"Environmentally sound and economically feasible water conservation measures" is defined as "those measures, methods, or technologies for efficient water use and for reducing water loss and waste or for reducing the amount of a withdrawal, consumptive use, or diversion that are, taking into account environmental impact, the age and nature of equipment and facilities involved, the processes employed, the energy impacts, and other appropriate factors, all of the following: 1. Environmentally sound. 2. Reflective of best practices applicable to the water use section. 3. Technically feasible and available. 4. Economically feasible and cost-effective based on an analysis that considers direct and avoided economic and environmental costs." Wis. Stat. § 281.346(1)(i); See also Compact Article 1.

An applicant shall document the water conservation planning and analysis used to identify the water conservation and efficiency measures that the applicant determined were feasible. Reference: Wis. Stat. § 281.346(4)(g).

In 2006, the City implemented a comprehensive water conservation plan to further reduce water use. Water conservation and protection efforts will be continued and monitored to determine which measures are the most effective. Highlights of the City's successful water conservation and efficiency measures are presented below. Additional details are presented in Section 2, Water System Overview: Waukesha Water Conservation and Efficiency and Appendix A.

Customer Metering. The City of Waukesha meters all water customers and monitors water use with accurate automatic flow meters that can be read remotely. Meters are monitored routinely. If a dramatic change in water use is observed, the City contacts a customer to promptly address potential water waste issues.

Limiting Unaccounted-for Water. All water utilities have unavoidable water loss. This water loss, called unaccounted-for water, is used for fighting fires, flushing mains, or is lost through leaks in water pipes. To minimize unaccounted-for water, the City monitors the system for leaks and estimates water used for routine system flushing. Historically, the City averages 4 to 7 percent unaccounted-for water,[6] which is less than the American Water Works Association-recommended benchmark of 10 percent.

Restrict Outdoor Sprinkling. The first conservation initiative implemented in 2006 was adoption of a sprinkling ordinance that affected all customer classes. The ordinance was successful in reducing the average and maximum day water demand. Comparisons show a 15 percent reduction in summer watering season water use from 2005 to 2008.

Conservation Water Rates. Waukesha adopted a conservation (inclining) rate structure for residential customers in 2007, becoming the first city in the state to charge customers more per gallon as water use increases.

Toilet Rebate Program. Toilets are the largest user of residential water, accounting for 26.7 percent of the water used in an average home.[7] Toilet replacement is one of the most effective ways to reduce indoor water use. The toilet rebate program was launched in October 2008, with a goal of saving 500,000 gallons per day by replacing old high-flow toilets with new high-efficiency toilets. To help meet this goal, the City is providing rebates for fixture replacement.

Water Conservation Education in Public Schools. Fifth- and ninth-grade students are taught about water conservation by Waukesha Water Utility staff. By visiting water facilities, operating tabletop groundwater models, and collaborating with teachers, the City has introduced water conservation to more than 17,000 students.[8]

No Significant Adverse Impacts from Diversion

A diversion proposal must not endanger the integrity of the Great Lakes basin ecosystem. A diversion proposal will not endanger the integrity of the basin ecosystem if it is determined that the proposal will have no significant adverse impact on the ecosystem. Reference: Compact Article 4, Section 4.9.3.e.; Wis. Stat. § 281.346(4)(e)1.e.

An application shall provide information about the potential impacts of the diversion on the waters of the Great Lakes basin and water dependent natural resources, and an assessment of the individual impacts of the proposal relative to the requirement that the diversion result in no significant adverse individual impacts. Reference: Wis. Stat. §§ 281.346(4)(b)4. & 5.

The application provides an assessment of the potential impacts of the diversion in Section 4, Water Supply Alternatives: Water Supply Alternative 3: Proposal to Use Lake Michigan Water. The application also provides an assessment of the potential impacts of the return flow in Section 5. These Sections demonstrate there will be no significant adverse impacts to the waters

[6] Waukesha Water Utility annual operating data submitted to Wisconsin Public Service Commission.

[7] *Handbook of Water Use and Conservation*. 2001, Amy Vickers.

[8] Waukesha Water Utility. 2009. Annual Educational Program Data.

and water dependent natural resources or the chemical, physical, or biological integrity of the Great Lakes Basin from this proposed diversion.

Waters. There will be no significant adverse impact to the quantity of water of the Great Lakes Basin. As discussed in Section 5, Return Flow, the City will meet the Compact requirement of returning to Lake Michigan the volume of water withdrawn less consumptive use. The City has further set a goal of returning 100 percent of the volume withdrawn from Lake Michigan.

Water Dependent Natural Resources. There will be no significant adverse impact to water dependent natural resources from the Lake Michigan withdrawal, but rather there will be an environmental benefit from converting the City of Waukesha's water supply from the deep aquifer to Lake Michigan water. Section 4, Water Supply Alternatives, discusses the groundwater level rebound benefits of stopping deep aquifer pumping. Section 5, Return Flow, discusses the City's plan to improve the aquatic habitat and fisheries in the Great Lakes tributary receiving return flow, which will improve water dependent natural resources.

Chemical Integrity. There will be no significant adverse impact to the chemical integrity of the Great Lakes Basin from the Lake Michigan withdrawal. The chemical integrity of the Great Lakes Basin will be protected because the quality of the return flow will meet all WDNR water quality permit requirements. In addition, return flow will either improve in-stream water quality or result in only minor changes as discussed in Section 5, Return Flow Alternatives.

Physical Integrity. There will be no significant adverse impact to the physical integrity of the Great Lakes Basin from the Lake Michigan withdrawal. The physical integrity of the Great Lakes Basin is protected by implementing the Return Flow Management Plan and meeting the return flow requirement. The physical integrity of potential receiving waters is also protected from increased erosion and sediment scour as described in Section 5, Return Flow Alternatives.

Biological Integrity. There will be no significant adverse impact to the biological integrity of the Great Lakes Basin from the Lake Michigan withdrawal. The biological integrity of the Great Lakes Basin is protected because there is no opportunity for invasive species to be introduced through the return flow because the flow is confined to a pipe from a wastewater treatment plant. Furthermore, improvements to the biological integrity of the Great Lakes tributary receiving return flow are expected because the return flow will provide more, and higher-quality functional in-stream habitat. The habitat improvements will benefit the fisheries and support water dependent natural resources in the Great Lakes tributary as described in Section 5, Return Flow Alternatives.

A diversion must be implemented so as to ensure that it will result in no significant adverse individual impacts or cumulative impacts to the quantity or quality of the waters and water dependent natural resources of the basin, including cumulative impacts that might result due to any precedent-setting aspects of the proposal, based upon a determination that the proposal will not have any significant adverse impacts on the sustainable management of the waters of the Great Lakes basin. Reference: Compact Article 4, Section 4.9.4.d.; Wis. Stat. §§ 281.346(4)(f)5.

"Cumulative impacts" is defined as "the impacts on the Great Lakes basin ecosystem that result from incremental effects of all aspects of a withdrawal, diversion, or consumptive use in addition to other past, present, and reasonably foreseeable future withdrawals, diversions, and consumptive uses regardless of who undertakes the other withdrawals, diversions, and consumptive uses, including individually minor but collectively significant withdrawals, diversions, and consumptive uses taking place over a period of time. Wis. Stat. § 281.346(1)(g); See also Compact, Article 1.

The proposed diversion will have no significant adverse individual or cumulative impacts on the quantity or quality of the waters and water dependent natural resources of the Basin. To the contrary, the proposed diversion is anticipated to have a net positive impact on the waters and water dependent natural resources.

The City proposes to use Lake Michigan for its water supply source. After use and treatment, the City will return the water to the basin. As a result of switching to a Lake Michigan source of water, the City would discontinue its use of groundwater from the deep aquifer. Discontinuing the use of groundwater would stop the cumulative adverse impacts to the groundwater resources identified in Section 4, Water Supply Alternatives.

As discussed in Section 5, Return Flow Management Plan, the City has a goal that the return volume will equal the withdrawn volume. By providing 100 percent return volume, there will be no volume change to the Great Lakes Basin and no significant cumulative impact to the water dependent industries (e.g. shipping and hydropower generation) in the Great Lakes.

Switching to a Lake Michigan water supply and discontinuing the withdrawal of groundwater from the deep aquifer would benefit the waters of the basin. Historically, water from the deep aquifer flowed to Lake Michigan. After groundwater pumping of the deep aquifer began, water from the deep aquifer was drawn down and was not available to feed Lake Michigan. As pumping increased, the flow of groundwater was actually reversed and water that would have otherwise fed Lake Michigan was dawn to the groundwater wells. Now, waters of the Great Lakes Basin are flowing into the deep aquifer rather than recharging Lake Michigan. The USGS estimates that 30 percent of the 33 mgd of water currently pumped by the deep aquifer wells in southeastern Wisconsin originates from inside the Lake Michigan Basin. See Section 3, Need for Water: Deep St. Peter Sandstone Aquifer. Switching from the groundwater supply to a Lake Michigan surface water supply would contribute to aquifer recovery and would eliminate the diversion of water from the Lake Michigan groundwatershed to the Mississippi River watershed.

Pumping the deep aquifer also pulls down water from the overlaying shallow aquifer to the deep aquifer. It is estimated that 18 percent of shallow aquifer baseflows are diverted toward deep wells and away from surface water resources. If pumping of the deep aquifer is replaced with a Lake Michigan supply, Waukesha will no longer pull water from the shallow aquifer to the deep aquifer. This will improve critical baseflows to surface water resources, including wetlands, streams and lakes.

The withdrawal of water from Lake Michigan will not endanger the integrity of the Lake Michigan ecosystem. This is because the return flow water quality will meet all WDNR requirements and the City has a goal to return 100 percent of the withdrawn volume. The return flow will also improve or maintain the physical and biological resources, and improve or have a minor change to the chemical resources of the tributary stream and Lake Michigan.

See also No Significant Adverse Impacts From Return Flow in this section.

Return Flow to the Basin

The applicant is to return the water withdrawn to the Great Lakes basin. If it will not, the applicant shall identify any entities that may return the water and provide evidence of support from each of those entities in the form of a letter or resolution. Reference: Wis. Stat. § 281.346(4)(b)4p.

The City will be responsible for returning the water withdrawn to the Great Lakes Basin.

A diversion proposal must provide that all water withdrawn shall be returned, either naturally or after use, to the source watershed less an allowance for consumptive use. Reference: Compact, Article 4, Section 4.9.4.c.; Wis. Stat. §§ 281.346(4)(f)3. also see 281.346(4)(f)4.

The proposal maximizes the amount of water withdrawn from the Great Lakes basin that will be returned to the source watershed and minimizes the amount of water from outside the Great Lakes basin that will be returned to the source watershed. Wis. Stat. § 281.346(4)(e)1.c.

"Source watershed" is defined as "the watershed from which a withdrawal originates." If water is withdrawn directly from a Great Lake, then the source watershed is the watershed of that Great Lake. If water is withdrawn from the watershed of a stream that is a direct tributary to a Great Lake, then the source watershed is the watershed of that Great Lake. Wis. Stat. § 281.346(1)(r); See also Compact Article 1.

The City will, at a minimum, return the amount of water withdrawn from Lake Michigan, less consumptive use, to the source watershed by managing return flow as described in Section 5, Return Flow Management Plan. The source watershed is the Lake Michigan watershed because the water is to be withdrawn from Lake Michigan. As the Compact and Wis. Stat. § 281.346(1)(r) provides in relevant part, "[i]f water is withdrawn directly from a Great Lake, then the source watershed is the watershed of that Great Lake."

The Compact and state law require that the amount of water returned to the source watershed to equal the withdrawn water volume less consumptive use. The City's goal is to exceed the Compact requirements by returning 100 percent of the withdrawn water over a management period. See Section 5, Return Flow: Return Flow Management Plan.

No surface water or groundwater from outside the basin may be used to satisfy any portion of the return flow requirement except if it is part of a water supply or wastewater treatment system that combines water from inside and outside the basin, and it is treated to meet applicable water quality discharge standards and to prevent the introduction of invasive species into the basin. In addition, Wisconsin law requires that if the returned water from outside the basin is returned through a structure on the bed of navigable water, the structure meet applicable permitting requirements. Reference: Compact Article 4, Section 4.9.4.c.; Wis. Stat. §§ 281.346(4)(f)3. and 281.346(4)(f)4

The proposal discusses how the City will minimize out-of-basin water in the return flow in See Section 5, Return Flow, Return Flow Management Plan: Minimizing Out-of Basin Water in Return Flow. Despite the City's best efforts, some out-of-basin water may be returned to the Lake Michigan watershed. Before this out-of-basin water would be discharged to the Lake Michigan watershed it would be collected and treated by the City's wastewater treatment system and to WDNR standards. The return flow will have an approved effluent discharge permit under Wis. Stat. § 283.31. The return flow will prevent the introduction of invasive species by only returning treated wastewater conveyed in a pipe directly from the WWTP to the return flow location. The applicable permits and associated operating requirements for the discharge (Wis. Stat. § 30.12 or § 30.12.4m) will be obtained before the return flow outfall is constructed.

Wisconsin law requires that the place at which the water is returned to the source watershed be as close as practicable to the place at which the water is withdrawn, unless the applicant demonstrates that returning the water at that place is one of the following: (a) not cost-effective; (b) not environmentally sound; or (c) not in the interest of public health. Reference: Wis. Stat. § 281.346(4)(f)3m.

The City considered return flow alternatives that discharged directly to Lake Michigan, to Lake Michigan tributaries in the Greater Milwaukee Watersheds, and to the Milwaukee Metropolitan

Sewerage District. See Section 5. The preferred return flow location is to Underwood Creek, a lake tributary that will return flow to Lake Michigan through the Menomonee River. Compared to Underwood Creek, return flow to the Root River or directly to Lake Michigan is not cost-effective. Return flow to Lake Michigan also does not provide the aquatic habitat benefits available in Underwood Creek.

Wisconsin law requires that, if water will be returned to the source watershed through a stream tributary to one of the Great Lakes, the applicant shall provide documentation of how the physical, chemical, and biological integrity of the receiving water will be protected and sustained, considering the state of the receiving water before the proposal is implemented and considering potential adverse impacts due to changes in temperature and nutrient loadings. If the receiving water is a surface water body that is tributary to one of the Great Lakes, the applicant shall include a description of the flow of the receiving water before the proposal is implemented, considering both low and high flow conditions. Reference: Wis. Stat. § 281.346(4)(b)4s, and § 281.346(4)(f)4m.

The City's preferred return flow location on Underwood Creek is analyzed in Section 5, Return Flow Alternatives. As demonstrated in that section, a discharge of return flow to Underwood Creek protects and sustains the physical, chemical, and biological integrity in accordance with Wis. Stat. §§ 30.12, 281.15, and 283.31. As discussed in Section 5, the physical integrity (geomorphology) of the stream will be protected (Appendix L), the chemical integrity of the stream will be protected (Appendix H), and the biological integrity of the stream will be protected (Appendix L).

In addition, the return flow will prevent the introduction of invasive species by only returning treated wastewater conveyed in a pipe directly from the WWTP to the return flow location. Temperature of the return flow has been considered and is consistent with other municipal wastewater discharges. See Section 5, Return Flow: Return Flow Alternatives: Return Flow to Underwood Creek: Water Quality. Changes in nutrient loadings were evaluated (Appendix H) and found to be less than 1 percent of expected annual loadings to Lake Michigan in the Greater Milwaukee area.

No Significant Adverse Impacts from Return Flow

A diversion must be implemented so as to ensure that it will result in no significant adverse individual impacts or cumulative impacts to the quantity or quality of the waters and water dependent natural resources of the basin, including cumulative impacts that might result due to any precedent-setting aspects of the proposal, based upon a determination that the proposal will not have any significant adverse impacts on the sustainable management of the waters of the Great Lakes basin. Reference: Compact Article 4, Section 4.9.4.d.; Wis. Stat. §§ 281.346(4)(f)5.

This requirement was discussed above with regard to the withdrawal from Lake Michigan, and is discussed here with regard to the return flow. Return flow will be implemented to ensure that no significant individual or cumulative adverse impacts result to the quantity and quality of the waters and water dependent natural resources. As discussed in Section 5, the proposal maintains, and in some cases improves, the chemical, physical, and biological integrity of the Great Lakes Basin.

The City exceeds the return flow requirements and results in a benefit to waters and water dependent natural resources of the basin in the following ways:

- The City of Waukesha has a return flow goal that is greater than water supply less consumptive use. The return flow goal has been set at 100 percent, which is higher than the Compact requirement (see Section 5).
- Return flow will be utilized as a resource to benefit habitat, fisheries, and water quality in a Lake Michigan tributary (see Application Section 5 and Appendixes G and L).
- Return flow water quality is more stringent than other Lake Michigan tributary dischargers and will improve the water quality in Underwood Creek by allowing the creek to meet water quality standards more often (see Application Section 5 and Appendix H).

The return flow to Lake Michigan will not endanger the integrity of the Lake Michigan ecosystem. This is because the return flow water quality will meet all WDNR requirements and the City has a goal to return 100 percent of the withdrawn volume. The return flow will also improve or maintain the physical and biological resources, and improve or have minor impact to the chemical resources of the tributary stream proposed for the return flow.

The net positive environmental benefits will improve, not endanger, the integrity of the Great Lakes Basin ecosystem. The return flow will protect and sustain the physical, chemical, and biological integrity of the Great Lakes Basin, and for some parameters, the return flow will have a beneficial improvement on these systems.

Any future application by others must follow the Compact requirements and will be evaluated at that time on its own merit. The Compact was developed to regulate Great Lakes diversions. This application, when viewed separately or cumulatively with other diversions, will not have any significant adverse impacts on the sustainable management of the waters of the Great Lakes basin.

Other Requirements

The proposal is implemented so as to ensure that it is in compliance with all applicable municipal, State and federal laws as well as regional interstate and international agreements, including the Boundary Waters Treaty of 1909. Reference: Compact Article 4, Section 4.9.4.f.; Wis. Stat. § 281.346(4)(f)7.

The City will meet all applicable municipal, state, and federal laws as well as regional interstate and international agreements. The requirements of the Boundary Waters Treaty of 1909 are not triggered by this proposal.

The proposal is consistent with an approved water supply service area plan under Wis. Stat. § 281.348 that covers the public water supply system. Reference: Wis. Stat. § 281.346(4)(e)1.em.

The Water Supply Service Area Plan for the City of Waukesha is contained in Appendix D. This plan has been approved by the City of Waukesha's governing body. It is consistent with the findings and recommendations of the SEWPRC Planning Report on Regional Water Supply Plan in Southeastern Wisconsin.

The proposal shall be subject to management and regulation by the Originating Party. Reference: Compact Article 4, Section 4.9.3.c.; Wis. Stat. § 281.346(4)(e).

The WDNR is the Originating Party and it will manage and regulate the diversion.

Review Process

The WDNR conducts a technical review. Reference: Wis. Stat. § 281.346(4)(e)1.f.

The WDNR notifies the regional body; the proposal undergoes regional review; and the WDNR considers the regional declaration of finding in determining whether to approve the proposal. Reference: Wis. Stat. § 281.346(4)(e)1.g., h. and i; Compact Article 4, Sections 4.5 and 4.9.3.f.

The proposal is approved by the Great Lakes Council. Reference: Wis. Stat. § 281.346(4)(e)1.j. Compact Article 4, Sections 4.7 and 5.9.3.g.

The Compact establishes the review process for this application. The City seeks to begin this review process by filing this application with the WDNR.

Conclusion

There are few communities with significant populations that are outside the Great Lakes Basin, within a straddling county, and as close to on of the Great Lakes as the City of Waukesha. Consequently, the Compact diversion exception standard is applicable to few communities of similar size to Waukesha, and communities further away will find a diversion less economically feasible. As required by the Compact, any community within a straddling county will also be evaluated individually for a water diversion based upon its ability to provide no significant individual or cumulative adverse impacts. With the City of Waukesha setting goals that exceed the Compact requirements, and rare similar circumstances of communities in straddling counties as close to on of the Great Lakes as the City of Waukesha, there are no significant adverse cumulative impacts possible with any precedents associated with this application.

The City submits this application seeking Lake Michigan water for public water supply. The City has stated a compelling need for Lake Michigan water and its request is supported by detailed alternatives evaluations from numerous experts, including the WDNR, USGS, WGNHS, academia and SEWRPC.

The City has demonstrated that its use of Lake Michigan water will not result in adverse impacts to the Great Lakes. Indeed, this application shows that the Great Lakes Basin will be benefited if the City switches from a groundwater supply to a Lake Michigan supply.

The City also believes it has demonstrated that this application meets all the Compact requirements with no exceptions, and that in numerous ways the City's application exceeds the requirements of the Compact and state law.

The Compact was developed to regulate Great Lakes diversions and protect the water and water dependent natural resources of the basin. Because this application meets all of the requirements of the Compact, and results in increased protection of the water and water dependent natural resources of the basin, the City respectfully requests that its application for Lake Michigan water be approved.

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Glossary

Applicant. A person who is required to submit a proposal that is subject to management and regulation under the Compact.

Aquifer. An underground storage area that holds water in layers of porous rock and sediments

Build-out condition. State that exists when all of the land available for development has been developed in a manner consistent with the regional plan, which could be more than 50 years in the future.

Community within a straddling county. Any city, village, or town that is not a straddling community and tat is located outside the Great Lakes basin but wholly within a county that lies partly with the Great Lakes basin.

Compact. The Great Lakes–St. Lawrence River Basin Water Resources Agreement.

Consumptive use. The portion of the water withdrawn or withheld from the basin that is lost or otherwise not returned to the basin due to evaporation, incorporation in products, or other processes.

Cost-effectiveness analysis. A systematic comparison of alternative means of providing a water supply in order to identify alternatives that will minimize total resources costs and maximize environmental benefits over a planning period.

Cumulative impacts. The impact on the Basin Ecosystem that results from incremental effects of all aspects of a withdrawal, diversion, or consumptive use in addition to other past, present and reasonably foreseeable future withdrawals, diversions and consumptive uses regardless who undertakes the other withdrawals, diversions, and consumption uses. Cumulative impacts can result from individually minor but collectively significant withdrawals, diversions, or consumptive uses take place over a period of time.

Deep aquifer. Made up of thick sandstone layers that extend 2,000 feet underground.

Diversion. A transfer of water from the Great Lakes basin into a watershed outside the Great Lakes basin into a watershed outside the Great Lakes basin, or from the watershed of one Great Lake to another, by any means of transfer, including a pipeline, canal, tunnel, aqueduct, channel, ship, tanker truck, or rail tanker.

Great Lakes basin. Means the watershed of the Great Lakes and the St. Lawrence River upstream from the Trois-Rivieres, Quebec.

Groundwatershed. An area from which all groundwater flows to the same river, lake, or ocean.

Originating party. The party within whose jurisdiction an Application or registration is made or required.

Proposal. A withdrawal, diversion, or consumptive use.

Public water supply purposes. The water distributed to the public through a physically connected system of treatment, storage and distribution facilities serving a group of largely residential customers that may also serve industrial, commercial, and other institutional operators. Water

withdrawn directly from the basin and not through such a system shall not be considered to be sued for public water supply purposes.

Recharge. Water added to an aquifer by rain, snowmelt, or exchange of surface waters.

Reasonable water supply alternative. A water supply alternative that is similar in cost to, an is environmentally sustainable and protective of public health as, the proposed new or increased Diversion and that does not have greater adverse environmental impacts than the proposed new or increased Diversion.

Source watershed. The watershed from which a withdrawal originates.

Shallow aquifer. Made up of sand, gravel, and clay. Left behind by glaciers. In some areas, includes and upper layer of rock.

Total resources costs. Monetary costs and direct and indirect environmental as well as other nonmonetary costs.

Water. means the ground and surface waters contained within the basin.

Water dependent natural resources. The interacting components of land, Water and living organisms affected by the waters of the basin.

Watershed . An area from which all surface waters (rives, stream, runoff) flows to the same river, lake, or ocean.

Waukesha. The City of Waukesha.

Withdrawal. The taking of water from surface water or groundwater.

Without adequate supplies of potable water. Without a water supply that is economically and environmentally sustainable in the long term to meet reasonable demands for a water supply in the quantity and quality that complies with applicable drinking water standards, is protective of public health, is available at a reasonable cost, and does not have adverse environmental impacts greater than those likely to result from the proposed new or increased diversion.

Appendix A

Waukesha Water Utility Water Conservation and Protection Plan

WATER CONSERVATION &
PROTECTION PLAN

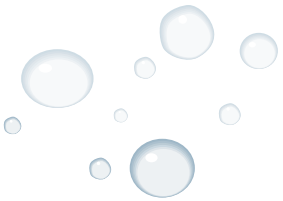
Approved March 2006

Waukesha Water Utility





GeoSyntec
Consultants



Prepared for:

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Executive Summary

Overview

Waukesha is proposing a groundwater conservation and protection plan to reduce water use, to ensure the availability of future drinking water supplies and to protect the environment.

Waukesha's existing supply is pumped primarily from a deep confined aquifer. The level of the aquifer has declined over the course of the last 100 years due to pumping from a large number of communities in southeastern Wisconsin and northeastern Illinois. While Waukesha's overall pumpage has decreased over the last 20 years, the aquifer continues to drop due to the fact that it recharges at a slow rate compared to unconfined aquifers in other parts of the state that are recharged by shallow groundwater. The declining aquifers have led to higher concentrations of radium and other contaminants. These problems are forcing the utility to increase water treatment as well as seek new water supplies.

Conserving water provides a number of benefits to water utility customers, the environment, and the utility itself. It saves money for customers by reducing their need for water and by reducing energy costs. The utility saves money through lower energy costs, lower pumping costs, and deferred capital costs. The environment benefits by lessening the strains on water resources.

The following discussion provides background information, a work plan and a schedule for developing a comprehensive water resources protection and conservation program for the City of Waukesha. This discussion concludes with a brief work plan of activities to complete the technical approach in three phases.

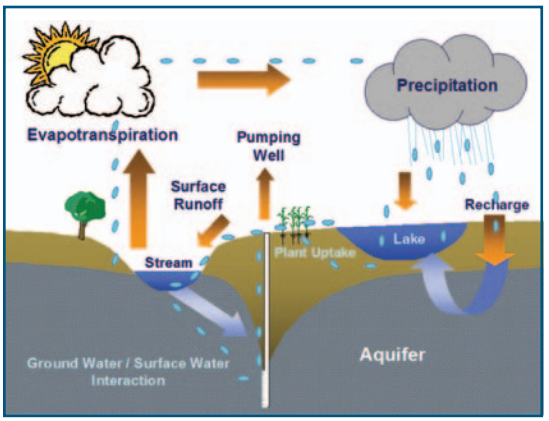


Figure 1. The Water Cycle
Source. Environmental Protection Agency

Recommendations

The Waukesha Water Utility (WWU) must make a decision concerning its long-term public water supply. Potential new water supplies all require conservation, whether it is Lake Michigan or local groundwater. The Great Lakes Governors and Premiers will require conservation before Waukesha can obtain a Lake Michigan surface water supply. Growing communities throughout Waukesha County will all need to coordinate their conservation efforts to ensure that there are adequate supplies for their customers if they seek additional local groundwater. Conservation and protection will help ensure the long-term viability of the sources shared with other Waukesha County communities. If the city obtains a Lake Michigan supply, strong conservation measures will be required by the Great Lakes Governors. **Regardless of the source, the conservation program should be comprehensive in protecting water resources throughout the water cycle** (See Figure 1).

The water conservation and protection plan is based on three primary goals:

1. Reduce water use to ensure that public water supplies are stretched
2. Protect sourcewater areas to ensure water sources are protected from pollution
3. Protect stormwater recharge areas to ensure that groundwater resources are replenished

These goals should be pursued through the following water conservation and protection measures:

1. Increase public awareness about water conservation starting with **"20% by 2020"**, **"Don't Flush Dollar$ Down the Drain"**, and **"Don't Get $oaked by Overwatering Your Lawn"** campaigns.
2. Continue upgrading water main to reduce system leakage. Audit system to detect leaks and prioritize upgrades.
3. Adopt a water sprinkling ordinance that restricts outdoor water use, as well as other residential, commercial, and industrial water use restrictions .
4. Work with the Wisconsin Public Service Commission to develop a water conserving rate structure.
5. Work with the Wisconsin Public Service Commission to develop a water use reduction program that is based on incentives and public education to decrease Waukesha Water Utility customer use.
6. Investigate the phase-out of residential sewer credit meters to discourage outdoor water use.

7. Work with the City of Waukesha, surrounding communities, and Waukesha County to revise existing subdivision and stormwater management ordinances to ensure that they encourage maximum infiltration of stormwater into local groundwater and wetlands and key infiltration areas for existing water resources. This includes the use of green infrastructure and low impact development.
8. Implement sourcewater protection measures in coordination with the county and Waukesha County communities. Zoning regulations should include the use of overlay zones to delineate recharge areas as well as other best management practices to protect source waters.
9. Investigate the reuse of Waukesha's wastewater. Reuse may involve "gray" water separation or redirection of treated wastewater for regional aquifer recharge.
10. Organize a stakeholder group to assist in updating and implementing the conservation plan.

Introduction and Rationale for the Project

Use of water resources by communities in southeastern Wisconsin and northeastern Illinois has reduced local groundwater availability and threatens streams, rivers and other environmental resources. It has led to a decrease in water quality and has increased the costs of water resource protection and water treatment.

The City of Waukesha, like many other Waukesha County communities located to the west of the Lake Michigan watershed surface divide, draws its water supply from Lake Michigan tributary groundwater in the deep sandstone aquifer located beneath this region (See Figure 2). In the past, this deep aquifer provided a plentiful, high quality source of water. The Maquoketa aquitard protected the deep aquifer from contamination sources in the Milwaukee metropolitan area. Furthermore, because the recharge areas to the west have been largely undeveloped, the deep sandstone aquifer was further protected.

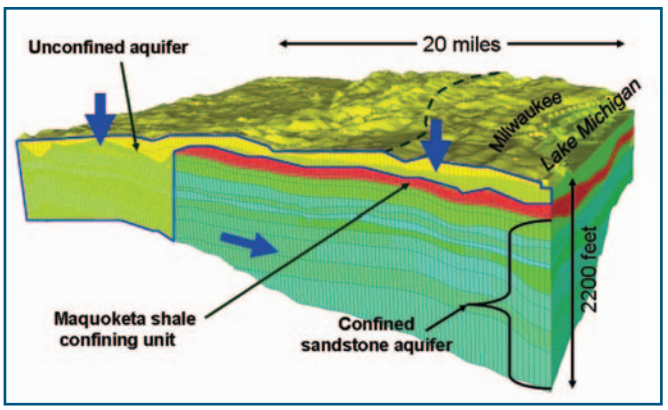


Figure 2. General Hydrogeology of Southeastern Wisconsin
Source: United States Geological Survey

The need for improved groundwater management in the region is further demonstrated by the call for the SEWRPC Regional Water Resource Study and the recent passage of Wisconsin's Groundwater Management Act creating a Groundwater Management Area in Southeast Wisconsin.

Pumping by communities in Milwaukee and Waukesha County over the last century led to a decrease in water levels in the deep aquifers that Waukesha and other communities use for drinking water supply have declined by over 600 feet. As a consequence of this water level decline, radium levels have steadily increased in Waukesha's public water supply wells to the point that they now exceed regulated levels. Waukesha is currently operating under a consent order with the Wisconsin Department of Natural Resources to find a solution to its water resource problems by December 2006.

The City of Waukesha has had success in reducing water use in recent years. The trend for water use is decreasing even as population has increased (See Figure 3). Furthermore, its residential and total per capita water use is among the lowest in southeastern Wisconsin (See Table 1).

Annual Water Use						
	Residential Water Use			Total Municipal Water Use		
County	Total (gallons per day X 1,000)	Per Person (gallons per capita per day)	Per Acre (gallons per acre per day)	Total (gallons per day X 1,000)	Per Person (gallons per capita per day)	Percent Unaccounted for Water
Kenosha	5,619	61	836	13,156	119	12
Milwaukee	51,942	70	1,282	148,378	160	7
Ozaukee	2,570	64	581	5,575	123	14
Racine	7,804	61	832	25,330	175	12
Walworth	2,565	57	474	6,250	111	16
Washington	3,488	66	724	6,411	96	13
Waukesha	11,404	60	506	23,093	102	11
Total Region	85,392	67	911	228,193	145	9

Table 1. Per Capita Water Use in Southeastern Wisconsin by County 2000

Source: Southeastern Wisconsin Regional Planning Commission and Public Service Commission of Wisconsin

However, the Utility's 2005 Master Plan indicates that potential groundwater supplies will be insufficient by 2030 due to growing population in Waukesha and surrounding communities. By 2030, Waukesha's maximum daily pumpage will increase to 17.5 million gallons per day. The deficiencies are only increasing. Continuing to utilize existing deep well sources will lead to the continued depletion of these Great Lakes tributary sources. As population further increases, it will become necessary to utilize much stronger demand-side conservation measures as well as sourcewater protection and stormwater management practices.

"While the overall amount of water pumped has increased for the residential and commercial sectors, per capita use has decreased."

Over the last decade, water use in Waukesha has increased in the residential and commercial sectors. According to the Utility's Master Plan, the relative percentages of water use have changed while overall water use has increased slightly. Metered residential water use has increased from 39% of total consumption to 44%, and in the commercial sector from 29% to 34%. These relative increases are primarily the result of decreases in industrial use. Metered industrial use declined from 28% to 17%, and public metered water use from dropped from 5% to 4%. While the overall amount of water pumped has increased for the residential and commercial sectors, per capita use has decreased. As such, the residential and commercial sectors should be targeted for conservation efforts.

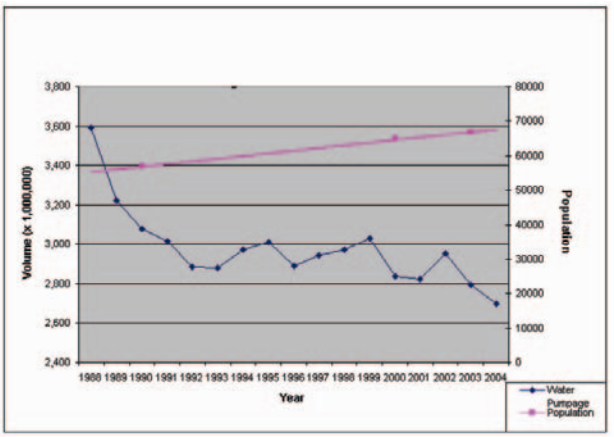


Figure 3. City of Waukesha Water Use and Population
Source: Waukesha Water Utility and the City of Waukesha

As development and population in the region continue to grow, the Southeast Wisconsin Regional Planning Commission (SEWRPC) estimates that groundwater withdrawals in the region are approaching 70 million gallons/day (MGD). The U.S. Geological Survey concluded that this historic heavy pumping rate by Milwaukee and surrounding suburbs in a confined aquifer that recharges more slowly that an unconfined aquifer has resulted in a zone of depression (See Figure 4). The impact has resulted in a reversal of flow in the deep aquifer system away from Lake Michigan, ongoing groundwater drawdown rates at about 6 feet/year, and declining groundwater quality as deeper groundwater contains higher levels of dissolved materials, including radium. All of these trends must be reversed to maintain sustainable groundwater supplies in southeast Wisconsin.

End-of-the-pipe water conservation is not enough to address the impacts of regional water use. Southeast Wisconsin's water resource problem must be addressed more comprehensively to protect, conserve, restore, and improve the groundwater resources that sustain its communities. Water resources can be significantly affected by development activities. Water resources move through the water cycle, sometimes called the hydrologic cycle. The water cycle is the continuous movement of water from ocean, lakes, rivers, and other water bodies to air and land then back to these water bodies through rain and snow in a cyclic pattern as water is used and re-used. Some water infiltrates (or seeps into) the ground or evaporates back into the atmosphere.

Southeast Wisconsin communities will need to supplement their sources of deep groundwater supply with groundwater drawn from shallow wells located in the surficial, sand and gravel aquifers in the less developed portions of Waukesha County. As urban development in the Milwaukee metropolitan area continues to move into Waukesha County, communities must act today to ensure that the groundwater resources in that region are preserved, protected, and enhanced. In addition, the city must look for more innovative ways to promote reuse of wastewater and enhance groundwater recharge. Poorly controlled residential, commercial, and industrial water withdrawals can weaken a community's ability to sustain residents and businesses.

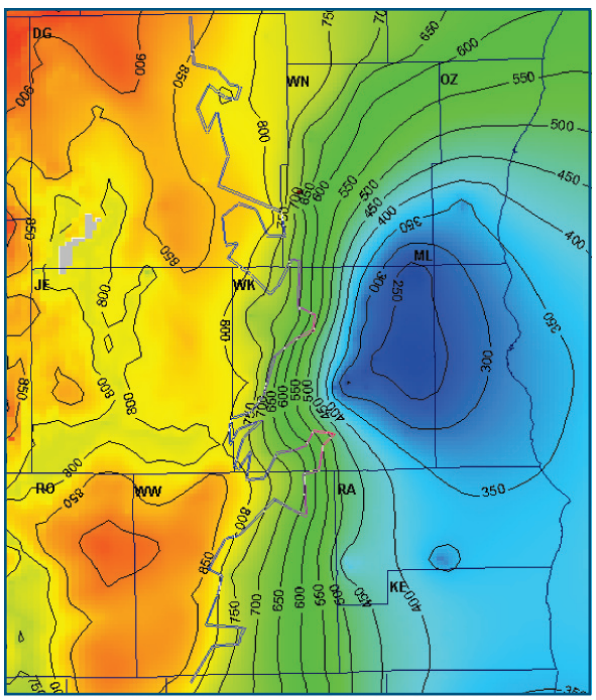


Figure 4. Groundwater Cone of Depression in the Sandstone Aquifer
Source: United States Geological Survey

Technical Approach: Source Water Management and Conservation Plan

Water conservation at the end of the pipe is not enough. Water resources must be protected at every step of the water management cycle through water reuse and enhanced groundwater recharge. Waukesha further recognizes that the city can undertake certain activities in the near term within its corporate jurisdiction, but other activities will need to be coordinated with other communities and the county. The city must work with Waukesha County and its neighboring communities because water resources transcend political boundaries. Regional water management will require additional time and effort to be implemented.

The water management plan encompasses three main activities:

1. Conserving residential, commercial, industrial, and government water use.
2. Protecting existing water resources.
3. Promoting the infiltration and reuse of stormwater and municipal wastewater.

The approach for completing each of these activities is described in the remainder of this report. More timeline details can be found on page 18.

Managing & Implementing Conservation

Introduction and Rationale for the Project

Managing and implementing conservation in Waukesha must be done through a structure that allows for development, implementation, monitoring and review of conservation activities to ensure that they are meeting the timeline and goals of the effort. The Water Conservation program will be implemented in the following eleven tasks:

a) Identify Conservation Goals

Waukesha has set a preliminary goal of a 20% reduction in per capita water use reduction in the city by 2020. This goal is based on prior experience with other municipal water conservation programs in other states. Waukesha is also seeking to reduce peak water demand by 1 million gallons per day (MGD) through controls on water sprinkling. WWU will identify the specific goals for the conservation program and the means to communicate the goals to city officials and the public.

b) Develop a program that provides monetary and other incentives to water users to reduce water use

Many water utilities use incentive-based programs to encourage water use reductions. This is usually done in tandem with a change in the rate structure that discourages the increased use of water. Appendix B provides background on the types of incentives that are offered as well as the effectiveness of different programs.

c) Develop a Waukesha Water Utility Conservation Demonstration Program

WWU will (1) document the conservation activities completed by the utility to date, and (2) prepare a demonstration program to further reduce water use within WWU buildings. The demonstration program will include an audit of current WWU water use and opportunities for leak prevention and hardware retrofits. WWU will document the water savings through the program and prepare information for distribution to the public and the press.

d) Develop a Water Use Profile and Forecast

Document the customer profile and characteristic (e.g., residential vs. commercial) demand by customer type, and overall average and peak water demand. Evaluate forecasts of future demand based on Waukesha Utility and City planning data, SEWRPC forecasts, and county growth data compiled by Southern Illinois University (Dziegielewski, et. al. 2004). Develop a water use profile by analyzing the historic and projected demand by customer sector. Evaluate water loss in the system and the impact of potential infrastructure improvements.

e) Develop a Decision Support Tool to Identify Appropriate Conservation Measures by Water User Sector

Based on the type of information presented in Appendix A, WWU will identify qualitative and quantitative criteria for selecting conservation measures. This work will build on the IWR Main application currently being developed by WWU. The decision support tool will evaluate and rank appropriate conservation measures by customer sector.

f) Evaluate and Design Conservation Measures

WWU will develop detailed plans for the identified conservation measures. Designs will include the types of control measures to be applied, the number of devices needed, the method for distributing and installing the measures, and the anticipated water savings from their application.

g) Identify and Assess Conservation Incentives and Benefits and Costs

WWU will estimate the conservation program benefits, including utility cost savings, as a justification for the conservation measures. WWU will demonstrate why the selected measures provide the greatest water use savings at the least costs.

h) Set Schedule for Conservation Measures and Incentives Implementation

Many of the conservation measures may be applied in phases. Factors governing the implementation schedule may include ease of implementation, cost, customer willingness to participate, and level of anticipated water conservation.

i) Implement Conservation Plan

The WWU will implement the final conservation plan encompassing the information gathered under the preceding tasks and coordinate with a stakeholder group that provides input and support. Circulate the plan to local stakeholders, government officials, and utility staff to generate support for and comment on the plan. Begin implementing the plan's measures and track progress. As part of the plan, anticipate impacts on utility revenues and any need for rate adjustments.

j) Conduct Public Outreach and Education

Actively promote implementation of the conservation plan through public education and outreach in the Waukesha schools and the press. Draw on existing education and outreach materials available through http://www.everydrop.org, http://www.waterwiser.org, and http://www.awwa.org, among others. Prepare outreach materials for distribution with water bills and at community events. Investigate the development of public service announcements and programs to be broadcast through local public access channels.

k) Monitor, Evaluate, and Revise Conservation Program as Needed

Conduct an ongoing monitoring program to assess the effectiveness of water use reduction activities through actual water use savings, customer participation, and costs of device maintenance. Regularly report on the program effectiveness to the Water Utility Commission and through annual reports to the public.

Reducing Water Use

Conservation Through Water Use Incentives and Restrictions

Waukesha has set a preliminary goal of a 20% reduction in per capita water use reduction in the city by 2020. This goal is based on prior experience with other municipal water conservation programs. Waukesha is also seeking to reduce peak water demand by 1 MGD through controls on water sprinkling.

These goals can be met through a combination of reducing leaks in the utility's water system, and reducing outdoor and indoor water use.

Detecting and Reducing Leakage in the Waukesha Water System

Leakage from the water system provides a significant opportunity to reduce the amount of water that is pumped from water supplies by WWU. The WWU should institute a more detailed water audit for the system to identify priority areas for water main replacement While leaks do go back into the groundwater system, the water does not go back into the deep aquifer that provides most of the utility's water supply. Reducing leaks increases water pressure within the system and reduces energy costs for water pumping.

Adopting an Outdoor Water Use Restriction Ordinance

One of the major difficulties facing the city is meeting peak demand. The highest peak days are during the summer when people are watering their lawns. Some of this peak demand is caused by overwatering of lawns during the middle of the day. Lawn watering during the heat of the day uses six times the amount of water than watering in the morning or early evening. Watering during the middle of the day, therefore, not only increases the amount of water required by the whole system, it unnecessarily increases water bills for the individual consumer. Further, by increasing the amount of water needed by the system, it increases costs for developing new wells and treating the water, affecting all ratepayers.

Studies have shown that an adequate amount of water for a lawn is one inch per week. The city should consider an ordinance restricting outdoor sprinkling to times when watering is more efficient. Outdoor sprinkling should only be allowed before 9 a.m. and after 5 p.m. Further consideration should be given to restricting the number of times per week that lawns can be watered. Example ordinance language is included in Appendix A.

This ordinance should be implemented in conjunction with a public education program to reduce sprinkling, **"Don't Get $oaked by Overwatering Your Lawn"**.

Non-Sprinkling Related Water Use Ordinance

There are additional water conservation activities that can be required by ordinance. In the Midwest, Illinois' ordinance requirements provide components that provide a basis for the start for an ordinance. The State of Illinois requires that any communities receiving water from Lake Michigan implement the following water use restrictions to ensure that water is used more efficiently. The requirements include:

- Leakage monitoring and correction for storage, transmission and distribution systems.
- Metering of all new construction.
- Metering of existing nonmetered services as part of any major remodeling.
- The adoption of ordinances which require the installation of closed system air conditioning in all new construction and in all remodeling.
- The adoption of ordinances which require that all lavatories for public use in new construction or remodeling be equipped with metering or self closing faucets.
- The adoption of ordinances which require that all newly constructed or remodeled car wash installations be equipped with a water recycling system.
- Development and implementation of public programs to encourage reduced water use.
- Installation of facilities and implementation of programs to reduce to a reasonable minimum, and to accurately account for, water used for navigational, lockage, and leakage purposes; and pollution treatment, control or abatement purposes.
- If receiving approval to use Lake Michigan water, prepare a phased program designed to end the use of deep aquifer water, other than for emergency or standby use, within five years of the receipt of Lake Michigan water.
- Limit hydrant uses to 1% or less of net annual pumpage in each annual accounting period.
- Adopt water rate structures based on metered water use and that water rate structures be developed which will discourage excessive water use.

Additional ordinance provisions that should be strongly considered include:

- Definitions for water conservation ordinance terminology
- Conservation signage and literature distribution
- Enforcement
- Water waste restrictions
- Conservation fees imposed
- Variance procedures
- Response to water shortage

Example ordinance language is included in Appendix A.

Indoor Conservation Measures

Conservation programs can be targeted in Waukesha in areas where there are likely to be older plumbing fixtures. These are in areas developed prior to 1994, when new plumbing requirements were instituted nationally. Bathroom fixtures, including toilets, faucets, showers, and baths, represent over 50% of indoor water use in the home (see Figure 5). There have also been significant changes in plumbing efficiency over time where there can be significant water savings realized within the city.

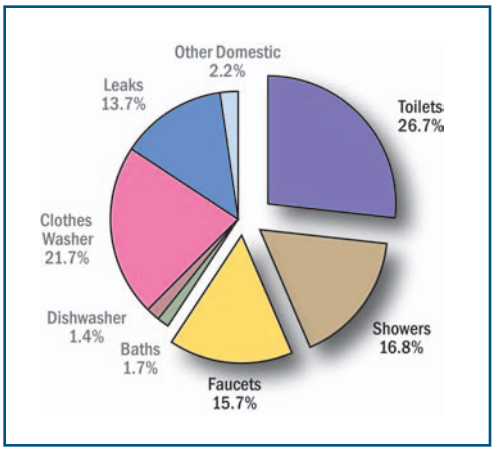


Figure 5. Average Indoor Water Use in a Nonconserving Home

Source: Handbook of Water Conservation and Protection

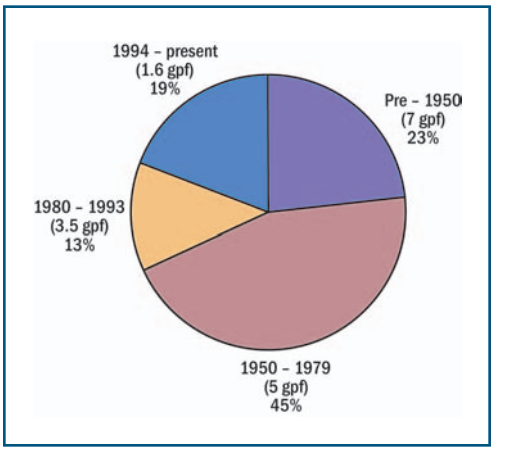


Figure 6. Date of Single Family Home Construction (and original Toilet gallons per flush (gpf)

Source: Waukesha Assessor's Office

Eighty-one percent of single family homes were built prior to 1994 when new plumbing fixtures were required to be water saving (See Figure 6). A map shows the location of areas where the original toilets were 7 gpf (yellow, pre 1950), 5 gpf (red, 1950-1979), and 3.5 gpf (green, 1980-1993). The groupings reveal areas where initial conservation activities can be targeted to maximize their effectiveness. The utility should target these homeowners in areas developed prior to 1994 to educate the owners about the potential savings associated with plumbing upgrades. These areas on the map (See Figure 7) are areas colored in yellow (pre 1950), red (1950-1979), and green (1980-1993). All new toilets installed in homes built since 1994 have 1.6 gallons per flush. If all homes in Waukesha were retrofitted with new toilets, water use would be reduced by up to 500,000 gallons per day, which represents a 5% reduction from the current average daily water use.

"If all homes in Waukesha were retrofitted with new toilets, water use would be reduced by up to 500,000 gallons per day…"

The water savings also represent a potential cost savings for utility customers. In homes that have toilets installed before 1950, a family of four could save $200 per year. A family of four changing 5 gpf toilets would save approximately $125 per year, and changing 3.5 gpf toilets would save the same family $70 per year.

Replacing showerheads installed prior to 1980 can also save significant water and money for homeowners. Replacing showerheads installed before 1980 can save about 5000 gallons per person per year. This saves approximately $25 per person per year in water and wastewater charges.

Develop a Waukesha Water Utility Conservation Demonstration Program

The city began the process of educating the public about the benefits of water conservation in plumbing fixtures with the announcement of the grant of plumbing fixtures at bathrooms in City Hall. The City Hall demonstration project was a first step. WWU will (1) document the conservation activities completed by the utility to date, and (2) prepare a demonstration program to further reduce water use within WWU buildings. The demonstration program will include an audit of current WWU water use and opportunities for leak prevention and hardware retrofits. These water savings will be documented and included in public outreach information for distribution to the public and the press.

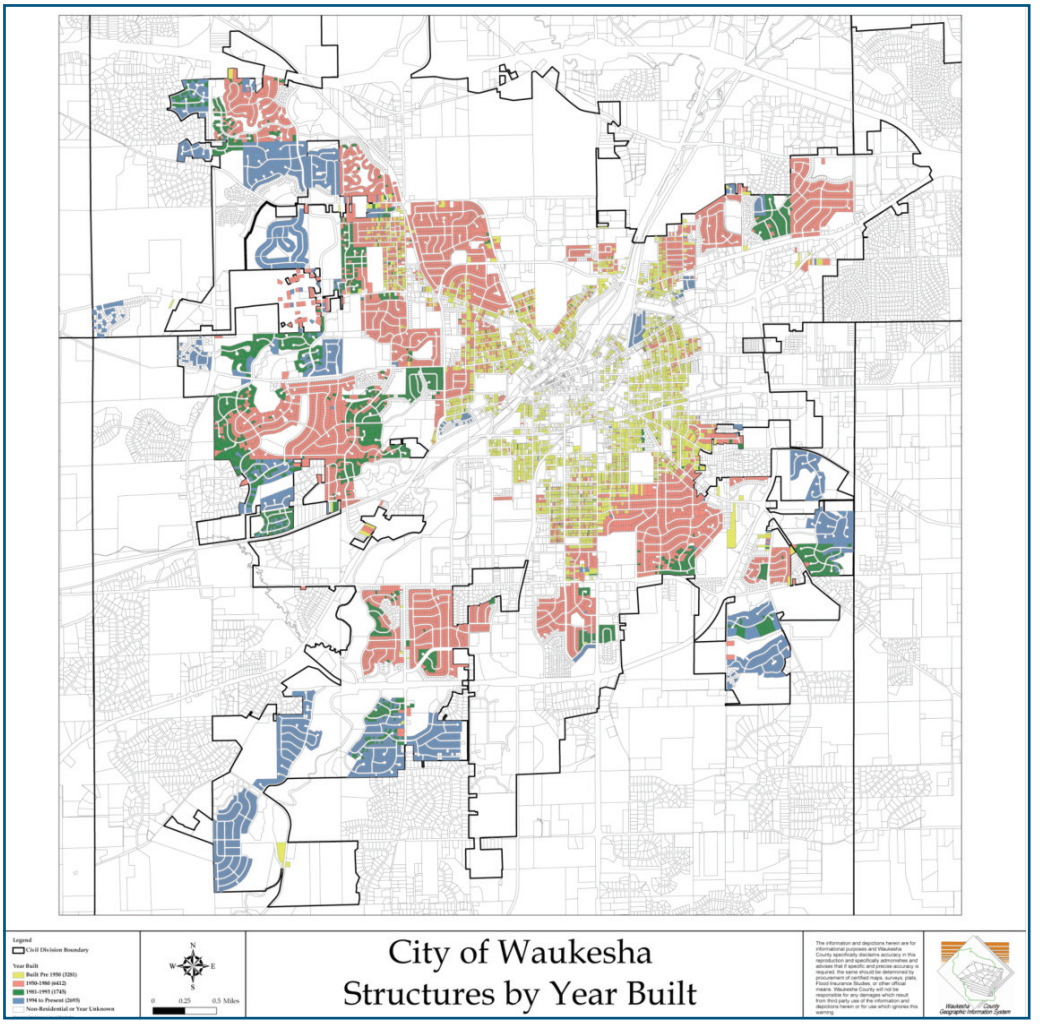


Figure 7. Map of City of Waukesha by Date of Construction
Source: Waukesha Assessor's Office

Implement Inclining Block Rate Structure

Currently, Waukesha has a decreasing block rate structure through which rates decrease as water use increase. This encourages water use and reduces water supply protections. Increasing rates as water use increases builds an incentive for changing plumbing fixtures in the home and reducing outdoor water use. WWU initiated discussions with the Public Service Commission regarding the use of this rate structure. It has not been used in Wisconsin to date, but is in use in other parts of the country. WWU will continue this discussion with the PSC.

Phase Out Residential Sewer Credit Meters

The city should also consider phasing out sewer credit meters for residential units. These meters measure the amount of water that leaves a home through the sewer system. It provides the basis for a credit on the sewer bill. Residences that have the meters do not pay for sewage treatment of the water that does not enter the system. These meters are not in wide usage nationwide because they do not discourage outdoor water use such as sprinkling. Eliminating sewer credit meters would increase the rates for outdoor sprinkling, providing more incentives for reducing water use. Increased revenues obtained by from the phase out of this program could be used by the city to create a conservation incentive program.

Fixture / appliance / location	Type of incentive (Examples)	Eligibility	Incentive value	Conservation level required / delivered
Showerheads	Rebate for replacement with water-conserving model (A)	Residential and commercial customers	Range from $25 up to $150 or 75% of the total cost (whichever is less) for each showerhead retrofitted with an ultra-low flow model	Required maximum of 2.5 gallons per minute per showerhead.
	Free replacement with water-conserving model (A, B, D)	Residential and commercial customers	Value of replacement showerhead.	Delivers 2.5 gallons per minute; has adjustable settings and a non-aerating spray with less temperature loss.
Toilets	Rebate for replacement with water-conserving model (A, B)	Residential and commercial customers; no limit on the number of reimbursed toilets per household or commercial building.	Range from $25 up to $150 or 75% of the total cost (whichever is less) for each toilet retrofitted with an ultra-low flow model	Required maximum of 1.6 gallons per flush per toilet.
	Free dye tablets for determining leaks in toilets (A, B, D)	Residential and commercial customers	Value of dye tablets	N/A
Clothes washing machines	Rebate for replacement with water-conserving model (A, B)	Residential customers	Range from $25 to $100 for all qualifying clothes washers.	Required to be a Level 1 or 2 clothes washers, as listed and posted online at a region-specific website.
Bathroom faucets	Free aerator attachment (A, B, D)	Residential and commercial customers	Value of aerator	Delivers a flow rate of 1.5 gallons per minute.
Kitchen faucets	Free aerator attachment (A, B, D)	Residential and commercial customers	Value of aerator	Delivers a flow rate of 2.2 gallons per minute (2.0 gpm in some cases).
Pre-rinse spray valves	Free replacement with water-conserving model (A)	Commercial customers (food service industry)	Value of the new, high-efficiency, high-velocity spray valve.	N/A

Table 2. Example Incentive Programs

Institute Incentive Programs.

Many water utilities around the country use incentive-based programs to encourage water use reductions. This is usually done in tandem with a change in the rate structure that discourages the increased use of water. Potential incentives are listed in Table 2. Additional information on incentive programs are listed in Appendix B. Pursuing this option is difficult as the Public Service Commission currently has not authorized costs for these types of conservation programs to be recaptured by utilities. However, the utility should continue discussions with the PSC to ensure that existing and future water sources are protected and used efficiently.

Evaluate Appropriate Conservation Measures by Water User Sector

Based on the type of information presented in Appendices A and B, WWU will work to identify qualitative and quantitative criteria for selecting conservation measures. This work will build on the IWR Main application currently being developed by WWU. The decision support tool will evaluate and rank appropriate conservation measures by customer sector.

Protect Existing Water Resources

Source Water Protection

Source water is water collected from streams, rivers, lakes, or groundwater for public drinking water supplies. Source water protection is designed to protect drinking water sources from sources of contamination. WWU will work with Waukesha County and surrounding communities through the county effort, with Wisconsin Department of Natural Resources (WDNR) through its identified Groundwater Management Area, and with the SEWRPC regional water supply study to ensure an aggressive source water protection effort.

Source water assessments are mandated under the Safe Drinking Water Act, but protection plans are a local management issue. A Waukesha County source water protection plan will include the following components:

1. Establish a stakeholder group involving Waukesha County and its communities, developers, the State, and other interested parties to begin organizing to develop a source water protection plan.

2. Identify the critical recharge areas for the aquifers to establish overlay planning areas for source water protection. Principal recharge areas for the shallow aquifer system will be identified using previous USGS and WDNR studies, along with aerial photos and soil surveys. Because the shallow system is largely unconfined, recharge occurs throughout the region. However, some areas preferentially recharge the aquifer system, such as areas containing wetlands and hydric soils. The recharge areas will be plotted using GIS as overlays on regional topographic maps.

3. Identify existing and potential future contaminant and recharge impairment threats. The City of Waukesha's source water assessment completed by WDNR indicates that the city's groundwater supply is susceptible to contamination by volatile organic compounds, synthetic organic compounds, nitrate, antimony, and arsenic. The system is moderately susceptible to microbial contamination. The system has low susceptibility to ethylene dibromide contamination. The source water assessment report further notes that no wellhead protection plan or ordinance is in place to protect the city's main production wells. As land in the recharge areas for existing and future production wells is developed, contaminant sources are introduced into the wellhead areas and impervious cover reduces recharge of the aquifer system. The current and future threats to Waukesha County's source water areas will be identified based on current land uses and projected growth patterns. The current and projected threats will be depicted on GIS map products.

4. Set priorities for managing the threats consistent with state statute and policy. Wisconsin is developing a set of statutes and policies governing municipal growth patterns and groundwater protection. Review the statutes and policies to set priorities for management activities in terms of contaminants or development practices to be addressed.

5. Document available and needed management tools to address the threats. A variety of land use planning and management tools are available to Waukesha County communities to affect growth patterns. These include zoning and overlay districts; subdivision, health, stormwater, and other ordinances; use of planned unit developments; and other management tools such as transfer of development rights, conservation easements, and condemnation. Through these management tools, communities can steer development away from critical recharge areas and promote practices such as low impact development and retrofit applications of stormwater best management practices (BMP) to increase stormwater infiltration and groundwater recharge. Identify a suite of existing management tools and recommend additional ordinances and policies based on the experience of other communities.

6. Develop a schedule and work plan for implementing the source water protection plan. Work with the communities to identify realistic schedules for implementing changes to community planning, ordinances, zoning, and other measures. Also, provide estimates of the costs involved in making the changes and will help identify resources available to support the communities.

Enhance Stormwater Infiltration and Wastewater Reuse

When it rains or snow melts, some stormwater goes into the ground and some goes into storm sewers. As more development occurs, more hard surfaces, such as rooftops and roadways are created, meaning there are fewer places where rain water can soak into the soil, nourish plants and remain part of the natural water cycle.

If there is less greenspace to absorb water, sewer systems are forced to handle more water, increasing the risks of flooding. Stormwater sent to sewers is no longer available to irrigate lawns or recharge groundwater. This reduces the amount of water available for drinking water and water to support environmental resources.

Stormwater runoff also can pick up pollutants such as oil and grease, chemicals, nutrients, metals, and bacteria as it flows across surfaces and transports it to destinations in groundwater, streams, rivers, and lakes.

Different areas and soils lead to variability in recharge capabilities. The developed areas of southeastern Wisconsin generally have lower recharge capabilities. Western Waukesha County has areas with the highest recharge rates in the region (See Figure 8). This area recharges local shallow aquifers as well as the deep aquifer that currently serves as Waukesha's primary water source.

The City of Waukesha and Waukesha County stormwater management plans must be reviewed to ensure that rainfall and snowmelt can go back into the ground to replenish groundwater and that pollution is reduced from entering streams, rivers and groundwater. This may involve the use of urban BMP retrofits, such as the replacement of concrete stormwater channels with grass swales, installation of porous pavement on public properties, and public education to encourage the use of rain barrels, biofilters, and more advanced practices including green roofs.

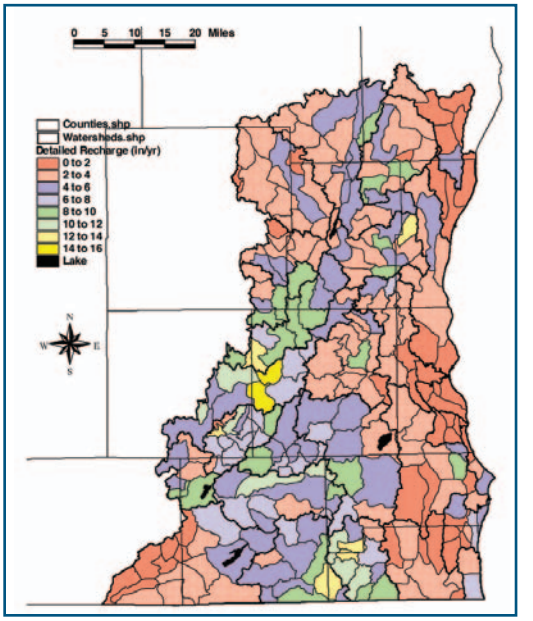


Figure 8. Groundwater Recharge (inches per year) in Southeastern Wisconsin

Source: United States Geological Survey

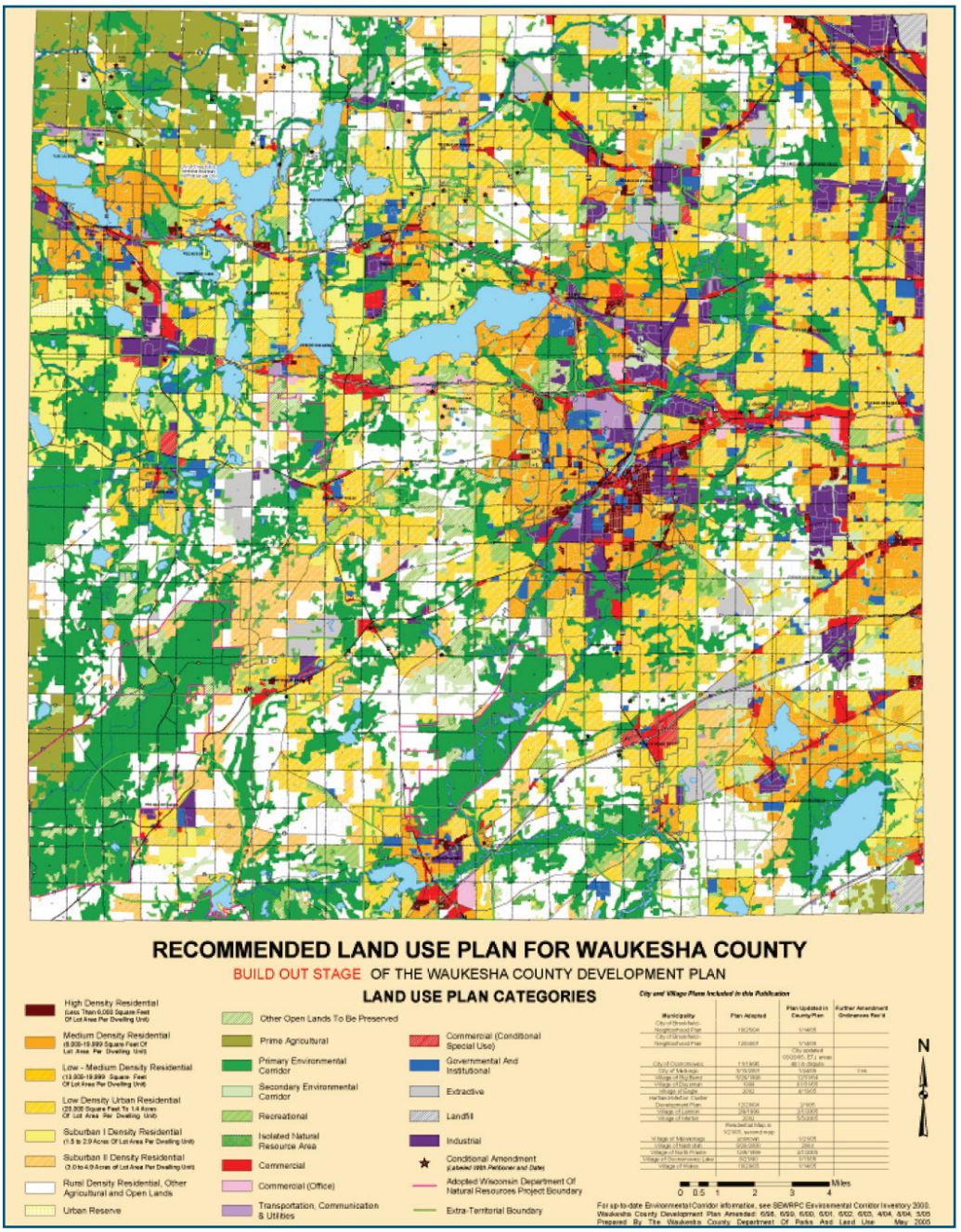


Figure 9. Recommended Land Use Plan for Waukesha County

Source: Waukesha County

Waukesha must also coordinate with Wisconsin DNR through the Groundwater Management Areas and with the SEWRPC regional water supply study to ensure that regional stormwater management supports groundwater recharge and protection.

Activities to be pursued include:

1. Identify Opportunities for Stormwater BMP Retrofits on Waukesha City property.
2. Review Proposed Retrofits with Waukesha Public Works Officials.
3. Design Two Stormwater BMP Retrofit Projects.
4. Oversee Stormwater BMP Implementation.
5. Work with Waukesha County to revise the recommended land use plan map (Figure 9) to protect critical recharge areas for shallow and deep groundwater resources (see Figure 8). In particular, land in the Kettle Moraine region is highly permeable and acts as recharge areas for shallow aquifers, the sandstone aquifer, and Lake Michigan.

Planning and Zoning

Waukesha's planning and zoning ordinances must be coordinated with its stormwater management plan to ensure that water is returned to the groundwater naturally rather than into storm sewers. New development must have minimal impact on the natural flow of water to groundwater that supports drinking water supplies and lakes, wetlands, and other environmental resources. Waukesha will consider a performance standard for all new development requiring the maintenance of pre-development hydrologic conditions.

This can be done through revision of local planning and zoning ordinances to require the use of low impact development (LID). It may be necessary to first update the local comprehensive plan to set a goal for open space and conservation planning and design. LID design integrates stormwater management and erosion and sedimentation control into natural systems that keep rainwater on site. This is different from traditional development that uses pipes and drains, ponds, and storm sewers to move water quickly off site and into streams, rivers, and lakes.

Appendix C provides model ordinance language specifically prepared for Wisconsin communities prepared by the University of Wisconsin Extension Service that is potentially appropriate for Waukesha. Appendix D is an example manual developed by the Town of Franklin, Massachusetts to assist planners and developers in implementing best management practices for low impact development.

Ordinance revisions will be completed in the following four tasks.

1. Gather and Review City and County Ordinances.
2. Meet with City and County Planners, Commission Members, and Elected Officials.
3. Evaluate Needed Ordinance Revisions.
4. Draft Ordinance Language.

Waukesha will first promulgate a city ordinance to control sprinkling. WWU will support the ordinance development in the following three tasks.

1. Calculate the peak water use reductions under different sprinkling reduction scenarios (e.g., odd/even restrictions, time-of-day restrictions, sprinkling bans).
2. Prepare draft ordinance language to achieve peak demand reductions.
3. Meet with city officials to review and revise the ordinance language.

Wastewater Reuse and Aquifer Recharge

WWU should investigate the feasibility of wastewater reuse of its wastewater in a manner that will not adversely affect groundwater resources. Waukesha's wastewater is currently discharged to the Fox River, which flows south into Illinois. Waukesha will investigate approaches for returning wastewater to recharge and replenish shallow and deep aquifer systems in compliance with Safe Drinking Water Act standards. Approaches that have been used in other parts of the country include spray irrigation, discharge to drainfields, or deep injection for aquifer storage and retrieval.

WWU will complete the following five tasks:

1. Gather Existing Data on Wastewater Characteristics and Parameters.
2. Develop Treatability Analysis to Determine Engineering Feasibility to Achieve Compliance with Drinking Water Quality Standards.
3. Conduct Bench Scale Tests to Determine Impact of Wastewater Reuse on Soil and Aquifer Materials.
4. Prepare Wastewater Reuse Proposal.
5. Support Proposal Review Process with WDNR.

Timeline for Implementing the Conservation Plan

Short Term Activities

1. **Implement Public Education Programs**
   - Website – educate the public why conservation is important and what they can do to help conserve water and, at the same time, save money. Also, provide information on rain gardens. (Completed)
   - 5th Grade Water Education - Continue working with the Waukesha School District by teaching fifth graders the water level in the aquifer, the importance of conservation and some practices that their families can implement. (in place)
   - Work with retailers to provide them with information to provide to customers on the benefits of updating indoor fixtures and outdoor watering devices.
2. **Continue Water Main & Property Replacement Effort**
   - Continue to replace old, outdated mains and service laterals. This will help to ensure a reduction in leaks. (In place)
3. **Develop Water Conserving Billing Structure**
   - Continue to work with the Public Service Commission to develop a billing structure that encourages water use conservation.
4. **Loop Water Mains**
   - Have contractors loop the water mains so that this will cut down on future hydrants to be flushed. (In place)
5. **Develop Outdoor Water Use Ordinances**
   - Create and implement ordinances that set limits on when sprinkling is allowed to reduce peak water use, reduce costs for customers, and encourage efficient outdoor sprinkling. (In process)
6. **Organize Stakeholder Group**
   - Create a stakeholder group to advise the utility on the conservation plan.
7. **Work with Housing Authority to Update Plumbing**
   - Begin working with Waukesha Housing Authority to update water fixtures at Waukesha public housing.
8. **Work with City Departments and Schools to Reduce Outdoor Water Use**
   - Identify opportunities for reduced outdoor water use in sprinkling parks and school fields.

9. **Audit Water Use in City Buildings**
   - Audit all city buildings in order to identify ways to reduce water usage.
10. **Work with the Focus on Energy Program**
   - Work with the Focus on Energy program to update showerheads at Waukesha hotels and hand sprayers at Waukesha restaurants.
11. **Coordinate Public Education Effort with Meter Change Out Program**
   - Prepare educational materials to leave with homeowners to make them more aware of water conservation effort.
   - Develop initial water audit system to identify homes that have not upgraded original plumbing.
12. **Begin Regional Source Water Protection Planning with Surrounding Communities and County**
   - Work with surrounding utilities to begin coordinating source water protection activities.

Mid-Term Activities

1. **Continue Education Programs**
   - Create Conservation Brochures & Signage.
   - Update curriculum for 5th Grade Water Education Classes.
   - Press Releases and update public outreach brochures.
   - Place water conservation information in WWU bills .
2. **Develop Incentives/Rebates Programs**
   - Evaluate rebate programs for targeted water using appliances and fixtures.
   - Evaluate rebates for the outdoor water use equipment (timers, sprayers).
   - Continue to work with the Public Service Commission to determine the feasibility and potential success of rebate programs.
   - Determine the feasibility of coordinating a residential water audit program with water meter change-out program that would link to an incentive/rebate program.
3. **Develop Water Use Restriction Ordinances**
   - Review plumbing requirements in ordinances: for new construction, remodeling, and retrofits, and Study potential for requiring plumbing updates at time of property sale.
4. **Recycle Filtered Backwash Water**
   - Implement a recycling process for Wells 8, 11, and 12.

5. **Implement city Water Audit**
    - Install water saving fixtures throughout the WWU.
    - Work with largest water users to audit facilities.
6. **Work with Commercial Sector to Encourage Water Conservation**
    - Update web site.
    - Make up brochures.
    - Mail out brochures to commercial properties.

Long Term Activities

1. **Continue and Accelerate System Leak Detection**
    - Update utility detection of leaks to identify priority areas in the system to reduce large leaks and reduce unaccounted for flow.
2. **Implement Unidirectional flushing**
3. **Implement Smart Growth – (Land Use Planning & Zoning)**
    - Work with others (surrounding communities, City, developers, etc.) to develop best management practices (Low Impact Development Practices) to prevent pollution from moving into the river. Consider revision of city plan, subdivision and zoning ordinances to encourage infiltration of stormwater into the ground.
4. **Update Storm Water Management Requirements**
    - Work with the City of Waukesha and Waukesha County to develop stronger stormwater ordinances to encourage infiltration.
5. **Work with Commercial & Industrial Sectors to Audit Water Use**
    - Work with commercial and industrial customers to identify areas to reduce water use and save customers money.

Water Conservation and Protection Plan Implementation to Date

The City of Waukesha has implemented the following water conservation and protection activities:

- ***Redefining the Residential Rate Structure.*** The Wisconsin Public Service Commission approved a conservation-based rate structure for the Waukesha Water Utility, a first for the State of Wisconsin. The new rate structure promotes water conservation by charging higher rates for residential customers using more than 30,000 gallons per billing period. Studies have shown that overall water use decreases as price increases.

- ***Outdoor Watering Ordinance.*** In April 2006, The Waukesha Common Council passed an outdoor watering ordinance that restricts lawn watering to no more than twice per week. As a result, overall water use during the summer fell approximately 10% with only one day exceeding 10 million gallons per day.

- ***City Hall Plumbing Retrofit:*** In 2006, Kohler donated toilets, urinals, and aerators for City Hall Bathroom facilities. 3.5 gallon per flush toilets were replaced with 1.6 gallon per flush toilets. Urinals were retrofitted so that they flushed by use of sensor instead of periodically flushing. Since installation, City Hall has seen water use reductions of between 15 and 25 percent over previous years.

- ***Establishment of a Waukesha County Conservation Planning Group.*** In 2006, Waukesha County and the City of Waukesha cooperated in establishing a Coalition to prepare and implement a water conservation public education strategy. The goal of the Coalition is to develop a unified message that can be used in existing and new public education materials. Presenting a water conservation message on a regional basis makes a lot of sense. Not only is it cost effective, it also sends a consistent message to residents and businesses in the Region. The Coalition will formally convene two to four times a year. The Coalition members meet quarterly.

- ***Phase II Stormwater Regulations Implementation.*** Waukesha has passed all of the Phase II Stormwater ordinances required by federal regulations:
    - ***Public Education and Outreach*** Outlined in the revised stormwater management plan.
    - ***Public Participation/Involvement*** Outlined in the revised stormwater management plan.
    - ***Illicit Discharge Detection and Elimination*** Developing and implementing a plan to detect and eliminate illicit discharges to the storm sewer system (includes developing a system map and informing the community about hazards associated with illegal discharges and improper disposal of waste). Ordinance passed 07/28/2005.
    - ***Construction Site Runoff Control*** Passed a construction site runoff control ordinance 07/28/05
    - ***Post-Construction Runoff Control***. Passed Post-Construction Runoff Control ordinance 02/16/06.
    - ***Pollution Prevention/Good Housekeeping*** Approved a revised stormwater management plan.

- ***School Education:*** The Waukesha Water Utility has partnered with the Waukesha School District to teach water education classes to fifth graders. This water program has taken place since 1990 to the present; and the Utility and the School District share the costs. Approximately 1,000 students attend these classes – its part of the students' science curriculum. There are two parts to this program. First, the students do an outdoor field investigation of the Fox River Sanctuary; and then, they visit one of our pumping stations. At the pumping station, they not only get a tour of the facility, but they also learn about the water cycle, where our water comes from, how it is treated and distributed, and future concerns dealing with quantity and quality. By the end of the lesson, students understand that water is a limited resource, human activities have a direct impact on the water quantity and quality, and that using water wisely is everyone's responsibility.

Addendum

Implementation

September 2006

April 2006: Outdoor Water Use Ordinance

CITY OF WAUKESHA
CODE BOOK INSERT

ORDINANCE NO. 20-06

CHAPTER 13
PUBLIC HEALTH
AND WELFARE

AN ORDINANCE TO CREATE CERTAIN PROVISIONS OF THE PUBLIC HEALTH AND WELFARE CODE OF THE MUNICIPAL CODE OF THE CITY OF WAUKESHA, WISCONSIN

THE COMMON COUNCIL OF THE CITY OF WAUKESHA DO ORDAIN AS FOLLOWS:

SECTION I. Section 13.11 of the Waukesha Municipal Code is hereby created to read as follows:

13.11 WATER CONSERVATION

(1) PURPOSE. The purpose of this section is to prevent overuse of the City's water resources to avoid substantial depletion of the water table and to ensure sufficient water supply is available at all times including peak usage periods. The Common Council finds that ensuring the provision of water, especially in emergency situations, is essential to the public interest.

(2) DEFINITIONS.

(a) Emergency Water Condition means a circumstance where any of the following conditions are met:

1. Water pressure to any customer cannot be sustained at a pressure greater than or equal to 20 pounds per square inch (PSI).

2. Water storage levels cannot be maintained above the preset fire reserve limits.

3. Water treatment capability cannot meet the demand placed on the system.

4. The City has declared a state of emergency pursuant to sections 5.06 (1) or (2) of the Code on the recommendation of the General Manager of the Water Utility or the General Manager's designee due to other circumstances which to a reasonable certainty shall result in a severe water shortage for the City if emergency measures are not taken.

(b) New Landscape means vegetation installed for no more than one (1) month which is: (1) installed at the time of construction of a new house, multi-family, industrial or commercial building; (2) installed as part of a governmental entity's capital improvement project; or (3) which alters more than one quarter of the area of an existing yard or which alters an area greater than 3000 square feet of an existing yard.

(c) Sprinkling means the act of applying water to outdoor vegetation for purposes of irrigating an area of land.

(3) SPRINKLING RESTRICTED. At all times between the first day of May and the first day of October, the following sprinkling restrictions shall be in effect.

(a) Properties having odd-numbered street addresses are prohibited from sprinkling lawns and gardens except on Tuesdays and Saturdays, at which time sprinkling is permitted at any time before 9:00 a.m. and after 5:00 p.m.

(b) Properties having even-numbered street addresses are prohibited from sprinkling lawns and gardens except on Thursdays and Sundays, at which time sprinkling is permitted at any time before 9:00 a.m. and after 5:00 p.m.

(c) Exceptions. Notwithstanding the prohibitions set forth in this section, the following activities are permitted at any time:

1. Sprinkling gardens, trees and shrubs through use of a hand-held watering can or other hand-held container or hose, provided, however, any such watering device must be utilized manually and cannot be left unattended.

2. Sprinkling or otherwise irrigating new landscape.

3. Sprinkling or otherwise irrigating outdoor sports complexes including but not limited to baseball diamonds.

4. Sprinkling activity conducted at cemeteries.

5. Any Sprinkling activity conducted pursuant to a Special Permit granted under sub. (5) of this section.

(4) EMERGENCY MEASURES. If an Emergency Water Condition is in effect, the General Manager of the Water Utility or a designee shall give notice to the public by posting a declaration in three (3) public places, the City website, Government Access cable channel, faxing the declaration to three area television news networks, and if possible by verbal announcement over the cable system. At the time the Water Utility Manager or a designee opines that the Emergency Water Condition has ended, the same notice procedure shall be followed to declare cessation of the emergency. During an Emergency Water Condition, the following emergency measures shall be in effect:

(a) All outdoor sprinkling or other irrigation activity is prohibited.

(b) The washing of sidewalks, driveways, parking areas, tennis courts, patios or other paved areas by the use of a pressurized source is prohibited.

(c) The washing of motor vehicles, trailers, and other self-propelled devices is prohibited except at facilities equipped with wash water recirculation systems.

(d) Outdoor use of any water-based play apparatus connected to a pressurized water source is prohibited.

(e) The filling of swimming pools, fountains, spas or other exterior water features is prohibited except on residential properties not equipped with working central air conditioning systems or when necessary to alleviate an immediate threat to a person's health or safety. As used in this section, "an immediate threat to a person's health or safety" shall include, but is not limited to, infirmities of aging, developmental, mental or physical disabilities, or like infirmities incurred at any age, or the frailties associated with being very young.

(f) Operation of outdoor misting systems used to cool public areas is prohibited unless their use is necessary to alleviate an immediate threat to a person's health or safety.

(g) Water obtained by means of a fire hydrant shall not be used for cleaning equipment of any kind.

(5) SPECIAL PERMIT. Any person may make an application for a Special Permit allowing Sprinkling during the hours prohibited by subs. (3)(a) and (3)(b) of this section.

(a) The application shall be made on a form provided by the Water Utility. The application shall indicate the address covered by the request; the time period within which sprinkling activity is requested; the name, address and contact information of a responsible party; and the reasons for the request.

(b) A Special Permit shall only be granted if the Water Utility General Manager or a designee finds that the permit is necessary to avoid an emergency condition effecting health, sanitation or fire protection of the applicant or the public; or if failure to grant the permit would substantially deprive the applicant of the applicant's financial livelihood. Conditions which reasonably relate to the goal of minimizing depletion of the water table may be placed on the time or manner of Sprinkling to be conducted under a Special Permit.

(c) The Water Utility General Manager or a designee shall grant or deny an application no later than ten (10) business days after the completed application is filed with the Utility. If an application is denied, an agent of the Utility shall so advise the applicant in writing of the denial and the reasons thereof within the ten-day period.

(d) Any person aggrieved by a decision to grant or deny a Special Permit under this subsection may appeal the decision to the Water Utility

Commission by filing a written notice of appeal with the Water Utility within twenty (20) days of receipt of notice of the decision. The Commission shall hold a hearing at its next meeting or at a reasonable time thereafter and permit the appellant to be heard and state his or her reasons for the need to overturn the decision of the Water Utility General Manager. The Commission shall then determine whether the decision of the General Manager was made consistent with the factors set forth in sub. (5)(b) and inform the appellant of its decision no later than thirty (30) days following the hearing. This hearing provision shall not be governed by the administrative review procedures provided for in Chapter 68, Wis. Stats.

(6) ENFORCEMENT AND PENALTY.

(a) Service of Notices. Whenever an employee or agent of the Water Utility determines there has been a violation or that there are reasonable grounds to believe there has been a violation of any provision of this section, said person or other Water Utility designee shall give written notice of such violation to the residents of the property by either: (1) affixing such notice onto or reasonably close to the front door of the property; or (2) depositing the notice in the U.S. Mail addressed to the person responsible for the property's water bill. Subsequent violation notices shall be served in the same manner if the violation persists for more than one (1) week. The Water Utility shall also deposit a copy or other facsimile of third and subsequent notices in the U.S. Mail addressed to the owner of the property as shown by the records on file with the Tax Assessor if the property owner is not responsible for the water bill.

(b) Referral to Police Department. If a violation of this section persists after three (3) or more violation notices have been served in the manner provided under sub. (5)(a) of this section, the Water Utility may refer the matter to the Police Department. If the Police Department determines there is sufficient evidence to proceed, a citation may be issued. Each day a violation continues constitutes a separate offense.

(c) Penalty. Any person subject to a penalty under this section shall be penalized as provided in §25.05 of this Municipal Code.

(d) Suspension of Service. The Water Utility may suspend water service to a property in violation of this section if all of the following conditions are met:

1. Five or more citations have been issued pursuant to sub. (5)(c) of this section.

2. The Water Utility Commission has adopted this ordinance as part of the Utility's rules and regulations.

3. The violation interferes with the water service of others.

4. No heat advisory, heat warning or heat emergency issued by the National Weather Service is in effect.

5. Suspension would otherwise not be prohibited by any rule of the Public Service Commission, including but not limited to Wis. Admin. Code PSC § 185.37.

SECTION II. All ordinances or parts of ordinances inconsistent with or contravening the provisions of this ordinance are hereby repealed.

SECTION III. This ordinance shall take effect and be in force from and after the date of its passage and publication.

Passed this 6th day of April, 2006.

Approved this 7th day of April, 2006.

/s/ Carol J. Lombardi
Mayor

Attest:

/s/ Thomas E. Neill
City Clerk

Appendix A

Water Conservation Example Ordinance Language

Water Conservation
Example Ordinance Language

Municipalities promote water conservation through measures in four categories:

- Restrictions,
- Incentives,
- Education, and
- Monitoring.

Restrictions are limitations on type, method, duration, frequency, or volume of water use. These requirements are established and explained in the creation of ordinances, which also detail enforcement and noncompliance penalties. Incentives typically take the form of a rate structure discouraging high water usage, or rebates and free replacements for upgrading household fixtures and appliances to more water-efficient models. Some municipalities reward conservation-minded residents in more creative ways, for example, by presenting awards to top water usage reducers. Educational approaches to water conservation range from instructing homeowners on how to check for plumbing leaks to distributing free booklets on water-wise gardening and drought-resistant plant varieties. In many municipalities, water usage monitoring is used as an opportunity to educate residents on conservation. Site evaluations by trained technicians serve a two-fold purpose of identifying leaks and aging infrastructure, and informing residents about the importance of reducing unaccounted-for flows.

Water use restrictions and requirements, as enumerated in ordinances, apply to a wide variety of residential, commercial, industrial, and municipal activities. This section provides examples of ordinances from municipalities across the country, categorized by activity:

- Water efficient plumbing requirements
- Outdoor water use restrictions
- Limitation of hydrant uses
- Water conservation for commercial consumers
- Installation of water meters
- Definitions for water conservation ordinance terminology
- Conservation signage and literature distribution
- Enforcement
- Water waste restrictions
- Conservation fees imposed
- Variance procedures
- Response to water shortage

Water Efficient Plumbing Requirements

Fixtures and appliances in the kitchen, bathroom, and laundry are the primary targets for water conservation. By setting water efficient plumbing requirements for new construction, remodeling, and/or retrofits, municipalities force residents to replace existing or potential water-wasting models. The following examples of water efficient plumbing ordinances are from Santa Monica, California[1] and Santa Fe County, New Mexico.[2]

7.18.050 Retrofit requirement upon purchase or change of ownership. (Santa Monica, California)

[1] City of Santa Monica, California, Municipal Code of Ordinances, Article 7: Public Works. http://www.epa.gov/owow/nps/ordinance/documents/SantaMonicaUR.pdf
[2] Santa Fe County ordinance addressing water conservation: http://www.co.santa-fe.nm.us/departments/land_use/water_harvesting/docs/Water_Conservation_Ordinance.pdf

No existing structure shall be sold or transferred unless all existing plumbing fixtures in the structure are retrofitted exclusively with water-conserving plumbing fixtures. Compliance with this Section shall be included as a condition of escrow. (Added by Ord. No. 1667CCS § 1 (part), adopted 2/9/93)

Retrofit requirement (Santa Fe, New Mexico)
For all new and remodeling construction and all replacements of existing plumbing fixtures, the water conservation plumbing standards set out below shall be met. In addition, with the exception of item (D), all existing water users shall retrofit their facilities such that the plumbing fixtures noted below are in place by January 1, 2005. Single and multi-family residential water users are exempt from this retrofit requirement.

A. Water closets, either flush tank, flushometer tank or flushometer valve operated, shall have an average consumption of not more than 1.6 gallons (6.1 liters) per flush. Water closets that use a "quick closing" flapper to limit the flush to 1.6 gallons shall not be used to satisfy this requirement.

B. Urinals shall have an average water consumption of not more than 1.0 gallon of water per flush, with the exception that, if approved by Santa Fe County, blowout urinals may be installed for public use in stadiums, race courses, fairgrounds and other structures used for outdoor assembly and similar uses.

C. Lavatory and kitchen faucets shall be equipped with aerators and shall be designed and manufactured so that they will not exceed a water flow rate of 2.5 gallons (9.5 liters) per minute.

D. Self-closing, metering or self-closing faucets shall be installed on lavatories intended to serve the transient public, such as those in, but not limited to, service stations, train stations, airports, restaurants and convention halls. These faucets shall deliver no more than .25 gallons of water (1.0 liters) of water per use.

E. Shower heads shall be designed and manufactured so that they will not exceed a water supply flow rate of 2.5 gallons (9.5 liters) per minute. Emergency safety showers are exempted from this provision.

F. Water-conserving fixtures shall be installed in strict accordance with the manufacturer's instructions to maintain their rated performance.

G. For all new and re-modeling construction, all of the requirements regarding water conserving devices shall be certified by a certificate of compliance by a licensed mechanical contractor or plumbing permittee before or at the time of the final plumbing inspection.

H. All outdoor timed irrigation systems must be equipped with a rain sensor so that the irrigation system does not operate when it is raining or has recently rained.

I. Exceptions to the above requirements may be permitted when necessary to maintain adequate health and safety standards.

Outdoor Water Use Restrictions

Municipalities commonly restrict outdoor water use for activities such as watering lawns and gardens or spraying driveways and sidewalks, however, the extent of these restrictions among municipalities may vary by time of day, season, current drought conditions, etc. Some municipalities employ watering rotations by precinct or street number; some make outdoor water use exceptions for installation of new landscaping and in emergency drought conditions. The following example of a water use ordinance is from Arlington Heights, Illinois[3].

[3] Arlington Heights, Illinois Water Use Ordinance. http://www.vah.com/info/Municipal_Code/CHAPTER%2021.pdf

Section 21-112: Outdoor Water Use Restrictions.

A. It shall be unlawful for any person, firm or corporation to use water from the municipal water works system for the purpose of sprinkling or watering a lawn or garden except between the hours of 8:00 A.M. and noon or between the hours of 7:00 P.M. and 9:00 P.M., Monday through Saturday. No outdoor sprinkling or watering is permitted on Sunday. Specifically exempt from the requirements of this Section are hand held hoses or sprinkling cans used for watering.

B. Any person, firm or corporation violating the terms of this Section shall be fined not less than $25 nor more than $750 for each offense.

C. Temporary 14 day sprinkling permits may be issued by the Director of Public Works to individuals who have special needs related to newly installed landscape materials.

D. In the event of an interruption to the municipal water works system water supply or in the event of an emergency, the Village President or Village Manager is hereby authorized to implement the Village's emergency water use plan and to impose immediate restrictions upon the use of water for outdoor water users, including but not limited to lawn and garden sprinkling, swimming pool filling, and ice rink activities. If deemed necessary, water service to certain users may be curtailed or terminated for the duration of the emergency.

Limitation of Hydrant Uses

Fire hydrants, as sources of vast volumes of public water, are critical for protecting communities in the event of fire. Therefore, ordinances strictly limit use of hydrants for purposes other than fire fighting, and describe specific maintenance requirements. Reducing hydrant use for non-emergency situations help conserve public water. The following example of a hydrant ordinance is from Arlington Heights, Illinois.

Section 21-111: Use and Maintenance of Fire Hydrants.

A. No person, firm or corporation shall open or draw water from any Village fire hydrant without prior permission from the Director of Public Works.

B. No person, firm or corporation shall tamper, alter, damage or interfere with any Village-owned fire hydrant.

C. All fire hydrants, public and private, shall be properly inspected, maintained and tested in accordance with AWWA and NFPA standards. Village-owned hydrants shall be painted red. Private hydrants whose flows are measured and recorded by a Village-owned meter shall be painted yellow. Private unmetered hydrants shall be painted red. All nozzle caps shall be painted with a reflectorized coating as specified by the Director of Public Works.

D. No object shall be erected, constructed, maintained or installed within four feet of a fire hydrant. This provision includes trees, bushes, shrubs, etc.

E. Water obtained from any Village-owned fire hydrant for any purpose other than fire fighting or related public safety uses shall be metered and the water consumption shall be billed at a rate to be determined by the Finance Director. Payment for such water shall be made in accordance with policies established by the Finance Director.

Water Conservation for Commercial Consumers

Many of the same conservation measures apply to residential and commercial water consumers, but in some cases, commercial water consumers have unique considerations due to the type or volume of their use. Certain industries such as hospitality and landscaping are particularly subject to reduction

in water use. The following examples of a water conservation ordinances for commercial consumers are from Santa Fe County, New Mexico and San Antonio, Texas.[4]

Water Use Restrictions for the Hospitality Industry (Santa Fe County, New Mexico)

A. All private and public eating establishments shall provide water and other beverages only upon request. This policy shall be clearly communicated to the customer in at least one of the following manners: on the menu, by use of a "table tent" or single signage on the table, or posting in a location clearly visible to all customers. All catering and banquet operations shall comply with the provisions of this subsection. The intent of this requirement is not to discourage the drinking of water but to discourage the washing of additional unnecessary glasses.

B. Lodging facilities shall not provide daily linen and towel changing for guests staying multiple nights unless the guest specifically requests each day that linens and towels be changed.

Water Use Restrictions for Various Commercial Water Users (San Antonio, Texas)

Sec. 34-272. Activities to be regulated on and after effective dates.
The following activities shall be regulated in the manner set out herein on and after the respective dates indicated in the sections and subsections. A person affected by such regulations may request a variance in the manner set out in Section 34-277. A violation of this section and subsections shall be subject to the enforcement provisions set out in Section 34-278. It shall be and is hereby declared unlawful for any person to violate, refuse or fail to implement the requirements of this Division 1.

Sec. 34-272.1 Power Washers.
A. Effective January 1, 2006, a person who uses a power washer in any commercial manner or for compensation shall register with the Director of Conservation, and obtain a certificate for such use.
B. Exempted from this requirement are persons who use power washers for personal use at their own home and homebuilders who are performing a one-time clean up at a newly constructed house.
C. Holders of NPDES / TPDES permits are deemed certified.
Comment. This comment does not have force of law, but is offered for clarification only. The intent of this registration protocol is to complement and make effective mandates necessary to "critical period' conservation rules found elsewhere in the City Code. The conservation rules in question are intended to prevent water waste under certain circumstances when "critical periods" are observed. Examples of persons subject to year round registration are those hired, employed or contracted to clean sidewalks, parking lots, commercial / public buildings and other impervious areas associated with commercial or domestic properties; professional painters; businesses using their own in-house power washers such as chain stores, grocery stores, and any other entity, public or private.

Sec. 34-272.2 Vehicle Wash Fundraisers.
Effective March 1, 2005, any vehicle wash fundraiser shall be exempted from the Vehicle Wash requirements.

Sec. 34-273. Activities to be regulated on and after January 1, 2006.
Except as provided by a specific and alternative application date, particularly systems analysis, the following activities shall be regulated in the manner set out herein on and after January 1, 2006. A person affected by such regulations may request a variance in the manner set out in Section 34-277. A violation of this section and subsections shall be subject to the enforcement provisions set out in Section 34-278. It shall be and is hereby declared unlawful for any person to violate, refuse or fail to implement the requirements of this Division 1.

Sec. 34-273.1 Minimum irrigation area and flow direction.

[4] San Antonio, Texas Water Conservation Ordinance, http://www.bexarmet.org/PDF_FILES/2005ConservationOrdinance.pdf

Newly installed irrigation systems using pop-up spray or rotor technology shall not be used in landscaped areas which have both: (a) dimensions less than five feet in length and/or width; and, b) impervious pedestrian or vehicular traffic surfaces along two (2) or more perimeters. Where pop-up sprays and rotor heads are allowed in newly installed irrigation systems, they (a) must direct flow away from any adjacent impervious surface and (b) shall not be placed within 4 (four) inches from an impervious surface.

Sec. 34-273.2 Annual irrigation system analysis for athletic fields, golf courses, and large properties.

A. An annual irrigation system analysis shall be required for all athletic fields, golf courses and large properties and shall be submitted in writing to the San Antonio Water System Conservation Department on or before May 1st of each year, beginning on May 1, 2006. Golf courses, other than those utilizing recycled water for irrigation in accordance with an agreement with SAWS, shall comply with residential irrigation requirements on areas other than tee boxes, fairways and greens.
B. Municipal tenants and lessees of golf courses, sports and athletic playing fields, and any other municipally owned properties, shall be responsible for compliance with this section and subsection. The SAWS shall look directly to such tenants and lessees for compliance unless the municipality concedes by contractual agreement with the tenant / lessee to assume the tenant / lessee's responsibility for compliance.

Sec. 34-273.3 Cooling towers (Effective January 1, 2006).

A. Cooling Towers, not utilizing; recycled water, shall operate a minimum of four cycles of concentration.
B. Newly constructed cooling towers shall be operated with conductivity controllers, as well as make-up and blowdown meters.

Sec. 34-273.4 Ice Machines.

Newly installed ice machines shall not be single pass water-cooled.

Sec. 34-273.5 Commercial Dining Facilities.

Commercial dining facilities shall:

A. Serve water only upon request.
B. Utilize positive shut-offs for hand-held dish-rinsing wands.
C. Utilize water flow restrictors for all garbage disposals.

Sec. 34-273.6 Vehicle wash facilities.

A. Vehicle wash facilities, commencing operation on or after January 1, 2006, using conveyorized, touchless, and / or rollover in-bay technology shall reuse a minimum of fifty percent of water from previous vehicle rinses in subsequent washes.
B. Vehicle wash facilities, commencing operation on or after January 1 2006, using reverse osmosis to produce water rinse with a lower mineral content, shall incorporate the unused concentrate in subsequent vehicle washes.
C. Regardless of date of operation commencement, self-service spray wands used shall emit no more than three gallons of water per minute.

Sec. 34-273.7 Vacuum Systems.

Vacuum systems shall not be water-cooled with single-pass potable water when alternative systems are available.

Sec. 34-274 Other Activities to be regulated on and after January 1,2006.

The following activities shall be regulated in the manner set out herein on and after January 1, 2006. A person affected by such regulations may request a variance in the manner set out in Section 34-277. A violation of this section and subsections shall be subject to enforcement provisions set out in Section 34-278. It shall be and is hereby declared unlawful for any person to violate, refuse or fail to implement the requirements of this Division 1.

Sec. 34-274.1 Condensate collection.
Newly constructed commercial buildings installing air conditioning systems on and after January 1, 2006, shall have a single and independent condensate wastewater line to collect condensate wastewater to provide for future utilization as (i) process water and cooling tower make-up and/or (ii) landscape irrigation water. Condensate wastewater shall not be allowed to drain into a storm sewer, roof drain overflow piping system public way or impervious surface.

Sec. 34-274.2. Rain Sensors.
Effective January, 1, 2006, rain sensors shall be installed and maintained on all irrigation systems equipped with automatic irrigation controllers.

Sec. 34-275 Landscaping Regulations generally applicable on and after January 1, 2006.
Except as specifically provided with alternative effective dates, persons affected by the regulations set out herein below shall comply on and after January 1, 2006, and may request a variance to such regulations in the manner set out in Section 34-277. A violation of this section and subsections shall be subject to the enforcement provisions set out in Section 34-278. It shall be and is hereby declared unlawful for any person to violate, refuse or fail to implement the requirements of this Division 1.

34-275.1 Xeriscape option.
Effective January 1, 2006, homebuilders and/or developers subdividing lots and/or constructing new single family residential homes shall offer a xeriscape option in any series of landscaping options offered to prospective home buyers.

34-275.2 Model.
Effective January 1, 2006, homebuilders and/or developers who construct model homes for a designated subdivision shall have at least one model home per subdivision landscaped according to a xeriscape design.

34-275.3 Zonal system.
In-ground irrigation systems installed on and after January 1, 2006, shall be zonal irrigation systems.

34-275.4 Turfgrass soil support.
A. Turfgrass installed during or associated with new construction on and after January 1 2006, shall have a minimum of four inches of soil under the turfgrass.
B. Drainage utility projects, water and power utility projects, public property maintenance or repair, and those governmental activities necessary to NPDES / TPDES compliance with federal or state rules and regulations implementing the federal Clean Water Act; or governmental actions to comply with the Americans with Disabilities Act, shall not be deemed new construction for purposes of this subsection.

34-275.5 Turfgrass dormancy qualities.
Turfgrass installed after January 1, 2007, shall have summer dormancy capabilities.
Legal comment: This comment does not have force of law, but is provided here for informational purposes only. The Texas Property Code, Chapter 202, Section 202.001, et. seq., entitled "Certain Restrictive Covenants," reflects a growing public interest in water conservation and its relationship to the public health, safety, and welfare. Texas Property Code, Chapter 202, Section 202.007, provides that a property owners association may not include or enforce a provision in a dedicatory instrument that prohibits or restricts a property owner from implementing certain efficient irrigation systems, including underground drip or other drip systems. Any dedicatory instrument provision, attempting to restrict a property owner from installing such efficient systems, is void. Therefore, such restrictions, running counter certain conservation efforts, cannot be enforced. Texas Real Property Code, Sec. 202.007(b). Added by Acts 2003. 78'h Legislature, chapter 1024. .6 1, Effective, September I, 2003.

As used within the Texas Property Code, "dedicatory instrument" means a governing instrument for the establishment, maintenance, and operation of a residential subdivision, planned unit development, condominium, townhouse regime, or any similar planned development. Texas Real Property Code, Sec. 202.007(I).

The Texas Property Code also allows that a property owners' association may restrict the type of turf used by a property owner in the planting of new turf [in the future] in order to encourage or require water conserving turf.

According to the Texas Property Code dedicatory instrument or other legal means, installation of efficient irrigation systems, including establishing visibility limitations for aesthetic purposes.

The SAWS endorses and advocates the use of dedicatory instruments and other legal obligations among private parties which understandings may support and promote a culture of water conservation.

Installation of Water Meters

Ordinances concerning the installation of water meters ensure that all customers served by the public water supply are metered by the municipality for the purpose of assessing charges. The municipality is responsible for ownership, installation, and maintenance of accurate, accessible meters. The following example of a water meter ordinance is from Arlington Heights, Illinois.

Section 21-110: Water Meters.

A. No premise shall be supplied with water from the municipal water works system until a meter is installed on the water service pipe and, where applicable, until a remote register reading device is installed on the exterior of the building being served.

B. The Village shall supply water meter devices, accessories and components for new customers. The cost of furnishing and installing each water meter and related accessories shall be paid for as part of the building permit fees for the subject premises.

C. All meters, registers, generators, vaults, interface devices, wires, cables, and appurtenances used in connection with the municipal water works system shall be supplied by the Village. Installation of the devices and components shall be accomplished in accordance with policies established by the Director of Public Works. The devices and components related to the metering system set forth above shall be owned, operated and maintained by the Village. The Village will not be responsible for maintenance of valves and/or service pipes attached to the metering devices or components.

D. The Village will be responsible for maintaining the water meter and accessories in good working order. Flow measurement accuracy and precision will be governed by applicable AWWA/ANSI standards. The property owner, occupant or tenant where the meter is installed is responsible and shall be held liable for any damage and attendant costs resulting from freezing, tampering, vandalism, etc. to the meter. The cost of repair, replacement, and/or adjustment of the meter shall be paid by the property owner, occupant, or tenant as soon as a bill is presented. The amount shall be a lien against the premises in which the meter is located to the same extent and with the same effect as delinquent water charges and sewer charges as provided for in Section 21-308 of the Code.

E. Water meters shall be installed in a location that is easily accessible. The installation of the meter shall ensure that all flows, including fire and domestic, are measured. Actual size, location and installation of the meter and accessories shall be approved by the Director of Public Works. No enclosures, cabinets, walls, etc. shall be erected that will obstruct or interfere with the reading, servicing, testing or replacement of the water meter. Property owners, occupants, or tenants constructing such obstructions around or near the water meters shall remove, remodel or relocate the obstruction to provide proper accessibility within ten days of receiving notice from the Village. Failure to provide reasonable accessibility for maintenance, servicing, testing, repair or replacement of water meters shall be cause for water service termination and water shut off.

Water service will be restored only after proper access to the water meter has been obtained to the satisfaction of the Director of Public Works.

F. Water meters and/or remote reading devices shall be read on a frequency determined by the Finance Director. Authorized representatives of the Village shall be allowed to enter buildings and/or premises at reasonable hours to make meter readings. In the event water meter readings cannot be obtained consistent with the established billing schedule, the Finance Director shall prepare estimated bills, based on historical usage data during similar billing periods from the preceding year(s).

G. The water meter installed on the water service is the meter of record and shall govern all bill calculations. The water meter register reading prevails over all other devices and readings. The remote register readings will be used for convenience in obtaining readings. It is the responsibility of the water customer, property owner, occupant or tenant to periodically verify agreement between the water meter reading(s) and the remote register reading(s). Any discrepancy between the meter readings and the remote register readings shall be immediately reported to the Village. Whenever a difference in readings exists, the water meter register reading will be used to determine consumption and to calculate the water bill.

H. Whenever any water meter fails to properly measure, record and register water passing through the meter, the customer shall be charged at the rate of consumption consistent with historical usage data during similar billing periods from preceding years. If no historical data exists, the Finance Director shall estimate the amount of water consumed during the period of meter failure. It shall be the responsibility of the water customer to pay for the amount of water consumption estimated by the Finance Director.

I. Water meters shall be tested and replaced on a frequency determined by the Director of Public Works. Normal repairs and replacement of meters shall be made by the Village at no cost to the property owner, occupant, or tenant. Costs of repair or replacement of meters necessitated as a result of freezing, neglect, carelessness or other improper conditions shall be charged against and collected from the water customer.

J. The Director of Public Works or authorized representative shall be allowed access during all reasonable hours to all water meters and backflow prevention devices for the purpose of testing meters for accuracy and testing other devices for satisfactory operation. Tests shall be conducted annually by the Village on all backflow prevention devices. The fee for testing Village-owned and maintained backflow prevention devices shall not exceed the charges in the contract for these services approved by the Board of Trustees and shall be paid by the users of the backflow prevention devices. All water meters shall be tested at the discretion of the Director of Public Works and in accordance with the manufacturers' suggested testing schedules. Additional testing may be required whenever erroneous or erratic meter readings are registered or when mechanical defects are observed. There shall be no charge for routine testing of water meters or for testing done at the Village's initiative.

Any water meter shall also be tested upon a customer’s complaint or request. Prior to the test, the customer shall agree in writing to pay testing fees if the meter is certified to be within three percent of being accurate. There shall be no testing fee if the water meter is certified as not being within three percent of being accurate. In such cases, the meter shall either be replaced with a properly certified meter or repaired so that the meter is within three percent of being accurate. Fees for testing meters at a customer's request and found to be within three percent of being accurate shall not exceed the charges in the contract for these services approved by the Board of Trustees.

All testing charges for water meters and backflow prevention devices shall be added to the water bill on a billing frequency approved by the Finance Director. If such charges and fees are not paid within 20 days from billing, penalties shall be added in accordance with the applicable Code provisions.

Definitions for Water Conservation Ordinance Terminology

Many ordinances preface restrictions with a section that defines terms used in the context of water conservation. The first example below of definitions for water conservation ordinance terminology is from the San Antonio Water System, Texas. The second example below is from the City of Santa Monica, California.

Sec. 34-271. Definitions. (San Antonio Water System, Texas)

As used in this article, the following terms shall have the following meanings:

Air conditioning system(s). A mechanical system generally consisting of a compressor, thermostat and duct work permanently installed in a building for the purpose of controlling humidity and temperature. For the purposes of this division, an air conditioning system does not include window units.

Automatic irrigation controller. A device that automatically activates and deactivates an irrigation system at times selected by the operator.

Blowdown meter. A meter that tracks the amount of water discharged from a cooling tower system.

Commercial dining facility. A business that serves prepared food and beverages to be consumed on the premises.

Concentration. Re-circulated water that has elevated levels of total dissolved solids as compared to the original make up water.

Conservation Department. The Conservation Department of the San Antonio Water System.

Conductivity controller. A device used to measure the conductivity of total dissolved solids in the water of a cooling system and control the discharge of water in order to maintain efficiency.

Cooling Tower. An open water recirculation device that uses fans or natural draft to draw or force air to contact and cool water through the evaporative process.

Director of Conservation. The Director of the Department of Conservation of the San Antonio Water System.

Impervious surface. Patios, pathways and other areas where firm footing is desired, constructed in such a way that does not allow water to penetrate the around. Examples include but are not limited to concrete slab patios, sidewalks and driveways, asphalt streets or pavers set with mortar.

Irrigation system. A system with fixed pipes and emitters or heads that apply water to landscape plants or turfgrass, including, but not limited to, in-ground and permanent irrigation systems.

Irrigation system analysis. A zone-by-zone analysis of an irrigation system that, at a minimum, includes a review of the following elements:

1. Design appropriateness for current landscape requirements
2. Irrigation spray heads and valves
3. Precipitation rates expressed in inches per hour
4. Annual maintenance plan that includes irrigation system maintenance, landscape maintenance, and a basic summer and winter irrigation scheduling plan.

Large property. A land tract owned by a general customer that equals or exceeds five acres in size and has an irritation system.

Low-flow toilet. A tank toilet that uses 1.6 gallons or less of water per flush.

Make-up Meter. A meter that measures the amount of water entering a cooling tower system.

NPDES / TPDES permit holders. Those entities that have valid state or federal permits commonly referred to as NPDES or TPDES [National Pollutant Discharge Elimination System / Texas Pollutant Discharge Elimination System] permits to satisfy requirements of the federal Clean Water Act.

Person. Any individual, corporation (including a government corporation), organization, state or federal governmental subdivision or agency, political subdivision of a state, interstate agency or body, business, trust, partnership, limited partnership, association, firm, company, joint stock company, joint venture, commission or any other legal entity.

Pervious Hardscape. Patios, pathways and other areas where firm footing is desired, constructed in such a way that allows for water to penetrate the ground. Examples include flagstone set in sand and wood plank decks, but exclude concrete slab patios and sidewalks or pavers set with mortar.

Positive shut-off. A valve that is held in a closed position by system pressure until overridden by an outside force.

Power washer. A machine that uses water or a water-based product applied at high pressure to clean impervious surfaces.

Rain sensor. A device designed to stop the flow of water to an automatic irrigation system when rainfall has been detected.

Recycled Water. Domestic or municipal wastewater which has been treated to a quality suitable for a beneficial use in accordance with applicable law.

Requestor. A customer who requests a variance under this Division.

Residential Customer. A single or multi-family dwelling unit containing two (2) or fewer family units.

Summer dormancy. The ability of turfgrass to survive without water for a period of sixty consecutive days during the months of May through September. Turfgrass with summer dormancy capabilities approved for use are set forth in the approved low water use plant list. The approved low water use plant list, as may be amended from time to time, shall be available from SAWS and located at www.saws.org/conservation.

Turfgrass. Perennial ground cover plants and grasses that are adapted to regular mowing and traffic through management.

Vacuum system. A system, often consisting of a pump, chamber, and tubes, that is used to create a vacuum for any of a variety of purposes, including but not limited to medical, dental and industrial applications.

Variance Administrator. Staff person in the Department of Conservation responsible for administering and hearing variance requests under this Division 1.

Vehicle wash facility. A permanently-located business that washes vehicles with water or water-based product, including but not limited to self-service car washes, full-service car washes, roll-over/in-bay style car washes, and fleet maintenance wash facilities.

Vehicle wash fundraiser. Any special-purpose vehicle wash event for which a fee is charged or donation accepted.

Water flow restrictor. An orifice or other device through which water passes at a restricted rate.

Xeriscape. A landscape consisting of a maximum of 50% turfgrass, with the remaining percentage of landscape incorporating low water use plants and/or pervious hardscape. The approved low water use plant list, as may be amended from time to time, shall be available from SAWS and located at www.saws.org/conservation.

Zonal irrigation system. An irrigation system that segregates by station areas of shrubs, ground cover, bedding plants, and turf to accommodate a diversity of watering requirements.

7.10.030 Definitions. (City of Santa Monica, California)

The following words and phrases shall have the following meanings when used in this Chapter:

Area Susceptible to Runoff. Any non-permeable surface directly exposed to precipitation or in the path of runoff which leads directly to neighboring properties or to the public right-of-way.

Best Management Practices ("BMP"). Practices principally applicable to construction sites and new developments that reduce the toxicity contained in, and the volume of, water which runs into storm drains, treatment facilities and the Santa Monica Bay. The Los Angeles Regional Water Quality Board ("Regional Board") has an approved list of BMPs and a list of technical resources and reference materials. Any BMP not specifically approved by the Regional Board may be used if they have been recommended in one of the listed technical resources and reference materials. The City Urban Runoff Management Coordinator and Engineering Department shall maintain updated copies of these lists and shall provide them upon request.

Good Housekeeping Requirements ("GHR"). Urban runoff pollution control practices applicable to existing properties, which have been demonstrated to significantly reduce and control urban runoff pollution that runs into storm drains, treatment facilities and the Santa Monica Bay.

New Development. For purposes of this Chapter, new development shall constitute any of the following:

1. Any construction project on a vacant site or on a site where fifty percent or more of the square footage of the structures is removed prior to construction.
2. Any construction project where an existing building or structure has been damaged, or is in need of repairs, or the owner desires to make repairs, alterations, or rehabilitation in an amount exceeding fifty percent of the replacement cost of the building or structure. For purposes of this subsection, the City's Building Officer shall determine the replacement cost of the building or structure and may use the most current building valuation table published by the International Conference of Building Officials. The Building Officer shall also determine the fair market value of any necessary repairs and may calculate the fair market value of repairs based on three responsible bids from properly licensed contractors.
3. Any construction project that (a) results in improvements to fifty percent or greater of the square footage of a building, (b) creates or adds at least five thousand square feet of impervious surfaces, or (c) creates or adds fifty percent or more of impervious surfaces.
4. Any construction project undertaken by the City where the runoff controls required by this Chapter are feasible and economical, as determined by the Director of the Department of Environmental and Public Works Management, but which would not otherwise constitute new development as defined by subdivisions (1), (2) or (3) of this subsection (D).

Source Control BMP. Non-structural activities, practices, and procedures that are designed to prevent urban runoff pollution.

Storm Event. 0.75 inches of rainfall within a consecutive twenty-four-hour period that is separated from the previous storm event by at least seventy-two hours of dry weather.

Structural BMP. Any structural facility designed and constructed to mitigate the adverse impacts of storm water and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Source Control and Treatment Control BMPs.

Treatment Control BMP. Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological or chemical process.

Urban Runoff or Urban Runoff Pollution. Water and suspended or dissolved materials deposited on surfaces and washed by storms or other sources of flowing water, through the flood control system to the ocean. Research studies have shown that urban runoff contributes many pollutants to receiving waters. Contamination includes bacteria and viruses, solid waste, and toxics such as heavy metals and petroleum-based compounds.

Urban Runoff Mitigation Plan. A plan that shall be submitted and approved in connection with any new development. (Added by Ord. No. 1992CCS § 1 (part), adopted 11/28/00)

Conservation Signage and Literature Distribution

Educating water consumers is a critical goal for municipalities. To this end, they often require public notices to instruct and encourage conservation. The following example of a conservation signage and literature distribution ordinance is from Santa Fe County, New Mexico.

A. Public, semi-public and governmental restrooms and shower facilities shall post not less than one (1) water conservation sign in each restroom and shower facility, the size of which shall not be less than eight and one-half inches (8.5) by eleven (11) inches. Such entities may use a sign provided by Santa Fe County or develop their own sign using text provided by Santa Fe County.

B. Hotels, motels and other lodgings shall provide a water conservation informational card or brochure in a visible location in each guest room. Such literature may be provided by Santa Fe County or the establishment itself using text provided by Santa Fe County.

C. Retail plant nurseries shall provide their “end-use” customers with County provided low water-use landscape literature and water efficient irrigation guidelines at the time of sale of any perennial plant. An “end-use customer” is the person or persons who will ultimately own the plant material. A landscape contractor or architect is not an end-use customer. In order to facilitate the purchasing of low water-use plants, nurseries are strongly encouraged to tag or sign their plants that require little or not supplemental water once established. For the sale of all turf or grass seed or sod, the customer shall be given County provided literature indicating the restrictions to planting water consumptive turf.

D. Landscape contractors, maintenance companies and architects shall provide their prospective clients with County-provided low water-use literature and water efficient irrigation guidelines at the time of presenting a service contract to the prospective client. Landscape professionals are strongly encouraged to educate their customers regarding the operation of their timed irrigation systems.

E. Title companies and others closing real estate transactions shall provide the entity purchasing a home, business or property with County-provided indoor and outdoor conservation literature at the time of closing.

F. The County departments shall provide indoor and outdoor conservation literature to all persons applying for a building permit and all persons initiating new water service to the County Water Utility.

G. The domestic well metering program applies to only those residents of Santa Fe County living or operating businesses on lots where restricted water usage and water meter reporting requirements were voluntarily accepted as a condition of the plat approval. All other residents of the County are exempt from this program.
    1. All properties that are required to report water meter readings as a condition of plat approval shall have the name and address of the property owner entered into the database when the building permit is issued.
    2. The final inspection field report shall require that the water meter be installed in order for final inspection approval.
    3. All properties that are required to have water meters shall also be required to test their water meter for reading accuracy every ten (10) years and replace if necessary.
    4. Each property that is required to report water meter reading will receive a mailing from Santa Fe County containing a post card that can be filled out with the meter reading and returned to Santa Fe County.
    5. Failure to submit the meter reading will result in the same penalties as outlined for other water violations.
    6. When water is used in excess of the amount allocated to the property, the first year a letter with educational/informational materials on how to reduce water use will be sent to the water user and they will be required to submit water meter readings every six months to track their progress. All subsequent water usage violations will result in the same penalties as outlined for other water violations.

Enforcement

Ordinance enforcement methods vary from warnings and citations to monetary fines to discontinuation of water service. The following examples of enforcement ordinances are from Santa Fe County, New Mexico; Santa Monica, California; San Antonio, Texas; and Durham, North Carolina.[5]

Enforcement and Penalties (Santa Fe County, New Mexico)

A. *Enforcement*. The Santa Fe County Utilities Department, the County Code Enforcement Officers, the Santa Fe County Sheriff's Department and the Santa Fe County Fire Department may enforce any and all of the County Water Conservation regulations. To the extent that the Board of County Commissioners may find it desirable to vest specific enforcement authority in other County personnel or other governmental agency, those individuals so vested shall also have the authority and responsibility to enforce regulations adopted County water conservation.

    The following schedule of fines shall be used for violations of this Ordinance. All violations on a single date at a single address constitute a single offense for purposes of enforcement.
    First violation: $50.00
    Second violation: $100.00
    Third violation: $200.00
    Fourth and all subsequent violations: $400.00

B. *Penalties*. Any person who violates the provisions of this Ordinance shall be prosecuted in a court of competent jurisdiction and penalized to the maximum extent allowed by law.

C. *Severability*. The provisions of this Ordinance shall be severable. If, any provision of this Ordinance is ruled to be invalid by a court of competent jurisdiction:

[5] The City of Durham Code, Article VI. Water Conservation. http://www.ci.durham.nc.us/departments/environ/ordinance.cfm

1. The effect of such judgment shall be limited to the specific provision or provisions that are expressly stated in the judgment to be invalid; and
2. Such judgment shall not affect, impair or nullify the validity of application of the remainder of this Ordinance that shall continue in full force and effect.

7.10.070 Enforcement and Penalties (Santa Monica, California)

A. The Director of the Department of Environmental and Public Works Management, or his or her designee, is authorized to enforce Sections 7.10.040, 7.10.050 and 7.10.060 as follows:
    1. For the first failure to comply with any provision of Sections 7.10.040, 7.10.050 and 7.10.060, the Department of Environmental and Public Works Management shall issue to the affected person a written notice that includes the following information:
        a. A statement specifying the violation committed;
        b. A specified time period within which the affected person must correct the failure or file a written notice disputing the notice of failure to comply;
        c. A statement of the penalty for continued noncompliance.
    2. For each subsequent failure to comply with any provision of Sections 7.10.040, 7.10.050 and 7.10.060 following written notice pursuant to this Section, the Director of the Department of Environmental and Public Works Management may levy a penalty not to exceed five hundred dollars. Any statement informing a violator of a citation shall include a notice setting forth the hearing rights provided in subsection (a)(3) below.
    3. Any person assessed a penalty pursuant to subsection (a)(2) may dispute the penalty by requesting a hearing on a form provided by the City within the time and manner set forth in Section 6.16.030, provided that no hearing request shall be deemed timely filed and no hearing shall be held unless, within the time period to request a hearing, the person deposits with the City Treasurer money in the amount of any unpaid penalty due under this Section. If as a result of the hearing it is determined that the penalty was wrongly assessed, the City shall refund any money deposited to the person. The decision of the Hearing Examiner shall be final except for judicial review and shall not be appealable to the City Council.
    4. It shall not be a defense to the assessment of any penalty or to any other civil enforcement action provided for under this Section for a person to assert that any violation of Sections 7.10.040, 7.10.050 and 7.10.060 was caused by the actions of a person other than the person assessed except if the violation was caused by the criminal or negligent action of a person who was not an agent, servant, employee or family member of the person.
    5. Any penalty collected hereunder shall be deposited in the City's Stormwater Fund to be used as reimbursement for the Department of Environmental and Public Works Management's costs and expenses of administration and enforcement of this Chapter.
B. Any violation of this Chapter shall constitute an infraction punishable by a fine of five hundred dollars. Each day that a violation occurs shall constitute a separate offense.
C. A violation of any provision of this Chapter is declared to be a public nuisance and may be abated pursuant to Santa Monica Municipal Code Chapter 8.96 or by means of a civil action.
D. The City may enforce the provisions of this Chapter by means of a civil action. The burden of proof in such cases shall be preponderance of the evidence.
E. Any person who commits an act, proposes to commit an act, or engages in any pattern and practice which violates this Chapter may be enjoined therefrom by any court of competent jurisdiction.
F. The penalties and remedies established by this Chapter are not exclusive, and nothing in this Chapter shall preclude any person from seeking any other remedies, penalties or procedures provided by law. (Added by Ord. No. 1992CCS § 1 (part), adopted 11/28/00)

Sec. 34-277 Enforcement (San Antonio, Texas)

Sec. 34-277.1 The President/CEO or his designee of the San Antonio Water System is hereby authorized to enforce this Division in the manner and to the extent allowed by law, including, but not limited to, filing complaints with the city municipal prosecutor's office for such violations, serving

notices of violations of this Division and filing civil enforcement actions. Such authorization does not diminish the City Attorney's authority in regard to enforcement of Chapter 34 provisions.

Sec. 34-277.2 Presumption and Exception. For purposes of this Division, it shall be presumed that the person, in whose name a water meter connection is registered with the water purveyor servicing the property, is the responsible party who has made, caused, allowed, or permitted a violation of the provisions of Article IV, Division 1. Proof that the particular premises had a water meter connection registered in the name of the defendant cited in a criminal complaint filed pursuant to this division shall constitute a prima facie presumption that the defendant is a person who made, caused, allowed or permitted a violation pursuant to the provisions of this Division. [Exception to this presumption is found in subsection 34-273.2 above, wherein a city, whose premises are used by a tenant / lessee, is generally not responsible for the tenant / lessee's compliance. In such cases the tenant / lessee of the city is responsible for compliance and the city shall have no duty to enforce against the tenant / lessee except to the extent the city's municipal courts may be fully utilized by the SAWS enforcement officers or other duly authorized governmental personnel charged with enforcement duties.

Sec. 34-277.3 The President/CEO or his or her designee is authorized and instructed to commence any action, in law or in equity, including the filing of criminal charges, deemed necessary for the purpose of enforcing this Division. The San Antonio Water System President/CEO or the designee may seek civil penalties, as may be allowed by statute, and any other legal or equitable relief available under common law, Chapter 54 of the Texas Local Government Code as it may be amended to address the subject matter of this Division, or any other applicable city, state or federal code or statute.

Sec. 34-277.4 Criminal. Any person violating any provision of this Division 1 of Article IV shall be guilty of a Class C misdemeanor and upon citation and conviction , shall be punished by a fine not less than fifty dollars ($50.00) and not more than one hundred dollars ($100.00) for the first offense; a fine not less than two hundred and fifty dollars ($250.00) and not more than five hundred dollars ($500.00) for the second offense; a fine of not less than one thousand dollars ($l,000.00) and not more than two thousand dollars ($2,000) for the third and additional offenses. Each violation of a particular section of this Division shall constitute a separate offense, and each day an offense continues shall be considered a new violation for purposes of enforcing this Division.
Civil. Civil penalties, imposed by courts of competent jurisdiction in Civil Actions for violations of this division, may also be assessed as may be allowed by applicable state law in any amount to be authorized by the State of Texas. Under Chapter 54 of the Texas Local Government Code, the SAWS and the Office of the City Attorney may presently pursue civil enforcement for injunctive relief and the imposition of $1,000.00 per day civil penalties appropriately imposed by the Court. This statutory remedy is in addition to the City's common law right to bring Civil Actions for injunctive relief to stop harmful acts, independent of authority found in the Texas Local Government Code.

Sec. 34-277.5 If, for any reason, any section, sentence, clause or part of this Division is held legally invalid, such judgment shall not prejudice, affect, impair or invalidate the remaining sections of this Division, but shall be confined to the specific section, sentence, clause, or part of this Division held legally invalid.

Sec. 23-166. Violation of article prohibited; enforcement. (Durham, North Carolina)

A. *Violation*. In the event that the manager shall declare one or more stages of water conservation as set forth herein, it shall be unlawful for any person to use or permit use of water supplied by the city in violation of any mandatory restrictions instituted.
B. *Enforcement*. It shall be the duty of the director of environmental resources to investigate violations of the mandatory restriction and issue orders consistent with the purpose and intent of this article. All customers shall cease any violation of the mandatory restrictions upon the order of the director of environmental resources. Any customer who violates any provision of the article, or who shall violate or fail to comply with any order made hereunder shall be subject to penalty or a combination of the penalties as follows:
    1. *Discontinuance of service*. The city may discontinue water service to any structure(s) or parcel(s) when the director of environmental resources gives written notice of any

violation of mandatory restrictions and intent to discontinue service. Water service shall be discontinued within twenty-four (24) hours unless the violation shall cease voluntarily.

When service is discontinued pursuant to the provisions of this section, service shall not be reinstated unless and until the director of environmental resources determines that the risk to the city water supply has been alleviated.

The customers shall have a right of appeal to the manager, upon serving written notice of appeal on the city manager within five (5) days after receiving notice of any violation and intent to discontinue service. The appellant will be notified by the city manager of the time and place for the hearing of the appeal. The manager shall act on the appeal as expeditiously as possible and shall notify the appellant in writing not later than two (2) days after the final decision.

2. *Equitable relief*. The provisions of this article may be enforced by an appropriate remedy, including a mandatory or prohibitory injunction, issuing from a court of competent jurisdiction.

C. *Penalty not a substitute remedy*. The imposition of one or more penalties for any violation shall not excuse any violation or permit it to continue. (Ord. No. 7028, 1, 7-28-86, revised 12-03-01)

Water Waste Restrictions

Wasting water is explicitly defined and prohibited in some municipalities. The following example of a water waste restriction ordinance is from Santa Fe County, New Mexico.

No person, firm, corporation, county, state, federal or municipal facility or operation shall cause or permit to occur any water waste. In general the occurrence of unforeseeable or unpreventable failure or malfunction of plumbing and irrigation system hardware shall not be deemed sufficient grounds for issuance of a citation or other enforcement proceedings unless and until the County issues a formal written notice.

Water waste means any non-beneficial use of water. Waste includes but is not limited to leaks from indoor and outdoor plumbing systems in excess of 0.25 gallons per minute.

For unforeseeable or unpreventable outdoor violations, the County shall generally issue a formal warning notice prior to taking enforcement action. Prior to taking formal enforcement action the County may instruct the water user not to operate the faulty system until it is appropriately repaired. If operating the system is integral to the operation of the facility the County may at its own discretion provide a period of time in which to remedy the violation prior to commencing formal enforcement action. Once a warning notice or an official citation has been issued for an outdoor occurrence, subsequent water waste events shall be subject to strict enforcement. Strict enforcement may include the issuance of citations and other such activities as the County deems necessary to bring the water user into compliance. For indoor water waste events and for those water waste events outdoors caused by a faulty system which is integral to the operation of the facility, the waste must be abated within 15 calendar days of the issuance of a warning notice or initiation of enforcement action. Enforcement action shall be taken if the waste continues beyond the 15-day period.

Water waste does not include:

A. Flow resulting from fire fighting or other routine inspection of fire hydrants or other training activities,
B. Water applied to abate spills of flammable or otherwise hazardous materials,
C. Water applied to prevent health, safety or accident hazards when alternate methods are not available,
D. Water that reaches or flows onto adjacent property or public or private right-of-way when caused by vandalism, wind, emergencies or acts of God,
E. Flow resulting from a routine inspection or maintenance of a water utility system,

F. Water used by Santa Fe County in the installation, maintenance, repair or replacement of public facilities and structures such as traffic control devices, storm and sanitary sewer structures and road or street improvements,
G. Water used by contractors or utilities including but not limited to sawcutting and pavement, compaction or other use required under terms of their contract,
H. Any water that is discharged as a result of well development or a pumping test.

Conservation Fees Imposed

Conservation fees can be used to penalize residents who waste water, reward residents who conserve it, and offset municipalities' costs for conservation programs. The following example of a conservation fee ordinance is from Santa Monica, California.

Conservation Fee

Environmental Resource Protection Fee Ordinance[6]

A. Communities near Santa Monica Bay pay a fee to protect and restore the Santa Monica Bay in Southern California. The Bay Saver Fee is a conservation incentive fee assessed to any residential water customer in the event that the property has not been retrofitted with water conserving fixtures. (SMMC 7.12.030)
B. How Much is the Bay Saver Fee?
   - Single-family dwellings: $4.00 per bill
   - Multi-family dwellings: $2.60 per unit per bill (includes apartments, condominiums, town homes)
C. How is the Fee Removed?
   Replace water wasting fixtures with water conserving ones, then have a free home assessment performed by a City Water Resources Specialist. Upon verification that all fixtures are in compliance, the fee will be removed. Call (310) 458-8459 to set-up an inspection.
D. What are Compliant Fixtures?
   - Toilets use a maximum of 1.6 gallons per flush or less (also known as ultra-low flow toilets or any toilet manufactured after 1992).
   - Showerheads and Faucets must use a maximum of 2.5 gallons per minute. Showerheads and faucets made after 1992 should be compliant.

7.12.030 Residential water conservation incentive fee program.[7]

A. The City Council by resolution may impose a conservation incentive fee on the charges for supplying water service to any residential consumer in the event the consumer has not installed any water conservation measure set forth in the resolution imposing the surcharge.
B. No person who has been relieved of the obligation to pay a conservation incentive fee because of the installation of any water conservation measure shall remove such water conservation measure without first notifying the City of such removal. In the event of such removal, the City may reimpose the conservation incentive fee. (Prior code § 7200B; added by Ord. No. 1505CCS, adopted 12/12/89)

Variance Procedures

The following example of a variance procedure is from San Antonio, Texas.

Sec. 34-276 Variances.
The authority to grant a variance and an appeal from such variance to the provisions of Article IV, Division 1, is hereby delegated to the San Antonio Water System in the manner described herein. A determination by the San Antonio Water System pursuant to this section shall be deemed final for purposes of appeal. Appeal procedures are detailed below.

[6] Bay Saver Fee Ordinance. http://santa-monica.org/epd/residents/Water/bay_saver_fee.htm
[7] Residential Water Conservation Incentive Fee Program. http://codemanage.com/santamonica/index.php?topic=7-7_12-7_12_030

Sec. 34-276.1 Variance. A person who is affected by these provisions may seek a variance in the manner set out herein. A person shall request a variance within thirty (30) days of the date a provision becomes apparently applicable to that person's activities and/or properties. For example, a person will have standing to seek a variance within thirty (30) days following receipt of a formal (citation) or informal notice of violation; prior to a notice of violation; or at the discretion of the variance administrator when, in the administrator's judgment to pursue a variance would clearly deny the applicant an opportunity to have justice and equity done for the applicant's case. In the latter situation, for purposes of justice and equity, the standard for allowing a variance application to be heard or considered are the common notions of rightness and fair play.

Sec. 34-276.2 Time, date, place. A person seeking a variance under these provisions shall make such request in writing to the Conservation Department. Such request shall be reviewed by the variance administrator. If the application, on its face, warrants a variance, the administrator may grant the request without hearing. Otherwise, the administrator shall review such request within thirty (30) days of receipt and shall inform the requestor in writing of the time, date and place for variance hearing, if necessary.

Sec. 34-276.3 Representation and notice of SAWS' response. First Hearing. The requestor may be represented by a duly authorized representative and may introduce such evidence as the requestor believes to be relevant. The administrator and appropriate Conservation Department personnel shall hear the request. The requestor shall receive written notification by the administrator within thirty (30) days of the date of the hearing whether such variance is granted or denied.

Sec. 34-276.4 Appeal. In the event the variance is granted, the decision of the administrator shall be final. Should the variance be denied, however, the requestor shall have ten (10) days from receipt of the denial of the variance to seek an appeal in writing. Within thirty (30) days of the written request for an appeal from the denial of a variance, the Director shall hear the appeal.

The requestor shall be informed in writing of the time, date and place where such appeal shall be heard. The requestor and/or his authorized representatives may present evidence to the Director why such appeal should be granted. The Director shall inform the requestor within thirty (30) days of the date of the hearing of the appeal whether the appeal has been granted or denied. The determination of the Director shall be final and shall be in writing. If a judicial appeal is pursued, applicant must take such appeal to District Court or other court of competent jurisdiction within 30 days of the Director's final determination, which further appeal shall be pursued under appropriate standards of the substantial evidence rule.

Sec. 34-276.5 Variance qualifications. Variances to the regulated activities in this Division 1 may be issued through the Department of Conservation's variance administrator provided that the general intent of Article IV, Division 1 has been met, and compliance with Article IV, Division 1, is proven to be impracticable to accomplish and to cause unnecessary hardship. The criteria to determine hardship shall include, but not be limited to, a showing of level of capital outlay and technical complexity in relation to conservation benefit to be derived, and time and effort required to accomplish compliance with this Division.

Sec. 34-276.6 The SAWS Director of Conservation shall also develop specific criteria to be used for the granting of variances from the provisions of Article IV, Division 1, which are appropriate to the provision for which a variance is being sought. Such criteria shall be applied equally to each request for variance under a particular provision. A requestor shall be furnished with the criteria to be utilized by the administrator and/or Director prior to his/her variance application and/or appeal being heard.

Response to Water Shortage

Municipalities typically develop ordinances to dictate the extent of conservation measures in the event of drought. In the following example of a water conservation ordinance in response to a water

shortage, Durham, North Carolina lays out a five-stage plan that incrementally reduces water consumption.

Sec. 23-167. Water conservation stages; recommendations; mandatory measures.[8]

Stage I. Continuing Voluntary Conservation Practices. Customers shall be encouraged to observe water conservation measures to reduce the wasting of water as follows:

a. Check plumbing and toilets for leaks annually, and if necessary repair.
b. Repair leaking faucets whenever they develop
c. Store drinking water in the refrigerator to avoid trying to run it cool at the tap.
d. Use shower for bathing purposes or reduce the depth of water used for tub baths. Limit showers to four (4) minutes where possible.
e. Refrain from running faucets while shaving, rinsing dishes or brushing teeth.
f. Install water flow restrictive devices in shower heads.
g. Install water-saving devices such as plastic bottles or commercial units in toilet tanks.
h. Wash full loads in clothes washers and dishwashers.
i. Review water uses and where feasible install recycle systems, particularly commercial and industrial customers.

Stage II. Voluntary Conservation. Customers shall be encouraged to observe the recommendations of Stage I and to increase the level of conservation effort as follows:

a. Limit the use of clothes washers and dishwashers, and when used, to operate fully loaded.
b. Reduce the flushing of toilets to the minimum whenever practical.
c. Limit lawn watering to only when grass shows signs of withering and apply water as slow as possible to achieve deep penetration.
d. Limit shrubbery watering to the minimum reusing household water when possible.
e. Limit car washing to the minimum.
f. Limit wash downs of outside areas such as sidewalks, patios, driveways, or other similar purposes.
g. Limit hours of operation of water-cooled air conditioners possible.
h. Use biodegradable disposable dishes and utensils, both for residential and commercial purposes, where feasible.

Stage III. Moderate Mandatory Conservation. Customers shall be encouraged to observe the recommendations of Stage I and II, and the level of the conservation effort shall be increased to require the following mandatory measures. No person shall:

a. Water lawns, grass, trees, shrubbery, flowers, golf greens or vegetable gardens except during the hours specified by the City Manager. Those hours shall, unless otherwise varied by the Manager, be between 5:00 am and 9:00 am OR 5:00 pm and 9:00 pm on Wednesdays and Saturdays. On each designated day, customers shall water during only one of the allowed periods. When adjustments are made by the Manger to the above times, they shall be published in the local newspapers of general circulation, and set forth on the City's web site, where appropriate.
b. Introduce water into wading pools or swimming pools except to the extent necessary to replenish losses due to evaporation or spillage, and maintain operation of chemical feed equipment.
c. Use water to wash down outside areas such as sidewalks, patios, driveways, or for other similar purposes.
d. Introduce water into any decorative fountain, pool or pond except where the water is recycled.
e. Serve water in a restaurant or similar establishment except upon request.
f. Use water for any unnecessary purpose or intentionally waste water.
g. Wash the exterior of a motor vehicle except where a private well system is used, or where 50% or more of the water is recycled or where it can be demonstrated that 30 gallons of water or less are used to wash the vehicle.

[8] The City of Durham Code, Article VI. Water Conservation. http://www.ci.durham.nc.us/departments/environ/ordinance.cfm

Provided, however, any customer may secure a written license from the city manger or his designee to use water contrary to the Stage III mandatory conservation measures where it can be shown to the manager's satisfaction that use of water pursuant to conditions prescribed by the city manager in the license will result in a thirty (30) percent of greater saving of water. Any license issued pursuant to this provision: (1) must be in the possession of the licensee whenever water is used contrary to the Stage III mandatory conservation measures; and (2) is subject to amendment or revocation by the city manager at any time for good cause.

All industrial, manufacturing and commercial enterprises shall reduce consumption with a goal reduction of at least 30%. Such enterprises shall document the specific efforts they have made to reduce consumption. (Ord. No. 7028, 1, 7-28-86, revised 2-4-02)

Stage IV - Severe Mandatory Conservation. Customers shall be encouraged to observe the conservation measures in Stages I and II and required to continue observing the mandatory requirements in Stage III except to the extent such mandatory requirements are modified by the restrictions regarding Stage IV conservation. The level of the conservation effort shall increase to require the following additional mandatory measures. No person shall:

a. Water or sprinkle any lawn, grass, trees, golf greens or flowers. Provided, however, that a person regularly engaged in the sale of plants shall be permitted to use water for irrigation of their commercial stock in trade, using the minimal amount for survival. State, County and City licensed landscape contractors may continue to water plantings which are under written warranty by hand-held hose, container or drip irrigation.
b. Water any vegetable garden or ornamental shrubs except by hand-held hose, container, or drip irrigation system, during hours specified by the City manger. Those hours shall, unless varied by the Manger, be between the hours of 5:00 am and 9:00 am OR 5:00 p.m. and 9:00 p.m. on Wednesdays and Saturdays. On each designated day, customers shall water during only one of the allowed periods. When adjustments are made by the Manager to the above times, they shall be published in local newspapers of general circulation, and set forth on the City's website, where appropriate.
c. Fill any wading pool or swimming pool or replenish any filled pool except to the minimum essential for operation of chemical feed equipment.
d. Make nonessential use of water for commercial or public use.
e. Operate water-cooled air conditioners or other equipment that do not recycle cooling water, except when health and safety are adversely affected.
f. Wash any motor vehicle or other type of mobile equipment. Provided, however, that any person regularly engaged in the business of washing motor vehicles and any commercial car wash facility shall be permitted to use water for such purposes, when 50% water savings are documented.

Provided, however, any customer may secure a written license from the city manager or his designee to use water contrary to the Stage IV mandatory conservation measures where it can be shown to the manager's satisfaction, and in the manager's sole discretion, that use of water pursuant to conditions prescribed by the city manager in the license will result in a 50% or greater saving of water. Any license issued pursuant to this provision: (1) must be in the possession of the licensee whenever water is used contrary to the Stage IV mandatory conservation measures; and (2) is subject to amendment or revocation by the city manager at any time for good cause.

All industrial, manufacturing and commercial enterprises shall reduce consumption with a goal reduction of at least 50%. Such enterprises shall document the specific efforts they have made to reduce consumption. (Ord. No. 7028, 1, 7-28-86, revised 2-4-02)

Stage V - Stringent Mandatory Conservation. Customers shall be encouraged to observe the conservation measures in Stages I and II and required to continue observing the mandatory requirements in Stages III and IV. The level of the conservation effort shall increase to require the following additional mandatory measures. No person shall:

a. Use water outside a structure except in an emergency involving fire.
b. Operate evaporative air conditioning units which recycle water except during the operating hours of the business.

c. Use any swimming pool or wading pool.
d. Wash any motor vehicle, including commercial washing unless a private well is used.

In addition to the conservation measures enumerated above, customer shall use plates, glasses, cups and eating utensils that are disposable and biodegradable.

Stage VI - Rationing. Customers shall be encouraged to observe the conservation measures in Stages I and II and require to continue observing the mandatory requirements of Stages III, IV and V. The level of the conservation effort shall increase to require the following mandatory measures:

a. Fire protection will be maintained, but where possible, tank trucks shall use raw water.
b. All industrial uses of water shall be prohibited.
c. All other uses of water will be limited to those necessary to meet minimum health and safety needs of the customers as determined by the city manager upon consultation with the director of environmental resources in light of conditions present.

Failure to act in accordance therewith or use of water in any manner or attempt to evade or avoid water rationing restrictions, shall be unlawful. (Ord. No.7028, 1, 7-28-86)

Illinois Water Conservation Requirements for Communities Using Lake Michigan Supplies

The following examples demonstrate rules for allocation of water across multiple municipalities. The first example, from the Illinois Department of Natural Resources, provides general rules governing the allocation of water from Lake Michigan.[9]

Section 3730.307 Conservation Practices and Other Permit Conditions (Illinois DNR)

A. The Department shall condition allocations within a user category upon required conservation practices for each user category as specified in subsections (B) and (C). Failure by any permittee to meet the conservation requirements applicable to it within a reasonable period of time will, upon notice, hearing and determination of such failure, constitute a violation of a Department order.
B. As a condition of receiving an allocation of Lake Michigan water, all permittees will agree to submit to the Department proposals designed to reduce or eliminate wasteful water use and to reduce unaccounted-for flows to 8% or less, based on net annual pumpage, and procedures used to determine efficiency of water metering or accounting in permittee's system.

The second example, from the Performance Standards Guidance publication for the Massachusetts Interbasin Transfer Act[10], governs water conservation requirements for interbasin transfer.

Must have implemented all practical water conservation measures:

1. A full leak detection survey should have been completed within the previous two years of the application. The proponent should provide documentation of their leak detection survey and of the repair of leaks identified during the survey. Leak detection surveys should be completed by methods at least as comprehensive as those described in the MWRA's leak detection regulations (360 CMR 12.00).

2. The water supply system should be 100% metered, including public facilities served by the proponent. A program of meter repair and/or replacement must be in place. Documentation of annual calibration of master meters and a description of the calibration program should be included in the application.

[9] Illinois Department of Natural Resources, Office of Water Resources, Division of Water Resource Management. General rules for the allocation of water from Lake Michigan. http://dnr.state.il.us/owr/resman/3730RULE.htm
[10] Massachusetts Department of Conservation and Recreation, Interbasin Transfer Act: Application Material. http://www.mass.gov/dcr/waterSupply/intbasin/download.htm

3. Unaccounted-for water should be 10% or less. The proponent should provide documentation of unaccounted-for water, in both gallons and percentage of the total water pumped and withdrawn, for each of the past five years. The definition of accounted-for and unaccounted-for water for use in Interbasin Transfer applications is given in Appendix C. The plan by which the community intends to maintain or reduce this level should be included in the water resources management plan required under Criterion #7.

4. The proponent should provide documentation to show that there are sufficient sources of funding to maintain the system, including covering the costs of operation, proper maintenance, planned capital improvements, and water conservation. The rate structure must encourage water conservation. Appendix D provides guidance on developing rate structures to encourage water conservation.

5. The proponent should bill its customers at least quarterly based on actual meter readings. Bills should be easily understandable to the customer (e.g. providing water use in gallons and including comparison of the previous year's use for same period).

6. A drought/emergency contingency plan, as described in 313 CMR 4.02, should be in place. This plan should include seasonal use guidelines, measures for voluntary and mandatory water use restrictions and describe how these will be implemented. There should be a mechanism in place to tie water use restrictions to streamflow and/or surface water levels in the affected basin(s) where this information is available. The plan should become part of the Local Water Resources Management Plan required under Criterion #7.

7. All government and other public buildings under the control of the proponent should have been retrofit with water saving devices.

8. Proponents should provide records of water audits conducted on public facilities. The most recent audit should have occurred within two years prior to the application for Interbasin Transfer approval.

9. If the community's residential gallons per capita/day is greater than 65, the proponent should be implementing a comprehensive residential conservation program that seeks to reduce residential water use through a retrofit, rebate or other similarly effective program for encouraging installation of household water saving devices, including faucet aerators, showerheads and toilets and through efforts to reduce excessive outdoor water use.

10. A broad-based public education program which attempts to reach every user at least two times per year, through such means as mailings, billboards, newspaper articles, cable television announcements or programs, or the use of other media, should be in place. Water suppliers should refer to the WRC's 1992 "Water Conservation Standards for the Commonwealth of Massachusetts" and the Massachusetts Water Works Association for recommended public education measures.

11. A program which identifies, ranks and works with all commercial, industrial and institutional customers according to amount of use in order to determine areas where the greatest potential for water savings exists, should be in place. The water supplier should make regular contact with these users to promote water conservation. Materials on water reuse and recirculation techniques should be provided, where appropriate.

12. A program of land use controls to protect existing water supply sources of the receiving area that meet the requirements of the Department of Environmental Protection.

13. As part of the local water resources management plan, there should be a long-term water conservation program, which complies with the 1992 Water Conservation Standards for the Commonwealth of Massachusetts, in place. This plan should reflect the goal of maintaining unaccounted-for at 10% or less of all water used, and of reducing future residential water use

through a comprehensive residential water conservation program, if residential gpcd is greater than 65. The water conservation program should also have a goal of operating the system to balance water supply with other environmental needs. If the transfer is approved, the proponent will need to submit a copy of its Public Water Supply Annual Statistical Report (required by DEP) to the Commission annually to demonstrate the continued effectiveness of the program.

Appendix B

Incentive programs

Overview of Example Incentive Programs for Water Conservation

Fixture / appliance / location	*Type of incentive (Examples)*	*Eligibility*	*Incentive value*	*Conservation level required / delivered*	*Application process*	*Savings*
Showerheads	Rebate for replacement with water-conserving model (A)	Residential and commercial customers	Range from $25 to up to $150 or 75% of the total cost (whichever is less) for each showerhead retrofitted with an ultra-low flow model	Required maximum of 2.5 gallons per minute per showerhead.	Application forms and specific information can be obtained by contacting a Water District representative by phone or email. Rebates are available until funds are depleted.	Depends on inefficiency of current showerheads.
	Free replacement with water-conserving model (A, B, D)	Residential and commercial customers	Value of replacement showerhead.	Delivers 2.5 gallons per minute; has adjustable settings and a non-aerating spray with less temperature loss.	Contact a Water District representative by phone to request a free showerhead.	Depends on inefficiency of current showerheads.
Toilets	Rebate for replacement with water-conserving model (A, B)	Residential and commercial customers; no limit on the number of reimbursed toilets per household or commercial building.	Range from $25 up to $150 or 75% of the total cost (whichever is less) for each toilet retrofitted with an ultra-low flow model	Required maximum of 1.6 gallons per flush per toilet.	Application forms and specific information can be obtained by contacting a Water District representative by phone or email. Rebates are available until funds are depleted.	Save over 10 gallons of water per person per day
	Free dye tablets for determining leaks in toilets (A, B, D)	Residential and commercial customers	Value of dye tablets	N/A	Visit the Water District office in person to pick up free dye tablets or call to request them by mail.	Depends on extent of leaking.
Clothes washing machines	Rebate for replacement with water-conserving model (A, B)	Residential customers	$100 for all qualifying level 1 clothes washers; $150 for all qualifying level 2 clothes washers.	Required to be a Level 1 or 2 clothes washers, as listed and posted online at a region-specific website.	Applications are available online and where high-efficiency clothes washers are sold.	On average annually, a household will save 5,100 gallons of water (approx. $13), $80 to $100 in electricity, and $54 in detergent costs.
Bathroom faucets	Free aerator attachment (A, B, D)	Residential and commercial customers	Value of aerator	Delivers a flow rate of 1.5 gallons per minute.	Contact a water district representative by phone to request a free faucet aerator.	Depends on inefficiency of current faucets.
Kitchen faucets	Free aerator attachment (A, B, D)	Residential and commercial customers	Value of aerator	Delivers a flow rate of 2.2 gallons per minute (2.0 gpm in some cases).	Contact a water district representative by phone to request a free faucet aerator.	Depends on inefficiency of current faucets.
Pre-rise spray valves	Free replacement with water-conserving model (A)	Commercial customers (food service industry). Existing pre-rinse sprayers must use hot water to clean dishes.	Value of the new, high-efficiency, high-velocity spray valve.	N/A	Call the Water District toll-free to request more information and apply.	A typical restaurant can save up to $1,000/yr in energy, water, and waste water costs. Savings range from $300-$1,300 depending on hours of usage per day. The high-efficiency spray valve conserves an average of 50 gallons of water

Fixture / appliance / location	*Type of incentive (Examples)*	*Eligibility*	*Incentive value*	*Conservation level required / delivered*	*Application process*	*Savings*
						and waste water per hour in comparison to pre-existing models.
Lawns and gardens	Rebates for converting high-water-use gardens into water-conserving landscapes (B)	Single-family homeowners. All changes must be made to an area that is currently being irrigated (not for an area that is not currently irrigated or to install landscaping at a new home or where no landscaping previously existed.)	Up to $1,000 for a portion of the cost of irrigation system parts and landscape materials, including permeable hardscape. Projects that involve replacing lawn with permeable hardscape may qualify for an additional bonus rebate of up to $2,500. Labor costs are not rebated.	Customers living on the west side of the Tunnel must use >300 gallons of water per day during a billing period that includes August. Customers living east of the Tunnel must use >500 gallons of water per day during a billing period that includes August.	Participation in the program is on a first-come first-served basis. In order to qualify for a rebate, all projects must be pre-approved and there are minimum water use requirements. The first step to participating in the program is to attend an informational meeting.	Depends on the size of the garden and specific conservation measures implemented.
	Free irrigation and rain gauge (C)	Residential customers	Value of gauge	N/A	Contact the Water District to request a free kit.	Save up to 50% on landscape water use
Entire household / organization / company	Graduated rate structure (C)	All residential customers are subject to charges.	Depends on households' total water usage.	Residential customers are charged under an "increasing block rate" system. Within each block each Ccf costs the same. The cost per Ccf increases with each higher block (e.g., the 16th Ccf costs more than the 15th Ccf).	N/A	Depends on households' total water usage. If residents' water use goes up in the summer (which it usually does), their water bill could go up even faster than their usage, if their usage enters the next higher rate block. This rate structure has the effect of charging high volume customers more per unit than low volume users.
	Water conservation awards (D)	All customers are eligible. One award given annually in each category: commercial entity, private consumer, and partner.	Value of recognition	Private consumer award in 2005 went to residents who reduced summertime water use by 53% from 2003 to 2004.	Selection is determined by the local Water & Sanitation District and the Regional Water Authority	Depends on household's or company's total water usage and percentage decrease year-to-year.

Sources:
(A) Coastside County Water District (Half Moon Bay, California) http://www.coastsidewater.org/water-conservation.html
(B) East Bay Municipal Utility District (San Francisco Bay Area, California) http://www.ebmud.com/conserving_&_recycling/
(C) Tucson Water Department (Tucson, Arizona) http://www.ci.tucson.az.us/water/conservation.htm
(D) The Eagle River Water & Sanitation District (Eagle/Vail, Colorado) http://www.erwsd.org

Benchmarks for Savings Due to Implementing Water Conservation Measures

Per Capita Comparison of Water Use Before and After Retrofit

	BASELINE *No conservations measures in place*					*POST-RETROFIT* *After implementing conservation measures*					*CHANGE DUE TO RETROFIT* *Post-retrofit - Baseline*					*% CHANGE* *Change due to retrofit / Baseline*				
Source	*Amy Vickers (1)*	*Tampa (2)*	*Bay Area (3)*	*Seattle (4)*	*Avg.*	*Amy Vickers (1)*	*Tampa (2)*	*Bay Area (3)*	*Seattle (4)*	*Avg.*	*Amy Vickers (1)*	*Tampa (2)*	*Bay Area (3)*	*Seattle (4)*	*Avg.*	*Amy Vickers (1)*	*Tampa (2)*	*Bay Area (3)*	*Seattle (4)*	*Avg.*
Use	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*	*gpcd*
Toilets	18.5	17.9	19.9	18.8	18.8	8.2	7.8	9.8	7.9	8.4	-10.3	-10.1	-10.1	-10.9	-10.4	-55.7%	-56.4%	-50.8%	-58.0%	-55.2%
Clothes washer	15.0	14.7	13.9	14.8	14.6	10.0	7.8	8.8	9.2	9.0	-5.0	-6.9	-5.1	-5.6	-5.7	-33.3%	-46.9%	-36.7%	-37.8%	-38.7%
Showers	11.6	12.7	12.0	9.0	11.3	8.8	9.1	10.7	8.7	9.3	-2.8	-3.6	-1.3	-0.3	-2.0	-24.1%	-28.3%	-10.8%	-3.3%	-16.7%
Faucets	10.9	9.4	10.5	9.2	10.0	10.8	6.2	10.5	8.0	8.9	-0.1	-3.2	0.0	-1.2	-1.1	-0.9%	-34.0%	0.0%	-13.0%	-12.0%
Leaks	9.5	18.8	25.7	6.5	15.1	4.0	3.7	8.9	2.2	4.7	-5.5	-15.1	-16.8	-4.3	-10.4	-57.9%	-80.3%	-65.4%	-66.2%	-67.4%
Baths	1.2	2.6	3.0	3.7	2.6	1.2	2.4	2.8	2.7	2.3	0.0	-0.2	-0.2	-1.0	-0.4	0.0%	-7.7%	-6.7%	-27.0%	-10.3%
Dishwasher	1.0	0.6	1.0	1.4	1.0	0.7	0.5	0.9	1.2	0.8	-0.3	-0.1	-0.1	-0.2	-0.2	-30.0%	-16.7%	-10.0%	-14.3%	-17.7%
Other domestic	1.6	0.5	0.1	0.2	0.6	1.6	1.2	0.4	0.1	0.8	0.0	0.7	0.3	-0.1	0.2	0.0%	140.0%	300.0%	-50.0%	97.5%
Indoor total	**69.3**	**77.2**	**86.1**	**63.6**	**74.1**	**45.3**	**38.7**	**52.8**	**40.0**	**44.2**	**-24.0**	**-38.5**	**-33.3**	**-23.6**	**-29.9**	**-34.6%**	**-49.9%**	**-38.7%**	**-37.1%**	**-40.1%**
Outdoor total	**31.7**	**25.8**	**59.6**	**n/a**	**39.1**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
GRAND TOTAL	**101.0**	**103.0**	**145.7**	**n/a**	**116.6**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Avg. res/HH	**n/a**	**2.91**	**2.56**	**2.54**	**2.67**	**n/a**	**2.81**	**2.52**	**2.51**	**2.61**	**n/a**	**-0.10**	**-0.04**	**-0.03**	**-0.06**	**n/a**	**-3.4%**	**-1.6%**	**-1.2%**	**-2.1%**

Sources:

(1) Amy Vickers, Handbook of Water Use and Conservation, Waterplow Press, Amherst MA. 2001. Data from Mayer, P.W., Residential End Uses of Water. 1999.

(2) Tampa Water Department Residential Water Conservation Study, January 2004. http://www.cuwcc.org/Uploads/product/Tampa-Final-Report.pdf

(3) East Bay Municipal Utility District (EBMUD) Residential Indoor Water Conservation Study, July 2003. http://www.cuwcc.org/Uploads/product/EBMUD-Final-Report.pdf

(4) Seattle Home Water Conservation Study, December 2000. http://www.cuwcc.org/Uploads/product/Seattle-Final-Report.pdf

Reference:

Waukesha 2004 water use was 63.6 gallons per capita per day.

The following example illustrates the requirements and application process for a clothes washing machine rebate program administered by Bay Area (California) Water Agencies.[1]

High-Efficiency Clothes Washer Rebate Program
Participating Bay Area Water Agencies are offering rebates from $50-$250 to residential customers who purchase and install a new, qualifying High-Efficiency Clothes Washer. Not only will you save water, energy and money, but you'll get cash back as well.

How to qualify:
To be eligible for the clothes washer rebate, just follow these simple steps:

1. Purchase a new, high efficiency clothes washer between July 1, 2005-December 31, 2005. See list of qualifying models.
2. Purchase must be installed at a site served by one of the nine participating Water Agencies.
3. Submit a rebate application form, within 60 days of installing your clothes washer, via mail or apply online now. Copies of the form are available at retail locations. You may also download the form in pdf format from www.conservationrebates.com and print it, then submit it by mail.
4. Submit a copy of your dated sales receipt with either the application form provided by your retailer or with the confirmation page you print after applying online.
5. Please read application form for complete program details or contact the Program Administrator, EGIA, at 800-587-3442 for further details or for the status of your rebate.

Online application forms requires the following information:

1. Date purchased
2. Water provider (i.e., city, district, company, etc.)
3. Store name (by location)
4. Appliance brand
5. Model number
6. Date installed
7. Purchase price
8. First name
9. Last name
10. Email
11. Utility account number
12. Installation address
13. Unit number
14. City
15. State
16. Zip code
17. Telephone number
18. Is the mailing address the same? (yes/no)
19. Qualifications:
    - Only the purchase of a new, eligible high-efficiency clothes washer, installed at a site served by one of the nine participating water agencies, will qualify for a rebate. Note for EBMUD customers: The clothes washer you purchase must be on the list of Qualifying Clothes Washers on the day you purchase the washer.
    - Purchases must be made between July 01, 2005 - December 31, 2005, or until funds are depleted, whichever comes first.
    - Submit a copy of your dated sales receipt with either this application form or with the confirmation page you print after applying online.
    - Sales receipt must include purchaser name and installation address, purchase date, installation date, purchase price, brand and model number.
    - Applications must be postmarked or received online within 60 days of installation.
    - Qualified clothes washer must remain at the installation site for a minimum of six (6) months after installation date.

[1] Clothes washer rebate program offered by participating Bay Area Water Agencies.
http://www.conservationrebates.com/programs/wat/ClotheswasherRebate.aspx

- Limit one (1) rebate per household within a five (5) year period except EBMUD customers who are limited to one (1) rebate per household.

Checkbox: "I agree to the above qualifications."

20. Please Note:
    - For questions regarding the program or for rebate status, please contact the Program administrator, EGIA, at 800-587-3442, Monday through Friday, 8:30 a.m. to 5:00 p.m.
    - Visit www.conservationrebates.com to submit your rebate online.
    - Please remember to submit a copy of your sales receipt after you have completed the application.
    - After your new clothes washer is installed, do not wait to submit your rebate application. All rebate applications must be postmarked no later than 60 days after installation.
    - List of Qualifying Clothes Washers and their rebate values are subject to change. For the most recent List visit www.conservationrebates.com or call 800-587-3442.
    - All customers, including online applicants, must mail a copy of their receipt or the rebate will not be processed.
    - Please allow up to 12 weeks for your completed application to be processed. Incomplete applications cannot be processed.
    - Participating water agencies and EGIA are not responsible for rebates lost or delayed in the mail.
    - Offer void where prohibited or restricted by law.

    Checkbox: "I have read the above notes."

21. Rebate Confirmation:

    Thank you for your participation in the Clothes Washer Rebate Program.
    Your Rebate number is: D600269
    Your Rebate was received on: 07/28/2005
    Upon verification of information submitted, your application will qualify for a $100.00 rebate, if funds have not yet been depleted.
    Please print a copy of this confirmation, and include with a copy of your sales receipt and utility bill for the address where appliance is installed and mail or fax to:

    Mail:
    EGIA/Water Rebates
    3800 Watt Ave., Suite 105
    Sacramento, CA 95821

    Fax:
    (800) 506-9073 Or (916) 609-5350

    Your rebate will not be processed until we receive a copy of your sales receipt and your confirmation page.
    The requested information must be postmarked by Sep 19, 2005.
    Your Receipt must include the following information:
    - Purchaser name.
    - Date of purchase.
    - Date of installation.
    - Address where appliance is to be installed.
    - Manufacturer Brand and Model number.
    - Purchase price of appliance.

    If you are unable to print a copy of this Confirmation page you must include the following information.
    - Receipt Copy
    - Utility Bill
    - Rebate Number
    - Applicant Name
    - Account
    - Brand
    - Model

    Once your information has been received and verified please allow 6 to 8 weeks for rebate check to arrive.

IMPORTANT:
Please have your Rebate number available when inquiring about your rebate.
Rebate questions should be directed to EGIA at (800) 587-3442.
Discrepancies can invalidate the rebate application.

The following appendix (Appendix D) from the Performance Standards Guidance publication for the Massachusetts Interbasin Transfer Act describes considerations for developing a rate structure that promotes water conservation.

Guidance on the Development of Rate Structures That Encourage Water Conservation

The Interbasin Transfer regulations require proponents to implement a rate structure which reflects the costs of operation, proper maintenance, proposed capital improvements, and water conservation and which encourage the same (313 CMR 4.05(3)(c)).

Guidance:
Proponents should refer to the American Water Works Association's Manual of Water Supply Practices: Water Rate Structures and Pricing, Seventh Edition (AWWA M34) and the 1992 WRC Water Conservation Standards for the Commonwealth of Massachusetts to help demonstrate that the portion of this criterion dealing with rate structures has been met.

Rate development principals:

1. Rate structures, including the elements of a rate structure that are intended to encourage conservation, should reflect the particular situation and needs of the community.
2. Rates that encourage conservation can also achieve other objectives, such as lifeline rates or low-income affordability rates.
3. Rates are only one component of a comprehensive water conservation program and should be designed to support and work with other elements of the program.

Funding Sources:

1. Is your water supply funded through an enterprise account or is some other accounting procedure used? If some other accounting procedure is used, describe. Are water supply revenues dedicated for water supply system use?
2. List the major cost categories covered by your rate revenues. Does it reflect the cost of operation, proper maintenance, proposed capital improvements, source protection and water conservation?
3. What elements of your water supply program are not covered by rates? How are these elements funded?

Rate Structure:

1. Provide your current rate structure.
2. Provide date of your most recent rate structure revision and a short description of the changes made.
3. Are there separate rates for different types of customers (residential, commercial, industrial, etc.)?
4. Describe how your rate structure encourages conservation. If your rate structure includes any of the following elements, describe their effectiveness.
    - Increasing block rates and number of customers in each block
    - Seasonal rates; include the number of residential customers which are billed at a higher use category due to seasonal water use and an average cost differential in a water bill for a customer whose seasonal use results in being billed at a higher use category.
    - Excess use rates
    - Goal-based rates
    - Drought rates
    - Second meter rates

Likewise, these standards and recommendations published in the Water Conservation Standards for the Commonwealth of Massachusetts[2] detail the benefits and requirements of full-cost pricing.

Water Conservation Standards and Recommendations: Pricing

Goals: To charge the full cost of providing water and to adopt a rate structure that encourages water conservation.

Background:
Full-cost pricing refers to price levels which recover all the direct and indirect costs associated with providing water. For all sectors of water use, knowing the costs associated with providing water and sewer services creates an appreciation of the importance of conserving water and promotes greater understanding of the direct relationship and environmental implications of individual water use and community water resources, especially during seasonal or drought shortages.

Standards:
1. The water pricing structure should include the full-cost of operating the water supply system, including but not limited to:
   - Pumping, maintenance, electricity/fuel
   - Treatment and associated treatment plant costs
   - Distribution system operation, repair, and maintenance
   - Watershed purchase/protection, well site purchase/protection, aquifer land acquisition
   - Capital replacement fund, capital depreciation account, and debt service
   - Purchase and installation of water conservation/retrofit devices
   - All aspects of a public education program including purchase and distribution of educational materials and related staff time
   - Hiring staff to run the water supply system, staff benefits package, and staff training and professional development
   - Leak detection and repair
2. Water supply system operations should be fully funded by water supply system revenues.
3. Each water supplier should regularly evaluate existing rate structures, including any peak demand and seasonal pricing components. In addition, the water supplier should consider all possible pricing options, such as increasing block rates, to enhance system reliability by encouraging efficient water use by consumers, particularly during periods of supply limitation.
4. Water and sewer rates, where applicable, should be billed so as to inform customers of their actual use and the cost of each; billing should be carried out at least quarterly (see Metering). The cost of reading and billing should be shared between the water and sewer operations.

Recommendations:
- Each water supplier should establish an enterprise account for water.
- Water suppliers should consider adopting increased seasonal rates to moderate peak demands and/or to protect/maintain supply levels.

[2] Available at http://www.mass.gov/dcr/waterSupply/intbasin/download.htm

EDUCATION

The published Water Conservation Standards for the Commonwealth of Massachusetts[3] provides guidelines for establishing the objectives and content of a public education program for water conservation.

Water Conservation Standards and Recommendations: Public Education

Goal: To promote public awareness of the long-term economic and environmental benefits of conserving water as a basis for the adoption of measures to achieve greater efficiency in using water and conservation of water resources.

Background: Public education is more than simply information dissemination; it is a key to getting public support by providing the basic understanding of sound water resources management and planning and explaining the associated economic and environmental benefits. In addition to the general public, the Conservation Coordinator should provide education to Boards of Selectmen, Water Commissioners or Superintendents, and others in policy-making positions or with line responsibility for carrying out the water conservation programs. Materials for education programs should be sought from the Massachusetts Water Works Association and the New England Water Works Association and other organizations and be funded by local water revenues.

Because public education depends on accurate data, the WRC supports a review of existing mechanisms for obtaining water use statistics from water withdrawers and other measures to develop/collect, disseminate, and interpret water resources data and provide technical assistance to communities.

Three main areas of emphasis for an educational program are:

- Explaining to water users all the costs involved in providing water, including planning, engineering, construction, operation, maintenance, treatment, wastewater facilities costs, piping, leak detection, compliance costs, salaries, protection costs, pensions, health care, staff training, public education, and other costs.
- Showing that investments in efficiency and conservation will provide water users with long term savings compared to a utility's costs of having to develop and treat new water supply sources and develop wastewater treatment facilities. For example, through a domestic device retrofit program, including follow-up visits or mailings, water suppliers can make customers aware that making a few simple changes can provide tangible savings.
- Highlighting the environmental benefits of reducing water demands, including the relationship of groundwater to surface water and the potential impacts of withdrawals on instream uses, such as habitats for fisheries and other wildlife and water-based recreation; the relationship between pumping and salt water intrusion for coastal areas; and the relationship between water quality and streamflow.

Standards: Because an almost infinite number of specific methods for information dissemination are available, no specific standards are stated, except that each community should develop and implement an education plan which should include most, if not all items in the following basic list. Water users and agencies should choose from these and other resources to create and implement programs best suited for their particular situation.

- The largest users should be targeted early on to realize the greatest potential savings and to demonstrate the benefits of a conservation program.
- Public Education should reach to the schools; develop/use media that will appeal to children, including getting them involved with environmental/ water resources projects and field trips.
- Bill Stuffers and/or bills should have a work sheet on the reverse to enable customers to track water use and conservation efforts and figure the dollar savings
- Public space advertising/media stories on successes (and failures)
- Conservation information centers, perhaps run jointly with electric or gas company.
- Speakers for community organizations

[3] Available at http://www.mass.gov/dcr/waterSupply/intbasin/download.htm

- Public service announcements; radio/T.V./audio-visual presentations on supply sources and current status
- Joint advertising with hardware stores to promote conservation devices.
- Use of civic and professional organization resources
- Special events such as Conservation Fairs
- Multilingual materials should be available as needed
- Contests and recognition for innovation could be incorporated into the public education program.
- Information on xeriscaping, gardening, and lawn care practices.

Examples of educational programs for water conservation:

General plumbing
- Free instructions on checking for water leaks. Repairing leaks may lower a household's water bill, sewage bill, and cost of heating water.

Lawns and gardens
- Free booklets on water-wise gardening.

MONITORING

The water department in Tucson, Arizona developed a survey program to provide residents with a free, comprehensive analysis of their water use and opportunities for further conservation.[4]

Residential Water Use Analysis
Tucson Water has resurrected the role of the Zanjero, the community water manager of the "old" Old Pueblo, to help Tucsonans manage the water use in their homes. The Zanjero Program offers residential customers with high historic water use an opportunity to have a free individualized water-use survey done at their home. The program is designed to help customers reduce water waste and lower their water bills. Here is a glimpse of the steps the Zanjero will take to identify water savings in a home.

Beginning the Survey
An inventory will be taken of all fixtures, such as the dishwasher, clothes washer, water treatment condition systems, and cooler. The water meter will be located and the volume recorded. The resident will be taught how to read the meter and use it to help detect leaks.

1. Record household information.
2. Inventory fixtures and record:
   - dishwasher
   - clothes washer
   - garbage disposal
   - air conditioner
   - bottled water
   - graywater
   - water softener
   - cooler
   - hot water recirculator
   - carbon or reverse osmosis water filter
3. Locate meter, record information on audit form, and teach resident how to read meter.

The Indoor Survey
Next, bathrooms and the kitchen and utility room will be inspected for leaks. The flow rate of the toilet, faucets, and showerheads will be measured. Showerheads and aerators will be replaced free of charge if needed. Leaking toilet flapper valves will also be replaced.

1. Inspect bathrooms.
   - Drop a dye tablet into toilet tank to test for leaks.

[4] Available at http://www.ci.tucson.az.us/water/zanjero_analysis.htm

- Estimate gallons per flush of toilet and record.
- Measure flow rates of showers and faucets and record.
- Observe for leaks and record.

2. Inspect kitchen/utility room.
   - Measure flow rate(s) of faucet(s) and record.
   - Observe for leaks and record.
3. Conclude interior inspection.
   - Return to bathroom and observe for toilet leaks; record information.
   - Review and discuss interior inspection results with homeowner.
   - Replace showerhead(s) and aerator(s) as appropriate.

The Outdoor Survey

An inventory will be taken of features such as pools, misting systems, evaporative cooler, and greenhouses. An assessment of the landscape and an evaluation of any lawn areas will include measuring the flow rate of irrigated areas, checking pressure, and reading the meter.

1. Review General Characteristics with customer. Inventory and record:
   - pool
   - misting system
   - pets/animals
   - evaporative cooler
   - spa
   - fountain/pond
   - greenhouse
   - water treatment/softener
2. Inspect front/back yards.
   - Provide assessment of landscape type:
     - planting density
     - high/medium/low water use
   - Measure landscaped areas and record:
     - prepare sketch map of site
   - Assess irrigation methods and record.
   - Conduct flow test for each valve/station and record.
   - Conduct visual inspection for leaks, breaks, missing plants, runoff, etc., and record.
   - Evaluate lawn area(s) and record:
     - soil probe
     - rooting depth
     - soil type
     - measure flow rate for turfed areas
       - check pressure
       - flag sprinkler heads
       - conduct visual inspection
     - set up cups (if visual inspection OK)
     - run spray irrigation system
     - collect cup data
   - Record meter reading.

Concluding the Survey

The auditor will go over the survey results with the customer, suggest steps they can take, and leave a conservation information Packet.

1. Review landscape audit findings with homeowner.
   - Discuss irrigation scheduling theory.
   - Review irrigation system deficiencies.
2. Complete water audit review checklist.
3. Leave printed materials/information packet.
4. Conclude meeting with customer: record time out on form.

Scheduling an Appointment
Conservation surveys are available to residential Tucson Water customers. You must be present during the two-hour survey. To schedule an appointment, call the Tucson Water Customer Service Office at (520) 791-3242.

Massachusetts, in its published Water Conservation Standards, emphasizes the importance of monitoring water use by detecting and repairing leaks and metering all users of the public water supply system.[5]

Water Conservation Standards and Recommendations: Leak Detection and Repair

Goals: To perform regular leak detection and promptly repair all leaks.

Background:
Detecting and fixing leaks can provide one of the largest returns on investment, especially in older systems, and should be carried out by all water suppliers. This should be a key ingredient in public educational programs, using crews in the street as a point of attention by media.

Standards:
1. A full leak detection survey of the distribution system should be completed every two years.
2. Leak detection and repair should be recognized as expenses of the water supply system and included in a full-cost pricing structure.

Recommendations:
- Because leak detection requires substantial skill, regularly trained, in-house teams are recommended; communities should investigate the advantages of sharing leak detection equipment and personnel to reduce costs.
- NEWWA and MWWA should be approached by DEP to consider providing standardized training and certification in leak detection and repair.
- Pressure reduction should be considered by suppliers for implementation where technically feasible and consistent with public health and safety considerations.
- There should be consideration given to assuring the penalty for water theft equals that of gas or electric theft.

Water Conservation Standards and Recommendations: Metering

Goals: To meter all residential, commercial, institutional, agricultural and municipal users of water supply systems and to bill them or otherwise account for their water use at least quarterly.

Background:
Complete system metering lets customers know how much water they are using, provides the supplier with valuable knowledge of customer use patterns, assists in demand management programs, and enables the supplier to bill the customer accurately. With accurate knowledge about current demand, the supplier can more effectively identify potential water savings, assist specific users to implement water saving measures, thereby providing the opportunity to reduce overall system demand and plan efficiently for system growth. Metering costs should be recovered through water rates.

Standards:
1. Each public water supplier should develop a program to implement 100% metering of all public sector and private users with meters of proper size and accuracy to ensure full registering of water flow.
2. The metering program should include regular meter maintenance, including testing, calibration, repair, replacement and checks for tampering to identify and correct illegal connections.

[5] Available at http://www.mass.gov/dcr/waterSupply/intbasin/download.htm

3. The metering program should include regular meter reading of all public sector users and regular accounting of their use (see Public Sector Water Use).
4. Meter reading and billing for domestic accounts should be done quarterly, with the understanding that customers should be billed on actual meter readings.
5. Master meters (which register the flows in the municipal system) should be calibrated annually.

Recommendations:

- Meter reading and billing for the largest users should be done more frequently than domestic accounts (for instance, billing should be monthly for the largest users); and meter maintenance should be more frequent.
- Exterior meter reading devices should be installed to improve the efficiency of meter readings.
- Meter reading and billing frequency would be most effective if done on a monthly basis, but unless a community has or develops the means to read the meters remotely, it may not prove cost-effective to read meters on a monthly basis.
- Suppliers should consider a 10-15 year period for meter replacement

Appendix C of the Performance Standards Guidance publication for the Massachusetts Interbasin Transfer Act details the contributors to accounted-for and unaccounted-for water use.

Accounted-For and Unaccounted-For Water Uses

For the purposes of Interbasin Transfer review, water uses should be broken down by specific category, as designated in the DEP Public Water Supply Annual Statistical Report.

Accounted-for water includes:

- Residential use
- Agricultural use
- Commercial use
- Industrial use
- Municipal use, including fire fighting, street cleaning, hydrant maintenance, and hydrant use for sewer flushing, where these uses can be confidently estimated. In the case of water use that is "confidently estimated" documentation of how the estimate was arrived at will need to be provided.
- Sales to other public water suppliers
- Process water, including bleeders, water main flushing (including new water mains), new water main filling, filter backwash, etc. where these uses can be confidently estimated. In the case of water use that is "confidently estimated" documentation of how the estimate was arrived at will need to be provided.
- Institutional/Tax exempt uses

Unaccounted-for water is the difference between water pumped or purchased and water that is metered or confidently estimated.

Unaccounted-for water should include:

- Master Meter Inaccuracies
- Domestic and Non-Domestic Meter Underregistration
- Errors in estimating for stopped meters
- Overregistering revenue meters
- Unauthorized hydrant openings
- Unavoidable leakage
- Recoverable leakage
- Illegal connections
- Standpipe overflows
- Data processing errors

Water suppliers may want to estimate the amount of unaccounted-for water by category, as required in Section D6 of DEP's Public Water Supply Annual Statistical Report (1998). This is will enable them to target suspected sources of unaccounted-for water for reduction.

Examples of monitoring programs for water conservation:

General plumbing

- Free site visit by a field staff member for leak location and assessment.

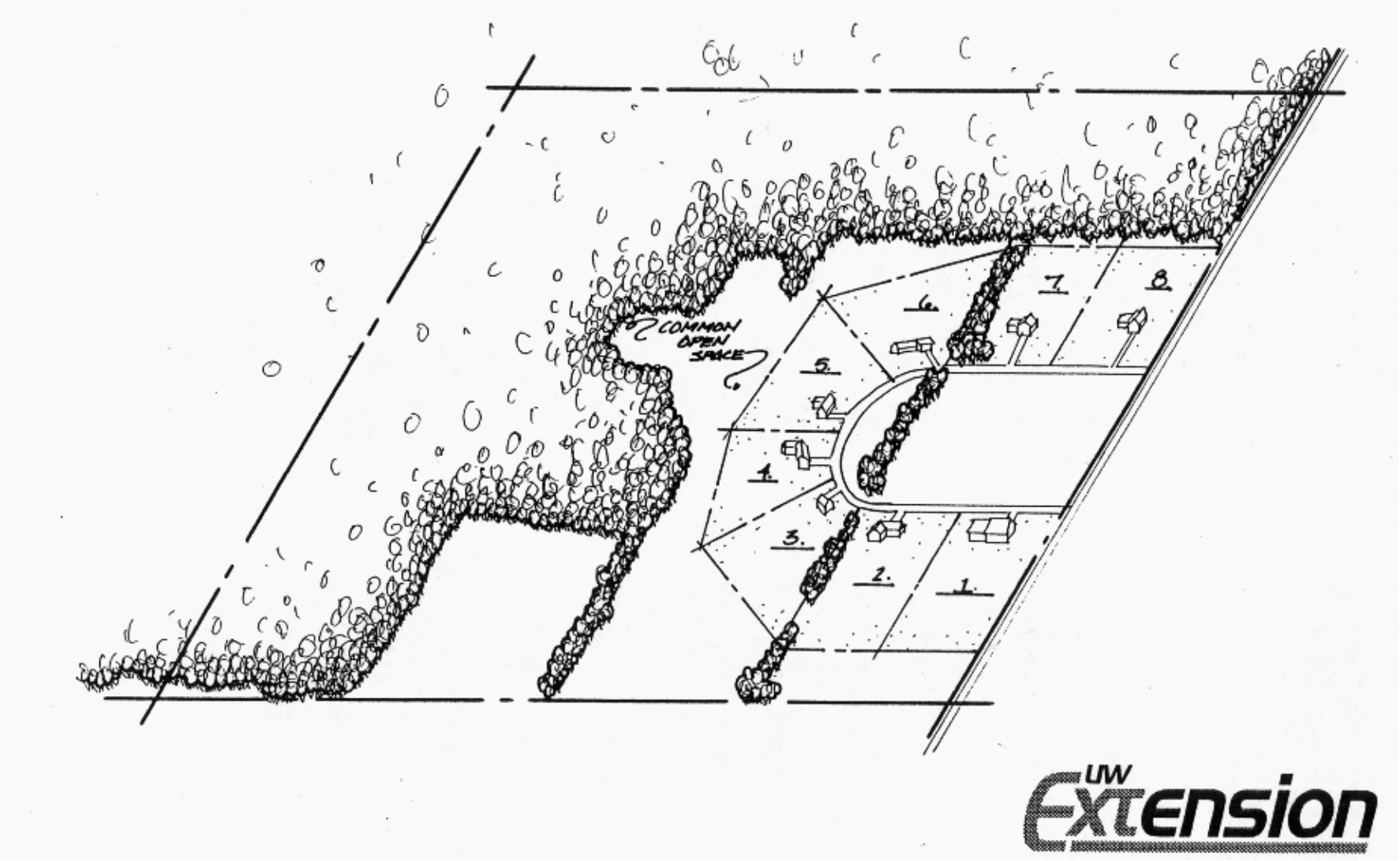
Large landscapes

- Free large landscape water surveys to evaluate a landscape's irrigation efficiency. A trained technician visits the site and evaluates the irrigation system. The technician will check for sprinkler and design inefficiencies, create a site-specific watering schedule, and make recommendations for improving the irrigation system.

Appendix C

Model Conservation Subdivision Ordinance

Ordinance for a Conservation Subdivision



Section 66.1027 of the Wisconsin Statutes, part of Wisconsin's recent "smart growth" law, requires that the University of Wisconsin Extension prepare "an ordinance for a conservation subdivision." This ordinance was prepared in response to that law. When Wisconsin's comprehensive planning and "smart growth" law was enacted in October 1999, as part of 1999 Wisconsin Act 9, the law required that cities, villages and towns with a population of at least 12,500 needed to adopt an ordinance for a conservation subdivision. That requirement was subsequently eliminated by 1999 Wisconsin Act 148. Local governments are not required to adopt this ordinance. It is provided for educational purposes only.

Acknowledgments

This document was prepared by Brian W. Ohm, J.D., Associate Professor in the Department of Urban & Regional Planning at the University of Wisconsin-Madison and land use law specialist with the University of Wisconsin-Extension, with assistance from Carrie Hirsch, project assistant funded through the College of Agricultural and Life Sciences, University of Wisconsin-Madison, and graduate student in the Department of Urban & Regional Planning, and Jim Lagro, PhD, RLA, Associate Professor in the Department of Urban & Regional Planning. The drawings were prepared by Tom Rogers, a student in the Department of Landscape Architecture, University of Wisconsin-Madison.

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Introduction To The Ordinance

This publication provides a brief introduction to the concepts, advantages and limitations of conservation subdivisions. The publication also includes an ordinance for a conservation subdivision. The text of the ordinance begins on page 7. The ordinance also includes a commentary on the ordinance text. The commentary is intended to make the document easier to read and understand while guiding local officials and others interested in pursuing conservation subdivisions for their communities.

The ordinance is meant as a guide and **is not** intended to be adopted "as is." **Each community must adapt the language and concepts of the ordinance to fit the unique circumstances found in that community.** The ordinance is written as a **subdivision ordinance** that can be adopted by cities, villages, towns with village powers, and counties under section 236.45 of the Wisconsin Statutes. It is not written as a **zoning ordinance**. Since many communities may not have an existing subdivision (or land division) ordinance, this ordinance includes standard language for the platting of land under the process established in Chapter 236 of the Wisconsin Statutes. That language appears in *italics* in the text. The language that pertains more directly to the concept of conservation design appears in a regular font. Communities that have an existing subdivision or land division ordinance should examine the design process and standards of that ordinance in comparison to this ordinance. Communities can change those standards to reflect the conservation design concepts our they could include a separate section in their subdivision ordinance providing for conservation subdivisions. As with any subdivision ordinance, local governments must have a plan commission (in the case of cities, villages, and towns with village powers) or a plan committee (in the case of counties) to recommend adoption of this ordinance and to help in the administration of this ordinance. Communities also may need to adapt other applicable ordinances (such as zoning), to ensure they are consistent with principles of conservation development. For general information on subdivision regulations see Chapter 7 in Brian W. Ohm, *Guide to Community Planning in Wisconsin* published by the University of Wisconsin-Extension in 1999.

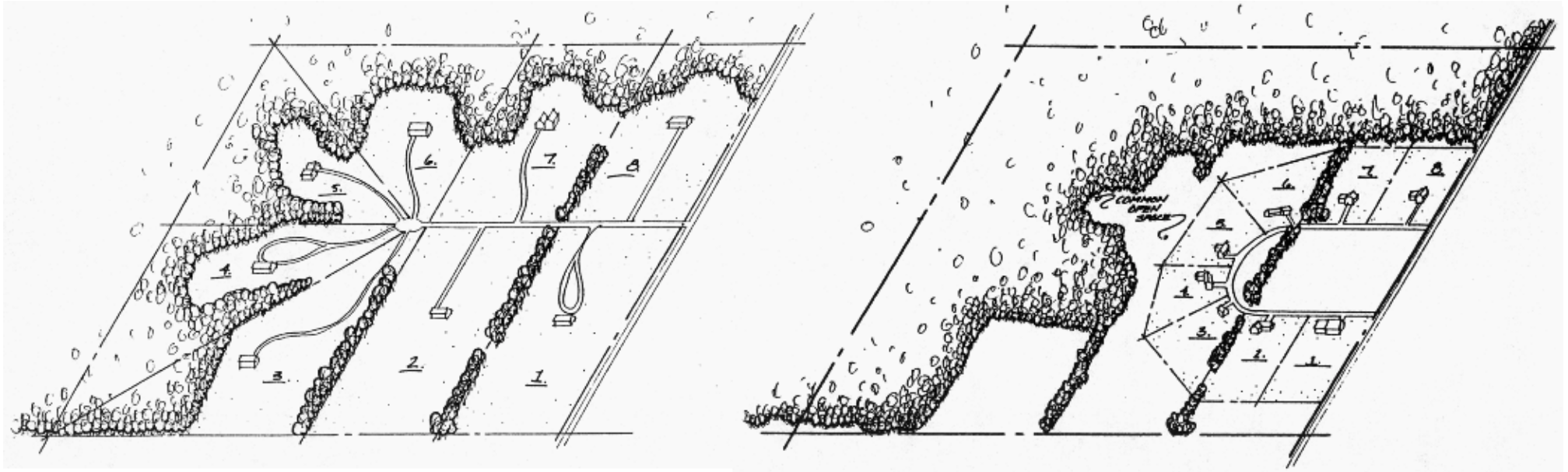
To better understand the context and build support for the use of conservation subdivisions, communities should provide the basis for a conservation subdivision ordinance through a comprehensive planning process. Through this planning process, local governments can understand how to craft their conservation subdivision ordinances to conserve the unique qualities of the Wisconsin landscape found in their community.

Brief Overview of Conservation Subdivisions

Conservation subdivisions can occur in a variety of settings, such as in urban areas, in a transition area between clearly rural and urban areas or in rural settings. Wisconsin's "smart growth" law defines a "conservation subdivision" as: "a housing development in a rural setting that is characterized by compact lots and common open space, and where the natural features of land are maintained to the greatest extent possible." This ordinance follows that definition of a conservation subdivision. There are also other ways to define and develop conservation subdivisions for other settings. Conservation design principles can also be incorporated in other local ordinances to help ensure that developments that do not constitute a "subdivision" meet conservation design principles.

Generally, conservation subdivisions allow for an adjustment in the location of residential dwelling units on a parcel of land so long as the total number of dwelling units does not exceed the number of units otherwise permitted in the zoning district. The dwelling units are grouped or "clustered" on only a portion of a parcel of land. The remainder of the site is preserved as open space, farmland, or as an environmentally and culturally sensitive area. This clustering of the dwellings into a small area is made possible by reducing the individual lot sizes. The open space is permanently protected and held in common ownership. Sometimes additional dwelling units may be permitted if certain objectives are achieved. Conservation subdivisions are an alternative approach to the conventional lot-by-lot division of land in rural areas which spreads development evenly throughout a parcel with little regard to impacts on the natural and cultural features of the area. See Figure A. Conservation subdivisions enable a developer to concentrate units on the most buildable portion of a site, preserving natural drainage systems, open space, and environmentally and culturally sensitive areas.

Figure A.



Conventional subdivision

Conservation subdivision

In order to determine the possible benefits of conservation subdivisions, while at the same time recognizing their limitations, it is important to understand their locational context. Comprehensive planning is essential for helping a community better understand the landscape, the unique issues affecting the community, and determining where conservation subdivisions are applicable and appropriate. Some of the issues communities need to think about include rural character and lifestyles, environmental protection, historic preservation, transportation, and compatibility with agriculture. This ordinance should **not be** used as a substitute **for comprehensive planning which can help determine the overall pattern of development in the community and the direction of growth. The conservation** subdivision is only one tool out of a mixture of different tools that communities can use to achieve the objectives of their comprehensive plan.

- Open Space

Public concern has grown over the loss of open space and rural character that seems to inevitably accompany development. Conservation subdivision design concepts promote and encourage the clustering of homes so as to create an interconnected network of permanent open space. The open space and common facilities, such as joint septic and water systems, are generally managed through a homeowners association, non-profit conservation organization such as a land trust, a local unit of government, or an individual who complies with the permanent conservation restrictions.

Some of the advantages of using conservation subdivisions for these purposes are (1) fostering a sense of community through carefully sited smaller lots and shared spaces; (2) protecting and restoring significant resources such as prime farmland, historic buildings, archaeological sites, mature woodlands, streams, ponds or wetlands, and scenic views, and (3) preserving rural character, which has an external effect of increasing land values.

- Farmland

As development pressures increase, property values of agricultural lands near developing areas have steadily increased. In many areas, the value of agricultural land for development is greater than the value of the land for agriculture. Land values, combined with the general uncertainties of the agricultural economy, create disincentives for farmers to stay in agriculture. Growth pressures have led to development in agricultural areas outside urban areas. As residential development encroaches on ongoing agricultural operations, conflicts arise between farmers and these new residents. These conflicts include: the generation of noise, lights and odor from farm operations; and traffic conflicts resulting from increased automobile traffic on narrow country roads.

Conservation subdivisions may not be the best means of protecting large blocks of agricultural land, nor are they the best measures to protect farming as a viable lifestyle. In order to sustain an agricultural community and ensure farming as a viable lifestyle, large blocks of contiguous land need to be protected and maintained. This would reduce the potential conflicts mentioned above. Conservation subdivisions can, however, protect small blocks of agricultural land and promote areas where agricultural and residential activities can co-

exist. This is significant for particular types of agricultural practices that have some economic and aesthetic benefits. This might include pick-your-own operations, community supported agricultural programs, organic vegetable production, hay and straw production and other specialty products and activities that use low chemical and low intensity production.

- Shoreland and Environmentally Sensitive Areas

The clustering of homes can direct development to areas more suitable for development and away from areas that are more environmentally sensitive, such as wetlands. Clustering can also provide for the preservation of archaeological sites, including Indian mounds and burial sites--which often occur near water--in the protected open space. In shoreland areas where residential development is permitted, conservation subdivisions can be instrumental in protecting and restoring desirable natural features, particularly scenic views of the water body concerned, and minimize negative environmental effects. Rather than providing a waterfront view for a limited number of very expensive homes, through the stringing out of houses along a lakefront or river's edge, the view can be preserved as a community amenity for all to enjoy, while still maintaining desired overall development densities. Scenic views from the waterway are also preserved. Finally, conservation subdivisions can help protect water quality through the maintenance of waterway buffers and better management of run off.

Conclusion

The challenge for landowners and local officials is how to continue to effectively meet the demand for rural housing in a way that respects and conserves the rural character, maintains natural resources, and protects environmental amenities. Conservation subdivisions are one tool that can be used to achieve these goals.

Additional Resources

In order to develop this ordinance, various *conservation, cluster,* and *open space* ordinances were collected from around Wisconsin and the Midwest from communities that have created and adopted a similar ordinance or are currently developing one. In addition, various regional, state and local organizations were contacted in order to develop a model that can easily be tailored to accommodate individual communities. Other reference materials on conservation subdivisions were also consulted.

The following ordinances and other materials were reviewed in preparation of this ordinance. These materials should be consulted for more detailed explanation and/or description of conservation subdivision principals and design guidelines.

Arendt, Randall, G., *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks* (1996).

Arendt, Randall, G., *Growing Greener: Putting Conservation into Local Plans and Ordinances* (1999).

East Central Wisconsin Regional Planning Commission, *Rural Development Guide for East Central Wisconsin Governments andLandowners*

(1999).

Freilich, Robert H. and Shultz, Michael M., *Model Subdivision Regulations* (1995).

Listokin, David and Walker, Carole, *The Subdivision and Site Plan Handbook* (1989).

Minnesota Planning, *From Policy to Reality. Model Ordinances for Sustainable Development* (2000).

Portage County (Wisconsin) Planning and Zoning Department, *Final Draft Portage County Subdivision Ordinance Amendment. Open Space Design Option* (2000).

Southeastern Wisconsin Regional Planning Commission, *Rural Cluster Development Guide* (1996).

Town of Greenville (Outagamie County, Wisconsin),*Subdivision Ordinance* (2000).

Town of Mt. Pleasant (Racine County, Wisconsin), *Zoning Ordinance.*

Town of Wayne (Washington County, Wisconsin), *Zoning Ordinance* (1999 Revisions).

Washington State Department of Community Development, *Evaluating Innovative Techniques for Resource Lands, Partl: Clustering* (1992).

Washington County (Minnesota) Planning and Administrative Services, Metropolitan Council, BRW, Inc., *Open Space Design Development:*

A Guide for Local Governments (1997).

Wisconsin Department of Natural Resources, *Department Position on Cluster Development* (1999).

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1. General Provisions

1.1 ***Title.*** *These regulations shall officially be known, cited, and referred to as the* Conservation Subdivision Ordinance *of [name of local government], Wisconsin (hereinafter "ordinance").*

Ordinances are often given an abbreviated title for reference purposes. This ordinance may be part of a larger set of ordinances governing land use.

1.2 **Purposes.** This ordinance is adopted for the following purposes:

1. To guide the future growth and development of the community consistent with the [name of city, village, town, county]' s adopted comprehensive plan.
2. To guide the detailed analysis of the development parcel so as to locate and coordinate appropriate areas for development and conservation.
3. To preserve the rural character through the permanent preservation of meaningful open space and sensitive natural resources.
4. To preserve scenic views by minimizing views of new development from existing roads.
5. To preserve prime agricultural land by concentrating housing on lands that have low agricultural potential.
6. To provide commonly-owned open space areas for passive and/or active recreational use by residents of the development and, where specified, the larger community.
7. To provide for a diversity of lot sizes, housing choices and building densities to accommodate a variety of age and income groups.
8. To provide buffering between residential development and non-residential uses.
9. To protect and restore environmentally sensitive areas and biological diversity, minimize disturbance to existing vegetation, and maintain environmental corridors.
10. To preserve significant archaeological sites, historic buildings and their settings.
11. To meet demand for housing in a rural setting.

All references in the ordinance appearing between brackets [ ] *are to be filled in with the appropriate reference by the jurisdiction adopting the ordinance.*

The purposes statement should incorporate language contained in the community's comprehensive plan.

1.3 ***Statutory Authorization.*** *This ordinance is adopted pursuant to the authority contained in section 236.45 of the Wisconsin Statutes.*

Cities, villages, towns with village powers and counties all have the authority to adopt subdivision regulations.

1.4 Jurisdiction. *[For cities and villages] Jurisdiction of this ordinance shall include all lands within the corporate limits of the [City, Village of_____ Wisconsin, and those lands within the extraterritorial jurisdiction of the [city/village] as established in Sections 61.35 [include for villages] and 62.23(2), 66.32, and 236.10 of the Wisconsin Statutes.*
[For towns/ Jurisdiction of these regulations shall include all lands within the corporate limits of the Town of_____ , Wisconsin.
[For counties] Jurisdiction of these regulations shall include all lands within the unincorporated areas of the County of _____, Wisconsin, and those lands within the jurisdiction of cities and villages to determine if the county has an objection to a p/at on the basis of planned public improvements under section 236.12 of the Wisconsin Statutes.

The ordinance does not apply to:

1. *Transfers of interests in land by will or pursuant to court order.*
2. *Cemetery plats under section 157.07 of the Wisconsin Statutes.*
3. *The sale or exchange of parcels of land between owners of adjoining property if additional lots are not thereby created and the lots resulting are not reduced below the minimum sizes required by this ordinance or other applicable laws or ordinances.*
4. *Assessors'plats made under section 70.27 of the Wisconsin Statutes, but such assessors' plats shall comply with sections 236. 15(1)(a)--(g) and 236.20(1), (2)(a)--(c), of the Wisconsin Statutes.*

1.5 Applicability and Compliance. The conservation subdivision standards apply to all divisions of a parent parcel of[20] acres or more by a subdivider where the division creates at least [four] new parcels. The number of new parcels that can be created shall be consistent with the applicable zoning ordinance for the parent parcel. The overall development density for the parent parcel is the same a would be allowed for a conventional subdivision in the existing zoning district except for those conservation subdivisions which qualify for a development bonus under section 4.2. The provisions of this ordinance apply to residential development within the following districts established in the [city, village, town, county] zoning ordinance: [identify zoning districts within which the

The minimum size of the conservation subdivision must be large enough to allow for creative site design and the protection of open space. The minimum size and number of parcels needs to be tailored to the unique circumstances of each community. This ordinance uses 20 acres. Other ordinances use a minimum size ranging from 5 to 40 acres. It may be possible to not use a minimum size. A

conservation subdivision ordinance should apply, such as agricultural and rural residential districts]. Conservation subdivisions shall not be permitted in the following districts established in the [city, village, town, county] zoning ordinance: [identify zoning districts within which the conservation subdivision ordinance should not apply (if any), such as higher density residential districts, Industrial districts and commercial districts].

community could also make the application of this ordinance optional.

The overall density of development needs to be established by the local comprehensive plan and the local zoning ordinance.

1. *No person shall divide any land under the provisions of this ordinance without compliance with all requirements of this ordinance and the following:*
   a. *The provisions of Wis. Stats. ch. 236 and Wis. Stats. § 80.08.*
   b. *The rules of the Wisconsin Department of Commerce, contained in Chapter COMM 83 and related chapters of the Wisconsin Administrative Code for land divisions not served by public sewer.*
   c. *The rules of the Division of Transportation Infrastructure Development, Wisconsin Department of Transportation, contained in Chapter TRANS 233 of the Wisconsin Administrative Code for subdivisions that abut a state trunk highway or connecting street.*
   d. *The rules of the Wisconsin Department of Natural Resources contained in Chapters 116, 117 [for cities and villages only], and 118 of the Wisconsin Administrative Code for shoreland, shore/and-wetland, and floodplain management.*
   e. *The comprehensive plan adopted by [name of city, village, town, county].*
   f. *All applicable local and county regulations, including zoning, sanitary, building and official mapping ordinances.*
   g. *All other applicable rules contained in the Wisconsin Administrative Code.*

1.6 Condominium Plats. A condominium p/at prepared under Chapter 703 of the Wisconsin Statutes, creating at least four units with a parent parcel size of 20 acres of more, shall be reviewed by the [city, village, town, county] in the same manner as a conservation subdivision as set forth in this ordinance and shall comply with the applicable design standards and required improvements of this

Condominium plats are not subject to the requirements of Chapter 236 of the Wisconsin Statutes. Rather they are governed by Chapter 703 of the Wisconsin Statutes.

ordinance.

1.7 Abrogation and Greater Restrictions

When other regulations provide "dual" standards, the more stringent pro visions should govern.

1. ***Public Provisions.*** *These regulations are not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, statute, or other provision of law except as provided in these regulations. Where any provision of these regulations imposes restrictions different from those imposed by any other provision of these regulations or any other ordinance, rule or regulation, or other provision of law, the provision which is more restrictive or imposes higher standards shall control.*
2. ***Private Provisions.*** *These regulations are not intended to abrogate any easement, covenant or any other private agreement or restriction, provided that where the provisions of these regulations are more restrictive than such easement, covenant, or other private agreement or restriction, the requirements of these regulations shall govern. Where the provisions of the easement, covenant, or private agreement impose duties and obligations more restrictive than these regulations, and the private provisions are not inconsistent with these regulations, then the private provisions shall be operative and supplemental to these regulations and the determinations made under the regulations.*

1.8 Interpretation*. In their interpretation and application, the provisions of these regulations shall be held to be the minimum requirements for the promotion of the public health, safety, and general welfare. These regulations shall be construed broadly in favor of the [city, village, town, county] to promote the purposes for which they are adopted.*

In limited instances, special site conditions may require more stringent pro visions to protect the public health, safety and we/fare.

1.9 Separability. *If any part or provision of these regulations or the application of these regulations to any person or circumstances is adjudged invalid by any court of competent jurisdiction, the judgment shall be confined in its operation to the part, provision, or application directly involved in the controversy in which the judgement shall be rendered. It shall not affect or impair the validity of the remainder of these regulations or the application of them to other*

A separabillty provision is often included in an ordinance to protect the whole if a section is declared invalid.

persons or circumstances. The [governing body of the city, village, town, county] hereby declares that it would have enacted the remainder of these regulations even without any such part, provision, or application which is judged to be invalid.

1.10 Enforcement, Violations, Penalties.

This pro vision is intended to ensure that subdivision standards are enforced by stating dearly that there will be penalties for violations and outlining the available appeals processes.

1. ***Violations.*** *It shall be unlawful to build upon, divide, convey, record, or monument any land in violation of this ordinance or state law, and no person shall be issued a building permit by the [city, village, town, county] authorizing the building on or improvement of any subdivision within the jurisdiction of this ordinance not of record as of the effective date of this ordinance until the requirements of this chapter have been filly met. The [city, village, town, county] may institute appropriate action or proceedings to enjoin violations of this ordinance or applicable state law.*
2. ***Penalties****. Penalties for violation of this ordinance shall be as follows:*
   a. *Any person who fails to comply with this chapter shall, upon conviction, be subject to the penalties as provided by the [city, village, town, county].*
   b. *Recordation improperly made has penalties provided in section 236.30 of the Wisconsin Statutes.*
   c. *Conveyance of lots in unrecorded plats has penalties provided for in section 236.31 of the Wisconsin Statutes.*
   d. *Monuments disturbed or not placed have penalties as provided for in section 236.32 of the Wisconsin Statutes.*
   e. *Assessor's p/at made under section 70.27 of the Wisconsin Statutes may be ordered by the city, village, town, county] as a remedy at the expense of the subdivider when a subdivision is created by successive divisions.*
3. *Appeals. Any person aggrieved by an objection to a p/at or a failure to approve a p/at under this ordinance may appeal therefrom, as provided in sections 236.13(5) and 62. 23(7)(e) 10, 14, and 15, of the Wisconsin Statutes, within 30 days of notification of the rejection of the p/at. Where failure to approve is based on an unsatisfied objection, the agency making the*

objection shall be made a party to the action. The court shall direct that the p/at be approved if it finds that the action of the approving or objecting agency is arbitrary, unreasonable, or discriminatory.

1.11 Modifications.

1. Authority; application.

a. Where, in the judgment of the [governing body of the city, village, town, county], it would be inappropriate to apply literally the provisions of this ordinance because exceptional or undue hardship would result, the [governing body or plan commission of the city, village, town, county] may waive or modify any requirements to the extent deemed just and proper.

b. Application for any such modification or waiver shall be made in writing by the subdivider at the time when the preliminary p/at is filed for consideration, stating filly all facts relied upon by the petitioner, and shall be supplemented with maps, plans, or other additional data that may aid the [governing body or plan commission] in the analysis of the proposed project.

Subdivision ordinances should include a provision for modifications from the ordinances for unique situations that may impose a hardship on the applicant. The modification provision for subdivision ordinances should not be confused with the process and law governing variances from zoning ordinances.

***2. Conditions for granting**. The [plan commission or governing body of the city, village, town, county] shall not grant modifications or waivers to this ordinance unless it shall make findings based upon the evidence presented to it in each specific case that:*

a. The granting of the modification will not be detrimental to the public safety, health, or welfare or injurious to other property or improvements in the neighborhood in which the property is located.

b. The conditions upon which the request for a modification is based are unique to the property for which the modification is sought and are not applicable generally to other property.

c. Because of the particular physical surroundings, shape, or topographical conditions of the spec4/ic property involved, a particular hardship to the owner would result, as distinguished from a mere inconvenience, financial hardship, or self-imposed hardship, if the strict letter of this ordinance were carried out.

The term "plan commission" is used in this ordinance to universally refer to city, village, town plan commissions, and county plan committees, etc.

Ordinance Language | Commentary

d. Such modification is necessary for the preservation and enjoyment of substantial property rights possessed by other similar properties in the vicinity.

3. Granting by [plan commission or governing body].

a. The [plan commission or governing body], if it approves of the modification to this ordinance, shall do so by motion or resolution and shall instruct the [planning department or zoning administrator] to notify the subdivider.

b. Such relief shall be granted without detriment to the public good, without impairing the intent and purpose of this chapter or the desirable general development of the [city, village, town, county] consistent with the [city, village, town, county] comprehensive plan or this ordinance.

c. Any modification granted can only provide the minimum relief needed to alleviate the unnecessary hardship or obtain reasonable use of the property.

4. A majority vote of the entire membership of the [plan commission or governing body of the city/village/town/county] shall be required to grant any modification of this ordinance, and the reasons shall be entered in the minutes.

***1.12 Fees.** The [governing body of the city, village, town, county] may, by resolution, establish reasonable fees for the administration of this ordinance.*

In general, a fee schedule will be accepted by the courts if the community can demonstrate the charges bear a reasonable relationship to the costs of administering the ordinance.

2. Definitions

The following definitions shall be observed and applied, except when the context clearly indicates otherwise. Words used in the present tense shall include the future tense. Words used in the singular form shall include the plural form. Words used in the plural form shall include the singular. The word "shall" is mandatory and the word "may" is permissive.

Definitions are intended to clarify the meaning of certain terms included in the ordinance.

2.1 Common open space. Undeveloped land within a conservation subdivision that has been designated, dedicated, reserved, or restricted in perpetuity from further development and is set aside for the use and enjoyment by residents of the development. Common open space shall not be part of individual residential lots. It shall be substantially free of structures, but may contain historic structures and archaeological sites including Indian mounds, and/or such recreational facilities for residents as indicated on the approved development plan.

2.2 Condominium. A community association combining individual unit ownership with shared use or ownership of common property or facilities, established in accordance with the requirements of the Condominium Ownership Act, Chapter 703 of the Wisconsin Statutes. A condominium is a legal form of ownership of real estate and not a specific building type or style.

2.3 Conservation easement. The grant of a property right or interest from the property owner to a unit of government or nonprofit conservation organization stipulating that the described land shall remain in its natural, scenic, open or wooded state, precluding future or additional development.

Wisconsin's law governing conservation easements is found at section 700.40 of the Wisconsin Statutes.

2.4 Conservation subdivision. A housing development in a rural setting that is characterized by compact lots and common open space, and where the natural features of the land are maintained to the greatest extent possible.

2.5 Development envelops. Areas within which grading, lawns, pavement and buildings will be located.

This definition is from Wisconsin "smart growth "law, Wis. Stat. § 66.1027(1) (a).

Ordinance Language	Commentary

2.6 **Gross acreage.** The total area of a parcel including the area of perimeter street rights-of-way to the center line of the street.

2.7 **Homeowners association.** A community association incorporated or not incorporated, combining individual home ownership with shared use or ownership of common property or facilities.

2.8 **Nonprofit conservation organization.** Any charitable corporation, charitable association or charitable trust (such as a land trust), the purposes or powers of which include retaining or protecting the natural, scenic or open space values of real property, assuring the availability of real property for agricultural, forest, recreational or open space use, protecting natural resources, maintaining or enhancing air or water quality, or preserving the historical, architectural, archaeological or cultural aspects of real property.

This definition is from Wisconsin's conservation easement law. Wis. Stat. § 700.40(1) (b)2.

2.9 **Parent parcel.** The existing parcel of record, as identified by individual tax parcel numbers, as of the effective date of this ordinance.

2.10 **Subdivider.** Any person, corporation, partnership, association, individual, firm, trust or agent dividing or proposing to divide land resulting in a conservation subdivision.

Ordinance Language | Commentary

3. Application Procedure and Approval Process

A similar application procedure and approval process should be required for all subdivisions in the community or it will be a disincentive for conservation subdivisions.

3.1 Initial Conference. Before submitting an application for a conservation subdivision, the subdivider shall schedule an appointment and meet with the [planning department, plan commission, other administrative staff] to discuss the procedure for approval of a conservation subdivision, including submittal requirements and design standards.

The basic purpose for the initial conference is to inform the applicant of the conservation subdivision approval procedures. The process outlined in this section is a collaborative process between the developer and the community which begins with this initial discussion. The community may also want to include staff from state agendas such as the Departments of Transportation and Natural Resources.

3.2 Initial Application. After the initial conference, the subdivider shall submit a series of maps and descriptive information to the [planning department, plan commission, other administrative staff] according to the following. Mapping for the initial application can be done in any combination of features as long as individual map components can be distinguished and the relationship between map components can be determined.

1. **Inventory and mapping of existing resources** including the following mapped at a scale of no less than one inch 50 feet:
   a. Topographic contours at 2-foot intervals.
   b. United States Department of Agriculture, Natural Resource Conservation Service soil type locations and identification of soil type characteristics such as agricultural capability, depth to bedrock and water table, and suitability for wastewater disposal systems. Type and stability of bedrock should also be noted, particularly in karst areas and areas with high potential for groundwater contamination due to fractured bedrock or the presence of arsenic and mercury.
   c. Hydrologic characteristics, including surface water bodies, floodplains, groundwater recharge and discharge areas, wetlands, natural swales, drainage ways, and steep slopes.
   d. Land cover on the site, according to general cover type (pasture, woodland, etc.), and stand-alone trees with a caliper of more than [24] inches measured four feet off the ground. The inventory shall include comments on the health and condition of the vegetation.
   f. Current and past land use, all buildings and structures on the land, cultivated areas, brownfields, waste sites, and history of waste disposal

The resource inventory identifies the land's features, including natural and cultural resources, scenic views, and other physical characteristics. The purpose of requiring the resource inventory is to ensure that the subdivision design takes into account the site's significant resources and to provide the plan commission with information to evaluate the subdivision's impact on those resources.

Communities with computerized land information systems may want to ask that the information be submitted in a digital format compatible with the local community's geographic information system.

practices, paved areas, and all encumbrances, such as easements or covenants.

g. Known critical habitat areas for rare, threatened or endangered species.

h. Views of the site, including views onto the site from surrounding roads, public areas and elevated areas, including photographs with a map indicating the location where the photographs were taken.

i. Unique geological resources, such as rock outcrops and glacial features.

j. Cultural resources: brief description of historic character of buildings and structures, historically important landscapes, and archeological features. This includes a review of existing inventories, including those the State Historical Society of Wisconsin maintains for historic buildings, archaeological sites, and burial sites.

2. Development yield analysis. The subdivider shall submit a table showing the maximum number of dwelling units that would be permitted under the [city, village, town, county] zoning ordinance, consistent with the minimum lot size, lot widths, set backs, and other provisions of the zoning ordinance and compare it to the number of dwelling units proposed. Land that is undevelopable because of other laws and ordinances that prohibit development in certain areas (e.g. floodplains, wetlands, steep slopes, and drainage ways) shall be excluded from the development yield analysis.

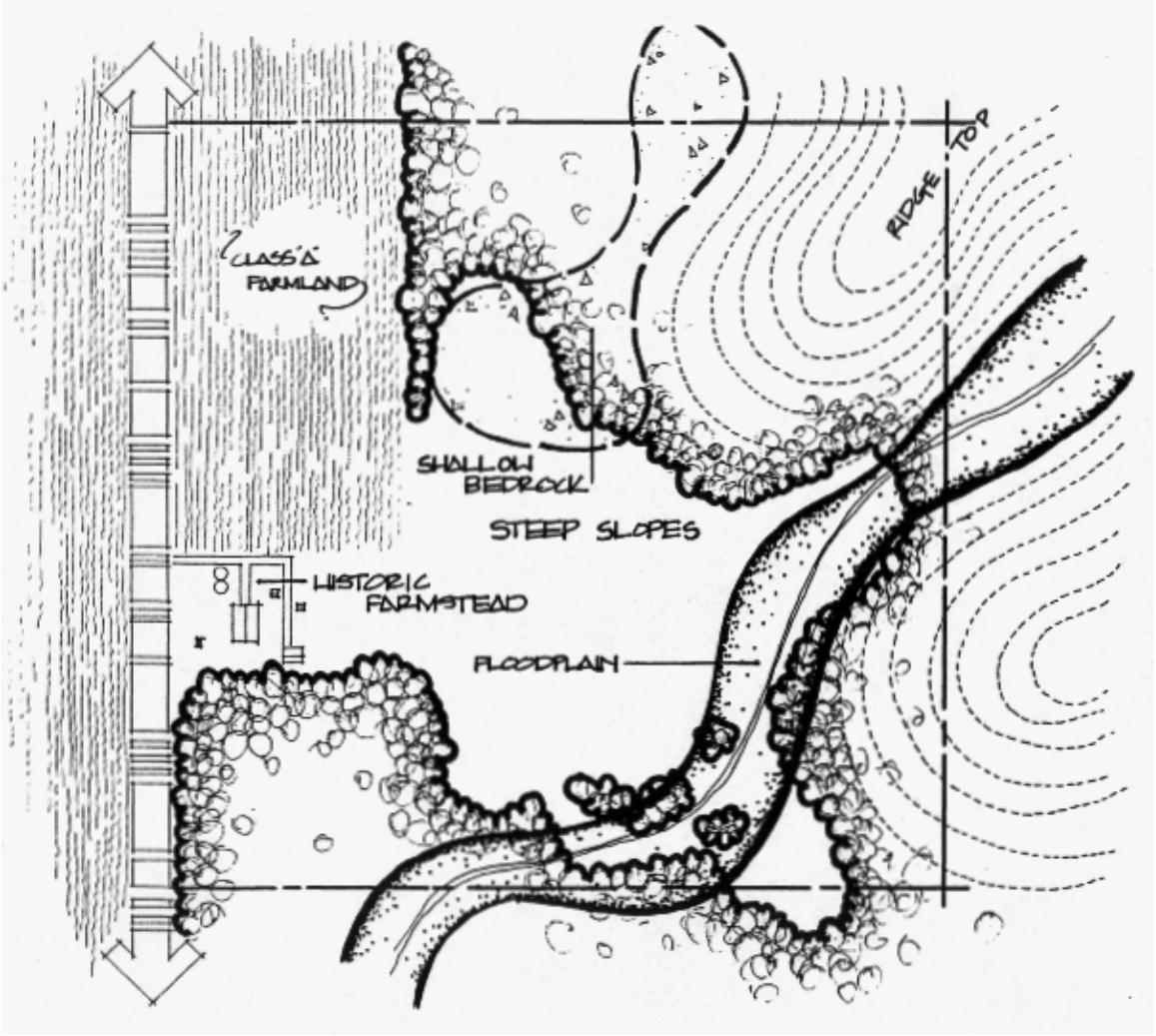
The development yield analysis shows the maximum number of dwelling units that would be permitted on a parcel under the applicable zoning ordinance. This analysis is used to ensure that conservation subdivisions are "development-neutral"--the number of units developed is the same as what would be permitted for conventional development.

3. Site analysis and concept plan. Using the inventory provided in section 3.2(1), the development yield analysis provided in section 3.2(2), and applying the design standards specified in section 4 of this ordinance, the subdivider shall submit a concept plan including at least the following information at a scale of no less than one inch = 50 feet:

a. Open space areas indicating which areas are to remain undeveloped and trail location.

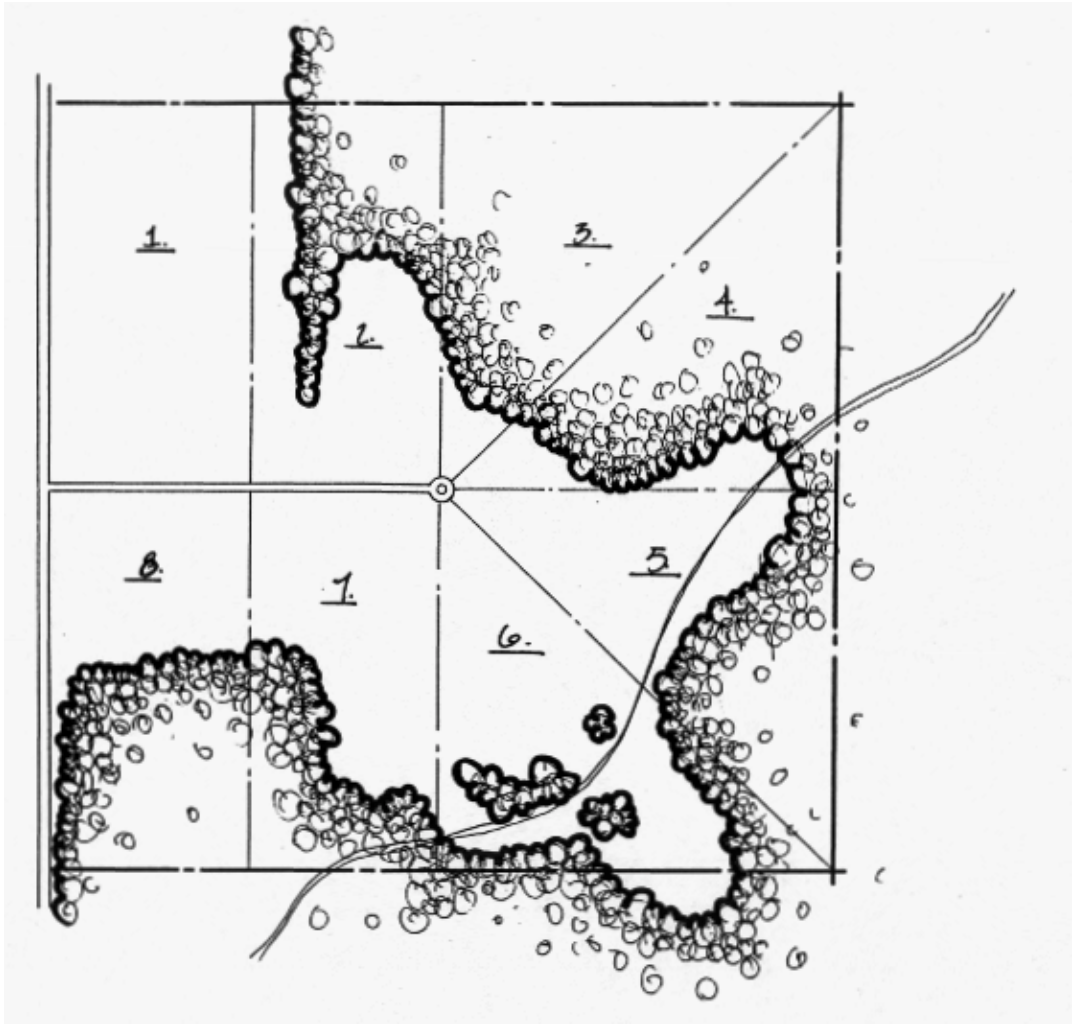
b. Boundaries of areas to be developed and proposed general street and lot layout.

c. Number and type (i.e., single-family, multi-family) of housing units proposed.



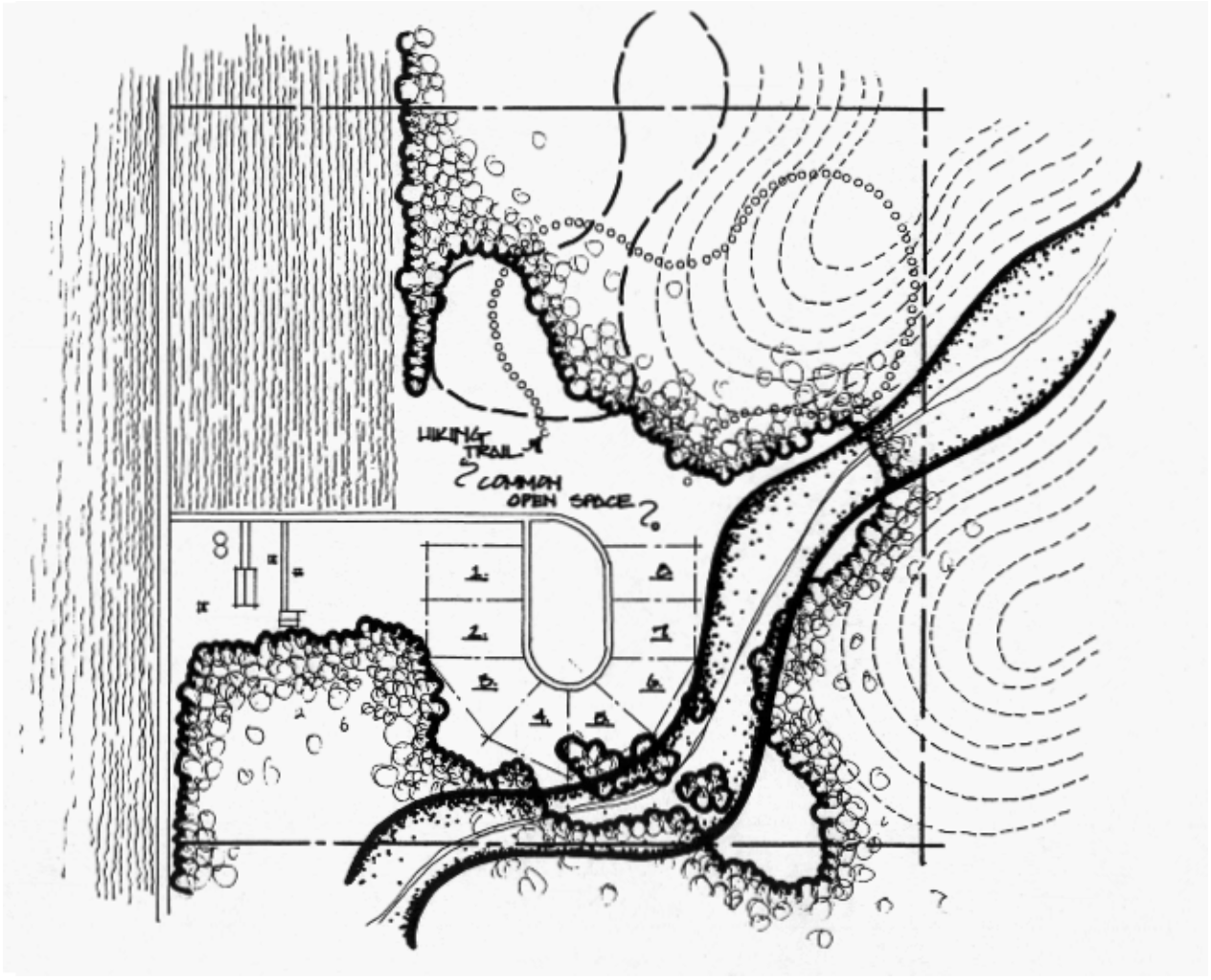
Step 1: *Inventory and mapping of existing resources for a hypothetical 40 acre site.*

Ordinance Language | Commentary



Step 2: *Development yield as permitted under existing ordinances (zoning, etc.) for the 40 acre site assuming a 5 acre minimum lot size zoning standard. 8 lots would be permitted under this scenario.*

Ordinance Language | Commentary



Step 3:

Concept map of the conservation subdivision showing the 8 lots that would be permitted, p/us the historic farmhouse, which would be preserved, for a total of 9 dwelling units.

Ordinance Language	Commentary

d. Proposed methods for and location of water supply, stormwater management (e.g., best management practices), and sewage treatment.
e. Inventory of preserved and disturbed natural features and prominent views.
f. Preliminary development envelops showing areas for lawns, pavement, buildings, and grading.
g. Proposed methods for ownership and management of open space.

It is important to know how surface drainage will be managed (e.g., swales, detention ponds, etc.) And how wastewater will be managed (e.g. individual on-site private systems--mounds, conventional, on-site cluster systems, or publicly owned wastewater treatment facility).

4. **General location map.** The subdivider shall submit a map showing the general outlines of existing buildings, land use, and natural features such as water bodies or wooded areas, roads and property boundaries within 500 feet of the tract. This information may be presented on an aerial photograph at a scale of no less than 1 inch: 400 feet.

3.3 **Review of Initial Application.** Within 30 days following the filing of a complete initial application the [planning department, plan commission, other administrative staff] shall meet with the subdivider to review the initial application. Staff from appropriate state agencies may also be requested by the [city, village, town, county] to review the application. The [planning department, plan commission, other administrative staff] shall make the determination of whether the initial application is complete. The [planning department, plan commission, other administrative staff] may also schedule a visit to the site with the subdivider to review the existing features of the site and the concept plan. The visit shall occur prior to or as part of the meeting. Within 30 days following the meeting, the [planning department, plan commission, other administrative staff] shall provide a written report informing the subdivider of any additions, changes, or corrections to the concept plan submitted as part of the initial application.

3.4 ***Preliminary Plat Review and Approval Procedures.*** *Following review and comment of the plan commission on the initial application, the subdivider or subdivider agent shall file an application for review and approval of the plan commission of a preliminary p/at with the [planning department, zoning administrator].*

The purpose of preliminary p/at approval is to enable the p/an commission to review all substantive aspects of the subdivision without forcing the developer to prepare a final set of p/at maps which will then be expensive to change. Preliminary plats are not required by state law.

Ordinance Language	Commentary
1. ***Referral.*** *Administrative staff and utility commission reviews. The [planning department, zoning administrator] shall provide copies of the preliminary p/at to [city, village, town, county] department heads, to the appropriate objecting agencies under Wis. Stat. § 236.12, and to the appropriate utilities for their review and comment. The [city, village, town, county] staff and utility comments will be forwarded to the plan commission and [governing body] for consideration during the review process.*	
2. ***Plan commission recommendation****. After review of the preliminary p/at and negotiations with the subdivider on changes and the kind and extent of public improvements that will be required, the plan commission shall recommend to the [governing body] disapproval, approval, or conditional approval of the preliminary p/at within 60 days of the filing date.*	
3. ***Public hearing.*** *The [planning department, zoning administrator] shall schedule a public hearing on the preliminary plat before the [plan commission, governing body]. The [planning department, zoning administrator] shall give notice of the [governing body's] review and public hearing on the preliminary p/at by listing it as an agenda item in the [governing body]'s meeting notice published in the official local government newspaper. The notice shall include the name of the applicant, the address of the property in question, and the requested action. Property owners within 200 feet of the proposed land division shall receive written notice of the public hearing.*	*Though not required by statute, it is important to hold a public hearing at the preliminary plat stage to ensure broader participation by citizens and other interested agencies.*
4. ***Board action.*** *After receipt of the plan commission's recommendation, the [governing body] shall, within 90 days of the date the p/at was filed with the [planning department, zoning administrator], approve, approve conditionally, or reject such p/at and shall state, in writing, conditions of approval or reasons for rejection, unless the time is extended by agreement with the subdivider. Failure of the [governing body] to act within 90 days or extension thereof shall constitute an approval of the preliminary p/at, unless other authorized agencies object to the p/at. The [planning department, zoning administrator] shall communicate to the subdivider the action of the village board. If the preliminary p/at is approved, the*	*The local governing body could also authorize the plan commission to take final action on the preliminary plat without referring it to the governing body.*

Ordinance Language | Commentary

[planning department, zoning administrator] shall endorse it for the [governing body].

5. ***Effect of approval.*** *Approval of a preliminary p/at shall be valid for six months from the date of approval. Approval or conditional approval of a preliminary p/at shall not constitute automatic approval of the final p/at. The preliminary p/at shall be deemed an expression of approval or conditional approval of the layout submitted as a guide to the preparation of the final p/at, which will be subject to further consideration by the plan commission and [governing body] at the time of its submission.*

6. ***Amendment.*** If the subdivider desires to amend the preliminary p/at as approved, the subdivider may resubmit the amended plat, which shall follow *the same procedure, except for the fee, unless the amendment is, in the opinion of the [plan commission, governing body], of such scope as to constitute a new p/at, in which case it shall be refiled.*

To eliminate uncertainties surrounding submission requirements for the preliminary plat, this subsection sets out the specific items that the applicant must submit to the government.

3.5 ***Preliminary Plat Requirements****. The preliminary p/at shall be prepared by a licensed land surveyor or engineer at a convenient scale not less than one (1) inch equals one hundred (100) feet. More than one (1) sheet may be used to present the information required in this section and shall include the following:*

To eliminate uncertainties surrounding submission requirements for the preliminary plat, this subsection sets out the specific items that the applicant must submit to the government.

1. ***Name of the Proposed Subdivision.*** *The proposed name of the subdivision shall not duplicate or be alike in pronunciation of the name of any p/at previously recorded in the County.*

2. ***Project Ownership and Development Information.***
   a. *Name, address, and telephone number of the legal owner and, if applicable, agent of the property.*
   b. *Name, address, and telephone number of the professional person(s) responsible for subdivision design, for the design of public improvements, and for surveys.*
   c. *Date of preparation.*

3. Existing Site Conditions. Provide this information on a property survey map.

a. Boundary line of the proposed site and all property to be subdivided. Include all contiguous land owned or controlled by the subdivider.

b. Location, width, and names of all existing platted streets and rights-of-way to a distance of 100 feet beyond the site.

c. Show the type, width and condition of street improvements; railroad or major utility rights-of-way; parks and other public open spaces; location and widths of existing snowmobile or other recreation trails; and permanent buildings and structures to a distance of 100 feet beyond the site, if any.

d. Location, widths, and names of all existing public and private easements to a distance of 100 feet beyond the site.

e. Identify by name and ownership boundary lines of all adjoining lands within 100 feet of the proposed plat.

f. Topographic data including contours at vertical intervals of not more than 2 feet. Elevation values shall be based on the National Geodetic Vertical Datum of 1929 (NGVD 29) or the North American Datum of 1988 (NAVD 88) or future adjustments to NAVD 88 as defined by the National Geodetic Survey and should also be so noted on the plat.

g. Significant natural resource features on the site, i.e. wetlands, floodplains, watercourses, existing wooded areas, steep slopes, drainage ways, rare, threatened and endangered species, and other natural resource features, views and other prominent visual features.

h. Burial sites categorized under Wis. Stat. § 157.70, Indian mounds, national and state register listed properties, and locally designated historic properties.

i. Existing soil classifications, including hydric soils.

j. Legal description of the property.

k. Existing zoning classifications for land in and abutting the subdivision.

1. Total acreage of the proposed site.

m. Provide graphic scale, north arrow, and date.

4. **Subdivision Design Features.** Provide this information on the Preliminary Plat.
   a. Layout of proposed streets, showing right-of-way widths, types of improvements, street surface widths, and proposed street names.
   b. Locations and type of proposed public easements (i.e. drainage, utility, pedestrian, public access to waterways, etc.); and all conservation easements.
   c. Layout of proposed blocks and lots within the plat.
   d. Basic data regarding proposed and existing (if applicable) lots and blocks, including numbers, dimensions, area.
   e. Minimum front, side and rear yard building setback lines for all lots.
   f. Indication of the use of any lot.
   g. Location and size of all proposed and existing sanitary sewer lines and water mains, proposed community sewer and water system, or individual on-site septic systems and potable water sources.
   h. Location and size of all proposed and existing storms sewers (lines, drain inlets, manholes), culverts, retention ponds, swales, infiltration practices and areas, and other stormwater facilities within the plat and to a distance of 100 feet beyond the site.
   i. Development envelopes showing areas for grading, lawns, pavement and buildings.
   j. Open space areas, other than pedestrian ways and utility easements, intended to be dedicated or reserved for public use, including the size of such area or areas in acres. Provide information on the conditions, if any, of the dedication or reservation.
   k. Management plan for restoration and long-term management of the open space areas.

5. Preliminary Construction Plans. Provide information on one or more sheets.
   a. Plan and Profile. Proposed street centerline profile grades, showing the existing and proposed profile grade lines.
   b. Grading and Erosion Control Plan. A plan showing existing and proposed grades, drainage patterns, and stormwater facilities. The plan

shall show the location and extent of grading activities in and adjacent to the plat, overall area of the site in acres, total impervious surface area of project, total pervious area, stockpile locations, erosion and sediment control facilities, and a schedule for erosion and sediment control practices including site specific requirements to prevent erosion at the source. Major trees to be preserved, with a diameter of [24] inches or more measured twelve (12) inches above ground level, shall be shown on the preliminary grading and erosion control plan. Adequate measures for protecting major trees shall be shown on the plan.

c. Provisions for sewage disposal, water supply, stormwater management, and flood control.

3.6 Final Plat Review and Approval Procedures. *A final subdivision p/at shall be filed in accordance with the following:*

1. Final Plat. *The subdivider shall prepare a final p/at and a letter of application in accordance with this ordinance and shall /fi/e 20 copies of the p/at and the application with the [planning department, zoning administrator] at least 21 days prior to the meeting of the plan commission at which action is desired. The owner or subdivider shall file the final p/at not later than six months after the date of approval of the preliminary plat; otherwise, the preliminary plat and final plat will be considered void unless an extension is requested in writing by the subdivider and for good cause granted by the [city, village, town, county]. The subdivider or subdivider's agent shall also submit at this time a current certified abstract of title or such other evidence as the [city, village, town, county] may require showing ownership or control in the applicant.*

2. Objecting Agencies. *The subdivider or the subdivider's agent shall submit the original plat to the Plat Review Section, Wisconsin Department of Administration, which shall forward two copies to each of the agencies authorized to object under section 236.12(2) of the Wisconsin Statutes. The department shall have the required number of copies made at the subdivider's expense.*

Review by the "objecting agencies is required under the original p/at to the Plat Review Section, Wisconsin Department of Chapter 236 of the Wisconsin Statutes.

3. ***Final Construction Plans.*** *Simultaneously with the filing of the final p/at, the owner shall file with the [planning department, zoning administrator] four copies of the final construction plans and specifications of public improvements required by the [city, village, town, county/.*

4. ***Installation, Protection and Maintenance Plans.*** *The subdivider shall also submit plans for areas to be protected and/or introduced native vegetation.*

5. ***Referral of Final Plat.*** *The [planning department, zoning administrator] shall provide copies of the final p/at to [city, village, town, county] department heads and to the appropriate utilities for their review and comment. The [city, village, town, county] staff and utility comments will be forwarded to the p/an commission and [governing body] for their consideration during the review process.*

6. ***Plan commission review.*** *The p/an commission shall examine the final plat as to its conformance with the preliminary p/at; any conditions of approval of the preliminary p/at; this chapter; and all applicable ordinances, rules, regulations, and comprehensive plan elements that may affect it and shall recommend approval, conditional approval, or rejection of the p/at to the [governing body].*
   a. *The p/an commission shall, within 30 days of the date of filing of the final p/at with the [planning department, zoning administrator], recommend approval, conditional approval, or rejection of the p/at and shall transmit the final p/at and application along with its recommendations to the [governing body]. The plan commission may hold the matter in abeyance if there is incomplete or inadequate information.*

7. ***[Governing body] review and approval.*** *The [governing body] shall, within 60 days of the date of filing the original final p/at with the [planning department, zoning administrator], approve or reject such plat unless the time is extended by agreement with the subdivider. If the plat is rejected, the reasons shall be stated in the minutes of the meeting and a written*

Chapter 236 of the Wisconsin Statutes also allow the governing body to delegate final plat approval to the plan commission.

statement of the reasons forwarded to the subdivider. The [governing body] may not inscribe its approval on the final p/at unless the [planning department, zoning administrator] certifies on the face of the p/at that the copies were forwarded to objecting agencies as required in this section, the date thereof and that no objections have been filed within 20 days or, if *filed, have been met.*

a. The [governing body] shall, when it determines to approve a final p/at, give at least ten days' prior written notice of its intention to the municipal clerk of any municipality within 1,000 feet of the final p/at.

b. If the [governing body] fails to act within 60 days, without a time extension and no unsatisfied objections having been filed, the p/at shall be deemed approved.

c. Recordation. After the final p/at has been approved by the [governing body] and required improvements either installed or a contract and sureties ensuring their installation is filed, the [planning department, zoning administrator] shall cause the certificate inscribed upon the p/at attesting to such approval to be duly executed and the p/at returned to the subdivider for recording with the county register of deeds along with all conservation easements and deed restrictions. The register of deeds cannot record the p/at unless it is offered within six months from the date of last approval.

d. Copies. The subdivider shall file eight copies of the final p/at with the [planning department, zoning administrator] for distribution to the approving agencies, affected sanitary districts, and other affected agencies for their files.

The Wisconsin Department of Transportation should receive a copy of the final p/at if the property is adjacent to a state trunk highway.

***3.7 Final Plat Requirements**. A final p/at prepared by a registered land surveyor shall be required for all subdivisions. It shall comply with the requirements of Wis. Stats. § 236.20 and this ordinance.*

1. Additional information. The final p/at shall show correctly on its face, in addition to the information required by Wis. Stats. § 236.20, the following:

a. Exact length and bearing of the centerline of all streets.

b. Exact street width along the line of any obliquely intersecting street.
c. Exact location and description of utility and drainage easements.
d. Railroad rights-of-way within and abutting the p/at.
e. All lands reserved for future public acquisition or reserved for the common use of property owners within the p/at, including public access to waterways.
f Restrictions relating to access control along public ways.
g. Setback or building lines.
h. Restrictive covenants, deed restrictions, conservation easements for *the proposed subdivision shall be filed with the final p/at.*
i. The legal instruments detailing the ownership of the common open space, as required in section *5,* which shall be filed with the final plat.
j. All final plats shall meet all the surveying and monumenting requirements of section 236.15 of the Wisconsin Statutes.
k State plane coordinate system. Where the p/at is located within a quarter section, the corners of which have been relocated, monumented, and coordinated by the [city, village, town, county], the p/at shall be tied directly to one of the section or quarter corners so relocated, monumented, and coordinated. The exact grid bearing and distance of such tie shall be determined by field measurements, and the material and state plane coordinates of the monument marking the relocated section or quarter corner to which the p/at is tied shall be indicated on the p/at.
1. Certificates. All final plats shall provide all the certificates required by section 236.21 of the Wisconsin Statutes. In addition, the surveyor shall certify that the surveyor has fully complied with all sections of this chapter.
m. Recording. The final p/at shall be recorded within 30 days of its approval by the [name of governing body].

3.8 Certified Survey Maps. Conservation subdivisions shall not be created by certified survey maps under section 236.34 of the Wisconsin Statutes.

Certified survey maps could be used if the same process and analysis of this ordinance is used.

4. Requirements for Design and Improvements

4.1 Land Suitability. No land shall be developed which is held to be unsuitable for any proposed use if identified as being environmentally sensitive. Areas identified as being environmentally sensitive include, but are not limited to:

1. All areas mapped as Floodplain by the Federal Emergency Management Agency (FEMA), Wisconsin Department of Natural Resources, or other public or private entity.
2. All wetlands as defined in NR 103.02(5) of the Wisconsin Administrative Code, including a *[75]* foot buffer.
3. All areas within *[75]* feet of the ordinary high-water mark of navigable streams and lakes, as identified by Wisconsin Department of Natural Resources Water Management Specialists.
4. All areas having slopes greater than [12] percent.
5. Areas that are known to provide habitat for rare, threatened or endangered species.
6. Burial sites and Indian mounds.
7. Drainage ways that contain running water during spring runoff, during storm events or when it rains. A [25] foot buffer from the edge of the drainage way shall be included.

These are areas where development is normally prohibited under conventional ordinances. Local ordinances that prohibit development in certain areas (such as floodplain, shore/and zoning, and wetland ordinances) should be cited in this section of the ordinance. Communities especially interested in the goal of protecting significant natural resources may choose to add to this fist of areas that should not be developed.

Not all counties use the 75 foot setback. Some counties have established more stringent set back provisions.

Protection of steep slopes is a local choke. In communities that prohibit development on steep slopes, the percent of slope protected ranges from 1 to 25 percent.

Areas determined to be environmentally sensitive may be included as common open space in a conservation subdivision but shall not be included in the development yield analysis in section 3.2. These lands shall be identified as an outlot or other designation that indicates the land is not available for development.

4.2 Development Yield. The number of residential units for a parcel shall be determined in accordance with the following:

1. The development yield analysis in section 3.2 shall establish the base development yield for the parcel.
2. The base development yield may be increased if the development complies with one or more of the following standards. Each standard provides a

The purpose behind development bonuses is to provide an incentive for achieving certain public policies objectives.

development yield bonus of [5]% in addition to the base development yield. The maximum bonus permitted is [20%].

a. Creating an endowment where the principal would generate sufficient annual interest to cover the conservation easement holder's yearly costs (taxes, insurance, maintenance, enforcement, etc.).
b. Providing for access by the general public to trails, parks, or other recreational facilities, excluding golf courses.
c. Providing affordable housing, to include a minimum of[25] percent of all units that would be affordable to moderate-income households, as defined by the U.S. Department of Housing and Urban Development.
d. Reusing historical buildings and structures, including those sites inventoried by the State Historical Society of Wisconsin. The U.S. Secretary of the Interior's Standards for Rehabilitation of Historic Properties shall apply.

Affordable housing needs should be addressed in the context of the housing element of the local government's comprehensive p/an

4.3 Performance Standards

1. General considerations

a. Conservation subdivisions shall identify a conservation theme or themes. This theme shall be identified at the time of the initial application. Conservation themes may include, but are not limited to, forest stewardship, water quality preservation, farmland preservation, natural habitat restoration, viewshed preservation, or archaeological and historic properties preservation. The plan commission shall have the ability to specify which areas shall be preserved.
b. The residential lot shall be large enough to accommodate a house and two car garage.

The goals of any conservation subdivision ordinance will likely differ in each jurisdiction and may differ from development to development.

2. Residential Lot Requirements

a. Minimum Lot Size
- Septic on-site: [1] acre.
- Septic off-lot: [1/4 acre].

b. Principal Building Setbacks
- Front lot line: [30] feet

The dimensions used here are one set. Other dimensions may be more appropriate for other communities.

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- Side lot line: [10] feet
- Rear lot line: [20] feet

c. Accessory Building Setbacks
- Side lot line: [15] feet
- Rear lot line: [10] feet

d. Lots shall be configured to minimize the amount of impervious surfaces. Maximum Lot Coverage: *[35]%* (includes buildings and other impervious surfaces).

e. Maximum Building Height: [35] feet

f. Most lots shall take access from interior local streets. Existing farmsteads to be preserved will have a driveway as part of the historic landscape that does not access a local street but should be preserved.

g. Lots shall be configured to minimize the amount of road length required for the subdivision.

h. Development envelopes shall be configured to minimize loss of woodlands.

i. If agricultural uses are being maintained, lots shall be configured in a manner that maximizes the usable area remaining for such agricultural uses with appropriate buffers between agricultural uses and residential structures.

j. All lots within a neighborhood shall abut open space on at least one side. A local street may separate lots from the open space.

k. Lots shall be oriented around one or more of the following:

i. A central green or square.

ii. A physical amenity such as a meadow, a stand of trees, or some other natural or restored feature.

1. Development envelopes should not be located on ridges, hilltops, along peripheral public roads or in other visually prominent areas.

m. Residential structures shall be oriented to maximize solar gain in the winter months.

n. A 30 foot native vegetation buffer shall be maintained around open water areas, unless a specific common beach or grassed area is identified.

o. Stormwater management [BMIPs]

i. Minimize the use of curb and gutter and maximize the use of open swales.

ii. Roof down spouts should drain to porous surfaces.

iii. Peak discharges during the 2 and 10 year storm events shall be no more than predeveloped conditions.

iv. The development should capture 80% of the sediments/pollutants from the 1 year storm event.

The challenge of providing standards is to foster creative design and protect key resources without "strait jacketing" the developer with too many requirements.

v. Landscape plantings should be used to increase infiltration and decrease runoff.
vi. Natural open drainage systems shall be preserved.

3. Residential Cluster Siting Standards

a. All residential lots and dwellings shall be grouped into clusters. Each cluster shall contain no more than [20] dwelling units and no less than [5] units.
b. Residential clusters shall be located to minimize negative impacts on the natural, scenic and cultural resources of the site and conflicts between incompatible uses.
c. Residential clusters shall avoid encroaching on rare plant communities, high quality sites, or endangered species identified by the Department of Natural Resources.
d. Whenever possible, open space shall connect with existing or potential open space lands on adjoining parcels and local or regional recreational trails.
e. Residential clusters should be sited to achieve the following goals, to the extent practicable.
   i. Minimize impacts to prime farmland soils and large tracts of land in agricultural use, and avoid interference with normal agricultural practices.
   ii. Minimize disturbance to woodlands, wetlands, grasslands, and mature trees.
   iii. Prevent downstream impacts due to runoff through adequate on-site storm water management practices.
   iv. Protect scenic views of open land from adjacent roads. Visual impact should be minimized through use of landscaping or other features.
   v. Protect archaeological sites and existing historic buildings or incorporate them through adaptive reuse.
f. Landscaping around the cluster may be necessary to reduce off site views of residences.

The ordinance should set a maximum number of lots that can be grouped/n a "cluster" to ensure development of a compact neighborhood of a manageable size.

4. Open Space Design

a. Common Open Space. The minimum open space required shall be owned and maintained under one of the alternatives listed in section 5, as approved by the [city, village, town, county]. The uses within the open space shall be accessible to the residents of the development. These uses may also be available to the general public providing the proper approvals are received. The required open

Ordinance Language	Commentary
space shall be undivided and restricted in perpetuity from future development, as specified in Section 5.	
b. Open space shall be designated as part of the development. The minimum required open space is 60 % of the gross acreage.	
c. Open Space Conservation Ranking (in order of significance). The areas to be preserved shall be identified on a case-by-case basis in an effort to conserve and provide the best opportunities to restore and enlarge the best quality natural features of each particular site.	
i. First priority will be given to intact natural communities, rare and endangered species, environmental corridors, natural and restored prairies, significant historic and archaeological properties, and steep slopes.	*The ordinance should prioritize which resources the community seeks to protect. With the except/on of resources protected by federal and state regulations, this is largely a local decision.*
ii. Second priority will be given to areas providing some plant and wildlife habitat and open space values.	
iii. Third priority will be given to areas providing little habitat but providing viewshed, recreation, or a sense of open space.	
d. The following areas or structures may be located within the open space area and shall be counted toward the overall open space percentage required:	
i. parking areas for access to and use of the open space developed at a scale limited to the potential users of the open space.	*Some impact on resources is probably unavoidable. The objective is to fry to minimize those impacts.*
ii. privately-held buildings or structures provided they are accessory to the use of the open space.	
iii. Shared septic systems and shared potable water systems.	
e. Road rights of way shall not be counted towards the required minimum open space.	
f No more than 50 percent of the required open space may consist of water bodies, ponds, floodplain, or wetlands.	
g. That portion of open space designed to provide plant and animal habitat shall be kept as intact as possible. Trails shall be designed to avoid fragmenting these areas.	*The calculation of open space should not include the acreage of existing natural waterways. The existing open waterways are protected under the Public Trust Doctrine and would be open space regardless if a p/at was developed or not. The open space should be located adjacent to existing natural waterways and include floodplain, wetlands, and uplands.*
h. Accessible open space in upland areas shall be available for recreational uses such as trails, play fields, or community gardens but should be designed in a manner that avoids adversely impacting archeological sites.	
i. A pathway system connecting open space areas accessible to neighborhood residents, and connecting these areas to neighborhood streets and to planned or	

developed trails on adjacent parcels shall be identified in the plan.

5. **Street Standards**

a. Neighborhood streets may take the form of a two-way street, a pair of one-way streets on either side of a landscaped median, or a one-way loop street around a small neighborhood green. Streets shall be developed according to the following standards that promote road safety, assure adequate access for fire and rescue vehicles, and promote adequate vehicular circulation:

b. The applicant must demonstrate that access to the development has the capacity to handle traffic generated by the proposed project, and will not endanger the safety of the general public.

c. Streets shall have the following design standards:

   i. Right-of-way widths. The right-of-way width for each road shall be wide enough to provide for all public services, including roadway drainage, sidewalks, trails, and walkways, utilities, and snow storage. The minimum right-of-way shall be provided in accordance with the following:

Right-of-Way	ADT less than 250	ADT over 250
One-way roadway	20’	30’
Two-way roadway	40’	50’

   ii. Travel land widths for local roads shall be determined by the expected average daily traffic (ADT) and shall be within the following ranges:

Travel Lanes	ADT < 100	100-250 ADT	>250
Two-way roadway*	18’-24’	20’-26’	22’-28’
One-way roadway*	11’-13’	11’-13’	11’-14’
(curbed sections**)	13’	13’	13’
Shoulder or gutter Pan width	2’-4’	2’ – 4’	2’ – 4’

*Does not include shoulder or gutter pan.

**Measured from curb face to curb face.

This subsection discusses subdivision street standards. The design standards included in this subsection are merely one alternative. The transportation element of a local comprehensive plan should help each community define its own standards for the design of streets and how streets within the conservation subdivision conned to the local and regional roadway system.

Street widths and alignments should be carefully scaled to neighborhood size. The goal of a compact, pedestrian-friendly neighborhood can be undermined if the typically wider road and right-of-way standards of conventional suburban development are used. Wide streets can also contribute to stormwater runoff problems. The ordinance provides a range of right-of-way and roadway dimensions, depending on the expected levels of daily traffic.

In calculating average daily traffic (ADT), traffic engineers assume that a single-family detached house generates about 10 (one-way) vehicle trips per day, with lower numbers for attached and multi-family dwellings.

d. Additional Standards:
   i. Design Speed: Maximum 25 miles per hour.
   ii. Vertical Curves: Minimum 50’ (when grade difference less than 1%, no curve is needed).
   iii. Horizontal Curves: Minimum radius of 125’
   iv. Road Grades: Maximum grade 8%
   v. Super-elevation: Maximum e= 0.04 feet/feet
   vi. Pavement Strength: 7 ton minimum
   viii. Clear Zones:
      - Shoulder sections: 10’ from edge of travel lane
      - Curbed sections: 2’ from face of curb

   ix. Bridges: Width shall be traveled way, plus 2’ each side. Design Loading for Structural Capacity HS-20, plus 5’ sidewalk necessary to maintain pedestrian crossing.
   x. Cul-de-sacs should be designed as semi-circular and circular loop roads. Minimum 30’ outside radius around a landscaped island with an minimum 10’ radius. Open space internal to these road features can be counted toward the open space requirements.
   xi. Sidewalks, trails, and other walkways. Minimum 5 feet width.

e. If determined necessary by the [zoning administrator, planning department] shade trees shall be planted on both sides of the street.
f. Street connections to adjacent parcels shall be provided in logical locations to avoid creating landlocked parcels and provide for connecting street patterns.
g. Streets that serve as collectors, interconnecting subdivisions and other major traffic generators, shall be designed according to the [city/village/town/county]’ s standards for collector roads.
h. Where streets will connect with streets having differing standards, the street dimensions shall be the same as those of the connecting street. All street widenings shall occur at the nearest intersection.
i. The developed area should have sidewalks on at least one side of the street.

6. Sewage and Water Facilities

a. Water for a conservation subdivision shall be provided by individual on-site wells or by one or more community wells meeting the permit requirements of the State of Wisconsin and the [city, village, town, county]. The use of shared or community wells is encouraged. Plans for shared or community wells should include a wellhead protection plan with separation distances for the zone of influence and sources of pollution.

Water and sewer facilities should be developed consistent with the local community's utilities and community facilities element of its comprehensive plan.

b. All conservation subdivisions shall be provided with adequate sewage treatment facilities meeting the standards of the [city, village, town, county] and the permit requirements of the Wisconsin Department of Commerce and the Department of Natural Resources. Where sewage treatment is not provided by a publicly owned wastewater treatment works, a common sewage treatment and disposal unit located on the common open space lands is encouraged.

The ability to use shared or community wells rather than individual ones is one advantage of conservation subdivisions. Community wells can be sited in the most suitable locations on each parcel, with maximum separation from wastewater disposal treatment facilities. This feature is especially beneficial in areas where groundwater is highly sensitive to contamination.

4.4 Financial Guarantee. *A financial guarantee ensuring the construction and completion of the common facilities shall be submitted to the [planning department, zoning administrator].*

Ordinance Language | Commentary

5. Ownership and Maintenance of Open Space and Common Facilities

This section outlines the options available for ownership and maintenance of the common open space.

5.1 **Alternatives.** The designated common open space and common facilities may be owned
and managed by one or a combination of the following:

1. A homeowners' association.
2. A condominium association established in accordance with the Condominium Ownership Act, Chapter 703 of the Wisconsin Statutes.
3. A nonprofit conservation organization.
4. The [name of city, village, town, county] or another governmental body empowered to hold an interest in real property.
5. An individual who will use the land for open space purposes as provided by a conservation easement.

5.2 **Homeowners' Association.** A homeowners association shall be established if the common open space is proposed to be owned by a homeowners association. Membership in the association is mandatory for all purchasers of homes in the development and their successors.

A typical ownership option is a homeowners association. This method gives the residents the greatest degree of control over the use and management of common open space.

The homeowners' association bylaws, guaranteeing continuing maintenance of the open space and other common facilities, and the declaration of covenants, conditions and restrictions of the homeowners association shall be submitted for approval to the [name of city, village, town or county] as part of the information required for the preliminary plat. The homeowners' association bylaws or the declaration of covenants, conditions and restrictions of the homeowners association shall contain the following information:

A homeowners' association is a formally constituted non-profit corporation made up of the property owners and/or residents of the development for the purpose of owning and maintaining the common open space and facilities. This section of the ordinance describes provisions required to be included in the homeowners' association documents which must be submitted to the local government for review and approval.

1. The legal description of the common land;
2. A description of common facilities;
3. The restrictions placed upon the use and enjoyment of the lands or facilities;
4. Persons or entities entitled to enforce the restrictions;
5. A mechanism to assess and enforce the common expenses for the land or facilities including upkeep and maintenance expenses, real estate taxes and insurance premiums;

6. A mechanism for resolving disputes among the owners or association members;
7. The conditions and timing of the transfer of ownership and control of land facilities to the association;
8. Any other matter the developer deems appropriate.

5.3 Condominium Associations. If the common open space and facilities is to be held under the Condominium Ownership Act, Chapter 703 of the Wisconsin Statutes, the condominium instruments shall identify the restrictions placed upon the use and enjoyment of the common open space. All common open space shall be held as a "common element" as defined in section 703.0 1(2) of the Wisconsin Statutes.

The State Historical Society of Wisconsin can accept a historic preservation easement on properties listed or determined eligible for the state and national registers of historic p/aces.

5.4 A Nonprofit Conservation Organization. If the common open space is to be held by a nonprofit conservation organization, the organization must be acceptable to the [city, village, town, county]. The conveyance to the nonprofit conservation organization must contain appropriate provisions for reversion in the event that the organization becomes unwilling or unable to uphold the terms of the conveyance.

5.5 Public Dedication of Open Space and Streets.

1. The [city, village, town, county] may accept the dedication of fee title or dedication of a conservation easement to the common open space. The [city, village, town, county] may accept the common open space provided:
   a. The common open space is accessible to the residents of the [city, village, town, county];
   b. The [city, village, town, county] agrees to and has access to maintain the common open space.
3. Streets or other public ways which have been designated on a duly adopted official map or element of the [city, village, town, county] comprehensive plan shall be dedicated or reserved by the subdivider to the [city, village, town, county]. The street or public way shall be made a part of the plat in the locations and dimensions indicated in the comprehensive plan and as set forth in this ordinance.

This pro vision, for example, would allow a farmer to continue farming a parcel of land which the use of that parcel for other purposes is limited by the conservation easement.

5.6.1 Individual Ownership. An individual may hold fee title to the land while a nonprofit or other qualified organization holds a conservation easement uses for the common open space.

5.7 Maintenance Plan. Every conservation subdivision must include a plan that provides evidence of a means to properly manage the common open space in perpetuity and evidence of the long-term means to properly manage and maintain all common facilities, including any storm water facilities. The plan shall be approved by, the [governing body, plan commission] prior to final plat approval.

1. The plan shall do the following:
   a. Designate the ownership of the open space and common facilities in accordance with section *5.1.*
   b. Establish necessary regular and periodic operation and maintenance responsibilities.
   c. Estimate staffing needs, insurance requirements, and other associated costs and define the means for funding the same on an on-going basis.
   d. Include a land stewardship plan specifically focusing on the long-term management of common open space lands. The land stewardship plan shall include a narrative, based on the site analysis required in section 3.2, describing:

i. Existing conditions including all natural, cultural, historic, and scenic elements in the landscape.

ii. The proposed end state for each common open space area; and the measures proposed for achieving the end state.

iii. Proposed restoration measures, including: Measures for correcting increasingly destructive conditions, such as erosion; and measures for restoring historic features
and habitats or ecosystems.

iv. The operations needed for maintaining the stability of the resources, including: mowing schedules; weed control; planting schedules; clearing and cleanup; at the [city, village, town county]’s discretion, the applicant may be required to place in escrow sufficient funds for the maintenance and operation

Ordinance Language	Commentary
costs of common facilities for a maximum of one year. 2. In the event that the organization established to own and maintain the open space and common facilities, or any successor organization, fails to maintain all or any portion of upon the residents and owners of the open space and common facilities, setting forth the manner in which the organization has failed to maintain the common facilities in reasonable condition. Such notice shall set forth the nature of corrections required and the time within which the corrections shall be made. Upon failure to comply within the time specified, the organization, or any successor organization, shall be considered in violation this Ordinance, in which case the bond, if any, may be forfeited, and any permits may be revoked or suspended. The [city, village, town, county] may enter the premises and take corrective action. a. The costs of corrective action by the [city, village, town, county] shall be assessed ratably, in accordance with tax assessments, against the properties that have the right of enjoyment of the common facilities and shall become a lien on said properties. The [city, village, town, county], at the time of entering upon such common facilities for the purpose of maintenance, shall file a notice of such lien in the office of the County Register of Deeds upon the properties affected by such lien. 3. Management plans can be amended by the owner identified under section *5.1* with the approval of the [plan commission, governing body].	the common facilities in reasonable order and conditio

Appendix D

Town of Franklin, Massachusetts
Best Management Practices Manual

Town of

Franklin





Best Development Practices



Guidebook

Version 1, November 2001

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Introduction

The Franklin Best Development Practices Guidebook (BDP Guidebook) is a set of guidelines for developers, designers and project reviewers intended to improve the quality of development in Franklin. The Guidebook describes the required and preferred design and construction practices in Franklin related to stormwater management, erosion and sedimentation control, landscape design, and site planning. **Any project proposed in Franklin that requires Planning Board or Zoning Board of Appeals (ZBA) approval shall comply with the requirements of this Guidebook.**

None of the practices in the Guidebook are new, and many have already been used extensively in Massachusetts. The Guidebook codifies these practices as official Town policy, thus taking some of the "guesswork" out of project design and review. The Guidebook also provides a single-source reference book for designers and reviewers working in Franklin. Recognizing that many best development practices are site-dependent, the Guidebook identifies a range of practices that are relevant to development and redevelopment projects on a variety of sites.

The Guidebook is divided into five sections. Section I is a **checklist for designers** to help them determine which best development practices are likely to be applicable to their project. Project reviewers will also use this checklist to assess the project's compliance with the requirements of the BDP Guidebook. Sections II through V discuss best development practices related to **stormwater management**, **erosion and sedimentation control**, **landscape design**, and **site planning**. These four sections describe the best development practices that are applicable in different situations and some technical details of the practices. References are provided for those who seek more information and design specifications for the various practices.

Thank you for taking the time to read this Guidebook. With your participation, the Town of Franklin will become a model for attractive and environmentally responsible community development.

I. Checklist for Designers

The Checklist for Designers is a summary of the best development practices that this Guidebook requires or recommends, and when they should be used. Prior to submitting an application for review, the applicant shall fill out this checklist to verify that he or she has complied with Franklin's policies and planned the development or redevelopment site in a way that furthers the goals discussed below. The checklist shall then be submitted with the application. The Planning Board and/or ZBA and their technical consultants will use the checklist to evaluate whether the application complies with this Guidebook.

Stormwater Management

GOALS and NEEDS addressed:

1. Protect local and regional wetlands and water bodies
2. Maximize groundwater recharge to retain a viable local groundwater supply
3. Ensure that Franklin complies with the EPA Stormwater Phase II Requirements

FRANKLIN POLICIES:

(A) All new development projects in Franklin shall meet the following three stormwater management performance standards. All redevelopment projects shall meet the standards to the maximum feasible extent, and, if they fail to meet the standards, shall retrofit or expand existing stormwater management systems to improve existing conditions.

1. Post-development peak discharge rates from the site shall not exceed pre-development peak discharge rates from the site.
2. Annual groundwater recharge from the post-development site shall approximate annual recharge from the pre-development site.
3. The stormwater management system shall remove at least 80% of the average annual load of total suspended solids (TSS) from the post-development stormwater created on developed site.

(B) Non-structural stormwater management systems should be used wherever site conditions allow, as outlined in the Guidebook. Drain pipe/catch basin systems may be used, in part or in whole, only if the applicant can demonstrate that other systems are not feasible due to site conditions.

BEST DEVELOPMENT PRACTICES One or more of the following must be used to meet the above policies.	Incorporated into Project?
Vegetated swales *(recommended to collect runoff from roadways & parking lots)*	❑
Vegetated filter strips *(recommended to filter and infiltrate runoff from roadways, parking lots, and driveways; use with (a) along roadsides and parking lots)*	❑
Constructed wetlands *(preferred method for stormwater retention & pollutant removal)*	❑
Bioretention cells *(recommended on residential lots and parking lot islands)*	❑
Pervious paving surfaces *(recommended in overflow parking and low-traffic areas)*	❑
Roof gardens *(encouraged on flat commercial and industrial rooftops)*	❑
Retention basins *(less preferred method for stormwater retention & pollutant removal)*	❑
Detention basins *(may be used in series with other practices, such as constructed wetlands, to provide pre-treatment)*	❑
Drain pipe/catch basin systems *(discouraged, unless other stormwater collection and conveyance systems have been demonstrated not to be feasible due to site conditions)*	❑
Have you documented that other systems are infeasible?	❑

Erosion and Sedimentation Control

GOALS and NEEDS addressed:

1. Minimize erosion
2. Prevent sedimentation of water bodies and its attendant environmental impacts

FRANKLIN POLICIES:

(A) Any proposed project on a previously undeveloped site shall accommodate the development program in a way that minimizes clearing and regrading, especially in areas of steep slopes, erosion-prone soils, or sensitive vegetation. For redevelopment projects, the site plan shall concentrate development in previously-disturbed areas to the extent possible.

(B) As a condition of approval, every proposed project shall submit and adhere to a construction management plan that addresses soil stabilization, sediment retention, perimeter protection, construction scheduling, traffic area stabilization and dust control.

BEST DEVELOPMENT PRACTICES The applicant must comply with all of the following requirements.	Incorporated into Project?
Clearing and regrading have been minimized	❑
Development is focused in previously disturbed areas *(for redevelopment projects)*	❑
A construction management plan has been prepared	❑
The construction management plan addresses:	
Soil stabilization *(cover or stabilize erodible surfaces not in immediate use)*	❑
Sediment retention *(runoff interceptors and sediment traps/ponds)*	❑
Perimeter protection *(vegetated buffers or silt fences at the limit of work)*	❑
Construction scheduling *(minimize disturbed area at any given time)*	❑
Traffic area stabilization *(crushed rock or similar at construction vehicle entrance and parking areas)*	❑
Dust control *(plan for stabilizing dusty surfaces when necessary)*	

Landscape Design

GOALS and NEEDS addressed:

1. Minimize demand for irrigation water
2. Maximize groundwater recharge from landscaped areas
3. Preserve native biodiversity by retaining habitat and defending against invasive species
4. Maximize the value to wildlife of human-managed landscapes

FRANKLIN POLICIES:

(A) Site plans and landscape plans for all proposed projects shall take appropriate steps, as outlined in the Guidebook, to minimize water use for irrigation and to allow for natural recharge of groundwater.

(B) Landscape plans shall follow the guidelines in the Guidebook for selecting species that are most appropriate to the site conditions. Native species and habitat-creating species shall be used in all landscape plans to the maximum extent possible while still meeting the site's landscaping needs. Invasive species identified in this Guidebook may not be planted in Franklin under any condition.

BEST DEVELOPMENT PRACTICES The applicant must comply with all of the following requirements.	Incorporated into Project?
Clearing and regrading have been minimized *(natural vegetation must be retained to the maximum extent possible, given the development program)*	❑
Irrigation, if present, is water efficient *(if an in-ground irrigation systems is proposed, it is a water efficient system with automatic sensors to prevent overwatering)*	❑
Landscaped areas retain water *(gardens are mulched and designed for water infiltration)*	❑
No invasive species are used *(species from the invasive species list may not be used)*	❑
Native and habitat-creating species are used *(species from these lists have been incorporated into the landscape design whenever possible)*	❑
Species are appropriate to the soil, site, and microclimate conditions *(select appropriate species from the lists of salt-tolerant, urban-tolerant, wetland, moist-tolerant and drought-tolerant species)*	❑

Site Planning

GOALS and NEEDS addressed:

1. Protect Franklin's natural environment, including habitat, water resources, and ecosystem services
2. Create a visually appealing community
3. Preserve the Town's historic and cultural heritage
4. Stabilize and increase property values
5. Encourage sustainable development

FRANKLIN POLICY:
Subdivision plans and site plans for all forms of development shall adhere to the principles of *environmental compatibility*, *aesthetic compatibility*, and *energy-efficient design*.

BEST DEVELOPMENT PRACTICES The site plan must address all of the following principles.	Incorporated into Project?
Unique natural features have been preserved *(the development program should avoid or else showcase significant natural features)*	❑
Historic and cultural resources have been preserved *(the development program should avoid or else showcase significant historic and cultural features)*	❑
Clearing, grading, and building placement consider viewsheds	❑
Cut and fill have been minimized	❑
Buildings blend into the natural topography	❑
Buildings are oriented to the sun and wind for maximum energy efficiency	
Vegetated protection from northwest (winter) winds is provided	❑
Deciduous species planted or retained close to the E, S and W building edges	❑

II. Stormwater Management

a. Overview and Policies

The need for a strong and innovative stormwater management policy is based on Franklin's attempt to address several challenges:

- Franklin has numerous wetlands and water bodies, and is at the headwaters of the Charles River, all of which are affected by polluted runoff.
- The Town relies on local groundwater aquifers for its public water supply; with Franklin facing seasonal water shortages, groundwater recharge is an essential function.
- The U.S. Environmental Protection Agency (EPA) has recently promulgated the so-called "Stormwater Phase II Requirements," which require communities like Franklin to manage polluted runoff effectively.[1] (Notes and references are provided in the endnotes.)

In order to ensure a minimum level of stormwater management for development and redevelopment projects, Franklin has adopted the following stormwater management performance standards.[2] The adoption of performance standards allows the design engineer to select one or more stormwater management systems that are most appropriate and cost-effective for the particular site.

FRANKLIN POLICY: All new development projects in Franklin must meet the following three stormwater management performance standards. All redevelopment projects shall meet the standards and if they fail to meet the standards, shall retrofit or expand existing stormwater management systems to improve existing conditions.

1. Post-development peak discharge rates from the site shall not exceed pre-development peak discharge rates from the site.
2. Annual groundwater recharge from the post-development site shall approximate annual recharge from the pre-development site.
3. The stormwater management system shall remove at least 80% of the average annual load of total suspended solids (TSS) from the post-development stormwater created on developed site.

There is a growing realization among water resource professionals that conventional systems of stormwater collection, conveyance, and end-of-the-pipe dry-basin detention are no longer sufficient to improve the water quality of surface water bodies. Therefore, the Town's general preference is that stormwater be conveyed and treated in natural and vegetated systems such as vegetated swales, filter strips, constructed wetlands, and bioretention cells. While some of these practices may be new to the Town of Franklin, they have been used successfully in other towns and states and have gained support from the EPA because of their generally superior performance

FRANKLIN POLICY: Non-structural stormwater management systems should be used wherever site conditions allow, as outlined in the Guidebook. Drain pipe/catch basin systems may be used, in part or in whole, only if the applicant can demonstrate that other systems are not feasible due to site conditions.

in attenuating peak runoff rates, filtering pollutants, recharging groundwater, and allowing retention of the natural landscape. Recognizing that non-structural systems are not appropriate in all situations, the Guidebook also discusses other practices that will be permissible in certain situations.

This section of the Guidebook discusses nine stormwater management practices that can be used, alone or in combination, to meet the performance standards. Other systems not discussed in this guidebook may also be acceptable if the applicant can demonstrate their fulfillment of the above standards. Table 2-1 provides a summary of the practices discussed in this chapter and when each practice is encouraged or allowed.

Table 2-1: Use of Stormwater Management Practices in Franklin

Practice	Franklin's Policy	Appropriate Uses
Vegetated Swales	Strongly encouraged	Roadsides, parking lots
Vegetated Filter Strips	Strongly encouraged	Roadsides, residential frontage areas, parking lots, perimeter protection
Constructed Wetlands	Strongly encouraged	Commercial and industrial sites, office campuses, subdivisions
Bioretention Cells (Rain Gardens)	Strongly encouraged	Residential lots, parking lot islands
Pervious Paving Surfaces	Encouraged	Parking overflow areas
Roof Gardens	Encouraged	Office/industrial buildings
Retention Basins	Neutral	Subdivisions, office developments
Detention Basins	Allowed in combination with other practices	All areas of development, if necessary
Drain Pipe/Catch Basin System	Allowed when other systems are not practical due to site constraints	All areas of development, if necessary

There are several factors to consider when deciding on which practice(s) to implement in any given project. Among these factors are the space required, soils and slopes on site, depth to the water table, maintenance requirements, pollutant removal efficiencies, cost, and ability to meet Franklin's stormwater performance standards.

b. Summary of Practices

Table 2-2 provides a summary of design and site considerations for the various stormwater management systems.

Table 2-2: Design and Site Considerations for Stormwater Practices[3]

	Vegetated Swales	Vegetated Filter Strips	Constructed Wetlands	Bioretention Cells	Pervious Paving	Retention Basins	Detention Basins	Catch Basins
Space Required	Bottom width: 2 ft. min. 6 ft. max.	Recommended minimum width: 10-20 ft.	5% of drainage area	Min width: 5-10 ft Min length: 10-20 ft Min. depth: 2-4 ft	Not a factor	Min. pool surface: 0.25 acres recom'd	1 acre foot per 4 acres drainage area	Not a factor
Soils	Permeable soils perform better, but wet swales can be used in less permeable soils	Permeable soils perform better, but soils are not a limitation	Soils are not a limitation	Permeable soils recom'd (infilt. rates >0.27 in/hr). Underdrains allow for less permeable soils.	Permeable soils perform better	Not a factor	Not a factor	Not a factor
Slope of Catchment Area	A design consideration, but usually not a limitation	A design consideration, but usually not a limitation	Max. 15% for forested; 5% for shrubs/ herbs	A design consideration, but usually not a limitation	Usually not a limitation	Maximum 15%	Maximum 15%	Not a factor
Water Table and Bedrock	Generally not a constraint	Generally not a constraint	Water table should be at or near soil surface, or else a liner can be used	2-4 ft above water table/bedrock recommended	2-5 ft above water table/ bedrock recom'd	Not a factor	Generally not a constraint	Not a factor
Proximity to Building Foundations	Min. 10 ft. down-gradient from buildings & foundations recom'd	Min. 10 ft. downgradient from buildings & foundations recom'd	Min. distance 10 ft.	Min. 10 ft. downgradient from buildings & foundations recom'd	Not a factor	Min. distance of 10 ft	Min. distance of 10 ft.	Not a factor
Max. Depth	N/A	N/A	4-6 ft.	2-4 ft., depending on soil type	N/A	3-6 ft.	3-12 ft.	N/A
Maintenance Requirement	Low: routine landscape maint.	Low: routine landscape maint.	Moderate; depends on sediment'n rate	Low: property owner can include in normal site landscape maint.	Low: routine landscape maint.	Moderate; depends on sediment'n rate	Moderate: routine sediment removal	Moderate: routine sediment removal

Table 2-3 should be used in determining compliance with Franklin's 80% TSS removal standard. TSS removal efficiency for each of the various stormwater management systems shall be presumed to be the value shown in Table 2-3 unless the applicant can provide additional satisfactory information or documentation that the system has a greater TSS removal efficiency. Other systems not discussed in this Guidebook may also be acceptable if the applicant can demonstrate their fulfillment of the Franklin stormwater management performance standards.

If more than one practice is used to achieve the required 80% TSS removal, the removal efficiency rates must be multiplied together, not added. For example, if the first practice has a 60% TSS removal rate and the second practice has a 20% removal rate, a total of only 68% of TSS would be removed. (60% of the total, plus 20% of the remaining 40% of TSS.)

Table 2-3: TSS Removal Rates for Stormwater Management Practices[4]

Practice	Design Rate for TSS Removal (use this number to calculate compliance with the 80% TSS removal requirement)	Range of Average TSS Removal Rates
Vegetated swale	70%	60-80%
Vegetated filter strip	30% per 10' of width[a]	30-65%, depending on width
Constructed wetland[b]	80%	65-80%
Bioretention cell	80%[c]	65-80%
Retention basin[b]	70%	60-80%
Detention basin[d]	60%	60-80%
Deep sump and hooded catch basin	25%	25% w/cleanout

[a] For widths greater than 10', TSS removal is determined multiplicatively. For example, for a 30' wide strip, the TSS removal rate would be (1- (0.7*0.7*0.7)) = 66%.

[b] Must have sediment a forebay or pre-treatment.

[c] If an underdrain is used, the water must be conveyed to a secondary treatment device such as a constructed wetland or a retention basin.

[d] Post-treatment is required (e.g., by a constructed wetland or retention basin).

c. Discussion of Practices

Each of the nine stormwater management practices is discussed in more detail below. References in the endnotes provide additional information on the use, design, and construction of these practices.

1. Vegetated Swales

Swales are earthen channels most commonly covered with a dense growth of grass or other vegetation, and are designed primarily to control water quantity and quality.[5] The design of vegetated swales has improved over the years, enabling engineers and hydrologists to implement them for a variety of different purposes. Depending on hydrological conditions and design, swales can be dry, wet, or grassed:

- **Dry swales** are channels filled with approximately 30 inches of soil (50% sand and 50% loam) that allows full infiltration of the stormwater.
- **Wet swales** are generally used when the water table is at or near the soil surface or when soils are poorly drained. Theses swales have a ponding area that should be planted with moist-tolerant species to enhance nutrient uptake and sediment retention.
- **Grassed swales** are planted with grass species that provide a dense cover and serve to provide sediment retention, nutrient uptake and filtration. They are suitable for sandy loam soils. Pollutants are removed from stormwater by the filtering action of the grass, sediment deposition, and/or infiltration into the soil. Grass swales are designed to remain dry most of the time and are specifically planted with species to enhance nutrient uptake and filtration.



Figure 2-1: A grass swale surrounding a parking lot

Design Considerations

Swales are easily implemented on large lot residential sites (½ to 1 acre or larger), office and industrial campuses, roadways where right-of-way widths are adequate, and parking lot medians and edges (see photo at left). Ideally, stormwater should flow from the impervious surface through a vegetated filter strip before entering the swales (see Figure 2-2). Typically, dry and grass swales are used for low density residential projects or very small impervious areas and require soils that have infiltration rates of 0.27-0.50 inches per hour. Wet swales, on the other hand, are convenient for treating highway runoff in low lying or flat terrain areas and need to be planted with water tolerant vegetation.

Swales should be built at a gentle slope so that water flows at a relatively low velocity. The minimum allowable slope is ½%, while the maximum slope is based on velocity. Water velocity in the swale should generally not exceed 3 feet per second, which typically corresponds to a

maximum slope of about 5%. If necessary, the swale may be steeper in places, provided that riprap or other stabilization is used to prevent scouring and erosion within the swale. The side slopes should be at a maximum of 3:1, and the length of the swale should be calculated to accommodate the entire calculated runoff volume from a 10-year storm. Regular maintenance such as mowing, sodding, and repair of eroded areas is necessary for swales. In addition, the accumulated sediment may need to be periodically removed, particularly during the construction and early site stabilization periods.

2. Vegetated Filter Strips

Filter strips are typically bands of close-growing vegetation, placed between pollutant source areas and the receiving water body (either a natural water body or a constructed swale). To protect natural water bodies (e.g., streams or wetlands), filter strips should consist of natural buffer strips already existing on the site. Not only do filter strips protect sensitive areas such as wetlands, woodlands and erodible soils; they also reduce runoff impacts by trapping sediment and sediment-bound pollutants, provide some infiltration, and slow and disperse stormwater flow over a wide area.[6] Figure 2-2 illustrates some of the biochemical processes by which filter strips remove pollutants.[7]

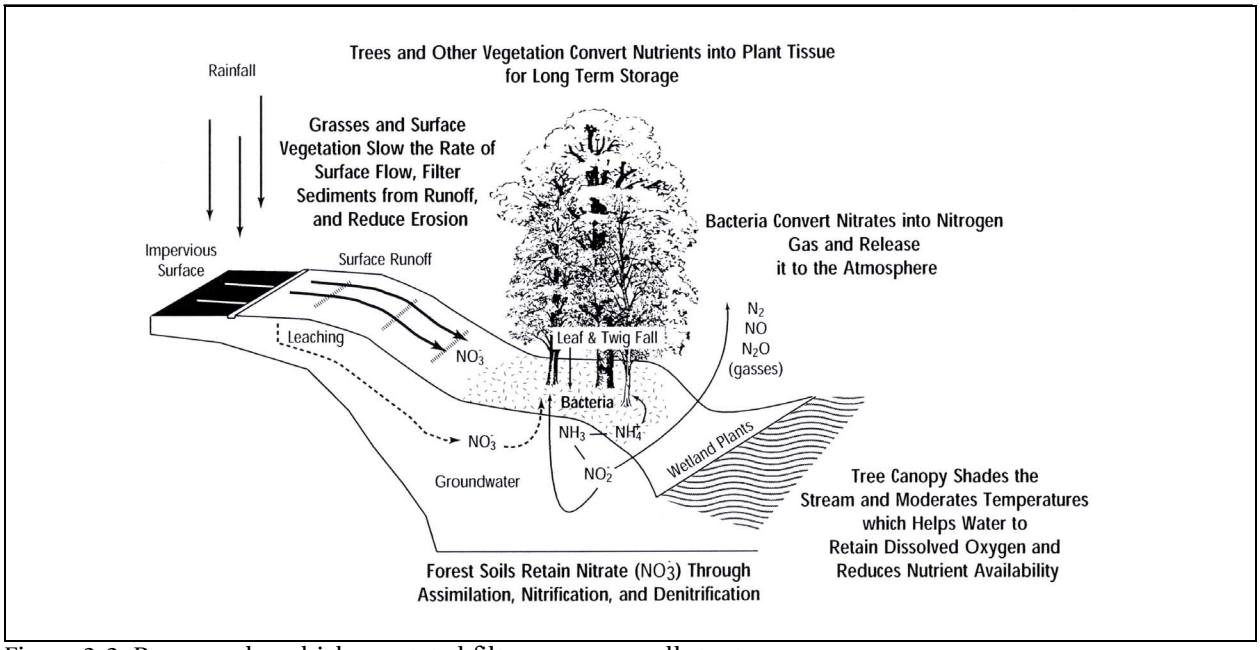


Figure 2-2: Processes by which vegetated filters remove pollutants

Design Considerations

Treatment of stormwater in filter strips is accomplished physically by a combination of filtration through the standing vegetation and infiltration into the underlying soils. In order to treat stormwater effectively, filter strips must be designed to function as overland flow systems where stormwater is evenly distributed. Because there is a high potential for short-circuiting of the filter strips and reduced pollutant removal, grading must be designed carefully to provide uniform flow into the filter strips.

If filter strips are wide enough and planted with appropriate plant species, they will provide wildlife habitat as well as visual amenities in the landscape. It is important to note that filter strips are usually implemented in combination with other stormwater management facilities that specifically control stormwater volume. Finally, for a filter strip to be efficient, a minimum width of 10-20 feet is recommended. Upkeep of filter strips should be incorporated into routine landscape maintenance, which would include raking the filter strip, removing large trash or debris that has accumulated, and regularly cleaning up sediment.

3. Constructed Wetlands

Constructed wetlands (or stormwater wetlands) are shallow pools that create growing conditions suitable for marsh plants. These systems are designed to maximize pollutant removal through retention, settling, and uptake by wetland plants.[8] Stormwater wetlands serve several benefits simultaneously. The primary purpose of constructed wetlands is to improve water quality by removing sediment and pollutants. However, these wetlands can also provide excellent habitat for wildlife and waterfowl. In general, a constructed wetland would be a suitable stormwater management practice for residential subdivisions and commercial developments.



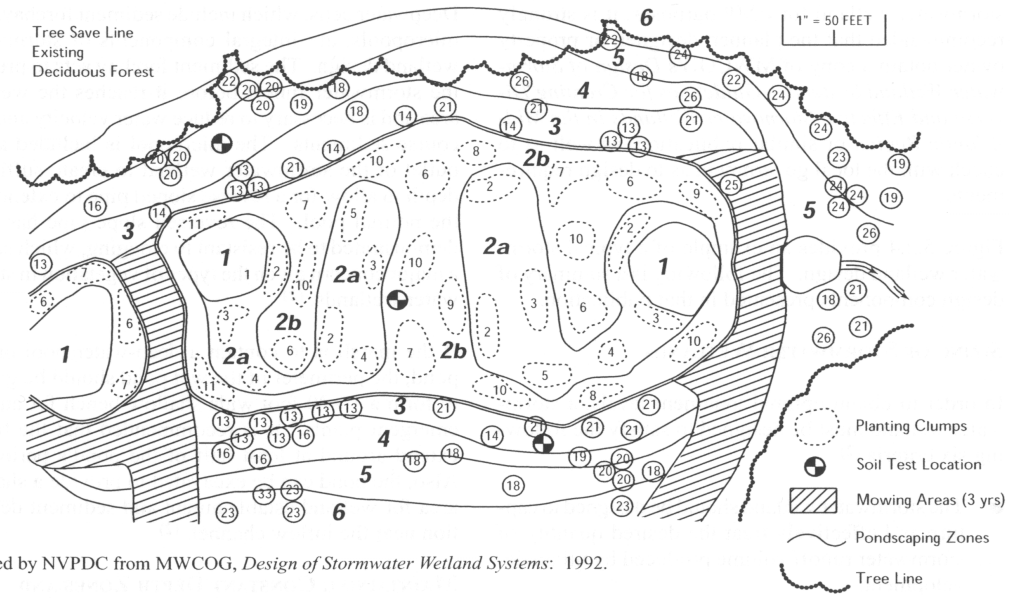
Figure 2-3: A constructed wetland

Design Considerations

Constructed wetlands must be designed with consideration to the size of the contributing watershed area, amount of baseflow, soil type, and available space. The contributing watershed may be as small as 5 acres; however, the smaller the watershed area, the more difficult it is to create sufficient drainage and runoff to keep the wetland perpetually wet. Since wetlands need to maintain soil moisture throughout the year, it is important to have a dry-weather baseflow or a groundwater supply. The preferred soil types for constructed wetlands are less-permeable soils that have relatively small pores and are less prone to evaporation.

The surface area of constructed wetlands should be at least 1% of the contributing drainage area, and the wetlands should have a length to width ratio of at least 1.5:1.[9] In order to increase the efficiency of the retention pond, a sediment forebay must be incorporated as a pretreatment device.

As with all other stormwater management practices, stormwater wetlands also require ongoing maintenance to retain their maximum effectiveness. However, several design features can decrease the amount of maintenance that a wetland needs. For example, a reverse-slope pipe or a weir outlet with a trash rack should be used to prevent clogging of the outlet; orifices should have diameters no less than 3″; and direct maintenance access should be provided to the forebay to allow for sediment removal. Selection of plant species is one of the most important parts of creating a stormwater wetland, as the plants are largely responsible for the pollutant and sediment retention and uptake. Please refer to Figure 2-4[10] for a sample wetland vegetation layout and **Section III** for a list of plant species suitable for planting in constructed wetlands.



Adapted by NVPDC from MWCOG, *Design of Stormwater Wetland Systems*: 1992.

PLANT MATERIALS (By Pondscaping Zone)

KEY SPECIES		QTY	SIZE
Zone 1: Deep Pool			
1	Wild Celery	25	Tubers, cheesecloth sinkers
Zone 2a: Low Marsh			
2	Duck Potato	375	(All) Containers
3	Pickerelweed	300	or peat pot 18" o.c.
4	Arrow Arum	275	
5	Wild Rice	150	
Zone 2b: High Marsh			
6	Common 3-Square	500	(All) Containers
7	Softstem Bulrush	500	or peatpot 18" o.c.
8	Lizards Tail	150	
9	Sweet Flag	150	
10	Rice Cutgrass	150	
11	Sedge spp.	150	
Zone 3: Shoreline			
12	Switchgrass over Red Fescue		
13	Button Bush	8	Container
14	River Birch	6	Container
21	Black Willow	12	1" caliper container
Zone 4: Riparian			
15	Tall Fescue, wildlife mix	100 lbs/ac	Hydroseed
13	Button Bush	4	Container
16	Green Ash	4	2" B&B
17	Arrowood Viburnum	24	Container on embankments
18	Silky Dogwood	4	2" B&B
19	Sycamore	4	2" B&B

KEY SPECIES		QTY	SIZE
Zone 5: Floodplain			
15	Tall Fescue	100 lbs/ac	Hydroseed
18	Silky Dogwood	4	2" B&B
26	Tulip Poplar	4	2" B&B
20	Elder Berry	9	Container
21	Black Willow	12	1" B&B
22	Shad Bush	4	1" B&B
Zone 6: Upland			
23	Willow Oak	6	2" B&B
24	Spice Bush	3	Container
19	Tulip Poplar	4	2" B&B
18	Silky Dogwood	2	2" B&B
Embankment			
23	Periwinkle	48	Container

PONDSCAPING NOTES

1. No trees in embankment or along mowed maintenance access area.
2. Tree-save line denotes limit of disturbance during wetland excavation.
3. Pondscaping zones and marsh planting zones to be confined in field after excavation.
4. Existing topsoil to be stockpiled and used to dress pondscaping zones 4,5, and 6.
5. Reinforcement planting after first growing season based on field inspection of marsh plan survival/colonization rates.
6. Three soil pit tests taken to confirm general soil properties.
7. Switchgrass overseeded on Red Fescue in Pondscaping Zone 3, Tall Fescue and Wildlife grass mix used in Zones 4,5, and 6 within three days of final grading for erosion control.
8. Six inches of wood mulch around all trees and shrubs (excluding trunk line), planting holes to be three times rootball diameter.

Figure 2-4: Sample wetland vegetation layout

4. Bioretention Cells (Rain Gardens)

Bioretention cells (otherwise known as rain gardens) are landscaped areas that mimic upland vegetation systems. These systems are designed to trap stormwater, infiltrate it, and treat it by means of vegetational uptake (uptake of certain minerals and nutrients by vegetation), biological degradation (microbial/bacterial metabolic activities), and/or gravitational sediment removal.

Runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants (see Figure 2-7[11]). Runoff passes first over or through a sand bed, which slows the runoff and distributes it evenly along the ponding area. The ponding area is made up of a surface organic layer, ground cover and the underlying planting soil. The ponding area is graded such that there is a depression in the middle where water remains until it infiltrates or evaporates. The depression should be designed to hold up to 6 inches of water.[12] An overflow structure should be provided for situations where the ponding area is not sufficient. As shown in Figure 2-7, the infiltrated water may also be collected through an underdrain and outlet, which would drain water to a constructed wetland or retention pond for further treatment.



Figure 2-5: A bioretention cell on a residential lot

Bioretention cells can be used in both residential and commercial projects. In residential subdivisions, bioretention cells are used to retain and infiltrate stormwater locally so that it does not need to be conveyed and treated by means of a more extensive stormwater management system. Each residential lot would typically have one or more bioretention cells (which are essentially landscaped gardens) that receive stormwater from the roof and driveway and infiltrate it to the ground. Each homeowner is responsible for maintaining the bioretention cell(s) on their property, just as they would maintain their garden.

In commercial projects, bioretention cells are installed as depressed islands in the parking lot. Stormwater is directed to these islands, where it is treated and infiltrates into the ground.



Figure 2-6: Bioretention cell in a parking lot

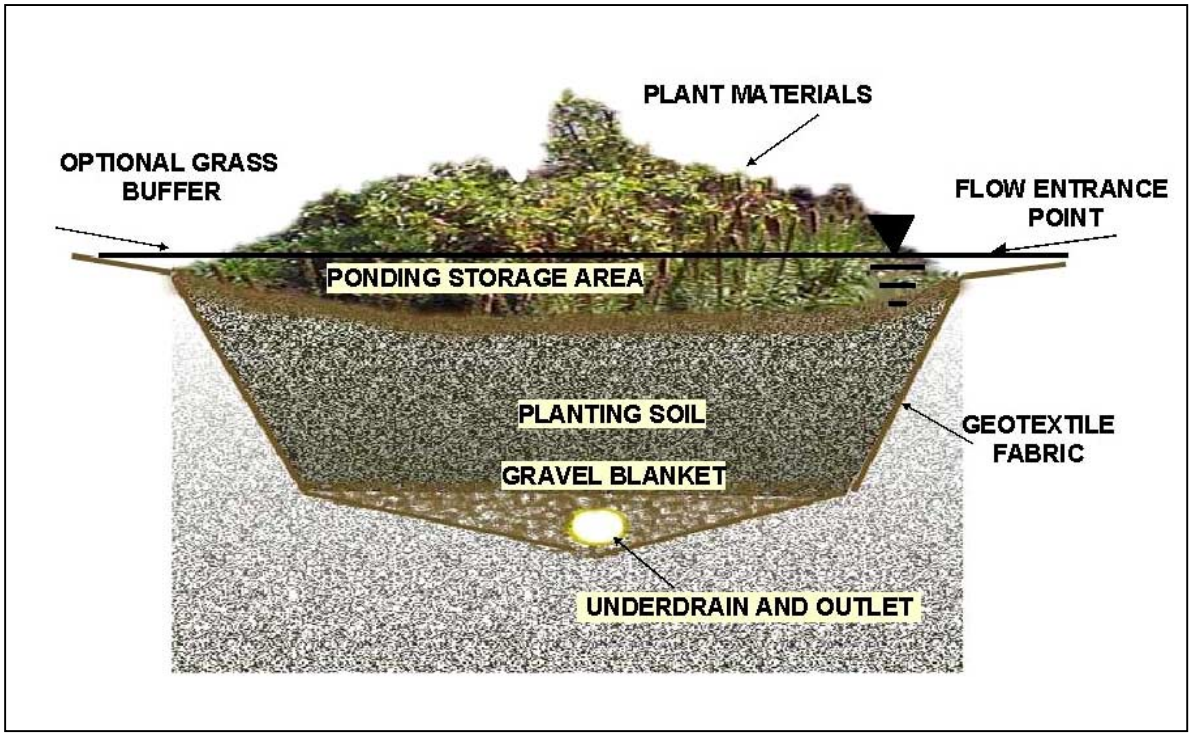


Figure 2-7: Bioretention cell

Design Considerations

The design of bioretention cells must consider the site area, slope, soils, groundwater, and maintenance needs. Figure 2-8[13] illustrates a typical bioretention cell installation. Bioretention cells should be designed to occupy 5 to 7 percent of the drainage area multiplied by the rational method runoff coefficient ("c") determined for the site.[14] Recommended minimum dimensions are 15 feet by 40 feet for bioretention cells receiving parking lot runoff. Bioretention cells on individual house lots can be much smaller.

The site should have shallow slopes (approximately 5% or less) so that water flow is guaranteed but velocity is not too high. An underdrain should be used in situations where soils are tight and there is a concern about the cell backing up or flooding. (In areas of less pervious soils, bioretention cells may be constructed by importing more permeable soils for the cell itself, in combination with an underdrain which prevents water from ponding above a less permeable natural soil layer.) An underdrain should also be used where the water table is close to the surface and there is a concern about groundwater pollution. In other situations, an underdrain generally is not needed.

Bioretention cells need to be maintained regularly to ensure the presence of mulch and good soil, attend to any diseased or dead plants, and remove collected sediment, litter and debris.

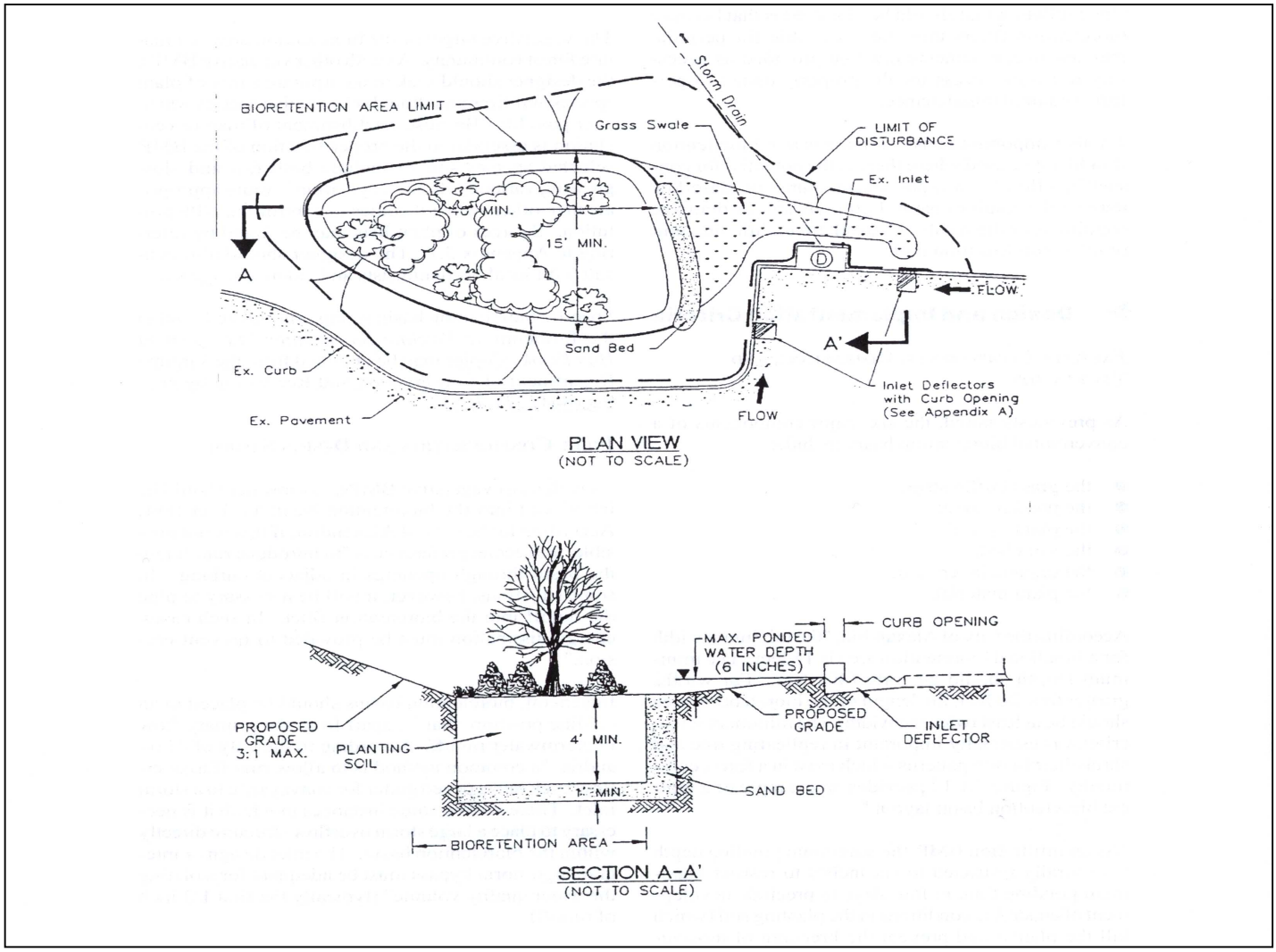


Figure 2-8: Typical design layout of a bioretention cell.

5. Pervious Paving Surfaces

Pervious paving surfaces typically consist of a permeable surface with an underlying crushed/broken stone reservoir to temporarily store runoff before it infiltrates into the ground. The main purposes of this application are to reduce the amount of stormwater runoff from paved areas and to infiltrate stormwater into the underlying soils. By reducing the amount of stormwater runoff, pervious paving surfaces reduce the cost of stormwater management.

Pervious paving surfaces that are now available include porous asphalt, pervious concrete and grass pavers. Porous asphalt and pervious concrete appear to be the same as traditional pavement from the surface, but incorporate void spaces to allow infiltration. These systems have been applied successfully in a few locations in New England where soils consist of particularly well-drained sands and gravels that allow the pores to drain rapidly. However, in areas of tighter soils, porous asphalt and pervious concrete are generally not recommended in this region because water remaining in the void areas is subject to the freeze-thaw cycle which stresses and weakens the pavement.



Figure 2-9: Grass pavers

Grass pavers, shown in Figure 2-9, are a viable option in New England's climate.[15] Grass pavers consist of concrete interlocking blocks or a synthetic fibrous gridded system with open areas designed to allow grass to grow. The design should allow for infiltration into the underlying soils so that stormwater does not pond near the surface.

Design Considerations

Grass pavers are most suitable for low-traffic areas such as the overflow areas of commercial or office parking lots, residential driveways, and service areas that will be subject to light traffic. Franklin recommends their use in these situations. If these systems are used, stormwater calculations should account for the reduced amount of runoff generated by areas with grass pavers. In general, grass paver systems should not be salted in the winter because this will threaten the viability of the plants. However, salting will not typically be required in the low-traffic areas where grass pavers are recommended.

6. Roof Gardens

Roof gardens are precultivated vegetation mats placed on several layers including a fertilizer layer, a substrate mat, a protective fleece and an impervious membrane. Roof gardens provide several functional benefits such as reducing stormwater runoff volume and pollutant load, increasing the energy efficiency of buildings, improving air quality by removing particles in the air and by photosynthesis, and increasing the aesthetic value of the area. Roof gardens can be built on almost any rooftop, from a residential building to a commercial or industrial building. Figure 2-10 shows a typical application.[16] The Town of Franklin recommends that roof gardens be used in large commercial, office, and institutional buildings that have flat roofs.



Figure 2-10: A roof garden in Stuttgart, Germany

Once established, roof gardens do not need extensive maintenance other than occasional fertilization and weeding. During the initial stage some watering might be required; however, usually within six months the plants are able to sustain themselves.

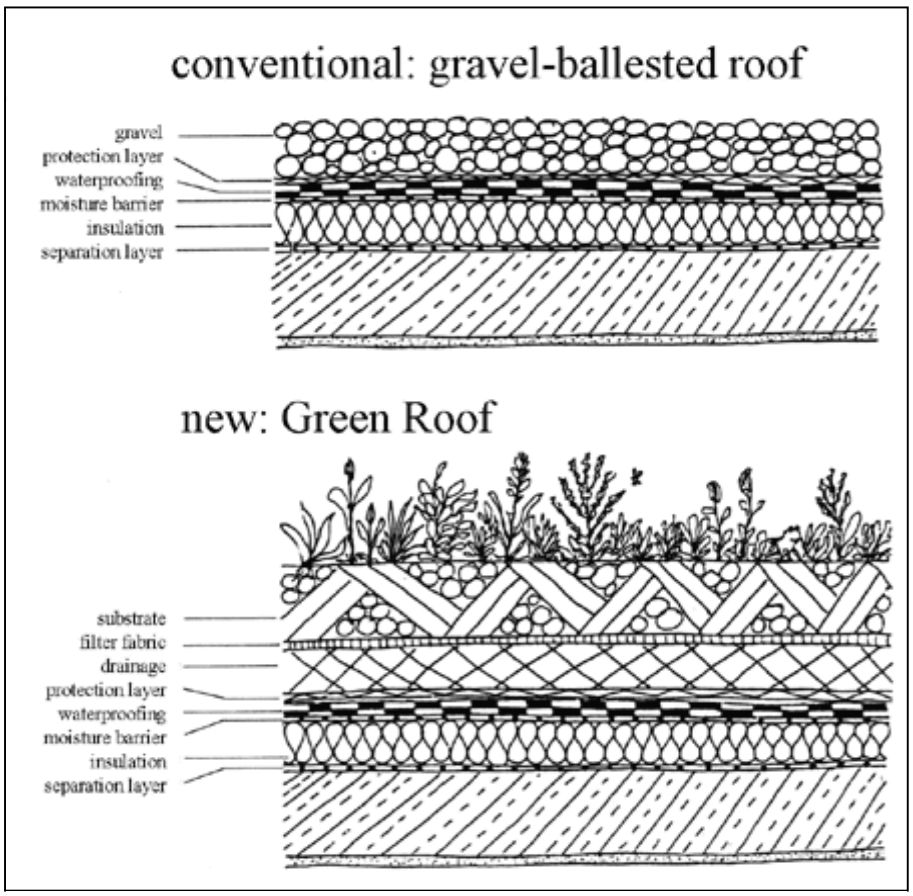


Figure 2-11: Typical roof garden design

Since the soil layer is not deep, it will not support tall vertical growth or large plants; therefore, cutting or mowing is not required. Load reserves of at least 15 pounds per square feet beyond snow load requirements are needed to install a roof garden.[17] If properly built over a suitable roofing membrane, roof gardens do not present a leaking problem.

7. Retention Basins

Retention basins are constructed to have a permanent pool of water to treat stormwater. The pool allows settling of sediments, removal of soluble pollutants by algal uptake, and some groundwater recharge as shown in Figure 2-12[18]. The basins are designed to include additional storage capacity to control peak discharge rates. The primary component of a retention basin is a deep, permanent pool, but the basin may also include a shallow marsh or a sediment forebay to increase sediment and nutrient removal.[19] In general, the Town of Franklin does not recommend that retention basins be used as the primary means of attenuating peak runoff rates or removing pollutants. Constructed wetlands are generally a preferred system since they have greater pollutant uptake functions. However, retention basins may be used in subdivisions as well as commercial and industrial areas when other stormwater management systems are not feasible or sufficient because of site conditions or the nature of the development program. Retention basins may also be used in series with constructed wetlands as a sediment trap, particularly during construction.



Figure 2-12: Retention basin

Design Considerations

Retention basins must drain a sufficiently large area to maintain a permanent pool of water. The minimum recommended area is typically around 10 acres, assuming impervious surface percentages typical of suburban developments.[20] Within the watershed area that drains to the retention basin, the slopes and the stormwater conveyance system must result in a metered flow of stormwater that does not flood the basin all at once. The use of filter strips and swales can help slow and infiltrate water on its way to the basin.

Retention basins can be constructed in a wide range of soil types. However, when native soils have a rapid percolation rate, soils should be compacted or supplemented sufficiently so that the pond does not dry up during the dry season. The soils should retain sufficient infiltration potential so that the pond also continues to play a role in groundwater recharge. In order to increase the efficiency of the retention basin, a sediment forebay must be incorporated as a pretreatment device. As with constructed wetlands, retention basins should use non-clogging outlets and large orifices (not less than 3 inches in diameter), and should provide easy dredging access to reduce long-term maintenance requirements and difficulties.

8. Detention Basins

Detention basins are depressed areas whose outlets have been designed to detain stormwater runoff for some minimum time to allow particles and associated pollutants to settle. Since the aim of detention basins is mainly to control flooding and remove sediments, they do need not to have a permanent pool and therefore can be dry during non-flood conditions. Typically, they are used in conjunction with other stormwater management systems such as retention basins or constructed wetlands as a primary treatment.

The Town of Franklin discourages the use of detention basins as the primary means of flood control. Instead, vegetated swales and filter strips should be used whenever possible to attenuate peak runoff rates. When site characteristics do not allow use of such practices, however, detention basins may be considered as part of the stormwater management system. In addition, detention basins may be used as a pre-treatment device to settle out particulates prior to discharge to a constructed wetland or retention basin, where additional treatment and infiltration will occur.

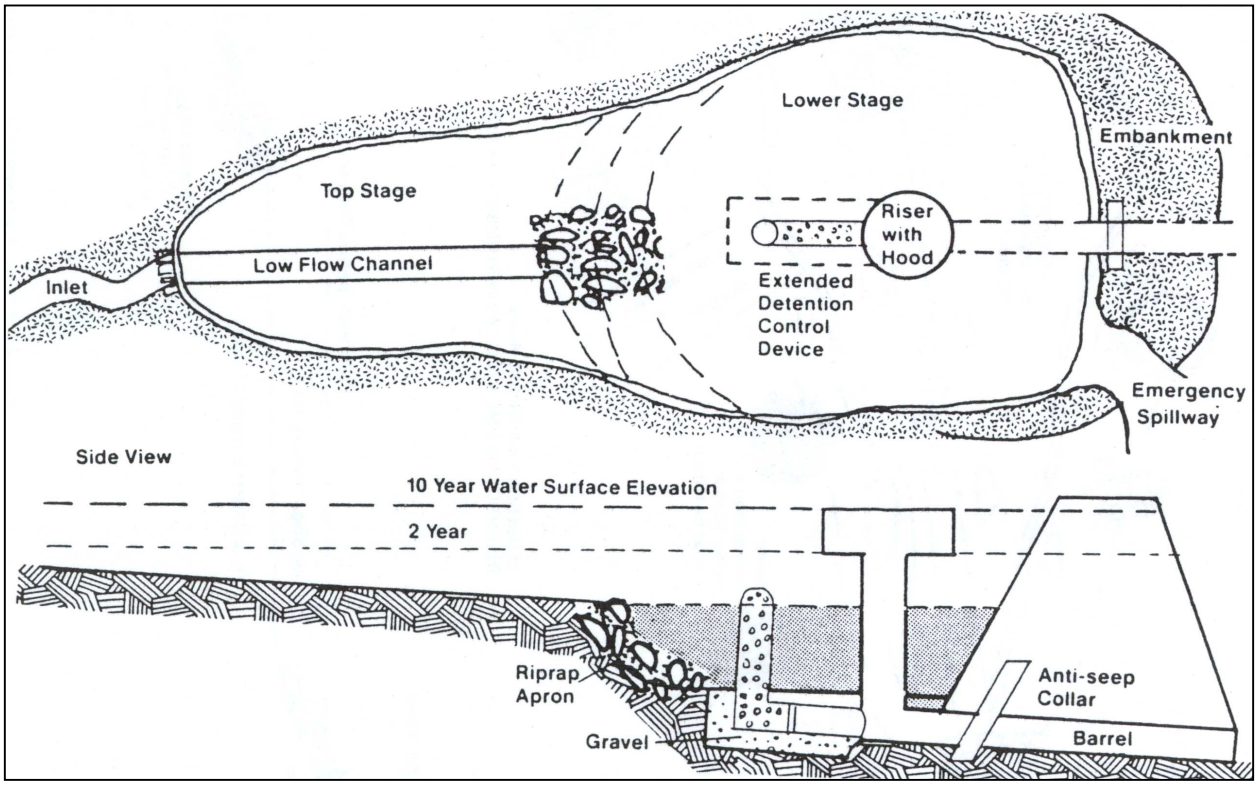


Figure 2-13: Schematic design of a dry extended detention pond

Design Considerations

Detention basins are most practical for use on sites that are at least 10 acres, which allows for the use of larger outlet orifices that are less likely to clog. Detention basins can be used on sites with a slope of up to about 15 percent. There is no minimum slope requirement, provided that there is enough change in elevation to ensure flow. Soil type is not a factor except in areas with rapidly percolating soils such as sand. In these areas, an impermeable liner should be used to prevent groundwater contamination from untreated runoff. Detention basins should be designed with sediment forebays, which allows sediment to be trapped prior to entering the detention basin. This feature also reduces maintenance requirements for the detention basin. As with constructed

wetlands, detention basins should use non-clogging outlets and large orifices (not less than 3 inches in diameter), and should provide easy dredging access to reduce long-term maintenance requirements and difficulties.

Any detention basin in the Town of Franklin must provide landscaping and planting to minimize its visual impacts. The plants selected for the ponding area should be able to withstand both wet and dry periods. Along the perimeter of the basin, however, the plants should be adapted to dry conditions and should create a visual vegetated buffer.

9. Catch Basins and Drain Pipes

Catch basins are storm drains that capture and roughly filter stormwater through a grate or curb inlet and capture sediment, debris and associated pollutants in a deep sump (Figure 2-14[21]). In most cases a hood is also included to separate oil and grease from the stormwater. The essential function of a catch basin is to act as a pretreatment device for other structures incorporated into a storm sewer system. The performance of a catch basin in removing sediment and pollutants will depend greatly on the size of the drainage area, the size of the sump, and the amount of maintenance it receives. Although catch basins are currently used in virtually all circumstances, they typically cannot remove pollutants as well as most of the other practices mentioned in this section and require frequent maintenance. Catch basins should only be used when the other practices mentioned in this section prove unfeasible. The designer must document the reason(s) why the other practices are not feasible before the use of catch basins may be approved.



Figure 2-14: A catch basin inlet

When catch basins are used, the Town will consider it preferable if they discharge individually or in pairs to nearby swales, constructed wetlands, or bioretention cells, rather than carrying runoff further to a larger retention/infiltration system. Lengthy catch basin-piped drain-manhole networks are discouraged. In general, the goal is to use vegetated, low-velocity channels to hold and infiltrate stormwater locally, not to efficiently capture and deliver stormwater to watercourses.

Design Considerations

Catch basins should be designed to hold a combined volume of at least 400 cubic feet per acre of contributing impervious area and have sumps that are at least four feet deep. The grates and inlets should be sized and constructed to pass the 10-year storm volume into the deep sump. Flow from the catch basin/drain pipe system should be directed to another stormwater management device, such as a constructed wetland, for further treatment. Catch basin inlets should be cleaned regularly (at least twice a year) and after large storms. Removed sediment should be disposed of in accordance with applicable local, state and federal guidelines and regulations.

III. Erosion and Sedimentation Control

Erosion and sedimentation control practices should be incorporated into the planning, construction, and operation of any project in Franklin. Specific measures must be presented for review prior to construction.

a. Site Planning

The most important erosion control practice is to minimize clearing and regrading, as discussed in **Section V**, Site Planning.

FRANKLIN POLICY: Any proposed project on a previously undeveloped site must accommodate the development program in a way that minimizes clearing and regrading, especially in areas of steep slopes, erosion-prone soils, or sensitive vegetation. For redevelopment projects, the site plan should concentrate development in previously-disturbed areas to the extent possible.

The initial step to control erosion and sedimentation lies in developing a plan that is appropriate to the site features including topography, soils, drainage ways, and natural vegetation. The site planning process should begin with a thorough evaluation of sensitive areas requiring protection as well as less sensitive areas suitable for development. The site plan should delineate a limit of work that limits clearing and regrading and protects the most sensitive areas, based on the criteria in Table 3-1. For example, in residential subdivisions, native vegetation should be retained on individual houselots to the extent possible, rather than creating larger lawns.

Table 3-1: Guidelines for identifying sensitive site features[22]

Topography	Drainage	Soils	Natural vegetation
Slopes that are steeper and/or longer typically create more erosion. Slopes that exceed the following thresholds are likely to be sensitive and erosion-prone: • Slopes of 5-7% longer than 300 feet • Slopes of 7-15% longer than 150 feet • Slopes of more than 15% longer than 75 feet	Where possible, retain natural drainage ways and depressions and utilize for stormwater conveyance	Consider factors such as erodibility, permeability, depth to water table and bedrock, and soils with shrink/swell potential or slippage tendencies. The most erodible soils contain high proportions of silt and very fine sand. The presence of clay or organic matter tends to decrease erodibility.	This is the most important factor in preventing erosion. Vegetated buffers filter runoff, decreasing runoff velocity, and increase infiltration capacity.

b. Construction Period Impacts

Prior to the commencement of construction, the limit of clearing and limit of work identified on the site plan and approved by the Town must be suitably marked. Acceptable markers include survey tape or plastic fences. These markers are in addition to any fences that the Conservation Commission may require for sensitive areas such as wetlands, streams and their buffers. Construction activities and construction traffic must be limited to the area identified on the site plan, and no stockpiling of materials, soils, or debris or other activity may occur outside of the limit of work.

FRANKLIN POLICY: As a condition of approval, every proposed project must submit and adhere to a construction management plan that addresses soil stabilization, sediment retention, perimeter protection, construction scheduling, traffic area stabilization and dust control.

1. Soil Stabilization

The construction management plan should outline a plan for cover and/or stabilization of erodible surfaces that are not the immediate focus of construction activity. The Town requires covering and stabilization as a way of minimizing soil erosion as well as sedimentation in the Town's water bodies and storm sewer system. Cover measures must be implemented on areas that have already been disturbed but will not be worked on during the next 7 days during dry conditions or next 2 days during wet conditions. Acceptable cover methods include, but are not limited to, the use of mulch, erosion control nets and blankets, plastic covering, seeding and sodding. These are described in the following paragraphs.

Mulching is generally considered to be a suitable short-term protective measure. The main purpose of mulching is to protect the site from erosion by stabilizing soils and reducing stormwater runoff velocity. Mulch can also enhance plant establishment by conserving moisture, holding fertilizer, seed and topsoil in place, and moderating soil temperature. The most commonly used mulches include straw, wood fiber or cellulose, compost and wood chips. The effectiveness of mulching depends on site characteristics and maintenance: if the site is prone to high winds or has steep slopes, additional steps should be taken to anchor the mulch, such as planting vegetation or providing netting or blanketing. The thickness of the cover should be maintained at all times and any area that has eroded should be remulched and anchored until it has been stabilized.



Figure 3-1: Geotextiles used for stabilizing a hillside

Similar to mulching, plastic covering is also acceptable as a short-term protective measure. This technique simply involves covering the area of concern with a plastic sheet and using tires or sandbags to weight the plastic down. Plastic covering is generally used on cut and fill slopes and stockpiles. Plastic covering should not be used if there is a sensitive area located downslope, because of the rapid runoff created by the plastic covering. Although this is a fairly easy technique to apply, it requires careful maintenance. The plastic cover can easily be torn or damaged by the sun and can clog drainage systems if not removed properly. Therefore, regular maintenance should be provided to ensure that the plastic is undamaged at all times and fully removed after it is no longer needed.

Seeding, sodding and erosion nets and blankets are usually more appropriate as long-term solutions for areas that will remain unworked for months. **Section IV** lists recommended species to plant for erosion control purposes. A well-designed landscaping plan can easily incorporate areas of planting for permanent erosion control. If the area must be stabilized immediately, then the use of sodding is more appropriate since it can provide immediate erosion protection. Sodding is appropriate for use on residential or commercial lawns, steeply-sloped areas, waterways and channels carrying intermittent flow, and areas around drop inlets that require stabilization.[23] Sod maintenance is essential during the establishment period. Sod should be

provided with adequate moisture and fertilizer. If the sod does not root and stay healthy, it should be replaced by new sodding or a different technique.

Erosion control nets or blankets, also referred to as geotextiles, are another suitable long-term stabilization technique (see Figure 3-1[24]). Geotextiles are used for preventing erosion and holding seed and mulch in place on steep slopes, as well as in channels to aid vegetation establishment. Geotextiles can be made of synthetic materials such as polypropylene, polyester, polyethylene, nylon, and polyvinyl chloride as well as biodegradable materials such as mulch matting, jute, coconut fiber and other wood fibers. For effective stabilization, good contact with the ground must be maintained and no erosion should occur beneath the net or blanket. Synthetic geotextiles can be sensitive to light and wind; therefore, they should be inspected regularly and any problematic areas should be repaired immediately.

2. Sediment Retention

Sediment retention from construction sites is a three-step process. First, all surface runoff from disturbed areas must be intercepted since this runoff contains high sediment loads. Second, the runoff must be conveyed to a sediment trap or pond where sediment removal will occur. Finally, the cleaned runoff must be discharged downslope of any disturbed areas. Typically, interceptor dikes and swales are used to intercept runoff; check dams are used to reduce flow velocity and remove sediment; ditches and pipes are used to convey the runoff; and riprap or level spreaders are used to dissipate runoff velocity in a non-erosive manner. As shown in Figure 3-2[25], interceptor dikes can collect the runoff and direct it to pipes and/or ditches which can convey the runoff to a sediment pond. The outflow from the pond can be connected to a stream (as shown in this case) or to a vegetated area. Riprap may be used to stabilize outlets. Check dams can be incorporated into the design to reduce the velocity of the runoff. Typically, check dams are installed in swales or ditches and consist of small gravel, rock, sandbag, log or straw dams.

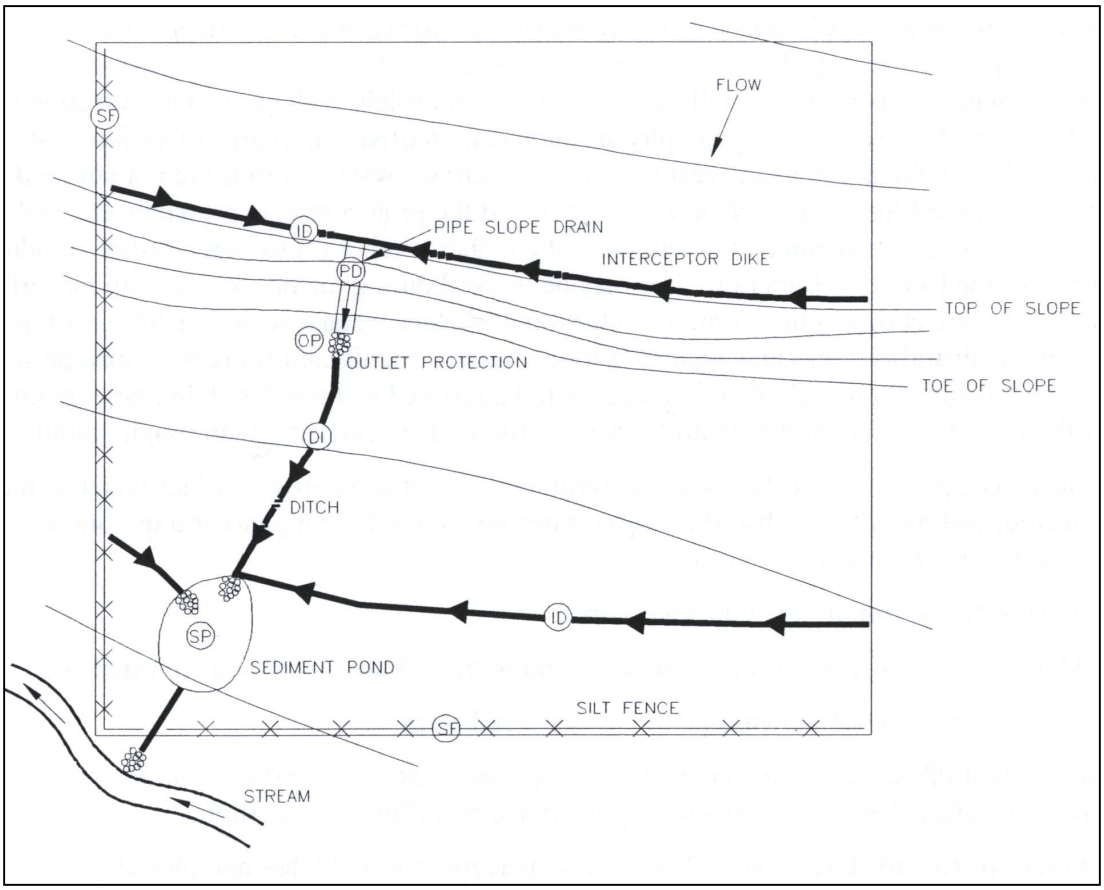


Figure 3-2: Sample sediment retention plan

As mentioned above, sediment must be conveyed to sediment traps or ponds prior to being discharged. Sediment traps should be used for areas less than about three acres, and sediment ponds should be used for larger areas. Stormwater runoff is conveyed through these structures, where sediment is settled (mostly small particles of 0.02 mm or so) and turbidity is slightly reduced.[26] When sediment reaches one foot in depth, the trap or the pond should be cleaned. Any embankments or slopes should also be routinely checked and any damage properly repaired. The construction management plan must state how surface runoff will be intercepted and settled before it is released into the ground or off-site.

3. Perimeter Protection

While interceptors and sediment traps/ponds discussed above will provide the primary sediment retention on construction sites, perimeter protection is also required to prevent residual sedimentation of adjacent lands and waters. The construction management plan should identify measures to prevent sediment from being transported off of the site. Again, the purpose of this requirement is to minimize sedimentation in the Town's water bodies, storm sewer system, and adjacent properties. Measures such as vegetated filter strips, silt fences, or brush barriers should be provided at the limit of work to filter runoff and capture sediment. In places where the limit of work is not near the edge of the site, a natural vegetation buffer of 40 feet is generally considered to be an acceptable retention system, except where the natural vegetation is a wetland, a wetland buffer or otherwise sensitive landscape feature, in which case a silt fence or similar device should generally be used. Figure 3-3[27] illustrates proper installation of hay bales for sediment retention purposes.

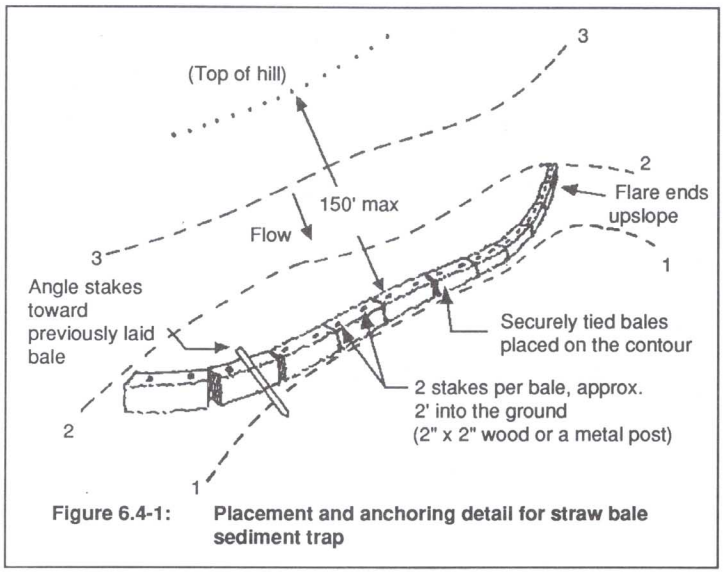


Figure 6.4-1: Placement and anchoring detail for straw bale sediment trap

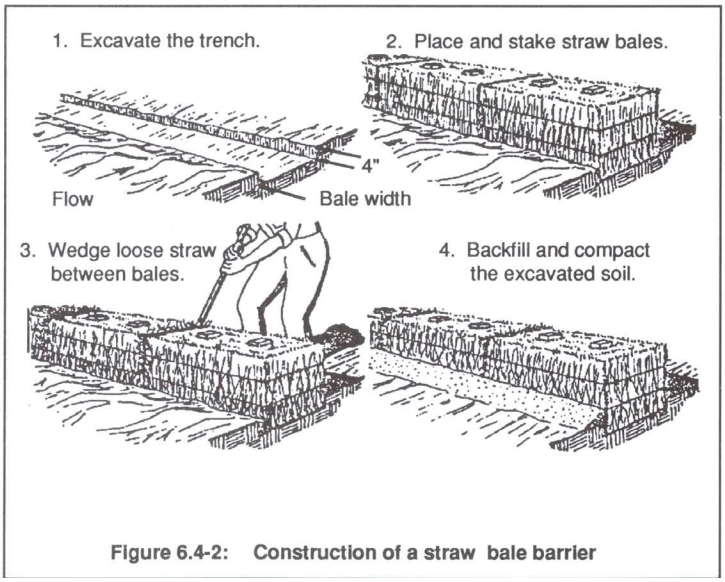


Figure 6.4-2: Construction of a straw bale barrier

Figure 3-3: Installation of hay bales for sediment retention purposes

4. Other Practices

Scheduling of Operations

The construction management plan should state when clearing, grubbing, grading, construction, and replanting will occur on each section of the site. If construction phasing has not been determined at the time of the initial permitting, this section of the construction management plan may be submitted later, but must be submitted at least 60 days prior to the desired commencement of construction. Construction must be phased by area so that the smallest practical area of land is exposed for the shortest possible time.

Traffic Area Stabilization

To reduce the amount of sediment transported off site by construction vehicles and to reduce the erosion of areas disturbed by vehicle traffic, roads and parking areas should be stabilized immediately after initial grading. Not only will this stabilization reduce amount of sediment transported out of the site; it will also reduce the amount of easily erodible mud that forms on site. Stabilization can be achieved by use of a 6 inch deep layer of crushed rock, gravel base, or crushed surfacing base on the area of construction entrances or roads and parking areas. For any area that will be subject to long-term or high-volume construction vehicle traffic, a truck wash should be implemented, with dirty water channeled through sediment traps or ponds prior to discharge.

Dust Control

The construction management plan should commit to minimizing wind transport of dust from exposed soil surfaces onto roadways, drainage ways, and surfaces waters by spraying exposed soils with water until they are sufficiently damp so as to not produce dust, but not so wet as to produce runoff, whenever weather conditions are dry and windy.

IV. Landscape Design

This section of the Guidebook addresses three critical goals for the Town: stabilizing water use at a sustainable level; creating landscapes that minimize natural habitat destruction and maximize habitat value; and encouraging the development of landscapes that provide environmental quality and visual relief.

a. Water-Sensitive Landscaping

Franklin currently suffers from a seasonal water supply shortage due in large part to lawn and garden watering. At the same time, development and the attendant rise in impervious surfaces is altering the natural hydrological cycle and reducing recharge to the aquifers. Without careful attention to water use and hydrologic systems, Franklin could face continued water shortages as well as large future expenditures related to public water supply.

FRANKLIN POLICY: Site plans and landscape plans for all proposed projects must take appropriate steps, as outlined in this section, to minimize water use for irrigation and to allow for natural recharge of groundwater.

On previously undeveloped ("greenfield") sites, the most important water-sensitive practice is to minimize the disturbance and clearing of natural vegetation. Guidelines to meet this objective are provided in **Section III** and **Section V** of this Guidebook. Typically, this will mean preserving some portion of the site as open space, plus reducing the area of lawn and garden in favor of native vegetation in both residential and commercial/industrial projects. In places where native vegetation is cleared, at least some of the area should function as a groundwater recharge system. For example, a landscaped garden could function as a bioretention cell through appropriate subsurface design and selection of species, or portions of a lawn could serve as a vegetated filter strips for driveway runoff if properly graded. In general, the landscape design should aim to:

- Retain and recharge water onsite;
- Preserve existing vegetation to the maximum extent possible;
- Preserve soil permeability during development; and
- Minimize the use of turf grass in landscaping, opting instead for a variety of native species.

To keep the water onsite, impervious areas need to be reduced to the maximum extent practical. Planting beds should be designed to conserve the water they receive. This can be achieved by grading the beds so that slope is gradual and stormwater runoff will have more time to percolate into the soil, and by using plant species that do not require large amounts of water.

To meet its water conservation objectives, Franklin discourages in-ground irrigation systems. However, if irrigation systems are proposed, they shall be water-efficient drip systems or soil soakers equipped with automatic sensors that prevent watering when soils are already wet, or when it is raining. Drip irrigation is defined as the frequent slow application of water to a very small area in the root zone of the plant. Water slowly drips through either porous plastic pipes or emitters located below the soil surface. Drip systems have been found to reduce water use by 20-50%.[28] Soil soakers consist of long plastic or canvas tubes perforated with tiny holes through which the water seeps as a fine mist. Soil soakers are connected to a garden hose and can be left in place on the surface of the planting bed or buried under the mulch.

For garden areas, landscape plans should specify the use of a suitable mulch. Use of mulch is beneficial for several reasons. Mulch layers:

- Help capture moisture for vegetation that would normally be lost through evaporation;
- Prevent erosion by protecting the soil surface from raindrop impacts and by reducing the velocity of overland flow;
- Help prevent crusting, sealing and compaction of the surface, thereby preserving the infiltration rate;
- Protect seeds by forming an insulating layer against extreme heat and cold and by creating a suitable microclimate for seed germination; and
- Reduce weed growth and the need for herbicide application.[29]

Good mulching materials include compost, pine bark, pine straw (pine needle bales), leaf mold, rotted manure, lawn clippings, aged and shredded hardwood bark, aged wood chips, and straw or chopped hay.

b. Plant Species

In the interest of striking an appropriate balance between community development and conservation, the Town of Franklin is committed to retaining natural habitats and habitat functions on developed sites to the maximum extent possible. In addition, to further the Town's water conservation goals, drought-tolerant species should be used in appropriate situations.

FRANKLIN POLICY: Landscape plans shall follow the guidelines in this section for selecting species that are most appropriate to the site conditions. Native species and habitat-creating species shall be used in all landscape plans to the maximum extent possible. Invasive species identified in this section shall not be planted in Franklin under any condition.

Landscape designers working on Franklin projects should use the following lists to select the most appropriate species for each portion of their site. Recognizing that many species are well-suited to several circumstances, there is much overlap among the nine lists of species provided below. Each list is also divided into different forms of plants, such as shade trees, ornamental trees, evergreen trees, deciduous shrubs, groundcovers, and flowers. The lists are not all-inclusive, and landscape designers may propose the use of other species not included here, provided they are not invasive species. However, these lists are intended to provide a sufficiently wide range of species that the Town considers generally acceptable under different circumstances. Information in this list is based on several sources including 974 CMR 3.05,[30] a wetlands creation manual,[31] landscaping catalogs,[32,33]and professional landscape architects and biologists.

1. Native Species

The following species are native to Franklin and well-adapted to the area's climate. Many of the species also provide good wildlife habitat value.

Shade Trees

Botanical Name	*Common Name*
Acer rubrum	Red Maple
Acer saccharum	Sugar Maple
Betula lenta[F]	Sweet Birch[F]
Betula alleghaniensis[F]	Yellow Birch[F]
Betula papyrifera	Paper Birch
Carya ovata[+]	Shagbark Hickory[+]
Castanea dentate	American Chestnut
Fagus grandifolia	American Beech
Fraxinus americana	White Ash
Fraxinus pennsylvanica	Green Ash
Juglans cinerea[+]	Butternut[+]
Liquidambar styraciflua[F]	Sweetgum[F]
Liriodendron tulipifera[F]	Tulip Tree[F]
Nyssa sylvatica	Black Tupelo
Platanus occidentalis	American Sycamore
Quercus alba[+F]	White Oak[+F]
Quercus bicolor[+F]	Swamp White Oak[+F]
Quercus coccinea[+F]	Scarlet Oak[+F]
Quercus palustris[+F]	Pin Oak[+F]
Quercus rubra	Northern Red Oak
Salix nigra	Black Willow
Sassafras albidum	Common Sassafras
Tilia americana 'Redmond'	Redmond Linden
Ulmus americana, disease-resist. var.	American Elm

Notes:
[+] Recommended for planting on the portions of the site away from walks or roads.
[F] These trees need extra care if they are planted during the fall season.
^ Canadian Hemlock is currently under attack by an insect that has no predator.

Evergreen Trees

Botanical Name	*Common Name*
Ilex opaca	American Holly
Juniperus virginiana	Eastern Red Cedar
Pinus rigida	Pitch Pine
Pinus strobus	Eastern White Pine
Thuja occidentalis	American Arborvitae
Tsuga canadensis	Canadian Hemlock^

Ornamental Trees

Botanical Name	*Common Name*
Alnus rugosa	Speckled Alder
Amelanchier canadensis	Shadblow Serviceberry
Amelanchier laevis	Allegany Serviceberry
Betula nigra[F]	River Birch[F]
Betula papyrifera[F]	Paper Birch[F]
Carpinus caroliniana[F]	American Hornbeam [F]
Cercis canadensis	Eastern Redbud
Cornus alternifolia[F]	Pagoda Dogwood[F]
Cornus florida ^[F]	Flowering Dogwood ^ [F]
Crataegus punctata	Dotted Hawthorn
Hamamelis virginiana	Common Witchhazel
Larix laracina	American Larch
Larix decidua	European Larch
Ostrya virginiana	Hop Hornbeam
Prunus pennsylvanica[F]	Pin Cherry[F]
Prunus virginiana[F]	Common Chokecherry[F]
Salix discolor	Pussy Willow
Viburnum lentago	Nannyberry Viburnum

Notes:
^ Cornus florida has been adversely affected by an anthracnose epidemic in the Northeast U.S. in the past two decades. Anthracnose spreads rapidly to other flowering dogwoods. Before using this species, check with local agricultural extensions for the status of anthracnose.
[F]These trees need extra care if they are planted during the fall season.

Deciduous Shrubs

Botanical Name	*Common Name*
Arctostaphylos uva-ursi	Bearberry
Aronia melanocarpa	Black Chokeberry
Clethra alnifolia	Summersweet Clethra
Comptonia peregrina	Sweetfern
Cornus alterniflora	Pagoda Dogwood
Cornus amomum	Silky Dogwood
Cornus racemosa	Gray Dogwood
Cornus rugosa	Redleaf Dogwood
Ilex verticillata	Common Winterberry
Lindera benzoin	Common Spicebush
Myrica pennsylvanica	Northern Bayberry
Azalea nudiflorum	Early Deciduous Pink Azalea
Rhododendron roseum	Roseshell Azalea
Rhododendron viscosum	Swamp Azalea
Rhus glabra	Smooth Sumac
Rhus typhina	Staghorn Sumac
Rosa carolina	Carolina Rose
Rubus odoratus	Flowering Raspberry
Sambucus canadensis	American Elder
Vaccinium corymbosum	Highbush Blueberry
Viburnum acerifolium	Mapleleaf Viburnum
Viburnum cassinoides	Witherod Viburnum
Viburnum dentatum	Arrowwood Viburnum
Viburnum trilobum	American Cranberrybush Viburnum

Evergreen Shrubs

Botanical Name	*Common Name*
Juniperus communis 'Compressa'	Common Juniper
Kalmia angustifolia	Sheeplaurel
Kalmia latifolia	Mountainlaurel
Taxus canadensis	Canadian Yew

Groundcovers

Botanical Name	*Common Name*
Cornus canadensis	Bunchberry Dogwood
Gaultheria procumbens	Checkerberry Wintergreen
Mitchella repens	Partridgeberry
Vaccinium angustifolium	Lowbush Blueberry
Vaccinium macrocarpum	Cranberry

Meadow Grasses/Wildflowers

Botanical Name	*Common Name*
Festuca elatior	Tall Fescue
Lolium perenne	Palmer II Perr. Ryegrass
Sorghastrum nutans	Indian Grass
Panicum	Blackwell Switchgrass
Andropogon gerardii Vitman	Big Bluestem
Schizachyrium scoparium	Little Bluestem
Calamagrostis canadensis	Blue Joint Reedgrass
Antennaria alpina	Alpine Pussy-Toes
Aristida dichotoma	Poverty Grass
Aster linariifolius	Bristly Aster
Eragrostis spectabilis	Purple Lovegrass
Houstonia caerulea	Bluets
Juncus bufonius	Toad Rush
Senecio aureus	Golden Ragwort

2. Salt Tolerant Species

These species are well-suited to roadsides and other locations that are likely to collect salty winter runoff.

Shade Trees

Botanical Name	*Common Name*
Acer campestre	Hedge Maple
Aesculus hippocastanum	Horse-chestnut
Betula lenta *[F]	Sweet Birch*[F]
Betula alleghaniensis *[F]	Yellow Birch*[F]
Fraxinus americana *	White Ash*
Gleditsia triacanthos inermis	Thornless Honeylocust
Nyssa sylvatica *	Black Tupelo*
Quercus alba *+	White Oak*+
Quercus macrocarpa+	Bur Oak+
Quercus robur+	English Oak+
Quercus rubra	Red Oak
Ulmus glabra	Scotch Elm
Ulmus pumila	Siberian Elm

Notes:
* Native Plants
+ Recommended for planting on portions of the site away from walks or roads.
[F] These trees need extra care if they are planted during the fall season.

Ornamental Trees

Botanical Name	*Common Name*
Amelanchier canadensis *	Shadblow Serviceberry*
Betula papyrifera *[F]	Paper Birch*[F]
Betula populifolia *[F]	Gray Birch*[F]
Prunus pennsylvanica *[F]	Pin Cherry*[F]
Prunus virginiana *[F]	Common Chokecherry*[F]
Pyrus calleryana[F]	Callery Pear[F]
Pyrus calleryana 'Bradford'	Bradford Pear
Salix discolor *	Pussy Willow*

Evergreen Trees

Botanical Name	*Common Name*
Juniperus virginiana *	Eastern Red Cedar*
Picea pungens 'glauca'	Blue Colorado Spruce
Pinus nigra	Austrian Pine
Pinus ponderosa	Ponderosa Pine
Pinus rigida *	Pitch pine*

Deciduous Shrubs

Botanical Name	*Common Name*
Arctostaphylos uva-ursi *	Bearberry*
Aronia melanocarpa *	Black Chokeberry*
Aronia prunifolia *	Purplefruit Chokeberry*
Hippophae rhamnoides	Common Seabuckthorn
Lindera benzoin *	Common Spicebush*
Myrica pennsylvanica *	Northern Bayberry*
Rhus glabra *	Smooth Sumac*
Rhus typhina *	Staghorn Sumac*
Salix humilis *	Prairie Willow*
Salix lucida *	Shining Willow*
Shepherdia argentea	Buffaloberry
Tamarix ramosissima	Five Stamen Tamarisk

Vaccinium corymbosum *	Highbush Blueberry*
Viburnum cassinoides *	Witherod Viburnum*
Viburnum dentatum *	Arrowwood Viburnum*

Notes:
* Native Plants
+ Recommended for planting on portions of the site away from walks or roads.
[F]These trees need extra care if they are planted during the fall season.

Evergreen Shrubs

Botanical Name	*Common Name*
Pinus mugo	Mugo Pine
Taxus canadensis *	Canadian Yew*

Groundcovers

Botanical Name	*Common Name*
Vaccinium angustifolium *	Late Lowbush Blueberry*
Vaccnium palladum	Early Lowbush Blueberry

3. Urban Tolerant Species

These species are suitable for planting in "high-stress" environments where there will be pavement within the tree's drip line, high levels of pedestrian or vehicular traffic, vehicle exhaust and air pollution, or other urban stressors. For example, most of these species are generally well-suited to being planted in parking lot islands or other narrow landscaped areas.

Shade Trees

Botanical Name	*Common Name*
Acer campestre	Hedge Maple
Acer rubrum *	Red Maple*
Acer saccharum *	Sugar Maple*
Carpinus betulus fastigiata[F]	Pyramidal European Hornbeam[F]
Celtis occidentalis	Hackberry
Cladastris lutea	Yellowwood
Corylus colurna	Turkish Hazelnut
Eucommia ulmoides	Hardy Rubber Tree
Fraxinus pennsylvanica *	Green Ash*
Gingko biloba	Maidenhair Tree (female +)
Gleditsia triacanthos inermis	Thornless Honeylocust
Liquidambar styraciflua *[F]	Sweet Gum*[F]
Maclura pomifera inermis 'Park'	Park Osage Orange
Nyssa sylvatica *	Black Tupelo*
Platanus acerifolia[F]	London Plane Tree[F]
Sophora japonica	Scholartree
Tilia cordata	Littleleaf Linden
Zelkova serrata[F]	Japanese Zelkova[F]

Notes:
* Native Plants
+ Recommended for planting on portions of the site away from walks or roads.
[F]These trees need extra care if they are planted during the fall season.

Ornamental Trees

Botanical Name	*Common Name*
Betula nigra *[F]	River Birch*[F]
Cercidiphyllum japonicum	Katsuratree
Chionanthus virginicus	White Fringetree
Cornus kousa[F]	Kousa Dogwood[F]
Crataegus phaenopyrum	Washington Hawthorn
Magnolia stellata[F]	Star Magnolia[F]
Ostrya virginiana *	American Hophornbeam*
Oxydendron arboreum[F]	Sourwood[F]

Prunus sargentii[F]	Sargent Cherry[F]
Pyrus calleryana[F]	Callery Pear[F]
Syringa reticulata	Japanese Tree Lilac

Deciduous Shrubs

Botanical Name	*Common Name*
Cornus sericea	Red Osier Dogwood
*Ilex verticillata**	Common Winterberry*
*Ilex verticillata 'Nana'**	Dwarf Winterberry*
Rhus aromatica 'Gro-low'	Dwarf Fragrant Sumac
Spiraea bumalda varieties	Spirea
*Vaccinium angustifolium**	Lowbush Blueberry*

Groundcovers

Botanical Name	*Common Name*
Cotoneaster horizontalis	Rockspray Cotoneaster
Hedera helix	English Ivy
Juniperus chinensis sargentii	Sargent Juniper
Juniperus horizontalis varieties	Creeping Juniper
Vinca minor	Periwinkle
Pachysandra terminalis	Japanese Pachysandra

4. Species for Erosion Control

These species can be used for stabilizing the ground and preventing erosion, and should be considered for planting in areas with steep slopes or unstable, erodible soils.

Botanical Name	*Common Name*
Aegopodioum podagraria 'Variegatum'	Variegated Snow-on-the-Mountain
Celastrus scandens	American Bittersweet
Clematis paniculata	Clematis
Cornus, shrubby types	Dogwood (Silky, Gray-stemmed, Gray, Redleaf)
Cotoneaster, low types	Cotoneaster
Cytisus spp.	Scotch Broom
Erica spp.	Heath
Euonymus fortunei 'Colorata' and cvs.	Wintercreeper
Forsythia suspensa and cvs.	Weeping Forsythia
Genista x 'Lydia'	Genista lydia
Hedera helix and cvs.	English Ivy
Hemerocallis, all	Daylilly
Houtuynia cordata 'Chameleon'	Chaeleon Houtuynia
Itea spp.	Sweetspire
Juniperus, low types	Juniper
Ligustrum, all	Privet
Myrica pennsylvanica	Northern Bayberry
Parthenocissus spp.	Ivy
Polygonum aubertii	Silver-vine Fleeceflower
Rhus aromatica and cvs.	Fragrant Sumac
Rosa, most	Most roses
Salix purpurea	Purpleosier Willow
Stephanandra incisa	Cutleaf Stephanandra
Symphoricarpos x chenaultii 'Hancock'	Chenault Coralberry
Vinca minor and cvs.	Periwinkle
Yucca filamentosa	Yucca

5. Wetland Species

This list of species is generally well-suited for planting in constructed wetlands, wet swales, and other stormwater management areas that will typically be wet. Plantings in each section of the wet area must be selected according to the hydrological conditions in that area. See Figure 2-4 for a sample wetland planting layout.

Herbaceous Plants

Botanical Name	*Common Name*	*Water Depth (see below)*
Osmunda cinnamomea	Cinnamon fern	Transitional
Osmunda regalis	Royal fern	Transitional
Symplocarpus foetidus	Skunk cabbage	Transitional
Scirpus cyperinus	Woolgrass	Shallow
Thelypteris palustri	Marsh fern	Shallow
Caltha leptosepala	Marsh Marigold	Shallow
Polygonum coccineum	Pennsylvania smartweed	Shallow
Lobelia cardinalis	Cardinal Flower	Shallow
Lobelia siphilitica	Great Lobelia	Shallow
Iris versicolor	Blue Flag Iris	Medium
Acorus calamus	Sweet flag	Medium
Calla palustris	Water arum	Medium
Sparganium eurycarpum	Burreed	Medium
Scirpus americanus	Three-square	Medium
Scirpus fluviatilis	River bulrush	Medium
Sagittaria latifolia	Arrowhead	Medium
Ponetederia cordata	Pickerelweed	Medium
Peltandra cordata	Arrow arum	Medium
Potamogeton pectinatus	Sago pondweed	Deep
Vallisneria americana	Tapegrass	Deep
Ranunculus flabellaris	Yellow water buttercup	Deep
Ranunculus aquatilis	White water buttercup	Deep
Scirpus validus	Bulrush	Deep
Nymphea odorata	Fragrant white lily	Deep
Nuphar luteum	Spatterdock	Deep
Brasenia schrebrri	Watershield	Deep

Transitional: seasonally flooded; Shallow: seasonally flooded to permanently flooded to 15 cm; Medium: 15 to 50-cm water depths; Deep: 50 to 200-cm water depths.

Shrubs

Botanical Name	*Common Name*
Clethra alnifolia	Summersweet Clethra
Cornus amomum	Silky Dogwood
Ilex verticillata	Winterberry
Kalmia angustifolia	Sheep Laurel
Lindera benzoin	Spicebush
Rhodendron viscosum	Swamp Azalea
Viburnum recognitum	Northern Arrowwood
Vaccinium corymbosum	Highbush Blueberry

Trees

Botanical Name	*Common Name*
Nyssa sylvatica	Black gum
Quercus bicolor	Swamp oak
Fraxinus americana[+]	White ash[+]
Fraxinus pennsylvanica *	Green Ash*
Acer rubrum[+]	Red Maple[+]
Quercus bicolor^	Swamp oak^
Betula nigra^	River birch^

Notes:
*Species that will tolerate flooding for more than 1 year
[+]Species that will tolerate flooding for one growing season
^Species that will tolerate flooding for less than 30 days during the growing season

Woody Wetland Plants

Botanical Name	*Common Name*
Salix nigra *	Black Willow*
Cephalanthus occidentalis *	Buttonbush*
Cornus stolonifera *	Red-osier Dogwood*
Sambucus canadensis[+]	Elder[+]
Vaccinium corymbosum[+]	Blueberry[+]
Chamaecyparis thyoides[+]	Atlantic white cedar[+]
Alnus rugosa[+]	Spackled Alder[+]
Nyssa sylvatica^	Black gum^
Ilex opaca^	American Holly^

6. Moist Tolerant Species

These species require significant moisture, and many are adapted to survive periods of standing water. In general, these species should only be planted where local soil and topography produce moist conditions. Landscape designers should not rely upon irrigation to sustain these species.

Woody Plants

Botanical Name	*Common Name*
Acer negundo	Box Elder
Acer rubrum	Red Maple
Alnus rugosa	Speckled Alder
Amelanchier	Serviceberry
Andromeda polifolia	Bog Rosemary
Aralia spinosa	Devil's Walkingstick
Aronia arbutifolia	Chokeberry
Azalea arborescens	Sweet Azalea
Azalea vaseyi	Pinkshell Azalea
Azalea viscosum	Swamp Azalea
Betula nigra	River Birch
Calluna vulgaris	Heather
Calycanthus floridus	Common Sweetshrub
Campsis radicans	Trumpet Creeper
Cephalanthus occidentalis	Buttonbush
Chamaecyparis thyoides	Atlantic White Cedar
Clethra acuminata	Mountain Pepperbush
Clethra alnifolia	Summersweet
Cornus spp.	Dogwood (Silky, Shrub, Gray)
Erica carnea	Heath
Gymnocladus dioicus	Kentucky Coffee Tree

Halesia diptera	Two-winged Silverbell
Hamamelis virginiana	Witchhazel
Ilex spp.	Holly
Ilex verticillata	Winterberry
Kalmia latifolia	Mountain Laurel
Larix spp.	Larch
Leucothoe fontanesiana	Drooping Leucothoe
Lindera benzoin	Spicebush
Magnolia virginiana	Sweetbay Magnolia
Malus	Crabapple
Myrica pennsylvanica	Bayberry
Nyssa sylvatica	Black Gum
Rhododendron canadense	Rhodora (for bogs only)
Rhododendron maximum	Rosebay Rhododendron
Rhus aromatica	Fragrant Sumac
Salix	Willow
Sambucus canadensis	American Elder
Sassafras albidum	Common Sassafras
Vaccinium	Blueberry, Cranberry
Zenobia pulverulenta	Dusty Zenobia

Perennials

Botanic Name	*Common Name*
Aconitum carmichaelii	Monkshood
Amsonia hubrechtii	Star Flower
Aruncus dioicus	Goatsbeard
Clatha palustris	Marsh Marigold
Chelone lyonii	Turtlehead
Cimicifuga	Snakeroot
Epimedium	Bishops' Cap
Ferns	Ferns
Filipendula ulmaria	Meadowsweet
Gillenia trifoliate	Bowman's Root
Helleborus niger	Christmas Rose
Hemerocallis	Daylilly
Hibiscus moscheutos	Rosemallow
Iberis sempervirens	Candy Tuft
Iris ensata	Japanese Iris
Iris siberica	Siberian Iris
Kirengeshoma palmate	Yellow Waxbells
Liatris spicata	Gayfeather
Limonium latifolium	Sea Lavender (for salt marsh only)
Lobelia cardinalis	Cardinal Flower
Lobelia siphilitica	Big Blue Lobelia
Monarda didyma	Beebalm
Petasites	Butterbur
Phlox divaricata	Woodland Phlox
Platycodonj grandiflorus	Balloon flower
Polygonatum	Solomon's Seal
Tradescantia x andersonianan	Spiderwort
Trillium	Wakerobin
Trollius	Globeflower

Grasses

Botanical Name	*Common Name*
Carex muskingumensis	Palm Sedge
Miscanthus sacchariflorus Giganteus	Giant Silver Banner Grass
Pennisetum alopecuroides	Fountain Grass
Sisyrinchium	Blue-eyed Grass
Typha angustifolia	Cattail

7. Drought Tolerant Species

These species require relatively little water, can survive longer periods without water, and/or are adapted to grow in well-drained soils. In the interest of minimizing the demand for irrigation water, these species should be considered in sunny areas with well-drained soil that are likely to experience dry conditions.

Woody Plants

Botanical Name	*Common Name*
Abies concolor	White Fir
Acer truncatum	Shantung Maple
Aesculus x carnea	Ruby Horsechestnut
Aesculus pavia	Red Buckeye
Aralia spinosa	Devil's Walkingstick
Arctostaphylos uva-ursi	Bearberry
Buddleia alternifolia	Fountain buddleia
Calluna vulgaris	Heather
Campsis radicans	Trumpet Creeper
Caragana microphylla	Littleleaf Caragana
Carpinus betulus	European Hornbeam
Carpinus caroliniana	American Hornbeam
Chaenomeles speciosa	Flowering Quince
Chamaecyparis thyoides	Atlantic White Cedar
Comptonia peregrina	Sweet Fern
Cornus racemosa	Gray Dogwood
Corylus colurna	Turkish Filbert
Cotinus coggygria	Smoke Tree
Crataegus crusgalli	Cockspur Hawthorn
Fraxinus pennsylvanica	Green Ash
Gleditsia tricanthos inermis	Honeylocust
Gymnocladus dioicus	Kentucky Coffee tree
Hamamelis	Witchhazel
Hybiscus syriacus	Rose-of-Sharon
Hydrangea	Hydrangea
Indigofera gerardiana	Himalayan Indigo
Jasminum nudiflorum	Winter Jasmine
Juniperus	Juniper
Kerria japonica	Japanese Kerria
Koelreuteria paniculata	Golden Rain Tree
Kolkwitzia amabilis	Beautybush
Microbiata decussata	Siberian Carpet Cypress
Myrica pensylvanica	Northern Barberry
Pinus banksiana	Jack Pine
Pinus mugo	Mugo Pine
Pinus nigra austriaca	Austrian Pine
Pinus strobus	Eastern White Pine

Platanus x acerfolia	London Planetree
Potentilla fruticosa	Potentilla
Prunus maritima	Beach plum (especially back and scarlet)
Quercus	Oak
Rhus	Sumac
Rosa rugosa	Rugosa Rose
Salix	Willow
Sambucus canadensis	American Elder
Sassafras albidum	Common Sassafras
Shepherdia argentea	Buffalo Berry
Sophora japonica	Scholartree
Stephanandra incisa	Cutleaf Stephanandra
Vitex agnus-castus	Chastetree

Perennials

Botanical Name	*Common Name*
Anthemis tinctoria	Golden Marguerite
Artemisia	Wormwood
Armeria maritime	Thrift
Asclepias tuberosa	Butterfly Milkweed
Aubrieta deltoidea	False Rock Cress
Aurinia saxatilis	Basket-of-Gold
Callirhoe involucrata	Poppy Mallow
Campanula carpatica	Carpathian Bellflower
Centaurea Montana	Mountain Bluet
Cerastium tomentosum	Snow-in-Summer
Echinacea purpurea	Coneflower
Echinops ritro	Globe Thistle
Eryngium planum	Sea Holly
Eupatorium	Hardy Ageratum
Gaillardia x grandiflora	Blanket Flower
Geranium dalmaticum	Cranesbill
Geranium macrorhizum	Bigroot
Gypsophila	Baby's Breath
Helianthus grosse-serratus	Sawtooth Sunflower
Hemerocallis fulva	Daylilly
Lamium maculatum	Spotted Dead Nettle
Lewisia cotyledon	Bitter Root
Nepera x faassenii	Persian Catmint
Oenothera	Evening Primrose
Opuntia humifusa	Prickly Pear
Papaver orientale	Poppy
Perovskia atriplicifolia	Russian Sage
Phlox subulata	Moss Pink
Polemonium caereum	Jacob's Ladder
Rudbeckia	Coneflower
Salvia verticillata	Purple Rain
Santolina chamaecyparissus	Lavender Cotton
Sedum	Stonecrop
Sempervivum	Houseleek
Stachys byzantina	Lamb's Ears
Stokesia laevis	Stoke's Aster
Thymus serpyllum	Mother-of-Thyme
Yucca	Desert Candle

Grasses

Botanical Name	*Common Name*
Bouteloua gracilis	Blue Gramma
Elymus arenarius	Blue Lyme Grass
Festuca cinerea	Blue Fescue
Schizachyrium scoparium	Little Bluestem

8. Habitat Creating Species

Habitat creating species provide food or home sites for birds and other animals.

The following plants provide good habitat value for birds and animals.

Trees

Botanical Name	*Common Name*
Acer rubrum	Red Maple
Acer saccharinum	Sugar Maple
Amelanchier canadensis	Serviceberry
Betula nigra	River Birch
Betula papyrifera	White Birch
Celtic occidentalis	Hackberry
Cornus, most	Dogwoods
Crataegus, most	Hawthorn
Malus, most	Crabapple
Nyssa sylvatica	Black gum
Picea glauca	White spruce
Picea pungens	Blue Spruce
Pinus strobus	White Pine
Populus, most	Poplars
Quercus alba	White Oak
Quercus palustris	Pin Oak
Quercus rubra	Red Oak
Sorbus aucuparia	Mountain Ash
Tsuga canadensis and cvs.	Eastern Hemlock

Shrubs

Botanical Name	*Common Name*
Amelanchier canadensis and cvs.	Serviceberry
Aralia spinosa	Devil's Walking Stick
Aronia spp. And cvs.	Chokeberry
Cornus, most	Dogwoods
Cotoneaster spp. and cvs.	Cotoneaster
Ilex glabra	Inkberry
Juniperus virginiana and cvs.	Eastern Red Cedar
Myrica pensylvanica	Bayberrry
Rosa rugosa	Rugosa Rose
Salix discolor	Pussy Willow
Viburnum dentatum	Arrowwood

The following plant species provide persistent fruit that lasts into the late fall and winter, thus providing food for wildlife during the critical months when food is most difficult to find.

Trees

Botanical Name	*Common Name*
Cornus mas	Cornelian Cherry Dogwood (Golden Glory)
Crataegus phaenopyrum	Washington Hawthorn
Malus spp., most	Crabapple

Shrubs

Botanical Name	*Common Name*
Aronia arbutifolia	Red Chokeberry
Ilex glabra	Inkberry
Juniperus spp. and cvs.	Juniper
Myrica pennsylvanica	Bayberry
Pyracantha coccinea and cvs.	Firethorn
Rhodotypos scandens	Black Jetbead
Rhus spp.	Sumac
Rosa rugosa and cvs.	Rugosa Rose
Rosa wichuriana and cvs.	Memorial Rose
Viburnum dilatatum	Linden Viburnum
Viburnum setigerum	Tea Viburnum

9. Invasive Species

Invasive plants are introduced species that tend to spread into natural habitats and outcompete native species because of their superior reproductive ability, aggressive growth pattern, or (most commonly) lack of native competitors, herbivores, parasites, or diseases. In terms of maintaining native biodiversity, invasive species are a serious threat because they compete with native species for limited land, water and sunlight. Franklin's policy prohibits the planting of invasive species that appear in the following list.

Shade Trees

Botanical Name	*Common Name*
Acer ginnala	Amur Maple
Acer platanoides	Norway Maple
Acer pseudoplatanus	Sycamore Maple
Populus alba	White Cottonwood
Robinia pseudoacacia	Black Locust

Deciduous Shrubs/Vines

Botanical Name	*Common Name*
Ampelopsis brevipedunculata	Porcelain Berry
Berberis thunbergii	Japanese Barberry
Berberis vulgaris	Common Barberry
Celastrus orbiculata	Oriental Bittersweet
Cynanchum louiseae	Black Swallow-wort
Elaeagnus umbellata	Autumn Olive
Elaeagnus angustifolia	Russian Olive
Euonymus alatus	Winged Euonymus
Euphorbia cyparissias	Cypress Spurge
Hesperis natonalis	Dame's Rocket

Ligustrum obtusifolium	Blunt-leaver Privet
Ligustrum vulgare	Privet
Lonicera japonica	Japanese Honeysuckle
Lonicera maackii	Amur Honeysuckle
Lonicera morrowii	Morrow's Honeysuckle
Lonicera tatarica	Tatarian Honeysuckle
Lonicera xbella	Morrow's x Tatarian Honeysuckle
Polygonum cuspidatum	Japanese Knotweed
Pueraria lobata	Kudzu
Rhamnus cathartica	Common Buckthorn
Rhamnus frangula	Shining Buckthorn
Rosa multiflora	Multiflora Rose

Meadow Grasses/Wildflowers

Botanical Name	*Common Name*
Achillea millefolium var. millefolium	Common Yarrow
Aegopodium podagraria	Goutweed
Alliaria petiolata	Garlic Mustard
Cabomba caroliniana	Fanwort
Centaurea maculosa	Spotted Knapweed
Cirsium canadense	Field or Canada Thistle
Coreopsis lanceolata	Lance-leaved Coreopsis (Tickseed)
Cytisus scoparius	Scotch Broom
Daucus carota	Queen Anne's Lace
Egeria densa	Giant Waterweek
Epilobium hirsutum	Hairy Willow-herb
Euphorbia cyparissias	Cypress Spurge
Galium mollugo	Field Madder
Glaucium flavum	Sea Poppy
Glechoma hederacea	Gill-over-the-ground (Ground Ivy)
Holcus lanatus	Velvet Grass
Hypericum perforatum	Common St. John's Wort
Iris pseudacorus	Yellow Iris
Linaria vulgaris	Butter and Eggs
Lysimachia nummularia	Moneywort
Lythrum salicaria	Purple Loosestrife
Myosotis scorpioides	True Forget-me-not
Myriophyllum heterophyllum	Variable Water-milfoil
Myriophyllum spicatum	Spiked Water-milfoil
Najas minor	Lesser Naiad
Nasturtium officinale	Watercress
Phalaris arundinace	Reed Canary Grass
Phragmites australis	Phragmites
Plantago lanceolata	Ribgrass (Lance-leaved Plantain)
Poa compressa	Canada Bluegrass
Potamogeton crispus	Curly or Crisped Pondweed
Ranunculus acris	Tall Buttercup
Ranunculus bulbosus	Bulbous Buttercup
Ranunculus repens	Creeping Buttercup
Ribes rubrum	Garden Red Currant
Rumex acetosella	Sheep Sorrel
Rumex crispus	Curled Dock
Rumex obtusifolius	Bitter or Broad-leaved Dock
Solanum dulcamara	Bittersweet Nightshade
Trapa natans	Water Chestnut

Tussilago farfara	Coltsfoot
Verbascum thapsus	Flannel-leaved Mullein

Lawn Grasses

Botanical Name	*Common Name*
Agrostis gigantea	Redtop, Upland Bentgrass
Festuca longifolia	Hard Fescue
Festuca ovina	Sheep Fescue

V. Site Planning

Franklin's site planning policy is intended to further the Town's goals of:

- **Protecting the environment**, including wildlife habitat, water resources, and "ecosystem services" such as groundwater recharge, flood attenuation and pollutant removal;
- **Creating a visually appealing community**;
- **Preserving the Town's cultural heritage**, including historic sites, view corridors, trees and other noteworthy features;
- **Stabilizing and increasing property values**; and
- **Encouraging sustainable development** that minimizes energy use and pollution.

FRANKLIN POLICY: Subdivision plans and site plans for all forms of development shall adhere to the principles of *environmental compatibility*, *aesthetic compatibility*, and *energy-efficient design*.

In order to minimize costs related to design and engineering (as well as construction), it is recommended that applicants follow the **four-step planning process** described in Appendix A. Creative designers will usually be able to find many cost savings in Franklin's site planning guidelines related to a reduction in clearing, cut and fill, replanting, and stormwater management needs.

Guidelines and criteria for site planning include the following:

- **Refrain from disturbing unique natural features of the site to the maximum extent possible.** Depending on the site, such features could include wooded areas, specimen trees (e.g. larger than 10" diameter at breast height), knolls, and rock outcroppings as well as the more typically conserved streams, wetlands and ponds. These features should be identified early in the site planning process (for example, in the survey or an early site visit) and incorporated into the site plan either as "focal points" for the development or as protected areas, whichever is more appropriate. In general, clearing of vegetation and alteration of topography shall be limited to the maximum percent lot coverage stated in the zoning bylaw (structures plus paving) plus 10% (e.g., 35% in the RR-I district and 70% in the C-II district). Native vegetation shall be planted in disturbed areas as needed to enhance or restore wildlife habitat. Disturbance shall be limited to construction areas only. Preservation of groups of trees (e.g., beech, oak, hickory, etc.) is encouraged.
- **Refrain from disturbing sites of historic and/or cultural significance.** Significant sites could include old buildings, cellar holes or graveyards, as well as historic trees that have a diameter at breast height of 20" or greater.
- **Preserve views and vistas both into and out of the site.** A visual analysis should be conducted to identify any scenic "windows" into the site and preserve the aesthetic value of these views whenever possible.
- **Minimize cut and fill.** Roads should follow the natural contours whenever possible, taking a steeper path only if necessary. Steep areas on individual house lots should generally be left as natural vegetation, not regraded to allow for a sloping lawn. This approach can reduce grading costs and stormwater control costs because it often results in

less land being disturbed, thereby creating fewer erosion or runoff problems. In addition, future homeowners will have fewer expenses and hassles related to maintaining steep lawns and landscaped areas, which are often costly to maintain and have low utility as yards.

- **Locate houses and buildings in a way that blends into the natural topography.** Buildings should not be set high up on a hill where they will be an eyesore or a focus of attention. Generally buildings should be situated near the grade of the road, unless this would require extensive regrading, in which case they may be higher or lower. For buildings located much above the road, an extra effort should be made to recess these buildings into the treeline to reduce their visual impact.

- **Conserve energy by orienting buildings to the sun and wind for maximum efficiency.** Buildings should be aligned to be protected from cold winter winds, shaded from summer sun, and open to winter sun. Protection from cold winter winds can be achieved by retaining natural vegetation at a building's northwest edge or by planting evergreen species such as white pine (*Pinus strobus*) in this location. For summer shading and winter heating, deciduous species can be planted close to the building, along the east, south and west exposures. Winter sunlight will penetrate the empty branches and provide heat. Home interiors should be laid out with time-of-day occupancy in mind.[34] Living and high-activity rooms should be placed on the south side where they are heated by the low winter sun and shaded from the high summer sun. Garages, utility rooms and closets can be positioned to provide insulating barriers on the northeast and northwest sides.

Appendix A

This Guidebook requires site plans and subdivision applications to consider the presence of natural, cultural, and aesthetic features on any proposed development or redevelopment site. To meet this requirement, the Town recommends that designers utilize a four-step planning process to identify and plan for these site features.[35] The Town also recommends this process as a way of expediting the project review and approval process and minimizing the need for re-designs.

Under the four-step process, the applicant first prepares an "environmental constraints and opportunities plan" for an initial Planning Board meeting. At this meeting, the applicant and the Planning Board identify those portions of the site that should be conserved (e.g., wetlands, viewsheds, specimen trees, historic sites), and those that are most suitable for development. This analysis should consider natural and visual features, as well as the site's orientation with respect to the sun and wind. With this input, the designer then identifies building sites and lays out the internal circulation network in a way that minimizes clearing, vegetation disturbance and regrading, and situates the buildings within the natural topography. The last step is to draw in the lot lines, if applicable. The goal of this process is not to reduce the overall development program, but rather to lay it out in a less expensive and more environmentally and aesthetically compatible fashion.

The four site planning steps are described below.

1. Constraints and Opportunities Plan

Site planning should begin with the preparation of a **constraints and opportunities plan** to understand the site's features and its context. The plan should identify water resources (wetlands, streams, ponds, vernal pools, floodplains, and springs or seeps), site conditions (steep slopes, significant rock outcroppings, landforms such as knolls and hollows, hydric soils, and prime aquifer recharge areas), ecological features (woodlands, wildlife habitat, and rare species), scenic/visual features (specimen trees, farmland and meadows, and views both into and out from the site), and historic and archaeological resources. The constraints and opportunities plan may be prepared in conjunction with the site survey, but will require more investigation and analysis than a survey usually provides. Ideally a multidisciplinary team with an engineer, scientist, and landscape architect will visit

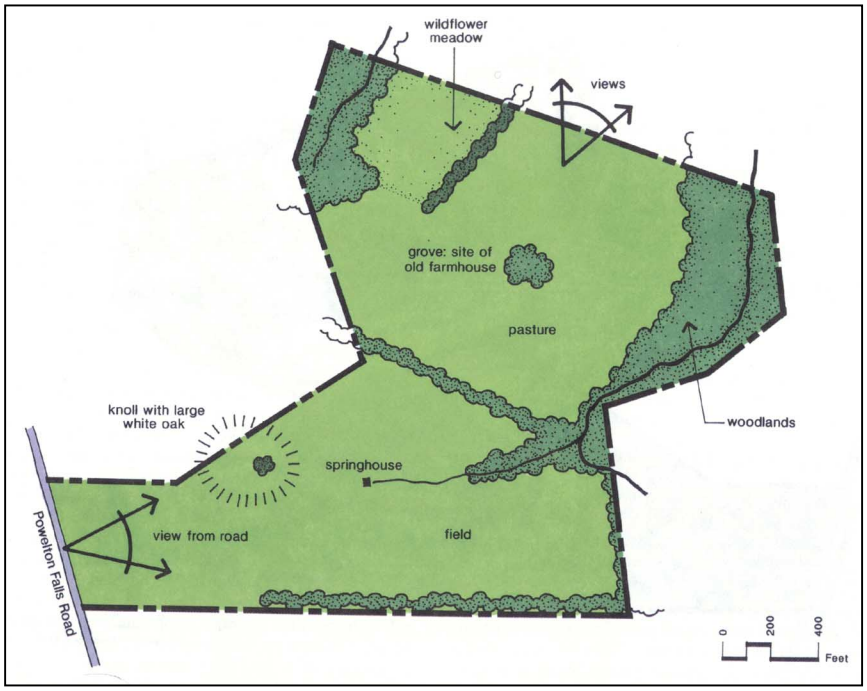


Figure A-1: Sample constraints and opportunities plan showing significant natural and cultural features as well as viewsheds.

the site and prepare the constraints and opportunities plan. During this step, the designer should also consider the locational context, including surrounding land uses, water resources, historic sites, and other features. The constraints and opportunities plan can either be a single plan or a series of layers of clear plastic or tracing paper, each representing one set of site features.

2. Identify the Conservation and Development Areas

Once all of the existing conditions information has been combined on the constraints and opportunities plan, the most suitable areas for development and conservation will become apparent. Conserved lands should include *primary conservation areas* (areas such as wetlands, floodplains, and steep slopes that are generally unbuildable due to environmental regulations or site conditions) as well as *secondary conservation areas* (unique or attractive site features, or areas that are important for environmental protection but not otherwise regulated). Working within the zoning guidelines, the designer should identify areas that will be conserved and areas that will be developed. The designer should be creative in trying to site the desired development program outside of the identified conservation areas, using Franklin's flexible development options if appropriate.

3. Locate the Building Sites and Lay Out the Roads and Trails

Building sites should be sited within the identified development areas to the maximum extent possible. Again, use of Franklin's various flexible development options may be necessary to meet this goal. In addition, the site will need to be designed carefully, with the site's constraints and opportunities in mind. Sensitive features in the conservation areas (e.g., vernal pools) should be buffered from the development areas, while scenic or historic features (e.g., knolls, meadows, or rock outcroppings) could be "showcased" by providing an open view to toward them. In residential projects, natural vegetation will often need to be retained on individual house lots so that the total development program can fit into a development area that is only a fraction of the site's total land area. Finally, buildings should be sited with consideration to the view from the



Figure A-2: Sample plan identifying conservation and development areas. Note that the conservation areas include both regulated areas (wetlands and streams) as well as significant site features identified in the constraints and opportunities plan (viewshed from the road, scenic knoll, and wildflower meadow).

public way as well as the view out from the buildings. In suburban and rural sections of the Town, developments should generally be as naturally camouflaged as possible.

As discussed in **Section V**, buildings should also be oriented to the sun and wind for maximum efficiency. Protection from cold winter winds can be achieved by retaining natural vegetation along a building's northwest edge or by planting evergreen species such as white pine (*Pinus strobus*) in this location. For summer shading and winter heating, deciduous species can be planted close to the building, along the east, south and west exposures. Winter sunlight will penetrate the empty branches and provide heat. Home interiors should be laid out with time-of-day occupancy in mind. Living and high-activity rooms should be placed on the south side where they are heated by the low winter sun and shaded from the high summer sun. Garages, utility rooms and closets can be positioned to provide insulating barriers on the east and west sides.

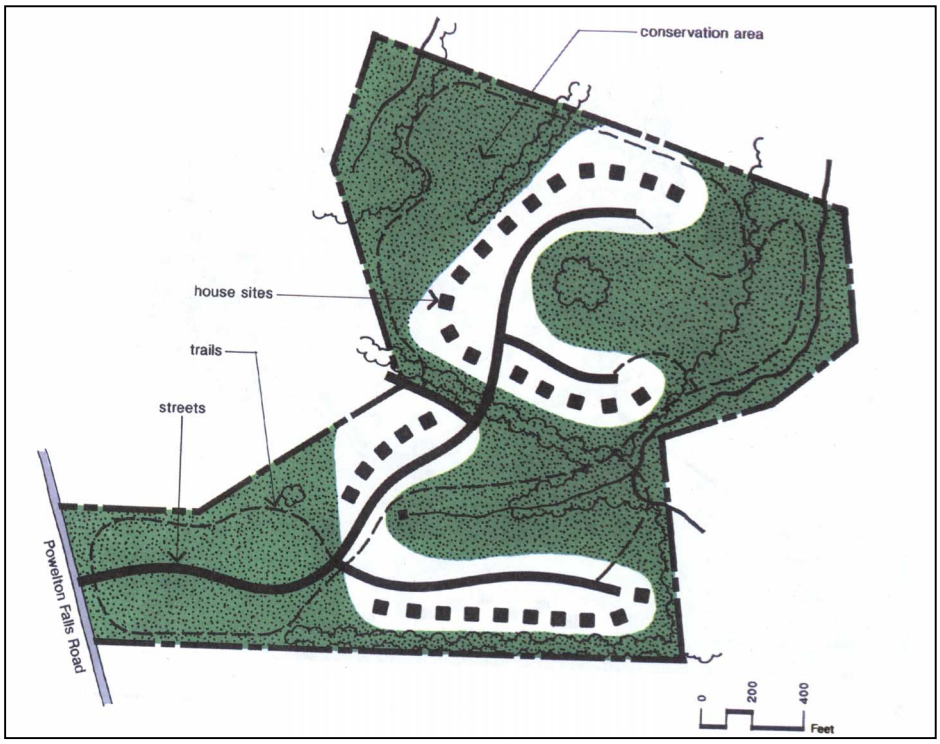


Figure A-3: Buildings and roads are sited within the development envelopes identified in Step 2.

During this step, the system of roads and pedestrian network (if any) should be laid out based on the most efficient way to access the building sites with a minimum of environmental and aesthetic impacts. From an engineering standpoint, it is important to consider the topography; from an environmental approach, to consider mature tree stands, wildlife habitat areas, wetlands, etc.; and from an aesthetic and speed control perspective to build "slow" roads. "Slow" roads are naturally curving, or have short straight segments connected with relatively tight bends that force drivers to go slowly. As with the siting of buildings, preserving vistas should be a prime consideration.

4. Draw in the Lot Lines

Once steps 1 through 3 have been completed, the lot lines (if any) can be drawn in based on the building locations. The location of the buildings may necessitate a subdivision plan that takes advantage of Franklin's flexible development options.

Figure A-4: Sample of a residential subdivision plan produced under the four-step planning process. Note that developed areas avoid, but are suituated to take advantage of, sensitive and scenic site features.





Figure A-5: Sample of a more conventional residential subdivision. Note that the developed areas destroy or obscure many of the site's natural and scenic features. **This type of site planning should be avoided in Franklin.**

Endnotes

[1] Overall, these practices will aid Franklin in meeting the EPA Stormwater Phase II requirements. The EPA's goals are to minimize polluted stormwater entering rivers and streams by reducing the discharge of pollutants to the maximum extent practicable; to protect water quality; and to satisfy the appropriate water quality requirements of the Clean Water Act. Phase I of EPA's plans was initiated in 1990 and regulated municipal separate storm sewer systems (MS4s) that were defined as "large" and "medium." Phase II, which was recently finalized, focuses on "small" MS4s. Franklin operates a small MS4 and is therefore subject to the Phase II requirements. To comply with the Phase II requirements, the EPA requires that towns set in place regulations and programs that include public education and outreach, public involvement, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control and pollution prevention/good housekeeping.

[2] These stormwater management standards are adopted from the Massachusetts Department of Environmental Protection (DEP) Stormwater Policy Handbook. The DEP standards already apply to any project that falls under the jurisdiction of the Wetlands Protection Act. Franklin has adopted three of the nine DEP standards, and has incorporated by reference the relevant portions for the DEP's Stormwater Policy Handbook that relate to the implementation of these standards. For Franklin standard #2 (DEP standard #3), engineers should consult the DEP Handbook to determine the requirement for on-site recharge and how to demonstrate compliance with this requirement. For Franklin standard #3 (DEP standard #4), engineers should also consult the DEP Handbook for additional information. The Stormwater Policy Handbook and an accompanying Stormwater Technical Handbook may be downloaded from the DEP's website at www.state.ma.us/dep or purchased at the state bookstore.

[3] Adapted from the *Low Impact Development (LID) Design Strategies: An Integrated Design Approach*, Department of Environmental Resources, Prince George's County, Maryland, June 1999, www.co.pg.md.us/Government/DER/PPD/pgcounty/pdf/LID/LiDNatl.pdf. Additional information from the *DEP Stormwater Policy Handbook* and *EPA Stormwater Phase II Best Management Practices Factsheets*, www.epa.gov/npdes/menuofbmps/menu.htm.

[4] Based on the table in the *DEP Stormwater Policy Handbook*, with additional information on other systems added from *Prince George's County LID Design Strategies*.

[5] *Prince George's County LID Design Strategies.*

[6] *Prince George's County LID Design Strategies.*

[7] *Northern Virginia Planning District Commission (NVPDC) Nonstructural Urban BMP Handbook*, Department of Conservation and Recreation/Division of Soil and Water Conservation, December 1996, www.novaregion.org.

[8] *NVPDC Nonstructural Urban BMP Guidebook.*

[9] *Stormwater Management Fact Sheet: Stormwater Wetlands*, The Stormwater Center, www.stormwatercenter.net.

[10] *NVDPC Nonstructural Urban BMP Handbook.*

[11] *Bioretention: A Low Impact Stormwater Best Management Practice*, University of Maryland, www.ence.umd.edu/~apdavis/Bioret.htm.

[12] *EPA Stormwater Technology Fact Sheet – Bioretention*, EPA 832–F-99–012.

[13] *Maryland Stormwater Design Manual.*

[14] EPA Stormwater Technology Fact Sheet.

[15] EPA Stormwater Phase II Best Management Practices Factsheets, www.epa.gov/npdes/menuofbmps/menu.htm.

[16] www.uncommonplants.com

[17] *Green Roofs: Stormwater Management From the Top Down*, Katrin Scholz-Brath, www.edcmag.com, January/February 2001.

[18] The University of Florida Natural Area Teaching Lab has been working on retention basin designs as part of their Stormwater Ecological Enhancement Project. See natl.ifas.ufl.edu.

[19] *DEP Stormwater Manual*.

[20] *DEP Stormwater Manual*.

[21] *EPA Stormwater Phase II Best Management Practices Factsheets*.

[22] *Prince George's County LID Design Strategies*.

[23] *EPA Stormwater Phase II Best Management Practices Factsheets*.

[24] Geotextiles and other erosion control and stormwater management products may be purchased from numerous commercial vendors. Vendors include Synthetic Industries, www.fixsoil.com; Pinelands Nursery, www.pinelandsnursery.com; North American Green, www.nagreen.com; and the American Excelsior Company, www.amerexcel.com/erosionindex.htm.

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[27] *Best Management Practices for Minnesota: Protecting Water Quality in Urban Areas*, Minnesota Pollution Control Agency, 1991.

[28] *NVPDC Nonstructural Urban BMP Handbook*.

[29] *NVPDC Nonstructural Urban BMP Handbook*.

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[31] *Creating Freshwater Wetlands*, Donald A. Hamoner, Lewis Publishers, Michigan, 1992.

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[33] Weston Nurseries Catalog, Hopkinton, MA, 1999, www.westonnurseries.com.

[34] *Best Development* Practices, Reid H. Ewing *et al.*, Planners Press, 1996.

[35] This process is the essentially the same as the planning process required for projects proposed under Franklin's Senior Village Overlay District. This process is based on the work of Randall Arendt as presented in his book *Conservation Subdivision Design*, 1996. The images used in this section of the Handbook are taken from Arendt's book.

Appendix C

Waukesha Water Utility Future Water Supply Study

Report

Future Water Supply

Prepared for

Waukesha Water Utility

March 2002

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Wisconsin Geological Survey

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University of Wisconsin-Madison

Dr. Ken Potter

Executive Summary

Purpose

This study was conducted to evaluate water supply alternatives for consideration by the Waukesha Water Utility to continue providing reliable, high quality, affordable drinking water to its customers.

Waukesha Water System

Waukesha obtains its drinking water from a sandstone aquifer (Cambrian-Ordovician) with ten active wells, each about 2,000 feet deep. The wells have a combined capacity of about 15 million gallons per day (mgd). The water system is shown in Figure E-1 (see following page).

During 2001, average day demand was about 8 mgd, and maximum day demand about 13 mgd. Anticipated increases in water demand have created the need to provide additional water supply capacity. The maximum day water demand could increase from 13 mgd to 22 mgd (or more) over the next 50 years.

The sandstone groundwater level near Waukesha is declining 5 to 10 feet per year. Groundwater level is currently about 500 feet below the ground surface, and still declining (Figure E-2). This decline increases pumping, operation, and maintenance costs.

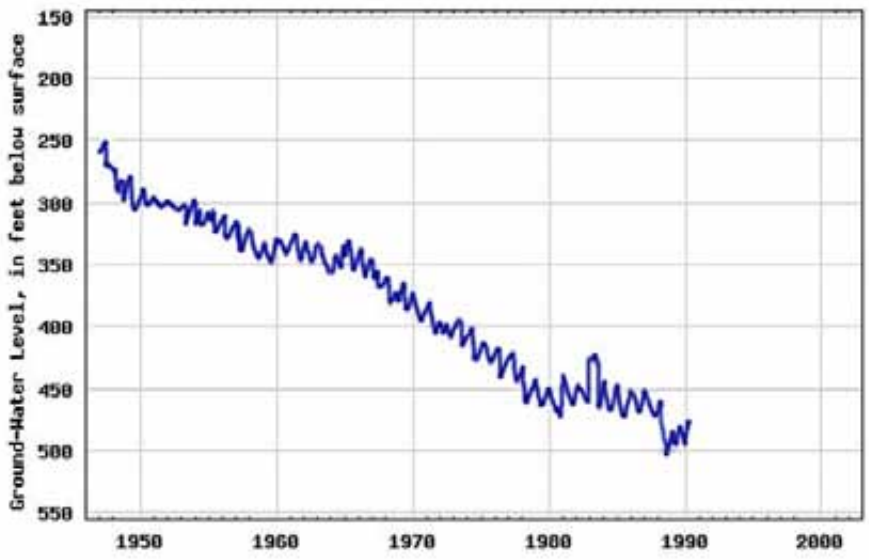
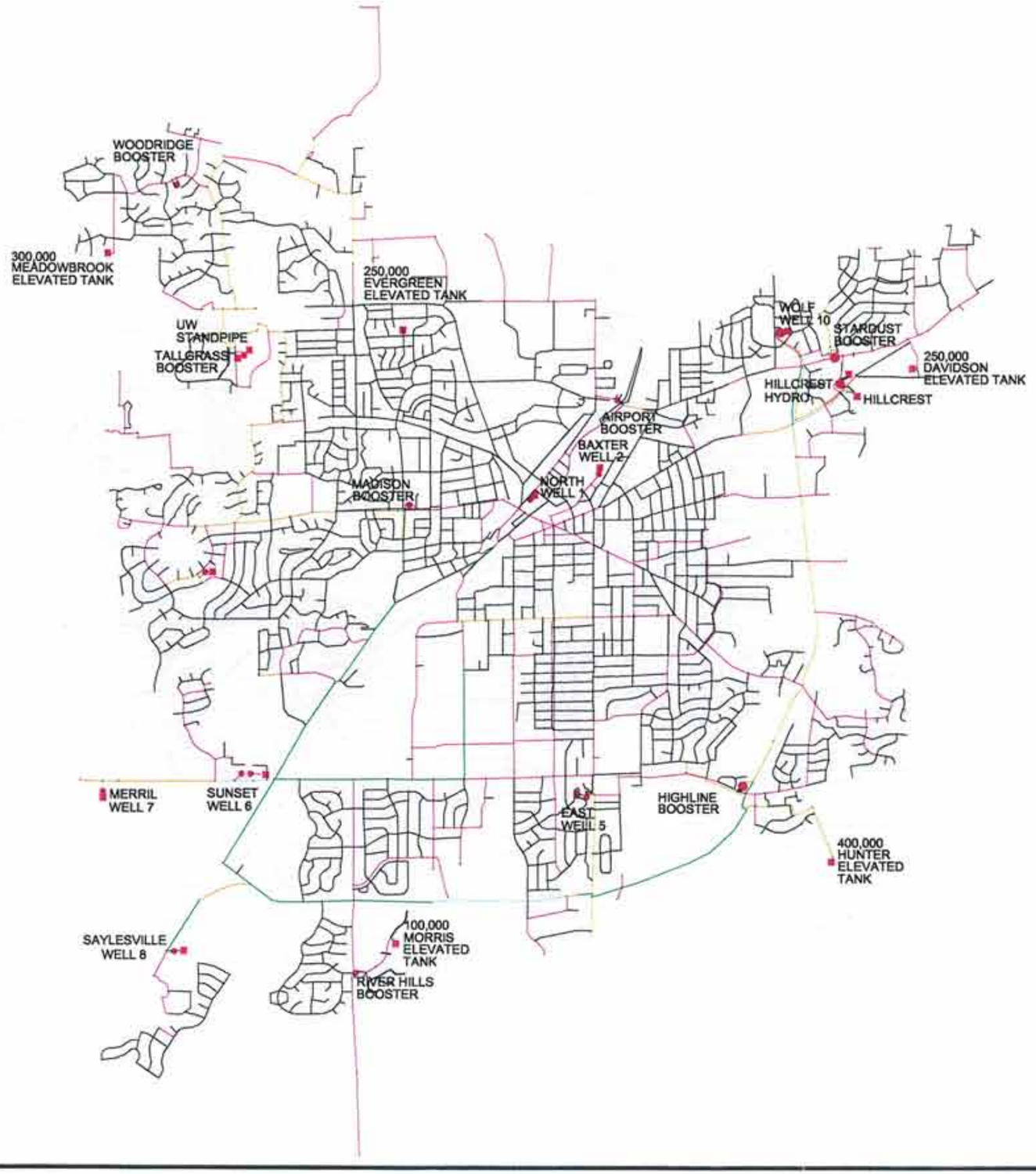


FIGURE E-2
Water Level Decline in Sandstone Aquifer (Source: USGS)

Water produced by Waukesha's sandstone wells has high levels of hardness and low levels of iron and manganese. With the exception of radium and gross alpha, the water meets all primary drinking water standards. In recent years, radionuclides (gross alpha) and total dissolved solids levels are increasing in certain wells (Figures E-3 and E-4).

Declining water levels and water quality (radionuclides, total dissolved solids), coupled with increasing water demand, have created the need to investigate alternative water sources. The current water supply situation is not critical. However, now is a prudent time to take proactive action and plan for the future.



Waukesha Water Utility

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FIGURE E-1

EXISTING WATER SYSTEM IN WAUKESHA

N

W E

S

LEGEND

- 24" WATER MAIN
- 20" WATER MAIN
- 16" WATER MAIN
- 12" WATER MAIN
- WELLS
- STORAGE TANKS

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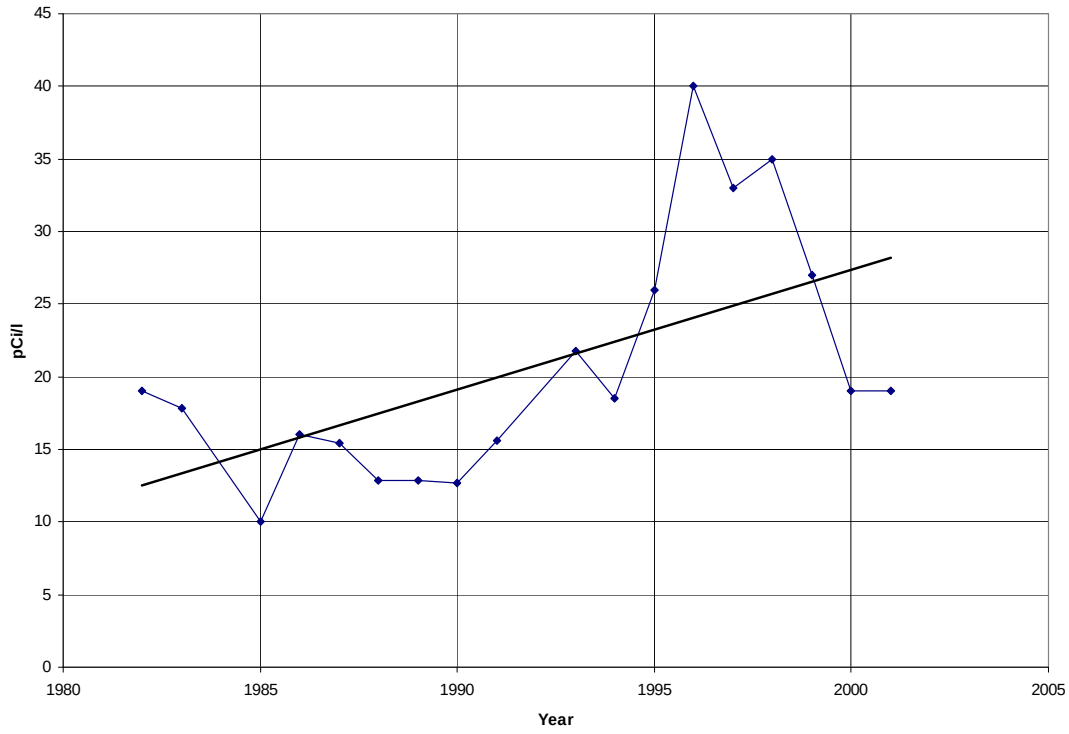

FIGURE E-3 Trends in Gross Alpha Levels
(Waukesha Water Distribution System)

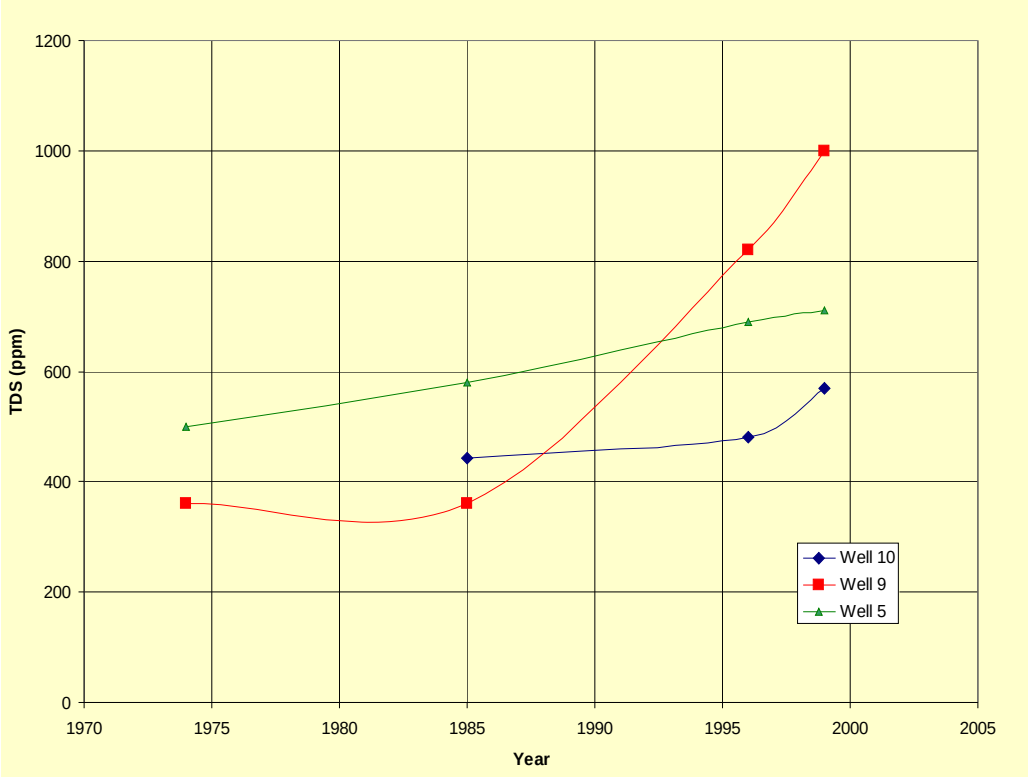

FIGURE E-4 Trends in Total Dissolved Solids

Water Supply Alternatives

Waukesha is fortunate to have a number of water supply sources available. Over 20 water supply alternatives and combinations of alternatives have been evaluated. Water supply sources require sustainable capacity for at least 50 years. This could become a peak day water demand of 22 mgd or more. After preliminary screening, the major water supply categories were:

Deep Sandstone Groundwater

- Near Waukesha
- West of Waukesha



Sandstone Well No. 3 in Waukesha

Shallow Groundwater

- South of Waukesha
- West of Waukesha



Fox River

Surface Water

- Lake Michigan
- Fox River
- Rock River



Lake Michigan

The general location of these water sources is shown in Figure E-5.

Evaluation of Alternatives

Benefits

A common set of evaluation criteria was established to measure the potential benefits of alternative water supplies. The criteria are:

- Reliability
- Regulations/Legal
- Political/Public Acceptance
- Operations and Maintenance
- Schedule
- Infrastructure

Based on these criteria, the alternatives were evaluated relative to each other by a broad group of stakeholders and a smaller group of utility personnel and consultants. The evaluation results shown on Figure E-6 were similar for each group. On the figure, graph bar height is proportional to benefits. As shown, the shallow aquifer alternatives generally have the highest benefits, followed by Lake Michigan alternatives. The sandstone alternatives had the lowest benefits.

JEFFERSON COUNTY

WAUKESHA COUNTY

MILWAUKEE COUNTY

WATERTOWN

ROCK RIVER

MAPLETON

NORTH LAKE

LAC LA BELLE

STONE BANK

OCONOMOWOC

OKAUCHEE

HARTLAND

KAUKAUNA

OCONOMOWOC LAKE

DELAFIELD

SUMMIT CORNERS

WAUKESHA

MUKWONAGO

WALES

SULLIVAN

NORTH PRAIRIE

EAGLE

ROCK BEDROCK VALLEY

TROY BEDROCK VALLEY (WESTERN PORTION)

TROY BEDROCK VALLEY (EASTERN PORTION)

BIG BEND

COLGATE

MENOMONEE FALLS

LANNON

SUSSEX

WEXTON

FOX RIVER

BUTLER

BROOKFIELD

PEWAUKEE

DUPLAINVILLE

ELM GROVE

GOERKES CORNERS

CITY OF WAUKESHA

NEW BERLIN

MUSKEGO

MENOMONEE BEDROCK VALLEY

LAKE MICHIGAN

LEGEND

- APPROXIMATE WESTERN EXTENT OF SILURIAN DOLOMITE
- APPROXIMATE LIMITS OF MAJOR BEDROCK VALLEYS
- APPROXIMATE TRACE OF SUBCONTINENTAL DIVIDE
- WATER
- CORPORATE LIMITS
- COUNTY BOUNDARIES
- 1 WAUKESHA WATER UTILITY WELL
- EXISTING LAKE MICHIGAN SERVICE AREA

FIGURE E-5

LOCATION OF WATER SUPPLIES

0 1 2 3 4000 8000

SCALE IN FEET

N

W E

S

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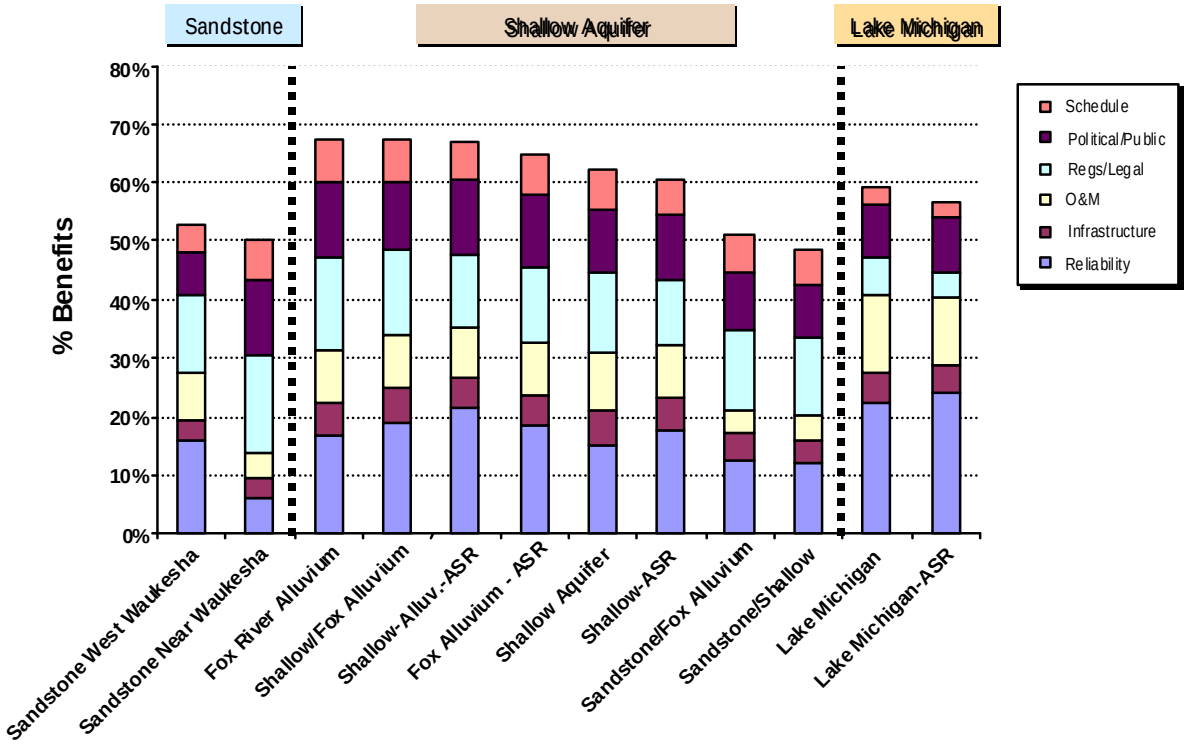

FIGURE E-6
Benefit Ranking Results

The water supply alternatives with the most benefits were the Fox River alluvium and a combination of the shallow aquifer and the Fox River alluvium aquifer. Both aquifers are south of Waukesha. Water from these aquifers would be treated and pumped to the water distribution system. A combination of two aquifers provides more reliability and flexibility for providing water than the single aquifer alternatives. The close proximity to Waukesha also reduces the amount of piping infrastructure.

Another alternative with high benefits uses the same aquifers (shallow and Fox River alluvium) combined with Aquifer Storage and Recovery (ASR). With ASR, treated water from the shallow aquifers would be stored in existing sandstone wells for use during high demand periods (Figure E-7). This significantly reduces water supply and treatment facility sizes and costs because the facilities are designed to deliver water based on average demands instead of maximum demands. This is analogous to running a factory at an 80 percent level of efficiency versus a 50 percent level of efficiency. ASR also increases water supply reliability and flexibility. Water can be provided from three sources, and environmental impacts from pumping any one groundwater supply can be minimized.

The Lake Michigan alternative provided slightly less benefit than the shallow aquifer alternative, but greater benefit than the sandstone aquifer. This alternative involves buying treated drinking water from a Lake Michigan water utility and pumping to Waukesha. The Lake Michigan alternative was rated as the most reliable and as the best in terms of operations and maintenance (O&M). However, concerns for obtaining permission for a diversion without sending wastewater back to the Great Lakes basin, and negotiating a water contract with another community caused this alternative to be ranked lowest in regulatory/legal, political/public acceptance, and schedule criteria.

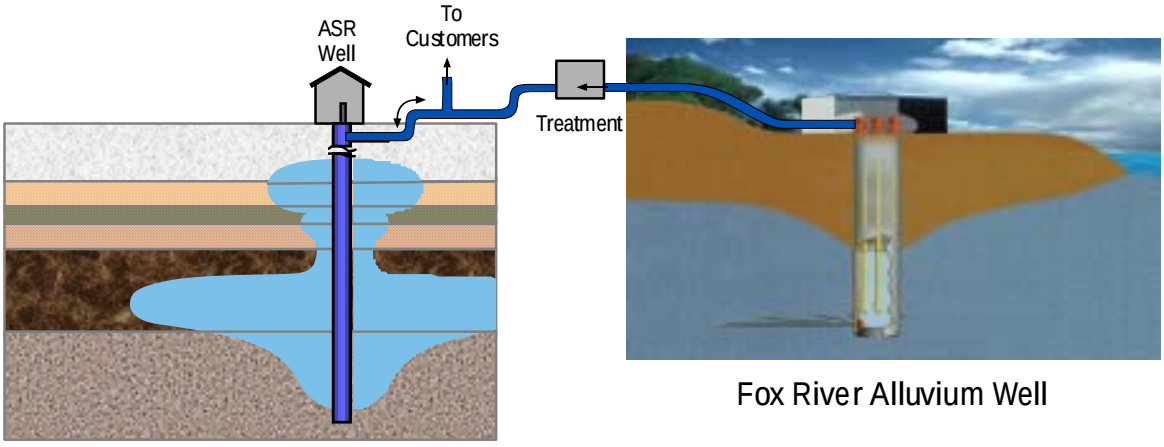

FIGURE E-7
Shallow Groundwater and ASR in Sandstone Wells

The sandstone alternative provided the least benefit. Reliability of the sandstone aquifer near Waukesha was low due to deteriorating water quality and declining groundwater levels. Most new sandstone wells would be located outside current City limits because of drawdown conditions. In addition, extensive treatment was required to deal with radionuclides and increasing levels of total dissolved solids. This created infrastructure and O&M concerns.

Placing sandstone wells west of Waukesha in the recharge area of the sandstone aquifer significantly improved reliability and reduced treatment requirements. However, this alternative was located the farthest distance from Waukesha, resulting in a need for significantly more pipeline infrastructure and concerns regarding political and public acceptance issues.

Costs

Capital and O&M costs were estimated for each alternative. A summary of these costs is presented on Figure E-8 and in Table E-1. The shallow aquifer alternatives present some of the lowest total costs. Total costs include capital costs plus 20 years of O&M costs (present worth). The lowest cost alternative is a shallow aquifer wellfield south of Waukesha and the use of ASR to store drinking water for use during high demand periods ($62 million total cost). The highest shallow aquifer alternative cost is the combination of the Fox River alluvium and shallow aquifer south of Waukesha ($83 million total cost). If ASR is combined with this alternative, the total cost is reduced from $83 million to $69 million because of the need for smaller pipes, smaller plants, and fewer wells. The Lake Michigan alternative has a total cost of $90 million. This alternative has the lowest capital cost ($42 million), but O&M costs are higher, mainly due to the cost of purchasing treated wholesale water from a Lake Michigan supplier. This alternative assumes that a permit would be issued, allowing diversion of Lake Michigan water without return to the Great Lakes basin. If return of water is required, the cost of this alternative will be double or more.

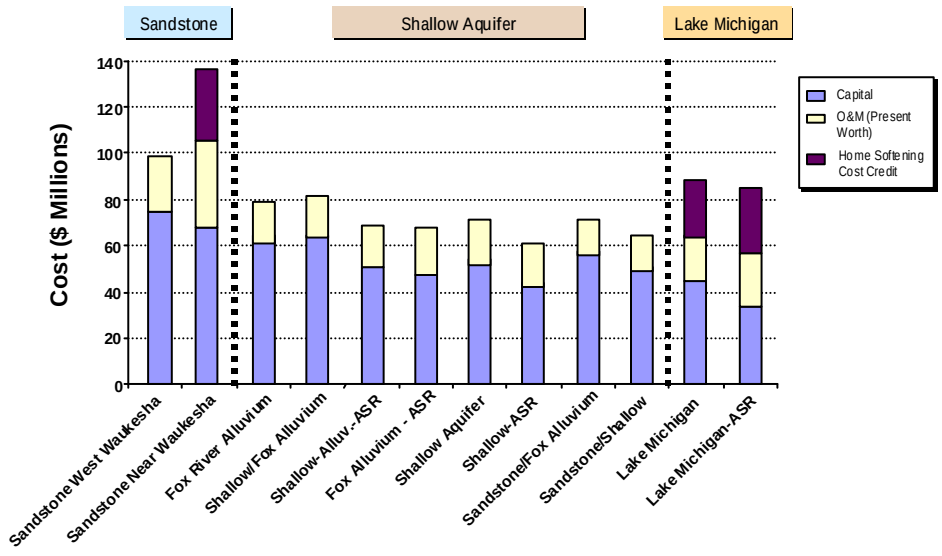

FIGURE E-8
Cost of Water Supply Alternatives

TABLE E-1
Summary Cost Estimate (in $ Millions)
Waukesha Water Supply Study

	Capital Cost[a]	O&M$/yr[b]	Increase Over Current O&M$/yr [c]	Total Cost [d]	Total Cost w/Home Softening Credit [e]
Sandstone Alternatives					
Sandstone Near Waukesha	$ 67	$ 5.9	$ 4.7	$ 135	$ 108
Sandstone West of Waukesha	$ 77	$ 1.8	$ 0.6	$ 98	
Shallow Aquifer Alternatives					
Shallow Aquifer	$ 56	$ 1.3	$ 0.1	$ 71	
Shallow Aquifer with ASR	$ 45	$ 1.5	$ 0.3	$ 62	
Fox River Alluvium	$ 62	$ 1.6	$ 0.4	$ 80	
Fox River Alluvium with ASR	$ 50	$ 1.7	$ 0.5	$ 69	
Shallow Aquifer/Sandstone	$ 51	$ 1.2	$ (0.01)	$ 65	
Fox River Alluvium/Sandstone	$ 57	$ 1.4	$ 0.2	$ 73	
Fox Alluvium/Shallow Aquifer	$ 66	$ 1.5	$ 0.3	$ 83	
Fox Alluvium/Shallow Aquifer with ASR	$ 52	$ 1.5	$ 0.3	$ 69	
Lake Michigan Alternatives					
Lake Michigan	$ 42	$ 4.2	$ 3.0	$ 90	$ 63
Lake Michigan with ASR	$ 36	$ 4.3	$ 3.1	$ 85	$ 58

[a] 2002 dollars, facilities for 22 mgd
[b] 10 mgd average day demand. Source of supply, treatment, and new transmission only
[c] Alternative O&M (column 2) minus existing O&M (10 mgd for source of supply & treatment only)
[d] Capital plus O&M present worth (20 yr, 6 percent)
[e] Subtracts capital and O&M costs of home softening (20 yr, 6 percent)

Water from Lake Michigan is naturally soft, whereas water from the shallow and sandstone aquifers is naturally hard. The shallow aquifer groundwater is a bit harder than the sandstone groundwater. Most Waukesha residents have home water softeners. If soft water from Lake Michigan was obtained, the home softeners and associated operational costs could be eliminated. The savings from providing soft water, mainly from avoiding the cost of salt purchase, is estimated at a total cost (20-year present worth) of about $27 million. If this home softening cost is subtracted from the cost of providing Lake Michigan water, the net Lake Michigan total cost is $63 million, which is almost the same as the least cost shallow aquifer alternative ($62 million).

Conclusions

Alternative Selection

The best alternatives provide high benefit at reasonable cost. The benefits and total costs for each alternative are shown on Figure E-9. The alternatives with the highest benefits and lowest costs are:

- Lake Michigan
- Shallow Aquifer

The Lake Michigan alternative cost includes the softening cost credit. It also assumes that a diversion permit would be granted which would not require returning water to the Great Lakes basin. If a diversion permit is not granted or return of water to the Great Lakes Basin is required, the Lake Michigan alternative is not viable. If a diversion permit is granted without a return flow or other requirements, Lake Michigan provides the most reliable and highest quality source of water for Waukesha and potentially other communities.

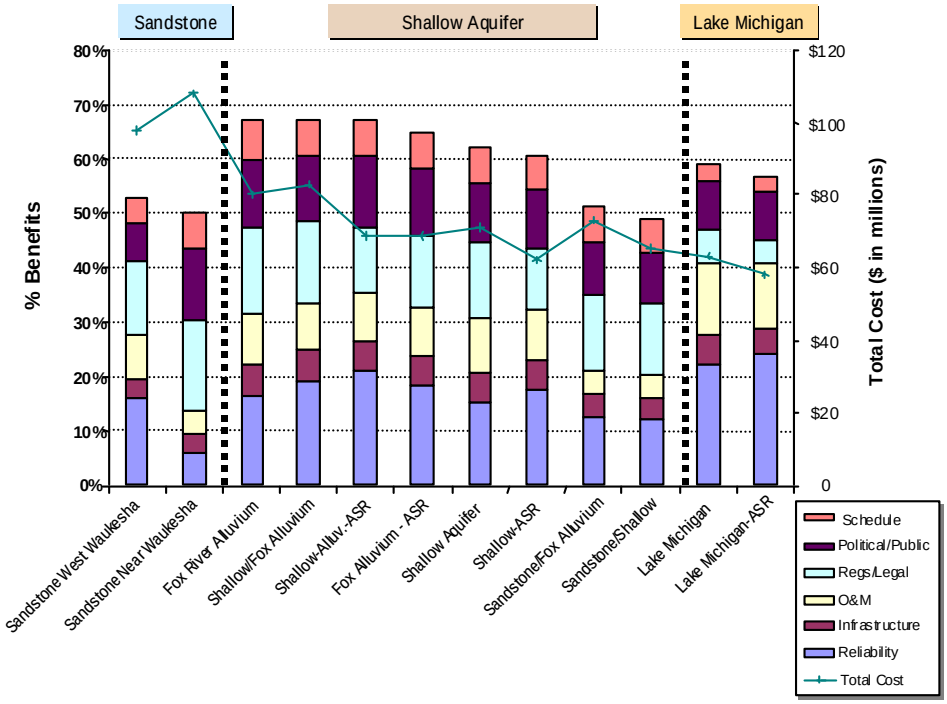

FIGURE E-9
Benefits and Costs

Of the shallow aquifer alternatives evaluated, those with the highest benefit and lowest cost are the shallow aquifer with ASR and the Fox River alluvium/shallow aquifer with ASR. The combination of Fox River alluvium, shallow aquifer, and ASR provides the most reliability and flexibility for delivering water and managing water resources. It is the preferred shallow aquifer alternative. However, future conditions and issues may change the best overall water supply source for Waukesha.

Implementation Plan

The shallow groundwater and Lake Michigan alternatives offer two excellent water supply sources for Waukesha. Implementation of a new water supply for Waukesha should proceed on a parallel path (Figure E-10).

Feasibility of the Lake Michigan supply will depend on obtaining a diversion permit where return of water to the Great Lakes basin is not required. It will also depend on negotiating a water contract with a Lake Michigan supplier. The criteria and process for evaluating the merits of a diversion are planned to be finalized in 2004 by the Council of Great Lakes Governors. However, investigations into the environmental impacts and requirements of a diversion can proceed at any time. Other activities that can proceed toward a Lake Michigan water supply include:

- Discussions with the Wisconsin Department of Natural Resources (WDNR) on regulatory requirements
- Discussions with potential Lake Michigan water suppliers
- Discussions with other communities facing similar water supply issues

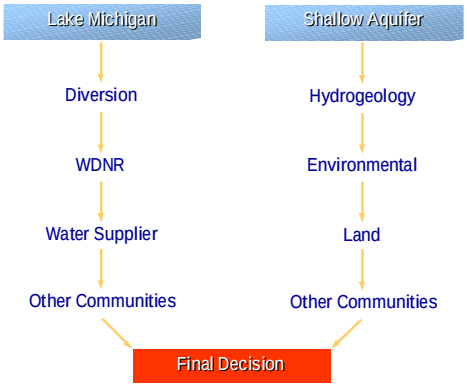

FIGURE E-10
Implementation Plan

Further steps toward a shallow aquifer supply include:

- Performing hydrogeologic investigations and constructing test wells in the shallow aquifer to determine optimum well locations, sustainable capacities, and environmental impacts
- Addressing land issues, including purchases, leases, and zoning
- Discussions with other communities regarding use of the shallow aquifer and potential partnerships in a water supply system

When information on these critical issues for the water supply alternatives is available, a final decision on the best water supply source can be made.

Water is essential for life and economic vitality. Waukesha has a proud history of supplying safe and affordable water. By planning for a future water supply, Waukesha will continue to provide residents with adequate quantities of safe and affordable drinking water.

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Acronyms and Abbreviations

ADD	average day demand
ASR	aquifer storage and recovery
AWWARF	American Water Works Association Research Foundation
ES	enforcement standard
gpcd	gallons per capita per day
gpd	gallons per day
GPM	gallons per minute
IJC	International Joint Commission
MCL	maximum contaminant limit
mgd	million gallons per day
O&M	operation and maintenance
ppm	parts per million
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SEWRPC	Southeastern Wisconsin Regional Planning Commission
SWTR	Surface Water Treatment Rule
TDS	total dissolved solids
UIC	underground injection control
USEPA	United States Environmental Protection Agency
WDNR	Wisconsin Department of Natural Resources
WGNHS	Wisconsin Geological and Natural History Survey
WRDA	Water Resources Development Act

SECTION 1

Introduction

1.1 Purpose

This study was conducted to evaluate water supply alternatives for consideration by the Waukesha Water Utility to continue providing reliable, high quality, affordable drinking water to its customers.

1.2 Scope of Work

This water supply study evaluated various water supply alternatives and combinations of alternatives. Both groundwater and surface water sources were evaluated using a reliable source of water for a 50-year time frame as a goal. The drinking water should meet all primary drinking water regulations and secondary standards.

The following general tasks were performed:

- Brainstormed water supply alternatives
- Developed evaluation criteria
- Determined weighting factors for the evaluation criteria
- Screened the alternatives and eliminated those that did not meet goals
- Evaluated the alternatives based on the criteria
- Ranked the alternatives based on the criteria
- Developed capital and operating costs for each alternative
- Compared the benefits and costs of each alternative
- Provided an implementation plan for the top alternatives
- Prepared a report summarizing the findings

1.3 Waukesha Water System

Waukesha obtains its drinking water from a sandstone aquifer (Cambrian-Ordovician) with ten active wells, each about 2,000 feet deep. The wells have a combined capacity of about 15 million gallons per day (mgd). The distribution system consists of seven pressure zones, 17 million gallons of ground and elevated storage, 15 booster pump stations, and about 280 miles of water mains. The water system is shown on Figure 1-1.

During 2001, average day demand was about 8 mgd, and maximum day demand about 13 mgd. Anticipated increases in water demand have created the need to provide additional water supply capacity. The maximum day water demand could increase from 13 mgd to 22 mgd (or more) over the next 50 years.

The sandstone groundwater level near Waukesha is declining 5 to 10 feet per year. Groundwater level is currently about 500 feet below the ground surface, and still declining. This decline increases pumping, operation, and maintenance costs.

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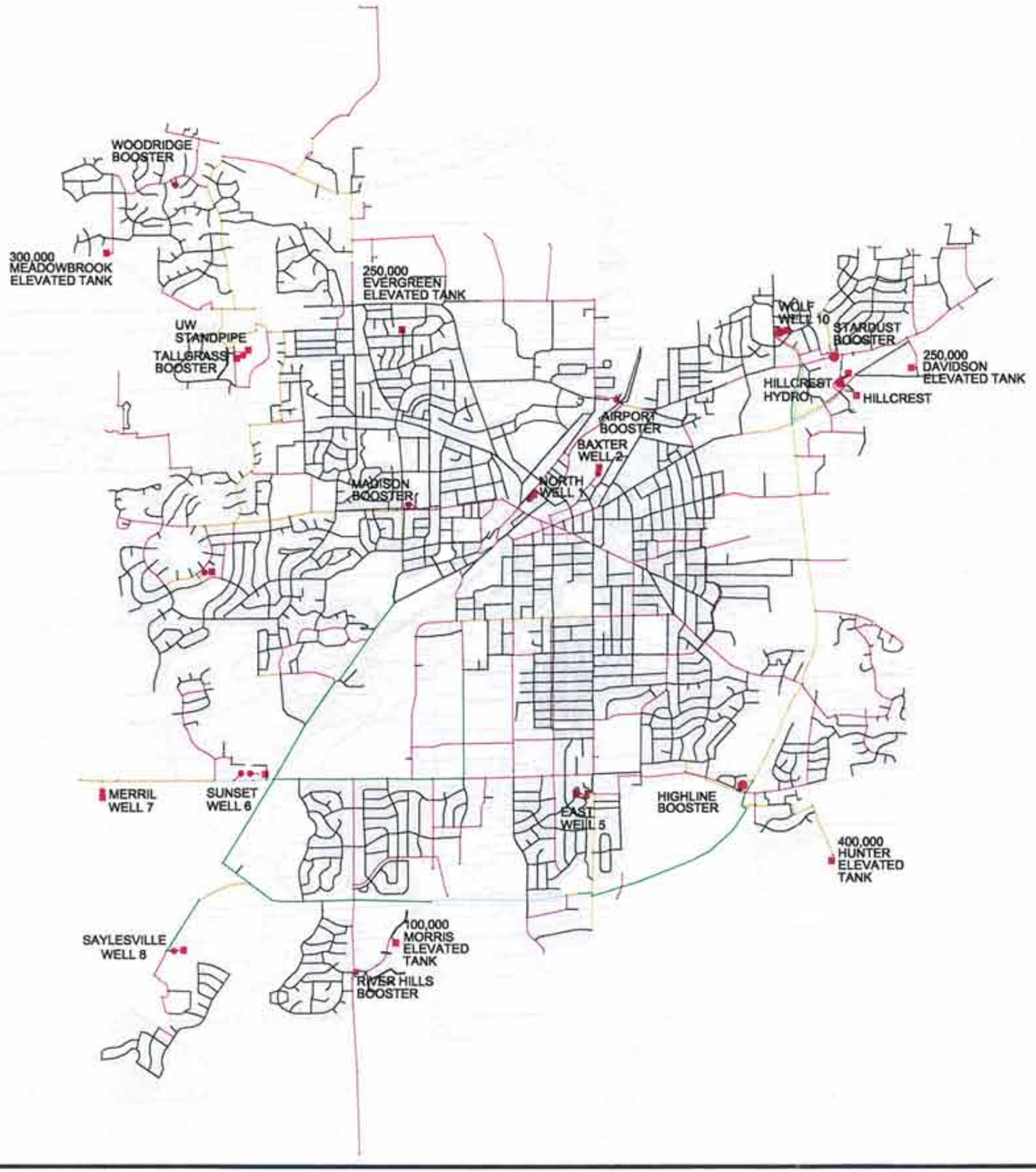

FIGURE 1-1

EXISTING WATER SYSTEM IN WAUKESHA



LEGEND

- 24" WATER MAIN
- 20" WATER MAIN
- 16" WATER MAIN
- 12" WATER MAIN
- WELLS
- STORAGE TANKS

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Water produced by Waukesha's sandstone wells has high levels of hardness and low levels of iron and manganese. With the exception of radium and gross alpha, the water meets all primary drinking water standards. In recent years, radionuclides (gross alpha) and total dissolved solids levels are increasing in certain wells.

Declining water levels and water quality (radionuclides, total dissolved solids), coupled with increasing water demand, have created the need to investigate alternative water sources. The current water supply situation is not critical. However, now is a prudent time to take proactive action and plan for the future.

1.4 Planning Criteria

1.4.1 Planning Period

A 50-year planning period (to 2050) was selected to evaluate water supply sources. This planning period was selected to look toward a reliable, sustainable water supply source for the planning area. Operation and maintenance (O&M) costs for the water supply alternatives were compared over a 20-year period.

1.4.2 Water Demand Forecasts

1.4.2.1 Population Forecasts

The Waukesha Water Utility completed a Water Utility Master Plan Update in 2000. The plan established a 2000 population of about 64,000, and forecasted a 2020 Utility Service Area Boundary and population of about 78,000. Growth forecasts were established based on a 1993 land use plan and a 1999 sewer service area plan, both prepared by the Southeastern Wisconsin Regional Planning Commission (SEWRPC). Review of the Sewer Service Area Plan for the City of Waukesha and environs (1999) indicated a 2020 forecasted population range of 77,400 (under an intermediate growth plan) to 105,400 (under a high growth plan). The forecast of the Utility Master Plan lies within that range and is consistent with the SEWRPC intermediate growth plan for the service area.

The 2020 Water Service Area identified in the Utility Master Plan is shown on Figure 1-2. This boundary is very similar to the 2020 Sanitary Sewer Service Area boundary.

There have not been any population forecasts or service area estimates completed for Waukesha for year 2050. SEWRPC is in the process of updating the regional land use plan and extending the population projections, but will not have information available for use in this study. Therefore, this study will use existing forecasts of 2020 populations and service area boundaries, as used in the Utility Master Plan and as consistent with the SEWRPC sewer service area plan, to establish forecasts for the year 2050.

TABLE 1-1
Population Trends and Projections
Future Water Supply

Year	Population	Percent Change	Year	Population	Percent Change
1900	7,419	—	1980	50,365	26.9
1910	8,740	17.8	1990	56,958	13.1
1920	12,558	43.7	2000	64,000	12.4
1930	17,176	36.8	2010	71,000	10.9
1940	19,242	12.0	2020	78,000	9.9
1950	21,233	10.3	**2030**	**86,111**	**10.4**
1960	30,004	41.3	**2040**	**95,065**	**10.4**
1970	39,695	32.3	**2050**	**104,950**	**10.4**

Source: Waukesha Water Utility Master Plan, February 2000
Note: Bolded values are forecasts beyond the 2020 Water Utility Master Plan data

Waukesha Water Utility

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FIGURE 1-2

FUTURE WATER SERVICE AREA

N

W E

S

0 .5 1 1.5 2 2.5

SCALE IN MILES

LEGEND

- **2050 WATER SERVICE AREA**
- **2020 SEWER SERVICE AREA**
- **1995 CITY BOUNARY**
- **PRIMARY ENVIRONMENTAL CORRIDOR**
- **SECONDARY ENVIRONMENTAL CORRIDOR**

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Forecasted year 2050 population levels are presented in Table 1-1. These levels are estimated using the growth rate between 2000 and 2020 from the Utility Master Plan. Note that the 2050 population is still within the 2020 high growth plan of 105,400. This growth trend assumes continued expansion of the urban service area boundaries to adjacent township lands to the south and west.

1.4.2.2 Service Area Projection

The current Waukesha Water Utility 2020 service area developed in the Utility Master Plan is roughly consistent with an updated version of the established 2020 sanitary sewer service area. The area includes a total of about 47 square miles, within which 9.6 square miles are environmentally significant lands. This leaves a net developable land area of 37.4 acres within the 2020 water service area. If development occurred to the 2020 population level forecast of 78,000 persons, there would be an average population density of 3.26 persons per acre of developable land. Projecting that density to the 2050 population of 105,000 persons would result in an incremental land requirement of 13 square miles.

Review of the 2020 Water Utility Service Area indicates that expanding the boundary to the south and west by a maximum of 1.5 miles in each direction would result in a gross increase of 17.5 square miles (Figure 1-2). Removing the environmentally significant land would result in a net increase of about 13 square miles.

This growth concept was reviewed by the City of Waukesha Department of Community Development. The general consensus was that 50-year forecasts were very difficult. There are many political and jurisdictional issues that will likely impact the growth, development, and shape of the Waukesha service area over that period. Given the 50-year population forecasts, the department thought it was reasonable to assume that the service area would grow in a similar fashion. The general 2050 water service area is shown on Figure 1-2. It reflects Master Plan growth forecasts and the general growth pattern to the south and west of the existing service area.

There are currently some instances in which either city water or sewer service is provided, but not both. Given this trend, it is possible that in the future, the Waukesha Water Utility could become a wholesale water supplier to adjacent communities. Under this scenario, the demand forecasts and water service area could be considerably different than the service area projected. For the purposes of this service area projection, however, we will assume that the population and service area growth will coincide and move to the south and west as shown on Figure 1-2. Regional water service area forecasts will be covered in a future SEWRPC planning effort.

1.4.2.3 Water Demand

The Utility Master Plan provided similar forecasts for water demand over the 20-year period from 2000 to 2020. Historic water demand trends were reviewed and future water demand was estimated for residential, commercial, industrial, and public institutional use. Water demand trends over the past 20 years have been characterized by the steady growth of residential, commercial, and public institutional demand, with a significant decline in industrial demand. This decline has resulted in an overall reduction in ADD from a high of 9.66 mgd in 1979 to 8.15 mgd in 1998.

Based on the forecasted population growth, and the similar growth of commercial, industrial, and public institutional demand, future water demand was forecasted from 1998 to 2020. The per-capita consumption rate was generally held constant at a level similar to the last 7 years (125 gallons per capita per day [gpcd]). The per-capita consumption rate included a constant factor for unaccounted for water at 5 percent.

Forecasts for water demand beyond 2020 were made using a straight-line projection. The results are shown in Table 1-2 and on Figure 1-3. This method was compared to a method that used forecasted population and a per capita consumption rate of 125 gpcd. The results indicated very similar values for average daily pumpage. Therefore, the straight-line projection will be used for year 2050 ADD.

TABLE 1-2
Historic and Projected Waukesha Water Pumpage
Future Water Supply

Year	Average Daily Pumpage (mgd)	Maximum Daily Pumpage (mgd)	Year	Average Daily Pumpage (mgd)	Maximum Daily Pumpage (mgd)
1990			2030	**11.32**	**18.68**
1998	8.15	13.45	2040	**12.31**	**20.31**
2010	9.32	15.37	2050	**13.30**	**21.95**
2020	10.33	17.04			

Source: 1998 Master Plan, Waukesha Water Utility
Note: Bold values are forecasts beyond the 2020 Utility Master Plan data

The maximum daily pumpage was established in the Master Plan by applying a factor of 1.65 times the average daily pumpage. This factor was applied to the straight-line projections beyond 2020 to yield the values shown in Table 1-2 and on Figure 1-3.

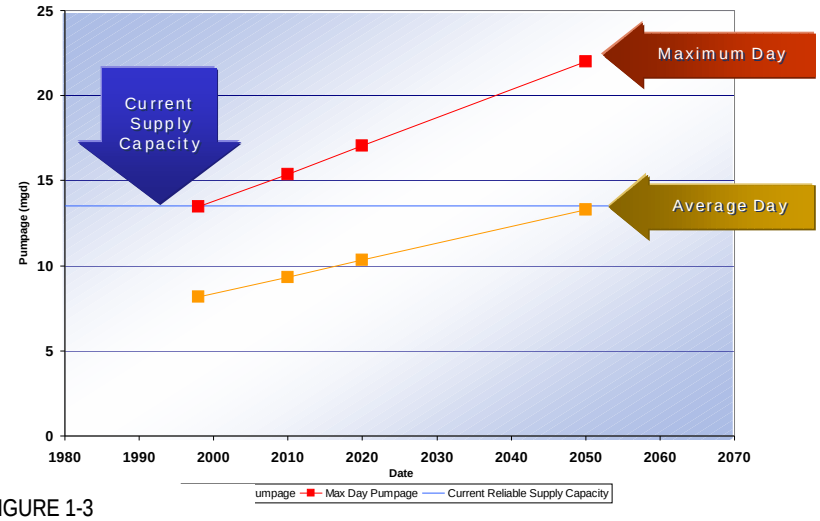


FIGURE 1-3
Water Demand Forecast

Water demand forecasts depend on many factors that cannot all be determined or controlled. The water demand projections and associated facilities represent an intermediate growth pattern. Growth could occur faster or slower based on economic, demographic, and other factors. If faster growth occurs, the water facilities described in this report will reach their capacity before 2050. Under the highest growth projection by SEWRPC, the water system capacity (22 mgd max day pumpage) would be realized around 2020.

SECTION 2

Water Supply Alternatives

2.1 Base Alternatives

The scope of work included evaluation of the following water supply alternatives:

- Sandstone aquifer
- Fox River
- Rock River
- Shallow aquifers (sand/gravel, dolomite, river alluvium)
- Lake Michigan

The general locations of these water supplies are shown on Figure 2-1.

A brainstorming meeting on September 17, 2001, identified other potential water supply alternatives including:

- Wellfield along Lake Michigan
- A dam on the Fox or Rock Rivers to create a reservoir
- Historic springs in Waukesha
- Wastewater reuse
- Milwaukee River
- Pewaukee Lake
- Quarry

Each of these alternatives will be generally described and screened for feasibility. Alternatives with fatal flaws will be eliminated from consideration.

2.1.1 Groundwater Sources

2.1.1.1 Overview of Major Aquifers

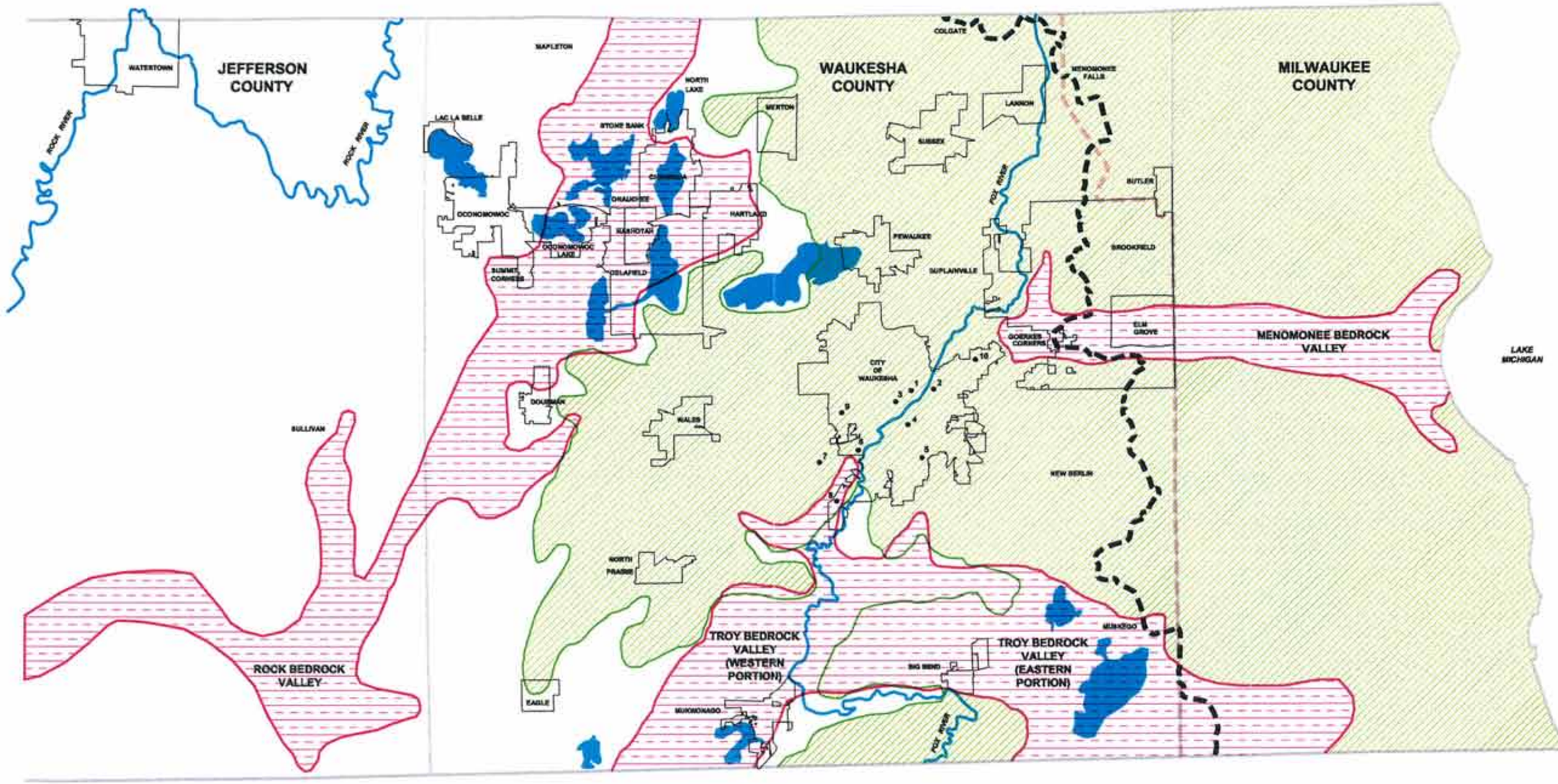
The City of Waukesha and Waukesha County have three aquifers available for development of high-capacity wells. These three aquifers include:

1) The shallow aquifer, which includes the sand and gravel beds in glacial drift and the shallow Silurian dolomite aquifer;

2) The Cambrian-Ordovician aquifer, in which the Ironton-Galesville and Mount Simon sandstone are the most productive units; and

3) The alluvial deposits along major rivers and streams.

The sandstone aquifer has been the major source of water for municipal systems served by groundwater in southeastern Wisconsin, and provides most of the municipal water in Waukesha County. The sand and gravel and dolomite aquifers have traditionally been the major source of water for private wells. However, both aquifers are becoming more important sources for municipal systems in Waukesha County.



LEGEND

- APPROXIMATE WESTERN EXTENT OF SILURIAN DOLOMITE
- APPROXIMATE LIMITS OF MAJOR BEDROCK VALLEYS
- APPROXIMATE TRACE OF SUBCONTINENTAL DIVIDE
- WATER
- CORPORATE LIMITS
- COUNTY BOUNDARIES
- WAUKESHA WATER UTILITY WELL
- EXISTING LAKE MICHIGAN SERVICE AREA

FIGURE 2-1

LOCATION OF WATER SUPPLIES

0 1 2 3 4000 8000

SCALE IN FEET

N W E S

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2.1.1.2 Sand and Gravel Aquifer

The uppermost aquifer consists of sand and gravel deposits in the unconsolidated glacial deposits. This aquifer is commonly called the sand and gravel aquifer. The extent of this aquifer is generally sporadic in the eastern half of Waukesha County, but it produces a significant portion of the water supply for several communities surrounding Waukesha. Several areas near the city have the potential to produce adequate quantities of water from this aquifer to meet the needs of the Waukesha Water Utility.

The sand and gravel aquifer offers many advantages, including faster local recharge, low radionuclide content, and lower costs compared to the sandstone aquifer. In spite of the advantages, development of the aquifer has been limited by the distribution of the permeable sand and gravel deposits. In most of southeastern Wisconsin, sand and gravel deposits are absent or too thin to support high-capacity wells. However, several geologic features contain channel deposits of permeable sand and gravel that can support wells producing over 1,000 gallons per minute (gpm). These geologic features include bedrock valleys, outwash deposits, and end moraine deposits. As these features cover a limited area of southeastern Wisconsin, sand and gravel aquifer wells must be sited in these specific areas to produce significant volumes of water.

2.1.1.3 Dolomite Aquifer

The regional bedrock lies below the surficial glacial deposits lies the regional bedrock. The bedrock is referred to as the Silurian dolomite. It serves as an aquifer (called the dolomite aquifer) for much of eastern Wisconsin. The dolomite itself is relatively dense and incapable of storing or transmitting significant quantities of water. The dolomite aquifer usually produces small quantities of water that are sufficient for private homes only. However, numerous zones of fractured rock exist within the dolomite, which can produce several hundred gpm from the void spaces created by the fractures and related solution cavities. It is only where the dolomite aquifer is fractured that it may produce enough water for municipal needs. The fractures tend to concentrate in regional fracture zones. The fracture zones are nearly vertical and are typically miles long, but only a few tens of feet wide.

Wells must directly penetrate a fracture zone or a related solution feature to produce significant volumes of water. In the past, fracture zones were nearly impossible to locate, and siting a high-capacity well in the dolomite aquifer was largely a hit or miss affair. This significantly limited the development of the aquifer for municipal wells. However, within the last 15 years, new geophysical techniques have been used in southeastern Wisconsin to locate regional fracture zones. This technology has made it possible to explore for high-capacity municipal wells in the dolomite aquifer. The dolomite aquifer has become an important water source for municipal wells for much of eastern Wisconsin, especially for the Cities of New Berlin and Brookfield, the Towns of Brookfield and Pewaukee, and the Villages of Germantown and Menomonee Falls (now on standby). The dolomite aquifer is only available in limited areas around the eastern, northern, and southern sides of Waukesha. Due to the restrictive requirements for siting a suitable dolomite well, it appears that the dolomite aquifer will only be able to produce a small portion of the water needed by the Waukesha Water Utility. However, the dolomite aquifer may provide water in portions of the system where other shallow sources are not available.

2.1.1.4 Sandstone Aquifer



FIGURE 2-2
Sandstone Well No. 3 in Waukesha

The sandstone aquifer is a major source of groundwater for municipal supplies in southeastern Wisconsin. Most municipal water in Waukesha County comes from wells in the sandstone aquifer. All ten of the Waukesha Water Utility wells produce water exclusively from the sandstone aquifer (Figure 2-2). About 50 communities and 200 industries in southeastern Wisconsin rely on the sandstone aquifer for at least part of their water supply. The sandstone aquifer provides about 95 percent of municipal supply in Waukesha County. From 1975 to 1995, municipal demand from the sandstone aquifer increased 27 percent in Walworth County, 29 percent in Waukesha County, and 54 percent in Washington County. In 1995, at least 92 municipal wells—including those for Milwaukee, Waukesha, Ozaukee, Washington, Racine, Kenosha, and Walworth Counties—produced about 28 mgd of water from the area sandstone aquifer (Jansen and Rau, 1998).

It is possible for the Waukesha Water Utility to develop additional well capacity in the sandstone aquifer. However, significant problems exist within the aquifer in eastern Waukesha County. These problems may make expanding the existing wellfield impractical as a long-term solution. However, it may be possible to develop additional capacity in the sandstone aquifer by developing new sandstone wells in more favorable areas.

The shallow aquifers are separated from the sandstone aquifer by the relatively impervious Maquoketa shale group. Where present, the Maquoketa Shale acts as a regional confining unit for the sandstone aquifer. Very little water seeps though the shale into the sandstone aquifer. Since the shale is present over most of eastern Waukesha County, the sandstone aquifer is confined and isolated from direct recharge in the area of heaviest demand. The sandstone aquifer in Waukesha County receives almost all of its recharge from the western portion of the county, where the Maquoketa shale is absent and surface water can infiltrate through the glacial deposits into the sandstone aquifer. A groundwater divide is present a short distance west of the Waukesha and Jefferson county border. Water entering the sandstone aquifer west of this divide flows westward, away from the City of Waukesha.

The sandstone aquifer is comprised of three major sandstone units, separated by lower permeability shale and dolomite units that act as confining layers. The sandstone units include the St. Peter, the Ironton-Galesville (also called the Wonewoc), and the Mount Simon sandstones. The sandstone aquifer consists of a series of shale, dolomite, and sandstone deposits, which are present from a depth of about 450 to about 1,500 to 3,000 feet.

The portion of the sandstone aquifer beneath the Maquoketa shale has historically been highly confined, with the hydraulic head in the aquifer being above ground level in the early years of

the development of the aquifer. Heavy pumping has caused a large cone of depression. As a result, water levels in the aquifer have dropped below the base of the Maquoketa shale in much of eastern Waukesha County. In this area, the sandstone aquifer is no longer confined, which causes significant changes in the hydraulics, geochemistry, and microbiology of the aquifer.

Pumpage from the sandstone aquifer has created a large cone of depression centered on eastern Waukesha County (Figure 2-3) (SEWRPC, 1976; and Jansen and Rau, 1998). The original groundwater gradient was from west to east (SEWRPC, 1976). The cone of depression has reversed the regional groundwater gradient in Ozaukee and Milwaukee Counties (Jansen and Rau, 1998). This condition has probably existed for about 50 years and is causing water to migrate westward from under Lake Michigan to the pumping center in eastern Waukesha County.

Well capacities from the deep sandstone aquifer vary as a function of the thickness and the characteristics of several permeable units. Specific capacity values (gpm per foot of draw down) can vary from slightly less than 1 gpm/ft to over 20 gpm/ft, depending on the location and depth of the well. Typically, the sandstone aquifer is capable of supporting pumping rates of at least 500 to over 2,000 gpm to a properly constructed well.

The water quality in the sandstone aquifer has historically been good in Waukesha County. The water, although very hard, has generally been suitable for most potable purposes. The water contains naturally elevated levels of radionuclides. Most sandstone wells in Waukesha County exceed the maximum contaminant limit (MCL) for radium and gross alpha (15 pCi/l). Many wells contain low levels of arsenic. In a few wells, arsenic has been detected at levels above the new MCL (10 µg/l).

Several water quality parameters have changed in the aquifer over the last 10 to 20 years. Total dissolved solids (TDS) levels have increased in many of the deepest wells in the county (Figure 2-4). Some wells have experienced rising TDS levels that have more than doubled in 10 years and have produced brackish water. Gross alpha levels have risen significantly in most sandstone aquifer wells in Waukesha County (Figure 2-5). Typically, gross alpha levels have more than doubled over the last 20 years, and are continuing to rise. The increasing trend complicates efforts to comply with the radionuclide MCLs.

The rise in TDS levels in the aquifer appears to be related to the upward migration of water from deeper portions of the aquifer. This condition is caused by extreme vertical gradient created by the regional cone of depression. The rise in gross alpha levels may be due to related processes or to other geochemical changes in the aquifer caused by the significant decrease in head.

Beneath the sandstone aquifer lies essentially impermeable Precambrian igneous and metamorphic rocks. The Precambrian deposits are not considered to be aquifer and represent the base of the regional aquifer system.

A large normal fault, the Waukesha fault, cuts through the Precambrian rock with over 1,000 feet of vertical displacement. The fault trends northeast to southwest, and runs directly through the City of Waukesha. The sandstone aquifer is significantly thicker on the down-thrown side of the fault. The fault cuts the Cambrian through Silurian rock units with lesser displacement higher in the section. The fault forms a steep vertical step in the sandstone aquifer, with the down-thrown side on the downgradient side of the regional groundwater flow.

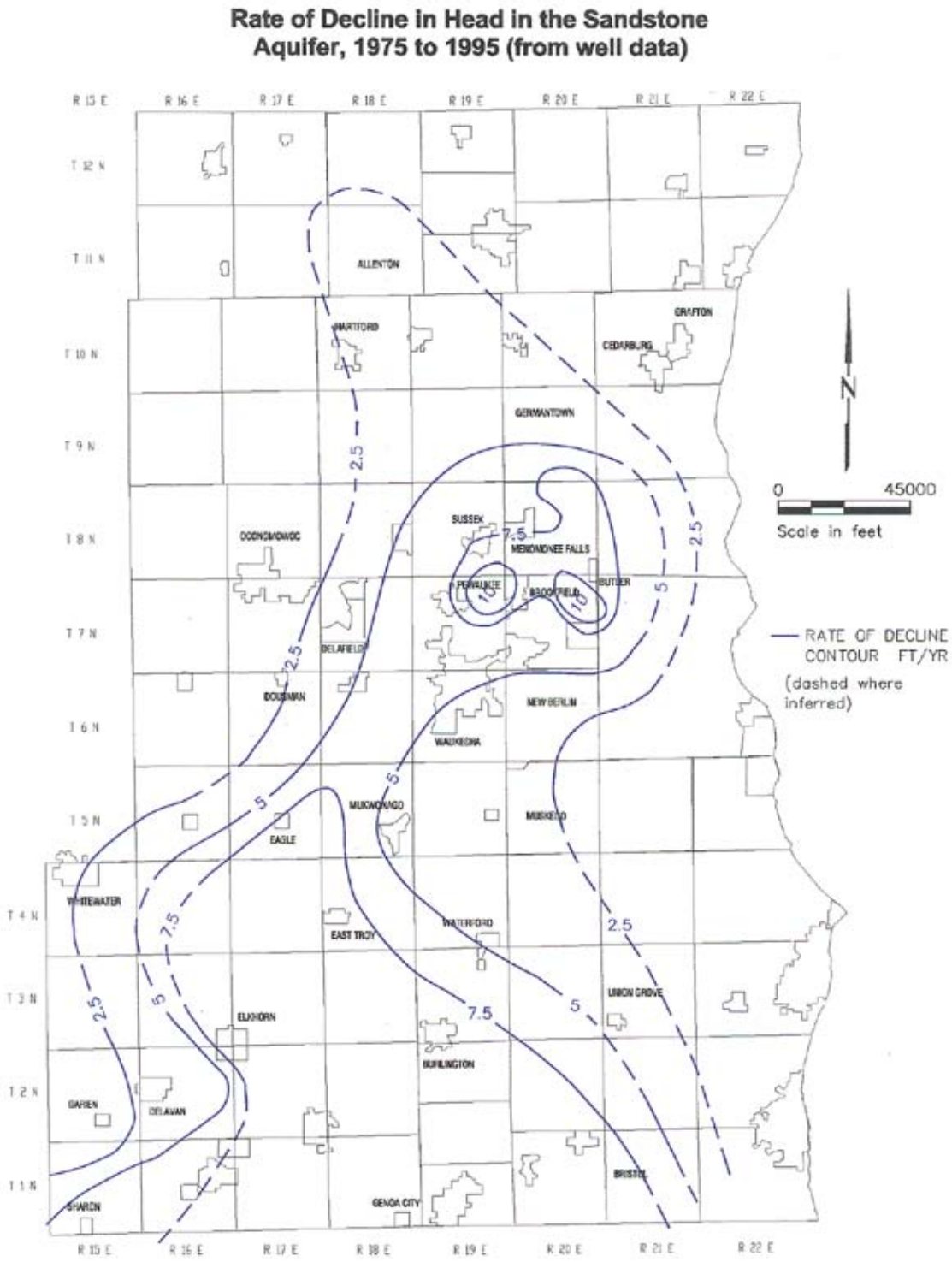

FIGURE 2-3
From Jansen and Rau, 1998

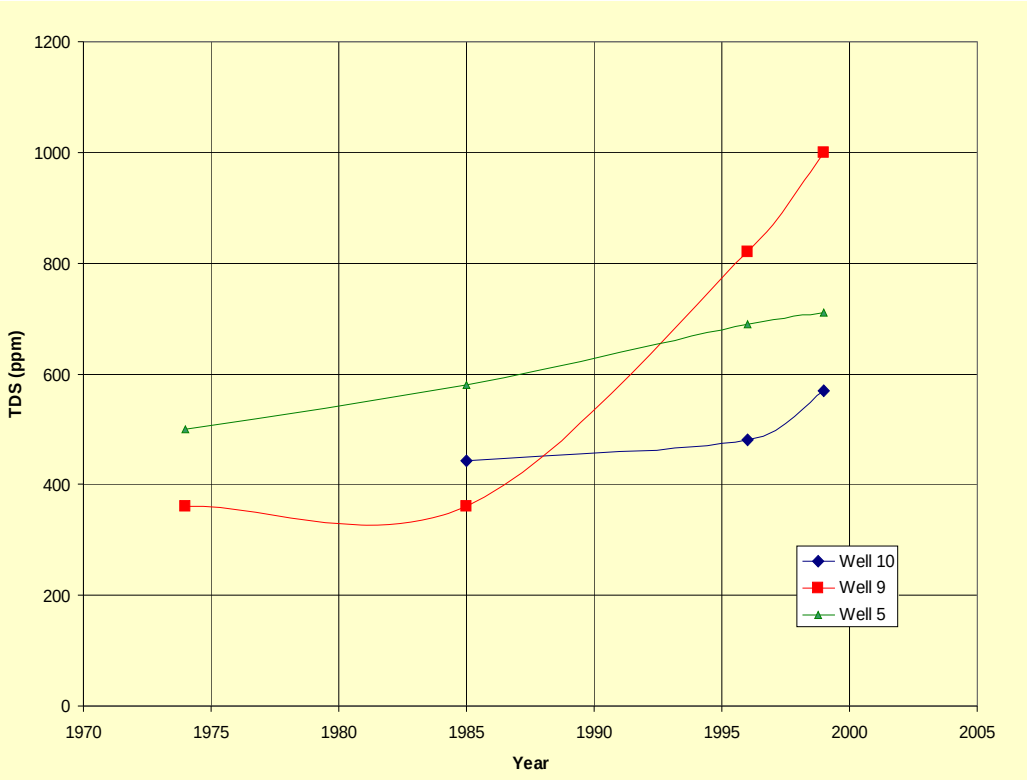

FIGURE 2-4 Trends in TDS–Sandstone Aquifer

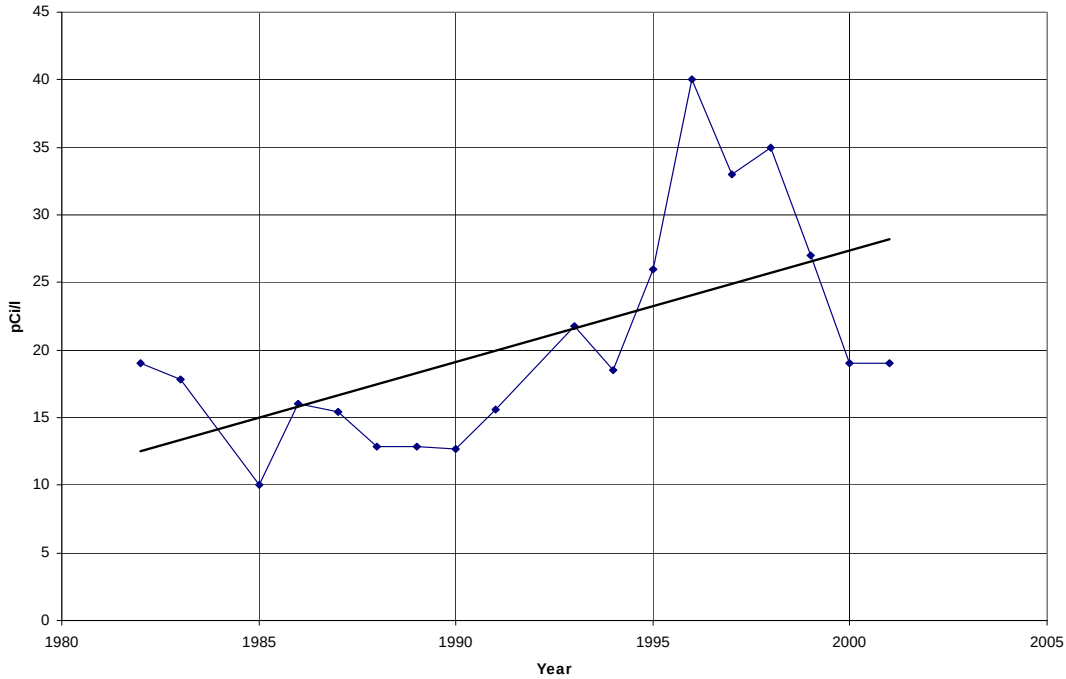

FIGURE 2-5 Trends in Gross Alpha Levels–Sandstone Aquifer

Recent geophysical and well rehabilitation studies have found that the ledge of Precambrian rock formed by the fault portion has created a zone of stagnation in the lower portion of the sandstone aquifer (AST and UWM, 2000). This portion of the aquifer predominantly contains saline water. Heavy pumpage has caused saline water to migrate upward into several of the deeper wells in Waukesha County. TDS levels have risen to troublesome levels in several wells, including at least three of the Waukesha Water Utility wells, which will make the water unusable without treatment or well rehabilitation to reduce salinity. One Waukesha Water Utility well has recently been successfully rehabilitated to significantly reduce salinity levels.

A mound of Precambrian rock has recently been detected on the up-thrown side of the fault in the northwest side of the city (AST, 2000a). An area of high conductivity groundwater was detected by surface geophysical methods. The data suggests that the area is likely to contain saline water caused by a stagnation zone behind the mound of impermeable Precambrian rock projecting into the permeable part of the aquifer.

2.1.1.5 Recharge to Aquifers

Groundwater enters an aquifer from a point of recharge and flows toward a point of discharge. Recharge areas are generally topographically high areas where water can percolate through permeable soil units down to the saturated zone of the aquifer. Discharge points are usually topographically low areas where the head in the aquifer forces water to surface discharge points, usually a stream, lake, or wetland. Water that enters the aquifer is stored in the aquifer until it reaches a discharge point. The volume of water stored in an aquifer fluctuates depending on changes in recharge and discharge. In an unconfined aquifer, changes in storage result in changes in the depth to water. In confined aquifers, changes in storage change the pressure head in the aquifer but do not change the saturated thickness of the aquifer. Most aquifers exist in a dynamic state with seasonal and longer-term changes in recharge and discharge, resulting in minor fluctuations in the storage component of the aquifer.

The concept of a dynamic equilibrium between recharge, discharge, and storage is known as the water budget. Aquifers have a limited budget of water, and if one component is changed, another component must also change to compensate. In practical terms, this means that significant changes to the recharge or discharge will result in a change in storage in the short-term and a change in discharge in the long-term. If the discharge component is increased, usually by adding pumping wells to the aquifer, the amount of water in storage is reduced around the well. If the resulting reduction in water levels can induce more recharge from surface sources, the system will reach a new equilibrium, and water levels and discharge will stabilize. If the recharge does not increase significantly, storage will continue to drop and the discharge to other sources will be reduced to accommodate the pumpage. If the pumpage is greater than the recharge, water levels will continue to decline until the wells are no longer able to maintain the pumping rate.

By this process, water pumped from wells must ultimately be replaced by increased recharge or the discharge to surface water bodies will decrease. If pumpage is great enough, discharge to surface water will eventually cease. Reduced groundwater discharge to surface water can significantly reduce water levels, particularly during periods of low precipitation.

This can result in the degradation or destruction of wetlands, deterioration of surface water quality, streams running dry for parts of the year, and lower water levels in lakes.

The same impacts can be caused by reducing the normal recharge to an aquifer. This can happen naturally, as in a drought, or due to man-made changes related to development. As areas are developed, impermeable surface area increases. The water is forced to run off these areas with essentially no infiltration. Typically, the run-off is channeled through storm drains to surface streams, and is lost as potential recharge to the aquifers. The reduction in recharge that occurs during development is a function of many factors, but reductions in the range of 30 percent are frequently estimated for typical suburban development.

In addition to reducing recharge, typical suburban development patterns often cause increased groundwater pumpage from wells. This typically results in a reduction of groundwater discharge to surface water bodies. The changes are typically subtle at first. However, if the changes are allowed to grow, negative impacts to the aquifer and environment can occur.

The magnitude and consequences of the changes depend on the characteristics of the aquifer in question. In eastern Waukesha County, the pumpage from the sandstone aquifer has exceeded recharge for decades. Because the aquifer is confined in this area, the decline in head in the aquifer has not caused a substantial increase in recharge to the aquifer, and the bulk of the water pumped has come from a loss of storage in the aquifer. This has resulted in the aquifer becoming "mined" for groundwater, with head in the aquifer declining by over 5 feet a year in much of eastern Waukesha County. Head will continue to decline in the aquifer unless pumping is reduced substantially on a regional basis. Left unchecked, the decline in head will eventually limit the volume of water that can be pumped from the aquifer. This process will eventually bring the pumping rate into balance with the recharge rate after the storage volume has been exhausted.

The decline in head in the sandstone aquifer has been accompanied by a rise in salinity in the water produced by several deep wells. The deterioration of water quality seen in the aquifer is typical for confined aquifers that are being heavily mined as water is drawn from storage from deeper parts of the aquifer. Water in the deeper parts of the aquifer has been in contact with the rock for much longer periods of time, which allows more mineral matter to be dissolved and increases the salinity of the water. This is the same pattern of regional decline and deteriorating water quality that was experienced in northeastern Illinois in the 1970s and 1980s. The trend was reversed when many large municipal water utilities changed to surface water sources and sandstone aquifer pumpage was substantially reduced.

The dolomite and sand and gravel aquifers receive more local recharge. Generally, these aquifers are covered by permeable soils, or perhaps a few feet to a few tens of feet of low permeability clay. Where the soils are relatively permeable, recharge can enter the aquifer easily. Where clay layers are present, they are generally not continuous, and areas where the clay is thin or absent are common. These areas act as "recharge windows," which allow local recharge to enter the aquifers. The ability of the dolomite and sand and gravel aquifers to recharge locally allows these aquifers to produce more water on a regional basis without significant declines in water levels. It also makes these aquifers more susceptible to local land use practices that can reduce the amount of local recharge or introduce contaminants into the aquifer. As a result, local management of the recharge areas of the dolomite and sand and gravel aquifers is much more important than for the sandstone aquifer.

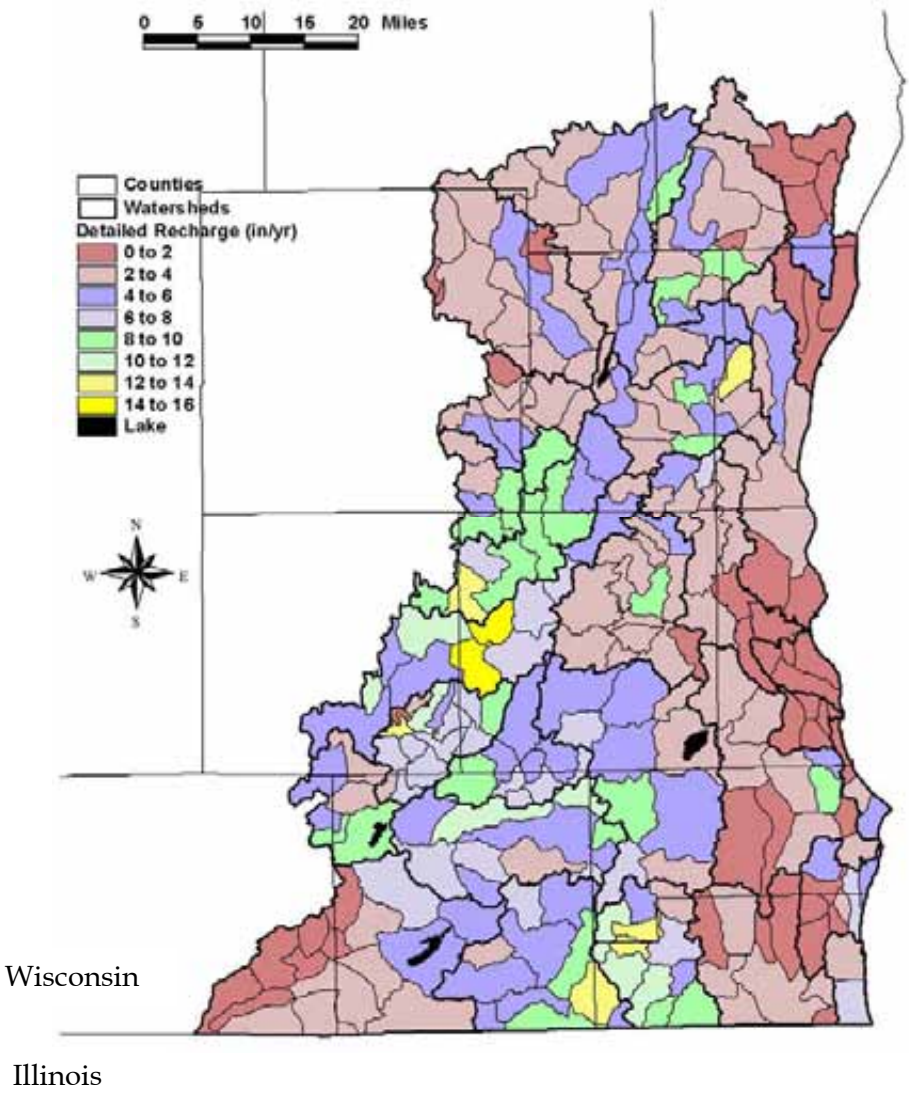

FIGURE 2-6
Recharge Rates for Southeastern Wisconsin

Given the increased importance of the sand and gravel and dolomite aquifers for meeting future water needs, proper aquifer management will be a crucial planning issue. Dr. Douglas Cherkauer has calculated groundwater recharge rates for southeastern Wisconsin. Figure 2-6 presents the estimated recharge rates (Cherkauer, 2001). Recharge varies from less than 2 inches per year, to 14 to 16 inches per year. For the purposes of comparison, the projected ADD for 2050 of 13.3 mgd could be sustained by the recharge from an area of 17.4 square miles at a recharge rate of 16 inches per year. An area of 139.7 square miles would be needed at a rate of 2 inches per year.

While it is currently not possible to quantify the volume of recharge necessary to maintain surface water, it is reasonable to assume that substantial diversions of recharge from current levels may have negative impacts to the environment and the aquifers. Given this assumption, it would seem prudent to develop management strategies to provide increased recharge to offset changes in recharge due to development and increased pumpage. Some

areas in the country have started using tertiary treated effluent for groundwater recharge. This approach is relatively expensive and creates a risk of groundwater contamination.

Several water utilities around the country have been using ponds and infiltration structures to artificially enhance the recharge of stormwater. While some risk of contamination is present if not handled properly, this is a proven technology with potential application for the city. Current Wisconsin Department of Natural Resources (WDNR) well codes and stormwater codes do not encourage artificial recharge. However, after discussions with several WDNR source water protection personnel, we have learned that the WDNR recognizes the need for these technologies and is looking into the means to make them easier to implement in Wisconsin. If the region continues to increase its reliance on the sand and gravel and dolomite aquifers, artificial recharge technologies may become necessary to maintain the aquifers, as well as to preserve the quality of surface water.

2.1.1.6 River Alluvium (Fox and Rock Rivers)

The limitations of recharge to a shallow aquifer can be overcome by designing a wellfield to induce infiltration from a surface water body, such as a river (Figure 2-7). By locating a wellfield in the permeable alluvial river sands immediately adjacent to a river, groundwater that would normally discharge to the river is intercepted by the wells. If the wellfield is pumped higher than the natural groundwater flux toward the river, water will be taken initially from storage in the alluvial sand aquifer and ultimately be replenished by recharge from the river as induced by the pumpage.

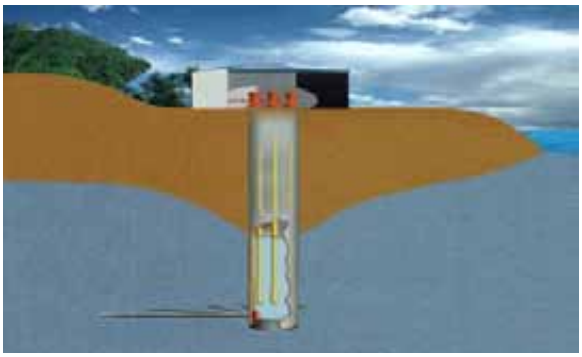

FIGURE 2-7
River Alluvium Well

The fundamental principles of this method involve using the vast volume of the permeable sand and gravel deposits adjacent to and under many rivers as a storage vessel to store water during high river stage flow for use by the wellfield. This method has the advantages of storing large volumes of water without a surface reservoir, and evening out the changes in water quality that occur in the river water.

These types of wellfields are usually called alluvial wellfields, although they are also called river bank filtration systems. They are commonly used in much of the Unites States, particularly where other aquifers are limited, stream flows are inadequate under low flow conditions, and surface water reservoirs are impractical or undesirable. They are also used extensively in Europe.

The volume and timing of the recharge is a function of several factors, including the groundwater flux toward the river, the permeability and extent of the alluvial deposits, the permeability of the river bed, the volume of pumpage from the wellfield, and the proximity of the wells to the river. Alluvial wellfields often consist of a line of shallow wells drilled adjacent to a river that are screened in river alluvium at depth of about 50 to 100 feet. Often, these wells

are drilled in the flood plain and have casings that extend above the flood level. In some areas, horizontal collector wells are used to obtain water from under the river bed itself.

Because these wellfields can induce higher recharge rates, they often have much higher sustainable capacities than typical shallow wells. For example, the Cities of Lincoln and Omaha Nebraska operate several alluvial wellfields in the Platte and Missouri River alluvial deposits. Several of these wellfields have produced tens of millions of gallons per day for decades. Modeling studies have shown that over 90 percent of the produced water comes from induced recharge from the river. In other areas, where groundwater discharge to the rivers is higher, the percentage of river water produced by the wellfield is lower.

The capacity of individual wells within an alluvial wellfield is limited by the thickness and the permeability of the formation. In several cases, the alluvial deposits are relatively thin, which limits the length of screen that can be installed, thus limiting the capacity of the well. In other cases, the permeable deposits are relatively shallow, which limits the draw down available to a vertical wells. In these types of aquifers, higher capacity can be obtained by drilling more vertical wells or by drilling a smaller number of horizontal wells. Horizontal wells can place a much longer section of screen within a thin aquifer and can produce much more water, creating a smaller draw down over a greater area of the aquifer. Several alluvial wellfields use horizontal wells drilled directly under the river bed. Most of these wells derive the major portion of their water from the rivers.

In the Waukesha area, there are at least two potential areas for developing an alluvial wellfield. The two most promising areas are the shallow sand and gravel deposits along the Fox River immediately south of the city and the potential shallow alluvial deposits along the Fox River (Figure 2-8). Of the two areas, the Fox River alluvium appears to be the most logical option for the Waukesha Water Utility.



FIGURE 2-8
Fox River

To the south of Waukesha, the Fox River runs above a bedrock valley that is a tributary of the much larger Troy bedrock valley. Boring logs from the area indicate that the bedrock valley is filled with a series of interlayered sand and gravel rich outwash deposits and clay rich till sheets. The upper 50 feet of the unconsolidated material consists primarily of permeable sand and gravel deposits. These deposits are probably glacial outwash deposits that predate the alluvium from the present day Fox River. The Fox River alluvium is believed to be in direct contact with the outwash deposits, which has the effect of greatly expanding the extent of permeable material in connection with the river. The permeable deposits appear to extend from Sunset Drive along the Fox River all the way to the Vernon Marsh. This unit appears to be very favorable for the construction of an alluvial wellfield, and may be particularly suitable for one or more horizontal wells.

The Rock River (Figure 2-9) is also likely to be surrounded by permeable alluvial sand and gravel deposits. However, regional geologic information indicates that in the area east of Watertown, the Rock River flows through clay rich till deposits with bedrock

within 50 feet of the surface. As a result, the extent of the permeable deposits is likely to be less than the deposits along the Fox River. Given that the alluvial deposits are likely to have a lower storage volume and yield less water during periods of low river flow, and given that about 15 miles of additional water main would be needed to access this source, it does not appear feasible. As a result, the Rock River alluvium will be deleted from further consideration, and further evaluation of alluvial wells will concentrate on the Fox River alluvium.



FIGURE 2-9
Rock River

2.1.2 River Water Sources – Fox and Rock Rivers

The City of Waukesha is located along the Fox River of the Mississippi River watershed. There are approximately 126 square miles of watershed upstream of the Prairie Avenue bridge in the city. The Rock River is located about 20 miles to the west-northwest of the city. There are approximately 969 square miles of watershed upstream of the City of Watertown. Both the Fox and Rock Rivers were considered as potential water sources for the Waukesha Water Utility.

The Fox River flows from the northeast to the southwest through the heart of the City of Waukesha. The watershed is rapidly developing with growth in the City of Waukesha, the City and Village of Pewaukee, the Village of Sussex, and portions of the City of Brookfield and village of Menomonee Falls. Wastewater treatment plants that discharge to the Fox River are located in the Village of Sussex, and in the Cities of Brookfield and Waukesha.

The Rock River flows to the west of the City of Waukesha. The closest segment is in Jefferson County about 3 miles west of Lac La Belle. The Rock River watershed is about 7 times the area of the Fox River Watershed and is characterized by small rural communities with associated wastewater treatment facilities. Land use is predominantly rural and natural areas including the Horicon Marsh.

2.1.2.1 River Flow

Flow records for the Fox River have been obtained at the Prairie Avenue bridge in Waukesha. This location is just downstream of the central city and upstream of the wastewater treatment plant. The average daily river flow over the past 20 years of record has been 76 mgd. That is about 27.7 billion gallons per year on average. The Waukesha Water Utility currently uses about 3 billion gallons per year. A plot of 10 years of river flow data from 1988 to 1998 is shown on Figure 2-10.

The Fox River has significant seasonal variations in flow. Summer dry weather flows drop well below seasonal averages. Figures 2-11 through 2-13 show river flow for wet, dry, and average precipitation years. Also shown is the forecasted Waukesha Water Utility water demand for the year 2050.

Review of this information indicates that the Fox River is not suitable as a single reliable source of water for the existing or future utility service area. Review of historic data

indicates that adequate dry weather flow, including an allowance for base, would have been available for only 4 of the past 20 years. A supplemental reservoir such as a large lake, quarry, or aquifer storage would be required to bridge the dry weather period. The reservoir capacities required for the dry years over the 20-year period of record are shown on Figure 2-14.

Flow records for the Rock River have been obtained at Watertown. The monitoring station is located just downstream of the closest point of connection from the city of Waukesha. The average daily river flow over the past 20 years of record is 441 mgd. That is about 161 billion gallons per year on average. The Waukesha Water Utility currently uses about 3 billion gallons per year. A plot of 10 years of river flow data from 1988 to 1998 is shown on Figure 2-15.

The Rock River also has significant seasonal flow variations. Summer dry weather flows drop well below seasonal averages. Figures 2-16 through 2-18 show river flow for wet, dry, and average precipitation years. Also shown is the existing and forecasted Waukesha Water Utility water demand for 2050.

Review of this information indicates that the Rock River is not suitable as a single reliable source of water for the existing or future Utility Service Area. Review of historic data indicates that adequate dry weather flow, including an allowance for base flow, would have been available for 16 of the past 20 years. A supplemental reservoir such as a large lake, quarry, or aquifer storage would be required to bridge the dry weather period. The reservoir capacities required for the dry years over the 20-year period of record are shown on Figure 2-19.

2.1.2.2 Water Quality

Water quality data has been obtained for the Fox and Rock Rivers. Generally, the water in both rivers is suitable as a water supply with adequate treatment. Due in part to the rural and open character of the watershed, water quality is better in the Rock River.

Both the Rock and Fox Rivers are designated as recreational waters. If they were to be used as a source of drinking water, their designation would change. This could result in stricter wastewater treatment plant effluent limitations and significant compliance costs for any wastewater plant discharging into these waters.

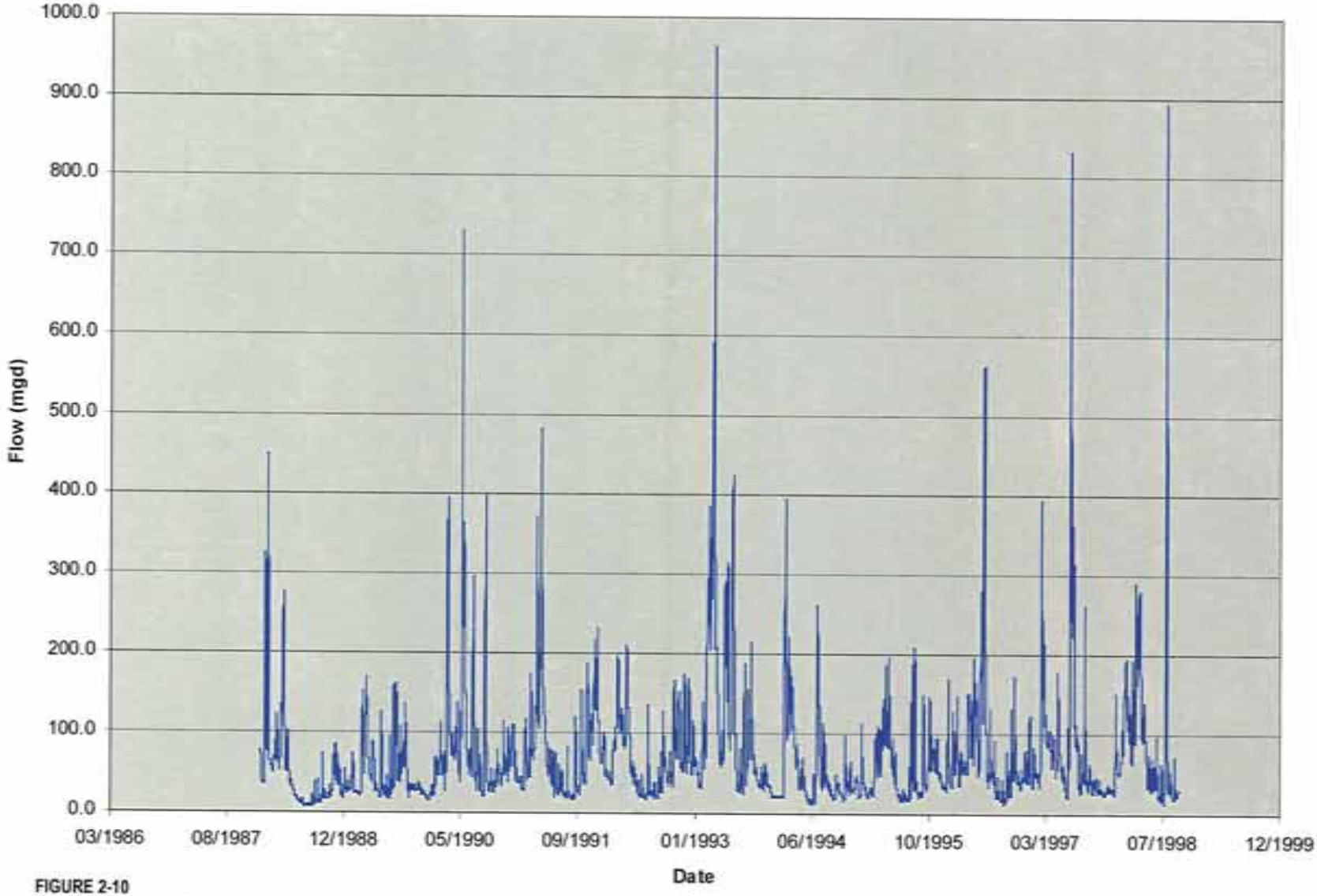

FIGURE 2-10
Fox River Historical Flow

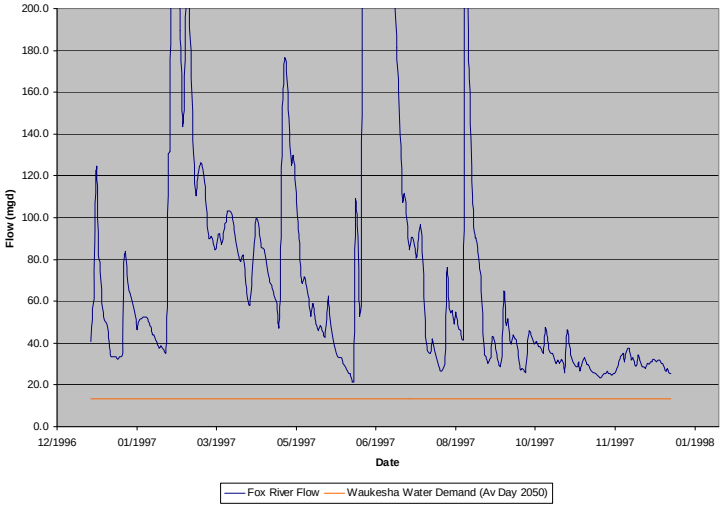

FIGURE 2-11
Fox River Flow (Wet Year)

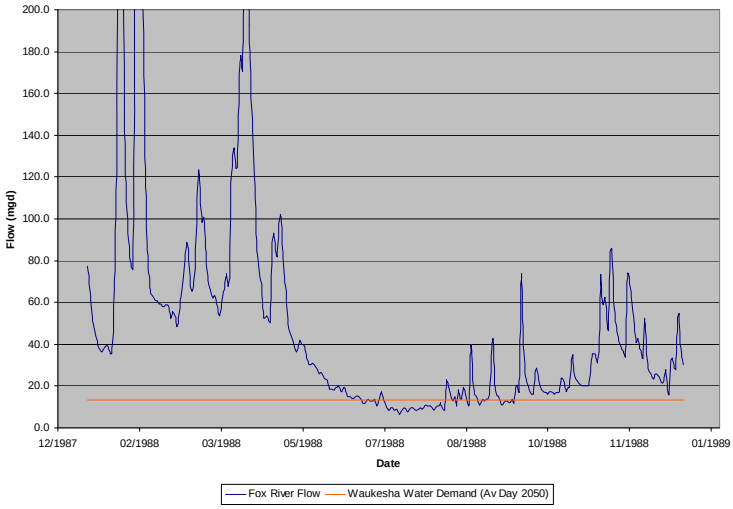

FIGURE 2-12
Fox River Flow (Dry Year)

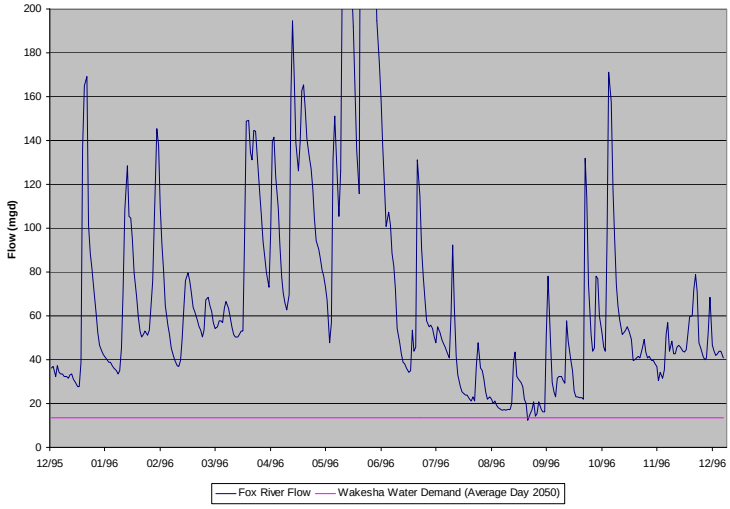

FIGURE 2-13
Fox River Flow (Average Year)

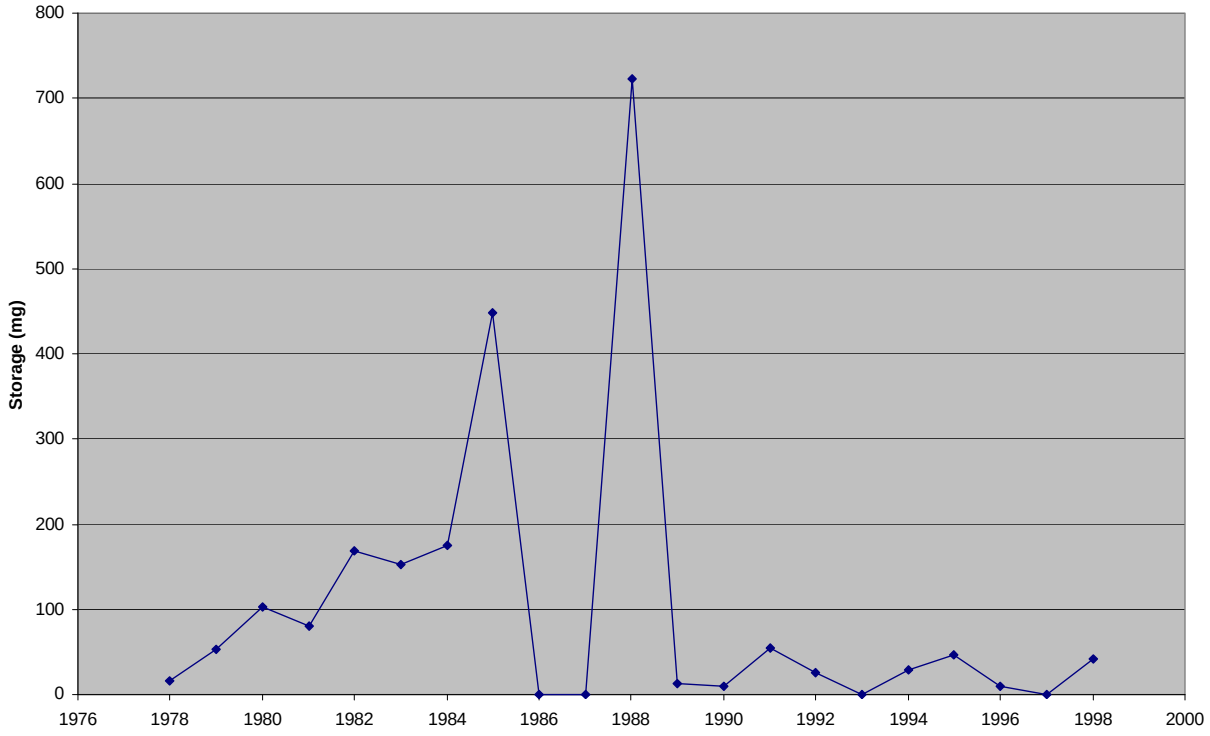

FIGURE 2-14 Reservoir Storage Required–Fox River

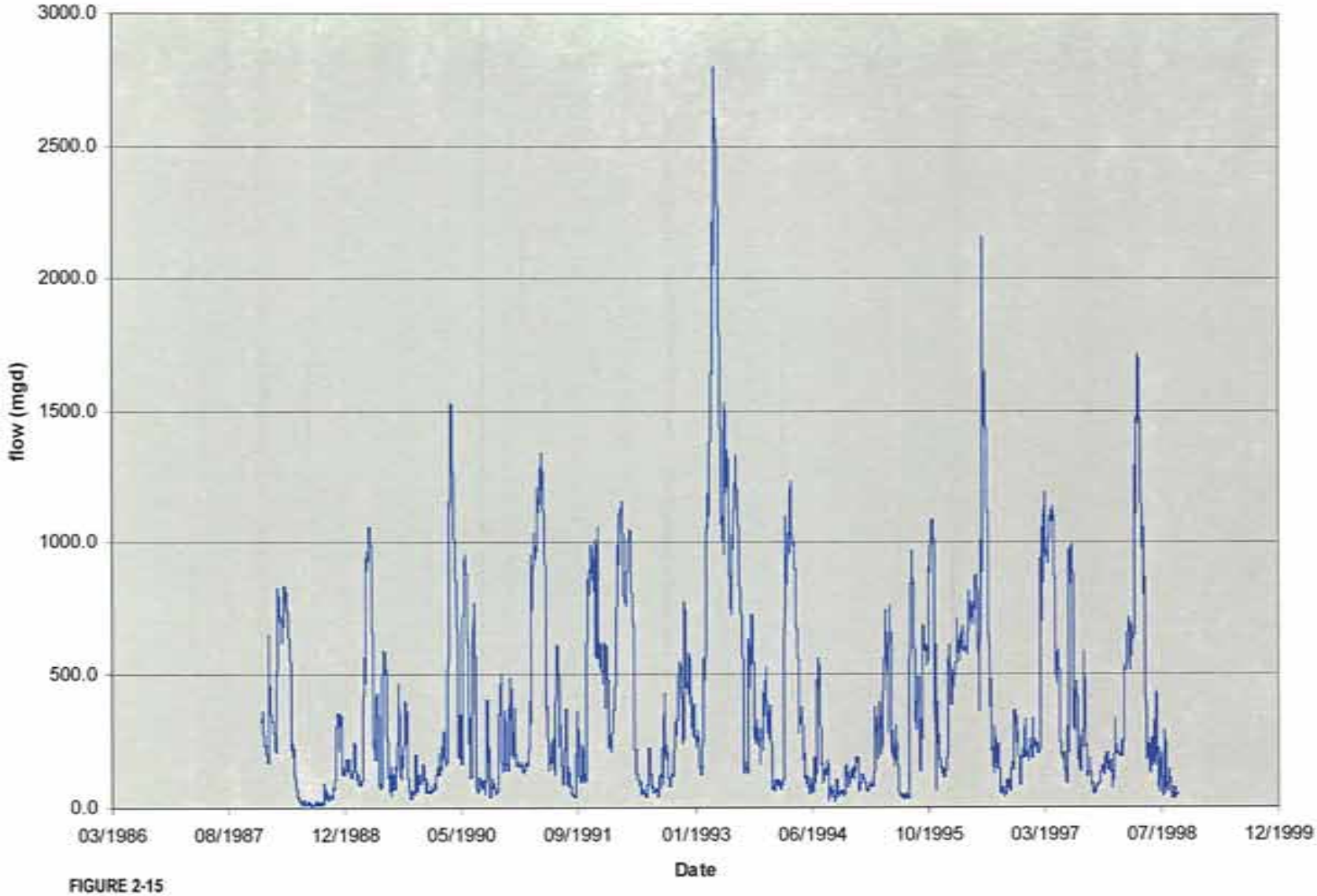

FIGURE 2-15
Rock River Historical Flow

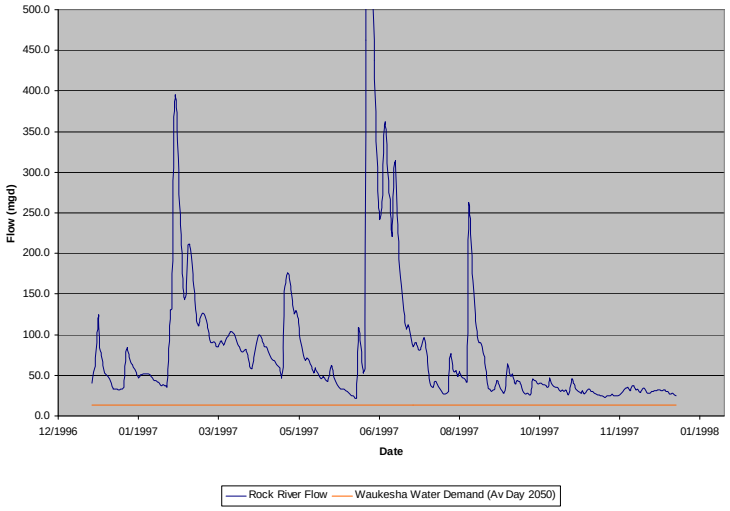

FIGURE 2-16
Rock River Flow (Wet Year)

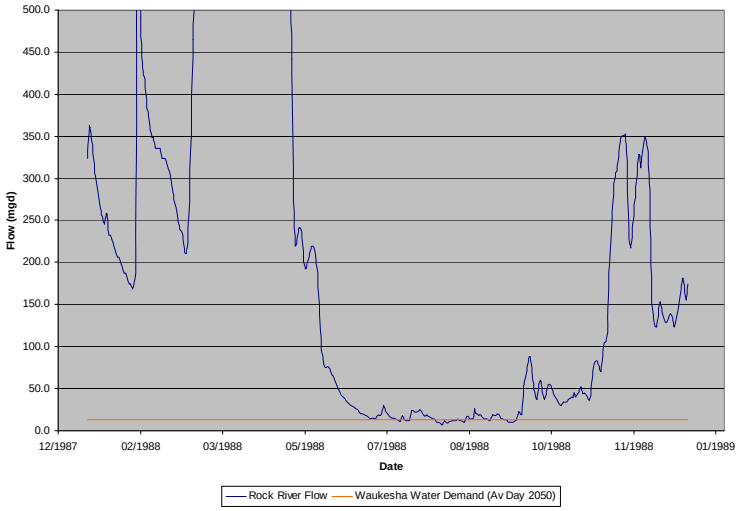

FIGURE 2-17
Rock River Flow (Dry Year)

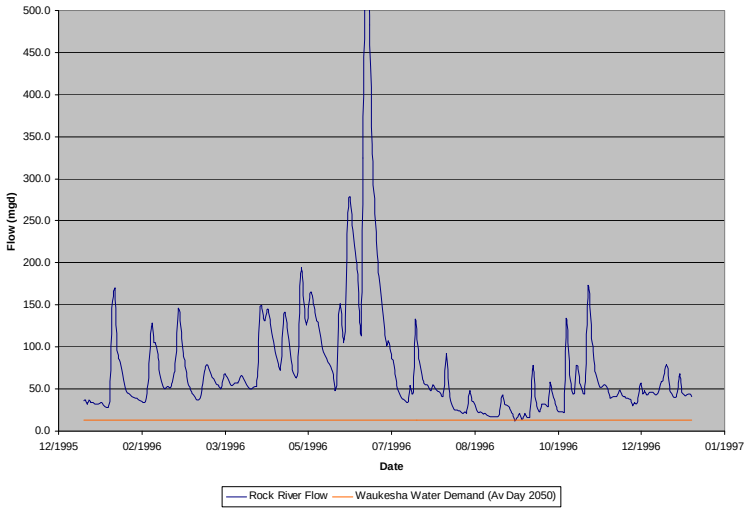

FIGURE 2-18
Rock River Flow (Average Year)

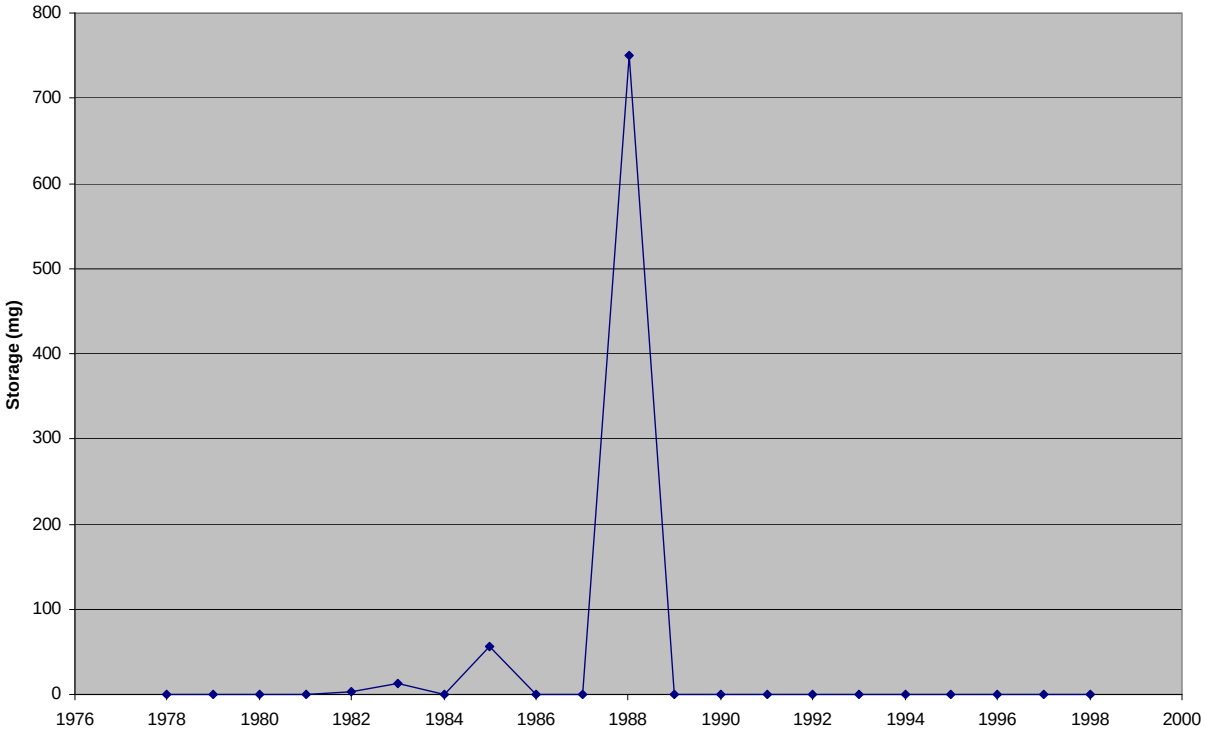

FIGURE 2-19 Reservoir Storage Required—Rock River

2.1.3 Lake Michigan

Lake Michigan is the second largest Great Lake by volume, and is the only Great Lake located entirely within the United States (Figure 2-20). The Lake Michigan Basin is an area of land where rivers, streams, and other surface waters drain into Lake Michigan. The extent of the Lake Michigan Basin is shown on Figure 2-21. The lake's drainage basin covers parts of four states and more than 45,000 square miles.



FIGURE 2-20 Lake Michigan

Hydrologically, Lake Michigan and Lake Huron are considered one lake because they are joined at the Straits of Mackinac. Lake Michigan's cul-de-sac formation results in water entering the lake, circulating slowly, and being retained for a long time before leaving through the Straits of Mackinac. It takes roughly 100 years for the water in the lake to be completely replaced.

The lake is 307 miles in length and 118 miles wide. Its maximum depth is 925 feet and average depth is 279 feet. The water surface area covers 22,300 square miles and the volume of the lake is 1,180 cubic miles, or 1.3 million billion gallons of fresh water.

The elevation of the lake surface fluctuates, but is historically about 577 feet above mean sea level. Fluctuations tend to coincide with climatic changes. The lake has a 1,660-mile shoreline made up largely of sand and pebble beaches.



FIGURE 2-21 Lake Michigan Basin (Watershed)

2.1.3.1 Lake Michigan Water Quality

Lake Michigan water quality is monitored by a number of local, state, and national agencies. Generally speaking, the quality of lake water in and around Milwaukee, Wisconsin, is good. Water of excellent quality is provided to consumers by one of a number of surface water treatment facilities in or near Milwaukee. Table 2-1 provides capacities of local treatment facilities.

TABLE 2-1
Lake Michigan Water Treatment Plant Capacities
Future Water Supply

No.	Facility Name	General Treatment Methods	Disinfection	Capacity	Available Capacity *
1	Port Washington	Rapid Sand	Chlorination	4 mgd	2 mgd
2	North Shore Water	Rapid Sand	Chlorination	16 mgd	9 mgd
3	Linnwood (Milwaukee)	Rapid Sand	Chlorination, Ozonation	276 mgd	Combined ±50 mgd
4	Howard Avenue (Milwaukee)	Rapid Sand	Chlorination, Ozonation	105 mgd	
5	Cudahy	Rapid Sand	Chlorination	6 mgd	2.3 mgd
6	South Milwaukee		Chlorination	8 mgd	4 mgd
7	Oak Creek	Rapid Sand	Chlorination	20 mgd	7.4 mgd
8	Racine	Rapid Sand	Chlorination	40 mgd	0 mgd
9	Kenosha	Membrane	Chlorination	34 mgd	15 mgd

* Available capacity is based on reported treatment plant capacity minus historic peak day or if not available, peak day from 1999 - 2000.

At the two Milwaukee treatment facilities, the Howard Avenue and Linnwood Plants, average raw water quality parameters are similar. The water is characterized by moderate hardness and alkalinity, with low color and generally low organic content.

Because the quantity available and the quality of the Lake Michigan supply are both considered excellent, the lake is often looked to as a source of supply for municipal water systems. Figure 2-22 provides the general location of the plants located within 50 miles of Waukesha.



1. Port Washington
2. North Shore Water
3. Linwood (Milwaukee)
4. Howard Avenue (Milwaukee)
5. Cudahy
6. South Milwaukee
7. Oak Creek
8. Racine
9. Kenosha

FIGURE 2-22 Location of Lake Michigan Water Plants

While each plant has its own unique methods for treating the lake water, treatment generally consists of coagulation, settling, filtration, and disinfection. The finished water provider is required, or it will soon will be required, to meet a variety of rules including:

- Surface Water Treatment Rule (SWTR) and Enhanced SWTR (Long-Term 1 & 2)
- Disinfection/Disinfection By-product Rules (Phase 1 and 2)
- Information Collection Rule
- Filter Backwash Rule

Some rules relate specifically to surface water plants, and are in addition to other rules all water utilities must meet.

One area of particular concern for surface water supplies since 1993 is *Cryptosporidium.* These concerns are—or have been— addressed by most treatment facilities using multiple barriers. For instance, the following discussion outlines the treatment practices and finished water quality of the Milwaukee Water Works.

The Milwaukee Water Works treats water by using various chemicals and processes to meet finished water product quality objectives. These include ozonation, alum coagulation, flocculation, settling, and filtration. Chlorine and ammonia are added for additional disinfection. Hydrofluosilicic acid is added at about 1 parts per million (ppm) for dental health, and phosphoric acid is added at about 2 ppm (as PO4) to reduce lead pipe corrosion.

Recently, the Milwaukee Water Works completed installation and placed into operation ozonation facilities at both treatment plants. Ozonation is now the primary method of disinfection. Ozone is an attractive water purification method for many reasons. It is a strong oxidant that reacts rapidly with most microrganisms and organic substances in water and does not impart tastes or odors. The effectiveness of ozone for inactivating viruses and killing bacteria is well known. It is the most powerful oxidant available for the chemical disinfection of a public drinking water supply, and is the most effective chemical disinfectant known for the inactivation of *Cryptosporidium*. Ozonation is typically installed at water treatment plants to achieve multiple water quality objectives. A common primary objective is to achieve enhanced disinfection without increasing chlorine dosage.

The water utility also practices chloramination, which is the combined application of ammonia and chlorine. Chloramination is performed at the end of the treatment process, prior to distribution. Chloramines are more stable than chlorine alone, providing a longer lasting residual disinfectant in the large distribution systems. Ammonia and chlorine are added at levels to achieve chloramine target concentrations of approximately 1 ppm in the distribution system.

The chemical, physical, and microbiological quality of finished water is constantly monitored at both treatment plants. The Linnwood treatment plant laboratory performs thousands of tests on the plant water treatment process, on water samples taken from the distribution system, and on water samples taken from new main construction. There are over 60 strategically located sites in the distribution system that are tested weekly. This physical, chemical, and microbiological testing goes on 24 hours per day, 7 days a week. The laboratory is certified by the State of Wisconsin to perform specified laboratory tests.

In late 1993, an outbreak of *Cryptosporidiosis* occurred in the Milwaukee area. This outbreak was associated with the public water supply and approximately 400,000 people were affected. Improvements implemented at both treatment plants since the outbreak include:

- Application of ozone as the primary method of disinfection
- Discontinuing the practice of recycling filter backwash water to avoid reintroduction of contaminants into the treatment process
- Improving the monitoring of filter effluent to better control the filtration process
- Improving control of chemical coagulant doses to improve particle removal
- Monitoring for *Cryptosporidium* in the raw, backwash, and treated water
- Developing new customer service systems to improve the response times to customer inquiries

In addition, the following completed work further enhances and protects the finished quality of Milwaukee water supplies:

- Relocation of a Lake Michigan intake pipe, which has reduced the influence of pollutants reaching the Howard Avenue plant
- Enhanced particle and turbidity removal at both treatment plants through improvements and upgrades to chemical feed systems and filters, including new dual media filters and underdrain systems

Water quality laboratory analysis results for plant finished water from the Milwaukee Water Works indicates that both plants are in compliance with all standards.

The following is an excerpt from the 2001 report on water quality issued by the Milwaukee Water Works, as required by the Safe Drinking Water Act:

"The Milwaukee Water Works (MWW) utilizes a multi-barrier approach to protecting the public health from waterborne diseases. In recent years, the utility has made improvements in source protection (A) by extending the south intake, in disinfection (B) by installing ozone facilities at both its treatment plants, and in filtration (C) by replacing underdrain systems and the filter media. The distribution system (D) is the final barrier in protecting against disease. Monitoring and testing in the distribution system is extensive…."

"MWW has never violated a contaminant level or any federal or state water quality standard. In this brochure, we have provided you with details about the source of water, what has been detected in it, and how it measures up against standards set by regulatory agencies. We continually strive to provide you with the highest quality drinking water available."

2.1.3.2 Lake Michigan Water Supply and Transmission

Providing Lake Michigan water to the City of Waukesha requires adequate treated water supply and transmission of the finished water to the city. Table 2-1 provides information regarding available treatment capacity at local plants.

Based upon these data, the only water system with the capacity to meet the current and projected Waukesha maximum water demands is the Milwaukee Water Works. Other water systems could provide adequate capacity with treatment plant expansion.

2.1.3.3 Milwaukee Water Facilities

The City of Milwaukee Water Works consists of two surface water filtration plants, three major pumping stations, 11 repumping stations, storage facilities, and about 1,900 miles of water mains serving approximately 160,000 residential, commercial, industrial, and public customers. The utility also provides wholesale service to the Cities of West Allis, Shorewood, Wauwatosa, Greendale, and Brown Deer; the Village of Menomonee Falls; and the Milwaukee County Institution Grounds. In 1999, the average day pumpage delivered by the Water Works was approximately 130 mgd. The peak day pumpage was about 190 mgd.

The total practical capacity of all of the Water Works facilities is approximately 380 mgd. Individually, the Linnwood purification plant, located in the north water production district, is capable of treating approximately 275 mgd. The Howard Avenue purification plant, located in the south water production district, is capable of treating approximately 105 mgd. Currently, the Milwaukee Water Works has a large surplus in treatment capacity.

Filtered water from the treatment plants is conveyed to three major pumping stations—the North Point Pumping Station, the Riverside Pumping Station, and the Howard Avenue Pumping Station. These major stations have pumping capacities which range from 165 to 240 mgd. From these facilities, water is further distributed to 11 booster stations throughout the city. These have total capacities which ranging from about 2.7 to 80 mgd. Most of the utility's pumping stations have two separate incoming power supply lines from the Wisconsin Electric Power Company system. In most cases, however, these separate feeds originate from the same substation. All pumping stations are equipped with independent sources of direct current electric power that operate pump control valves, supervisory control and data acquisition (SCADA) systems, and instrumentation devices. In the event of a power outage, the DC power sources continue to operate these systems and provide an indication to the main control center that a power outage has occurred.

The Milwaukee Water Works Control Center is located on the fourth floor at 841 North Broadway in Milwaukee, Wisconsin. The water systems operators monitor and control all of the pumping used to deliver water to the consumers after treatment. Operators have the responsibility of coordinating all of the activities of the Water Works pumping operations to maintain adequate pressure in the seven pressure districts of the service area. The load centers at the Linnwood and Howard treatment plants control and monitor the pumpage from Lake Michigan and the purification process.

The West Allis water system, which borders the northern portion of New Berlin at the Waukesha county border, is supplied by the Milwaukee Water Works through Milwaukee's high district service area. This district also serves much of the City of Milwaukee. This service area is primarily supplied by the Riverside Pumping Station, located at 1311 East Chambers Street. This station is the largest source of finished water in the Milwaukee Water Works distribution system, supplying water to about 60 percent of the Water Works customers. Pumping equipment at this station includes nine electric driven centrifugal units with individual capacities ranging from 15 to 30 mgd, a total capacity of 240 mgd, and a

reliable capacity of 210 mgd. The average daily pumpage delivered by this station is approximately 50 mgd. The suction source for this station is finished water from the Linnwood treatment plant, which is conveyed by gravity through a 9-foot-diameter tunnel from the plant to the booster station.

The system-wide maximum day pumpage experienced by the Milwaukee Water Works, 322.25 million gallons, occurred on August 2, 1988. On that day, the Riverside station pumped 137 million gallons into the system.

The southern areas of Milwaukee County that border Waukesha County, Greenfield, and Hales Corners are provided service from the southwest service area. This area has a hydraulic grade of 966 feet, which is almost 100 feet higher than the Riverside district. Water is boosted to the Riverside side district from the Riverside station. The area of the Milwaukee system near Hales Corners can provide a hydraulic grade roughly 66 feet greater than the area around West Allis.

The Milwaukee system contains a network of water transmission mains ranging in size from 12 to 60 inches. The closest main with adequate capacity to meet a maximum day demand for Waukesha is located near the intersection of Howard Avenue and 92nd Street. From this point, it would take roughly 8 miles of large diameter water main to provide capacity for Waukesha.

2.1.4 Lake Michigan Wellfield

The compact between the Great Lakes governors strictly limits diversions of surface water out of the Great Lakes Basin. However, the compact did not recognize the connection between groundwater and surface water until recently. Research has shown that there are permeable sand and gravel and dolomite units that extend under Lake Michigan and connect Lake Michigan to the shallow aquifers in eastern Ozaukee County (Cherkauer, 1990). Under these conditions, it would be possible to construct a wellfield along the Lake Michigan shoreline and induce recharge from the lake. The produced water would have characteristics very similar to Lake Michigan water, but it would be considered groundwater for the purposes of the compact.

In past years, this legal distinction might have provided an avenue to pump groundwater that has been largely derived from Lake Michigan over the sub-continental divide without triggering the need to permit a diversion out of the Great Lakes Basin. However, in anticipation of just such an event, the WDNR enacted NR 142, which requires WDNR approval for any diversion of water greater than 2 mgd out of a surface water basin. The WDNR has indicated that they would consider such a wellfield as a diversion, and would require a permit from the Council of Great Lakes Governors. Further, the Council of Great Lakes Governors is revising the rules covering diversions under an instrument known as Annex 2001. A specific goal of Annex 2001 is to recognize the connection between surface water and groundwater. It is likely that such a wellfield would also be viewed as a diversion by the council under their future diversion rules.

In addition to the regulatory issues, developing a wellfield adjacent to Lake Michigan would require significant areas of lakefront property, and at least 15 to 20 miles of pipeline through potentially uncooperative municipalities. Given these obstacles, it does not appear that a

wellfield along Lake Michigan would provide any advantages over a direct diversion of Lake Michigan water. As a result, this alternative will be eliminated from further consideration.

2.1.5 Fox or Rock River Dam

Both the Fox and Rock Rivers are unable to sustain adequate flow volumes to supply the needs of the Waukesha Water Utility during dry weather. Providing a dam on the Fox River was evaluated in the 1970 Fox River Watershed Plan as a method of bridging the summer dry periods by impounding wet weather flows. The concept was not carried forward in the 1979 Regional Water Quality Management Plan, as it would have required a significant areas of land purchase and would have posed significant regulatory and environmental challenges not likely to be resolved. Therefore, the concept of providing a dam on either the Fox or Rock Rivers will not be considered further.

2.1.6 Historic Springs in Waukesha

The City of Waukesha was once famous for its natural springs that were thought to have healing properties. These springs were fed by the confined water of the shallow sand and gravel aquifer. Many of these springs still exist, but deliver only small quantities of water relative to the demand of the current and future city (Figure 2-23). Therefore, the use of these historic springs as a source of water for the Waukesha Water Utility will not be considered further.



FIGURE 2-23
Hobo Springs: Waukesha, Wisconsin

2.1.7 Wastewater Reuse

Treated wastewater can be used for potable water supply either directly or indirectly. Direct potable reuse of wastewater involves treating wastewater plant effluent to drinking water quality, as shown on Figure 2-24. Although technically feasible, this method of wastewater reuse is discouraged because of the multiple barriers required, the higher health risks posed, the high costs involved, and the public perceptions of safety. Several communities have demonstrated direct potable reuse, and tests have indicated that the water meets drinking water standards. However, none have successfully implemented direct potable reuse for public consumption, even in areas of limited water.

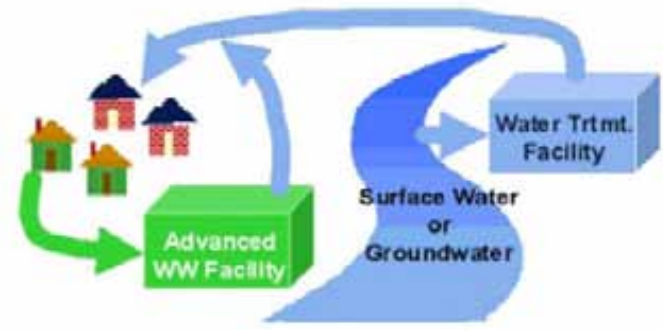

FIGURE 2-24
Direct Potable Reuse

Indirect potable reuse involves discharging treated wastewater to a receiving water body, then using that receiving water body as a source of drinking water supply (Figure 2-25).

Indirect potable reuse can be either planned or unplanned. Much of the Great Lakes Basin practices unplanned indirect potable reuse because wastewater plants discharge into the Great Lakes, which is a source of drinking water. There are no regulations for indirect potable reuse practices. However, the federal government enlisted the National Research Council to develop guidelines (*1998 Issues in Potable Reuse: The Viability of Augmenting Water Supplies with Reclaimed Water*). One of the major conclusions from that report asserts that indirect potable reuse is an option of last resort, after other high quality sources have been exhausted and conservation implemented. Since there are other sources of higher quality water for Waukesha, wastewater reuse will not be considered further as a source of potable water.

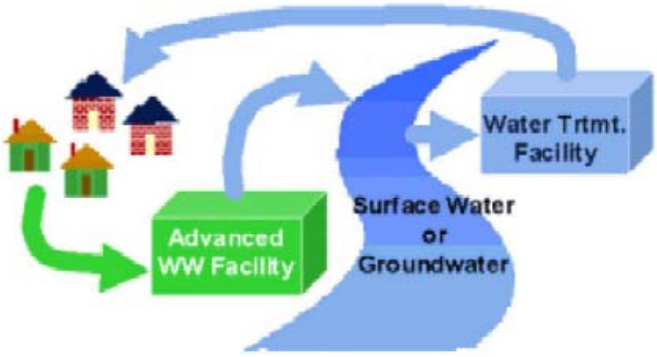

FIGURE 2-25
Indirect Potable Reuse

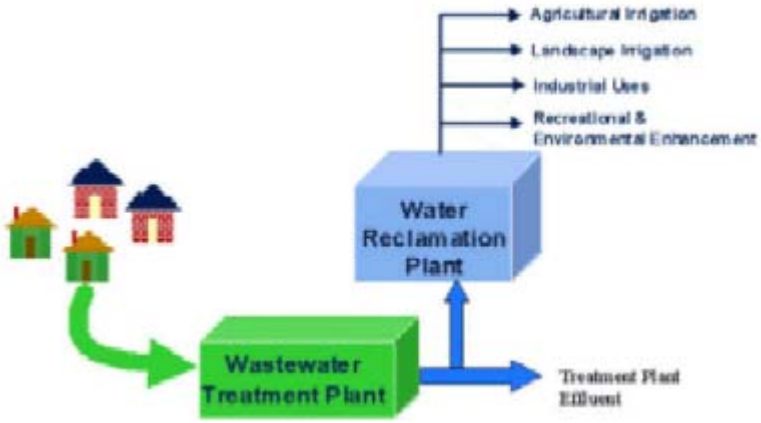

FIGURE 2-26
Non-Potable Reuse

Treated wastewater can also be considered for non-potable reuse, as shown on Figure 2-26. Golf courses and industries that require large volumes of non-potable water are candidates for non-potable reuse. The wastewater would require further treatment, and separate pumps and pipes would be required to deliver the water to potential customers. Non-potable reuse is used to supplement water demands, but is only part of the water supply equation. Non-potable reuse is most commonly practiced in arid regions with limited water supplies. In Waukesha, there would be limited and seasonal demand for non-potable water. Although non-potable water from treated wastewater may become a potential supplemental water source in the future, it is a small part of the entire water supply picture, it is costly, and it will not be considered further in this report as a main water supply source.

2.1.8 Milwaukee River

The Milwaukee River was also considered as a possible source of water for the Waukesha Water Utility. However, water quality is expected to be the lowest of the possible surface water sources. In addition, the river experiences summer low-flow periods, much like the Fox and Rock Rivers, which limit it as a reliable source during dry weather. The river water is also located a considerable distance from the City of Waukesha. It is slightly closer than the Rock River and significantly further than the other surface water sources. The conveyance route from the Milwaukee River would be significantly more complex than any

of the other surface water options. Distances from various water sources to Waukesha are shown below:

- City of Milwaukee water from Lake Michigan: 8 miles
- Fox River: 0 miles
- Rock River: 17 miles
- Milwaukee River: 15 miles

The Milwaukee River is a tributary to the Lake Michigan Watershed. Therefore, diversion of Milwaukee River water requires the same consideration as the Lake Michigan/City of Milwaukee option. Given the lowest water quality, the limited low-flow volume, the transportation distance and complexity, and the Lake Michigan diversion situation, it does not appear reasonable to consider it as a viable source of water for the City of Waukesha. Therefore, the Milwaukee River will not be considered further as a potential source of water for the City of Waukesha.

2.1.9 Pewaukee Lake

Pewaukee Lake is located about 5 miles north of the center of the City of Waukesha. Its surface area of approximately 2,500 acres, and it contains about 12 billion gallons of water. The lake watershed is about 18,000 acres, or 28 square miles. The lake includes about 14 miles of shore land that is mostly high-value residential development. The lake is the source water for the Pewaukee River, which flows southeast to the Fox River upstream of the City of Waukesha. The source water for the lake is precipitation to the lake, runoff from the lake watershed, or infiltration/exfiltration to the shallow sand and gravel aquifer. The surface of the sand and gravel aquifer is reflected by the lake water surface.

Given that the annual Waukesha Water Utility water demand is 3 (2000) to 5 (2050) billion gallons per year, and the lake storage capacity is approximately 12 billion gallons, there are some serious questions about the use of the lake as a primary source of water. As a secondary source, there may be better potential. Secondary sources are required for the river sources to bridge the dry weather periods. Secondary sources may include such reservoirs as a quarry, lake, or aquifer that can serve to bridge the summer dry period.

Like the river water sources, Pewaukee Lake is also most vulnerable during the dry summer months. It must continue to provide base flow to the Pewaukee River and maintain its level to accommodate the high demand for summer recreational activities. One week of Water Utility demand is equal to about 1 inch of lake level. Dry periods can last up to 2 months, resulting in a significant potential draw down. Some replenishment from the sand and gravel aquifer is expected to offset the draw down, but significant impacts on Pewaukee River flows and lake levels during dry weather periods are likely.

2.1.10 Waukesha Quarry

The limestone quarry is located north of the City of Waukesha along the Fox River and just downstream of the confluence with the Pewaukee River (Figure 2-27). There are two quarry sites, one located on each side of STH-164. Both quarries are active and are expected to have many years of viable operation remaining. The combined quarry volume is approximately 5.75 billion gallons. Groundwater is drawn down to the bottom of each quarry. WDNR records

indicate pumping in the range of 2 mgd, considerably less than the water demand of the Waukesha Water Utility. This water is pumped into the adjacent Fox River.

The quarry is not a good primary source of water because of the relatively low dewatering pumping rate, but it may hold the potential to be a secondary source of water as a reservoir used to supplement river flows during dry weather. The natural recovery rate of the groundwater in the quarries may not be enough to provide the water volume necessary to bridge dry periods. Supplemental water diverted from the Fox River during high river flows may be necessary to provide the required storage volume. Diversion of river water into the quarry may have some groundwater regulatory issues associated with it.



FIGURE 2-27
Waukesha Quarry

Given the anticipated long-term operation of the quarry, its use as a reservoir to supplement the Waukesha Water Utility water supply does not appear to be feasible. If there is a change in the plans to continue the quarry operation, the supplemental reservoir concept could be revisited.

2.1.11 Base Alternatives Summary

Fourteen separate water supply alternatives were evaluated for feasibility. A number of alternatives had fatal flaws (i.e., the inability to supply adequate water) and were screened out. A summary of the water sources that have been screened out are as follows:

Water Source	**Primary Reason for Screening**
Fox River	Inadequate year round supply
Rock River	Inadequate year round supply
Fox or Rock River Dam	Environmental and public concerns
Waukesha Quarry	Inadequate supply, other uses
Waukesha Springs	Inadequate supply
Pewaukee Lake	Limited supply, adverse environmental impacts
Milwaukee River	Poor quality, diversion issues
Wastewater Reuse	Public perception, water quality, limited supply
Milwaukee Wellfield	Political, legal, and infrastructure concerns
Dolomite Aquifer	Inadequate supply, limited sites

The base alternatives to be carried forward include:

- Sandstone aquifer
- Shallow aquifer (Fox River alluvium or sand/gravel)
- Lake Michigan

2.2 Combinations of Alternatives

The base alternatives can be combined to form additional water supply alternatives. There are many advantages to several sources of supply, including:

- Additional quantity
- More reliability/redundancy
- More flexibility for operations
- Ability to minimize environmental impacts
- Ability to phase implementation

If a Lake Michigan supply is obtained, there would not be any need for additional water supply quantity. For this reason, Lake Michigan was not combined with any other new water supply source. However, the sandstone wells may be desired as a backup supply for improved reliability.

Therefore, the following combinations of water supplies were carried forward for analysis:

- Sandstone/Shallow Aquifer
- Sandstone/Fox River Alluvium
- Shallow Aquifer/Fox River Alluvium

This creates a total of seven water supply alternatives to be carried forward for analysis. A general description of the combination alternatives is presented below.

2.2.1 Sandstone/Shallow Aquifer

In this alternative, shallow aquifer water would blended with existing sandstone water. The shallow aquifer would supply about 70 percent of the water. Shallow aquifer water would be blended with sandstone water at existing sandstone well sites so that the blended water would be below radionuclide regulations.

The shallow wellfield would consist of 11 wells. The water would be treated in a 15 mgd iron/manganese removal treatment plant and disinfected with chlorine. The treated water would be conveyed into Waukesha and sent to existing wells 6 through 9 for blending before being pumped into the distribution system. Existing wells 1 through 5 and 10 would be put on standby status.

2.2.2 Sandstone/Fox River Alluvium

In this alternative, Fox River alluvium water would be blended with existing sandstone water. The Fox River alluvium aquifer would supply about 70 percent of the water. Fox River alluvium aquifer water would be blended with sandstone water at existing sandstone well sites so the blended water quality would meet radionuclide regulations.

The Fox River alluvium wellfield would consist of five horizontal wells. The water would be treated in a 15 mgd direct filtration treatment plant and disinfected with chlorine and ultraviolet light. The treated water would be conveyed into Waukesha and sent to existing wells 6 through 9 for blending before being pumped into the distribution system. Existing wells 1 through 5 and 10 would be put on standby status.

2.2.3 Shallow Aquifer/Fox River Alluvium

In this alternative, Fox River alluvium water and shallow aquifer water to the South of Waukesha would be provided. About half the water would be provided from each source.

The Fox River alluvium wellfield would consist of four horizontal wells. The water would be treated in an 11 mgd direct filtration treatment plant and disinfected with chlorine and ultraviolet light.

The shallow aquifer wellfield would consist of eight vertical wells. The water would be treated in an 11 mgd iron/manganese removal treatment plant and disinfected with chlorine.

The treated water would be conveyed into Waukesha and tied into the existing distribution system. Existing sandstone wells would be put on standby status.

2.2.4 Aquifer Storage and Recovery

2.2.4.1 Description

Aquifer Storage and Recovery (ASR) was first used in the United States at Wildwood, New Jersey in 1968 as a method to help the area water utility meet summer peak demands, which could be as much as five times the ADD. ASR allows a utility to take excess capacity, available during low demand periods, and store it in aquifers through wells where it may be later recovered to meet seasonal peak demands (Figure 2-28). The treated water that is stored safely underground typically does not require treatment upon recovery and still meets all drinking water standards. Chlorine is typically added to maintain distribution system disinfectant residual when the water is recovered for use.

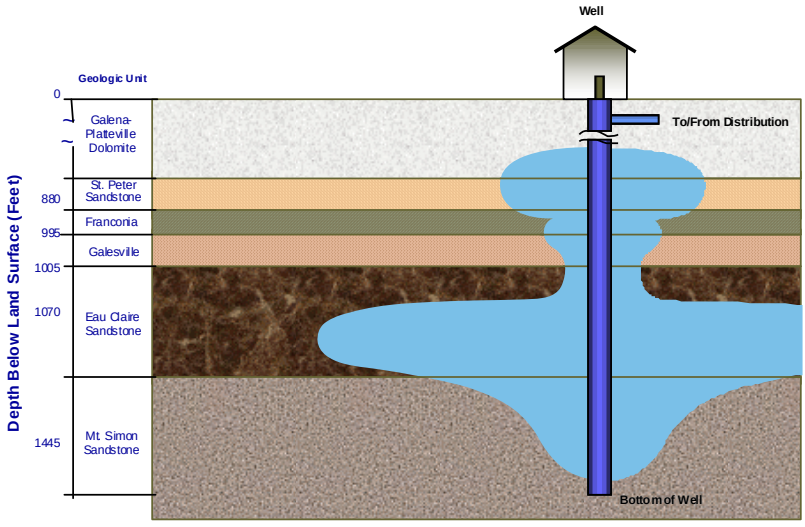

FIGURE 2-28
Aquifer Storage and Recovery

Since 1968, over 40 water utilities in 14 states have used operational ASR systems. Over 50 other pilot systems are being developed in these and seven other states. Wisconsin has an operating ASR well in Oak Creek, and another is being constructed in Green Bay. The Oak Creek ASR well proved that Lake Michigan water stored in the Sandstone aquifer maintains good quality, and it proved that Lake Michigan water stored in the sandstone aquifer does not pick up any radium.

ASR has been used for one or more of 23 different benefits. The most common benefit is deferment or elimination of the need to expand water treatment facilities to meet peak

demand, which often results in a cost savings of 50 percent or more when compared to other methods. Other common primary and secondary benefits of ASR include:

- Restoration of declining water levels in deep aquifers caused by decades of over-pumping
- Recovery of previously stored water to avoid seasonal surface water quality variations in nitrate, turbidity, pesticides, taste and odor, or other parameters that increase the cost or complexity of water treatment
- Optimization of treatment plant sizing and reductions in the cost of water supply expansion programs
- Maintains capital investment in idle wells by returning them to beneficial use
- Provides large volume storage for emergency or drought supply
- Minimizes the transmission and distribution system sizing requirements needed to meet peak flow rates

Lastly, since the September 11, 2001, terrorist acts upon the United States have become a primary concern. The military has identified ASR as an acceptable method for storing potable water out of harm's way at military installations around the world.

2.2.4.2 Application to Waukesha

ASR could be used to economically augment any of the water supply alternatives being considered. One or more of the existing or new sandstone wells could be converted for ASR use with another source of suitable potable water.

Shallow Aquifer Alternative. ASR could be used by the Waukesha Water Utility to optimize facilities for a shallow aquifer source. Instead of being sized for maximum day demand, the treatment facility could be sized slightly larger than ADD. When water demand is below ADD, the excess treated water could be recharged into an ASR well. The treated water recharged into the ASR well would displace the radium-bearing native sandstone groundwater and create a zone of potable water stored around the well for recovery during the summer. This eliminates the need for radium treatment.

Potable water from the shallow aquifer would be stored in ASR wells. ASR would allow the Waukesha Water Utility flexibility for future expansion since both the shallow wellfield and ASR wells could be developed with actual rather than forecasted growth.

Lake Michigan Alternative. If the Waukesha Water Utility is successful in procuring a source of treated Lake Michigan water, the water could be recharged into the existing sandstone wells within the city to provide a redundant water supply for emergencies or seasonal peaking. Furthermore, depending on the Lake Michigan water purchase contract terms, ASR could allow the Waukesha Water Utility more flexibility in negotiating off-peak water prices by using their own ASR wells to minimize or eliminate the variability in seasonal flow rates. This near-constant flow rate scenario may also allow the Waukesha Water Utility to reduce the transmission main and pump station sizing needed to meet peak season flows.

Sandstone Aquifer Alternative. If existing sandstone wells are used, ASR could be used by the Waukesha Water Utility to optimize the size of radium removal water treatment facilities.

Water from several sandstone wells could be routed to a treatment facility sized slightly larger than ADD. When water demand is below ADD, the excess treated water could be recharged into an ASR well. The treated water recharged into the ASR well would displace the radium-bearing native groundwater and create a zone of potable water stored around the well for recovery during the summer.

If new sandstone wells are developed that produce radium-free water from areas near the aquifer's recharge area, this water could be used in a similar manner to restore the existing wells to beneficial use without the need for providing radium removal treatment.

2.2.4.3 ASR Regulatory Status

The Oak Creek Water and Sewer Utility began developing the first ASR system in Wisconsin in 1996. They have since proven that ASR can be used successfully for seasonal peaking using treated Lake Michigan water and the deep sandstone aquifer in Southeastern Wisconsin. During the summer of 2001, they recovered their third full-scale cycle (42 million gallons each) into their distribution system with conditional approval from WDNR.

Green Bay is currently constructing ASR facilities and will begin testing them in 2002, also using Lake Michigan water and existing sandstone aquifer wells. ASR may allow Green Bay to supply water to nine neighboring communities and save $150 million in capital costs.

Prior to 1996, potable water injection was not even considered by WDNR. In fact, there is a prohibition against injection wells– assuming any injection well would be disposing of waste. The 1986 Safe Drinking Water Act (SDWA) amendments included Underground Injection Control (UIC) provisions. Many states, including Wisconsin, have primacy to oversee the UIC program. ASR wells are currently included under Class V "non-hazardous other" wells, which include septic tanks and a variety of other miscellaneous underground injection practices. Due to the breadth of Class V, the United States Environmental Protection Agency (USEPA) allows Class V practices to be permitted on a case-by-case basis or "by rule."

ASR is practiced in 14 states. Wisconsin is in the process of passing ASR legislation, along with at least five other states. WDNR has drafted rules for ASR that will be taken to the WDNR board for comment in 2002. The draft rules allow potable water to be stored underground and discuss meeting the groundwater regulations.

SECTION 3

Evaluation Criteria

A workshop meeting was conducted on October 2, 2001 to determine evaluation criteria for the water supply alternatives. The following six criteria groups were agreed to during the meeting:

- **Reliability**
  - Adequate quantity
  - Source water quality, vulnerability, and consistency
  - Redundancy
  - Sustainability over 50 years
- **Infrastructure**
  - Treatment requirements
  - Intake, wells, pumping, and transmission
  - Integration with distribution system
- **Operations and Maintenance**
  - Staffing levels
  - Residuals handling and wastewater plant impacts
  - Distribution system operation (pumping and compatibility of water quality)
  - Treatment plant operations
  - Ease of overall operation
  - Safety
- **Regulations/Legal**
  - SDWA compliance
  - WDNR compliance and permits
  - Impacts on other natural resources
  - Liability
  - Impact on permit conditions for stormwater and wastewater dischargers
  - Land requirements, zoning, and land use
  - Other regulations or agreements
- **Political and Public Acceptance**
  - Neighborhood aesthetics
  - Home softening impacts
  - Public perception (quality, reliability)
  - Political issues (Great Lakes governors; state; county and township; and local)
  - Potential for a regional solution
- **Schedule**
  - Time to implement
  - Ability to phase

3.1 Rank Evaluation Criteria

Each of the six criteria groups were ranked in hierarchical order of importance, from the most to the least important. For ranking purposes, each criteria group was compared to the other criteria groups to develop a "forced ranking." The results are shown below. For example, Reliability (criterion A) was more important than Infrastructure (criterion B), so an "A" was placed in the Reliability row.

Forced Criteria Ranking							Points	Rank
Reliability	A	a	a	a	a	a	6	1
Infrastructure		B	c	d	e	f	1	6
Operations and Maintenance			C	d	e	c	3	4
Regulations/Legal				D	d	d	5	2
Political and Public					E	e	4	3
Schedule						F	2	5

In descending order of importance, this process resulted in a ranking as follows:

- Reliability
- Regulations/Legal
- Political and Public Acceptance
- Operations and Maintenance
- Schedule
- Infrastructure

The criteria were weighted according to the given ranking. The top-ranking criterion (Reliability) was given a weight of 100. The other criteria were weighted relative to this score, with the weight of a criterion of lower rank never being higher than the one above it. Three scores from the Waukesha Water Utility and one average score from the consultants were used. The results are summarized below.

Criteria					Average
Reliability	100	100	100	100	100
Regulations/Legal	95	99	95	90	95
Political/Public	75	80	80	81	79
Operations and Maintenance	60	40	60	70	58
Schedule	50	20	50	55	44
Infrastructure	40	10	40	50	35

Based on the data, the weight of each criterion will be the average weight, expressed as a percentage, as shown on Figure 3-1.

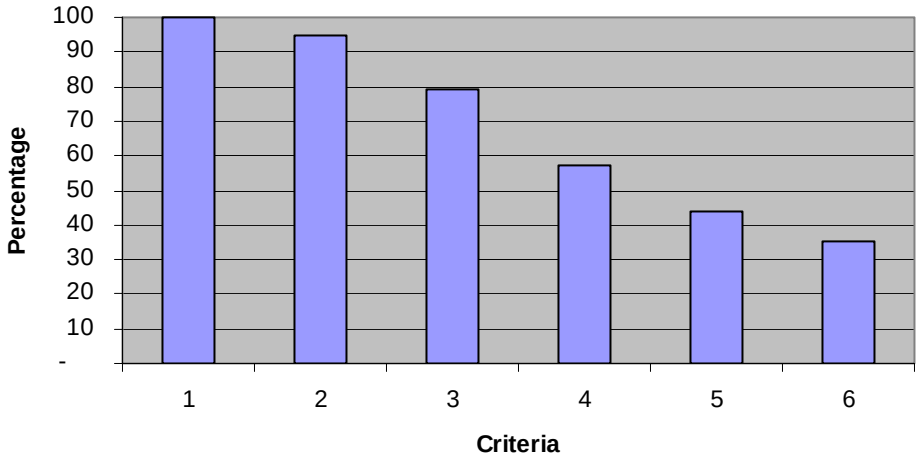

FIGURE 3-1
Evaluation Criteria Weighting

3.2 Evaluation Methodology

Water supply alternatives are evaluated based on the criteria (Section 3), then scored by a team of evaluators on a scale of 1 (worst) to 10 (best) in each of the six categories (Section 5). The scores from each of the evaluators are averaged and weighed accordingly. For example, if the average score for the criterion Political and Public Acceptance for Alternative A is 4, the weighted score would be 3.16 (4 × 79 percent). Weighted scores from all criteria are added for each alternative.

The weighted scores are compared to life cycle costs to develop Benefit/Cost relationships. Based on this information, the alternatives determined to provide the most value for the cost are selected (Section 6).

SECTION 4

Evaluation of Alternatives

4.1 Alternative 1 – Sandstone Aquifer

Water from the sandstone aquifer may be able to meet current and future needs using several approaches. Though multiple variations could be discussed, the options can be separated into two distinct pathways:

- Expand the existing wellfield
- Develop a new wellfield in a more favorable location

The relative merits and limitation of each option are presented in this section. These options are not mutually exclusive, and hybrid solutions that combine portions of each option are possible. The alternatives are described below.

4.1.1 Alternative 1a – Expand Existing Wellfield

This alternative consists of adding nine new sandstone wells southwest of the City of Waukesha. Existing wells 6 through 10 would be maintained, but wells 1 through 5 would be abandoned due to lower capacity and old age. Three treatment plants for radium and TDS removal would be added; one for well 9, one for well 10, and one for wells 6 through 8 and the new wells. The major facilities are shown on Figure 4-1.

4.1.1.1 Reliability

The Waukesha Water Utility currently operates a field of ten wells in the sandstone aquifer. This wellfield has been a reliable source of water since well 1 was drilled in 1935. The aquifer is protected from surface contamination by the Maquoketa shale, which makes the risk of well contamination relatively low. The existing wellfield and related distribution system represent a significant capital asset for the Waukesha Water Utility, and there are numerous advantages to maintaining the existing system. These include maximizing the use of existing capital investments and minimizing the technical and political problems associated with developing a new source of supply. New wells could be drilled adjacent to the existing wellfield to meet future demands. However, over the last few years several factors have emerged that call into question the long-term viability of the expanding the existing wellfield.

Many of the existing wells are old and are not constructed to current municipal well code requirements. The oldest well is 66 years old, while the youngest is 22 years old. Five of the active wells are over 50 years old. Based on the age and construction of many of the existing wells, it is reasonable to assume that additional wells may experience physical failures such as casing leaks or bore hole collapse, which will require extensive rehabilitation or replacement of affected wells.

The concentration of high-capacity wells in southeastern Wisconsin is causing the head in the sandstone aquifer to drop. This problem is most pronounced in eastern Waukesha County, where head in the aquifer has declined by over 500 feet from predevelopment

Waukesha Water Utility

SERVING WAUKESHA SINCE 1998

FIGURE 4-1

SANDSTONE WATER SYSTEM NEAR WAUKESHA

N

W E

S

0 1 2 3 4 5 10,000

SCALE IN FEET

LEGEND

- EXISTING WELL TO BE ABANDONED
- EXISTING WELL TO BE RETAINED
- PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

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conditions. Figure 2-3 shows the rate of decline in head between 1975 and 1995 in southeastern Wisconsin (Jansen and Rau, 1998). During this period, the Waukesha Water Utility wellfield experienced an average rate of decline of about 5 feet/year. The rate of decline was approximately twice this rate in municipal wellfields located immediately to the north of the Waukesha Water Utility. Reliable estimates of future rates of decline will not be available for about one to two years, until the SEWRPC regional groundwater model has been completed. However, a screening model completed in 1996 (Jansen and Rau, 1998) indicated that pumping levels in several wells in eastern Waukesha County could exceed 1,000 feet within 20 to 50 years, depending on the rate of increase in demand from the aquifer. Unless some level of regional management of pumpage can be accomplished, further water level declines may make long-term reliance on the sandstone aquifer economically non-viable.

The large cone of depression in the sandstone aquifer has created a strong vertical gradient between the upper portion of the aquifer and the sandstone units in the aquifer below the depth of the municipal wells. The resulting upward gradient heads is causing migration of saline water from the deepest portion of the aquifer into the producing interval. This has resulted in a significant rise in the TDS levels in several of the deepest and largest producing wells in eastern Waukesha County.

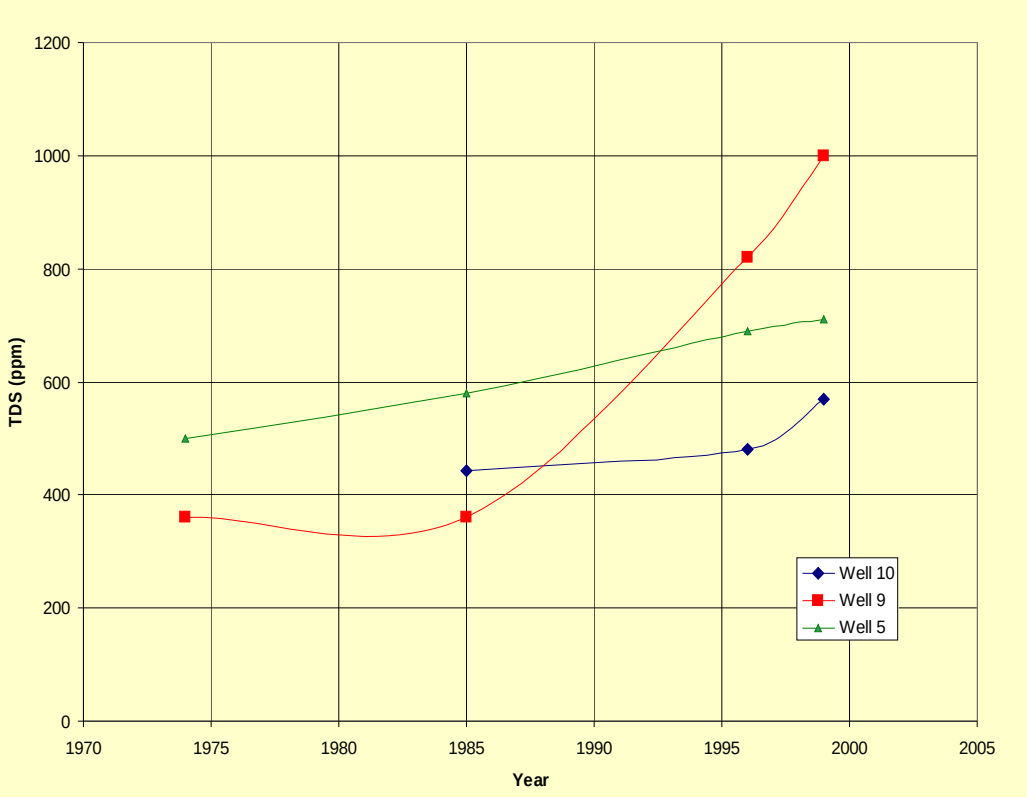


FIGURE 4-2
Trends in Total Dissolved Solids–Sandstone Aquifer

Figure 4-2 shows the trend in TDS levels in Waukesha Water Utility wells 5, 9, and 10 between 1974 and 1999. These are the three deepest wells and are generally the heaviest

pumped wells. TDS levels have risen between 28 and 142 percent in the these wells over a 25-year period, with the largest changes occurring over the last 15 years. Well 9 reached TDS levels of 1,000 ppm before a recent well rehabilitation project reduced the concentration by about 50 percent at the expense of over 50 percent of the specific capacity of the well. Similar increases in TDS are likely in other wells as they are pumped harder to meet future demand. These increases could be potentially reversed by rehabilitating the wells. Unfortunately, the reduction in TDS will come at a significant loss in capacity, and the long-term effectiveness of the rehabilitation process has not been demonstrated.

The rise in TDS levels may place practical limits on the production capacity of the existing wellfield before declining pumping levels force a reduction in pumpage. The reduction in capacity will have to be offset with water from a new source or from additional sandstone aquifer wells. Recent geophysical investigations to map the distribution of saline water in the sandstone (AST, 2000a; AST, 2000b) have indicated that the zone of saline water is pervasive in the deeper portion of the aquifer on the down-thrown side of the Waukesha fault where all of the existing Waukesha Water Utility wells are located. A recent geophysical survey (AST, 2001) to screen two potential sandstone well sites on the up-thrown side of the Waukesha fault in the northwest portion of the city of Waukesha indicated that a previously unknown zone of saline water may be present in a stagnation zone behind a mound of impermeable Precambrian rock that projects into the aquifer to the northwest of the sites. The presence of the Precambrian mound has been confirmed by logs of a municipal well in Delafield, as well as from high resolution aeromagnetic data (Mudrey, 2001).

The data suggests that any new sandstone wells drilled in the northwest side of the city run the risk of encountering high TDS groundwater, and any sandstone wells drilled on the down-thrown side of the Waukesha fault run the risk of accelerating the upward migration of saline water from deeper within the aquifer. Based on this information, any new sandstone wells should be drilled no deeper than about 1,500 to 1,800 feet and pumped at typical rates of about 1,000 gpm. The wells could be pumped at rates of up to about 1,500 gpm for short periods by using a variable speed pumps. These problems could be largely avoided by drilling wells closer to the recharge zone for the aquifer where better water quality is expected, as described in Alternative 1b.

The water produced by all ten of the Waukesha Water Utility wells exceeds the MCL for radium and gross alpha. At present, all of the Waukesha Water Utility wells would need treatment or well rehabilitation to comply with the radionuclide standards. Several treatment processes are available to reduce radium and gross alpha levels. Some wells can be reconstructed to reduce radionuclide levels.

While these technologies will probably be sufficient to bring the water into compliance, some recently discovered trends in radionuclide levels may complicate compliance strategies. Distribution system samples indicate that gross alpha levels have more than doubled from about 1982 to present (Figure 4-3), while radium levels have not risen. Similar trends have been observed in most water utilities using sandstone wells in Waukesha County. Studies are under way by the Wisconsin State Laboratory of Hygiene to identify the specific elements responsible for the increase in gross alpha levels.

The cause of rising gross alpha is presently unknown. This trend is significant because it raises questions about the long-term effectiveness of any treatment process or well

reconstruction designed to treat gross alpha. Some of the alpha emitting elements in the decay series of radium 226 and radium 228 can not be effectively removed by ion exchange or lime softening treatment. Depending upon the particular elements responsible for the rising gross alpha levels, it may be necessary to install membrane treatment, which would substantially increase the cost of compliance.

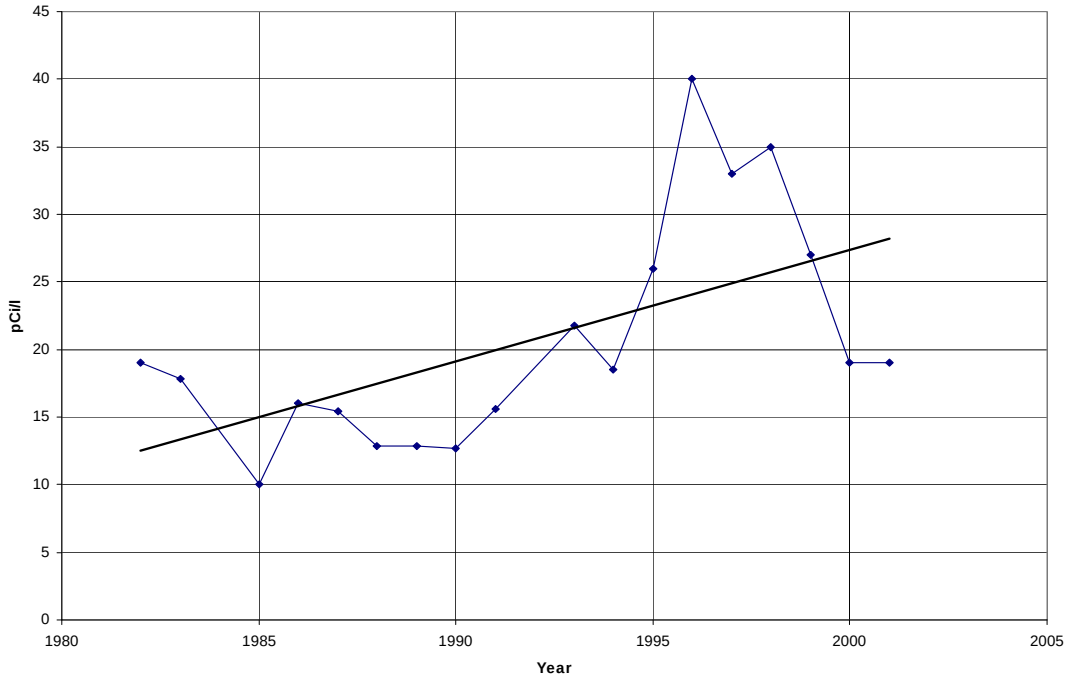


FIGURE 4-3
Trends in Gross Alpha–Sandstone Aquifer

In addition to the TDS and radionuclide issues, several other water quality problems could affect the long-term reliability of the existing sandstone aquifer wellfield. The arsenic standard has been reduced from 50 ppb to 10 ppb. Seven of the Waukesha Water Utility wells were sampled by the WDNR in 1999 for arsenic. The data indicated that all of the seven Waukesha Water Utility wells sampled were well below the new standard. However, review of the sample description logs that have been completed by the Wisconsin Geological and Natural History Survey (WGNHS) for several of the Waukesha Water Utility wells indicated that sulfide minerals are present in the aquifer. Arsenic levels may increase in the wells if these minerals are exposed to oxygen due to dropping pumping levels caused by declining heads in the aquifer.

In addition, the dropping pumping levels are starting to expose the upper portion of the aquifer to both air and the vegetable grade food oil used as a pump lubricant. The oil provides oxygen and a carbon source for natural bacteria in the aquifer. One of the Waukesha Water Utility wells has experienced positive coliform tests (negative for fecal coliform) due to this process. Similar problems have been experienced in other sandstone wells in Waukesha County in recent years.

4.1.1.2 Infrastructure

Wells. Assuming that the capacity of the existing wellfield can be maintained, a minimum of 6 mgd of new capacity will be needed to meet projected future demands. However, it is likely that the capacity of the existing wellfield can not be maintained due to declining heads, the probable need for additional well reconstruction to reduce TDS levels, and the potential need to abandon older wells as they reach the end of their service life.

Existing sandstone wells that are preserved would have to be brought into compliance with the radionuclides MCLs. This could be accomplished through a combination of treatment, well reconstruction, or blending with water from shallow aquifers. Given the layout of the wellfield, wells 6, 7, and 8 are attractive candidates for treatment at a single plant. Wells 1 through 5 do not produce enough water to justify the cost of treatment. Wells 9 and 10 could be treated with separate plants at or near the well sites. However, the capacity of both of these wells is likely to be reduced to deal with rising TDS levels. For the purpose of this analysis, it was assumed that wells 1 through 5 would be abandoned and the capacity of wells 9 and 10 would be reduced to about 2 mgd each. Given these assumptions, the capacity of the existing wellfield would be about 11 mgd.

To meet the forecasted maximum day pumpage of 22 mgd, a minimum of 11 mgd of new capacity would be needed. If the average capacity of each new sandstone well is limited to 1,000 gpm, approximately nine new sandstone wells will be needed to meet the reliable capacity requirements. Most of these wells will probably be drilled to the south and the west of the existing wellfield due to minimum spacing requirements, the presence of other municipal wellfields to the east and north, and the potential presence of a zone of elevated TDS water in the aquifer to the northwest. Assuming a minimum separation of approximately 1-mile between wells, approximately 5 to 10 miles of transmission main will be needed to accommodate the new wells.

Treatment for Sandstone Aquifer Water. All of the existing wells and most or all of the new wells will need some sort of rehabilitation or treatment to comply with the radionuclide MCL. Treatment may also be required for TDS or aesthetic water quality parameters such as hardness or iron. Construction of one or more treatment plant with modifications of the existing distribution system would also be required.

Water from the sandstone aquifer is hard with low levels of iron and manganese (Table 4-1). The sandstone groundwater is not treated (beyond chlorination and silicate sequestration) in Waukesha or many other communities using this aquifer. The only parameters not meeting primary drinking water regulations are radium and gross alpha.

If the sandstone aquifer continues to be used as the sole source of drinking water, and current radionuclide regulations are enforced, radium and gross alpha will have to be reduced below the MCL (5 pCi/L combined radium 226 and radium 228, 15 pCi/L gross alpha).

TABLE 4-1
Sandstone Aquifer Water Quality Data
Future Water Supply

	Typical Value	MCL Primary Standard	Secondary Standard
Total Hardness (mg/L as $CaCO_3$)	250-480		
Calcium (mg/L)	61-130		
Magnesium (mg/L)	20-26		
Total Alkalinity (mg/L as $CaCO_3$)	220-230		
pH	7.5		
Sulfate (mg/L)	36-140		250
Chloride (mg/L)	4.1-30		250
Total Dissolved Solids (mg/L)	300-710		500
Iron (mg/L)	0.2-0.4		0.3
Manganese (mg/L)	0.03		0.05
Sodium (mg/L)	40		20
Radium 226+228 (pCi/L)	5.8-13	5	
Gross Alpha (pCi/L)	13-38	15	

Source: City of Waukesha Wells 1, 2, 4, 5, 6, 7, 8, 9 and 10

There are many treatment processes for radium reduction, including:

- Lime softening
- Ion exchange (zeolite softening resin or radium specific resins)
- Membrane softening (nanofiltration or reverse osmosis)
- Adsorption onto iron and manganese oxide coated filter media (or hydrous manganese oxides)

All of these processes are capable of reducing radium, and all have their respective advantages and disadvantages. Lime softening removes hardness along with radium, but it produces a solid waste that requires disposal. Ion exchange softening also removes hardness and radium, but it increases sodium levels in drinking water and produces a liquid brine waste (sodium, calcium, and magnesium chlorides). Membranes remove hardness and radium along with many other cations and anions (sulfates, arsenic, and chlorides). However, membranes also produce a liquid brine waste, but the brine is concentrated groundwater so no additional salts are added to the environment. Iron and manganese filtration is less effective at radium removal, but the process is less complex and costly. Iron and manganese filtration does not soften the water or remove other cations or anions.

Determining the optimum radium removal treatment process is beyond the scope of this study. Of the treatment processes described above, membrane softening provides the best overall water quality. Given the trend toward higher dissolved solids and gross alpha in the sandstone wells, a treatment process that removes these elements is prudent for a long-term

solution. Although the exact constituents contributing to the higher gross alpha levels are not yet known, membrane softening (nanofiltration or low-pressure reverse osmosis) has the best potential for removal when compared to the other treatment alternatives mentioned.



FIGURE 4-4
Spiral Wound Membrane Cartridge

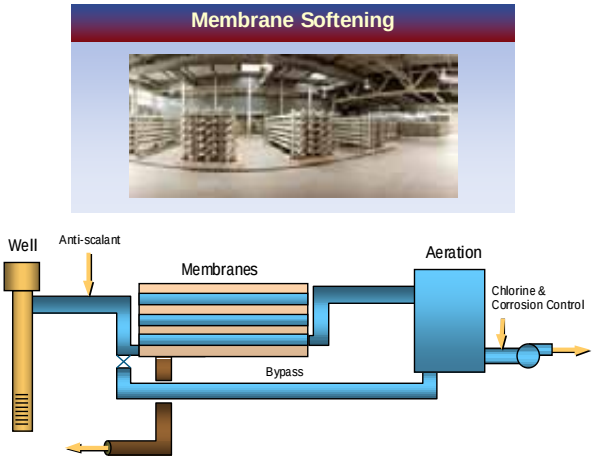


FIGURE 4-5
Membrane Treatment Process

Nanofiltration removes radium, calcium, magnesium and other divalent ions. It is lower pressure (around 100 psi) than reverse osmosis, and thus is lower in cost. Nanofiltration involves passing water through a semi-permeable membrane that rejects many dissolved solids and allows water and some monovalent ions to pass. The membranes are typically spiral wound in a cartridge as shown on Figure 4-4. A number of cartridges are assembled into a skid as shown on Figure 4-5. Anti-scalants are added to the membrane feed water to reduce the chance of membrane fouling by precipitants. If these anti-scalants include acid, carbon dioxide is produced and can be removed by aeration. A portion of the water can be bypassed around the nanofiltration process. For example, if the radium concentration of a well was 20 pCi/L, about 20 percent of the water could be bypassed while still meeting the radium limits. This also reduces the cost of treatment.

A typical nanofiltration treatment process is shown on Figure 4-5. Treatment for iron/manganese reduction may be required before membranes, depending on the concentrations in the groundwater. If aeration is required for carbon dioxide removal, the water would be collected after aeration and pumped into the distribution system.

A minimum number of treatment plants is desirable to minimize O&M costs. In this alternative, it was assumed that wells 6 through 8 and nine new wells would be directed to a central treatment plant in the southwest portion of the city. Wells 9 and 10 would have their own separate treatment plants, while wells 1 through 5 would be placed on standby or abandoned.

Transmission. Transmission lines would be needed to bring water from wells 6 through 8 together to a central treatment plant, then back into the distribution system. In addition, transmission lines from the nine new wells would be needed to convey water to and from a new treatment plant. Approximately 12 miles of transmission main are required.

4.1.1.3 Regulations/Legal

Expanding the existing wellfield will only be viable if the water is brought into compliance with the radionuclide MCL. It is also likely that most of the new sandstone wells will be located in the surrounding townships. The townships may attempt to prevent this by refusing to rezone land or to grant rights-of-way for transmission lines. If the head in the aquifer continues to decline, future pumpage may be restricted by some regulatory body that may require the Waukesha Water Utility to find alternate sources in the future.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing of treatment processes will likely be required.

4.1.1.4 Political and Public Acceptance

Expanding the existing wellfield will not be acceptable to the public unless the water complies with the MCL for radionuclides and aesthetic water quality parameters improve. While using an existing investment may seem attractive, the cost of treating the existing wells more than offsets any savings achieved. In addition, most regulatory bodies will not perceive expansion of the wellfield as a permanent solution unless the issues of declining head and deteriorating water quality can be addressed. Continued use of the confined portion of the sandstone aquifer minimizes environmental impacts on surface water and avoids conflicts with shallow domestic wells in surrounding rural areas.

The treatment plants will require aesthetic features to make them acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The transmission pipes would require easements, and distribution pipes would be located largely within the city limits, resulting in potential traffic slow-downs during construction.

4.1.1.5 Operations and Maintenance

Wells. Many of the O&M procedures that would be required for this alternative are similar to the current practices of the Waukesha Water Utility. However, the level of these activities would be increased significantly due to the additional wells that would be needed and the higher levels of maintenance that will be required to service the existing wells. As the head in the aquifer continues to drop, deeper pump settings and higher pumping costs will be necessary. Eventually, the remaining line shaft pumps will need to be replaced by submersible pumps. Larger pumps with higher horsepower motors will be needed over time with greater capital costs and higher O&M requirements. If the pump settings approach shot holes in the well bores, sand pumping and bore hole collapse problems could occur. As the pump setting get deeper, some wells may have to be straightened or re-drilled to accommodate the pumps.

The continued decline in head may also accelerate the increase in TDS in the aquifer, which will require additional well rehabilitation or treatment. Periodic nuisance bacteria problems are likely in wells that used food grade vegetable oil in the past. These wells may require periodic cleaning and disinfection.

Water Treatment. New treatment plants will require additional maintenance for the building and equipment. Maintenance activities for the following equipment would be required: instrumentation and controls, valve and piping, membrane skids, HVAC, chemical systems,

and general building facilities. The membranes do not last indefinitely, and need to be replaced every 5 to 10 years depending on water quality and operating procedures.

Membrane plants can be automated so that full-time attendance is not required. The treatment plants should be checked several times a day for proper operation and chemical feed. The anti-scalant chemical and chlorine would be added to the treated water. If one of the plants will be out of operation for a long time (i.e., winter), procedures to protect the membranes would be recommended.

The water quality resulting from nanofiltration will be much softer with lower dissolved solids, which is different from what has been in the distribution system piping since the beginning of the water system. Therefore, there is potential for pipe scale to dissolve and enter the water supply. In addition, lead corrosion conditions may change. A distribution system water quality study should be conducted to determine any adverse impacts and methods to minimize effects. In many cases, adverse effects are short-term and related to aesthetics (i.e., red water).

Water Plant Residuals. Residuals from a nanofiltration plant consist of a liquid brine concentrate. Approximately 10 percent of the water treated by nanofiltration is wasted. If it is assumed that 25 percent of the water is bypassed, about 7.5 percent of the total well flow would be wasted to the sanitary sewer. At the current ADD of 8 mgd, the waste volume would be about 0.6 mgd. At a maximum day demand of 15 mgd, the waste volume would be about 1.1 mgd. It should be noted that this volume of waste would require additional groundwater supply to meet water demands.

The waste brine from nanofiltration is just concentrated groundwater. The concentration of various constituents is roughly 10 times the concentration in the groundwater (Table 4-1). Monovalent ions such as sodium and chloride are not removed by nanofiltration and would not be concentrated in the waste brine.

Radium levels in the waste brine would range from 50 to around 200 pCi/L depending on the level in the well. These levels are below those required by WDNR for special handling as radioactive, so discharge to the sanitary sewer should be acceptable.

Besides the additional volume of water, the wastewater plant should not receive additional solids (dissolved or particulate). Although the brine has concentrated dissolved solids, the total amount of dissolved solids entering the wastewater plant will not be increased because it will be blended with the membrane softened water in the sewer system. Actually, the dissolved solids entering the wastewater plant will decrease significantly if home softening is reduced, especially sodium and chloride.

Transmission. The additional pipe and valves will require maintenance, similar to existing pipe and valves in the Waukesha Water System.

4.1.1.6 Schedule

Expanding the existing wellfield offers some flexibility in schedule since wells can be added as needed. However, all wells will probably be required to be compliant with the radionuclide standard, which will require major capital investment and changes in the infrastructure. Design and construction of water treatment plants could take about

2 to 3 years to complete. If a pilot-plant study is required, another year would be needed. Transmission main improvements may be constructed in this time frame as well.

4.1.2 Alternative 1b – Develop a New Wellfield in a More Favorable Area

This alternative consists of adding 11 new sandstone wells about 11 miles west of the City of Waukesha. Existing wells would be abandoned or kept as standby. A treatment plant for removal or iron/manganese would be provided. The major facilities are shown on Figure 4-6.

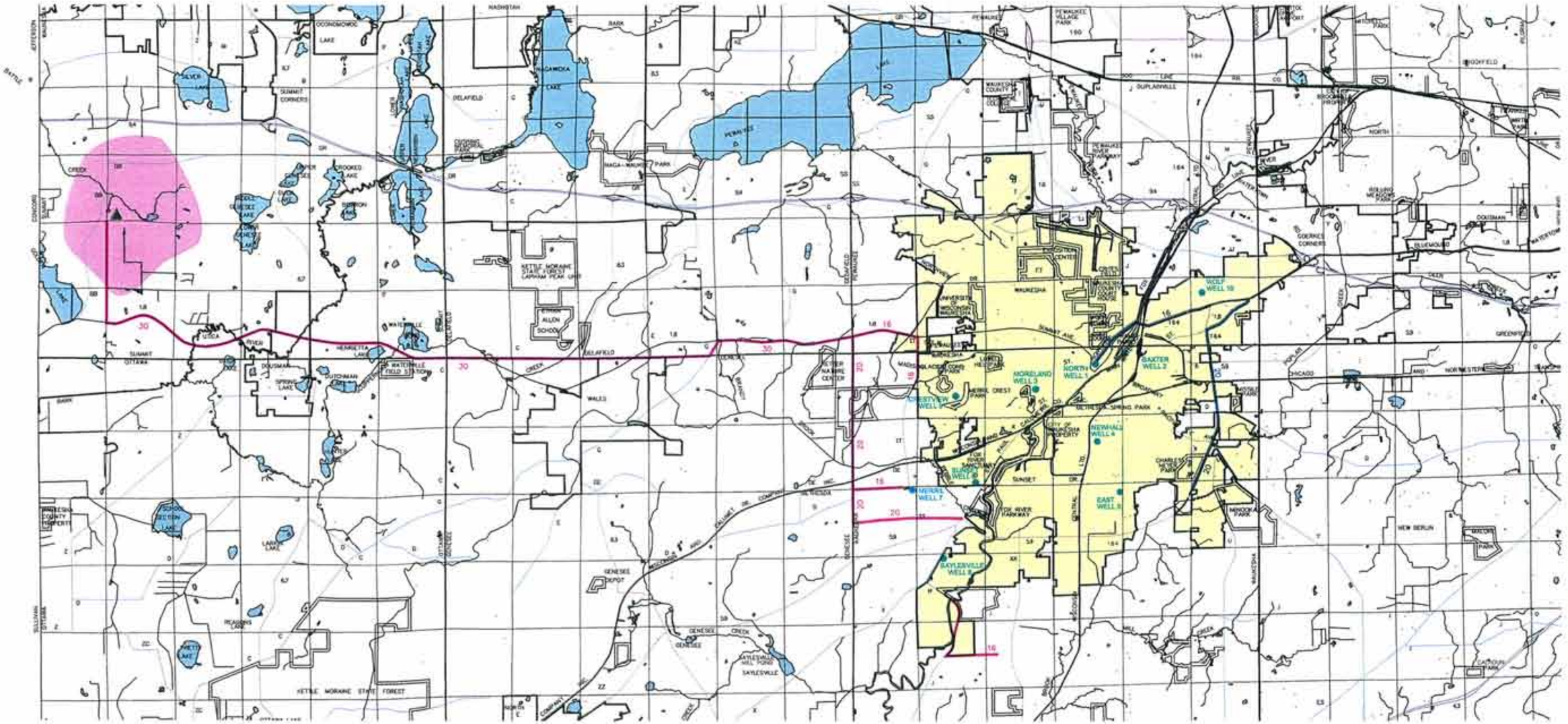
4.1.2.1 Reliability

The problems currently experienced by the existing Waukesha Water Utility wellfield are related to the fact that the wells are all located in the confined portion of the aquifer near the center of the regional cone of depression. If the wellfield were located in the recharge area west of the Maquoketa shale subcrop, it would not be experiencing the same problems.

A large bedrock valley is present west of the Maquoketa subcrop. This valley is an extension of the Rock bedrock valley that extends into Illinois. This area is indicated on Figure 4-7, and covers portions of the Townships of Oconomowoc, Summit, and Ottawa. The valley is filled with glacial deposits that are predominantly sand and gravel. The valley extends through the upper confining unit of the sandstone and places saturated sand and gravel units directly in contact with the sandstone aquifer. The sandstone aquifer tends to be more permeable in this area. Most of the confining units within the sandstone are thin or absent, allowing faster vertical recharge throughout the full thickness of the sandstone aquifer. This valley is the major recharge source for the sandstone aquifer in Waukesha County.

Figure 4-7 shows the portion of the sandstone aquifer recommended for unconfined sandstone aquifer wells and the location of a potential unconfined sandstone wellfield. The location of the wellfield on Figure 4-7 is only conceptual. The actual position of any wellfield or individual well would be determined based on local geologic conditions and land availability.

Two municipal water systems with sandstone wells, Oconomowoc and Dousman, are located in this area. The data from these wells can be used to draw conclusions as to the properties of the aquifer in the recharge area. Because the valley is a major recharge feature that receives recharge from the surface, the water entering the sandstone is younger and generally of much better quality. TDS levels and radionuclides are lower than under the confined portion of the aquifer. TDS levels are generally below 500 ppm and most wells are well below the radionuclide standards. Water levels in the aquifer are not declining significantly in this area in spite of the large draw down occurring in the confined portion of the aquifer. Static water levels in municipal wells in this area have been essentially stable and typically are within 100 feet of the surface. The aquifer is thinner in this area, generally less than 1,000 feet, but capacity of wells in the area is relatively high, generally over 1,000 gpm, due to the ample recharge and high permeability of the sandstone.



LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

0 1 2 3 4000 8000
SCALE IN FEET

Waukesha Water Utility
SERVING WAUKESHA SINCE 1886

N
W E
S

FIGURE 4-6

SANDSTONE WATER SYSTEM
WEST OF WAUKESHA

CH2MHILL

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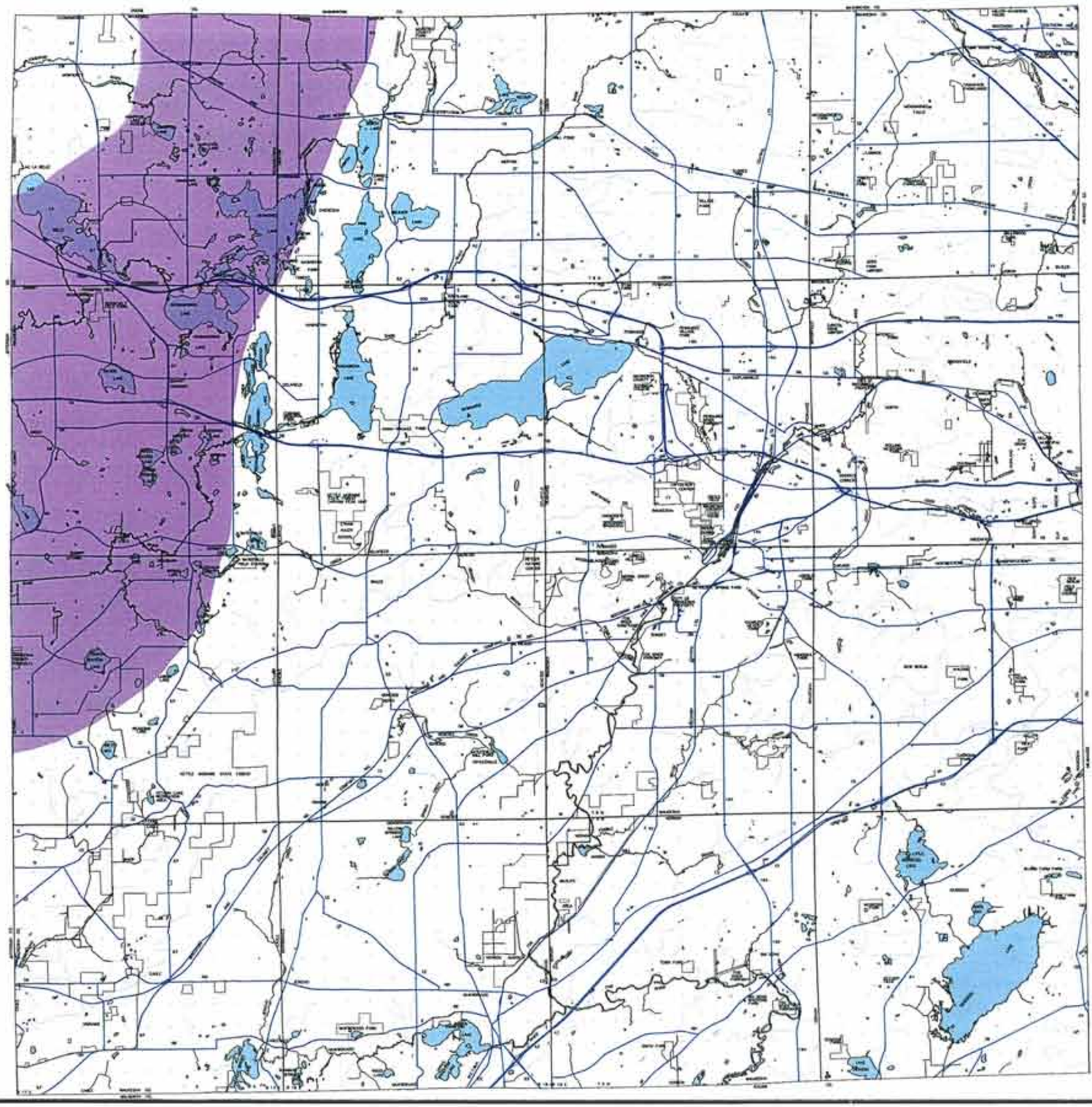

Waukesha Water Utility

SERVING WAUKESHA SINCE 1886

FIGURE 4-7

RECOMMENDED EXPLORATION AREA FOR UNCONFINED SANDSTONE AQUIFER WELL FIELD

N
W E
S

0 1 2 3 4 5

SCALE IN MILES

LEGEND

RECOMMENDED EXPLORATION AREA

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Moving the Waukesha Water Utility wellfield or portions of it to the recharge area would have two major benefits. First, the water quality would be substantially improved. It is likely that the TDS of the water would be below 500 ppm and remain relatively constant over time. Secondly, the sustainable capacity of the wellfield would be increased. By pumping from the recharge area, the wellfield would be intercepting the same water that it currently produces, just at a point where the water is younger and of higher quality. The cone of depression would be much shallower due to the unconfined nature of the aquifer in this area and the availability of ample recharge. The draw down created by the wellfield would induce more recharge into the system, increasing the sustainable capacity of the aquifer. In addition, by moving a major pumping center out of eastern Waukesha County, static water levels in the confined portion of the aquifer would recover, reducing the pumping costs for the remaining wells in the confined portion of the aquifer and extending its useful life.

Inducing more recharge into the sandstone aquifer has some potentially undesirable effects. Most significant is the potential to impact surface water bodies. The pumpage is likely to reduce base flows to some streams and may have measurable affects on some springs and wetlands. However, it is unlikely that the induced recharge would have measurable impacts on the lakes in the area.

The proposed wellfield is directly analogous to the wellfield in Dane County, Wisconsin. The municipal water utilities for Madison and the surrounding communities, along with several large industrial users, pump approximately 50 mgd from the sandstone aquifer in the county. This pumpage has dropped water levels in the sandstone aquifer approximately 60 feet below predevelopment conditions in the area of highest pumpage. The area of highest pumpage is within the City of Madison where the shallow confining unit is absent and the Madison-area lakes are in direct connection with the permeable portion of the aquifer. The extensive pumpage has induced recharge from the shallow aquifer, which has affected several springs and decreased base flows in several streams. Portions of the lake beds are now recharging the aquifer where groundwater was previously discharging to the lakes under predevelopment conditions. While this is certainly not a desirable condition, the induced recharge to the aquifer occurs over such a large area that the actual vertical flux through any given area is relatively small, so that the actual loss of water through the lake bed is negligible compared to the natural flux through the lakes. As a result, the affect on the lakes after decades of heavy pumpage is not measurable.

While the new wellfield would be more susceptible to surface contamination than the existing wellfield, the travel time through the unconsolidated units into the sandstone aquifer is likely to be decades to perhaps a few hundred years. Given the travel time from a surface spill area to the intake of a sandstone well, and given the large amount of dilution within the unconsolidated material and the sandstone aquifer that would occur, the risk of contamination of the wells would be low.

4.1.2.2 Infrastructure

Wells. Assuming the new wells will have a typical capacity of 1,500 gpm, 11 new wells will be needed to provide the ultimate reliable capacity of the Waukesha Water Utility. Assuming that some of the existing wells could be retained, the total number of wells needed could be somewhat lower. Assuming a wellfield designed with a minimum spacing

of 0.5 mile between wells, approximately 10 to 12 miles of transmission main with approximately 5 miles of smaller diameter feeder lines would be needed.

Treatment. An objective of this study is to provide water that meets all primary (enforceable) and secondary (non-enforceable) drinking water standards. Available water quality data indicate that the sandstone aquifer in this area meets primary drinking water standards. However, secondary standards for iron and manganese may be exceeded, depending on local conditions. Secondary standards are aesthetic and do not represent a health concern.

For the purposes of this study, the conservative assumption of treatment for iron and manganese removal was made. Iron and manganese removal may not be required depending on the concentrations in the actual wells and public acceptance. However, iron/manganese treatment can also remove some radium if levels approach the MCL.

Sequestering is an alternative to treatment for removal of iron and manganese. Sequestering involves adding a chemical, such as a polyphosphate or a silicate, that binds the iron and manganese in a soluble form without removing it from the water. A careful review of impacts of a sequestering chemical on the distribution system pipe scale would be required before implementation. Sequestering can be considered further during implementation if the sandstone aquifer becomes a preferred alternative and if radium levels are well below the MCL.

Iron and manganese can be removed by a number of processes, including:

- Aeration or chemical oxidation, detention, filtration
- Greensand filtration
- Lime softening
- Biological filtration

Although all the treatment processes mentioned above will remove iron and manganese, greensand filtration was chosen because:

- Simplicity of operation and lower costs than some other alternatives
- Adequate removal efficiency for the levels likely to be encountered

A typical iron/manganese removal treatment process is shown on Figure 4-8. Greensand is a mineral (glauconite, a clay composed of hydrous aluminosilicate) that is treated so that its surface is coated with manganese dioxide. The greensand is typically placed below a layer of anthracite coal, which filters out the larger particles and makes the greensand filter more effective. Potassium permanganate can be continuously added to the water for

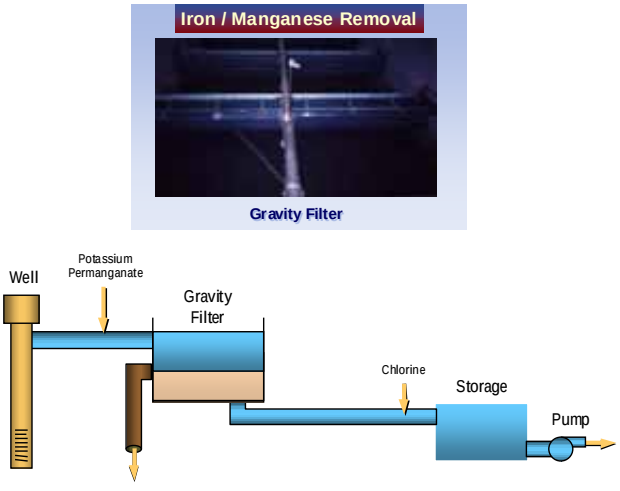

FIGURE 4-8
Treatment for Iron/Manganese Removal

oxidation of soluble iron and manganese and regeneration of the filter media. The water can pass through a pressurized vessel or concrete gravity box containing the greensand and anthracite where iron and manganese are removed by filtration, ion exchange, and adsorption. Based on the large size of this treatment plant, gravity filtration will likely be more economical than pressure filters.

The filters are backwashed periodically to remove the captured iron and manganese; this water is sent to waste. Sanitary sewer may not be available to discharge this waste, so a lagoon would be provided for solids accumulation and eventual disposal. Chlorine is added to the filtered water. Chlorine can also be added before filtration to reduce the potassium permanganate dose.

A single water treatment plant would be desirable to minimize O&M and costs. The wellfield water could be conveyed to the plant, treated, then pumped to the distribution system.

With this alternative, the existing wells would be abandoned or placed on standby. Existing storage tanks and pump stations would be used to convey water through the distribution system.

Transmission. Transmission from a western wellfield to Waukesha would be accomplished with dual 30-inch-diameter transmission lines. The second line would provide a degree of reliability and redundancy. About 11 miles of large transmission main would be required.

Another 14 miles of 20- and 16-inch water main are required to distribute the treated groundwater throughout the City of Waukesha.

4.1.2.3 Regulations/Legal

Under current high-capacity well law, the Waukesha Water Utility cannot be prevented from developing a wellfield in the recharge area. Future regulations may seek to quantify and limit the impact of municipal wells on surface water. It is possible that pumpage restrictions may be placed on the wellfield if negative impacts to the environment can be documented.

Local townships are likely to be very concerned about the perceived threats to their local water supplies and loss of autonomy. They may elect to resist zoning changes or grant rights-of-way that may be required to develop a wellfield. These issues may be largely resolved through the formation of a water authority that grants itself greater extraterritorial rights.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing of treatment processes is not likely to be required.

4.1.2.4 Political and Public Acceptance

The customers of the Waukesha Water Utility would probably perceive a great benefit in improved water quality and a more sustainable source of supply. The development of a large wellfield outside of the City corporate limits is likely to draw strong opposition from a number of surrounding townships and municipalities. The number of objecting parties could be reduced if the wellfield was seen as part of a regional water authority providing water to several communities.

A number of environmental and citizen groups may object to the wellfield based on perceived risk to surface water resources. These concerns could be addressed to some extent by the use of comprehensive groundwater models to predict the effect on the aquifer and optimize the wellfield design to minimize impacts to surface water. However, even if the

wellfield can be demonstrated to have no significant impacts to the environment, some groups may remain opposed.

The treatment plants will require aesthetic features to make them acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The long transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic slow-downs during construction.

4.1.2.5 Operations and Maintenance

Wells. The proposed wellfield will have lower O&M costs because the wells will be newer, pumping levels will be on the order of 200 to 300 feet, and the water will be of higher quality.

The wellfield will require one or more long transmission lines, which will require additional maintenance.

Treatment. A greensand filtration facility would consist of several filters and chemical systems (potassium permanganate and chlorine) housed in a building. A storage tank and pump station would also be included. The filtration system can be automated for backwash based on volume of water treated, time, effluent iron concentration, headloss, or other parameters.

Potassium permanganate is added to the well water before greensand filtration. This chemical is delivered as a granular solid in drums. The dry chemical is transferred to a hopper, dissolved into solution, and added to the water through metering pumps or other measuring devices. Typical doses of potassium permanganate are 0.6 mg per mg of iron and 2 mg per mg of manganese. The chemical feedrate can be automatically adjusted based on flowrate. More sophisticated controls can adjust chemical doses based on iron concentrations and flowrate.

Chlorine can be in liquid (sodium hypochlorite) or gas form. Sodium hypochlorite is more expensive, but safer to handle. For the purposes of this report, the use of sodium hypochlorite is assumed. Sodium hypochlorite is delivered by bulk truck and unloaded into storage tanks. The chemical is transferred to a day tank and can be fed through metering pumps. Provisions to feed chlorine before and after filtration should be made.

A greensand filter plant can be automated so continuous attention by operators is not required. The treatment system should be checked several times a day for proper filtration and backwashing, pressures and flowrates, chemical storage levels and feed rates, and general water quality.

A new treatment plant will require additional maintenance for the building and equipment. Activities may include instrument calibration, valve and piping maintenance, HVAC maintenance, filter media replacement, and chemical system and general building maintenance.

Water Plant Residuals. When a greensand filter accumulates iron and manganese, the filter media becomes clogged and the required head to drive water through the media increases. At

some point, the filter must be backwashed to remove the accumulated iron and manganese by reversing the flow through the media and washing the solids to waste. Assuming a sanitary sewer is not available nearby, the backwash waste can be discharged to a lagoon. The lagoon can be constructed with a sand bottom so water filters into the ground and the iron and manganese particles remain. Periodically, the particles are removed and disposed of in a landfill or land applied.

For a groundwater with 1 mg/L iron and 0.1 mg/L manganese, the estimated amount of dry solids in the backwash water is about 32 lb./million gallons of water treated. This amounts to about 256 pounds per day with the current average day water demand (8 mgd) and about 480 pounds per day with the current maximum day demand (15 mgd). The solids are mainly inorganic with very low biological oxygen demand.

The volume of backwash wastewater can vary significantly depending on operational procedures, filter design, and water quality characteristics. An AWWARF study of nine iron and manganese removal plants indicated that the average backwash volume was 1.4 percent of the treated water flow. Therefore, the volume of wastewater would be about 112,000 gallons per day (gpd) on an average day, and about 210,000 gpd on a maximum day. The backwash flow is intermittent and instantaneous flowrates would be higher than the daily averages stated above. An equalization tank for backwash waste may or may not be required, depending on the location of the lagoon in relation to the treatment plant.

Transmission. The additional pipe and valves will require maintenance, similar to existing pipe and valves in the Waukesha Water System.

4.1.2.6 Schedule

The wells can be built as needed to provide the necessary capacity, while the existing sandstone wells are phased out. The treatment plant can be constructed in conjunction with the wells. Design and construction time frames are roughly 2 to 3 years. It may also be possible to use the water as a blending source for one or more of the existing wells on the west side of the wellfield (wells 6, 7, and 8), which may extend the useful life of these wells and postpone the need for some new wells.

The transmission line will be needed before any water can be delivered into the system. Obtaining zoning approval and easements may slow the process. Once these hurdles are cleared, a 3- to 4-year design and construction schedule is typical.

4.1.3 Alternative 2 – Fox River Alluvium

This alternative consists of adding six new horizontal wells just south of the City of Waukesha along the Fox River. Existing sandstone wells would be abandoned or retained on standby. A treatment plant for disinfection and removal of iron/manganese would be provided. The major facilities are shown on Figure 4-9.

4.1.3.1 Reliability

Properly developing an alluvial wellfield involves a balance between the characteristics of the aquifer and river system. In the Waukesha area, there are at least two potential areas for developing and alluvial wellfield. The two most promising areas are the shallow sand and

gravel deposits along the Fox River immediately south of the city and potential shallow alluvial deposits along the Fox River.

To the south of Waukesha, the Fox River runs above a bedrock valley that is a tributary of the much larger Troy bedrock valley. Boring logs from the area indicate that the bedrock valley is filled with a series of interlayered sand and gravel rich outwash deposits and clay rich till sheets. The upper 50 feet of the unconsolidated material consists primarily of permeable sand and gravel deposits. In 1999, a dewatering system was operated for construction of a subdivision along River Road immediately west of the Fox River. According to a representative of the dewatering contractor, a total of 23 wells were installed and operated as needed during construction. The wells were generally 50 feet deep and each well was reported to have a capacity of about 1,000 gpm. The system typically produced about 5,000 gpm during the construction project. This information suggests that the shallow unconsolidated units in the area consist of a generally uniform permeable sand and gravel deposit that may be in direct hydraulic connection with the Fox River. The upper sand and gravel unit is isolated from deeper sand and gravel units by at least one clay till sheet. The depth to bedrock in the area is 150 feet or greater.

Figure 4-10 shows the extent of the alluvial deposits that would be suitable for siting an alluvial wellfield. The figure also shows the position of a potential alluvial wellfield. The location of the wellfield as shown on Figure 4-10 is only conceptual. The actual position of any wellfield or individual well would be determined on the basis of local geologic conditions and land availability.

The large storage volume provided by the sand and gravel deposits would offset seasonal periods of low flow in the Fox River. Given the extent of the shallow sand and gravel unit along the Fox River, the potential for developing a sufficient source capacity to satisfy the Waukesha Water Utility demands is good. The water is hard, naturally low in radionuclides, but may contain some constituents above secondary MCLs such as iron or manganese. The transit time and mixing of ground and surface water that would occur in the aquifer would buffer any changes in water quality or temperature that occur in the river. Due to the shallow well depths, the water will need adequate disinfection as a minimum. If subsequent testing indicates that the water is classified as groundwater under the direct influence of surface water, additional treatment would be required.

The wellfield is likely to produce a significant portion of its water from groundwater flowing toward the river. Given the high permeability of the soils and the relatively shallow depth of the aquifer, the groundwater portion of the wellfield will be vulnerable to contamination. As a result, it will be important to select wellfield locations that minimize the potential for contamination from upgradient sources. Well head protection will be a critical element for maintaining the wellfield.

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FIGURE 4-9

FOX RIVER ALLUVIAL WELL FIELD

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W E
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0 1 2 3 4 5 10,000
SCALE IN FEET

LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

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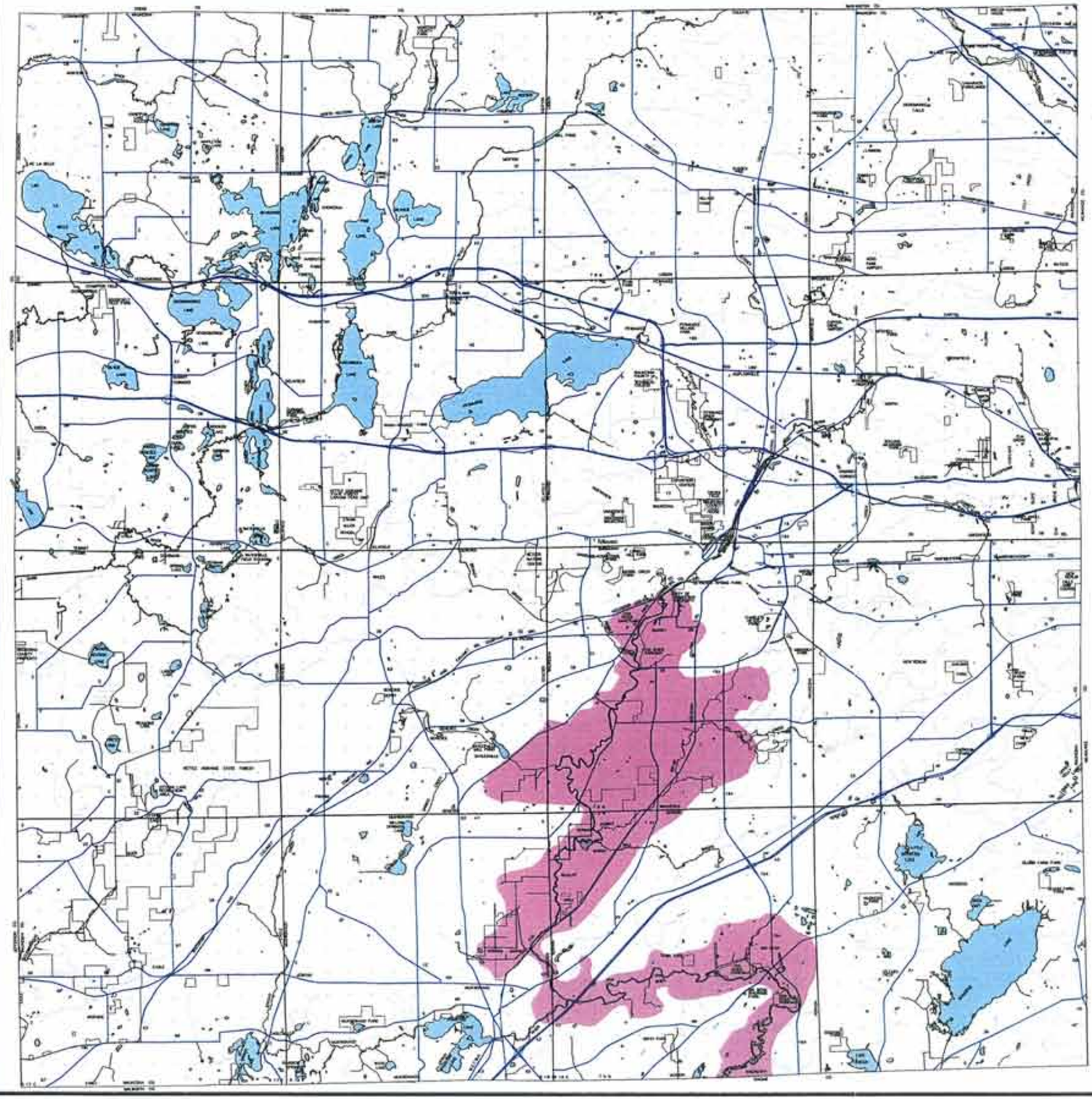
FIGURE 4-10

RECOMMENDED ALLUVIAL WELL FIELD EXPLORATION AREA







LEGEND

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4.1.3.2 Infrastructure

Wells. Given the reported performance of the dewatering system near River Road, a properly designed vertical well should probably be able to produce approximately 1,000 gpm. A minimum of 16 vertical wells would be required to produce the 22 mgd needed for maximum ultimate demands (reliable capacity with one well out of service). Assuming the wellfield is designed to induce recharge from the river, well spacings of 500 feet or less may be possible. If the wells are constructed on one side of the river, the wellfield would extend a minimum of 6,500 feet along the river. If wells are constructed on both sides of the river, the wellfield would extend approximately 3,000 feet along the river. It appears that sufficient undeveloped land is available to accommodate either design.

Horizontal wells could be used instead of vertical wells. Given the permeable nature of the sand and gravel deposits, a horizontal well should be able to produce at least 3,000 gpm. A minimum of six horizontal wells would be needed to meet ultimate demand (reliable capacity with one well out of service). Depending on the aquifer properties, the spacing between the horizontal wells will probably need to be larger than for the vertical wells. For the sake of comparison, a spacing of between 1,000 feet to 0.5 mile between the wells would require between 1 to 2 miles to accommodate the wellfield if the wells are placed on one side of the river. It is unlikely that horizontal wells could be placed directly opposite each other on both sides of the river.

About 1 to 4 miles transmission line would be required for a vertical wellfield, with an additional mile of feeder lines. Additional modifications to the distribution system are required to accommodate the water entering the system.

Treatment for Fox River Alluvium Water. The Fox River alluvium water quality is assumed to be similar to that of the sand/gravel aquifer (Table 4-2). However, there is a possibility that this water may be influenced by the Fox River depending on well construction, location, and seasonal water variations. The WDNR regulations (NR 811 and 809) state that groundwater under the direct influence of surface water must be treated according to surface water regulations. The presence of *Cryptosporidium*, *Giardia*, or Coliform bacteria at any time would designate a groundwater as under the direct influence of surface water. As a conservative assumption, the Fox River alluvium water will be treated as groundwater under the direct influence of surface water.

The major treatment impacts include requirements for particle removal and additional disinfection. There are many treatment processes that can be used to meet the regulations. It is beyond this scope of work to determine the optimum treatment method. For the purposes of this study, it is assumed that the Fox River alluvium will be treated by direct filtration (coagulation, flocculation, gravity filtration) followed by ultraviolet light and chlorine disinfection. The filtered water will be collected in a clearwell and pumped to the distribution system. A schematic of the treatment process is shown on Figure 4-11.

TABLE 4-2
Shallow (Sand & Gravel) Aquifer Water Quality Data
Future Water Supply

	Typical Value	MCL Primary Standard	Secondary Standard
Total Hardness (mg/L as $CaCO_3$)	420		
Calcium (mg/L)	90		
Magnesium (mg/L)	45		
Total Alkalinity (mg/L as $CaCO_3$)	320		
pH	7.3		
Sulfate (mg/L)	60		250
Chloride (mg/L)	60-170		250
Total Dissolved Solids (mg/L)	470-540		500
Iron (mg/L)	0.1-0.9		0.3
Manganese (mg/L)	0.02-0.05		0.05
Sodium (mg/L)	23-60		20
Radium 226+228 (pCi/L)	BD	5	
Gross Alpha (pCi/L)	BD	15	
Radon (pCi/L)	BD		

BD = Below Detection
Data Source: WDNR Mukwonago Wells 5 & 6; Oconomowoc Well 4; Hartland Wells 2, 4 & 5

Currently, there are no municipal water systems in Wisconsin designated as groundwater under the direct influence of surface water. However, discussions with WDNR indicate that this treatment process should be acceptable, but would likely require pilot testing depending on actual conditions. Ultraviolet light is very effective in inactivating protozoan pathogens such as *Cryptosporidium* and *Giardia*, along with many bacteria and viruses. Chlorine is not effective against *Cryptosporidium*. Ultraviolet light disinfection may not be required if adequate disinfection is achieved with chlorine and *Cryptosporidium* is absent. However, the conservative assumption to include ultraviolet light disinfection was made.

A shallow unconfined aquifer like the Fox River alluvium is susceptible to contamination. Potential contaminants include volatile organic compounds, herbicides, and nitrates. Although treatment for these contaminants is not required unless they are detected, flexibility to add processes to the treatment plant should be designed.

A single water treatment plant would be desirable to minimize O&M and costs. The wellfield water could be conveyed to the plant, treated, then pumped to the distribution system.

Transmission. Transmission from a Fox River alluvium wellfield to Waukesha would be accomplished with dual 30-inch-diameter transmission lines. The second line would provide a degree of reliability and redundancy. About 3 miles of large transmission main would be required.

Another 11 miles of 20- and 16-inch water main are required to distribute the treated groundwater throughout the City of Waukesha.

4.1.3.3 Regulations/Legal

The alluvial wellfield will probably be scrutinized carefully to determine the level of treatment required. If the wellfield is classified as groundwater under the direct influence of surface water, some surface water treatment will be required. The well sites will need to comply with NR 811, which specifies a minimum lot size and minimum setbacks from a variety of potential groundwater contamination sources. Currently, NR 811 does not recognize any connection between surface and groundwater. Therefore, it appears that the wellfield would not need to gain approval for any surface water diversion from the Fox River, though the WDNR may want to review this point.

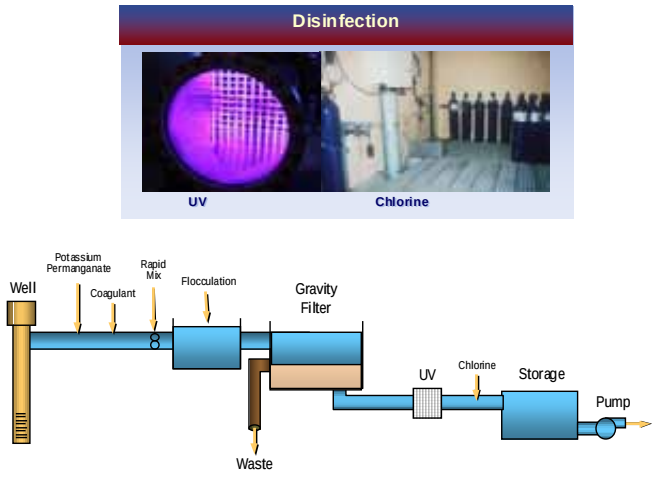

FIGURE 4-11
Treatment for Fox River Alluvium Water

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing of treatment processes is likely to be required.

This alternative will require the least amount of transmission piping, and thus issues such as easements would be minimized.

4.1.3.4 Political and Public Acceptance

The public may have some initial resistance about drinking water that comes in part from the Fox River. However, with appropriate treatment and public education, most of these concerns should be addressed. Environmental groups may be concerned about the potential impact on the Fox River, particularly during low flows. However, most of the water will be returned to the river through the Waukesha wastewater treatment plant a few miles upstream of the likely wellfield location. The water derived from aquifer storage during low-flow periods of the Fox River will augment the base flow conditions by replacing more water than is infiltrated.

The treatment plants will require aesthetic features to make them acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise be minimized where possible.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic slow-downs.

4.1.3.5 Operations and Maintenance

Wells. Alluvial wellfields are more prone to plugging and biofouling than traditional wells due to the higher dissolved oxygen and total organic carbon content of the induced river water. These problems can be controlled through close monitoring of the hydraulic performance of the wells and proactive well rehabilitation practices. Vertical wells could also be used in the alluvial aquifer if desired.

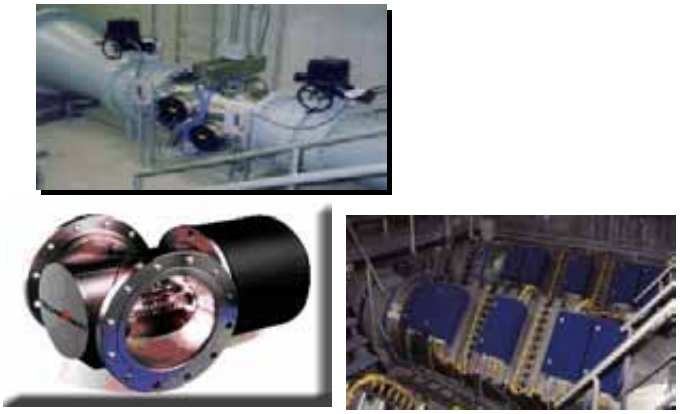

FIGURE 4-12
UV Disinfection Equipment

Water Treatment Plant. A surface water treatment plant will have mixing equipment (rapid mix, flocculation), chemical storage, and feed systems as well as filters. The filter media will be in concrete boxes with associated pipes and valves. The controls can also be automated so that operators do not have to be onsite 24 hours a day. Chemical systems (potassium permanganate, coagulant, and chlorine) will be will be stored and fed onsite. Typical monitoring includes flowrate, chemical feed rates and residuals, filter headloss, turbidity, and iron/manganese. All these parameters can be monitored on-line and sent to a computer data collection system.

The ultraviolet light disinfection system consists of lamps in an enclosed pipe. Typical equipment configurations are shown on Figure 4-12. This disinfection system can be automated for day to day operations. Monitoring will include recording light intensity, flowrate, UV 254 absorbance, and IT (irradiance multiplied by time) as a measure of disinfecting power. All these parameters can be measured on-line and sent to a computer

data collection system. Typical maintenance items include replacing lamps (1 to 2 times per year), sensors (every 1 to 3 years), quartz sleeves and lamp ballasts (5 to 10 years), and occasionally (1 to 2 times per year) manually cleaning the lamps and sleeves. Most ultraviolet systems are equipped with automatic wipers for routine quartz sleeve cleaning. Iron can reduce ultraviolet disinfection effectiveness and should be minimized for optimum ultraviolet performance.

A pump station will have O&M procedures for the pumps, pipes, and valves.

The treatment system should be checked several times a day for proper filtration and backwashing, pressures and flowrates, chemical storage levels and feed rates, and general water quality. Additional distribution system water quality parameters will have to be measured, including chlorine residual, heterotrophic plate counts, and coliforms.

A new treatment plant will require additional maintenance for the building and equipment. Activities may include instrument calibration, valve and piping maintenance, HVAC maintenance, filter media replacement, chemical system maintenance, and general building maintenance.

Water Plant Residuals. Filters will accumulate precipitated iron and manganese, along with coagulant chemical. When the filter media becomes clogged, the required head to drive water through the media increases. At some point, the filter must be backwashed to remove the accumulated coagulant, iron, and manganese. This is accomplished by reversing the flow through the media and washing the solids to waste. In this alternative, it is assumed that a sanitary sewer will be available roughly 1 mile from the water plant. Backwash waste can be discharged to the sewer and treated at the wastewater plant.

For water with 1 mg/L iron and 0.1 mg/L manganese, the estimated amount of dry solids in the backwash water is about 32 lb./million gallons of water treated. At coagulant doses for direct filtration, typical solids production would be about the same as that from the iron/manganese. This amounts to about 500 pounds per day of dry solids with the current average day water demand (8 mgd) and about 960 pounds per day with the current maximum day demand (15 mgd). The solids are mainly inorganic with very low biological oxygen demand. The above numbers assume the suspended solids in the water are very low, which is expected from an alluvial wellfield.

The volume of backwash wastewater can vary significantly depending on operational procedures, filter design, and water quality characteristics. Typical backwash volumes are about 1 to 3 percent of the treatment plant flow. Therefore, the volume of wastewater would be about 160,000 gpd on a current average day and 300,000 gpd on a maximum day. The backwash flow is intermittent and instantaneous flowrates would be higher than the daily averages stated above. An equalization tank for backwash waste may be required to minimize pipe size.

Transmission. The additional transmission pipe and valves will require maintenance, similar to existing pipe and valves in the Waukesha Water System.

4.1.3.6 Schedule

Developing an alluvial wellfield will require some initial site investigations and pumping tests. Other studies that may take a year include a pilot-plant study to evaluate treatment

requirements and an environmental impact evaluation of the groundwater and surface water resources.

The design and construction of the wellfield will require about 2 to 3 years. The treatment facilities and pipelines could be completed within this time frame.

4.2 Alternative 3 – Shallow Aquifers (Sand/Gravel, Dolomite)

The shallow aquifers of Waukesha County consist of the sand and gravel aquifer and the dolomite aquifer. Both aquifers are hydraulically connected and are recharged by local precipitation. The distribution and characteristics of the two aquifers are different and described separately.

A shallow aquifer alternative consists of 16 new vertical wells located 2 to 3 miles south of the City of Waukesha. Existing sandstone wells would be abandoned or kept as standby. A treatment plant for removal of iron/manganese would be provided. The major facilities are shown on Figure 4-13.

4.2.1 Alternative 3a – Sand and Gravel Aquifer

4.2.1.1 Reliability

The unconsolidated soils above bedrock in the Waukesha area predominantly consist of a series of glacial deposited during the Wisconsin Ice Age. Pre-Wisconsin glacial deposits may be present at the base of some bedrock valleys. Modern alluvial sediments cover the glacial deposits along the floodways of several rivers. When the glacial deposits are thick and permeable enough, they form an aquifer commonly called the sand and gravel aquifer. The occurrence of the sand and gravel is generally sporadic in the eastern half of Waukesha County, but produces a significant portion of the water supply for several surrounding communities.

Figure 4-14 shows the thickness of unconsolidated material in Waukesha County. The glacial deposits within the city are typically too thin or impermeable to act as aquifers for high-capacity wells. However, thick, permeable sand and gravel deposits are present in several areas near Waukesha. Figure 4-14 shows the elevation of the bedrock surface. The areas of thick unconsolidated materials generally correspond to buried river valleys incised into the bedrock prior to the last glacial advance. These bedrock valleys have been filled with glacial sediments that serve as aquifers for several municipal systems in the county.

These aquifers consist of permeable sand and gravel deposits from outwash deposits of sand and gravel deposited by water flowing off the receding ice mass during periods of glacial retreat. Some older channel deposits from rivers flowing in the bedrock valleys prior to the deposition of the glacial deposits may be present at the very base of some bedrock valleys. Following deposition of a sand and gravel deposit units during a glacial retreat, the outwash units were usually buried by clay rich till deposits from a readvance of the ice sheet. This pattern is repeated several times in most valleys. This results in a layer cake type pattern of permeable sand and gravel deposits under low permeability clay till or glacial lake clay deposits. Most bedrock valley aquifers contain two to three permeable sand and gravel units between low permeability clay confining units. The sand and gravel units are

generally not uniform and the capacity of an individual well will vary depending on the relative permeability of the sand and gravel units at that location.

There are three significant bedrock valley features in Waukesha County. The closest bedrock valley to the city is the Troy bedrock valley. The Troy bedrock valley generally runs west to east about 1 mile south of the city. A smaller tributary valley extends into the city along the Fox River. The Troy bedrock valley trends to the southwest into Illinois where it merges into a larger system of buried bedrock valleys. The Troy bedrock valley actually consists of two segments: one segment is part of an old drainage that flowed to the southwest, and the other segment flowed to the east toward Lake Michigan. The divide between these two segments is located roughly due south of the city.

Figure 4-15 is a geologic cross section through the Troy bedrock valley about 2 miles south of the city. The bedrock elevation in the center of the Troy bedrock is about 500 feet with over 400 feet of glacial deposits filling the valley. Past well site exploration work in the valley determined that the glacial deposits contain at least two permeable sand bodies suitable for high-capacity wells. Well capacities of between 500 to 1,500 gpm are possible from properly sited wells. The water is naturally low in radionuclides, but may exceed some secondary MCLs, especially for iron.

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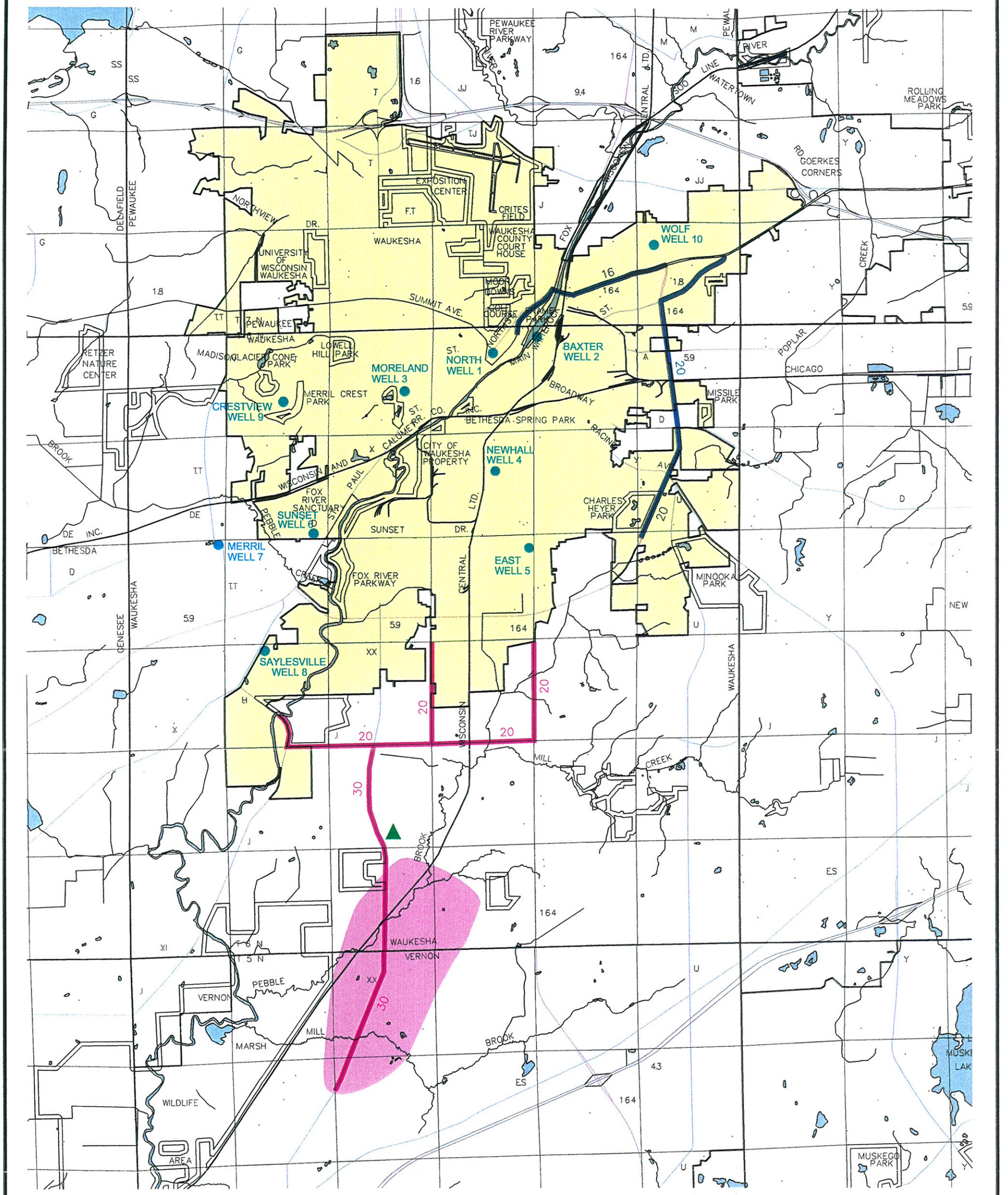

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FIGURE 4-13

SHALLOW AQUIFER WATER SUPPLY

N
W E
S

LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

0 1 2 3 4 5 10,000
SCALE IN FEET

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FIGURE 4-14

DEPTH TO BEDROCK IN WAUKESHA COUNTY

N

W E

S

0 1 2 3 4 5

SCALE IN MILES

LEGEND

75 **DEPTH TO BEDROCK**

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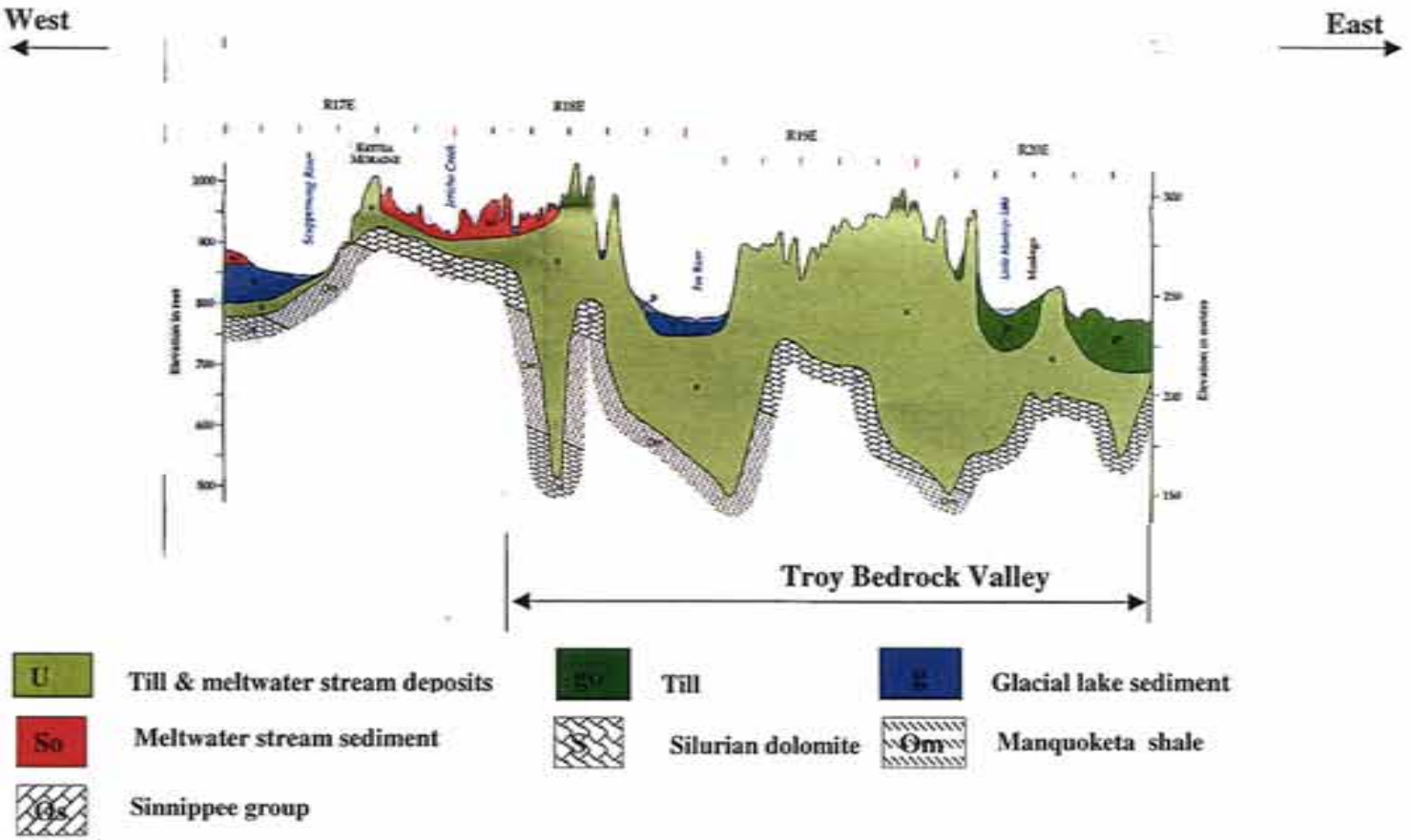
Figure 4-15
Geologic Cross-Section Through Northern Waukesha County
Showing the Troy Bedrock Valley



Modified from Clayton, 2001

The Rock bedrock valley lies about 7 miles west of the city. This valley trends southwest to northeast through the northwest part of the county, and extends into Illinois where it merges with a larger bedrock valley system. The Rock River lies several miles west of the Rock bedrock valley in Waukesha and eastern Jefferson Counties. The Rock River joins the Rock bedrock valley near Fort Atkinson and the two features follow similar paths into Illinois.

Figure 4-16 is a geologic cross section through the Rock bedrock valley immediately north of the city. The elevation of the bedrock surface is approximately 550 feet in the center of the Rock bedrock valley. Glacial material is over 350 feet thick in parts of the valley. Several municipal water systems operate wells in the aquifer. A properly sited well should produce roughly 1,000 to 2,000 gpm, with higher yields possible in some circumstances. The water quality is very similar to the groundwater in the Troy bedrock valley.

The Menomonee bedrock valley is a smaller valley that starts about 1 mile northeast of the city and trends nearly due east toward Lake Michigan. The elevation of the bedrock at the base of the valley is about 700 feet with a maximum of about 250 feet of glacial fill. Exploration work conducted for the City of Brookfield indicated that the sand and gravel deposits are generally not as thick or permeable as the Troy or Rock bedrock valley aquifers. The expected yield of wells in this valley is about 500 gpm. The valley runs under heavily developed land with numerous potential sources of contamination. Based on limited potential wells capacity and the limited land availability, the Menomonee bedrock valley is probably not a potential water source for the Waukesha Water Utility.

Figure 4-17 shows the location of two potential sand and gravel wellfields. The wellfields are located in the Troy and Rock bedrock valleys. The location of the wellfields as shown on the map is only conceptual. The actual position of any wellfield or individual well would be determined on the basis of local geologic conditions and land availability.

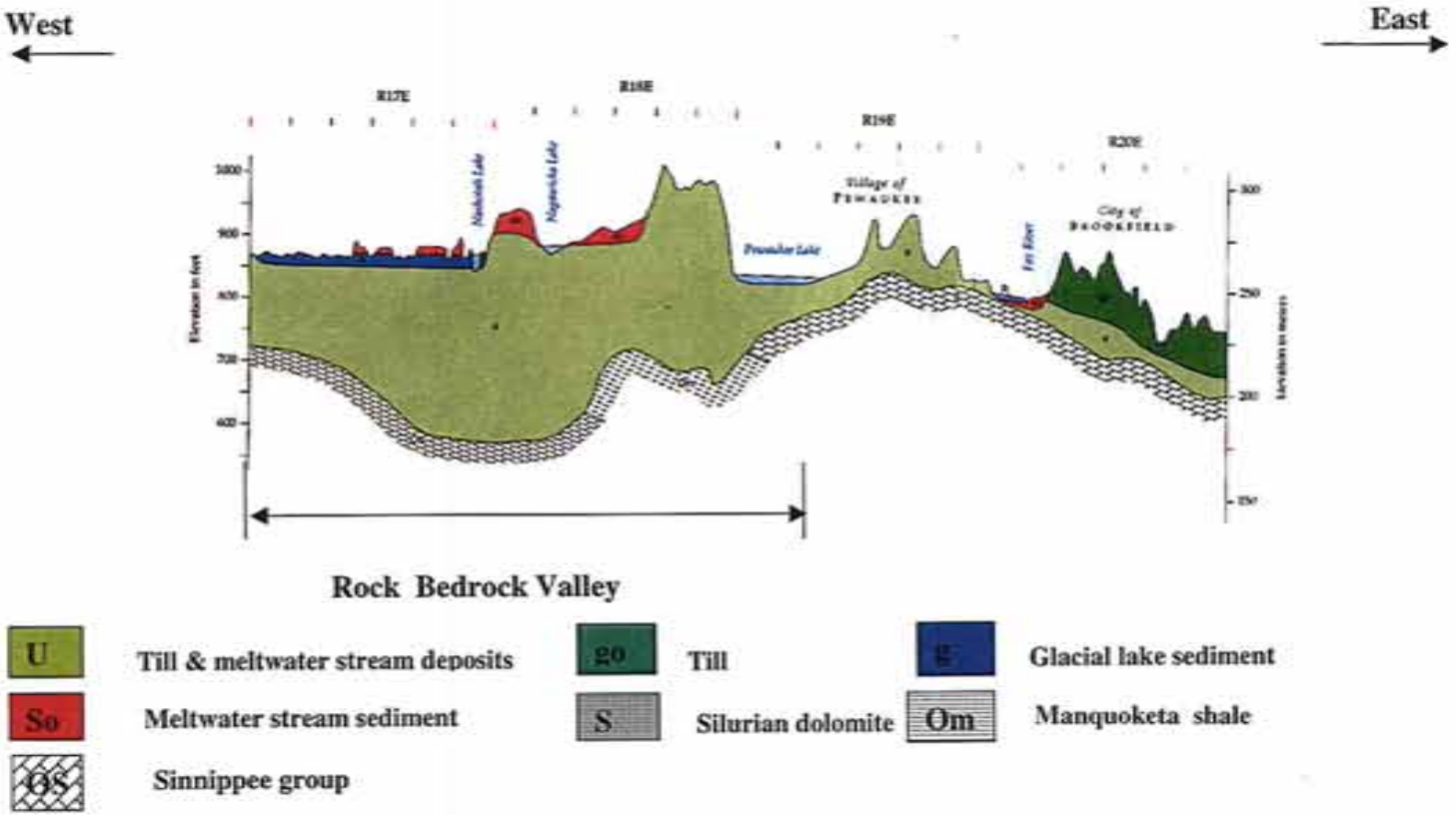
4.2.1.2 Infrastructure

Wells. Assuming the new wells will have a typical capacity of 1,000 gpm, 16 new wells will be needed to provide the ultimate capacity of the Waukesha Water Utility (reliable capacity with one well out of service). The length of water main required will depend on which bedrock valley aquifer is developed. If the Troy bedrock valley is used, about 3 to 5 miles of transmission main will be needed. Assuming a wellfield designed with a minimum spacing of 0.25 mile between wells, about 2 to 3 miles of smaller diameter feeder lines would also be needed. Treatment facilities for iron or manganese will be assumed for the purposes of this study.

Treatment for Shallow Aquifer Water. The shallow aquifer (sand gravel or dolomite) water quality is summarized in Table 4-2. This water is characterized as hard with moderate iron and manganese levels.

Treatment for shallow aquifer water will include iron/manganese removal and chlorination. The treatment process will be similar to that described for the Western sandstone wells (Alternative 1b).

Figure 4-16
Geologic Cross-Section Through Northern Waukesha County
Showing the Troy Bedrock Valley



Modified from Clayton, 2001

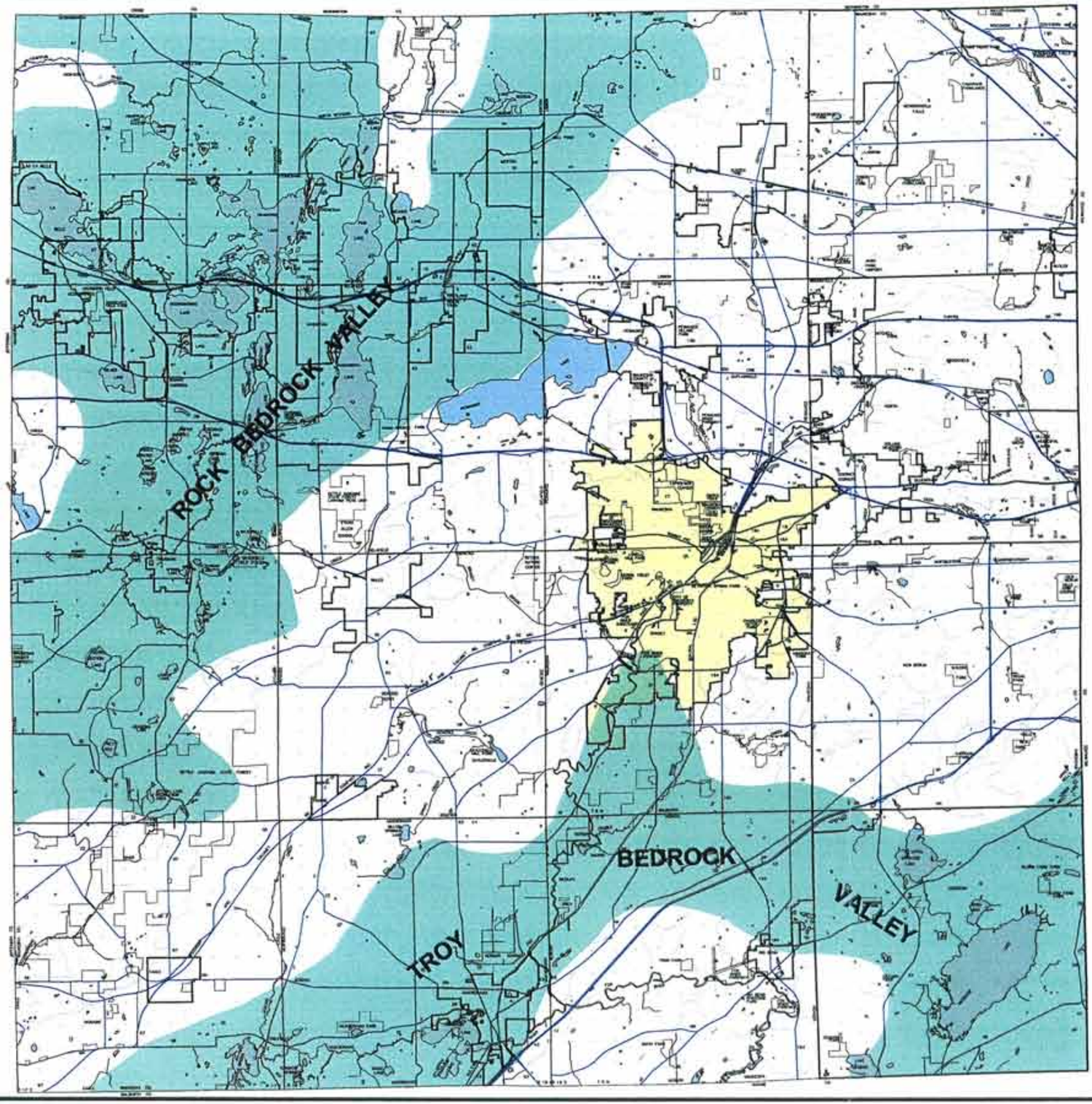


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FIGURE 4-17

RECOMMENDED SAND AND GRAVEL AQUIFER EXPLORATION AREA

N
W E
S

0 1 2 3 4 5
SCALE IN MILES

LEGEND

APPROXIMATE EXTENT OF MAJOR BEDROCK VALLEYS

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Transmission. Transmission from a Troy bedrock valley wellfield to Waukesha would be accomplished with dual 30-inch-diameter transmission lines. The second line would provide a degree of reliability and redundancy. About 5 miles of large transmission main would be required.

Another 11 miles of 20- and 16-inch water main are required to distribute the treated groundwater throughout the City of Waukesha.

4.2.1.3 Regulations/Legal

Current well siting requirements will allow the Waukesha Water Utility to pursue a wellfield in either bedrock valley. Local townships and municipalities are likely to resist granting any needed zoning changes or granting rights-of-way for transmission lines. Extensive development of the shallow sand and gravel units in either bedrock valley aquifer could affect local stream flows or surface water bodies. The WDNR does not currently have a mechanism for denying well permits based on surface water impacts but rule changes to that affect are likely in the next few years. Developing wells in deeper sand and gravel units below confining layers will reduce the impact on surface water.

The wellfield will require a well head protection plan to satisfy NR 811 requirements and protect the wells from contamination from agricultural sources. The Waukesha Water Utility will have no zoning control to enforce the well head protection ordinance because the wellfield will be beyond Waukesha corporate limits. As mentioned previously, formation of a water authority may eliminate some of the local ordinances and zoning requirements.

The vulnerability of the sand and gravel aquifer will vary depending on the degree of impermeable cover over the aquifer and the surrounding land use. If deeper sand bodies below clay confining units are developed, the wells may have relatively low susceptibility to contamination. If shallower sand units with no clay confining units are developed, the wells will be much more vulnerable to contamination and local land use will be more important. If this is not possible, it may be necessary to acquire larger tracts of land or find mechanisms to influence land use on surrounding properties. This might be accomplished by providing incentives to surrounding landowners to grow crops that require lower inputs of fertilizers and chemicals and prevent high density developments with septic tanks. As a result, the most effective protection for these wells would probably come from finding aquifers with low susceptibility or by controlling large areas of land, such as in a park.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing of treatment processes is not likely to be required.

4.2.1.4 Political and Public Acceptance

The customers of the Waukesha Water Utility should perceive a net benefit from obtaining water that complies with radionuclide standards. There may be some perception that the water is better because it comes from more a rural area. Local townships, citizen groups, and other municipalities may oppose the wellfield.

The treatment plant will require aesthetic features to make it acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic slow-downs.

4.2.1.5 Operations and Maintenance

Wells. The O&M of a shallow aquifer wellfield should be similar to the current level of effort. More sampling and maintenance may be required due to a greater number of wells. However, pumping and repair costs will probably be lower due to shallower well depths and pumping levels. Treatment facilities built to meet secondary MCLs would require additional maintenance.

Water Treatment. O&M requirements for an iron/manganese plant would be similar to the Western sandstone wellfield, described under Alternative 1b.

Water Plant Residuals. Water plant residuals for an iron/manganese removal plant would be similar to the Western sandstone wellfield, described under Alternative 1b.

Transmission. The additional transmission pipe and valves will require maintenance, similar to existing pipe and valves in the Waukesha Water System.

4.2.1.6 Schedule

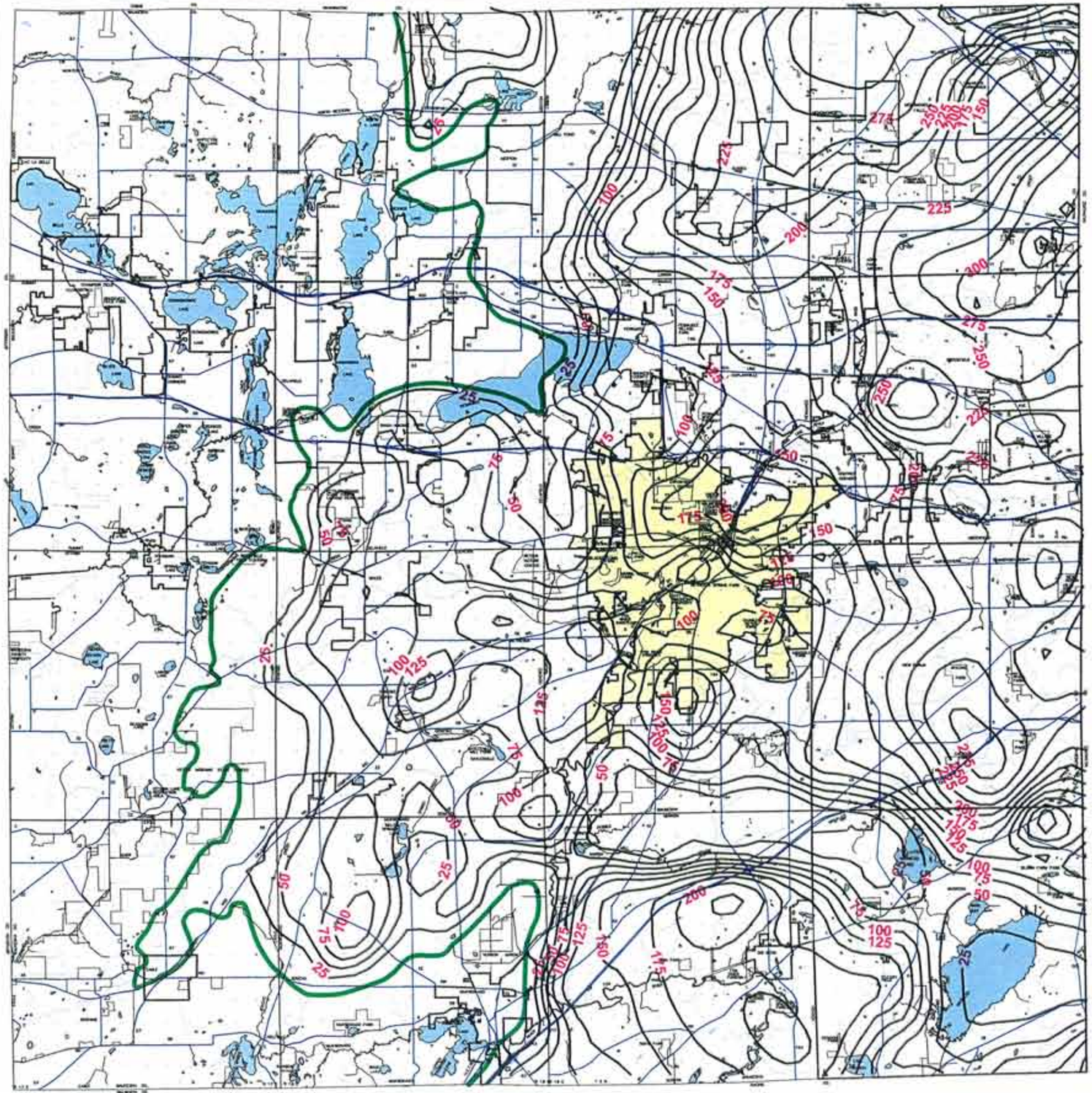
The wellfield can be developed in stages as the water is needed. The water main and initial wellfield could be on-line within 3 to 5 years. Treatment and transmission facilities could be built concurrently.

4.2.2 Alternative 3b – The Dolomite Aquifer

4.2.2.1 Reliability

Below the glacial deposits lies the regional bedrock, the Silurian dolomite commonly called the Niagaran dolomite. The Silurian dolomite extends from the base of the unconsolidated deposits to a maximum depth of about 350 feet in eastern Waukesha County. The dolomite aquifer is near the surface in portions of Waukesha County and is mined for aggregate in several quarries. The dolomite is over 300 feet thick in portions of northeastern Waukesha County but has been removed by erosion in much of the western half of the county (Figure 4-18). The Waukesha Water Utility wellfield lies near the western edge of the dolomite.

The Silurian dolomite serves as an aquifer for much of eastern Wisconsin that is called the dolomite aquifer. The dolomite itself is relatively dense and incapable of storing or transmitting significant quantities of water. The dolomite aquifer usually produces small quantities of water sufficient for private homes only. However, numerous zones of fractured rock exist within the dolomite, which can produce several hundred gallons per minute from the void spaces created by the fractures and related solution cavities. It is only where the dolomite aquifer is fractured that it produces enough water for municipal needs. The fractures tend to concentrate in regional fracture zones. The fracture zones are nearly vertical and are typically several miles long, but only a few tens of feet wide. The difficulty in locating the fracture zones with sufficient accuracy has limited the use of the aquifer for high-capacity wells.



Waukesha Water Utility

SERVING WAUKESHA SINCE 1886

FIGURE 4-18

THICKNESS OF SILURIAN DOLOMITE IN WAUKESHA COUNTY

N
W E
S

0 1 2 3 4 5
SCALE IN MILES

LEGEND

75 THICKNESS OF DOLOMITE

APPROXIMATE WESTERN EXTENT OF SILURIAN DOLOMITE

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Within the last 15 years, new geophysical techniques have been used in southeastern Wisconsin to locate regional fracture zones. This technology has made it possible to explore for high-capacity municipal wells in the dolomite aquifer. The dolomite aquifer has become an important water source for municipal wells for much of eastern Wisconsin, including the Cities of New Berlin and Brookfield, the Towns of Brookfield and Pewaukee, and the Villages of Germantown and Menomonee Falls.

Properly sited dolomite wells can yield up to 1,400 gpm, though capacities of 500 to 700 gpm are more common. The dolomite aquifer receives its recharge through the overlying glacial deposits. The dolomite aquifer can be locally confined where the glacial deposits are composed of dense clay. Where the glacial deposits are thin, the dolomite is susceptible to contamination from surface sources. The cone of depression of a dolomite aquifer well is typically elliptical with the long axis along the fracture zone. The shape and orientation of the cone of depression can be hard to define, which makes effective well head protection more difficult. As a result, it is usually prudent to site new dolomite aquifer wells in areas where the glacial materials offer some degree of natural protection from surface contamination rather than to rely on land use controls within a well head protection area defined on limited data.

The water quality of the dolomite aquifer is generally hard but otherwise acceptable. Radionuclides are typically low, but a few dolomite wells with gross alpha levels of up to 7 pCi/L have been found in Waukesha County. Though these levels are well below the MCL, they can have a significant impact if the water is to be used as a blending source. Some aesthetic water quality parameters above secondary MCLs, such as iron, sulfate, and TDS, are common. Several private dolomite wells with arsenic levels above the new MCL have been found in the county. Several municipal dolomite wells have measurable arsenic levels below the MCL. A few municipal dolomite wells appear to have experienced rising arsenic levels over the last 5 to 10 years.

The probability of finding a reasonable well yield from the dolomite aquifer is greater when the aquifer is greater than about 150 to 200 feet thick. Figure 4-18 shows the portion of Waukesha County is generally thick enough to warrant exploration for a high-capacity well. The City of Waukesha is located near the western edge of the dolomite aquifer. The dolomite aquifer is too thin in most of the city to make finding an adequate yield likely. This fact, in conjunction with the minimum required setback from a variety of potential contaminant sources mandated by the municipal well code (NR 811), makes serious exploration efforts for high-capacity dolomite wells within most of the City of Waukesha impractical. The dolomite is thin or absent to the west of the city. However, the dolomite is thick enough in the northeastern portion of the city, as well as in portions of the Towns of Brookfield and Vernon, and the Cities of Pewaukee and New Berlin, to potentially serve as a high-capacity aquifer.

Siting a dolomite aquifer well is an extensive process requiring significant exploration and testing. Large areas are usually screened to arrive at few potential well sites. The minimum setbacks from contaminant sources mandated by NR 811 typically limit the number of potential sites that can be developed. The elongated cone of depression created by dolomite wells typically limits the number of wells that can be drilled into a single fracture zone. As a result, suitable sites on multiple fracture zones will be needed to develop more than one or two dolomite wells. Given the limited area suitable for exploration, and a typical capacity of 500 to 700 gpm, it is unlikely that anything more than a small fraction of the Waukesha

Water Utility's water need can be met from the dolomite aquifer. However, one or two dolomite wells could be developed to augment the system's capacity or serve as a blending source to reduce radionuclides in existing sandstone aquifer wells, particularly well 10, which is located in an area with favorable dolomite thickness.

One of the major limitations of siting a dolomite well is the difficulty in encountering a narrow vertical fracture zone with a vertical well. Large pieces of land may be available, but surface developments may make it impossible to put the well house directly over the fracture. Horizontal drilling techniques can be used to intercept the fracture zones under surface obstruction and place the well house where it is more convenient. While to our knowledge no horizontal dolomite wells have been drilled in the state, we have discussed the concept with the WDNR and several drilling contractors. We believe that this technology is technically feasible and can be permitted under existing well code. This technology may make development of dolomite wells for the Waukesha Water Utility more feasible.

4.2.2.2 Infrastructure

The level of infrastructure needed to accommodate new dolomite wells would be minimal. Assuming that the wells are drilled within or immediately adjacent to the existing wellfield, the amount of new transmission line required will be minimal. Longer runs of dedicated raw water mains may be needed if the water is used for blending with specific Sandstone aquifer wells.

Treatment facilities for iron and manganese may be needed to meet secondary MCLs.

Water treatment and transmission requirements would be similar to those described above for sand/gravel aquifer alternatives.

4.2.2.3 Regulations/Legal

Dolomite aquifer well siting requirements are well established in NR 811. In addition to the minimum setbacks from potential contaminant sources, deeper casing can be required in areas with thin unconsolidated cover over bedrock or near quarries.

The wellfield will require a well head protection plan to satisfy NR 811 requirements and protect the wells from contamination from agricultural sources. The Waukesha Water Utility will have no zoning control to enforce the well head protection ordinance if the wellfield will be beyond the Waukesha corporate limits. The irregular shape of the cone of depression around the dolomite wells will make it difficult to define an accurate well head protection area. These factors will make it difficult to enact effective well head protection efforts to minimize the risk of contamination. However, if the wells are located in areas with thick deposits of clay above the dolomite, the risk of contamination to the aquifer will be significantly reduced making enforcement of a well head protection plan less important.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing of treatment processes is not likely to be required.

4.2.2.4 Political and Public Acceptance

The Waukesha Water Utility's customers should perceive a net benefit from getting water that complies with radionuclide standards. Local townships and other municipalities may oppose the wellfield if it is located in or near their corporate limits.

The treatment plant will require aesthetic features to make it acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic slow-downs.

4.2.2.5 Operations and Maintenance

Wells. The O&M of dolomite wells should be similar to the current level of effort. More sampling and maintenance may be required due to the greater number of wells to produce an equivalent amount of water. However, the pumping and repair costs will probably be lower due to the shallower well depths and pumping levels.

Water Treatment. Any treatment facilities built to meet secondary MCLs would require additional maintenance, as described under the shallow aquifer alternative.

Transmission. Water transmission main requirements would be similar to those described above for sand/gravel aquifer.

4.2.2.6 Schedule

The wellfield can be developed in stages as the water is needed. The wells could be on-line within 2 to 3 years. Any treatment or transmission facilities could be built concurrently.

4.3 Alternative 4 – Lake Michigan

As previously discussed, Lake Michigan water could best be provided from the Milwaukee Water Works. While other options exist, the current infrastructure in the Milwaukee system best lends itself to the provision of water to Waukesha. In this section, the relative merits and limitations of providing Lake Michigan water will be presented. Generally, the evaluation of Lake Michigan as a source is not dependent on the water provider. In instances where the evaluation dictates that the provider be identified, it is assumed Milwaukee is the source.

This alternative consists of a transmission line from Milwaukee to Waukesha, and a storage tank and pump station near the Hillcrest reservoir site. The major facilities are shown on Figure 4-19.

4.3.1 Reliability

The long-term reliability of Lake Michigan as a source of supply is excellent. The quantity of water contained in the lake is roughly 160 thousand times the annual projected water use for the city. Annual recharge to the lake is about 13 trillion gallons. Water quality is considered very good and the chance of major contamination is low.

To transmit the water to the city, a long, large diameter water main would be required. A dual water transmission main will be assumed in this alternative to provide more reliability than a single main.

Since the Milwaukee water treatment plant improvements, Milwaukee water is considered to be some of the safest around. The WDNR has indicated that "The Department believes the City of Milwaukee drinking water quality is among the best in the nation. …"

Waukesha Water Utility
SERVING WAUKESHA SINCE 1880

FIGURE 4-19

LAKE MICHIGAN SUPPLY

TO 92ND ST. AND HOWARD AVE.

N
W E
S

LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED STORAGE ADDITION

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Infrastructure

In order to make reasonable projections of the infrastructure required for Lake Michigan water, assumptions regarding a supplier must be made. As previously state, the logical and most cost-effective supplier is Milwaukee. To bring water to the Waukesha system, the following assumptions have been made.

- The 60-inch main on west Howard Avenue at South 92nd Street would be the start of a transmission main to provide service to Waukesha.
- About 9 miles of dual 30-inch water main would be required to transmit water.
- Water would be delivered to the Hillcrest reservoir and distributed from that location.
- A pumping station will be required to boost pressure along the pipeline.
- A new 5-million-gallon storage reservoir is assumed.
- Distribution system improvements will be required to transmit water throughout the system due to the changes in supply location.

4.3.3 Regulations/Legal

There are many issues that govern the transfer of water from Lake Michigan to the City of Waukesha. International agreements, as well as agreements among the Great Lakes states, inhibit the diversion of Great Lakes surface water to other drainage basins. No net loss diversions, such as diversions over the subcontinental divide where equal or greater amounts of water are returned, have been allowed in the past. There are questions, however, regarding the future of such diversions. The following is a discussion of the water law related to water diversions.

4.3.3.1 Boundary Water Treaty

On January 11, 1909, a Boundary Water Treaty between the United States of America and "His Majesty the King of the United Kingdom of Great Britain and Ireland and of the British Domains beyond the Seas, Emperor of India..." was signed. The treaty was designed to prevent and provide a means to resolve disputes over the use of shared water and establish the International Joint Commission (IJC). The IJC also was established to provide independent advice on a variety of transboundary environmental issues. The IJC has been diligent in their attention to issues under their purview. One particular element of the treaty requires the IJC to approve all diversions of water that affect the level and flow of the Great Lakes. While this is an important component, it falls short of addressing small scale diversions.

4.3.3.2 Great Lakes Charter

In the early 1980s, it became apparent to the Great Lakes governors that additional measures were required to better manage the Great Lakes water. In particular, it was determined that the smaller water uses and diversions not covered by the Boundary Water Treaty needed to be addressed. As a result, the governors created the Council of Great Lakes Governors to meet these goals.

In 1985, the council oversaw the development and implementation of the Great Lakes Charter. The charter was a voluntary agreement between the governors of the Great Lakes and premiers of Ontario and Quebec. The charter put forth a number of principles to be used in governing Great Lakes water management decisions. The charter first provided that proposed diversions and consumptive uses of greater than 5 mgd would trigger a process by which a governor or premier could object to a particular use. Furthermore, the states and provinces agreed to more closely define a plan to collectively manage the water resources. That management would be achieved by establishing a Water Resources Management Committee.

4.3.3.3 Water Resources Development Act

The third, and most important component for Waukesha, is a binding federal law requiring the Great Lakes governors to review and approve *any* diversion of Great Lakes water within the United States. This law is called the Water Resources Development Act (WRDA) of 1986. Since implementation of the charter and WRDA, all of the proposals that have gone through the formal review process have been for small-scale diversions to communities just outside the Great Lakes Basin. One proposal to increase the Chicago River diversion to raise Mississippi water levels was withdrawn. As time has progressed, the detail involved in evaluating diversion proposals has increased.

In 1989, the Village of Pleasant Prairie, Wisconsin, requested a temporary diversion of a small volume of water. One governor failed to approve the diversion but also did not object when the project moved forward. Many believe this is an unsanctioned diversion.

Later, Michigan's governor did withhold approval of a diversion proposed by Lowell, Indiana. He cited a number of reasons for not approving the diversion, including lack of imminent danger to health, safety, and welfare and lack of conservation measures on the city's behalf.

The most recent case is the Akron, Ohio, proposal. It is the only formal approval of a diversion since the WRDA of 1986. Basically, after a number of years of review and submittals, all governors approved the diversion. The last state to approve was Michigan and that approval was qualified "... only to the extent that it results in no net loss of water to the Great Lakes watershed and does not diminish, degrade or lower the water quality of Lake Erie or its tributaries, or result in a new or increased loading of pollutants to the water of Lake Erie or its tributaries." After all these conditions were met, the project still had many critics, mostly from environmental groups.

4.3.3.4 Annex 2001

On February 22, 2000, the IJC submitted the final report to the United States and Canada regarding protection of the waters of the Great Lakes. That report was the culmination of efforts by the Study Team on Consumption, Diversion & Export of Water, a task force of the IJC. The recommendations contained in the document are by far the most restrictive to date. The first recommendation, Removal, reads as follows:

> "Without prejudice to the authority of the federal governments of the United States and Canada, the governments of the Great Lakes states and Ontario and Quebec should not permit any proposal for removal of water from the Great Lakes Basin to proceed unless the proponent can demonstrate that the

removal would not endanger the integrity of the ecosystem of the Great Lakes Basin and that:

a) there are no practical alternatives for obtaining the water,

b) full consideration has been given to the potential cumulative impacts of the proposed removal, taking into account the possibility of similar proposals in the foreseeable future,

c) effective conservation practices will be implemented in the place to which the water would be sent,

d) sound planning practices will be applied with respect to the proposed removal, and,

e) there is no net loss to the area from which the water is taken and, in any event, there is no greater than a 5 percent loss (the average loss of all consumptive uses within the Great Lakes Basin); and the water is returned in a condition that, using the best available technology, protects the quality of and prevents the introduction of alien invasive species into the waters of the Great Lakes.

In reviewing proposals for removals of water from the Great Lakes to near-Basin communities, consideration should be given to the possible interrelationships between aquifers and ecosystems in the requesting communities and aquifers and ecosystems in the Great Lakes Basin."

Subsequent recommendations are contained in a proposed annex to the charter called "Annex 2001," which applies to all new water uses and diversions. Annex 2001 calls for conservation, reinforcement of the Great Lakes charter and existing institutions, and research into the relationship between groundwater and the Great Lakes Basin.

Annex 2001 recognizes the critical connection between surface and groundwater. For most shallow aquifers, the groundwater divides will be fairly close to the surface water divides, so the areas where conflicts might arise will be fairly limited. However, for some deeper aquifers, the area of the aquifer that discharges into the Great Lakes is much larger than the surface water basin.

For example, the groundwater divide for the deep sandstone aquifer of eastern Wisconsin lies as much as 30 miles west of the surface water divide. This area includes several communities such as Waukesha that produce most or all of their water from the sandstone aquifer. Conceivably, it could be argued that these communities are intercepting groundwater that would have normally flowed into the Great Lakes and are now diverting it into the Mississippi River Basin via their wastewater plants. It would be unreasonable to attempt to limit the future use of the sandstone aquifer in these communities or to require these communities to return their effluent to the Great Lakes Basin.

Returning effluent to the Great Lakes Basin from water systems using sandstone aquifer water would greatly diminish base flow conditions on several rivers such as the Fox River in southeastern Wisconsin and northeastern Illinois. This would cause deterioration in surface

water quality and riparian habitat during dry years. Similar problems are likely in other portions of the Great Lakes Basin.

The Great Lakes Basin is already being affected by the removal of water from the sandstone aquifer. By pumping and intercepting groundwater that flowed west to east and eventually flowed into the Great Lakes in predevelopment times, a subsurface diversion has been created. Not only is water being intercepted that eventually would have reached the basin, the hydraulic gradient in the sandstone has been reversed and flow has been induced away from Lake Michigan. If the use of the sandstone aquifer is diminished or even stopped in southeastern Wisconsin, conceivably the hydraulic gradient would return to predevelopment conditions. We believe this could be a valuable argument to use to request a Great Lakes water supply.

Basically, the theory is that Waukesha and other local communities are already diverting water and therefore should be grandfathered under diversion law. Furthermore, changing from an underground diversion to a lake water diversion could result in complying with the Annex 2001 by providing an improvement to the waters and water-dependent resources of the Great Lakes Basin. Specifically, stopping the pumpage of sandstone aquifer groundwater could:

- Contribute to recharging the aquifer and restoration of groundwater levels
- Contribute to more groundwater entering the Great Lakes Basin
- Reduce groundwater chemistry changes (i.e., reverse the current trend toward higher TDSs and radium)
- Reduce the huge amounts of salt discharged into the environment by home water softening devices

To make any proposal for Lake Michigan water withdrawal more attractive to the governing bodies, there are potential credits that can be explored to replace the withdrawn surface water and/or improve the waters and water-dependent resources of the Great Lakes Basin. Credits may come in one of the following ways:

- Directly returning treatment plant effluent to the Great Lakes Basin
- Restoring historic diversion from the Mississippi Basin to the Great Lakes Basin
- Receiving credit for biological and environmental projects resulting in improvements to the environment
- Reducing lake shore erosion by withdrawing and storage during high lake levels and withdrawing from storage during low lake levels

Such actions may be necessary to ensure that any ecological consequences of a Lake Michigan diversion are more than offset to result in an improvement. Annex 2001 is scheduled to be completed in late 2003 or early 2004. Annex 2001 will:

- Forge a new binding agreement to manage the Great Lakes waters
- Create a new standard requiring an improvement to the water and water-dependent natural resources of the Great Lakes before allowing new water uses
- Implement the new standard for interim decisions under the WRDA

- Obtain better information so that the water is managed rationally
- Include the premiers in reviewing and consulting on all new proposed diversion subject to the WRDA
- Lower the "trigger level" for reviewing proposed diversions to include any proposed diversions that are subject to the governors' authority under the WRDA

Improvements to the waters of the Great Lakes required by Annex 2001 will require the mitigation of adverse effects of a new water use by improving the resources of the Great Lakes in some way, and will also include strong provisions for water conservation. Diversions which result in a net loss of water of over 1 mgd and meet Annex criteria will have to be reviewed. The proposals will be judged for conservation and impacts on natural resources. Pre-existing uses are exempted.

4.3.3.5 Wisconsin Diversion Codes

Two specific sections of the Wisconsin Administrative Code, NR 142 and NR 811, refer to diversion of water from the Great Lakes Basin. NR 811.13(1)(c) states:

> "A supplier of water shall obtain approval from the department prior to creating a water loss or interbasin diversion as defined in S.NR 142.01, in accordance with the requirements of Ch. NR 142."
>
> "Interbasin diversion" is described in NR 142 as "… a transfer of waters of the state from either the Great Lakes basin or the upper Mississippi River basin to any other basin."

Chapter NR 142 goes on to present the means by which the department may approve withdrawals of over 100,000 gpd (about 70 gpm); interbasin diversions; and Great Lakes Basin water loss. The provisions of this chapter require the notification of Great Lakes governors and premiers only if the department receives an application for a withdrawal greater than 5,000,000 gpd.

Discussions with WDNR water supply representatives indicate that the WDNR may have differing views regarding required approvals from the Council of Great Lakes Governors. The resolution of this issue is well beyond the authority of this study. We do recommend that Waukesha receive a legal opinion on the issue prior to proceeding with any action on the permanent Lake Water Supply Plan.

4.3.4 Political and Public Acceptance

Obtaining water from Lake Michigan has issues related to political and public acceptance. This section will discuss the following issues:

- *Cryptosporidium*
- Milwaukee and other supplier service agreements
- Wastewater disposal issues
- Water quality

4.3.4.1 *Cryptosporidium*

Following the *Cryptosporidium* outbreak in Milwaukee in 1993, much public attention was focused on lake water as a source of drinking water. While the Milwaukee Treatment Facilities have been upgraded and other local plants are also monitoring and improving their processes, the perception that another outbreak could happen is still present. The more recent communities to receive lake water, Menomonee Falls and Butler, both initially had to deal with similar concerns. For the most part, the concerns in these areas were dealt with and customers have complemented the quality of the lake water.

4.3.4.2 Milwaukee Service Agreements

If the City of Milwaukee is the source of supply, there is potential that the city may try and control "urban sprawl" by linking allowable water sales to new construction. There are factions in Milwaukee's local government who believe this is the best way politically to handle water sales. Other communities with surface water treatment plants have generally not been as restrictive as Milwaukee.

4.3.4.3 Wastewater Disposal Issues

Should Waukesha receive lake water and also be required to return an equal amount of water to the Great Lakes Basin, a number of other issues arise. First, SEWRPC has indicated that it would be highly unlikely that they would agree to discharging treatment plant effluent to any of the streams or rivers in the Great Lakes Basin. Areas in and around Underwood Creek, the Root River, and other streams are already at or near capacity and additional flow would exacerbate the problem.

Another option is discharge of Waukesha sewage plant effluent into the Milwaukee metro sewer collection system, or directly to the lake. In either case, pipes would be constructed through communities Waukesha does not have political control over. A user fee would be charged for discharging even treated wastewater into the sewer system.

Untreated sewage could be pumped into the Milwaukee metro sewer system. This would eliminate the cost of operating the Waukesha wastewater plant, but additional user fees would be charged by Milwaukee Metro Sewerage District. Capacity problems in Milwaukee and other facilities could make this a political issue.

In all cases above, there are serious legal, political, and cost issues if wastewater has to be returned to the Great Lakes Basin. An alternative approach is use of constructed wetlands for treated sewage effluent. The effluent would have to infiltrate shallow aquifers in the Great Lakes Basin. Other environmental improvements may also be implemented in lieu of returning wastewater to the Great Lakes basin.

4.3.4.4 Water Quality

Water quality from Lake Michigan is generally viewed in an positive manner. Lower hardness and iron in Lake Michigan water compared to the current groundwater should be viewed positively. Typical water quality parameters are listed in Table 4-3.

TABLE 4-3
Lake Michigan Treated Water Quality
Future Water Supply

	Typical Value	MCL Primary Standard	Secondary Standard
Total Hardness (mg/L as $CaCO_3$)	120		
Calcium (mg/L)	35		
Magnesium (mg/L)	10		
Total Alkalinity (mg/L as $CaCO_3$)	95		
pH	7.5		
Sulfate (mg/L)	10		250
Chloride (mg/L)	10		250
Total Dissolved Solids (mg/L)	170		500
Iron (mg/L)	BD		0.3
Manganese (mg/L)	BD		0.05
Sodium (mg/L)	10		20
Radium 226+228 (pCi/L)	BD	5	
Gross Alpha (pCi/L)	BD	15	
Radon (pCi/L)	BD		

BD=Below Detection
Data Source: Milwaukee Waterworks

4.3.5 Operations and Maintenance

Many of the O&M procedures will be eliminated if Lake Michigan water is the sole source of supply. The existing wells will not be needed or used only on standby. If they are not used on standby, the electrical cost to pump water will be reduced because of the difference in lift required to pump from Milwaukee to the central zone versus lifting from the sandstone aquifer. If the wells are used on standby, monthly visits to remaining stations are recommended to run the pumps and verify operations. Maintenance for the distribution system will increase slightly due to the construction of new mains.

It is likely that the addition of chlorine will be required to boost levels provided by Milwaukee or another provider. The levels required should be less than currently provided because the delivered water will already have background levels. All other routine maintenance should remain relatively the same.

One final area of concern is the potential impacts to the water distribution piping and plumbing resulting from changing water chemistry. It is possible that increased flushing, digging, pH adjustment, or combinations may be required after lake water has been used for a period of time. Without pilot testing on a representative section of the system, it is

difficult to predict impacts. Indications are from Menomonee Falls and Franklin, which have similar conditions to Waukesha, that impacts are minimal.

4.3.6 Schedule

The schedule to provide lake water depends largely on the ability of the City of Waukesha to obtain a diversion and arrive at an agreement with a surface water provider. As previously mentioned, Milwaukee is the only existing surface water treatment plant with sufficient capacity to serve Waukesha. If a new or expanded plant needs to be constructed, the schedule will be extended. However, if an agreement can be made with Milwaukee water and a diversion granted in a timely manner, a connection could be in service within about 3 to 4 years.

4.4 Alternative 5 – Sandstone/Shallow Aquifer

This alternative consists of 11 new vertical wells 2 to 3 miles south of the City of Waukesha, along with an iron/manganese removal plant. Existing sandstone wells 6 through 9 would be used for blending. The remaining wells would be abandoned or kept as standby. Additional piping to bring treated shallow aquifer water to sandstone wells 6 through 9 would be required. The major facilities are shown on Figure 4-20.

4.4.1 Reliability

While it appears feasible to develop a new source of supply from a single groundwater source, there are advantages to be derived from using multiple sources. The shallow sand and gravel or dolomite aquifer could be used in conjunction with the sandstone aquifer to develop a reliable source of supply for the Waukesha Water Utility. By developing a new source, the demand from the existing wellfield can be reduced, thereby reversing or reducing the decline in head and negative changes in water quality. Ideally, the existing sandstone wells would be reserved for peak demands, thereby substantially reducing annual pumpage from the aquifer while avoiding heavy pumpage from the shallow aquifers during dry periods.

The existing sandstone wells that are retained would have to be brought into compliance with the radionuclides MCLs through some combination of traditional treatment, well reconstruction, or blending with water from shallow aquifers. Given the layout of the wellfield, wells 6, 7, and 8 are attractive candidates for blending with water from the shallow aquifers. Given the radium and gross alpha levels in these wells, the ratio shallow aquifer water to sandstone aquifer water needed to meet the MCLs would be at least 2:1 or greater. Given this mixing ratio, a minimum of 15 mgd of water will be needed from the shallow aquifer to meet the projected peak day of 22 mgd. This will also provide enough water from the shallow aquifers to meet projected ADDs, making it possible to only pump the sandstone wells to meet MDDs.

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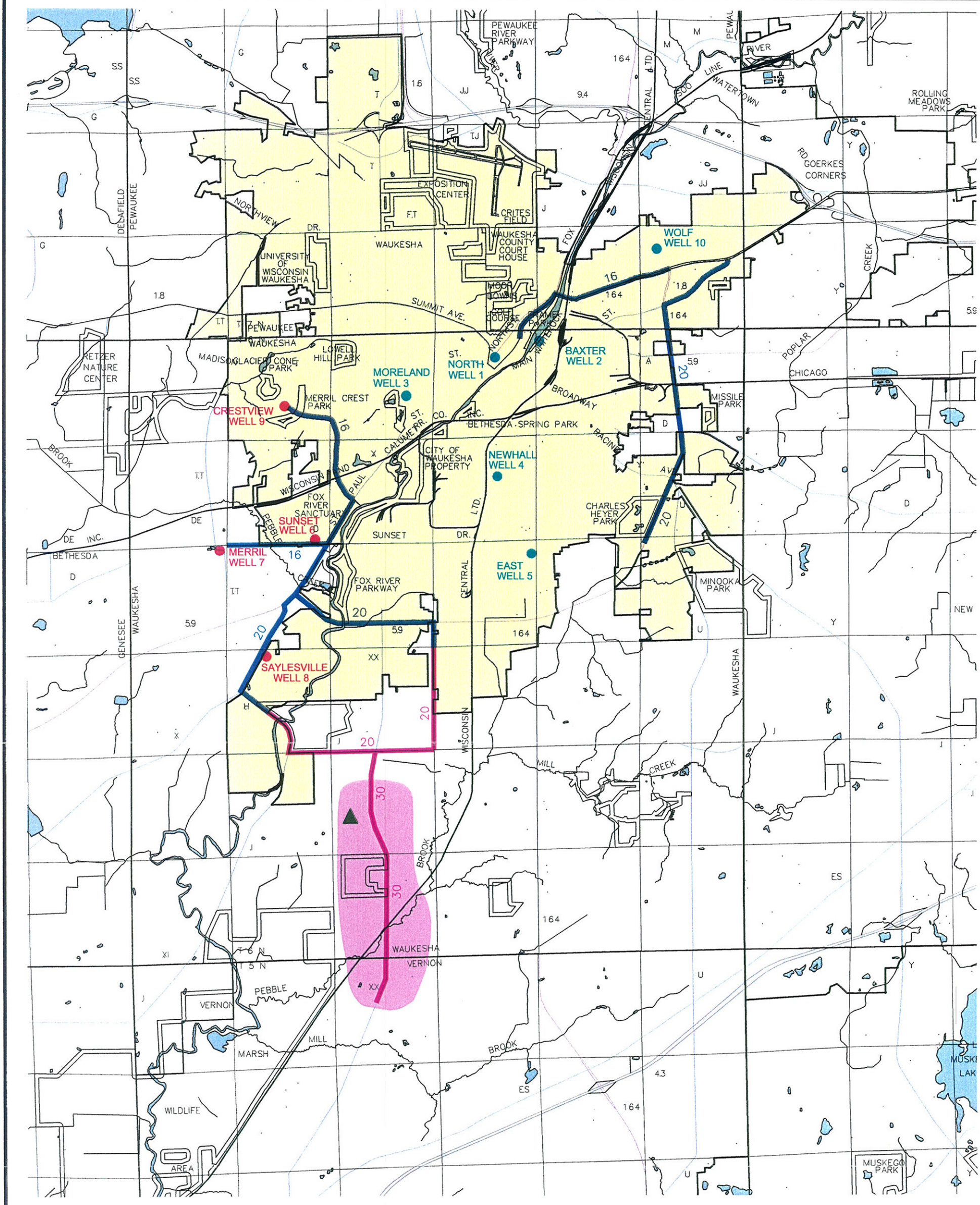

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FIGURE 4-20

COMBINED SANDSTONE AND SHALLOW AQUIFER WATER SUPPLY

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LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

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SCALE IN FEET

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Wells 1 through 5 do not produce enough water to justify the cost to treat or blend the water. Wells 9 and 10 could potentially be blended with low radium water or treated at or near the well sites. However, due to the location of these wells, both of these options are probably cost prohibitive. For the purpose of this analysis, it was assumed that wells 1 through 5 and 9 and 10 would be abandoned. This would leave approximately 8.8 mgd of capacity from the sandstone aquifer, which is sufficient to make up the difference between the projected capacity from the shallow aquifer and the peak day demand. If some low cost means of controlling radium levels at the well head were to become available, the cost of saving additional sandstone wells would be reduced dramatically and the volume of shallow water that would be needed would be reduced significantly.

The Troy bedrock valley aquifer is the most logical choice for the shallow aquifer water due to its close proximity to the city. Depending on the depth of the aquifer and the degree of protection from clay confining units, the wellfield could be vulnerable to surface contamination. Proper well siting and well head protection will be critical elements of maintaining a viable source of supply. Given that the wellfield is likely to be out of the corporate limits of the city, siting wells that have natural protection from contamination may prove to be the most effective strategy to avoid contamination problems.

It would also be possible to develop new sandstone wells in the recharge area in western Waukesha County that are coupled with sand and gravel wells in the Rock or Troy bedrock valley aquifers. This would have the advantage of reducing the demand from any one source and providing a blending option to offset potential water quality issues from any individual aquifer. However, the cost of the transmission main required to bring this water back to the city makes these options less attractive.

Given the multiple potential sources of groundwater available to the Waukesha Water Utility, it will be possible to find an optimal blend of supply sources that minimizes overall costs and provides more options to adjust to unknown changes in future conditions. Developing more than one supply source limits the impact on any one resource and provides operational flexibility to adapt to changes in regulation, seasonable variability in the availability of water, and changes in source water characteristics such as rising arsenic levels. However, if the sandstone aquifer is not managed more effectively on a regional basis, the continued decline in head may require more shallow aquifer water to offset a reduction in the sustained yield in the sandstone aquifer over time.

4.4.2 Infrastructure

Assuming that the shallow aquifer wells can produce an average of approximately 1,000 gpm, 11 wells will be needed to provide a reliable capacity of about 15 mgd. Roughly 3 to 4 miles of transmission main and 3 miles of feeder main will be needed to collect the water from the wellfield and move it into the city. Additional piping and controls will be needed to blend the water with wells 6, 7, and 8. Modifications to the distribution system will be needed to get the water to the city and accommodate a single entry point.

4.4.2.1 Treatment for Shallow Aquifer Water

Treatment for shallow aquifer water will include iron/manganese removal and chlorination. The treatment process will be the same as that described above for the sand/gravel aquifer, except the treatment plant will be 15 mgd instead of 22 mgd.

4.4.2.2 Transmission

Transmission from a Troy bedrock valley wellfield to Waukesha would be accomplished with dual 24-inch-diameter transmission lines. The second line would provide a degree of reliability and redundancy. About 5 miles of large transmission main would be required. Another 11 miles of 20- and 16-inch water main would be required to distribute the treated groundwater throughout the City of Waukesha.

Additional piping for bringing shallow aquifer water to the sandstone wells will be required. Approximately 6 miles of blending water main would be required.

4.4.3 Regulations/Legal

Producing water from multiple aquifers is consistent with the long standing practices of several surrounding communities. It is generally considered to be a wise supply strategy and should not be opposed by any regulatory body. The concept of blending water to meet radionuclides rules is also being practiced by several neighboring communities. Modifications to the distribution system and controls will be required to ensure that all points of entry into the distribution system meet radionuclide standards. This can be accomplished by blending in reservoir or using in-line mixers in the piping from a sandstone well prior to the point of entry.

The wellfield will require a well head protection plan to satisfy NR 811 requirements and protect the wells from contamination from agricultural sources. The Waukesha Water Utility will have no zoning control to enforce the well head protection ordinance because the wellfield will be beyond the Waukesha corporate limits. As a result, finding an aquifer with natural protection, such as a clay confining layer, may be the most effective form of well head protection than can be achieved. If this is not possible, it may be necessary to acquire larger tracts of land or find mechanisms to influence land use on surrounding properties. This might be accomplished through providing incentives to surrounding landowners to grow crops that require lower inputs of fertilizers and chemicals and prevent high density developments with septic tanks.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. The blending scheme and controls will also be evaluated by WDNR for radionuclide compliance. Pilot testing of iron/manganese treatment processes are not likely to be required.

4.4.4 Political and Public Acceptance

The public should perceive a benefit from obtaining radionuclide-compliant water. However, the water will not be radium free as in other alternatives. If the water from the shallow sources is treated to meet secondary standards, the public should perceive a net improvement in aesthetic properties of the water. Some change in iron concentrations may be experienced when the sandstone wells are in use. Assuming that the TDS levels of the sandstone wells can be controlled at present levels, the hardness of the blended water will not be noticeably different than the shallow water.

The treatment plant will require aesthetic features to make it acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic

slow-downs. The blending alternatives have the most water transmission main run through Waukesha streets because of the additional blending pipe required.

4.4.5 Operations and Maintenance

4.4.5.1 Wells

Retiring most of the sandstone wells will reduce the O&M costs of the system. The shallow wells will have significantly lower costs to operate and maintain due to the shallower pump settings and lower pumping costs.

Blending at the sandstone wells to meet radionuclide standards will increase the operational complexity and monitoring of the water system. Radium levels in the sandstone wells and flowrates from both sources must be balanced to ensure radium standards are not exceeded. The requirements for adequate water volume and pressure must be balanced with radium concentration requirements.

Assuming regional demand from the sandstone aquifer does not rise significantly, the local reduction in pumping from the sandstone aquifer is expected to provide some degree of rebound in water levels. This should reduce pumping costs and stabilize maintenance costs to some degree.

4.4.5.2 Water Treatment

O&M requirements for an iron/manganese plant would be similar to the shallow aquifer alternative discussed previously. However, the size of the plant would be smaller.

4.4.5.3 Water Plant Residuals

Water plant residuals for an iron/manganese removal plant would be similar to the shallow aquifer alternative discussed previously. However the quantity of residuals would be about 30 percent less.

4.4.5.4 Transmission

The additional transmission pipe and valves would require maintenance, similar to existing pipe and valves in the Waukesha Water System. This alternative has more distribution system mains than others because of the blending pipes required.

4.4.6 Schedule

From the perspective of meeting demand, the shallow water source can be added as needed to meet increasing demands. However, to comply with the radionuclide rule, at least 10 mgd of shallow water would be needed at implementation, and at least an additional 5 mgd of shallow capacity added as demand dictates. Time frames for implementation will be similar to the shallow aquifer alternative, but an additional year or so might be required due to the blending water main passing through the city.

4.5 Alternative 6 – Sandstone/Fox River Alluvium

This alternative consists of five new horizontal wells south of the City of Waukesha along the Fox River. A treatment plant for disinfection and iron/manganese removal is provided.

Existing sandstone wells 6 through 9 would be used for blending. The remaining wells would be abandoned or kept as standby. Additional piping to bring treated Fox River alluvium water to sandstone wells 6 through 9 would be required. The major facilities are shown on Figure 4-21.

4.5.1 Reliability

The option of using the alluvial aquifer water in combination with the sandstone aquifer is very similar to the option of using the shallow aquifer described above. The probable location of an alluvial wellfield is in the same general vicinity of the proposed Troy bedrock valley aquifer wellfield. Given the location and condition of the existing sandstone wells, wells 6, 7, and 8 could be retained to meet peak demands. These wells could be brought into compliance with radionuclide standards by blending with the alluvial water. By retaining several sandstone wells, the capacity of the alluvial wellfield can be reduced and heavy pumpage during period of low flow in the Fox River can be avoided. If necessary, the capacity of the shallow alluvial deposits can be increased through enhanced recharge of stormwater or peak flows from the river.

The alluvial wellfield is likely to produce a significant portion of its water from groundwater flowing toward the river. Given the high permeability of the soils and the relatively shallow depth of the aquifer, the groundwater portion of the wellfield will be vulnerable to contamination. As a result, it will be important to select wellfield locations that minimize the potential for contamination from upgradient sources. Well head protection will be a critical element for maintaining the wellfield.

4.5.2 Infrastructure

4.5.2.1 Wells

Assuming that the vertical wells in the alluvial aquifer can produce an average of approximately 1,000 gpm, 11 wells will be needed to provide a reliable capacity of approximately 15 mgd. Horizontal wells can generally produce five to ten times as much water as a vertical well. Assuming that a horizontal well could produce at least 3,000 gpm, then five horizontal wells would be required to provide a reliable capacity of 15 mgd. Existing sandstone wells 6, 7, and 8 would be capable of providing enough capacity for peak days. Piping modifications to accommodate blending will be required.

4.5.2.2 Treatment

Treatment for Fox alluvium aquifer water will include direct filtration, ultraviolet light disinfection, and chlorination. The treatment process will be the same as for the Fox River alluvium aquifer, except the treatment plant will be 15 mgd instead of 22 mgd.

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FIGURE 4-21

COMBINED SANDSTONE AND ALLUVIAL AQUIFER WATER SUPPLY

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SCALE IN FEET

LEGEND

- **EXISTING WELL TO BE ABANDONED**
- **PROPOSED NEW WELL FIELD (CONCEPTUAL LOCATION)**
- **PROPOSED NEW TRANSMISSION MAIN**
- **PROPOSED WATER MAIN ADDITION**
- **PROPOSED TREATMENT FACILITY**

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4.5.2.3 Transmission

Transmission from a Fox River alluvium wellfield to Waukesha would be accomplished with dual 24-inch-diameter transmission lines. The second line would provide a degree of reliability and redundancy. About 3 miles of large transmission main would be required. Another 11 miles of 20- and 16-inch water main would be required to distribute the treated groundwater throughout the City of Waukesha.

Additional piping for bringing alluvium aquifer water to the sandstone wells will be required. Approximately 6 miles of blending water main would be required.

4.5.3 Regulations/Legal

Producing water from multiple aquifers is consistent with the long standing practices of several surrounding communities. It is generally considered to be a wise supply strategy and should not be opposed by any regulatory body. The concept of blending water to meet radionuclides rules is also being practiced by several neighboring communities. It will require modifications to the distribution system and controls to ensure that all points of entry into the distribution system meet radionuclide standards. This can be accomplished by blending in a reservoir or using in-line mixers in the piping from a sandstone well prior to the point of entry.

The use of an alluvial wellfield may be subjected to higher treatment requirements due to the potential for the influence of surface water. Though not specifically addressed by current regulations, the WDNR may require that the impacts of the alluvial wellfield on the Fox River be documented. However, since the water is returned to the river upstream from the wellfield, the impacts are expected to be minimal.

It may be possible to develop an alluvial wellfield that is largely within the city or land owned by Waukesha County. This should provide the city with significant advantages in terms of obtaining land for well sites and pipelines. It will also simplify the well head protection process.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. The blending scheme and controls will also be evaluated by WDNR for radionuclide compliance. Pilot testing of the treatment processes is likely to be required.

4.5.4 Political and Public Acceptance

The public should perceive a benefit from obtaining radionuclide compliant water. If the water from the alluvial wellfield is treated to meet secondary standards, the public should perceive a net improvement in aesthetic properties of the water. Some change in iron concentrations may be experienced when the sandstone wells are in use. Assuming that the TDS levels of the sandstone wells can be controlled at present levels, the hardness of the blended water will not be noticeably different than the shallow water.

The treatment plant will require aesthetic features to make it acceptable to nearby citizens and comply with zoning requirements. Truck traffic and noise should be minimized where possible.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic

slow-downs. The blending alternatives have the most water transmission main run through Waukesha streets because of the additional blending pipe required.

4.5.5 Operations and Maintenance

4.5.5.1 Wells

Alluvial wellfields are more prone to plugging and biofouling than traditional wells due to the higher dissolved oxygen and total organic carbon content of the induced river water. These problems can be controlled through close monitoring of the hydraulic performance of the wells and proactive well rehabilitation practices.

Blending at the sandstone wells to meet radionuclide standards will increase the operational complexity and monitoring of the water system. Radium levels in the sandstone wells and flowrates from both sources must be balanced to ensure radium standards are not exceeded. The requirements for adequate water volume and pressure must be balanced with radium concentration requirements.

Assuming the regional demand from the sandstone aquifer does not rise significantly, the local reduction in pumping from the sandstone aquifer is expected to provide some degree of rebound in water levels. This should reduce pumping costs and stabilize maintenance costs to some degree.

4.5.5.2 Water Treatment

O&M requirements for a direct filtration plant with ultraviolet would be similar to the Fox River alluvium alternative discussed previously. However, the size of the plant would be smaller (15 versus 22 mgd).

4.5.5.3 Water Plant Residuals

Water plant residuals for a direct filtration plant would be similar to the Fox River alluvium alternative discussed previously. However the quantity of residuals would be about 30 percent less.

4.5.5.4 Transmission

The additional transmission pipe and valves would require maintenance, similar to existing pipe and valves in the Waukesha Water System. The blending alternatives have more distribution system mains than others because of the blending pipes required.

4.5.6 Schedule

From the perspective of meeting demand, the Fox River alluvium water source can be added as needed to meet increasing demands. However, to comply with the radionuclide rule, at least 10 mgd of Fox River alluvium water would be needed at implementation, and at least an additional 5 mgd of Fox River alluvium capacity added as demand dictates. Time frames for implementation will be similar to the Fox River alluvium alternative, but an additional year or so might be required due to the blending water main passing through the city.

4.6 Alternative 7 – Shallow Aquifer/Fox River Alluvium

This alternative consists of four new horizontal wells south of the City of Waukesha along the Fox River and eight vertical shallow aquifer wells. A treatment plant for disinfection and iron/manganese removal is provided for the Fox River alluvium water. An iron/manganese removal plant is provided for the shallow aquifer water. Existing sandstone wells would be abandoned or kept as standby. The major facilities are shown on Figure 4-22.

4.6.1 Reliability

Obtaining water from both the shallow aquifer and the alluvial aquifer provides the most flexibility in developing and operating the shallow wellfield. If the Troy bedrock valley aquifer is used in conjunction with the Fox River alluvial aquifer, many of the facilities, such as the transmission main and possibly the treatment plant, can be used jointly. In addition to sharing facilities, conjunctive use of the two aquifers will allow the Waukesha Water Utility to shift demand as environmental conditions dictate. In the event of a spill in the Fox River, pumpage could be shifted to the Troy bedrock valley until the spill had passed. In the event of extremely dry years, pumpage could be shifted to the Troy bedrock valley to minimize any impacts on stream flow from induced recharge and to augment stream flow by adding water from the Troy bedrock valley aquifer to the river through the wastewater treatment plant. Having the alluvial wellfield available during normal flow conditions reduces the water that must be drawn from the Troy bedrock valley aquifer on a sustained basis, thereby reducing any negative impacts to the aquifer or surface water features.

This alternative assumes that two water plants will be built, one for each water source. This provides more reliability than all the water being treated by one plant.

4.6.2 Infrastructure

4.6.2.1 Wells

For the purposes of this study, we have assumed that the capacity is split evenly between the two wellfields (11 mgd each). Assuming that the Troy bedrock valley aquifer produces and average of 1,000 gpm per well, eight wells would be needed. The alluvial wellfield could consist of either four horizontal wells or eight vertical wells.

4.6.2.2 Treatment

Treatment for Fox alluvium aquifer water (direct filtration, ultraviolet light disinfection, and chlorination) will be accomplished in a new 11-mgd water plant. The treatment process will be the same as that described above for the Fox River alluvium aquifer, except the treatment plant will be 11 mgd instead of 22 mgd.

Treatment for shallow aquifer water (iron/manganese removal and chlorination) will be accomplished in a new 11-mgd water plant. The treatment process will be the same as that described above for the shallow aquifer, except the treatment plant will be 11 mgd instead of 22 mgd.

Treatment could be done in one 22-mgd water plant as well. However, having the ability to produce potable water from two plants provides more reliability and is beneficial for future growth and ability to serve customers (i.e., less future distribution and transmission mains).

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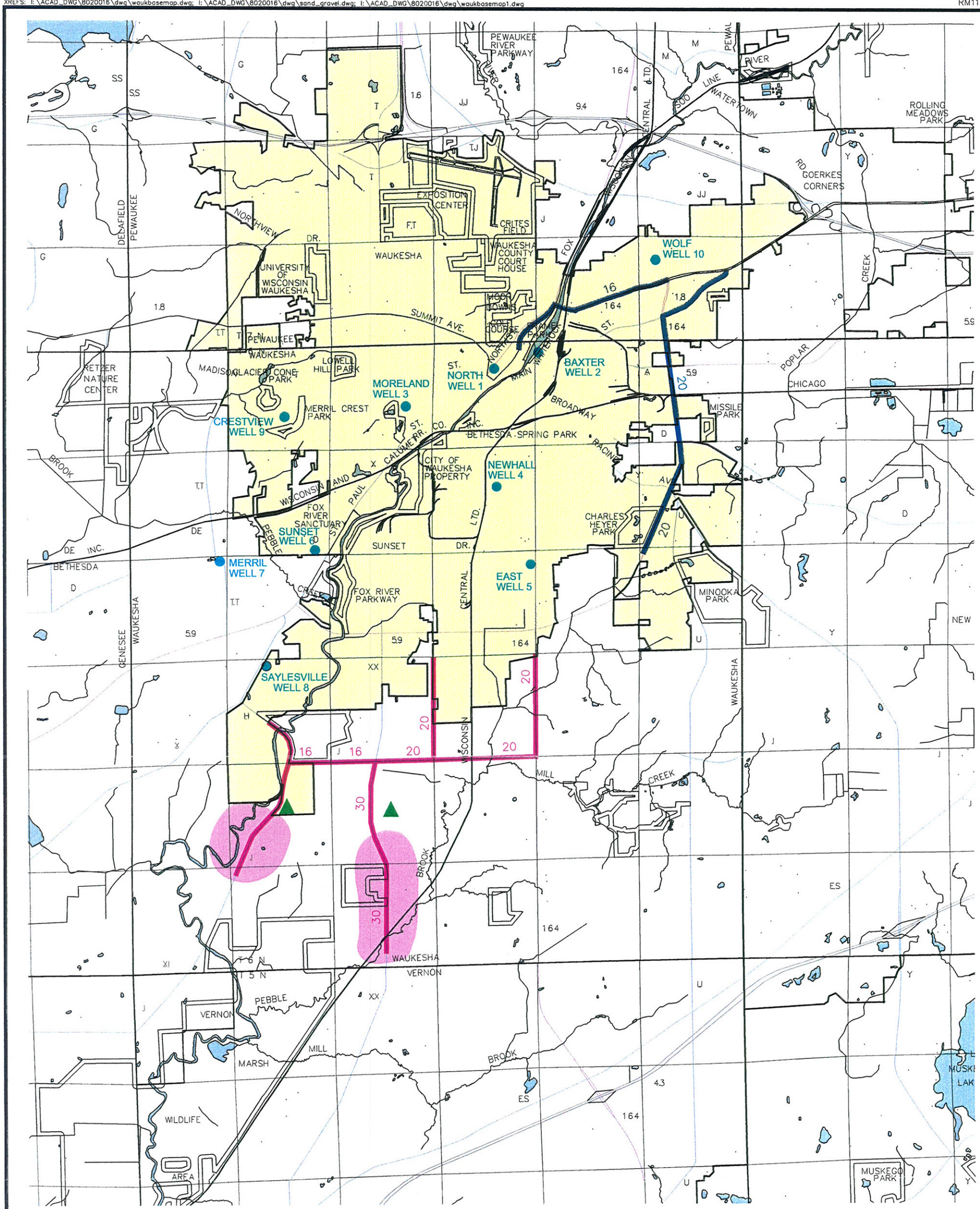

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LEGEND

- EXISTING WELL TO BE ABANDONED
- PROPOSED NEW WELL FIELDS (CONCEPTUAL LOCATION)
- PROPOSED NEW TRANSMISSION MAIN
- PROPOSED WATER MAIN ADDITION
- PROPOSED TREATMENT FACILITY

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FIGURE 4-22

COMBINED SHALLOW AND ALLUVIAL AQUIFER WATER SUPPLY

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4.6.2.3 Transmission

Transmission from the two wellfields to Waukesha could be accomplished with dual 30-inch-diameter transmission lines. About 3 miles of large transmission main would be required. Smaller transmission lines would be needed from the shallow aquifer treatment plant. Another 11 miles of 20- and 16-inch water main would be required to distribute the treated groundwater throughout the City of Waukesha.

4.6.3 Regulations/Legal

Producing water from multiple aquifers is consistent with the long standing practices of several surrounding communities. It is generally considered to be a wise source of supply strategy and should not be opposed by any regulatory body. Both wellfields will require a well head protection plan to satisfy NR 811 requirements and protect the wells from contamination. The Waukesha Water Utility will have no zoning control to enforce the well head protection ordinance for the Troy bedrock valley wellfield because the wellfield will be beyond the Waukesha corporate limits. As a result, finding an aquifer with natural protection, such as a clay confining layer, may be the most effective form of well head protection that can be achieved. If this is not possible, it may be necessary to acquire larger tracts of land or find mechanisms to influence land use on surrounding properties. This might be accomplished through providing incentives to surrounding landowners to grow crops that require lower inputs of fertilizers and chemicals and prevent high density developments with septic tanks.

The alluvial wellfield is likely to produce a significant portion of its water from groundwater flowing toward the river. Given the high permeability of the soils and the relatively shallow depth of the aquifer, the groundwater portion of the wellfield will be vulnerable to contamination. As a result, it will be important to select wellfield locations that minimize the potential for contamination from upgradient sources. Well head protection will be a critical element for maintaining the wellfield.

Portions of the alluvial aquifer wellfield will also be beyond the corporate limits. Given the limited ability enforce well head ordinances beyond their corporate limits, it may be necessary to find means of controlling surrounding land use either through incentives to landowners or by siting wells in favorable locations, such as park land.

The treatment plant will require WDNR approval based on NR 811 and 809 requirements. Pilot testing for the Fox River alluvium source is likely to be required.

4.6.4 Political and Public Acceptance

The public should perceive a benefit from obtaining radionuclide compliant water. If the water is treated to meet secondary standards, the public should perceive a net improvement in aesthetic properties of the water.

The public may have some initial resistance about drinking water that comes in part from the Fox River. However, with appropriate treatment and public education, most of these concerns should be addressed. Environmental groups may be concerned about the potential impact on the Fox River, particularly during low flows. However, most of the water will be returned to the river through the Waukesha wastewater treatment plant a few miles

upstream of the likely wellfield location. The water derived from aquifer storage during low-flow periods of the Fox River will augment the base flow conditions by replacing more water than is infiltrated.

Surrounding townships may be concerned about impacts to private wells and wetlands around the Troy bedrock valley wellfield. With proper testing and well siting, it should be possible to minimize these impacts.

The treatment plants will require aesthetic features to make them acceptable to nearby citizens and comply with zoning requirements. Since there are two plants, the issues may be more numerous than alternatives with only one treatment plant. Truck traffic and noise should be minimized where possible. Again, two plants will increase the traffic and noise over one plant.

The transmission main would require easements and could result in some public opposition. Some transmission lines would be run in the city limits, resulting in traffic slow-downs.

4.6.5 Operations and Maintenance

4.6.5.1 Wells

Retiring the sandstone wells will reduce the O&M costs of the system. The shallow wells will have significantly lower costs to operate and maintain due to the shallower pump settings and lower pumping costs.

4.6.5.2 Water Treatment

O&M requirements for the treatment plants would be similar to those described previously. However, O&M will be greater for two 11-mgd water plants compared to one 22-mgd water plant.

4.6.5.3 Water Plant Residuals

Water plant residuals handling will be similar to that described previously for these sources. However, residuals from two smaller treatment plants will increase O&M over that of one larger treatment plant.

4.6.5.4 Transmission

The additional transmission pipe and valves will require maintenance, similar to existing pipe and valves in the Waukesha Water System.

4.6.6 Schedule

The wellfields could be constructed to meet current demands and expanded as necessary to meet future demands as needed. Given the time needed for exploration, testing, and construction, sufficient capacity could be on-line within a 3- to 5-year period.

Construction of two smaller water plants will take more time than one large plant, mainly due to siting, land purchase, zoning, and other site-specific issues.

4.7 Aquifer Storage and Recovery

As mentioned previously, ASR can be used with any of the alternatives to enhance reliability, provide more water management flexibility, and reduce costs. Application of ASR would involve storing drinking water in existing sandstone wells during periods of lower demand (i.e., winter) and pumping it out during periods of higher demand (i.e., summer). ASR would have the following impacts on the alternatives:

- Increased reliability because drinking water would be stored at various well locations for use when needed.
- Increased operational flexibility because another source of water would be provided in the event of emergencies (i.e., failure of pipes or treatment plants). In addition, ASR could be used if one or more sources of water are stressed from drought conditions.
- Reduced costs because wells, treatment plants, and pipes could be sized closer to ADD instead of maximum day demand. Typical operations would be to produce water more consistently at slightly above ADD and store it on the sandstone aquifer during low demand and pump it out of the aquifer during high demand.
- Use of existing facilities and resources (sandstone wells, storage tanks, and pump stations) would save some of Waukesha's infrastructure investment and assist with water distribution.

To illustrate these points, the use of ASR with shallow aquifer alternatives (Troy bedrock valley, Fox River alluvium, or a combination of the two) on each evaluation criteria will be discussed.

4.7.1 Reliability

ASR provides more reliability by providing another drinking water source. The most reliable alternative is to have both Fox River alluvium water and shallow aquifer water with ASR. Even if both sources are unavailable due to contamination or infrastructure failure, or drought, ASR could be used to provide at least the ADD.

4.7.2 Infrastructure

4.7.2.1 Wells

ASR would reduce the number of shallow aquifer wells from 16 to 10, and the Fox River alluvium horizontal wells from six to five.

Four or five of the existing sandstone wells would be modified for ASR. This involves additional piping and valves in existing pump stations.

4.7.2.2 Treatment

ASR would reduce the size of treatment plants from 22 to 14 mgd.

4.7.2.3 Transmission

Transmission mains from the wellfields to Waukesha could be smaller because they would have to deliver 14 mgd instead of 22 mgd. In addition, less distribution system pipeline would be required because use of existing wells would help distribute water around the system.

4.7.3 Regulations/Legal

As mentioned previously, ASR regulations are being finalized by WDNR. The requirements of these regulations may include a monitoring well and additional testing to determine the fate of some chlorine by-products in the aquifer.

4.7.4 Political and Public Acceptance

Additional information may be required to educate the public on ASR. Use of the existing sandstone aquifer may be appealing to some since this is the historical source of drinking water.

4.7.5 Operations and Maintenance

4.7.5.1 Wells

Sandstone wells retained for ASR use will need to be maintained in a similar manner as now. With much less sandstone water being used, pumping levels should increase and maintenance requirements decrease. Only four or five of the existing 10 wells would be used. The other wells could be used as standby or abandoned.

4.7.5.2 Water Treatment

O&M requirements for the treatment plant would decrease because the size would be reduced from 22 to 14 mgd.

4.7.5.3 Water Plant Residuals

Water plant residuals handling would decrease because the size would be reduced from 22 to 14 mgd.

4.7.5.4 Transmission

The quantity and size of transmission and distribution system pipes would decrease, potentially decreasing O&M requirements.

4.7.6 Schedule

ASR would add another component to the construction of facilities. Conversion of existing wells to ASR wells could be done in the same time frame as new wells and treatment plants. The conversion would have to be phased to maintain water supply capacity during construction.

SECTION 5

Benefit Ranking of Alternatives

5.1 Methods

The method of determining evaluation criteria and assigning relative weights was discussed in Section 3. The criteria were used by a team of evaluators to rank each alternative for its ability to provide benefits. Initially, a large group of evaluators was used to get a broad perspective on the benefits of major water supply alternatives. Groups represented included:

- Waukesha Water Utility staff
- Waukesha Water Commission
- WDNR
- SEWRPC
- City Legal Counsel
- US Geologic Survey
- University of Wisconsin
- Wisconsin Geologic Survey
- CH2M HILL
- Ruekert & Mielke

When the alternatives were evaluated and developed further, a smaller group of evaluators (consultants and water utility) repeated the benefit ranking of alternatives. Overall, the results were similar with both groups.

5.2 Results

Figure 5-1 shows the results of the benefit ranking. The height of the bar is proportional to the benefit the alternative provides. Therefore, the higher the bar the more benefits. The alternatives were grouped into three major categories:

- Sandstone aquifer
- Shallow aquifer
- Lake Michigan

The general conclusions that follow can be made from the benefit analysis.

5.2.1 Sandstone Aquifer

The sandstone alternatives provided the lowest benefit as a group. Reliability of the sandstone aquifer near Waukesha was low because of declining water quality and groundwater levels. In addition, more extensive treatment was required to deal with radium and increasing TDSs. This created infrastructure and O&M concerns.

Placing sandstone wells west of Waukesha in the recharge area of the sandstone aquifer improved reliability significantly. However, this alternative was located farthest from Waukesha with significantly more pipeline infrastructure and concerns for political and public acceptance issues.

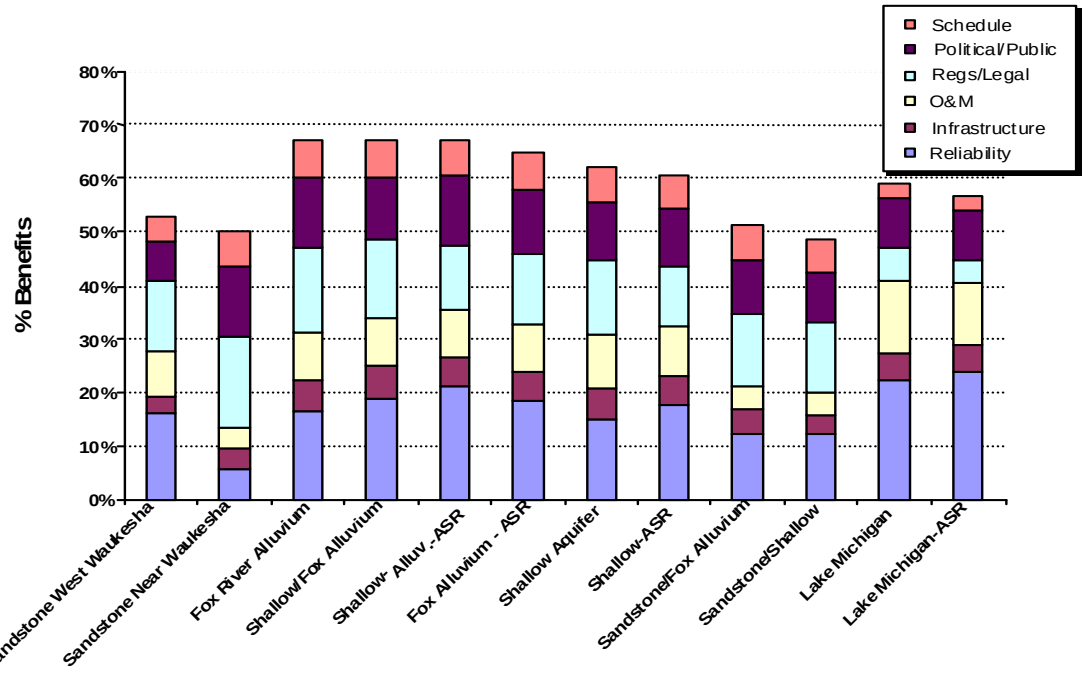

FIGURE 5-1
Benefit Ranking Results

5.2.2 Shallow Aquifer

Eight shallow aquifer alternatives and combinations of alternatives were evaluated. ASR was included with three alternatives. Blending sandstone water with shallow aquifer water was included in two alternatives. Overall, the shallow aquifer alternatives provided the highest benefit.

The alternatives with the highest benefits were the shallow aquifer/Fox River alluvium combination and Fox River alluvium alone. These were followed very closely (0.1 percentage point) by the shallow aquifer/Fox River alluvium/ASR combination. Although the Fox River alluvium alternative was rated lower on reliability, it is located closest to Waukesha and scored higher on legal, political, and public acceptance issues. The combination of shallow aquifer and Fox River alluvium was rated higher in reliability because there are two sources of water, and the shallow aquifer has more protection (clay confining layer) from contaminants. The shallow aquifer/Fox River alluvium/ASR alternative was rated highest in this group for reliability because it has three sources of water.

The lowest ranked shallow aquifer alternatives involved blending with sandstone water. O&M concerns with balancing water demand requirements and radium levels were a factor. Significantly more piping in the city limits was also required.

5.2.3 Lake Michigan

The Lake Michigan alternatives were evaluated with and without ASR. Lake Michigan was slightly lower in benefits than the shallow aquifer alternatives, but higher than the sandstone aquifer. Lake Michigan was rated the most reliable and best O&M of all alternatives. However, concerns for getting permission for a diversion without sending wastewater back to the Great Lakes Basin caused this alternative to be ranked lowest in regulatory/legal, political and public acceptance, and schedule.

SECTION 6

Costs

Capital and O&M costs were estimated for each alternative. A summary of these costs is presented in Table 6-1. Capital costs include new facilities needed for an operational system with a 22-mgd capacity. Capital costs also include land purchase, allowances for additional studies, permits, and easements. A 20-percent contingency and 15 percent for engineering, legal, and administrative costs was included in each alternative capital cost estimate. Costs are in 2002 dollars.

Annual O&M costs for each alternative are also presented in Table 6-1. Costs were based on a 10-mgd ADD. These costs include source of supply, treatment, residuals disposal, transmission, and water purchase where applicable (Lake Michigan). A 5-percent contingency was added to O&M costs. The increase in each alternative's O&M costs over current water system costs is also presented in Table 6-1 to estimate impacts on the water utility budget.

Total cost is the capital cost plus present worth O&M cost (20 years at 6 percent). This number can be used to compare the various alternatives. As shown in Table 6-1, the sandstone alternatives have the highest total cost. Costs for the sandstone wells near Waukesha are driven by the capital and high O&M cost of treatment. Costs for the sandstone wells west of Waukesha are driven by the high cost of long transmission pipes from the wellfield to Waukesha.

The shallow aquifer alternatives have some of the lowest total costs. There is a range of costs depending on location of the wellfield, treatment required, and use of ASR. The lowest cost alternative is a shallow aquifer wellfield south of Waukesha and the use of ASR to store drinking water for use during high demand periods ($62 million total cost). ASR reduces capital costs significantly because it reduces the number of wells, size of pipes, and size of treatment plants. These facilities are sized closer to ADD (about 14 mgd) instead of maximum day demand (22 mgd). The highest shallow aquifer alternative cost is the combination of the Fox River alluvium and shallow aquifer south of Waukesha ($83 million total cost). These costs are driven by more pipe for multiple sources, two treatment plants, and a higher degree of treatment for the Fox River alluvium. If ASR is combined with this alternative, the total cost is reduced from $83 million to $69 million total cost because of smaller pipes, smaller plants, and less wells.

Lake Michigan water has a total cost of $90 million. This alternative has the lowest capital cost ($42 million), but the O&M costs are high, mainly from the cost of purchasing treated wholesale water from a Lake Michigan supplier. This alternative assumes that a permit will be issued that allows the use of Lake Michigan water without returning it to the Great Lakes Basin. If return of water to the Great Lakes Basin is required, the cost of this alternative will be double or more.

TABLE 6-1
Summary Cost Estimate (in $ millions)
Future Water Supply

	Capital Cost[a]	O&M$/yr[b]	Increase Over Current O&M$/yr [c]	Total Cost [d]	Total Cost w/Home Softening Credit [e]
Sandstone Alternatives					
Sandstone Near Waukesha	$ 67	$ 5.9	$ 4.7	$ 135	$ 108
Sandstone West of Waukesha	$ 77	$ 1.8	$ 0.6	$ 98	
Shallow Aquifer Alternatives					
Shallow Aquifer	$ 56	$ 1.3	$ 0.1	$ 71	
Shallow Aquifer with ASR	$ 45	$ 1.5	$ 0.3	$ 62	
Fox River Alluvium	$ 62	$ 1.6	$ 0.4	$ 80	
Fox River Alluvium with ASR	$ 50	$ 1.7	$ 0.5	$ 69	
Shallow Aquifer/Sandstone	$ 51	$ 1.2	$ (0.01)	$ 65	
Fox River Alluvium/Sandstone	$ 57	$ 1.4	$ 0.2	$ 73	
Fox Alluvium/Shallow Aquifer	$ 66	$ 1.5	$ 0.3	$ 83	
Fox Alluv/Shallow Aquifer with ASR	$ 52	$ 1.5	$ 0.3	$ 69	
Lake Michigan Alternatives					
Lake Michigan	$ 42	$ 4.2	$ 3.0	$ 90	$ 63
Lake Michigan with ASR	$ 36	$ 4.3	$ 3.1	$ 85	$ 58

[a] 2002 dollars, facilities for 22 mgd.
[b] 10 mgd average day demand. Source of supply, treatment, and new transmission only.
[c] Alternative O&M (column 2) minus existing O&M (10 mgd for source of supply & treatment only).
[d] Capital plus O&M present worth, 20 years, 6%.
[e] Subtracts capital and O&M cost of home softening, 20 years, 6%.

Lake Michigan water is naturally soft. Water from the shallow and sandstone aquifer is hard. A comparison of hardness and iron between the water sources is on Figure 6-1. The shallow aquifer is a bit harder than the sandstone. It also has higher iron, but the iron removal plant would reduce the iron levels to low levels similar to Lake Michigan water. Currently, many Waukesha residents have home water softeners. If soft water from Lake Michigan was obtained, the home softeners would not be needed and the associated cost of operating them would be eliminated. There is a cost advantage to providing soft water estimated at a 20-year present worth of about $27 million, mostly from the cost of salt purchase. If this home softening cost is subtracted from the cost of providing Lake Michigan water, the alternative total cost is $63 million, which is close to the lowest shallow aquifer alternative ($62 million).

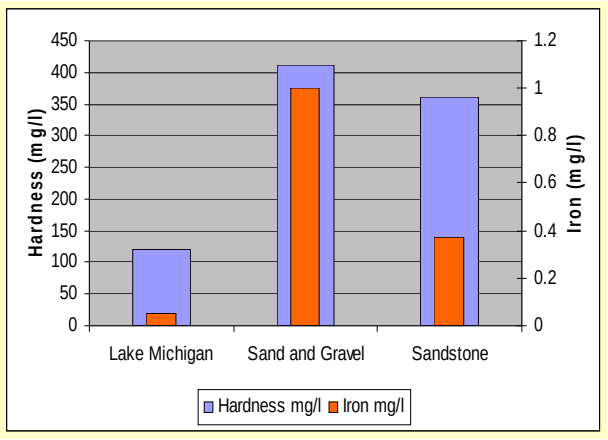

FIGURE 6-1
Hardness and Iron in Source Waters

These cost estimates were prepared without detailed engineering design. The purpose of the cost estimate is for guidance in project evaluation and implementation based on information available at the time of the estimate. The final cost of the project will depend on market conditions, actual site conditions, final project scope, schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented here.

6.1 Benefits and Costs

The best alternatives provide high benefits at reasonable costs. The alternative benefits from Section 5 and present worth costs from Section 6 are combined on Figure 6-2. The alternatives with the highest benefits and lowest costs are:

- Lake Michigan
- Shallow Aquifer

The Lake Michigan alternative cost includes the softening cost credit. It also assumes a diversion permit will be granted and will not require returning water to the Great Lakes Basin or other environmental improvements. If a diversion permit is not granted or return of water to the Great Lakes Basin is required, the Lake Michigan alternative is not cost effective. If a diversion permit is granted without a return flow requirement, Lake Michigan provides the most reliable and highest quality source of water for Waukesha and potentially other communities.

Of the eight shallow aquifer alternatives evaluated, the ones with the highest benefit and lowest cost are:

- Shallow aquifer with ASR
- Fox River alluvium/shallow aquifer with ASR

The combination of Fox River alluvium, shallow aquifer, and ASR provides the most reliability and flexibility for delivering water and managing water resources. It is the preferred shallow aquifer alternative. However, future conditions and issues may change the best water supply alternative for Waukesha.

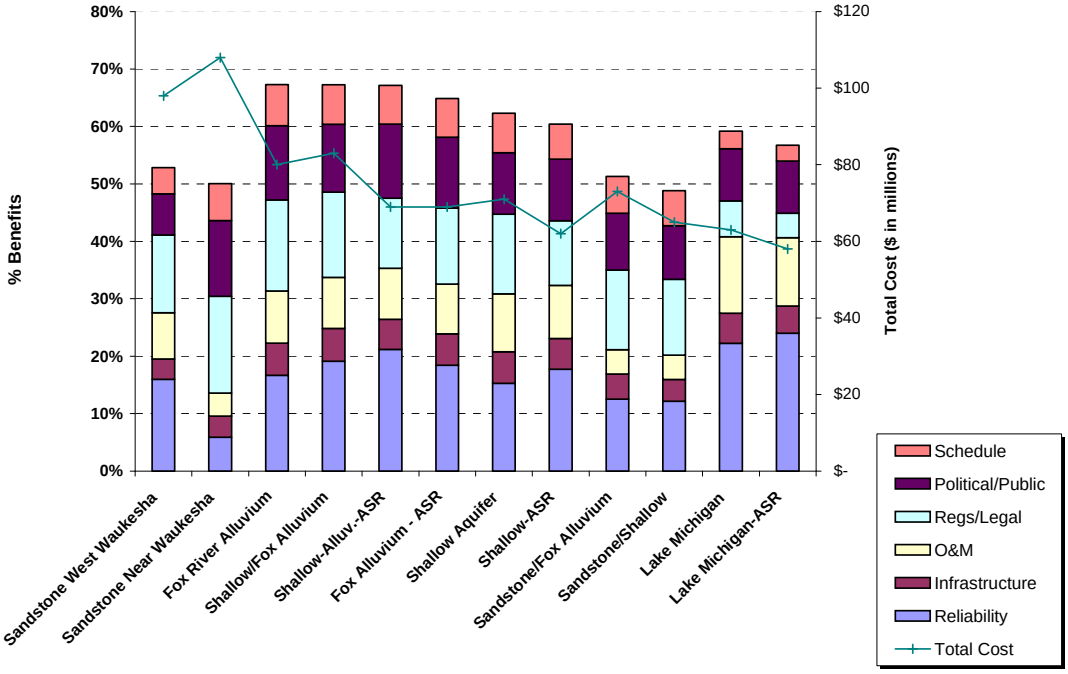

FIGURE 6-2
Benefits and Costs

SECTION 7

Summary and Implementation Plan

7.1 Summary

Over 20 water supply alternatives were evaluated for the Waukesha Water Utility. The alternatives were screened down to seven, then evaluated in detail. The three major categories of water supply sources are the sandstone aquifer; shallow aquifer; and Lake Michigan.

These alternatives were evaluated based on the following criteria:

- Reliability
- Infrastructure
- Regulations/Legal
- Political and Public Acceptance
- Operations and Maintenance
- Schedule

Capital and operating costs were developed for the alternatives. The alternatives with the highest benefits and lowest costs are:

- Lake Michigan
- Shallow aquifer

7.2 Implementation Plan

Implementation of a new water supply for Waukesha should proceed on a parallel path as shown on Figure 7-1.

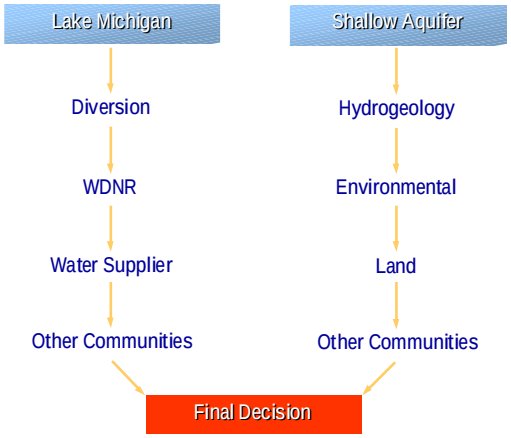

FIGURE 7-1
Implementation Plan

The feasibility of the Lake Michigan supply will depend on obtaining a diversion permit where return of water to the Great Lakes Basin is not required. Feasibility will also depend on negotiating a water contract with a Lake Michigan Water supplier. The criteria and process for evaluating the merits of a diversion are planned to be finalized in 2004 by the Council of Great Lakes Governors. However, investigations into the environmental impacts and requirements of a diversion can begin at any time. Other activities that can proceed toward a Lake Michigan water supply include:

- Discussions with WDNR on regulatory requirements
- Discussions with potential Lake Michigan water suppliers
- Discussions with other communities facing similar water supply issues

Further steps toward a shallow aquifer supply include:

- Hydrogeologic investigations and test wells in the shallow aquifer to determine optimum well locations, sustainable capacities, and environmental impacts
- Land issues including purchase, lease, and zoning
- Discussions with other communities regarding use of the shallow aquifer and potential partners in a water supply system

When information on the critical issues for the water supply sources becomes available, a final decision on the best water supply source can be made. Engineering design activities can then commence, followed by construction, start-up, and operation of the new water supply system.

SECTION 8

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Appendix D

Water Supply Service Area Plan for the City of Waukesha

Report

Water Supply Service Area Plan for the City of Waukesha

Prepared for

City of Waukesha, Wisconsin

April 2010

CH2MHILL
135 S. 84th Street, Suite 325
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Report

Water Supply Service Area Plan for the City of Waukesha

Submitted to

City of Waukesha, Wisconsin

April 2010

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Supplemental Information [on compact disk]

SEWRPC, 2008. Regional Water Supply Plan for Southeastern Wisconsin*

Final Draft Technical Memorandum: Summary of Water Requirements

Waukesha Water Utility Future Water Supply Study

Results of Groundwater Modeling Study: Shallow Groundwater Source—Fox River & Vernon Marsh Area

Cost Estimate Update

Environmental Report

*Not on compact disk; available for purchase from SEWRPC

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Water Supply Service Area Plan for the City of Waukesha

In compliance with the requirements of the Great Lakes–St. Lawrence River Basin Water Resources Compact and the Wisconsin Compact implementing statute (§281.346, Wis. Stats. and §281.348, Wis. Stats), the City of Waukesha, Wisconsin, is submitting a water supply service area plan for the 20-year planning period from 2010 to 2030. The City is submitting the plan for review by the Wisconsin Department of Natural Resources (WDNR) because the City is applying for a Great Lakes diversion with return flow.

1. Background

1.1 City of Waukesha Water System

The City of Waukesha water system comprises groundwater supply, treatment, storage, and conveyance assets, shown schematically in Exhibit 1. The City's system is a "public water supply"—a means of distributing water to the public through a physically connected system of supply, treatment, storage, and distribution facilities that serve a group of largely residential customers, and that also serves industrial, commercial, and public customers. (§ 281.348(d), Wis. Stat.) The City also maintains a water utility administration building with offices for customer service, billing, supervisory control and data acquisition system control, meter testing, fleet storage, and equipment storage.

1.2 Waukesha Water Conservation and Efficiency

Since 2006, the City has implemented a variety of water conservation measures. These best practices, including implementation of rates that encourage water conservation, were authorized by the Wisconsin Public Service Commission. Further, the City's universal metering, leak detection and repair program, public education and landscape water controls are compliant with draft water conservation and water use efficiency rule (Wis. Admin. Code NR852.04(2)) being developed by the Wisconsin Department of Natural Resources (WDNR).

1.2.1 Accounting for Water

Measuring all water used is essential to ensuring wise water use. The City meters all water customers and monitors water use with accurate automatic flow meters that can be read remotely. Water use is described on customer bills in terms of gallons rather than cubic feet. This small detail helps customers understand how water use relates to behavior. Also, with automatic meters, City staff can easily monitor meter records. If a dramatic change in water use is observed, the City contacts a customer to promptly address potential water waste issues.

All water utilities, including the Waukesha Water Utility, have unavoidable water loss. This water loss, called unaccounted-for water, is used for fighting fires or flushing mains, or is lost through leaks in water pipes. To minimize unaccounted-for water, the City monitors the system for leaks and estimates water used for routine system flushing.

EXHIBIT 1
City of Waukesha Water System Schematic

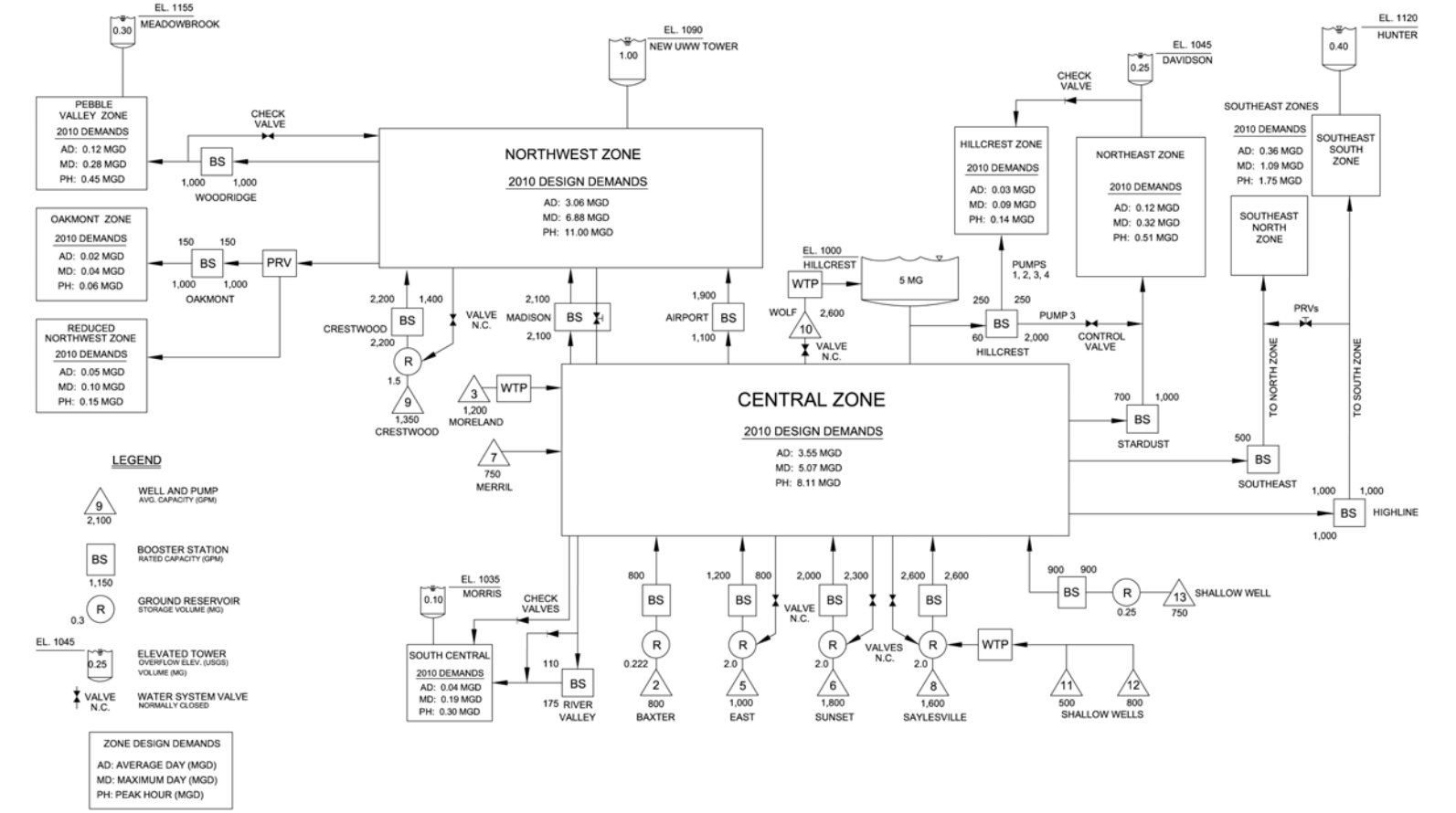


EXHIBIT 1
Current Water System Schematic
Waukesha Water Utility
Waukesha, Wisconsin

Source: Adapted from AECOM Master Plan, 2006

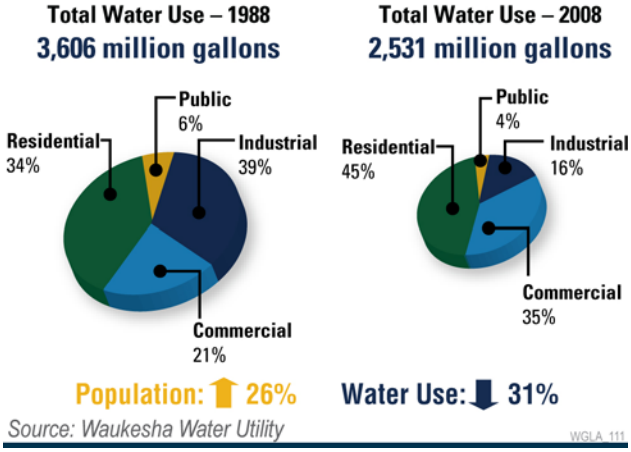
WBG110509184022MKE WGLA_150_Current_WWU_Schematic_v1

Historically, the City averages 4 to 7 percent unaccounted-for water,[2] which is less than the American Water Works Association-recommended benchmark of 10 percent.[3]

1.2.2 Water Conservation Measures

Total water use by City customers has dropped 31 percent from 1988 to 2008, despite a 26 percent population increase (Exhibit 2). Some of the decline in water use is attributed to industry leaving the area and the recent economic recession, but some of the reduction can be attributed to the City's water conservation and protection plan. In 2006, the City implemented a comprehensive water conservation plan to further reduce water use. Water conservation and protection efforts will be continued and monitored to determine which measures are the most effective. Highlights of the City's plan for continued investment in water conservation are presented in Exhibit 3.

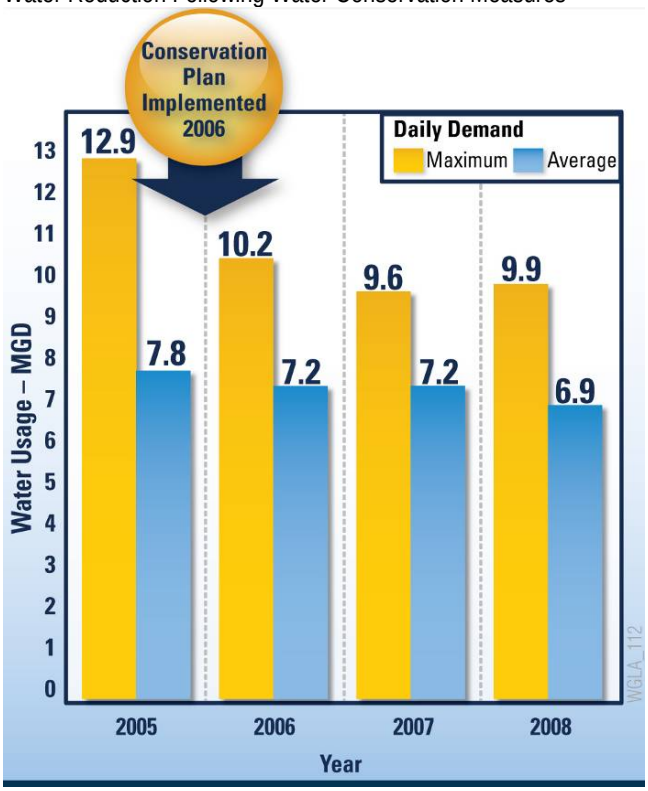
EXHIBIT 2
City of Waukesha Population and Water Use 1988–2008



Restrict Outdoor Sprinkling. The first conservation initiative implemented in 2006 was adoption of a sprinkling ordinance that affected all customer classes. The ordinance was targeted at reducing peak demand and reducing overall average day demand.

Water bill inserts, refrigerator magnets, and press releases were used to educate the public regarding the ordinance. In 2007, street signs with sprinkler ordinance information were installed. These actions were successful in reducing the average and maximum day water demand. Comparisons show a 15 percent reduction in summer watering season water use from 2005 to 2008 (Exhibit 4). The baseline year of 2005 was chosen because it is the year before implementation of the conservation plan.

EXHIBIT 4
Water Reduction Following Water Conservation Measures



[2] Waukesha Water Utility annual operating data submitted to Wisconsin Public Service Commission.
[3] AWWA Leak Detection and Accountability Committee, 1991.

EXHIBIT 3

City of Waukesha Water Conservation and Protection Plan Goals

Relative Water Savings Benefit Scale: = Minimal = Moderate = Major

Short-term Goals

Provide Public Education on Web Site – Teach the public why they should conserve water and how they can help, mentioning the resulting time and cost savings. Provide information on rain gardens and rain barrels.	
Continue Student Water Education – Teach Waukesha students about the water level in the aquifer, the importance of conservation, and practices their families can implement.	
Develop Outdoor Water Use Ordinance – Create and implement an ordinance that sets limits on sprinkling times to reduce peak water use and costs for customers.	
Communicate Monetary Benefits of Water Conservation – Place water conservation cost savings information in customer bills.	
Accelerate Water Main and Lateral Replacement – Continue to replace outdated mains and service laterals, helping to ensure a reduction in leaks.	
Promote Water Conservation – Create brochures, magnets, signage, and a public service announcement; attend events to promote conservation.	
Implement Conservation Water Rates – Develop with the Public Service Commission a water pricing structure that encourages conservation.	
Loop Water Mains – Have contractors loop the water mains to reduce hydrant flushing water requirements.	
Organize Regional Stakeholder Groups – Create stakeholder groups to promote regional water conservation through residential contests, commercial and industrial customer groups, regional water utility collaboration, and educational events for conservation.	
Recycle Filtered Backwash Water – Implement a recycling process for Wells 8, 11, and 12.	
Audit Water Use in City Buildings – Starting with City Hall, audit all city buildings to identify ways to reduce water use.	
Develop Incentives/Rebates Programs – Continue to work with the Public Service Commission to determine the feasibility and potential success of rebate programs.	
Implement Rain Barrel Program – Work with the Coalition to provide rain barrels for landscaping maintenance water supply.	
Become a Member of WaterSense – Gain current information on tested products to meet performance standards of plumbing fixtures for our rebate programs.	
Join Alliance for Water Efficiency – Acquire and implement best management practices for water conservation.	
Initiate Restaurant Table Tents and Other Water-saving Ideas – Work with the Coalition and Wisconsin Conference for Restaurants to develop "table tents" that explain water conservation at restaurants.	

Mid-term Goals

Continue Student Water Education Programs – Update curriculum.	
Continue Public Outreach Program – Provide press releases, and update brochures and materials. Update Utility Web site.	
Maintain Water System Leak Detection Program – Update Utility leak detection to identify priority areas in the system to reduce large leaks and reduce unaccounted-for flow.	
Implement City Water Audit – Install water-saving fixtures throughout Utility facilities.	
Evaluate Indoor Incentives/Rebates Programs – Evaluate rebate programs for targeted water-using appliances and fixtures.	
Evaluate Outdoor Incentives/Rebates Programs – Evaluate rebates for outdoor water use equipment (timers, sprayers).	
Evaluate Residential Audit Feasibility – Determine the feasibility of coordinating a residential water audit program with a water meter change-out program that would link to an incentive/rebate program.	
Review Water Use Restriction Ordinances – Review plumbing requirements in ordinances for new construction, remodeling, and retrofits, and study potential for requiring plumbing updates at time of property sale.	
Enhance Outreach to Commercial Sector – Provide commercial businesses (i.e., car washes, laundromats, hair salons) and retailers with information for customers about the benefits of updating indoor fixtures and outdoor watering devices.	
Reduce City Departments and Schools Outdoor Water Use – Identify opportunities for reduced outdoor sprinkling in parks and school fields.	
Evaluate Sewer Credit Meters – Investigate the phase-out of residential sewer credit meters to further encourage reductions in outdoor water use.	
Pilot Low-impact Development on City Properties – Add green infrastructure, such as rain gardens and permeable pavement, to City properties.	
Work with Housing Authority to Update Public Housing Plumbing – Work with Waukesha Housing Authority to update water fixtures in Waukesha public housing.	
Replace Plumbing Fixtures with Efficient Devices – Work with the Wisconsin Focus on Energy Program to update shower heads at hotels and hand sprayers at restaurants.	
Form Regional Source Water Protection Planning Committee – Work with surrounding utilities to better coordinate source water protection.	
Communicate Monetary Benefits of Water Conservation – Place individual account water use information on the internet and on water bills.	
Fix a Leak Week in March – Get involved with EPA's Fix a Leak Week by including dye tablets and a brochure in all water bills.	

Long-term Goals

Implement Unidirectional Flushing – Update the flushing program to maximize velocities in the main for flushing, thereby reducing the amount of water needed to clean the water mains.	
Implement Smart Growth Land Use Planning and Zoning – Work with other entities (surrounding communities, developers, businesses) to develop Low-impact Development Practices to prevent pollution from entering the Fox River. Consider revision of Comprehensive Plan and zoning ordinances to encourage infiltration of stormwater into the ground.	
Audit Commercial and Industrial Sectors Water Use – Work with commercial and industrial customers to identify areas to reduce water use and save customers' money.	
Evaluate Gray Water Systems – Investigate reuse of the City's wastewater after it is returned to the Lake Michigan watershed. Reuse may involve "gray" water separation or redirection of treated wastewater for regional aquifer recharge.	

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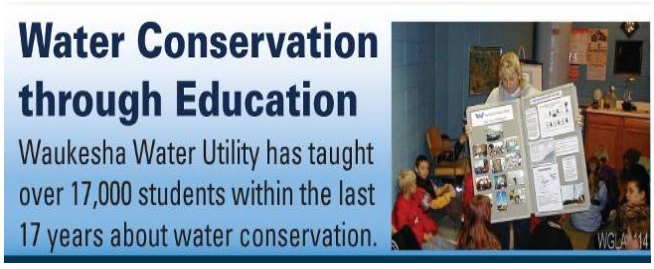
Conservation Water Rates. Waukesha adopted a conservation (inclining) rate structure for residential customers in 2007, becoming the first city in the state to charge customers more per gallon as water use increases. The City recently strengthened and expanded the conservation water rate model to include increasing the cost in each rate tier and reducing the amount of water allowed before reaching the next tier. Exhibit 5 summarizes the single-family residential rates before and since water conservation rates were implemented. The Utility has focused on residential users because they represent the largest customer class with the most significant fluctuations in water use. Water rates for commercial and industrial customers have increased by larger percentages than for residential customers. To date, non-residential customers have realized major water use reductions through individual conservation efforts and collaboration with City officials. Because 20 percent of the industry and commercial business class uses 80 percent of the water,[4] a few key changes with a small number major water users has resulted in significant water savings.

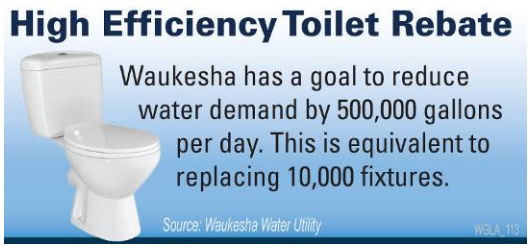
EXHIBIT 5
City of Waukesha Water Conservation Rates

Quarterly Use (gal.)	Current Rate ($ / 1,000 gal.)
Tier 1: 0 to 10,000	2.05
Tier 2: 10,001 to 30,000	2.65
Tier 3: over 30,000	3.40
Quarterly Use (gal.)	**2007 Rate ($ / 1,000 gal.)**
Tier 1: 0 to 30,000	1.95
Tier 2: 30,001 to 40,000	2.20
Tier 3: over 40,000	2.70
Quarterly Use (gal.)	**Pre-conservation Rate ($ / 1,000 gal.)**
Tier 1: 0 to 40,000	1.69
Tier 2: 75,000 to 1,425,000	1.14
Tier 3: over 1,425,000	1.02

Water Conservation Education in Public Schools. The hallmark of the City's water conservation public outreach program is its contribution to the environmental education curriculum in the City of Waukesha. Fifth- and ninth-grade students are taught about water conservation by Waukesha Water Utility staff. By visiting water facilities, operating tabletop groundwater models, and collaborating with teachers, the City has introduced water conservation to more than 17,000 students.[5]



Toilet Rebate Program. After the City's measurable success with outdoor water use reduction, more attention was focused on indoor water use. Toilets are the largest user of residential water, accounting for 26.7 percent of the water used in an average home.[6] Toilet replacement is one the most effective ways to reduce indoor water use. The toilet rebate program was launched in October 2008, with a goal of saving 500,000 gallons per day by replacing old high-flow toilets with new high-efficiency toilets. To help meet this goal, the City is providing



[4] Waukesha Water Utility annual operating data, 2009.
[5] Waukesha Water Utility. 2009. Annual Educational Program Data.
[6] Amy Vickers. 2001. *Handbook of Water Use and Conservation*.

rebates for fixture replacement.

Regional Conservation Coalition.

In 2006, leaders from the City of Waukesha and Waukesha County created the Waukesha County Water Conservation Coalition. Water supply is a regional issue and cooperation among the area's water users will improve the results of conservation initiatives. The coalition of business, government, education, and local stakeholder groups, collaborated on countywide messages on water conservation.

Waukesha County Water Conservation Coalition:

- Initiated rain barrel distribution to increase outdoor use of stormwater instead of drinking water
- Created restaurant table tents that say, "Water served upon request. By reducing water waste and washing chemical use, our restaurant is protecting the environment. Thank you for your cooperation and helping us do the right thing."
- Sponsored a residential water conservation contest with prizes going to greatest water use reductions

1.3 Waukesha Water Supply Sources

The City of Waukesha's current source of water supply is groundwater. The City of Waukesha has 11 functional wells, 8 in the deep aquifer and 3 in the shallow aquifer (Exhibit 6). Approximately 87 percent of Waukesha's supply is from the deep St. Peter Sandstone aquifer, which has severely declining water levels and significant water quality issues. About 13 percent of Waukesha's supply is from the shallow Troy Bedrock Valley aquifer, which feeds sensitive surface water resources and also has water quality issues.

EXHIBIT 6
Waukesha Water Utility Supply Wells

Well No.	Well Depth (ft)	Capacity (mgd)
1	Abandoned because of contamination	N/A
2	1,835	1.15
3	1,995	1.40
4	Abandoned because of contamination	N/A
5	2,120	1.44
6	2,075	2.59
7	1,658	1.08
8	2,024	2.16
9	1,730 (backup service only)	1.94
10	2,145	3.74
11	127	0.47
12	149	0.90
13	105	1.01

With the passage of the Great Lakes–St. Lawrence River Basin Water Resources Compact, Lake Michigan became a potential source of water supply for the City of Waukesha. Because the City lies wholly within a county that is partially in the Basin, the City may apply to withdraw Lake Michigan water for public water service and return treated water to the Great Lakes Basin.

The potential sources of water supply for the City are discussed below and in Section 3 Water Supply Alternatives.

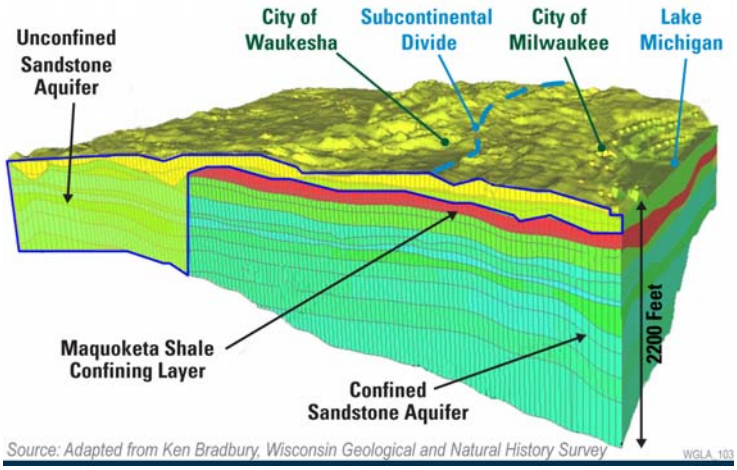
1.3.1 Deep Sandstone Aquifer

The City's deep aquifer wells are constructed to depths of greater than 2,100 feet and withdraw water from 800 to 1,000 feet below ground. Since the 1840s, the aquifer has served as a source of water supply for many communities in Wisconsin and Illinois. Today deep aquifer water supply pumping in southeastern Wisconsin results in additional groundwater level declines of 5 to 9 feet per year.[7]

[7] Waukesha Water Utility operating data.

The dramatic drawdown of the aquifer (an estimated 500 to 600 feet in the confined aquifer since the nineteenth century[8]) is in part attributed to the Maquoketa shale confining layer, a geological feature that limits the recharge of the aquifer by rain and snow (Exhibit 7).

EXHIBIT 7
Hydrogeology of Southeastern Wisconsin



Not all of the St. Peter Sandstone aquifer is confined. Parts of the aquifer are unconfined but located outside the jurisdiction of the City. In the unconfined part of the aquifer in southeastern Wisconsin, groundwater levels have declined more than 100 feet. The largest capacity wells in that area supply the City of Oconomowoc and had an average annual flow of 1.8 mgd.[9, 10] In addition to significant draw down and associated environmental impacts, the installation of more wells to meet the City's needs will undoubtedly result in legal challenges because Wisconsin law protects against municipal withdrawal of large amounts of water from a particular area and transporting that water to other locations for its use. Installation of high capacity wells in the unconfined aquifer would interfere with other communities' and land owners' beneficial use of the water and would expose the City to numerous damage claims from other municipalities and homeowner associations.[11]

The deep aquifer is not an adequate source of supply for the City because pumping exceeds the rate at which the aquifer can be renewed. The quantity of available groundwater is decreasing. The deep aquifer is not a reliable, adequate source of supply for the future.

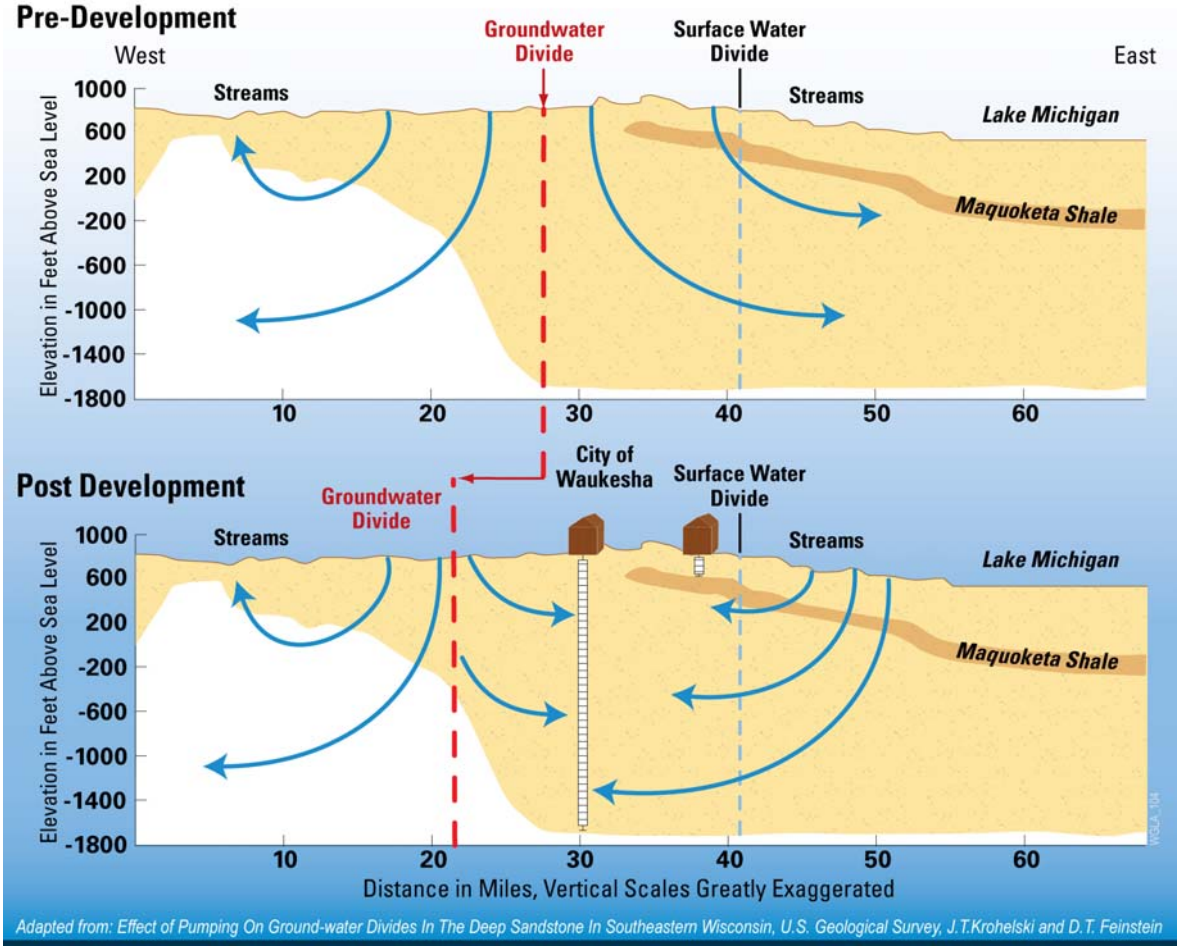
Waukesha's Water Supply Linkage to Great Lakes Basin. The drawdown of the deep sandstone aquifer and continued pumping are also having a measurable impact on the Great Lakes Basin. The U.S. Geological Survey (USGS), the Wisconsin Geological and Natural History Survey (WGNHS), and other leading researchers in Wisconsin and Illinois have conducted extensive modeling and studies of the deep sandstone aquifer. USGS recently determined that most of water withdrawn from southeastern Wisconsin over the last 136 years was not derived from groundwater storage but rather from captured baseflow.[12] Baseflow is groundwater that under natural conditions would discharge to streams and lakes, including Lake Michigan. Because of pumping, groundwater has been diverted to wells instead of supplying water to surface water resources.

Groundwater pumping has also moved the groundwater divide—the boundary that defines the flow of groundwater toward Lake Michigan or to the Mississippi River—farther to the west (Exhibit 8). The natural hydrogeology has been altered so that the deep aquifer, which

[8] SEWRPC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, p.102–103.
[9] SEWRPC. 2008. *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Chapter II, p. 107
[10] Utility operating data, City of Oconomowoc. 2009.
[11] State v. Michaels Pipeline Construction Inc., 63 Wis.2d 278, 292 (1974).
[12] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin.*

historically fed the Lake Michigan Basin with groundwater, now draws water from the Lake Michigan Basin. Even though the City's wells are outside the Great Lakes surface water divide, they withdraw water from both the Mississippi River Basin and the Great Lakes Basin. The USGS estimates that 30 percent of the 33 mgd of water pumped by the deep aquifer wells in southeastern Wisconsin originates from inside the Lake Michigan Basin.[13]

EXHIBIT 8
Flow of Groundwater in the St. Peter Sandstone Aquifer



Reducing or eliminating pumping of the deep sandstone aquifer would have a significant positive effect on groundwater levels. Measurements taken after other communities have replaced deep aquifer groundwater supplies with a Lake Michigan supply indicate recovery of the aquifer. In areas of northeastern Illinois, where groundwater withdrawal has ceased because communities have converted from the deep St. Peter Sandstone aquifer to a Lake Michigan supply, groundwater levels at former pumping centers recovered more than 100 feet.[14] For southeastern Wisconsin, the USGS estimated that if all pumping of the deep

[13] D. T. Feinstein, USGS. October 2006.*Where do the deep wells in southeastern Wisconsin get their water?*

[14] S. L. Burch. 2002. *A Comparison of Potentiometric Surfaces for the Cambrian-Ordovician Aquifers of Northeastern Illinois, 1995 and 2000.* Illinois State Water Survey Data/Case Study 2002-02.

aquifer ceased in year 2000, the aquifer would similarly recover over this century. Specifically, USGS estimates that :[15]

- To replace 50 percent of the water drawn out of storage, it would take 13 years for the shallow portion and 9 years for the deep portion of the aquifer to recover.
- To replace 90 percent of the water drawn out of storage, it would take 100 years for the shallow portion and 70 years for the deep portion of the aquifer to recover.

Based upon the available scientific evidence, it has been shown that the City's groundwater supply is derived in part from groundwater that is interconnected hydrologically to the Lake Michigan Basin. Ceasing groundwater pumping of the deep aquifer will reduce amount of groundwater withdrawn from the Lake Michigan Basin. [16]

Deep Aquifer Groundwater Quality. As water is pumped from greater depths, naturally occurring contaminants, primarily radium and total dissolved solids (TDS), are present in progressively high concentrations and require removal to meet drinking water standards. The City's groundwater supply has radium levels up to three times the United States Environmental Protection Agency's (USEPA's) drinking water maximum contaminant level (MCL) of 5 picocuries per liter (piC/L). The naturally occurring radioactive isotopes radium-226 and radium-228 are present in the aquifer because of parent elements in the sandstone. The isotopes are known to be carcinogenic. The concentration of radium in the City's groundwater supply is as high as 15 piC/L, which is among the highest levels in the country.

To provide drinking water that is compliant with regulations, the City developed an interim plan with the WDNR that includes blending radium-free groundwater from three new shallow wells with water from some deep wells with high radium. The interim plan includes adding radium removal facilities at 2 deep wells with combined capacity of 5 mgd. The City has until 2018 to complete the capital investments needed for full compliance with the radium standard, which it proposes to do with Great Lakes water. Even as the City is engaged in the rigorous application process for a Great Lakes diversion with return flow, it is developing a new 4-mgd shallow aquifer wellfield to provide firm capacity of radium-compliant water. The new wells will help the City increase the reliability of its system to meet radium regulations in the short term.

USEPA regulates TDS, hardness, and salts as a secondary drinking water standard. The standard for TDS is 500 mg/L. For the City of Waukesha, continued use of the deep aquifer eventually will require treatment to remove salts. As groundwater levels decline, the concentration of TDS increases. Currently, TDS concentrations in the City's wells range from 300 to 1,000 mg/L. To mitigate high TDS concentration, wells can be partially blocked to avoid high TDS water. Plugging reduces well capacity by as much as 35 percent, as evidenced by modifications to the City's Well No. 9.[17] When TDS concentrations are consistently at 1,000 mg/L greater, it is common practice to treat the water to remove salts. Desalting, or desalination, is a costly and energy-intensive process that would be necessary for the long-term continued use of the deep wells.

[15] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin.*
[16] Ibid.
[17] Waukesha Water Utility operating data for Well 9, 2000 and 2006.

Cumulative Impacts of **Deep St. Peter Sandstone Aquifer** Pumping. The City's deep aquifer pumping contributes to the following cumulative impacts:

- Groundwater level decline on the order of 5 to 9 feet per year
- Baseflow reduction of 12 percent to surface water resources in the region, as water is drawn toward deep wells[18]
- Reversal of the natural flow system that has caused more than 10 times the water that once flowed east toward Lake Michigan through the deep aquifer in southeastern Wisconsin to now converge from all directions on pumping centers19
- Diversion of as much as 30 percent of the water replenishing the deep aquifer from the Waters of the Basin20
- Ultimate discharge of water from the Great Lakes Basin to the Mississippi River Basin

1.3.2 Shallow Troy Bedrock Valley Aquifer

The City draws about 13 percent of its water supply from the shallow aquifer (Troy Bedrock Valley formation) overlying the Maquoketa shale. That formation is a source of water supply for the Village of Mukwonago and the City of Muskego; it is also hydraulically connected to sensitive environmental resources including the Vernon Marsh Wildlife Area, Pebble Brook (a Class II trout stream), and Pebble Creek. Because of quantity and quality concerns with the deep aquifer, the City has considered the shallow aquifer as a greater source of supply.

To estimate the impacts of the City significantly increasing its withdrawal from the shallow aquifer, hydrogeologic modeling was conducted with the Troy Bedrock Valley Aquifer Model.[21] The model predicted groundwater level draw down and the baseflow reduction index if additional City wells are in service. Baseflow is groundwater that discharges to, or feeds, surface water bodies. The groundwater discharge is the inflow that keeps surface waters flowing during dry periods. Estimating the loss of baseflow from groundwater pumping is critical to understanding whether the shallow aquifer is a sustainable water supply. To quantify impacts on baseflow, a baseflow reduction index was used in regional water supply planning studies.[22, 23]

$$\text{baseflow reduction index} = [(\text{net baseflow}_{2005} - \text{net baseflow}_{1900})/\text{net baseflow}_{1900}] \times 100$$

where net baseflow is $\text{surface water flow}_{out} - \text{surface water flow}_{in}$.

Although the wells needed to meet the City's demands in the model were spread over an extensive area and located at least 1,300 feet from sensitive water resources, additional shallow aquifer withdrawal resulted in severe drawdown at the wells of up to 50 to 100 feet

18 USGS. Groundwater in the Great Lakes Basin: The Case of Southeastern Wisconsin.

19 D. T. Feinstein, USGS, October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*

20 Ibid.

21 SEWRPC. January 2010. *Southeastern Wisconsin Regional Planning Commission Report No.188.*

22 SEWRPC. *A Regional Water Supply Plan for Southeastern Wisconsin,* pp 38–50.

23 Douglas S. Cherkauer. 2009. *Groundwater Budget Indices and their Use in Assessing Water Supply Plans for Southeastern Wisconsin,* Technical Report 46, Preliminary Draft. Department of Geosciences, University of Wisconsin—Milwaukee, p. 11.

and reduction of baseflow to surface waters ranging from 17 to 340 percent.[24] For reference, the historical baseflow reduction index for Waukesha County from 1920 to 2000 is less than 10 percent.[25]

Shallow Aquifer Groundwater Quality. Groundwater from the shallow aquifer requires treatment to meet secondary drinking water standards of 0.3 mg/L for iron, 0.05 mg/L for manganese, and primary standard of 10 ppb for arsenic. Given the results of the Troy Bedrock Valley aquifer modeling, there is also evidence that both the Fox River water and groundwater could be impacted by contaminants from septic waste disposal systems that would be drawn into shallow wells. To address these contaminants, conventional surface water treatment is needed to provide safe drinking water.

Expansion of the Troy Bedrock Valley aquifer supply is not a reasonable water source because withdrawing the quantity of water needed by the City would have a devastating cumulative impacts on state-protected water resources.

Cumulative Impacts of Shallow Troy Bedrock Valley Aquifer Pumping. Additional shallow aquifer pumping by the City would contribute to the following cumulative impacts:

- Significant decline of groundwater levels
- Baseflow reduction indices ranging from 17 to 340 percent for surface waters including the Vernon Marsh Wildlife Area and the Pebble Brook Class II trout stream
- Over 400 existing private wells could be impacted by the City pumping as little at 6.4 mgd from the shallow aquifer to meet the public water system demand26

1.3.3 Water Conservation Practices

Water savings from conservation is another source of water supply. Based on the effectiveness of current water conservation measures and projected water use across various customer classes over the water supply planning period, and beyond, it is estimated that an additional 10 percent water savings may be gained through conservation. This volume, approximately 1 mgd, is not sufficient to offset the future water demands.

1.3.4 Lake Michigan

The purpose of the Compact is to encourage adaptive water management and conservation of Great Lakes Basin (Basin) water resources. The Compact is designed to protect, conserve, restore and improve the Waters and Water Dependent Natural Resources of the Basin. The City of Waukesha may be successful in an application for a Lake Michigan diversion if the following conditions of the Compact are met:

- The diverted water will be used solely for the City's public water supply because the City is without adequate supplies of potable water.
- The portion of diverted water that is returned to the Waters of Basin is maximized and the portion of the returned water that is from the Mississippi River basin is minimized.

[24] *Results of Groundwater Modeling Study Shallow Aquifer Groundwater Source, Fox River & Vernon Marsh Area, Waukesha Water Utility*, RJN Environmental Services, April 2010.

[25] Cherkauer, p. 13.

[26] RJN Environmental Services.

- The City does not have a reasonable water supply alternative within the Mississippi River basin, including conservation of existing groundwater supplies.
- The diversion with return flow does not endanger the integrity of the Basin ecosystem.

In preparation for the passage of the Great Lakes Compact, the City participated in a case study funded by the Great Lakes Protection Fund. The study—*Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply*—arrived at several critical conclusions about a potential diversion for the City. Chief among them was that changing sources from the current groundwater supply to a withdrawal from Lake Michigan would improve the groundwater resources of the Great Lakes Basin through ceasing groundwater pumping. Further, the Lake Michigan withdrawal has no measurable effect on the Basin.[27]

Cumulative Impacts of a Lake Michigan Supply. Switching from a groundwater to a Lake Michigan supply would have the following cumulative impacts:

- Assist in the recovery of both surface water and groundwater resources.
- Assist in the restoration of the natural flow system wherein the deep aquifer feeds the Waters of the Great Lakes.
- Eliminate the diversion of water from the Lake Michigan groundwatershed to the Mississippi River Basin.
- Result in no impact on Lake Michigan water level for the proposed diversion of 10.9 mgd with return flow.
- Prevent radium in wastewater treatment plant sludge from being discharged into the environment

1.3.5 Combined Lake Michigan and Groundwater

To limit the Great Lakes diversion to the smallest reasonable quantity, a combination of Lake Michigan water and shallow aquifer water was evaluated by the City. An alternative with deep aquifer water and Lake Michigan water was not developed. One reason is that Illinois and Wisconsin are both supportive of the goal of eliminating the use of the deep St. Peter Sandstone aquifer. The goal is to enhance recovery of the deep aquifer. Another reason for not combining water sources is related to the practical public water system operating challenges of continuously meeting water quality regulations and system pressure requirements. See Section 4 for additional discussion. Under the shallow aquifer/Lake Michigan supply alternative, return flow to the Great Lakes Basin would consist of both Lake Michigan water and Mississippi River Basin groundwater. It is not evident that this alternative meets the intent of the Compact to protect the Basin ecosystem by minimizing the return of water from outside the Great Lakes Basin.

[27] Great Lakes Protection Fund, *Case Study Report – Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply*, August 2003, p. ES-5.

2. Water Supply Service Area Planning

2.1 Delineated Water Service Area

To prepare a long-term Water Service Area Supply Plan, the City obtained a delineation of a 20-year water supply service area attendant to the Waukesha Water Utility. The delineation was prepared by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) for use in developing a water supply plan in support of an application for a Lake Michigan water source. Under ch. NR 121, Wis. Adm. Code, SEWRPC is granted authority to delineate the proposed water supply service area for the public water supply systems—including the City of Waukesha—in its planning area. (§ 281.348 (3)(c)(9)(cm), Wis. Stat.)

Exhibit 9 shows the proposed delineated service area and other land use plan information. Eighty-five percent of the planned water service area is already developed or designated as natural and environmentally sensitive areas to be preserved in a manner consistent with the regional land use plan.[28] Fifteen percent of the planned water service area would be available for future development.

2.2 Water Service Area Population Projections and Water Demand Forecasts

SEWRPC prepared population projections for the City of Waukesha water supply service area.[29, 30] To account for economic uncertainty, SEWRPC prepared regional population projections assuming low, intermediate, and high growth scenarios. SEWRPC estimated a Waukesha water supply service area population of 88,500 in 2035 under an intermediate growth scenario. The estimated "ultimate population" for the water supply service area is 97,400. The ultimate population projection represents a condition beyond the SEWRPC 2035 planning horizon. It occurs when all land available for development has been developed in a manner consistent with the regional land use plan. For water supply planning purposes, the City assumed the ultimate population will be reached in 2050. Exhibit 10 shows the population projections. The interpolated projections for the 20-year planning period (2010–2030) are also depicted. (§ 281.348 (3)(c)(3m), Wis. Stat.)

SEWRPC prepared future water demand forecasts based on intermediate population projections. The demand forecasts considered water service area demographics, land use plans, and water use data from years 2000, 2004, and 2005.[31] The 2035 water demand forecasts were prepared using multiple factors including implementation of water conservation practices. Water conservation measures were estimated to result in 4 to 10 percent average day demand water savings, depending on the type of water supply.[32] For the Waukesha water service area, a 10 percent average day demand reduction was selected and factored into the water demand forecasts. This reduction represents an increase in water conversation effectiveness over and above the current levels of water conservation. Exhibit 11 summarizes the 2035 water demand forecasts.

[28] SEWRPC. 2008. Preliminary Draft, *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Chapter I, p. 5-6.

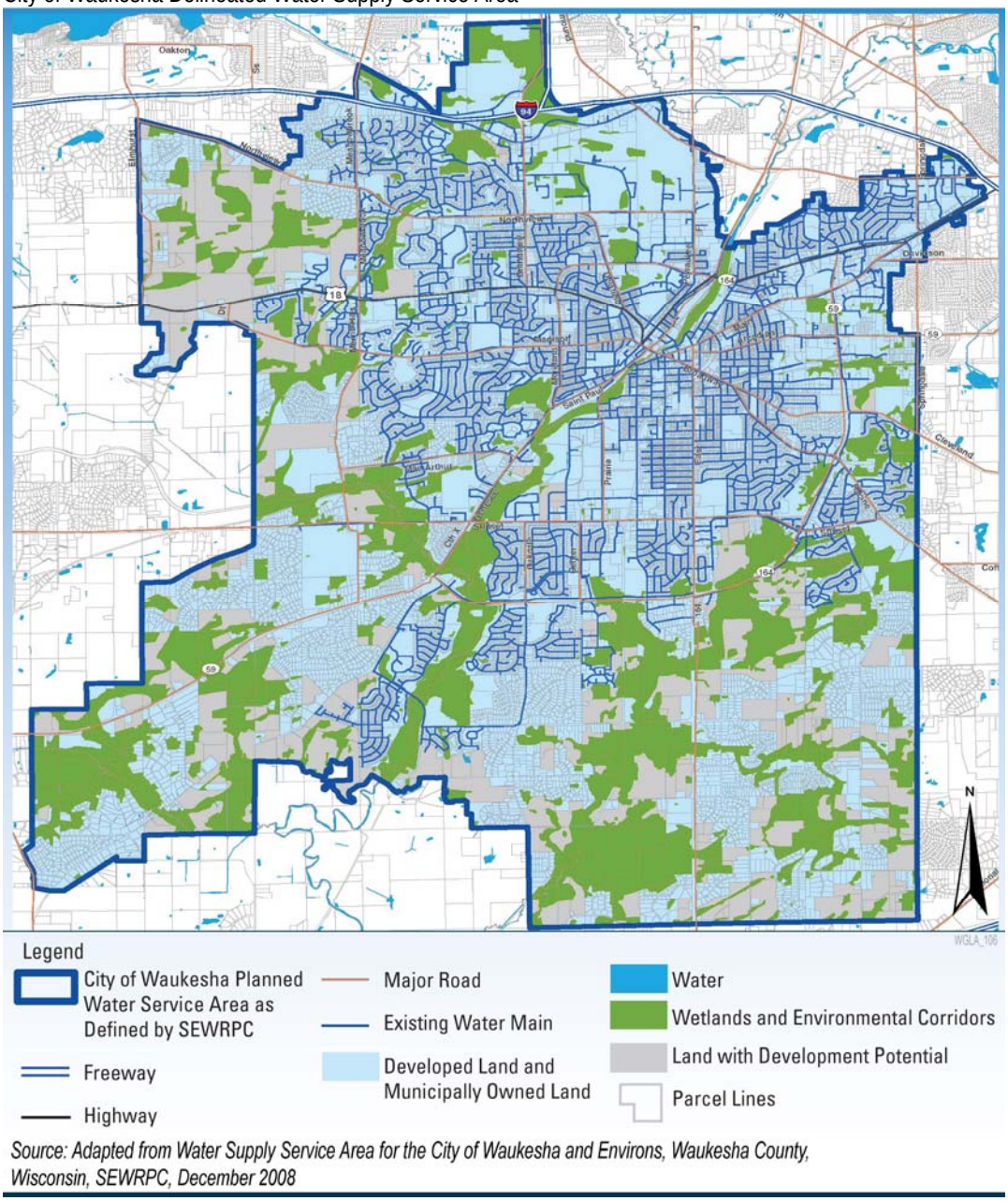
[29] Ibid. Chapter IV, p. 52.

[30] Kenneth R. Yunker, P.E., SEWRPC/Executive Director. March 17, 2009. Letter to Steven Crandall Community Development Director, City of Waukesha.

[31] SEWRPC. 2008. Chapter IV, p.7.

[32] Ibid., Chapter IV, p. 39.

EXHIBIT 9
City of Waukesha Delineated Water Supply Service Area



Source: Adapted from Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin, SEWRPC, December 2008

EXHIBIT 10
City of Waukesha Water Supply Service Area Population Projections

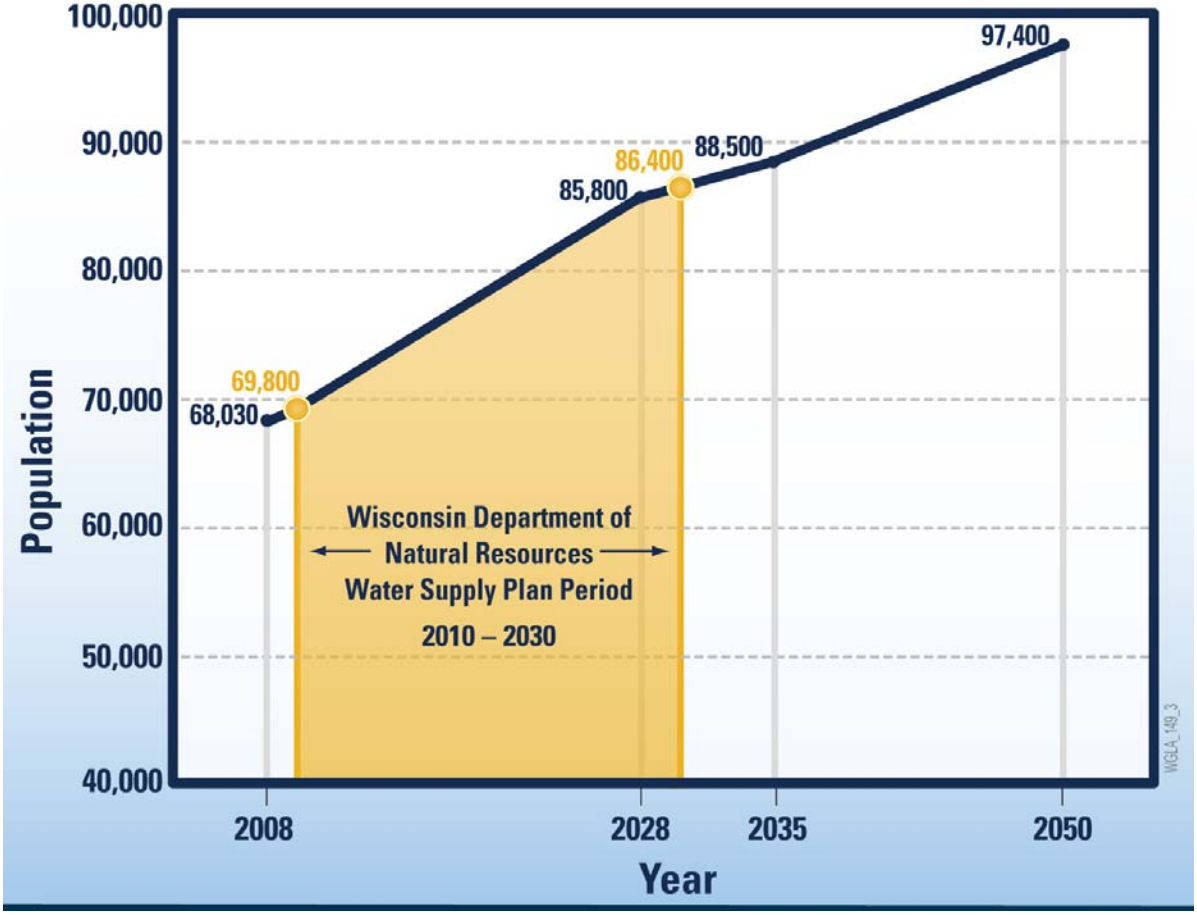


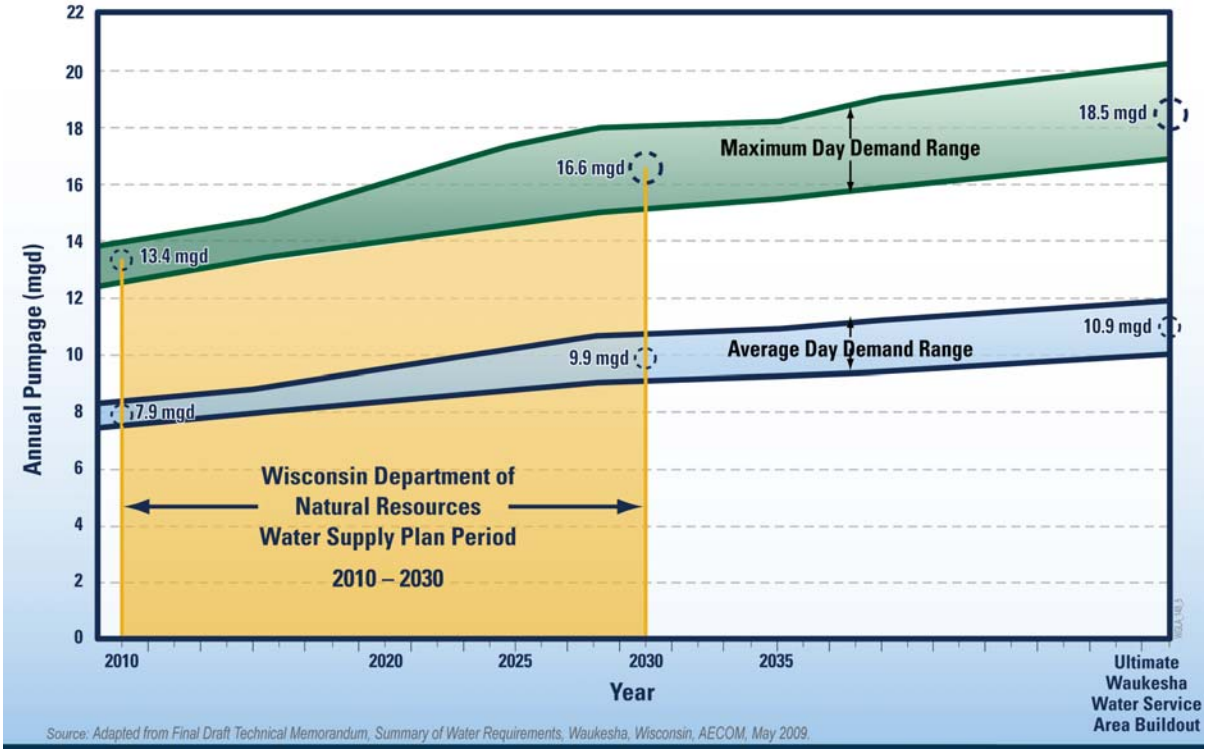
EXHIBIT 11
2035 Water Demand Forecasts

Water Use	Value
2035 Average Daily Pumpage Including 5 percent allowance for firefighting flow and unaccounted for water and 10 percent additional water conservation	9.8 mgd
2035 Average Daily Demand Including 10 percent additional water conservation	9.3 mgd
2035 Average Daily Demand Without water conservation	10.2 mgd
2035 Maximum Day Demand Based on 1.37 peaking factor and including 10 percent additional water conservation	13.7 mgd
2035 Per Capita Water Use Based on 2035 Population of 88,500	111 gallons/capita day

Preliminary Draft *Planning Report on Regional Water Supply Plant for Southeastern Wisconsin*, Chapter IV, pp. 52, 53, 72

The City used the SEWRPC planning projections, 38 years of Waukesha water system operating data, the service area land use plan, and City's water conservation and protection plan to develop water demand forecasts for the ultimate water service area population of 97,400. Ranges of average- and maximum-day demands, developed by considering greater variability in population and water conservation were prepared, as shown in Exhibit 12. The interpolated demand forecasts for the 20-year planning period (2010–2030) are also depicted. (§ 281.348 (3)(c)(3), Wis. Stat.)

EXHIBIT 12
City of Waukesha Water Supply Service Area Demand Projections



Two water demand factors vary between the SEWRPC and City forecasts. First, the City's amount of unaccounted-for water and firefighting flow historically equals 4 to 7 percent of total water pumpage. For long-range planning, the City used a realistic, but conservative value of 7 percent, in lieu of the 5 percent value used by SEWRPC on the basis of Waukesha's performance in 2000, 2004, and 2005.

Second, the City used a more conservative peaking factor to estimate maximum day demand. A peaking factor a 1.68 was used after consideration of several decades of Waukesha system performance and the inherent uncertainty of very long-range water supply plans that need to address potential impacts of climate change, including drought. The peaking factor of 1.37 used by SEWRPC was based on peak flows in 2000, 2004, and 2005. Exhibit 13 tabulates the demand values.

EXHIBIT 13
Ultimate Water Service Supply Area Water Demand Forecasts

Water Use	Value
Ultimate Average Daily Including 7 percent allowance for firefighting flow and unaccounted for water and continued water conservation	10.9 mgd
Ultimate Average Daily Demand Without water conservation	12.0 mgd
Ultimate Maximum Day Demand Based on 1.68 peaking factor and including continued water conservation	18.5 mgd
Ultimate Per Capita Water Use Based on Ultimate Population of 97,400	112 gallons/capita/day

Final Draft Technical Memorandum, Summary of Water Requirements, Waukesha, Wisconsin, AECOM, May 2009

2.3 Waukesha Water Consumptive Use

"Consumptive use" means a use of water that results in the loss of or failure to return some or all of the water to the basin from which the water is withdrawn because of evaporation, incorporation into products, or other processes. (§ 281.346(1)(e), Wis. Stats.). Public water suppliers can calculate their consumptive use coefficients following the USGS Winter Base-Rate Method.[33] Based on water utility data over the past 10 years, the City of Waukesha annual average consumptive use is 8 percent. By comparison, the USGS found consumptive use in the Great Lakes can range as high as 74 percent for the domestic and public sector, with an average between 12 to 15 percent.[34, 35]

3. Alternative Plans for Water Supply

The City and others have studied extensively the water resources in the Waukesha area.[36, 37, 38] Based on this work the City developed alternative plans to meet the needs of the water supply service area. The alternative plans are consistent with the applicable Regional Water Supply Plan prepared by SEWRPC. (§ 281.348(8), Wis. Stat.) Further, the alternative plans assume the City continues water conservation and efficiency measures. (§ 281.346 (5m) d, Wis. Stat.)

Because a Great Lakes supply is among the alternatives considered, plans were evaluated on the basis of the following criteria (§ 281.348(4), 281.348 (5), Wis. Stat.):

- Environmental impact to the Waters of the Great Lakes Basin
- Protection of public health

[33] USGS, Kimberly H. Shaffer. 2009. Scientific Investigations Report: 2009-5096.

[34] USGS. 2008. Consumptive Water Use in the Great Lakes Basin. Fact Sheet 2008-3032, page 3.

[35] USGS. 2007. *Consumptive Water Use Coefficients for the Great Lakes Basin and Climatically Similar Areas.* Scientific Investigations Report 2007-5197, page 25.

[36] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*

[37] SEWRPC. 2008.

[38] Cherkauer. 2009.

- Long-term sustainability to provide the public with adequate supplies of potable water for generations
- Implementability (infrastructure and land requirements, legal issues, operational complexity and public impact issues)

Costs of the alternatives were also estimated. The cost estimates assume that existing water storage and distribution system infrastructure will be used to the extent practicable. (§ 281.348(6), Wis. Stat.)

3.1 Previous Studies of Water Supply Alternatives

Extensive studies have investigated various water supply alternatives for the City of Waukesha. The results and conclusions from a few of those studies are summarized below.

3.1.1 Future Water Supply Study

In March 2002, the City of Waukesha Water Utility completed a future water supply study.[39] Stakeholders in this study included representatives from the water utility, City of Waukesha, WDNR, SEWRPC, USGS, the WGNHS, and the University of Wisconsin–Madison. The study looked at 14 water supply sources and combinations of them:

- Deep aquifer near Waukesha (confined)
- Deep aquifer west of Waukesha (unconfined)
- Shallow groundwater south of Waukesha
- Shallow groundwater west of Waukesha
- Dolomite aquifer
- Fox River
- Rock River
- Lake Michigan
- Dam on the Fox or Rock River
- Waukesha quarry
- Waukesha springs
- Pewaukee Lake
- Milwaukee River
- Wastewater reuse

Nine water supply sources were eliminated for the reasons listed in Exhibit 14.[40]

The water supply alternatives that passed the initial screening process included the following:

- Deep confined aquifer
- Deep unconfined aquifer
- Shallow groundwater near Waukesha
- Shallow groundwater and deep confined aquifer
- Lake Michigan

These remaining alternatives, and combinations of them, were evaluated by a broad group of stakeholders using the following criteria:

- Reliability as a long-term, high-quality water supply
- Regulations, environmental impacts, and land and legal requirements
- Political issues and public acceptance
- Operational and maintenance requirements
- Schedule for implementation
- Infrastructure requirements

[39] CH2M HILL with Ruekert & Mielke. *Future Water Supply Study*, 2002.
[40] Ibid.

EXHIBIT 14
Water Supply Alternatives Eliminated

Potential Water Supply Source	Primary Reason for Not Being a Reasonable Alternative
Dolomite Aquifer	Insufficient water in the aquifer to meet the needs of the City of Waukesha.
Fox River	Inability to provide a reliable supply during dry periods, when public water supply is most needed.
Rock River	Inability to provide a reliable supply during dry periods, when public water supply is most needed.
Dam on the Fox or Rock River	Environmental impacts, regulatory issues, and public/property concerns.
Waukesha Quarry	Inadequate supply, water quality contamination potential, used for other purposes.
Waukesha Springs	Insufficient water in the aquifer to meet the needs of the City of Waukesha.
Pewaukee Lake	Insufficient water to meet the needs of the City of Waukesha, adverse environmental impacts, property owner concerns.
Milwaukee River	Poor quality, environmental impacts.
Wastewater Reuse	Public health and perception, water quality concerns, treatment requirements, limited supply, seasonal demand, regulatory issues.

A brief summary of the results follows.[41]

Continued use of the deep confined aquifer (current water supply for Waukesha) was ranked lowest because:

- It is not sustainable over the long term due to drastically declining water levels and water quality requiring extensive treatment (radium and total dissolved solids removal)
- Negative environmental impacts to the deep aquifer, shallow aquifers, surface water and hydrologically connected waters of the Great Lakes Basin
- Potential negative public health impacts from radium and high dissolved solids in the water
- It also had the highest cost for facilities and long term operations and maintenance

The deep unconfined aquifer alternative, far west of Waukesha, also was ranked low because:

- Negative impacts to the surrounding groundwater and surface water environment due to groundwater table drawdown and water budget depletion
- Negative impacts to other water users currently using this source
- Poor public acceptance and potential lawsuits
- Extensive infrastructure requirements due to the distance from Waukesha
- High costs for facilities and long term operations and maintenance

With the deep aquifer alternatives ranking lowest, the Future Water Supply Study report recommended further evaluation of the highest ranked alternatives:

- Lake Michigan

[41] Ibid.

- Shallow aquifer sources

Key recommendations relating to the Lake Michigan alternative included evaluating diversion permit requirements and identifying a Lake Michigan water provider. The alternatives analysis noted that the Lake Michigan alternative provided the most reliable and highest quality source of water for Waukesha, a reasonable water supply.

For the shallow aquifer alternatives, the report recommended evaluating sustainable capacities from the aquifers, environmental impacts of extracting additional shallow groundwater, land issues, and impacts on other shallow aquifer users. Evaluation of these items was not in the scope of the Future Water Supply study. However, subsequent reports addressed these issues.[42]

3.1.2 SEWRPC Regional Water Supply Plan

SEWRPC is charged by law with making and adopting a comprehensive plan for the physical development of the region. In 2008, SEWRPC released a draft report titled, *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*. This plan is an extensive evaluation of water supply alternatives for the seven-county area, including the City of Waukesha, to year 2035.

Water supply alternatives were evaluated on the basis of five overall objectives:

1. Support of existing land use patterns
2. Conservation and wise use of the surface water and groundwater supplies
3. Protection of public health, safety, and welfare
4. Economical and efficient systems
5. Responsive and adaptable plans

Each objective had several sub-objectives or standards. Two key standards under Objective 2 were as follows:

- Manage the use of the deep and shallow aquifers so as to minimize ecological impacts on the surface water system of the region.
- Use groundwater and surface water for water supply purposes in a manner that minimizes adverse impacts to the water resources, including lakes, streams, springs, and wetlands.

Similar to the Future Water Supply Study, the SEWRPC study screened alternative water supplies and ultimately identified similar water supply alternatives. The water supply alternatives evaluated for the region included the following:

- Lake Michigan
- Shallow aquifers
- Deep aquifer
- Shallow aquifers and artificial recharge using rainwater and treatment plant effluent
- Deep aquifer and artificial recharge using treated Lake Michigan water
- Combinations of these alternatives

[42] SEWRPC. 2008.

The Future Water Supply Study did not evaluate artificial aquifer recharge. This alternative assumes that the shallow aquifer will be artificially recharged with rainwater infiltration facilities, or that treated wastewater effluent will be artificially recharged into the shallow aquifer. By artificially increasing the amount of water infiltrating into the shallow aquifer, surface water baseflow reduction can be decreased. However, SEWRPC noted several issues and concerns:

- WDNR regulations do not allow using treated wastewater effluent to recharge a potable drinking water aquifer. A high level of treatment would be required for this to be considered. Capital and operating costs would be very high. SEWRPC estimates capital costs of advanced wastewater treatment alone would be $12.6 million for 1 mgd.[43] Transmission mains from the Waukesha wastewater plant to recharge areas would add another $4 million.
- Large land areas are required, with significant costs and public concerns. An important issue is who owns and controls the use on these lands. SEWRPC estimated more than 100 acres would be needed for Waukesha, even if it relies on the deep aquifer for more than half of its water supply.[44]
- The water is more vulnerable to contamination, which might increase the cost of treatment and risk to public health.
- The long-term feasibility of artificial recharge is unknown. Long-term soil permeability for effective recharge might be compromised in the long term. Plugging of the aquifer would reduce effectiveness over time. Restoration or decommissioning of facilities would add to costs.
- Rainfall recharge will be subject to drought constraints.

Because of the issues above, artificial recharge was not considered in this application.

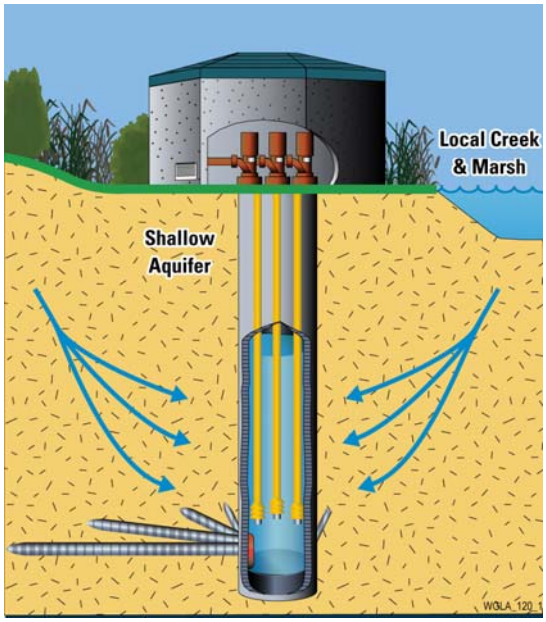
The SEWRPC report did not evaluate a deep unconfined aquifer alternative west of Waukesha, as was done in the Future Water Supply Study. SEWRPC assumed that groundwater supplies will be located within 1 mile of the 2035 water supply service area to minimize public concerns and municipal boundary issues. Even though a groundwater supply may meet all applicable laws and regulations, property owners may institute a common law nuisance claim against the entity withdrawing groundwater. If there is "unreasonable harm" from withdrawing groundwater, the withdrawer may be responsible for mitigating damages.[45]

Installing high capacity wells in the unconfined aquifer west of the Maquoketa shale presents not only a number of logistical but also definite legal problems. Installation of high capacity wells in an unconfined aquifer would create legal challenges, expose the City to numerous damage claims from lake area homeowners and municipalities, and be a source of continuing controversy in the region. The City, for example, could be liable if withdrawal of water caused unreasonable harm through lowering the water table for residential and municipal wells in the area. The City could be liable if its withdrawal of groundwater has a direct and substantial

[43] Ibid.
[44] Ibid.
[45] Ibid.

effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels). Damages could include the cost of new wells, deepening existing wells, the cost of water treatment as water quality declines and replacement of well pumps. Additionally, recently proposed groundwater protection legislation (March 8, 2010) requires not only environmental review of proposed high capacity wells, but also expanding review provisions so that they apply to a proposed high capacity well in a groundwater management area before WDNR approves or develops a groundwater management plan for the area.

EXHIBIT 15
A Shallow Aquifer Water Supply Affects Surface Waters and Groundwater



Extensive groundwater and surface water modeling was conducted in the evaluation of these alternatives. Major findings include the following:

- Increased pumping of the deep aquifer would continue to draw down groundwater levels, creating poorer water quality (higher concentrations of radium and TDS), increasing negative impacts on surface waters and hydrologically connected waters of the Great Lakes Basin, and increasing the water budget deficits.
- Increased pumping of the shallow aquifer would reduce baseflows to surface waters, produces water budget deficits, and has negative environmental impacts on sensitive surface water ecosystems, such as Vernon Marsh, Pebble Brook, and Pebble Creek (a high quality trout stream)[46] near Waukesha.
- Shallow aquifer recharge with rainfall or treated wastewater infiltration would increase baseflows, but would create land use concerns and public health concerns due to contamination, and requires overcoming regulatory hurdles along with constructing extensive, costly facilities.
- A Lake Michigan supply to some straddling communities and counties west of the subcontinental divide (with return flow) would reduce the ecological stress on the deep aquifer, shallow aquifer, and associated waters and water dependent natural resources of the Great Lakes Basin compared to the other alternatives.
- The amount of chlorides and sodium discharged into the environment by home water-softening devices would increase greatly under any groundwater alternative. The SEWRPC report estimated that eliminating groundwater softening by providing Lake Michigan water to some communities east and west of the divide (including Waukesha) would eliminate 5.2 million pounds of chlorides discharged to the Cedar Creek, Milwaukee River, and Lake Michigan environments.[47]

[46] WDNR, Wisconsin Trout Streams, PUB-FH-306, 2002.
[47] SEWRPC. 2008.

- Shallow groundwater supplies are more susceptible to contamination than a Lake Michigan supply. This could result in an increased risk to public health and the need for advanced water treatment facilities that would increase costs, energy use, and green-house gas emissions.

Comparing alternatives under which the City of Waukesha obtains a Lake Michigan water supply with return flow to alternatives using current or new groundwater supplies (deep and shallow aquifers), **SEWRPC concluded that the Lake Michigan alternative "offers advantages related to a greater improvement in the deep aquifer long-term sustainability, reductions in chloride discharges to the surface waters, and improvement in groundwater-derived baseflow inputs to the surface water system." On that basis, SEWRPC issued a draft recommendation for the City of Waukesha to change to a Lake Michigan water supply.** This recommendation was reviewed, and 32 experts in the region concurred.[48]

A 2009 study provided further groundwater/surface water modeling of the SEWRPC alternatives, with projections to 2035.[49] The study evaluated alternatives for the City of Waukesha similar to those in the SEWRPC Regional Water Supply Plan. The analysis showed that a Lake Michigan water supply for the City of Waukesha would improve the deep aquifer water levels and eliminate its negative impacts on the shallow aquifer and surface water baseflow reductions in the whole region. **A Lake Michigan supply to Waukesha would also increase deep aquifer flows to the Lake Michigan Basin, since they are hydrologically connected.**[50, 51, 52] The study issued cautions against Waukesha's or other similarly situated communities reliance on a future groundwater supply west of the divide, noting that groundwater levels and environmental impacts would worsen.[53]

These studies evaluated alternatives up to 2035, only 25 years from now.[54, 55] This is a relatively limited planning period, given that water supply planning typically looks out 50 years and more. A community water supply must be sustainable in the long term, or the capital, operations, and environmental costs of development are too high to make it reasonable. Developing a short-term water supply puts communities at risk of paying twice for the large capital costs involved.

3.1.3 Unconfined Deep Aquifer

The Future Water Supply Study evaluated a deep unconfined aquifer alternative west of Waukesha, but the SEWRPC did not. SEWRPC assumed that groundwater supplies will be located within 1 mile of the 2035 utility service area to minimize public concerns and municipal boundary issues.[56]

Installing high capacity wells in the unconfined aquifer west of the Maquoketa shale presents not only logistical but also definite legal problems. Installation of high capacity

[48] http://www.sewrpc.org/SEWRPC/DataResources/CommissionAdvisoryCommittees/RegionalWaterSupplyPlanningAdv.htm

[49] Cherkauer. 2009.

[50] USGS. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*, March 2007.

[51] D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*

[52] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[53] Cherkauer. 2009.

[54] SEWRPC. 2008.

[55] Cherkauer. 2009.

[56] SEWRPC. 2008.

wells in an unconfined aquifer could result in legal challenges and expose the City to numerous damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. Under Wisconsin law, the City could be liable if its withdrawal of water caused unreasonable harm through lowering the water table for residential and municipal wells in the area (State v. Michaels Pipeline Construction, Inc., 63 Wis.2d 278, 217 N.W.2d 339). The City could be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels). Damages could include the cost of new wells, deepening existing wells, the cost of water treatment as water quality declines and replacement of well pumps. Additionally, groundwater protection legislation has been recently introduced (on March 12, 2010), which would require environmental review of proposed high capacity wells located in a groundwater management area, even before WDNR approves or develops a groundwater management plan for the area. For these and other reasons detailed in the Future Water Study, the unconfined deep aquifer west of the Maquoketa shale was screened out as a reasonable water supply.

As discussed previously, two significant reasons that the deep unconfined aquifer was ranked low in the Future Water Supply study is negative impact to the groundwater and surface water environment and negative impacts on other water communities using the same aquifer. Near Oconomowoc, the deep unconfined aquifer has dropped about 100 feet in the last 100 years.[57] This has occurred with the small pumping demands of Oconomowoc of around 1 to 2 mgd. Increasing the water pumped out of that aquifer by a factor of 5 to 10 or more will have significant impacts not only on the aquifer drawdown and surrounding water ecosystems, but on municipal and private wells in the area.

3.2 Water Supply Alternatives Evaluation

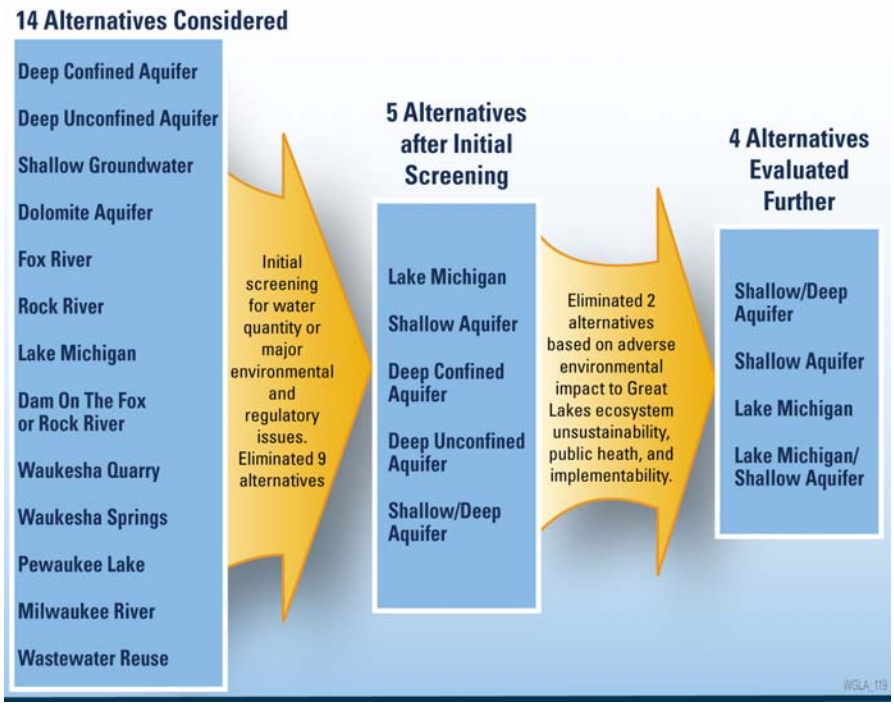
Extensive evaluations of water supply alternatives for the City of Waukesha and the region have previously been conducted. This application requests the use of Lake Michigan water. To be eligible for Lake Michigan water, the City must show that there is no reasonable water supply alternative within the basin the City is located in. For this application, the City compared its Lake Michigan request to the top ranked water supply alternatives. The water supply alternatives were chosen based on the screening done in previous studies.[58] Exhibit 16 summarizes the alternatives screening.

The water supply alternatives include:

- Deep and shallow aquifer
- Shallow aquifer and Fox River alluvium
- Lake Michigan
- Lake Michigan and shallow aquifer

[57] SEWRPC. 2008, Figure 7.
[58] SEWRPC. 2008; CH2M HILL et al. 2002.

EXHIBIT 16
Water Supply Alternative Screening



A general description of each alternative is provided, along with comparisons to the following evaluation criteria:

- **Environmental Impacts**
  - Impact on ground and surface waters of the Great Lakes Basin
  - Impact on ecosystems flora and fauna
  - Greenhouse gas emissions
- **Long-Term Sustainability**
  - Reliability during droughts and infrastructure failures
  - Ability to provide adequate supplies of potable water to the public for generations without negative environmental impacts
- **Public Health**
  - Quality of the water for human consumption
  - Potential for contamination
- **Implementability**
  - Infrastructure requirements
  - Operation and maintenance requirements
  - Land requirements, legal issues, easements, public impact

Each alternative was rated by the following categories:

○ No negative impact
⦿ Minor negative impact
● Moderate negative impact
● Significant negative impact

3.2.1 Water Supply Alternative 1: Continued Use of Deep and Shallow Aquifers

Alternative 1 consists of continued use of the deep St. Peter Sandstone aquifer and shallow Troy Bedrock Valley aquifer south of Waukesha. The future average annual water usage would be 10.9 mgd based on water demand projections (Section 2).

To meet a future maximum day demand of 18.5 mgd, infrastructure would be in place for 7.6 mgd firm capacity from the deep wells and 10.9 mgd from the shallow wells. The maximum capacity from the shallow aquifer would be achieved by relying upon the current 1.2 mgd firm capacity from existing wells (No. 11, 12, 13), plus developing an additional 9.7 mgd firm capacity (capacity with the largest well out of operation) by installing 14 new wells south of Waukesha near Vernon Marsh in the Troy Bedrock Valley aquifer.

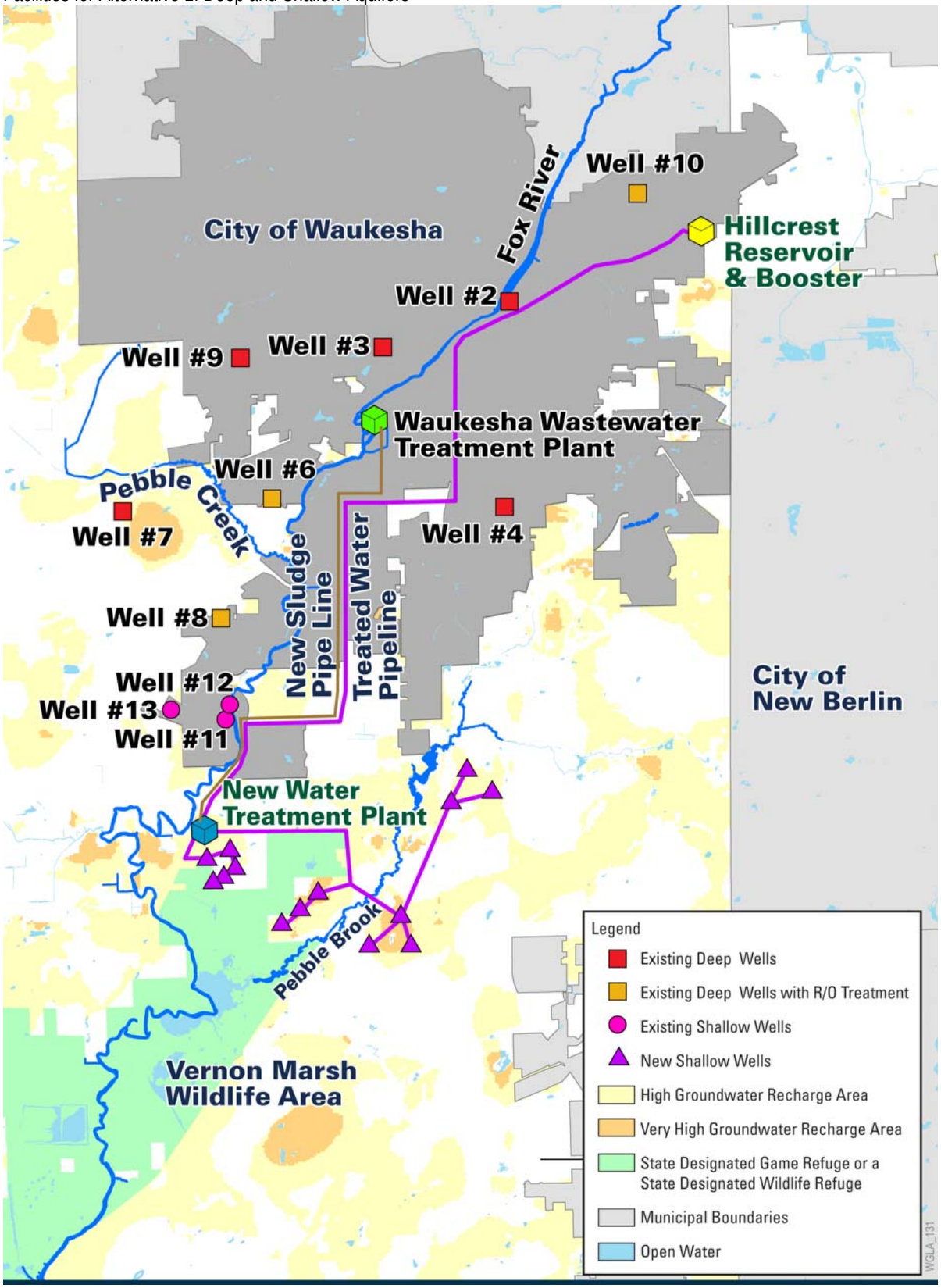
Water from the shallow wells would need to undergo treatment for iron, manganese and microorganism removal. The recent discovery of arsenic in the shallow aquifer at future well sites means arsenic treatment would be required as well. The shallow well water would be pumped from the wells to a new treatment plant. A new pump station would convey treated water to the City of Waukesha and connect with the water distribution system and Hillcrest reservoir, the largest reservoir in Waukesha used as a point to deliver water to the City.

Exhibit 17 shows the facilities for Alternative 1. For the purposes of this alternative, the capacity of the City's deep wells was estimated to decrease 30 percent in the future. Waukesha's deep wells vary in age from 30 to 75 years. Several wells have been abandoned because of contamination and decreasing capacity. One well had TDS concentrations greater than 1,000 mg/L and was rehabilitated to reduce the TDS (blocking off part of the well hole). In doing so, the well capacity was reduced over 35 percent. The Future Water Supply Study warned that many of the wells were not constructed to current well codes and could experience physical failures such as casing leaks or borehole collapse, which would require extensive rehabilitation or replacement.[59]

Capacity is also expected to decrease from the deep wells because the groundwater elevation continues to drop. Currently it is over 600 feet below predevelopment levels. This declining water level causes water quality problems (increased TDS, radium, and gross alpha levels). As a result, treatment would be installed at the three largest deep wells (No. 6, 8, 10) to reduce TDS and radium. Since the deep wells are on small lots, adjacent residential property would need to be purchased and homes demolished to make room for the additional treatment facilities. It was assumed that the three deep wells will have their own treatment facility, and that water from the remaining deep wells and shallow wells will be blended at the Hillcrest reservoir. Treatment to remove TDS would produce a concentrated salt waste stream equal to about 7.5 percent of the water pumped (assuming 25 percent bypass). The lost capacity would be made up with shallow wells. This is consistent with the Future Water Supply Study.[60]

[59] CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*
[60] Ibid.

EXHIBIT 17
Facilities for Alternative 1: Deep and Shallow Aquifers



Environmental Impacts.

Deep Aquifer. Studies have shown that the deep aquifer is hydrologically connected to the waters of the Lake Michigan Basin.[61] Before development, the deep groundwater below southeast Wisconsin flowed toward Lake Michigan. Pumping water from the deep aquifer reduces the amount of water that would flow to the waters of the Lake Michigan Basin, and actually reverses the flow so that it is away from Lake Michigan.[62] The USGS estimates that 30 percent of the 33 mgd of water currently pumped by the deep aquifer wells in Southeast Wisconsin originates from inside the Lake Michigan Basin.[63] The largest pumping center with the highest drawdown is in Waukesha County.[64]

Reducing the amount of water that would have flowed into the Lake Michigan Basin by deep aquifer pumping has negative environmental impacts on the waters of the Lake Michigan Basin. By stopping deep aquifer pumping in Waukesha alone, an improvement in the hydrology and hydrogeology of the waters of the Lake Michigan Basin can be realized.[65]

In addition, water pumped from the deep aquifer removes water that would otherwise be available to local surface water resources. The USGS and WGNHS indicate that 70 percent of water pumped from the deep aquifer would have gone to inland surface waters. The remaining 30 percent originates from inside the Lake Michigan Basin and 4 percent of that is contributed by Lake Michigan.[66] Reducing natural flows to surface waters by pumping the deep aquifer has negative environmental impacts both inside and outside the Lake Michigan Basin.

Adverse environmental impacts are also occurring because of the depletion of the deep aquifer. Recharge is limited for the deep aquifer near Waukesha because of the shale confining layer, causing continued depletion of the aquifer along with increasing TDS and radionuclides. In addition, dropping groundwater levels can expose sulfide minerals to oxygen and increase arsenic levels. This oxygen can also provide conditions for growth of pathogenic microorganisms in wells, which as occurred in a number of deep wells.[67] Changing the physical and biological nature of the aquifer creates negative environmental impacts.

Shallow Aquifer. Pumping the shallow aquifer can cause negative environmental impacts on ground and surface water resources. SEWRPC estimates that about 85 percent of water extracted from the shallow aquifer is diverted or extracted from surface waters.[68] This would negatively affect sensitive and valuable environmental areas near Waukesha, such as Pebble Brook, Pebble Creek (a trout stream), and Vernon Marsh. SEWRPC estimated parts of Vernon Marsh and Pebble Creek could see the baseflow decrease more than 25 percent if the City of Waukesha continues using a combination of deep and shallow groundwater, with artificial recharge.[69] A subsequent study estimated significant baseflow reductions would occur near Waukesha even if only 3.9 mgd of shallow groundwater was pumped and artificial recharge

[61] USGS. March 2007. *Groundwater in the Great Lakes Basin: The Case for Southeastern Wisconsin*; D. T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?*; CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[62] Feinstein. 2006.

[63] Ibid.

[64] Ibid.

[65] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

[66] Feinstein. 2006.

[67] CH2M HILL with Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*

[68] SEWRPC. 2008.

[69] Ibid.

was used.[70] Under Alternative 1, Waukesha would need a maximum of 10.9 mgd of shallow aquifer water without artificial recharge, so the negative impacts to baseflow reduction and groundwater/surface water ecosystems would be much greater.

For this application, the recently completed Troy Bedrock Valley groundwater model[71] was used to simulate shallow aquifer groundwater drawdown and baseflow reduction for Alternative 1. Although a maximum day pumpage of 10.9 mgd may need to be extracted from the shallow aquifer, an annual average well pumpage of 6.4 mgd was the withdrawal amount modeled.

The results on groundwater drawdown are shown in Exhibit 18.[72] The results show significant shallow aquifer drawdown (about 50 feet) near the wells. Water levels would also be lower in a large portion of the Vernon Marsh and near Pebble Brook. A groundwater drawdown of 1 foot is significant in a wetland as it may affect root structures of aquatic plants. In addition, there are many private wells in the drawdown area that could be affected, along with potential contamination from associated septic tanks.

Water extracted from the aquifer reduces the water that would naturally flow to wetlands, lakes and streams (base flow). The model estimated that baseflow would be reduced as shown below with this alternative.[73] This baseflow reduction can have significant negative environmental impacts to the water ecosystems. Not only would groundwater be intercepted and not reach surface waters, under this scenario water also would be drawn from the Fox River.

Resource	Baseflow Reduction (%) from pumping 17 shallow wells for a total of 6.4 mgd
Fox River	142
Pebble Brook	61
Vernon Marsh	7
Mill Brook	29
Pebble Creek	9

Water transmission mains extending from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha, would have environmental impacts during construction. Additional information on the environmental impacts is included in Supplemental Information.

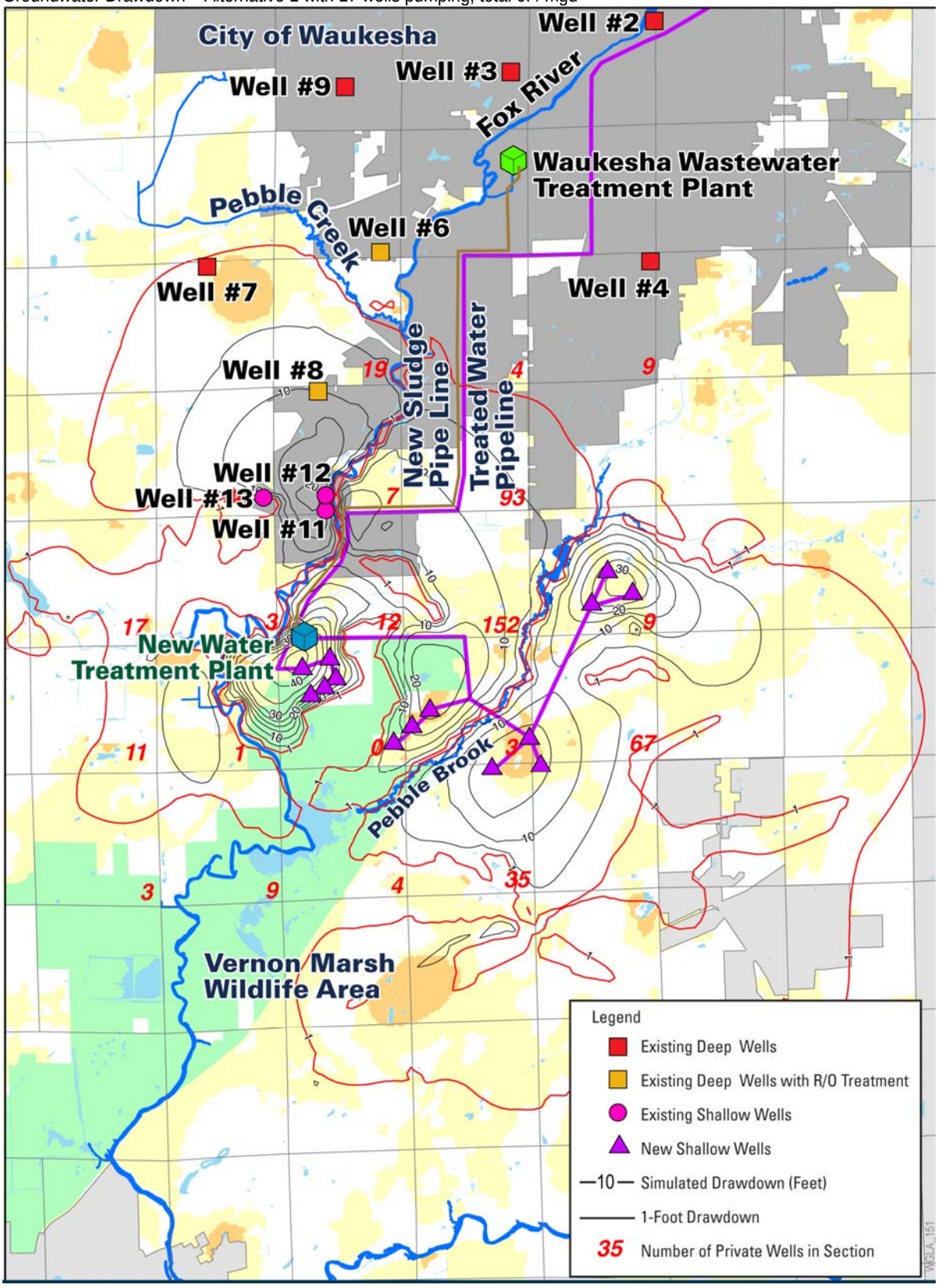
[70] Cherkauer. 2009.

[71] Troy Bedrock Valley Aquifer Model. Memorandum Report Number 188. Prepared by Ruekert & Mielke for SEWRPC. Reviewed by Dr. Kenneth R. Bradbury – Wisconsin Geological and Natural History Survey. January 2010.

[72] RJN Environmental Services, LLC. March 2010. Results of Groundwater Modeling Study Shallow Groundwater Source, Fox River & Vernon Marsh Area. Reviewed by Dr. Kenneth R. Bradbury – Wisconsin Geological and Natural History Survey.

[73] Ibid.

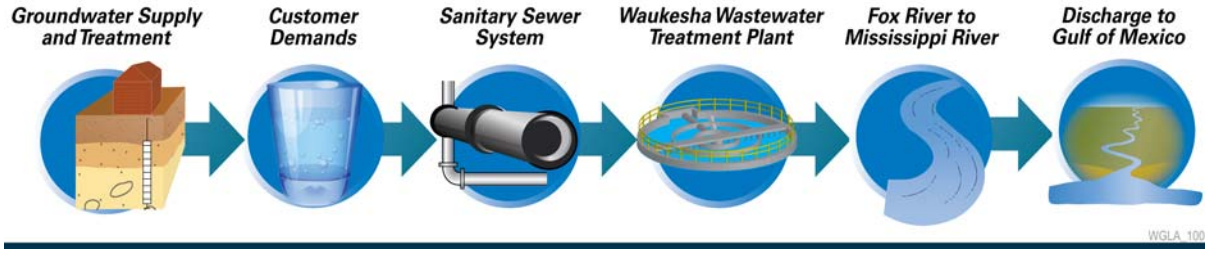
EXHIBIT 18
Groundwater Drawdown – Alternative 1 with 17 wells pumping, total 6.4 mgd



3.2.2 Deep and Shallow Aquifers Combined

Water is not returned to its source when deep or shallow groundwater is pumped and discharged to surface water. Water is transferred out of the Great Lakes and Mississippi river ecosystem and eventually to the ocean (Exhibit 19). This results in less water in the Great Lakes and Mississippi river watersheds and associated negative environmental impacts. One of the decision making standards of the Compact (4.11.1) states "All Water withdrawn shall be returned, either naturally or after use to the Source watershed less allowance for Consumptive Use." Since the deep aquifer and the waters of the Lake Michigan Basin are hydrologically connected, pumping the deep aquifer and discharging the water into the Fox River does not comply with this Compact decision-making standard.

EXHIBIT 19
Groundwater Supply Water Cycle



Both the deep and shallow groundwaters are hard, requiring use of home water softeners. Continued and expanded use of water softeners increases salt discharge into the environment. It is estimated that Waukesha discharges 7.4 million pounds of salt into the Fox River each year from home water softeners. Water use also increases with the use of home water softeners. It is estimated that each household water softener produces 40 gallons of salty wastewater per regeneration. TDS removal treatment concentrates salts that also are discharged into the environment and increases wastewater volumes. Continued use of hard groundwater would increase water and energy use while degrading conservation efforts.

Finally, it is estimated that Alternative 1 would discharge 31,000 tons of greenhouse gases per year (carbon dioxide equivalent) through pumping from aquifers, water treatment, and pumping from the wellfield to Waukesha. That is equivalent to powering about 3,000 homes for a year.[74]

Considering the environmental impacts of Alternative 1, a rating of "significant negative impact" was applied.

Long-Term Sustainability. The City seeks Lake Michigan water because its current water source is not sustainable.

The deep aquifer water levels are very low and dropping. Water quality is degrading and radium and TDS levels are increasing. Two wells have recently been abandoned due to contamination from outside sources. Capacity in some wells is decreasing due to the ever increasing depth that water needs to be pumped from (over 600 feet from the surface now and dropping 5 to 9 feet per year). In order to continue withdrawing water, the existing pumps may need to be replaced with larger and different type (submersible) pumps to draw water from lower levels. This will increase costs and energy.

[74] U.S. Energy Information Administration. http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home

Current deep aquifer pumping could be reduced by using more shallow groundwater. That would slow the drawdown but may not eliminate it. The amount of deep aquifer pumping by other communities (about 75 percent of the total deep aquifer usage in southeastern Wisconsin) would also greatly affect drawdown.

Using the shallow groundwater as a replacement for the deep aquifer pumping would not be sustainable. As described above, pumping for average day water demands result in significant groundwater drawdown and baseflow reduction, causing negative environmental impacts to wetlands, streams, lakes and rivers. This negative impact will increase during drought periods and when water demands are higher. As the shallow aquifer depends on rainwater for recharge, it is less reliable during drought conditions, when water supply is needed most. It is unlikely that the shallow aquifer could provide adequate water for maximum day demands during a drought, and even less likely if it could do so without severe negative impacts to the environment.

The deep aquifer is not significantly affected by drought, since the shale confining layer above the aquifer limits recharge near Waukesha. Having two sources of water is more reliable than having only one.

It should also be noted that treatment requirements for the deep and shallow aquifers would require more water to be pumped because the treatment process itself uses water. This would require more water to be pumped out of the ground to meet demand and thus decrease water efficiency. Treatment of all the water supply in multiple treatment plants is required. This would increase operation and maintenance efforts and costs, plus produce a salty liquid waste stream.

Considering the long-term sustainability of Alternative 1, a rating of "significant negative impact" was applied.

Public Health. The deep aquifer exceeds the radium and gross alpha regulations. While drinking water regulations can be met with proper treatment, if there is a malfunction in the treatment process or if new contaminants appear, the public may be exposed to these contaminants. One of Waukesha's deep wells has already been contaminated from outside sources in recent years and shut down, and another deep well has been shut down due to potential contamination from a nearby landfill. Similar contamination may occur in the future requiring abandoning the wells or installing expensive treatment. The deep wells are all located within City limits, so there are numerous sources of contamination present.

In addition, the deep groundwater is high in TDS, mainly from calcium, magnesium, carbonates, chlorides and sulfate. Home softening takes out calcium and magnesium, but adds sodium. Sodium has been identified as an item to limit if you have certain health conditions such as heart disease. The shallow groundwater is also high in TDS.

Shallow aquifers are more susceptible to contamination than deep confined aquifers and large surface water bodies. Without a confining layer, the porous sand and gravel of shallow aquifers can quickly pass contaminants into the drinking water. Preventing a potential source of contamination (i.e., industry, gas station) from locating near the wellfield is difficult, particularly when the wellfield is located outside of a municipality's borders. The proposed shallow wellfield here will be located outside of the City limits, and, as a result, the City would have limited zoning control to enforce a wellhead protection ordinance to

protect the well. A wellhead protection program is required by WDNR to protect municipal wells from contamination. Buying large tracts of land or trying to influence land use zoning around the wellfield is possible, but costly and the effectiveness is uncertain.

Arsenic was recently detected in a future shallow aquifer wellfield site near Waukesha. The future shallow wells may exceed arsenic regulations and would require treatment. In addition, City pumping of wells located in the shallow could impact private wells. Private wells may run dry or encounter water quality problems due to additional shallow aquifer pumping. If this should occur, new wells or deeper wells would be needed. Exhibit 4-5 shows the number of private wells that may be affected by a shallow wellfield. Private wells are often located near septic systems. These septic systems could be another source of contamination such as pathogenic microorganisms or nitrate, in situations where groundwater pumping pulls the contaminants towards the well.

With the Lake Michigan proposal, the deep aquifer would no longer be used and the potential public exposure to radionuclide and other contaminants would be eliminated. In addition, water resources, private wells and municipalities on groundwater near Waukesha would not be affected if Waukesha obtains a Lake Michigan water supply. Home softening would no longer be needed, and the water would contain much less sodium and TDS than a groundwater supply, making it healthier to consume.

Considering the public health impacts of Alternative 1, a rating of "moderate negative impact" was applied.

Implementability. The City's ability to implement Alternative 1, which requires the installation of 14 new shallow wells, would be difficult for several reasons.

First, Waukesha is part of a groundwater management area, and as a result, more requirements and restrictions could be placed on groundwater development. Additionally, groundwater protection legislation has been recently introduced (on March 12, 2010). The legislation would require environmental review of proposed high capacity wells located in a groundwater management area before WDNR approves or develops a groundwater management plan for the area.

Second, the shallow aquifer wellfield would be installed outside the City's boundaries. Significant land purchase/lease and controls outside the city limits would be required. Residents near the shallow aquifer wellfield have opposed high-capacity wells because of concerns about adequate water supply and impacts to wetlands, private wells, and other environmental resources.

Installation of wells in the unconfined aquifer may create legal challenges and expose the City to numerous damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. The City, for example, could be liable if its withdrawal of water causes unreasonable harm through lowering the water table for residential and municipal wells in the area. The City could also be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels).

If new wells need to be installed in the future because of declining water levels in existing wells or the need to locate wells farther from surface water resources, wells may need to be

located a greater distance from Waukesha. Locating wells further from Waukesha would increase costs, energy usage, and legal/public concerns. The environmental and legal impacts described above would become more severe.

If the new shallow wells can be built, a new water treatment plant would be required to remove iron, manganese, arsenic and microorganisms. If new contaminants are discovered, additional treatment would need to be constructed. A new pump station and transmission pipes are required to convey the treated water to the Hillcrest reservoir in Waukesha and throughout the City. The water treatment plant would be located outside the City limits and require land purchase or lease. The new wells, water plant, and pump station would require ongoing operation and maintenance.

Water transmission mains would need to be constructed from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha. This would require easements, and construction through rural and urban conditions.

Additional treatment for the water still pumped from the deep aquifer would result in significantly increased operation and maintenance requirements. If TDS is removed with reverse osmosis (RO) treatment, it would consist of pretreatment to condition the water, RO treatment with membranes, aeration to remove dissolved gases, and chemical addition for corrosion control and disinfection. It is assumed that the concentrated waste brine and chemical cleaning waste solution can be discharged to the sewer. This may cause TDS increases in the wastewater plant influent. In addition, residential housing would need to be bought and demolished to make room for the treatment facilities at the three well sites. This may require legal condemnation procedures.

Some of the deep aquifer water supply would be softened by RO, but the shallow aquifer supply would still be hard. Blending the different waters before distribution would be required to mitigate water quality issues (red water, corrosion) that could lead to customer complaints. However, this requires additional piping in the water distribution system to blend waters from different sources.

Considering the implementability of Alternative 1, a rating of "significant negative impact" was applied. Exhibit 20 summarizes the criteria for Alternative 1.

EXHIBIT 20
Water Supply Evaluation: Alternative 1

Water Supply Alternative	Environmental Impact	Long-term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●

○ **No negative impact**
⊙ Minor negative impact
◎ Moderate negative impact
● Significant negative impact

3.2.3 Water Supply Alternative 2: Shallow Aquifer and Fox River Alluvium

Alternative 2 uses the shallow aquifer south of Waukesha for Waukesha's entire water supply. The future average annual water usage would be 10.9 mgd based on water demand projections (Section 2). To meet a future maximum day demand of 18.5 mgd, infrastructure would be built

for 4.5 mgd of firm capacity through 4 new wells along the Fox River south of Waukesha, in what is called the Fox River alluvium. Another 12.8 mgd firm capacity would be obtained through 14 new wells in the Troy Bedrock Valley south of Waukesha and adjacent to Vernon Marsh. The remaining 1.2 mgd firm capacity would be obtained from Waukesha's existing shallow wells 11 through 13.

The wells would pump water to a central treatment plant south of Waukesha. The water would be treated for iron, manganese, arsenic and microorganism removal. A pump station and pipelines would convey treated water to the Hillcrest reservoir in Waukesha and through the distribution system. Exhibit 21 shows the facilities for Alternative 2.

Environmental Impacts. Pumping the shallow aquifer can cause negative environmental impacts on groundwater and surface water resources (see Alternative 1 discussion). Alternative 2 would have greater negative environmental impacts than Alternative 1, since almost twice the amount of shallow groundwater would be pumped. The Troy Bedrock Valley aquifer south of Waukesha has several sensitive environmental areas (Vernon Marsh, Pebble Creek). Additional information on environmental impacts is included in Supplemental Information.

For this application, the recently completed Troy Bedrock Valley groundwater model[75] was used to simulate shallow aquifer groundwater drawdown and baseflow reduction for Alternative 2. Although the City may need to extract a maximum day pumpage of 18.5 mgd from the shallow aquifer occasionally, only the annual average well pumpage of 10.9 mgd was modeled to simulate a future average day water demand.

The results on groundwater drawdown are shown in Exhibit 22.[77] The results show significant shallow aquifer drawdown (105 feet) near the wells. Water levels would also be lowered in a large portion of the Vernon Marsh and near Pebble Brook. A groundwater drawdown of 1 foot is significant in a wetland as it may affect root structures of aquatic plants. The model estimated that base flow would be reduced 346 percent to the Fox River and 58 percent to Pebble Brook in this alternative. This would have very significant negative environmental impacts to the water ecosystems and is not sustainable.

Drawdown in the shallow aquifer can be reduced by spreading more wells out over a larger area and reducing the capacity of each well. Exhibit 23 shows the groundwater drawdown if the number of shallow wells increases from 12 to 28 and the wellfield land area is nearly doubled.

[75] Ruekert & Mielke, for SEWRPC. January 2010. Troy Bedrock Valley Aquifer Model. Memorandum Report Number 188. Reviewed by Dr. Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey.

[77] RJN Environmental Services, LLC. March 2010. Results of Groundwater Modeling Study Shallow Groundwater Source, Fox River & Vernon Marsh Area. Reviewed by Dr. Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey.

EXHIBIT 21
Facilities for Alternative 2: Shallow Aquifer and Fox River Alluvium

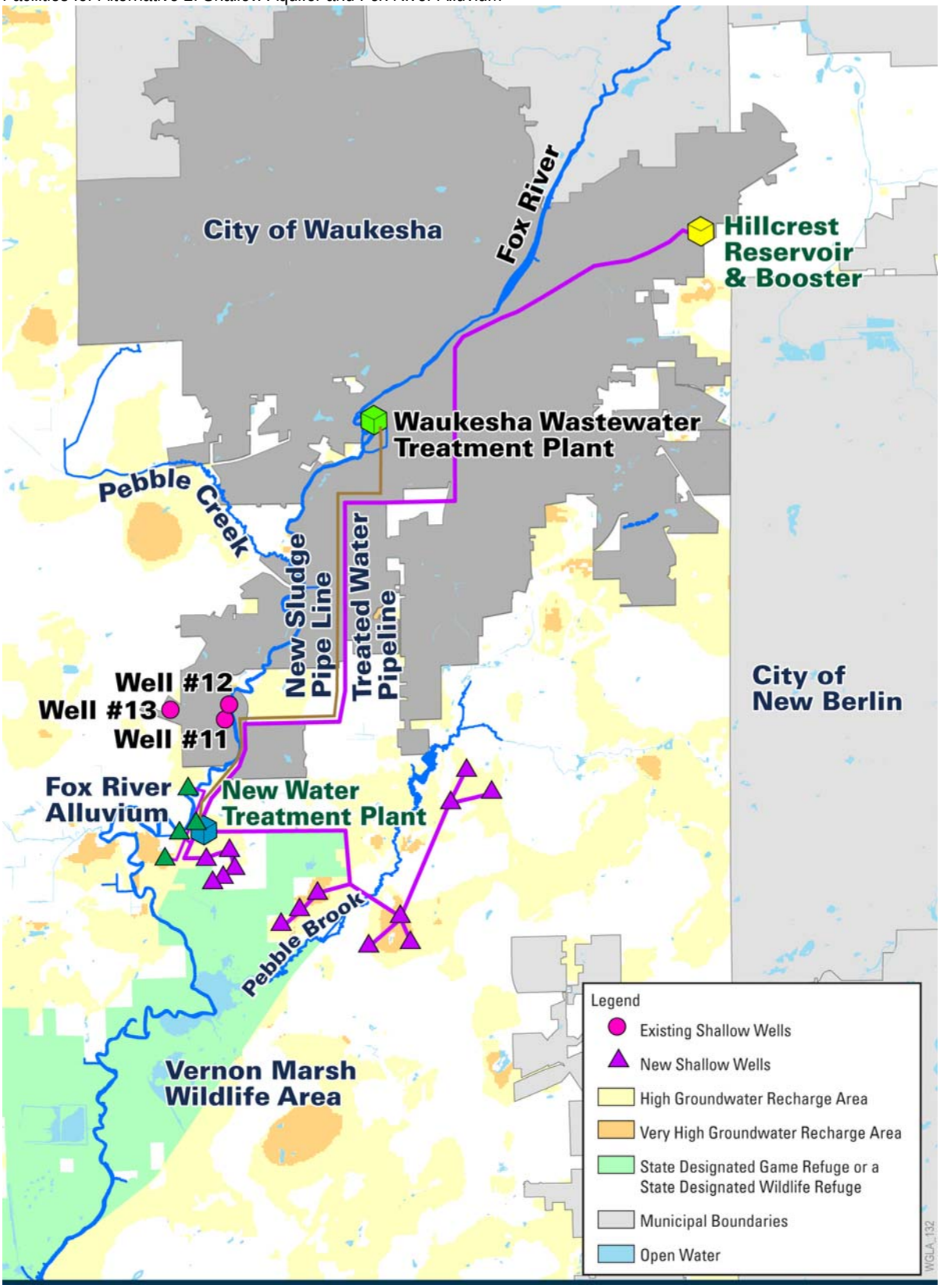


EXHIBIT 22
Groundwater Drawdown—Alternative 2 with 12 Wells Pumping, 10.9 mgd

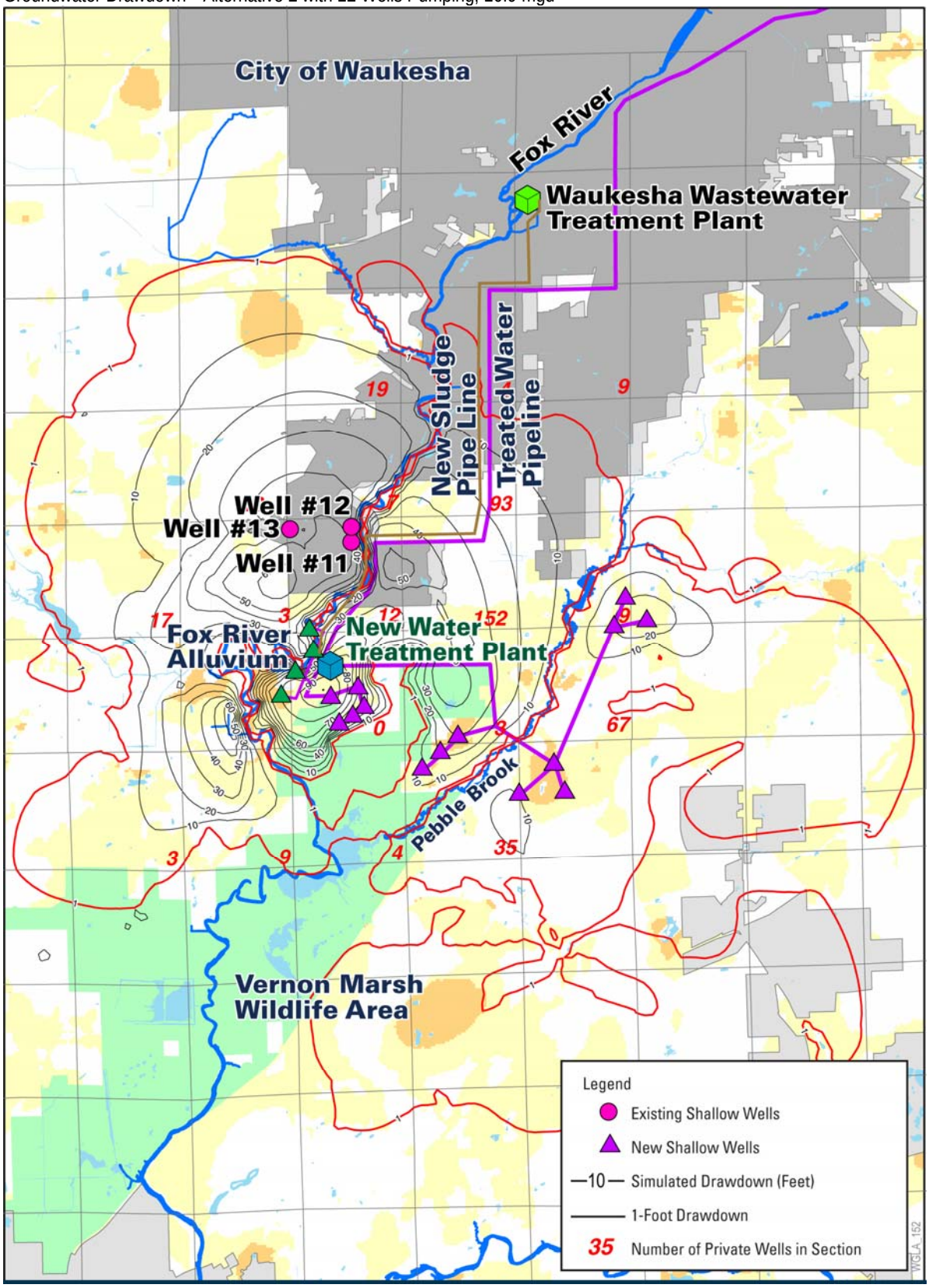
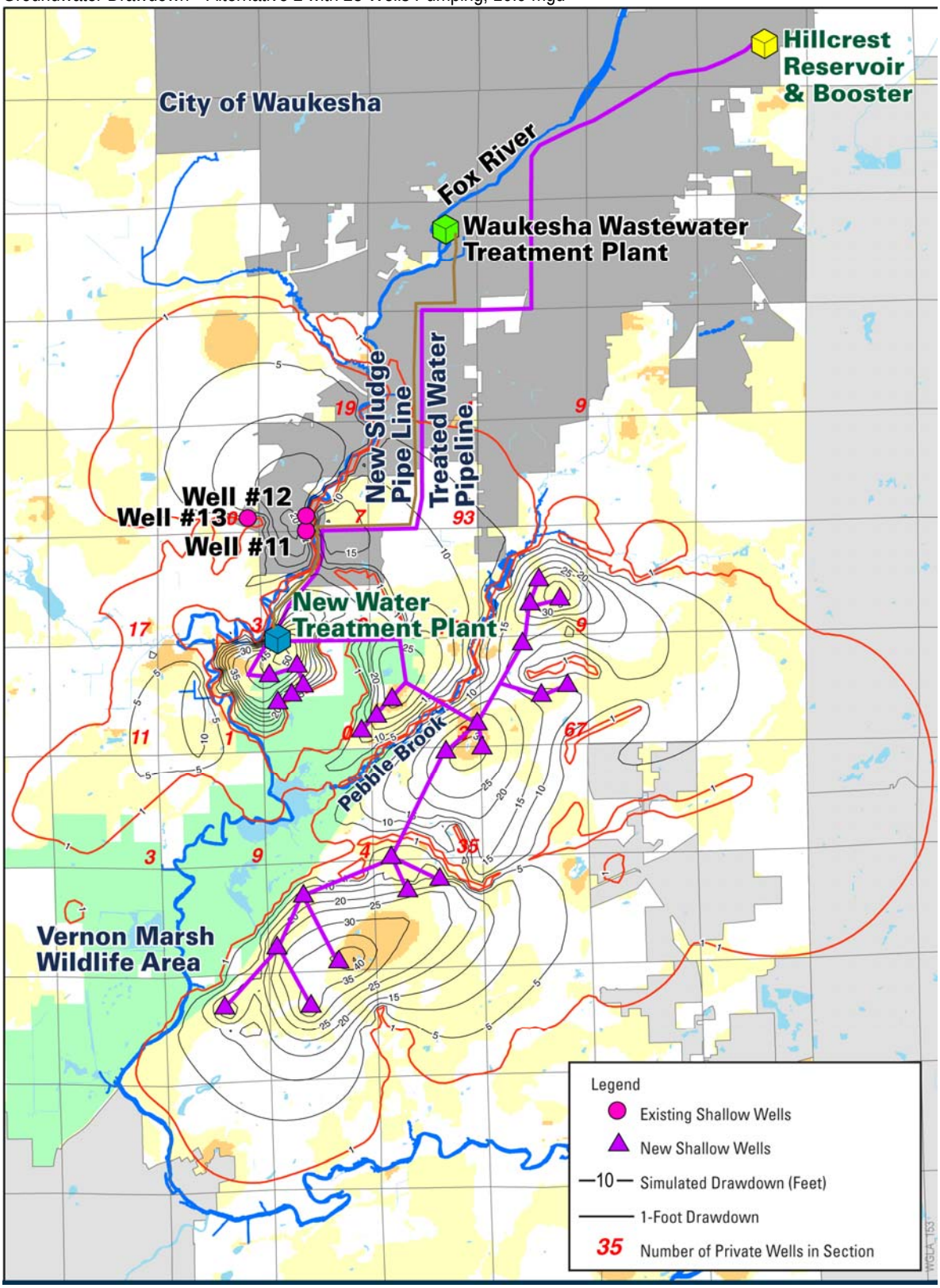


EXHIBIT 23
Groundwater Drawdown—Alternative 2 with 28 Wells Pumping, 10.9 mgd



Although this reduces the drawdown from a maximum of 105 to 55 feet, there is a larger area affected by reduced groundwater levels. Base flow reduction decreases from 346 percent to 156 percent in the Fox River, but increases in the other resources as shown below.[78] Spreading the wells over a larger area and reducing the pumping from each well still would have a very significant negative impact on the baseflow to sensitive wetlands and streams.

Resource	Baseflow Reduction (%) from pumping 28 shallow wells for a total of 10.9 mgd
Fox River	156
Pebble Brook	82
Vernon Marsh	51
Mill Brook	94
Pebble Creek	10

This modeling of the shallow aquifer shows that development of a wellfield for a City the size of Waukesha would be very difficult from an environmental impacts standpoint.

On a much smaller scale, the Village of Mukwonago installed a single shallow groundwater well in the southern area of the Vernon Marsh wildlife area and monitored the effects to a nearby marsh and calcareous fen, a rare Wisconsin wetland. According to the WDNR, the well appears to have created a cone of depression that is affecting the fens, along with the endangered plant species that depend on the groundwater supply.[79, 80] The long-term impacts of pumping this well are being evaluated by WDNR.A benefit of Alternative 2 is that Waukesha's deep aquifer pumpage would be eliminated, and therefore deep aquifer water levels would increase under Waukesha. The amount of the actual increase in water levels in the deep aquifer would depend on how many other communities continue to use it. If enough communities reduce deep aquifer pumping, increasing deep aquifer levels would have an environmental benefit.[81, 82, 83]

If shallow groundwater is used as the City's water source, return flow would not remain in the region. Instead, treated wastewater would be discharged to the Fox River and transferred out of the Great Lakes and Mississippi River ecosystem, eventually discharging to the ocean (Exhibit 19). This would result in less water in the Great Lakes and Mississippi River watersheds and associated negative environmental impacts.

If shallow groundwater is used, customers would continue to use home water softeners as shallow groundwater is hard. Negative environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) are similar to those under Alternative 1.

78 Ibid.

79 Letter to City of Waukesha Common Council from Brian Glenzinski, Vernon Marsh Wildlife Area Property Manager, WDNR. July 18, 2006.

80 Lisa Gaummitz, T. Asplund, and M. R. Matthews. June 2004. "A Growing Thirst of Groundwater." *Wisconsin Natural Resources.*

81 http://wi.water.usgs.gov/glpf/cs_pmp_src.html.

82 SEWRPC. 2008.

83 Cherkauer. 2009.

In order to use the shallow aquifer wellfield, the City would be required to construct water transmission mains from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha. Environmental impacts associated with construction of this alternative are included in Supplemental Information.

Alternative 2 would discharge 19,000 tons of greenhouse gases (carbon dioxide equivalent) annually through pumping from aquifers, water treatment, and pumping from the wellfield to Waukesha.

Considering the environmental impacts of Alternative 2, a rating of "significant negative impact" was applied.

Long-Term Sustainability. This alternative relies on multiple wells spread out over a large area. All wells would draw from the same aquifer. Relying upon one aquifer is less reliable than relying upon two aquifers as Alternative 1 does.

The shallow aquifer is dependent on rainwater for recharge and is less reliable during drought conditions, when water supply is needed most. Given the modeling of the shallow aquifer conducted at average day conditions, it is unlikely that this shallow aquifer could provide the City's maximum water demand during a drought. Furthermore, the negative impacts of groundwater drawdown and baseflow reduction at average day water demand conditions as demonstrated by the model would be worse in a drought situation. Pumping the shallow aquifer for the City's maximum water demand during a drought could result in severe negative impacts to the environment.

Treatment requirements for the shallow aquifers would also reduce the amount of water available to customers because the treatment requirements would require water and produce waste streams. However, the waste streams would only be about 2 to 3 percent of pumped water, much less than the TDS removal treatment in Alternative 1. Treatment of all the water supply in one treatment plant would reduce operation and maintenance efforts and costs compared to the multiple treatment plants in Alternative 1, but reduce reliability because there is only one treatment plant.

Considering the long-term sustainability of Alternative 2, a rating of "significant negative impact" was applied.

Public Health. Shallow aquifers are more susceptible to contamination than deep confined aquifers and large surface water bodies. Contaminants may be undetected for some time, exposing the public to health risks. Proper drinking water treatment can meet regulations as long as new contaminants are known before the water treatment plant is designed. If new contaminants are undetected or there is a malfunction in the treatment process, contaminants may be exposed to the public.

In addition, the Fox River alluvium may have exposure to additional contaminants from the Fox River. The Fox River is listed as impaired for PCBs[84] and is known to contain compounds that may be regulated in the future such as endocrine disrupters.

WDNR requires a wellhead protection program to protect municipal wells from contamination. Waukesha would have no zoning control to enforce the wellhead protection

[84] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html

ordinance because the shallow wellfield is outside the City limits. Preventing a potential source of contamination such as a gas station or industry from locating near the wellfield will be difficult without owning the land. Buying large tracts of land or influencing land use and zoning on surrounding properties is possible, but costly and the effectiveness is uncertain.

Other wells in the influence of the new wellfield may run dry or encounter water quality problems due to additional shallow aquifer pumping. Exhibit 4-10 shows the number of private wells that may be affected by a shallow wellfield. Private wells are associated with septic systems as well. These septic systems under the influence of a wellfield cone of depression could be sources of contamination such as pathogenic microorganisms or nitrate.

Groundwater is high in TDS, mainly from calcium, magnesium, carbonates, chlorides and sulfate. Home softening takes out calcium and magnesium, but adds sodium. Sodium has been identified as an item to limit if people have certain health conditions such as heart disease.

Under Alternative 2, the deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants would be eliminated.

Considering the public health impacts of Alternative 2, a rating of "moderate negative impact" was applied.

Implementability. For the Troy Bedrock Valley and Fox River alluvium wellfields, significant land purchase/lease and controls outside the city limits would be required. Local residents have opposed high-capacity wells because of concerns about adequate water supply and impacts to wetlands, private wells, and other environmental resources. Installation of wells an unconfined aquifer may create legal challenges and expose the City to damage claims from lake area homeowners and municipalities and would be a source of continuing controversy in the region. The City, for example, could be liable if its withdrawal of water causes unreasonable harm through lowering the water table for residential and municipal wells in the area. The City could also be liable if its withdrawal of groundwater had a direct and substantial effect upon the water of a watercourse or lake (i.e., effects to base flow or lake levels).

Because the Waukesha area is part of a groundwater management area, more requirements and restrictions could be placed on groundwater development. Additionally, groundwater protection legislation has been recently introduced in Wisconsin by the relevant committee chairs (on March 12, 2010). The legislation would require environmental review of proposed high capacity wells in a groundwater management area before WDNR approves or develops a groundwater management plan for the area.

The legal issues with siting new wells and impacting other entities discussed in Alternative 1 would be much greater in Alternative 2 because the City would be installing nearly twice as many wells and they would cover a larger land area. This land is outside the Waukesha municipal boundaries.

A new water treatment plant, pump station, and transmission pipes would be required to convey the treated water to the Hillcrest reservoir in Waukesha and through the distribution system. The treatment plant would be located outside the City limits and require land purchase or lease. The new wells, water plant, and pump station would require additional

operations and maintenance. Water transmission mains from the shallow aquifer wellfield to the treatment plant, and from the treatment plant to Waukesha would require, easements, and construction through rural and urban conditions.

Treatment of all the water supply in one treatment plant would reduce operation and maintenance efforts and costs compared to the multiple treatment plants in Alternative 1, but reduce reliability because there is only one treatment plant.

If well capacity decreases due to declining water levels or wells need to be located a greater distance from surface water resources, wells may need to be located a greater distance from Waukesha, which would increase costs, energy, and public concerns. The environmental and legal impacts described above would still be present, and may increase.

Considering the implementability of Alternative 2, a rating of "significant negative impact" was applied. Exhibit 24 summarizes the criteria for water supply Alternatives 1 and 2.

EXHIBIT 24
Water Supply Evaluation: Alternatives 1 and 2

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◉	●
Shallow aquifer and Fox River alluvium	●	●	◉	●

○ No negative impact
⊙ Minor negative impact
◉ Moderate negative impact
● Significant negative impact

3.2.4 Water Supply Alternative 3: Proposal to Use Lake Michigan Water

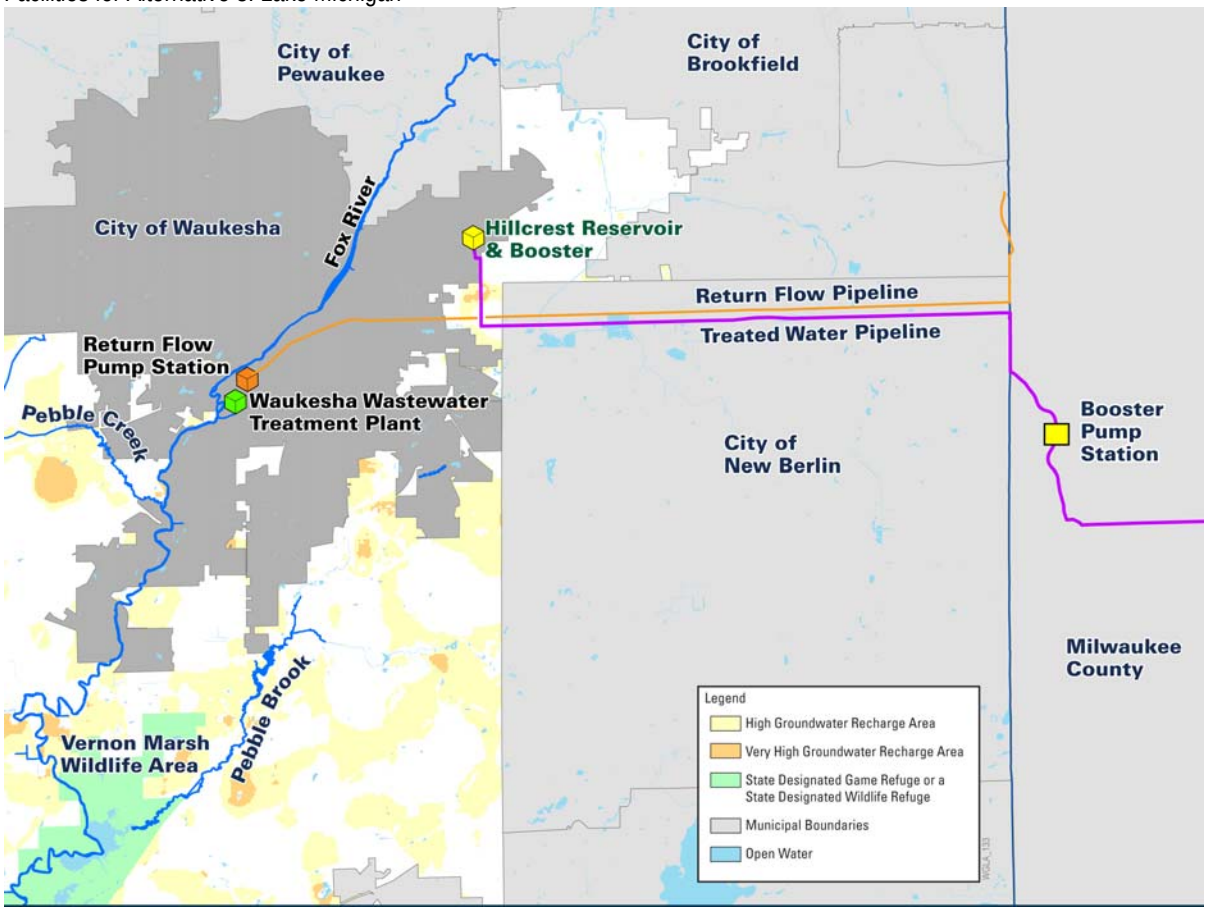
This application seeks authority to obtain water supply from Lake Michigan. The City seeks to obtain treated potable drinking water from a Lake Michigan water utility, and convey it to Waukesha through a transmission pipeline and booster pump station to the Hillcrest reservoir in Waukesha (Exhibit 25). This application seeks to withdraw 10.9 mgd of water on a future average day, and 18.5 mgd on a future maximum day; the same as the other alternatives. Water used by Waukesha would be returned to the Lake Michigan watershed.

To estimate infrastructure requirements and costs, Alternative 3 assumes connection to Milwaukee's water system at a large transmission main near 60th Street and Howard Avenue. Milwaukee is the closest Lake Michigan water utility to Waukesha and has excess capacity to provide water. Other options for a Lake Michigan water supply include the Cities of Oak Creek or Racine. The Lake Michigan water supplier would be determined after negotiations with the various cities.

There are several options for a return flow pipeline, all starting at the Waukesha wastewater treatment plant with a pump station. Discharge location options include Underwood Creek, Root River, and Lake Michigan through an outfall. The Underwood Creek location has the shortest distance and is the preferred alternative.

Environmental Impacts. If Lake Michigan water is obtained, the City would cease pumping the deep aquifer and groundwater levels would begin to increase. Using the Southeastern

EXHIBIT 25
Facilities for Alternative 3: Lake Michigan



Wisconsin Regional Groundwater Model and assuming Waukesha stops pumping from the deep aquifer, the deep aquifer cone of depression may recover 100 feet over time.[85] SEWRPC estimates deep aquifer water levels could rise as much as 270 feet if deep aquifer pumping ceased in several communities, including Waukesha.[86] Ceasing deep aquifer pumping in northeastern Illinois allowed water levels to rise 300 feet between 1980 and 2000 at Villa Park and Elmhurst, Illinois.[87] Similar aquifer recovery is becoming evident near Green Bay, Wisconsin, where Brown County water utilities stopped pumping the deep aquifer and started using Lake Michigan water.

Increasing deep aquifer water levels would result in an environmental benefit because more water would be provided to the waters and water dependant natural resources of the Lake Michigan Basin.[88] A 2003 study concluded that ceasing groundwater pumping from Waukesha's deep wells would have a beneficial effect on streams and wetlands and help

[85] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply.*

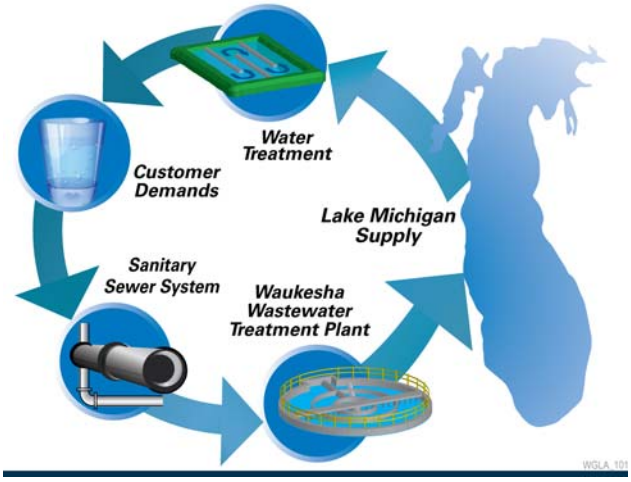
[86] SEWRPC. 2008.

[87] S. L. Burch. 2002. *A Comparison of Potentiometric Surfaces for the Cambrian-Ordovician Aquifers of Northeastern Illinois, 1995 and 2000.* Illinois State Water Survey Data/Case Study 2002-02.

[88] D.T. Feinstein, USGS. October 2006. *Where do the deep wells in southeastern Wisconsin get their water?* http://wi.water.usgs.gov/glpf/index.html

restore the natural flow regimes toward, rather than away from Lake Michigan.[89] This has a significant benefit to the waters and water dependent natural resources of the Lake Michigan Basin. In addition, water sent to Waukesha is returned to Lake Michigan (Exhibit 26). This preserves the waters and water dependent natural resources of the Lake Michigan Basin and protects the integrity of the Great Lakes ecosystem. There is no measurable impact on Lake Michigan water quantity.[90] In contrast, a groundwater supply alternative diverts water from the region.

EXHIBIT 26
Lake Michigan Water Cycle



Current and future negative environmental impacts of pumping deep and shallow groundwater and reducing baseflows would be eliminated, thus protecting sensitive and valuable environmental areas such as Pebble Brook, Pebble Creek, and Vernon Marsh.

Another benefit of using Lake Michigan water is that it is relatively soft and customers do not need home water softeners. The negative environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) would be eliminated under Alternative 3.

It is estimated that Alternative 3 would discharge 15,000 tons of greenhouse gases per year (carbon dioxide equivalent) through pumping from Milwaukee and returning the water to the Great Lakes Basin. This is less than the deep and shallow aquifer alternatives (Exhibit 27). Using the Lake Michigan alternative would save enough electricity to power about 1,600 homes for a year compared to the current water supply sources (Alternative 1).[91]

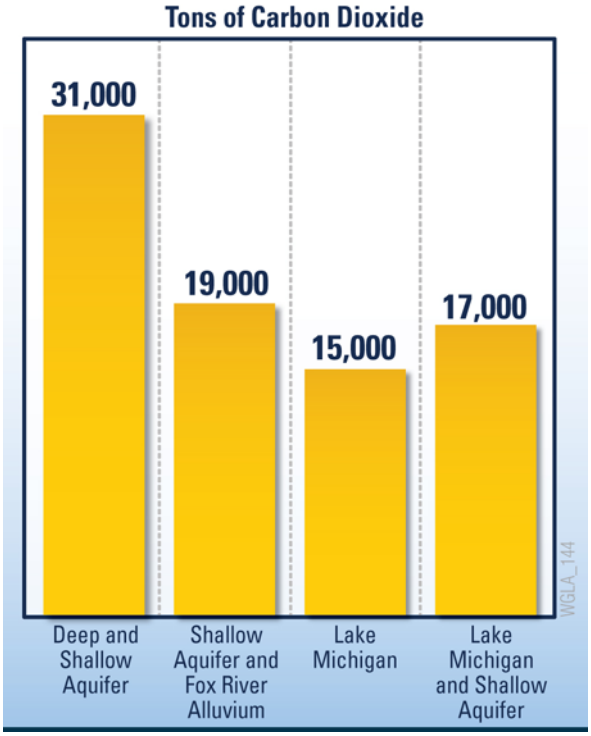
Water transmission mains from a Lake Michigan supplier to Waukesha, the booster pump stations, and return flow pipelines from the Waukesha wastewater plant to Underwood Creek would have environmental impacts during construction (see Supplemental Information). However, existing utility corridors would be used for pipeline routing where possible to minimize environmental impacts.

Overall, the City believes a Lake Michigan water supply results in a net environmental benefit compared to using a groundwater supply. This is consistent with SEWRPC's conclusion that the Lake Michigan alternative "offers advantages related to a greater improvement in the deep aquifer long-term sustainability, reductions in chloride discharges to the surface waters, and improvement in groundwater-derived baseflow inputs to the surface water system."[92]

[89] CH2M HILL, Ruekert & Mielke, et al. 2003. *Making a Decision on Improvement: An Annex 2001 Case Study Demonstration Involving Waukesha Water Supply*.
[90] Ibid.
[91] U.S. Energy Information Administration. http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home
[92] SEWRPC. 2008. *Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Preliminary Draft.

Considering the environmental impacts of Alternative 3, a rating of "no negative impact" was applied. There is actually an environmental benefit to the waters and water dependent natural resources of the Lake Michigan Basin because groundwater pumping would be eliminated, and as a result baseflow to surface waters would increase. In addition, there would be less of a need for water softening and salt discharge into the environment would decrease.

EXHIBIT 27
Greenhouse Gas Emissions from
Water Supply Alternatives



Long-Term Sustainability. Lake Michigan would provide Waukesha with an adequate quantity of high-quality water. The water source would provide long-term sustainability indefinitely because the water used would be recycled to its source. Lake Michigan is also a reliable water source because it is much more resistant to drought conditions than groundwater.

Using a Lake Michigan water supply also restores the hydrologic conditions and functions of the source watershed by stopping deep aquifer pumping and restoring flow toward, rather than away from Lake Michigan. This improves the long-term reliability and sustainability of the water resources in the region.

The infrastructure needed to provide Lake Michigan water is less than that for groundwater because no additional treatment or wellfields are needed. Existing treatment and pumping infrastructure from a Lake Michigan suppler would be used. In addition, long term operation and maintenance of pipelines and pump stations are simpler and less expensive than those of wellfields and water treatment plants.

Waukesha would maintain their shallow wells as an emergency backup to the Lake Michigan supply. This will increase reliability.

Considering the long-term sustainability of Alternative 3, a rating of "no negative impact" was applied.

Public Health. Treated Lake Michigan water is high quality and safe. Millions of people are provided with drinking water from Lake Michigan. Contamination is possible, as with all supplies, but the large size and high quality of Lake Michigan water makes this a rare occurrence. Lake Michigan water suppliers have some of the most stringent water quality programs and advanced treatment processes to assure high quality water.

The deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants is eliminated. Private wells and municipalities on groundwater near Waukesha would not be adversely affected if Waukesha obtains a Lake Michigan water supply because Waukesha would no longer be pumping groundwater. Home softening

would no longer be needed, and the water would contain much less sodium and TDS than a groundwater supply, making it healthier to consume.

Considering the public health impacts of Alternative 3, a rating of "minor negative impact" was applied.

Implementability. Alternative 3 requires an agreement with a Lake Michigan water supplier to provide water. Waukesha has letters from three Lake Michigan water utilities willing to negotiate a contract. It would also require approval from the Governors of the Great Lakes States under the terms of the Compact.

Land purchase requirements would be less than a groundwater alternative, because no treatment plant or wellfield are required. Land use issues for wellhead protection, well and treatment plant siting are eliminated. Public concerns over impacts to groundwater levels and long-term wetland impacts are also eliminated.

A new pump station and transmission pipe would be required to convey the treated drinking water to the Hillcrest reservoir in Waukesha. A new pump station and transmission pipe would be required to convey treated wastewater from the wastewater treatment plant to Underwood Creek. The drinking water pump station would be located outside the City limits and require land purchase or lease. Water transmission mains to and from Waukesha would require routing studies, easements, and construction through rural and urban conditions. There are no treatment plants or wellfields for Waukesha to operate with Alternative 3, making operation and maintenance of the water utility much simpler than that of a groundwater alternative.

Considering the implementability of Alternative 3, a rating of "moderate negative impact" was applied. Exhibit 28 summarizes the criteria for water supply Alternatives 1, 2, and 3.

EXHIBIT 28
Water Supply Evaluation: Alternatives 1, 2, and 3

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●
Lake Michigan	○	○	⊙	◎

○ No negative impact
⊙ Minor negative impact
◎ Moderate negative impact
● Significant negative impact

3.2.5 Water Supply Alternative 4: Lake Michigan and Shallow Aquifer

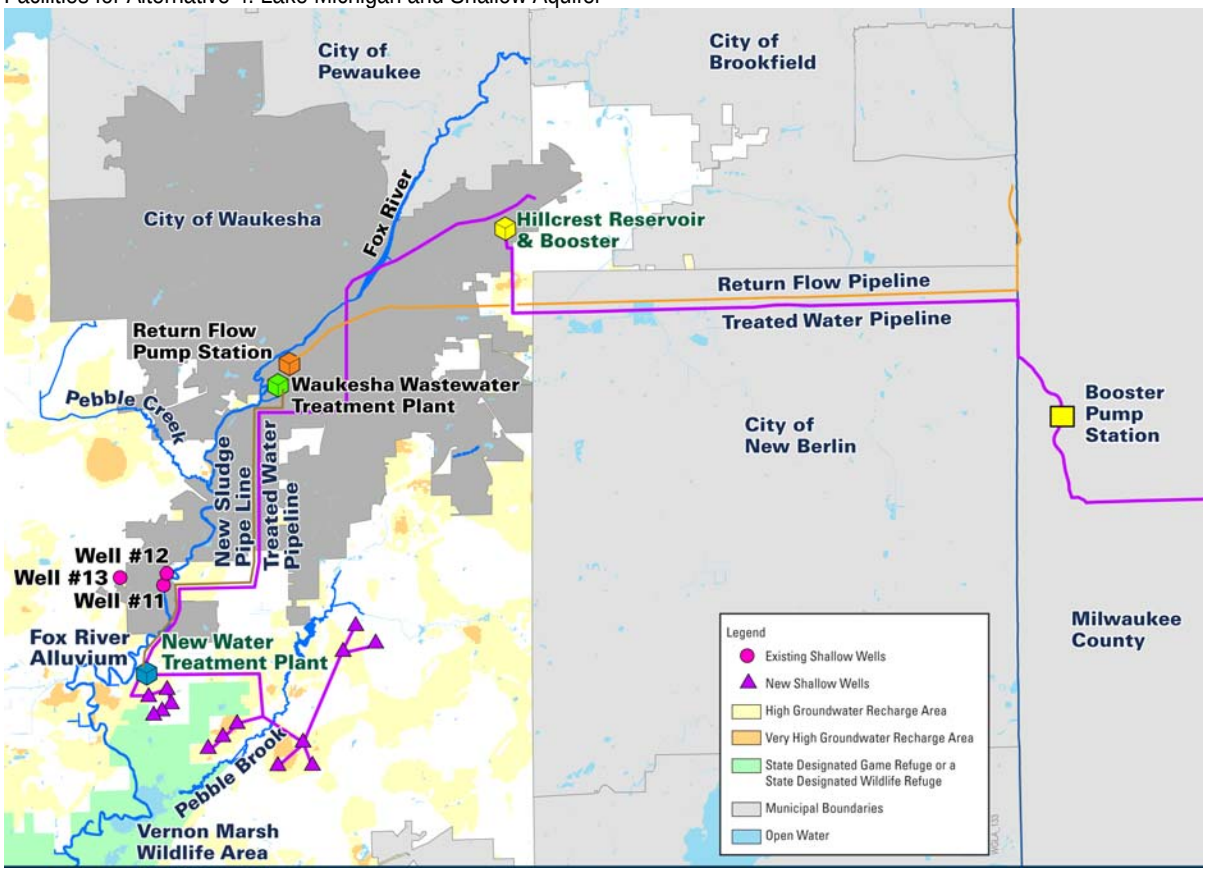
Alternative 4 consists of obtaining about 40 percent the City's required potable water (4.5 mgd average day demand, 7.6 mgd maximum day demand) from a Lake Michigan water utility and the other 60 percent (6.4 mgd average day demand, 10.9 mgd maximum day demand) from the shallow aquifer in the Mississippi River Basin. The shallow aquifer supply quantity is the same as in Alternative 1. This amount of shallow aquifer water caused significant negative environmental impacts on water resources, so using a higher amount of shallow aquifer water and less Lake Michigan water was not deemed reasonable

for the purposes of this alternative. A slightly higher or lower amount of shallow aquifer water would not significantly change the results of this alternative analysis.

The Lake Michigan supply would be conveyed to Waukesha through a transmission pipeline and booster pump station to the Hillcrest reservoir in Waukesha. Additional distribution system piping would convey water through the City. Water used by Waukesha would be returned to the Lake Michigan watershed via Underwood Creek.

The supply from the shallow aquifer would be provided by existing and new wells. Existing shallow wells 11 through 13 would provide firm capacity for 1.2 mgd. The remaining 9.7 mgd would come from 14 wells in the Troy Bedrock Valley south of Waukesha. These wells would be combined into a central water treatment plant and the treated water pumped to the Hillcrest reservoir in Waukesha for blending with Lake Michigan water. The facilities are shown in Exhibit 29.

EXHIBIT 29
Facilities for Alternative 4: Lake Michigan and Shallow Aquifer



Environmental Impacts. Current and future negative environmental impacts of pumping the shallow aquifer would be the same as Alternative 1. Groundwater drawdown would negatively affect sensitive and valuable environmental areas such as Pebble Brook, Pebble Creek, and Vernon Marsh, and the reduction in baseflow to these water resources would negatively impact ecosystems.

Home water softening would continue because although Lake Michigan water is relatively soft the shallow groundwater is hard. Blending the two waters will reduce the hardness, but

hardness will still be relatively high and a significant reduction in home softener use is not anticipated. The negative environmental impacts associated with home water softening (salt discharge to surface waters, additional water and energy use) would remain.

It is estimated that Alternative 4 would discharge 17,000 tons of greenhouse gases per year (carbon dioxide equivalent). Greenhouse gases would be produced by the pumping needed to convey water from and back to Lake Michigan. In addition, pumping from the shallow aquifer, treating the water and pumping the water to Waukesha uses energy and produces greenhouse gases. This alternative produces more greenhouse gases than the Lake Michigan Alternative 3 (see Exhibit 27).

Water transmission mains from a Lake Michigan supplier to Waukesha, the booster pump stations, and return flow pipelines from the Waukesha wastewater plant to Underwood creek would have environmental impacts during construction (see Supplemental Information). Existing utility corridors would be used for pipeline routing where possible to minimize environmental impacts. Developing the shallow aquifer wellfield, pipelines, treatment plant and pump station would also have environmental impacts during construction.

Considering the environmental impacts of Alternative 4, a rating of "significant negative impact" was applied.

Long-Term Sustainability. Lake Michigan as a drinking water source for Waukesha provides adequate quantity, high-quality, and long-term reliability indefinitely by allowing water to be recycled to its source. Alternative 4 also restores the hydrologic conditions and functions of the source watershed by stopping deep aquifer pumping and restoring flow toward, rather than away from Lake Michigan.

Lake Michigan water is much more resistant to drought conditions than groundwater. During a drought Waukesha could rely more on Lake Michigan and less on the shallow aquifer, increasing reliability. The infrastructure needed to provide Lake Michigan water is similar to Alternative 3, with the main difference being a smaller pipe. In addition, a shallow aquifer wellfield, treatment plant, pump station and pipeline are needed. Waukesha would have to maintain not only the Lake Michigan supply, but also the shallow aquifer supply. Blending the two waters would require attention to water chemistry so customers are receiving consistent water quality and distribution system corrosion is minimized.

Considering the long-term sustainability of Alternative 3, a rating of "moderate negative impact" was applied.

Public Health. Treated Lake Michigan water is high quality and safe. Millions of people are provided with drinking water from Lake Michigan. Contamination is possible, as with all supplies, but the large size and high quality of Lake Michigan makes this a rare occurrence. Lake Michigan water suppliers have some of the most stringent water quality programs and advanced treatment processes to assure high quality water.

The deep aquifer would no longer be used, and potential public exposure to radionuclide and other contaminants is eliminated.

The contamination and wellhead protection issues with the shallow aquifer remain (see Alternative 1). Private wells will be affected by the shallow aquifer pumping and septic systems may contribute contaminants into the water supply. However, if a contamination

issue should occur, Waukesha could rely more on the Lake Michigan water supply. Home softening would still be needed, so the increased sodium and TDS would still be present.

Considering the public health impacts of Alternative 3, a rating of "minor negative impact" was applied.

Implementability. Alternative 4 still requires an agreement with a Lake Michigan water supplier to provide water, and approval from the Governors of the Great Lakes states under the terms of the Compact. Since a large portion of Waukesha's water supply would come from shallow groundwater and be blended with Lake Michigan water, minimizing out of Basin return water to comply with section 4.9.3(b) of the Compact would not be possible. This would apply even if a much smaller amount of groundwater were used with a Lake Michigan water supply.

A Lake Michigan supply will have the same issues and requirements of pipeline routing studies, easements, land purchase and construction through rural and urban conditions.

Land purchase and easement requirements for the shallow aquifer supply would be similar to Alternative 1. Land use and legal issues for wellhead protection, well and treatment plant siting remain. Public concerns over impacts to groundwater levels and long-term wetland impacts are also still present.

In Alternative 4, Waukesha would operate and maintain the Lake Michigan supply in addition to the shallow aquifer wellfield, treatment plant and pumping/pipelines. This will make operation and maintenance of the water utility more complex than that of a Lake Michigan alternative.

Considering the implementability of Alternative 3, a rating of "significant negative impact" was applied. Exhibit 30 summarizes the criteria for water supply Alternatives 1, 2, 3, and 4.

EXHIBIT 30
Water Supply Evaluation: Alternatives 1, 2, 3, and 4

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◎	●
Shallow aquifer and Fox River alluvium	●	●	◎	●
Lake Michigan	○	○	⊙	◎
Lake Michigan, deep and shallow aquifers	●	◎	⊙	●

○ No negative impact
⊙ Minor negative impact
◎ Moderate negative impact
● Significant negative impact

Using the deep aquifer with Lake Michigan water instead of the shallow aquifer will have similar results and impacts. However, since the deep aquifer will continue to be pumped, the benefit of increasing water levels and restoration of the natural groundwater flow toward Lake Michigan will not be realized. In addition, the old deep wells are less reliable. The wells are 30 to 75 years old and have some of the largest pumps of their kind which have to be custom built. If a failure occurs with the pumping equipment, it could be many months before repairs can be made. This situation has occurred on Waukesha's well 10 recently. The deep wells also have more water quality issues than new shallow wells with

treatment. Radium treatment facilities will be over half their expected life when a Lake Michigan supply is finished, and will require replacement in the near future. Additional treatment for TDS removal in the future will be a large expense in both capital and operating costs (See Alternative 1). Other issues with using the deep aquifer for a portion of Waukesha's water supply are explained in the Alternative 1 description. For these reasons, a Lake Michigan and deep aquifer supply alternative was not developed in detail.

3.3 Combinations of Water Supply Sources

In general, water utilities rarely have more than two primary water supply sources. A main principal of public drinking water supply is to obtain the water supply source with the highest quality and most reliability. If this water supply does not have adequate quantity, the next highest quality water supply source is obtained. Using multiple sources of water is possible when necessary, but increases costs along with operational and maintenance complexity. Impacts to the environment can increase if unsustainable sources are tapped, and public health protection can decrease if lower quality water sources are used.

For example, a quarry north of Waukesha was evaluated as a potential water source, but screened out due to inadequate capacity (2 mgd) and contamination concerns.[93] Using this 2 mgd quarry capacity to supplement a deep and shallow aquifer supply instead of obtaining an additional 2 mgd from the shallow aquifer would actually increase the capital cost about $19 million. Under this example, having three sources of water (deep aquifer, shallow aquifer, quarry) instead of two (deep and shallow aquifer) would increase costs and operational complexity, and also increase risk to public health by using a poorer quality water source.

3.4 Summary of Water Supply Alternatives

Major studies previously conducted by the City of Waukesha[94] and others[95, 96] thoroughly evaluated the water supply alternatives for the City of Waukesha. Through these studies, potentially feasible water supply options were identified. This application analyzes four alternatives for Waukesha's water supply:

- Deep and shallow aquifers
- Shallow aquifer and Fox river alluvium
- Lake Michigan
- Lake Michigan and shallow aquifer

Each alternative was evaluated against four criteria:

- Environmental impact
- Long-term sustainability
- Public health
- Implementability

Exhibit 31 summarizes the water supply alternatives evaluation results. The evaluation results show the Lake Michigan alternative (Alternative 3) has the most environmental

93 CH2M HILL and Ruekert & Mielke. 2002. *Future Water Supply Report for the Waukesha Water Utility.*
94 Ibid.
95 SEWRPC. 2008.
96 Cherkauer. 2009.

benefit for the waters and water dependent natural resources of the Lake Michigan Basin, is the most reliable and sustainable in the long term, provides excellent public health protection, and is implementable. A Lake Michigan water supply also provides higher quality potable water to consumers. Exhibit 32 shows the total dissolved solids in each water supply. The much lower total dissolved solids in the Lake Michigan water supply not only eliminates the need for home softening; it also is more healthy for consumers and the environment, and better for many industrial and commercial uses.

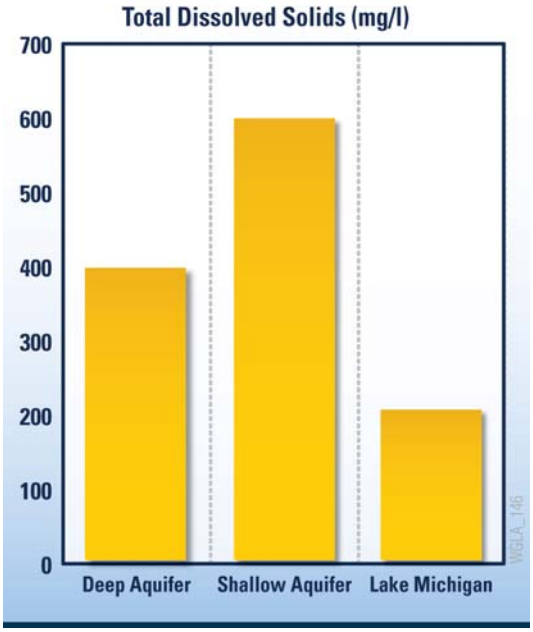
EXHIBIT 31
Water Supply Alternatives Evaluation Summary

Water Supply Alternative	Environmental Impact	Long-Term Sustainability	Public Health	Implementability
Deep and shallow aquifers	●	●	◉	●
Shallow aquifer and Fox River alluvium	●	●	◉	●
Lake Michigan	○	○	⊙	◉
Lake Michigan and shallow aquifers	●	◉	⊙	●

○ No negative impact ◉ Moderate negative impact
⊙ Minor negative impact ● Significant negative impact

Estimated costs for each alternative are summarized in Exhibit 33. These cost estimates were prepared for guidance in comparing alternatives based on information available at the time of the estimate. Detailed engineering design has not been done. The final cost estimate of any project will depend on market conditions, site conditions, final project scope, schedule, and other variable factors. As a result, final project costs may vary from the estimates presented here.

EXHIBIT 32
Water Quality Comparison between Water Supply Alternatives



The cost comparison of the alternatives shows that the Lake Michigan water supply is the most cost-effective in the long term. There is no cost advantage of a groundwater supply or combination groundwater/Lake Michigan supply over a Lake Michigan supply. See Supplemental Information for detailed capital, operation, and maintenance cost estimates.

The groundwater supply alternatives are not reasonable alternatives under the Wisconsin Compact implementing statute (§281.346(1) (ps), Wis. Stats.). Under Wisconsin law, "a reasonable water supply alternative means a water supply alternative that is similar in cost to, and as environmentally sustainable and protective of public health as, the proposed new or increased diversion and that does not have greater negative environmental impacts than the proposed new or increased diversion." Compared to a Lake Michigan water supply, the

EXHIBIT 33
Water Supply Alternative Cost Estimates

Water Supply Alternative	Capital Cost[a] ($ million)	Annual Operation/Maintenance Cost ($ million)	20 yr. Present Worth Cost ($ million, 6%)	50 yr. Present Worth Cost ($ million, 6%)
Deep and shallow aquifers	189	7.2	272	302
Shallow aquifer and Fox River alluvium	184	7.4	269	301
Lake Michigan with return flow to Underwood Creek	164	6.2	235	262
Lake Michigan and shallow aquifer	238	7.5	324	356

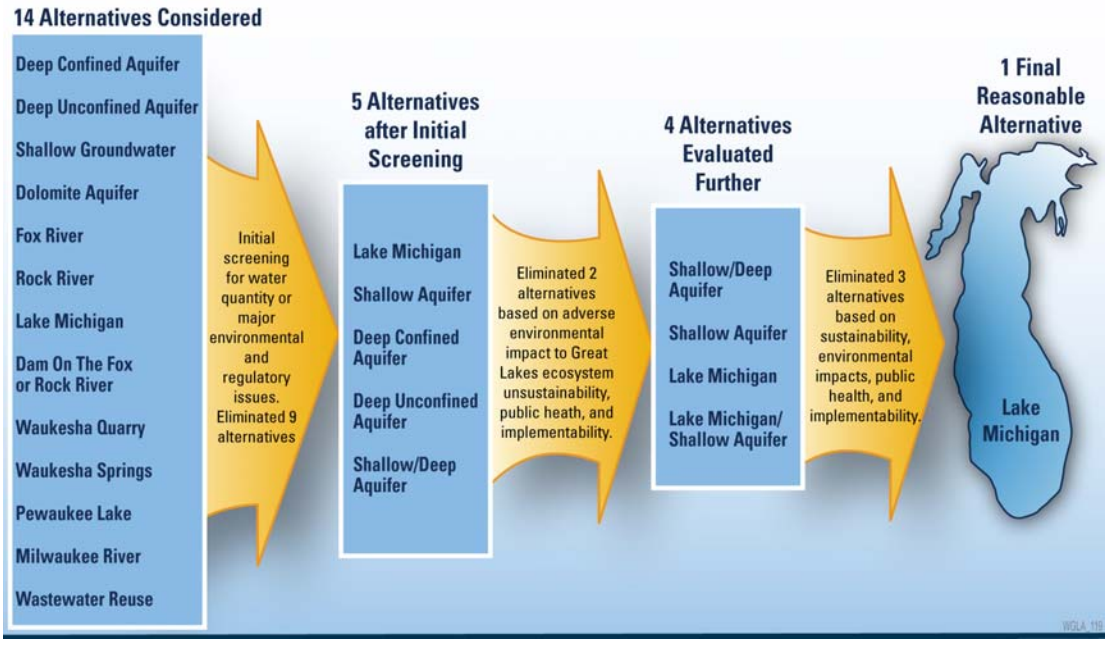
[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

groundwater supply alternatives create greater negative environmental impacts, are less sustainable, less protective of public health and are more expensive.

4. Summary

Analyses of Waukesha's water supply alternatives demonstrate that a Lake Michigan water supply is the only reasonable solution for the City of Waukesha (Exhibit 34). It provides the most reliable, cost-effective, and high quality drinking water for the future. It protects the integrity of the Great Lakes Basin ecosystem. A Lake Michigan water supply will result in termination of deep aquifer pumping which will restore the natural flow regime of the groundwater towards the Lake Michigan Basin instead of away from it. This will eliminate negative environmental impacts of using groundwater and improve the Great Lakes water and water-related ecosystems.

EXHIBIT 34
Final Water Supply Alternative Selection



This analysis also demonstrates that that there is no reasonable water supply alternative to a Lake Michigan supply within the basin in which Waukesha is located. The groundwater water supply options have much greater negative environmental impacts than using Lake Michigan, are not sustainable long-term and are not as protective of public health.

Appendix E

Facility Plan Amendment for Wastewater Treatment Plant Improvements for Returning Water Withdrawn from Lake Michigan

Facility Plan Amendment

Wastewater Treatment Plant Improvements for Returning Water Withdrawn from Lake Michigan

Prepared for

City of Waukesha

April 2010

CH2MHILL
135 S. 84th Street, Suite 325
Milwaukee, WI 53214

Facility Plan Amendment

Wastewater Treatment Plant Improvements for Returning Water Withdrawn from Lake Michigan

Submitted to

City of Waukesha

April 2010

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A Current WPDES Permit
B Letter from the Wisconsin Department of Natural Resources: WWTP WPDES Effluent Limits

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1. Background Information and Existing Conditions

1.1 Need for Proposed Project

Continued use of the deep aquifer as a water supply for the City of Waukesha and other communities in southeastern Wisconsin and northeastern Illinois is unsustainable because of decreasing quantity and increasingly poor water quality. Dramatic drawdown in the aquifer is exacerbated by the Maquoketa shale aquitard, which limits groundwater recharge in much of the region. The water quality withdrawn from the increasingly deeper parts of the aquifer has continued to degrade. For example, levels of radium (a naturally-occurring radioactive isotope known to cause cancer) and total dissolved solids become worse with aquifer depth.

To provide a permanent and sustainable source of clean water for its service area, the City of Waukesha is applying for a Lake Michigan water supply in their *Draft Application for Lake Michigan Water Supply* (Application). The Great Lakes Water Resources Compact (Compact) requires the City of Waukesha to return the water that it withdraws from Lake Michigan, less an allowance for consumption.

The City of Waukesha's wastewater treatment plant (WWTP) currently discharges to the Fox River, which is in the Mississippi River watershed. A Lake Michigan water supply would require a new outfall from the WWTP, for the return flow to the Lake Michigan watershed. This document identifies alternatives for returning flow to the Lake Michigan watershed for a Lake Michigan water supply, and is submitted as an amendment to the *Waukesha Wastewater Treatment Facility Plan* (July 1990). Additional facilities planning may be required beyond this amendment to evaluate WWTP capacity and potential improvements to meet future wastewater treatment needs.

1.2 Planning Areas

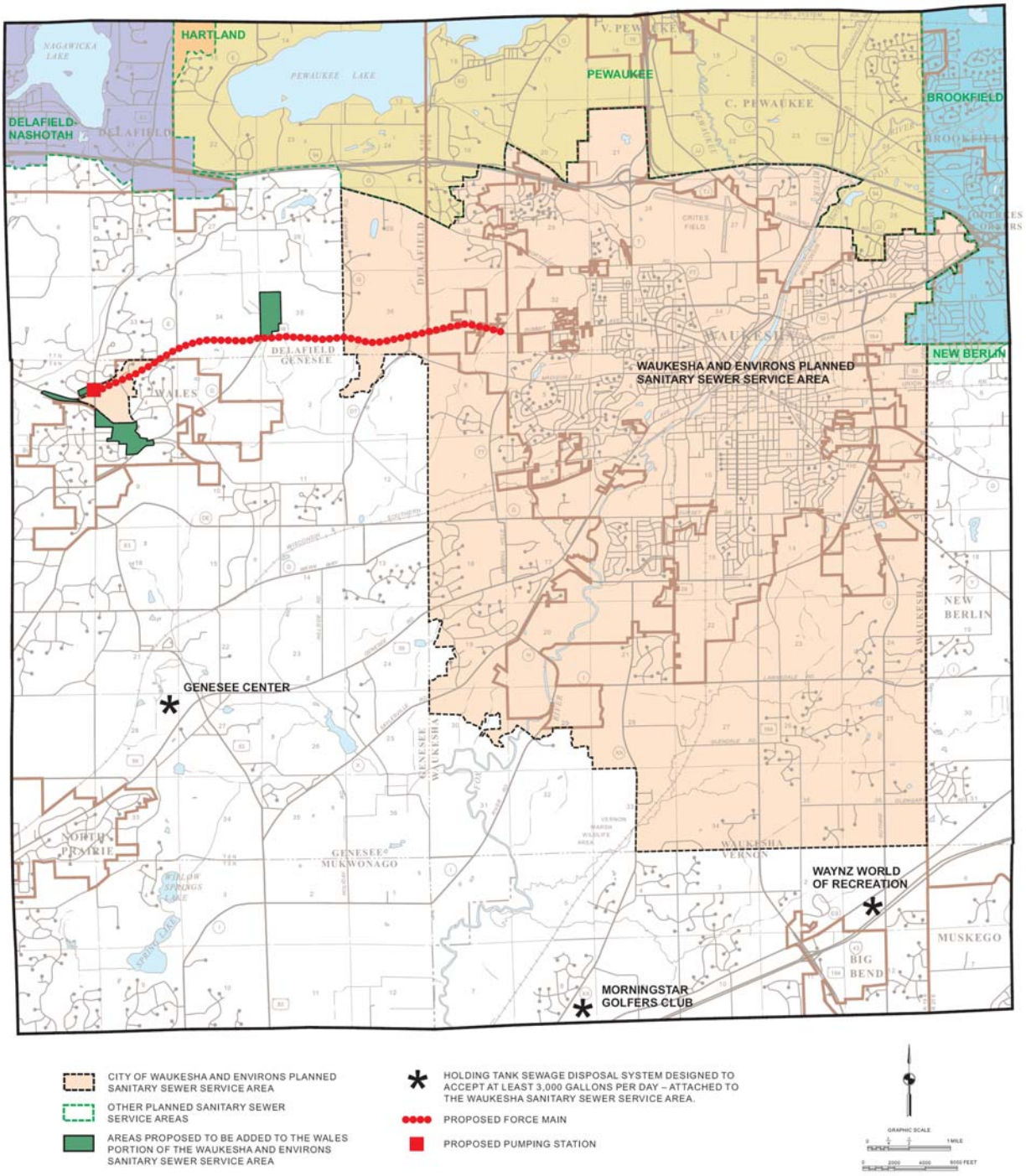
The sanitary sewer and water supply planning (service) areas are discussed below.

1.2.1 Sanitary Sewer Planning Area

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) defined the planning area for the City of Waukesha sanitary sewer collection system.[1] The area consists of all the City and Town of Waukesha, and portions of the Brookfield, New Berlin, Muskego, Pewaukee, Delafield, Genesee, Mukwonago, Wales and Vernon. The area also includes some holding and septage tanks, such as the two tanks located at the Kettle Moraine High School. The sanitary sewer service area is shown in Figure 1.

[1] SEWRPC, Sanitary Sewer Service Area for the City of Waukesha and Environs. March 1999. (Amended February 2001, June 2002, September 2003, September 2004, September 2005, September 2006, and December 2007.)

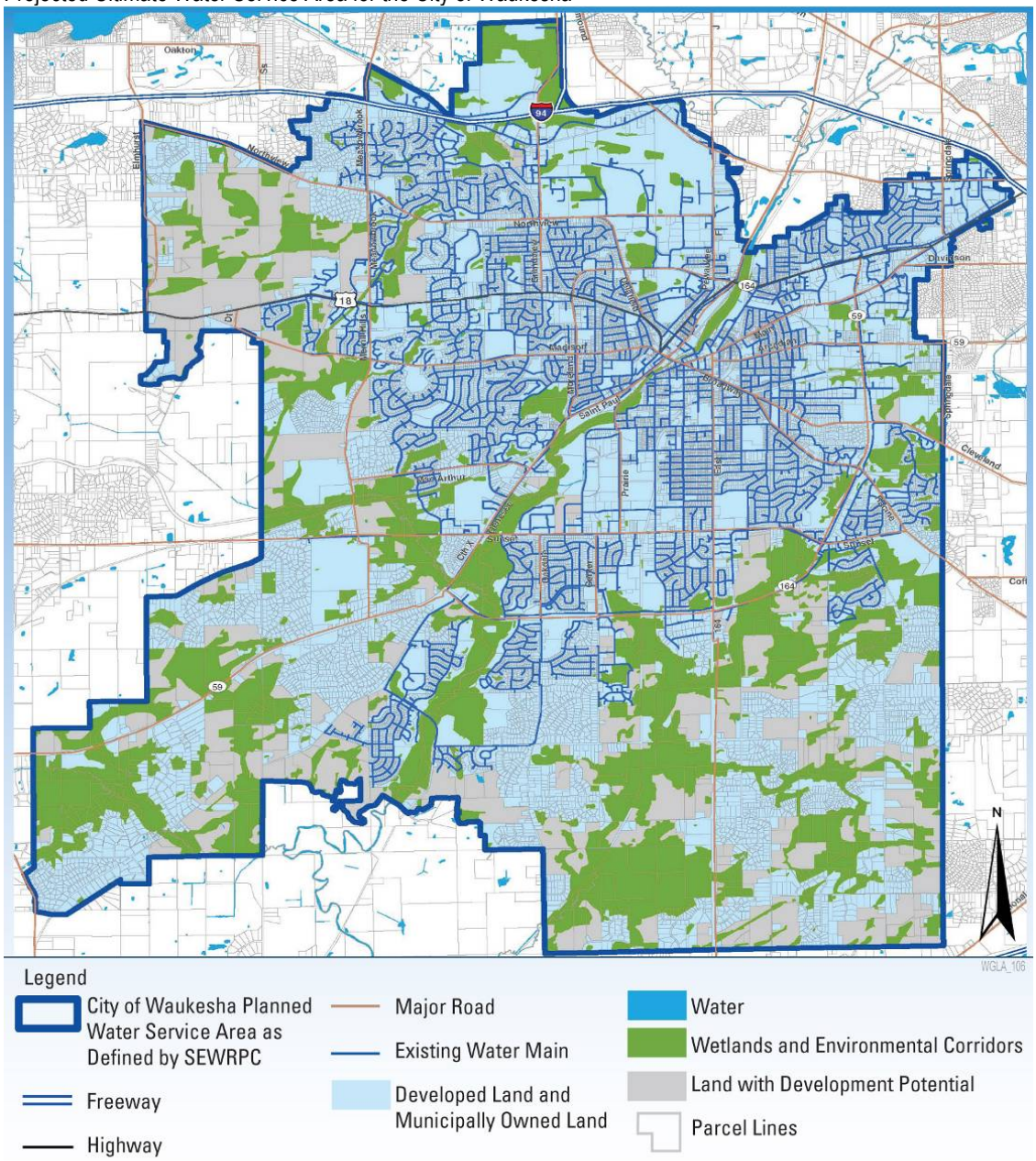
FIGURE 1
Sanitary Sewer Service Planning Area (SEWRPC, 2007)



1.2.2 Water Supply Planning Area

SEWRPC delineated a water supply service area which includes the City of Waukesha corporate limits plus a few small adjacent areas.[2] A detailed discussion of the water supply service area is included in Appendix D of the Application. The projected ultimate water supply service area is shown in Figure 2.

FIGURE 2
Projected Ultimate Water Service Area for the City of Waukesha



Source: Adapted from SEWRPC/Philip Evenson, Executive Director. 2008. Letter to Waukesha Water Utility/Daniel S. Duchniak, P.E., General Manager. December 23, attachment.

[2] SEWRPC, December 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 2.

1.2.3 Comparison of Planning Areas

The planned water supply service area and the planned sanitary sewer service area are very similar, but there are three differences between them:

- A portion of the Village of Wales and three sewage holding tanks are within the planned sanitary sewer service area (Figure 1) but not within the planned water supply area. The total future population that may be served in the Village of Wales is estimated to be about 500 persons[3].
- An area south of Interstate 94 along Bluemound Road between the Fox River and State Highway 164 is within the City of Waukesha planned sanitary sewer service area but not in the planned water supply service area. The area is currently served by the City of Pewaukee's municipal water supply system but the sanitary sewer flow is treated by the City of Waukesha.
- A portion of the Town of Genesee along the State Highway 59 and County Highway X corridor, immediately west of the Town of Waukesha, is within the planned water supply service area but not in the sanitary sewer service area. This area does not currently receive drinking water from the City of Waukesha, but is planned to in the future because it is identified as a special well casing area by the WDNR due to groundwater bacterial contamination.[4] Sanitary sewer service for these water users is anticipated to be provided by onsite wastewater treatment systems. This area includes about 530 parcels.[5]

Because the differences between the planned water supply and sanitary sewer service areas are very small, SEWRPC concluded that the City of Waukesha planned water supply service area is consistent with the City of Waukesha sanitary sewer service area as incorporated in the adopted regional water quality management plan.[6]

To demonstrate the current small differences in the service areas, 2009 sanitary and water supply flow data was analyzed to compare the water balance between metered water supply data and metered sanitary sewer flow data. The total flow to the City of Waukesha WWTP from customers that only receive sanitary sewer services (i.e. customers that do not receive drinking water from the City of Waukesha but have their sanitary sewage treated by the City) averaged 0.51 million gallons per day (mgd). In comparison, the total water demand from customers that only receive drinking water from the City of Waukesha (i.e. customers that do not receive wastewater treatment from the City of Waukesha but receive drinking water from them) averaged 0.14 mgd. The difference between the two resulted in an average 0.37 mgd more sanitary sewer flow to the City of Waukesha than water supply. Compared to an average annual WWTP flow rate of about 10 mgd, the additional flow from the sanitary sewer service area is small (3.7 percent).

---

[3] SEWRPC, *Sanitary Sewer Service Area for the City of Waukesha and Environs*, September 2006 and December 2007 Amendments. http://www.sewrpc.org/ publications/capr/capr-100_ssa_city_of_waukesha.pdf.

[4] SEWRPC, December 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 3.

[5] City of Waukesha parcel data. March 22, 2010.

[6] SEWRPC, December 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 3.

1.3 Wastewater Treatment Plant Effluent

The Wisconsin Pollutant Discharge Elimination System (WPDES) permit for the City of Waukesha WWTP is effective until December 31, 2012. The WPDES permit is included in Attachment A and is generally summarized in Table 1. The WWTP is an activated sludge treatment facility with tertiary dual media filtration (sand and anthracite) and ultraviolet light disinfection. The plant consistently produces high quality effluent that has very low BOD (biochemical oxygen demand), TSS (total suspended solids), NH_3-N (ammonia) and TP (total phosphorus).

A summary of the average monthly WWTP effluent concentrations is summarized in Table 2 (and discussed in more detail in Appendix H of the Application) and a summary of the average daily WWTP effluent flow over the last several years is shown in Figure 3. The average daily WWTP effluent flow ranges from about 9 to 12 mgd.

TABLE 1
General Summary of Current City of Waukesha WWTP WPDES Effluent Permit Limits

Parameter	Permit Limit
BOD_5, total	≤8.2 to 10 mg/L weekly (varies by season)
TSS, total	≤10 mg/L weekly
NH_3-N (ammonia), total	≤2 to 6 mg/L monthly (varies by season)
Dissolved oxygen	≥7 mg/L daily, (≥6.7 mg/L in September)
Total phosphorus (TP)	≤1 mg/L monthly
Fecal coliform	≤400#/100 mL monthly geometric mean (May–September)

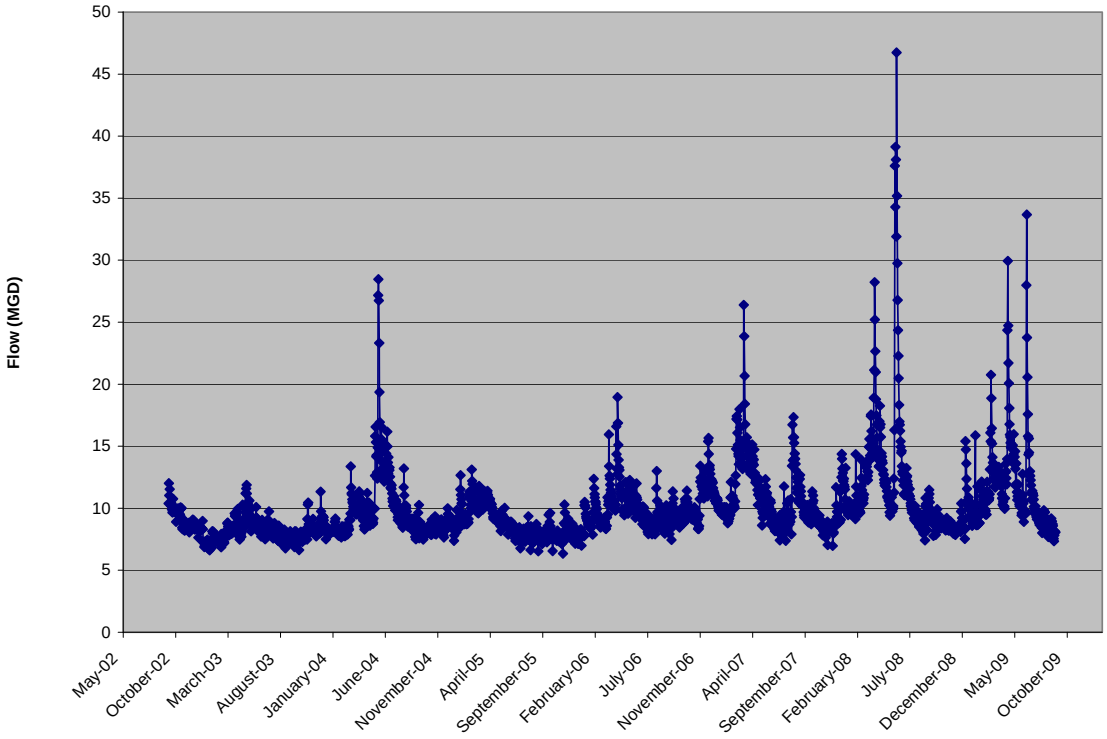
TABLE 2
Waukesha WWTP Average Monthly Effluent Concentrations (October 2002–August 2009)

Month	Flow (mgd)	BOD_5 (mg/L)	Ammonia (as N) (mg/L)	TP (mg/L)	Dissolved Oxygen (mg/L)	Temp (°C)	TSS (mg/L)	Fecal Coliform (cfu/100 mL)[a]	Copper (µg/L)[b]	Zinc (µg/L)[b]
Jan.	9.4	1.7	0.10	0.11	10.3	12.0	0.9	ND	6.6	42.0
Feb.	9.3	1.7	0.06	0.10	10.5	11.5	0.9	ND	12.4	48.6
March	11.3	1.7	0.14	0.12	10.4	12.3	1.1	ND	6.1	49.6
April	12.3	1.7	0.09	0.10	9.7	14.1	1.4	ND	8.6	22.0
May	11.5	2.0	0.20	0.12	9.0	16.4	1.2	2	7.1	45.7
June	12.1	2.6	0.14	0.21	8.2	18.8	1.8	49	6.1	30.5
July	9.2	1.8	0.05	0.16	8.0	20.6	1.0	2	6.1	29.3
Aug.	9.0	1.8	0.07	0.19	7.9	21.3	1.1	2	6.3	37.2
Sept.	8.8	2.1	0.10	0.21	8.0	20.8	1.0	2	8.7	39.0
Oct.	8.8	1.6	0.04	0.24	8.7	18.6	1.1	ND	5.7	36.6
Nov.	8.6	1.6	0.07	0.21	9.5	16.0	1.1	ND	6.7	33.8
Dec.	9.2	1.6	0.07	0.15	10.3	13.3	1.1	ND	9.3	47.4

[a]Geometric means were used for fecal coliform data. The numbers shown in the table represent the average geometric mean for each month.
[b]Data for copper and zinc between 2005 and 2009.

cfu – colony forming units; ND – no disinfection.

FIGURE 3
City of Waukesha WWTP Effluent Average Daily Flow



1.4 Infiltration and Inflow

The City of Waukesha has been implementing an aggressive infiltration and inflow (I&I) reduction program to reduce the amount of clear-water entering the sanitary sewer collection system. Like all communities with sanitary sewer collection systems, some I&I is observed in the City of Waukesha during wet periods and storm events. I&I contributes to the collection system flows during these times and subsequently receive the same treatment at the WWTP as do sanitary flows. The City of Waukesha's collection system and WWTP have adequate conveyance and treatment capacity to provide treatment of the I&I, but the City has continued the I&I reduction program to minimize the treatment costs associated with the I&I, and to minimize the I&I that could be part of the return flow.

Over the past several years many projects have been completed that contribute to reducing I&I, including sewer televising, smoke testing and dye tracing pipes and structures; replacing sewer laterals, cracked pipes and manholes; lining and sealing manholes and sewers; and identifying and correcting sump pump and foundation drain connections to the sanitary sewer. The City is continuing to investigate I&I throughout the collection system to prioritize projects that provide the most efficient I&I reduction. These efforts include sewer system modeling, in-pipe flow monitoring, sewer televising and smoke testing, and completing a sewer system evaluation survey (SSES).

2. Alternatives Identification

Five alternatives were considered for providing return flow to the Lake Michigan. Each alternative requires a pump station at the WWTP site to convey the return flow over the Lake Michigan watershed divide. The alternatives include:

- Alternative 1: Return Flow to Underwood Creek—Return treated wastewater effluent to Underwood Creek in Waukesha County, a tributary to Lake Michigan through the Menomonee River in Milwaukee.
- Alternative 2: Return Flow to Root River—Return treated wastewater effluent to the Root River in Milwaukee County, a tributary to Lake Michigan in Racine.
- Alternative 3: Return Flow Direct to Lake Michigan—Return treated wastewater effluent directly to Lake Michigan.
- Alternative 4: Return untreated wastewater to the Milwaukee Metropolitan Sewerage District for treatment and return to Lake Michigan.
- Alternative 5: Return treated wastewater to the Milwaukee Metropolitan Sewerage District for treatment and return to Lake Michigan.

The alternatives only considered a pump station at the WWTP site because there is available land owned by the City and it provides the least challenges for operation, maintenance, and implementation (compared to an off-site pump station location). Alternatives for a gravity return flow were not considered because it would require a very deep pipe that would require a tunnel for several miles, and would be much more expensive than the other alternatives that were evaluated in detail. The five alternatives are discussed below.

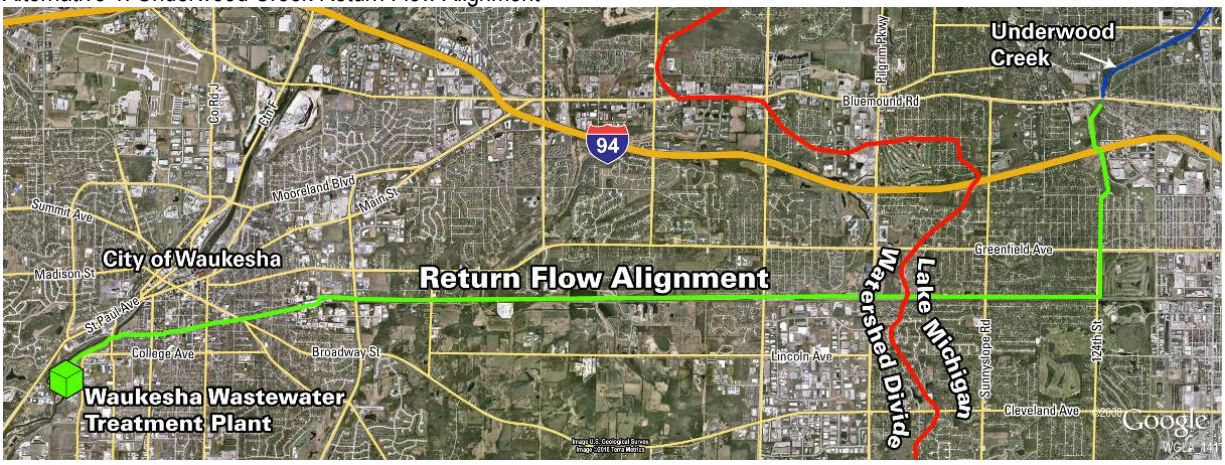
2.1 Alternative 1: Underwood Creek

Return flow to Underwood Creek is expected to occur in Waukesha County, near the crossing of Underwood Creek and Bluemound Road. From that location, Underwood Creek flows about 2.6 river miles to its confluence with the Menomonee River in Wauwatosa before flowing another 10 river miles to Lake Michigan in the City of Milwaukee.

A screening level layout was developed for the return flow pipeline (Figure 4). It begins at the City of Waukesha WWTP, and proceeds north and east through a City park and along an alley and minor streets for about 1.3 miles. The pipeline continues east for another 1.3 miles following an abandoned railroad corridor planned for a future recreational trail, where it joins with an utility corridor and bike trail and runs for another 7 miles. The pipeline continues north 1.9 miles along a street, bike path and Underwood Creek Parkway until it ends near the confluence of the north and south branch of Underwood Creek. In total, the pipeline consists of about 11.5 miles of 36-inch diameter pipe.

The return flow rate is based on the amount of drinking water supplied to the City of Waukesha. The return flow rate is anticipated to range from about 7.5 mgd to 13 mgd. Wastewater flow exceeding 13 mgd is anticipated to be discharged to the existing Fox River outfall.

FIGURE 4
Alternative 1: Underwood Creek Return Flow Alignment



The effect of the return flow on water quality, habitat and fisheries, and geomorphic stability in Underwood Creek were analyzed for the City's Lake Michigan Application. The return flow will have some impact on water quality, but will improve the water quality of Underwood Creek for some parameters (Appendix H in Application). The return flow will have a beneficial effect on habitat and fisheries (Appendix L in Application), and it will not negatively affect the geomorphic stability of the creek (Appendix G in Application). As discussed in the Application, the City will continue to meet current and future WDNR effluent limits for an Underwood Creek discharge.

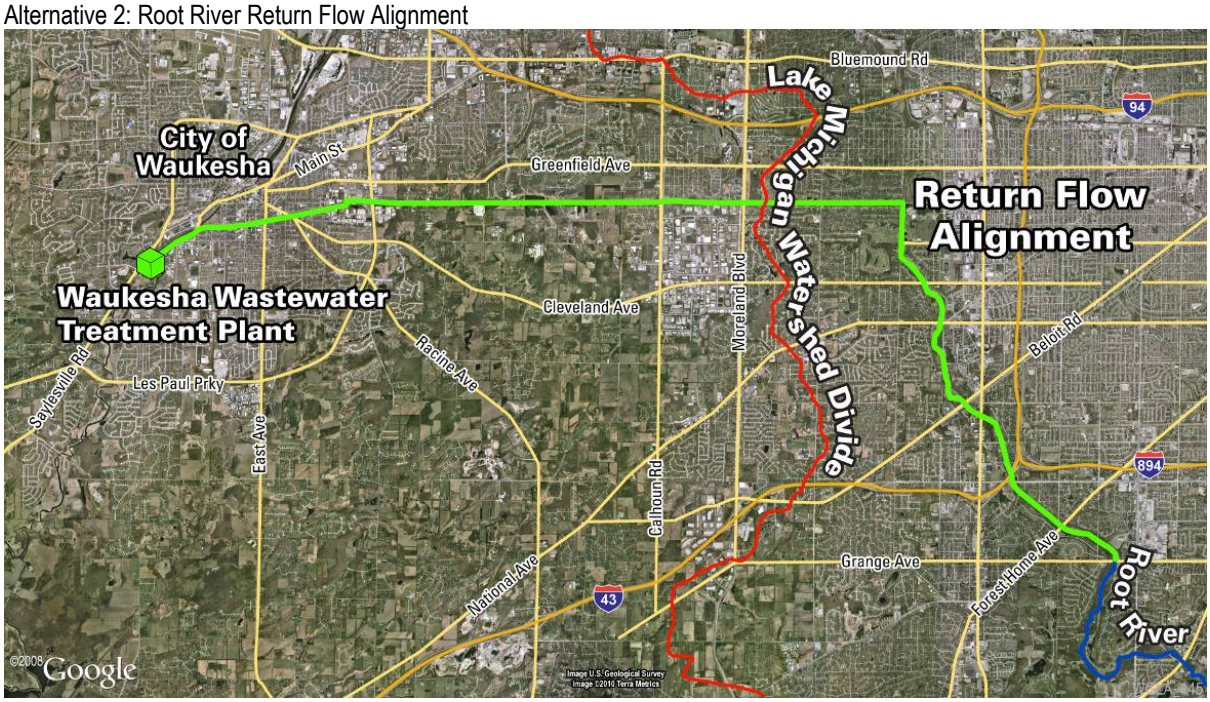
2.2 Alternative 2: Root River

The Root River flows through parts of Milwaukee and Racine counties, and into Lake Michigan at Racine, Wisconsin. The river has more natural channel (e.g., natural bottom substrate and vegetated river banks) than does Underwood Creek, and it has a mixture of land uses between its headwaters and Lake Michigan. The headwaters of the Root River are heavily urbanized, the middle reaches are primarily agriculture and lower density development, and the lower parts of the watershed near Lake Michigan are heavily urbanized.

The conceptual pipeline alignment for return flow to the Root River is the same as the pipeline for Underwood Creek for about the first 9.6 miles. Where the Underwood Creek pipeline heads north toward Underwood Creek, the Root River pipeline would head southeast for 6 miles toward the Root River (Figure 5) following streets, a parkway, and a bike trail. In total, the pipeline consists of about 15.5 miles of 36-inch diameter pipe.

The return flow rate is the same as the Underwood Creek alternative, and is anticipated to range from about 7.5 mgd to 13 mgd. Wastewater flow exceeding 13 mgd is anticipated to be discharged to the existing Fox River outfall.

FIGURE 5
Alternative 2: Root River Return Flow Alignment



The effects of return flow on the Root River are expected to be similar with Underwood Creek. The effects on water quality, habitat and fisheries, and geomorphic stability are discussed in Section 5 of the Application.

2.3 Alternative 3: Direct to Lake Michigan

A screening-level alignment for return flow directly to Lake Michigan was developed to evaluate the environmental effects and costs (Figure 6). The conceptual pipeline alignment is the same as that for Underwood Creek and Root River for the first 9.6 miles. Where the two pipelines diverge, the Lake Michigan alignment continues east about 11.2 miles parallel to a railroad corridor. As the alignment nears Lake Michigan, it continues east about 1.2 miles along a city street where it intersects with the Lake. The alignment extends into Lake Michigan about 0.5 miles to provide an offshore outfall. In total, the pipeline consists of about 23.5 miles of 36-inch diameter pipe.

The return flow rate is the same as the Underwood Creek alternative, and is anticipated to range from about 7.5 mgd to 13 mgd. Wastewater flow exceeding 13 mgd is anticipated to be discharged to the existing Fox River outfall.

FIGURE 6
Alternative 3: Direct to Lake Michigan Return Flow Alignment



The return flow will not negatively affect the habitat and fisheries, or the geomorphic stability of the lake. Water quality impacts to Lake Michigan are expected to be similar as the Underwood Creek and Root River alternatives because for all three alternatives, the return flow ultimately ends in Lake Michigan. This is discussed further in Section 5 of the Application.

2.4 Alternative 4: Return Untreated Wastewater to MMSD

This alternative includes constructing about 10 miles of 36-inch force main from the City of Waukesha WWTP to the MMSD collection system. The City of Waukesha's wastewater would combine with flow in the MMSD collection system and be conveyed to either of MMSD's two treatment plants.

The return flow rate is the same as the Underwood Creek alternative, and is anticipated to range from about 7.5 mgd to 13 mgd. Wastewater flow exceeding 13 mgd is anticipated to be discharged to the existing Fox River outfall.

The City of Waukesha would continue to operate a WWTP, to allow discharge to the Fox River during periods when sanitary sewer flow exceeds the maximum planned return flow rate of 13 mgd. To minimize out-of-basin water in the return flow (as required by the Compact), discharge of treated sanitary sewer flow would continue to the Fox River for the flow in excess of the maximum return flow. This intermittent operation of the WWTP would not be possible without significant modification of the existing WWTP processes.

Improvements to the MMSD collection system and treatment plants are likely required. The MMSD system is capacity limited during wet weather, so any flow returned to MMSD would likely require additional conveyance and treatment capacity equivalent to the return flow rate.

The Southeastern Wisconsin Regional Planning Commission included an alternative similar to this in its evaluation of return flow alternatives, but it was not recommended because the

cost exceeded that of return flow directly to Lake Michigan or to a Lake Michigan tributary.[7] Consequently, this alternative was not evaluated further for these reasons, and for those discussed above.

2.5 Alternative 5: Return Treated Wastewater to MMSD

This alternative includes the continued use the City of Waukesha WWTP for all discharges to the Fox River and return flow to MMSD. After the wastewater is treated at the City of Waukesha WWTP, the return flow would combine with flow in the MMSD collection system and be conveyed to either of MMSD's two treatment plants. The combined flow would receive treatment at the MMSD facilities for discharge directly to Lake Michigan. The same as the previous alternative, a 10-mile, 36-inch force main would convey the return flow from the WWTP to the MMSD collection system.

The return flow rate is the same as the Underwood Creek alternative, and is anticipated to range from about 7.5 mgd to 13 mgd. Wastewater flow exceeding 13 mgd is anticipated to be discharged to the existing Fox River outfall.

This alternative would be less challenging to implement than the previous alternative for providing untreated return flow to MMSD because the City of Waukesha's WWTP would operate continuously like its current operation (compared to the intermittent operation for only Fox River discharges as discussed in the previous alternative). However, it would still require the same capacity improvements to the MMSD system, which contribute to making this alternative much more costly than the other alternatives for return flow.[8]

Providing double-treatment of the return flow (first at the City of Waukesha WWTP and then at MMSD) is also an inefficient use of resources for no significant improvement in return flow water quality. As was with the previous alternative, this alternative was not evaluated further for the reasons discussed above.

3. Effluent Limits

The Wisconsin Department of Natural Resources (WDNR) has provided effluent limits (Attachment B) for a return flow using existing stream conditions for Underwood Creek and the Root River. The proposed limits are summarized below, and are very similar to those in the current WPDES permit (Table 1):

- Maximum effluent BOD and TSS concentrations between 5 to 10 mg/L
- Minimum effluent dissolved oxygen concentration of 7 mg/L.
- Maximum effluent TP concentration of 1 mg/L, but may decrease in the future with rules being developed.
- Limitations for NH_3-N ammonia nitrogen will be driven by effluent quality and would likely be more stringent than the maximum 2 to 6 mg/l in the current permit.

[7] SEWRPC. 2008. Planning Report No. 52: A Regional Water Supply Plan for Southeastern Wisconsin. Chapter 9, Page 37.
[8] Ibid.

- Limitations for mercury will remain as in the current permit (alternative limitations under NR 106.145). Limitations for other bioaccumulating chemicals of concern will not apply because they have not been detected.
- Limitations for chloride (alternative limitations under NR 106, Subchapter VII) and associated reduction requirements will continue.
- Disinfection, as currently applied, must continue.
- Specific provisions of NR 207.04(2)(a), that effluent limitations for an existing discharge, will remain unchanged if the treatment facility can meet those existing limitations. Existing effluent quality and permit limitations must be maintained.

4. Alternatives Analysis

The return flow alternatives considered economic and nonmonetary criteria for identifying the preferred alternative. These analyses are summarized below.

4.1 Economic Analysis

Cost estimates for the alternatives are summarized in Table 3 (details of the cost estimates are included in Appendix M of the Application). Cost estimates were developed for return flow to Underwood Creek, Root River, and direct to Lake Michigan. The cost estimates include a pump station at the City of Waukesha WWTP, a pipeline, and an outfall. The cost estimates were prepared for comparing alternatives based on information available at the time of the estimate. Detailed engineering design has not been completed. The final cost estimate of any project will depend on market conditions, site conditions, final project scope, schedule, and other variable factors. As a result, final project costs may vary from the estimates presented here. Cost estimates were not developed for the alternatives for return flow to MMSD because the alternatives were not further evaluated after initial screening, as discussed above.

TABLE 3
Cost Comparison for Return Flow Alternatives

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
1: Underwood Creek	$56,174,000	$119,000	$57,539,000	$58,050,000
2: Root River	$75,963,000	$145,000	$77,627,000	$78,249,000
3: Direct to Lake Michigan	$109,848,000	$159,000	$111,672,000	$112,355,000

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.
Includes a 6% discount rate for present worth analysis.

Return flow to Underwood Creek is the least cost alternative primarily because it has the shortest pipeline and least amount of infrastructure. The Root River return flow alignment is more costly primarily because it requires about 4 more miles of force main and a more powerful pump station. The direct Lake Michigan return flow is the most expensive of the three alternatives primarily because it requires about 12 more miles of force main compared

to Underwood Creek, a more powerful pump station, and an offshore outfall into Lake Michigan. As discussed above, the return flow alternatives to MMSD were eliminated after initial screening and therefore detailed cost estimates were not completed.

4.2 Nonmonetary Analysis

4.2.1 Alternative 1: Underwood Creek

Underwood Creek has been adversely affected by urbanization but a return flow could provide improvements to the creek. Engineered stormwater infrastructure routes runoff into the creek, rather than allowing infiltration into the ground and then to the stream as subsurface flow, as in the past. As a result, stream baseflow has been reduced, particularly at low flows and drought periods. The MMSD is rehabilitating a 1-mile stretch of Underwood Creek by removing much of the concrete streambed lining and rehabilitating the watercourse to reestablish aquatic and wetland habitat. One goal is to improve fish passage, as described in *Underwood Creek Rehabilitation and Flood Management Project; Preliminary Engineering Design Project.* As described in Section 5 and Appendix L of the Application, the return flow could support the rehabilitation efforts and provide additional environmental improvements.

This alternative also has the shortest pipeline and therefore would result in the least amount of construction, traffic disruptions and noise.

4.2.2 Alternative 2: Root River

Similar to return flow to Underwood Creek, a Root River return flow could also provide benefits to the river. These are discussed in Section 5 of the Application.

This alternative is expected to have more impacts during construction because the pipeline is longer, it requires more infrastructure, and its construction will likely have a longer duration than a return flow to Underwood Creek.

4.2.3 Alternative 3: Direct to Lake Michigan

This alternative has the greatest construction impacts because it requires the most infrastructure. Besides the need for construction in Lake Michigan with this alternative, the impacts to Lake Michigan are expected to be the same as the previous alternatives because all the alternatives ultimately flow to Lake Michigan. However, return flow directly to Lake Michigan would have no environmental benefit beyond returning the water to the Lake Michigan, because the return flow would be conveyed in a pipe, instead of through surface water.

This alternative requires the most infrastructure and therefore is expected to have the most construction impact. The proposed alignment also follows a railroad corridor through highly urbanized areas, where construction is expected to be more difficult compared to the previous alternatives. The impacts of this alternative are discussed in more detail in Section 5 of the Application.

4.2.4 Alternative 4: Return MMSD Untreated Wastewater to MMSD

As discussed above, this alternative was not considered after initial screening. It is not considered a sustainable or viable option.

4.2.5 Alternative 5: Return MMSD Treated Wastewater to MMSD

As discussed above, this alternative was not considered after initial screening. It is not considered a sustainable or viable option.

5. Environmental Assessment

As part of the Application, an *Environmental Report* (Appendix N) has been completed that evaluates the environmental affects of the return flow alternatives. In summary, a return flow to Underwood Creek has the least environmental impacts, and it provides an environmental improvement to the habitat and fisheries within Underwood Creek. A detailed evaluation is included in the Application.

6. Recommended Plan

Return flow to Underwood Creek is the preferred alternative because it is least cost, it has the least infrastructure and construction impacts, it can provide an improvement to the habitat and fisheries in Underwood Creek, and it requires the smallest pump station at the City of Waukesha WWTP, which will have the least energy demand.

The City of Waukesha WWTP site is about elevation 800 feet. The highest point along the length of the return flow alignment is about 900 feet, and the discharge to Underwood Creek is about 720 feet. The pump station will be designed to overcome the static head of about 100 feet, plus the friction losses in the pipeline. A plan view of the WWTP site with a potential location of a new effluent pump station is shown in Figure 7 and the pipeline alignment to Underwood Creek is shown in Figure 8.

FIGURE 7
City of Waukesha WWTP Site Plan Showing Potential Location of a Return Flow Pump Station

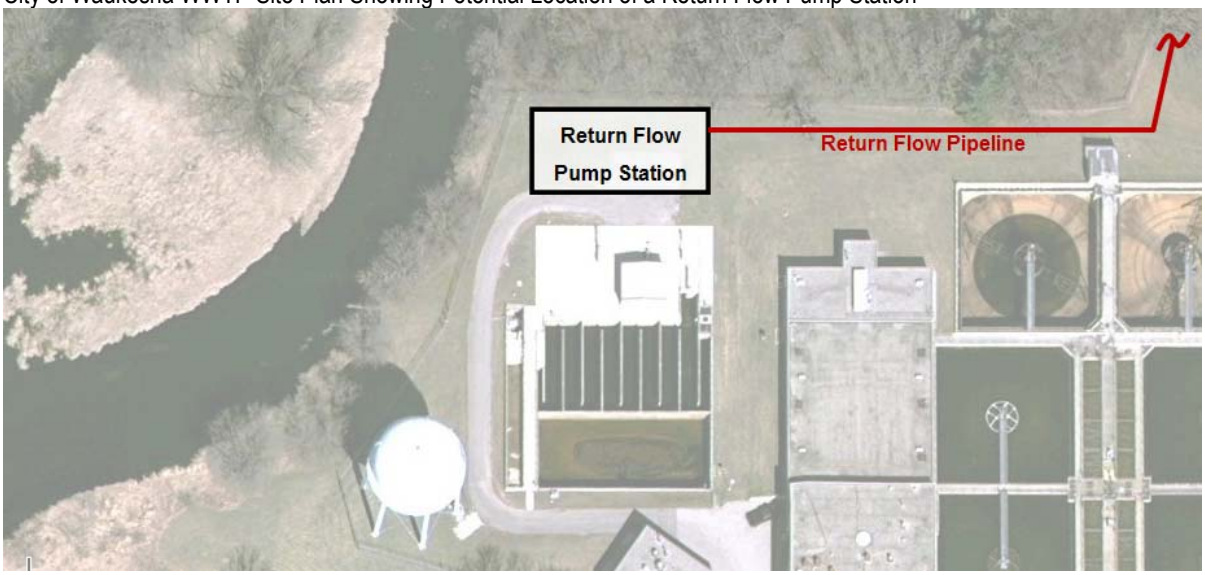


FIGURE 8
Underwood Creek Return Flow Pipeline Alignment



Attachment A
Current WPDES Permit

WISCONSIN
DEPT. OF NATURAL RESOURCES

WPDES PERMIT

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

PERMIT TO DISCHARGE UNDER THE WISCONSIN POLLUTANT DISCHARGE ELIMINATION SYSTEM

Waukesha City

is permitted, under the authority of Chapter 283, Wisconsin Statutes, to discharge from a facility located at
600 Sentry Drive
to

The Southeastern Fox River in Waukesha County

in accordance with the effluent limitations, monitoring requirements and other conditions set forth in this permit.

The permittee shall not discharge after the date of expiration. If the permittee wishes to continue to discharge after this expiration date an application shall be filed for reissuance of this permit, according to Chapter NR 200, Wis. Adm. Code, at least 180 days prior to the expiration date given below.

State of Wisconsin Department of Natural Resources
For the Secretary

By _____
Timothy Thompson
Basin Engineer

May 9, 2008
Date Permit Signed/Issued

PERMIT TERM: EFFECTIVE DATE - June 01, 2008 **EXPIRATION DATE - December 31, 2012**

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1 Influent Requirements

1.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
702	Samples shall be taken ahead of the Parshall flume, after screening and grit removal. This sample point is ahead of recycle flows.

1.2 Monitoring Requirements

The permittee shall comply with the following monitoring requirements.

1.2.1 Sampling Point 702 - INFLUENT

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Daily	Continuous	
BOD_5, Total		mg/L	Daily	24-Hr Flow Prop Comp	
Suspended Solids, Total		mg/L	Daily	24-Hr Flow Prop Comp	
Mercury, Total Recoverable		ng/L	Monthly	24-Hr Flow Prop Comp	
Cadmium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	
Chromium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	
Copper, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Lead, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	
Nickel, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	
Zinc, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	

1.2.1.1 Sample Analysis

Samples shall be analyzed using a method which provides adequate sensitivity so that results can be quantified, unless not possible using the most sensitive approved method.

1.2.1.2 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

2 In-Plant Requirements

2.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
101	Field Blank for Effluent Mercury
102	Flows that exceed the capacity of the expanded UV system and that have received preliminary, primary, secondary and tertiary treatment but not disinfection

2.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

2.2.1 Sampling Point 101 - Mercury Effluent Blank

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Mercury, Total Recoverable		ng/L	Monthly	Grab	See 3.2.1.3

2.2.2 Sampling Point 102 - In-Plant Diversion

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Per Occurrence	Continuous	See 2.2.2.1

2.2.2.1 In-Plant Diversion Requirements

This permit includes a compliance schedule to conduct tests on the UV disinfection system to evaluate the need for future additional disinfection facilities. A proposed plan of action for necessary upgrade of the disinfection system shall be submitted at the end of the study, along with an implementation schedule. If a diversion occurs between May 1 and September 30, the following conditions and monitoring shall apply:

- Fecal coliform limit shall remain in full force and effect following any diversion around the UV system. Regardless of the permit required sample frequency for fecal coliform, within 24 hours following any diversion around the UV system, the fecal coliform of disinfected effluent, tertiary effluent before disinfection and final effluent shall be sampled. The facility shall demonstrate compliance by a mass balance to estimate the final effluent fecal coliform density as follows: $[FC]_{eff} = \{Q_{uv}[FC]_{uv} + Q_{bypass}[FC]_{bypass}\}/Q_{eff}$

  where:

  Q_{eff} = flow rate of final plant effluent
  Q_{uv} = flow rate of disinfected effluent
  Q_{bypass} = flow rate of bypassed tertiary effluent

$[FC]_{eff}$ = fecal coliform density of final plant effluent (CFU/100 mL)
$[FC]_{uv}$ = fecal coliform density of disinfected effluent
$[FC]_{bypass}$ = fecal coliform density of tertiary effluent before disinfection

- The flow rate of the diverted flow shall be submitted on the monthly Discharge Monitoring Report (DMR or eDMR). Also, the plant flow trend chart(s) covering the day(s) of the diversion, and indicating the duration of the diversion event, shall be submitted electronically, with the Discharge Monitoring Report form, or with the electronic discharge monitoring form certification, no later than the 15th of the month following the month of the diversion(s).

2.2.2.2 Wet Weather SSO

The Burr Oak lift station is located at 1861 Oakdale Drive and is equipped with an overflow pipe that could discharge extreme wet weather flows into a ditch that discharges into the Fox River. The WWTP personnel have the capability to remotely monitor activities at the Burr Oak lift station through the SCADA system.
Bypasses and overflows of wastewater from the City of Waukesha sanitary sewerage system, including discharges from lift stations are prohibited and are not authorized by this permit. The Department may initiate legal action regarding such occurrences as authorized by s. 283.89, Wis. Stats., as provided in item 6.2.6 of this permit.

3 Surface Water Requirements

3.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
001	Flow proportional composite samples shall be taken from the effluent drop box after the UV disinfection system and the Parshall flume, before the outfall pipe. Grab samples shall also be taken from the effluent drop box .

3.2 Monitoring Requirements and Effluent Limitations

The permittee shall comply with the following monitoring requirements and limitations.

3.2.1 Sampling Point (Outfall) 001 - EFFLUENT

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Daily	Continuous	See 3.2.1.4
BOD_5, Total	Weekly Avg	8.5 mg/L	Daily	24-Hr Flow Prop Comp	July and August limit
BOD_5, Total	Weekly Avg	8.2 mg/L	Daily	24-Hr Flow Prop Comp	September limit
BOD_5, Total	Weekly Avg	10 mg/L	Daily	24-Hr Flow Prop Comp	October-June limit
Suspended Solids, Total	Weekly Avg	10 mg/L	Daily	24-Hr Flow Prop Comp	
pH Field	Daily Max	9.0 su	Daily	Grab	
pH Field	Daily Min	6.0 su	Daily	Grab	
Nitrogen, Ammonia (NH_3-N) Total	Daily Max	24 mg/L	Daily	24-Hr Flow Prop Comp	Limit applicable to only January, February, March, April, November and December
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	11 mg/L	Daily	24-Hr Flow Prop Comp	January limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	12 mg/L	Daily	24-Hr Flow Prop Comp	February, November and December limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	13 mg/L	Daily	24-Hr Flow Prop Comp	March limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	10 mg/L	Daily	24-Hr Flow Prop Comp	April and October limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	8.5 mg/L	Daily	24-Hr Flow Prop Comp	May limit

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	5.6 mg/L	Daily	24-Hr Flow Prop Comp	June limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	3.9 mg/L	Daily	24-Hr Flow Prop Comp	July limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	4.2 mg/L	Daily	24-Hr Flow Prop Comp	August limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	5.8 mg/L	Daily	24-Hr Flow Prop Comp	September limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.0 mg/L	Daily	24-Hr Flow Prop Comp	January limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.2 mg/L	Daily	24-Hr Flow Prop Comp	February limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	6.0 mg/L	Daily	24-Hr Flow Prop Comp	March limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.6 mg/L	Daily	24-Hr Flow Prop Comp	April limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	4.9 mg/L	Daily	24-Hr Flow Prop Comp	May limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	3.1 mg/L	Daily	24-Hr Flow Prop Comp	June limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	2.0 mg/L	Daily	24-Hr Flow Prop Comp	July limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	2.1 mg/L	Daily	24-Hr Flow Prop Comp	August limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	2.9 mg/L	Daily	24-Hr Flow Prop Comp	September limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	4.5 mg/L	Daily	24-Hr Flow Prop Comp	October limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.4 mg/L	Daily	24-Hr Flow Prop Comp	November limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.1 mg/L	Daily	24-Hr Flow Prop Comp	December limit
Dissolved Oxygen	Daily Min	6.7 mg/L	Daily	Grab	September limit
Dissolved Oxygen	Daily Min	7.0 mg/L	Daily	Grab	October-August limit
Chloride	Weekly Avg	756 mg/L	4/Month	24-Hr Comp	See 3.2.1.6
Phosphorus, Total	Monthly Avg	1.0 mg/L	Daily	24-Hr Flow Prop Comp	
Fecal Coliform	Geometric Mean	400 #/100 ml	3/Week	Grab	May-September limit
Cadmium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2
Chromium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2
Copper, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	See 3.2.1.2

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Lead, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2
Mercury, Total Recoverable	Daily Max	5.0 ng/L	Monthly	Grab	See 3.2.1.3
Nickel, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2
Zinc, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	See 3.2.1.2
Acute WET		TU_a	Annual	24-Hr Flow Prop Comp	See 3.2.1.5
Chronic WET		rTU_c	1/ 6 Months	24-Hr Flow Prop Comp	See 3.2.1.5

3.2.1.1 Average Annual Design Flow

The average annual design flow of the permittee's wastewater treatment facility is 14 MGD.

3.2.1.2 Sample Analysis

Samples shall be analyzed using a method which provides adequate sensitivity so that results can be quantified, unless not possible using the most sensitive approved method.

3.2.1.3 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

3.2.1.4 Peak Flow Reporting

For any calendar day during the disinfection season (May 1st through September 30th) where the peak instantaneous effluent flow is greater than 35 MGD, the permittee shall submit a plant flow trend chart. The chart(s) may be submitted electronically, with the Discharge Monitoring Report form, or with the electronic discharge monitoring form certification, no later than the 15th of the month following the month of the peak flow(s).

3.2.1.5 Whole Effluent Toxicity (WET) Testing

Primary Control Water: The SE Fox River, upstream and outside the mixing zone of the discharge (outfall 001) or any other known discharge

Instream Waste Concentration (IWC): 92%

Dilution series: At least five effluent concentrations and dual controls must be included in each test.

- **Acute:** 100, 50, 25, 12.5, 6.25% and any additional selected by the permittee.
- **Chronic:** 100, 75, 50, 25, 12.5% and any additional selected by the permittee.

WET Testing Frequency: Tests are required during the following quarters.

- **Acute:** Oct-Dec, 2008; July-Sept, 2009; Oct-Dec, 2010; July-Sept, 2011; Jan-March, 2012;
- **Chronic:** July-Sept, 2008; Oct-Dec, 2008; Jan-March, 2009; July-Sept, 2009; Apr-June, 2010; Oct-Dec, 2010; Jan-March, 2011; July-Sept, 2011; Jan-March, 2012; July-Sept, 2012.

Reporting: The permittee shall report test results on the Discharge Monitoring Report form, and also complete the "Whole Effluent Toxicity Test Report Form" (Section 6, "*State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition*"), for each test. The original, complete, signed version of the Whole Effluent Toxicity Test Report Form shall be sent to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., P.O. Box 7921, Madison, WI 53707-7921, within 45 days of test completion. The original Discharge Monitoring Report (DMR) form and one copy shall be sent to the contact and location provided on the DMR by the required deadline.

Determination of Positive Results: An acute toxicity test shall be considered positive if the Toxic Unit - Acute (TU_a) is greater than 1.0 for either species. The TU_a shall be calculated as follows: If $LC_{50} \geq 100$, then $TU_a = 1.0$. If LC_{50} is < 100, then $TU_a = 100 \div LC_{50}$. A chronic toxicity test shall be considered positive if the Relative Toxic Unit - Chronic (rTU_c) is greater than 1.0 for either species. The rTU_c shall be calculated as follows: If $IC_{25} \geq$ IWC, then $rTU_c = 1.0$. If $IC_{25} <$ IWC, then $rTU_c =$ IWC $\div IC_{25}$.

Additional Testing Requirements: Within 90 days of a test which showed positive results, the permittee shall submit the results of at least 2 retests to the Biomonitoring Coordinator on "Whole Effluent Toxicity Test Report Forms". The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

3.2.1.6 Chloride Variance – Implement Source Reduction Measures

The 4X/monthly monitoring for chloride shall be done on four consecutive days within a week.

This permit contains a variance to the water quality-based effluent limit (WQBEL) for chloride granted in accordance with s. NR 106.83(2), Wis. Adm. Code. As conditions of this variance the permittee shall (a) maintain effluent quality at or below the interim effluent limitation specified in the table above, (b) implement the chloride source reduction measures specified below, and (c) perform the actions listed in the compliance schedule. (See the Schedules of Compliance section herein.):

Source reduction measures shall include, but shall not be limited to the following elements. Where applicable, the frequency and suggested means of reporting are in brackets:

- Report daily minimum and maximum air temperature (for December through April) and precipitation (year round [DMRs]
- Continue education of homeowners on softener efficiency and reductions (via flyers, news releases, bill inserts, web site, or other means)[in reports as required in Section 5.3 of this permit]
- Recommend/require hard water for outside water sources [in reports as required in Section 5.3 of this permit]
- Track salt use for road de-icing [by June 30th of each year; report shall cover the entire winter season before the reporting date. Reporting may be done as a letter, e-mail, or as part of the DMR]
- Provide information on sanitary and storm sewer improvements [in reports as required by Section 5.3 of this permit]
- Provide information on any anticipated changes to chloride concentration/loading as a result of changes to municipal water supply quality/quantity [in reports as required by Section 5.3 of this permit]

4 Land Application Requirements

4.1 Sampling Point(s)

The discharge(s) shall be limited to land application of the waste type(s) designated for the listed sampling point(s) on Department approved land spreading sites or by hauling to another facility.

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
002	Samples shall be taken and composited from the belt presses during press runs, before discharge to the sludge storage building. Grab samples are also taken from stacks in the sludge storage building prior to land application.

4.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

4.2.1 Sampling Point (Outfall) 002 - Anaerobic Belt Pressed Sludge

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Solids, Total		Percent	1/ 2 Months	Grab Comp	
Arsenic Dry Wt	Ceiling	75 mg/kg	1/ 2 Months	Grab Comp	
Arsenic Dry Wt	High Quality	41 mg/kg	1/ 2 Months	Grab Comp	
Cadmium Dry Wt	Ceiling	85 mg/kg	1/ 2 Months	Grab Comp	
Cadmium Dry Wt	High Quality	39 mg/kg	1/ 2 Months	Grab Comp	
Copper Dry Wt	Ceiling	4,300 mg/kg	1/ 2 Months	Grab Comp	
Copper Dry Wt	High Quality	1,500 mg/kg	1/ 2 Months	Grab Comp	
Lead Dry Wt	Ceiling	840 mg/kg	1/ 2 Months	Grab Comp	
Lead Dry Wt	High Quality	300 mg/kg	1/ 2 Months	Grab Comp	
Mercury Dry Wt	Ceiling	57 mg/kg	1/ 2 Months	Grab Comp	
Mercury Dry Wt	High Quality	17 mg/kg	1/ 2 Months	Grab Comp	
Molybdenum Dry Wt	Ceiling	75 mg/kg	1/ 2 Months	Grab Comp	
Nickel Dry Wt	Ceiling	420 mg/kg	1/ 2 Months	Grab Comp	
Nickel Dry Wt	High Quality	420 mg/kg	1/ 2 Months	Grab Comp	
Selenium Dry Wt	Ceiling	100 mg/kg	1/ 2 Months	Grab Comp	
Selenium Dry Wt	High Quality	100 mg/kg	1/ 2 Months	Grab Comp	
Zinc Dry Wt	Ceiling	7,500 mg/kg	1/ 2 Months	Grab Comp	
Zinc Dry Wt	High Quality	2,800 mg/kg	1/ 2 Months	Grab Comp	
Nitrogen, Total Kjeldahl		Percent	1/ 2 Months	Grab Comp	
Nitrogen, Ammonium (NH_4-N) Total		Percent	1/ 2 Months	Grab Comp	
Phosphorus, Total		Percent	1/ 2 Months	Grab Comp	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Phosphorus, Water Extractable		Percent	1/2 Months	Grab Comp	
Potassium, Total Recoverable		Percent	1/2 Months	Grab Comp	
PCB Total Dry Wt	Ceiling	50 mg/kg	Once	Grab Comp	See 4.2.1.5
PCB Total Dry Wt	High Quality	10 mg/kg	Once	Grab Comp	See 4.2.1.5
Radium 226 Dry Wt		pCi/g	Quarterly	Grab Comp	

Other Sludge Requirements	
Sludge Requirements	**Sample Frequency**
List 3 Requirements – Pathogen Control: The requirements in List 3 shall be met prior to land application of sludge.	**Quarterly**
List 4 Requirements – Vector Attraction Reduction: The vector attraction reduction shall be satisfied prior to, or at the time of land application as specified in List 4.	**Quarterly**

4.2.1.1 List 2 Analysis

If the monitoring frequency for List 2 parameters is more frequent than "Annual" then the sludge may be analyzed for the List 2 parameters just prior to each land application season rather than at the more frequent interval specified.

4.2.1.2 Changes in Feed Sludge Characteristics

If a change in feed sludge characteristics, treatment process, or operational procedures occurs which may result in a significant shift in sludge characteristics, the permittee shall reanalyze the sludge for List 1, 2, 3 and 4 parameters each time such change occurs.

4.2.1.3 Multiple Sludge Sample Points (Outfalls)

If there are multiple sludge sample points (outfalls), but the sludges are not subject to different sludge treatment processes, then a separate List 2 analysis shall be conducted for each sludge type which is land applied, just prior to land application, and the application rate shall be calculated for each sludge type. In this case, List 1, 3, and 4 and PCBs need only be analyzed on a single sludge type, at the specified frequency. If there are multiple sludge sample points (outfalls), due to multiple treatment processes, List 1, 2, 3 and 4 and PCBs shall be analyzed for each sludge type at the specified frequency.

4.2.1.4 Sludge Which Exceeds the High Quality Limit

Cumulative pollutant loading records shall be kept for all bulk land application of sludge which does not meet the high quality limit for any parameter. This requirement applies for the entire calendar year in which any exceedance of Table 3 of s. NR 204.07(5)(c), is experienced. Such loading records shall be kept for all List 1 parameters for each site land applied in that calendar year. The formula to be used for calculating cumulative loading is as follows:

[(Pollutant concentration (mg/kg) x dry tons applied/ac) ÷ 500] + previous loading (lbs/acre) = cumulative lbs pollutant per acre

When a site reaches 90% of the allowable cumulative loading for any metal established in Table 2 of s. NR 204.07(5)(b), the Department shall be so notified through letter or in the comment section of the annual land application report (3400-55).

4.2.1.5 Sludge Analysis for PCBs

The permittee shall analyze the sludge for Total PCBs one time during **2009**. The results shall be reported as "PCB Total Dry Wt". Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with Table EM in s. NR 219.04, Wis. Adm. Code and the conditions specified in Standard Requirements of this permit. PCB results shall be submitted by January 31, following the specified year of analysis.

4.2.1.6 Lists 1, 2, 3, and 4

List 1 **TOTAL SOLIDS AND METALS** See the Monitoring Requirements and Limitations table above for monitoring frequency and limitations for the List 1 parameters
Solids, Total (percent)
Arsenic, mg/kg (dry weight)
Cadmium, mg/kg (dry weight)
Copper, mg/kg (dry weight)
Lead, mg/kg (dry weight)
Mercury, mg/kg (dry weight)
Molybdenum, mg/kg (dry weight)
Nickel, mg/kg (dry weight)
Selenium, mg/kg (dry weight)
Zinc, mg/kg (dry weight)

List 2 **NUTRIENTS** See the Monitoring Requirements and Limitations table above for monitoring frequency for the List 2 parameters
Solids, Total (percent)
Nitrogen Total Kjeldahl (percent)
Nitrogen Ammonium (NH4-N) Total (percent)
Phosphorus Total as P (percent)
Phosphorus, Water Extractable (as percent of Total P)
Potassium Total Recoverable (percent)

List 3

PATHOGEN CONTROL FOR CLASS B SLUDGE

The permittee shall implement pathogen control as listed in List 3. The Department shall be notified of the pathogen control utilized and shall be notified when the permittee decides to utilize alternative pathogen control.

The following requirements shall be met prior to land application of sludge.

Parameter	Unit	Limit
Fecal Coliform*	MPN/gTS or CFU/gTS	2,000,000
OR, ONE OF THE FOLLOWING PROCESS OPTIONS		
Aerobic Digestion	Air Drying	
Anaerobic Digestion	Composting	
Alkaline Stabilization	PSRP Equivalent Process	

* The Fecal Coliform limit shall be reported as the geometric mean of 7 discrete samples on a dry weight basis.

List 4

VECTOR ATTRACTION REDUCTION

The permittee shall implement any one of the vector attraction reduction options specified in List 4. The Department shall be notified of the option utilized and shall be notified when the permittee decides to utilize an alternative option.

One of the following shall be satisfied prior to, or at the time of land application as specified in List 4.

Option	Limit	Where/When it Shall be Met
Volatile Solids Reduction	≥38%	Across the process
Specific Oxygen Uptake Rate	≤1.5 mg O_2/hr/g TS	On aerobic stabilized sludge
Anaerobic bench-scale test	<17 % VS reduction	On anaerobic digested sludge
Aerobic bench-scale test	<15 % VS reduction	On aerobic digested sludge
Aerobic Process	>14 days, Temp >40°C and Avg. Temp > 45°C	On composted sludge
pH adjustment	>12 S.U. (for 2 hours) and >11.5 (for an additional 22 hours)	During the process
Drying without primary solids	>75 % TS	When applied or bagged
Drying with primary solids	>90 % TS	When applied or bagged
Equivalent Process	Approved by the Department	Varies with process
Injection	-	When applied
Incorporation	-	Within 6 hours of application

4.2.1.7 Daily Land Application Log

Daily Land Application Log		
Discharge Monitoring Requirements and Limitations The permittee shall maintain a daily land application log for biosolids land applied each day when land application occurs. The following minimum records must be kept, in addition to all analytical results for the biosolids land applied. The log book records shall form the basis for the annual land application report requirements.		
Parameters	**Units**	**Sample Frequency**
DNR Site Number(s)	Number	Daily as used
Outfall number applied	Number	Daily as used
Acres applied	Acres	Daily as used
Volume applied	As appropriate * /day	Daily as used
Application rate per acre	unit */acre	Daily as used
Nitrogen applied per acre	lb/acre	Daily as used
Method of Application	Injection, Incorporation, or surface applied	Daily as used

*gallons, cubic yards, dry US Tons or dry Metric Tons

5 Schedules of Compliance

5.1 Mercury Pollutant Minimization Program

An alternative mercury effluent limitation of 5.0 ng/L is included in this permit pursuant to NR 106.145(6); therefore, the permittee shall implement a pollutant minimization program as outlined below.

Required Action	Date Due
Implement the Mercury Pollutant Minimization Program (PMP) Plan: The permittee shall continue to implement the mercury PMP plan as amended by the Department	
Submit the first annual status report: The permittee shall submit to the Department an annual status report on the progress of the PMP as required by s. NR 106.145(7), Wis. Adm. Code. Submittal of the first annual status report is required by the Date Due. The final report shall be submitted three months prior to permit expiration. Note: If the permittee wishes to apply for an alternative mercury effluent limitation, that application is due with the application for permit reissuance by 6 months prior to permit expiration. The permittee should submit or reference the PMP plan as updated by the Annual Status Report or more recent developments as part of that application.	09/30/2008
Second annual report: Submit the second annual report	09/30/2009
Third annual report: Submit the third annual report	09/30/2010
Fourth annual report: Submit the fourth annual report	09/30/2011
Final report: Submit the final progress report	06/30/2012

5.2 Ultraviolet Disinfection System Evaluation and Upgrade

Tests shall be conducted on the UV disinfection system to evaluate the need for future additional disinfection facilities. A proposed plan of action for necessary upgrade of the disinfection system shall be submitted to the Department at the end of the study, along with an implementation schedule.

Required Action	Date Due
Plan of Study: Submit a plan of study for the evaluation of the UV disinfection system. The study shall include an evaluation of the hydraulic capacities and effectiveness of the system under various conditions of flow, lamp intensities and different system configurations. The study shall also include an evaluation of alternatives for additional disinfection needs.	06/30/2008
Submit the First Annual Report: Submit a report of the study carried out in the previous year. The report shall include an analysis of information collected from the study and an assessment of progress on completing the work called for in the plan.	01/31/2009
Second Annual Report: Submit a report as described in item 2.	01/31/2010
Submit Final Report : Submit the final report for the plan of study carried out on the UV system, along with a proposed plan of action and implementation schedule.	01/31/2011
Complete Action: Complete the plan of action and implementation program approved by the Department.	03/31/2012

5.3 Chloride Target Value

As a condition of the variance to the water quality based effluent limitation(s) for chloride granted in accordance with s. NR 106.83(2), Wis. Adm. Code, the permittee shall perform the following actions.

Required Action	Date Due
Chloride Progress Report: Submit a progress report, that shall indicate which chloride source reduction measures have been implemented. Chloride source reduction measures are noted in Section 3.2.1.5 of this permit. Note that the interim limitation of 756 mg/l, weekly average, remains enforceable until new enforceable limits are established in the next permit issuance. The first chloride progress report is to be submitted by the Date Due.	12/31/2008
Chloride Progress Report #2: Submit a chloride progress report.	09/30/2010
Final Chloride Report: Submit a final report documenting the success in meeting the chloride target value of 440 mg/l, weekly average, as well as the anticipated future reduction in chloride sources and chloride effluent concentrations. This report shall also include proposed target values and source reduction measures for negotiations with the department if the permittee intends to seek a renewed chloride variance per s. NR 106.83, Wis. Adm. Code, for the reissued permit. Note that the target value is the benchmark for evaluating the effectiveness of the chloride source reduction measures, but is not an enforceable limitation under the terms of this permit.	03/31/2012

5.4 Electrical Power System Improvement

A compliance schedule to provide alternative power source(s) to critical areas of the treatment process and to improve the power system within the facility.

Required Action	Date Due
Complete Action: Complete the plan of action for the improvement of the electrical power system at the wastewater treatment facility including providing alternative power source(s) at critical points of the plant's treatment system, such as the preliminary treatment building, the primary effluent pump station and the blower building, when a power failure occurs.	03/31/2009

6 Standard Requirements

NR 205, Wisconsin Administrative Code: The conditions in ss. NR 205.07(1) and NR 205.07(2), Wis. Adm. Code, are included by reference in this permit. The permittee shall comply with all of these requirements. Some of these requirements are outlined in the Standard Requirements section of this permit. Requirements not specifically outlined in the Standard Requirement section of this permit can be found in ss. NR 205.07(1) and NR 205.07(2).

6.1 Reporting and Monitoring Requirements

6.1.1 Monitoring Results

Monitoring results obtained during the previous month shall be summarized and reported on a Department Wastewater Discharge Monitoring Report. The report may require reporting of any or all of the information specified below under 'Recording of Results'. This report is to be returned to the Department no later than the date indicated on the form. When submitting a paper Discharge Monitoring Report form, the original and one copy of the Wastewater Discharge Monitoring Report Form shall be submitted to the return address printed on the form. A copy of the Wastewater Discharge Monitoring Report Form or an electronic file of the report shall be retained by the permittee.

All Wastewater Discharge Monitoring Reports submitted to the Department after January 1, 2008 should be submitted using the electronic Discharge Monitoring Report system, but due to the fact that the proposed permit for Waukesha is expected to be effective no earlier than January 1st, 2008, the permittee would have difficulty incorporating new or changed monitoring information into the electronic system used by the plant to comply with electronic discharge reporting by January 1st, 2008. The Department will allow a reasonable time beyond this date to accommodate needed changes by the permittee.

If the permittee monitors any pollutant more frequently than required by this permit, the results of such monitoring shall be included on the Wastewater Discharge Monitoring Report.

The permittee shall comply with all limits for each parameter regardless of monitoring frequency. For example, monthly, weekly, and/or daily limits shall be met even with monthly monitoring. The permittee may monitor more frequently than required for any parameter.

An Electronic Discharge Monitoring Report Certification sheet shall be signed and submitted with each electronic Discharge Monitoring Report submittal. This certification sheet, which is not part of the electronic report form, shall be signed by a principal executive officer, a ranking elected official or other duly authorized representative and shall be mailed to the Department at the time of submittal of the electronic Discharge Monitoring Report. The certification sheet certifies that the electronic report form is true, accurate and complete. Paper reports shall be signed by a principal executive officer, a ranking elected official, or other duly authorized representative.

6.1.2 Sampling and Testing Procedures

Sampling and laboratory testing procedures shall be performed in accordance with Chapters NR 218 and NR 219, Wis. Adm. Code and shall be performed by a laboratory certified or registered in accordance with the requirements of ch. NR 149, Wis. Adm. Code. Groundwater sample collection and analysis shall be performed in accordance with ch. NR 140, Wis. Adm. Code. The analytical methodologies used shall enable the laboratory to quantitate all substances for which monitoring is required at levels below the effluent limitation. If the required level cannot be met by any of the methods available in NR 219, Wis. Adm. Code, then the method with the lowest limit of detection shall be selected. Additional test procedures may be specified in this permit.

6.1.3 Pretreatment Sampling Requirements

Sampling for pretreatment parameters (cadmium, chromium, copper, lead, nickel, zinc, and mercury) shall be done during a day each month when industrial discharges are occurring at normal to maximum levels. The sampling of the

influent and effluent for these parameters shall be coordinated. All 24 hour composite samples shall be flow proportional.

6.1.4 Recording of Results

The permittee shall maintain records which provide the following information for each effluent measurement or sample taken:

- the date, exact place, method and time of sampling or measurements;
- the individual who performed the sampling or measurements;
- the date the analysis was performed;
- the individual who performed the analysis;
- the analytical techniques or methods used; and
- the results of the analysis.

6.1.5 Reporting of Monitoring Results

The permittee shall use the following conventions when reporting effluent monitoring results:

- Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 0.1 mg/L, report the pollutant concentration as < 0.1 mg/L.

- Pollutant concentrations equal to or greater than the limit of detection, but less than the limit of quantitation, shall be reported and the limit of quantitation shall be specified.

- For the purposes of reporting a calculated result, average or a mass discharge value, the permittee may substitute a 0 (zero) for any pollutant concentration that is less than the limit of detection. However, if the effluent limitation is less than the limit of detection, the department may substitute a value other than zero for results less than the limit of detection, after considering the number of monitoring results that are greater than the limit of detection and if warranted when applying appropriate statistical techniques.

6.1.6 Compliance Maintenance Annual Reports

Compliance Maintenance Annual Reports (CMAR) shall be completed using information obtained over each calendar year regarding the wastewater conveyance and treatment system. The CMAR shall be submitted by the permittee in accordance with ch. NR 208, Wis. Adm. Code, by June 30, each year on an electronic report form provided by the Department.

In the case of a publicly owned treatment works, a resolution shall be passed by the governing body and submitted as part of the CMAR, verifying its review of the report and providing responses as required. Private owners of wastewater treatment works are not required to pass a resolution; but they must provide an Owner Statement and responses as required, as part of the CMAR submittal.

A separate CMAR certification document, that is not part of the electronic report form, shall be mailed to the Department at the time of electronic submittal of the CMAR. The CMAR certification shall be signed and submitted by an authorized representative of the permittee. The certification shall be submitted by mail. The certification shall verify the electronic report is complete, accurate and contains information from the owner's treatment works.

6.1.7 Records Retention

The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by the permit, and records of all data used to complete the application for the permit for a period of at least 3 years from the

date of the sample, measurement, report or application. All pertinent sludge information, including permit application information and other documents specified in this permit or s. NR 204.06(9), Wis. Adm. Code shall be retained for a minimum of 5 years.

6.1.8 Other Information

Where the permittee becomes aware that it failed to submit any relevant facts in a permit application or submitted incorrect information in a permit application or in any report to the Department, it shall promptly submit such facts or correct information to the Department.

6.2 System Operating Requirements

6.2.1 Noncompliance Notification

- The permittee shall report the following types of noncompliance by a telephone call to the Department's regional office within 24 hours after becoming aware of the noncompliance:
  - any noncompliance which may endanger health or the environment;
  - any violation of an effluent limitation resulting from an unanticipated bypass;
  - any violation of an effluent limitation resulting from an upset; and
  - any violation of a maximum discharge limitation for any of the pollutants listed by the Department in the permit, either for effluent or sludge.

- A written report describing the noncompliance shall also be submitted to the Department's regional office within 5 days after the permittee becomes aware of the noncompliance. On a case-by-case basis, the Department may waive the requirement for submittal of a written report within 5 days and instruct the permittee to submit the written report with the next regularly scheduled monitoring report. In either case, the written report shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times; the steps taken or planned to reduce, eliminate and prevent reoccurrence of the noncompliance; and if the noncompliance has not been corrected, the length of time it is expected to continue.

NOTE: Section 292.11(2)(a), Wisconsin Statutes, requires any person who possesses or controls a hazardous substance or who causes the discharge of a hazardous substance to notify the Department of Natural Resources **immediately** of any discharge not authorized by the permit. The discharge of a hazardous substance that is not authorized by this permit or that violates this permit may be a hazardous substance spill. To report a hazardous substance spill, call DNR's 24-hour HOTLINE at **1-800-943-0003**

6.2.2 Flow Meters

Flow meters shall be calibrated annually, as per s. NR 218.06, Wis. Adm. Code.

6.2.3 Raw Grit and Screenings

All raw grit and screenings shall be disposed of at a properly licensed solid waste facility or picked up by a licensed waste hauler. If the facility or hauler are located in Wisconsin, then they shall be licensed under chs. NR 500-536, Wis. Adm. Code.

6.2.4 Sludge Management

All sludge management activities shall be conducted in compliance with ch. NR 204 "Domestic Sewage Sludge Management", Wis. Adm. Code.

6.2.5 Prohibited Wastes

Under no circumstances may the introduction of wastes prohibited by s. NR 211.10, Wis. Adm. Code, be allowed into the waste treatment system. Prohibited wastes include those:

- which create a fire or explosion hazard in the treatment work;
- which will cause corrosive structural damage to the treatment work;
- solid or viscous substances in amounts which cause obstructions to the flow in sewers or interference with the proper operation of the treatment work;
- wastewaters at a flow rate or pollutant loading which are excessive over relatively short time periods so as to cause a loss of treatment efficiency; and
- changes in discharge volume or composition from contributing industries which overload the treatment works or cause a loss of treatment efficiency.

6.2.6 Unscheduled Bypassing

Any unscheduled bypass or overflow of wastewater at the treatment works or from the collection system is prohibited, and the Department may take enforcement action against a permittee for such occurrences under s. 283.89, Wis. Stats., unless:

- The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
- There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
- The permittee notified the Department as required in this Section.

Whenever there is an unscheduled bypass or overflow occurrence at the treatment works or from the collection system, the permittee shall notify the Department within 24 hours of initiation of the bypass or overflow occurrence by telephoning the wastewater staff in the regional office as soon as reasonably possible (FAX, email or voice mail, if staff are unavailable).

In addition, the permittee shall within 5 days of conclusion of the bypass or overflow occurrence report the following information to the Department in writing:

- Reason the bypass or overflow occurred, or explanation of other contributing circumstances that resulted in the overflow event. If the overflow or bypass is associated with wet weather, provide data on the amount and duration of the rainfall or snow melt for each separate event.
- Date the bypass or overflow occurred.
- Location where the bypass or overflow occurred.
- Duration of the bypass or overflow and estimated wastewater volume discharged.
- Steps taken or the proposed corrective action planned to prevent similar future occurrences.
- Any other information the permittee believes is relevant.

6.2.7 Scheduled Bypassing

Any construction or normal maintenance which results in a bypass of wastewater from a treatment system is prohibited unless authorized by the Department in writing. If the Department determines that there is significant

public interest in the proposed action, the Department may schedule a public hearing or notice a proposal to approve the bypass. Each request shall specify the following minimum information:

- proposed date of bypass;
- estimated duration of the bypass;
- estimated volume of the bypass;
- alternatives to bypassing; and
- measures to mitigate environmental harm caused by the bypass.

6.2.8 Proper Operation and Maintenance

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control which are installed or used by the permittee to achieve compliance with the conditions of this permit. The wastewater treatment facility shall be under the direct supervision of a state certified operator as required in s. NR 108.06(2), Wis. Adm. Code. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training as required in ch. NR 114, Wis. Adm. Code, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of the permit.

6.3 Surface Water Requirements

6.3.1 Permittee-Determined Limit of Quantitation Incorporated into this Permit

For pollutants with water quality-based effluent limits below the Limit of Quantitation (LOQ) in this permit, the LOQ calculated by the permittee and reported on the Discharge Monitoring Reports (DMRs) is incorporated by reference into this permit. The LOQ shall be reported on the DMRs, shall be the lowest quantifiable level practicable, and shall be no greater than the minimum level (ML) specified in or approved under 40 CFR Part 136 for the pollutant at the time this permit was issued, unless this permit specifies a higher LOQ.

6.3.2 Appropriate Formulas for Effluent Calculations

The permittee shall use the following formulas for calculating effluent results to determine compliance with average limits and mass limits:

Weekly/Monthly average concentration = the sum of all daily results for that week/month, divided by the number of results during that time period.

Weekly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the week.

Monthly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the month.

6.3.3 Visible Foam or Floating Solids

There shall be no discharge of floating solids or visible foam in other than trace amounts.

6.3.4 Percent Removal

During any 30 consecutive days, the average effluent concentrations of BOD_5 and of total suspended solids shall not exceed 15% of the average influent concentrations, respectively. This requirement does not apply to removal of total suspended solids if the permittee operates a lagoon system and has received a variance for suspended solids granted under NR 210.07(2), Wis. Adm. Code.

6.3.5 Chloride Notification

The permittee shall notify the Department in writing of any proposed changes which may affect the characteristics of the wastewater, which results in an increase in the concentration of chloride, under the authority of sections 283.31(4)(b) and 283.59(1), Stats. This notification shall include a description of the proposed source of chlorides and the anticipated increase in concentration. Following receipt of the notification, the Department may propose a modification to the permit.

6.3.6 Fecal Coliforms

The limit for fecal coliforms shall be expressed as a monthly geometric mean.

6.3.7 Seasonal Disinfection

Disinfection shall be provided from May 1 through September 30 of each year. Monitoring requirements and the limitation for fecal coliforms apply only during the period in which disinfection is required. Whenever chlorine is used for disinfection or other uses, the limitations and monitoring requirements for residual chlorine shall apply. A dechlorination process shall be in operation whenever chlorine is used.

6.3.8 Whole Effluent Toxicity (WET) Monitoring Requirements

In order to determine the potential impact of the discharge on aquatic organisms, static-renewal toxicity tests shall be performed on the effluent in accordance with the procedures specified in the *"State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition" (PUB-WT-797*, November 2004) as required by NR 219.04, Table A, Wis. Adm. Code). All of the WET tests required in this permit, including any required retests, shall be conducted on the *Ceriodaphnia dubia* and fathead minnow species. Receiving water samples shall not be collected from any point in contact with the permittee's mixing zone and every attempt shall be made to avoid contact with any other discharge's mixing zone.

6.3.9 Whole Effluent Toxicity (WET) Identification and Reduction

Within 60 days of a retest which showed positive results, the permittee shall submit a written report to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., PO Box 7921, Madison, WI 53707-7921, which details the following:

- A description of actions the permittee has taken or will take to remove toxicity and to prevent the recurrence of toxicity;

- A description of toxicity reduction evaluation (TRE) investigations that have been or will be done to identify potential sources of toxicity, including some or all of the following actions:

(a) Evaluate the performance of the treatment system to identify deficiencies contributing to effluent toxicity (e.g., operational problems, chemical additives, incomplete treatment)

(b) Identify the compound(s) causing toxicity

(c) Trace the compound(s) causing toxicity to their sources (e.g., industrial, commercial, domestic)

(d) Evaluate, select, and implement methods or technologies to control effluent toxicity (e.g., in-plant or pretreatment controls, source reduction or removal)

- Where corrective actions including a TRE have not been completed, an expeditious schedule under which corrective actions will be implemented;
- If no actions have been taken, the reason for not taking action.

The permittee may also request approval from the Department to postpone additional retests in order to investigate the source(s) of toxicity. Postponed retests must be completed after toxicity is believed to have been removed.

6.3.10 Whole Effluent Toxicity (WET) and Chloride Source Reduction Measures

Acute whole effluent toxicity testing requirements and acute whole effluent toxicity limitations may be held in abeyance by the department until chloride source reduction actions are completed, according to s. NR 106.89, Wis. Adm. Code, if either:

- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride exceeds 2,500 mg/L, or
- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride is less than 2,500 mg/L, but in excess of the calculated acute water quality-based effluent limitation, and additional data are submitted which demonstrate that chloride is the sole source of acute toxicity.

Chronic whole effluent toxicity testing requirements and chronic whole effluent toxicity limitations may be held in abeyance by the department until chloride source reduction actions are completed, according to s. NR 106.89, Wis. Adm. Code, if either:

- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride exceeds 2 times the calculated chronic water quality-based effluent limitation, or
- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride is less than 2 times the calculated chronic water quality-based effluent limitation, but in excess of the calculated chronic water quality-based effluent limitation, and additional data are submitted which demonstrate that chloride is the sole source of chronic toxicity.

Following the completion of chloride source reduction activities, the department shall evaluate the need for whole effluent toxicity monitoring and limitations.

6.4 Pretreatment Program Requirements

The permittee is required to operate an industrial pretreatment program as described in the program initially approved by the Department of Natural Resources including any subsequent program modifications approved by the Department, and including commitments to program implementation activities provided in the permittee's annual pretreatment program report, and that complies with the requirements set forth in 40 CFR Part 403 and ch. NR 211, Wis. Adm. Code. To ensure that the program is operated in accordance with these requirements, the following general conditions and requirements are hereby established:

6.4.1 Inventories

The permittee shall implement methods to maintain a current inventory of the general character and volume of wastewater that industrial users discharge to the treatment works and shall provide an updated industrial user listing annually and report any changes in the listing to the Department by March 31 of each year as part of the annual pretreatment program report required herein.

6.4.2 Regulation of Industrial Users

6.4.2.1 Limitations for Industrial Users:

The permittee shall develop, maintain, enforce and revise as necessary local limits to implement the general and specific prohibitions of the state and federal General Pretreatment Regulations.

6.4.2.2 Control Documents for Industrial Users (IUs)

The permittee shall control the discharge from each significant industrial user through individual discharge permits as required by s. NR 211.235, Wis. Adm. Code and in accordance with the approved pretreatment program procedures and the permittee's sewer use ordinance. The discharge permits shall be modified in a timely manner during the stated term of the discharge permits according to the sewer use ordinance as conditions warrant. The discharge permits shall include at a minimum the elements found in s. NR 211.235(1), Wis. Adm. Code and references to the approved pretreatment program procedures and the sewer use ordinance.

The permittee shall provide a copy of all newly issued, reissued, or modified discharge permits to the Department.

6.4.2.3 Review of Industrial User Reports, Inspections and Compliance Monitoring

The permittee shall require the submission of, receive, and review self-monitoring reports and other notices from industrial users in accordance with the approved pretreatment program procedures. The permittee shall randomly sample and analyze industrial user discharges and conduct surveillance activities to determine independent of information supplied by the industrial users, whether the industrial users are in compliance with pretreatment standards and requirements. The inspections and monitoring shall also be conducted to maintain accurate knowledge of local industrial processes, including changes in the discharge, pretreatment equipment operation, spill prevention control plans, slug control plans, and implementation of solvent management plans.

At least one time per year the permittee shall inspect and sample the discharge from each significant industrial user, or more frequently if so specified in the permittee's approved pretreatment program. At least once every 2 years the permittee shall evaluate whether each significant industrial user needs a slug control plan. If a slug control plan is needed, the plan shall contain at a minimum the elements specified in s. NR 211.235(4)(b), Wis. Adm. Code.

6.4.2.4 Enforcement and Industrial User Compliance Evaluation & Violation Reports

The permittee shall enforce the industrial pretreatment requirements including the industrial user discharge limitations of the permittee's sewer use ordinance. The permittee shall investigate instances of noncompliance by collecting and analyzing samples and collecting other information with sufficient care to produce evidence admissible in enforcement proceedings or in judicial actions. Investigation and response to instances of noncompliance shall be in accordance with the permittee's sewer use ordinance and approved Enforcement Response Plan.

The permittee shall make a semiannual report on forms provided or approved by the Department. The semiannual report shall include an analysis of industrial user significant noncompliance (i.e. the Industrial User Compliance Evaluation, also known as the SNC Analysis) as outlined in s.NR 211.23(1)(j), Wis. Adm. Code, and a summary of the permittee's response to all industrial noncompliance (i.e. the Industrial User Violation Report). The Industrial User Compliance Evaluation Report shall include monitoring results received from industrial users pursuant to s. NR 211.15(1)-(5), Wis. Adm. Code. The Industrial User Violation Report shall include copies of all notices of noncompliance, notices of violation and other enforcement correspondence sent by the permittee to industrial users, together with the industrial user's response. The Industrial User Compliance Evaluation and Violation Reports for the period January through June shall be provided to the Department by September 30 of each year and for the period July through December shall be provided to the Department by March 31 of the succeeding year, unless alternate submittal dates are approved.

6.4.2.5 Publication of Violations

The permittee shall publish a list of industrial users that have significantly violated the municipal sewer use ordinance during the calendar year, in the largest daily newspaper in the area by March 31 of the following year pursuant to s. NR 211.23(1)(j), Wis. Adm. Code. A copy of the newspaper publication shall be provided as part of the annual pretreatment report specified herein.

6.4.2.6 Multijurisdictional Agreements

The permittee shall establish agreements with all contributing jurisdictions as necessary to ensure compliance with pretreatment standards and requirements by all industrial users discharging to the permittee's wastewater treatment system. Any such agreement shall identify who will be responsible for maintaining the industrial user inventory, issuance of industrial user control mechanisms, inspections and sampling, pretreatment program implementation, and enforcement.

6.4.3 Annual Pretreatment Program Report

The permittee shall evaluate the pretreatment program, and submit the Pretreatment Program Report to the Department on forms provided or approved by the Department by March 31 annually, unless an alternate submittal date is approved. The report shall include a brief summary of the work performed during the preceding calendar year, including the numbers of discharge permits issued and in effect, pollution prevention activities, number of inspections and monitoring surveys conducted, budget and personnel assigned to the program, a general discussion of program progress in meeting the objectives of the permittee's pretreatment program together with summary comments and recommendations.

6.4.4 Pretreatment Program Modifications

- Future Modifications: The permittee shall within one year of any revisions to federal or state General Pretreatment Regulations submit an application to the Department in duplicate to modify and update its approved pretreatment program to incorporate such regulatory changes as applicable to the permittee. Additionally, the Department or the permittee may request an application for program modification at any time where necessary to improve program effectiveness based on program experience to date.

- Modifications Subject to Department Approval: The permittee shall submit all proposed pretreatment program modifications to the Department for determination of significance and opportunity for comment in accordance with the requirements and conditions of s. NR 211.27, Wis. Adm. Code. Any substantial proposed program modification shall be subject to Department public noticing and formal approval prior to implementation. A substantial program modification includes, but is not limited to, changes in enabling legal authority to administer and enforce pretreatment conditions and requirements; significant changes in program administrative or operational procedures; significant reductions in monitoring frequencies; significant reductions in program resources including personnel commitments, equipment, and funding levels; changes (including any relaxation) in the local limitations for substances enforced and applied to users of the sewerage treatment works; changes in treatment works sludge disposal or management practices which impact the pretreatment program; or program modifications which increase pollutant loadings to the treatment works. The Department shall use the procedures outlined in s. NR 211.30, Wis. Adm. Code for review and approval/denial of proposed pretreatment program modifications. The permittee shall comply with local public participation requirements when implementing the pretreatment program.

6.4.5 Program Resources

The permittee shall have sufficient resources and qualified personnel to carry out the pretreatment program responsibilities as listed in ss. NR 211.22 and NR 211.23, Wis. Adm. Code.

6.5 Land Application Requirements

6.5.1 Sludge Management Program Standards And Requirements Based Upon Federally Promulgated Regulations

In the event that new federal sludge standards or regulations are promulgated, the permittee shall comply with the new sludge requirements by the dates established in the regulations, if required by federal law, even if the permit has not yet been modified to incorporate the new federal regulations.

6.5.2 General Sludge Management Information

The General Sludge Management Form 3400-48 shall be completed and submitted prior to any significant sludge management changes.

6.5.3 Sludge Samples

All sludge samples shall be collected at a point and in a manner which will yield sample results which are representative of the sludge being tested, and collected at the time which is appropriate for the specific test.

6.5.4 Land Application Characteristic Report

Each report shall consist of a Characteristic Form 3400-49 and Lab Report, unless approval for not submitting the lab reports has been given. Both reports shall be submitted by January 31 following each year of analysis.

The permittee shall use the following convention when reporting sludge monitoring results: Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 1.0 mg/kg, report the pollutant concentration as < 1.0 mg/kg .

All results shall be reported on a dry weight basis.

6.5.5 Monitoring and Calculating PCB Concentrations in Sludge

When sludge analysis for "PCB, Total Dry Wt" is required by this permit, the PCB concentration in the sludge shall be determined as follows.

Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with the following provisions and Table EM in s. NR 219.04, Wis. Adm. Code.

- EPA Method 1668 may be used to test for all PCB congeners. If this method is employed, all PCB congeners shall be delineated. Non-detects shall be treated as zero. The values that are between the limit of detection and the limit of quantitation shall be used when calculating the total value of all congeners. All results shall be added together and the total PCB concentration by dry weight reported. **Note**: It is recognized that a number of the congeners will co-elute with others, so there will not be 209 results to sum.
- EPA Method 8082A shall be used for PCB-Aroclor analysis and may be used for congener specific analysis as well. If congener specific analysis is performed using Method 8082A, the list of congeners tested shall include at least congener numbers 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187, and 206 plus any other additional congeners which might be reasonably expected to occur in the particular sample. For either type of analysis, the sample shall be extracted using the Soxhlet extraction (EPA Method 3540C) (or the Soxhlet Dean-Stark modification) or the pressurized fluid extraction (EPA Method 3545A). If Aroclor analysis is performed using Method 8082A, clean up steps of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.11 mg/kg as possible. Reporting protocol, consistent with s. NR 106.07(6)(e), should be as

follows: If all Aroclors are less than the LOD, then the Total PCB Dry Wt result should be reported as less than the highest LOD. If a single Aroclor is detected then that is what should be reported for the Total PCB result. If multiple Aroclors are detected, they should be summed and reported as Total PCBs. If congener specific analysis is done using Method 8082A, clean up steps of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.003 mg/kg as possible for each congener. If the aforementioned limits of detection cannot be achieved after using the appropriate clean up techniques, a reporting limit that is achievable for the Aroclors or each congener for the sample shall be determined. This reporting limit shall be reported and qualified indicating the presence of an interference. The lab conducting the analysis shall perform as many of the following methods as necessary to remove interference:

3620C – Florisil	3611B - Alumina
3640A - Gel Permeation	3660B - Sulfur Clean Up (using copper shot instead of powder)
3630C - Silica Gel	3665A - Sulfuric Acid Clean Up

6.5.6 Land Application Report

Land Application Report Form 3400-55 shall be submitted by January 31, following each year non-exceptional quality sludge is land applied. Non-exceptional quality sludge is defined in s. NR 204.07(4), Wis. Adm. Code.

6.5.7 Other Methods of Disposal or Distribution Report

The permittee shall submit Report Form 3400-52 by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied.

6.5.8 Approval to Land Apply

Bulk non-exceptional quality sludge as defined in s. NR 204.07(4), Wis. Adm. Code, may not be applied to land without a written approval letter or Form 3400-122 from the Department unless the Permittee has obtained permission from the Department to self approve sites in accordance with s. NR 204.06 (6), Wis. Adm. Code. Analysis of sludge characteristics is required prior to land application. Application on frozen or snow covered ground is restricted to the extent specified in s. NR 204.07(3) (l), Wis. Adm. Code.

6.5.9 Soil Analysis Requirements

Each site requested for approval for land application must have the soil tested prior to use. Each approved site used for land application must subsequently be soil tested such that there is at least one valid soil test in the four years prior to land application. All soil sampling and submittal of information to the testing laboratory shall be done in accordance with UW Extension Bulletin A-2100. The testing shall be done by the UW Soils Lab in Madison or Marshfield, WI or at a lab approved by UW. The test results including the crop recommendations shall be submitted to the DNR contact listed for this permit, as they are available. Application rates shall be determined based on the crop nitrogen recommendations and with consideration for other sources of nitrogen applied to the site.

6.5.10 Land Application Site Evaluation

For non-exceptional quality sludge, as defined in s. NR 204.07(4), Wis. Adm. Code, a Land Application Site Request Form 3400-053 shall be submitted to the Department for the proposed land application site. The Department will evaluate the proposed site for acceptability and will either approve or deny use of the proposed site. The permittee may obtain permission to approve their own sites in accordance with s. NR 204.06(6), Wis. Adm. Code.

6.5.11 Class B Sludge: Fecal Coliform Limitation

Compliance with the fecal coliform limitation for Class B sludge shall be demonstrated by calculating the geometric mean of at least 7 separate samples. (Note that a Total Solids analysis must be done on each sample). The geometric mean shall be less than 2,000,000 MPN or CFU/g TS. Calculation of the geometric mean can be done using one of the following 2 methods.

Method 1:

Geometric Mean = $(X_1 \times X_2 \times X_3 \ldots \times X_n)^{1/n}$

Where X = Coliform Density value of the sludge sample, and where n = number of samples (at least 7)

Method 2:

Geometric Mean = antilog$[(X_1 + X_2 + X_3 \ldots + X_n) \div n]$

Where X = $\log_{10}$ of Coliform Density value of the sludge sample, and where n = number of samples (at least 7)

Example for Method 2

Sample Number	Coliform Density of Sludge Sample	$\log_{10}$
1	6.0×10^5	5.78
2	4.2×10^6	6.62
3	1.6×10^6	6.20
4	9.0×10^5	5.95
5	4.0×10^5	5.60
6	1.0×10^6	6.00
7	5.1×10^5	5.71

The geometric mean for the seven samples is determined by averaging the $\log_{10}$ values of the coliform density and taking the antilog of that value.

$(5.78 + 6.62 + 6.20 + 5.95 + 5.60 + 6.00 + 5.71) \div 7 = 5.98$

The antilog of $5.98 = 9.5 \times 10^5$

6.5.12 Vector Control: Volatile Solids Reduction

The mass of volatile solids in the sludge shall be reduced by a minimum of 38% between the time the sludge enters the digestion process and the time it either exits the digester or a storage facility. For calculation of volatile solids reduction, the permittee shall use the Van Kleeck equation or one of the other methods described in "Determination of Volatile Solids Reduction in Digestion" by J.B. Farrell, which is Appendix C of EPA's *Control of Pathogens in Municipal Wastewater Sludge* (EPA/625/R-92/013). The Van Kleeck equation is:

$$VSR\% = \frac{VS_{IN} - VS_{OUT}}{VS_{IN} - (VS_{OUT} \times VS_{IN})} \times 100$$

Where: VS_{IN} = Volatile Solids in Feed Sludge (g VS/g TS)

VS_{OUT} = Volatile Solids in Final Sludge (g VS/g TS)

VSR% = Volatile Solids Reduction, (Percent)

7 Summary of Reports Due

FOR INFORMATIONAL PURPOSES ONLY

Description	Date	Page
Mercury Pollutant Minimization Program -Implement the Mercury Pollutant Minimization Program (PMP) Plan	See Permit	14
Mercury Pollutant Minimization Program -Submit the first annual status report	September 30, 2008	14
Mercury Pollutant Minimization Program -Second annual report	September 30, 2009	14
Mercury Pollutant Minimization Program -Third annual report	September 30, 2010	14
Mercury Pollutant Minimization Program -Fourth annual report	September 30, 2011	14
Mercury Pollutant Minimization Program -Final report	June 30, 2012	14
Ultraviolet Disinfection System Evaluation and Upgrade -Plan of Study	June 30, 2008	14
Ultraviolet Disinfection System Evaluation and Upgrade -Submit the First Annual Report	January 31, 2009	14
Ultraviolet Disinfection System Evaluation and Upgrade -Second Annual Report	January 31, 2010	14
Ultraviolet Disinfection System Evaluation and Upgrade -Submit Final Report	January 31, 2011	14
Ultraviolet Disinfection System Evaluation and Upgrade -Complete Action	March 31, 2012	14
Chloride Target Value -Chloride Progress Report	December 31, 2008	15
Chloride Target Value -Chloride Progress Report #2	September 30, 2010	15
Chloride Target Value -Final Chloride Report	March 31, 2012	15
Electrical Power System Improvement -Complete Action	March 31, 2009	15
Compliance Maintenance Annual Reports (CMAR)	by June 30, each year	17
Industrial User Compliance Evaluation and Violation Reports	Semiannual	23
Pretreatment Program Report	Annually	24
General Sludge Management Form 3400-48	prior to any significant sludge management changes	25
Characteristic Form 3400-49 and Lab Report	by January 31 following each year of analysis	25
Land Application Report Form 3400-55	by January 31, following each year non-exceptional quality sludge is land applied	26

Report Form 3400-52	by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied	26

Report forms shall be submitted to the address printed on the report form. Any facility plans or plans and specifications for municipal, industrial pretreatment and non industrial wastewater systems shall be submitted to the Bureau of Watershed Management, P.O. Box 7921, Madison, WI 53707-7921. All other submittals required by this permit shall be submitted to:
Southeast Region - Waukesha, 141 NW Barstow St., Room 180, Waukesha, WI 53188

Attachment B

Letter from the Wisconsin Department of Natural Resources: WWTP WPDES Effluent Limits

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Jim Doyle, Governor
Matthew J. Frank, Secretary

101 S. Webster St.
Box 7921
Madison, Wisconsin 53707-7921
Telephone 608-266-2621
FAX 608-267-3579
TTY Access via relay - 711

October 16, 2008

Mr. Daniel Duchniak, General Manager
Waukesha Water Utility
115 Delafield St.
Waukesha, WI 53188-3615

Subject: WPDES Effluent Limitations

Dear Mr. Duchniak:

The purpose of this letter is to provide a written response to your letter of April 7, 2008. You requested effluent limitations for a potential discharge from the City of Waukesha wastewater treatment plant (WWTP) to three Lake Michigan tributaries – Underwood Creek, Menomonee River and Root River. A meeting held on July 28, 2008 provided us all an opportunity to discuss your request and clarify any associated issues. My response at this time will be somewhat brief, reflect the phone messages I left on September 23 and, I hope, provide additional direction to the City for preparing a wastewater facility plan under the provisions of NR 110, Wis. Adm. Code.

Simultaneously, you are receiving a letter from Eric Ebersberger describing the content of a potential application for diversion of Great Lakes water. That letter contains an outline of our current expectations for the content of an application for diversion, including elements relating to return flow from a system that withdraws water from the Great Lakes basin. So as not to be redundant, my letter is limited to information relating to the quality of the discharge of the return flow and Eric's letter contains directions for the manner in which other potential effects of the discharge must be evaluated. It is our expectation that the wastewater facility plan for the project (prepared under NR 110) and the portion of the application relating to return flows will be submitted as one and contain an analysis of impacts of the wastewater flows in the tributaries on river stage, flood flows and storage and associated impacts. Similarly, an assessment of the effects associated with the diversion of the wastewater discharge out of the Fox River must be included. Finally, it must also, as identified in Eric's accompanying letter, demonstrate that the amount of return flow is equal to that withdrawn as described in the "Great Lakes Compact" legislation.

A significant factor in our evaluation is the current level of treatment provided for conventional pollutants by the Waukesha WWTP. Typically, effluent BOD and suspended solids are measured and reported at 2 mg/L or less. Ammonia nitrogen is less than 1 mg/L nearly all the time, phosphorus is usually less than 20% of the 1 mg/L permit limit and effluent DO exceeds the 7 mg/L minimum permit limit. Regardless of discharge location, it is expected that this level of treatment will continue to be provided and a permit to discharge to Lake Michigan tributaries will be at least as stringent as existing effluent quality.

Water Quality Standards – Each of the proposed discharge sites is located on a stream classified as a fish and aquatic life water. Although Underwood Creek currently contains a dissolved oxygen variance (see NR 104.06(2), Wis. Adm. Code), the Department believes the 5 mg/L dissolved oxygen standard for fish and aquatic life should be the criterion used to establish effluent limitations for that discharge location.

Of the three waterbodies, portions of the Menomonee River and Root River are listed by the Department as "impaired" under section 303(d) of the Clean Water Act. Listed pollutants include bacteria, phosphorus, sediments and PCBs. Underwood Creek is not listed specifically, although it has characteristics similar to other waters in the area that are listed as "impaired". If and when a Total Maximum Daily Load (TMDL) is established for any impaired waterbody, the limits provided below may change.

Antidegradation – Wisconsin's antidegradation policy states that "no waters of the state shall be lowered in quality unless it has been affirmatively demonstrated to the department that such a change is justified as a result of necessary economic and social development..." (NR 102.05(1), Wis. Adm. Code). This policy is implemented through NR 207 for WPDES permitted discharges. The unique character of this proposed discharge does not, in many respects, conform to the provisions and decision parameters contained in the NR 207 rule. For example, a discharge to the Lake Michigan tributaries is not a "new discharge" or an "increased discharge" under the definitions of the rule. Therefore, a reasonable analysis of this proposal using the specific provisions of the rule simply does not fit the circumstance.

However, we believe it is important and significant that any discharge such as that proposed here, abide by the basic principles of the antidegradation policy. That is, there should be no lowering of water quality unless allowed and appropriately justified and then only if the uses in the receiving water are maintained.

Within your application for a discharge of return flow to Lake Michigan tributaries, the Department will seek to assure that the specific provisions of NR 207.04(2)(a) are maintained. This rule paragraph states that effluent limitations for an existing discharge will remain unchanged if the treatment facility can meet those existing limitations. Therefore, irrespective of any other calculations of limits we could produce, you must maintain existing effluent quality and permit limitations to meet these requirements will be proposed for any WPDES permit application to discharge to the Lake Michigan tributaries.

At this time, we have undertaken a specific evaluation only for a proposed discharge to Underwood Creek. As you have proposed, this stream has the lowest flow condition and, therefore, produces the most stringent effluent limitations. Effluent limitations for a discharge to the Root River would be nearly identical to those for an Underwood Creek discharge because low flow values are similar. Limitations for a discharge directly to the Menomonee River may be less stringent, but only minimally so. As you will see, the aforementioned maintenance of existing effluent quality to meet the antidegradation policy will essentially drive the proposed effluent limitations for any discharge.

In summary, proposed effluent limitations are similar to those in the existing WPDES permit, including the following:

- Limitations for BOD and suspended solids will be in the range of 5 to 10 mg/L, with a minimum effluent DO value of 7 mg/L;
- Limitations for phosphorus are 1 mg/L, except at they may change with new rules currently under development;
- Limitations for ammonia nitrogen will be driven by existing effluent quality and would likely be more stringent than those in the current permit;
- Limitations for mercury will remain as in the current permit (alternative limitations under NR 106.145);
- Limitations for other bioaccumulating chemicals of concern will not apply because they have not been detected;
- Limitations for chloride (alternative limitations under NR 106, Subch. VII) and associated source reduction requirements will continue;
- Disinfection, as currently applied, must continue.

Given this information, we believe the appropriate scope of the wastewater facilities plan should be limited to that associated with the infrastructure necessary to return flow to the Lake Michigan basin. As noted in prior communications, the facilities planning rule requires you to evaluate the alternative of connecting wastewater discharges to other nearby systems, including the Milwaukee Metropolitan Sewerage District. Such evaluation must include an assessment of the cost-effectiveness of a connection as described in NR 110, Wis. Adm. Code. Lastly, the facilities plan must conform to any Water Quality Management Plan adopted by the Southeastern Wisconsin Regional Planning Commission.

I am hopeful that this reply and our earlier communication provide sufficient information to allow you to proceed with facilities planning for this project. If you wish to meet with us to discuss this matter further or have questions, please contact me. Feel free, also, to maintain other contacts with Department staff to discuss various technical aspects of this project.

Sincerely,

Duane H. Schuettpelz
Bureau of Watershed Management

Cc: Todd Ambs – AD/8
Pat Henderson – AD/8
Russ Rasmussen – WT/3
Bruce Baker – AD/8
Jill Jonas – DG/5
James McNelly – SER, Milwaukee
Eric Ebersberger – DG/5
Michael Hahn – SEWRPC

Appendix G

Technical Memorandum: Underwood Creek Effluent Return Evaluation, July 23, 2009

SEH TECHNICAL MEMORANDUM

TO: Daniel Duchniak, Waukesha Water Utility

FROM: Tom Sear, SEH
Dale Miller, Mainstream Restoration
Ryan Van Camp, SEH

COPY: Tom Chapman, MMSD

DATE: July 23, 2009

RE: Underwood Creek Effluent Return Evaluation

SEH No.: 108425

Executive Summary

Waukesha Water Utility (WWU) is interested in determining the impact of a proposed effluent discharge on a 6,600-foot long segment of rehabilitated Underwood Creek watercourse, given that the rehabilitated channel has been designed for a base flow equal to 3 cubic feet per second (cfs). WWU has contracted with SEH to perform an evaluation of the impact of adding an approximate 20 cfs effluent return to the existing Underwood Creek base flow. The results of this evaluation are summarized herein, and address: (1) the rehabilitated main and low flow channel designs; (2) the hydraulic response of these rehabilitated channels to a range of discharges; and (3) the hydraulic, geomorphic and fisheries impacts of adding the effluent return to the Underwood Creek base flow.

Hydraulic conditions associated with a range of discharges were determined using a HEC-RAS hydraulic model of the rehabilitated main and low flow channels, extending from the confluence with the Menomonee River to Mayfair Road. HEC-RAS cross-sections were developed at riffle sections. This hydraulic evaluation demonstrated that the Phase 1 main and low flow channel designs, associated with the upstream 2,400 feet of rehabilitated watercourse, are appropriately designed for the desired capacities (200 cfs and 3 cfs, respectively). Preliminary Phase 2 channel dimensions are also provided that will require some adjustment during final design.

The proposed effluent return to Underwood Creek will have a negligible effect on the hydraulic and geomorphic conditions during average and peak discharge events. The addition of an effluent return to the Underwood Creek base flow (3 cfs) was evaluated over a range of modified low flow conditions, including 10 and 23 cfs, which resulted in water depths increasing between 0.15 and 0.80 feet (1.8 and 9.6 inches). Velocity increased from a negligible amount to a maximum of 1 foot per second (fps).

As a result of this evaluation, the following was concluded:

1. Current and Low Flow Channel Design: The current main and low flow channel design properly convey the design discharges (200 cfs and 3 cfs, respectively). Although,

supplemental channel dimension definition will be needed during the completion of the Phase 2 final design, particularly within the steeper portions of the Phase 2 channel segment.

2. Sediment Transport Considerations: The majority of sediment transport tends to occur when the main channel is running full, a condition known as bankfull. For the current Underwood Creek channel design, this occurs when the discharge rate is approximately 200 cfs and shear stresses are approximately 1.0 pounds per square foot (lbs/sq.ft.). Sheer stresses that occur at discharges less than 50 cfs are relatively minor (less than 0.50 lbs/sq.ft.), and will not affect sediment transport. Therefore, the addition of an effluent return to Underwood Creek will not affect sediment transport.
3. Fisheries Considerations: The most significant impact resulting from the effluent return is the water depth in the main channel outside the low flow channel. These variable water depths, however, are not expected to impact fish passage, since fish will move to the portion of the channel with a suitable water depth. A key parameter to fish passage is the minimum water depth, which is accommodated by the original low flow channel design. Should the low flow discharge increase, the resulting water depth outside the low flow channel will only enhance fish passage by creating additional flow within the channel cross-section.
4. Alternative Low Flow Channel Design Not Recommended: An alternative low flow channel design was developed for comparative purposes, assuming a base flow equal to 23 cfs. However, the resulting change in channel hydraulics, compared to those provided by the current low flow channel design, does not justify developing the alternative low flow channel for the purpose of enhancing fish passage. In addition, given the anticipated fluctuations of the effluent return, a greater concern is that a modified low flow channel could be too large when the base flow is diminished, resulting in unacceptably low water depths.

Introduction

The Waukesha Water Utility (WWU) is proposing to use Great Lakes (Lake Michigan) water as their public water supply. Since the City of Waukesha is located west of the sub-continental divide, the Great Lakes Compact requires that this water be returned to Lake Michigan, minus an allowance for consumptive use. As a result, the WWU is investigating the discharge of treated wastewater effluent into Underwood Creek, in the vicinity of 124th Street and Bluemound Road, which would return water to the Great Lakes Basin that was previously pumped from Lake Michigan to the City of Waukesha. It is anticipated that the desired effluent diversion to Underwood Creek will have an Average Daily Flow (ADF) ranging from 17 to 20 cubic feet per second (cfs), which can also be interpreted as 7,600 to 9,000 gallons per minute (gpm), or 11 to 13 million gallons per day (mgd).

The Milwaukee Metropolitan Sewerage District (MMSD) has an ongoing *Underwood Creek Rehabilitation and Flood Management (R&FM) Project* that extends approximately 6,600 feet from the confluence with the Menomonee River to Mayfair Road (Highway 100). The Underwood Creek R&FM - Phase 1 Project is currently under construction, and extends approximately 2,400 feet downstream of Mayfair Road. The final design and construction of the Phase 2 Project, to occur in the future, will rehabilitate the remaining 4,400 feet of watercourse down to the Menomonee River confluence.

Given the above, the WWU is interested in determining the impact of the proposed effluent discharge on the rehabilitated Underwood Creek watercourse, given that the Phase 1

rehabilitated channel has been designed for a base flow equal to 3 cfs. Accordingly, WWU has contracted with SEH to perform an associated watercourse evaluation, with the objective of evaluating the impact of adding approximately 20 cfs to the existing Underwood Creek base flow. The results of this evaluation are summarized herein, and address: (1) the rehabilitated main and low flow channel designs for the Underwood Creek R&FM – Phase 1 and 2 Projects; (2) the hydraulic response of these rehabilitated channels to a range of discharges, extending from base flow to the main channel design capacity; and (3) the hydraulic, geomorphic and fisheries impacts of adding the desired effluent return to the Underwood Creek base flow.

Underwood Creek R&FM – Phase 1 and 2 Project Descriptions

Construction of watercourse improvements associated with the MMSD Underwood Creek R&FM – Phase 1 Project will result in the development of approximately 2,400 feet of rehabilitated stone-lined channel between Mayfair Road (Highway 100) and the Canadian Pacific Railway (CPR) Bridge, located just upstream of the Interstate 45 Bridge. These Phase 1 watercourse improvements, initiated in December 2008, are planned to be complete in June 2010, and include a single rehabilitated channel with an inner low flow channel that have design conveyance capacities equal to approximately 200 and 3 cfs, respectively. Rehabilitated main and low flow channel dimensions and bed slopes for Phase 1 were obtained from the project construction drawings provided in Attachment 1. In particular, Drawing GV-7 (Sheet 41) provides a typical cross-section at a riffle section, which illustrates the rehabilitated main channel with the inner low flow channel.

The MMSD Underwood Creek R&FM – Phase 2 Final Design and Construction Project will be completed in the future, which will rehabilitate approximately 4,200 feet of watercourse downstream of the Phase 1 Project. Preliminary Phase 2 channel bed slopes are defined in the MMSD *Underwood Creek R&FM Preliminary Engineering (PE) Design Report*, dated August 2006. Although the final design is not yet developed, it is likely that the Phase 2 rehabilitated main channel and interior low flow channel will have discharge capacities similar to those adopted for the Phase 1 Project. Phase 2 bed slopes were obtained from the preliminary drawings provided in Attachment 2. For analysis presented herein, the Phase 2 main and low flow channel dimensions were estimated using Manning's Equation, assuming uniform flow conditions.

Representative main and low flow channel dimensions and slopes, for the Phase 1 and 2 Projects, are presented in Table 1. Average bed slope was a key parameter value in the determination of the channel dimensions, which consist of a trapezoidal channel with bottom width, top width, depth and side slope. As presented on Table 1, the bed slope is generally flatter in Phase 1 Project segment (typically 0.194%). Near the upstream limit of the Phase 2 Project, over a length of 180 feet, the bed slope is much steeper (0.83%), gradually declining to 0.10% at the downstream limit of the project. As such, the main and low flow channel dimensions were adjusted to reflect the changing bed slope.

Basis for HEC-RAS Hydraulic Simulation

Hydraulic conditions associated with a range of discharges were determined using a HEC-RAS hydraulic model of the rehabilitated (Phase 1 and 2) main and low flow channels, extending from the confluence with the Menomonee River to Mayfair Road. HEC-RAS cross-sections were developed at riffle sections (pools sections were not considered). Information pertaining to this hydraulic evaluation is provided below.

1. Simulated Discharges: Seven sets of discharges were input to the HEC-RAS model in order to evaluate the hydraulic response for a range of flow conditions for the main and low flow channel. These discharges include 3 cfs (base flow) and 23 cfs (base flow discharge with an assumed 20 cfs ADF effluent diversion). Also, given previously developed design peak discharge events, it was determined that discharges resulting from land surface runoff events (50 cfs and greater) increase approximately 35 percent downstream of Station 147+50, which is located approximately 300 feet downstream of the CPR Railroad Bridge. It was assumed that smaller discharge events (less than 50 cfs) resulted primarily from interflow and groundwater inputs, and a 35 percent increase in discharge at Station 147+50 was not warranted for these events. Accordingly, the discharges used in the HEC-RAS hydraulic simulations are:
   a. *Station 147+50 to 176+20*: 3, 5, 10, 23, 50, 100 and 200 cfs
   b. *Station 110+50 to 147+50*: 3, 5, 10, 23, 70, 136 and 270 cfs.
2. HEC-RAS Cross-Sections: Representative HEC-RAS cross-sections, illustrating the main and low flow channels for the stations listed on Table 1, are provided on the exhibits described below. Each of these exhibits also presents seven water surface elevations (WSE) associated with the range of discharges presented above.
   a. *Phase 1 Channel Cross-Sections* - Exhibits A-1 through A-5 present main and low flow channel cross-sections at Stations 172+00, 163+50, 157+00, 153+50 and 152+50, respectively, which can be located on the drawings included in Attachment 1.
   b. *Phase 2 Channel Cross-Sections* - Exhibits B-1 through B-6 present main and low flow channel cross-sections at Stations 149+50, 147+50, 146+00, 133+40, 118+40 and 110+50, respectively, which can be located on the drawings included in Attachment 2.
3. HEC-RAS Channel Bed and WSE Profiles: Channel bed and WSE profiles for the discharges identified above are illustrated on Exhibit C, which also identifies the location of main channel stations referenced elsewhere. Evident from this exhibit are the variable channel bed slopes summarized on Table 1.
4. HEC-RAS Summary Output Table: Attachment 3 includes a tabular summary of HEC-RAS hydraulic output, which includes for each station and discharge (Q Total) the following hydraulic data: minimum channel elevation (Min Ch El), water surface elevation (W.S. Elev), average channel shear stress (Shear Chan), energy grade elevation (E.G. Elev), energy grade slope (E.G. Slope), channel velocity (Vel. Chnl), flow area, top width, and channel Froude number (Froude # Chl).
5. Station and River Mile References: Rehabilitated main and low flow channel information presented in Attachments 1 and 2 are referenced to the Rehabilitated Main Channel Baseline (RMCB) Stations, which are measured in feet from the confluence with the Menomonee River (Note: The RMCB Station at the Menomonee River confluence is equal to 7+00 feet). The HEC-RAS output provided in Attachment 3 is referenced to River Mile (RM), which is measured in miles from the Menomonee River confluence. Both sets of cross-section markers are provided in Table 1 for comparison purposes.

HEC-RAS Model Simulation Results Relative to the Current Main and Low Flow Channel Design

In regard to the HEC-RAS hydraulic simulation output referenced above, the following observations are noted, as related to the currently designed rehabilitated main channel and interior low flow channel.

1. Main Channel WSEs: As presented on Exhibits A-1 through B-6, the main channel dimensions summarized on Table 1 provide reasonable WSEs for the desired main channel discharge capacity (200 cfs upstream of Station 147+50 and 270 cfs downstream of Station 147+50). In particular:
   a. *Phase 1 Dimensions* - Main channel dimensions provided for Phase 1 (currently under construction) provide a WSE near the top of bank (typically within one foot), as illustrated on Exhibits A-1 through A-5.
   b. *Phase 2 Dimensions* – In general, preliminary main channel dimensions provided for Phase 2 also provide a WSE near the top of bank, as illustrated on Exhibits B-1 through B-6. However, additional analysis is recommended during the completion of the future final main channel design in order to provide a conveyance capacity closer to the desired main channel discharges, particularly along the steeper portions of the channel (Station 133+40 to 149+50).
2. Low Flow Channel WSEs: As presented on Exhibits A-1 though B-6, the low flow channel dimensions summarized on Table 1 also provide reasonable WSEs for the desired low flow discharge capacity (3 cfs). In particular:
   a. *Phase 1 Dimensions* – Low flow channel dimensions provided for Phase 1 (currently under construction) provide a WSE near the top of the low flow channel bank (typically within 0.2 feet), as illustrated on Exhibits A-1 through A-5.
   b. *Phase 2 Dimensions* – In general, preliminary low flow channel dimensions provided for Phase 2 also provide a WSE near the top of bank, as illustrated on Exhibits B-1 through B-6. However, additional analysis is again recommended during the completion of the future final low flow channel design in order to provide a conveyance capacity closer to the desired low flow channel discharge (3 cfs). Of particular importance is the segment of low flow channel (Station 146+00 to 149+50) where the WSE resulting from 3 cfs exceeds the top of the low flow channel by approximately 0.05 feet.
3. Channel Shear Stresses: The majority of sediment transport will tend to occur when the main channel is running full, a condition known as bankfull. The shear stress on the channel bed at bankfull appears adequate (typically around 1 lbs/sq. ft., as shown in Attachment 3). Sheer stresses that occur at discharges less than 50 cfs (70 cfs downstream of Station 147+50), as presented in Attachment 3, are relatively minor (less than 0.50 lbs/sq.ft.), which will not affect sediment transport.

Anticipated Impact Resulting from the Proposed Effluent Return

In regard to the anticipated impact of the proposed effluent return on the rehabilitated Underwood Creek channel, the following observations are noted:

1. Impact on Underwood Creek Discharges: The following is noted regarding the impact of the proposed effluent return on Underwood Creek discharges.
   a. *Average and Peak Discharge Events* - There is general agreement that a proposed effluent return to Underwood Creek equal to 20 cfs or less (ADF) will have a negligible effect on the hydraulic and geomorphic conditions during average and peak discharge events. This lack of effect is due to the short durations of average and peak discharge events, and the relatively minor percent increase in overall flow resulting from the effluent return.
   b. *Base Flow Events* - The addition of an effluent return to the Underwood Creek base flow (3 cfs) could have a relatively significant impact on the resulting main channel discharge rate, recognizing that the actual effluent return value is dependent on weather and operational conditions. For instance, it is noted that a 20 cfs effluent return could experience an operational diurnal fluctuation that would cause the instantaneous flow rate to range from approximately 6 cfs to 28 cfs during a typical 24 hour period. Weather conditions that could affect the effluent return rate include wet weather patterns that induce infiltration and inflow (I&I) to the sanitary collection system; and warm and dry weather conditions that reduce I&I, while increasing outdoor watering. As a result, it is best to evaluate the impact of an effluent return on Underwood Creek over a range of potential discharge conditions, as presented in Attachment 3, which includes results from discharges equal to 3, 5, 10 and 23 cfs.
2. Impact on Main Channel Hydraulics (Existing Design): The following is noted regarding the impact on main channel hydraulics due to the addition of the effluent return, assuming a range of discharge conditions and the existing design of the main and low flow channel.
   a. *Water Depth and Velocity Impacts* – Using the data provided in Attachment 3, Table 2 summarizes the WSEs, water depths and average velocities resulting from a range of base flow discharges, including 3, 10 and 23 cfs. Table 2 also presents the change in water depth and average velocity, assuming an increase in the base flow discharge from 3 cfs to 10 and 23 cfs. As presented on Table 2, the increase in water depth varies from 0.15 feet (1.8 inches) to 0.80 feet (9.6 inches). The average velocity varies from a slight reduction (-0.07 fps) to and increase equal to 1.04 fps.
   b. *Water Depth Outside the Low Flow Channel* - As illustrated on Exhibits A-1 through B-6, the WSEs resulting from the 23 cfs discharge event (3 cfs base flow plus an assumed 20 cfs ADF effluent return) results in water depths in the main channel (outside the low flow channel) ranging from 0.33 to 0.78 feet (4.0 to 9.4 inches). Given the results summarized in Table 2, a channel discharge equal to 10 cfs would result in water depths (outside the low flow channel) ranging from 0.13 to 0.39 feet (1.6 to 4.7 inches).
   c. *Geomorphic Impacts* – As provided in Attachment 3 and stated previously, average channel shear stresses associated with discharges less than 50 cfs (70 cfs downstream of Station 147+50) will not significantly contribute to sediment transport. Therefore, the

addition of the effluent return, given the above stated discharge range, will not impact sediment transport conditions in the rehabilitated Underwood Creek channel.

3. Impact on Fisheries: The following is noted regarding the anticipated impact on fisheries due to the effluent return.
   a. *Indicator Species* - The indicator fish species for the rehabilitated Underwood Creek channel has been identified as Northern pike, a relatively weak swimming fish. For the purposes of evaluating water velocity in the low flow channel relative to the swimming capabilities of this fish species, an average maximum velocity ranging from 1.5 to 1.7 feet per second (fps) was used.
   b. *Average Channel Velocities* - Average channel velocities reported in Attachment 3, for discharges equal to or less than 23 cfs, are generally less than the targeted velocity range for Northern Pike, indicating that the effluent return discharge will have minimal impact on upstream fish passage during base flow conditions.
   c. *Need for Additional Channel Design* - It is noted, however, that certain portions of the rehabilitated channel, primarily located where the bed gradient is steeper downstream of the CPR Railroad Bridge, do exceed this desirable velocity range. In these cases, the dimensions and slope of the low flow channel will need further refinement in order to lower velocities and better accommodate fish passage. Also, appropriate placement of boulders in riffle sections and pools can also help mitigate the impact of these higher velocities on fish passage.
   d. *Water Depths Outside the Low Flow Channel* – Perhaps the most significant impact of the effluent return is the water depth in the main channel outside the low flow channel, as described previously. These variable water depths, however, are not expected to impact fish passage, since fish will move to the portion of the channel with a suitable water depth. A key parameter to fish passage is the minimum water depth, which is accommodated by the original low flow channel design. Should the low flow discharge increase, the resulting water depth outside the low flow channel will only enhance fish passage by creating additional flow area within the channel cross-section.
4. Alternative Low Flow Channel Design: For comparative purposes, an alternative low flow channel design was developed to convey a 23 cfs base flow along the Phase 1 and 2 Project segments. The modified low flow channel dimensions were created using Manning's Equation and are also presented in Table 1. The following is noted regarding these modified low flow channel designs, which are not recommended because they would provide no additional benefit in comparison to the current low flow channel design.
   a. *Depths of Flow and Velocities* - As presented on Table 1, the depths associated with these modified low flow channels are 1.50 feet in the Phase 1 channel segment, and 0.56 to 1.20 feet in the Phase 2 channel segment. Corresponding average channel velocities were 1.5 fps in the Phase 1 channel segment, and 1.0 to 2.1 fps in the Phase 2 channel segment.
   b. *Channel Bottom and Top Widths* – The additional base flow was generally accommodated by developing a wider channel bottom, then by increasing channel depth as needed. In this manner, base flow velocities are kept at an acceptable range of values, given the associated increase in channel roughness and wetted perimeter.

c. *Impact on Existing Main Channel Design* – The modified low flow channel designs provided in Table 1 will fit within the bottom of the existing main channel. An example (Phase 1) modified low flow channel is presented in Exhibit D. Similar modified channel cross-sections would be developed for the Phase 2 watercourse segment. In most instances, the top of the low flow channel would essentially merge directly into the bottom of the main channel.

d. *Necessity of Modified Low Flow Channel* – Given the above results, the velocities and shear stresses of the modified low flow channels, assuming a base flow equal to 23 cfs, will be similar to those provided using the existing low flow channel design. The principal difference will be the depth of flow, which will be slightly greater for the modified low flow channel during low flow events. However, this slight difference does not warrant redesigning the low flow channel for the purpose of enhancing fish passage. In addition, given the anticipated fluctuations of the effluent return, a greater concern is that the modified low flow channel could be too large when the base flow is diminished, resulting in unacceptably low water depths.

5. Effluent Return Benefits: The following is noted regarding the potential benefits associated with the development of an effluent return to the rehabilitated Underwood Creek watercourse, as currently designed.

   a. *Fisheries Benefit* – As stated previously, an increased water depth outside the low flow channel will enhance fish passage by creating additional flow area within the channel cross-section. It is acknowledged that fish will move to the portion of the main channel that has a suitable flow depth, and the key is to provide a minimum depth, which is accommodated by the previously designed low flow channel.

   b. *Floodplain Hydration* – Having a higher low flow depth in the main channel will also slightly increase groundwater elevations in the floodplain in the vicinity of channel, which will improve hydration for the wetland plantings. The extent of this enhancement can not be determined without additional study.

   c. *Other Biological Benefits* – It is generally acknowledged that a greater base flow discharge will provide enhanced aquatic habitat by virtue of there being more water in the main channel. The extent of this improvement, however, is beyond the scope of this evaluation, and is dependent on the water quality characteristics of the effluent return and the identified desirable aquatic species.

List of Attachments

- **Tables**
  - Table 1: Underwood Creek – Phase 1 and 2 Projects, Rehabilitated Main and Low Flow Channel Dimensions
  - Table 2: Underwood Creek – Phase 1 and 2 Projects, Depth and Velocity Changes due to Increased Baseflow
- **Exhibits**
  - Exhibits A: Phase 1 Project – Main and Low Flow Channels
    - A-1: River Station (RS) 1.180, Station (STA) 172+00
    - A-2: RS 1.032, STA 163+50
    - A-3: RS 0.919, STA 157+00
    - A-4: RS 0.858, STA 153+50
    - A-5: RS 0.841, STA 152+50
  - Exhibits B: Phase 2 Project – Main and Low Flow Channels
    - B-1: RS 0.792, STA 149+50
    - B-2: RS 0.754, STA 147+50
    - B-3: RS 0.726, STA 146+00
    - B-4: RS 0.491, STA 133+40
    - B-5: RS 0.207, STA 118+40
    - B-6: RS 0.058, STA 110+50
  - Exhibit C: Underwood Creek – Channel Bottom and Water Surface Profiles
  - Exhibit D: Underwood Creek – Phase 1 Rehabilitated Main Channel With Modified Low Flow Channel
- **Attachments**
  - Attachment 1: Underwood Creek Rehabilitation and Flood Management - Phase 1 Bid and Construction Drawings, April 2008
  - Attachment 2: Underwood Creek Rehabilitation and Flood Management - Phase 2 Preliminary Engineering Drawings, January 2006
  - Attachment 3: Underwood Creek Main and Low Flow Channels, HEC-RAS Summary Output

Table 1

Underwood Creek - Phase 1 and 2 Projects
Rehabilitated Main and Low Flow Channel Dimensions

Phase	River Mile (RM)	Main Channel Station (feet)	Location Description	Trapezoidal Channel Dimensions											
				Average Bottom Slope (percent)	Main Channel				Low Flow Channel (Q = 3 cfs)				Low Flow Channel (Q = 23 cfs)			
					Bottom Width (feet)	Top Width (feet)	Depth (feet)	Side Slopes (ft/ft)	Bottom Width (feet)	Top Width (feet)	Depth (feet)	Side Slopes (ft/ft)	Bottom Width (feet)	Top Width (feet)	Depth (feet)	Side Slopes (ft/ft)
1	1.26	176+20	Upstream limit of Phase 1 Project	Existing Concrete Lined Channel												
				0.194%												
	1.18	172+00			18.3	22.3	3.17	2:1	3.5	8.0	0.75	3:1	6.0	15.0	1.50	3:1
				0.194%												
	1.032	163+50			26.1	30.0	3.37	2:1	3.5	8.0	0.75	3:1	6.0	15.0	1.50	3:1
				0.194%												
	0.919	157+00			22.1	26.2	3.50	2:1	3.5	8.0	0.75	3:1	6.0	15.0	1.50	3:1
				0.194%												
	0.858	153+50			26.0	30.1	2.93	2:1	3.5	8.0	0.75	3:1	6.0	15.0	1.50	3:1
				0.834%												
	0.841	152+50	Phase 1 and 2 Project Transition		22.1	26.2	3.02	2:1	3.5	8.0	0.75	3:1	16.0	19.8	0.63	3:1
	0.82	150+70	CPR Railroad Bridge	Channel slope and dimensions beneath bridge to be determined in Phase 2 Project												
2	0.792	149+50			20.0	27.9	3.00	2:1	3.5	6.2	0.45	3:1	16.0	19.8	0.63	3:1
				0.830%												
	0.754	147+50	Main Channel flow increases by 35%		24.0	32.6	3.13	2:1	3.5	6.2	0.45	3:1	16.0	19.8	0.63	3:1
				0.830%												
	0.726	146+00			26.2	35.0	3.20	2:1	3.5	6.2	0.45	3:1	16.0	19.8	0.63	3:1
				0.650%												
	0.491	133+40			21.0	33.4	4.10	2:1	3.5	7.1	0.60	3:1	22.0	25.4	0.56	3:1
				0.290%												
	0.207	118+40			22.0	38.3	4.10	2:1	5.5	9.4	0.65	3:1	15.9	21.0	0.85	3:1
				0.100%												
	0.058	110+50	Downstream limit of Phase 2 Project		22.0	38.3	4.10	2:1	5.5	9.4	0.65	3:1	14.8	22.0	1.20	3:1

Note: Manning n (roughness) = 0.045 throughout.

Table 2

Underwood Creek - Phase 1 and 2 Projects
Depth and Velocity Changes due to Increased Baseflow

Phase	River Mile (RM)	Main Channel Station (feet)	Location Description	Base Flow Depths and Velocities										Change from 3 cfs Base Flow			
					Base Flow = 3 cfs			Base Flow = 10 cfs			Base Flow = 23 cfs			Base Flow = 10 cfs		Base Flow = 23 cfs	
				Min Ch El (ft)	W.S. Elev (ft)	Water Depth (ft)	Vel Chnl (fps)	W.S. Elev (ft)	Water Depth (ft)	Vel Chnl (fps)	W.S. Elev (ft)	Water Depth (ft)	Vel Chnl (fps)	Water Depth (ft)	Vel Chnl (fps)	Water Depth (ft)	Vel Chnl (fps)
1	1.26	176+20	Upstream limit of Phase 1 Project	Existing Concrete Lined Channel													
	1.18	172+00		688.18	688.82	0.64	0.87	689.24	1.06	1.01	689.58	1.40	1.40	0.42	0.14	0.76	0.53
	1.032	163+50		686.53	687.17	0.64	0.87	687.59	1.06	0.80	687.94	1.41	1.06	0.42	-0.07	0.77	0.19
	0.919	157+00		685.27	685.91	0.64	0.87	686.34	1.07	0.88	686.68	1.41	1.20	0.43	0.01	0.77	0.33
	0.858	153+50		684.56	685.00	0.44	1.43	685.44	0.88	1.30	685.64	1.08	1.77	0.44	-0.13	0.64	0.34
	0.841	152+50	Phase 1 and 2 Project Transition	683.73	684.20	0.47	1.28	684.65	0.92	1.24	684.84	1.11	1.87	0.45	-0.04	0.64	0.59
	0.82	150+70	CPR Railroad Bridge	Channel hydraulic characeristics beneath bridge to be determined in Phase 2 Project													
2	0.792	149+50		681.98	682.49	0.51	0.90	682.67	0.69	1.41	682.89	0.91	1.94	0.18	0.51	0.40	1.04
	0.754	147+50	Main Channel flow increases by 35%	680.33	680.84	0.51	0.85	680.99	0.66	1.35	681.19	0.86	1.84	0.15	0.50	0.35	0.99
	0.726	146+00		679.11	679.63	0.52	0.77	679.79	0.68	1.23	679.99	0.88	1.68	0.16	0.46	0.36	0.91
	0.491	133+40		670.87	671.44	0.57	1.01	671.77	0.90	1.03	672.07	1.20	1.40	0.33	0.02	0.63	0.39
	0.207	118+40		666.49	667.12	0.63	0.65	667.53	1.04	0.72	667.92	1.43	0.97	0.41	0.07	0.80	0.32
	0.058	110+50	Downstream limit of Phase 2 Project	665.70	666.30	0.60	0.69	666.71	1.01	0.76	667.09	1.39	1.02	0.41	0.07	0.79	0.33

Exhibits

Exhibits A: Phase 1 Project – Main and Low Flow Channels

A-1: River Station (RS) 1.180, Station (STA) 172+00

A-2: RS 1.032, STA 163+50

A-3: RS 0.919, STA 157+00

A-4: RS 0.858, STA 153+50

A-5: RS 0.841, STA 152+50

Exhibits B: Phase 2 Project – Main and Low Flow Channels

B-1: RS 0.792, STA 149+50

B-2: RS 0.754, STA 147+50

B-3: RS 0.726, STA 146+00

B-4: RS 0.491, STA 133+40

B-5: RS 0.207, STA 118+40

B-6: RS 0.058, STA 110+50

Exhibit C

Underwood Creek – Channel Bottom and Water Surface Profiles

Exhibit D

Underwood Creek – Phase 1 Rehabilitated Main Channel With Modified Low Flow Channel

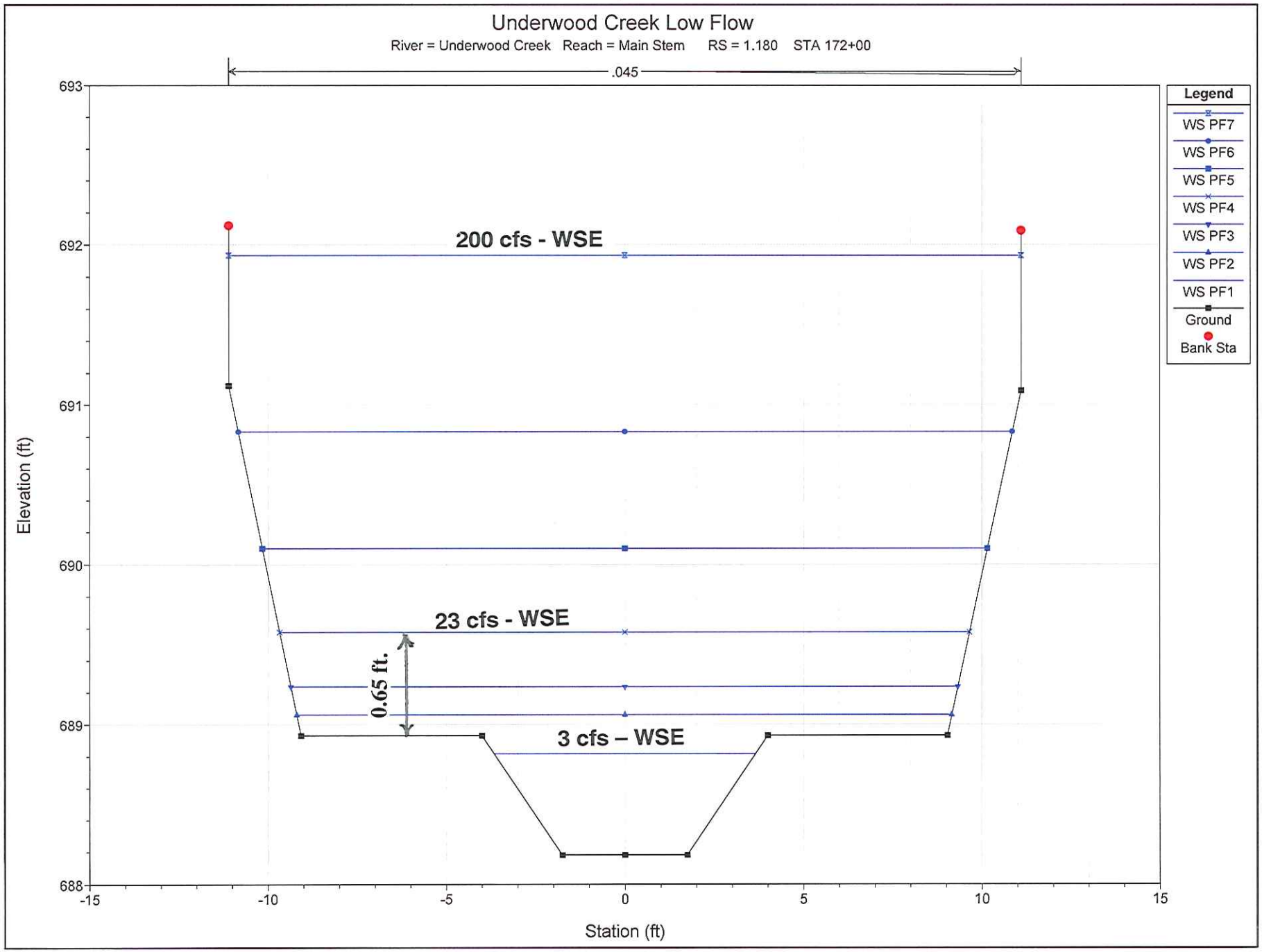


Exhibit A-1
Phase 1 Project - Main and Low Flow Channels

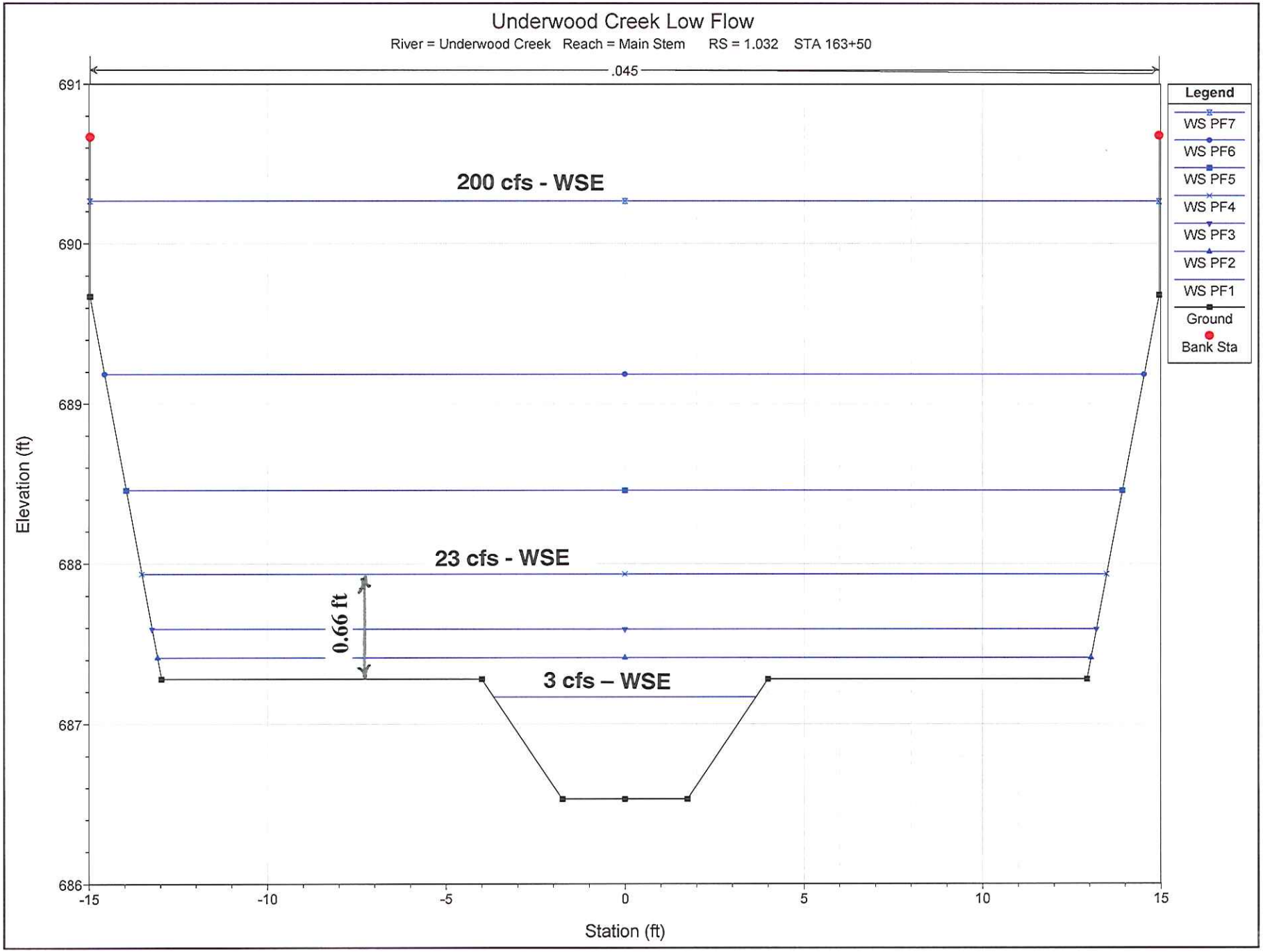


Exhibit A-2
Phase 1 Project - Main and Low Flow Channels

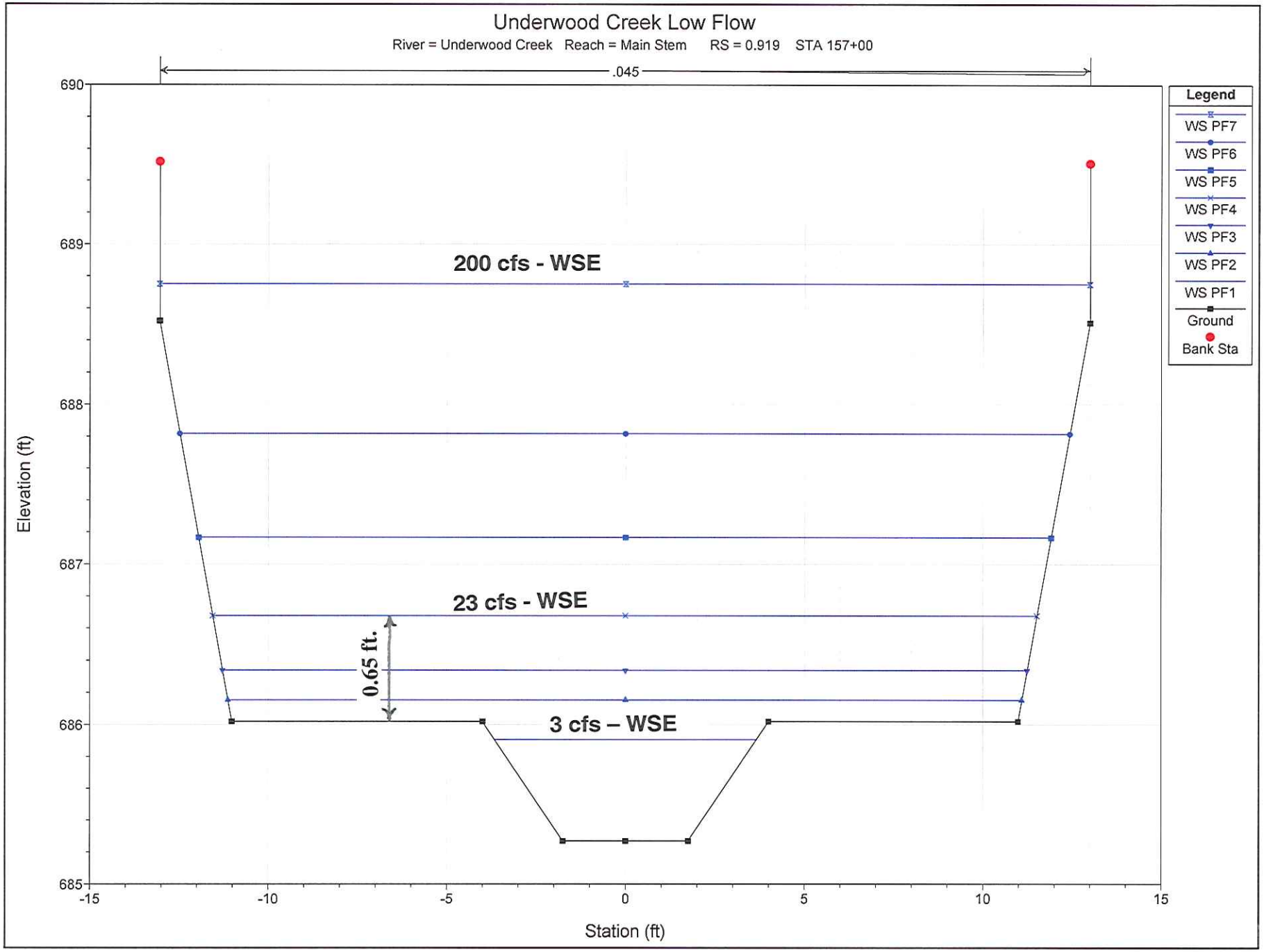


Exhibit A-3
Phase 1 Project - Main and Low Flow Channels

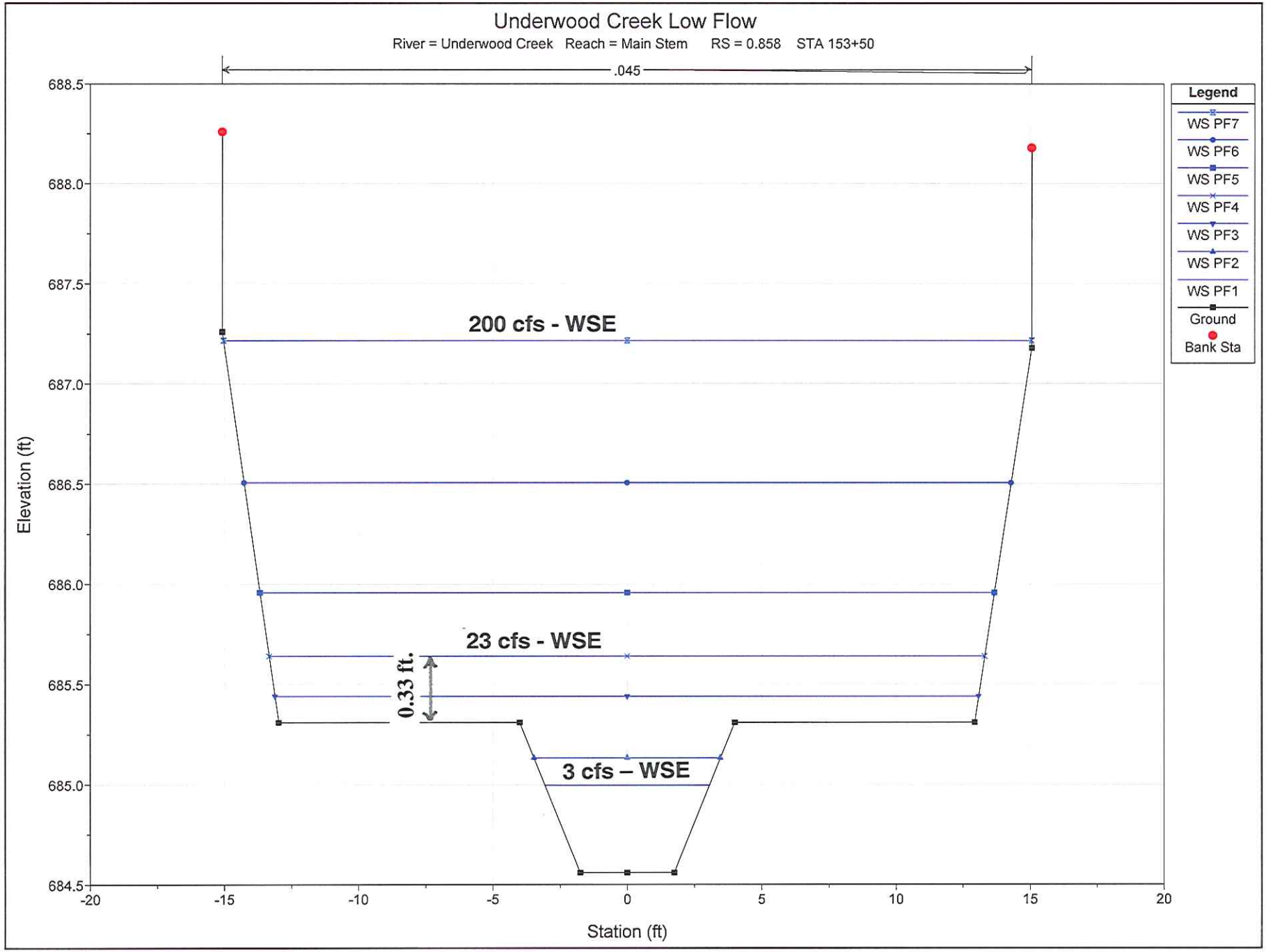


Exhibit A-4
Phase 1 Project - Main and Low Flow Channels

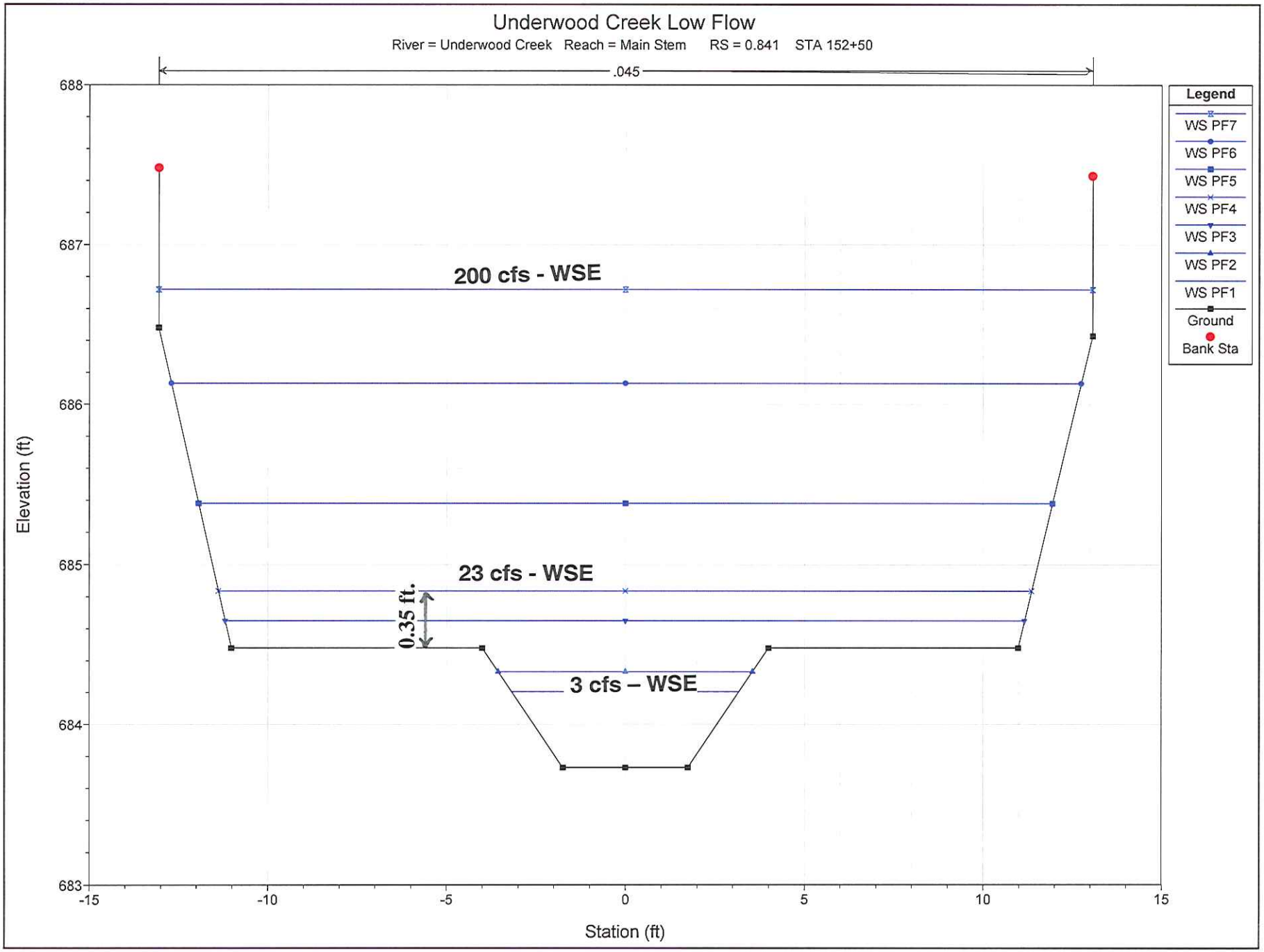


Exhibit A-5
Phase 1 Project - Main and Low Flow Channels

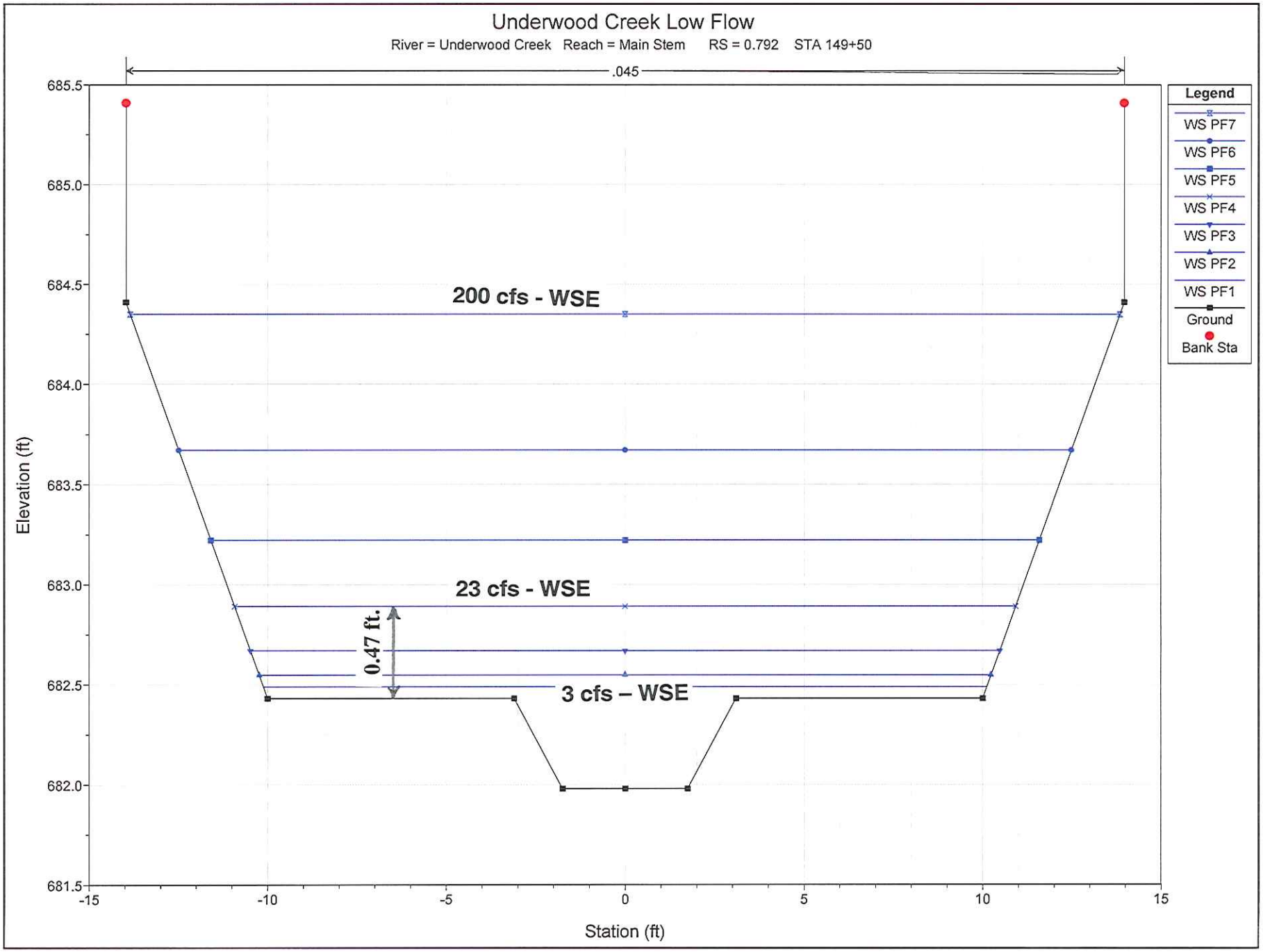


Exhibit B-1
Phase 2 Project - Main and Low Flow Channels

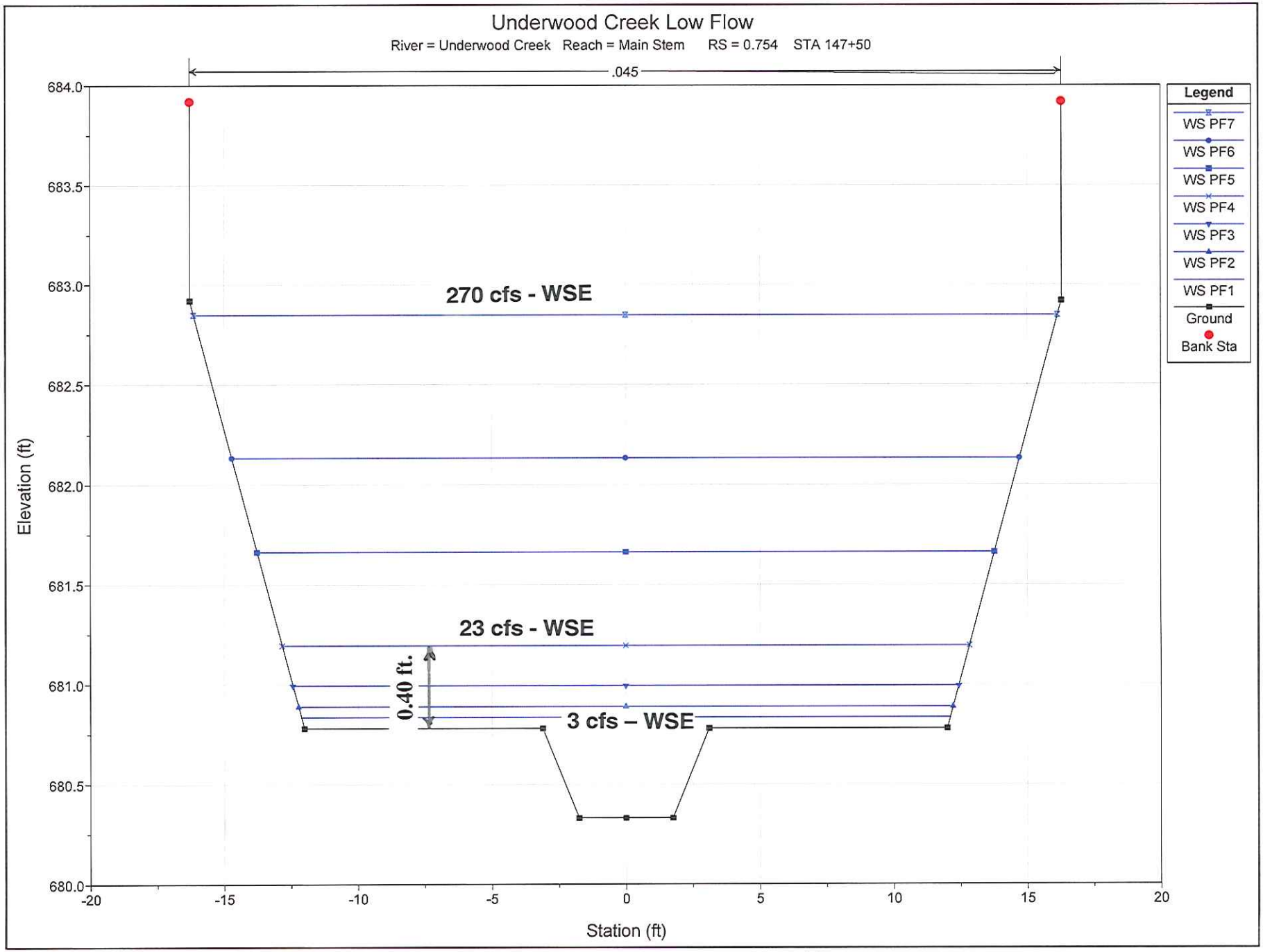


Exhibit B-2
Phase 2 Project - Main and Low Flow Channels

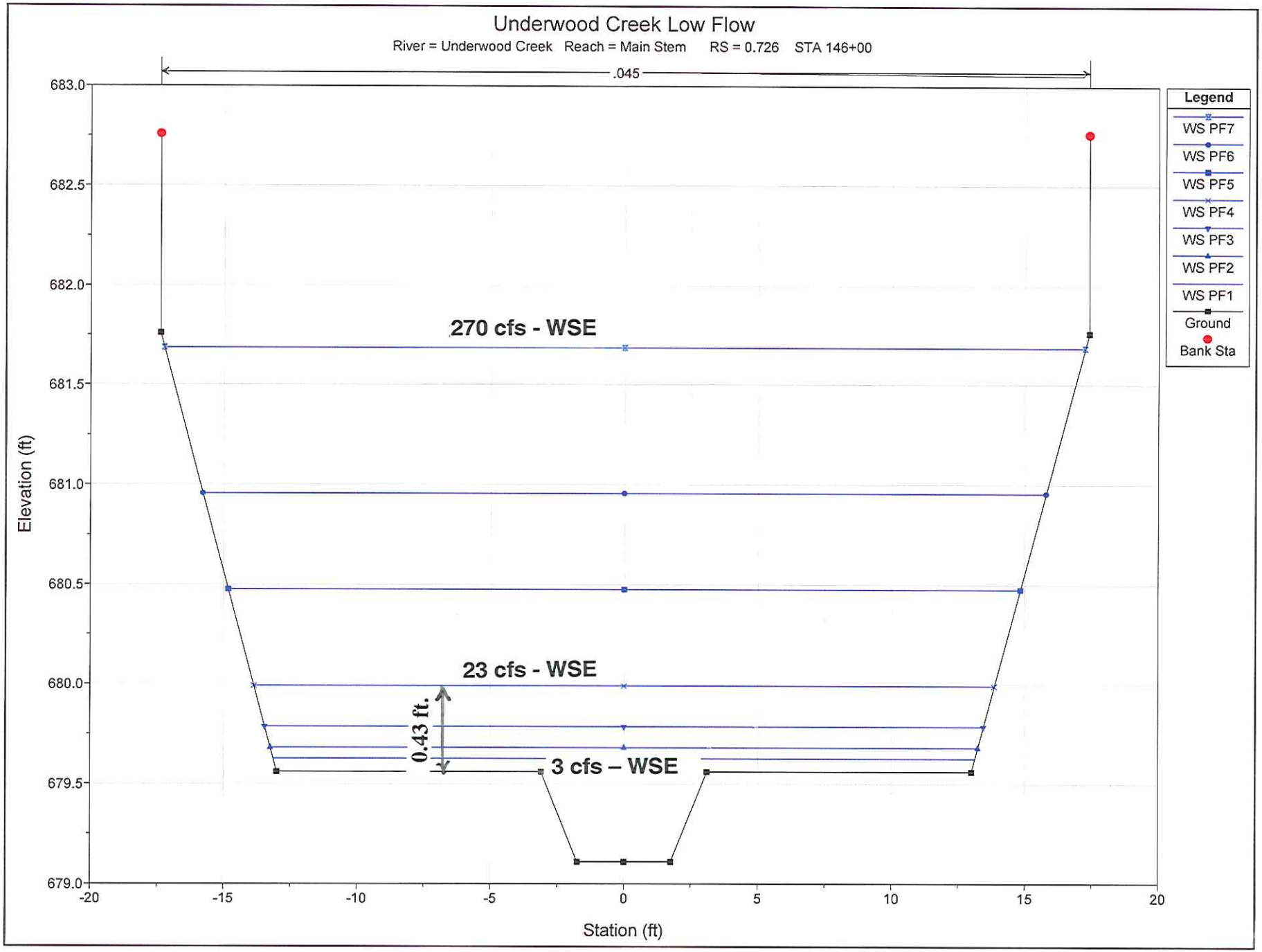


Exhibit B-3
Phase 2 Project - Main and Low Flow Channels

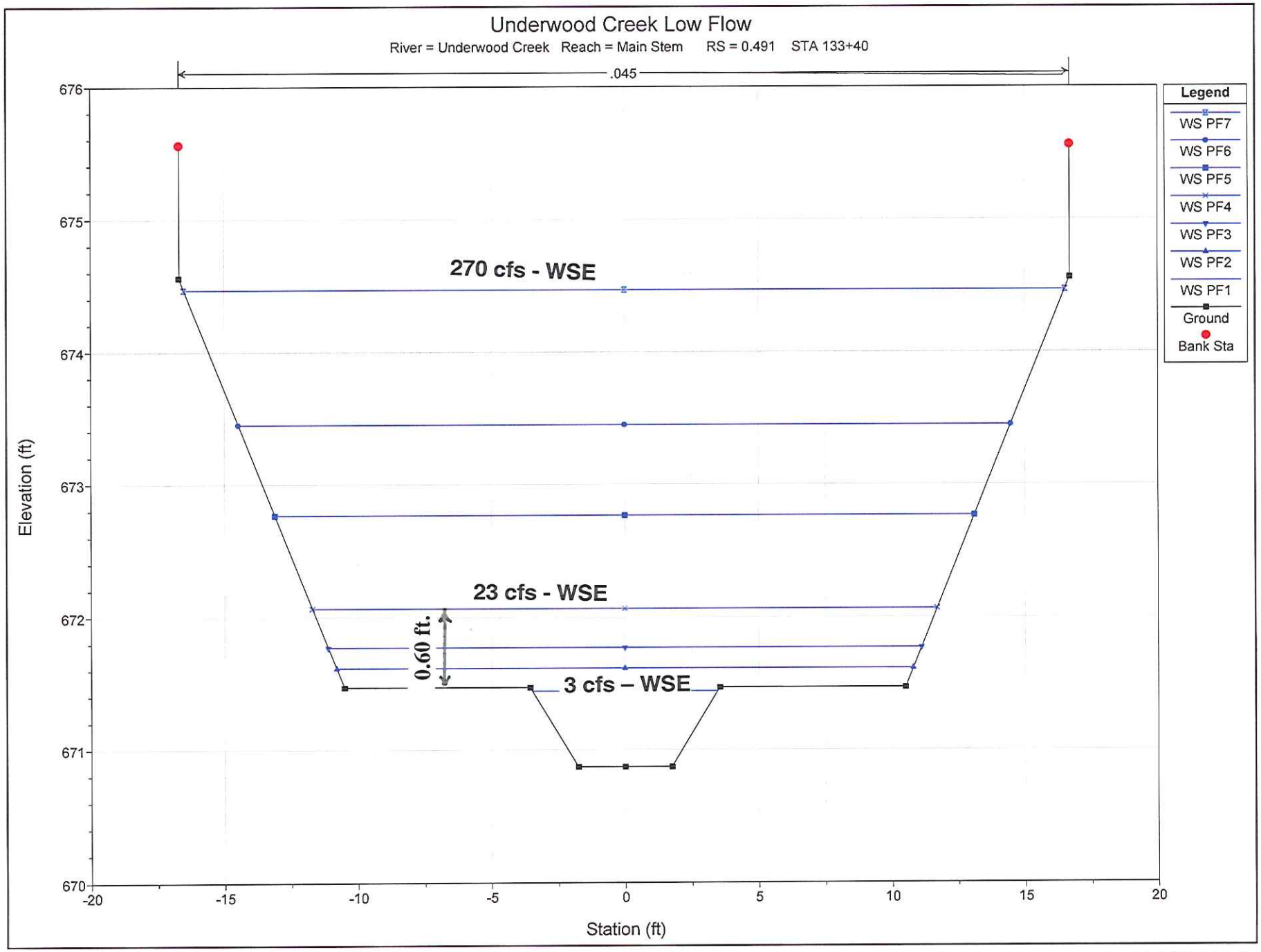


Exhibit B-4
Phase 2 Project - Main and Low Flow Channels

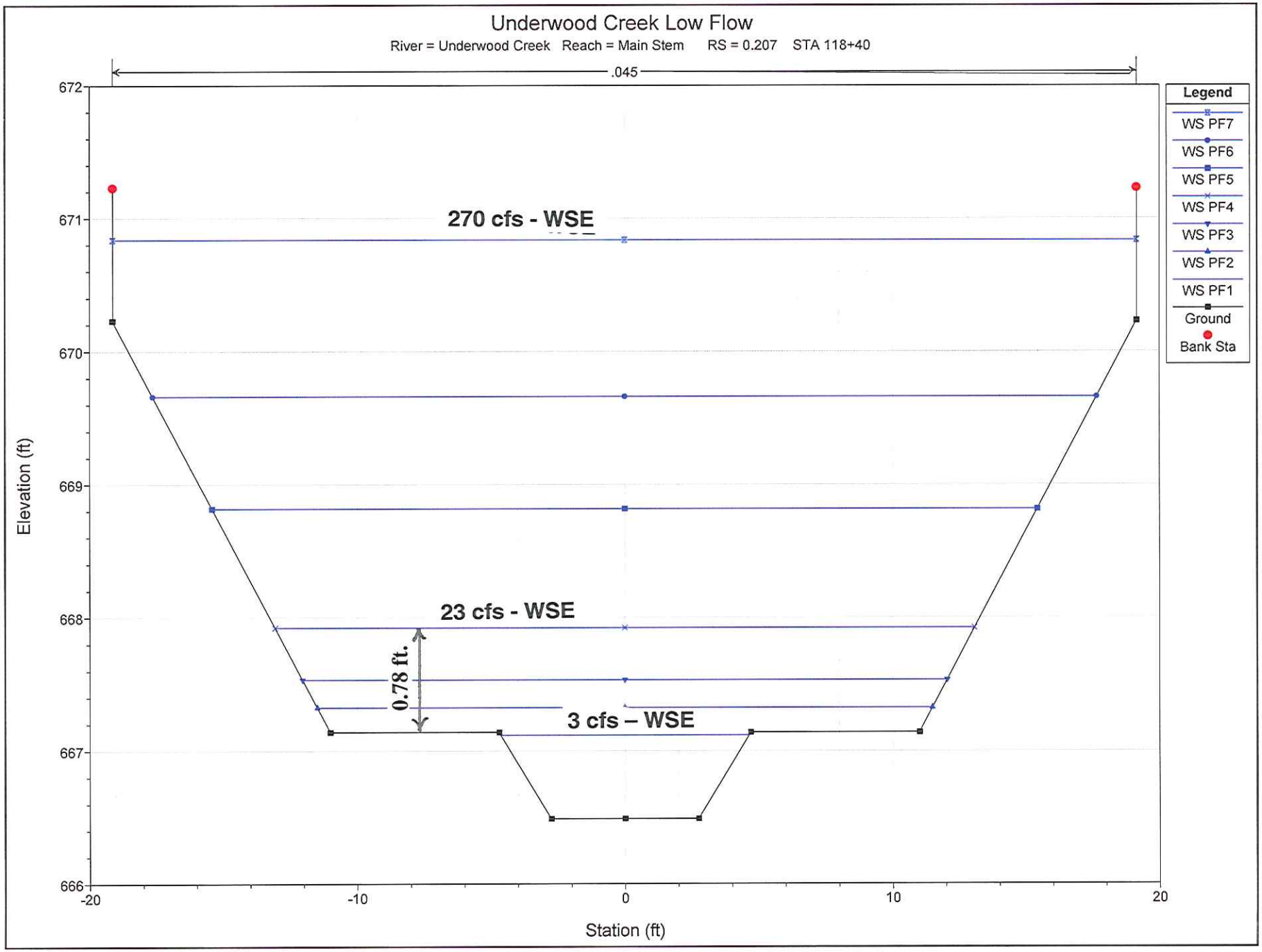


Exhibit B-5
Phase 2 Project - Main and Low Flow Channels

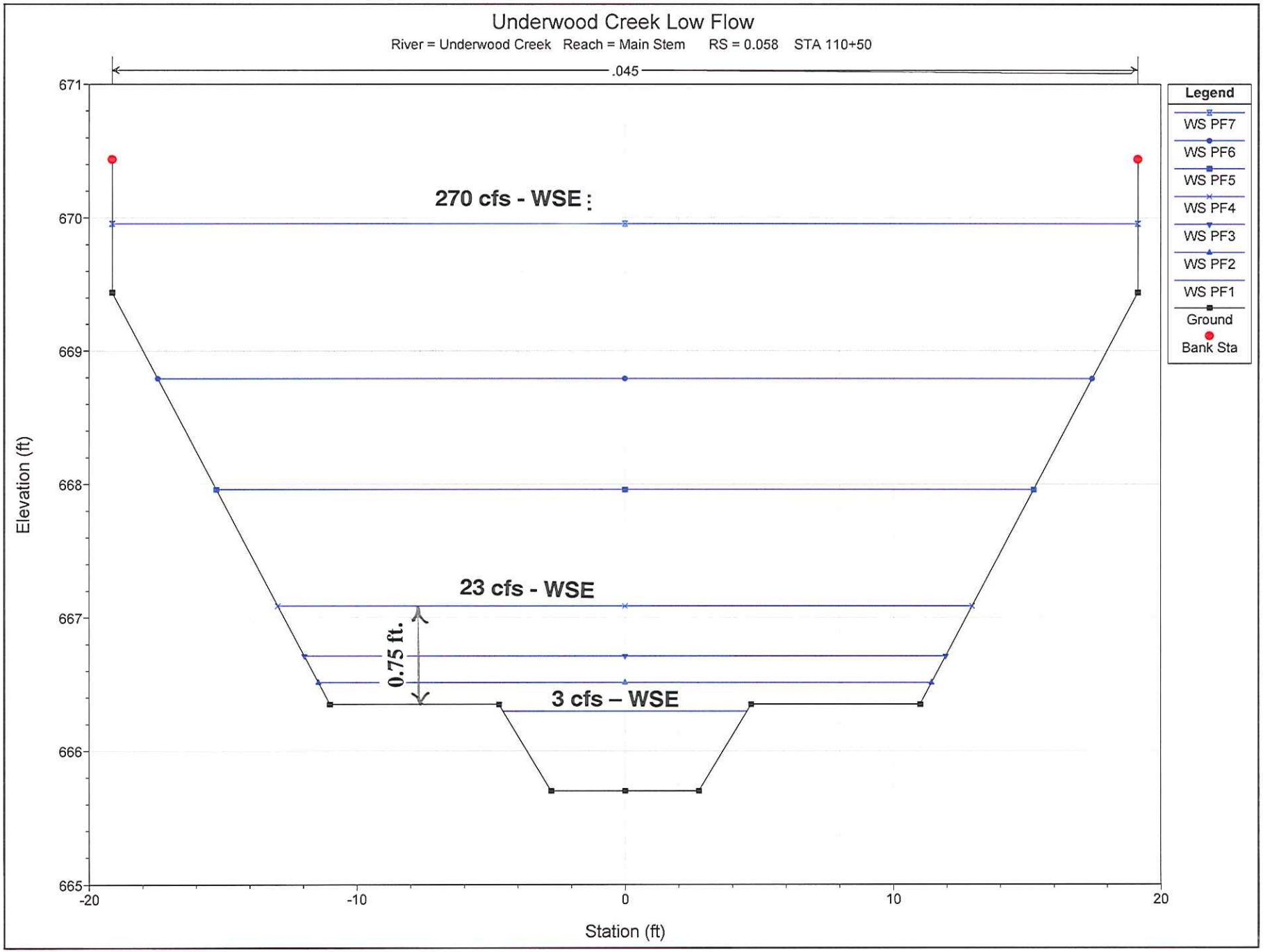


Exhibit B-6
Phase 2 Project - Main and Low Flow Channels

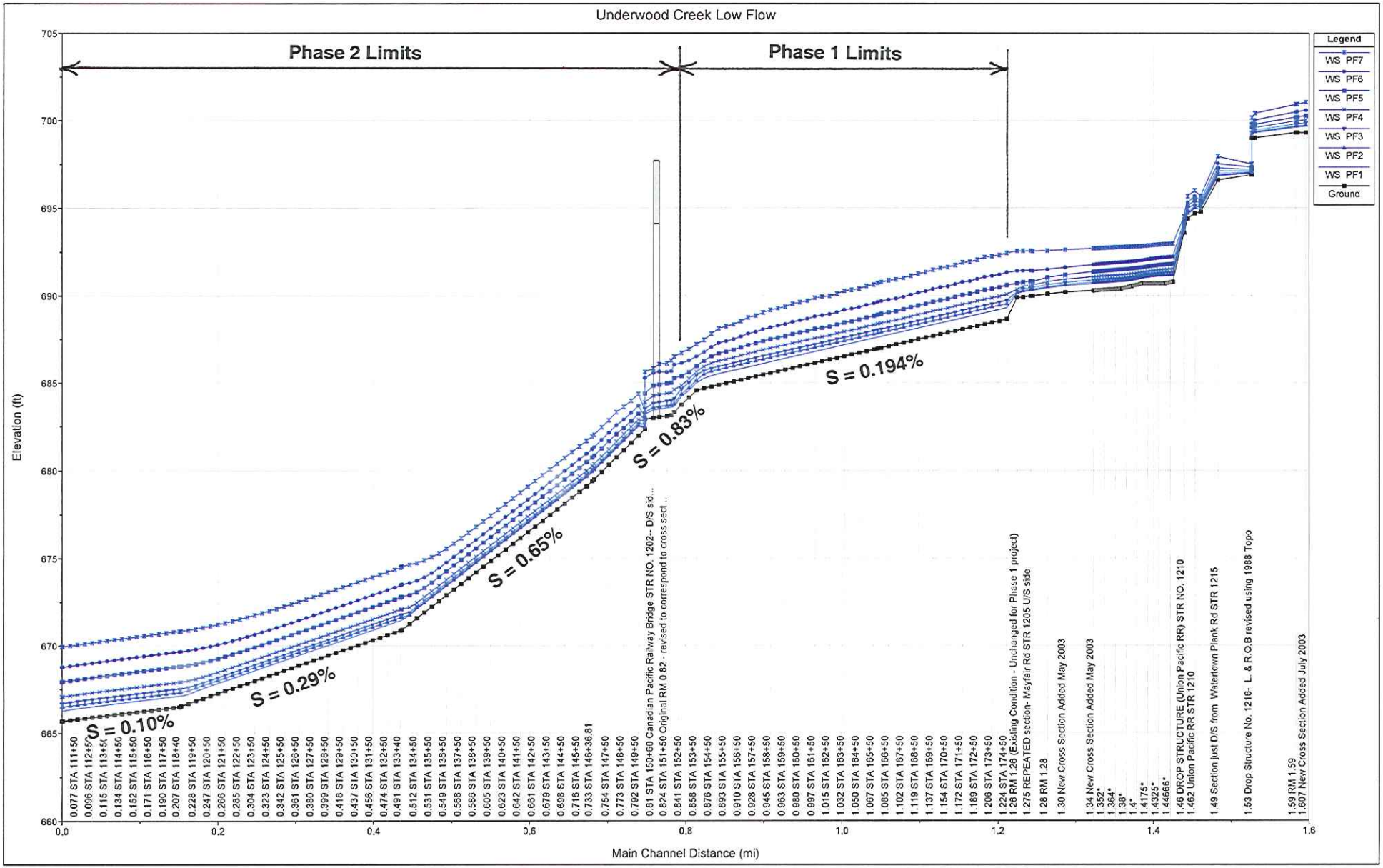
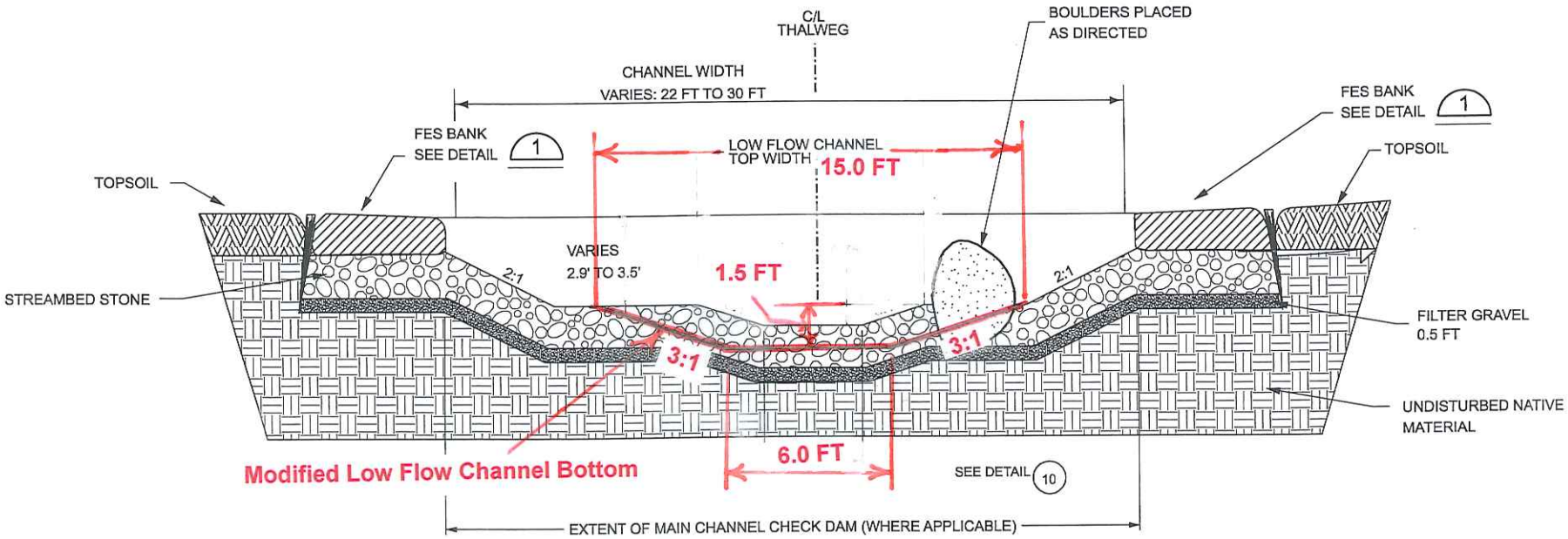


Exhibit C

Underwood Creek – Channel Bottom and Water Surface Profiles



MAIN CHANNEL CROSS-SECTION AT RIFFLE
TYPICAL SECTION

Exhibit D
Underwood Creek – Phase 1 Rehabilitated Main Channel
With Modified Low Flow Channel

Attachment 1

Underwood Creek Rehabilitation and Flood Management - Phase 1
Bid and Construction Drawings
April 2008

Contract Documents

Milwaukee Metropolitan
Sewerage District

Watercourse

Underwood Creek Rehabilitation and Flood Management - Phase 1

Contract W21005C01

Plans

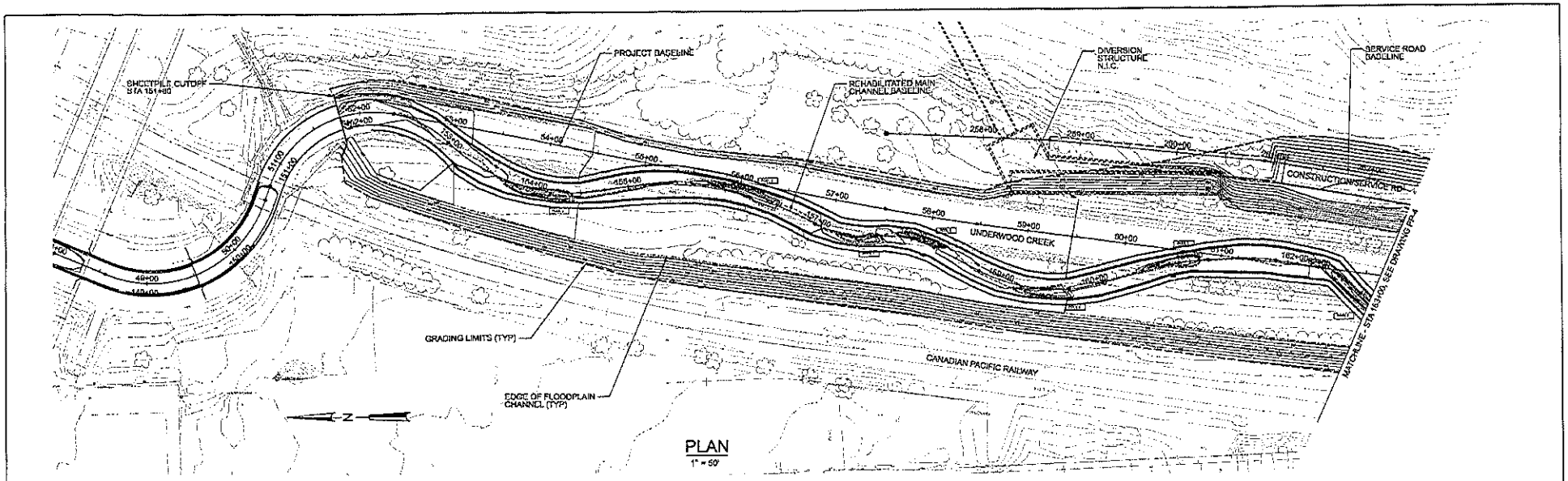
For information regarding this project call: David C. Fowler, Senior Project Manager: (414) 277-6368

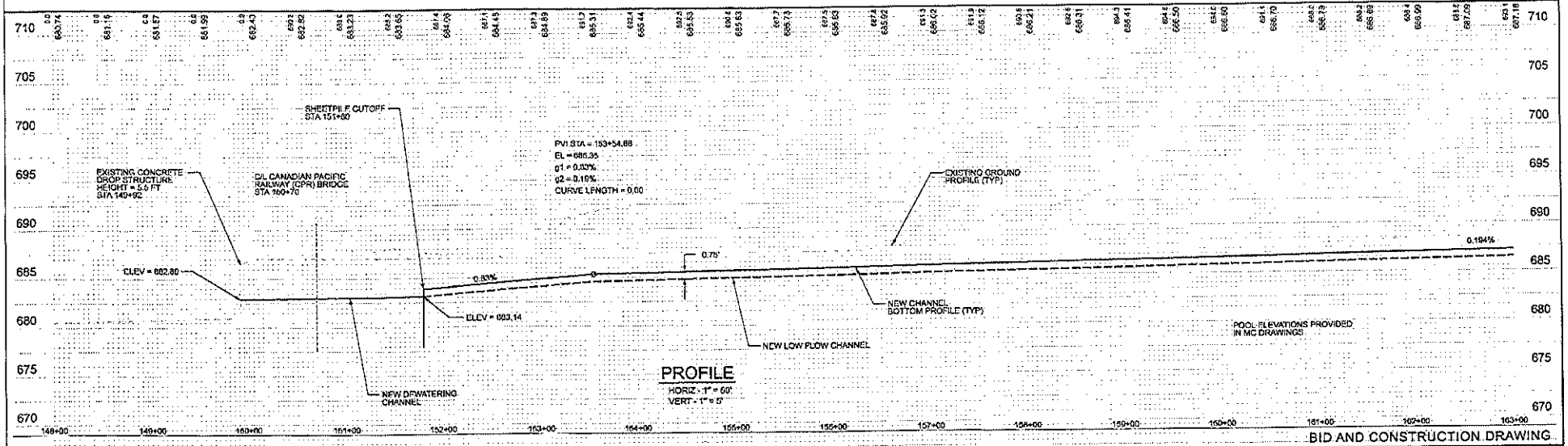
MMSD
Preserving The Environment · Improving Water Quality

Bid - April 2008

BID AND CONSTRUCTION DRAWING SET

MMSD FILE NO. 151-572.DGN





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0" ——— 1"
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DR	M. WEBER
CHK	T.SEAR
APVD	T. SEAR

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SEH

SHORT ELLIOTT HENDRICKSON INC.

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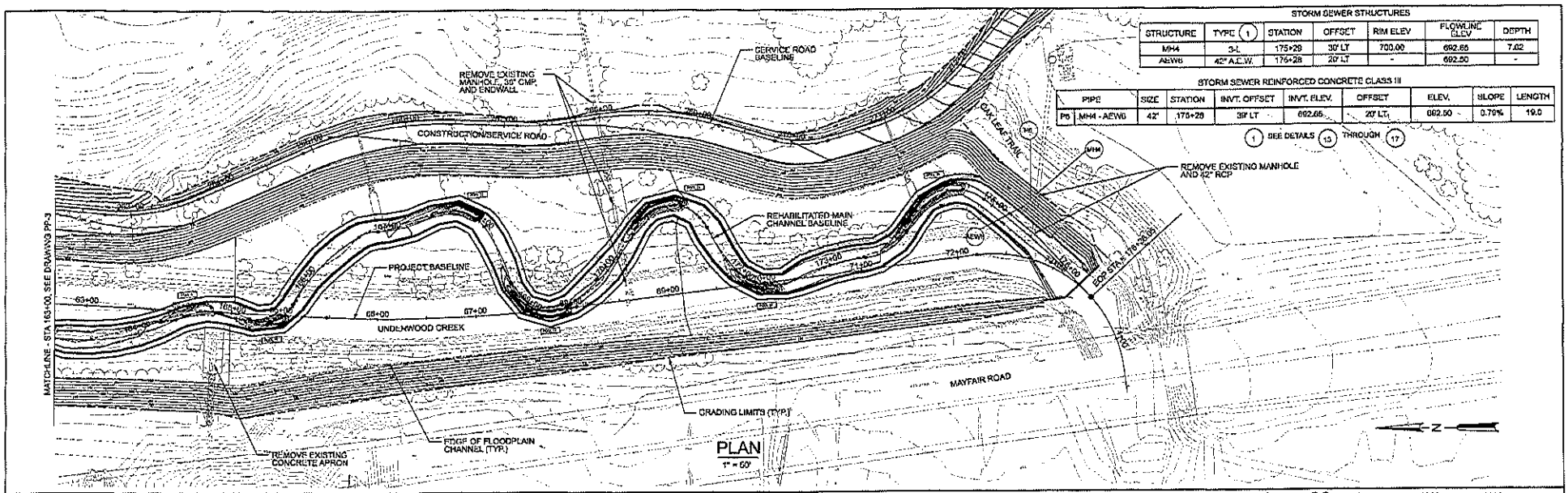
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
REHABILITATED MAIN CHANNEL
PLAN AND PROFILE

DRAWING NO.:	PP-3
SHEET:	14
DATE:	APRIL, 2009
CONTRACT:	W21005C01
MMSD FILE:	151-585.DGN



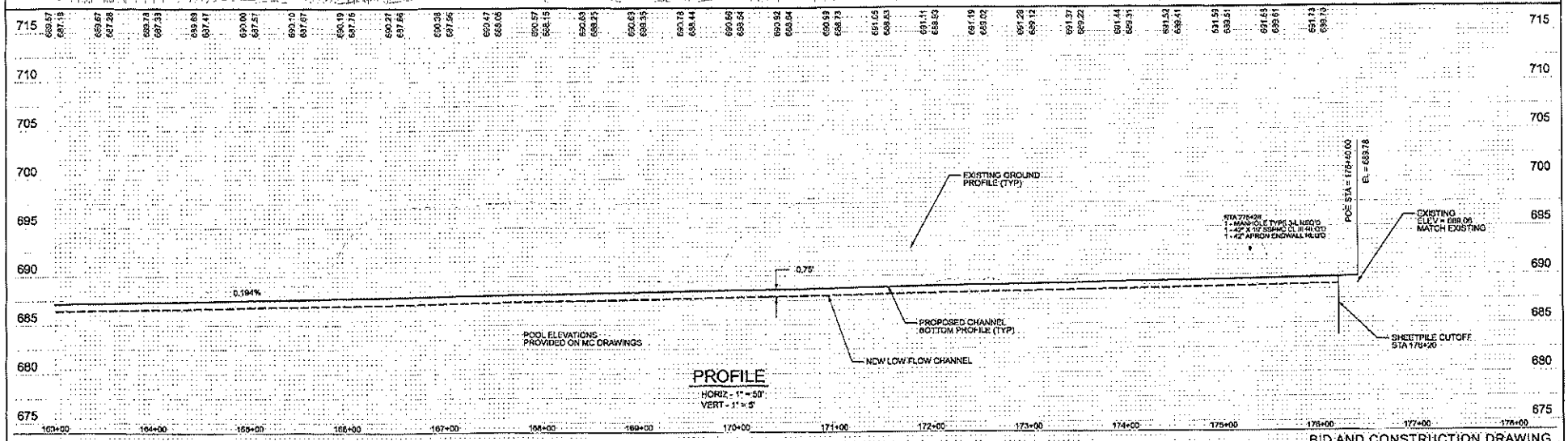
STORM SEWER STRUCTURES

STRUCTURE	TYPE (1)	STATION	OFFSET	RIM ELEV	FLOWLINE ELEV	DEPTH
MH4	3-L	175+29	39' LT	700.00	692.65	7.02
AEW6	42" A.E.W.	176+28	20' LT	-	692.50	-

STORM SEWER REINFORCED CONCRETE CLASS III

PIPE		SIZE	STATION	INVT. OFFSET	INVT. ELEV.	OFFSET	ELEV.	SLOPE	LENGTH
P6	MH4 - AEW6	42"	175+29	39' LT	692.65	20' LT	692.50	0.79%	19.0

(1) SEE DETAILS (13) THROUGH (17)



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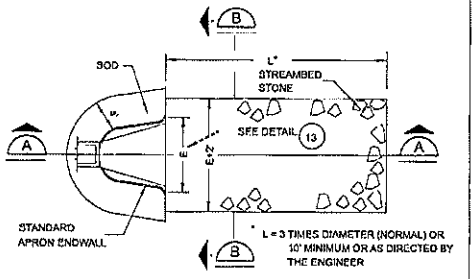
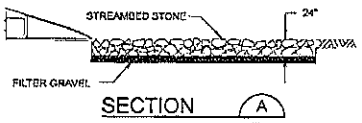
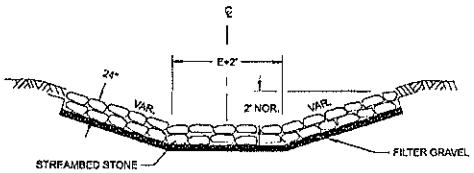
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
REHABILITATED MAIN CHANNEL
PLAN AND PROFILE

DRAWING NO.:	PP-4
SHEET:	15
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-589.DGN





SECTION A

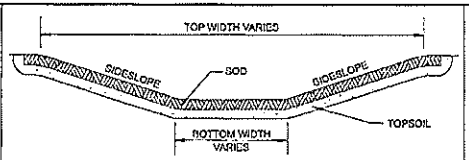


SECTION B

STORM WATER CONVEYANCE DETAILS

NTS

1



	GRASSED SWALE			STORM SEWER	
RMCB		AVG.	BOTTOM	STREAMBED	FILTER
STATION	SIDESLOPE	DEPTH	WIDTH	STONE	GRAVEL
164+80	4:1	1.0'	11.0'	GRADE II	GRADE II
168+95	4:1	0.5'	4.0'	GRADE I	GRADE I
170+30	3:1	2.0'	12.0	GRADE II	GRADE II
174+15	4:1	0.5'	4.0'	GRADE I	GRADE I

FLOODPLAIN SOD SWALE DETAIL

NTS

2

PLAN

1" = 20'

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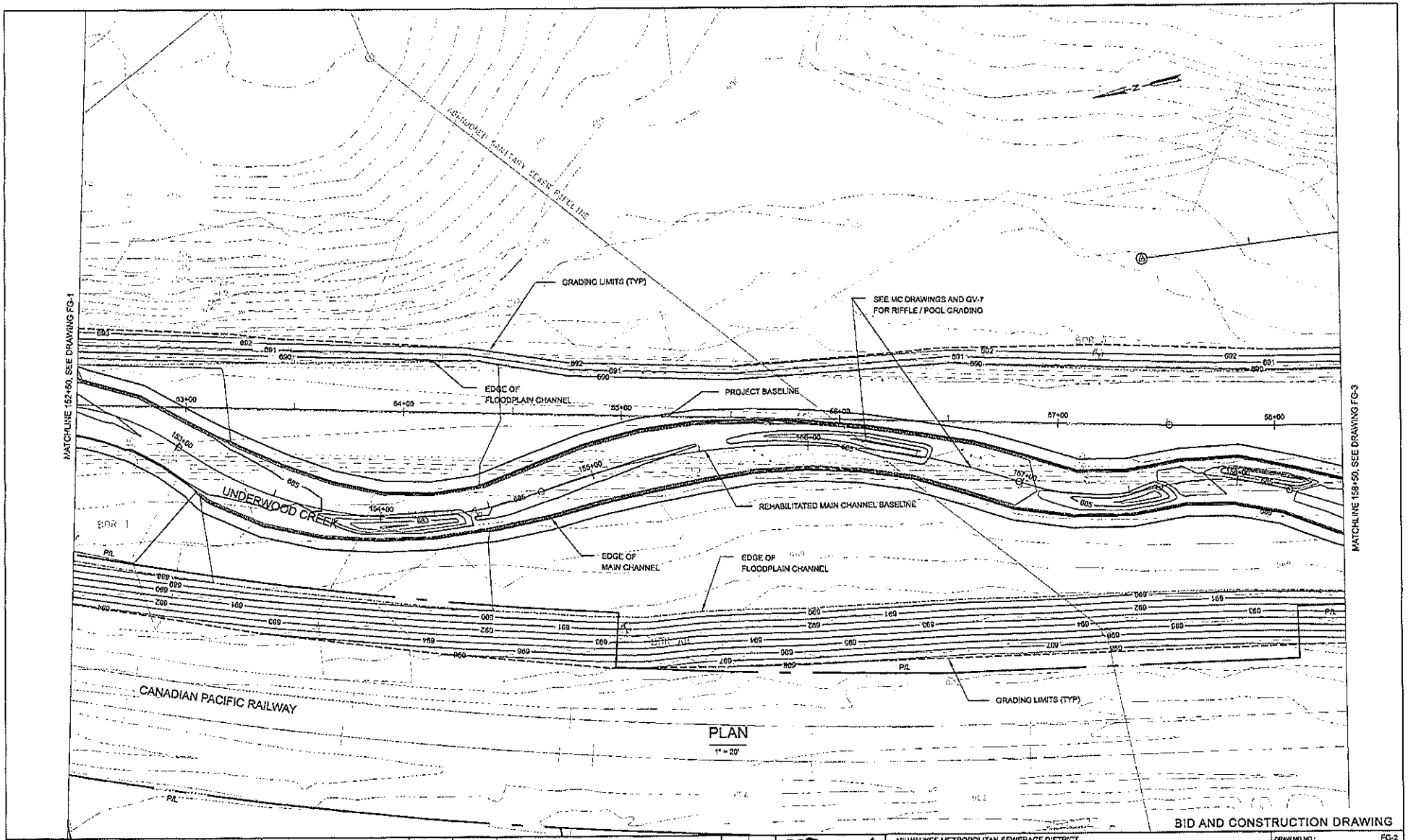
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN AND SECTIONS

DRAWING NO.:	FG-1
SHEET:	22
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	161-593.DGN



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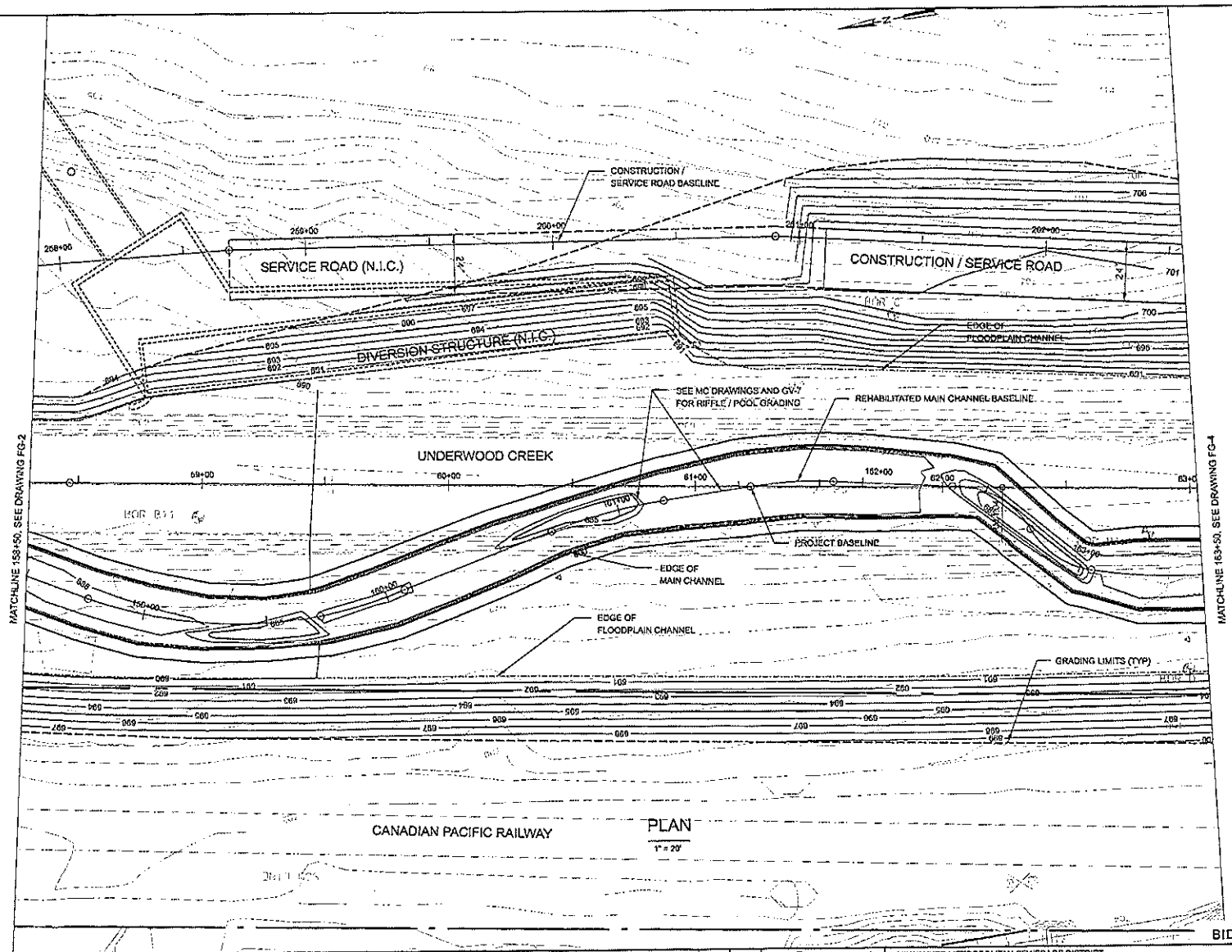
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

DRAWING NO.:	FG-2
SHEET:	23
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-504.DGN



PLAN
1" = 20'

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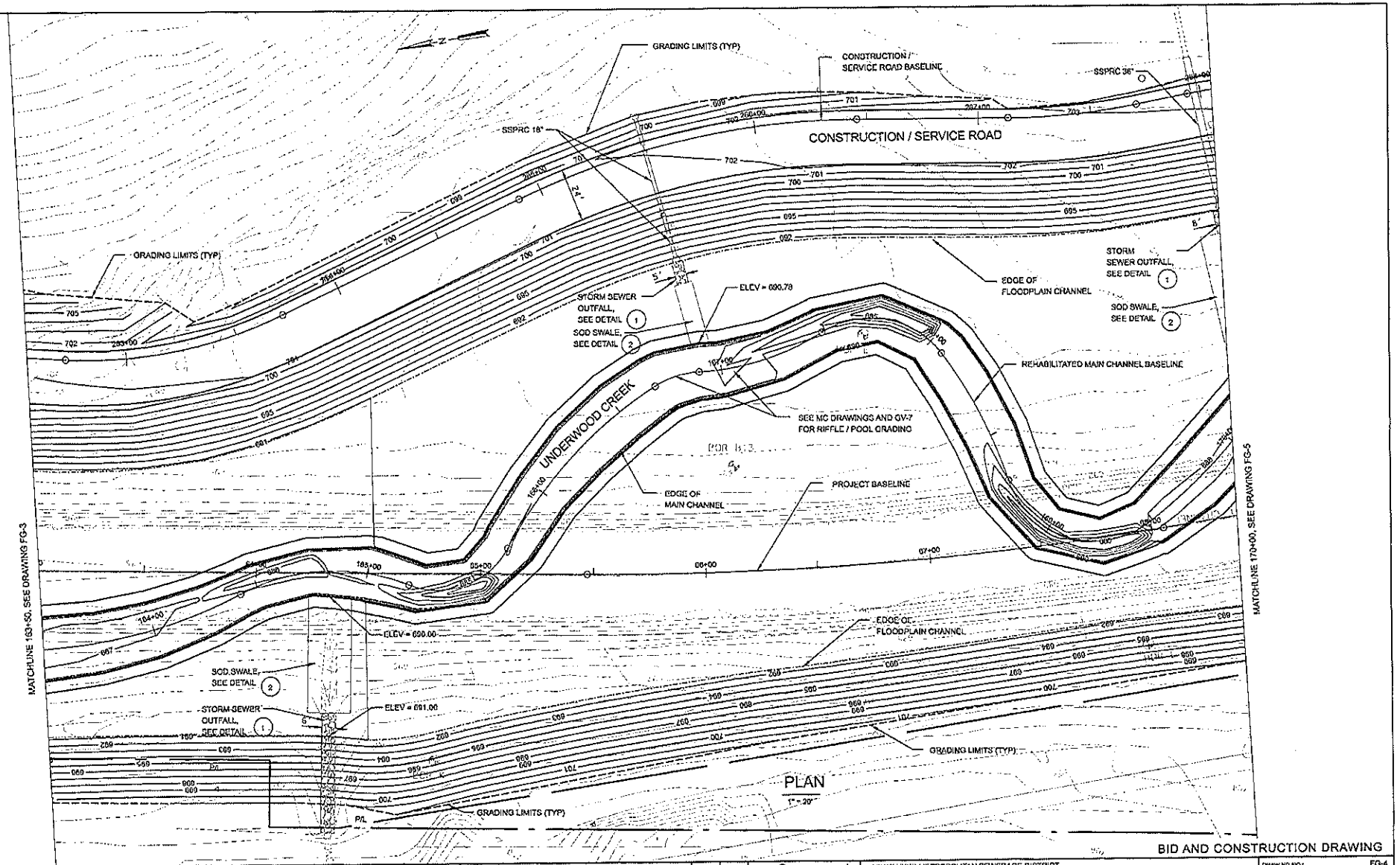
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

DRAWING NO.:	FG-3
SHEET:	24
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	161-595.DGN



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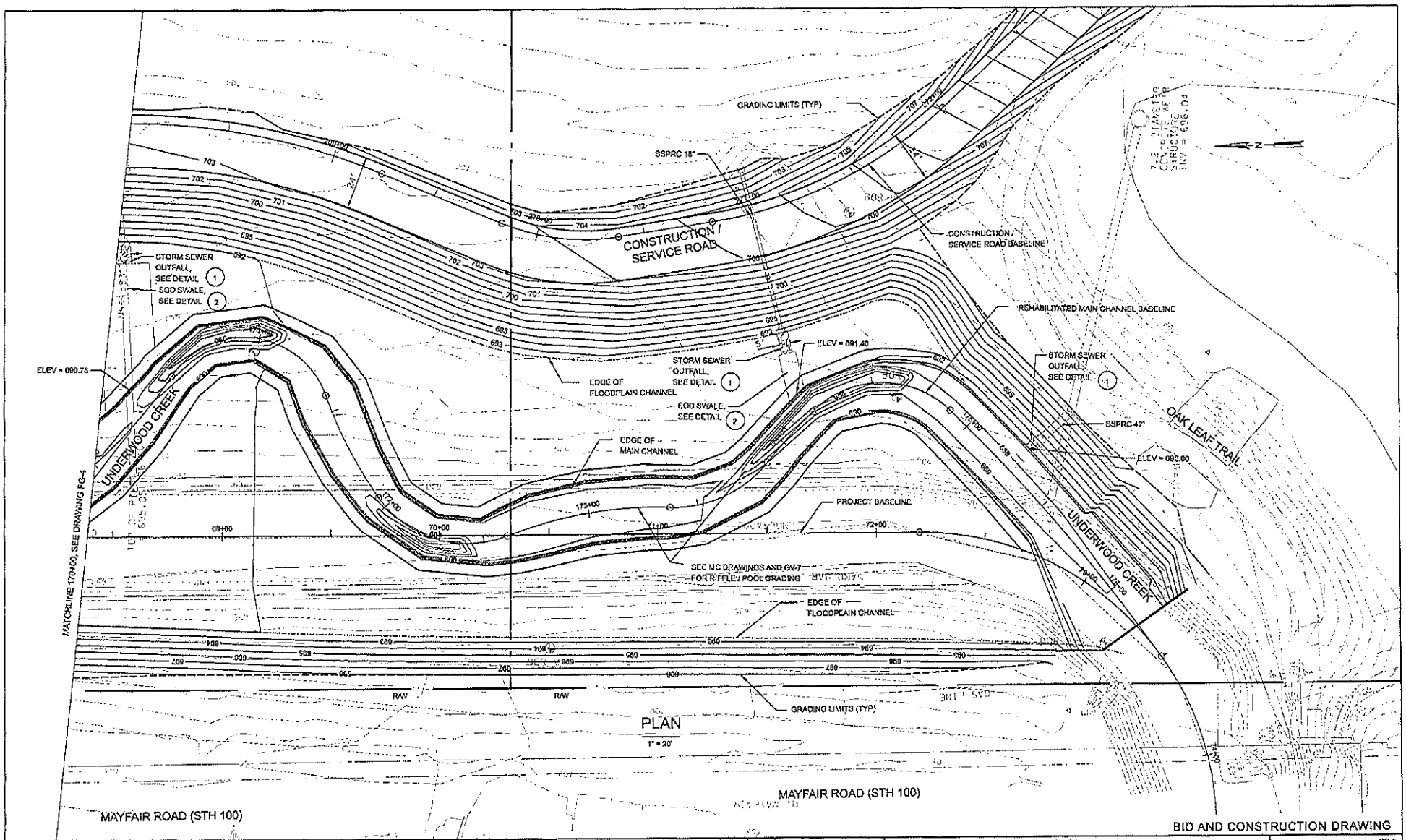
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

DRAWING NO.:	FG-4
SHEET:	25
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-596.DGN



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WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

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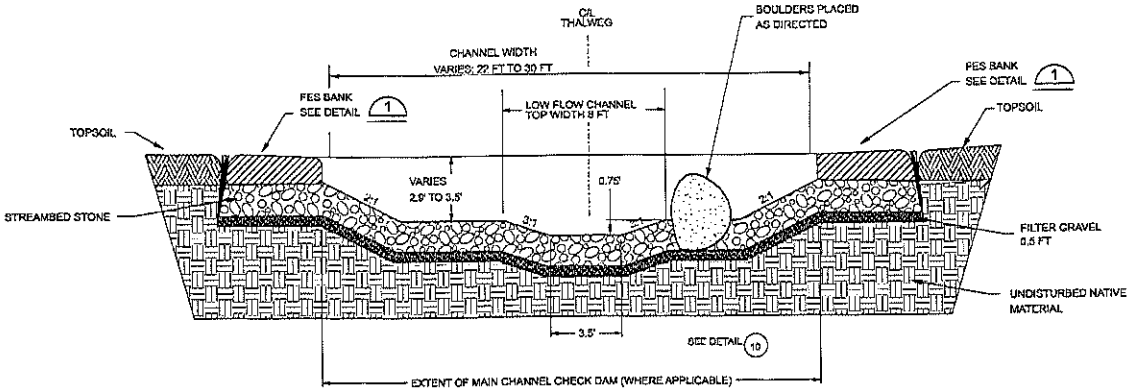
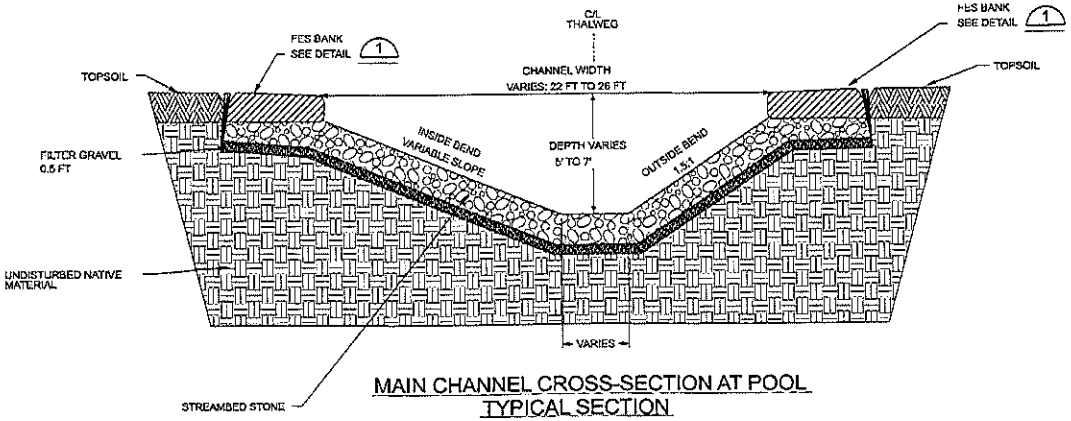
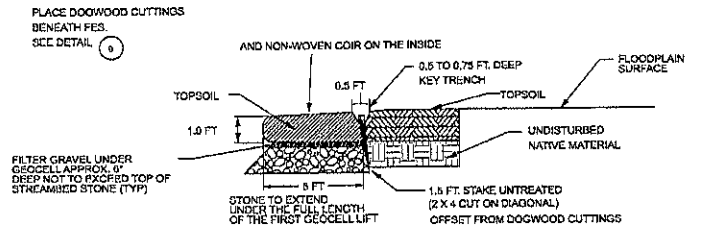
SHEET:	28
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-597.DGN



MAIN CHANNEL CROSS-SECTION AT RIFFLE TYPICAL SECTION



MAIN CHANNEL CROSS-SECTION AT POOL TYPICAL SECTION



FABRIC ENCAPSULATED SOIL (FES) BANK DETAIL 1

NTS

REHABILITATED MAIN CHANNEL STREAMBED STONE AND RIP RAP PLACEMENT (1)				
RMCD STATION		STREAMBED STONE		RIP RAP
BEGIN	END	GRADE I	GRADE II	
151+80	152+05			YES
152+05	152+50		YES	
152+50	158+60	YES		
158+60	165+70		YES	
165+70	167+40	YES		
167+40	168+10		YES	
168+10	168+60	YES		
168+60	169+90		YES	
169+90	170+50	YES		
170+50	171+30		YES	
171+30	171+80	YES		
171+80	172+00		YES	
172+00	173+70	YES		
173+70	175+70		YES	
175+70	176+20			YES

BOULDER PLACEMENT		
RMCD STATION		NUMBER OF BOULDERS TO BE PLACED
BEGIN	END	AS DIRECTED
152+30	153+80	18
154+50	155+60	13
156+80	157+10	6
157+75	157+80	1
158+25	159+05	10
159+65	160+45	16
161+10	162+35	15
163+05	164+10	13
164+80	164+95	2
165+60	166+90	16
167+95	168+45	6
169+40	170+25	10
171+15	171+80	8
172+50	173+55	13
174+80	176+50	23
TOTAL		184

1) MINIMUM DEPTH OF STREAMBED STONE AND RIP RAP LAYER

STREAMBED STONE		
GRADE I	GRADE II	RIP RAP
1.5'	2.0'	3'

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DR M. WEBER
CHK T.SCAR
APVD T. SCAR

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REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

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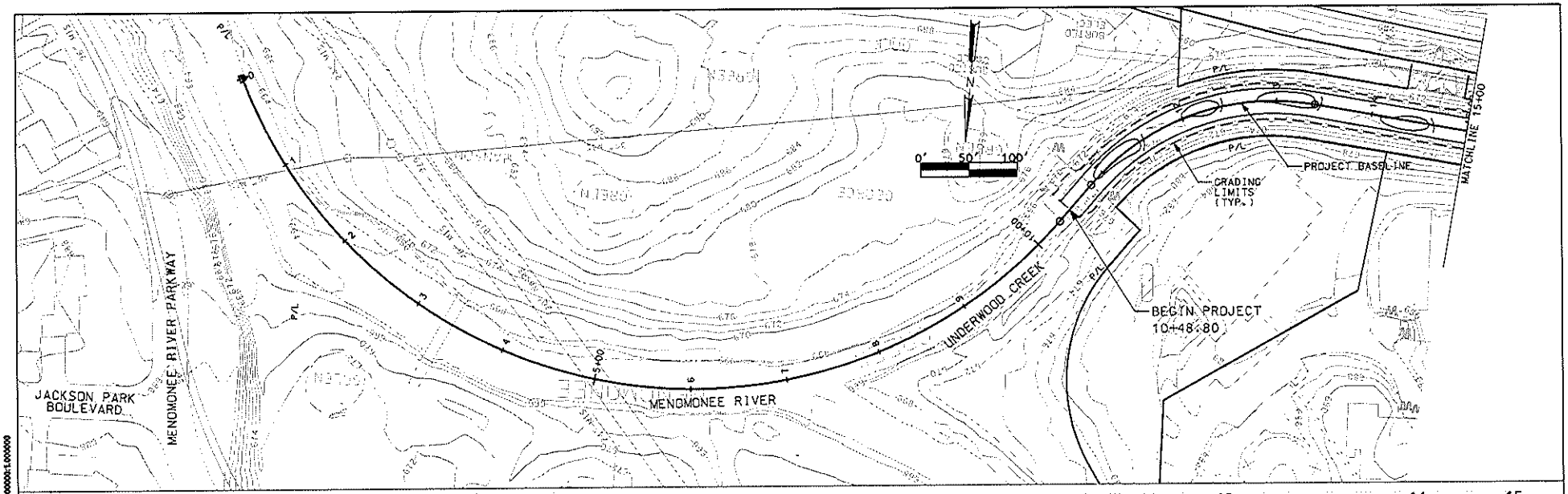
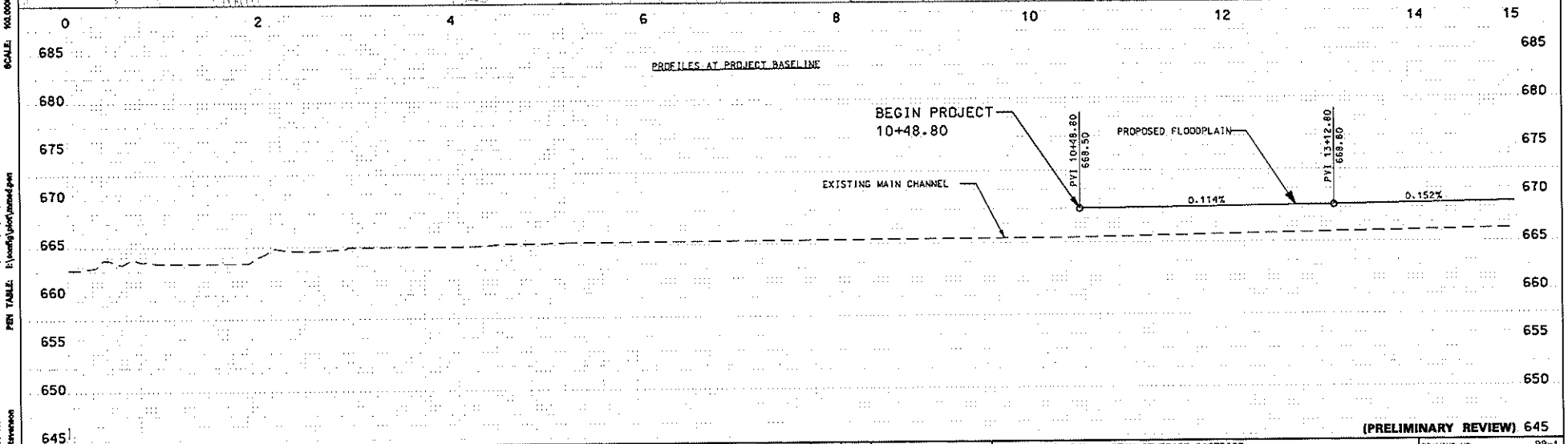
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
GEOMORPHIC AND VEGETATION
TYPICAL CHANNEL SECTIONS

DRAWING NO.:	GV-7
SHEET:	41
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-612.DGN

Attachment 2

Underwood Creek Rehabilitation and Flood Management - Phase 2
Preliminary Engineering Drawings
January 2006





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This Design Prepared For MMSD By:
TETRA TECH
In Association With
HNTB

REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

mmsd
Preserving The Environment · Improving Water Quality

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-1
SHEET:	12
DATE:	JANUARY, 2006
CONTRACT:	W21005001
MMSD FILE:	XXX-XXX.DGN

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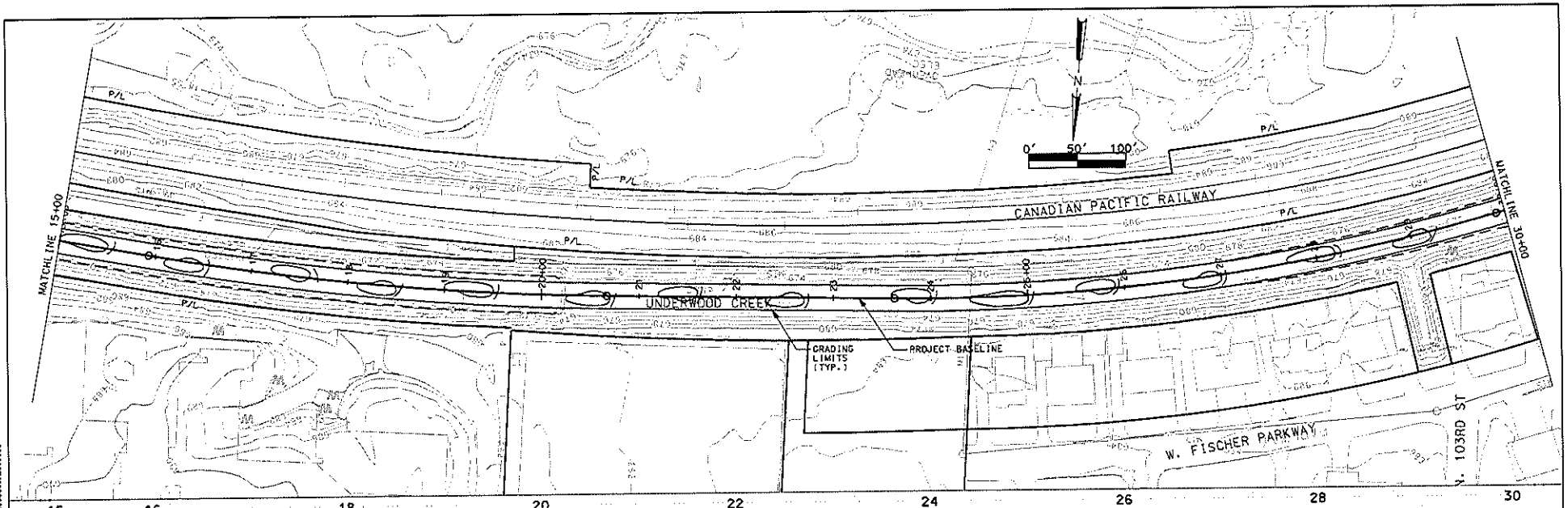
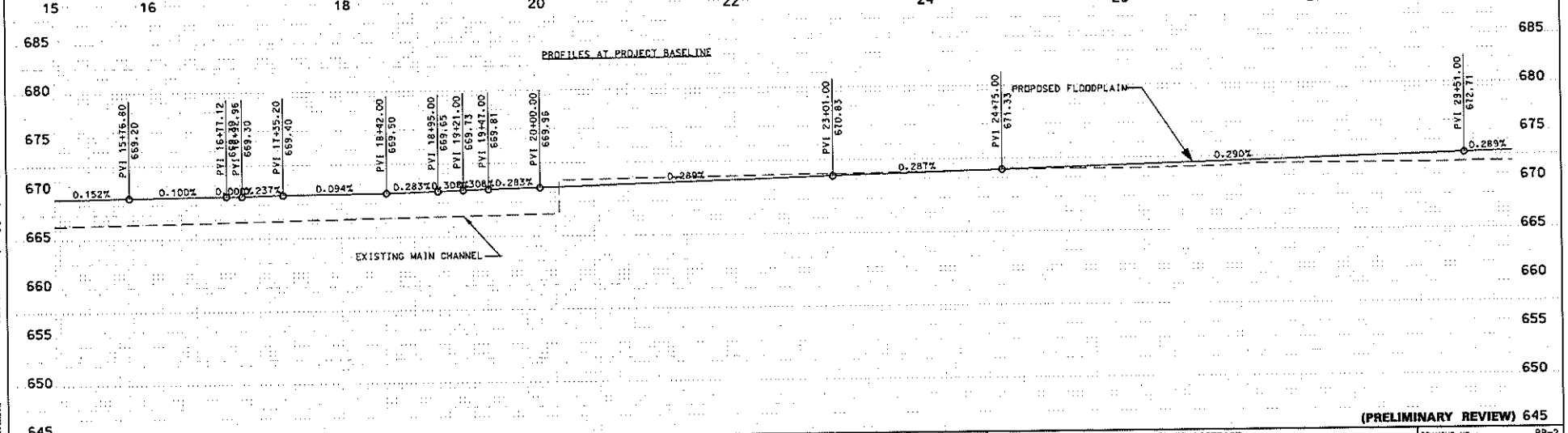
PLOTTED BY: mstevenson





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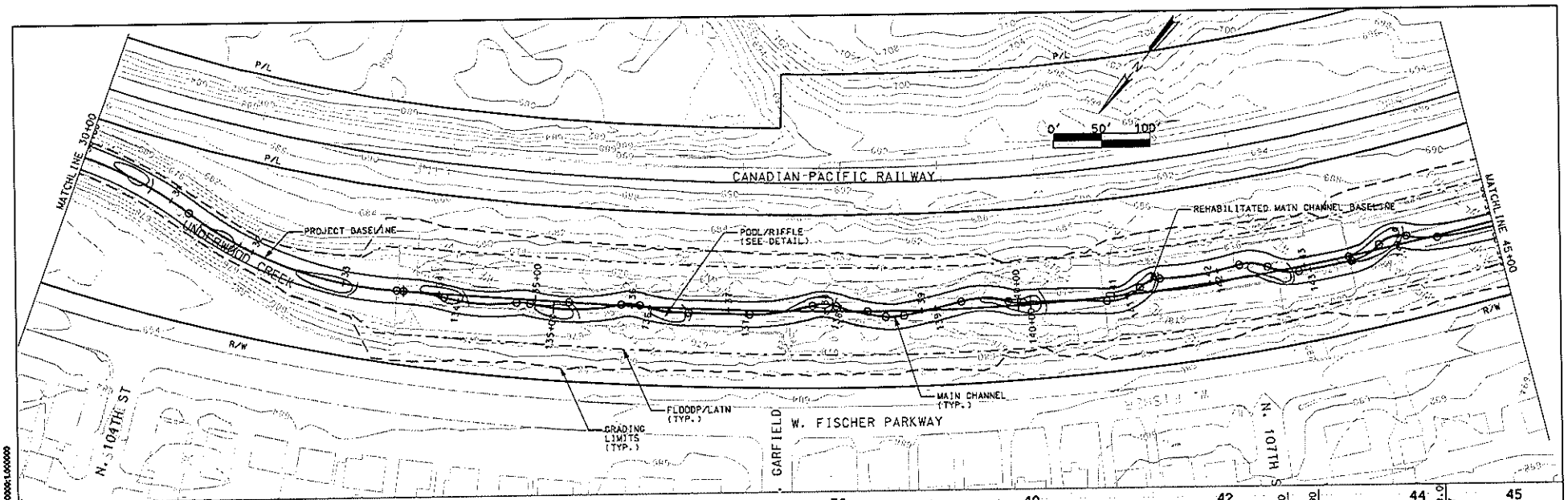

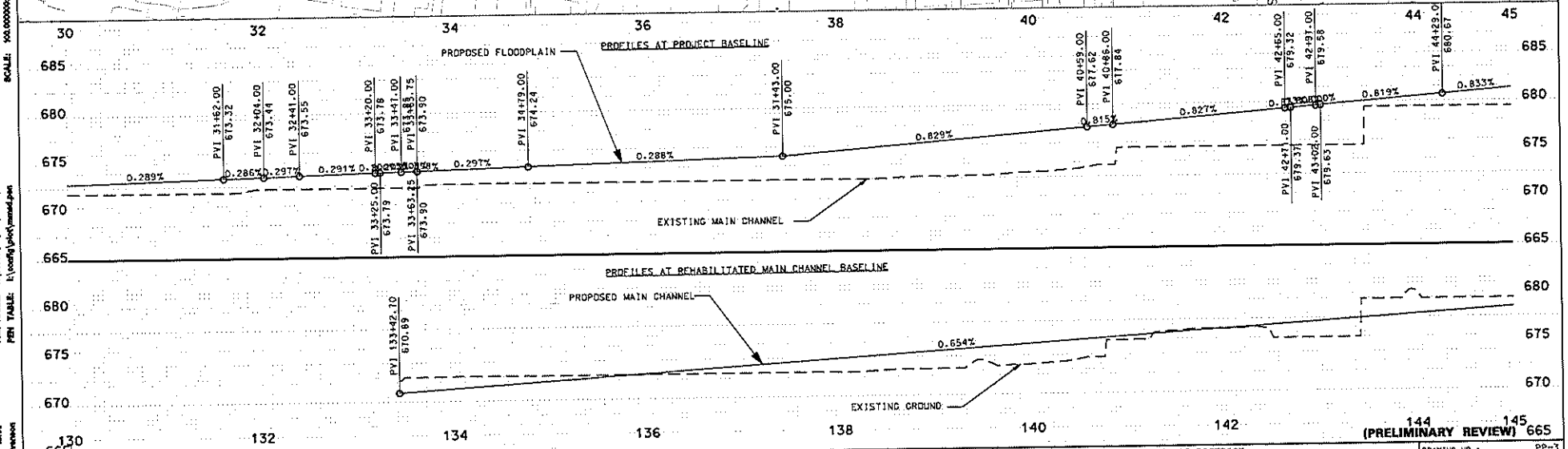

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MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-3
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DATE:	JANUARY, 2006
CONTRACT:	W21005001
MMSD FILE:	XXX-XXX.DGN

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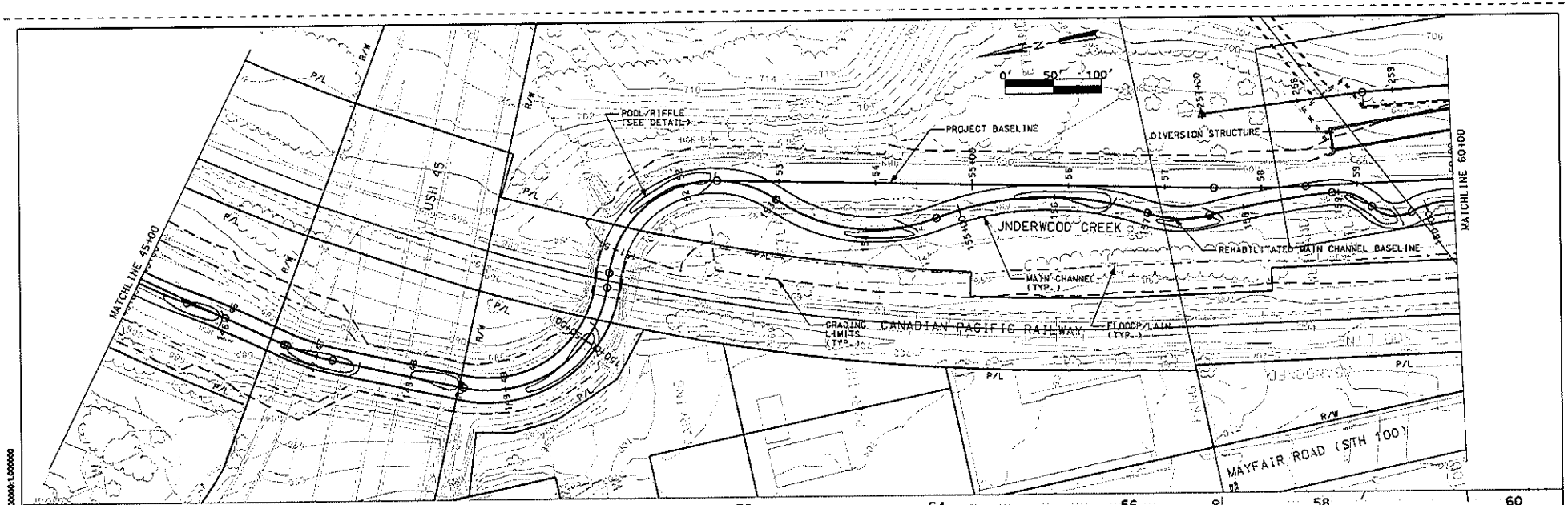

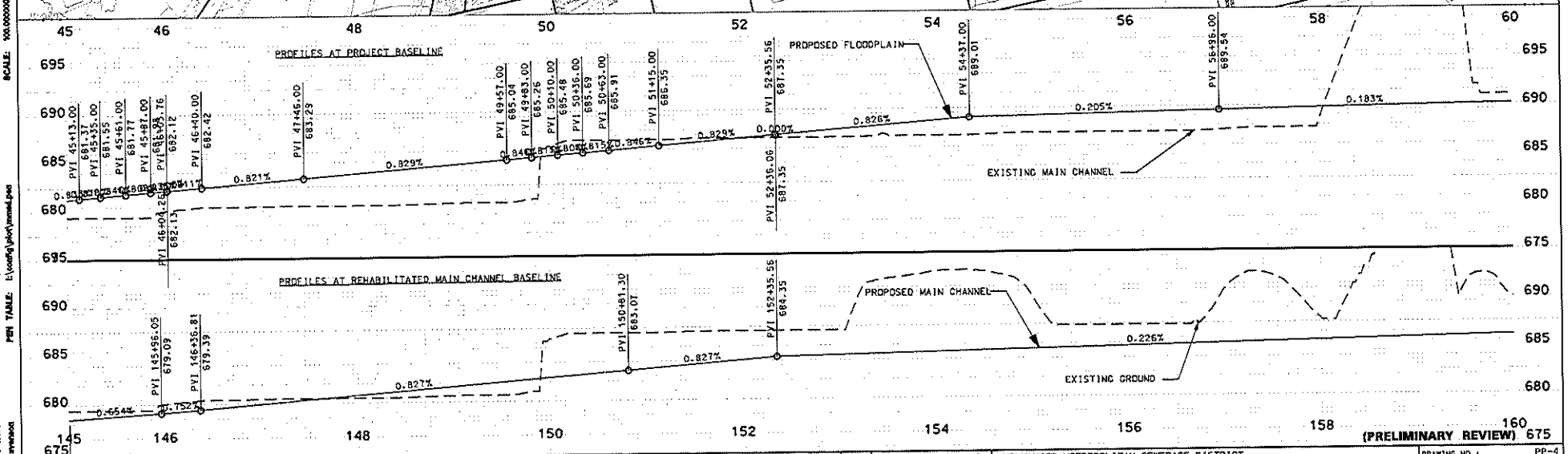

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UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-4
SHEET:	15
DATE:	JANUARY, 2006
CONTRACT:	W21005001
MMSD FILE:	XXX-XXX.DGN

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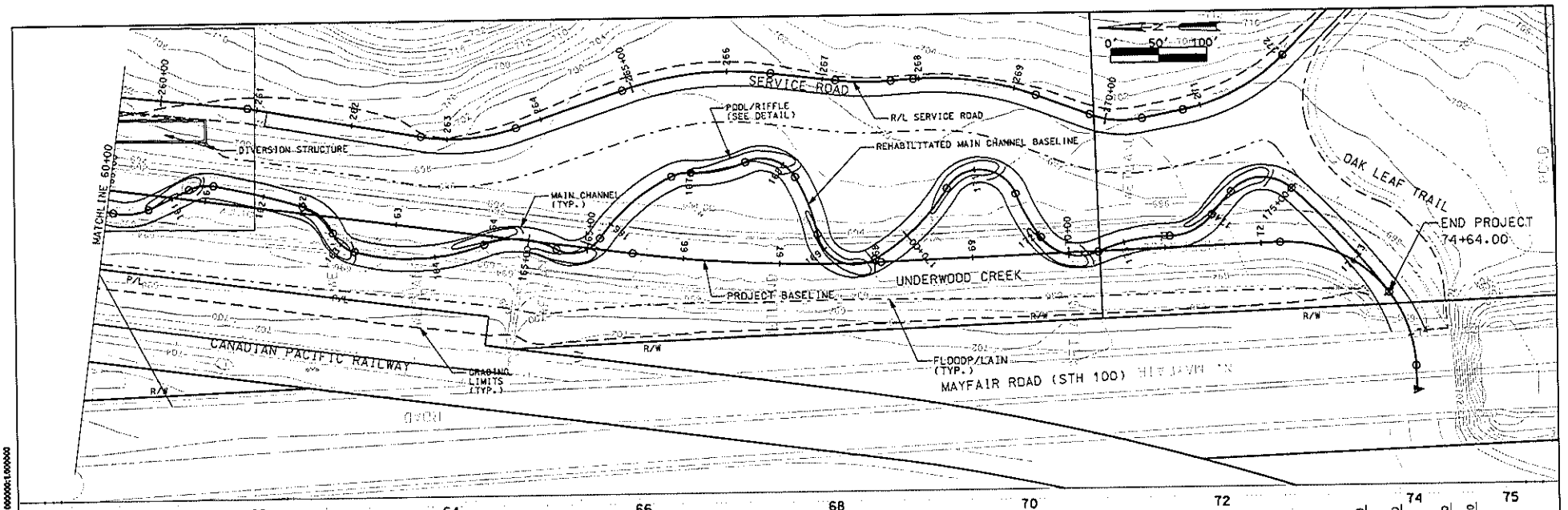

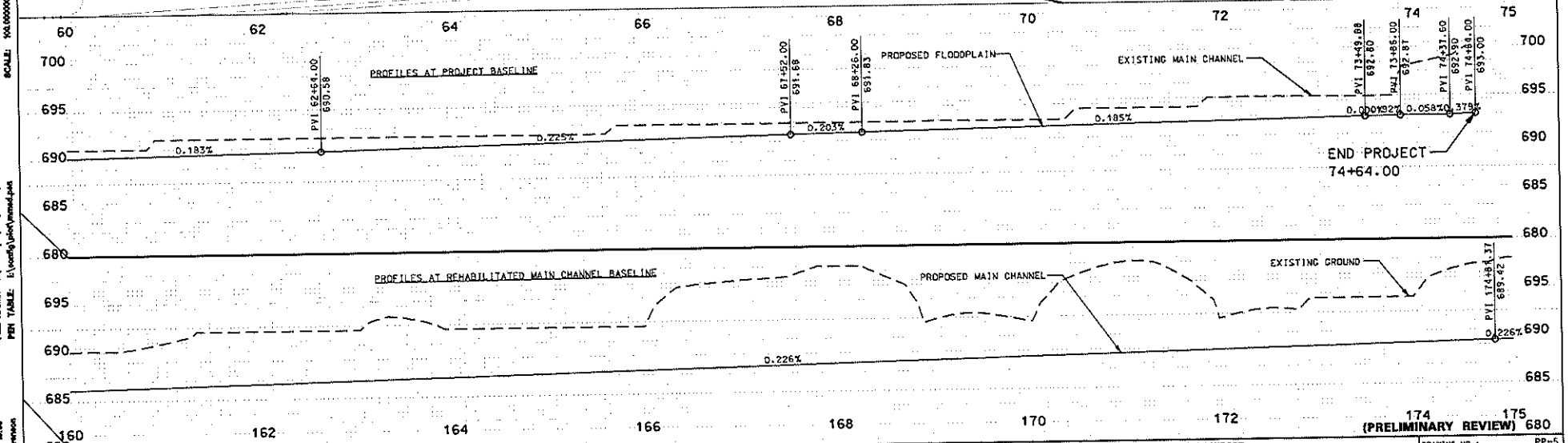

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PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-5
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DATE:	JANUARY, 2006
CONTRACT:	W21005D01
MMSD FILE:	XXX-XXX.DGN

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Attachment 3

Underwood Creek Main and Low Flow Channels
HEC-RAS Summary Output

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	1.26	PF1	3.00	689.90	690.10	0.06	690.15	0.009029	1.81	1.66	16.28	1.00
Underwood Creek	Main Stem	1.26	PF2	5.00	689.90	690.15	0.07	690.21	0.008370	2.00	2.50	20.00	1.00
Underwood Creek	Main Stem	1.26	PF3	10.00	689.90	690.23	0.08	690.31	0.007608	2.29	4.36	26.41	0.99
Underwood Creek	Main Stem	1.26	PF4	23.00	689.90	690.36	0.10	690.47	0.006855	2.72	8.47	36.81	1.00
Underwood Creek	Main Stem	1.26	PF5	50.00	689.90	690.71	0.05	690.78	0.001464	2.22	22.52	41.52	0.53
Underwood Creek	Main Stem	1.26	PF6	100.00	689.90	691.41	0.03	691.47	0.000377	1.88	53.09	45.02	0.31
Underwood Creek	Main Stem	1.26	PF7	200.00	689.90	692.55	0.02	692.61	0.000169	1.86	107.68	50.67	0.22
Underwood Creek	Main Stem	1.224	PF1	3.00	688.66	689.30	0.06	689.31	0.001957	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.224	PF2	5.00	688.66	689.54	0.04	689.55	0.001987	0.74	6.72	18.35	0.22
Underwood Creek	Main Stem	1.224	PF3	10.00	688.66	689.73	0.07	689.74	0.002060	0.98	10.19	18.71	0.23
Underwood Creek	Main Stem	1.224	PF4	23.00	688.66	690.07	0.11	690.10	0.002210	1.37	16.77	19.37	0.26
Underwood Creek	Main Stem	1.224	PF5	50.00	688.66	690.60	0.18	690.65	0.002301	1.84	27.13	20.36	0.28
Underwood Creek	Main Stem	1.224	PF6	100.00	688.66	691.33	0.26	691.41	0.002324	2.35	42.49	21.75	0.30
Underwood Creek	Main Stem	1.224	PF7	200.00	688.66	692.43	0.37	692.57	0.002323	2.99	66.91	22.12	0.30
Underwood Creek	Main Stem	1.215	PF1	3.00	688.56	689.20	0.05	689.21	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	1.215	PF2	5.00	688.56	689.45	0.04	689.46	0.001905	0.73	6.81	18.36	0.21
Underwood Creek	Main Stem	1.215	PF3	10.00	688.56	689.62	0.07	689.64	0.002145	0.99	10.06	18.70	0.24
Underwood Creek	Main Stem	1.215	PF4	23.00	688.56	689.96	0.12	689.99	0.002338	1.40	16.47	19.35	0.27
Underwood Creek	Main Stem	1.215	PF5	50.00	688.56	690.48	0.19	690.53	0.002409	1.87	26.74	20.34	0.29
Underwood Creek	Main Stem	1.215	PF6	100.00	688.56	691.21	0.27	691.29	0.002394	2.38	42.09	21.74	0.30
Underwood Creek	Main Stem	1.215	PF7	200.00	688.56	692.31	0.38	692.45	0.002359	3.00	66.61	22.20	0.31
Underwood Creek	Main Stem	1.206	PF1	3.00	688.47	689.11	0.06	689.12	0.001982	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.206	PF2	5.00	688.47	689.35	0.04	689.36	0.002027	0.68	7.33	23.22	0.21
Underwood Creek	Main Stem	1.206	PF3	10.00	688.47	689.52	0.06	689.53	0.001937	0.88	11.35	23.55	0.22
Underwood Creek	Main Stem	1.206	PF4	23.00	688.47	689.86	0.09	689.88	0.001782	1.18	19.48	24.18	0.23
Underwood Creek	Main Stem	1.206	PF5	50.00	688.47	690.39	0.13	690.43	0.001649	1.54	32.49	25.17	0.24
Underwood Creek	Main Stem	1.206	PF6	100.00	688.47	691.13	0.18	691.19	0.001552	1.94	51.66	26.55	0.24
Underwood Creek	Main Stem	1.206	PF7	200.00	688.47	692.25	0.25	692.35	0.001489	2.44	81.91	27.01	0.25
Underwood Creek	Main Stem	1.198	PF1	3.00	688.37	689.01	0.06	689.02	0.001957	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.198	PF2	5.00	688.37	689.25	0.04	689.26	0.001936	0.64	7.79	26.15	0.21
Underwood Creek	Main Stem	1.198	PF3	10.00	688.37	689.44	0.05	689.45	0.001586	0.79	12.63	26.49	0.20
Underwood Creek	Main Stem	1.198	PF4	23.00	688.37	689.79	0.07	689.81	0.001366	1.04	22.07	27.15	0.20
Underwood Creek	Main Stem	1.198	PF5	50.00	688.37	690.33	0.10	690.35	0.001248	1.36	36.89	28.15	0.21
Underwood Creek	Main Stem	1.198	PF6	100.00	688.37	691.07	0.14	691.12	0.001176	1.71	58.46	29.54	0.21
Underwood Creek	Main Stem	1.198	PF7	200.00	688.37	692.20	0.19	692.28	0.001136	2.17	92.22	29.92	0.22
Underwood Creek	Main Stem	1.189	PF1	3.00	688.27	688.91	0.05	688.92	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	1.189	PF2	5.00	688.27	689.16	0.04	689.17	0.001894	0.73	6.82	18.35	0.21
Underwood Creek	Main Stem	1.189	PF3	10.00	688.27	689.34	0.07	689.36	0.002011	0.97	10.26	18.70	0.23
Underwood Creek	Main Stem	1.189	PF4	23.00	688.27	689.69	0.11	689.72	0.002152	1.36	16.90	19.35	0.26
Underwood Creek	Main Stem	1.189	PF5	50.00	688.27	690.22	0.18	690.27	0.002244	1.83	27.33	20.32	0.28
Underwood Creek	Main Stem	1.189	PF6	100.00	688.27	690.95	0.26	691.04	0.002284	2.34	42.69	21.67	0.29
Underwood Creek	Main Stem	1.189	PF7	200.00	688.27	692.05	0.37	692.19	0.002308	2.98	67.03	22.12	0.30
Underwood Creek	Main Stem	1.180	PF1	3.00	688.18	688.82	0.06	688.83	0.001982	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.180	PF2	5.00	688.18	689.06	0.05	689.07	0.002035	0.75	6.67	18.34	0.22
Underwood Creek	Main Stem	1.180	PF3	10.00	688.18	689.24	0.07	689.25	0.002231	1.01	9.94	18.68	0.24
Underwood Creek	Main Stem	1.180	PF4	23.00	688.18	689.58	0.12	689.61	0.002361	1.40	16.42	19.32	0.27
Underwood Creek	Main Stem	1.180	PF5	50.00	688.18	690.10	0.19	690.15	0.002397	1.87	26.77	20.30	0.29
Underwood Creek	Main Stem	1.180	PF6	100.00	688.18	690.83	0.27	690.92	0.002384	2.37	42.12	21.68	0.30
Underwood Creek	Main Stem	1.180	PF7	200.00	688.18	691.93	0.38	692.07	0.002364	3.01	66.54	22.20	0.31
Underwood Creek	Main Stem	1.172	PF1	3.00	688.08	688.72	0.06	688.73	0.001958	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.172	PF2	5.00	688.08	688.96	0.04	688.97	0.001937	0.64	7.79	26.15	0.21
Underwood Creek	Main Stem	1.172	PF3	10.00	688.08	689.15	0.05	689.16	0.001589	0.79	12.62	26.49	0.20
Underwood Creek	Main Stem	1.172	PF4	23.00	688.08	689.50	0.07	689.52	0.001371	1.04	22.05	27.15	0.20
Underwood Creek	Main Stem	1.172	PF5	50.00	688.08	690.03	0.10	690.06	0.001254	1.36	36.82	28.14	0.21
Underwood Creek	Main Stem	1.172	PF6	100.00	688.08	690.78	0.14	690.82	0.001185	1.71	58.31	29.53	0.22
Underwood Creek	Main Stem	1.172	PF7	200.00	688.08	691.90	0.19	691.97	0.001147	2.17	91.99	30.06	0.22
Underwood Creek	Main Stem	1.163	PF1	3.00	687.98	688.62	0.05	688.63	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	1.163	PF2	5.00	687.98	688.87	0.04	688.88	0.001895	0.73	6.82	18.35	0.21
Underwood Creek	Main Stem	1.163	PF3	10.00	687.98	689.05	0.07	689.07	0.002018	0.98	10.25	18.68	0.23
Underwood Creek	Main Stem	1.163	PF4	23.00	687.98	689.40	0.11	689.43	0.002164	1.36	16.86	19.30	0.26
Underwood Creek	Main Stem	1.163	PF5	50.00	687.98	689.93	0.18	689.98	0.002266	1.84	27.22	20.24	0.28
Underwood Creek	Main Stem	1.163	PF6	100.00	687.98	690.65	0.26	690.74	0.002319	2.36	42.42	21.54	0.30
Underwood Creek	Main Stem	1.163	PF7	200.00	687.98	691.75	0.38	691.89	0.002353	3.00	66.59	22.16	0.31
Underwood Creek	Main Stem	1.154	PF1	3.00	687.89	688.53	0.06	688.54	0.001984	0.87	3.44	7.31	0.22
Underwood Creek	Main Stem	1.154	PF2	5.00	687.89	688.77	0.05	688.78	0.002035	0.75	6.67	18.33	0.22
Underwood Creek	Main Stem	1.154	PF3	10.00	687.89	688.94	0.07	688.96	0.002248	1.01	9.91	18.65	0.24
Underwood Creek	Main Stem	1.154	PF4	23.00	687.89	689.28	0.12	689.32	0.002384	1.41	16.36	19.26	0.27
Underwood Creek	Main Stem	1.154	PF5	50.00	687.89	689.80	0.19	689.86	0.002432	1.88	26.62	20.20	0.29
Underwood Creek	Main Stem	1.154	PF6	100.00	687.89	690.53	0.27	690.62	0.002433	2.39	41.77	21.51	0.30
Underwood Creek	Main Stem	1.154	PF7	200.00	687.89	691.63	0.39	691.77	0.002426	3.03	65.94	22.21	0.31
Underwood Creek	Main Stem	1.145	PF1	3.00	687.79	688.43	0.06	688.44	0.001960	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.145	PF2	5.00	687.79	688.67	0.04	688.68	0.001946	0.64	7.77	26.14	0.21
Underwood Creek	Main Stem	1.145	PF3	10.00	687.79	688.85	0.05	688.86	0.001616	0.80	12.55	26.46	0.20
Underwood Creek	Main Stem	1.145	PF4	23.00	687.79	689.21	0.07	689.22	0.001391	1.05	21.94	27.08	0.21
Underwood Creek	Main Stem	1.145	PF5	50.00	687.79	689.74	0.10	689.77	0.001276	1.37	36.59	28.03	0.21
Underwood Creek	Main Stem	1.145	PF6	100.00	687.79	690.48	0.14	690.52	0.001211	1.73	57.83	29.34	0.22
Underwood Creek	Main Stem	1.145	PF7	200.00	687.79	691.59	0.20	691.67	0.001177	2.19	91.14	30.02	0.22

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	1.137	PF1	3.00	687.69	688.33	0.05	688.34	0.001907	0.86	3.49	7.35	0.22
Underwood Creek	Main Stem	1.137	PF2	5.00	687.69	688.58	0.04	688.59	0.001887	0.70	7.10	20.29	0.21
Underwood Creek	Main Stem	1.137	PF3	10.00	687.69	688.77	0.06	688.78	0.001855	0.92	10.92	20.62	0.22
Underwood Creek	Main Stem	1.137	PF4	23.00	687.69	689.12	0.10	689.14	0.001863	1.26	18.30	21.23	0.24
Underwood Creek	Main Stem	1.137	PF5	50.00	687.69	689.64	0.15	689.69	0.001898	1.68	29.71	22.14	0.26
Underwood Creek	Main Stem	1.137	PF6	100.00	687.69	690.37	0.22	690.45	0.001917	2.16	46.35	23.41	0.27
Underwood Creek	Main Stem	1.137	PF7	200.00	687.69	691.47	0.32	691.59	0.001939	2.75	72.63	24.12	0.28
Underwood Creek	Main Stem	1.128	PF1	3.00	687.60	688.24	0.06	688.25	0.001993	0.87	3.43	7.31	0.22
Underwood Creek	Main Stem	1.128	PF2	5.00	687.60	688.48	0.04	688.49	0.002004	0.75	6.70	18.33	0.22
Underwood Creek	Main Stem	1.128	PF3	10.00	687.60	688.66	0.07	688.68	0.002149	1.00	10.05	18.65	0.24
Underwood Creek	Main Stem	1.128	PF4	23.00	687.60	689.01	0.12	689.04	0.002272	1.39	16.60	19.26	0.26
Underwood Creek	Main Stem	1.128	PF5	50.00	687.60	689.53	0.18	689.58	0.002365	1.86	26.84	20.17	0.28
Underwood Creek	Main Stem	1.128	PF6	100.00	687.60	690.25	0.27	690.34	0.002412	2.39	41.85	21.43	0.30
Underwood Creek	Main Stem	1.128	PF7	200.00	687.60	691.33	0.39	691.48	0.002445	3.04	65.75	22.20	0.31
Underwood Creek	Main Stem	1.119	PF1	3.00	687.50	688.14	0.06	688.15	0.001982	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.119	PF2	5.00	687.50	688.38	0.04	688.39	0.001986	0.70	7.19	21.80	0.21
Underwood Creek	Main Stem	1.119	PF3	10.00	687.50	688.56	0.06	688.58	0.001878	0.89	11.18	22.12	0.22
Underwood Creek	Main Stem	1.119	PF4	23.00	687.50	688.91	0.09	688.94	0.001794	1.21	18.99	22.73	0.23
Underwood Creek	Main Stem	1.119	PF5	50.00	687.50	689.44	0.14	689.48	0.001765	1.61	31.12	23.64	0.25
Underwood Creek	Main Stem	1.119	PF6	100.00	687.50	690.16	0.20	690.23	0.001742	2.05	48.79	24.92	0.26
Underwood Creek	Main Stem	1.119	PF7	200.00	687.50	691.26	0.28	691.36	0.001732	2.61	76.76	25.75	0.27
Underwood Creek	Main Stem	1.111	PF1	3.00	687.40	688.04	0.06	688.05	0.001957	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.111	PF2	5.00	687.40	688.28	0.04	688.29	0.001985	0.72	6.90	19.63	0.22
Underwood Creek	Main Stem	1.111	PF3	10.00	687.40	688.47	0.06	688.48	0.001985	0.95	10.57	19.94	0.23
Underwood Creek	Main Stem	1.111	PF4	23.00	687.40	688.81	0.11	688.84	0.002051	1.31	17.55	20.53	0.25
Underwood Creek	Main Stem	1.111	PF5	50.00	687.40	689.33	0.16	689.38	0.002112	1.76	28.41	21.41	0.27
Underwood Creek	Main Stem	1.111	PF6	100.00	687.40	690.05	0.24	690.13	0.002140	2.26	44.29	22.63	0.28
Underwood Creek	Main Stem	1.111	PF7	200.00	687.40	691.14	0.35	691.26	0.002161	2.88	69.56	23.54	0.29
Underwood Creek	Main Stem	1.102	PF1	3.00	687.30	687.94	0.05	687.95	0.001899	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	1.102	PF2	5.00	687.30	688.19	0.04	688.20	0.001904	0.73	6.81	18.39	0.21
Underwood Creek	Main Stem	1.102	PF3	10.00	687.30	688.36	0.07	688.38	0.002123	0.99	10.10	18.76	0.24
Underwood Creek	Main Stem	1.102	PF4	23.00	687.30	688.70	0.12	688.73	0.002337	1.39	16.50	19.46	0.27
Underwood Creek	Main Stem	1.102	PF5	50.00	687.30	689.21	0.19	689.27	0.002433	1.87	26.73	20.53	0.29
Underwood Creek	Main Stem	1.102	PF6	100.00	687.30	689.93	0.27	690.02	0.002440	2.38	42.00	22.03	0.30
Underwood Creek	Main Stem	1.102	PF7	200.00	687.30	691.01	0.38	691.15	0.002397	3.00	66.77	23.18	0.31
Underwood Creek	Main Stem	1.093	PF1	3.00	687.21	687.85	0.06	687.86	0.001980	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.093	PF2	5.00	687.21	688.09	0.04	688.10	0.002034	0.70	7.11	21.57	0.22
Underwood Creek	Main Stem	1.093	PF3	10.00	687.21	688.26	0.06	688.27	0.002081	0.93	10.79	21.85	0.23
Underwood Creek	Main Stem	1.093	PF4	23.00	687.21	688.59	0.10	688.62	0.002042	1.27	18.17	22.41	0.25
Underwood Creek	Main Stem	1.093	PF5	50.00	687.21	689.11	0.15	689.15	0.001964	1.67	29.96	23.28	0.26
Underwood Creek	Main Stem	1.093	PF6	100.00	687.21	689.83	0.21	689.90	0.001897	2.12	47.26	24.49	0.27
Underwood Creek	Main Stem	1.093	PF7	200.00	687.21	690.92	0.30	691.04	0.001860	2.68	74.70	25.37	0.27
Underwood Creek	Main Stem	1.085	PF1	3.00	687.11	687.75	0.06	687.76	0.001951	0.87	3.46	7.33	0.22
Underwood Creek	Main Stem	1.085	PF2	5.00	687.11	687.99	0.04	688.00	0.001960	0.64	7.76	26.13	0.21
Underwood Creek	Main Stem	1.085	PF3	10.00	687.11	688.17	0.05	688.18	0.001671	0.81	12.42	26.44	0.21
Underwood Creek	Main Stem	1.085	PF4	23.00	687.11	688.51	0.07	688.53	0.001462	1.07	21.60	27.03	0.21
Underwood Creek	Main Stem	1.085	PF5	50.00	687.11	689.04	0.10	689.07	0.001337	1.39	36.04	27.94	0.22
Underwood Creek	Main Stem	1.085	PF6	100.00	687.11	689.77	0.14	689.82	0.001263	1.75	57.01	29.21	0.22
Underwood Creek	Main Stem	1.085	PF7	200.00	687.11	690.87	0.20	690.95	0.001228	2.22	89.89	30.03	0.23
Underwood Creek	Main Stem	1.076	PF1	3.00	687.01	687.65	0.05	687.67	0.001886	0.86	3.50	7.37	0.22
Underwood Creek	Main Stem	1.076	PF2	5.00	687.01	687.90	0.04	687.91	0.001838	0.67	7.42	22.24	0.21
Underwood Creek	Main Stem	1.076	PF3	10.00	687.01	688.08	0.05	688.09	0.001755	0.87	11.50	22.55	0.21
Underwood Creek	Main Stem	1.076	PF4	23.00	687.01	688.43	0.09	688.45	0.001700	1.18	19.45	23.15	0.23
Underwood Creek	Main Stem	1.076	PF5	50.00	687.01	688.96	0.13	688.99	0.001674	1.57	31.83	24.05	0.24
Underwood Creek	Main Stem	1.076	PF6	100.00	687.01	689.68	0.19	689.75	0.001658	2.01	49.83	25.31	0.25
Underwood Creek	Main Stem	1.076	PF7	200.00	687.01	690.78	0.27	690.88	0.001661	2.56	78.16	26.15	0.26
Underwood Creek	Main Stem	1.071	PF1	3.00	686.97	687.61	0.06	687.62	0.001987	0.87	3.44	7.31	0.22
Underwood Creek	Main Stem	1.071	PF2	5.00	686.97	687.85	0.04	687.86	0.001995	0.70	7.11	21.25	0.21
Underwood Creek	Main Stem	1.071	PF3	10.00	686.97	688.04	0.06	688.05	0.001890	0.90	11.05	21.56	0.22
Underwood Creek	Main Stem	1.071	PF4	23.00	686.97	688.38	0.09	688.41	0.001846	1.23	18.65	22.16	0.24
Underwood Creek	Main Stem	1.071	PF5	50.00	686.97	688.91	0.14	688.95	0.001833	1.64	30.48	23.06	0.25
Underwood Creek	Main Stem	1.071	PF6	100.00	686.97	689.63	0.21	689.70	0.001823	2.10	47.70	24.30	0.26
Underwood Creek	Main Stem	1.071	PF7	200.00	686.97	690.72	0.30	690.83	0.001832	2.67	74.86	25.18	0.27
Underwood Creek	Main Stem	1.067	PF1	3.00	686.92	687.56	0.06	687.57	0.001982	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.067	PF2	5.00	686.92	687.80	0.04	687.81	0.002003	0.75	6.70	18.32	0.22
Underwood Creek	Main Stem	1.067	PF3	10.00	686.92	687.98	0.07	688.00	0.002137	0.99	10.06	18.62	0.24
Underwood Creek	Main Stem	1.067	PF4	23.00	686.92	688.33	0.12	688.36	0.002295	1.39	16.54	19.20	0.26
Underwood Creek	Main Stem	1.067	PF5	50.00	686.92	688.84	0.19	688.90	0.002406	1.88	26.66	20.06	0.29
Underwood Creek	Main Stem	1.067	PF6	100.00	686.92	689.56	0.27	689.65	0.002469	2.41	41.46	21.26	0.30
Underwood Creek	Main Stem	1.067	PF7	200.00	686.92	690.63	0.40	690.78	0.002530	3.08	64.97	22.18	0.32
Underwood Creek	Main Stem	1.058	PF1	3.00	686.82	687.46	0.06	687.47	0.001958	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.058	PF2	5.00	686.82	687.70	0.04	687.71	0.001978	0.70	7.17	21.57	0.21
Underwood Creek	Main Stem	1.058	PF3	10.00	686.82	687.89	0.06	687.90	0.001879	0.90	11.14	21.87	0.22
Underwood Creek	Main Stem	1.058	PF4	23.00	686.82	688.23	0.09	688.25	0.001852	1.23	18.73	22.44	0.24
Underwood Creek	Main Stem	1.058	PF5	50.00	686.82	688.75	0.14	688.79	0.001843	1.64	30.56	23.30	0.25
Underwood Creek	Main Stem	1.058	PF6	100.00	686.82	689.47	0.21	689.54	0.001828	2.09	47.82	24.50	0.26
Underwood Creek	Main Stem	1.058	PF7	200.00	686.82	690.55	0.30	690.66	0.001839	2.67	74.98	25.38	0.27

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	1.050	PF1	3.00	686.72	687.36	0.05	687.37	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	1.050	PF2	5.00	686.72	687.61	0.04	687.62	0.001904	0.73	6.81	18.33	0.21
Underwood Creek	Main Stem	1.050	PF3	10.00	686.72	687.78	0.07	687.80	0.002149	1.00	10.05	18.63	0.24
Underwood Creek	Main Stem	1.050	PF4	23.00	686.72	688.11	0.12	688.14	0.002393	1.41	16.32	19.18	0.27
Underwood Creek	Main Stem	1.050	PF5	50.00	686.72	688.62	0.19	688.68	0.002516	1.90	26.29	20.04	0.29
Underwood Creek	Main Stem	1.050	PF6	100.00	686.72	689.33	0.28	689.43	0.002565	2.44	40.95	21.23	0.31
Underwood Creek	Main Stem	1.050	PF7	200.00	686.72	690.39	0.41	690.54	0.002621	3.11	64.21	22.17	0.32
Underwood Creek	Main Stem	1.041	PF1	3.00	686.63	687.27	0.06	687.28	0.001984	0.87	3.44	7.31	0.22
Underwood Creek	Main Stem	1.041	PF2	5.00	686.63	687.51	0.04	687.52	0.002028	0.69	7.29	22.87	0.21
Underwood Creek	Main Stem	1.041	PF3	10.00	686.63	687.68	0.06	687.69	0.001984	0.89	11.20	23.16	0.23
Underwood Creek	Main Stem	1.041	PF4	23.00	686.63	688.01	0.09	688.04	0.001892	1.21	19.00	23.72	0.24
Underwood Creek	Main Stem	1.041	PF5	50.00	686.63	688.53	0.14	688.57	0.001791	1.59	31.44	24.59	0.25
Underwood Creek	Main Stem	1.041	PF6	100.00	686.63	689.25	0.19	689.31	0.001720	2.02	49.62	25.81	0.26
Underwood Creek	Main Stem	1.041	PF7	200.00	686.63	690.32	0.27	690.43	0.001702	2.56	78.06	26.71	0.26
Underwood Creek	Main Stem	1.032	PF1	3.00	686.53	687.17	0.06	687.18	0.001961	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	1.032	PF2	5.00	686.53	687.41	0.04	687.42	0.001938	0.64	7.78	26.12	0.21
Underwood Creek	Main Stem	1.032	PF3	10.00	686.53	687.59	0.05	687.60	0.001635	0.80	12.50	26.43	0.20
Underwood Creek	Main Stem	1.032	PF4	23.00	686.53	687.94	0.07	687.95	0.001450	1.06	21.64	27.00	0.21
Underwood Creek	Main Stem	1.032	PF5	50.00	686.53	688.46	0.10	688.49	0.001340	1.39	36.00	27.88	0.22
Underwood Creek	Main Stem	1.032	PF6	100.00	686.53	689.19	0.15	689.23	0.001280	1.76	56.73	29.10	0.22
Underwood Creek	Main Stem	1.032	PF7	200.00	686.53	690.27	0.21	690.35	0.001269	2.25	88.86	29.92	0.23
Underwood Creek	Main Stem	1.024	PF1	3.00	686.43	687.07	0.05	687.08	0.001907	0.86	3.49	7.35	0.22
Underwood Creek	Main Stem	1.024	PF2	5.00	686.43	687.32	0.04	687.33	0.001908	0.73	6.80	18.33	0.21
Underwood Creek	Main Stem	1.024	PF3	10.00	686.43	687.50	0.07	687.51	0.002112	0.99	10.10	18.63	0.24
Underwood Creek	Main Stem	1.024	PF4	23.00	686.43	687.83	0.12	687.86	0.002334	1.40	16.45	19.20	0.27
Underwood Creek	Main Stem	1.024	PF5	50.00	686.43	688.34	0.19	688.40	0.002458	1.89	26.49	20.07	0.29
Underwood Creek	Main Stem	1.024	PF6	100.00	686.43	689.05	0.28	689.14	0.002532	2.43	41.14	21.27	0.31
Underwood Creek	Main Stem	1.024	PF7	200.00	686.43	690.10	0.41	690.25	0.002633	3.12	64.11	22.14	0.32
Underwood Creek	Main Stem	1.015	PF1	3.00	686.34	686.98	0.06	686.99	0.001993	0.87	3.43	7.31	0.22
Underwood Creek	Main Stem	1.015	PF2	5.00	686.34	687.22	0.04	687.23	0.002037	0.73	6.89	19.88	0.22
Underwood Creek	Main Stem	1.015	PF3	10.00	686.34	687.39	0.07	687.40	0.002262	0.98	10.20	20.16	0.24
Underwood Creek	Main Stem	1.015	PF4	23.00	686.34	687.71	0.11	687.74	0.002340	1.36	16.91	20.71	0.27
Underwood Creek	Main Stem	1.015	PF5	50.00	686.34	688.23	0.17	688.28	0.002308	1.80	27.72	21.57	0.28
Underwood Creek	Main Stem	1.015	PF6	100.00	686.34	688.94	0.25	689.02	0.002283	2.30	43.50	22.76	0.29
Underwood Creek	Main Stem	1.015	PF7	200.00	686.34	689.99	0.36	690.12	0.002321	2.94	68.12	23.70	0.31
Underwood Creek	Main Stem	1.006	PF1	3.00	686.24	686.88	0.06	686.89	0.001982	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	1.006	PF2	5.00	686.24	687.12	0.04	687.13	0.002005	0.65	7.70	26.12	0.21
Underwood Creek	Main Stem	1.006	PF3	10.00	686.24	687.29	0.05	687.30	0.001804	0.82	12.13	26.40	0.21
Underwood Creek	Main Stem	1.006	PF4	23.00	686.24	687.63	0.07	687.65	0.001559	1.09	21.16	26.96	0.22
Underwood Creek	Main Stem	1.006	PF5	50.00	686.24	688.15	0.11	688.18	0.001398	1.41	35.52	27.84	0.22
Underwood Creek	Main Stem	1.006	PF6	100.00	686.24	688.87	0.15	688.92	0.001325	1.78	56.09	29.04	0.23
Underwood Creek	Main Stem	1.006	PF7	200.00	686.24	689.94	0.22	690.02	0.001323	2.28	87.69	29.92	0.23
Underwood Creek	Main Stem	0.997	PF1	3.00	686.14	686.78	0.06	686.79	0.001958	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	0.997	PF2	5.00	686.14	687.02	0.04	687.03	0.001937	0.64	7.78	26.12	0.21
Underwood Creek	Main Stem	0.997	PF3	10.00	686.14	687.20	0.05	687.21	0.001615	0.80	12.55	26.42	0.20
Underwood Creek	Main Stem	0.997	PF4	23.00	686.14	687.56	0.07	687.57	0.001392	1.05	21.92	27.01	0.21
Underwood Creek	Main Stem	0.997	PF5	50.00	686.14	688.09	0.10	688.12	0.001284	1.37	36.48	27.89	0.21
Underwood Creek	Main Stem	0.997	PF6	100.00	686.14	688.81	0.14	688.86	0.001250	1.75	57.15	29.09	0.22
Underwood Creek	Main Stem	0.997	PF7	200.00	686.14	689.87	0.21	689.95	0.001273	2.25	88.76	29.93	0.23
Underwood Creek	Main Stem	0.989	PF1	3.00	686.04	686.68	0.05	686.69	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	0.989	PF2	5.00	686.04	686.93	0.04	686.94	0.001897	0.73	6.81	18.33	0.21
Underwood Creek	Main Stem	0.989	PF3	10.00	686.04	687.11	0.07	687.13	0.002050	0.98	10.19	18.63	0.23
Underwood Creek	Main Stem	0.989	PF4	23.00	686.04	687.46	0.11	687.49	0.002209	1.37	16.73	19.20	0.26
Underwood Creek	Main Stem	0.989	PF5	50.00	686.04	687.97	0.18	688.03	0.002339	1.86	26.90	20.06	0.28
Underwood Creek	Main Stem	0.989	PF6	100.00	686.04	688.68	0.27	688.77	0.002467	2.41	41.46	21.23	0.30
Underwood Creek	Main Stem	0.989	PF7	200.00	686.04	689.71	0.41	689.86	0.002653	3.13	63.93	22.13	0.32
Underwood Creek	Main Stem	0.980	PF1	3.00	685.95	686.59	0.06	686.60	0.001983	0.87	3.44	7.31	0.22
Underwood Creek	Main Stem	0.980	PF2	5.00	685.95	686.83	0.04	686.84	0.002004	0.70	7.13	21.44	0.21
Underwood Creek	Main Stem	0.980	PF3	10.00	685.95	687.01	0.06	687.02	0.001963	0.91	10.96	21.73	0.23
Underwood Creek	Main Stem	0.980	PF4	23.00	685.95	687.36	0.09	687.38	0.001875	1.24	18.61	22.31	0.24
Underwood Creek	Main Stem	0.980	PF5	50.00	685.95	687.88	0.14	687.92	0.001851	1.64	30.46	23.18	0.25
Underwood Creek	Main Stem	0.980	PF6	100.00	685.95	688.59	0.21	688.66	0.001881	2.11	47.30	24.35	0.27
Underwood Creek	Main Stem	0.980	PF7	200.00	685.95	689.62	0.31	689.73	0.001982	2.74	73.07	25.27	0.28
Underwood Creek	Main Stem	0.971	PF1	3.00	685.85	686.49	0.06	686.50	0.001957	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	0.971	PF2	5.00	685.85	686.73	0.04	686.74	0.001971	0.69	7.27	22.22	0.21
Underwood Creek	Main Stem	0.971	PF3	10.00	685.85	686.92	0.06	686.93	0.001803	0.88	11.41	22.53	0.22
Underwood Creek	Main Stem	0.971	PF4	23.00	685.85	687.27	0.09	687.29	0.001707	1.18	19.41	23.11	0.23
Underwood Creek	Main Stem	0.971	PF5	50.00	685.85	687.79	0.13	687.83	0.001689	1.58	31.72	23.98	0.24
Underwood Creek	Main Stem	0.971	PF6	100.00	685.85	688.50	0.19	688.56	0.001728	2.04	49.11	25.15	0.26
Underwood Creek	Main Stem	0.971	PF7	200.00	685.85	689.53	0.29	689.64	0.001835	2.65	75.60	26.06	0.27
Underwood Creek	Main Stem	0.963	PF1	3.00	685.75	686.39	0.05	686.40	0.001901	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	0.963	PF2	5.00	685.75	686.64	0.04	686.65	0.001901	0.74	6.80	18.22	0.21
Underwood Creek	Main Stem	0.963	PF3	10.00	685.75	686.82	0.07	686.83	0.002081	0.99	10.12	18.52	0.24
Underwood Creek	Main Stem	0.963	PF4	23.00	685.75	687.16	0.12	687.19	0.002259	1.39	16.58	19.08	0.26
Underwood Creek	Main Stem	0.963	PF5	50.00	685.75	687.67	0.19	687.73	0.002418	1.88	26.56	19.91	0.29
Underwood Creek	Main Stem	0.963	PF6	100.00	685.75	688.36	0.29	688.46	0.002603	2.46	40.66	21.03	0.31
Underwood Creek	Main Stem	0.963	PF7	200.00	685.75	689.36	0.44	689.52	0.002865	3.21	62.23	22.00	0.34

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.954	PF1	3.00	685.66	686.30	0.06	686.31	0.001983	0.87	3.44	7.31	0.22
Underwood Creek	Main Stem	0.954	PF2	5.00	685.66	686.54	0.04	686.55	0.001999	0.69	7.23	22.22	0.21
Underwood Creek	Main Stem	0.954	PF3	10.00	685.66	686.72	0.06	686.73	0.001925	0.89	11.18	22.51	0.22
Underwood Creek	Main Stem	0.954	PF4	23.00	685.66	687.07	0.09	687.09	0.001801	1.20	19.09	23.07	0.23
Underwood Creek	Main Stem	0.954	PF5	50.00	685.66	687.58	0.14	687.62	0.001779	1.60	31.20	23.92	0.25
Underwood Creek	Main Stem	0.954	PF6	100.00	685.66	688.27	0.20	688.34	0.001836	2.08	48.14	25.05	0.26
Underwood Creek	Main Stem	0.954	PF7	200.00	685.66	689.27	0.31	689.38	0.001973	2.71	73.83	26.04	0.28
Underwood Creek	Main Stem	0.945	PF1	3.00	685.56	686.20	0.06	686.21	0.001959	0.87	3.45	7.33	0.22
Underwood Creek	Main Stem	0.945	PF2	5.00	685.56	686.44	0.04	686.45	0.001977	0.69	7.26	22.22	0.21
Underwood Creek	Main Stem	0.945	PF3	10.00	685.56	686.63	0.06	686.64	0.001811	0.88	11.39	22.52	0.22
Underwood Creek	Main Stem	0.945	PF4	23.00	685.56	686.98	0.09	687.00	0.001712	1.19	19.39	23.09	0.23
Underwood Creek	Main Stem	0.945	PF5	50.00	685.56	687.49	0.13	687.53	0.001723	1.59	31.51	23.94	0.24
Underwood Creek	Main Stem	0.945	PF6	100.00	685.56	688.18	0.20	688.25	0.001809	2.07	48.37	25.06	0.26
Underwood Creek	Main Stem	0.945	PF7	200.00	685.56	689.17	0.31	689.29	0.001970	2.71	73.86	26.05	0.28
Underwood Creek	Main Stem	0.936	PF1	3.00	685.46	686.10	0.05	686.11	0.001906	0.86	3.49	7.36	0.22
Underwood Creek	Main Stem	0.936	PF2	5.00	685.46	686.35	0.04	686.36	0.001888	0.71	7.04	19.83	0.21
Underwood Creek	Main Stem	0.936	PF3	10.00	685.46	686.54	0.06	686.55	0.001871	0.93	10.80	20.15	0.22
Underwood Creek	Main Stem	0.936	PF4	23.00	685.46	686.88	0.10	686.91	0.001947	1.29	17.90	20.73	0.24
Underwood Creek	Main Stem	0.936	PF5	50.00	685.46	687.39	0.16	687.44	0.002081	1.75	28.63	21.58	0.27
Underwood Creek	Main Stem	0.936	PF6	100.00	685.46	688.06	0.25	688.15	0.002270	2.30	43.54	22.71	0.29
Underwood Creek	Main Stem	0.936	PF7	200.00	685.46	689.03	0.39	689.17	0.002540	3.03	66.08	23.61	0.32
Underwood Creek	Main Stem	0.928	PF1	3.00	685.37	686.01	0.06	686.02	0.001990	0.87	3.43	7.31	0.22
Underwood Creek	Main Stem	0.928	PF2	5.00	685.37	686.25	0.04	686.26	0.002006	0.75	6.70	18.32	0.22
Underwood Creek	Main Stem	0.928	PF3	10.00	685.37	686.43	0.07	686.45	0.002141	0.99	10.06	18.62	0.24
Underwood Creek	Main Stem	0.928	PF4	23.00	685.37	686.77	0.12	686.80	0.002325	1.40	16.46	19.17	0.27
Underwood Creek	Main Stem	0.928	PF5	50.00	685.37	687.27	0.20	687.32	0.002563	1.91	26.12	19.99	0.30
Underwood Creek	Main Stem	0.928	PF6	100.00	685.37	687.92	0.31	688.02	0.002854	2.53	39.52	21.06	0.33
Underwood Creek	Main Stem	0.928	PF7	200.00	685.37	688.85	0.48	689.03	0.003241	3.34	59.85	22.12	0.36
Underwood Creek	Main Stem	0.919	PF1	3.00	685.27	685.91	0.06	685.92	0.001977	0.87	3.44	7.32	0.22
Underwood Creek	Main Stem	0.919	PF2	5.00	685.27	686.15	0.04	686.16	0.001975	0.69	7.26	22.22	0.21
Underwood Creek	Main Stem	0.919	PF3	10.00	685.27	686.34	0.06	686.35	0.001806	0.88	11.40	22.52	0.22
Underwood Creek	Main Stem	0.919	PF4	23.00	685.27	686.68	0.09	686.70	0.001793	1.20	19.11	23.07	0.23
Underwood Creek	Main Stem	0.919	PF5	50.00	685.27	687.17	0.14	687.21	0.001889	1.63	30.61	23.86	0.25
Underwood Creek	Main Stem	0.919	PF6	100.00	685.27	687.82	0.22	687.89	0.002045	2.15	46.48	24.92	0.28
Underwood Creek	Main Stem	0.919	PF7	200.00	685.27	688.75	0.34	688.88	0.002283	2.84	70.40	26.05	0.30
Underwood Creek	Main Stem	0.910	PF1	3.00	685.17	685.81	0.06	685.82	0.001945	0.87	3.46	7.33	0.22
Underwood Creek	Main Stem	0.910	PF2	5.00	685.17	686.06	0.04	686.06	0.001917	0.74	6.78	18.22	0.21
Underwood Creek	Main Stem	0.910	PF3	10.00	685.17	686.24	0.07	686.25	0.002080	0.99	10.12	18.50	0.24
Underwood Creek	Main Stem	0.910	PF4	23.00	685.17	686.56	0.12	686.60	0.002411	1.42	16.24	19.02	0.27
Underwood Creek	Main Stem	0.910	PF5	50.00	685.17	687.03	0.21	687.09	0.002802	1.97	25.32	19.76	0.31
Underwood Creek	Main Stem	0.910	PF6	100.00	685.17	687.65	0.34	687.76	0.003236	2.64	37.83	20.74	0.34
Underwood Creek	Main Stem	0.910	PF7	200.00	685.17	688.53	0.54	688.72	0.003799	3.53	56.72	22.03	0.39
Underwood Creek	Main Stem	0.902	PF1	3.00	685.08	685.71	0.06	685.72	0.002058	0.88	3.39	7.28	0.23
Underwood Creek	Main Stem	0.902	PF2	5.00	685.08	685.96	0.04	685.97	0.002045	0.74	6.80	19.30	0.22
Underwood Creek	Main Stem	0.902	PF3	10.00	685.08	686.13	0.07	686.14	0.002273	0.99	10.07	19.57	0.24
Underwood Creek	Main Stem	0.902	PF4	23.00	685.08	686.44	0.12	686.47	0.002574	1.42	16.24	20.08	0.28
Underwood Creek	Main Stem	0.902	PF5	50.00	685.08	686.89	0.21	686.95	0.002929	1.97	25.44	20.81	0.31
Underwood Creek	Main Stem	0.902	PF6	100.00	685.08	687.49	0.33	687.59	0.003313	2.62	38.18	21.78	0.35
Underwood Creek	Main Stem	0.902	PF7	200.00	685.08	688.34	0.53	688.53	0.003821	3.48	57.45	23.12	0.39
Underwood Creek	Main Stem	0.893	PF1	3.00	684.98	685.61	0.06	685.62	0.002098	0.89	3.37	7.26	0.23
Underwood Creek	Main Stem	0.893	PF2	5.00	684.98	685.86	0.04	685.87	0.002064	0.67	7.48	24.81	0.21
Underwood Creek	Main Stem	0.893	PF3	10.00	684.98	686.03	0.05	686.04	0.001932	0.86	11.65	25.08	0.22
Underwood Creek	Main Stem	0.893	PF4	23.00	684.98	686.33	0.09	686.36	0.001915	1.18	19.49	25.58	0.24
Underwood Creek	Main Stem	0.893	PF5	50.00	684.98	686.78	0.14	686.82	0.002020	1.61	31.09	26.31	0.26
Underwood Creek	Main Stem	0.893	PF6	100.00	684.98	687.38	0.22	687.45	0.002172	2.12	47.12	27.28	0.28
Underwood Creek	Main Stem	0.893	PF7	200.00	684.98	688.24	0.34	688.36	0.002421	2.81	71.17	28.63	0.31
Underwood Creek	Main Stem	0.884	PF1	3.00	684.88	685.50	0.06	685.51	0.002161	0.90	3.33	7.23	0.23
Underwood Creek	Main Stem	0.884	PF2	5.00	684.88	685.76	0.04	685.77	0.002027	0.66	7.56	25.13	0.21
Underwood Creek	Main Stem	0.884	PF3	10.00	684.88	685.93	0.05	685.94	0.001820	0.84	11.92	25.42	0.22
Underwood Creek	Main Stem	0.884	PF4	23.00	684.88	686.24	0.08	686.26	0.001820	1.16	19.89	25.92	0.23
Underwood Creek	Main Stem	0.884	PF5	50.00	684.88	686.68	0.14	686.72	0.001969	1.59	31.48	26.64	0.26
Underwood Creek	Main Stem	0.884	PF6	100.00	684.88	687.27	0.22	687.34	0.002150	2.11	47.47	27.61	0.28
Underwood Creek	Main Stem	0.884	PF7	200.00	684.88	688.12	0.34	688.24	0.002423	2.80	71.43	28.98	0.31
Underwood Creek	Main Stem	0.876	PF1	3.00	684.78	685.39	0.06	685.40	0.002324	0.92	3.25	7.16	0.24
Underwood Creek	Main Stem	0.876	PF2	5.00	684.78	685.65	0.05	685.66	0.002213	0.77	6.50	18.30	0.23
Underwood Creek	Main Stem	0.876	PF3	10.00	684.78	685.82	0.08	685.84	0.002422	1.03	9.68	18.60	0.25
Underwood Creek	Main Stem	0.876	PF4	23.00	684.78	686.11	0.14	686.15	0.003038	1.52	15.15	19.09	0.30
Underwood Creek	Main Stem	0.876	PF5	50.00	684.78	686.51	0.27	686.59	0.003885	2.18	22.88	19.77	0.36
Underwood Creek	Main Stem	0.876	PF6	100.00	684.78	687.05	0.44	687.18	0.004660	2.97	33.71	20.68	0.41
Underwood Creek	Main Stem	0.876	PF7	200.00	684.78	687.80	0.73	688.05	0.005684	4.02	49.80	21.97	0.47
Underwood Creek	Main Stem	0.867	PF1	3.00	684.69	685.25	0.08	685.27	0.003196	1.03	2.90	6.86	0.28
Underwood Creek	Main Stem	0.867	PF2	5.00	684.69	685.48	0.08	685.50	0.005216	0.97	5.14	19.48	0.33
Underwood Creek	Main Stem	0.867	PF3	10.00	684.69	685.69	0.09	685.70	0.003180	1.09	9.14	19.85	0.28
Underwood Creek	Main Stem	0.867	PF4	23.00	684.69	685.93	0.18	685.97	0.004262	1.65	13.98	20.30	0.35
Underwood Creek	Main Stem	0.867	PF5	50.00	684.69	686.26	0.33	686.35	0.005551	2.39	20.93	20.92	0.42
Underwood Creek	Main Stem	0.867	PF6	100.00	684.69	686.76	0.52	686.91	0.006199	3.18	31.43	21.82	0.47
Underwood Creek	Main Stem	0.867	PF7	200.00	684.69	687.45	0.84	687.73	0.007215	4.26	46.96	23.09	0.53

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.858	PF1	3.00	684.56	685.00	0.17	685.03	0.008116	1.43	2.09	6.11	0.43
Underwood Creek	Main Stem	0.858	PF2	5.00	684.56	685.13	0.21	685.18	0.008167	1.67	2.99	6.94	0.45
Underwood Creek	Main Stem	0.858	PF3	10.00	684.56	685.44	0.14	685.47	0.007980	1.30	7.72	26.19	0.42
Underwood Creek	Main Stem	0.858	PF4	23.00	684.56	685.64	0.23	685.69	0.007700	1.77	12.98	26.63	0.45
Underwood Creek	Main Stem	0.858	PF5	50.00	684.56	685.96	0.34	686.04	0.007013	2.32	21.56	27.34	0.46
Underwood Creek	Main Stem	0.858	PF6	100.00	684.56	686.51	0.39	686.62	0.005053	2.71	36.89	28.56	0.42
Underwood Creek	Main Stem	0.858	PF7	200.00	684.56	687.22	0.56	687.40	0.004969	3.46	57.75	30.09	0.44
Underwood Creek	Main Stem	0.849	PF1	3.00	684.14	684.56	0.19	684.59	0.009298	1.50	2.00	6.02	0.46
Underwood Creek	Main Stem	0.849	PF2	5.00	684.14	684.71	0.22	684.75	0.008533	1.70	2.94	6.90	0.46
Underwood Creek	Main Stem	0.849	PF3	10.00	684.14	685.00	0.18	685.04	0.009673	1.46	6.83	22.25	0.47
Underwood Creek	Main Stem	0.849	PF4	23.00	684.14	685.23	0.27	685.29	0.008329	1.93	11.92	22.76	0.47
Underwood Creek	Main Stem	0.849	PF5	50.00	684.14	685.60	0.36	685.70	0.006792	2.43	20.57	23.59	0.46
Underwood Creek	Main Stem	0.849	PF6	100.00	684.14	686.27	0.38	686.39	0.004318	2.71	36.87	25.08	0.39
Underwood Creek	Main Stem	0.849	PF7	200.00	684.14	686.93	0.64	687.14	0.005395	3.72	53.74	26.38	0.46
Underwood Creek	Main Stem	0.841	PF1	3.00	683.73	684.20	0.13	684.23	0.005917	1.28	2.34	6.35	0.37
Underwood Creek	Main Stem	0.841	PF2	5.00	683.73	684.33	0.19	684.37	0.006829	1.57	3.19	7.10	0.41
Underwood Creek	Main Stem	0.841	PF3	10.00	683.73	684.65	0.12	684.67	0.005615	1.24	8.06	22.35	0.36
Underwood Creek	Main Stem	0.841	PF4	23.00	683.73	684.84	0.25	684.89	0.007571	1.87	12.27	22.74	0.45
Underwood Creek	Main Stem	0.841	PF5	50.00	683.73	685.38	0.23	685.44	0.003647	2.00	24.98	23.88	0.34
Underwood Creek	Main Stem	0.841	PF6	100.00	683.73	686.13	0.26	686.21	0.002568	2.30	43.51	25.46	0.31
Underwood Creek	Main Stem	0.841	PF7	200.00	683.73	686.72	0.52	686.90	0.004052	3.41	58.74	26.13	0.40
Underwood Creek	Main Stem	0.832	PF1	3.00	683.31	683.64	0.38	683.70	0.023128	2.06	1.46	5.45	0.70
Underwood Creek	Main Stem	0.832	PF2	5.00	683.31	683.78	0.37	683.85	0.016672	2.15	2.32	6.34	0.63
Underwood Creek	Main Stem	0.832	PF3	10.00	683.31	684.09	0.38	684.16	0.023323	2.04	4.89	18.70	0.70
Underwood Creek	Main Stem	0.832	PF4	23.00	683.31	684.60	0.15	684.64	0.003466	1.54	14.95	20.74	0.32
Underwood Creek	Main Stem	0.832	PF5	50.00	683.31	685.26	0.15	685.31	0.001979	1.70	29.45	22.58	0.26
Underwood Creek	Main Stem	0.832	PF6	100.00	683.31	686.03	0.21	686.10	0.001833	2.13	46.84	22.58	0.26
Underwood Creek	Main Stem	0.832	PF7	200.00	683.31	686.51	0.53	686.69	0.004216	3.42	58.44	26.15	0.40
Underwood Creek	Main Stem	0.829	PF1	3.00	683.14	683.58	0.03	683.63	0.001320	1.76	1.70	4.75	0.52
Underwood Creek	Main Stem	0.829	PF2	5.00	683.14	683.72	0.04	683.79	0.001334	2.07	2.42	5.32	0.54
Underwood Creek	Main Stem	0.829	PF3	10.00	683.14	683.98	0.05	684.08	0.001356	2.54	3.93	6.36	0.57
Underwood Creek	Main Stem	0.829	PF4	23.00	683.14	684.42	0.07	684.58	0.001388	3.23	7.13	8.12	0.61
Underwood Creek	Main Stem	0.829	PF5	50.00	683.14	685.01	0.10	685.25	0.001409	3.98	12.56	10.45	0.64
Underwood Creek	Main Stem	0.829	PF6	100.00	683.14	685.66	0.17	686.03	0.002801	4.85	20.63	20.45	0.85
Underwood Creek	Main Stem	0.829	PF7	200.00	683.14	686.28	0.16	686.61	0.002560	4.63	43.19	41.33	0.80
Underwood Creek	Main Stem	0.824	PF1	3.00	683.10	683.54	0.03	683.59	0.001313	1.76	1.70	4.76	0.52
Underwood Creek	Main Stem	0.824	PF2	5.00	683.10	683.68	0.04	683.75	0.001332	2.07	2.42	5.32	0.54
Underwood Creek	Main Stem	0.824	PF3	10.00	683.10	683.94	0.05	684.04	0.001360	2.55	3.93	6.36	0.57
Underwood Creek	Main Stem	0.824	PF4	23.00	683.10	684.38	0.07	684.54	0.001396	3.23	7.12	8.12	0.61
Underwood Creek	Main Stem	0.824	PF5	50.00	683.10	684.96	0.10	685.21	0.001417	3.99	12.53	10.45	0.64
Underwood Creek	Main Stem	0.824	PF6	100.00	683.10	685.60	0.09	685.98	0.001530	4.90	20.42	20.08	0.86
Underwood Creek	Main Stem	0.824	PF7	200.00	683.10	686.12	0.10	686.54	0.001858	5.23	38.25	41.24	0.96
Underwood Creek	Main Stem	0.815	PF1	3.00	683.03	683.48	0.03	683.52	0.001223	1.72	1.75	4.79	0.50
Underwood Creek	Main Stem	0.815	PF2	5.00	683.03	683.62	0.03	683.68	0.001285	2.04	2.45	5.35	0.53
Underwood Creek	Main Stem	0.815	PF3	10.00	683.03	683.87	0.05	683.97	0.001342	2.53	3.95	6.37	0.57
Underwood Creek	Main Stem	0.815	PF4	23.00	683.03	684.31	0.07	684.47	0.001394	3.23	7.12	8.12	0.61
Underwood Creek	Main Stem	0.815	PF5	50.00	683.03	684.89	0.10	685.14	0.001420	3.99	12.53	10.45	0.64
Underwood Creek	Main Stem	0.815	PF6	100.00	683.03	685.63	0.08	685.80	0.001356	3.31	30.20	29.00	0.57
Underwood Creek	Main Stem	0.815	PF7	200.00	683.03	686.07	0.15	686.41	0.001737	4.65	43.01	29.00	0.67
Underwood Creek	Main Stem	0.8125		Bridge									
Underwood Creek	Main Stem	0.81	PF1	3.00	682.98	683.43	0.03	683.47	0.001235	1.72	1.74	4.79	0.50
Underwood Creek	Main Stem	0.81	PF2	5.00	682.98	683.56	0.04	683.63	0.001332	2.07	2.42	5.33	0.54
Underwood Creek	Main Stem	0.81	PF3	10.00	682.98	683.81	0.05	683.92	0.001402	2.57	3.89	6.34	0.58
Underwood Creek	Main Stem	0.81	PF4	23.00	682.98	684.25	0.07	684.41	0.001451	3.28	7.02	8.08	0.62
Underwood Creek	Main Stem	0.81	PF5	50.00	682.98	684.83	0.10	685.08	0.001465	4.04	12.39	10.41	0.65
Underwood Creek	Main Stem	0.81	PF6	100.00	682.98	685.56	0.09	685.75	0.001595	3.48	28.70	29.00	0.62
Underwood Creek	Main Stem	0.81	PF7	200.00	682.98	685.82	0.22	686.29	0.003019	5.53	36.18	29.00	0.87
Underwood Creek	Main Stem	0.805	PF1	3.00	682.90	683.19	0.08	683.32	0.005478	2.86	1.05	4.17	1.00
Underwood Creek	Main Stem	0.805	PF2	5.00	682.90	683.31	0.10	683.47	0.004823	3.23	1.55	4.62	0.98
Underwood Creek	Main Stem	0.805	PF3	10.00	682.90	683.51	0.13	683.74	0.004478	3.89	2.57	5.44	1.00
Underwood Creek	Main Stem	0.805	PF4	23.00	682.90	683.87	0.17	684.23	0.004080	4.77	4.82	6.90	1.01
Underwood Creek	Main Stem	0.805	PF5	50.00	682.90	684.38	0.21	684.88	0.003656	5.66	8.84	8.93	1.00
Underwood Creek	Main Stem	0.805	PF6	100.00	682.90	685.27	0.18	685.57	0.004934	4.38	22.83	38.96	1.01
Underwood Creek	Main Stem	0.805	PF7	200.00	682.90	685.62	0.23	686.08	0.004198	5.42	36.91	40.36	1.00
Underwood Creek	Main Stem	0.800	PF1	3.00	682.33	682.44	6.24	683.23	0.995002	7.12	0.42	4.16	3.94
Underwood Creek	Main Stem	0.800	PF2	5.00	682.33	682.50	6.13	683.37	0.670929	7.51	0.67	4.50	3.44
Underwood Creek	Main Stem	0.800	PF3	10.00	682.33	682.61	6.22	683.65	0.430160	8.17	1.22	5.19	2.97
Underwood Creek	Main Stem	0.800	PF4	23.00	682.33	682.80	9.78	684.12	1.269508	9.22	2.49	20.06	4.61
Underwood Creek	Main Stem	0.800	PF5	50.00	682.33	682.90	11.09	684.72	0.796909	10.84	4.61	20.48	4.03
Underwood Creek	Main Stem	0.800	PF6	100.00	682.33	683.08	11.55	685.35	0.480990	12.11	8.26	21.18	3.42
Underwood Creek	Main Stem	0.800	PF7	200.00	682.33	683.43	10.18	685.87	0.235757	12.54	15.94	22.59	2.63
Underwood Creek	Main Stem	0.792	PF1	3.00	681.98	682.49	0.08	682.50	0.008210	0.90	3.35	20.23	0.39
Underwood Creek	Main Stem	0.792	PF2	5.00	681.98	682.55	0.11	682.57	0.008288	1.10	4.56	20.47	0.41
Underwood Creek	Main Stem	0.792	PF3	10.00	681.98	682.67	0.16	682.70	0.007883	1.41	7.09	20.96	0.43
Underwood Creek	Main Stem	0.792	PF4	23.00	681.98	682.89	0.27	682.95	0.008022	1.94	11.83	21.85	0.47
Underwood Creek	Main Stem	0.792	PF5	50.00	681.98	683.22	0.41	683.33	0.008111	2.59	19.29	23.18	0.50
Underwood Creek	Main Stem	0.792	PF6	100.00	681.98	683.67	0.60	683.84	0.008199	3.32	30.10	24.98	0.53

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.792	PF7	200.00	681.98	684.35	0.84	684.62	0.008047	4.17	47.99	27.70	0.56
Underwood Creek	Main Stem	0.783	PF1	3.00	681.57	682.08	0.09	682.09	0.008454	0.90	3.32	20.23	0.39
Underwood Creek	Main Stem	0.783	PF2	5.00	681.57	682.14	0.11	682.16	0.008236	1.09	4.57	20.47	0.41
Underwood Creek	Main Stem	0.783	PF3	10.00	681.57	682.25	0.17	682.28	0.008548	1.45	6.91	20.93	0.44
Underwood Creek	Main Stem	0.783	PF4	23.00	681.57	682.47	0.28	682.53	0.008476	1.98	11.63	21.81	0.48
Underwood Creek	Main Stem	0.783	PF5	50.00	681.57	682.80	0.42	682.91	0.008361	2.62	19.10	23.14	0.51
Underwood Creek	Main Stem	0.783	PF6	100.00	681.57	683.26	0.60	683.43	0.008201	3.32	30.10	24.98	0.53
Underwood Creek	Main Stem	0.783	PF7	200.00	681.57	683.96	0.82	684.22	0.007798	4.12	48.50	27.78	0.55
Underwood Creek	Main Stem	0.773	PF1	3.00	681.15	681.66	0.08	681.67	0.008233	0.90	3.34	20.23	0.39
Underwood Creek	Main Stem	0.773	PF2	5.00	681.15	681.72	0.12	681.73	0.008478	1.10	4.53	20.46	0.41
Underwood Creek	Main Stem	0.773	PF3	10.00	681.15	681.84	0.17	681.87	0.008057	1.42	7.04	20.95	0.43
Underwood Creek	Main Stem	0.773	PF4	23.00	681.15	682.06	0.27	682.12	0.008107	1.95	11.79	21.83	0.47
Underwood Creek	Main Stem	0.773	PF5	50.00	681.15	682.40	0.41	682.50	0.007961	2.58	19.40	23.18	0.50
Underwood Creek	Main Stem	0.773	PF6	100.00	681.15	682.88	0.56	683.04	0.007484	3.22	31.01	25.10	0.51
Underwood Creek	Main Stem	0.773	PF7	200.00	681.15	683.60	0.76	683.85	0.007017	3.98	50.21	27.94	0.52
Underwood Creek	Main Stem	0.764	PF1	3.00	680.74	681.25	0.08	681.26	0.008112	0.89	3.36	20.23	0.39
Underwood Creek	Main Stem	0.764	PF2	5.00	680.74	681.31	0.11	681.33	0.007927	1.08	4.62	20.48	0.40
Underwood Creek	Main Stem	0.764	PF3	10.00	680.74	681.42	0.18	681.45	0.008646	1.45	6.89	20.92	0.45
Underwood Creek	Main Stem	0.764	PF4	23.00	680.74	681.63	0.30	681.69	0.009343	2.04	11.28	21.75	0.50
Underwood Creek	Main Stem	0.764	PF5	50.00	680.74	682.07	0.33	682.15	0.005987	2.35	21.26	23.52	0.44
Underwood Creek	Main Stem	0.764	PF6	100.00	680.74	682.56	0.48	682.70	0.006026	3.00	33.31	25.49	0.46
Underwood Creek	Main Stem	0.764	PF7	200.00	680.74	683.30	0.66	683.52	0.005782	3.75	53.38	27.94	0.48
Underwood Creek	Main Stem	0.754	PF1	3.00	680.33	680.84	0.08	680.85	0.008800	0.85	3.52	24.22	0.39
Underwood Creek	Main Stem	0.754	PF2	5.00	680.33	680.89	0.11	680.91	0.008690	1.04	4.82	24.44	0.41
Underwood Creek	Main Stem	0.754	PF3	10.00	680.33	680.99	0.16	681.02	0.008556	1.35	7.39	24.85	0.44
Underwood Creek	Main Stem	0.754	PF4	23.00	680.33	681.19	0.25	681.25	0.008309	1.84	12.47	25.66	0.47
Underwood Creek	Main Stem	0.754	PF5	70.00	680.33	681.66	0.47	681.79	0.008488	2.81	24.92	27.53	0.52
Underwood Creek	Main Stem	0.754	PF6	136.00	680.33	682.13	0.67	682.33	0.008396	3.55	38.34	29.42	0.55
Underwood Creek	Main Stem	0.754	PF7	270.00	680.33	682.85	0.94	683.16	0.008322	4.47	60.39	32.27	0.58
Underwood Creek	Main Stem	0.745	PF1	3.00	679.91	680.42	0.07	680.43	0.008052	0.83	3.62	24.24	0.38
Underwood Creek	Main Stem	0.745	PF2	5.00	679.91	680.47	0.10	680.49	0.008035	1.01	4.94	24.45	0.40
Underwood Creek	Main Stem	0.745	PF3	10.00	679.91	680.58	0.15	680.60	0.008281	1.34	7.47	24.87	0.43
Underwood Creek	Main Stem	0.745	PF4	23.00	679.91	680.78	0.24	680.83	0.008084	1.83	12.58	25.67	0.46
Underwood Creek	Main Stem	0.745	PF5	70.00	679.91	681.25	0.46	681.37	0.008203	2.78	25.19	27.57	0.51
Underwood Creek	Main Stem	0.745	PF6	136.00	679.91	681.72	0.65	681.92	0.008206	3.52	38.63	29.45	0.54
Underwood Creek	Main Stem	0.745	PF7	270.00	679.91	682.44	0.93	682.75	0.008197	4.45	60.70	32.31	0.57
Underwood Creek	Main Stem	0.735	PF1	3.00	679.50	680.01	0.08	680.02	0.008631	0.85	3.54	24.23	0.39
Underwood Creek	Main Stem	0.735	PF2	5.00	679.50	680.06	0.10	680.08	0.008490	1.03	4.85	24.44	0.41
Underwood Creek	Main Stem	0.735	PF3	10.00	679.50	680.17	0.15	680.19	0.008370	1.34	7.44	24.86	0.43
Underwood Creek	Main Stem	0.735	PF4	23.00	679.50	680.36	0.25	680.42	0.008278	1.84	12.48	25.66	0.47
Underwood Creek	Main Stem	0.735	PF5	70.00	679.50	680.84	0.46	680.96	0.008279	2.79	25.12	27.56	0.51
Underwood Creek	Main Stem	0.735	PF6	136.00	679.50	681.31	0.66	681.50	0.008247	3.53	38.56	29.45	0.54
Underwood Creek	Main Stem	0.735	PF7	270.00	679.50	682.03	0.93	682.34	0.008192	4.45	60.71	32.31	0.57
Underwood Creek	Main Stem	0.733	PF1	3.00	679.39	679.90	0.08	679.91	0.008139	0.83	3.60	24.24	0.38
Underwood Creek	Main Stem	0.733	PF2	5.00	679.39	679.95	0.10	679.97	0.008148	1.02	4.92	24.45	0.40
Underwood Creek	Main Stem	0.733	PF3	10.00	679.39	680.06	0.15	680.09	0.008178	1.33	7.50	24.87	0.43
Underwood Creek	Main Stem	0.733	PF4	23.00	679.39	680.26	0.25	680.31	0.008133	1.83	12.55	25.67	0.46
Underwood Creek	Main Stem	0.733	PF5	70.00	679.39	680.73	0.46	680.85	0.008243	2.78	25.16	27.56	0.51
Underwood Creek	Main Stem	0.733	PF6	136.00	679.39	681.20	0.65	681.40	0.008216	3.52	38.61	29.45	0.54
Underwood Creek	Main Stem	0.733	PF7	270.00	679.39	681.92	0.93	682.23	0.008162	4.44	60.78	32.32	0.57
Underwood Creek	Main Stem	0.726	PF1	3.00	679.11	679.63	0.06	679.63	0.006980	0.77	3.90	26.26	0.35
Underwood Creek	Main Stem	0.726	PF2	5.00	679.11	679.68	0.09	679.69	0.006893	0.94	5.33	26.48	0.37
Underwood Creek	Main Stem	0.726	PF3	10.00	679.11	679.79	0.13	679.81	0.006841	1.23	8.16	26.90	0.39
Underwood Creek	Main Stem	0.726	PF4	23.00	679.11	679.99	0.20	680.03	0.006688	1.68	13.72	27.71	0.42
Underwood Creek	Main Stem	0.726	PF5	70.00	679.11	680.48	0.38	680.58	0.006612	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.726	PF6	136.00	679.11	680.96	0.54	681.12	0.006594	3.21	42.39	31.57	0.49
Underwood Creek	Main Stem	0.726	PF7	270.00	679.11	681.69	0.77	681.94	0.006573	4.06	66.53	34.49	0.51
Underwood Creek	Main Stem	0.725	PF1	3.00	679.08	679.60	0.06	679.61	0.006183	0.74	4.04	26.28	0.33
Underwood Creek	Main Stem	0.725	PF2	5.00	679.08	679.65	0.08	679.67	0.006383	0.92	5.46	26.50	0.36
Underwood Creek	Main Stem	0.725	PF3	10.00	679.08	679.76	0.12	679.78	0.006544	1.21	8.27	26.92	0.38
Underwood Creek	Main Stem	0.725	PF4	23.00	679.08	679.96	0.20	680.01	0.006505	1.66	13.84	27.73	0.41
Underwood Creek	Main Stem	0.725	PF5	70.00	679.08	680.45	0.37	680.55	0.006519	2.52	27.79	29.67	0.46
Underwood Creek	Main Stem	0.725	PF6	136.00	679.08	680.93	0.54	681.09	0.006531	3.20	42.52	31.59	0.49
Underwood Creek	Main Stem	0.725	PF7	270.00	679.08	681.66	0.76	681.92	0.006530	4.05	66.67	34.51	0.51
Underwood Creek	Main Stem	0.716	PF1	3.00	678.78	679.30	0.06	679.31	0.006842	0.77	3.92	26.27	0.35
Underwood Creek	Main Stem	0.716	PF2	5.00	678.78	679.35	0.09	679.36	0.006846	0.94	5.35	26.48	0.37
Underwood Creek	Main Stem	0.716	PF3	10.00	678.78	679.46	0.13	679.48	0.006709	1.22	8.21	26.91	0.39
Underwood Creek	Main Stem	0.716	PF4	23.00	678.78	679.66	0.20	679.71	0.006526	1.66	13.83	27.73	0.42
Underwood Creek	Main Stem	0.716	PF5	70.00	678.78	680.15	0.38	680.25	0.006615	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.716	PF6	136.00	678.78	680.63	0.54	680.79	0.006566	3.20	42.44	31.58	0.49
Underwood Creek	Main Stem	0.716	PF7	270.00	678.78	681.36	0.76	681.62	0.006544	4.05	66.63	34.50	0.51
Underwood Creek	Main Stem	0.707	PF1	3.00	678.45	678.97	0.06	678.98	0.006314	0.75	4.02	26.28	0.34
Underwood Creek	Main Stem	0.707	PF2	5.00	678.45	679.02	0.08	679.04	0.006547	0.92	5.42	26.49	0.36
Underwood Creek	Main Stem	0.707	PF3	10.00	678.45	679.13	0.12	679.16	0.006291	1.19	8.37	26.93	0.38
Underwood Creek	Main Stem	0.707	PF4	23.00	678.45	679.34	0.20	679.38	0.006308	1.65	13.97	27.75	0.41
Underwood Creek	Main Stem	0.707	PF5	70.00	678.45	679.82	0.37	679.92	0.006455	2.51	27.87	29.68	0.46
Underwood Creek	Main Stem	0.707	PF6	136.00	678.45	680.31	0.53	680.46	0.006467	3.19	42.65	31.61	0.48

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.707	PF7	270.00	678.45	681.04	0.76	681.29	0.006486	4.04	66.82	34.52	0.51
Underwood Creek	Main Stem	0.698	PF1	3.00	678.13	678.65	0.06	678.66	0.006686	0.76	3.95	26.27	0.35
Underwood Creek	Main Stem	0.698	PF2	5.00	678.13	678.71	0.08	678.72	0.006254	0.91	5.49	26.51	0.35
Underwood Creek	Main Stem	0.698	PF3	10.00	678.13	678.81	0.13	678.83	0.006743	1.22	8.20	26.91	0.39
Underwood Creek	Main Stem	0.698	PF4	23.00	678.13	679.02	0.20	679.06	0.006438	1.66	13.89	27.75	0.41
Underwood Creek	Main Stem	0.698	PF5	70.00	678.13	679.50	0.38	679.60	0.006596	2.53	27.69	29.67	0.46
Underwood Creek	Main Stem	0.698	PF6	136.00	678.13	679.98	0.54	680.14	0.006588	3.21	42.41	31.60	0.49
Underwood Creek	Main Stem	0.698	PF7	270.00	678.13	680.71	0.76	680.96	0.006565	4.06	66.58	34.53	0.51
Underwood Creek	Main Stem	0.689	PF1	3.00	677.80	678.32	0.06	678.33	0.006407	0.75	4.00	26.28	0.34
Underwood Creek	Main Stem	0.689	PF2	5.00	677.80	678.37	0.09	678.38	0.006811	0.93	5.35	26.48	0.37
Underwood Creek	Main Stem	0.689	PF3	10.00	677.80	678.48	0.12	678.50	0.006544	1.21	8.27	26.92	0.38
Underwood Creek	Main Stem	0.689	PF4	23.00	677.80	678.68	0.21	678.72	0.006755	1.68	13.68	27.71	0.42
Underwood Creek	Main Stem	0.689	PF5	70.00	677.80	679.17	0.38	679.27	0.006614	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.689	PF6	136.00	677.80	679.65	0.54	679.81	0.006566	3.20	42.44	31.58	0.49
Underwood Creek	Main Stem	0.689	PF7	270.00	677.80	680.38	0.76	680.64	0.006544	4.05	66.63	34.50	0.51
Underwood Creek	Main Stem	0.679	PF1	3.00	677.47	677.99	0.06	678.00	0.006676	0.76	3.95	26.27	0.35
Underwood Creek	Main Stem	0.679	PF2	5.00	677.47	678.04	0.08	678.06	0.006477	0.92	5.44	26.49	0.36
Underwood Creek	Main Stem	0.679	PF3	10.00	677.47	678.15	0.12	678.17	0.006435	1.20	8.32	26.92	0.38
Underwood Creek	Main Stem	0.679	PF4	23.00	677.47	678.35	0.20	678.40	0.006466	1.66	13.87	27.74	0.41
Underwood Creek	Main Stem	0.679	PF5	70.00	677.47	678.84	0.37	678.94	0.006455	2.51	27.87	29.68	0.46
Underwood Creek	Main Stem	0.679	PF6	136.00	677.47	679.33	0.53	679.48	0.006467	3.19	42.65	31.61	0.48
Underwood Creek	Main Stem	0.679	PF7	270.00	677.47	680.06	0.76	680.31	0.006486	4.04	66.82	34.52	0.51
Underwood Creek	Main Stem	0.670	PF1	3.00	677.15	677.67	0.06	677.68	0.006209	0.74	4.04	26.28	0.33
Underwood Creek	Main Stem	0.670	PF2	5.00	677.15	677.72	0.08	677.74	0.006397	0.92	5.46	26.50	0.36
Underwood Creek	Main Stem	0.670	PF3	10.00	677.15	677.83	0.12	677.86	0.006337	1.20	8.35	26.93	0.38
Underwood Creek	Main Stem	0.670	PF4	23.00	677.15	678.03	0.20	678.07	0.006680	1.68	13.73	27.72	0.42
Underwood Creek	Main Stem	0.670	PF5	70.00	677.15	678.52	0.38	678.62	0.006595	2.53	27.69	29.67	0.46
Underwood Creek	Main Stem	0.670	PF6	136.00	677.15	679.00	0.54	679.16	0.006587	3.21	42.41	31.60	0.49
Underwood Creek	Main Stem	0.670	PF7	270.00	677.15	679.73	0.76	679.98	0.006567	4.06	66.57	34.53	0.51
Underwood Creek	Main Stem	0.661	PF1	3.00	676.82	677.34	0.06	677.35	0.006758	0.76	3.94	26.27	0.35
Underwood Creek	Main Stem	0.661	PF2	5.00	676.82	677.39	0.08	677.41	0.006724	0.93	5.37	26.49	0.36
Underwood Creek	Main Stem	0.661	PF3	10.00	676.82	677.50	0.13	677.52	0.006708	1.22	8.21	26.91	0.39
Underwood Creek	Main Stem	0.661	PF4	23.00	676.82	677.70	0.20	677.75	0.006530	1.66	13.82	27.73	0.42
Underwood Creek	Main Stem	0.661	PF5	70.00	676.82	678.19	0.38	678.29	0.006614	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.661	PF6	136.00	676.82	678.67	0.54	678.83	0.006567	3.20	42.44	31.58	0.49
Underwood Creek	Main Stem	0.661	PF7	270.00	676.82	679.40	0.76	679.66	0.006548	4.05	66.61	34.50	0.51
Underwood Creek	Main Stem	0.651	PF1	3.00	676.49	677.01	0.06	677.02	0.006381	0.75	4.00	26.28	0.34
Underwood Creek	Main Stem	0.651	PF2	5.00	676.49	677.06	0.08	677.08	0.006395	0.92	5.46	26.50	0.36
Underwood Creek	Main Stem	0.651	PF3	10.00	676.49	677.17	0.12	677.20	0.006296	1.19	8.37	26.93	0.38
Underwood Creek	Main Stem	0.651	PF4	23.00	676.49	677.38	0.20	677.42	0.006318	1.65	13.97	27.75	0.41
Underwood Creek	Main Stem	0.651	PF5	70.00	676.49	677.86	0.37	677.96	0.006452	2.51	27.88	29.68	0.46
Underwood Creek	Main Stem	0.651	PF6	136.00	676.49	678.34	0.53	678.50	0.006470	3.19	42.65	31.61	0.48
Underwood Creek	Main Stem	0.651	PF7	270.00	676.49	679.08	0.76	679.33	0.006494	4.04	66.80	34.52	0.51
Underwood Creek	Main Stem	0.642	PF1	3.00	676.17	676.69	0.06	676.70	0.006740	0.76	3.94	26.27	0.35
Underwood Creek	Main Stem	0.642	PF2	5.00	676.17	676.74	0.08	676.75	0.006744	0.93	5.37	26.49	0.36
Underwood Creek	Main Stem	0.642	PF3	10.00	676.17	676.85	0.13	676.87	0.006690	1.22	8.22	26.91	0.39
Underwood Creek	Main Stem	0.642	PF4	23.00	676.17	677.05	0.20	677.10	0.006515	1.66	13.84	27.74	0.41
Underwood Creek	Main Stem	0.642	PF5	70.00	676.17	677.54	0.38	677.64	0.006603	2.53	27.68	29.67	0.46
Underwood Creek	Main Stem	0.642	PF6	136.00	676.17	678.02	0.54	678.18	0.006597	3.21	42.39	31.60	0.49
Underwood Creek	Main Stem	0.642	PF7	270.00	676.17	678.75	0.77	679.00	0.006582	4.06	66.52	34.52	0.52
Underwood Creek	Main Stem	0.633	PF1	3.00	675.84	676.36	0.06	676.37	0.006634	0.76	3.96	26.27	0.34
Underwood Creek	Main Stem	0.633	PF2	5.00	675.84	676.42	0.08	676.43	0.006347	0.91	5.47	26.50	0.35
Underwood Creek	Main Stem	0.633	PF3	10.00	675.84	676.52	0.12	676.55	0.006337	1.20	8.35	26.93	0.38
Underwood Creek	Main Stem	0.633	PF4	23.00	675.84	676.72	0.20	676.76	0.006682	1.68	13.73	27.72	0.42
Underwood Creek	Main Stem	0.633	PF5	70.00	675.84	677.21	0.38	677.31	0.006595	2.53	27.69	29.67	0.46
Underwood Creek	Main Stem	0.633	PF6	136.00	675.84	677.69	0.54	677.85	0.006587	3.21	42.41	31.60	0.49
Underwood Creek	Main Stem	0.633	PF7	270.00	675.84	678.42	0.76	678.67	0.006563	4.05	66.59	34.53	0.51
Underwood Creek	Main Stem	0.623	PF1	3.00	675.51	676.03	0.06	676.04	0.006794	0.76	3.93	26.27	0.35
Underwood Creek	Main Stem	0.623	PF2	5.00	675.51	676.08	0.08	676.09	0.006750	0.93	5.37	26.48	0.36
Underwood Creek	Main Stem	0.623	PF3	10.00	675.51	676.19	0.13	676.21	0.006708	1.22	8.21	26.91	0.39
Underwood Creek	Main Stem	0.623	PF4	23.00	675.51	676.39	0.20	676.44	0.006528	1.66	13.83	27.73	0.42
Underwood Creek	Main Stem	0.623	PF5	70.00	675.51	676.88	0.38	676.98	0.006614	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.623	PF6	136.00	675.51	677.36	0.54	677.52	0.006566	3.20	42.44	31.58	0.49
Underwood Creek	Main Stem	0.623	PF7	270.00	675.51	678.09	0.76	678.35	0.006540	4.05	66.64	34.50	0.51
Underwood Creek	Main Stem	0.614	PF1	3.00	675.18	675.70	0.06	675.71	0.006527	0.75	3.98	26.27	0.34
Underwood Creek	Main Stem	0.614	PF2	5.00	675.18	675.75	0.08	675.77	0.006509	0.92	5.43	26.49	0.36
Underwood Creek	Main Stem	0.614	PF3	10.00	675.18	675.86	0.12	675.89	0.006287	1.19	8.37	26.93	0.38
Underwood Creek	Main Stem	0.614	PF4	23.00	675.18	676.07	0.20	676.11	0.006308	1.65	13.97	27.75	0.41
Underwood Creek	Main Stem	0.614	PF5	70.00	675.18	676.55	0.37	676.65	0.006455	2.51	27.87	29.68	0.46
Underwood Creek	Main Stem	0.614	PF6	136.00	675.18	677.04	0.53	677.19	0.006467	3.19	42.65	31.61	0.48
Underwood Creek	Main Stem	0.614	PF7	270.00	675.18	677.77	0.76	678.02	0.006479	4.04	66.85	34.53	0.51
Underwood Creek	Main Stem	0.605	PF1	3.00	674.86	675.38	0.06	675.39	0.006650	0.76	3.95	26.27	0.34
Underwood Creek	Main Stem	0.605	PF2	5.00	674.86	675.43	0.08	675.45	0.006496	0.92	5.43	26.50	0.36
Underwood Creek	Main Stem	0.605	PF3	10.00	674.86	675.54	0.13	675.56	0.006756	1.22	8.19	26.91	0.39
Underwood Creek	Main Stem	0.605	PF4	23.00	674.86	675.75	0.20	675.79	0.006453	1.66	13.88	27.74	0.41
Underwood Creek	Main Stem	0.605	PF5	70.00	674.86	676.23	0.38	676.33	0.006596	2.53	27.69	29.67	0.46
Underwood Creek	Main Stem	0.605	PF6	136.00	674.86	676.71	0.54	676.87	0.006587	3.21	42.41	31.60	0.49

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.605	PF7	270.00	674.86	677.44	0.76	677.69	0.006550	4.05	66.63	34.54	0.51
Underwood Creek	Main Stem	0.596	PF1	3.00	674.53	675.05	0.06	675.06	0.006805	0.76	3.93	26.27	0.35
Underwood Creek	Main Stem	0.596	PF2	5.00	674.53	675.10	0.09	675.11	0.006819	0.93	5.35	26.48	0.37
Underwood Creek	Main Stem	0.596	PF3	10.00	674.53	675.21	0.12	675.23	0.006536	1.21	8.28	26.92	0.38
Underwood Creek	Main Stem	0.596	PF4	23.00	674.53	675.41	0.21	675.45	0.006742	1.68	13.69	27.71	0.42
Underwood Creek	Main Stem	0.596	PF5	70.00	674.53	675.90	0.38	676.00	0.006613	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.596	PF6	136.00	674.53	676.38	0.54	676.54	0.006565	3.20	42.45	31.58	0.49
Underwood Creek	Main Stem	0.596	PF7	270.00	674.53	677.11	0.76	677.37	0.006513	4.05	66.73	34.51	0.51
Underwood Creek	Main Stem	0.586	PF1	3.00	674.20	674.72	0.06	674.73	0.006527	0.75	3.98	26.27	0.34
Underwood Creek	Main Stem	0.586	PF2	5.00	674.20	674.78	0.08	674.79	0.006242	0.91	5.50	26.50	0.35
Underwood Creek	Main Stem	0.586	PF3	10.00	674.20	674.88	0.12	674.90	0.006426	1.20	8.32	26.93	0.38
Underwood Creek	Main Stem	0.586	PF4	23.00	674.20	675.08	0.20	675.13	0.006477	1.66	13.86	27.73	0.41
Underwood Creek	Main Stem	0.586	PF5	70.00	674.20	675.57	0.37	675.67	0.006456	2.51	27.87	29.68	0.46
Underwood Creek	Main Stem	0.586	PF6	136.00	674.20	676.06	0.53	676.21	0.006465	3.19	42.66	31.61	0.48
Underwood Creek	Main Stem	0.586	PF7	270.00	674.20	676.79	0.75	677.04	0.006426	4.03	67.03	34.55	0.51
Underwood Creek	Main Stem	0.577	PF1	3.00	673.88	674.40	0.06	674.41	0.006458	0.75	3.99	26.28	0.34
Underwood Creek	Main Stem	0.577	PF2	5.00	673.88	674.45	0.09	674.46	0.006831	0.93	5.35	26.48	0.37
Underwood Creek	Main Stem	0.577	PF3	10.00	673.88	674.56	0.12	674.59	0.006356	1.20	8.35	26.93	0.38
Underwood Creek	Main Stem	0.577	PF4	23.00	673.88	674.76	0.20	674.80	0.006671	1.67	13.73	27.72	0.42
Underwood Creek	Main Stem	0.577	PF5	70.00	673.88	675.25	0.38	675.35	0.006596	2.53	27.69	29.67	0.46
Underwood Creek	Main Stem	0.577	PF6	136.00	673.88	675.73	0.54	675.89	0.006584	3.21	42.42	31.60	0.49
Underwood Creek	Main Stem	0.577	PF7	270.00	673.88	676.47	0.75	676.72	0.006441	4.03	67.00	34.58	0.51
Underwood Creek	Main Stem	0.568	PF1	3.00	673.55	674.07	0.06	674.08	0.006785	0.76	3.93	26.27	0.35
Underwood Creek	Main Stem	0.568	PF2	5.00	673.55	674.12	0.08	674.14	0.006464	0.92	5.44	26.50	0.36
Underwood Creek	Main Stem	0.568	PF3	10.00	673.55	674.23	0.13	674.25	0.006699	1.22	8.21	26.91	0.39
Underwood Creek	Main Stem	0.568	PF4	23.00	673.55	674.43	0.20	674.48	0.006538	1.66	13.82	27.73	0.42
Underwood Creek	Main Stem	0.568	PF5	70.00	673.55	674.92	0.38	675.02	0.006616	2.53	27.66	29.65	0.46
Underwood Creek	Main Stem	0.568	PF6	136.00	673.55	675.40	0.54	675.56	0.006552	3.20	42.47	31.58	0.49
Underwood Creek	Main Stem	0.568	PF7	270.00	673.55	676.15	0.74	676.40	0.006310	4.00	67.44	34.60	0.51
Underwood Creek	Main Stem	0.558	PF1	3.00	673.22	673.74	0.06	673.75	0.006348	0.75	4.01	26.28	0.34
Underwood Creek	Main Stem	0.558	PF2	5.00	673.22	673.79	0.08	673.81	0.006631	0.93	5.40	26.49	0.36
Underwood Creek	Main Stem	0.558	PF3	10.00	673.22	673.90	0.12	673.93	0.006312	1.20	8.36	26.93	0.38
Underwood Creek	Main Stem	0.558	PF4	23.00	673.22	674.11	0.20	674.15	0.006353	1.65	13.94	27.75	0.41
Underwood Creek	Main Stem	0.558	PF5	70.00	673.22	674.59	0.37	674.69	0.006445	2.51	27.89	29.68	0.46
Underwood Creek	Main Stem	0.558	PF6	136.00	673.22	675.08	0.53	675.24	0.006413	3.18	42.77	31.62	0.48
Underwood Creek	Main Stem	0.558	PF7	270.00	673.22	675.85	0.72	676.09	0.006067	3.95	68.32	34.70	0.50
Underwood Creek	Main Stem	0.549	PF1	3.00	672.90	673.42	0.06	673.43	0.006434	0.75	3.99	26.28	0.34
Underwood Creek	Main Stem	0.549	PF2	5.00	672.90	673.47	0.08	673.49	0.006440	0.92	5.45	26.50	0.36
Underwood Creek	Main Stem	0.549	PF3	10.00	672.90	673.58	0.13	673.60	0.006687	1.22	8.22	26.91	0.39
Underwood Creek	Main Stem	0.549	PF4	23.00	672.90	673.78	0.21	673.82	0.006798	1.68	13.65	27.71	0.42
Underwood Creek	Main Stem	0.549	PF5	70.00	672.90	674.27	0.38	674.37	0.006605	2.53	27.68	29.67	0.46
Underwood Creek	Main Stem	0.549	PF6	136.00	672.90	674.76	0.53	674.91	0.006437	3.18	42.73	31.64	0.48
Underwood Creek	Main Stem	0.549	PF7	270.00	672.90	675.56	0.70	675.79	0.005789	3.89	69.38	34.78	0.49
Underwood Creek	Main Stem	0.540	PF1	3.00	672.57	673.09	0.06	673.09	0.007018	0.77	3.89	26.26	0.35
Underwood Creek	Main Stem	0.540	PF2	5.00	672.57	673.14	0.09	673.15	0.007004	0.94	5.31	26.48	0.37
Underwood Creek	Main Stem	0.540	PF3	10.00	672.57	673.25	0.12	673.27	0.006569	1.21	8.26	26.92	0.38
Underwood Creek	Main Stem	0.540	PF4	23.00	672.57	673.46	0.20	673.50	0.006428	1.66	13.89	27.75	0.41
Underwood Creek	Main Stem	0.540	PF5	70.00	672.57	673.94	0.38	674.04	0.006556	2.52	27.74	29.68	0.46
Underwood Creek	Main Stem	0.540	PF6	136.00	672.57	674.45	0.51	674.60	0.006172	3.14	43.32	31.71	0.47
Underwood Creek	Main Stem	0.540	PF7	270.00	672.57	675.29	0.65	675.51	0.005224	3.77	71.66	34.78	0.46
Underwood Creek	Main Stem	0.531	PF1	3.00	672.24	672.76	0.06	672.77	0.006240	0.74	4.03	26.28	0.33
Underwood Creek	Main Stem	0.531	PF2	5.00	672.24	672.82	0.08	672.83	0.006146	0.91	5.52	26.51	0.35
Underwood Creek	Main Stem	0.531	PF3	10.00	672.24	672.92	0.13	672.94	0.006634	1.21	8.24	26.91	0.39
Underwood Creek	Main Stem	0.531	PF4	23.00	672.24	673.12	0.21	673.16	0.006763	1.68	13.68	27.71	0.42
Underwood Creek	Main Stem	0.531	PF5	70.00	672.24	673.62	0.37	673.71	0.006397	2.50	27.95	29.69	0.45
Underwood Creek	Main Stem	0.531	PF6	136.00	672.24	674.16	0.48	674.30	0.005591	3.04	44.72	31.87	0.45
Underwood Creek	Main Stem	0.531	PF7	270.00	672.24	675.07	0.58	675.27	0.004484	3.59	75.18	34.78	0.43
Underwood Creek	Main Stem	0.521	PF1	3.00	671.91	672.42	0.07	672.43	0.007570	0.79	3.80	26.25	0.37
Underwood Creek	Main Stem	0.521	PF2	5.00	671.91	672.47	0.09	672.49	0.007858	0.98	5.13	26.45	0.39
Underwood Creek	Main Stem	0.521	PF3	10.00	671.91	672.59	0.12	672.61	0.006587	1.21	8.26	26.92	0.39
Underwood Creek	Main Stem	0.521	PF4	23.00	671.91	672.80	0.20	672.84	0.006459	1.66	13.87	27.74	0.41
Underwood Creek	Main Stem	0.521	PF5	70.00	671.91	673.32	0.34	673.41	0.005753	2.42	28.91	29.82	0.43
Underwood Creek	Main Stem	0.521	PF6	136.00	671.91	673.92	0.42	674.04	0.004638	2.86	47.52	32.22	0.42
Underwood Creek	Main Stem	0.521	PF7	270.00	671.91	674.88	0.50	675.06	0.003648	3.36	80.24	34.78	0.39
Underwood Creek	Main Stem	0.512	PF1	3.00	671.59	672.12	0.05	672.13	0.005085	0.70	4.29	26.32	0.31
Underwood Creek	Main Stem	0.512	PF2	5.00	671.59	672.19	0.06	672.20	0.004424	0.82	6.11	26.60	0.30
Underwood Creek	Main Stem	0.512	PF3	10.00	671.59	672.27	0.12	672.30	0.006312	1.20	8.36	26.94	0.38
Underwood Creek	Main Stem	0.512	PF4	23.00	671.59	672.47	0.20	672.51	0.006706	1.68	13.71	27.72	0.42
Underwood Creek	Main Stem	0.512	PF5	70.00	671.59	673.07	0.29	673.15	0.004574	2.25	31.11	30.13	0.39
Underwood Creek	Main Stem	0.512	PF6	136.00	671.59	673.73	0.34	673.84	0.003559	2.62	51.83	32.77	0.37
Underwood Creek	Main Stem	0.512	PF7	270.00	671.59	674.74	0.42	674.89	0.002892	3.13	86.37	34.78	0.35
Underwood Creek	Main Stem	0.503	PF1	3.00	671.26	671.76	0.09	671.77	0.010776	0.88	3.42	26.19	0.43
Underwood Creek	Main Stem	0.503	PF2	5.00	671.26	671.78	0.17	671.80	0.017702	1.25	4.01	26.28	0.56
Underwood Creek	Main Stem	0.503	PF3	10.00	671.26	671.92	0.14	671.95	0.007850	1.28	7.82	26.85	0.42
Underwood Creek	Main Stem	0.503	PF4	23.00	671.26	672.21	0.15	672.24	0.004428	1.47	15.60	27.98	0.35
Underwood Creek	Main Stem	0.503	PF5	70.00	671.26	672.91	0.21	672.96	0.002860	1.94	36.15	30.78	0.31
Underwood Creek	Main Stem	0.503	PF6	136.00	671.26	673.60	0.26	673.68	0.002474	2.33	58.39	33.54	0.31

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.503	PF7	270.00	671.26	674.63	0.35	674.76	0.002215	2.87	93.99	34.78	0.31
Underwood Creek	Main Stem	0.493	PF1	3.00	670.93	671.48	0.04	671.49	0.003477	0.62	4.81	26.40	0.26
Underwood Creek	Main Stem	0.493	PF2	5.00	670.93	671.63	0.03	671.64	0.001286	0.56	8.91	27.01	0.17
Underwood Creek	Main Stem	0.493	PF3	10.00	670.93	671.80	0.04	671.80	0.001389	0.75	13.33	27.66	0.19
Underwood Creek	Main Stem	0.493	PF4	23.00	670.93	672.10	0.07	672.12	0.001494	1.05	21.90	28.87	0.21
Underwood Creek	Main Stem	0.493	PF5	70.00	670.93	672.81	0.13	672.85	0.001603	1.61	43.58	31.72	0.24
Underwood Creek	Main Stem	0.493	PF6	136.00	670.93	673.51	0.19	673.58	0.001657	2.04	66.67	34.51	0.26
Underwood Creek	Main Stem	0.493	PF7	270.00	670.93	674.55	0.28	674.65	0.001681	2.63	102.64	34.78	0.27
Underwood Creek	Main Stem	0.492	PF1	3.00	670.89	671.46	0.03	671.47	0.002459	0.56	5.35	26.48	0.22
Underwood Creek	Main Stem	0.492	PF2	5.00	670.89	671.63	0.02	671.63	0.000945	0.51	9.79	27.15	0.15
Underwood Creek	Main Stem	0.492	PF3	10.00	670.89	671.79	0.04	671.79	0.001131	0.70	14.21	27.79	0.17
Underwood Creek	Main Stem	0.492	PF4	23.00	670.89	672.09	0.06	672.11	0.001318	1.01	22.79	29.00	0.20
Underwood Creek	Main Stem	0.492	PF5	70.00	670.89	672.80	0.13	672.84	0.001500	1.57	44.54	31.87	0.23
Underwood Creek	Main Stem	0.492	PF6	136.00	670.89	673.50	0.19	673.56	0.001582	2.01	67.73	34.66	0.25
Underwood Creek	Main Stem	0.492	PF7	270.00	670.89	674.54	0.28	674.64	0.001629	2.60	103.69	34.78	0.27
Underwood Creek	Main Stem	0.491	PF1	3.00	670.87	671.44	0.08	671.46	0.002966	1.01	2.98	6.93	0.27
Underwood Creek	Main Stem	0.491	PF2	5.00	670.87	671.62	0.05	671.63	0.003059	0.80	6.28	21.58	0.26
Underwood Creek	Main Stem	0.491	PF3	10.00	670.87	671.77	0.08	671.79	0.002978	1.03	9.72	22.21	0.27
Underwood Creek	Main Stem	0.491	PF4	23.00	670.87	672.07	0.13	672.10	0.002937	1.40	16.46	23.40	0.29
Underwood Creek	Main Stem	0.491	PF5	70.00	670.87	672.77	0.23	672.83	0.002914	2.07	33.81	26.20	0.32
Underwood Creek	Main Stem	0.491	PF6	136.00	670.87	673.45	0.32	673.55	0.002905	2.58	52.62	28.93	0.34
Underwood Creek	Main Stem	0.491	PF7	270.00	670.87	674.47	0.44	674.63	0.002885	3.21	84.19	33.02	0.35
Underwood Creek	Main Stem	0.484	PF1	3.00	670.75	671.33	0.08	671.34	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.484	PF2	5.00	670.75	671.50	0.05	671.51	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.484	PF3	10.00	670.75	671.66	0.08	671.67	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.484	PF4	23.00	670.75	671.95	0.12	671.98	0.002871	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.484	PF5	70.00	670.75	672.65	0.23	672.72	0.002883	2.06	33.92	26.20	0.32
Underwood Creek	Main Stem	0.484	PF6	136.00	670.75	673.33	0.32	673.44	0.002885	2.58	52.72	28.93	0.34
Underwood Creek	Main Stem	0.484	PF7	270.00	670.75	674.35	0.44	674.51	0.002872	3.20	84.29	33.00	0.35
Underwood Creek	Main Stem	0.474	PF1	3.00	670.61	671.18	0.08	671.20	0.002994	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.474	PF2	5.00	670.61	671.36	0.05	671.37	0.002955	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.474	PF3	10.00	670.61	671.51	0.08	671.53	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.474	PF4	23.00	670.61	671.81	0.13	671.84	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.474	PF5	70.00	670.61	672.51	0.23	672.57	0.002922	2.07	33.78	26.19	0.32
Underwood Creek	Main Stem	0.474	PF6	136.00	670.61	673.19	0.32	673.29	0.002909	2.59	52.59	28.93	0.34
Underwood Creek	Main Stem	0.474	PF7	270.00	670.61	674.21	0.44	674.37	0.002883	3.21	84.21	33.02	0.35
Underwood Creek	Main Stem	0.465	PF1	3.00	670.46	671.04	0.08	671.05	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.465	PF2	5.00	670.46	671.21	0.05	671.22	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.465	PF3	10.00	670.46	671.37	0.08	671.38	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.465	PF4	23.00	670.46	671.66	0.12	671.69	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.465	PF5	70.00	670.46	672.36	0.23	672.43	0.002884	2.06	33.92	26.20	0.32
Underwood Creek	Main Stem	0.465	PF6	136.00	670.46	673.04	0.32	673.15	0.002884	2.58	52.73	28.93	0.34
Underwood Creek	Main Stem	0.465	PF7	270.00	670.46	674.07	0.44	674.23	0.002864	3.20	84.37	33.01	0.35
Underwood Creek	Main Stem	0.456	PF1	3.00	670.32	670.89	0.08	670.91	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.456	PF2	5.00	670.32	671.07	0.05	671.08	0.002953	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.456	PF3	10.00	670.32	671.22	0.08	671.24	0.003010	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.456	PF4	23.00	670.32	671.52	0.13	671.55	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.456	PF5	70.00	670.32	672.22	0.23	672.28	0.002922	2.07	33.78	26.19	0.32
Underwood Creek	Main Stem	0.456	PF6	136.00	670.32	672.90	0.32	673.00	0.002907	2.59	52.60	28.93	0.34
Underwood Creek	Main Stem	0.456	PF7	270.00	670.32	673.92	0.44	674.08	0.002873	3.20	84.31	33.03	0.35
Underwood Creek	Main Stem	0.446	PF1	3.00	670.17	670.75	0.08	670.76	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.446	PF2	5.00	670.17	670.92	0.05	670.93	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.446	PF3	10.00	670.17	671.08	0.08	671.09	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.446	PF4	23.00	670.17	671.37	0.12	671.40	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.446	PF5	70.00	670.17	672.07	0.23	672.14	0.002884	2.06	33.92	26.20	0.32
Underwood Creek	Main Stem	0.446	PF6	136.00	670.17	672.76	0.32	672.86	0.002881	2.58	52.75	28.93	0.34
Underwood Creek	Main Stem	0.446	PF7	270.00	670.17	673.78	0.43	673.94	0.002852	3.20	84.49	33.02	0.35
Underwood Creek	Main Stem	0.437	PF1	3.00	670.03	670.60	0.08	670.62	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.437	PF2	5.00	670.03	670.78	0.05	670.79	0.002953	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.437	PF3	10.00	670.03	670.93	0.08	670.95	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.437	PF4	23.00	670.03	671.23	0.13	671.26	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.437	PF5	70.00	670.03	671.93	0.23	671.99	0.002922	2.07	33.78	26.20	0.32
Underwood Creek	Main Stem	0.437	PF6	136.00	670.03	672.61	0.32	672.71	0.002904	2.58	52.62	28.93	0.34
Underwood Creek	Main Stem	0.437	PF7	270.00	670.03	673.64	0.43	673.80	0.002859	3.20	84.46	33.05	0.35
Underwood Creek	Main Stem	0.427	PF1	3.00	669.88	670.46	0.08	670.47	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.427	PF2	5.00	669.88	670.63	0.05	670.64	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.427	PF3	10.00	669.88	670.79	0.08	670.80	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.427	PF4	23.00	669.88	671.08	0.12	671.11	0.002871	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.427	PF5	70.00	669.88	671.78	0.23	671.85	0.002883	2.06	33.92	26.20	0.32
Underwood Creek	Main Stem	0.427	PF6	136.00	669.88	672.47	0.32	672.57	0.002876	2.58	52.78	28.93	0.34
Underwood Creek	Main Stem	0.427	PF7	270.00	669.88	673.50	0.43	673.65	0.002836	3.19	84.66	33.04	0.35
Underwood Creek	Main Stem	0.418	PF1	3.00	669.74	670.31	0.08	670.33	0.002994	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.418	PF2	5.00	669.74	670.49	0.05	670.50	0.002955	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.418	PF3	10.00	669.74	670.64	0.08	670.66	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.418	PF4	23.00	669.74	670.94	0.13	670.97	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.418	PF5	70.00	669.74	671.64	0.23	671.70	0.002921	2.07	33.78	26.20	0.32
Underwood Creek	Main Stem	0.418	PF6	136.00	669.74	672.32	0.32	672.43	0.002898	2.58	52.66	28.94	0.34

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.418	PF7	270.00	669.74	673.35	0.43	673.51	0.002839	3.19	84.66	33.07	0.35
Underwood Creek	Main Stem	0.408	PF1	3.00	669.59	670.17	0.08	670.18	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.408	PF2	5.00	669.59	670.34	0.05	670.35	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.408	PF3	10.00	669.59	670.50	0.08	670.51	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.408	PF4	23.00	669.59	670.79	0.12	670.82	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.408	PF5	70.00	669.59	671.49	0.23	671.56	0.002882	2.06	33.92	26.20	0.32
Underwood Creek	Main Stem	0.408	PF6	136.00	669.59	672.18	0.31	672.28	0.002869	2.57	52.82	28.94	0.34
Underwood Creek	Main Stem	0.408	PF7	270.00	669.59	673.21	0.43	673.37	0.002812	3.18	84.91	33.07	0.35
Underwood Creek	Main Stem	0.399	PF1	3.00	669.45	670.02	0.08	670.04	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.399	PF2	5.00	669.45	670.20	0.05	670.21	0.002953	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.399	PF3	10.00	669.45	670.35	0.08	670.37	0.003010	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.399	PF4	23.00	669.45	670.65	0.13	670.68	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.399	PF5	70.00	669.45	671.35	0.23	671.41	0.002920	2.07	33.79	26.20	0.32
Underwood Creek	Main Stem	0.399	PF6	136.00	669.45	672.03	0.32	672.14	0.002887	2.58	52.73	28.95	0.34
Underwood Creek	Main Stem	0.399	PF7	270.00	669.45	673.07	0.43	673.23	0.002811	3.18	84.95	33.11	0.35
Underwood Creek	Main Stem	0.389	PF1	3.00	669.30	669.88	0.08	669.89	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.389	PF2	5.00	669.30	670.05	0.05	670.06	0.002797	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.389	PF3	10.00	669.30	670.21	0.08	670.22	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.389	PF4	23.00	669.30	670.50	0.12	670.53	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.389	PF5	70.00	669.30	671.20	0.23	671.27	0.002881	2.06	33.93	26.20	0.32
Underwood Creek	Main Stem	0.389	PF6	136.00	669.30	671.89	0.31	671.99	0.002855	2.57	52.91	28.95	0.34
Underwood Creek	Main Stem	0.389	PF7	270.00	669.30	672.93	0.43	673.09	0.002779	3.17	85.26	33.11	0.35
Underwood Creek	Main Stem	0.380	PF1	3.00	669.16	669.73	0.08	669.75	0.002994	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.380	PF2	5.00	669.16	669.91	0.05	669.92	0.002955	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.380	PF3	10.00	669.16	670.06	0.08	670.08	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.380	PF4	23.00	669.16	670.36	0.13	670.39	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.380	PF5	70.00	669.16	671.06	0.23	671.12	0.002918	2.07	33.80	26.20	0.32
Underwood Creek	Main Stem	0.380	PF6	136.00	669.16	671.75	0.31	671.85	0.002869	2.57	52.83	28.96	0.34
Underwood Creek	Main Stem	0.380	PF7	270.00	669.16	672.80	0.42	672.95	0.002772	3.16	85.37	33.16	0.35
Underwood Creek	Main Stem	0.370	PF1	3.00	669.01	669.59	0.08	669.60	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.370	PF2	5.00	669.01	669.76	0.05	669.77	0.002795	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.370	PF3	10.00	669.01	669.92	0.08	669.93	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.370	PF4	23.00	669.01	670.21	0.12	670.24	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.370	PF5	70.00	669.01	670.91	0.23	670.98	0.002877	2.06	33.95	26.21	0.32
Underwood Creek	Main Stem	0.370	PF6	136.00	669.01	671.61	0.31	671.71	0.002833	2.56	53.05	28.97	0.33
Underwood Creek	Main Stem	0.370	PF7	270.00	669.01	672.66	0.42	672.81	0.002733	3.15	85.75	33.17	0.35
Underwood Creek	Main Stem	0.361	PF1	3.00	668.87	669.44	0.08	669.46	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.361	PF2	5.00	668.87	669.62	0.05	669.63	0.002953	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.361	PF3	10.00	668.87	669.77	0.08	669.79	0.003010	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.361	PF4	23.00	668.87	670.07	0.13	670.10	0.002955	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.361	PF5	70.00	668.87	670.77	0.23	670.83	0.002911	2.07	33.82	26.20	0.32
Underwood Creek	Main Stem	0.361	PF6	136.00	668.87	671.46	0.31	671.57	0.002840	2.57	53.02	28.99	0.33
Underwood Creek	Main Stem	0.361	PF7	270.00	668.87	672.52	0.42	672.68	0.002718	3.14	85.95	33.23	0.34
Underwood Creek	Main Stem	0.351	PF1	3.00	668.72	669.30	0.08	669.31	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.351	PF2	5.00	668.72	669.47	0.05	669.48	0.002795	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.351	PF3	10.00	668.72	669.63	0.08	669.64	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.351	PF4	23.00	668.72	669.92	0.12	669.95	0.002872	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.351	PF5	70.00	668.72	670.62	0.23	670.69	0.002868	2.06	33.98	26.21	0.32
Underwood Creek	Main Stem	0.351	PF6	136.00	668.72	671.32	0.31	671.43	0.002796	2.55	53.28	29.00	0.33
Underwood Creek	Main Stem	0.351	PF7	270.00	668.72	672.39	0.41	672.54	0.002671	3.12	86.44	33.26	0.34
Underwood Creek	Main Stem	0.342	PF1	3.00	668.58	669.15	0.08	669.17	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.342	PF2	5.00	668.58	669.33	0.05	669.34	0.002953	0.79	6.35	21.60	0.26
Underwood Creek	Main Stem	0.342	PF3	10.00	668.58	669.48	0.08	669.50	0.003010	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.342	PF4	23.00	668.58	669.78	0.13	669.81	0.002954	1.40	16.43	23.39	0.29
Underwood Creek	Main Stem	0.342	PF5	70.00	668.58	670.48	0.23	670.55	0.002899	2.07	33.87	26.21	0.32
Underwood Creek	Main Stem	0.342	PF6	136.00	668.58	671.18	0.31	671.29	0.002793	2.55	53.32	29.03	0.33
Underwood Creek	Main Stem	0.342	PF7	270.00	668.58	672.26	0.41	672.41	0.002645	3.11	86.76	33.33	0.34
Underwood Creek	Main Stem	0.332	PF1	3.00	668.43	669.01	0.08	669.02	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.332	PF2	5.00	668.43	669.18	0.05	669.19	0.002795	0.77	6.46	21.61	0.25
Underwood Creek	Main Stem	0.332	PF3	10.00	668.43	669.34	0.08	669.35	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.332	PF4	23.00	668.43	669.63	0.12	669.66	0.002871	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.332	PF5	70.00	668.43	670.34	0.22	670.40	0.002849	2.06	34.05	26.22	0.32
Underwood Creek	Main Stem	0.332	PF6	136.00	668.43	671.05	0.30	671.15	0.002737	2.53	53.66	29.06	0.33
Underwood Creek	Main Stem	0.332	PF7	270.00	668.43	672.13	0.40	672.28	0.002588	3.09	87.39	33.37	0.34
Underwood Creek	Main Stem	0.323	PF1	3.00	668.29	668.86	0.08	668.88	0.002994	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.323	PF2	5.00	668.29	669.03	0.06	669.04	0.003124	0.80	6.24	21.58	0.26
Underwood Creek	Main Stem	0.323	PF3	10.00	668.29	669.19	0.08	669.21	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.323	PF4	23.00	668.29	669.49	0.13	669.52	0.002954	1.40	16.44	23.39	0.29
Underwood Creek	Main Stem	0.323	PF5	70.00	668.29	670.19	0.23	670.26	0.002871	2.06	33.97	26.22	0.32
Underwood Creek	Main Stem	0.323	PF6	136.00	668.29	670.91	0.30	671.01	0.002718	2.53	53.81	29.10	0.33
Underwood Creek	Main Stem	0.323	PF7	270.00	668.29	672.00	0.40	672.15	0.002544	3.07	87.88	33.38	0.33
Underwood Creek	Main Stem	0.313	PF1	3.00	668.14	668.72	0.08	668.73	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.313	PF2	5.00	668.14	668.89	0.05	668.90	0.002803	0.77	6.45	21.61	0.25
Underwood Creek	Main Stem	0.313	PF3	10.00	668.14	669.05	0.08	669.06	0.002849	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.313	PF4	23.00	668.14	669.34	0.12	669.37	0.002870	1.39	16.58	23.41	0.29
Underwood Creek	Main Stem	0.313	PF5	70.00	668.14	670.05	0.22	670.12	0.002809	2.05	34.21	26.25	0.32
Underwood Creek	Main Stem	0.313	PF6	136.00	668.14	670.78	0.30	670.88	0.002645	2.51	54.29	29.14	0.32

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.313	PF7	270.00	668.14	671.88	0.39	672.02	0.002470	3.04	88.70	33.38	0.33
Underwood Creek	Main Stem	0.304	PF1	3.00	668.00	668.57	0.08	668.59	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.304	PF2	5.00	668.00	668.74	0.06	668.75	0.003121	0.80	6.25	21.58	0.26
Underwood Creek	Main Stem	0.304	PF3	10.00	668.00	668.90	0.08	668.92	0.003010	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.304	PF4	23.00	668.00	669.20	0.13	669.23	0.002952	1.40	16.44	23.39	0.29
Underwood Creek	Main Stem	0.304	PF5	70.00	668.00	669.91	0.22	669.98	0.002812	2.05	34.21	26.26	0.32
Underwood Creek	Main Stem	0.304	PF6	136.00	668.00	670.65	0.29	670.74	0.002602	2.49	54.61	29.21	0.32
Underwood Creek	Main Stem	0.304	PF7	270.00	668.00	671.76	0.38	671.90	0.002409	3.02	89.42	33.38	0.33
Underwood Creek	Main Stem	0.295	PF1	3.00	667.85	668.43	0.08	668.44	0.002857	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.295	PF2	5.00	667.85	668.60	0.05	668.61	0.002814	0.78	6.45	21.61	0.25
Underwood Creek	Main Stem	0.295	PF3	10.00	667.85	668.76	0.08	668.78	0.002848	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.295	PF4	23.00	667.85	669.05	0.12	669.08	0.002864	1.39	16.60	23.41	0.29
Underwood Creek	Main Stem	0.295	PF5	70.00	667.85	669.78	0.22	669.84	0.002732	2.03	34.53	26.29	0.31
Underwood Creek	Main Stem	0.295	PF6	136.00	667.85	670.52	0.28	670.62	0.002506	2.46	55.29	29.28	0.32
Underwood Creek	Main Stem	0.295	PF7	270.00	667.85	671.64	0.37	671.78	0.002320	2.98	90.49	33.38	0.32
Underwood Creek	Main Stem	0.285	PF1	3.00	667.71	668.28	0.08	668.30	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.285	PF2	5.00	667.71	668.45	0.06	668.46	0.003108	0.80	6.25	21.58	0.26
Underwood Creek	Main Stem	0.285	PF3	10.00	667.71	668.61	0.08	668.63	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.285	PF4	23.00	667.71	668.91	0.13	668.94	0.002942	1.40	16.46	23.40	0.29
Underwood Creek	Main Stem	0.285	PF5	70.00	667.71	669.64	0.22	669.70	0.002699	2.02	34.67	26.33	0.31
Underwood Creek	Main Stem	0.285	PF6	136.00	667.71	670.40	0.28	670.49	0.002435	2.44	55.84	29.38	0.31
Underwood Creek	Main Stem	0.285	PF7	270.00	667.71	671.53	0.36	671.66	0.002243	2.95	91.49	33.38	0.31
Underwood Creek	Main Stem	0.276	PF1	3.00	667.56	668.14	0.08	668.15	0.002860	0.99	3.02	6.96	0.27
Underwood Creek	Main Stem	0.276	PF2	5.00	667.56	668.31	0.05	668.32	0.002833	0.78	6.43	21.61	0.25
Underwood Creek	Main Stem	0.276	PF3	10.00	667.56	668.47	0.08	668.49	0.002843	1.01	9.86	22.23	0.27
Underwood Creek	Main Stem	0.276	PF4	23.00	667.56	668.77	0.12	668.80	0.002837	1.38	16.65	23.42	0.29
Underwood Creek	Main Stem	0.276	PF5	70.00	667.56	669.51	0.21	669.57	0.002580	1.99	35.18	26.39	0.30
Underwood Creek	Main Stem	0.276	PF6	136.00	667.56	670.28	0.27	670.37	0.002313	2.39	56.81	29.48	0.30
Underwood Creek	Main Stem	0.276	PF7	270.00	667.56	671.42	0.35	671.55	0.002139	2.91	92.87	33.38	0.31
Underwood Creek	Main Stem	0.266	PF1	3.00	667.42	667.99	0.08	668.01	0.002995	1.01	2.97	6.92	0.27
Underwood Creek	Main Stem	0.266	PF2	5.00	667.42	668.16	0.06	668.17	0.003088	0.80	6.27	21.58	0.26
Underwood Creek	Main Stem	0.266	PF3	10.00	667.42	668.32	0.08	668.34	0.003011	1.03	9.69	22.21	0.28
Underwood Creek	Main Stem	0.266	PF4	23.00	667.42	668.62	0.12	668.65	0.002890	1.39	16.55	23.41	0.29
Underwood Creek	Main Stem	0.266	PF5	70.00	667.42	669.38	0.20	669.44	0.002496	1.97	35.57	26.47	0.30
Underwood Creek	Main Stem	0.266	PF6	136.00	667.42	670.17	0.26	670.26	0.002211	2.36	57.69	29.63	0.30
Underwood Creek	Main Stem	0.266	PF7	270.00	667.42	671.32	0.34	671.45	0.002047	2.87	94.20	33.38	0.30
Underwood Creek	Main Stem	0.257	PF1	3.00	667.27	667.85	0.08	667.86	0.002876	1.00	3.01	6.96	0.27
Underwood Creek	Main Stem	0.257	PF2	5.00	667.27	668.02	0.05	668.03	0.002863	0.78	6.41	21.61	0.25
Underwood Creek	Main Stem	0.257	PF3	10.00	667.27	668.18	0.08	668.20	0.002825	1.01	9.88	22.24	0.27
Underwood Creek	Main Stem	0.257	PF4	23.00	667.27	668.48	0.12	668.51	0.002772	1.37	16.77	23.44	0.29
Underwood Creek	Main Stem	0.257	PF5	70.00	667.27	669.27	0.19	669.32	0.002324	1.92	36.41	26.58	0.29
Underwood Creek	Main Stem	0.257	PF6	136.00	667.27	670.07	0.25	670.15	0.002065	2.30	59.03	29.78	0.29
Underwood Creek	Main Stem	0.257	PF7	270.00	667.27	671.22	0.33	671.35	0.001933	2.81	95.94	33.38	0.29
Underwood Creek	Main Stem	0.247	PF1	3.00	667.13	667.70	0.08	667.71	0.003023	1.01	2.96	6.91	0.27
Underwood Creek	Main Stem	0.247	PF2	5.00	667.13	667.88	0.05	667.89	0.003059	0.80	6.28	21.58	0.26
Underwood Creek	Main Stem	0.247	PF3	10.00	667.13	668.03	0.08	668.05	0.002941	1.02	9.76	22.22	0.27
Underwood Creek	Main Stem	0.247	PF4	23.00	667.13	668.34	0.12	668.37	0.002730	1.36	16.85	23.46	0.28
Underwood Creek	Main Stem	0.247	PF5	70.00	667.13	669.16	0.18	669.21	0.002176	1.88	37.22	26.72	0.28
Underwood Creek	Main Stem	0.247	PF6	136.00	667.13	669.97	0.23	670.05	0.001938	2.25	60.33	29.98	0.28
Underwood Creek	Main Stem	0.247	PF7	270.00	667.13	671.13	0.31	671.25	0.001831	2.77	97.63	33.38	0.28
Underwood Creek	Main Stem	0.238	PF1	3.00	666.98	667.55	0.08	667.57	0.002923	1.00	3.00	6.94	0.27
Underwood Creek	Main Stem	0.238	PF2	5.00	666.98	667.73	0.05	667.74	0.002911	0.78	6.38	21.60	0.25
Underwood Creek	Main Stem	0.238	PF3	10.00	666.98	667.89	0.08	667.91	0.002800	1.01	9.91	22.24	0.27
Underwood Creek	Main Stem	0.238	PF4	23.00	666.98	668.22	0.11	668.24	0.002484	1.32	17.36	23.54	0.27
Underwood Creek	Main Stem	0.238	PF5	70.00	666.98	669.06	0.17	669.11	0.001958	1.82	38.53	26.90	0.27
Underwood Creek	Main Stem	0.238	PF6	136.00	666.98	669.88	0.22	669.96	0.001777	2.19	62.11	30.19	0.27
Underwood Creek	Main Stem	0.238	PF7	270.00	666.98	671.05	0.30	671.16	0.001713	2.71	99.73	33.38	0.28
Underwood Creek	Main Stem	0.228	PF1	3.00	666.84	667.40	0.08	667.42	0.003209	1.04	2.90	6.86	0.28
Underwood Creek	Main Stem	0.228	PF2	5.00	666.84	667.59	0.05	667.60	0.003004	0.79	6.32	21.59	0.26
Underwood Creek	Main Stem	0.228	PF3	10.00	666.84	667.75	0.08	667.77	0.002772	1.01	9.94	22.25	0.27
Underwood Creek	Main Stem	0.228	PF4	23.00	666.84	668.10	0.10	668.13	0.002243	1.28	17.93	23.65	0.26
Underwood Creek	Main Stem	0.228	PF5	70.00	666.84	668.97	0.16	669.01	0.001765	1.76	39.88	27.11	0.26
Underwood Creek	Main Stem	0.228	PF6	136.00	666.84	669.80	0.21	669.87	0.001636	2.13	63.89	30.45	0.26
Underwood Creek	Main Stem	0.228	PF7	270.00	666.84	670.97	0.28	671.08	0.001607	2.65	101.81	33.38	0.27
Underwood Creek	Main Stem	0.219	PF1	3.00	666.69	667.22	0.09	667.24	0.003817	1.10	2.73	6.71	0.30
Underwood Creek	Main Stem	0.219	PF2	5.00	666.69	667.44	0.05	667.45	0.002995	0.79	6.32	21.59	0.26
Underwood Creek	Main Stem	0.219	PF3	10.00	666.69	667.63	0.07	667.64	0.002329	0.95	10.50	22.35	0.25
Underwood Creek	Main Stem	0.219	PF4	23.00	666.69	668.00	0.09	668.02	0.001825	1.20	19.15	23.84	0.24
Underwood Creek	Main Stem	0.219	PF5	70.00	666.69	668.89	0.14	668.93	0.001531	1.67	41.80	27.38	0.24
Underwood Creek	Main Stem	0.219	PF6	136.00	666.69	669.73	0.19	669.79	0.001475	2.06	66.17	30.73	0.25
Underwood Creek	Main Stem	0.219	PF7	270.00	666.69	670.89	0.27	671.00	0.001491	2.59	104.29	33.38	0.26
Underwood Creek	Main Stem	0.209	PF1	3.00	666.55	667.13	0.04	667.14	0.001348	0.72	4.18	8.96	0.19
Underwood Creek	Main Stem	0.209	PF2	5.00	666.55	667.34	0.03	667.34	0.001529	0.63	7.89	22.72	0.19
Underwood Creek	Main Stem	0.209	PF3	10.00	666.55	667.54	0.04	667.55	0.001328	0.79	12.73	23.81	0.19
Underwood Creek	Main Stem	0.209	PF4	23.00	666.55	667.93	0.06	667.95	0.001202	1.03	22.39	25.86	0.19
Underwood Creek	Main Stem	0.209	PF5	70.00	666.55	668.83	0.11	668.86	0.001135	1.47	47.64	30.58	0.21
Underwood Creek	Main Stem	0.209	PF6	136.00	666.55	669.67	0.15	669.72	0.001123	1.81	75.33	35.02	0.22

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.209	PF7	270.00	666.55	670.85	0.21	670.93	0.001122	2.26	119.29	38.28	0.23
Underwood Creek	Main Stem	0.207	PF1	3.00	666.49	667.12	0.03	667.12	0.001002	0.65	4.63	9.26	0.16
Underwood Creek	Main Stem	0.207	PF2	5.00	666.49	667.33	0.02	667.33	0.001001	0.56	9.01	22.98	0.16
Underwood Creek	Main Stem	0.207	PF3	10.00	666.49	667.53	0.04	667.54	0.001002	0.72	13.92	24.08	0.17
Underwood Creek	Main Stem	0.207	PF4	23.00	666.49	667.92	0.06	667.94	0.001010	0.97	23.69	26.13	0.18
Underwood Creek	Main Stem	0.207	PF5	70.00	666.49	668.82	0.10	668.85	0.001032	1.42	49.20	30.84	0.20
Underwood Creek	Main Stem	0.207	PF6	136.00	666.49	669.66	0.14	669.71	0.001050	1.76	77.11	35.29	0.21
Underwood Creek	Main Stem	0.207	PF7	270.00	666.49	670.84	0.20	670.91	0.001066	2.23	121.23	38.28	0.22
Underwood Creek	Main Stem	0.200	PF1	3.00	666.45	667.08	0.03	667.08	0.001002	0.65	4.63	9.26	0.16
Underwood Creek	Main Stem	0.200	PF2	5.00	666.45	667.29	0.02	667.29	0.001000	0.55	9.01	22.98	0.16
Underwood Creek	Main Stem	0.200	PF3	10.00	666.45	667.49	0.04	667.50	0.001002	0.72	13.92	24.08	0.17
Underwood Creek	Main Stem	0.200	PF4	23.00	666.45	667.88	0.06	667.90	0.001011	0.97	23.68	26.13	0.18
Underwood Creek	Main Stem	0.200	PF5	70.00	666.45	668.78	0.10	668.81	0.001035	1.42	49.16	30.84	0.20
Underwood Creek	Main Stem	0.200	PF6	136.00	666.45	669.62	0.14	669.67	0.001053	1.77	77.04	35.28	0.21
Underwood Creek	Main Stem	0.200	PF7	270.00	666.45	670.79	0.20	670.87	0.001069	2.23	121.12	38.28	0.22
Underwood Creek	Main Stem	0.190	PF1	3.00	666.40	667.03	0.03	667.03	0.001003	0.65	4.62	9.26	0.16
Underwood Creek	Main Stem	0.190	PF2	5.00	666.40	667.24	0.02	667.24	0.001001	0.56	9.01	22.98	0.16
Underwood Creek	Main Stem	0.190	PF3	10.00	666.40	667.44	0.04	667.45	0.001003	0.72	13.91	24.07	0.17
Underwood Creek	Main Stem	0.190	PF4	23.00	666.40	667.83	0.06	667.85	0.001013	0.97	23.67	26.12	0.18
Underwood Creek	Main Stem	0.190	PF5	70.00	666.40	668.73	0.10	668.76	0.001038	1.43	49.10	30.83	0.20
Underwood Creek	Main Stem	0.190	PF6	136.00	666.40	669.57	0.14	669.62	0.001057	1.77	76.93	35.27	0.21
Underwood Creek	Main Stem	0.190	PF7	270.00	666.40	670.74	0.20	670.82	0.001073	2.23	120.98	38.28	0.22
Underwood Creek	Main Stem	0.181	PF1	3.00	666.35	666.98	0.03	666.98	0.001003	0.65	4.62	9.26	0.16
Underwood Creek	Main Stem	0.181	PF2	5.00	666.35	667.19	0.02	667.19	0.001001	0.56	9.01	22.98	0.16
Underwood Creek	Main Stem	0.181	PF3	10.00	666.35	667.39	0.04	667.40	0.001004	0.72	13.91	24.07	0.17
Underwood Creek	Main Stem	0.181	PF4	23.00	666.35	667.78	0.06	667.80	0.001016	0.97	23.65	26.12	0.18
Underwood Creek	Main Stem	0.181	PF5	70.00	666.35	668.67	0.10	668.71	0.001042	1.43	49.03	30.82	0.20
Underwood Creek	Main Stem	0.181	PF6	136.00	666.35	669.51	0.14	669.56	0.001061	1.77	76.82	35.25	0.21
Underwood Creek	Main Stem	0.181	PF7	270.00	666.35	670.69	0.20	670.76	0.001078	2.23	120.83	38.28	0.22
Underwood Creek	Main Stem	0.171	PF1	3.00	666.30	666.93	0.03	666.93	0.001005	0.65	4.62	9.26	0.16
Underwood Creek	Main Stem	0.171	PF2	5.00	666.30	667.14	0.02	667.14	0.001002	0.56	9.01	22.98	0.16
Underwood Creek	Main Stem	0.171	PF3	10.00	666.30	667.34	0.04	667.35	0.001006	0.72	13.90	24.07	0.17
Underwood Creek	Main Stem	0.171	PF4	23.00	666.30	667.73	0.06	667.75	0.001018	0.97	23.63	26.11	0.18
Underwood Creek	Main Stem	0.171	PF5	70.00	666.30	668.62	0.10	668.65	0.001047	1.43	48.96	30.80	0.20
Underwood Creek	Main Stem	0.171	PF6	136.00	666.30	669.46	0.14	669.51	0.001066	1.77	76.71	35.23	0.21
Underwood Creek	Main Stem	0.171	PF7	270.00	666.30	670.63	0.20	670.71	0.001082	2.24	120.67	38.28	0.22
Underwood Creek	Main Stem	0.162	PF1	3.00	666.25	666.88	0.03	666.88	0.001007	0.65	4.62	9.26	0.16
Underwood Creek	Main Stem	0.162	PF2	5.00	666.25	667.09	0.02	667.09	0.001003	0.56	9.00	22.97	0.16
Underwood Creek	Main Stem	0.162	PF3	10.00	666.25	667.29	0.04	667.30	0.001008	0.72	13.90	24.07	0.17
Underwood Creek	Main Stem	0.162	PF4	23.00	666.25	667.68	0.06	667.69	0.001022	0.97	23.60	26.11	0.18
Underwood Creek	Main Stem	0.162	PF5	70.00	666.25	668.57	0.10	668.60	0.001052	1.43	48.88	30.79	0.20
Underwood Creek	Main Stem	0.162	PF6	136.00	666.25	669.41	0.14	669.46	0.001071	1.78	76.58	35.21	0.21
Underwood Creek	Main Stem	0.162	PF7	270.00	666.25	670.58	0.20	670.66	0.001087	2.24	120.50	38.28	0.22
Underwood Creek	Main Stem	0.152	PF1	3.00	666.20	666.83	0.03	666.83	0.001009	0.65	4.62	9.25	0.16
Underwood Creek	Main Stem	0.152	PF2	5.00	666.20	667.03	0.02	667.04	0.001003	0.56	9.00	22.97	0.16
Underwood Creek	Main Stem	0.152	PF3	10.00	666.20	667.24	0.04	667.25	0.001010	0.72	13.89	24.07	0.17
Underwood Creek	Main Stem	0.152	PF4	23.00	666.20	667.63	0.06	667.64	0.001026	0.98	23.57	26.10	0.18
Underwood Creek	Main Stem	0.152	PF5	70.00	666.20	668.52	0.10	668.55	0.001058	1.43	48.79	30.78	0.20
Underwood Creek	Main Stem	0.152	PF6	136.00	666.20	669.35	0.14	669.40	0.001076	1.78	76.44	35.19	0.21
Underwood Creek	Main Stem	0.152	PF7	270.00	666.20	670.52	0.20	670.60	0.001092	2.24	120.31	38.28	0.22
Underwood Creek	Main Stem	0.143	PF1	3.00	666.15	666.78	0.03	666.78	0.001012	0.65	4.61	9.25	0.16
Underwood Creek	Main Stem	0.143	PF2	5.00	666.15	666.98	0.02	666.99	0.001005	0.56	9.00	22.97	0.16
Underwood Creek	Main Stem	0.143	PF3	10.00	666.15	667.19	0.04	667.20	0.001013	0.72	13.87	24.07	0.17
Underwood Creek	Main Stem	0.143	PF4	23.00	666.15	667.58	0.06	667.59	0.001032	0.98	23.53	26.09	0.18
Underwood Creek	Main Stem	0.143	PF5	70.00	666.15	668.46	0.10	668.49	0.001064	1.44	48.70	30.76	0.20
Underwood Creek	Main Stem	0.143	PF6	136.00	666.15	669.30	0.14	669.35	0.001082	1.78	76.30	35.17	0.21
Underwood Creek	Main Stem	0.143	PF7	270.00	666.15	670.47	0.20	670.55	0.001097	2.25	120.12	38.28	0.22
Underwood Creek	Main Stem	0.134	PF1	3.00	666.10	666.72	0.03	666.73	0.001015	0.65	4.60	9.25	0.16
Underwood Creek	Main Stem	0.134	PF2	5.00	666.10	666.93	0.02	666.94	0.001007	0.56	8.99	22.97	0.16
Underwood Creek	Main Stem	0.134	PF3	10.00	666.10	667.14	0.04	667.15	0.001017	0.72	13.85	24.06	0.17
Underwood Creek	Main Stem	0.134	PF4	23.00	666.10	667.53	0.06	667.54	0.001038	0.98	23.48	26.08	0.18
Underwood Creek	Main Stem	0.134	PF5	70.00	666.10	668.41	0.10	668.44	0.001071	1.44	48.59	30.74	0.20
Underwood Creek	Main Stem	0.134	PF6	136.00	666.10	669.25	0.14	669.29	0.001089	1.79	76.14	35.15	0.21
Underwood Creek	Main Stem	0.134	PF7	270.00	666.10	670.41	0.20	670.49	0.001103	2.25	119.92	38.28	0.22
Underwood Creek	Main Stem	0.124	PF1	3.00	666.05	666.67	0.03	666.68	0.001021	0.65	4.60	9.24	0.16
Underwood Creek	Main Stem	0.124	PF2	5.00	666.05	666.88	0.02	666.89	0.001011	0.56	8.98	22.97	0.16
Underwood Creek	Main Stem	0.124	PF3	10.00	666.05	667.09	0.04	667.10	0.001023	0.72	13.83	24.06	0.17
Underwood Creek	Main Stem	0.124	PF4	23.00	666.05	667.47	0.06	667.49	0.001045	0.98	23.43	26.07	0.18
Underwood Creek	Main Stem	0.124	PF5	70.00	666.05	668.36	0.10	668.39	0.001079	1.44	48.47	30.72	0.20
Underwood Creek	Main Stem	0.124	PF6	136.00	666.05	669.19	0.14	669.24	0.001096	1.79	75.97	35.12	0.21
Underwood Creek	Main Stem	0.124	PF7	270.00	666.05	670.36	0.20	670.44	0.001109	2.26	119.71	38.28	0.22
Underwood Creek	Main Stem	0.115	PF1	3.00	666.00	666.62	0.03	666.63	0.001028	0.65	4.58	9.23	0.16
Underwood Creek	Main Stem	0.115	PF2	5.00	666.00	666.83	0.02	666.84	0.001016	0.56	8.96	22.97	0.16
Underwood Creek	Main Stem	0.115	PF3	10.00	666.00	667.04	0.04	667.05	0.001030	0.72	13.80	24.05	0.17
Underwood Creek	Main Stem	0.115	PF4	23.00	666.00	667.42	0.06	667.44	0.001055	0.98	23.36	26.06	0.18
Underwood Creek	Main Stem	0.115	PF5	70.00	666.00	668.30	0.10	668.33	0.001088	1.45	48.33	30.70	0.20
Underwood Creek	Main Stem	0.115	PF6	136.00	666.00	669.14	0.14	669.19	0.001104	1.79	75.78	35.09	0.22

HEC-RAS Plan: Low Flow Rev Ph2 Locations: User Defined (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear Chan	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(lb/sq ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Underwood Creek	Main Stem	0.115	PF7	270.00	666.00	670.30	0.20	670.38	0.001116	2.26	119.48	38.28	0.23
Underwood Creek	Main Stem	0.105	PF1	3.00	665.95	666.57	0.03	666.58	0.001038	0.66	4.57	9.22	0.16
Underwood Creek	Main Stem	0.105	PF2	5.00	665.95	666.78	0.02	666.79	0.001024	0.56	8.94	22.96	0.16
Underwood Creek	Main Stem	0.105	PF3	10.00	665.95	666.99	0.04	667.00	0.001040	0.73	13.76	24.04	0.17
Underwood Creek	Main Stem	0.105	PF4	23.00	665.95	667.37	0.06	667.38	0.001066	0.99	23.28	26.04	0.18
Underwood Creek	Main Stem	0.105	PF5	70.00	665.95	668.25	0.10	668.28	0.001098	1.45	48.18	30.67	0.20
Underwood Creek	Main Stem	0.105	PF6	136.00	665.95	669.08	0.15	669.13	0.001112	1.80	75.58	35.06	0.22
Underwood Creek	Main Stem	0.105	PF7	270.00	665.95	670.25	0.21	670.33	0.001123	2.26	119.23	38.28	0.23
Underwood Creek	Main Stem	0.096	PF1	3.00	665.90	666.52	0.03	666.53	0.001051	0.66	4.55	9.21	0.17
Underwood Creek	Main Stem	0.096	PF2	5.00	665.90	666.73	0.02	666.74	0.001035	0.56	8.91	22.95	0.16
Underwood Creek	Main Stem	0.096	PF3	10.00	665.90	666.93	0.04	666.94	0.001054	0.73	13.70	24.03	0.17
Underwood Creek	Main Stem	0.096	PF4	23.00	665.90	667.31	0.06	667.33	0.001080	0.99	23.18	26.02	0.19
Underwood Creek	Main Stem	0.096	PF5	70.00	665.90	668.19	0.11	668.22	0.001109	1.46	48.02	30.64	0.21
Underwood Creek	Main Stem	0.096	PF6	136.00	665.90	669.02	0.15	669.07	0.001121	1.80	75.37	35.03	0.22
Underwood Creek	Main Stem	0.096	PF7	270.00	665.90	670.19	0.21	670.27	0.001131	2.27	118.98	38.28	0.23
Underwood Creek	Main Stem	0.086	PF1	3.00	665.85	666.47	0.03	666.47	0.001070	0.66	4.52	9.19	0.17
Underwood Creek	Main Stem	0.086	PF2	5.00	665.85	666.68	0.03	666.68	0.001053	0.56	8.87	22.94	0.16
Underwood Creek	Main Stem	0.086	PF3	10.00	665.85	666.88	0.04	666.89	0.001072	0.73	13.62	24.01	0.17
Underwood Creek	Main Stem	0.086	PF4	23.00	665.85	667.26	0.06	667.27	0.001097	1.00	23.07	26.00	0.19
Underwood Creek	Main Stem	0.086	PF5	70.00	665.85	668.13	0.11	668.17	0.001122	1.46	47.83	30.61	0.21
Underwood Creek	Main Stem	0.086	PF6	136.00	665.85	668.97	0.15	669.02	0.001131	1.81	75.14	35.00	0.22
Underwood Creek	Main Stem	0.086	PF7	270.00	665.85	670.13	0.21	670.21	0.001139	2.27	118.70	38.28	0.23
Underwood Creek	Main Stem	0.077	PF1	3.00	665.80	666.41	0.03	666.42	0.001095	0.67	4.49	9.17	0.17
Underwood Creek	Main Stem	0.077	PF2	5.00	665.80	666.63	0.03	666.63	0.001080	0.57	8.80	22.93	0.16
Underwood Creek	Main Stem	0.077	PF3	10.00	665.80	666.83	0.04	666.84	0.001098	0.74	13.52	23.99	0.17
Underwood Creek	Main Stem	0.077	PF4	23.00	665.80	667.20	0.06	667.22	0.001118	1.00	22.92	25.97	0.19
Underwood Creek	Main Stem	0.077	PF5	70.00	665.80	668.08	0.11	668.11	0.001136	1.47	47.63	30.57	0.21
Underwood Creek	Main Stem	0.077	PF6	136.00	665.80	668.91	0.15	668.96	0.001142	1.82	74.88	34.96	0.22
Underwood Creek	Main Stem	0.077	PF7	270.00	665.80	670.07	0.21	670.15	0.001148	2.28	118.41	38.28	0.23
Underwood Creek	Main Stem	0.067	PF1	3.00	665.75	666.36	0.03	666.36	0.001132	0.68	4.43	9.14	0.17
Underwood Creek	Main Stem	0.067	PF2	5.00	665.75	666.57	0.03	666.58	0.001120	0.57	8.70	22.90	0.16
Underwood Creek	Main Stem	0.067	PF3	10.00	665.75	666.77	0.04	666.78	0.001134	0.75	13.39	23.96	0.18
Underwood Creek	Main Stem	0.067	PF4	23.00	665.75	667.15	0.06	667.16	0.001144	1.01	22.75	25.94	0.19
Underwood Creek	Main Stem	0.067	PF5	70.00	665.75	668.02	0.11	668.05	0.001153	1.48	47.39	30.53	0.21
Underwood Creek	Main Stem	0.067	PF6	136.00	665.75	668.85	0.15	668.90	0.001154	1.82	74.61	34.92	0.22
Underwood Creek	Main Stem	0.067	PF7	270.00	665.75	670.02	0.21	670.10	0.001157	2.29	118.10	38.28	0.23
Underwood Creek	Main Stem	0.058	PF1	3.00	665.70	666.30	0.03	666.31	0.001189	0.69	4.36	9.09	0.18
Underwood Creek	Main Stem	0.058	PF2	5.00	665.70	666.51	0.03	666.52	0.001199	0.59	8.51	22.86	0.17
Underwood Creek	Main Stem	0.058	PF3	10.00	665.70	666.71	0.04	666.72	0.001188	0.76	13.19	23.92	0.18
Underwood Creek	Main Stem	0.058	PF4	23.00	665.70	667.09	0.06	667.10	0.001179	1.02	22.53	25.89	0.19
Underwood Creek	Main Stem	0.058	PF5	70.00	665.70	667.96	0.11	668.00	0.001171	1.49	47.13	30.49	0.21
Underwood Creek	Main Stem	0.058	PF6	136.00	665.70	668.79	0.15	668.85	0.001168	1.83	74.32	34.87	0.22
Underwood Creek	Main Stem	0.058	PF7	270.00	665.70	669.96	0.21	670.04	0.001167	2.29	117.77	38.28	0.23
Underwood Creek	Main Stem	0.057	PF1	3.00	665.69	666.29	0.03	666.30	0.001163	0.68	4.39	9.11	0.17
Underwood Creek	Main Stem	0.057	PF2	5.00	665.69	666.51	0.03	666.51	0.001163	0.58	8.60	22.88	0.17
Underwood Creek	Main Stem	0.057	PF3	10.00	665.69	666.71	0.04	666.72	0.001164	0.75	13.27	23.93	0.18
Underwood Creek	Main Stem	0.057	PF4	23.00	665.69	667.08	0.06	667.10	0.001164	1.02	22.62	25.90	0.19
Underwood Creek	Main Stem	0.057	PF5	70.00	665.69	667.96	0.11	667.99	0.001164	1.48	47.22	30.48	0.21
Underwood Creek	Main Stem	0.057	PF6	136.00	665.69	668.79	0.15	668.84	0.001163	1.83	74.39	34.85	0.22
Underwood Creek	Main Stem	0.057	PF7	270.00	665.69	669.95	0.21	670.03	0.001165	2.29	117.83	38.28	0.23

Appendix H

Water Quality Model of Proposed Discharge to Underwood Creek

Draft Water Quality Model of Proposed Discharge to Underwood Creek

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: January 25, 2010

Executive Summary

The City of Waukesha Wastewater Treatment Plant is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. To simulate water quality changes to Underwood Creek and the downstream Menomonee River, a watershed water quality model previously developed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) was obtained and updated to include a new point source for Waukesha return flow.

The updated model simulated the SEWRPC existing condition and preferred alternative (recommended plan) scenarios with Waukesha return flow set either equal to average historical operating conditions (the expected discharge condition) based upon October 2002 through August 2009 data or equal to a worst case scenario using higher flow rates and worse water quality discharge conditions (maximum potential discharge condition). The analysis used 11 years of continuous simulation, the same as the SEWRPC models.

The water quality modeling found that average water quality improved or continued to meet water quality standards or background reference concentrations for 3 out of 4 water quality parameters (fecal coliform, dissolved oxygen, and total suspended solids).

For the fourth water quality parameter (phosphorus), concentrations increased and were more frequently higher than the planning level goal used in the SEWRPC modeling (0.1 mg/L). However, the modeling results indicate that with return flow, nuisance algae growth will decrease in Underwood Creek and the Menomonee River. The WDNR is developing new phosphorus standards that could further reduce the phosphorus discharge concentration in the return flow.

Introduction

The City of Waukesha Wastewater Treatment Plant is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) developed a set of watershed simulation models to evaluate management of water quality from both point and non-point sources in the Greater Milwaukee area. The models for the Menomonee River system were utilized to evaluate the potential water quality changes of the return flow within Underwood Creek and the Menomonee River downstream of its confluence with Underwood Creek. This technical memorandum (TM) describes the process used to adapt

the SEWRPC models for evaluation of the return flow as well as the results of the evaluations.

Background

The City of Waukesha Wastewater Treatment Plant currently discharges treated effluent to the Fox River in the Mississippi River watershed. With a proposed future Lake Michigan water source, return flow back to the Great Lakes basin (Lake Michigan) will be required. The Waukesha Wastewater Treatment Plant has been investigating the potential for returning flow to Underwood Creek, a tributary to the Menomonee River and Lake Michigan. The analysis documented in this memorandum describes water quality changes associated with return flow to Underwood Creek.

SEWRPC undertook a large-scale effort detailed in *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (RWQMPU) (SEWRPC, 2007) to evaluate water quality under current conditions and potential future scenarios in the Greater Milwaukee area. These evaluations were based in part on water quality modeling using the U.S. EPA's Hydrologic Simulation Program - FORTRAN (HSPF) (Bicknell et al., 2000). This model simulates watershed hydrology, pollutant loading in runoff from the watershed, and the fate and transport of pollutants in streams and rivers. The SEWRPC model included pollutant contributions from non-point sources in the watershed, point sources, and sanitary sewer overflows (SSO). Scenarios evaluated in the model included existing conditions (Existing) and a variety of management practices which could improve water quality in the study area. A final set of management practices were selected and considered as the "Preferred Alternative" (PA).

CH2M HILL requested the HSPF models from SEWRPC to evaluate water quality changes in Underwood Creek with a proposed return flow. SEWRPC provided the HSPF models for all model segments in the Menomonee River Basin for the Existing scenario and the PA scenario.

Scenarios Modeled

Four new scenarios were modeled using continuous simulation over an 11-year period consistent with the SEWRPC RWQMPU to assess the changes under existing and future conditions with Waukesha return flow. The discharge was characterized either by actual historical effluent quality for the expected discharge condition scenario or by a worse case scenario that combined permit limits and high observed concentrations into a maximum potential discharge condition scenario. Table 1 lists the modeled scenarios.

TABLE 1
Description of Scenarios Modeled

Scenario	Description
1	Existing Conditions (no discharge to Underwood Creek)
2A	Existing Conditions with Return Flow to Underwood Creek – Expected Discharge Condition
2B	Existing Conditions with Return Flow to Underwood Creek – Maximum Potential Discharge Condition
3	RWQMPU Recommended Plan Conditions (no discharge to Underwood Creek)
3A	RWQMPU Recommended Plan Conditions with Return Flow to Underwood Creek - Expected Discharge Condition
3B	RWQMPU Recommended Plan Conditions with Return Flow to Underwood Creek – Maximum Potential Discharge Condition

Determination of Discharge Characteristics

The expected discharge concentration scenarios are characterized using monthly water quality data measured at the plant under current operating conditions. These values were calculated using data from October 1, 2002 to August 31, 2009. The processing and tabulation of these data are provided as Attachment 1 of this document. A summary of the typical values are provided as Table 2.

The maximum potential discharge condition set of runs uses discharge characteristics as specified in the plant's Wisconsin Pollutant Discharge Elimination System (WPDES) permit. If a water quality parameter was not included in the WPDES permit, representative values based upon current operation were used. In the case of phosphorus, the plant currently operates at a much lower level than the 1 mg/l permit limit and future phosphorus regulations are pending that could lower the limit. As a result, the value for the highest monthly average (October) under current actual operating conditions was used (0.24 mg/l). The estimates for TKN were specified as organic N in the model. This is conservative since TKN also includes ammonia and ammonia is specified separately. To be conservative, a future return flow rate higher than the 12.0 mgd requested beyond 2035 average day water supply demand was used (12.9 mgd = 20 cfs) as a conservative estimation of potential average day return flow. The typical values calculated based on current operation were used if there is no permit limit. In the case of fecal coliform outside of the disinfection season, to be conservative, a high value available for normal operating conditions without disinfection was used (915 cfu/100mL). Preliminary information from additional sampling indicates 915 cfu/100mL is very conservative because all additional samples reported to date have been much less than 915 cfu/100mL. The discharge characteristics for the maximum potential discharge condition runs are provided in Table 3.

Modification of the SEWRPC Models

The models for the Existing and PA scenarios were modified to include the proposed discharge to Underwood Creek. This discharge is a new input to the model. Point source inputs to the HSPF model can be specified through the use of timeseries text files. The HSPF file structure for both scenarios were modified to read in two additional files, one which specified flow, thermal load (in British Thermal Units (BTUs)), and fecal coliform and one which specified the sediment, nutrient, dissolved oxygen, and metals related water quality parameters for the point source discharge. The values in the two files are input on a 15-minute time-step and were based on monthly values specified in Tables 2 and 3.

The HSPF models were also modified to specify the location of the new discharge. Based on information from the Waukesha Wastewater Treatment Plant, this was set to model segment 901 of the Menomonee watershed (See Figure 1). Since HSPF is a lumped model, a discharge to any point in segment 901 is modeled as entering at the upstream end of segment 901. For this reason, an exact location is not required.

The baseline and return flow scenarios were run using the WinHSPF interface. The original models were run using HSPF version 12 but this is a DOS based program and WinHSPF is the version of the model currently supported by the US EPA. Differences in the coding of the model results in a slight but insignificant difference from the original model runs. The baseline and scenario models were all run using WinHSPF to provide a representative comparison of results run under the same computing platform.

TABLE 2
Expected Discharge Condition (Monthly Average Values - based on 10/02 through 8/09 data)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	Org N (mg/L)	Ammonia (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO_4 (mg/L)	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Cu (µg/L)	Zn (µg/L)
January	9.4	14.5	1.7	0.98	0.10	18.6	0.11	0.07	10.3	12.0	0.9	915	6.6	42.0
February	9.3	14.4	1.7	0.98	0.06	19.1	0.10	0.06	10.5	11.5	0.9	915	12.4	48.6
March	11.3	17.4	1.7	0.98	0.14	16.1	0.12	0.08	10.4	12.3	1.1	915	6.1	49.6
April	12.3	19.1	1.7	0.98	0.09	12.9	0.10	0.06	9.7	14.1	1.4	915	8.6	22.0
May	11.5	17.7	2.0	0.98	0.20	13.9	0.12	0.08	9.0	16.4	1.2	2	7.1	45.7
June	12.1	18.7	2.6	0.98	0.14	12.7	0.21	0.14	8.2	18.8	1.8	49	6.1	30.5
July	9.2	14.3	1.8	0.98	0.05	16.8	0.16	0.11	8.0	20.6	1.0	2	6.1	29.3
August	9.0	14.0	1.8	0.98	0.07	14.8	0.19	0.13	7.9	21.3	1.1	2	6.3	37.2
September	8.8	13.7	2.1	0.98	0.10	16.2	0.21	0.14	8.0	20.8	1.0	2	8.7	39.0
October	8.8	13.6	1.6	0.98	0.04	17.3	0.24	0.16	8.7	18.6	1.1	915	5.7	36.6
November	8.6	13.3	1.6	0.98	0.07	18.1	0.21	0.14	9.5	16.0	1.1	915	6.7	33.8
December	9.2	14.2	1.6	0.98	0.07	20.7	0.15	0.10	10.3	13.3	1.1	915	9.3	47.4

TABLE 3
Maximum Potential Discharge Condition (Monthly Values)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	Org N (mg/L)	Ammonia (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO_4 (mg/L)	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Cu (µg/L)	Zn (µg/L)
January	12.9	20.0	10.0	0.98	5.0	18.6	0.24	0.16	7.0	12.0	10.0	915	6.6	42.0
February	12.9	20.0	10.0	0.98	5.2	19.1	0.24	0.16	7.0	11.5	10.0	915	12.4	48.6
March	12.9	20.0	10.0	0.98	6.0	16.1	0.24	0.16	7.0	12.3	10.0	915	6.1	49.6
April	12.9	20.0	10.0	0.98	5.6	12.9	0.24	0.16	7.0	14.1	10.0	915	8.6	22.0
May	12.9	20.0	10.0	0.98	4.9	13.9	0.24	0.16	7.0	16.4	10.0	400	7.1	45.7
June	12.9	20.0	10.0	0.98	3.1	12.7	0.24	0.16	7.0	18.8	10.0	400	6.1	30.5
July	12.9	20.0	8.5	0.98	2.0	16.8	0.24	0.16	7.0	20.6	10.0	400	6.1	29.3
August	12.9	20.0	8.5	0.98	2.1	14.8	0.24	0.16	7.0	21.3	10.0	400	6.3	37.2
September	12.9	20.0	8.2	0.98	2.9	16.2	0.24	0.16	6.7	20.8	10.0	400	8.7	39.0
October	12.9	20.0	10.0	0.98	4.5	17.3	0.24	0.16	7.0	18.6	10.0	915	5.7	36.6
November	12.9	20.0	10.0	0.98	5.4	18.1	0.24	0.16	7.0	16.0	10.0	915	6.7	33.8
December	12.9	20.0	10.0	0.98	5.1	20.7	0.24	0.16	7.0	13.3	10.0	915	9.3	47.4

Evaluation of Results

The SEWRPC model includes output at numerous locations for the purpose of comparison. Results were compared at the established assessment points and at each model segment below the confluence with Underwood Creek. The five evaluation locations are MN-14 (the outlet of Underwood Creek), MN-15(Reach 883 at the confluence of Underwood Creek and the Menomonee River), MN-17 (Reach 908 on the Menomonee River below the confluence with Underwood Creek), MN-18 (Reach 919), and Reach 922 (the most downstream segment in the HSPF model). These locations are shown on Figure 1.

The results of each scenario run were summarized for comparison with the existing conditions and are summarized in Table 4 through Table 8. No results comparison to the SEWRPC findings for the baseline existing and PA runs are available for Reach 922 since this was not one of the assessment points described in the original SEWRPC study (SEWRPC, 2007).

For fecal coliform, results are evaluated by comparing mean values as well as geometric mean (geomean) values. The overall geomean values were calculated using the entire 11-year dataset. For the evaluation of compliance with the geomean standard, a rolling 30-day geomean was calculated and compared to the standard.

Expected Discharge Condition Results

Fecal Coliform

The expected discharge condition shows dramatic improvement in Underwood Creek and good improvement in the Menomonee River for mean recreational season (May-September) fecal coliform concentration at all locations for all models.

The expected discharge condition improves compliance with the fecal coliform single sample standard during the recreational season (May-September) for all models at all assessment points.

It was observed that the compliance calculations were providing artificial results because the 30-day rolling average used in the geometric mean calculation requires data from outside of the recreational season. Data from outside the recreational season included the high discharge value (915 cfu/100mL) assumed for the October through April season. Preliminary information from additional sampling indicates 915 cfu/100mL is very conservative because all additional samples reported to date have been much less than 915 cfu/100mL. Consequently, the period of June through September was used to compare alternatives and calculate compliance during the summer recreational season. The findings indicate fecal coliform compliance improves or stays the same at all locations for all models.

Dissolved Oxygen

Under the expected discharge condition, dissolved oxygen concentration is lower but not significantly and compliance with the DO standard does not change for both the existing and recommended plan alternative SEWRPC models.

Total Phosphorus

The WDNR is currently developing phosphorus standards. When the standards are finalized, it is expected that many wastewater treatment plants in Wisconsin will have to

reduce their phosphorus discharge. The Waukesha Wastewater Treatment Plant will have to meet the WDNR phosphorus discharge limits whether discharging to the Fox River or Underwood Creek. While the WDNR final requirements are unknown, the new requirement may be more stringent than that represented in the expected discharge condition scenarios.

Under the expected discharge condition, the phosphorus concentration increases in Underwood Creek, but the percentage of time the recommended phosphorus planning level goal is met only decreases by 1 to 2 percent indicating very little change in meeting the phosphorus planning level goal in Underwood Creek. In the Menomonee River, the phosphorus concentration increases, with the percentage of time the recommended phosphorus planning level goal is met either staying the same (2 assessment points) or reduced (2 assessment points).

Total Suspended Solids

Under the expected discharge condition, average total suspended solids concentration improves at all locations for both the existing and recommended plan alternative SEWRPC models.

Maximum Potential Discharge Condition Results

Fecal Coliform

The maximum potential discharge condition shows good improvement in Underwood Creek and good improvement in the Menomonee River for mean recreational season (May-September) fecal coliform concentration at all locations for all models.

The maximum potential discharge condition improves compliance or stays the same with the fecal coliform single sample standard during the recreational season (May–September) for all models at all assessment points.

For the maximum potential discharge condition, the fecal coliform concentration was conservatively set to always be equal to the permit limit (400 cfu/100 ml). Making the assumption that the discharge concentration will be this high every day is an overly conservative assumption when comparing compliance with the geometric mean standard, which is intended to be a long-term 30 day average comparison. For example, the fecal coliform geometric mean standard is only 200 cfu/mL which makes the conservative discharge concentration twice as high as the standard. The single sample standard is consequently a more appropriate point for compliance comparison under the worst case scenario represented by the maximum potential discharge condition. As noted in the above paragraph, single sample standard compliance always improves or stays the same during the recreational season for all models at all assessment points.

Dissolved Oxygen

Under the maximum potential discharge condition, dissolved oxygen concentration is lower but not significantly and compliance with the dissolved oxygen standard does not change for both the existing and recommended plan SEWRPC models.

Total Phosphorus

The WDNR is currently developing phosphorus standards. When the standards are finalized, it is expected that many wastewater treatment plants in Wisconsin will have to

reduce their phosphorus discharge. The Waukesha Wastewater Treatment Plant will have to meet the WDNR phosphorus discharge limits whether discharging to the Fox River or Underwood Creek. While the WDNR final requirements are unknown, the new requirement could easily be more stringent than that represented in the maximum potential discharge condition scenarios.

Under the maximum potential discharge condition, the phosphorus concentration increases at all assessment points. Mean annual phosphorus concentration before return flow ranges from 0.057 to 0.132 mg/L and from 0.092 to 0.178 mg/L with return flow at the maximum potential discharge condition scenarios.

With increases in phosphorus concentration, there is a potential to cause increased algae growth, which is measured by chlorophyll *a* concentration. The SEWRPC model calibration noted that, "some of the highest chlorophyll concentrations coincide with low dissolved nutrient concentrations. This suggests a situation where nutrients are typically present in concentrations that are less limiting than other factors" (SEWRPC, 2007 Appendix D). As a result, higher phosphorus concentrations would not necessarily be expected to cause increased algae growth. To check this theory, the model predicted chlorophyll *a* concentrations were examined at assessment point MN-14 in Underwood Creek and assessment point MN-18 in the Menomonee River. A comparison between the baseline and maximum potential discharge scenario indicates that average chlorophyll *a* concentration would go down from 8.8ug/L to 2.1ug/L at assessment point MN-14 and from 5.5 ug/L to 4.5 ug/L at assessment point MN-18. These results indicate that algae growth would decrease at these locations in Underwood Creek and the Menomonee River even though slightly higher phosphorus concentrations would be present.

Total Suspended Solids

Under the maximum potential discharge condition, total suspended solids concentration either increases slightly or decreases slightly depending upon the assessment point in both the existing conditions and preferred alternative SEWRPC models. In all cases the median concentration stayed at least 45 percent better than the reference concentration (an estimated background concentration) of 17.2 mg/L used in the SEWRPC modeling, even when there was a slight increase in concentration.

Independent Review

The model was reviewed by an independent third party to verify model set-up and data interpretation accuracy. The company, Tetra Tech, the original developers of the model conducted the independent review. Results of their review are included as Attachment 2.

Conclusions

Fecal Coliform

Mean fecal coliform concentration shows dramatic to good improvement at all locations for all models. Compliance with standards showed improvement or stayed the same in all cases.

Dissolved Oxygen

Dissolved oxygen concentration is lower but not significantly and compliance with the dissolved oxygen standard does not change under all modeling scenarios.

Total Phosphorus

While the phosphorus concentration increases at all assessment points, the potential of the higher concentration to cause a negative impact is low. The SEWRPC model calibration noted that, "some of the highest chlorophyll concentrations coincide with low dissolved nutrient concentrations. This suggests a situation where nutrients are typically present in concentrations that are less limiting than other factors" (SEWRPC, 2007 Appendix D). Modeling results indicate that algae growth would decrease in Underwood Creek and the Menomonee River even though slightly higher phosphorus concentrations would be present with return flow. WDNR phosphorous standards under development could also reduce future phosphorus discharge limits.

Total Suspended Solids

The total suspended solids average concentration improves at all locations under the expected discharge condition while under the maximum potential discharge condition, total suspended solids concentration either increases slightly or decreases slightly depending upon the assessment point. In all cases the median concentration stayed significantly better than the reference concentration used in the SEWRPC modeling.

References

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Jobes, T.H., and Donigian, A.S., Jr. 2001. Hydrological Simulation Program -- FORTRAN, User's Manual for version 12. U.S. Environmental Protection Agency. Mountain View, CA.

SEWRPC. 2007. Planning Report Number 50, A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds. Milwaukee, WI.

FIGURE 1.
Menomonee River Watershed HSPF Model Segments, Potential Discharge Location, and Assessment Points

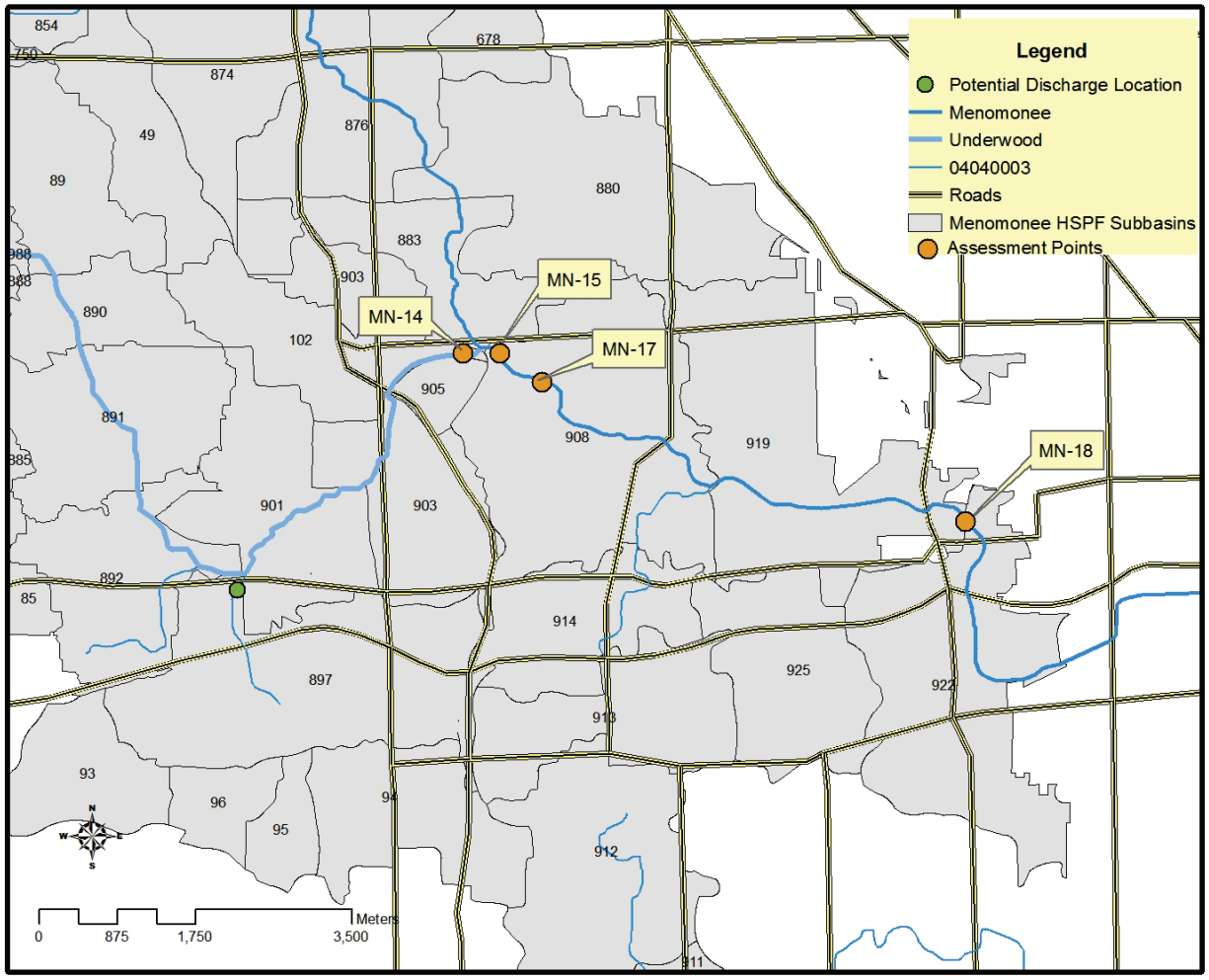

TABLE 4
Reach 905 – Assessment Point MN-14 Underwood Creek

		Existing	Existing Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**
Fecal Coliform Bacteria (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	3,032	1,950	2,064
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	80	82	82
	Geometric mean (cells per 100 ml), June-September 122 days	413	150	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	117	121	Note 1
Dissolved Oxygen	Mean (mg/l)	11.0	10.6	10.5
	Median (mg/l)	11.1	10.4	10.3
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.066	0.086	0.147
	Median (mg/l)	0.043	0.080	0.144
	Percent of time meeting planning goal (0.1 mg/l)	80	79	2
Total Suspended Solids	Mean (mg/l)	16.9	11.2	16.6
	Median (mg/l)	7.9	3.3	9.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 5

Reach 883 – Assessment Point MN-15 Menomonee Mainstem

		Existing	Existing Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	3,098	2,566	2,568
	Percent compliance with single sample standard (<400 cells per 100ml)	60	64	61
	Geometric mean (cells per 100 ml), June-September 122 days	474	326	Note 1
	Days of compliance with geometric mean standard (<200 cells per 100 ml), (June-September) per year	6	22	Note 1
Dissolved Oxygen	Mean (mg/l)	11.0	10.7	10.4
	Median (mg/l)	11.1	10.7	10.4
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.9	99.9	99.9
Total Phosphorus	Mean (mg/l)	0.063	0.073	0.101
	Median (mg/l)	0.042	0.061	0.094
	Percent of time meeting planning goal (0.1 mg/l)	82	82	56
Total Suspended Solids	Mean (mg/l)	15.6	13.8	16.4
	Median (mg/l)	5.7	4.6	7.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 6
Reach 908 – Assessment Point MN-17 Menomonee River Downstream of Honey Creek

		Existing	Existing Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,604	3,110	3,129
	Percent compliance with single variance sample standard (<2,000 cells per 100ml)	74	76	76
	Geometric mean (cells per 100 ml), June-September 122 days	499	360	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	111	118	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.7	10.5
	Median (mg/l)	11.1	10.7	10.5
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.110	0.129	0.169
	Median (mg/l)	0.072	0.109	0.156
	Percent of time meeting planning goal (0.1 mg/l)	63	44	16
Total Suspended Solids	Mean (mg/l)	16.3	14.6	16.9
	Median (mg/l)	6.1	5.0	7.7

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 7
Reach 919 – Assessment Point MN-18 Menomonee River near Upstream Limit of Estuary

		Existing	Existing Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,550	3,112	3,119
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	74	76	76
	Geometric mean (cells per 100 ml), June-September 122 days	471	349	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	112	118	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.4
	Median (mg/l)	11.0	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.132	0.142	0.178
	Median (mg/l)	0.101	0.123	0.166
	Percent of time meeting planning goal (0.1 mg/l)	50	35	12
Total Suspended Solids	Mean (mg/l)	16.0	14.4	15.0
	Median (mg/l)	5.7	4.6	5.8

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 8
Reach 922 – Assessment Point Menomonee River at Upstream Limit of Estuary

		Existing	Existing Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,409	3,023	3,026
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	75	77	77
	Geometric mean (cells per 100 ml), June-September 122 days	411	321	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	116	119	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.7	10.6
	Median (mg/l)	10.9	10.7	10.6
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.068	0.074	0.094
	Median (mg/l)	0.048	0.061	0.085
	Percent of time meeting planning goal (0.1 mg/l)	81	81	68
Total Suspended Solids	Mean (mg/l)	15.8	14.5	14.7
	Median (mg/l)	5.4	4.6	5.1

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 9
Reach 905 – Assessment Point MN-14 Underwood Creek

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,351	871	1,046
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	83	86	86
	Geometric mean (cells per 100 ml), June-September 122 days	213	86	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	122	122	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.4	10.1
	Median (mg/l)	11.2	10.3	10.1
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.057	0.081	0.140
	Median (mg/l)	0.039	0.078	0.139
	Percent of time meeting planning goal (0.1 mg/l)	85	83	3
Total Suspended Solids	Mean (mg/l)	12.8	8.9	14.5
	Median (mg/l)	5.9	2.9	9.4

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 10
Reach 883 – Assessment Point MN-15 Menomonee Mainstem

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,527	1,260	1,326
	Percent compliance with single sample standard (<400 cells per 100ml)	65	67	65
	Geometric mean (cells per 100 ml), June-September 122 days	260	184	Note 1
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September), per year	35	62	Note 1
Dissolved Oxygen	Mean (mg/l)	10.8	10.5	10.2
	Median (mg/l)	10.9	10.6	10.2
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.9	99.9	99.9
Total Phosphorus	Mean (mg/l)	0.059	0.070	0.097
	Median (mg/l)	0.042	0.061	0.092
	Percent of time meeting planning goal (0.1 mg/l)	85	85	59
Total Suspended Solids	Mean (mg/l)	12.4	11.1	13.7
	Median (mg/l)	4.6	3.8	7.0

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 11
Reach 908 – Assessment Point MN-17 Menomonee River Downstream of Honey Creek

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,812	1,557	1,607
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	80	80
	Geometric mean (cells per 100 ml), June-September 122 days	272	201	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.3
	Median (mg/l)	11.0	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.104	0.123	0.162
	Median (mg/l)	0.073	0.107	0.153
	Percent of time meeting planning goal (0.1 mg/l)	64	45	17
Total Suspended Solids	Mean (mg/l)	13.2	11.8	14.2
	Median (mg/l)	4.9	4.1	7.0

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 12
Reach 919 – Assessment Point MN-18 Menomonee River near Upstream Limit of Estuary

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,847	1,618	1,653
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	80	81
	Geometric mean (cells per 100 ml), June-September 122 days	263	199	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.4
	Median (mg/l)	10.9	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.126	0.136	0.171
	Median (mg/l)	0.101	0.121	0.162
	Percent of time meeting planning goal (0.1 mg/l)	49	36	13
Total Suspended Solids	Mean (mg/l)	13.1	11.8	12.5
	Median (mg/l)	4.8	4.0	5.4

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 13
Reach 922 – Assessment Point Menomonee River at Upstream Limit of Estuary

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,831	1,628	1,657
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	81	81
	Geometric mean (cells per 100 ml), June-September 122 days	254	197	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.9	10.8
	Median (mg/l)	11.1	10.9	10.8
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.065	0.072	0.092
	Median (mg/l)	0.048	0.062	0.085
	Percent of time meeting planning goal (0.1 mg/l)	83	83	69
Total Suspended Solids	Mean (mg/l)	13.4	12.2	12.4
	Median (mg/l)	4.9	4.1	4.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

Attachment 1
Summary of Waukesha WWTP Effluent Data Analysis

Summary of Waukesha WWTP Effluent Data Analysis

PREPARED FOR: Project Team

PREPARED BY: CH2M HILL

DATE: November 16, 2009

This memorandum documents the methods and procedures used to compile data provided by the Waukesha Wastewater Treatment Plant (WWTP). The data is anticipated to be used to predict in-stream water quality parameter changes with a future WWTP return flow to a Lake Michigan tributary river. The WWTP effluent is routinely monitored for the following characteristics:

- Flow (million gallons per day, MGD)
- Total Suspended Solids (TSS, mg/L)
- Temperature (^{o}C)
- Dissolved Oxygen (DO, mg/L)
- Biochemical Oxygen Demand (BOD, mg/L)
- Total Phosphorus (TP, mg/L)
- Ammonia (NH_3-N, mg/L)
- Fecal Coliforms (# per 100 mL)
- Copper (Cu, µg/L)
- Zinc (Zn, µg/L)

WWTP effluent data was provided by Randy Thater (WWTP) for the period between October 1, 2002 to August 31, 2009. October 1, 2002 represents the first day of operation of the UV Disinfection system when prior to this date, the effluent was disinfected with chlorine. Effluent data was not provided prior to this time because the use of a chlorine disinfectant would not provide representative effluent data for current and future conditions. The data was provided in two distinct data sets that represent two different computer systems at the WWTP (October 1, 2002 to April 30, 2004 and May 1, 2004 to August 31, 2009). The effluent data was consolidated into one Excel spreadsheet to allow it to be summarized into monthly averages.

Because the data was collected over a long period of time, some assumptions were required to allow the data to be analyzed and compared over the entire period. These assumptions and the rationale for each are summarized below.

- The copper and zinc average monthly effluent concentrations between October 1, 2002 and April 30, 2004 were greater than the more recent effluent data (copper was about 10 times greater and zinc was about 3 times greater). It is not known why the values were greater. Because the most recent effluent data (May 2004 through August 2009) represents effluent concentrations that are most indicative of a potential return flow, only these average monthly effluent concentrations are used.

- The geometric mean monthly fecal coliform values consistent with permit reporting requirements were calculated for May through September months because this is the time when disinfection is required by the WWTP's effluent permit. May 2003 fecal coliform data was excluded from the analysis because this was the first month of operation for the UV system and incomplete data were available for the entire month. Fecal coliform effluent permit requirements for two other municipal wastewater dischargers whose effluent discharges to a Lake Michigan tributary (Cedarburg, WI discharges to Cedar Creek and Grafton, WI discharges to the Milwaukee River) confirmed the same disinfection season permit requirements as Waukesha's permit. Because the permit requirements for fecal coliform were the same between the three discharges, the WWTP's effluent data was used to analyze the potential return flow on a seasonal disinfection basis.
- When effluent concentrations were below the detection limits, the actual concentration is a value less than the detection limit. Because the actual concentration cannot be determined, the days where the concentration was reported less than the detection limit were replaced with a value equal to the detection limit (e.g., if the effluent zinc concentration was reported as < 10 µg/L, the value was assumed to be 10 µg/L). This approach provides a conservatively high value for purposes of calculating water quality parameter concentrations. For parameters that were limited by detection limits, any zero-value or blank entries were excluded from the analysis.

The water quality modeling requires additional effluent parameters than what is routinely collected by the WWTP, specifically orthophosphate (OP), nitrate (NO_3-N), and total Kjeldahl nitrogen (TKN). To support the modeling, the WWTP staff collected three composite effluent samples on 9/21/09, 9/22/09 and 9/23/09 (Table 1) and analyzed them for these parameters. The samples were used to calculate ratios or averages (Table 2) which were used to estimate average monthly effluent values for OP, NO_3-N, and TKN, similar to the other effluent parameters summarized above. A summary of the methods used to estimate the parameters is below.

TABLE 1
Waukesha Wastewater Treatment Plant Effluent Composite Sample Data

Effluent Constituents	9/21/2009	9/22/2009	9/23/2009	Average
Flow (MGD)	8	8.1	8.4	8.2
TSS (mg/L)	<1.0	<1.0	<1.0	<1.0
Temperature (Deg C)	19.8	19.7	20.4	20
Phosphorus (mg/L)	0.31	0.26	0.26	0.28
NH3-N (mg/L)	<0.04	<0.04	<0.04	<0.04
BOD (mg/L)	<2.0	<2.0	<2.0	<2.0
D.O. (mg/L)	8.7	8.4	8.6	8.6
Fecal Coliform (No/100mL)	1	1	0	1
Nitrate-Nitrite (mg/L)	12	12	13	12.3
Orthophosphate (mg/L)	0.22	0.18	0.16	0.19
TKN (mg/L)	0.57	0.26	0.98	0.6

Orthophosphate: The OP concentration represents dissolved reactive phosphorus that is not removed in settling or filtration. The TP concentration includes the dissolved reactive

phosphorus and also includes colloidal and particulate phosphorus. Most of the particulate phosphorus is removed in filtration, however a portion of the smaller particulates and colloidal phosphorus can pass through filtration as part of the WWTP effluent. To estimate the monthly average effluent OP (similar to the other effluent parameters discussed above), the calculated monthly average TP from the WWTP effluent data was proportioned by the fraction of OP measured in the three samples. The effluent ratio of OP to TP should be generally similar unless upstream chemical dosing changes (affecting precipitation of soluble phosphorus) or filter performance deteriorates. For the three composite samples, the OP/TP ratio ranged between 0.62 and 0.71, with an average ratio of 0.67. Using the average OP/TP ratio of 0.67, the average monthly effluent TP concentration was multiplied by 0.67 to obtain the monthly average effluent OP concentration.

TABLE 2
Average Waukesha Wastewater Treatment Plant Effluent Ratios (9/21/09 – 9/23/09)

Effluent OP/TP	0.67
Effluent NO_3-N/Aeration Basin Influent NH3-N	1.17

Nitrate: To estimate the average monthly WWTP effluent NO_3-N concentration, the aeration basin influent ammonia (NH_3-N) concentration was used. The concentration of NH_3-N in the aeration basin influent is an appropriate surrogate for effluent NO_3-N data because the ratio of effluent NO_3-N to influent NH_3-N is relatively constant on average. This is because:

- NO_3-N is formed as influent NH_3-N and influent organic nitrogen that is solubilized to NH_3-N are oxidized to NO_3-N in secondary treatment.
- The ratio of NH_3-N to TKN, which includes ammonia and organic nitrogen, is relatively constant on average.
- NH_3-N is almost fully converted to NO_3-N in the aeration basin and because there is no anoxic zone where dissolved NO_3-N is converted to nitrogen gas, NO_3-N formed in secondary treatment is not removed.

Because aeration basin influent NH_3-N was not available for the three NO_3-N sample dates, the NH_3-N average of the day before and the day after the three NO_3-N samples was used to calculate this ratio. After speaking with Randy Thater of the WWTP, it was expected that the aeration basin influent NH_3-N was fairly constant during the week of sampling because there was no biosolids dewatering occurring, which has been observed to change the influent NH_3-N. Using this composite sample data, the ratio of WWTP effluent NO_3-N to aeration basin influent NH_3-N was calculated to be 1.17. This ratio was then used in conjunction with the historic monthly average aeration basin influent NH_3-N data to estimate the monthly average effluent NO_3-N (i.e., by multiplying the average monthly aeration basin influent NH_3-N by 1.17).

Total Kjeldahl Nitrogen: Effluent TKN was assumed to be 0.98 mg/L, which was the highest TKN observed in the three composite effluent samples. Effluent TKN varies based on the amount of solids and ammonia in the effluent. When effluent TSS is less than 1 mg/L and effluent ammonia is less than 0.04 mg/L, as observed in the three composite samples, TKN would likely be less than 1 mg/L, which was observed.

The calculated average monthly WWTP effluent concentrations for the above water quality parameters are summarized in Table 3.

TABLE 3
Waukesha Wastewater Treatment Plant Average Monthly Effluent Values (October 2002- August 2009)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	TKN (as N) (mg/L)	Ammonia (as N) (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO4 (mg/L)[3]	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)[1]	Cu (µg/L)[2]	Zn (µg/L)[2]
January	9.4	14.5	1.7	0.98	0.10	18.6	0.11	0.07	10.3	12.0	0.9	ND	6.6	42.0
February	9.3	14.4	1.7	0.98	0.06	19.1	0.10	0.06	10.5	11.5	0.9	ND	12.4	48.6
March	11.3	17.4	1.7	0.98	0.14	16.1	0.12	0.08	10.4	12.3	1.1	ND	6.1	49.6
April	12.3	19.1	1.7	0.98	0.09	12.9	0.10	0.06	9.7	14.1	1.4	ND	8.6	22.0
May	11.5	17.7	2.0	0.98	0.20	13.9	0.12	0.08	9.0	16.4	1.2	2	7.1	45.7
June	12.1	18.7	2.6	0.98	0.14	12.7	0.21	0.14	8.2	18.8	1.8	49	6.1	30.5
July	9.2	14.3	1.8	0.98	0.05	16.8	0.16	0.11	8.0	20.6	1.0	2	6.1	29.3
August	9.0	14.0	1.8	0.98	0.07	14.8	0.19	0.13	7.9	21.3	1.1	2	6.3	37.2
September	8.8	13.7	2.1	0.98	0.10	16.2	0.21	0.14	8.0	20.8	1.0	2	8.7	39.0
October	8.8	13.6	1.6	0.98	0.04	17.3	0.24	0.16	8.7	18.6	1.1	ND	5.7	36.6
November	8.6	13.3	1.6	0.98	0.07	18.1	0.21	0.14	9.5	16.0	1.1	ND	6.7	33.8
December	9.2	14.2	1.6	0.98	0.07	20.7	0.15	0.10	10.3	13.3	1.1	ND	9.3	47.4

[1]Geometric means were used for fecal coliform data. The numbers shown in the table represent the average geometric mean for each month (i.e. the geometric mean was determined for the seven Januaries in the dataset. These seven geometric means were then averaged.
[2]Data for Copper (Cu) and Zinc (Zn) from 2002-2004 was not used as described above.
[3]Based on Effluent OP/TP (Orhophosphate/Total Phosphorus) ratio of 0.67, determined from three samples collected 9/21, 9/22, and 9/23
ND – No Disinfection. The WPDES permit only has a disinfection requirement and associated limit on fecal coliforms from May-September. As a result, UV disinfection is only operated from May-September.

Attachment 2
Independent Model Review Findings

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MEMORANDUM

To:	Daniel S. Duchniak, PE (WWU) Klaus Albertin (CH2M HILL)	**Date:**	December 3, 2009
From:	Jonathan Butcher, Ph.D., P.H.	**Project:**	Waukesha Water Diversion
Subject:	Underwood Creek Model Review		

The City of Waukesha Water Utility (WWU) is proposing to route return flow from their Wastewater Treatment Plant to Underwood Creek. To analyze the potential impacts of the proposed discharge, CH2M HILL modified an existing water quality model of the Menomonee River system, including Underwood Creek. This model is an HSPF model developed for the Southeastern Wisconsin Regional Planning Commission (SEWRPC) by Tetra Tech to support the regional water quality management plan update. Results of this analysis are presented in a technical memorandum dated November 24, 2009 from CH2M HILL to the City of Waukesha.

The City of Waukesha contracted with Tetra Tech to provide an independent review of the modified water quality model. Dr. Jonathan Butcher, the reviewer, was the lead developer of the Menomonee River model for SEWRPC, and is intimately familiar with the modeling system. Klaus Albertin of CH2M HILL provided the draft report and the accompanying modeling files to Tetra Tech for review.

Detailed review of the modeling files and supporting information revealed only one significant flaw (in the specification of the point source input files). CH2M HILL was apprised of this issue and has re-run the model to correct the error. Therefore, the revised model is appropriate and ready for the evaluation of the proposed discharge, although some corrections may be needed in the way that results are reported. I do suggest, however, that Waukesha may wish to re-evaluate the representation of "typical conditions" discharge characteristics. Some additional comparisons of conditions with and without the discharge may also be useful.

Specific aspects of the review are documented below.

Applicability of the Modeling System

The modeling system developed for SEWRPC uses U.S. EPA's Hydrologic Simulation Program-FORTRAN (HSPF). The model is implemented at a 15-minute time step and is set up to run over the evaluation period of 1/1/1987 – 12/31/1997. Weather data are available and set up to cover the period of 1983-2002; however, SEWRPC specifically selected 1987-1997 as a representative base period for the evaluation of future water quality management plans. Use of this same time period is appropriate for evaluating the general impact of the proposed discharge on water quality time series. The dynamic model analysis should likely be supplemented with a separate, steady-state critical condition analysis for end-of-pipe permit limit calculations.

The SEWRPC Menomonee River model provides a complete representation of flow, sediment, nutrients, bacteria, algae, BOD/DO, and water temperature and has been calibrated and validated for each of these components. The model was also set up to simulate concentrations of copper and zinc. However, as directed by SEWRPC, simulation of the metals is in a simplified form and not rigorously calibrated. Caution should thus be used in analysis of model results for copper.

Modeling Files

SEWRPC provided the basic modeling files to CH2M HILL, representing the Existing and Preferred Alternative (PA) production run scenarios, where the PA scenario represents 2020 land use with proposed management strategies. These final scenarios were selected from a much larger set of scenarios conducted by Tetra Tech. Internally, the final Existing scenario is known as the ESM run, representing existing land use and management combined with CSO/SSO simulation using Streamline Mouse, while the SEWRPC PA scenario is Tetra Tech's PA2 run.

HSPF execution is controlled by User Control Input (UCI) files. A separate file is provided for each major subwatershed in the Menomonee. I compared the UCI files provided by CH2M HILL to those in the Tetra Tech archive and determined that the files used for Scenarios 1 and 2 (representing existing conditions) are identical those developed for the ESM run, while the files used for Scenario 3 (future conditions) are identical to those developed for the PA2 run, with two exceptions: (1) the addition of the new discharge to Underwood Creek, and (2) additions to write water temperature output for the evaluation points in the Underwood Creek and Menomonee-Downstream submodels.

The model also depends on the weather data and text "mutsin" files that provide information on point source discharges, CSOs, and SSOs. The weather data files used by CH2M HILL are identical to those in the Tetra Tech archive. The mutsin files for a run are stored in two directories – a global directory for point source discharges that do not change with scenario, and a scenario-specific directory for discharges that vary by scenario. SEWRPC neglected to provide the global mutsin files to CH2M HILL, so Tetra Tech provided these directly. I confirmed that the appropriate scenario-specific mutsin files were used by CH2M HILL and that these are identical to the ones in the Tetra Tech archive.

Scenario Modification

Modifications of the existing models to address the proposed discharge are simple and straightforward. The only change required in the UCI files was the addition of new point source mutsin files representing the proposed Waukesha discharge and their linkage to reach 901 in the Underwood Creek submodel. As noted above, no other changes were made to the existing UCI files except for the provision of additional write statements for water temperature. I confirmed that these modifications to the UCI files were implemented correctly.

Completion of the scenarios also required construction of mutsin files to represent the Waukesha discharge. CH2M HILL did this via two separate mutsin files, one representing flow, thermal load, and bacterial load, and the other representing loads of other pollutants. (The CH2M HILL memorandum implies that the first file contains only "monthly flow and temperature"; however, fecal coliform bacteria loads are also transmitted via this file.)

The mutsin input must be supplied to the model at the simulation time step of 15 minutes and in the appropriate units. As originally developed by CH2M HILL, the mutsin files specified values at the start (end of the first hour of the first day) of each month, but were implemented with a missing value flag of 3 in the UCI file – indicating that missing values are to be filled with the next available value. The effect of this is that the model read a value for the first hour of a month, then treated the next interval as missing and substituted the next available value, which is entered for the first of the next month. This resulted in a shift in the values. That is, all but the first hour of the January simulation uses February flows and loads. As the number entered for January was intended to represent an average for the month of January, the model was not correctly interpreting the input. I notified CH2M HILL of this problem, which can be remedied by changing the date representation to the last hour of the last day of the month instead of the

first hour of the first day. The CH2M HILL modeler indicated that the models will be rerun and the memorandum revised to incorporate this correction.

As noted above, the mutsin file must provide loads in the correct units and at the modeled 15-minute time interval. The model is implemented in English units, so the mutsin file must be set up as follows:

- Flow: AF/15-min
- Nutrient and metals load: lb/15-min
- Bacterial load: cfu/15-min
- Thermal load: BTUs (relative to freezing)/15-min
- Solids: tons/15-min

Point source monitoring data are typically in MGD for flow, mg/L for standard pollutants, temperature for thermal load, and cfu/100 ml for bacteria. Converting these to mutsin units can be tricky. I confirmed that all unit conversions were performed properly. There are several minor criticisms, which do not impact model performance. First, the text incorrectly says the first mutsin "specified monthly flow and temperature", whereas it is actually specifying 15-minute flow and thermal load. Second, the header in the first mutsin incorrectly says that FC is being given in cfu/100 ml, whereas the units are cfu/15-min. Finally, the spreadsheet calculation of bacterial load uses a factor of 28.33 to convert from cubic feet to liters. The correct factor should be 28.317; however, any discrepancies that might have resulted appear to be eliminated by round off to two significant digits (scientific notation) in the mutsin file.

Confirmation of Model Runs

I implemented the model files provided by CH2M HILL and confirmed that they do indeed run as intended.

Model output for segments upstream of Underwood Creek, as well as for Scenario 1 in Underwood Creek and downstream, should be identical to those obtained previously by Tetra Tech. I compared a variety of output files and determined that results were very close, but not identical, for output of daily average pollutant concentrations, with a maximum difference of about 2 percent in fecal coliform concentrations. Investigations of the causes of this discrepancy revealed that it is not due to any differences in model input. Rather, the differences arose because CH2M HILL ran the models with WinHSPFLt, whereas the SEWRPC models were implemented with an older DOS version of HSPF running in batch mode. The two versions of the model differ slightly in their calculation of daily averages – particularly for constituents that vary widely in concentration over the course of a day – due to the accumulation of round off error in the underlying FORTRAN code.

The CH2M HILL modeler confirmed that they had also rerun the baseline (Scenario 1) model with WinHSPFLt. Therefore, the comparison presented in the memorandum is done on a consistent basis and the difference in round off error between the two models is not a problem for the purposes of the analysis.

Analysis of Scenario Results

Scenario results are presented in a series of tables, for four assessment points in Underwood Creek and the downstream Menomonee River, which assess various water quality statistics with and without the proposed discharge. I have some minor issues with the reporting of statistics; however, the most important thing is that they are reported in a consistent way, allowing comparison across scenarios.

The actual results will be revised to correct the representation of the new point source, as noted above. It is, however, also important to review the way in which the results are calculated and presented. CH2M HILL did not provide the spreadsheets used to calculate the tables; however, I made an independent investigation of the results based on the output files created by the current version of the model. In general, the reported means, geometric means, and medians appear to correctly represent the output of the model. Most of the percent compliance (or days per year) results also appear to correctly represent the

model. It is, however, worth noting that these statistics are based on daily average output, not on the raw model output at 15-minute intervals. This has an impact on the percent compliance and geometric mean outputs, but is not a problem given use of a consistent comparison to baseline conditions. I do note that the "days of compliance" results should be stated to be on a "per year" basis.

In at least two cases there appears to be some discrepancy in the reported model results for fecal coliform bacteria. The first is for the "Days of compliance with geometric mean standard (<1000 cells per 100 ml)." I assume this is simply a count of the average number of days per year when the daily average concentration is less than 1000 as comparison to running 30-day geometric means yields a much lower count. For Station MN-14, the reported number of days in Table 4 is Existing Baseline: 268; Scenario 2A: 203; and Scenario 2B: 174. Tetra Tech's previous analysis of the existing conditions run yielded a count of 235 days; my reanalysis of the output for scenarios 2A and 2B yielded 230 days in both cases. CH2M HILL should thus recheck the calculations for this statistic, and correct it if necessary; or, if it is correct, explain how it was calculated.

The second discrepancy is with the recreation-season calculation of percent compliance with the single sample standard of 1000 cells per 100 ml. In Table 4, CH2M HILL reports 34 percent compliance at Station MN-14, and similar low percentages of compliance are reported for other stations. My calculations show that the rate should be about 86% for the existing baseline and about 82% for Scenarios 2A and 2B. That the reported numbers are wrong is obvious from the fact that 34 percent of the 153 days in May through September yields 52 days per year in compliance with the 2000 per 100 ml, whereas the number of days in compliance with the 1000 per 100 ml standard is reported as around 130 per year. It appears that the discrepancy is due to calculating the percentage by dividing the number of recreation-season days in compliance by 365, rather than by the number of days contained within the recreation season (153).

It is worth noting that the simulations with the new discharge present show at least a small degradation in the frequency during which the fecal coliform standards are met. As is discussed below, this seems to be due to the assumption that the non-recreation season fecal coliform concentration in the effluent is always equal to 915 per 100 ml, just less than the geometric mean standard.

The memorandum states that "Copper values are higher in the discharge scenarios", but does not provide numeric results in the revised version (the initial version of the memorandum that was provided to Tetra Tech did give numeric copper results). As noted above, Tetra Tech does not consider the model to be calibrated for copper; therefore, it is probably best to omit the copper comparison entirely.

On the other hand, a comparison of ammonia-N concentrations with and without the discharge would likely be of interest. Impacts on conditions downstream in the harbor are also likely to be of considerable interest. I suggest that model results may also need to be analyzed to evaluate changes in mass loading of nutrients and bacteria to the harbor with and without the new discharge.

Representation of the Discharge

The proposed discharge is represented in two ways, first as typical monthly average values based on data from October 2002 to August 2009, and second at permit limits. I believe this is adequate for the purposes of the study. It is worth noting that plant discharge is likely to be positively correlated with precipitation, and a more refined representation would use daily flows that are matched to the model simulation period. This was apparently not possible as the production run period of the model (1987-1997) is different from the effluent monitoring period. The effect of a positive correlation between effluent discharge and precipitation (and thus with instream flow) would be that more of the discharge would occur when instream dilution capacity is greater. The existing analysis, with constant monthly values, is therefore likely conservative in that it will tend to overestimate loading from the Waukesha discharge during low flow conditions when impact will be greatest.

CH2M HILL's memorandum discusses the determination of discharge characteristics only briefly, and does not include the promised Attachment 1 ("Summary of Waukesha WWTP Effluent Data Analysis").

Two anomalies stand out in the representation of the actual conditions discharge (Table 2). The first is that the fecal coliform concentration during the non-recreation season is always assigned a value of 915 cfu/100 ml. This is the permit limit value. I assume that this value was assigned because fecal coliform has not been monitored during the non-recreation season? However, I doubt that the concentration is always exactly at the permit limit. A more reasonable representation of existing conditions might provide more favorable statistics. If this is not possible, justification for use of the 915 concentration should be provided in the text.

Table 4 also assigns for existing conditions a TKN concentration that is always equal to 0.98. This appears to be the value used for organic N in the permit limit table. Again, justification needs to be provided – although N concentrations are not used in the comparison of existing conditions and conditions with the discharge at this time.

Summary

The model application appears to be correct and defensible, with the exception of the time series representation of the discharge, which is being corrected by CH2M HILL. In addition, the methods by which the summary reporting statistics are calculated should be further reviewed. Once these changes and checks are made, the results should be ready for submission to the appropriate regulatory authorities.

Attachment 3
Review Response

Response to Comments on the Underwood Creek and Menomonee River HSPF Model Analysis

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: January 13, 2010

The City of Waukesha Water Utility (WWU) is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. To analyze the potential water quality changes of the proposed discharge, CH2M HILL modified an existing water quality model of the Menomonee River system, including Underwood Creek. This model is an HSPF model developed for the Southeastern Wisconsin Regional Planning Commission (SEWRPC) by Tetra Tech to support the Regional Water Quality Management Plan Update (RWQMPU). Results of this analysis are presented in a technical memorandum from CH2M HILL to the City of Waukesha.

The City of Waukesha contracted with Tetra Tech to provide an independent review of the modified water quality model. This document summarizes the comments that TetraTech provided as well as a response to comments by CH2M HILL.

Comment 1:

As originally developed by CH2M HILL, the mutsin files specified values at the start (end of the first hour of the first day) of each month, but were implemented with a missing value flag of 3 in the UCI file – indicating that missing values are to be filled with the next available value. The effect of this is that the model read a value for the first hour of a month, then treated the next interval as missing and substituted the next available value, which is entered for the first of the next month. This resulted in a shift in the values.

Response 1:

Values in the mutsin files were shifted so that missing values would be filled with the representative values. The models were rerun and results were updated to reflect the revision of the mutsin files. The changes to the results were slight for all parameters except fecal coliform. This correction improved compliance with the recreational season standard since the fecal coliform values varied significantly between the summer recreational season and winter months..

Comment 2:

The text incorrectly says the first mutsin "specified monthly flow and temperature", whereas it is actually specifying 15-minute flow and thermal load. Second, the header in the first mutsin incorrectly says that FC is being given in cfu/100 ml, whereas the units are cfu/15-min.

Response 2:

This comment was addressed in the final technical memorandum (TM).

Comment 3:

The spreadsheet calculation of bacterial load uses a factor of 28.33 to convert from cubic feet to liters. The correct factor should be 28.317; however, any discrepancies that might have resulted appear to be eliminated by round off to two significant digits (scientific notation) in the mutsin file.

Response 3:

As noted in the comment, the effect of this difference in conversion factors is very minor and would at most conservatively overestimate coliform loading by less than 0.5 percent.

Comment 4:

Model output … for a variety of output files and determined that results were very close, but not identical, for output of daily average pollutant concentrations, with a maximum difference of about 2 percent in fecal coliform concentrations. Investigations of the causes of this discrepancy revealed that it is not due to any differences in model input. Rather, the differences arose because CH2M HILL ran the models with WinHSPFLt, whereas the SEWRPC models were implemented with an older DOS version of HSPF running in batch mode. The two versions of the model differ slightly in their calculation of daily averages – particularly for constituents that vary widely in concentration over the course of a day – due to the accumulation of round off error in the underlying FORTRAN code.

Response 4:

All scenarios including the baseline models (existing and preferred alternative) were run with WinHSPFLt. Therefore, the comparison presented in the memorandum is done on a consistent basis and the difference in round off error between the two models is not a problem for the purposes of the analysis. As noted in the comment, the existing and preferred alternatives results may differ from those previously reported due to the minor differences in model computer platform calculation procedures.

Comment 5:

It is, however, also important to review the way in which the results are calculated and presented. CH2M HILL did not provide the spreadsheets used to calculate the tables; however, I made an independent investigation of the results based on the output files created by the current version of the model. In general, the reported means, geometric means, and medians appear to correctly represent the output of the model. Most of the percent compliance (or days per year) results also appear to correctly represent the model. It is, however, worth noting that these statistics are based on daily average output, not on the raw model output at 15-minute intervals. This has an impact on the percent compliance and geometric mean outputs, but is not a problem given use of a consistent comparison to baseline conditions. I do note that the "days of compliance" results should be stated to be on a "per year" basis.

In at least two cases there appears to be some discrepancy in the reported model results for fecal coliform bacteria. The first is for the "Days of compliance with geometric mean standard (<1000 cells per 100 ml)." I assume this is simply a count of the average number of days per year when the daily average concentration is less than 1000 as comparison to running 30-day geometric means yields a much lower count. For Station MN-14, the reported number of days in Table 4 is Existing Baseline: 268; Scenario 2A: 203; and Scenario 2B: 174. Tetra Tech's previous analysis of the existing conditions run yielded a count of 235 days; my reanalysis of the output for scenarios 2A and 2B yielded 230 days in both cases. CH2M HILL should thus recheck the calculations for this statistic, and correct it if necessary; or, if it is correct, explain how it was calculated.

The second discrepancy is with the recreation-season calculation of percent compliance with the single sample standard of 1000 cells per 100 ml. In Table 4, CH2M HILL reports 34 percent compliance at Station MN-14, and similar low percentages of compliance are reported for other stations. My calculations show that the rate should be about 86% for the existing baseline and about 82% for Scenarios 2A and 2B. That the reported numbers are wrong is obvious from the fact that 34 percent of the 153 days in May through September yields 52 days per year in compliance with the 2000 per 100 ml, whereas the number of days in compliance with the 1000 per 100 ml standard is reported as around 130 per year. It appears that the discrepancy is due to calculating the percentage by dividing the number of recreation-season days in compliance by 365, rather than by the number of days contained within the recreation season (153).

Response 5:

Tables in the final TM were revised to state compliance is on a per year basis. The TM was also revised to state that the calculation of the geomean standard compliance used a 30-day rolling geomean calculation. This results in a much lower number as noted in the comment. The calculations and tables were revised to calculate the percent compliance during the summer using the total number of recreation season days (153 days).

Comment 6:

It is worth noting that the simulations with the new discharge present show at least a small degradation in the frequency during which the fecal coliform standards are met. As is discussed below, this seems to be due to the assumption that the non-recreation season fecal coliform concentration in the effluent is always equal to 915 per 100 ml, just less than the geometric mean standard.

Response 6:

It is agreed that the specification of fecal coliform as 915 cfu/100 mL for the non-recreation contact period has a significant impact on the statistics for fecal coliform. Monitoring is not typically performed during the non-recreation season so a high level was used to be conservative. More representative numbers could improve the compliance statistics.

Comment 7:

The memorandum states that "Copper values are higher in the discharge scenarios", but does not provide numeric results in the revised version (the initial version of the

memorandum that was provided to Tetra Tech did give numeric copper results). As noted above, Tetra Tech does not consider the model to be calibrated for copper; therefore, it is probably best to omit the copper comparison entirely.

Response 7:

Discussion of copper was removed from the TM.

Comment 8:

…. a comparison of ammonia-N concentrations with and without the discharge would likely be of interest. Impacts on conditions downstream in the harbor are also likely to be of considerable interest. I suggest that model results may also need to be analyzed to evaluate changes in mass loading of nutrients and bacteria to the harbor with and without the new discharge.

Response 8:

Data for comparison between scenarios was provided for those water quality parameters which the Waukesha Wastewater Treatment Plant currently has in its permit.

Comment 9:

Two anomalies stand out in the representation of the actual conditions discharge (Table 2). The first is that the fecal coliform concentration during the non-recreation season is always assigned a value of 915 cfu/100 ml. This is the permit limit value. I assume that this value was assigned because fecal coliform has not been monitored during the non-recreation season? However, I doubt that the concentration is always exactly at the permit limit. A more reasonable representation of existing conditions might provide more favorable statistics. If this is not possible, justification for use of the 915 concentration should be provided in the text.

Table 4 also assigns for existing conditions a TKN concentration that is always equal to 0.98. This appears to be the value used for organic N in the permit limit table. Again, justification needs to be provided – although N concentrations are not used in the comparison of existing conditions and conditions with the discharge at this time.

Response 9:

The final TM was revised to address this comment. The TM will emphasize that the discharge was characterized either by actual historical effluent quality for the expected discharge condition scenario or by permit limits and high observed concentrations for the maximum potential discharge condition scenario.

Appendix K

Final Draft Technical Memorandum: Summary of Water Requirements

AECOM

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Final Draft Technical Memorandum

May 28, 2009

To: Nancy Quirk, Waukesha Water Utility

Copy: Richard Hope, AECOM

From: Kathy Beduhn, AECOM

Subject: **Summary of Water Requirements**
Waukesha, Wisconsin

As part of the 2006 Water System Master Plan project, historical water customer demands and pumpage records were reviewed and future water requirements were projected. This technical memorandum summarizes updated water pumpage projections considering 2006, 2007, and 2008 water pumpage and sales information and updated population projections for the City of Waukesha.

POPULATION PROJECTIONS

The Wisconsin Department of Administration estimated the 2008 population of the City of Waukesha to be 68,030.

The following table summarizes the population projections developed by the Southeastern Wisconsin Regional Planning Commission for the Waukesha water supply service area that were used to update water pumpage projections.

SUMMARY OF POPULATION PROJECTIONS

Year	Population
2028	85,800
2035	88,500
Ultimate	97,400

Source: Letter from Southeastern Wisconsin Regional Planning Commission dated March 17, 2009 (included in Attachment A).

WATER CONSUMPTION

The following sections summarize historical water consumption including water metered and sold to customers, total water pumpage, per capita water usage, and system maximum day demand.

Metered Water Sales and Water Pumpage

A summary of historical water sales and pumpage is provided in Table 1. Water sales and total pumpage have decreased slightly in the past 5 years. Over the 39-year period of data summarized in the table, water sales varied from a low of 2,366 million gallons per year (MGY) in 2008 to a high of 3,462 MGY in 1988. Total pumpage over the 39-year period has varied from a low of 2,366 MGY in 2008 to 3,607 MGY in 1988.

Per Capita Water Usage

City of Waukesha residential, commercial, and public water usage can be related to the City's population. An analysis of per capital water consumption for each of these customer classifications was performed from sales records and is summarized in Table 2. As indicated in this table, overall per capita sales to residential, commercial, and public customers have all remained fairly constant or declined slightly since the early 1990s. Figure 1 illustrates the City of Waukesha per capital consumption trends since 1970.

To project future water needs, the average daily water usage projection for customers was updated to reflect recent trends in water consumption. The per capital water consumption rate is summarized in the following table.

PER CAPITA WATER CONSUMPTION RATE

Per Capita Sales	Residential	Commercial	Public
Average 1970 to 2008	53 gpcd	32 gpcd	8 gpcd
Maximum 1970 to 2008	72 gpcd	39 gpcd	13 gpcd
Minimum 1970 to 2008	43 gpcd	19 gpcd	4 gpcd
Average 2000 to 2008	46 gpcd	36 gpcd	5 gpcd
Average 2005 to 2008	45 gpcd	34 gpcd	4 gpcd
Used for Projection	45 gpcd	35 gpcd	5 gpcd
Note: gpcd = gallons per capita per day			

System Maximum Day Pumpage

Table 3 summarizes the average and maximum day pumpage for each year from 1970 to 2008. A statistical analysis was performed of historical maximum day pumpage ratios. Two periods of analysis were examined, the entire period of 1970 to 2008, and the latest 11-year period from 1998 to 2008. Table 4 summarizes the results of this analysis.

Table 4 also includes an analysis of expected maximum day pumpage ratios for various confidence levels. To evaluation future water supply needs, a maximum day pumpage ratio of 168 percent was used which provides a confidence level of 98 percent based on maximum day pumpage ratios over the last 39 years and an approximately 96 percent confidence level over the last 11 years

WATER CONSUMPTION AND PUMPAGE PROJECTIONS

Water sales and pumpage projections were based on assumptions of water demand, coupled with estimates of future populations. A detailed summary of the individual components of the projected water sales and pumpage requirements is provided in Table 5. The industrial sales projections are based on planning data provided during the Water System Master Plan project that included an ultimate industrial acreage slightly less than the existing acreage and some large customer surveys indicating a decline in current water usage. In addition, unaccounted-for water (difference between pumpage and sales) was estimated to be 7 percent.

Figure 2 and Figure 3 illustrate the projected average and maximum day water supply requirements, respectively. The supply projections for the ultimate population projection for the City of Waukesha are illustrated as year 2050. The lower band illustrated on Figures 2 and 3 represents the projected water supply requirements based on current knowledge of water usage and population trends; however, there are uncertainties inherent to these projections. Because of the importance of not underestimating the future water supply needs, upper bands for projected water supply requirements were established. The upper bands for water supply projections illustrated in Figure 2 (average day) and Figure 3 (maximum day) are based on the following:

1. Residential per capita demand increased from 45 gpcd to 50 gpcd.
2. Commercial per capita demand increased from 35 gpcd to 39 gpcd.
3. Public per capita demand increased from 5 gpcd to 6 gpcd.
4. Increased population projection for 2028 by 10 percent to 94,380.
5. Increased population projection for 2035 by 10 percent to 97,350.
6. Increased ultimate population projection by 10 percent to 107,140.
7. Population projection was assumed to remain as projected to 2015 and then estimated linearly to the 2028 increased population projection.

It is recommended for long-term planning purpose that the upper band for average and maximum day water supply be used. It is also recommended that water supply be continually updated to ensure a proactive response to changes in population growth, development, and water demand patterns are addressed

SUMMARY

The following table summarizes the upper band of water supply needs for the City of Waukesha which is recommended to be used for planning purposes.

SUMMARY OF WATER SUPPLY NEEDS

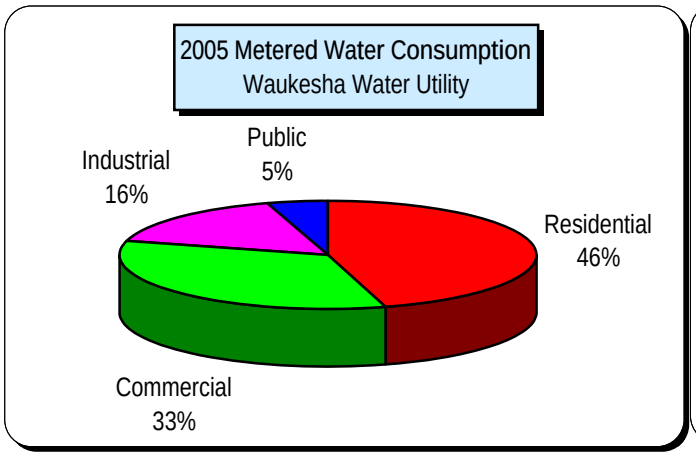
Year	Average Day Demand	Maximum Day Demand
2015	8.8 MGD	14.8 MGD
2028	10.7 MGD	18.0 MGD
2035	11.0 MGD	18.5 MGD
Ultimate (2050)	12.0 MGD	20.2 MGD
Note: MGD= million gallons per day		

TABLES

TABLE 1
WATER SALES AND PUMPAGE HISTORY
WAUKESHA, WISCONSIN

Year	Annual Water Sales (MGY)					Total Sales (MGY)	Total Pumpage (MGY)	Percent Pumpage Metered
	Residential	Commercial	Industrial	Public	Other			
1970	822.892	276.190	1,535.995	169.083	11.906	2,816.1	3,006.8	93.7%
1971	890.447	280.171	1,447.088	167.631	19.188	2,804.5	3,012.4	93.1%
1972	881.497	287.192	1,565.355	172.490	31.935	2,938.5	3,072.7	95.6%
1973	975.877	323.378	1,465.842	192.700	15.252	2,973.0	3,128.1	95.0%
1974	1,025.621	328.510	1,537.468	**206.624**	13.291	3,111.5	3,242.7	96.0%
1975	1,052.895	330.920	1,594.955	187.992	21.310	3,188.1	3,336.3	95.6%
1976	1,216.208	312.331	1,539.435	192.299	**43.691**	3,304.0	3,337.7	99.0%
1977	**1,221.868**	318.338	1,528.131	186.411	25.995	3,280.7	3,297.2	99.5%
1978	1,210.372	331.961	1,575.439	192.370	25.298	3,335.4	3,376.2	98.8%
1979	1,010.523	611.688	**1,610.236**	182.680	35.070	3,450.2	3,526.8	97.8%
1980	1,006.519	610.472	1,514.522	178.821	21.278	3,331.6	3,372.4	98.8%
1981	988.866	605.862	1,381.485	181.293	28.538	3,186.0	3,137.9	**101.5%**
1982	955.905	582.575	1,167.949	173.322	31.914	2,911.7	2,983.5	97.6%
1983	1,013.178	624.780	1,125.678	190.081	21.608	2,975.3	3,025.1	98.4%
1984	992.981	624.760	1,265.934	167.928	9.780	3,061.4	3,222.1	95.0%
1985	1,046.448	636.325	1,329.419	182.512	17.915	3,212.6	3,317.3	96.8%
1986	979.119	646.851	1,266.090	171.550	16.013	3,079.6	3,172.0	97.1%
1987	1,016.124	665.474	1,283.305	186.079	17.982	3,169.0	3,348.3	94.6%
1988	1,184.474	724.986	1,346.657	189.440	16.381	**3,461.9**	**3,606.7**	96.0%
1989	1,085.159	745.900	1,166.538	169.859	16.908	3,184.4	3,239.0	98.3%
1990	1,034.574	724.123	1,030.874	160.143	1.042	2,950.8	3,076.6	95.9%
1991	1,104.334	756.742	965.288	178.332	35.004	3,039.7	3,054.8	99.5%
1992	1,060.875	794.856	745.217	101.682	0.000	2,702.6	2,873.2	94.1%
1993	1,016.286	815.077	810.622	94.230	0.000	2,736.2	2,882.5	94.9%
1994	1,076.528	846.078	769.630	104.456	0.000	2,796.7	2,974.1	94.0%
1995	1,077.515	856.522	765.975	119.209	0.000	2,819.2	3,011.5	93.6%
1996	1,087.119	860.396	763.133	120.014	0.000	2,830.7	2,892.3	97.9%
1997	1,089.493	821.105	783.390	117.377	0.000	2,811.4	2,945.3	95.5%
1998	1,109.478	837.823	796.217	116.833	0.000	2,860.4	2,974.5	96.2%
1999	1,112.499	847.914	722.097	177.408	0.000	2,859.9	3,028.4	94.4%
2000	1,067.184	848.664	660.364	108.873	0.000	2,685.1	2,816.7	95.3%
2001	1,128.475	874.030	586.552	114.492	0.000	2,703.5	2,822.0	95.8%
2002	1,185.745	**914.138**	612.856	119.173	0.000	2,831.9	2,953.2	95.9%
2003	1,176.115	895.850	461.885	120.071	0.000	2,653.9	2,795.9	94.9%
2004	1,117.325	854.624	435.004	121.601	0.000	2,528.6	2,699.0	93.7%
2005	1,193.851	874.418	428.518	120.126	0.000	2,616.9	2,831.5	92.4%
2006	1,077.127	858.062	424.603	109.846	0.000	2,469.6	2,620.5	94.2%
2007	1,086.542	846.566	404.079	110.532	0.000	2,447.7	2,618.7	93.5%
2008	1,056.650	827.543	382.413	99.646	0.000	2,366.3	2,531.0	93.5%

Maximum Value =



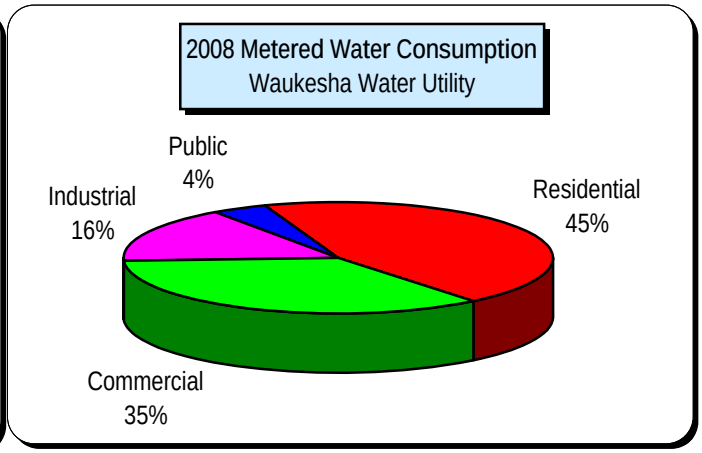


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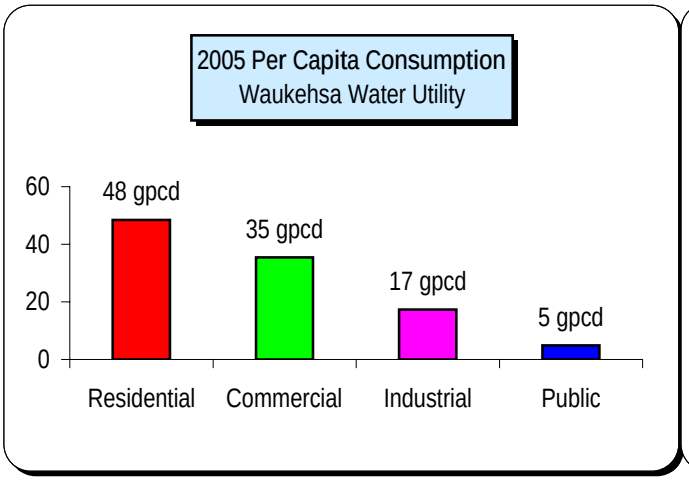
TABLE 2
HISTORICAL PER CAPITA CONSUMPTION
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

Year	Estimated Population	Gallons per capita per day				
		Residential	Commercial	Industrial	Public	Total
1970	39,695	56.8	19.1	106.0	11.7	194
1971	40,762	59.8	18.8	97.3	11.3	188
1972	41,829	57.7	18.8	102.5	11.3	192
1973	42,896	62.3	20.7	93.6	12.3	190
1974	43,963	63.9	20.5	95.8	12.9	194
1975	45,030	64.1	20.1	97.0	11.4	194
1976	46,097	72.3	18.6	91.5	11.4	196
1977	47,164	71.0	18.5	88.8	10.8	191
1978	48,231	68.8	18.9	89.5	10.9	189
1979	49,298	56.2	34.0	89.5	10.2	192
1980	50,365	54.8	33.2	82.4	9.7	181
1981	51,024	53.1	32.5	74.2	9.7	171
1982	51,684	50.7	30.9	61.9	9.2	154
1983	52,343	53.0	32.7	58.9	9.9	156
1984	53,002	51.3	32.3	65.4	8.7	158
1985	53,662	53.4	32.5	67.9	9.3	164
1986	54,321	49.4	32.6	63.9	8.7	155
1987	54,980	50.6	33.2	63.9	9.3	158
1988	55,639	58.3	35.7	66.3	9.3	170
1989	56,299	52.8	36.3	56.8	8.3	155
1990	56,958	49.8	34.8	49.6	7.7	142
1991	57,613	52.5	36.0	45.9	8.5	145
1992	58,268	49.9	37.4	35.0	4.8	127
1993	58,923	47.3	37.9	37.7	4.4	127
1994	59,578	49.5	38.9	35.4	4.8	129
1995	60,232	49.0	39.0	34.8	5.4	128
1996	60,887	48.9	38.7	34.3	5.4	127
1997	61,542	48.5	36.6	34.9	5.2	125
1998	62,197	48.9	36.9	35.1	5.1	126
1999	63,027	48.4	36.9	31.4	7.7	124
2000	64,825	45.1	35.9	27.9	4.6	113
2001	65,324	47.3	36.7	24.6	4.8	113
2002	66,237	49.0	37.8	25.3	4.9	117
2003	66,807	48.2	36.7	18.9	4.9	109
2004	66,816	45.8	35.0	17.8	5.0	104
2005	67,580	48.4	35.4	17.4	4.9	106
2006	67,750	43.6	34.7	17.2	4.4	100
2007	67,880	43.9	34.2	16.3	4.5	99
2008	68,030	42.6	33.4	15.4	4.0	96
Maximum Value =						



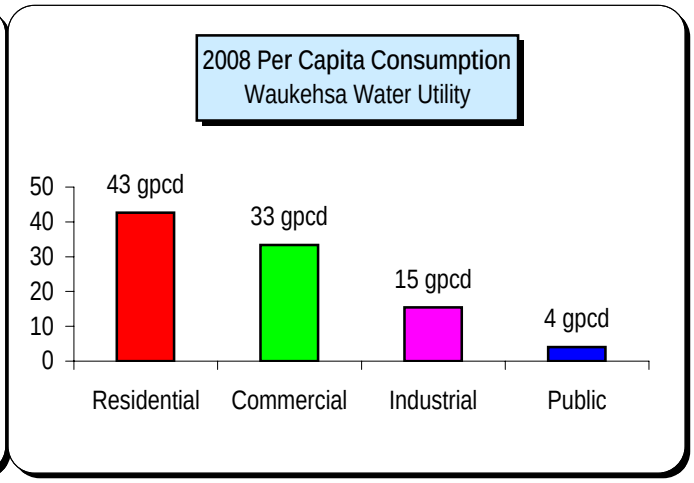


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TABLE 3
DAILY PUMPAGE VARIATIONS
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

Year	Avg. Day Pumpage (MGD)	Max. Day Pumpage (MGD)	Date of Maximum Day	Ratio of Max. to Avg. Day	Year	Avg. Day Pumpage (MGD)	Max. Day Pumpage (MGD)	Date of Maximum Day	Ratio of Max. to Avg. Day
1970	8.24	12.30	07/07	1.49	1990	8.43	11.67	07/17	1.38
1971	8.25	12.84	07/07	1.56	1991	8.37	12.31	08/28	1.47
1972	8.40	11.91	05/25	1.42	1992	7.85	13.86	06/11	1.77
1973	8.57	12.42	07/18	1.45	1993	7.90	10.09	08/27	1.28
1974	8.88	12.87	07/19	1.45	1994	8.15	12.40	06/19	1.52
1975	9.14	13.30	07/31	1.45	1995	8.25	12.81	06/22	1.55
1976	9.12	14.04	07/17	1.54	1996	7.90	10.66	08/14	1.35
1977	9.03	13.24	05/13	1.47	1997	8.07	11.84	06/10	1.47
1978	9.25	12.86	08/14	1.39	1998	8.15	12.79	07/14	1.57
1979	9.66	13.35	07/19	1.38	1999	8.30	11.59	07/07	1.40
1980	9.21	14.04	06/25	1.52	2000	7.72	10.15	06/27	1.31
1981	8.60	12.91	07/08	1.50	2001	7.73	12.53	07/09	1.62
1982	8.17	11.08	06/07	1.36	2002	8.09	12.78	07/17	1.58
1983	8.29	12.07	06/22	1.46	2003	7.66	11.67	08/22	1.52
1984	8.80	12.13	08/06	1.38	2004	7.39	10.48	09/13	1.42
1985	9.09	13.45	07/17	1.48	2005	7.76	12.87	06/23	1.66
1986	8.69	11.71	07/18	1.35	2006	7.18	10.23	07/18	1.42
1987	9.17	15.19	06/18	1.66	2007	7.17	9.59	06/14	1.34
1988	9.85	15.20	06/29	1.54	2008	6.93	9.93	08/19	1.43
1989	8.87	12.31	06/23	1.39					

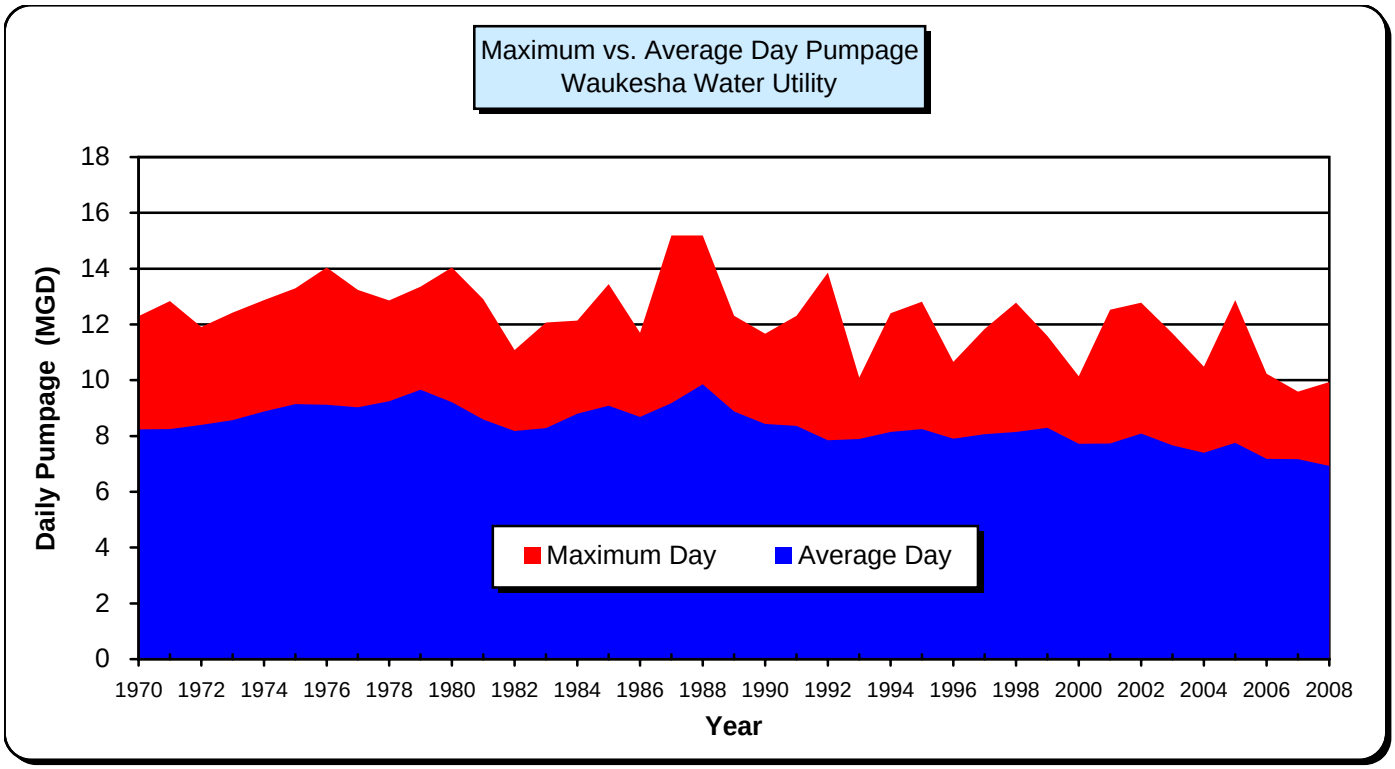

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TABLE 4

STATISTICAL ANALYSIS:
RATIO OF MAXIMUM TO AVERAGE DAY DEMAND

WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

	1998 to 2008	1970 to 2008
Number of years of Data	11	39
Maximum Ratio - Max. to Avg. Day Pumpage	165.9%	176.6%
Minimum Ratio - Max. to Avg. Day Pumpage	131.5%	127.8%
Average Ratio Max. to Avg. Day Pumpage	148.0%	146.9%
Standard Deviation	11.1%	10.3%

Confidence Level (%)	Ratio of Max. to Avg. Day Pumpage	Ratio of Max. to Avg. Day Pumpage
80%	157%	156%
85%	159%	158%
90%	162%	160%
95%	166%	164%
98%	171%	168%
99%	174%	171%

Note

The "Confidence Level" represents the probability (%) that in any given year, the actual ratio of maximum to average day pumpage will be less than or equal to the ratio indicated in the table. The ratios in the table were determined based on a statistical analysis of historical ratios over each period of analysis, assuming a normal distribution.

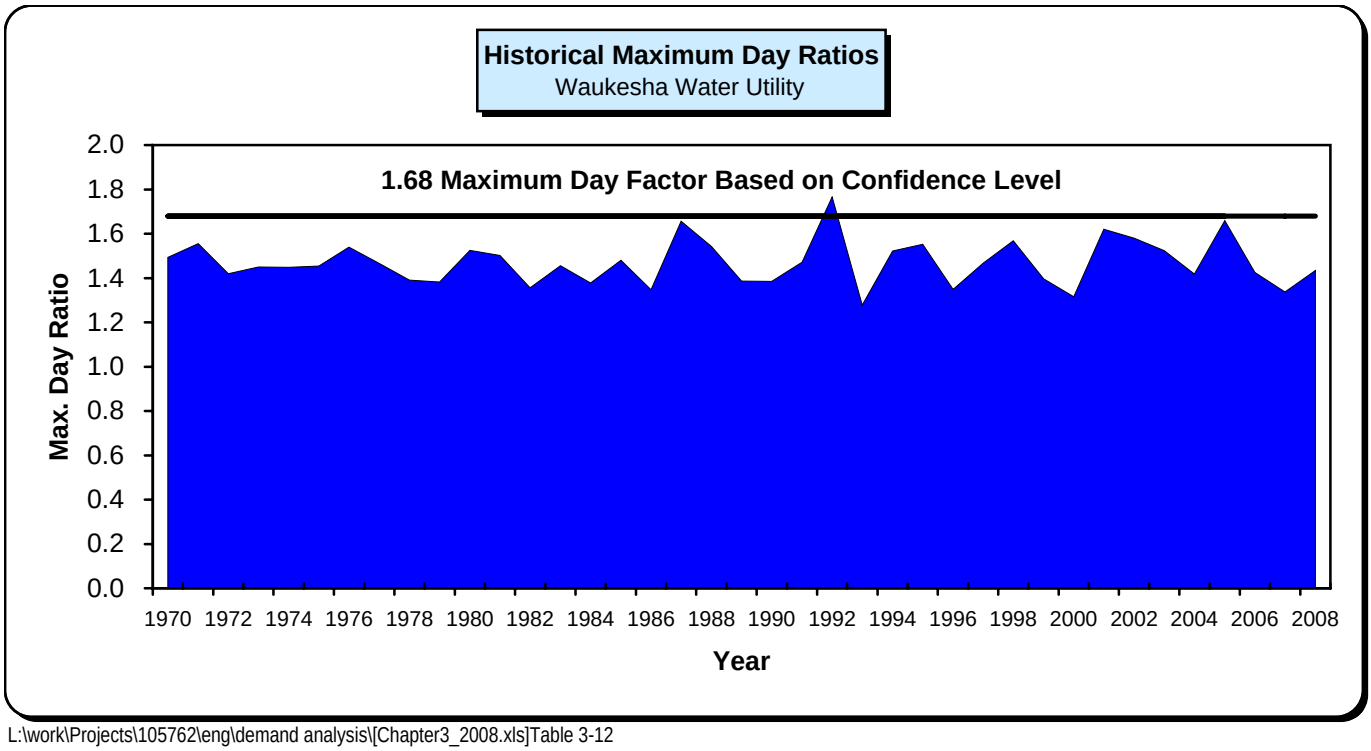

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TABLE 5

WATER SALES AND PUMPAGE PROJECTIONS

WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

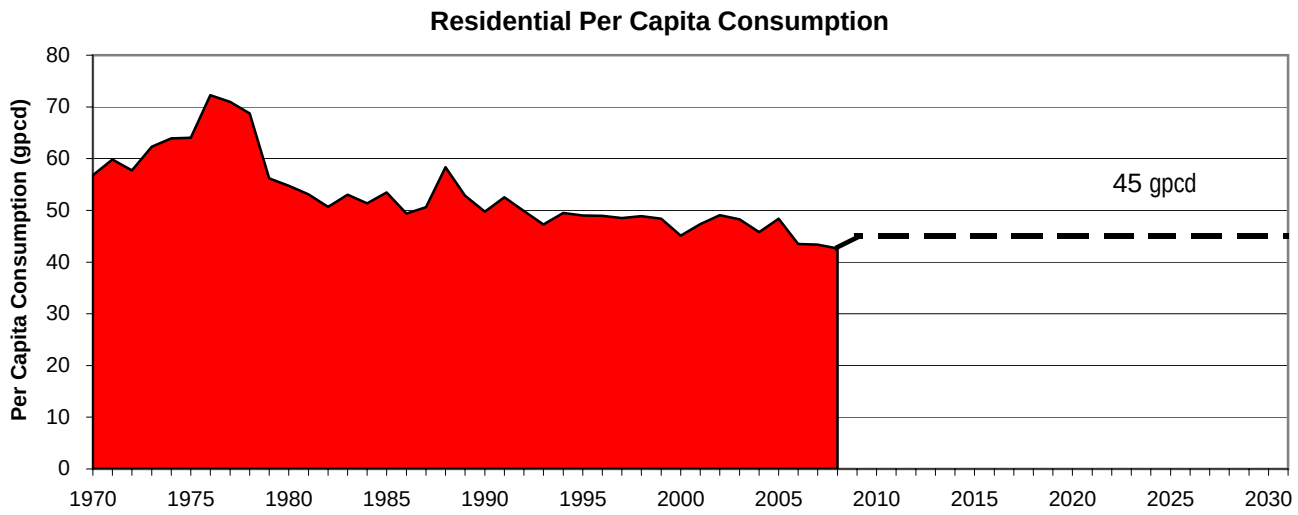
Customer Classification	Actual 2008	Projected 2028	Projected 2035	Projected Ultimate
Population Served	68,030	85,800	88,500	97,400
Residential Sales				
Per Capita Sales (gpcd)	43	45	45	45
Annual Sales (MGY)	1,057	1,410	1,450	1,600
Public Sales				
Per Capita Sales (gpcd)	4	5	5	5
Annual Sales (MGY)	100	160	160	180
Commercial Sales				
Per Capita Sales (gpcd)	33	35	35	35
Annual Sales (MGY)	828	1,100	1,130	1,240
Industrial Sales				
Annual Sales:				
Existing Sales (MGY)	382	415	400	400
TOTAL METERED SALES (MGY)	***2,370***	***3,090***	***3,140***	***3,420***
Unaccounted-For Water (MGY)	161	230	240	260
TOTAL PUMPAGE (MGY)	***2,531***	***3,320***	***3,380***	***3,680***
AVERAGE DAY DEMAND (MGD)	**6.93**	**9.10**	**9.26**	**10.08**
MAXIMUM DAY DEMAND (MGD)	**9.93**	**15.28**	**15.56**	**16.94**

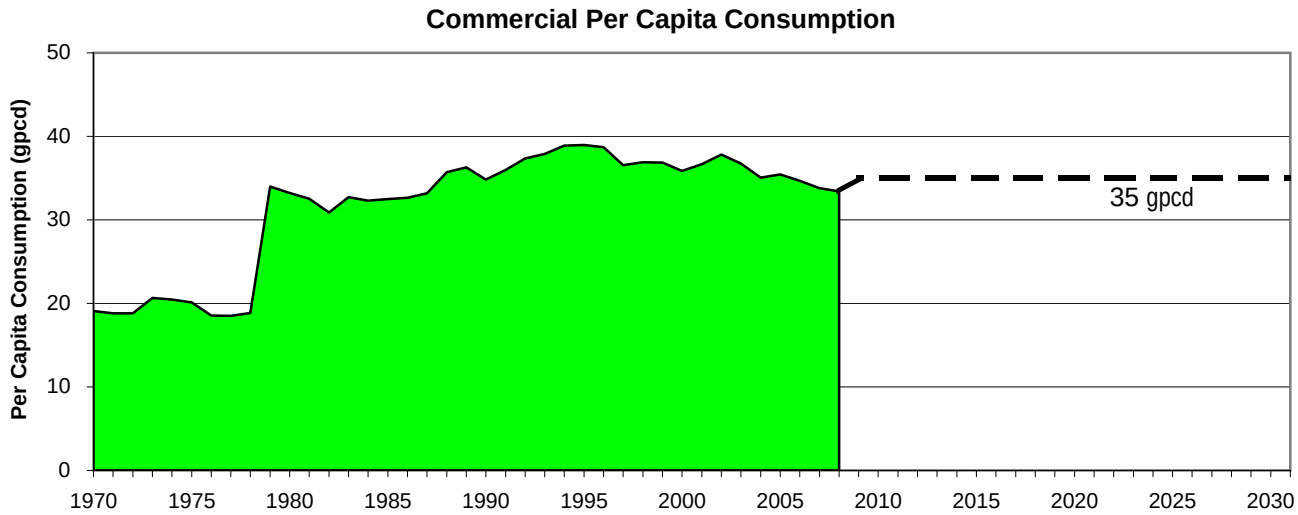
Notes:

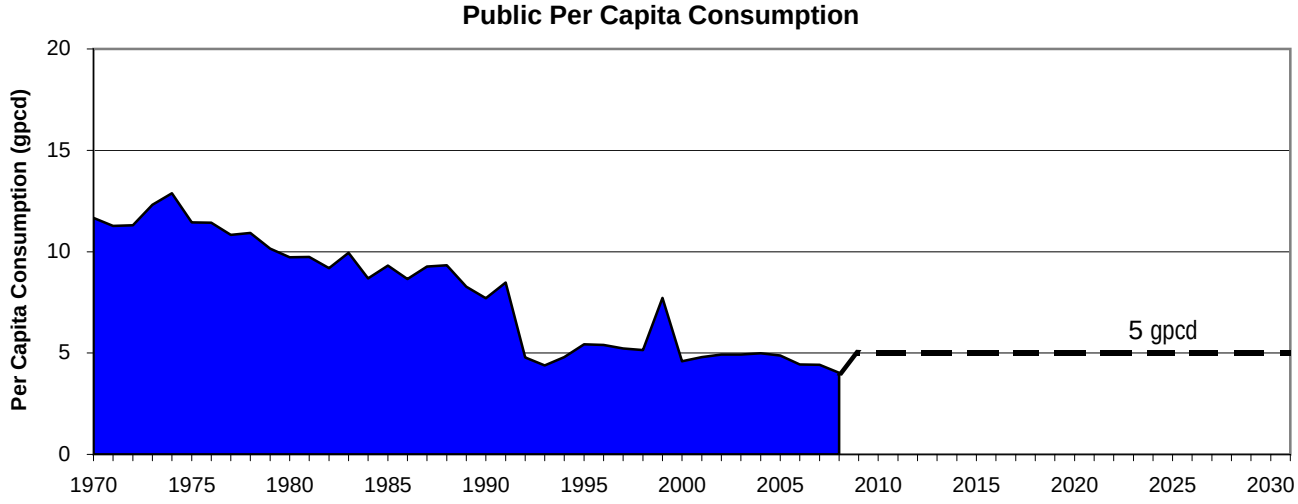
Projected populations from Southeastern Wisconsin Regional Planning Commission letter dated March 17, 2009.
Industrial sales projections based on planning data provided during Water System Master Plan project of ultimate industrial acreage slighly decreasing from existing acreage and some large customer surveys indicating decline in water usage.
Unaccounted-for water was projected at 7% of total pumpage for future years.
Maximum day demand 1.68 times average day demand.

L:\work\Projects\105762\eng\demand analysis\[Chapter3_2008.xls]Table 3-14

FIGURES







AECOM

FIGURE 1
HISTORICAL PER CAPITA CONSUMPTION
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

MAY 2009 105762

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L:\work\Projects\105762\eng\demand analysis\[Chapter3_2008.xls]Figure 2

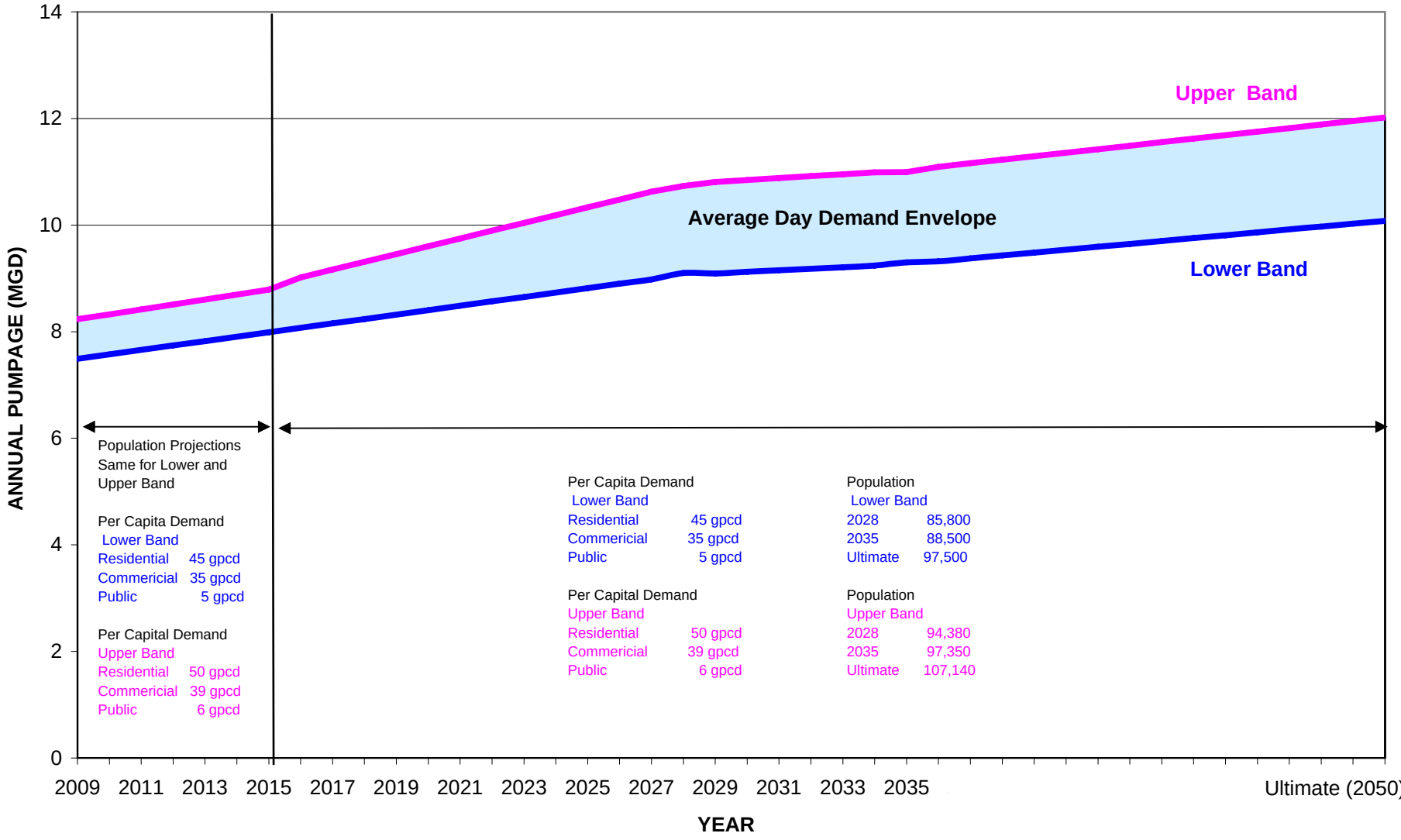

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FIGURE 2
ANNUAL AVERAGE DAY
WATER PUMPAGE PROJECTIONS
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

MAY 2009 105762

L:\work\Projects\105762\eng\demand analysis\[Chapter3_2008.xls]Figure 3

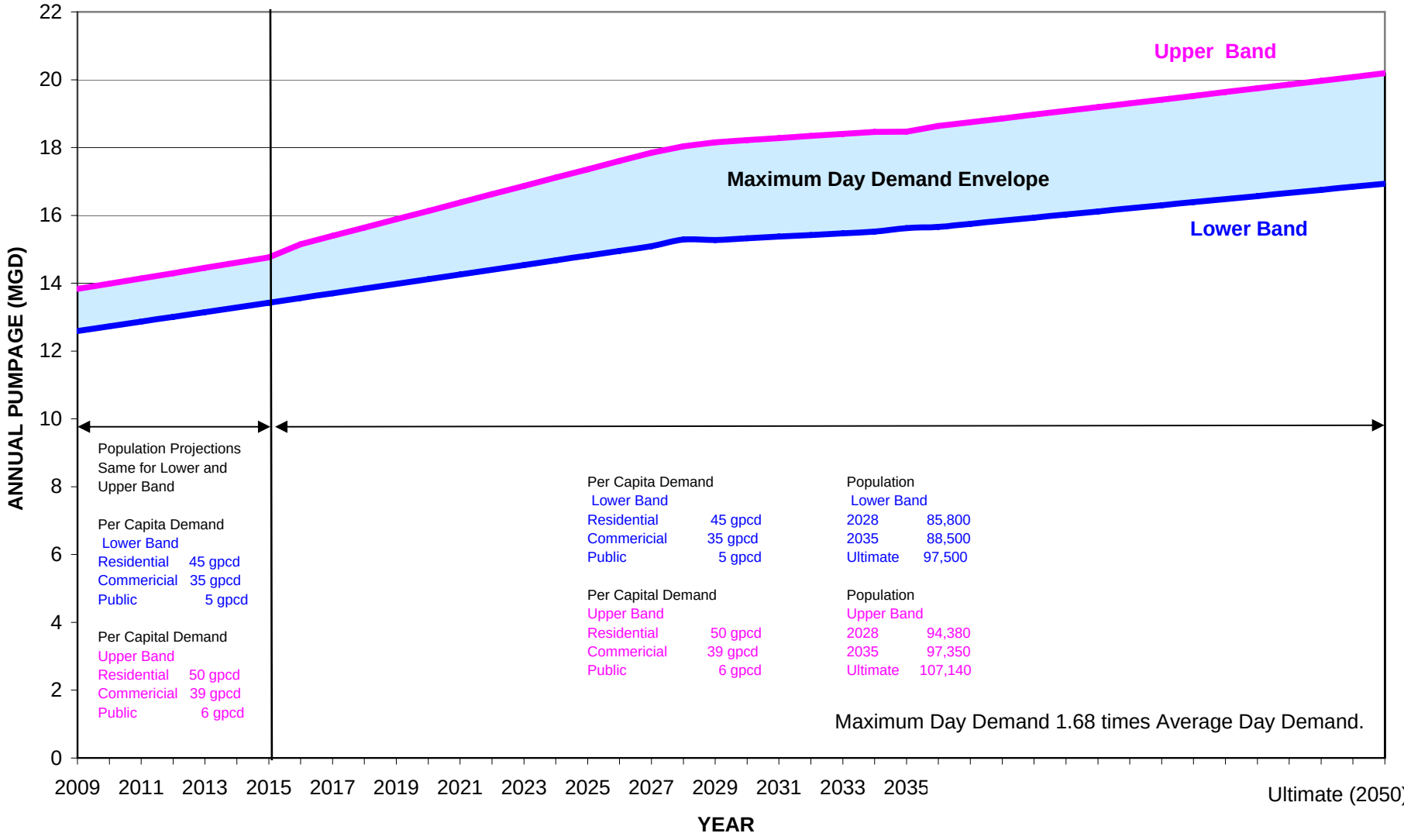

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FIGURE 3
ANNUAL MAXIMUM DAY
WATER PUMPAGE PROJECTIONS
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN

MAY 2009 105762

ATTACHMENT A

POPULATION PROJECTIONS

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
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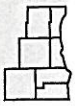


Received
MAR 19 2009
Waukesha Water Utility

March 17, 2009

Mr. Steven Crandell
Community Development Director,
City of Waukesha
201 Delafield Street
Waukesha, WI 53188-3633

Dear Mr. Crandell:

In response to your request, the Regional Planning staff has prepared an estimate of the ultimate population for the Waukesha water supply service area. The ultimate population for the water supply service is estimated at 97,400 persons. This compares to the year 2000 population of 75,500 persons and a planned year 2028 population of 85,800 persons, as set forth in the SEWRPC staff memorandum entitled "Response to Request by the City of Waukesha Water Utility to Delineate the 20-Year Planned Water Supply Service Area for the Utility." The ultimate population is an estimate of the population that could be accommodated within the water supply service area, assuming full development conditions as envisioned under the land use element of the Waukesha County comprehensive plan, with input on population densities for various residential land use categories and other aspects of the plan from your staff.

The 2028 population represents a step on the way to the 2035 population of 88,500 persons set forth in the ongoing regional water supply plan. The ultimate population within the water supply service area represents a condition beyond the 2035 planning horizon adopted for the regional water supply plan.

We trust that this responds to your request. Should you have any questions, feel free to call.

Sincerely,

Kenneth R. Yunker, P.E.
Executive Director

KRY/WJS/lgh
#143499 v1 - response to s crandell

cc: Michael G. Hahn, SEWRPC
Robert P. Biebel, SEWRPC

Appendix L

Return Flow Effects on Habitat in Underwood Creek and Menominee River

Return Flow Effects on Habitat in Underwood Creek and Menomonee River

TO: Waukesha Water Utility

FROM: CH2M HILL

DATE: January 23, 2010

The City of Waukesha is applying for a new Lake Michigan water supply that would require return flow. The return flow would come from the City of Waukesha wastewater treatment plant. This memorandum summarizes potential changes to the functional habitats in Underwood Creek and the Menomonee River that would result from return flow to Underwood Creek. This document expands on a previous study that evaluated the return flow effects on the geomorphic stability of Underwood Creek[1].

Executive Summary

Previous studies have determined that a return flow to Underwood Creek would not affect the geomorphic stability of the creek. This study evaluated the return flow influence on habitat and aquatic resources in Underwood Creek and the Menomonee River for locations downstream of the return flow discharge location. Information from representative areas indicates that:

- The habitat of dominant fish and macroinvertebrates could be improved with additional flow, especially in the rehabilitated segment of the creek and during periods when the creek flows are low (baseflow flow conditions).
- Underwood Creek often experiences extended periods when there is no flow in the creek because of ice or dry conditions when there is little precipitation. At those times, return flow would provide the greatest habitat improvement because periods of no flow could be eliminated.
- During baseflow and low flow periods, return flow would provide additional water depth to improve fish passage through the riffle and concrete parts of the creek, to deepen pools within the restored reach, and to provide more wetted perimeter habitat near the creek banks and overhanging vegetation.
- Return flow is expected to slightly increase shear stresses in the creek, which are insignificant to the geomorphic stability of the creek, but could improve the bottom substrate habitat by reducing embeddedness (fine sediment accumulation in coarse substrates) to support coarse (e.g., gravel) sediment habitat.

[1] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009,

- Most of the creek is concrete lined, but the areas that have already been rehabilitated or that will be rehabilitated in the future will benefit the most from additional flow.
- When creek flow is high (e.g., flow events greater than a 2-year flow), return flow is a small portion of the total creek flow. During these times, return flow is not expected to have a significant effect on the creek habitat.

Return flow influence on the larger Menomonee River is expected to benefit the habitat downstream of its confluence with Underwood Creek for the same reasons. Because the return flow will be a smaller percentage of the total river flow, it will improve fish passage, submerged habitat, and embeddedness to a lesser degree. When river flows are high, return flow is not expected to have a significant effect on river habitat because it will be a very small percentage of the total river flow.

Introduction

In support of the City of Waukesha's application for a Great Lakes drinking water supply, field data were collected and hydraulic models were used to assess the potential changes to habitat in Underwood Creek and the Menomonee River, for areas downstream of a future return flow. The location of the return flow discharge is anticipated to be in Waukesha County near the intersection of Underwood Creek and Bluemound Road. The distance from the creek at this location to its confluence with the Menomonee River (Figure 1) is roughly 2.6 miles and includes mostly concrete-lined channels (Figure 2) with a 2,400-foot section that was recently rehabilitated[2] (Figure 3). The downstream 4,400 feet of creek (immediately downstream of the rehabilitated reach) to the confluence with Menomonee River is mostly concrete-lined, with a short segment that has a concrete low-flow channel and vegetated floodplain (Figure 4) and a natural 300-foot segment at the end of the reach. That reach is expected to be rehabilitated in the future, but final design has not yet been completed.[3] Downstream of the creek confluence with the Menomonee River, the river is mostly an urban-natural channel with a natural bottom, vegetated riverbanks, and limited areas of concrete (Figure 5).

[2] Milwaukee Metropolitan Sewerage District (MMSD). 2008. "Watercourse: Underwood Creek Rehabilitation and Flood Management – Phase 1." Designed by Short Elliott Hendrickson, Inc.

[3] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 2.

FIGURE 1
Underwood Creek and Menomonee River

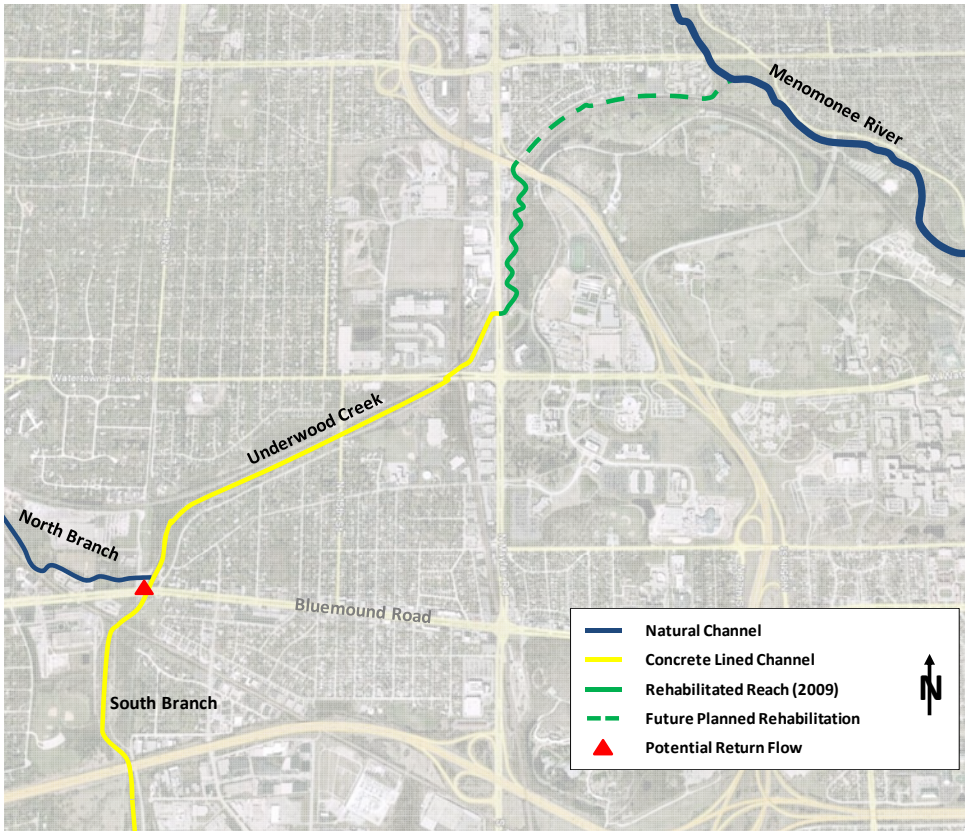


FIGURE 2
Concrete Lining in Underwood Creek



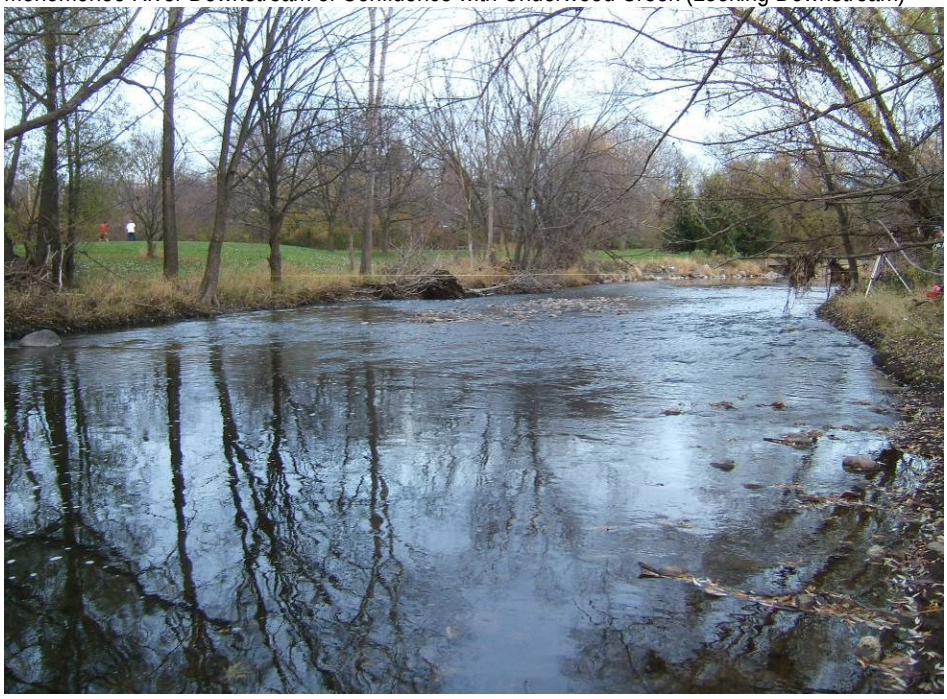
FIGURE 3
Rehabilitated Reach of Underwood Creek (during Construction)



FIGURE 4
Underwood Creek Concrete-Lined Low Flow Channel with Vegetated Floodplain



FIGURE 5
Menomonee River Downstream of Confluence with Underwood Creek (Looking Downstream)



Field Survey

A field survey was completed and included surveying cross sections at several locations in the creek and river, for low-flow portions of the cross section (i.e., the floodplain was not surveyed). The field survey conducted qualitative assessments of the existing aquatic habitat. The field survey was also completed to provide data on how additional flow could change the functional habitat (e.g., how additional flow could change the wetted perimeter, embeddedness, cross sectional flow area, flow depth, vegetation influence, etc).

Previously developed HEC-RAS hydraulic models of Underwood Creek[4] and the Menomonee River[5] were used in conjunction with the surveyed cross sections to evaluate the potential effect the addition of the return flow may have on the functional habitat within the creek and river. The functional habitat evaluation was completed with consideration for the dominant fish and macroinvertebrates identified for these water bodies (Attachment A).

Return Flow Effect on Underwood Creek Habitat

The rehabilitated parts of the creek provide greater functional habitat than the concrete lined parts because the bottom substrate is coarse grained sediments (gravel and cobbles); it provides various habitat features such as riffles, runs, pools, and glides; it meanders and includes other habitat features like rock boulders; the vegetation will overhang the channel once it is mature; and the creek will be reconnected with its floodplain. The concrete-lined creek provides less functional habitat because there is little or no vegetation providing cover; the water depth is

[4] Underwood Creek HEC-RAS Model. Underwood Creek Rehabilitation and Flood Management Project. Short Elliott Hendrickson Inc., 2009. Computer Model.

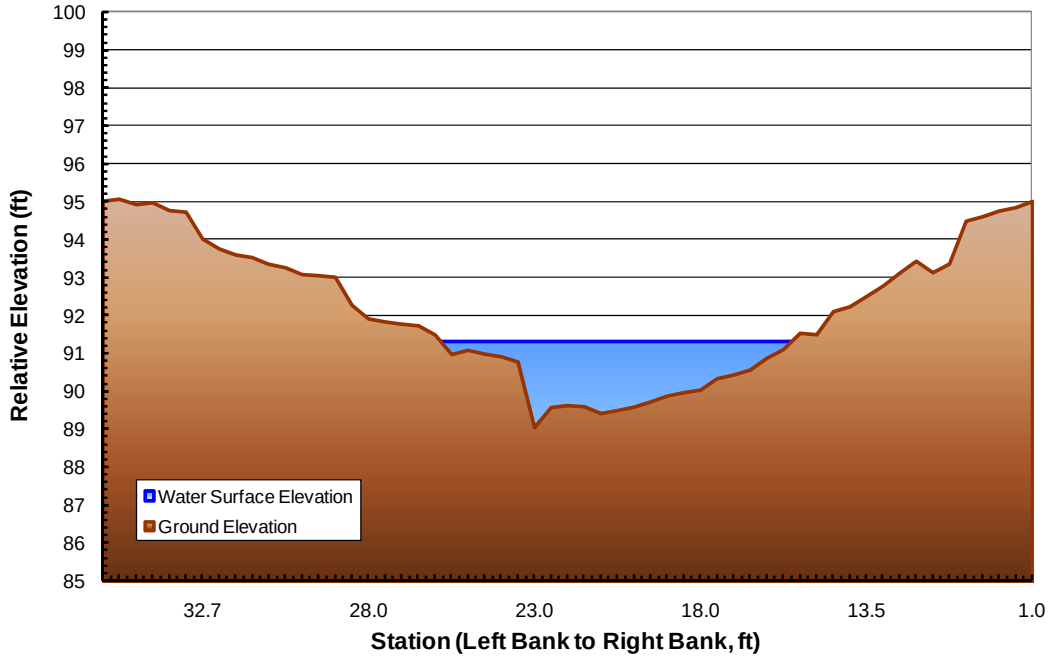
[5] Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Milwaukee Metropolitan Sewerage District, 2001. Computer Model. Modified for newer HEC-RAS model v3.1.3.

very shallow and there are several drops that are barriers to fish passage during low flow periods; the bottom substrate does not support a functional benthic community; and the uniformity of the channel provides limited areas for fish to hold or seek refuge.

There are concrete-lined areas upstream and downstream of the rehabilitated reach, and its habitat resources are not fully used because there are barriers (concrete lining and drop structures) between it and the Menomonee River. However, because the downstream part of the creek is planned to be rehabilitated using similar design concepts, these areas of the creek are expected to provide functional habitat that is connected with the aquatic community in the river.

Two cross sections were surveyed in the rehabilitated portion of the creek, one at a pool (Figure 6) and one at a riffle-run (Figure 7). The cross sections were collected when the creek was very near its baseflow of 3 cubic feet per second (cfs), where the flow is well within main channel, and bottom substrate was readily visible. (The cross sections were surveyed using a relative benchmark elevation of 100 feet for each cross section.)

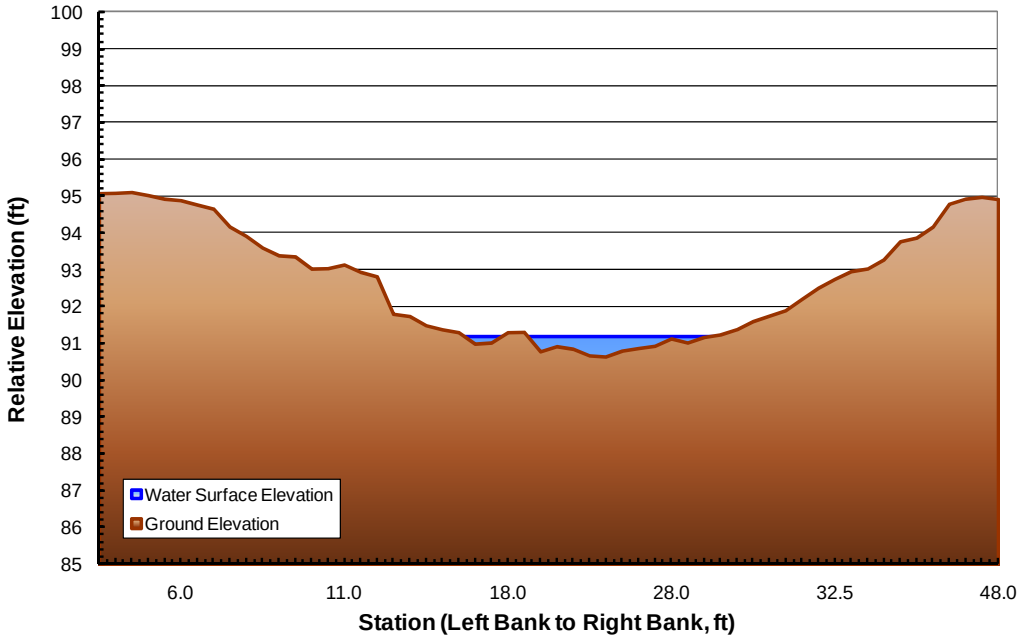
FIGURE 6
Baseflow at a Pool in the Underwood Creek Rehabilitated Reach



A hydraulic analysis was completed as part of the geomorphic stability analysis for a potential return flow of 20 cfs.[6] It estimated an increase in the water surface elevation between 0.15 to 0.80 foot in the existing and future rehabilitated reach during baseflow conditions. At two locations that coincide with this habitat evaluation, an increase in water surface elevation of 0.78 foot was estimated. Shown in Figures 8 and 9 are cross sections at the two locations that were surveyed as part of this study. These cross sections were used because they provide greater detail of the creek than do the cross sections used in the geomorphic hydraulic analysis.

[6] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 1 and Attachment 3.

FIGURE 7
Baseflow at a Riffle-run in the Underwood Creek Rehabilitated Reach



During baseflow periods, the return flow also increases the average velocity, cross sectional flow area, shear stress, and the wetted perimeter in the creek. These increases will have a negligible effect on the hydraulic and geomorphic conditions in the creek[8], but the increase in flow is expected to benefit the habitat within the creek during baseflow periods by reducing the extent to which fine sediments fill the coarse sediment substrate (embeddedness), providing deeper pools and riffles for more functional fish passage, and providing more wetted perimeter to support a greater benthic community.

To supplement the hydraulic analysis completed as part of the geomorphic stability analysis, additional hydraulic modeling was completed for return flows of 11.6 and 30 cfs. The 11.6 cfs flow was chosen because it represents the existing average day water demand. The 30-cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs. As expected, the lower return flow has less of an increase in cross sectional flow area, shear stress, and wetted perimeter compared to 20-cfs return flow and the 30-cfs return flow has more. Table 1 summarizes the modeling output for the surveyed cross sections during baseflow periods. Similar to the 20 cfs results, the model results are applied to the surveyed cross sections.

[8] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 1.

FIGURE 8
Underwood Creek Water Surface Elevation with 20-cfs Return Flow (23-cfs total flow) at Pool

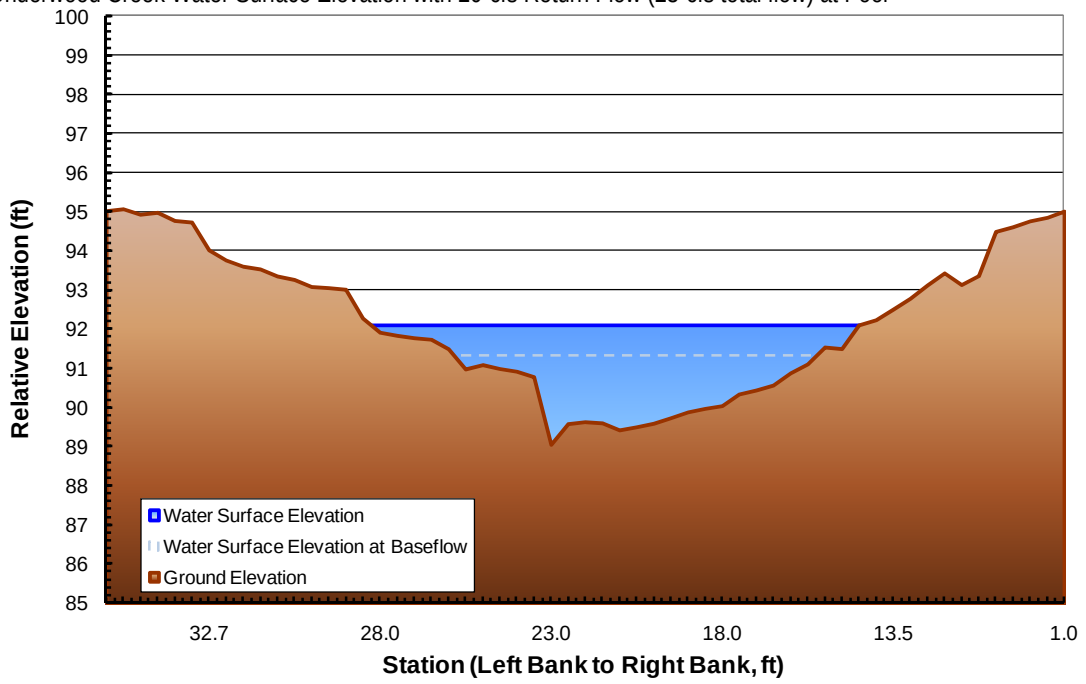


FIGURE 9
Underwood Creek Water Surface Elevation with 20-cfs Return Flow (23-cfs Total Flow) at Riffle-run

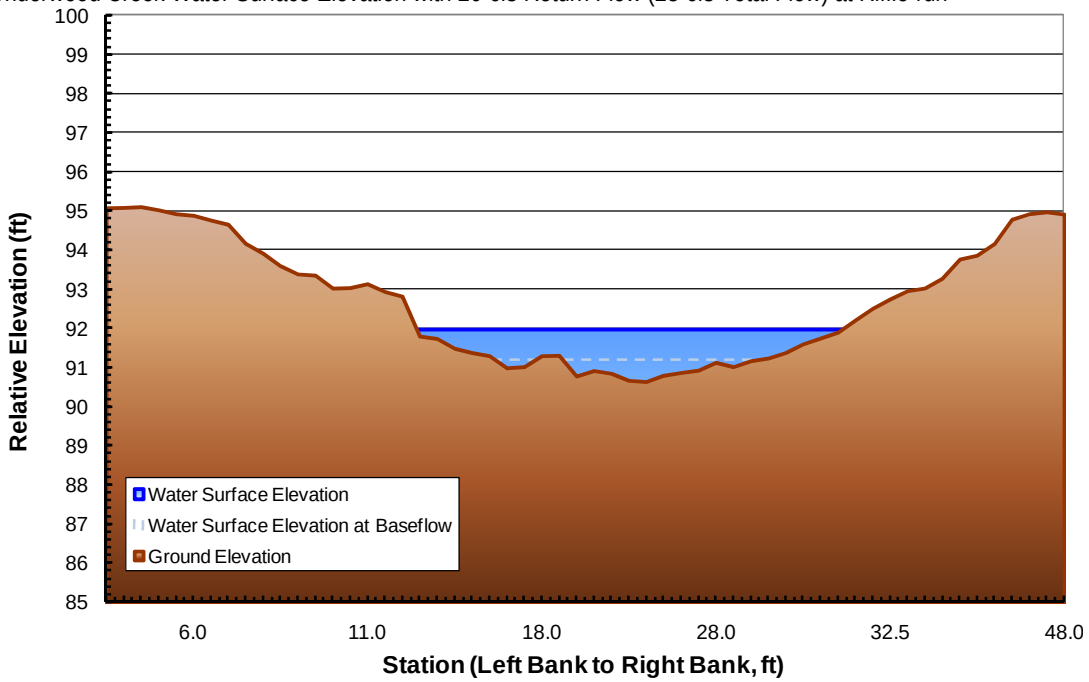


TABLE 1
Underwood Creek Summary Output for Surveyed Cross Sections During Baseflow with Varying Return Flow

		Baseflow with Return Flow of		
	Baseflow	**11.6 cfs**	**20 cfs**	**30 cfs**
Average velocity (ft/sec)	0.85	1.11	1.32	1.51
Channel shear stress (lb/ft^2)	0.05	0.08	0.11	0.13
Flow area (ft^2)	3.51	13.13	17.43	21.84
Wetted perimeter (ft)	Riffle-run: 11.6 Pool: 12.6	Riffle-run: 18.6 Pool: 15.8	Riffle-run: 19.7 Pool: 16.3	Riffle-run: 20.2 Pool: 18.0

Note: Model results assuming Phases I and II of the channel rehabilitation are complete and the channel vegetated. Wetted perimeter calculated from surveyed cross sections.

When creek flow is high during large storms (e.g., 2-year flow events and larger), the return flow is a very small part of the creek flow and is not expected to have a significant effect on the creek habitat. For example, a 20-cfs return flow is only 1.5 to 2.0 percent of the 2-year flow (for locations in the creek downstream of the potential return flow location)[9] and 0.29 to 0.76 percent of the 100-year flow. For a 30-cfs flow, it is only 2.2 to 3.0 percent of the 2-year creek flow and 0.44 to 1.1 percent of the 100-year flow. This results in very little or no change to the calculated average velocity, shear stress, flow area, or wetted perimeter with 30 cfs return flow for a 2-, 5- and 100-year creek flow (Table 2).

TABLE 2
Underwood Creek Summary Output for Surveyed Cross Sections during High Flow Periods with Varying Return Flow

	2-year Creek Flow	2-year Creek Flow plus 30 cfs Return Flow	5-year Creek Flow	5-year Creek Flow plus 30 cfs Return Flow	100-year Creek Flow	100-year Creek Flow plus 30 cfs Return Flow
Average velocity (ft/sec)	5.32	5.38	6.61	6.66	7.20	7.21
Channel shear stress (lb/ft^2)	0.97	0.99	1.38	1.39	1.54	1.54
Flow area (ft^2)	321.2	327.7	502.7	507.9	678.0	685.6
Wetted perimeter (ft)	118.1	118.4	133.3	133.8	163.1	164.7

Note: The 30 cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs. Model results assuming Phases I and II of the channel rehabilitation are complete and the channel vegetated.

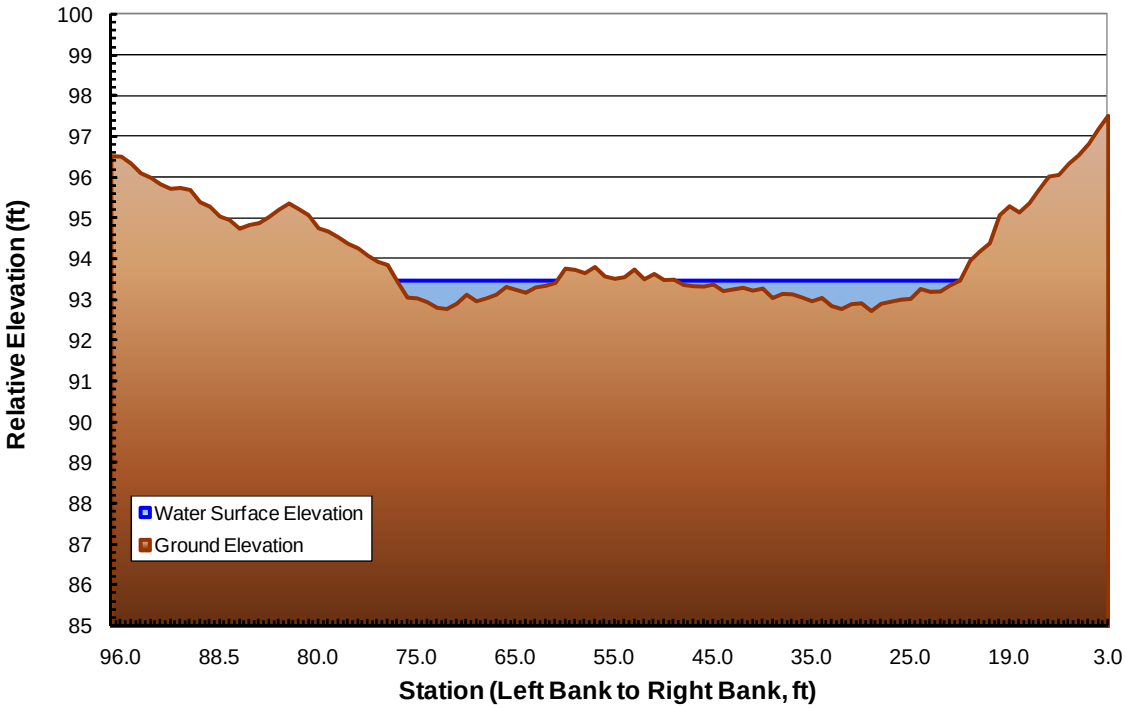
Dominant fish and macroinvertebrates, and associated preferred habitats were identified for these areas (Attachment A). Based on that analysis and the results above, the habitats for the dominant species would most benefit from a return flow during periods of low flow, such as baseflow conditions, and it would be expected that the fish and benthic communities would also improve because of the improvements to the functional habitat. Underwood Creek often experiences extended periods when there is no flow in the creek due to ice or dry conditions with little precipitation. During such times, return flow would provide the greatest habitat improvement because the periods with no flow would be eliminated.

[9] Underwood Creek HEC-RAS Model. Underwood Creek Rehabilitation and Flood Management Project. Short Elliott Hendrickson Inc., 2009. Computer Model.

Return Flow Effect on Menomonee River Habitat

The Menomonee River is much larger than Underwood Creek, when comparing watershed size, average annual flows, and cross sectional areas of the river and creek, and therefore the addition of return flow will have a less significant effect on the habitat within the river. To estimate the potential changes in habitat, a cross section was surveyed at a riffle on the river immediately downstream of the confluence with the creek. The location was chosen because it was very near a location within the hydraulic model (river mile 8.37), which was used to predict changes in the river hydraulics that would influence habitat changes. The base flow rate of about 8 cfs was estimated from low flow periods of average daily flow at the USGS gauge (#04087120). Figure 10 shows the surveyed cross section during baseflow, including exposed substrate in the center of the cross section that is not functional for fish or macroinvertebrates.

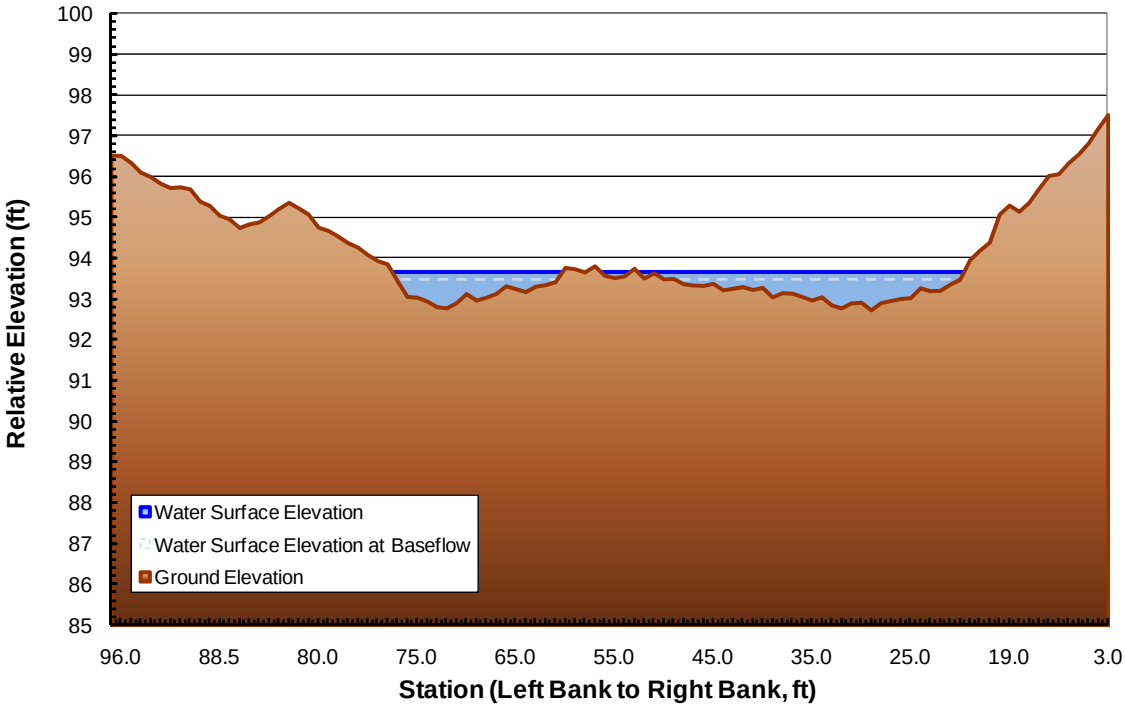
FIGURE 10
Baseflow at Surveyed Riffle Cross Section in the Menomonee River



A HEC-RAS hydraulic analysis was completed during this study for a potential return flow of 20 cfs, which predicted a slight increase in the water surface elevation of 0.17 foot under baseflow conditions (Figure 11). There is exposed substrate at that location, and the increased cross sectional flow area provided by the return flow provides greater functional area for fish and macroinvertebrates.

The return flow in the river is expected to also have a negligible effect on the hydraulic and geomorphic conditions in the river, the same conclusion reached for the creek. The return flow is estimated to slightly increase the average velocity, shear stress and the wetted perimeter in the river. The return flow is estimated to have a greater increase in cross sectional flow area, where the area would increase by 60 percent for a 20-cfs return flow. These increases are expected have a benefit to the river habitat, similar to the benefits within the creek.

FIGURE 11
Menomonee River Water Surface Elevation with 20-cfs Return Flow (28 cfs Total Flow)



The return flow could benefit the river by reducing the opportunity for fine sediments to fill the coarse sediment substrate (embeddedness), providing deeper pools and riffles for more functional fish passage, and providing more wetted perimeter to support a greater benthic community. The river has a better functioning aquatic community than the creek (Attachment A), where the return flow could have a greater benefit to the river aquatic community.

Hydraulic modeling was completed for a return flow of 11.6, 20, and 30 cfs. As expected, the lower return flow has less of an increase in cross sectional flow area, shear stress and wetted perimeter compared to the larger return flow. Table 3 summarizes the modeling output for the surveyed cross section during baseflow periods.

TABLE 3
Menomonee River Summary Output for Surveyed Cross Section During Baseflow with Varying Return Flow

		Baseflow with Return Flow of		
	Baseflow	11.6 cfs	20 cfs	30 cfs
Average velocity (ft/sec)	0.5	1.0	1.14	1.27
Channel shear stress (lb/ft^2)	0.01	0.05	0.06	0.07
Flow area (ft^2)	15.1	19.2	24.3	30.0
Wetted perimeter (ft)	43.8	48.8	50.8	53.9

Note: Wetted perimeter calculated from surveyed cross sections.

When the river flow is high during large storms (e.g., 2-year flow events and larger), the return flow is a very small portion of the river flow. As with the creek, return flow during these times is not expected to have a significant effect on the river habitat. For example, a 20-cfs return flow is only 0.30 to 0.59 percent of the 2-year flow (for locations in the river downstream of the potential return flow location)[10] and 0.11 to 0.21 percent of the 100-year flow. For a 30-cfs return flow, it is only 0.45 to 0.88 percent of the 2-year river flow and 0.16 to 0.32 percent of the 100-year flow. This results in very little or no change to the calculated average velocity, shear stress, flow area, or wetted perimeter with 30-cfs return flow for a 2-, 5- and 100-year river flow (Table 4).

TABLE 4
Menomonee River Summary Output for Surveyed Cross Section during High Flow Periods with Varying Return Flow

	2-year River Flow	2-year River Flow plus 30 cfs Return Flow	5-year River Flow	5-year River Flow plus 30 cfs Return Flow	100-year River Flow	100-year River Flow plus 30 cfs Return Flow
Average velocity (ft/sec)	6.86	6.88	7.14	7.14	6.70	6.69
Channel Shear Stress (lb/ft^2)	0.85	0.85	0.85	0.85	0.66	0.66
Flow Area (ft^2)	790.2	800.5	1,579.1	1,593.3	3,670.1	3,684.7
Wetted Perimeter (ft)	260.9	270.3	481.4	481.7	531.7	532.0

Note: The 30 cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs.

Dominant fish and macroinvertebrates and associated preferred habitats were identified for these areas (Attachment A). Based on that analysis and the results above, the habitats for the dominant species would most benefit from a return flow during periods of low flow. It would be expected that the fish and benthic communities would also improve because of the improvements to the functional habitat.

[10] Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Milwaukee Metropolitan Sewerage District, 2001. Computer Model. Modified for newer HEC-RAS model v3.1.3.

Attachment A

Desktop Fisheries Analysis Assessment for Underwood Creek Return Flow

Desktop Fisheries Analysis Assessment for Underwood Creek Return Flow

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: January 23, 2010

This memorandum reviews historical fisheries and macroinvertebrate data collected from Underwood Creek and the Menomonee River both upstream of and near the confluence of the Creek. The object of this review is to present an overview of historical fish community structure and selected habitat preferences in areas where return flow from the City of Waukesha could occur. This review summarizes biological information within the Menomonee River watershed that could offer comparisons to Underwood Creek now or in a future restored condition. Summary benthic macroinvertebrate and habitat information is also presented to give a broader perspective of Underwood Creek's biological and physical nature.

Physical Description

The physical nature of Underwood Creek from the potential return flow location to about Highway 100 (Mayfair Road) is predominantly a trapezoidal concrete channel with little habitat for fish. The relatively smooth concrete channel does provide some limited substrate for benthic macroinvertebrates and algae colonization. There is very little overhead tree or shrub cover.

A total of approximately 2,400 feet of the concrete stream channel in Underwood Creek from about Highway 100 downstream to about the Chicago, Milwaukee, St. Paul and Pacific Railroad Bridge (Highway 45 overpass) was removed in 2009 and rehabilitated to a meandering stream channel with numerous pools/riffles. The bottom substrate material is largely cobble and boulders with some large to medium gravel.

From the downstream end of the rehabilitated channel to roughly 300 feet upstream of the confluence with the Menomonee River the stream channel is also a trapezoidal concrete channel with several drop structures. Little fish habitat exists in this portion of Underwood Creek. The drop structures preclude movement of fish to the restored area under normal baseflow. A future Phase 2 channel restoration plan includes removing most of the remaining concrete all the way to the Menomonee River.

The last 300 feet of Underwood Creek before the confluence with the Menomonee River has natural substrate. Several pools and riffles are present along with large amounts of woody debris. The stream bottom is largely cobble, with varying amounts of sand, gravel, and silt.

Available Data Review

Inquiries were made to various organizations to determine data already available for Underwood Creek and the Menomonee River. Inquiries were made with the Milwaukee

Metropolitan Sewerage District, the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and the Wisconsin Department of Natural Resources. These three organizations, and local academic institutions in conjunction with the United States Geological Service (USGS), have been collaborating in data-sharing efforts as part of the Regional Water Quality Management Plan Update efforts lead by SEWRPC. The data have been compiled into an overall database. Relevant portions of this database were made available to conduct this review.

Fisheries

The USGS obtained the most recent fisheries data for lower Underwood Creek and the Menomonee River near Underwood Creek in 2004 and 2007. Data collected by the USGS were from both concrete-lined and natural channel segments at the downstream end of Underwood Creek. The results of these two stream surveys identified about 20 species of fish. Table 1 lists the 14 most abundant species collected, along with their preferred habitat characteristics. Underwood Creek sampling found 12 species. The consolidated information in Table 1 is from information collected from several sources (see Attachment A-1). These species are common in other subwatersheds in the Menomonee River Basin.

TABLE 1
Summary of Preferred Habitat Characteristics for Dominant Fish Species in the Menomonee River Watershed

Dominant Fish Species	Found in Underwood 2004 or 2007	Preferred Current Velocity Range	Stream Gradient	General Habitat Characteristics	Dominant Substrate Preference
Pearl dace	X			Pools	Sand/gravel
Creek chub	X	< 0.98 ft/sec	3-23 m/km	Pools	Sand/gravel
White sucker	X	1.31 ft/sec	Wide range	Wide range	Gravel/sand
Long nose dace	X	> 1.48 ft/sec	1.9-18.7 m/km	Riffles	Gravel/rubble
Blunt nose minnow	X			Wide range	Gravel/sand
Black nose dace	X	0.49–1.48 ft/sec	11.4–23.3 m/km	Rocky runs and pools	Gravel/sand
Central stoneroller	X			Rocky riffles, runs, and pools	Gravel/sand/rubble
Common shiner	X			Rocky pools near riffles	Hard bottom/gravel/sand/rubble
Fathead minnow	X			Muddy pools	Sand/rubble/gravel
Largemouth bass	X	> 0.33 ft/sec			Vegetated areas, sand/gravel/mud
Green sunfish	X	< 0.33ft/sec	0.2–5.7 m/km	50% pools	Vegetated cover
Johnny darter				Pools	Sand/mud
Bluegill	X	< 0.33ft/sec	≤ 0.5 m/km	60% pool areas	Submerged vegetation/ logs/brush
Central mud minnow				Quiet areas	Soft mud bottom/dense vegetation

ft/sec = feet per second m/km = meters per kilometer

The following assessment of water quality/habitat quality is based on fish community structure as expressed in the Index of Biotic Integrity (IBI). The IBI, derived from 2004 and 2007 data (Thomas et al. 2007), is a multi-metric index that uses information on fish species richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish to assess the health and well being of a water body. The index is composed of several metrics (measurement endpoints, such as catch per unit effort), which are then summed into a final value (Index Value). That value is then compared to a standard value that reflects a stream condition with little human influence. The IBI scores in Table 1 are based on a rating system of warmwater streams in Wisconsin (Lyons 1992).

The index of biotic integrity rating suggests that there are variations year to year and factors limiting the fishery in the lower part of Underwood Creek and the Menomonee River near the creek. The concrete-lined segments of Underwood Creek are considered habitat limiting.

TABLE 2
Fish IBI Assessment Results

Location	Year of Survey	IBI Score	Biotic Integrity Rating
Menomonee River at Menomonee Falls, WI	2004	30	Fair
Menomonee River at Menomonee Falls, WI	2007	15	Very Poor
Underwood Creek at Wauwatosa, WI [a]	2004	10	Very Poor
Underwood Creek at Wauwatosa, WI [a]	2007	37	Fair
Menomonee River at Wauwatosa, WI	2004	12	Very Poor
Menomonee River at Wauwatosa, WI	2007	40	Fair

Legend: 100–65 excellent, 64–50 good, 49–30 fair, 29–20 poor, 19–0 very poor

[a] Sample location included areas of concrete-lined channel.

Source: USGS 2004 and 2007 data

Benthic Macroinvertebrates

Benthic macroinvertebrates are small aquatic organisms that are often used to assess stream health. Table 2 presents benthic macroinvertebrate data collected by the USGS in 2007, which were developed into an index to assess relative quality. Aquatic worms and midges were the dominant groups collected in the lower Underwood Creek. Likewise, the Menomonee River sample location far upstream of the confluence with Underwood Creek in Menomonee Falls was also dominated by midges, but a few mayflies were present, which represent a more sensitive group. The Menomonee River sample location downstream of the confluence was dominated by mayflies, caddisflies, and riffle beetles. Table 3 presents consolidated benthic macroinvertebrate information from selected stations in 2007.

General Habitat Information

The part of Underwood Creek that is not concrete lined at the confluence with the Menomonee River generally is a pool with two well-defined riffle areas. The substrate material is composed largely of gravel, with some sand and silt. No formal measurement of

TABLE 3
Consolidated Benthic Macroinvertebrate Information from Selected Stations in 2007

Location	Number of Species	HBI-10	HBI Rating
Menomonee River at Menomonee Falls, WI	24	4.77	Good
Underwood Creek at Wauwatosa, WI [a]	21	6.66	Fairly Poor
Menomonee River at Wauwatosa, WI	22	5.85	Fair

Legend: HBI/HBI-10: < 3.50, excellent; 3.51–4.50, very good; 4.51–5.50, good; 5.51–6.50, fair; 6.51–7.50, fairly poor; 7.51–8.50, poor; 8.51–10.00, very poor

[a] Sample location included areas of concrete-lined channel.

Source: Hilsenhoff 1987 and 1998

embeddedness was conducted during a field visit, but qualitatively it appeared that the bottom substrate is roughly 25 percent or more embedded. Depth of pool areas was less than 2 feet. The Menomonee River just downstream of the confluence with Underwood Creek exhibited a large riffle area, with some exposure of cobble and coarse gravel. The pool area downstream of the riffle was roughly 2 feet deep with a cobble bottom. Embeddedness was 25 percent or more.

Summary

The fish community in Underwood Creek was limited to 12 of the 20 species found at 3 sampling locations within the Menomonee River watershed. The dominant species in lower Underwood Creek and the Menomonee River near the creek are considered tolerant of local environmental conditions, as indicated by the IBI. The benthic macroinvertebrate community structure in Underwood Creek was restricted in community structure and indicated habitat limiting factors, as suggested by the Hilsenhoff Biotic Index.

The concrete-lined parts of Underwood Creek and the many drop structures continue to impede fish passage. The rehabilitated channel that is isolated from the Menomonee River has habitat features that fish and macroinvertebrates would use once the Phase 2 concrete channel removal restores stream connectivity.

General habitat characteristics and dominant substrate preferences were identified for the dominant fish species in Underwood Creek and Menomonee River near the creek. Habitat conditions in Underwood Creek are limiting for the fish and benthic communities; however, if the habitat were to be improved by providing more or higher quality habitat, it would be expected that the fish and benthic communities would also improve.

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Attachment A-1

Literature Review of Habitat Preferences for Dominant Fish Species near Underwood Creek

ATTACHMENT A-1

Literature Review of Habitat Preferences for Dominant Fish Species near Underwood Creek

Main sources of information were Froese and Pauly (2009), Becker (1983), Stuber et al. (1982a, 1982b, 1982c), McMahon (1982), Twomey et al. (1984), Edwards et al. (1983), and Trial et al. (1983).

Pearl Dace

Adults inhabit pools of creeks and small rivers, also ponds and lakes. Encountered in clear to slightly turbid water most frequently at depths less than 0.5 m (Becker 1983). Usually occurs over sand or gravel, most often in streams < 3m wide (Becker 1983). Feeds on copepods, cladocerans, chironomids, beetles, filamentous algae, and *Chara* (Scott and Crossman, 1973).

Creek Chub

Inhabits rocky and sandy pools of headwaters, creeks and small rivers (Page and Burr 1991). Mostly found in tiny, intermittent streams. Young feed on small aquatic invertebrates. Adults consume small fish, crayfish, and other large invertebrates (Etnier and Starnes 1993). One of the most common fishes in eastern North America.

Optimum habitat is small, clear, cool streams with moderate to high gradient, gravel substrate, well defined riffles, and pools with abundant cover and abundant food (Trautman 1957; Monshenko and Gee 1973; Hocutt and Stauffer 1975). Creek chubs are found in streams with gradients of 3 to 23 m/km with their greatest abundance in gradients of 7 to 13.4 m/km (Monshenko and Gee 1973; Hocutt and Stauffer 1975). They are most abundant in small streams 0.5 to 7 m in width (Hocutt and Stauffer 1975) and less than 1 m in average depth (Barber and Minckley 1971).

Most abundant in streams with alternating pools and riffle-run areas (Trautman 1957; Minckley 1963; Monshenko and Gee 1973). Rubble substrate in riffles, abundant aquatic vegetation (Hynes 1970), and abundant streambank vegetation (Monshenko and Gee 1973; Cummins 1974) are conditions associated with high production of food types consumed by creek chubs. Adults generally occur in streams with an average velocity of less than 60 cm/sec (Minckley 1963; Monshenko and Gee 1973). Most abundant in stream sections of deep runs and pools with surface velocities ≤ 30 cm/sec (Monshenko and Gee 1973). Fry are found along the edges of pools with surface velocities ≤ 10 cm/sec (Clark 1943; Minckley 1963; Copes 1978).

White Sucker

Inhabits a wide range of habitats, from rocky pools and riffles of headwaters to large lakes. Usually occurs in small, clear, cool creeks and small to medium rivers. Moves to shallower water near sunrise and sunset to feed. Fry (1.2 cm) feed on plankton and other small

invertebrates; bottom feeding commences upon reaching a length of 1.6 to 1.8 cm. Prey for birds, fishes, lamprey, and mammals (Scott and Crossman 1973).

Stream populations of white sucker reach maximum abundance in low to moderate stream gradients of 2.8 to 7.8 m/km (Hocutt and Stauffer 1975). Inhabit primarily pools and areas of slow to moderate velocity (about 40 cm/sec). Water movement is important to suckers, and they are generally absent when flow is less than 10 cm/sec (Minckley 1963).

Longnose Dace

Inhabit rubble and gravel riffles (sometimes runs and pools) of fast creeks and small to medium rivers. Young up to 4 months are pelagic (Scott and Crossman 1973). Form schools (Scott and Crossman 1973). Feed on mayflies, blackflies, and midges (Scott and Crossman 1973). Spawn over pits in loose gravel substrate (Bartnik 1970).

Most abundant in swift flowing, steep gradient, headwater streams of large river systems (Kuehn 1949; Reed 1959; Reed and Moulton 1973). Probably live in streams with a gradient from 1.9 to 18.7 m/km (Kuehne 1962). All age groups occur in very shallow water, usually < 0.3 m deep (Gee and Northcote 1963) and rarely > 1 m deep (Sigler and Miller 1963). Overhead cover and shelter from the current is required during all seasons (Bartnik 1973). Usually collected in streams with current velocities > 45 cm/sec (Gee and Northcote 1963).

Bluntnose Minnow

Occurs almost anywhere in its range but most common in clear rocky streams (Robins et al. 1991; Etnier and Starnes 1993). Found most often over sand and gravel substrates (Becker 1983). Often associated with submerged vegetation (Becker 1983). Feeds on algae, detritus, entomostraca, and immature insects, especially midge larvae and pupae (Etnier and Starnes 1993).

Blacknose Dace

Inhabits rocky runs and pools of headwaters, creeks and small rivers (Page and Burr 1991; Etnier and Starnes 1993). Feeds on aquatic insects; also on diatoms and other algae. Blacknose dace spawn on substrates of sand, gravel, and cobble.

Prefers swift streams (Traver 1929; Harlan and Speaker 1951; Scarola 1973). Greatest densities of blacknose dace adults occur when surface velocities are between 15 and 45 cm/sec (Gibbons and Gee 1972). Common at gradients of 11.4 and 23.3 m/km, but almost entirely absent at 67.2 m/km (Burton and Odum 1945). Low gradients (, 5 m/km) are also avoided (Trautman 1957; Gibbons and Gee 1972).

Central Stoneroller

Inhabits rocky riffles, runs, and pools of headwaters, creeks and small to large rivers (Page and Burr 1991; Etnier and Starnes 1993). Generally found in riffle and pool sections of streams over rubble, gravel, and sand (Becker 1983). Subadults and adults feed on detritus, filamentous algae, and diatoms, and occasionally on small aquatic insects; young on rotifers and microcrustacea (Etnier and Starnes 1993).

Common Shiner

Adults inhabit rocky pools near riffles in clear, cool creeks and small to medium rivers. Sometimes occurs in lakes in northern part of range. Oviparous (Breder and Rosen 1966), nest spawners (Coker et al. 2001). Hybridization between *Luxilus cornutus* and *L. chrysocephalus* occurs frequently in areas where the ranges of the two species overlap.

Typically occurs in small and medium-sized streams with clear, cool water, moderate current; and unvegetated gravel to rubble (Lee et al. 1980). These minnows frequent pools in streams more often than rapids (Adams and Hankinson 1928). They congregate in pools immediately below cascades, but not in deadwater or long pools, which are common at stream mouths. When the pH drops below 5.8, reproduction ceases and the population disappears (Harvey 1980).

Fathead Minnow

Inhabits muddy pools of headwaters, creeks and small rivers (Welcomme 1988). Also found in ponds and lakes (Etnier and Starnes 1993). Tolerates unsuitable conditions (e.g., turbid, hot, poorly oxygenated, intermittent streams) (Welcomme 1988). Feeds on detritus and algae (Etnier and Starnes 1993). Introductions consequently caused the spread of the enteric red-mouth disease throughout northern Europe which infected wild and cultured trouts and eels (Welcomme 1988). Maintained a relatively high metabolic rate and level of activity under hypoxic conditions (Klinger et al. 1982). Individuals that survived the hypoxic conditions during winter had rapid growth rates after ice-off (Held and Peterka 1974).

Largemouth Bass

Inhabits clear, vegetated lakes, ponds, swamps. Also in backwaters and pools of creeks and rivers (Page and Burr 1991). Prefers quiet, clear water and over-grown banks. Adults feed on fishes, crayfish and frogs; young feed on crustaceans, insects and small fishes. Sometimes cannibalistic. Does not feed during spawning, or when the water temperature is below 5°C and above 37°C (Billard 1997).

Adult largemouth bass are most abundant in areas with vegetation (Jenkins et al. 1952); availability (Saiki and Tash 1979) and in areas of low current velocity, based on catch data (Hardin and Bovee 1978). Increased water levels in reservoirs may reduce prey availability due to increased cover for prey species. Stable to decreased water levels concentrate prey, which increased feeding and growth rates of adult bass (Heman et al. 1969). Thus, stable to slightly negative midsummer fluctuations (0 to 3m) are considered optimal for adult largemouth bass.

Optimal spawning substrate is gravel (Newell 1969; Robinson 1961), but other substrates such as vegetation, roots, sand, and mud are suitable (Harlan and Speaker 1956; Mraz and Cooper 1957; Marz et al. 1961). Silty, mucky bottoms are unsuitable (Robinson 1961). Water velocities as low as 40 cm/sec may result in mortality of embryos (Dudley 1969), Hardin and Bovee (1978) reported that velocities >10 cm/sec were avoided by the species Largemouth bass spawn at depths ranging from 0.15 m to 7.5 m. Optimal current velocities fro fry are 4 cm/sec (Hardin and Bovee 1978), and fry cannot tolerate current velocities > 27 cm/sec.

Green Sunfish

Inhabits quiet pools and backwaters of sluggish streams; lakes and ponds. Often near vegetation (Page and Burr 1991**;** Welcomme 1988). Juveniles feed on immature insects and microcrustaceans (Welcomme 1988).

Optimal riverine habitat consists of at least 50 percent pool area. Species abundance is positively correlated with percent vegetation cover (Moyle and Nichols 1973). Have been found at a wide range of gradients, varying from 0.2 to 5.7 m/km (Cross 1954; Funk 1975a). Most abundant at lower (≤ 2 m/km) gradients (Trautman 1957; Funk 1975b). Prefers small to medium-sized (< 30 m width) streams (Trautman 1957; Cross 1967; Moyle and Nichols 1973).

High species abundance is positively correlated with moderate (25 to 100 JTU) turbidities (Trautman 1957; Cross 1967; Moyle and Nichols 1973), although the species occurs in both clear and turbid water (Jenkins and Finnell 1957). Dissolved oxygen requirements are presumably similar to those of the bluegill sunfish. Thus, optimal dissolved oxygen levels are > 5 mg/l (Petit 1973), and lethal levels are ≤ 1.5 mg/l (Moore 1942). Optimal pH range is from 6.5 to 85. (Stroud 1967), mortality may occur at levels ≤ 4.0 or ≥ 10.35 (Trama 1954; Calabrese 1969; Ultsch 1978).

Based on catch data, preferred current velocities are ≤ 10 cm/sec, but adults will tolerate velocities up to 25 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978). Optimal current velocities for fry are ≤ 5 cm/sec, and fry avoid areas with velocities exceeding 8 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Johnny Darter

Occurs in sandy and muddy, sometimes rocky, pools of headwaters, creeks; small to medium rivers; and sandy shores of lakes (Page and Burr 1991; Welcomme 1988). Also found in streams (Welcomme 1988). Adults feed on midge larvae, mayfly nymphs, caddis larvae, and microcrustaceans; young on entomostracans and tiny midge larvae (Welcomme 1988). Eggs are found clustered on underside of stone and guarded by males (Page 1983).

Bluegill

Found frequently in lakes, ponds, reservoirs and sluggish streams (Page and Burr 1991; Welcomme 1988). Lives preferably in deep weed beds (Page and Burr 1991). Active mainly during dusk and dawn. Adults feed upon snails, small crayfish, insects, worms and small minnows (Page and Burr 1991). Young feed on crustaceans, insects and worms (Page and Burr 1991; Welcomme 1988).

In riverine habitats, bluegills are mostly restricted to areas of low velocity (Hubbs and Lagler 1958). Hardin and Bovee (1978) developed probability curves showing that adults prefer current velocities < 10 cm/sec but will tolerate up to 45 cm/sec. Abundance has been correlated to a high percentage (60%) pool area and negatively correlated to a high percent riffle/run area (Moyle and Nichols 1973). Optimal stream gradient (≤ 0.5 m/km) is based on the preference for low gradient, lentic-type waters (Trautman 1957).

Uses cover in riverine habitats is in the form of submerged vegetation or logs and brush, especially juveniles and small adults (Moyle and Nichols 1973; Scott and Crossman 1973). However, an excessive abundance of vegetation can inhibit utilization of prey by bluegills.

Optimal temperatures for fry are 25 to 32°C (Hardin and Bovee 1978). Optimal current velocities are < 5 cm/sec; fry are not found in areas with velocities greater than about 7.5 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Central Mudminnow

Occurs in quiet areas of streams, sloughs, swamps and other wetlands over soft mud bottom and debris (Page and Burr 1991, Welcomme 1988). Often found in dense vegetation. Tolerates drought, low oxygen levels and extremes water temperature (Page and Burr 1991). Feeds on aquatic insects, amphipods, isopods, and snails (Welcomme 1988).

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Appendix M
Cost Estimates Update

Cost Estimates for Water Supply Alternatives

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: April 2, 2010

Background

To plan for the City of Waukesha's long-term water supply needs, the Waukesha Water Utility conducted water supply studies and contributed to regional water supply planning efforts. During the past several years, alternative water supply strategies were investigated at the conceptual level, including cost estimates. The cost estimates were developed to meet the intent of Act 227, Wisconsin's Compact implementation statute, and water supply planning law (2007) as part of an application for Great Lakes water.

Cost Estimate Basis

The cost estimates are based on conceptual information (proposed asset type, location, and capacity) and no design has been completed. They support strategic planning efforts that assess the feasibility of different alternatives and screen project options. The estimates are prepared for the purpose of long-range capital planning. They were prepared for guidance in comparing alternatives based on information available at the time of the estimate. Detailed engineering design has not been done. The final cost estimate of any project will depend on market conditions, site conditions, final project scope, schedule, and other variable factors. As a result, final project costs may vary from the estimates presented here.

Examples of estimating methods include cost/capacity curves, scale-up factors, historical cost information and parametric modeling techniques. The cost estimates include:

- Preliminary pipeline alignments and facility siting plans to meet Wisconsin Department of Natural Resources environmental reporting and cost-effectiveness reporting requirements. This also provided more information on high cost items such as pipeline highway and water crossings.
- Treatment strategies for the groundwater supply alternatives considered water quality data on both the deep and shallow aquifers. For example, arsenic removal treatment was used for shallow groundwater because of the recent discovery of arsenic in the future shallow wellfield. Disinfection was used because shallow groundwater modeling indicated a significant surface water influence could be present. The trend of increasing TDS in the deep aquifers resulted in desalination treatment being added in 2020.

CH2M HILL's proprietary Parametric Cost Estimating System (CPES) was used to generate water treatment plant construction, operation, and maintenance cost estimates by inputting fundamental water treatment process design criteria. The tool generates facility footprints to support site layout development and facility planning for quick assessment of cost and

space impacts of alternatives. CPES uses updated industry databases and actual costs from other projects.

- Development costs for new shallow wells reflect recent shallow well costs and Lathers property wellfield planning.
- Electrical power costs reflect 2009 Water Utility rates.
- Backup power generation systems were included in the estimates for pump stations, wells, and treatment plants.
- Wastewater disposal costs were included for the water treatment plant residuals.
- Greenhouse gas estimates were prepared for all the alternatives to quantify this environmental impact.

Construction cost estimates include the following:

- Contractor bonds and insurance: 3 percent
- Contractor mobilization and demobilization: 5 percent
- Contractor overhead: 8 percent
- Contractor profit: 4 percent
- Project contingency: 25 percent

Further, the estimated total construction costs include:

- Engineering, planning, and design: 8 percent
- Permitting, legal, and administration: 12 percent
- Engineering services during construction: 8 percent

Capital and Life-Cycle Costs

Table 1 summarizes the capital, operation/maintenance and present worth costs of the water supply alternatives. Appendix M contains the detailed backup for the estimates.

TABLE 1
Water Supply Alternative Cost Estimates

Water Supply Alternative	Capital Cost[a] ($ million)	Annual Operation/Maintenance Cost ($ million)	20 yr Present Worth Cost ($ million, 6%)	50 yr Present Worth Cost ($ million, 6%)
Deep and shallow aquifers	189	7.2	272	302
Shallow aquifer and Fox River alluvium	184	7.4	269	301
Lake Michigan with return flow to Underwood creek	164	6.2	235	262
Lake Michigan and Shallow Aquifer	238	7.5	324	356

[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision etc), 25% contingency, and costs for permitting, legal, engineering, administrative.

Major changes from the last cost estimate include:

- Wellfield costs for Alternatives 1 and 2 increased because of a larger distance between shallow wells and additional wells. Changes were made based on recent shallow aquifer groundwater modeling results and attempting to reduce impacts on water resources.
- A new alternative was added. Alternative 4 includes the Lake Michigan supply and return system and the shallow aquifer. The Lake Michigan supply and return system has a smaller capacity (24-inch-diameter pipelines vs. 36-inch-diameter pipelines in Alternative 3). The shallow aquifer supply and treatment system is the same as in Alternative 1.

Waukesha Water Utility
Construction Cost Summary of Water Supply Alternatives

	Alternative 1 - Deep and Shallow Wells	Alternative 2 - Shallow Wells and Fox River Alluvium	Alternative 3 - Lake Michigan	Alternative 4 - Lake Michigan and Shallow Wells
Deep Well Treatment Plant				
3 RO plants for Wells 6,8,10	$ 17,467,000			
Shallow Aquifer Water Treatment Plant				
One @ 10.9 mgd	$ 29,864,000			$ 29,864,000
One @18.5 mgd		$ 37,355,000		$ -
Shallow Aquifer Wellfield				
14 new wells @ 0.75 mgd ea.	$ 12,800,000			$ 12,800,000
18 new wells@ 0.75 to 1.5 mgd ea.		$ 17,815,000		
Shallow Aquifer Supply Pipeline to Waukesha				
10 miles of 24" for 10.9 mgd	$ 18,573,000			$ 18,573,000
10 miles of 36" for 18.5 mgd		$ 27,855,000		
Lake Michigan Pipeline to Waukesha				
14 miles of 36" for 18.5 mgd			$ 38,522,000	
14 miles of 24" for 7.6 mgd				$ 25,682,000
Lake Michigan Pump Station to Waukesha				
one @18.5 mgd			$ 8,573,000	
one @ 7.6 mgd				$ 5,282,822
Waukesha Pipeline to Lake Michigan				
11 miles of 36" for 18.5 mgd			$ 25,515,000	
11 miles of 24" for 7.6 mgd				$ 17,011,000
Waukesha Pump Station to Lake Michigan				
one @18.5 mgd			$ 3,508,000	
one @ 7.6 mgd				$ 2,161,686
Distribution System Improvements				
3 miles of 20", 2 miles of 16"		$ 8,465,000	$ 8,465,000	$ 8,465,000
2.5 miles of 20", 7 miles of 16"	$ 15,855,993			
Wastewater Force Main				
5 miles of 6"	$ 3,332,000	$3,332,000		$ 3,332,000
Subtotal	**$ 97,891,993**	**$ 94,822,000**	**$ 84,583,000**	**$ 123,171,508**
3% markup for Bonds & Insurance	$ 2,937,000	$ 2,845,000	$ 2,538,000	$ 3,696,000
5% markup for Mob/Demob	$ 4,895,000	$ 4,742,000	$ 4,230,000	$ 6,159,000
8% markup for Contractors Overhead	$ 8,458,000	$ 8,193,000	$ 7,309,000	$ 10,643,000
4% markup for Contractors profit	$ 4,229,000	$ 4,097,000	$ 3,655,000	$ 5,322,000
25% Contingency	$ 29,603,000	$ 28,675,000	$ 25,579,000	$ 37,248,000
Subtotal Markups and Contingency	**$ 50,122,000**	**$ 48,552,000**	**$ 43,311,000**	**$ 63,068,000**
Total Project Construction Costs	**$ 148,013,993**	**$ 143,374,000**	**$ 127,894,000**	**$ 186,239,508**
8% allowance for engineering and design	$ 11,842,000	$ 11,470,000	$ 10,232,000	$ 14,900,000
12% allowance for permitting, legal and admin.	$ 17,762,000	$ 17,205,000	$ 15,348,000	$ 22,349,000
8% allowance for engr services during construction	$ 11,842,000	$ 11,470,000	$ 10,232,000	$ 14,900,000
Subtotal Other Project Costs	**$ 41,446,000**	**$ 40,145,000**	**$ 35,812,000**	**$ 52,149,000**
TOTAL PROJECT CAPITAL COST	**$ 189,000,000**	**$ 184,000,000**	**$ 164,000,000**	**$ 238,000,000**

Alternative 1:
Deep and Shallow Aquifers

Alternative 1 - Deep and Shallow Aquifers		
Deep Well Treatment Plant (present worth of future cost)		**$17,467,000**
Shallow Aquifer Water Treatment Plant		**$29,864,000**
Shallow Aquifer Wellfield		**$12,800,000**
Supply Pipeline to Waukesha		**$ 18,573,000**
Distribution System Improvements		**$ 15,855,993**
Wastewater Force Main		**$3,332,000**
Subtotal Construction Cost		**$97,891,993**
3% markup for Bonds & Insurance	$2,937,000	
5% markup for Mob/Demob	$4,895,000	
8% markup for Contractors Overhead	$8,458,000	
4% markup for Contractors profit	$4,229,000	
25% Contingency	$29,603,000	
Subtotal Markups and Contingency		**$50,122,000**
Total Project Construction Costs		**$148,013,993**
8% allowance for engineering and design	11,842,000	
12% allowance for permitting, legal and admin.	17,762,000	
8% allowance for engr services during construction	11,842,000	
Subtotal Other Project Costs		**$41,446,000**
TOTAL PROJECT CAPITAL COST		**$189,000,000**

Alternative 1 - Deep and Shallow Aquifer				
		Planning Period	Deep Well Capital Costs	
	2009	Declining		R/O Treatment
Deep Well	Capacity, mgd	Capacity, mgd	Land Cost	
2	1.15	0.81		
3	1.4	0.98		
5	1.44	1.01		
6	2.59	1.63	$500,000	$6,579,000
7	1.08	0.76		
8	2.16	1.36	$500,000	$5,329,000
9	1.94	1.36		
10	3.74	2.36	$500,000	$9,868,000
	total	10.26		
	Firm	7.90	$1,500,000	$21,776,000
		2010 total	$23,276,000	
		2020 @3%/yr inflation	$ 31,280,998	
		2010, P/F=0.5584	**17,467,309**	

CH2M HILL Parametric Cost Estimating System (CPES)

FACILITIES DESIGN & CONSTRUCTION COST MODULE

File Version: 1/7/2010

Click for CPES QA/QC | To Concrete Wall Thickness Help | To Cost Summary Matrix | To Unit Cost Database

Project Name:	Waukesha Nanofiltration Groundwater WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	3.0 mgd Nanofiltration WTP
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months):	24
Mid-Point of Construction:	Jan/2012

Roundup to the nearest: $1

☐ This Report is for INTERNAL Distributio

☐ This Report is for EXTERNAL Distributio

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Cost
	Yes	BWRO: NanoFilt	$5,219,952
	Yes	Air Stripper: Degas	$837,013
	Yes	In-Plant PS: FWPS	$1,095,437
	Yes	Liquid Chemical: NaOH	$306,023

SUBTOTAL - PROJECT COST			$7,458,425
ADDITIONAL PROJECT COSTS:			
Demolition	0%		$0
Overall Sitework	10%		$745,843
Plant Computer System	5%		$372,922
Yard Electrical	7%		$544,466
Yard Piping	10%		$745,843
UD #1 Default Description	0%		$0
UD #2 Default Description	0%		$0
UD #3 Default Description	0%		$0
SUBTOTAL with Additional Project Costs			$9,867,499

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	B	C	D	E	F
1347					
1348	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
1349					
1350	SITEWORK				
1351	Membrane Area:				
1352	Excavation	233.34	CY	*$5.35*	$1,249
1353	Imported Structural Backfill	185.08	CY	*$40.56*	$7,506
1354	Native Backfill	23.26	CY	*$6.58*	$153
1355	Haul Excess	210.08	CY	*$6.58*	$1,382
1356	Pipe Trench Area:				
1357	Excavation	650.82	CY	*$5.35*	$3,483
1358	Imported Structural Backfill	93.86	CY	*$40.56*	$3,807
1359	Native Backfill	276.03	CY	*$6.58*	$1,816
1360	Haul Excess	374.79	CY	*$6.58*	$2,466
1361	CIP / Cartridge Filter Area:				
1362	Excavation	199.09	CY	*$5.35*	$1,066
1363	Imported Structural Backfill	156.90	CY	*$40.56*	$6,363
1364	Native Backfill	20.86	CY	*$6.58*	$137
1365	Haul Excess	178.23	CY	*$6.58*	$1,173
1366	Electrical Room:				
1367	Excavation	91.60	CY	*$5.35*	$490
1368	Imported Structural Backfill	66.30	CY	*$40.56*	$2,689
1369	Native Backfill	15.48	CY	*$6.58*	$102
1370	Haul Excess	76.12	CY	*$6.58*	$501
1371	Pretreatment Liquid Chemicals Area:				
1372	Excavation	102.79	CY	*$5.35*	$550
1373	Imported Structural Backfill	77.33	CY	*$40.56*	$3,136
1374	Native Backfill	14.44	CY	*$6.58*	$95
1375	Haul Excess	88.35	CY	*$6.58*	$581
1376	CIP Liquid Chemicals Area:				
1377	Excavation	89.85	CY	*$5.35*	$481
1378	Imported Structural Backfill	66.67	CY	*$40.56*	$2,704
1379	Native Backfill	13.56	CY	*$6.58*	$89
1380	Haul Excess	76.29	CY	*$6.58*	$502
1381	CIP Dry Chemicals Area:				
1382	Excavation	48.12	CY	*$5.35*	$258
1383	Imported Structural Backfill	33.19	CY	*$40.56*	$1,346
1384	Native Backfill	9.78	CY	*$6.58*	$64
1385	Haul Excess	38.34	CY	*$6.58*	$252
1386	Chemical Neutralization System Area:				
1387	Excavation	131.60	CY	*$5.35*	$704
1388	Imported Structural Backfill	100.76	CY	*$40.56*	$4,086
1389	Native Backfill	16.74	CY	*$6.58*	$110
1390	Haul Excess	114.86	CY	*$6.58*	$756
1391	Flushing System and Permeate Transfer Area:				
1392	Excavation	0.00	CY	*$5.35*	$0
1393	Imported Structural Backfill	0.00	CY	*$40.56*	$0
1394	Native Backfill	0.00	CY	*$6.58*	$0
1395	Haul Excess	0.00	CY	*$6.58*	$0
1396	Pilot Skid Area:				
1397	Excavation	0.00	CY	*$5.35*	$0
1398	Imported Structural Backfill	0.00	CY	*$40.56*	$0
1399	Native Backfill	0.00	CY	*$6.58*	$0
1400	Haul Excess	0.00	CY	*$6.58*	$0
1401	Other Areas:				
1402	Excavation	0.00	CY	*$5.35*	$0
1403	Imported Structural Backfill	0.00	CY	*$40.56*	$0
1404	Native Backfill	0.00	CY	*$6.58*	$0
1405	Haul Excess	0.00	CY	*$6.58*	$0
1406	Allowance for Misc Items	5%		$50,098.07	$2,505
1407	Subtotal				$52,603
1408	CONCRETE				
1409	Slab on Grade:				
1410	Process Building	382.22	CY	*$345.93*	$132,222
1411	Trench Walls:				
1412	Membrane Pipe Trench	35.20	CY	*$683.50*	$24,059
1413	Equipment Pads:				
1414	Pumps:				
1415	High Pressure Membrane Feed Pumps (Active)	0.20	CY	*$345.93*	$69
1416	High Pressure Membrane Feed Pumps (Standby)	0.40	CY	*$345.93*	$139
1417	Interstage Booster Pumps (Active)	0.00	CY	*$345.93*	$0
1418	Interstage Booster Pumps (Standby)	0.00	CY	*$345.93*	$0
1419	Flushing Pumps (Active)	0.00	CY	*$345.93*	$0
1420	Flushing Pumps (Standby)	0.00	CY	*$345.93*	$0
1421	Permeate Transfer Pumps (Active)	0.00	CY	*$345.93*	$0
1422	Permeate Transfer Pumps (Standby)	0.00	CY	*$345.93*	$0
1423	Cleaning Solution Recirculation Pump (Active)	0.67	CY	*$345.93*	$232
1424	Cleaning Solution Recirculation Pump (Standby)	0.00	CY	*$345.93*	$0
1425	Dry Chemicals Transfer Pump (Active)	0.00	CY	*$345.93*	$0
1426	Spent Chemicals Neutralization Pumps (Active)	1.12	CY	*$345.93*	$386
1427	Spent Chemicals Neutralization Pumps (Standby)	1.12	CY	*$345.93*	$386

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	B	C	D	E	F
1428	Pretreatment Chemical Metering Pumps:				
1429	Sulfuric Acid Active Metering Pump	1.00	CY	*$345.93*	$346
1430	Sulfuric Acid Standby Metering Pump	1.00	CY	*$345.93*	$346
1431	Hydrochloric Acid Active Metering Pump	0.00	CY	*$345.93*	$0
1432	Hydrochloric Acid Standby Metering Pump	0.00	CY	*$345.93*	$0
1433	Scale Inhibitor Active Metering Pump	1.00	CY	*$345.93*	$346
1434	Scale Inhibitor Standby Metering Pump	1.00	CY	*$345.93*	$346
1435	Other Chemical 1 Active Metering Pump	0.00	CY	*$345.93*	$0
1436	Other Chemical 1 Standby Metering Pump	0.00	CY	*$345.93*	$0
1437	Other Chemical 2 Active Metering Pump	0.00	CY	*$345.93*	$0
1438	Other Chemical 2 Standby Metering Pump	0.00	CY	*$345.93*	$0
1439	Liquid CIP Chemical Transfer Pumps:				
1440	Sodium Hydroxide Active Transfer Pump	0.50	CY	*$345.93*	$173
1441	Sodium Hydroxide Standby Transfer Pump	0.00	CY	*$345.93*	$0
1442	Hydrochloric Acid Active Transfer Pump	0.00	CY	*$345.93*	$0
1443	Hydrochloric Acid Standby Transfer Pump	0.00	CY	*$345.93*	$0
1444	Sodium EDTA Active Transfer Pump	0.50	CY	*$345.93*	$173
1445	Sodium EDTA Standby Transfer Pump	0.00	CY	*$345.93*	$0
1446	Other Chemical 3 Active Transfer Pump	0.00	CY	*$345.93*	$0
1447	Other Chemical 3 Standby Transfer Pump	0.00	CY	*$345.93*	$0
1448	Other Chemical 4 Active Transfer Pump	0.00	CY	*$345.93*	$0
1449	Other Chemical 4 Standby Transfer Pump	0.00	CY	*$345.93*	$0
1450	Tanks:				
1451	Flushing Tanks	0.00	CY	*$345.93*	$0
1452	Cleaning Solution Tanks	7.07	CY	*$345.93*	$2,445
1453	Dry Chemicals Solution Preparation Tanks	0.00	CY	*$345.93*	$0
1454	Neutralization Tanks	9.42	CY	*$345.93*	$3,260
1455	Pretreatment Chemicals Bulk Storage Tanks:				
1456	Sulfuric Acid	0.00	CY	*$345.93*	$0
1457	Hydrochloric Acid	0.00	CY	*$345.93*	$0
1458	Scale Inhibitor	0.00	CY	*$345.93*	$0
1459	Other Chemical 1	0.00	CY	*$345.93*	$0
1460	Other Chemical 2	0.00	CY	*$345.93*	$0
1461	Liquid CIP Chemicals Bulk Storage Tanks:				
1462	Sodium Hydroxide	0.00	CY	*$345.93*	$0
1463	Hydrochloric Acid	0.00	CY	*$345.93*	$0
1464	Sodium EDTA	0.00	CY	*$345.93*	$0
1465	Other Chemical 3	0.00	CY	*$345.93*	$0
1466	Other Chemical 4	0.00	CY	*$345.93*	$0
1467	Pretreatment Chemicals Containment Area Walls:				
1468	Sulfuric Acid	2.34	CY	*$557.50*	$1,304
1469	Hydrochloric Acid	0.00	CY	*$557.50*	$0
1470	Scale Inhibitor	2.14	CY	*$557.50*	$1,193
1471	Other Chemical 1	0.00	CY	*$557.50*	$0
1472	Other Chemical 2	0.00	CY	*$557.50*	$0
1473	Liquid CIP Chemicals Containment Area Walls:				
1474	Sodium Hydroxide	1.59	CY	*$557.50*	$887
1475	Hydrochloric Acid	0.00	CY	*$557.50*	$0
1476	Sodium EDTA	2.24	CY	*$557.50*	$1,248
1477	Other Chemical 3	0.00	CY	*$557.50*	$0
1478	Other Chemical 4	0.00	CY	*$557.50*	$0
1479	Allowance for Misc Items	5%		$169,558.46	$8,478
1480	Subtotal				$178,036
1481	MASONRY	High			
1482	CMU Building Over Membrane and Other Covered Areas	7223.06	SF	*$157.92*	$1,140,678
1483	Subtotal	7223.06	SF		$1,140,678
1484	METALS				
1485	Grating Over Pipe Trenches:				
1486	Membrane Pipe Trench:	1055.98	SF	*$72.38*	$76,432
1487	Metal Stairways				
1488	Pretreatment and Liquid CIP Chemicals	8.00	EA	*$1,579.22*	$12,634
1489	Allowance for Misc Items	10%		$89,066.04	$8,907
1490	Subtotal				$97,973
1491	DOORS & WINDOWS				
1492	Roll-Up Doors (14' wide)	4.00	EA	*$2,939.34*	$11,757
1493	Single Entry Doors (4' wide)	4.00	EA	*$828.95*	$3,316
1494	Double Entry Doors (6' wide)	1.00	EA	*$1,243.43*	$1,243
1495	Allowance for Misc Items	10%		$16,316.61	$1,632
1496	Subtotal				$17,948
1497	EQUIPMENT				
1498	***Equipment Purchase Prices (Installation Cost is NOT Included):***				
1499	Reverse Osmosis Train:				
1500	Skids & Manifold Piping	2.00	LS	*$458,744.93*	$917,490
1501	Pressure Vessels (for 8 inch membranes)	108.00	EA	*$1,316.88*	$142,223
1502	Membrane Elements (8 inches in diameter)	756.00	EA	*$455.84*	$344,618
1503	Cartridge Filters (919 gpm)	2.00	EA	*$43,662.10*	$87,324
1504	Bypass Blend Cartridge Filters (0 gpm)	0.00	EA	*$35,517.01*	$0
1505	CIP Cartridge Filters (1200 gpm)	1.00	EA	*$50,356.43*	$50,356
1506	Pumps:				
1507	High Pressure Membrane Feed Pumps (Active) (157 hp each)	1.00	EA	*$38,828.05*	$38,828
1508	High Pressure Membrane Feed Pumps (Standby) (157 hp each)	2.00	EA	*$38,828.05*	$77,656
1509	Insterstage Booster Pumps (Active) (0 hp each)	0.00	EA	*$22,610.32*	$0

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	B	C	D	E	F
1510	Interstage Booster Pumps (Standby) (0 hp each)	0.00	EA	$22,610.32	$0
1511	Flushing Pumps (Active) (90 hp each)	0.00	EA	$0.00	$0
1512	Flushing Pumps (Standby) (90 hp each)	0.00	EA	$0.00	$0
1513	Permeate Transfer Pumps (Active) (0 hp each)	0.00	EA	$0.00	$0
1514	Permeate Transfer Pumps (Standby) (0 hp each)	0.00	EA	$0.00	$0
1515	Cleaning Solution Recirculation Pump (Active) (70 hp each)	1.00	EA	$29,379.74	$29,380
1516	Cleaning Solution Recirculation Pump (Standby) (70 hp each)	0.00	EA	$0.00	$0
1517	Dry Chemicals Transfer Pump (Active) (0 hp each)	0.00	EA	$22,569.63	$0
1518	Spent Chemicals Neutralization Pumps (Active) (70 hp each)	1.00	EA	$10,419.76	$10,420
1519	Spent Chemicals Neutralization Pumps (Standby) (70 hp each)	1.00	EA	$10,419.76	$10,420
1520	Pretreatment Chemical Metering Pumps:				
1521	Sulfuric Acid Active Metering Pump (1 hp each)	1.00	EA	$5,614.98	$5,615
1522	Sulfuric Acid Standby Metering Pump (1 hp each)	1.00	EA	$5,614.98	$5,615
1523	Hydrochloric Acid Active Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1524	Hydrochloric Acid Standby Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1525	Scale Inhibitor Active Metering Pump (1 hp each)	1.00	EA	$5,614.98	$5,615
1526	Scale Inhibitor Standby Metering Pump (1 hp each)	1.00	EA	$5,614.98	$5,615
1527	Other Chemical 1 Active Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1528	Other Chemical 1 Standby Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1529	Other Chemical 2 Active Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1530	Other Chemical 2 Standby Metering Pump (0 hp each)	0.00	EA	$5,614.98	$0
1531	Liquid CIP Chemical Transfer Pumps:				
1532	Sodium Hydroxide Active Transfer Pump (0 hp each)	1.00	EA	$22,569.63	$22,570
1533	Sodium Hydroxide Standby Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1534	Hydrochloric Acid Active Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1535	Hydrochloric Acid Standby Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1536	Sodium EDTA Active Transfer Pump (0 hp each)	1.00	EA	$22,569.63	$22,570
1537	Sodium EDTA Standby Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1538	Other Chemical 3 Active Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1539	Other Chemical 3 Standby Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1540	Other Chemical 4 Active Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1541	Other Chemical 4 Standby Transfer Pump (0 hp each)	0.00	EA	$22,569.63	$0
1542	Energy Recovery Devices (Turbocharger):				
1543	Turbocharger for Interstage Pressure Boost (Active) (0 hp each)	0.00	EA	$35,587.35	$0
1544	Turbocharger for Interstage Pressure Boost (Standby) (0 hp each)	0.00	EA	$35,587.35	$0
1545	Tanks:				
1546	Flushing Tanks (6580 gallons each)	0.00	EA	$20,300.26	$0
1547	Cleaning Solution Tanks (5141 gallons each)	1.00	EA	$18,575.31	$18,575
1548	Dry Chemicals Solution Preparation Tanks (0 gallons each)	0.00	EA	$12,412.12	$0
1549	Neutralization Tanks (41952 gallons each)	1.00	EA	$62,702.27	$62,702
1550	Pretreatment Chemicals Bulk Storage Tanks				
1551	Sulfuric Acid (0 gallons each)	0.00	EA	$0.00	$0
1552	Hydrochloric Acid (8225 gallons each)	0.00	EA	$41,660.38	$0
1553	Scale Inhibitor (0 gallons each)	0.00	EA	$0.00	$0
1554	Other Chemical 1 (9400 gallons each)	0.00	EA	$25,853.48	$0
1555	Other Chemical 2 (9400 gallons each)	0.00	EA	$25,853.48	$0
1556	Liquid CIP Chemicals Bulk Storage Tanks				
1557	Sodium Hydroxide (0 gallons each)	0.00	EA	$0.00	$0
1558	Hydrochloric Acid (8225 gallons each)	0.00	EA	$41,660.38	$0
1559	Sodium EDTA (0 gallons each)	0.00	EA	$0.00	$0
1560	Other Chemical 3 (9306 gallons each)	0.00	EA	$25,594.94	$0
1561	Other Chemical 4 (9306 gallons each)	0.00	EA	$25,594.94	$0
1562	Dry CIP Chemicals Bulk Storage Silos				
1563	Citric Acid (0 cf each)	0.00	EA	$0.00	$0
1564	Trisodium Phosphate (1350 cf each)	0.00	EA	$0.00	$0
1565	Sodium Tripolyphosphate (1125 cf each)	0.00	EA	$0.00	$0
1566	Other Chemical 5 (1227 cf each)	0.00	EA	$0.00	$0
1567	Mixers:				
1568	Static Mixer	1.00	EA	$3,187.26	$3,187
1569	CIP Tank Mixers (6 hp each)	1.00	EA	$16,485.80	$16,486
1570	Dry Chemicals Mixers (0 hp each)	0.00	EA	$0.00	$0
1571	Heaters & Chillers:				
1572	CIP Heaters (212 kw per each)	2.00	EA	$43,962.14	$87,924
1573	Dry Chemicals Heater (0 kw per each)	0.00	EA	$0.00	$0
1574	CIP Chillers (87122 BTU/hr each)	0.00	BTU/hr	$0.00	$0
1575					
1576	Equipment Installation Factor:				
1577	Equipment Installation Factor (Default = 20% * Equipment Purchase Price)	20%		$905,476.06	$181,095
1578	Allowance for Misc Items	5%		$905,476.06	$45,274
1579	Subtotal				$2,191,558
1580	I&C				
1581	Instruments				
1582	Flow Elements	8.00	EA	$7,238.07	$57,905
1583	Isolation Valve Actuators (Electric)	42.00	EA	$5,064.93	$212,727
1584	Isolation Valve Actuators (Pneumatic)	0.00	EA	$5,064.93	$0
1585	Conductivity Meters	6.00	EA		$0
1586	Turbiditymeters	2.00	EA		$0
1587	Temperature Elements	2.00	EA		$0
1588	pH Meters	4.00	EA		$0
1589	ORP Meters	4.00	EA		$0
1590	Pressure Indicators Transmitters	6.00	EA	$7,120.57	$42,723
1591	Pressure Elements	16.00	EA	$593.38	$9,494
1592	Level Indicator Transmitters	2.00	EA	$6,764.54	$13,529
1593	Chemical Tank Radar Level Transmitters	0.00	EA	$824.29	$0

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	B	C	D	E	F
1594	Chemical Tank Beacon	0.00	EA	*$824.29*	$0
1595	Drum or Tote Weigh Scale	4.00	EA	*$1,099.05*	$4,396
1596	Metering Pump Discharge Pressure Switch	2.00	EA	*$549.53*	$1,099
1597	Chemical Magmeters	2.00	EA	*$549.53*	$1,099
1598	Sump Pump Float Switch	5.00	EA	*$274.76*	$1,374
1599	Eyewash Station	7.00	EA	*$824.29*	$5,770
1600	Number of Analog I/O Counts	75.00	EA	*$208.82*	$15,662
1601	Number of Digital I/O Counts	252.00	EA	*$49.46*	$12,463
1602	Number of Local Panels	2.00	EA		$0
1603	Number of PLC's	1.00	EA	*$10,990.54*	$10,991
1604	I&C Conduit Wire	11946.67	LF	*$9.53*	$113,837
1605	Allowance for Misc Items	5%		$503,069.07	$25,153
1606	Subtotal				$528,223
1607	CONVEYING SYSTEMS				
1608	Bridge Crane	1.00	EA	*$55,749.49*	$55,749
1609	Bridge Crane Rail	63.83	LF	*$28.96*	$1,848
1610	Allowance for Misc Items	5%		$57,597.87	$2,880
1611	Subtotal				$60,478
1612	MECHANICAL				
1613	Pipe:				
1614	Cartridge Filtration Influent Header (CFIH, 14 inch, FRP)	11.50	LF	*$145.90*	$1,678
1615	Cartridge Filtration Influent Lateral (CFIL, 8 inch, FRP)	41.34	LF	*$81.04*	$3,351
1616	Cartridge Filtraition Effluent Lateral (CFEL, 8 inch, FRP)	22.01	LF	*$81.04*	$1,784
1617	Cartridge Filtration Effluent Header (CFEH, 14 inch, FRP)	15.50	LF	*$145.90*	$2,261
1618	Reverse Osmosis Influent Dump Header (ROIDH, 14 inch, FRP)	10.00	LF	*$145.90*	$1,459
1619	Reverse Osmosis Influent Header (ROIH, 14 inch, FRP)	63.83	LF	*$145.90*	$9,313
1620	High Pressure Pump Suction (HPPS, 12 inch, FRP)	23.33	LF	*$124.28*	$2,900
1621	High Pressure Pump Discharge (HPPD, 12 inch, Duplex SST)	0.00	LF	*$730.79*	$0
1622	Low Pressure Brine Outlet (ERD Discharge) (LPBRO, 6 inch, Duplex SST)	18.33	LF	*$340.35*	$6,240
1623	Reverse Osmosis Influent Lateral (1st Stage) (ROIL1, 14 inch, Duplex SST)	24.89	LF	*$860.93*	$21,428
1624	Reverse Osmosis Influent Lateral (2nd Stage) (ROIL2, 8 inch, Duplex SST)	8.33	LF	*$470.50*	$3,921
1625	Reverse Osmosis Influent Lateral (3rd Stage) (ROIL3, 0 inch, Duplex SST)	0.00	LF	*($50.08)*	$0
1626	Reverse Osmosis Influent Skid Sub Lateral (1st Stage) (ROISL1, 10 inch, Duplex SST)	42.50	LF	*$0.00*	$0
1627	Reverse Osmosis Influent Skid Sub Lateral (2nd Stage) (ROISL2, 8 inch, Duplex SST)	21.25	LF	*$0.00*	$0
1628	Reverse Osmosis Influent Skid Sub Lateral (3rd Stage) (ROISL3, 0 inch, Duplex SST)	0.00	LF	*$0.00*	$0
1629	Brine Skid Sub Lateral (1st Stage) (BSL1, 6 inch, Duplex SST)	42.50	LF	*$0.00*	$0
1630	Brine Skid Sub Lateral (2nd Stage) (BSL2, 8 inch, Duplex SST)	21.25	LF	*$0.00*	$0
1631	Brine Skid Sub Lateral (3rd Stage) (BSL3, 0 inch, Duplex SST)	0.00	LF	*$0.00*	$0
1632	Brine Lateral (1st Stage) (BL1, 10 inch, Duplex SST)	33.33	LF	*$600.64*	$20,021
1633	Brine Lateral (2nd Stage) (BL2, 8 inch, Duplex SST)	86.25	LF	*$470.50*	$40,580
1634	Brine Lateral (3rd Stage) (BL3, 0 inch, Duplex SST)	0.00	LF	*($50.08)*	$0
1635	Brine Header (BH, 6 inch, Duplex SST)	59.83	LF	*$340.35*	$20,364
1636	Permeate Lateral (1st Stage) (PL1, 10 inch, FRP)	84.08	LF	*$102.66*	$8,632
1637	Permeate Lateral (2nd Stage) (PL2, 8 inch, FRP)	14.97	LF	*$81.04*	$1,213
1638	Permeate Lateral (3rd Stage) (PL3, 0 inch, FRP)	0.00	LF	*($5.42)*	$0
1639	Permeate Header to Flush Tank (PHFT, 12 inch, FRP)	44.79	LF	*$124.28*	$5,567
1640	Cleaning Solution Pump Suction Header (CSPSH, 10 inch, FRP)	4.00	LF	*$102.66*	$411
1641	Cleaning Solution Pump Suction Lateral (CSPSL, 10 inch, FRP)	4.00	LF	*$102.66*	$411
1642	Cleaning Solution Pump Discharge Lateral (CSPDL, 10 inch, FRP)	5.72	LF	*$102.66*	$587
1643	Cleaning Solution Pump Discharge Header (CSPDH, 10 inch, FRP)	13.01	LF	*$102.66*	$1,336
1644	Cleaning Solution Pump Recycle (CSPR, 10 inch, FRP)	16.80	LF	*$102.66*	$1,725
1645	Cleaning Solution Cartridge Filtration Influent Lateral (CSCFIL, 10 inch, FRP)	4.00	LF	*$102.66*	$411
1646	Cleaning Solution Cartridge Filtration Effluent Lateral (CSCFEL, 10 inch, FRP)	4.00	LF	*$102.66*	$411
1647	Cleaning Solution Supply Header (CSSH, 10 inch, FRP)	59.59	LF	*$102.66*	$6,117
1648	Cleaning Solution Supply Lateral (CSSL, 10 inch, FRP)	4.50	LF	*$102.66*	$462
1649	Brine Cleaning Solution Return Header (BCSRH, 10 inch, FRP)	79.10	LF	*$102.66*	$8,120
1650	Brine Cleaning Solution Return Lateral (BCSRL, 10 inch, FRP)	22.30	LF	*$102.66*	$2,290
1651	Permeate Cleaning Solution Return Header (PCSRH, 3 inch, FRP)	79.10	LF	*$27.00*	$2,136
1652	Permeate Cleaning Solution Return Lateral (PCSRL, 3 inch, FRP)	53.64	LF	*$27.00*	$1,448
1653	Permeate Flushing Line (PFL, 10 inch, FRP)	59.83	LF	*$102.66*	$6,143
1654	Bypass Blend Cartridge Filter Influent (BBCFIL, 6 inch, FRP)	0.00	LF	*$59.43*	$0
1655	Bypass Blend Cartridge Filter Effluent (BBCFEL, 6 inch, FRP)	0.00	LF	*$59.43*	$0
1656	Bypass Blend Line (BBL, 6 inch, FRP)	32.00	LF	*$59.43*	$1,902
1657	Common Spare High Pressure Pump Suction (CSHPPS, 12 inch, FRP)	14.67	LF	*$124.28*	$1,823
1658	Common Spare High Pressure Pump Discharge (CSHPPD, 12 inch, Duplex SST)	85.50	LF	*$730.79*	$62,482
1659	Fittings:				
1660	Cartridge Filtration Influent Header (CFIH, 14 inch, FRP)	1.00	EA	*$583.58*	$584
1661	Cartridge Filtration Influent Lateral (CFIL, 8 inch, FRP)	4.00	EA	*$324.18*	$1,297
1662	Cartridge Filtraition Effluent Lateral (CFEL, 8 inch, FRP)	2.00	EA	*$324.18*	$648
1663	Cartridge Filtration Effluent Header (CFEH, 14 inch, FRP)	1.00	EA	*$583.58*	$584
1664	Reverse Osmosis Influent Dump Header (ROIDH, 14 inch, FRP)	3.00	EA	*$583.58*	$1,751
1665	Reverse Osmosis Influent Header (ROIH, 14 inch, FRP)	2.00	EA	*$583.58*	$1,167
1666	High Pressure Pump Suction (HPPS, 12 inch, FRP)	0.00	EA	*$497.11*	$0
1667	High Pressure Pump Discharge (HPPD, 12 inch, Duplex SST)	2.00	EA	*$3,025.68*	$6,051

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	B	C	D	E	F
1668	Low Pressure Brine Outlet (ERD Discharge) (LPBRO, 6 inch, Duplex SST)	6.00	EA	*$1,374.61*	$8,248
1669	Reverse Osmosis Influent Lateral (1st Stage) (ROIL1, 14 inch, Duplex SST)	0.00	EA	*$3,576.04*	$0
1670	Reverse Osmosis Influent Lateral (2nd Stage) (ROIL2, 8 inch, Duplex SST)	8.00	EA	*$1,924.96*	$15,400
1671	Reverse Osmosis Influent Lateral (3rd Stage) (ROIL3, 0 inch, Duplex SST)	0.00	EA	*($276.47)*	$0
1672	Reverse Osmosis Influent Skid Sub Lateral (1st Stage) (ROISL1, 10 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1673	Reverse Osmosis Influent Skid Sub Lateral (2nd Stage) (ROISL2, 8 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1674	Reverse Osmosis Influent Skid Sub Lateral (3rd Stage) (ROISL3, 0 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1675	Brine Skid Sub Lateral (1st Stage) (BSL1, 6 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1676	Brine Skid Sub Lateral (2nd Stage) (BSL2, 8 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1677	Brine Skid Sub Lateral (3rd Stage) (BSL3, 0 inch, Duplex SST)	0.00	EA	*$0.00*	$0
1678	Brine Lateral (1st Stage) (BL1, 10 inch, Duplex SST)	2.00	EA	*$2,475.32*	$4,951
1679	Brine Lateral (2nd Stage) (BL2, 8 inch, Duplex SST)	4.00	EA	*$1,924.96*	$7,700
1680	Brine Lateral (3rd Stage) (BL3, 0 inch, Duplex SST)	0.00	EA	*($276.47)*	$0
1681	Brine Header (BH, 6 inch, Duplex SST)	0.00	EA	*$1,374.61*	$0
1682	Permeate Lateral (1st Stage) (PL1, 10 inch, FRP)	6.00	EA	*$410.65*	$2,464
1683	Permeate Lateral (2nd Stage) (PL2, 8 inch, FRP)	2.00	EA	*$324.18*	$648
1684	Permeate Lateral (3rd Stage) (PL3, 0 inch, FRP)	0.00	EA	*($21.69)*	$0
1685	Permeate Header to Flush Tank (PHFT, 12 inch, FRP)	5.00	EA	*$497.11*	$2,486
1686	Cleaning Solution Pump Suction Header (CSPSH, 10 inch, FRP)	1.00	EA	*$410.65*	$411
1687	Cleaning Solution Pump Suction Lateral (CSPSL, 10 inch, FRP)	0.00	EA	*$410.65*	$0
1688	Cleaning Solution Pump Discharge Lateral (CSPDL, 10 inch, FRP)	2.00	EA	*$410.65*	$821
1689	Cleaning Solution Pump Discharge Header (CSPDH, 10 inch, FRP)	0.00	EA	*$410.65*	$0
1690	Cleaning Solution Pump Recycle (CSPR, 10 inch, FRP)	4.00	EA	*$410.65*	$1,643
1691	Cleaning Solution Cartridge Filtration Influent Lateral (CSCFIL, 10 inch, FRP)	1.00	EA	*$410.65*	$411
1692	Cleaning Solution Cartridge Filtration Effluent Lateral (CSCFEL, 10 inch, FRP)	1.00	EA	*$410.65*	$411
1693	Cleaning Solution Supply Header (CSSH, 10 inch, FRP)	5.00	EA	*$410.65*	$2,053
1694	Cleaning Solution Supply Lateral (CSSL, 10 inch, FRP)	0.00	EA	*$410.65*	$0
1695	Brine Cleaning Solution Return Header (BCSRH, 10 inch, FRP)	5.00	EA	*$410.65*	$2,053
1696	Brine Cleaning Solution Return Lateral (BCSRL, 10 inch, FRP)	4.00	EA	*$410.65*	$1,643
1697	Permeate Cleaning Solution Return Header (PCSRH, 3 inch, FRP)	5.00	EA	*$108.01*	$540
1698	Permeate Cleaning Solution Return Lateral (PCSRL, 3 inch, FRP)	4.00	EA	*$108.01*	$432
1699	Permeate Flushing Line (PFL, 10 inch, FRP)	1.00	EA	*$410.65*	$411
1700	Bypass Blend Cartridge Filter Influent (BBCFIL, 6 inch, FRP)	0.00	EA	*$237.71*	$0
1701	Bypass Blend Cartridge Filter Effluent (BBCFEL, 6 inch, FRP)	0.00	EA	*$237.71*	$0
1702	Bypass Blend Line (BBL, 6 inch, FRP)	1.00	EA	*$237.71*	$238
1703	Common Spare High Pressure Pump Suction (CSHPPS, 12 inch, FRP)	0.00	EA	*$497.11*	$0
1704	Common Spare High Pressure Pump Discharge (CSHPPD, 12 inch, Duplex SST)	2.00	EA	*$3,025.68*	$6,051
1705	Valves:				
1706	Cartridge Filtration Influent Header (CFIH, 14 inch,)	0.00	EA	*$8,676.59*	$0
1707	Cartridge Filtration Influent Lateral (CFIL, 8 inch,)	2.00	EA	*$4,798.76*	$9,598
1708	Cartridge Filtraition Effluent Lateral (CFEL, 8 inch,)	2.00	EA	*$4,798.76*	$9,598
1709	Cartridge Filtration Effluent Header (CFEH, 14 inch,)	0.00	EA	*$8,676.59*	$0
1710	Reverse Osmosis Influent Dump Header (ROIDH, 14 inch,)	1.00	EA	*$8,676.59*	$8,677
1711	Reverse Osmosis Influent Header (ROIH, 14 inch,)	0.00	EA	*$8,676.59*	$0
1712	High Pressure Pump Suction (HPPS, 12 inch,)	2.00	EA	*$7,383.98*	$14,768
1713	High Pressure Pump Discharge (HPPD, 12 inch, SST Teflon Lined)	0.00	EA	*$7,383.98*	$0
1714	Low Pressure Brine Outlet (ERD Discharge) (LPBRO, 6 inch, SST Teflon Lined)	2.00	EA	*$3,506.15*	$7,012
1715	Reverse Osmosis Influent Lateral (1st Stage) (ROIL1, 14 inch, SST Teflon Lined)	2.00	EA	*$8,676.59*	$17,353
1716	Reverse Osmosis Influent Lateral (2nd Stage) (ROIL2, 8 inch, SST Teflon Lined)	2.00	EA	*$4,798.76*	$9,598
1717	Reverse Osmosis Influent Lateral (3rd Stage) (ROIL3, 0 inch, SST Teflon Lined)	0.00	EA	*($371.68)*	$0
1718	Reverse Osmosis Influent Skid Sub Lateral (1st Stage) (ROISL1, 10 inch, SST Teflon Lined)	0.00	EA	*$0.00*	$0
1719	Reverse Osmosis Influent Skid Sub Lateral (2nd Stage) (ROISL2, 8 inch, SST Teflon Lined)	0.00	EA	*$0.00*	$0
1720	Reverse Osmosis Influent Skid Sub Lateral (3rd Stage) (ROISL3, 0 inch, SST Teflon Lined)	0.00	EA	*$0.00*	$0
1721	Brine Skid Sub Lateral (1st Stage) (BSL1, 6 inch, SST Teflon Lined)	0.00	EA	*$0.00*	$0
1722	Brine Skid Sub Lateral (2nd Stage) (BSL2, 8 inch, SST Teflon Lined)	2.00	EA	*$0.00*	$0
1723	Brine Skid Sub Lateral (3rd Stage) (BSL3, 0 inch, SST Teflon Lined)	0.00	EA	*$0.00*	$0
1724	Brine Lateral (1st Stage) (BL1, 10 inch, SST Teflon Lined)	2.00	EA	*$6,091.37*	$12,183
1725	Brine Lateral (2nd Stage) (BL2, 8 inch, SST Teflon Lined)	2.00	EA	*$4,798.76*	$9,598
1726	Brine Lateral (3rd Stage) (BL3, 0 inch, SST Teflon Lined)	0.00	EA	*($371.68)*	$0
1727	Brine Header (BH, 6 inch, SST Teflon Lined)	0.00	EA	*$3,506.15*	$0
1728	Permeate Lateral (1st Stage) (PL1, 10 inch,)	4.00	EA	*$6,091.37*	$24,365
1729	Permeate Lateral (2nd Stage) (PL2, 8 inch,)	2.00	EA	*$4,798.76*	$9,598
1730	Permeate Lateral (3rd Stage) (PL3, 0 inch,)	0.00	EA	*($371.68)*	$0
1731	Permeate Header to Flush Tank (PHFT, 12 inch,)	1.00	EA	*$7,383.98*	$7,384
1732	Cleaning Solution Pump Suction Header (CSPSH, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1733	Cleaning Solution Pump Suction Lateral (CSPSL, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1734	Cleaning Solution Pump Discharge Lateral (CSPDL, 10 inch,)	2.00	EA	*$6,091.37*	$12,183

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	B	C	D	E	F
1735	Cleaning Solution Pump Discharge Header (CSPDH, 10 inch,)	0.00	EA	*$6,091.37*	$0
1736	Cleaning Solution Pump Recycle (CSPR, 10 inch,)	2.00	EA	*$6,091.37*	$12,183
1737	Cleaning Solution Cartridge Filtration Influent Lateral (CSCFIL, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1738	Cleaning Solution Cartridge Filtration Effluent Lateral (CSCFEL, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1739	Cleaning Solution Supply Header (CSSH, 10 inch,)	0.00	EA	*$6,091.37*	$0
1740	Cleaning Solution Supply Lateral (CSSL, 10 inch,)	2.00	EA	*$6,091.37*	$12,183
1741	Brine Cleaning Solution Return Header (BCSRH, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1742	Brine Cleaning Solution Return Lateral (BCSRL, 10 inch,)	2.00	EA	*$6,091.37*	$12,183
1743	Permeate Cleaning Solution Return Header (PCSRH, 3 inch,)	0.00	EA	*$1,567.23*	$0
1744	Permeate Cleaning Solution Return Lateral (PCSRL, 3 inch,)	2.00	EA	*$1,567.23*	$3,134
1745	Permeate Flushing Line (PFL, 10 inch,)	1.00	EA	*$6,091.37*	$6,091
1746	Bypass Blend Cartridge Filter Influent (BBCFIL, 6 inch,)	0.00	EA	*$3,506.15*	$0
1747	Bypass Blend Cartridge Filter Effluent (BBCFEL, 6 inch,)	0.00	EA	*$3,506.15*	$0
1748	Bypass Blend Line (BBL, 6 inch,)	1.00	EA	*$3,506.15*	$3,506
1749	Common Spare High Pressure Pump Suction (CSHPPS, 12 inch,)	1.00	EA	*$7,383.98*	$7,384
1750	Common Spare High Pressure Pump Discharge (CSHPPD, 12 inch, SST Teflon Lined)	2.00	EA	*$7,383.98*	$14,768
1751	Allowance for Misc Items	5%		$548,162.49	$27,408
1752	Subtotal				$601,229
1753	ELECTRICAL				
1754	MCC's				
1755	Sections	8.00	EA	*$6,783.10*	$54,265
1756	AFD's				
1757	High Pressure Membrane Feed Pumps (Active) (157 hp each)	1.00	EA	*$149.20*	$23,465
1758	High Pressure Membrane Feed Pumps (Standby) (157 hp each)	2.00	EA	*$149.20*	$46,930
1759	Insterstage Booster Pumps (Active) (0 hp each)	0.00	EA	*$0.00*	$0
1760	Interstage Booster Pumps (Standby) (0 hp each)	0.00	EA	*$0.00*	$0
1761	Flushing Pumps (Active) (90 hp each)	0.00	EA	*$0.00*	$0
1762	Flushing Pumps (Standby) (90 hp each)	0.00	EA	*$0.00*	$0
1763	Permeate Transfer Pumps (Active) (0 hp each)	0.00	EA	*$0.00*	$0
1764	Permeate Transfer Pumps (Standby) (0 hp each)	0.00	EA	*$0.00*	$0
1765	Cleaning Solution Recirculation Pump (Active) (70 hp each)	1.00	EA	*$181.91*	$12,734
1766	Cleaning Solution Recirculation Pump (Standby) (70 hp each)	0.00	EA	*$0.00*	$0
1767	Dry Chemicals Transfer Pump (Active) (0 hp each)	0.00	EA	*$0.00*	$0
1768	Spent Chemicals Neutralization Pumps (Active) (70 hp each)	0.00	EA	*$0.00*	$0
1769	Spent Chemicals Neutralization Pumps (Standby) (70 hp each)	0.00	EA	*$0.00*	$0
1770	Sulfuric Acid Active Metering Pump (1 hp each)	0.00	EA	*$0.00*	$0
1771	Sulfuric Acid Standby Metering Pump (1 hp each)	0.00	EA	*$0.00*	$0
1772	Hydrochloric Acid Active Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1773	Hydrochloric Acid Standby Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1774	Scale Inhibitor Active Metering Pump (1 hp each)	0.00	EA	*$0.00*	$0
1775	Scale Inhibitor Standby Metering Pump (1 hp each)	0.00	EA	*$0.00*	$0
1776	Other Chemical 1 Active Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1777	Other Chemical 1 Standby Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1778	Other Chemical 2 Active Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1779	Other Chemical 2 Standby Metering Pump (0 hp each)	0.00	EA	*$0.00*	$0
1780	Sodium Hydroxide Active Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1781	Sodium Hydroxide Standby Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1782	Hydrochloric Acid Active Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1783	Hydrochloric Acid Standby Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1784	Sodium EDTA Active Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1785	Sodium EDTA Standby Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1786	Other Chemical 3 Active Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1787	Other Chemical 3 Standby Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1788	Other Chemical 4 Active Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1789	Other Chemical 4 Standby Transfer Pump (0 hp each)	0.00	EA	*$0.00*	$0
1790	Switchgear				
1791	Units	0.00	EA	*$0.00*	$0
1792	Electrical Conduit & Wire	1825.60	LF	*$9.53*	$17,396
1793	Allowance for Misc Items	10%		$137,393.22	$13,739
1794	Subtotal				$168,528
1795					
1796	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
1797	Item 1 Description	0.00		0.00	$0
1798	Item 2 Description	0.00		0.00	$0
1799	Item 3 Description	0.00		0.00	$0
1800	Item 4 Description	0.00		0.00	$0
1801	Item 5 Description	0.00		0.00	$0
1802	Item 6 Description	0.00		0.00	$0
1803	Item 7 Description	0.00		0.00	$0
1804	Item 8 Description	0.00		0.00	$0
1805	Item 9 Description	0.00		0.00	$0
1806	Item 10 Description	0.00		0.00	$0
1807	Item 11 Description	0.00		0.00	$0
1808	Item 12 Description	0.00		0.00	$0
1809	Item 13 Description	0.00		0.00	$0
1810	Item 14 Description	0.00		0.00	$0
1811	Item 15 Description	0.00		0.00	$0
1812	Subtotal				$0
1813					
1814	Subtotal				$5,037,253
1815					

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	B	C	D	E	F
1816	ALLOWANCES		User Over-write		
1817	Finishes Allowance	1.0%		$5,219,952	$52,200
1818	I & C Allowance	0.5%		$5,219,952	$26,100
1819	Mechanical Allowance	1.0%		$5,219,952	$52,200
1820	Electrical Allowance	1.0%		$5,219,952	$52,200
1821					
1822	**Facility Cost**	**2,250,000**	**GPD**	**$2.32**	**$5,219,952**

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DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST
SITEWORK:				
Sitework Prep for Air Stripper / Air Scrubber Pad	203.63	CY	*$13.16*	$2,680
Wetwell:				
Excavation	59.21	CY	*$5.35*	$0
Structural Backfill	22.75	CY	*$40.56*	$0
Backfill	7.36	CY	*$6.58*	$0
Haul Excess	51.85	CY	*$6.58*	$341
Allowance for Misc Items	5%		$3,020.90	$151
Subtotal				$3,172
CONCRETE:				
Air Stripper / Air Scrubber Slab on Grade	12.72	CY	*$345.93*	$4,400
Air Stripper Pads	7.44	CY	*$345.93*	$2,575
Air Supply Fan Pads	8.86	CY	*$345.93*	$3,064
Recirculation Pump Pads	0.00	CY	*$345.93*	$0
Wetwell:				
Slab on Grade	15.98	CY	*$382.16*	$0
Walls	25.27	CY	*$683.50*	$0
Elevated Slab	4.87	CY	*$1,088.69*	$0
Effluent Transfer Pump Pads	0.53	CY	*$345.93*	$0
Allowance for Misc Items	5%		$10,038.59	$502
Subtotal				$10,541
MASONRY:	High			
Electrical Room	189	SF	*$157.92*	$29,865
CMU Building Over Degasifiers	515	SF	*$157.92*	$81,354
CMU Building Over Pump Station	0	SF	*$157.92*	$0
Subtotal				$111,219
EQUIPMENT:				
Air Stripping Tower (including Inlet Distributor, Tower, Packing, Sump & Fan)	2.00	EA	*$186,286.49*	$372,573
Air Fans	2.00	EA		
Air Scrubbers (Biological)	0.00	EA	*($930,830.02)*	$0
Recirculation Pumps	0.00	EA	*$6,189.03*	$0
Effluent Transfer Pumps:				
Active Pump # 1	29.87	HP	*$2,623.49*	$0
Active Pump # 2	0.00	HP	*$0.00*	$0
Active Pump # 3	0.00	HP	*$0.00*	$0
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	29.87	HP	*$2,623.49*	$0
Permeate Makeup Supply Pumps (Active)	1.00	EA	*$5,696.45*	$5,696
Permeate Makeup Supply Pumps (Standby)	0.00	EA	*$0.00*	$0
Effluent Static Mixer	1.00	EA	*$4,980.12*	$4,980
Allowance for Misc Items	10%		$372,572.98	$37,257
Subtotal				$420,507
MECHANICAL:				
Pipe				
Feed Water Inlet Header-FWIH (12-inch , Exposed , Ductile Iron , Cement Mortar , Paint)	19	LF	*$82.21*	$1,582
Feed Water Inlet Lateral-FWIL (8-inch , Exposed , Welded Steel , Cement Mortar , Paint)	40	LF	*$146.11*	$5,844
Degasifier Air Influent Header-DAIH (24-inch , Exposed , FRP , None , None)	18	LF	*$126.39*	$2,306
Degasifier Air Influent Lateral-DAIL (16-inch , Exposed , FRP , None , None)	6	LF	*$86.59*	$520
Water Effluent Lateral-WEL (8-inch , Exposed , FRP , None , None)	16	LF	*$46.80*	$749
Scrubber Air Influent Header-SAIH (24-inch , Exposed , FRP , None , None)	0	LF	*$126.39*	$0

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Scrubber Air Influent Lateral-SAIL (24-inch , Exposed , FRP , None , None)	0	LF	*$126.39*	$0
Scrubber Air Discharge-SAD (24-inch , Exposed , FRP , None , None)	0	LF	*$126.39*	$0
Scrubber Recirculation Pipe-SRP (2-inch , Exposed , Ductile Iron , None , Paint)	0	LF	*$11.98*	$0
Pump Discharge Lateral-PDL (12-inch , Exposed , Welded Steel , Cement Mortar , Paint)	10	LF	*$219.17*	$2,192
Pump Discharge Header-PDH (10-inch , Exposed , Welded Steel , Cement Mortar , Paint)	37	LF	*$182.64*	$6,819
Permeate Makeup Supply Lateral-PML (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	10	LF	*$73.06*	$755
Permeate Makeup Supply Header-PMH (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	19	LF	*$73.06*	$1,364
Elbows				
Feed Water Inlet Header-FWIH (12-inch , Exposed , Ductile Iron , Cement Mortar , Paint)	1	EA	*$1,725.47*	$1,725
Feed Water Inlet Lateral-FWIL (8-inch , Exposed , Welded Steel , Cement Mortar , Paint)	4	EA	*$879.95*	$3,520
Degasifier Air Influent Header-DAIH (24-inch , Exposed , FRP , None , None)	2	EA	*$1,664.01*	$3,328
Degasifier Air Influent Lateral-DAIL (16-inch , Exposed , FRP , None , None)	0	EA	*$1,107.19*	$0
Water Effluent Lateral-WEL (8-inch , Exposed , FRP , None , None)	2	EA	*$550.38*	$1,101
Scrubber Air Influent Header-SAIH (24-inch , Exposed , FRP , None , None)	0	EA	*$1,664.01*	$0
Scrubber Air Influent Lateral-SAIL (24-inch , Exposed , FRP , None , None)	0	EA	*$1,664.01*	$0
Scrubber Air Discharge-SAD (24-inch , Exposed , FRP , None , None)	0	EA	*$1,664.01*	$0
Scrubber Recirculation Pipe-SRP (2-inch , Exposed , Ductile Iron , None , Paint)	0	EA	*$287.58*	$0
Pump Discharge Lateral-PDL (12-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$1,319.92*	$0
Pump Discharge Header-PDH (10-inch , Exposed , Welded Steel , Cement Mortar , Paint)	3	EA	*$1,099.93*	$3,300
Permeate Makeup Supply Lateral-PML (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$439.97*	$0
Permeate Makeup Supply Header-PMH (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	1	EA	*$439.97*	$440
Tees				
Feed Water Inlet Header-FWIH (12-inch , Exposed , Ductile Iron , Cement Mortar , Paint)	1	EA	*$2,865.10*	$2,865
Feed Water Inlet Lateral-FWIL (8-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$2,004.85*	$0
Degasifier Air Influent Header-DAIH (24-inch , Exposed , FRP , None , None)	2	EA	*$2,177.82*	$4,356
Degasifier Air Influent Lateral-DAIL (16-inch , Exposed , FRP , None , None)	0	EA	*$1,458.34*	$0
Water Effluent Lateral-WEL (8-inch , Exposed , FRP , None , None)	0	EA	*$738.87*	$0
Scrubber Air Influent Header-SAIH (24-inch , Exposed , FRP , None , None)	0	EA	*$2,177.82*	$0
Scrubber Air Influent Lateral-SAIL (24-inch , Exposed , FRP , None , None)	0	EA	*$2,177.82*	$0
Scrubber Air Discharge-SAD (24-inch , Exposed , FRP , None , None)	0	EA	*$2,177.82*	$0
Scrubber Recirculation Pipe-SRP (2-inch , Exposed , Ductile Iron , None , Paint)	0	EA	*$477.52*	$0
Pump Discharge Lateral-PDL (12-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$3,007.27*	$0
Pump Discharge Header-PDH (10-inch , Exposed , Welded Steel , Cement Mortar , Paint)	1	EA	*$2,506.06*	$2,506
Permeate Makeup Supply Lateral-PML (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$1,002.42*	$0
Permeate Makeup Supply Header-PMH (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$1,002.42*	$0
Valves				
Feed Water Inlet Header-FWIH (12-inch , Exposed , Ductile Iron , Cement Mortar , Paint)	0	EA	*$8,401.82*	$0
Feed Water Inlet Lateral-FWIL (8-inch , Exposed , Welded Steel , Cement Mortar , Paint)	2	EA	*$6,435.71*	$12,871
Degasifier Air Influent Header-DAIH (24-inch , Exposed , FRP , None , None)	0	EA	*$16,803.65*	$0
Degasifier Air Influent Lateral-DAIL (16-inch , Exposed , FRP , None , None)	2	EA	*$11,202.43*	$22,405
Water Effluent Lateral-WEL (8-inch , Exposed , FRP , None , None)	2	EA	*$5,601.22*	$11,202
Scrubber Air Influent Header-SAIH (24-inch , Exposed , FRP , None , None)	0	EA	*$16,803.65*	$0
Scrubber Air Influent Lateral-SAIL (24-inch , Exposed , FRP , None , None)	0	EA	*$16,803.65*	$0
Scrubber Air Discharge-SAD (24-inch , Exposed , FRP , None , None)	0	EA	*$16,803.65*	$0
Scrubber Recirculation Pipe-SRP (2-inch , Exposed , Ductile Iron , None , Paint)	0	EA	*$1,400.30*	$0
Pump Discharge Lateral-PDL (12-inch , Exposed , Welded Steel , Cement Mortar , Paint)	2	EA	*$9,653.56*	$19,307

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Pump Discharge Header-PDH (10-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$8,044.63*	$0
Permeate Makeup Supply Lateral-PML (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	1	EA	*$3,217.85*	$3,218
Permeate Makeup Supply Header-PMH (4-inch , Exposed , Welded Steel , Cement Mortar , Paint)	0	EA	*$3,217.85*	$0
Allowance for Misc Items	5%		$91,749.43	$4,587
Subtotal				$118,862
ELECTRICAL:				
MCC's				
Sections	7	EA	*$6,783.10*	$47,482
AFD's				
Air Stripper Fan (Active) (4 hp each)	2	EA	*$4,617.76*	$9,236
Air Stripper Fan (Standby) (4 hp each)	0	EA	*$4,617.76*	$0
Recirculation Pump (Active) (0 hp each)	0	EA	*$4,125.89*	$0
Recirculation Pump (Standby) (0 hp each)	0	EA	*$4,125.89*	$0
Effluent Transfer Pump (Active) (30 hp each)	1	EA	*$7,798.45*	$0
Effluent Transfer Pump (Standby) (30 hp each)	1	EA	*$7,798.45*	$0
Permeate Makeup Supply Pumps (Active)	0	EA	*$4,371.83*	$0
Permeate Makeup Supply Pumps (Standby)	0	EA	*$4,371.83*	$0
Switchgear				
Units	0	EA	*$31,202.24*	$0
Electrical Conduit & Wire	98	lf	*$9.53*	$935
Allowance for Misc Items	5%		$57,652.30	$2,883
Subtotal				$60,535
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$724,835
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$862,899	$17,258
I & C Allowance	4%		$862,899	$34,516
Mechanical Allowance	5%		$862,899	$43,145
Electrical Allowance	5%	2%	$862,899	$17,258
Facility Cost	**2,250,000**	**GPD**	**$0.37**	**$837,012**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	1088.34	CY	***$5.35***	$5,825
Imported Structural Backfill	57.32	CY	***$40.56***	$2,325
Native Backfill	608.68	CY	***$6.58***	$4,005
Haul Excess	479.66	CY	***$6.58***	$3,156
Allowance for Misc Items	5%		$15,311.28	$766
Subtotal				$16,077
CONCRETE:				
Wet Well:				
Foundation	19.11	CY	***$382.16***	$7,302
Perimeter Walls	60.44	CY	***$683.50***	$41,313
Operating Floor:				
Elevated Slab (Including floor over Discharge Header Vault)	24.26	CY	***$1,088.69***	$26,414
Pump Pads	0.48	CY	***$345.93***	$167
Other Equipment Pads	1.00	CY	***$345.93***	$346
Discharge Pipe Vault:				
Slab on Grade	10.03	CY	***$345.93***	$3,469
Walls	12.36	CY	***$683.50***	$8,451
Allowance for Misc Items	5%		$87,462.34	$4,373
Subtotal				$91,835
MASONRY:	High			
CMU Building	655.07	SF	***$157.92***	$103,450
Subtotal				$103,450
METALS:				
Checker Plate Over Intake Pipe Gate = (Diameter of Influent Pipe +2') * (2 Feet Wide) (sf)	6.33	SF	***$72.38***	$458
Checker Plate Over Discharge Pipe Header = ((Discharge Pipe Diameter * 2) * ("S" * Total Number of Pumps)	19.83	SF	***$72.38***	$1,436
Ladder	17.92	VLF	***$99.36***	$1,781
Allowance for Misc Items	10%		$3,674.86	$367
Subtotal				$4,042
THERMAL & MOISTURE PROTECTION:				
Wet Well Liner	0.00	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Size of Sluice Gate (per side in inches)	14.00	in		
Sluice Gate	1.00	EA	***$3,467.45***	$3,467
Pumps:				
Active Pump # 1	70.24	HP	***$1,236.99***	$86,887
Active Pump # 2	70.24	HP	***$1,236.99***	$86,887
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0
Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	70.24	HP	***$1,236.99***	$86,887
AFD's				

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Active Pump # 1	70.24	HP	***$181.71***	$12,763
Active Pump # 2	70.24	HP	***$181.71***	$12,763
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0
Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	70.24	HP	***$181.71***	$12,763
Allowance for Misc Items	10%		$298,950.93	$29,895
Subtotal				$332,313
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$547,718
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$1,095,437	$21,909
I & C Allowance	8.0%		$1,095,437	$87,635
Mechanical Allowance	25.0%		$1,095,437	$273,859
Electrical Allowance	15.0%		$1,095,437	$164,316
Facility Cost	**211**	**Total Pump HP**	**$5,198.49**	**$1,095,437**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	71.29	CY	*$5.35*	$382
Imported Structural Backfill	36.37	CY	*$40.56*	$1,475
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	71.29	CY	*$6.58*	$469
Allowance for Misc Items	5%		$2,325.61	$116
Subtotal				$2,442
CONCRETE:				
Slab on Grade	26.14	CY	*$345.93*	$9,043
Containment Walls	7.75	CY	*$683.50*	$5,299
Bulk Tank Pads	17.10	CY	*$345.93*	$5,917
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	5.56	CY	*$345.93*	$1,922
Electrical Room				
Slab on Grade	3.04	CY	*$345.93*	$1,051
Allowance for Misc Items	5%		$23,692.53	$1,185
Subtotal				$24,877
MASONRY:	High			
CMU Building	822.00	SF	*$157.92*	$129,812
Subtotal				$129,812
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	1.00	EA	*$20,154.94*	$20,155
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$33,630.90	$3,363
Subtotal				$36,994
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	1.00	each	*$824.29*	$824
Chemical Tank Beacons	1.00	each	*$824.29*	$824
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	5.00	each	*$208.82*	$1,044
Number of Digital I/O Counts	17.00	each	*$49.46*	$841
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	140.00	lf	*$9.53*	$1,334
Allowance for Misc Items	10%		$28,936.76	$2,894
Subtotal				$31,830
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	57.00	lf	*$10.36*	$591
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	57.00	lf	*$11.98*	$683
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,512.50	$251
Subtotal				$2,764
ELECTRICAL:				
# MCC Sections	5.00	#	*$6,783.10*	$33,915
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	40.00	lf	*$9.53*	$381
Allowance for Misc Items	10%		$34,296.63	$3,430
Subtotal				$37,726
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$275,420
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$306,023	$6,120
I & C Allowance	2%		$306,023	$6,120
Mechanical Allowance	4%		$306,023	$12,241
Electrical Allowance	2%		$306,023	$6,120
Facility Cost	**982**	**Building SF**	**$311.63**	**$306,023**

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CH2M HILL Parametric Cost Estimating System (CPES)

FACILITIES DESIGN & CONSTRUCTION COST MODULE

File Version: 1/5/2010

Click for CPES QA/QC | To Concrete Wall Thickness Help | To Cost Summary Matrix | To Unit Cost Database

Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months):	24
Mid-Point of Construction:	Jan/2012

Roundup to the nearest: $1,000

☐ This Report is for INTERNAL Distributio

☐ This Report is for EXTERNAL Distributio

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Cost
	Yes	Inline Rapid Mix: RMX	$623,000
	Yes	Flocculation: FLOC	$1,527,000
	Yes	Lamella Clarifier: LAM	$2,367,000
	Yes	Filters: FILT	$5,024,000
	Yes	Surge Basin-Decanter: BWW	$1,535,000
	No	UV Disinfection: UVD	$0
	Yes	Concrete Clearwell: FWT	$1,313,000
	No	Steel Clearwell: FWT	$0
	No	In-Plant PS: FWPS	$0
	Yes	Vertical Turbine PS: FWPS	$3,042,000
	Yes	Filter BW PS: BWSPS	$1,101,000
	Yes	U.D. Facility: GEN	$0
	Yes	Liquid Chemical: FeCl3	$393,000
	Yes	Liquid Chemical: NaOCl	$296,000
	Yes	Liquid Chemical: FLUOR	$186,000
	Yes	Liquid Chemical: POLYPHOS	$185,000
	Yes	O&M Building: OMB	$2,849,000
SUBTOTAL - PROJECT COST			$20,441,000
ADDITIONAL PROJECT COSTS:			
Demolition	0%		$0
Overall Sitework	10%		$2,045,000
Plant Computer System	5%		$1,023,000
Yard Electrical	7%		$1,493,000
Yard Piping	14%		$2,862,000
UD #1 Default Description	0%		$0
UD #2 Default Description	0%		$0
UD #3 Default Description	0%		$0
SUBTOTAL with Additional Project Costs			$27,864,000

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	B	C	D	E	F
132					
133	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
134					
135	SITEWORK:				
136	Excavation	140.81	CY	$ 5.35	$754
137	Imported Structural Backfill	83.82	CY	$ 40.56	$3,399
138	Native Backfill	0.00	CY	$ 6.58	$0
139	Haul Excess	140.81	CY	$ 6.58	$927
140	Allowance for Misc Items	5%		$ 5,079.48	$254
141	Subtotal				$5,333
142					
143	CONCRETE:				
144	Wall Footing	9.31	CY	$ 345.93	$3,220
145	Stem Walls	0.00	CY	$ 683.50	$0
146	Slab on Grade	27.50	CY	$ 345.93	$9,513
147	Pipe Supports	14.00	EA	$ 438.67	$6,141
148	Electrical Room Slab on Grade	2.13	CY	$ 345.93	$737
149	Allowance for Misc Items	5%		$19,613	$981
150	Subtotal				$20,593
151					
152	MASONRY:	Moderate			
153	CMU Building	864.20	SF	$ 131.60	$113,730
154	Electrical Room	57.56	SF	$ 131.60	$7,574
155	Subtotal	921.76			$121,304
156					
157	EQUIPMENT:				
158	Inline Mixer (20-inch)	2.00	EA	$ 27,983.82	$55,968
159	Allowance for Misc Items	10%		$ 55,967.63	$5,597
160	Subtotal				$61,564.39
161					
162	INSTRUMENTS & CONTROLS:				
163	Instruments				
164	Mag Meter (12-inch)	2.00	EA	$ 10,574.21	$21,148
165	pH / Temperature	1.00	EA	$ 2,093.45	$2,093
166	Turbidity	1.00	EA	$ 3,133.05	$3,133
167	Streaming Current Detector	0.00	EA	$ 10,680.85	$0
168	UV Absorbance	1.00	EA	$ 21,794.63	$21,795
169	Conductivity	0.00	EA	$ 2,057.84	$0
170	Sample Panels	2.00	EA	$ 3,948.04	$7,896
171	Isolation Valve Actuators	4.00	each	$5,064.93	$20,260
172	Flow Control Valve Actuators	2.00	each	$5,064.93	$10,130
173	Number of Analog I/O Counts	12.00	each	$208.82	$2,506
174	Number of Digital I/O Counts	33.60	each	$49.46	$1,662
175	Number of PLC's	1.00	each	$10,331.10	$10,331
176	I&C Conduit & Wire	552.52	lf	$9.53	$5,265
177	Allowance for Misc Items	10%		$ 106,218.79	$10,622
178	Subtotal				$116,841
179					
180	CONVEYING SYSTEMS:				
181	Monorail Hoist (3 Ton)	1.00	EA	$ 55,749.49	$55,749
182	Hoist Rail	105.17	LF	$ 28.96	$3,045
183	Allowance for Misc Items	10%		$ 58,794.83	$5,879
184	Subtotal				$64,674
185					
186	MECHANICAL:				
187	Pipe:				
188	Rapid Mix Pipe (20-inch, RW, Exposed ,Steel ,Cement Mortar ,Paint)	33.33	lf	$365.28	$12,176

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	B	C	D	E	F
189	Flow Control Pipe (12-inch, FCP, Exposed ,Steel ,Cement Mortar ,Paint)	16.00	lf	*$219.17*	$3,507
190	Elbows:				
191	Rapid Mix Pipe (20-inch)	4.00	each	*$2,199.87*	$8,799
192	Valves:				
193	Rapid Mix Isolation Valves (20-inch)	4.00	each	*$16,089.26*	$64,357
194	Flow Control Valve (12-inch)	2.00	each	*$9,653.56*	$19,307
195	Allowance for Misc Items	10%		$108,146.20	$10,815
196	Subtotal				$118,961
197					
198	ELECTRICAL:				
199	MCC's				
200	Sections	5.00	each	*$6,783.10*	$33,915
201	AFD's				
202	Mechanical Mixers (3 hp each)	0.00	each	*$4,494.79*	$0
203	Switchgear				
204	Units	0.00	each	*$31,202.24*	$0
205	Electrical Conduit & Wire	85.00	lf	*$9.53*	$810
206	Allowance for Misc Items	10%		$34,725	$3,473
207	Subtotal				$38,198
208					
209	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
210	Item 1 Description	0.00		0.00	$0
211	Item 2 Description	0.00		0.00	$0
212	Item 3 Description	0.00		0.00	$0
213	Item 4 Description	0.00		0.00	$0
214	Item 5 Description	0.00		0.00	$0
215	Item 6 Description	0.00		0.00	$0
216	Item 7 Description	0.00		0.00	$0
217	Item 8 Description	0.00		0.00	$0
218	Item 9 Description	0.00		0.00	$0
219	Item 10 Description	0.00		0.00	$0
220	Item 11 Description	0.00		0.00	$0
221	Item 12 Description	0.00		0.00	$0
222	Item 13 Description	0.00		0.00	$0
223	Item 14 Description	0.00		0.00	$0
224	Item 15 Description	0.00		0.00	$0
225	Subtotal				$0
226					
227	Subtotal				$547,469
228					
229	ALLOWANCES:		**User Over-write**		
230	Finishes Allowance	2.0%		$622,124	$12,442
231	I & C Allowance	5%		$622,124	$31,106
232	Mechanical Allowance	0%		$622,124	$0
233	Electrical Allowance	5%		$622,124	$31,106
234					
235	Facility Cost	**12,000,000**	**GPD**	**$0.05**	**$622,124**

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	B	C	D	E	F
188					
189	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
190					
191	SITEWORK:				
192	Excavation	3,805	CY	***$5.35***	$20,366
193	Imported Structural Backfill	617	CY	***$40.56***	$25,021
194	Native Backfill	1,032	CY	***$6.58***	$6,793
195	Haul Excess	2,773	CY	***$6.58***	$18,244
196	Allowance for Misc Items	5%		$70,423.45	$3,521
197	Subtotal				$73,945
198					
199	CONCRETE:				
200	Influent Channel:				
201	Foundation	42	CY	***$382.16***	$16,188
202	Channel Walls (Only 3 walls are covered here. The 4th wall is covered in the Flocc Basin.)	70	CY	***$683.50***	$47,563
203	Elevated Slab	25	CY	***$1,088.69***	$27,007
204	Flocc Basin				
205	Foundation	218	CY	***$382.16***	$83,323
206	Basin Walls (Only 3 walls are covered here. The Effluent wall is covered in the Influent Channel of the Lamella Clarifier)	119	CY	***$683.50***	$81,280
207	Under Baffle Wall	40	CY	***$683.50***	$27,065
208	Over Baffle Wall	40	CY	***$683.50***	$27,065
209	Elevated Slab	81	CY	***$1,088.69***	$88,341
210	Flocc Bearing Supports	42	EA	$0.00	$0
211	Electrical Room				
212	Slab on Grade	4	CY	***$345.93***	$1,435
213	Allowance for Misc Items	5%		$399,265.97	$19,963
214	Subtotal				$419,229
215					
216	MASONRY:	**Moderate**			
217	CMU Building	4,312	SF	***$131.60***	$567,498
218	Electrical Room	112	SF	***$131.60***	$14,739
219	Subtotal	4,424			$582,238
220					
221	METALS:				
222	Aluminum Handrail	233	LF	***$72.38***	$16,854
223	Additional Handrail with NO Building	0	LF	***$72.38***	$0
224	Stairs (1 per basin)	16	RISERS	***$394.80***	$6,270
225	Allowance for Misc Items	10%		$23,124.34	$2,312
226	Subtotal				$25,437
227					
228	WOODS & PLASTICS:				
229	FRP Weir	6	LF	$32.90	$183
230	FRP Ladder	4	EA	$1,137.15	$4,549
231	Allowance for Misc Items	5%		$4,732.07	$237
232	Subtotal				$4,969
233					
234	THERMAL & MOISTURE PROTECTION:				
235	Concrete Liner	0	SF	**$16.00**	$0
236	Allowance for Misc Items	10%		$0.00	$0
237	Subtotal				$0
238					
239	DOORS & WINDOWS:				
240	O/U Baffling ON/OFF Factor	*0*			
241	Serpentine Baffling ON/OFF Factor	*1*			$0
242	Stainless Steel Door (2' x 2') for O/U Baffling	0	EA	$1,052.81	$0
243	Stainless Steel Door (2' x 2') for Serpentine Baffling	4	EA	$1,052.81	$4,211
244	Stainless Steel Door (7' x 2.5')	0	EA	$4,606.05	$0
245	Allowance for Misc Items	5%		$4,211.24	$211
246	Subtotal				$4,422
247					

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	B	C	D	E	F
248	EQUIPMENT:				
249	Horizontal Paddle Wheel Flocculation Mechanism (Paddles & Drives)	0	LF	***$0.00***	$0
250	Vertical Paddle Wheel Flocculation Mechanism (Paddles & Drives)	18	EA	***$0.00***	$0
251	Vertical Turbine Flocculation Mechanism (Turbines & Drives)	18	HP	***$1,477.12***	$26,588
252	Vertical Turbine Flocculator VFD's	18	HP	***$596.65***	$10,740
253	Fabricated Slide Gate	2	EA	***$6,077.92***	$12,156
254	Allowance for Misc Items	10%		$49,483.61	$4,948
255	Subtotal				$54,432
256					
257	ELECTRICAL:				
258	*MCC's*				
259	Sections	12	each	***$6,783.10***	$81,397
260	*AFD's*				
261	Flocculation Mixers Stage 1 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
262	Flocculation Mixers Stage 2 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
263	Flocculation Mixers Stage 3 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
264	Flocculation Mixers Stage 4 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
265	Flocculation Mixers Stage 5 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
266	Flocculation Mixers Stage 6 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
267	*Switchgear*				
268	Units	0	each	***$31,202.24***	$0
269	Electrical Conduit & Wire	1,752	lf	***$9.53***	$16,694
270	Allowance for Misc Items	10%		$174,571.06	$17,457
271	Subtotal				$192,028
272					
273	INSTRUMENTS & CONTROLS:				
274	Instruments				
275	Level Switch	2	each	***$549.53***	$1,099
276	Number of Analog I/O Counts	43	each	***$208.82***	$9,021
277	Number of Digital I/O Counts	108	each	***$49.46***	$5,341
278	Number of PLC's	1	each	***$10,331.10***	$10,331
279	I&C Conduit & Wire	1,827	lf	***$9.53***	$17,406
280	Allowance for Misc Items	10%		$43,198.52	$4,320
281	Subtotal				$47,518
282					
283	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
284	Item 1 Description	0.00		0.00	$0
285	Item 2 Description	0.00		0.00	$0
286	Item 3 Description	0.00		0.00	$0
287	Item 4 Description	0.00		0.00	$0
288	Item 5 Description	0.00		0.00	$0
289	Item 6 Description	0.00		0.00	$0
290	Item 7 Description	0.00		0.00	$0
291	Item 8 Description	0.00		0.00	$0
292	Item 9 Description	0.00		0.00	$0
293	Item 10 Description	0.00		0.00	$0
294	Item 11 Description	0.00		0.00	$0
295	Item 12 Description	0.00		0.00	$0
296	Item 13 Description	0.00		0.00	$0
297	Item 14 Description	0.00		0.00	$0
298	Item 15 Description	0.00		0.00	$0
299	Subtotal				$0
300					
301	Subtotal				$1,404,217
302					
303	ALLOWANCES:		**User Over-write**		

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	B	C	D	E	F
304	Finishes Allowance	2.0%		$1,526,323	$30,526
305	I & C Allowance	2%		$1,526,323	$30,526
306	Mechanical Allowance	2%		$1,526,323	$30,526
307	Electrical Allowance	2%		$1,526,323	$30,526
308					
309	Facility Cost	12,000,000	GPD	$0.13	$1,526,323

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	B	C	D	E	F
180					
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
182					
183	SITEWORK:				
184	Excavation	4,244	CY	$ 5.35	$22,713
185	Imported Structural Backfill	653	CY	$ 40.56	$26,492
186	Native Backfill	1,176	CY	$ 6.58	$7,738
187	Haul Excess	3,068	CY	$ 6.58	$20,185
188	Allowance for Misc Items	5%		$77,128	$3,856
189	Subtotal				$80,985
190					
191	CONCRETE:				
192	Influent Channel:				
193	Foundation	37	CY	$ 382.16	$14,026
194	Channel Walls	77	CY	$ 683.50	$52,960
195	Elevated Slab	22	CY	$ 1,088.69	$24,216
196	Basin				
197	Foundation	138	CY	$ 382.16	$52,925
198	Channel Walls	264	CY	$ 683.50	$180,519
199	Elevated Slab	38	CY	$ 1,088.69	$41,369
200	Concrete Curb (8" X 8")	73	LF	$ 32.90	$2,402
201	Effluent Channel:				
202	Foundation	37	CY	$ 382.16	$14,026
203	Walls	77	CY	$ 683.50	$52,960
204	Elevated Slab	22	CY	$ 1,088.69	$24,216
205	Electrical Room				
206	Slab on Grade	2	CY	$ 345.93	$737
207	Allowance for Misc Items	5%		$460,355	$23,018
208	Subtotal				$483,373
209					
210	MASONRY:	Moderate			
211	CMU Building	4,746	SF	$ 131.60	$624,619
212	Electrical Room	58	SF	$ 131.60	$7,574
213	Subtotal	4,804			$632,193
214					
215	METALS:				
216	Aluminum Handrail	269	LF	$ 72.38	$19,470
217	Allowance for Misc Items	10%		$ 19,470.17	$1,947
218	Subtotal				$21,417
219					
220	WOODS & PLASTICS:				
221	FRP Ladder	4	EA	$ 1,443.20	$5,773
222	Allowance for Misc Items	5%		$ 5,772.82	$289
223	Subtotal				$6,061
224					
225	THERMAL & MOISTURE PROTECTION:				
226	Concrete Liner	0	SF	$16.00	$0
227	Allowance for Misc Items	10%		$0.00	$0
228	Subtotal				$0
229					
230	EQUIPMENT:				
231	Lamella Clarifier [WPL * PW * #P/T *# * COS(PAR)]	25,063	PLATE AREA (SF)	$ 19.45	$487,452
232	Fabricated Slide Gate	2	EA	$ 6,077.92	$12,156
233	Hoseless Sludge Collector	4	EA	$ 66,857.09	$267,428
234	Allowance for Misc Items	10%		$ 767,035.90	$76,704
235	Subtotal				$843,739
236					
237	INSTRUMENTS & CONTROLS:				
238	Instruments				
239	Turbidimeters	4	EA	$ 3,133.05	$12,532
240	Number of Analog I/O Counts	5	each	$208.82	$1,002.34
241	Number of Digital I/O Counts	24	each	$49.46	$1,186.98
242	Number of PLC's	1	each	$10,331.10	$10,331.10
243	I&C Conduit & Wire	321	LF	$9.53	$3,061.92
244	Allowance for Misc Items	10%		$28,115	$2,811.45
245	Subtotal				$30,926
246					

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	B	C	D	E	F
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
247	MECHANICAL:				
248	Solids Collection Pipe (4-inch, USL , Immersed , Steel)	317	LF	*$66.15*	$20,969
249	Solids Collection Pipe Elbows	16	each	*$439.97*	$7,040
250	Mud Valves	4	EA	*$1,974.02*	$7,896
251	Allowance for Misc Items	10%		$35,905	$3,590
252	Subtotal				$39,495
253					
254	ELECTRICAL:				
255	MCC's				
256	Sections	5	each	*$6,783.10*	$33,915
257	AFD's				
258	Sludge Collectors (total facility) (1 hp each)	-	each	*$4,248.86*	$0
259	Switchgear				
260	Units	-	each	*$31,202.24*	$0
261	Electrical Conduit & Wire	161	LF	*$9.53*	$1,530.96
262	Allowance for Misc Items	10%		$35,446	$3,544.64
263	Subtotal				$38,991
264					
265	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
266	Item 1 Description	0.00		0.00	$0
267	Item 2 Description	0.00		0.00	$0
268	Item 3 Description	0.00		0.00	$0
269	Item 4 Description	0.00		0.00	$0
270	Item 5 Description	0.00		0.00	$0
271	Item 6 Description	0.00		0.00	$0
272	Item 7 Description	0.00		0.00	$0
273	Item 8 Description	0.00		0.00	$0
274	Item 9 Description	0.00		0.00	$0
275	Item 10 Description	0.00		0.00	$0
276	Item 11 Description	0.00		0.00	$0
277	Item 12 Description	0.00		0.00	$0
278	Item 13 Description	0.00		0.00	$0
279	Item 14 Description	0.00		0.00	$0
280	Item 15 Description	0.00		0.00	$0
281	Subtotal				$0
282					
283	Subtotal				$2,177,181
284					
285	ALLOWANCES:		**User Over-write**		
286	Finishes Allowance	2.0%		$2,366,502	$47,330
287	I & C Allowance	2%		$2,366,502	$47,330
288	Mechanical Allowance	2%		$2,366,502	$47,330
289	Electrical Allowance	2%		$2,366,502	$47,330
290					
291	Facility Cost	**12,000,000**	**GPD**	**$0.20**	**$2,366,502**

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	B	C	D	E	F
317	[redacted]				
318	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
319	SITEWORK:				
320	Soil Excavation	5429.67	CY	***$5.35***	$29,061
321	Imported Structural Backfill	640.14	CY	***$40.56***	$25,961
322	Backfill	110.89	CY	***$6.58***	$730
323	Haul Excess	5318.78	CY	***$6.58***	$34,998
324	Stair Case:				
325	Soil Excavation	638.48	CY	***$5.35***	$3,417
326	Imported Structural Backfill	87.11	CY	***$40.56***	$3,533
327	Backfill	32.89	CY	***$6.58***	$216
328	Haul Excess	605.59	CY	***$6.58***	$3,985
329	Blower Room:				
330	Soil Excavation	81.35	CY	***$5.35***	$435
331	Imported Structural Backfill	102.89	CY	***$40.56***	$4,173
332	Backfill	4.04	CY	***$6.58***	$27
333	Haul Excess	77.31	CY	***$6.58***	$509
334	Electrical Room:				
335	Soil Excavation	16.29	CY	***$5.35***	$87
336	Imported Structural Backfill	19.63	CY	***$40.56***	$796
337	Backfill	1.46	CY	***$6.58***	$10
338	Haul Excess	14.83	CY	***$6.58***	$98
339	Allowance for Misc Items	5%		$108,034.91	$5,402
340	Subtotal				$113,437
341					
342	CONCRETE:				
343	Filters				
344	Foundation (Includes Filter, Gullet Channel, Filter Influent/Backwash Wastewater Channel) (FSOGW * FSOGL * FOSGT) / 27 *#TF	314.52	CY	***$382.16***	$120,198
345	Pipe Gallery Wall	214.75	CY	***$683.50***	$146,779
346	Gullet Wall	42.53	CY	***$683.50***	$29,069
347	Filter Influent / Backwash Waste Channel Walls	362.33	CY	***$683.50***	$247,653
348	Filter Influent / Backwash Waste Channel Lower Elevated Slab	20.99	CY	***$1,088.69***	$22,849
349	Filter Influent / Backwash Waste Channel Upper Elevated Slab	28.33	CY	***$1,088.69***	$30,846
350	End Walls	221.13	CY	***$683.50***	$151,141
351	Common Filter Influent				
352	Slab on Grade	55.14	CY	***$345.93***	$19,076
353	Common Influent Channel Wall	179.54	CY	***$683.50***	$122,718
354	Common Influent Channel Elevated Slab	24.54	CY	***$1,088.69***	$26,719
355	Filter Gallery				
356	Slab on Grade	389.93	CY	***$345.93***	$134,890
357	Filter Gallery Elevated Slab	57.77	CY	***$1,088.69***	$62,891
358	Pipe Supports	1.84	CY	***$32.90***	
359	Blower Room				
360	Slab on Grade	55.50	CY	***$345.93***	$19,201
361	Blower Room Walls	29.08	CY	***$683.50***	$19,879
362	Stair Case				
363	Slab on Grade	46.22	CY	***$345.93***	$15,990
364	Stair Case Walls	25.58	CY	***$683.50***	$17,481
365	Electrical Room				
366	Slab on Grade	3.04	CY	***$345.93***	$1,051
367	Electrical Room Walls	9.71	CY	***$683.50***	$6,638
368	Allowance for Misc Items	5%		$1,195,069.53	$59,753
369	Subtotal				$1,254,823
370					
371	MASONRY:	Moderate			
372	CMU Filter Building	7599.82	SF	***$131.60***	$1,000,147
373	Blower Room	691.67	SF	***$131.60***	$91,024
374	Electrical Room	82.00	SF	***$131.60***	$10,791
375	Subtotal				$1,101,963
376					
377	METALS:				

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	B	C	D	E	F
378	Metal Guardrail with Pickets	415.33	LF	***$72.38***	$30,062
379	Filter Access Hatch	13.44	SF	***$109.91***	
380	Stairs (FBD * 12/8)	32.00	Risers	***$394.80***	$12,634
381	Allowance for Misc Items	10%		$42,695.87	$4,270
382	Subtotal				$46,965
383					
384	THERMAL & MOISTURE PROTECTION:				
385	Concrete Liner	0	SF	***$16.00***	$0
386	Allowance for Misc Items	10%		$0.00	$0
387	Subtotal				$0
388					
389	EQUIPMENT:				
390	Fabricated Slide Gates, 42-inch	2	EA	***$7,111.04***	$14,222
391	Underdrain - Leopold Type S	1,852	SF	***$69.90***	$129,455
392	Wash Troughs				
393	Conventional	0	LF	***$234.61***	$0
394	Media Retaining	223	LF	***$531.99***	$118,633
395	Media				
396	Bottom Media - Sand (ES=0.5 UC=1.4)	1,852	CF	***$17.47***	$32,364
397	Middle Media - Coal (ES=0 UC=0)	0	CF	***$23.30***	$0
398	Top Media - Coal (ES=1 UC=1.4)	7,408	CF	***$23.30***	$172,607
399	Air Scour Blowers (88 hp each)	2	EA	***$71,524.98***	$143,050
400	Allowance for Misc Items	10%		$610,331.42	$61,033
401	Subtotal				$671,365
402					
403	INSTRUMENTS & CONTROLS:				
404	Instruments				
405	Filter Effluent Magmeter (16-inch)	4.00	EA	***$14,438.40***	$57,754
406	Combined Filter Effluent Magmeter (30-inch)	0.00	EA	***$23,932.23***	$0
407	Isolation Valve Actuators	24.00	EA	***$5,064.93***	$121,558
408	Control Valve Actuators	4.00	EA	***$5,064.93***	$20,260
409	Turbidimeters	4	EA	***$3,133.05***	$12,532
410	Particle Counters	4	EA	***$6,764.54***	$27,058
411	Level Transmitters	4	EA	***$7,120.57***	$28,482
412	Differential Pressure Transmitters	4	EA	***$7,120.57***	$28,482
413	Filter Influent Level Transmitter	2	EA	***$7,120.57***	$14,241
414	Air Scour Differential Pressure Transmitter	2	EA	***$7,120.57***	$14,241
415	Air Scour Discharge Pressure Indicator Transmitter	2	EA	***$7,120.57***	$14,241
416	Number of Analog I/O Counts	53	EA	***$208.82***	$11,026
417	Number of Digital I/O Counts	149	EA	***$49.46***	$7,359
418	Number of PLC's	1	EA	***$10,331.10***	$10,331
419	I&C Conduit & Wire	3,438	LF	***$9.53***	$32,760
420	Allowance for Misc Items	10%		$400,325.99	$40,033
421	Subtotal				$440,359
422					
423	CONVEYING SYSTEMS:				
424	Monorail Hoist (3 Ton)	1	EA	***$3,257.13***	$3,257
425	Hoist Rail	162	LF	***$32.90***	$5,324
426	Allowance for Misc Items	5%		$8,581.61	$429
427	Subtotal				$9,011
428					
429	MECHANICAL:				
430	Pipe				
431	Air Scour Pipe-BAW (12-inch , Exposed , Steel , None , None)	216	LF	***$198.45***	$42,899

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	B	C	D	E	F
432	Filter Influent Header Pipe-FIH (30-inch , Buried , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$547.92*	$0
433	Filter Influent Pipe-FIH (20-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$365.28*	$0
434	Filter Effluent Pipe-FE (16-inch , Exposed , Steel , Cement Mortar , Paint)	50	LF	*$292.22*	$14,613
435	Filter Effluent Pipe-FE (16-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	50	LF	*$292.22*	$14,613
436	Filter Control Valve Pipe-FCV (12-inch , Exposed , Steel , None , None)	32	LF	*$198.45*	$6,350
437	Filter Effluent Header Pipe-FEH (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	64	LF	*$547.92*	$34,884
438	Filter to Waste-FTW (16-inch , Exposed , Steel , Cement Mortar , Paint)	43	LF	*$292.22*	$12,612
439	Filter to Waste-FTW (16-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	153	LF	*$292.22*	$44,807
440	Backwash Supply Pipe-BWS (30-inch , Exposed , Steel , Cement Mortar , Paint)	170	LF	*$547.92*	$93,186
441	Backwash Supply Pipe-BWS (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	48	LF	*$547.92*	$26,300
442	Backwash Waste Pipe-BWW (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	10	LF	*$547.92*	$5,479
443	Elbows				
444	Air Scour Pipe-BAW (12-inch , Steel)	16	EA	*$1,319.92*	$21,119
445	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$3,299.80*	$0
446	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$2,199.87*	$0
447	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$1,759.89*	$7,040
448	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$1,759.89*	$7,040
449	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$1,319.92*	$0
450	Filter Effluent Header Pipe-FEH (30-inch , Steel)	0	EA	*$3,299.80*	$0
451	Filter to Waste-FTW (16-inch , Steel)	6	EA	*$1,759.89*	$10,559
452	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$1,759.89*	$0
453	Backwash Supply Pipe-BWS (30-inch , Steel)	2	EA	*$3,299.80*	$6,600
454	Backwash Supply Pipe-BWS (30-inch , Steel)	2	EA	*$3,299.80*	$6,600
455	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$3,299.80*	$0
456	Tees				
457	Air Scour Pipe-BAW (12-inch , Steel)	4	EA	*$3,007.27*	$12,029
458	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$7,518.19*	$0
459	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$5,012.12*	$0
460	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$4,009.70*	$16,039
461	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$4,009.70*	$0
462	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$3,007.27*	$0
463	Filter Effluent Header Pipe-FEH (30-inch , Steel)	0	EA	*$7,518.19*	$0
464	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$4,009.70*	$0
465	Filter to Waste-FTW (16-inch , Steel)	2	EA	*$4,009.70*	$8,019
466	Backwash Supply Pipe-BWS (30-inch , Steel)	6	EA	*$7,518.19*	$45,109
467	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$7,518.19*	$0
468	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$7,518.19*	$0
469	Crosses				
470	Air Scour Pipe-BAW (12-inch , Steel)	2	EA	*$4,009.70*	$8,019
471	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$10,024.25*	$0
472	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$6,682.83*	$0
473	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$5,346.27*	$0
474	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$5,346.27*	$0
475	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$4,009.70*	$0
476	Filter Effluent Header Pipe-FEH (30-inch , Steel)	2	EA	*$10,024.25*	$20,048
477	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$5,346.27*	$0
478	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$5,346.27*	$0
479	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$10,024.25*	$0
480	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$10,024.25*	$0
481	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$10,024.25*	$0
482	Valves				
483	Air Scour Pipe-BAW (12-inch ,V500 - BFV)	4	EA	*$9,653.56*	$38,614
484	Filter Influent Header Pipe-FIH (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0

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	B	C	D	E	F
485	Filter Influent Pipe-FIH (20-inch ,V500 - BFV)	4	EA	*$16,089.26*	$64,357
486	Filter Effluent Pipe-FE (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
487	Filter Effluent Pipe-FE (16-inch ,V500 - BFV)	0	EA	*$12,871.41*	$0
488	Filter Control Valve Pipe-FCV (12-inch ,V500 - BFV)	4	EA	*$9,653.56*	$38,614
489	Filter Effluent Header Pipe-FEH (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0
490	Filter to Waste-FTW (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
491	Filter to Waste-FTW (16-inch ,V500 - BFV)	0	EA	*$12,871.41*	$0
492	Backwash Supply Pipe-BWS (30-inch ,V500 - BFV)	4	EA	*$24,133.90*	$96,536
493	Backwash Supply Pipe-BWS (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0
494	Backwash Waste Pipe-BWW (30-inch ,V500 - BFV)	4	EA	*$24,133.90*	$96,536
495	Allowance for Misc Items	5%		$901,593.08	$45,080
496	Subtotal				$946,673
497					
498	ELECTRICAL:				
499	MCC's				
500	Sections	5	EA	*$6,783.10*	$33,915
501	AFD's				
502	Air Scour Blowers (88 hp each)	-	EA	*$14,946.94*	$0
503	Switchgear				
504	Units	-	EA	*$31,202.24*	$0
505	Electrical Conduit & Wire	127	LF	*$9.53*	$1,213
506	Allowance for Misc Items	5%		$35,128.81	$1,756
507	Subtotal				$36,885
508					
509	USER DEFINED ESTIMATE ITEMS	QUANT	UNIT	$/UNIT	TOTAL COST
510	Item 1 Description	0.00		0.00	$0
511	Item 2 Description	0.00		0.00	$0
512	Item 3 Description	0.00		0.00	$0
513	Item 4 Description	0.00		0.00	$0
514	Item 5 Description	0.00		0.00	$0
515	Item 6 Description	0.00		0.00	$0
516	Item 7 Description	0.00		0.00	$0
517	Item 8 Description	0.00		0.00	$0
518	Item 9 Description	0.00		0.00	$0
519	Item 10 Description	0.00		0.00	$0
520	Item 11 Description	0.00		0.00	$0
521	Item 12 Description	0.00		0.00	$0
522	Item 13 Description	0.00		0.00	$0
523	Item 14 Description	0.00		0.00	$0
524	Item 15 Description	0.00		0.00	$0
525	Subtotal				$0
526					
527	Subtotal				$4,621,479.61
528					
529	ALLOWANCES:		**User Over-write**		
530	Finishes Allowance	2%		$5,023,347	$100,466.95
531	Mechanical Allowance	2%		$5,023,347.40	$100,466.95
532	I&C Allowance	2%		$5,023,347.40	$100,466.95
533	Electrical Allowance	2%		$5,023,347.40	$100,466.95
534					
535	**Facility Cost**	**12,000,000**	**GPD**	**$0.42**	**$5,023,347**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation				
Influent Channel, Surge Basin & Decant Pump	5311.63	CY	*$5.35*	$28,429
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1502.22	CY	*$5.35*	$8,040
Pipe Vault	351.82	CY	*$5.35*	$1,883
Imported Structural Backfill				
Influent Channel, Surge Basin & Decant Pump	426.72	CY	*$40.56*	$17,306
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	80.20	CY	*$40.56*	$3,252
Pipe Vault	70.17	CY	*$40.56*	$2,846
Native Backfill				
Influent Channel, Surge Basin & Decant Pump	1115.38	CY	*$6.58*	$7,339
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	32.00	CY	*$6.58*	$211
Pipe Vault	103.39	CY	*$6.58*	$680
Haul Excess				
Influent Channel, Surge Basin & Decant Pump	4196.25	CY	*$6.58*	$27,612
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1470.22	CY	*$6.58*	$9,674
Pipe Vault	248.42	CY	*$6.58*	$1,635
Allowance for Misc Items	5%		$108,907.43	$5,445
Subtotal				$114,353
CONCRETE:				
Surge Basin:				
Foundation	308.85	CY	*$382.16*	$118,028
Perimeter Walls	382.34	CY	*$683.50*	$261,329
Influent Channel Wall	62.23	CY	*$683.50*	$42,536
Concrete Curb (8" X 8")	76.89	LF	*$32.90*	$2,530
Backwash Recycle Sump:				
Slab on Grade	18.89	CY	*$345.93*	$6,534
Walls	90.62	CY	*$683.50*	$61,940
Elevated Slab	9.23	CY	*$1,088.69*	$10,045
Backwash Sludge Sump:				
Slab on Grade	13.33	CY	*$345.93*	$4,612
Walls	66.77	CY	*$683.50*	$45,640
Elevated Slab	6.88	CY	*$1,088.69*	$7,491
Dry Pit:				
Slab on Grade	5.31	CY	*$345.93*	$1,836
Walls	32.33	CY	*$683.50*	$22,096
Elevated Slab	3.49	CY	*$1,088.69*	$3,802
Pipe Vault:				
Lower Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Upper Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Walls	32.67	CY	*$683.50*	$22,333
Electrical Room Slab on Grade	5.27	CY	*$345.93*	$1,822
Allowance for Misc Items	5%		$677,117.15	$33,856
Subtotal				$710,973
MASONRY:	Moderate			
Pump Sumps and Pipe Vault	0.00	SF	*$131.60*	$0
Electrical Room	80.89	SF	*$131.60*	$10,645
Subtotal	80.89			$10,645
METALS:				
Influent Channel:				
Grating	185.56	SF	*$72.38*	$13,431
Surge Basin:				
Grating	4.00	SF	*$72.38*	$290
Backwash Recycle Sump:				
Grating	4.00	SF	*$72.38*	$290
Backwash Sludge Sump:				
Grating	4.00	SF	*$72.38*	$290
Dry Pit:				

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Ladder	27.60	VLF	*$99.36*	$2,742
Pipe Vault:				
Grating	4.00	SF	*$72.38*	$290
Stairs	16.00	RISERS	*$394.80*	$6,317
Allowance for Misc Items	10%		$23,647.47	$2,365
Subtotal				$26,012
DOORS & WINDOWS:				
Backwash Recycle Sump:				
Aluminum Access Hatch (10' x 5')	1.00	EA	*$4,400.75*	$4,401
Backwash Sludge Sump:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Dry Pit:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Pipe Vault:				
Aluminum Access Hatch (3' x 3')	2.00	EA	*$1,098.21*	$2,196
Allowance for Misc Items	5%		$8,793.60	$440
Subtotal				$9,233
EQUIPMENT:				
Floating Decanter Plate System	0.00	SF	*$72.94*	$0
Traveling Solids Removal Mechanism	2.00	EA	*$66,857.09*	$133,714
Washwater Decant Pump (Submersible Pump)	3.00	EA	*$18,993.38*	$56,980
Sludge Pump (Submersible Pump)	2.00	EA	*$12,409.63*	$24,819
Mixers	0.00	HP	*$1,580.26*	$0
Allowance for Misc Items	10%		$215,513.57	$21,551
Subtotal				$237,065
I&C:				
Instruments				
Backwash Waste Recycle Header Magmeter (BWRH, 12 inch)	1.00	EA	$10,573.93	$10,574
Isolation Valve Actuators (Electric)	5.00	EA	*$5,064.93*	$25,325
Level Transmitters	1.00	EA	*$7,120.57*	$7,121
Number of Analog I/O Counts	6.00	EA	*$208.82*	$1,253
Number of Digital I/O Counts	30.00	EA	*$49.46*	$1,484
Number of Local Panels	1.00	EA	*$10,331.10*	$10,331
Number of PLC's	1.00	EA	*$10,990.54*	$10,991
I&C Conduit Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$69,552.80	$3,478
Subtotal				$73,030
MECHANICAL:				
Pipe:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	LF	*$657.50*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	LF	*$123.32*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	16.22	LF	*$219.17*	$3,555
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	LF	*$219.17*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	81.00	LF	*$54.81*	$4,439
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	16.22	LF	*$109.58*	$1,778
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	LF	*$109.58*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	54.00	LF	*$109.58*	$5,917
Elbows:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$3,959.76*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$2,588.21*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	1.00	EA	*$1,319.92*	$1,320
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$1,319.92*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	6.00	EA	*$1,150.31*	$6,902
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$659.96*	$660
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$659.96*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	4.00	EA	*$659.96*	$2,640
Tee:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$9,021.82*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$4,297.65*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	2.00	EA	*$3,007.27*	$6,015

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Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$3,007.27*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	0.00	EA	*$1,910.07*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$1,503.64*	$1,504
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Valves:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$28,960.68*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$12,602.74*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	3.00	EA	*$5,601.22*	$16,804
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	2.00	EA	*$4,826.78*	$9,654
Allowance for Misc Items	5%		$61,186.86	$3,059
Subtotal				$64,246
ELECTRICAL:				
# MCC Sections	8.00	EA	*$6,783.10*	$54,265
Switchgear	0.00	EA	*$31,202.24*	$0
Adjustable Frequency Drives				
Basin Mixer	0.00	EA	*$4,125.89*	$0
Sludge Pumps (Active)	1.00	EA	*$4,871.14*	$4,871
Sludge Pumps (Standby)	1.00	EA	*$4,871.14*	$4,871
Recycle Pumps (Active)	2.00	EA	*$6,299.20*	$12,598
Recycle Pumps (Standby)	1.00	EA	*$6,299.20*	$6,299
Electrical Conduit & Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$85,380.01	$4,269
Subtotal				$89,649
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,335,206.98
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2%		$1,534,721	$30,694.41
I & C Allowance	3%		$1,534,720.67	$46,041.62
Mechanical Allowance	5%		$1,534,720.67	$76,736.03
Electrical Allowance	3%		$1,534,720.67	$46,041.62
Facility Cost	**2,519,600**	**Gallons**	**$0.61**	**$1,534,721**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Circular Clearwell				
Excavation	14,515	CY	*$5.35*	$77,691
Imported Structural Backfill	1,523	CY	*$40.56*	$61,784
Native Backfill	2,973	CY	*$6.58*	$19,563
Haul Excess	11,542	CY	*$6.58*	$75,949
Rectangular Clearwell				
Excavation	0	CY	*$5.35*	$0
Imported Structural Backfill	0	CY	*$40.56*	$0
Native Backfill	0	CY	*$6.58*	$0
Haul Excess	0	CY	*$6.58*	$0
Allowance for Misc Items	5%		$234,986.14	$11,749
Subtotal				$246,735
CONCRETE:				
Circular Clearwell				
Prestressed Concrete Tank (2000000 gallons)	1	EA	*$872,030.58*	$872,031
Rectangular Clearwell				
Foundation	0	CY	*$382.16*	$0
Columns	0	CY	*$683.50*	$0
Walls	0	CY	*$683.50*	$0
Elevated Slab	0	CY	*$1,088.69*	$0
Concrete Baffling	0	CY	*$683.50*	$0
Allowance for Misc Items	5%		$872,030.58	$43,602
Subtotal				$915,632
METALS & PLASTICS:				
Polypropylene Baffling	0	SF	*$10.99*	$0
Stainless Steel Baffling	0	SF	*$45.79*	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
THERMAL & MOISTURE PROTECTION:				
Concrete Liner	0	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,162,368
ALLOWANCES:		**User Over-write**		
Metals Allowance	1.0%		$1,249,858	$12,499
Finishes Allowance	2.0%		$1,249,858	$24,997

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Equipment Allowance	1.0%		$1,249,858	$12,499
I & C Allowance	2%		$1,249,858	$24,997
Mechanical Allowance	5%		$1,249,858	$62,493
Electrical Allowance	1%		$1,249,858	$12,499
Facility Cost	**2,000,000**	**Gallons**	**$0.66**	**$1,312,350**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	701.75	CY	*$5.35*	$0
Imported Structural Backfill	358.27	CY	*$40.56*	$0
Native Backfill	89.16	CY	*$6.58*	$0
Haul Excess	612.60	CY	*$6.58*	$0
Forebay:				
Excavation	7114.29	CY	*$5.35*	$0
Imported Structural Backfill	437.87	CY	*$40.56*	$0
Native Backfill	1838.49	CY	*$6.58*	$0
Haul Excess	5275.80	CY	*$6.58*	$0
Office:				
Excavation	0.00	CY	*$5.35*	$0
Imported Structural Backfill	0.00	CY	*$40.56*	$0
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	0.00	CY	*$6.58*	$0
Surge Protection:				
Excavation	117.15	CY	*$5.35*	$627
Imported Structural Backfill	86.04	CY	*$40.56*	$3,489
Native Backfill	18.55	CY	*$6.58*	$122
Haul Excess	98.59	CY	*$6.58*	$649
Allowance for Misc Items	5%		$4,887.33	$244
Subtotal				$5,132
CONCRETE:				
Pump Station				
Foundation	256.01	CY	*$382.16*	$0
Pump Pad Epoxy	0.74	CY	$3,412.56	$2,528
Pump Pad Support	7.78	CY	*$345.93*	$2,692
Pipe Supports	4.19	CY	*$345.93*	$1,448
Electrical Room				
Foundation	14.61	CY	*$345.93*	$5,055
Surge Protection				
Foundation	20.70	CY	*$345.93*	$7,161
Office				
Foundation	0.00	CY	*$345.93*	$0
Pump Station Forebay				
Slab on Grade for Rectangular Tank	231.48	CY	*$345.93*	$0
Support Walls for Rectangular	342.22	CY	*$683.50*	$0
Support Columns for Rectangular	16.50	CY	*$683.50*	$0
Elevated Slab for Rectangular	91.36	CY	*$1,088.69*	$0
Pump Baffling (for all cases)	16.43	CY	*$683.50*	$0
Sump Walls	86.37	CY	*$683.50*	$0
Sump Concrete Fill	184.06	CY	*$382.16*	$0
Prestressed Concrete Tank (422429 gallons)	0.00	EA	$0.00	$0
Allowance for Misc Items	5%		$18,883.83	$944
Subtotal				$19,828
MASONRY:	Moderate			
Pump Station Building	2235.55	SF	*$197.40*	$441,303
Office Building	0.00	SF	*$131.60*	$0
Surge Building	558.89	SF	*$131.60*	$73,551
Electrical Room	394.53	SF	*$131.60*	$51,921
Subtotal	3188.98			$566,775
METALS:				
Pump Removal Hatches	73.33	SF	*$109.91*	$8,060
Allowance for Misc Items	10%		$8,059.73	$806
Subtotal				$8,866
THERMAL & MOISTURE PROTECTION:				
Wet Well Liner	0.00	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	1.00	EA	*$167,150.63*	$167,151
Active Pump # 2	1.00	EA	*$167,150.63*	$167,151
Active Pump # 3	1.00	EA	*$167,150.63*	$167,151

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Active Pump # 4	1.00	EA	*$167,150.63*	$167,151
Active Pump # 5	0.00	EA	*$0.00*	$0
Active Pump # 6	0.00	EA	*$0.00*	$0
Active Pump # 7	0.00	EA	*$0.00*	$0
Active Pump # 8	0.00	EA	*$0.00*	$0
Active Pump # 9	0.00	EA	*$0.00*	$0
Active Pump # 10	0.00	EA	*$0.00*	$0
Standby Pump	1.00	EA	*$167,150.63*	$167,151
Allowance for Misc Items	10%		$835,753.14	$83,575
Subtotal				$919,328
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	10.00	each	*$5,064.93*	$50,649
Control Valve Actuators	5.00	each	*$5,064.93*	$25,325
Level Indicator Transmitters	2.00	each	*$6,764.54*	$13,529
Level Swithces	2.00	each	*$7,120.57*	$14,241
Pressure Indicator Transmitters	6.00	each	*$7,120.57*	$42,723
Pressure Switches	10.00	each	*$7,120.57*	$71,206
Number of Analog I/O Counts	37.20	each	*$208.82*	$7,768
Number of Digital I/O Counts	104.40	each	*$49.46*	$5,163
Number of PLC's	5.00	each	*$10,331.10*	$51,656
I&C Conduit & Wire	2380.06	lf	*$9.53*	$22,679
Allowance for Misc Items	10%		$ 304,939.30	$30,494
Subtotal				$335,433
MECHANICAL:				
Pipe:				
Discharge Lateral Pipe (14-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	35.00	LF	*$53.41*	$1,869
Discharge Header Pipe (30-inch,DIS, Exposed/Buried, Steel, Cement Mortar, Cement Mortar)	42.50	LF	*$744.31*	$31,633
Pump Discharge Pipe (10-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	4.17	LF	*$55.90*	$233
Elbows:				
Discharge Header Pipe (30-inch)	2.00	EA	*$2,831.95*	$5,664
Tees:				
Discharge Header Pipe (30-inch)	5.00	EA	*$5,509.28*	$27,546
Valves:				
Discharge Lateral Isolation Valve (14-inch, BFV)	5.00	EA	*$1,529.44*	$7,647
Pump Control Valve (14-inch, Check Valve)	5.00	EA	*$1,529.44*	$7,647
Discharge Header Isolation Valve (30-inch, BFV)	1.00	EA	*$5,934.12*	$5,934
Air Release Vacuum Valves	15.00	EA	*$3,297.16*	$49,457
Allowance for Misc Items	10%		$137,631.79	$13,763
Subtotal				$151,395
ELECTRICAL:				
MCC's				
Sections	7.00	each	*$6,783.10*	$47,482
AFD's				
Active Pump # 1	450.00	HP	*$132.14*	$59,461
Active Pump # 2	450.00	HP	*$132.14*	$59,461
Active Pump # 3	450.00	HP	*$132.14*	$59,461
Active Pump # 4	450.00	HP	*$132.14*	$59,461
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	450.00	HP	*$132.14*	$59,461
Switchgear				
Units	0.00	each	*$31,202.24*	$0
Electrical Conduit & Wire	340.01	lf	*$9.53*	$3,240
Allowance for Misc Items	5%		$348,025	$17,401
Subtotal				$365,427
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0

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Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$2,372,183
ALLOWANCES:		**User Over-write**		
Finishes Allowance	5%		$3,041,261	$152,063
I & C Allowance	2%		$3,041,261	$60,825
Surge Allowance	5%		$3,041,261	$152,063
Mechanical Allowance	5%		$3,041,261	$152,063
Electrical Allowance	5%		$3,041,261	$152,063
Facility Cost	**2,250**	**Total Pump HP**	**$1,351.67**	**$3,041,261**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	1575.42	CY	***$5.35***	$0
Imported Structural Backfill	86.68	CY	***$40.56***	$0
Native Backfill	828.79	CY	***$6.58***	$0
Haul Excess	746.63	CY	***$6.58***	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
CONCRETE:				
Wet Well:				
Foundation	28.89	CY	***$382.16***	$0
Perimeter Walls	64.42	CY	***$683.50***	$0
Operating Floor:				
Elevated Slab (Including floor over Discharge Header Vault)	36.61	CY	***$1,088.69***	$0
Pump Pads	1.63	CY	***$345.93***	$565
Other Equipment Pads	1.00	CY	***$345.93***	$346
Discharge Pipe Vault:				
Slab on Grade	13.66	CY	***$345.93***	$4,725
Walls	17.16	CY	***$683.50***	$11,727
Allowance for Misc Items	5%		$17,362.33	$868
Subtotal				$18,230
MASONRY:	Moderate			
CMU Building	988.44	SF	***$131.60***	$130,080
Subtotal				$130,080
METALS:				
Checker Plate Over Intake Pipe Gate = (Diameter of Influent Pipe +2') * (2 Feet Wide) (sf)	10.00	SF	***$72.38***	$724
Checker Plate Over Discharge Pipe Header = ((Discharge Pipe Diameter * 2) * ("S" * Total Number of Pumps)	57.98	SF	***$72.38***	$4,197
Ladder	15.55	VLF	***$99.36***	$1,545
Allowance for Misc Items	10%		$6,464.96	$646
Subtotal				$7,111
EQUIPMENT:				
Size of Sluice Gate (per side in inches)	36.00	Inches		
Sluice Gate	1.00	EA	***$6,330.27***	$6,330
Pumps:				
Active Pump # 1	124.39	HP	***$790.52***	$98,332
Active Pump # 2	124.39	HP	***$790.52***	$98,332
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0
Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	124.39	HP	***$790.52***	$98,332
AFD's				
Active Pump # 1	124.39	HP	***$156.14***	$19,422
Active Pump # 2	124.39	HP	***$156.14***	$19,422
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0

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Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	124.39	HP	***$156.14***	$19,422
Allowance for Misc Items	10%		$353,259.39	$35,326
Subtotal				$394,916
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$550,338
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$1,100,676	$22,014
I & C Allowance	8.0%		$1,100,676	$88,054
Mechanical Allowance	25.0%		$1,100,676	$275,169
Electrical Allowance	15.0%		$1,100,676	$165,101
Facility Cost	**373**	**Total Pump HP**	**$2,949.56**	**$1,100,676**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	89.00	CY	*$5.35*	$476
Imported Structural Backfill	45.41	CY	*$40.56*	$1,842
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	89.00	CY	*$6.58*	$586
Allowance for Misc Items	5%		$2,903.46	$145
Subtotal				$3,049
CONCRETE:				
Slab on Grade	31.46	CY	*$345.93*	$10,882
Containment Walls	6.37	CY	*$683.50*	$4,356
Bulk Tank Pads	29.50	CY	*$345.93*	$10,204
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	2.00	CY	*$345.93*	$692
Corridor				
Slab on Grade	7.50	CY	*$345.93*	$2,594
Electrical Room				
Slab on Grade	3.41	CY	*$345.93*	$1,179
Allowance for Misc Items	5%		$29,906.78	$1,495
Subtotal				$31,402
MASONRY:	Moderate			
CMU Building	1226.00	SF	*$131.60*	$161,343
Subtotal				$161,343
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$16,973.34*	$33,947
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	3.00	EA	*$6,737.98*	$20,214
Allowance for Misc Items	10%		$54,160.63	$5,416
Subtotal				$59,577
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	3.00	each	*$549.53*	$1,649
Magmeter	2.00	each	*$549.53*	$1,099
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	9.00	each	*$208.82*	$1,879
Number of Digital I/O Counts	26.00	each	*$49.46*	$1,286
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	297.00	lf	*$9.53*	$2,830
Allowance for Misc Items	10%		$34,460.81	$3,446
Subtotal				$37,907
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	61.00	lf	*$10.36*	$632
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	61.00	lf	*$11.98*	$731
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	12.00	each	*$7.95*	$95
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	12.00	each	*$63.16*	$758
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	3.00	each	*$8.27*	$25
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	3.00	each	*$109.33*	$328
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Allowance for Misc Items	10%		$3,184.53	$318
Subtotal				$3,503
ELECTRICAL:				
# MCC Sections	6.00	#	*$6,783.10*	$40,699
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	243.00	lf	*$9.53*	$2,315
Allowance for Misc Items	10%		$43,014.07	$4,301
Subtotal				$47,315
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$353,071
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$392,301	$7,846
I & C Allowance	2%		$392,301	$7,846
Mechanical Allowance	4%		$392,301	$15,692
Electrical Allowance	2%		$392,301	$7,846
Facility Cost	**1,226**	**Building SF**	**$319.98**	**$392,301**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	76.22	CY	*$5.35*	$408
Imported Structural Backfill	38.89	CY	*$40.56*	$1,577
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	76.22	CY	*$6.58*	$502
Allowance for Misc Items	5%		$2,486.65	$124
Subtotal				$2,611
CONCRETE:				
Slab on Grade	28.07	CY	*$345.93*	$9,711
Containment Walls	4.73	CY	*$683.50*	$3,232
Bulk Tank Pads	25.13	CY	*$345.93*	$8,694
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	6.94	CY	*$345.93*	$2,402
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$24,500.49	$1,225
Subtotal				$25,726
MASONRY:	Moderate			
CMU Building	1050.00	SF	*$131.60*	$138,181
Subtotal				$138,181
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$17,367.52*	$34,735
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$48,211.01	$4,821
Subtotal				$53,032
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	6.00	each	*$208.82*	$1,253
Number of Digital I/O Counts	20.00	each	*$49.46*	$989
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	225.00	lf	*$9.53*	$2,144
Allowance for Misc Items	10%		$31,752.48	$3,175
Subtotal				$34,928
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	59.00	lf	*$10.36*	$611
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	59.00	lf	*$11.98*	$707
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,557.19	$256
Subtotal				$2,813
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$266,266
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$295,851	$5,917
I & C Allowance	2%		$295,851	$5,917
Mechanical Allowance	4%		$295,851	$11,834
Electrical Allowance	2%		$295,851	$5,917
Facility Cost	**1,050**	**Building SF**	**$281.76**	**$295,851**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	51.83	CY	*$5.35*	$277
Imported Structural Backfill	26.44	CY	*$40.56*	$1,072
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	51.83	CY	*$6.58*	$341
Allowance for Misc Items	5%		$1,690.92	$85
Subtotal				$1,775
CONCRETE:				
Slab on Grade	20.15	CY	*$345.93*	$6,969
Containment Walls	3.83	CY	*$683.50*	$2,617
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	4.72	CY	*$345.93*	$1,634
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$11,680.12	$584
Subtotal				$12,264
MASONRY:	Moderate			
CMU Building	714.00	SF	*$131.60*	$93,963
Subtotal				$93,963
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	2.20	each	*$1,099.05*	$2,422
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	7.00	each	*$208.82*	$1,462
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	122.47	lf	*$9.53*	$1,167
Allowance for Misc Items	10%		$29,861.98	$2,986
Subtotal				$32,848
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	51.00	lf	*$10.36*	$528
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	51.00	lf	*$11.98*	$611
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,378.44	$238
Subtotal				$2,616
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$167,266
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$185,851	$3,717
I & C Allowance	2%		$185,851	$3,717
Mechanical Allowance	4%		$185,851	$7,434
Electrical Allowance	2%		$185,851	$3,717
Facility Cost	**714**	**Building SF**	**$260.30**	**$185,851**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	51.83	CY	*$5.35*	$277
Imported Structural Backfill	26.44	CY	*$40.56*	$1,072
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	51.83	CY	*$6.58*	$341
Allowance for Misc Items	5%		$1,690.92	$85
Subtotal				$1,775
CONCRETE:				
Slab on Grade	20.15	CY	*$345.93*	$6,969
Containment Walls	3.83	CY	*$683.50*	$2,617
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	4.72	CY	*$345.93*	$1,634
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$11,680.12	$584
Subtotal				$12,264
MASONRY:	Moderate			
CMU Building	714.00	SF	*$131.60*	$93,963
Subtotal				$93,963
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	1.37	each	*$1,099.05*	$1,501
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	6.00	each	*$208.82*	$1,253
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	108.22	lf	*$9.53*	$1,031
Allowance for Misc Items	10%		$28,596.74	$2,860
Subtotal				$31,456
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	51.00	lf	*$10.36*	$528
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	51.00	lf	*$11.98*	$611
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,378.44	$238
Subtotal				$2,616
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$165,874
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$184,305	$3,686
I & C Allowance	2%		$184,305	$3,686
Mechanical Allowance	4%		$184,305	$7,372
Electrical Allowance	2%		$184,305	$3,686
Facility Cost	**714**	**Building SF**	**$258.13**	**$184,305**

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Description	Quantity	Unit	$/Unit	Total Cost
O&M BUILDING	6000.00	SF	$474.70	$2,848,226
Subtotal				$2,848,226
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$2,848,226
ALLOWANCES:				
Finishes Allowance	0.0%		$2,848,226	$0
I & C Allowance	0%		$2,848,226	$0
Mechanical Allowance	0%		$2,848,226	$0
Electrical Allowance	0%		$2,848,226	$0
Facility Cost	**6,000**	**SF**	**$474.70**	**$2,848,226**

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Alternative 1 - Deep and Shallow Aquifer

Shallow Well Capital Costs						
Shallow Well	Shallow Well Capacity, mgd	Land	Wells and Pumphouses	Sitework Electric Utility	Shallow well Treatment Facility	Interconnecting Piping
Vernon 1	0.75	$160,000	$300,000	$750,000		$ 907,200
Vernon 2	0.75	$160,000	$300,000	$644,000		$ 132,000
Vernon 3	0.75	$160,000	$300,000			$ 662,400
Vernon 4	0.75	$160,000	$300,000			$ 1,152,000
Vernon 5	0.75	$160,000	$300,000			$ 2,112,000
Vernon 6	0.75	$160,000	$300,000			
Vernon 7	0.75	$160,000	$300,000			
Lather 1	0.75	$160,000	$300,000			
Lather 2	0.75	$160,000	$300,000			
Lather 3	0.75	$160,000	$300,000			
Lather 4	0.75	$160,000	$300,000			
Lather 5	0	$160,000	$300,000			
Vernon 8	0.75	$160,000	$300,000			
Vernon 9	0.75	$160,000	$300,000			
Wells 11-13 firm	1.2	$2,240,000	$4,200,000	$1,394,000	$29,864,000	$4,965,600
					Includes $2 million for Land	
	10.95					
	Total Wellfield	**$12,799,600**				

Alternative 1 Finished Water pipeline

Pipelines		**$16,884,000**
10% allowance for pipeline valves & appurtenances		**$1,689,000**
Pipeline Construction Cost		**$18,573,000**
Pipeline Construction Cost		**$18,573,000**
3% markup for Bonds & Insurance	$558,000	
5% markup for Mob/Demob	$929,000	
8% markup for Contractors Overhead	$1,561,000	
4% markup for Contractors profit	$843,000	
25% Contingency	$5,616,000	
Subtotal Markups and Contingency		**$9,507,000**
Total Project Construction Costs		**$28,080,000**
8% allowance for pipeline engineering and design	2,247,000	
12% allowance for permitting, legal and administration	3,370,000	
8% allowance for pipeline engr services during construction	2,247,000	
Subtotal Other Project Costs		**$7,864,000**
GRAND TOTAL PROJECT COST		**$35,944,000**

Alternative 1 - Deep and Shallow Aquifer Finished Water Pipeline

Water Forcemain		
Segment	Miles	Diameter
A	6	24
B	5	24

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$1,462,856	Co. Rd I, wetland
2	$1,976,832	In Co HWY H
3	$1,520,640	In Oakdale
4	$1,556,755	In Oakdale, cross Les Paul
5	$1,535,086	In Sunset Drive, cross SW Ave
6	$1,823,247	In NW Ave, cross College
7	$2,682,613	NW Ave to Main, at Fox River
8	$7,234	Main Street, businesses
9	$2,995,129	In Co. Road Y, wetland, cross 164
10	$1,322,957	City streets, Open country to Hillcrest
subtotal	**$16,883,349**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	213	213
Low urban	1.00	288	288
Medium urban	1.19	343	343
High urban	1.37	395	395
Groundwater	**1.30**	**374**	**374**
Forest	1.15	331	331
Gravel roads	0.85	245	245
Creek crossing	2.00	576	576
HWY crossing	4.00	1152	1152

miles	0.13	0.25	0.5
feet	660	1320	2640
	4620	3960	2640

Alternative 1 Distribution System Costs			
Distribution Improvements		**$**	**14,414,539**
10% allowance for pipeline valves & appurtenances		**$**	**1,441,454**
Pipeline Construction Cost			**$15,855,993**
3% markup for Bonds & Insurance	$476,000		
5% markup for Mob/Demob	$793,000		
8% markup for Contractors Overhead	$1,332,000		
4% markup for Contractors profit	$720,000		
25% Contingency	$4,795,000		
Subtotal Markups and Contingency			**$8,116,000**
Total Project Construction Costs			**$23,971,993**
5% allowance for pipeline engineering and design	1,439,000		
12% allowance for permitting, legal and administration	1,199,000		
8% allowance for pipeline engr services during construction	1,918,000		
Subtotal Other Project Costs			**$4,556,000**
GRAND TOTAL PROJECT COST			**$28,528,000**

Alternative 1 - Deep and Shallow Distribution System Improvements

Water Forcemain		
Segment	Miles	Diameter
A	2.5	20
B	2.1	16
C	5.1	16
Unit cost	$/dia-in	12

Blending Pipes

Mile	Cost	Comments
1 mi of 20"	$1,736,064	Assume High Urban
1 mi of 16"	$1,388,851	Assume High Urban
	$4,414,811	20" Distribution
	$2,916,588	16" Distribution
	$7,083,141	16" Blending
subtotal	**$14,414,539**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	178	142
Low urban	1.00	240	192
Medium urban	1.19	286	228
High urban	1.37	329	263
Groundwater	**1.30**	**312**	**250**
Forest	1.15	276	221
Gravel roads	0.85	204	163
Creek crossing	2.00	480	384
HWY crossing	4.00	960	768

miles	0.13	0.25	0.5
feet	660	1320	2640

Alternative 1&2 Wastewater Forcemain

Pipelines		**$3,029,000**
10% allowance for pipeline valves & appurtenances		**$303,000**
Pipeline Construction Cost		**$3,332,000**
Pipeline Construction Cost		**$3,332,000**
3% markup for Bonds & Insurance	$100,000	
5% markup for Mob/Demob	$167,000	
8% markup for Contractors Overhead	$280,000	
4% markup for Contractors profit	$152,000	
25% Contingency	$1,008,000	
Subtotal Markups and Contingency		**$1,707,000**
Total Project Construction Costs		**$5,039,000**
5% allowance for pipeline engineering and design	303,000	
12% allowance for permitting, legal and administration	252,000	
08% allowance for pipeline engr services during construction	404,000	
Subtotal Other Project Costs		**$959,000**
GRAND TOTAL PROJECT COST		**$5,998,000**

Alternative 1 & 2 - Wastewater Force Main

Wastewater Forcemain		
Segment	Miles	Diameter
A	2	6
B	3	6

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$416,275	In Sentry Dr., Cross 2 access roads, Chapman Dr, Spring city Dr, W. Sunset Dr
2	$452,390	In Sunset Dr, cross access road, dozens of residential drive ways, Oakdale Dr, Wisteria, School Dr. Burr Oak, HWY 59
3	$452,390	Cross Foxwood Trail, River Plain, Dale, Mary Ann, Red Oak
4	$833,026	In HWY H, cross HWY, Red clover, 0.5 mi wetland
5	$874,368	In Co Rd I, wetland
subtotal	**$3,028,450**	

Alignment Category	Pipeline Construction Difficulty Factors (source: C	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	53	53
Low urban	1.00	72	72
Medium urban	1.19	86	86
High urban	1.37	99	99
Groundwater	1.30	94	94
Forest	1.15	83	83
Gravel roads	0.85	61	61
Creek crossing	2.00	144	144
HWY crossing	4.00	288	288

miles	0.13	0.25	0.5	0.05
feet	660	1320	2640	264

	O&M Cost Alternative 1 - Deep and Shallow wells						
Source of Supply		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	**Total**
	Deep Well pumping/maintenance	$/1000 gal	1,387,000	$ 0.350	$ 485,450	$ 485,450	
	Shallow Well Pumping/Maintenance	$/1000 gal	2,007,500	$ 0.140	$ 281,050	$ 281,050	
	Total Supply						$ 766,500
Treatment/Pumping		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	Deep Wells 6,7,8					$ 646,449	
	Shallow Wells					$ 2,226,000	
	Residuals		144175	$ 4	$ 576,700	$ 576,700	
	Total Treatment/Pumping						$ 3,449,149
Home Softening		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	Salt/Equipment/Replacment	1				$ 2,863,894	
							$ 2,863,894
Transmission		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	O&M	$/lf/yr	137,280	$ 0.52	$ 71,386	$ 71,386	
	Total Transmission						$ 71,386
Alternative Total O&M ($/yr.)							**$ 7,200,000**
PRESENT WORTH (6%, 20 yrs)							**$ 83,000,000**
PRESENT WORTH (6%, 50 yrs)							**$ 113,000,000**

CH2M HILL Parametric Cost Estimating System (CPES)

FACILITIES LIFE CYCLE COST ANALYSIS

File Version: 1/5/2010

Import File: C:\Documents and Settings\jcurl\Desktop\WaukeshaWI\Waukesha 3.0 mgd NF GW WTP.xls

Browse...

Click for CPES QA/QC

Project Name:	Waukesha Nanofiltration Groundwater WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	3.0 mgd Nanofiltration WTP
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months)	24
Mid-Point of Construction:	Jan/2012

Life Cycle Analysis:

i =	6.00%
n =	25
Annual Inflation %:	4.50%

To Global Life Cycle Data Sheet

To Annual O & M Cost Summary Sheet

☑ This Report is for INTERNAL Distribution

☐ This Report is for EXTERNAL Distribution

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Construction Cost	Annual O&M Cost (Escalated)	Life Cycle Cost (NPV)
	Yes	BWRO: NanoFilt	$9,139,656	$433,740	$14,684,307
	Yes	Air Stripper: Degas	$1,465,532	$42,217	$2,005,200
	Yes	In-Plant PS: FWPS	$1,918,009	$76,024	$2,889,840
	Yes	Liquid Chemical: NaOH	$535,818	$154,723	$2,513,689
		Additional Project Costs:			
		Biosolids Disposal	$0	$0	$0
		Standard Items	$4,218,067	$115,121	$5,689,695
		User Defined Items	$0	$0	$0
		Plant O & M Labor		$173,963	$2,223,822
TOTAL - Life Cycle Analysis			$17,277,082	$995,788	$30,006,553

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Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	271	50%	8,760	$ 0.06	$ 49,567

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	7,223	2.00	8,760	$ 0.06	$ 7,087

Specialty Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Citric Acid	100%	50%	4	$ 2,500.00	$ 4,983
Hydrochloric Acid	100%	50%	-	$ 360.00	$ -
Scale Inhibitor	100%	50%	10	$ 4,400.00	$ 22,159
Sodium Hydroxide	100%	50%	2	$ 825.32	$ 1,027
Sodium Tripolyphosphate	100%	50%	-	$ 3,100.00	$ -
Sodium EDTA	100%	50%	2	$ 1,260.00	$ 1,256
Sulfuric Acid	100%	50%	81	$ 138.09	$ 5,564
Trisodium Phosphate	100%	50%	-	$ 2,700.00	$ -
Other Liquid CIP Chemical 1	100%	50%	-	$ -	$ -
Other Liquid CIP Chemical 2	100%	50%	-	$ -	$ -
Other Dry CIP Chemical 1	100%	50%	-	$ -	$ -
Other Pretreatment Chemical 1	100%	50%	-	$ -	$ -
Other Pretreatment Chemical 2	100%	50%	-	$ -	$ -
Total Specialty Chemicals					$ 34,988

Specialty Items:			Number per Relacement	Cartridge Filter Cost / Each	Cost
Process Cartridge Filter Replacements			1,236	$ 11.00	$ 13,596
CIP Cartridge Filter Replacements			1,408	$ 11.00	$ 15,488
Membrane Elements			378		$ 30,886
Input Membrane Replacement Frequency (yrs)	5	Typically 3 to 5 years			
Input Membrane Module Cost	*Membrane Size = 8 inches*	*Membrane Cost:* $ 513.35			
Total Specialty Items					$ 59,970

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 67,831
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 219,443	10.0%	$ 21,944

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$	241,388
Contingency					10%	$	24,139
Total Annual O&M Cost						$	265,526

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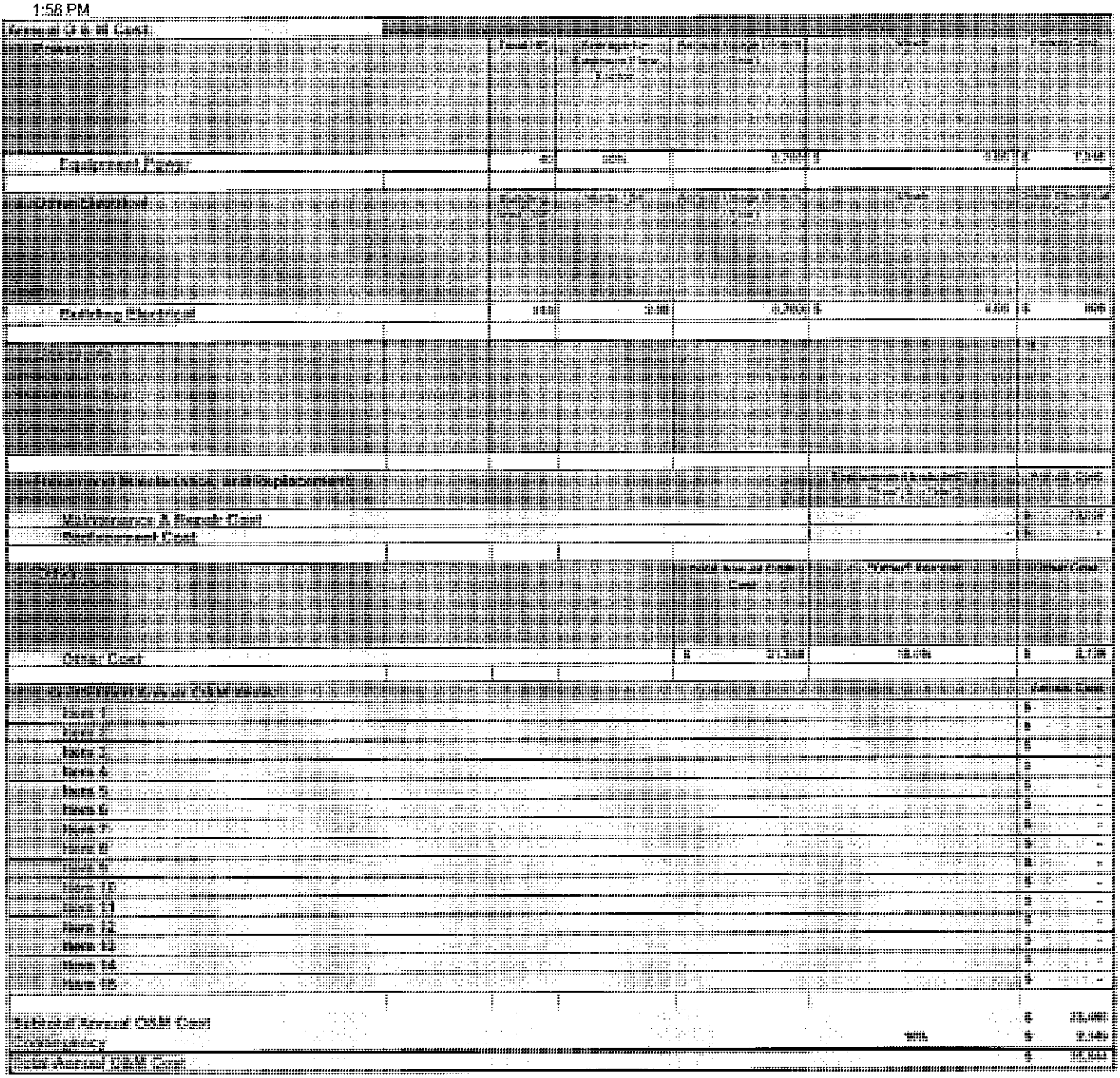

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Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	140	50%	8,760	$ 0.06	$ 25,607
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	655	2.00	8,760	$ 0.06	$ 643
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 12,213
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 38,462.57	10.0%	$ 3,846
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 42,309
Contingency				10%	$ 4,231
Total Annual O&M Cost					$ 46,540

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Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	822	2.00	8,760	$ 0.06	$ 806
Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	183	$ 825.32	$ 75,371
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 75,371
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 1,736
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 78,279	10.0%	$ 7,828
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 86,107
Contingency				10%	$ 8,611
Total Annual O&M Cost					$ 94,718

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C H2M HILL P arametric Cost E stimating S ystem (CPES)

FACILITIES LIFE CYCLE COST ANALYSIS

File Version: 1/5/2010

Import File: \\Gecko\wbg\Curl\WaukeshaWI\Treatment plant Surface water alt 1.xls Brows

Click for CPES QA/QC

Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months)	24
Mid-Point of Construction:	Jan/2012

Life Cycle Analysis:
i = 6.00%
n = 25
Annual Inflation %: 4.50%

To Global Life Cycle Data Sheet

To Annual O & M Cost Summary Sheet

This Report is for INTERNAL Distribution

This Report is for EXTERNAL Distribution

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Construction Cost	Annual O&M Cost (Escalated)	Life Cycle Cost (NPV)
	Yes	Inline Rapid Mix: RMX	$1,124,218	$10,054	$1,252,729
	Yes	Flocculation: FLOC	$2,758,162	$20,477	$3,019,917
	Yes	Lamella Clarifier: LAM	$4,276,418	$99,959	$5,554,216
	Yes	Filters: FILT	$9,077,505	$74,615	$10,031,332
	Yes	Surge Basin-Decanter: BWW	$2,773,337	$38,555	$3,266,193
	No	UV Disinfection: UVD	$0	$0	$0
	Yes	Concrete Clearwell: FWT	$2,371,500	$1,111	$2,385,692
	No	Steel Clearwell: FWT	$0	$0	$0
	No	In-Plant PS: FWPS	$0	$0	$0
	Yes	Vertical Turbine PS: FWPS	$5,495,750	$738,581	$14,937,283
	Yes	Filter BW PS: BWSPS	$1,988,991	$44,586	$2,558,947
	Yes	U.D. Facility: GEN	$0	$0	$0
	Yes	Liquid Chemical: FeCl3	$708,914	$220,946	$3,533,337
	Yes	Liquid Chemical: NaOCl	$534,622	$98,204	$1,789,986
	Yes	Liquid Chemical: FLUOR	$335,846	$8,675	$446,737
	Yes	Liquid Chemical: POLYPHOS	$333,051	$39,577	$838,978
	Yes	O&M Building: OMB	$5,146,925	$11,636	$5,295,664
		Additional Project Costs:			
		Biosolids Disposal	$0	$0	$0
		Standard Items	$13,413,828	$384,177	$18,324,898
		User Defined Items	$0	$0	$0
		Plant O & M Labor		$434,906	$5,559,555
TOTAL - Life Cycle Analysis			$50,339,067	$2,226,059	$78,795,464
Construction Cost per GPD (based on Maximum Daily Flow Rate)			$4.19 / GPD		
Non-Construction Cost					
Capital Cost per GPD (based on Maximum Daily Flow Rate)			$4.19 / GPD		(Note: "Capital Cost" equals Construction Cost plus Non-Construction Cost)
Annual O & M Cost per 1,000 Gallons (based on Average Annual Daily Flow Rate)				$ 1.016 / Thousand Gallons	

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Rapid Mixing (Inline)

To Summary Sheet

Construction Cost:					$1,124,217
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	6	50%	8,760	$ 0.06	$ 1,097
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	922	2.00	8,760	$ 0.06	$ 905
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes"; 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 3,084
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 5,086	10.0%	$ 509
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 5,595
Contingency				10%	$ 559
Total Annual O&M Cost					$ 6,154

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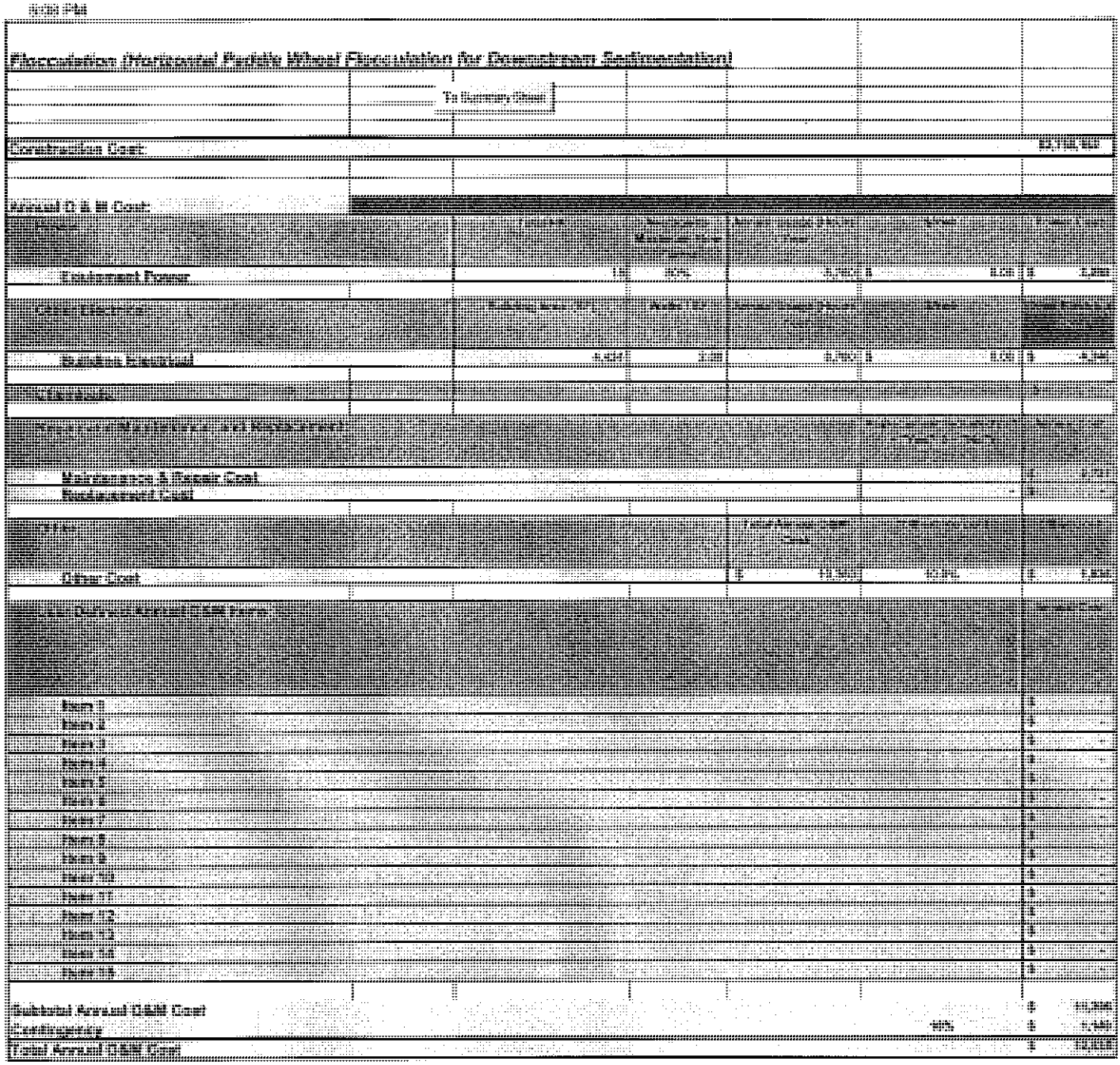

Lamella Clarifier

To Summary Sheet

Construction Cost:					$4,276,417
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	4	50%	8,760	$ 0.06	$ 732
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	4,804	2.00	8,760	$ 0.06	$ 4,713
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 45,127
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 50,572	10.0%	$ 5,057
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 55,629
Contingency				10%	$ 5,563
Total Annual O&M Cost					$ 61,192

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Filters

To Summary Sheet

Construction Cost:	$9,077,505

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	5	50%	8,760	$ 0.06	$ 915

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	7,600	2.00	8,760	$ 0.06	$ 7,457

Chemicals:	Annual Usage (tons)	Annual Facility Usage (% of year)	$/ton	Chemical Cost
GAC	-	100%	$ 2,400.00	$ -
Total Chemical Cost				$ -

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 29,379
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 37,750	10.0%	$ 3,775

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

Subtotal Annual O&M Cost		$ 41,525
Contingency	10%	$ 4,153
Total Annual O&M Cost		$ 45,678

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Large System Combination Wastewater Surge Basin and Floating Tube Decanter Clarification (>= 5 MGD)

To Summary Sheet

Construction Cost:					$2,773,337
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	43	50%	8,760	$ 0.06	$ 7,865
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	81	2.00	8,760	$ 0.06	$ 79
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 11,562
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 19,506	10.0%	$ 1,951
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 21,457
Contingency				10%	$ 2,146
Total Annual O&M Cost					$ 23,602

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Concrete Tank

To Summary Sheet

Construction Cost:					$2,371,500
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	-	2.00	8,760	$ 0.06	$ -
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 562
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 562	10.0%	$ 56
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 618
Contingency				10%	$ 62
Total Annual O&M Cost					$ 680

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In-Plant Pump Station

To Summary Sheet

Construction Cost:					**$6,620,228**
Annual O & M Cost:					
Power:	**Total HP**	**Average-to-Maximum Flow Factor**	**Annual Usage (Hours / Year)**	**$/kwh**	**Power Cost**
Equipment Power	2,666	50%	8,760	$ 0.06	$ 487,626
Other Electrical:	**Building Area (SF)**	**Watts / SF**	**Annual Usage (Hours / Year)**	**$/kwh**	**Other Electrical Cost**
Building Electrical	1,022	2.00	8,760	$ 0.06	$ 1,003
Chemicals:					$ -
Repair and Maintenance, and Replacement:				**Replacement Included? (1 = "Yes", 0 = "No")**	**Annual Cost**
Maintenance & Repair Cost					$ 74,141
Replacement Cost				-	$ -
Other:			**Total Annual O&M Cost**	**"Other" Percent**	**Other Cost**
Other Cost			$ 562,769.52	10.0%	$ 56,277
User Defined Annual O&M Items:					**Annual Cost**
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 619,046
Contingency				10%	$ 61,905
Total Annual O&M Cost					$ 680,951

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Vertical Turbine Pump Station

To Summary Sheet

Construction Cost:	$5,495,750

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	1,800	50%	8,760	$ 0.06	$ 329,230

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	3,189	2.00	8,760	$ 0.06	$ 3,129

Chemicals:	
	$ -

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 41,314
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 373,672	10.0%	$ 37,367

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

Subtotal Annual O&M Cost		$ 411,039
Contingency	10%	$ 41,104
Total Annual O&M Cost		$ 452,143

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Granular Media Filter Backwash Supply Pump Station

To Summary Sheet

Construction Cost:					$1,988,991
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	21	50%	8,760	$ 0.06	$ 3,841
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	988	2.00	8,760	$ 0.06	$ 969
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 17,747
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 22,557	10.0%	$ 2,256
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 24,813
Contingency				10%	$ 2,481
Total Annual O&M Cost					$ 27,294

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost:	**$708,913**

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	3	50%	8,760	$ 0.06	$ 549

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,226	2.00	8,760	$ 0.06	$ 1,203

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	274	$ 782.93	$ 107,249
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					**$ 107,249**

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 2,783
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 111,783	10.0%	$ 11,178

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$	122,962
Contingency	10%	$	12,296
Total Annual O&M Cost		$	135,258

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $534,621

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,050	2.00	8,760	$ 0.06	$ 1,030

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	55	$ 1,672.13	$ 45,811
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 45,811

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 2,477
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 49,684	10.0%	$ 4,968

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$ 54,653
Contingency					10%	$ 5,465
Total Annual O&M Cost						$ 60,118

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $335,845

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	714	2.00	8,760	$ 0.06	$ 701

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	15	$ 360.00	$ 2,630
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 826.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 2,630

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 692
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 4,389	10.0%	$ 439

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$	4,828
Contingency	10%	$	483
Total Annual O&M Cost		$	5,310

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $333,051

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	714	2.00	8,760	$ 0.06	$ 701

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	18	$ 2,000.00	$ 18,265
Total Chemical Cost					$ 18,265

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 692
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 20,023	10.0%	$ 2,002

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$	22,026
Contingency					10%	$	2,203
Total Annual O&M Cost						$	24,228

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O & M Building

To Summary Sheet

Construction Cost:					$5,146,924
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	6,000	2.00	8,760	$ 0.06	$ 5,887
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ -
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 5,887	10.0%	$ 589
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 6,475
Contingency				10%	$ 648
Total Annual O&M Cost					$ 7,123

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City of Waukesha Home Water Softening Costs

Total number of residential meters (2010)	17,104
Percent of meters that have water softening units	80%
Salt Cost ($/year) [a]	$ 1,551,675
Lbs salt per year	7,388,928
Annual Maintenance & electricity [b]	$ 273,664
Cost for repair/replacement of equipment [c]	$ 1,038,555
Total Softening Cost ($/yr)	**$ 2,863,894**

a Assumes 45 lb of salt per month per customer, $0.21/lb
b Assumes $20 per customer per year
c Asumes 10 year replacement, starting in 2020, $1,000/unit, A/F 0.0759

Alternative 2:
Shallow and Fox River Alluvium

Alternative 2 - Shallow and Fox River Alluvium		
Shallow Aquifer Wells		**$17,815,000**
Shallow Aquifer Water Treatment Plant		**$37,355,000**
Transmission Main to Waukesha		**$27,855,000**
Distribution Improvements		**$ 8,465,000**
Wastewater Force Main		**$3,332,000**
Subtotal Construction Cost		**$94,822,000**
3% markup for Bonds & Insurance	$2,845,000	
5% markup for Mob/Demob	$4,742,000	
8% markup for Contractors Overhead	$8,193,000	
4% markup for Contractors profit	$4,097,000	
25% Contingency	$28,675,000	
Subtotal Markups and Contingency		**$48,552,000**
Total Project Construction Costs		**$143,374,000**
8% allowance for engineering and design	11,470,000	
12% allowance for permiting, legal and admin.	17,205,000	
8% allowance for engr services during construction	11,470,000	
Subtotal Other Project Costs		**$40,145,000**
TOTAL PROJECT CAPTIAL COST		**$184,000,000**

Alternative 2 - Shallow Aquifer and Fox River Alluvium

Fox River Alluvium Well Field Capital Costs					
Well	Capacity mgd	Land Cost	Well Cost	Shallow Electric Utility	Interconnecting Piping
		$1,000,000	$2,800,000	$495,000	$715,200

TOTAL **$5,010,200**

Alternative 2 - Shallow Aquifer and Fox River Alluvium

Vernon Marsh Shallow Well Capital Costs						Shallow Aquifer Surface Water Treatment Plant		
Shallow Well	Shallow Well Capacity (mgd)	Land	Wells and Pumphouses	Sitework Electric Utility	Interconnecting Piping	Facility	FW Trans Main	Sludge Forcemain
Vernon 1,2	1.5	$300,000	$600,000	$750,000	$ 912,000			
Vernon 3,4	1.5	$300,000	$600,000	$ [illegible]	$ 132,000			
Vernon 5,6	1.5	$300,000	$600,000		$ 652,400			
Vernon 7,8	2	$400,000	$800,000		$ 1,152,000			
Vernon 9,10	2	$400,000	$800,000		$ 2,112,000			
Vernon 11,12	2	$400,000	$800,000					
Vernon 13,14	2	$400,000	$800,000					
Vernon 15,16	2							
Firm	14							
		$2,240,000	$4,200,000	$1,394,000	$4,970,400	$37,355,000	$27,855,000	$3,332,000

TOTAL **$12,804,400**

CH2M HILL Parametric Cost Estimating System (CPES)

FACILITIES DESIGN & CONSTRUCTION COST MODULE

File Version: 1/5/2010

Click for CPES QA/QC | To Concrete Wall Thickness Help | To Cost Summary Matrix | To Unit Cost Database

Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months):	24
Mid-Point of Construction:	Jan/2012

Roundup to the nearest: $1,000

☐ This Report is for INTERNAL Distributio

☐ This Report is for EXTERNAL Distributio

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Cost
	Yes	Inline Rapid Mix: RMX	$700,000
	Yes	Flocculation: FLOC	$1,814,000
	Yes	Lamella Clarifier: LAM	$2,940,000
	Yes	Filters: FILT	$6,591,000
	Yes	Surge Basin-Decanter: BWW	$1,535,000
	Yes	UV Disinfection: UVD	$1,342,000
	Yes	Concrete Clearwell: FWT	$1,313,000
	No	Steel Clearwell: FWT	$0
	No	In-Plant PS: FWPS	$0
	Yes	Vertical Turbine PS: FWPS	$4,233,000
	Yes	Filter BW PS: BWSPS	$1,101,000
	Yes	U.D. Facility: GEN	$0
	Yes	Liquid Chemical: FeCl3	$396,000
	Yes	Liquid Chemical: NaOCl	$296,000
	Yes	Liquid Chemical: FLUOR	$189,000
	Yes	Liquid Chemical: POLYPHOS	$207,000
	Yes	O&M Building: OMB	$4,748,000
SUBTOTAL - PROJECT COST			$27,405,000
ADDITIONAL PROJECT COSTS:			
Demolition		0%	$0
Overall Sitework		10%	$2,741,000
Plant Computer System		5%	$1,371,000
Yard Electrical		7%	$2,001,000
Yard Piping		14%	$3,837,000
UD #1 Default Description		0%	$0
UD #2 Default Description		0%	$0
UD #3 Default Description		0%	$0
SUBTOTAL with Additional Project Costs			$37,355,000

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Description	Quantity	Unit	$/Unit	Total Cost
O&M BUILDING	10000.00	SF	$474.70	$4,747,044
Subtotal				$4,747,044
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$4,747,044
ALLOWANCES:				
Finishes Allowance	0.0%		$4,747,044	$0
I & C Allowance	0%		$4,747,044	$0
Mechanical Allowance	0%		$4,747,044	$0
Electrical Allowance	0%		$4,747,044	$0
Facility Cost	**10,000**	**SF**	**$474.70**	**$4,747,044**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	60.98	CY	*$5.35*	$326
Imported Structural Backfill	31.11	CY	*$40.56*	$1,262
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	60.98	CY	*$6.58*	$401
Allowance for Misc Items	5%		$1,989.32	$99
Subtotal				$2,089
CONCRETE:				
Slab on Grade	23.12	CY	*$345.93*	$7,997
Containment Walls	4.17	CY	*$683.50*	$2,847
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	5.56	CY	*$345.93*	$1,922
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$13,227.45	$661
Subtotal				$13,889
MASONRY:	Moderate			
CMU Building	840.00	SF	*$131.60*	$110,545
Subtotal				$110,545
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	2.28	each	*$1,099.05*	$2,502
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	7.00	each	*$208.82*	$1,462
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	145.54	lf	*$9.53*	$1,387
Allowance for Misc Items	10%		$30,162.07	$3,016
Subtotal				$33,178
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	54.00	lf	*$10.36*	$559
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	54.00	lf	*$11.98*	$647
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,445.47	$245
Subtotal				$2,690
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$186,190
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$206,878	$4,138
I & C Allowance	2%		$206,878	$4,138
Mechanical Allowance	4%		$206,878	$8,275
Electrical Allowance	2%		$206,878	$4,138
Facility Cost	**840**	**Building SF**	**$246.28**	**$206,878**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	51.83	CY	*$5.35*	$277
Imported Structural Backfill	26.44	CY	*$40.56*	$1,072
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	51.83	CY	*$6.58*	$341
Allowance for Misc Items	5%		$1,690.92	$85
Subtotal				$1,775
CONCRETE:				
Slab on Grade	20.15	CY	*$345.93*	$6,969
Containment Walls	3.83	CY	*$683.50*	$2,617
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	4.72	CY	*$345.93*	$1,634
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$11,680.12	$584
Subtotal				$12,264
MASONRY:	Moderate			
CMU Building	714.00	SF	*$131.60*	$93,963
Subtotal				$93,963
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	3.67	each	*$1,099.05*	$4,037
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	9.00	each	*$208.82*	$1,879
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	147.44	lf	*$9.53*	$1,405
Allowance for Misc Items	10%		$32,132.39	$3,213
Subtotal				$35,346
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	51.00	lf	*$10.36*	$528
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	51.00	lf	*$11.98*	$611
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,378.44	$238
Subtotal				$2,616
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$169,764
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$188,626	$3,773
I & C Allowance	2%		$188,626	$3,773
Mechanical Allowance	4%		$188,626	$7,545
Electrical Allowance	2%		$188,626	$3,773
Facility Cost	**714**	**Building SF**	**$264.18**	**$188,626**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	76.22	CY	*$5.35*	$408
Imported Structural Backfill	38.89	CY	*$40.56*	$1,577
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	76.22	CY	*$6.58*	$502
Allowance for Misc Items	5%		$2,486.65	$124
Subtotal				$2,611
CONCRETE:				
Slab on Grade	28.07	CY	*$345.93*	$9,711
Containment Walls	4.73	CY	*$683.50*	$3,232
Bulk Tank Pads	25.13	CY	*$345.93*	$8,694
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	6.94	CY	*$345.93*	$2,402
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$24,500.49	$1,225
Subtotal				$25,726
MASONRY:	Moderate			
CMU Building	1050.00	SF	*$131.60*	$138,181
Subtotal				$138,181
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$17,367.52*	$34,735
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$48,211.01	$4,821
Subtotal				$53,032
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	6.00	each	*$208.82*	$1,253
Number of Digital I/O Counts	20.00	each	*$49.46*	$989
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	225.00	lf	*$9.53*	$2,144
Allowance for Misc Items	10%		$31,752.48	$3,175
Subtotal				$34,928
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	59.00	lf	*$10.36*	$611
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	59.00	lf	*$11.98*	$707
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,557.19	$256
Subtotal				$2,813
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$266,266
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$295,851	$5,917
I & C Allowance	2%		$295,851	$5,917
Mechanical Allowance	4%		$295,851	$11,834
Electrical Allowance	2%		$295,851	$5,917
Facility Cost	**1,050**	**Building SF**	**$281.76**	**$295,851**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	89.00	CY	*$5.35*	$476
Imported Structural Backfill	45.41	CY	*$40.56*	$1,842
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	89.00	CY	*$6.58*	$586
Allowance for Misc Items	5%		$2,903.46	$145
Subtotal				$3,049
CONCRETE:				
Slab on Grade	31.46	CY	*$345.93*	$10,882
Containment Walls	6.87	CY	*$683.50*	$4,699
Bulk Tank Pads	29.50	CY	*$345.93*	$10,204
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	2.00	CY	*$345.93*	$692
Corridor				
Slab on Grade	7.50	CY	*$345.93*	$2,594
Electrical Room				
Slab on Grade	3.41	CY	*$345.93*	$1,179
Allowance for Misc Items	5%		$30,249.22	$1,512
Subtotal				$31,762
MASONRY:	Moderate			
CMU Building	1226.00	SF	*$131.60*	$161,343
Subtotal				$161,343
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$18,113.65*	$36,227
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	3.00	EA	*$6,737.98*	$20,214
Allowance for Misc Items	10%		$56,441.24	$5,644
Subtotal				$62,085
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	3.00	each	*$549.53*	$1,649
Magmeter	2.00	each	*$549.53*	$1,099
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	9.00	each	*$208.82*	$1,879
Number of Digital I/O Counts	26.00	each	*$49.46*	$1,286
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	297.00	lf	*$9.53*	$2,830
Allowance for Misc Items	10%		$34,460.81	$3,446
Subtotal				$37,907
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	61.00	lf	*$10.36*	$632
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	61.00	lf	*$11.98*	$731
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	12.00	each	*$7.95*	$95
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	12.00	each	*$63.16*	$758
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	3.00	each	*$8.27*	$25
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	3.00	each	*$109.33*	$328
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Allowance for Misc Items	10%		$3,184.53	$318
Subtotal				$3,503
ELECTRICAL:				
# MCC Sections	6.00	#	*$6,783.10*	$40,699
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	243.00	lf	*$9.53*	$2,315
Allowance for Misc Items	10%		$43,014.07	$4,301
Subtotal				$47,315
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$355,940
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$395,488	$7,910
I & C Allowance	2%		$395,488	$7,910
Mechanical Allowance	4%		$395,488	$15,820
Electrical Allowance	2%		$395,488	$7,910
Facility Cost	**1,226**	**Building SF**	**$322.58**	**$395,488**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	1575.42	CY	***$5.35***	$0
Imported Structural Backfill	86.68	CY	***$40.56***	$0
Native Backfill	828.79	CY	***$6.58***	$0
Haul Excess	746.63	CY	***$6.58***	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
CONCRETE:				
Wet Well:				
Foundation	28.89	CY	***$382.16***	$0
Perimeter Walls	64.42	CY	***$683.50***	$0
Operating Floor:				
Elevated Slab (Including floor over Discharge Header Vault)	36.61	CY	***$1,088.69***	$0
Pump Pads	1.63	CY	***$345.93***	$565
Other Equipment Pads	1.00	CY	***$345.93***	$346
Discharge Pipe Vault:				
Slab on Grade	13.66	CY	***$345.93***	$4,725
Walls	17.16	CY	***$683.50***	$11,727
Allowance for Misc Items	5%		$17,362.33	$868
Subtotal				$18,230
MASONRY:	Moderate			
CMU Building	988.44	SF	***$131.60***	$130,080
Subtotal				$130,080
METALS:				
Checker Plate Over Intake Pipe Gate = (Diameter of Influent Pipe +2') * (2 Feet Wide) (sf)	10.00	SF	***$72.38***	$724
Checker Plate Over Discharge Pipe Header = ((Discharge Pipe Diameter * 2) * ("S" * Total Number of Pumps)	57.98	SF	***$72.38***	$4,197
Ladder	15.55	VLF	***$99.36***	$1,545
Allowance for Misc Items	10%		$6,464.96	$646
Subtotal				$7,111
EQUIPMENT:				
Size of Sluice Gate (per side in inches)	36.00	Inches		
Sluice Gate	1.00	EA	***$6,330.27***	$6,330
Pumps:				
Active Pump # 1	124.39	HP	***$790.52***	$98,332
Active Pump # 2	124.39	HP	***$790.52***	$98,332
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0
Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	124.39	HP	***$790.52***	$98,332
AFD's				
Active Pump # 1	124.39	HP	***$156.14***	$19,422
Active Pump # 2	124.39	HP	***$156.14***	$19,422
Active Pump # 3	0.00	HP	***$0.00***	$0
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0

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Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	124.39	HP	***$156.14***	$19,422
Allowance for Misc Items	10%		$353,259.39	$35,326
Subtotal				$394,916
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$550,338
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$1,100,676	$22,014
I & C Allowance	8.0%		$1,100,676	$88,054
Mechanical Allowance	25.0%		$1,100,676	$275,169
Electrical Allowance	15.0%		$1,100,676	$165,101
Facility Cost	**373**	**Total Pump HP**	**$2,949.56**	**$1,100,676**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	766.13	CY	*$5.35*	$0
Imported Structural Backfill	394.33	CY	*$40.56*	$0
Native Backfill	92.56	CY	*$6.58*	$0
Haul Excess	673.58	CY	*$6.58*	$0
Forebay:				
Excavation	9387.95	CY	*$5.35*	$0
Imported Structural Backfill	667.68	CY	*$40.56*	$0
Native Backfill	1838.49	CY	*$6.58*	$0
Haul Excess	7549.46	CY	*$6.58*	$0
Office:				
Excavation	0.00	CY	*$5.35*	$0
Imported Structural Backfill	0.00	CY	*$40.56*	$0
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	0.00	CY	*$6.58*	$0
Surge Protection:				
Excavation	129.07	CY	*$5.35*	$691
Imported Structural Backfill	95.68	CY	*$40.56*	$3,880
Native Backfill	19.56	CY	*$6.58*	$129
Haul Excess	109.51	CY	*$6.58*	$721
Allowance for Misc Items	5%		$5,420.31	$271
Subtotal				$5,691
CONCRETE:				
Pump Station				
Foundation	284.38	CY	*$382.16*	$0
Pump Pad Epoxy	0.74	CY	$3,412.56	$2,528
Pump Pad Support	10.50	CY	*$345.93*	$3,632
Pipe Supports	5.32	CY	*$345.93*	$1,842
Electrical Room				
Foundation	50.50	CY	*$345.93*	$17,471
Surge Protection				
Foundation	23.33	CY	*$345.93*	$8,069
Office				
Foundation	0.00	CY	*$345.93*	$0
Pump Station Forebay				
Slab on Grade for Rectangular Tank	231.48	CY	*$345.93*	$0
Support Walls for Rectangular	342.22	CY	*$683.50*	$0
Support Columns for Rectangular	16.50	CY	*$683.50*	$0
Elevated Slab for Rectangular	91.36	CY	*$1,088.69*	$0
Pump Baffling (for all cases)	16.43	CY	*$683.50*	$0
Sump Walls	86.37	CY	*$683.50*	$0
Sump Concrete Fill	184.06	CY	*$382.16*	$0
Prestressed Concrete Tank (704049 gallons)	0.00	EA	$0.00	$0
Allowance for Misc Items	5%		$33,541.85	$1,677
Subtotal				$35,219
MASONRY:	Moderate			
Pump Station Building	2519.25	SF	*$197.40*	$497,305
Office Building	0.00	SF	*$131.60*	$0
Surge Building	629.81	SF	*$131.60*	$82,884
Electrical Room	1363.60	SF	*$131.60*	$179,452
Subtotal	4512.66			$759,641
METALS:				
Pump Removal Hatches	73.33	SF	*$109.91*	$8,060
Allowance for Misc Items	10%		$8,059.73	$806
Subtotal				$8,866
THERMAL & MOISTURE PROTECTION:				
Wet Well Liner	0.00	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	1.00	EA	*$219,989.00*	$219,989
Active Pump # 2	1.00	EA	*$219,989.00*	$219,989
Active Pump # 3	1.00	EA	*$219,989.00*	$219,989

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Active Pump # 4	1.00	EA	*$219,989.00*	$219,989
Active Pump # 5	0.00	EA	*$0.00*	$0
Active Pump # 6	0.00	EA	*$0.00*	$0
Active Pump # 7	0.00	EA	*$0.00*	$0
Active Pump # 8	0.00	EA	*$0.00*	$0
Active Pump # 9	0.00	EA	*$0.00*	$0
Active Pump # 10	0.00	EA	*$0.00*	$0
Standby Pump	1.00	EA	*$219,989.00*	$219,989
Allowance for Misc Items	10%		$1,099,945.01	$109,995
Subtotal				$1,209,940
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	10.00	each	*$5,064.93*	$50,649
Control Valve Actuators	5.00	each	*$5,064.93*	$25,325
Level Indicator Transmitters	2.00	each	*$6,764.54*	$13,529
Level Swithces	2.00	each	*$7,120.57*	$14,241
Pressure Indicator Transmitters	6.00	each	*$7,120.57*	$42,723
Pressure Switches	10.00	each	*$7,120.57*	$71,206
Number of Analog I/O Counts	37.20	each	*$208.82*	$7,768
Number of Digital I/O Counts	104.40	each	*$49.46*	$5,163
Number of PLC's	5.00	each	*$10,331.10*	$51,656
I&C Conduit & Wire	2407.48	lf	*$9.53*	$22,940
Allowance for Misc Items	10%		$ 305,200.54	$30,520
Subtotal				$335,721
MECHANICAL:				
Pipe:				
Discharge Lateral Pipe (18-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	45.00	LF	*$68.67*	$3,090
Discharge Header Pipe (36-inch,DIS, Exposed/Buried, Steel, Cement Mortar, Cement Mortar)	45.00	LF	*$896.07*	$40,323
Pump Discharge Pipe (12-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	5.00	LF	*$59.36*	$297
Elbows:				
Discharge Header Pipe (36-inch)	2.00	EA	*$3,449.05*	$6,898
Tees:				
Discharge Header Pipe (36-inch)	5.00	EA	*$6,723.69*	$33,618
Valves:				
Discharge Lateral Isolation Valve (18-inch, BFV)	5.00	EA	*$2,759.13*	$13,796
Pump Control Valve (18-inch, Check Valve)	5.00	EA	*$2,759.13*	$13,796
Discharge Header Isolation Valve (36-inch, BFV)	1.00	EA	*$7,386.98*	$7,387
Air Release Vacuum Valves	15.00	EA	*$3,297.16*	$49,457
Allowance for Misc Items	10%		$168,662.47	$16,866
Subtotal				$185,529
ELECTRICAL:				
MCC's				
Sections	3.00	each	*$6,783.10*	$20,349
AFD's				
Active Pump # 1	700.00	HP	*$128.86*	$90,202
Active Pump # 2	700.00	HP	*$128.86*	$90,202
Active Pump # 3	700.00	HP	*$128.86*	$90,202
Active Pump # 4	700.00	HP	*$128.86*	$90,202
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	700.00	HP	*$128.86*	$90,202
Switchgear				
Units	8.00	each	*$31,202.24*	$249,618
Electrical Conduit & Wire	343.93	lf	*$9.53*	$3,277
Allowance for Misc Items	5%		$724,256	$36,213
Subtotal				$760,469
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0

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Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$3,301,075
ALLOWANCES:		**User Over-write**		
Finishes Allowance	5%		$4,232,147	$211,607
I & C Allowance	2%		$4,232,147	$84,643
Surge Allowance	5%		$4,232,147	$211,607
Mechanical Allowance	5%		$4,232,147	$211,607
Electrical Allowance	5%		$4,232,147	$211,607
Facility Cost	**3,500**	**Total Pump HP**	**$1,209.18**	**$4,232,147**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Circular Clearwell				
Excavation	14,515	CY	*$5.35*	$77,691
Imported Structural Backfill	1,523	CY	*$40.56*	$61,784
Native Backfill	2,973	CY	*$6.58*	$19,563
Haul Excess	11,542	CY	*$6.58*	$75,949
Rectangular Clearwell				
Excavation	0	CY	*$5.35*	$0
Imported Structural Backfill	0	CY	*$40.56*	$0
Native Backfill	0	CY	*$6.58*	$0
Haul Excess	0	CY	*$6.58*	$0
Allowance for Misc Items	5%		$234,986.14	$11,749
Subtotal				$246,735
CONCRETE:				
Circular Clearwell				
Prestressed Concrete Tank (2000000 gallons)	1	EA	*$872,030.58*	$872,031
Rectangular Clearwell				
Foundation	0	CY	*$382.16*	$0
Columns	0	CY	*$683.50*	$0
Walls	0	CY	*$683.50*	$0
Elevated Slab	0	CY	*$1,088.69*	$0
Concrete Baffling	0	CY	*$683.50*	$0
Allowance for Misc Items	5%		$872,030.58	$43,602
Subtotal				$915,632
METALS & PLASTICS:				
Polypropylene Baffling	0	SF	*$10.99*	$0
Stainless Steel Baffling	0	SF	*$45.79*	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
THERMAL & MOISTURE PROTECTION:				
Concrete Liner	0	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,162,368
ALLOWANCES:		**User Over-write**		
Metals Allowance	1.0%		$1,249,858	$12,499
Finishes Allowance	2.0%		$1,249,858	$24,997

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Equipment Allowance	1.0%		$1,249,858	$12,499
I & C Allowance	2%		$1,249,858	$24,997
Mechanical Allowance	5%		$1,249,858	$62,493
Electrical Allowance	1%		$1,249,858	$12,499
Facility Cost	**2,000,000**	**Gallons**	**$0.66**	**$1,312,350**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	1383.87	CY	***$5.35***	$7,407
Imported Structural Backfill	76.18	CY	***$40.56***	$3,090
Native Backfill	308.73	CY	***$6.58***	$2,031
Haul Excess	1075.14	CY	***$6.58***	$7,075
Allowance for Misc Items	5%		$19,602.35	$980
Subtotal				$20,582
CONCRETE:				
Process Building Slab on Grade	73.32	CY	***$345.93***	$25,364
Concrete Walls	57.78	CY	***$683.50***	$39,491
Electrical Room Slab on Grade	0.15	CY	***$345.93***	$51
Allowance for Misc Items	5%		$64,906.76	$3,245
Subtotal				$68,152
MASONRY:	Moderate			
CMU Building	1546.67	SF	***$131.60***	$203,543
Subtotal				$203,543
METALS:				
Stairway from Building Doors to Floor	30.00	Risers	***$394.80***	$11,844
Stairway from Grating to Floor	18.00	Risers	***$394.80***	$7,106
Grating	469.33	SF	***$72.38***	$33,971
Handrail	56.00	LF	***$72.38***	$4,053
Allowance for Misc Items	10%		$56,974.61	$5,697
Subtotal				$62,672
EQUIPMENT:				
UV Reactors	2.00	EA	***$185,134.72***	$370,269
Sump Pump	1.00	EA	***$6,077.92***	$6,078
Allowance for Misc Items	10%		$376,347.36	$37,635
Subtotal				$413,982
INSTRUMENTS & CONTROLS:				
Mag Meters	2.00	EA	***$17,912.55***	$35,825
UV Absorbance Analyzer	1.00	EA	***$21,794.63***	$21,795
Allowance for Misc Items	5%		$57,619.74	$2,881
Subtotal				$60,501
CONVEYING SYSTEMS:				
Bridge Crane	1.00	EA	***$25,289.83***	$25,290
Crane Rail	53.33	LF	***$56.12***	$2,993
Allowance for Misc Items	10%		$28,282.91	$2,828
Subtotal				$31,111
MECHANICAL:				
Inlet and Outlet Pipe Headers (36 inch diameter)	1.00	LS	***$82,262.74***	$82,263
UV Train Pipe Systems (24 inch diameter)	2.00	EA	***$24,962.51***	$49,925
Allowance for Misc Items	10%		$132,187.76	$13,219
Subtotal				$145,407
ELECTRICAL:				
UPS	0.00	KW	***$1,316.01***	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0

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Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,005,951
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$1,341,268	$26,825
I & C Allowance	5%		$1,341,268	$67,063
Mechanical Allowance	8%		$1,341,268	$107,301
Electrical Allowance	10%		$1,341,268	$134,127
Facility Cost	**20,000,000**	**GPD**	**$0.07**	**$1,341,268**

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Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation				
Influent Channel, Surge Basin & Decant Pump	5311.63	CY	*$5.35*	$28,429
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1502.22	CY	*$5.35*	$8,040
Pipe Vault	351.82	CY	*$5.35*	$1,883
Imported Structural Backfill				
Influent Channel, Surge Basin & Decant Pump	426.72	CY	*$40.56*	$17,306
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	80.20	CY	*$40.56*	$3,252
Pipe Vault	70.17	CY	*$40.56*	$2,846
Native Backfill				
Influent Channel, Surge Basin & Decant Pump	1115.38	CY	*$6.58*	$7,339
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	32.00	CY	*$6.58*	$211
Pipe Vault	103.39	CY	*$6.58*	$680
Haul Excess				
Influent Channel, Surge Basin & Decant Pump	4196.25	CY	*$6.58*	$27,612
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1470.22	CY	*$6.58*	$9,674
Pipe Vault	248.42	CY	*$6.58*	$1,635
Allowance for Misc Items	5%		$108,907.43	$5,445
Subtotal				$114,353
CONCRETE:				
Surge Basin:				
Foundation	308.85	CY	*$382.16*	$118,028
Perimeter Walls	382.34	CY	*$683.50*	$261,329
Influent Channel Wall	62.23	CY	*$683.50*	$42,536
Concrete Curb (8" X 8")	76.89	LF	*$32.90*	$2,530
Backwash Recycle Sump:				
Slab on Grade	18.89	CY	*$345.93*	$6,534
Walls	90.62	CY	*$683.50*	$61,940
Elevated Slab	9.23	CY	*$1,088.69*	$10,045
Backwash Sludge Sump:				
Slab on Grade	13.33	CY	*$345.93*	$4,612
Walls	66.77	CY	*$683.50*	$45,640
Elevated Slab	6.88	CY	*$1,088.69*	$7,491
Dry Pit:				
Slab on Grade	5.31	CY	*$345.93*	$1,836
Walls	32.33	CY	*$683.50*	$22,096
Elevated Slab	3.49	CY	*$1,088.69*	$3,802
Pipe Vault:				
Lower Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Upper Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Walls	32.67	CY	*$683.50*	$22,333
Electrical Room Slab on Grade	5.27	CY	*$345.93*	$1,822
Allowance for Misc Items	5%		$677,117.15	$33,856
Subtotal				$710,973
MASONRY:	Moderate			
Pump Sumps and Pipe Vault	0.00	SF	*$131.60*	$0
Electrical Room	80.89	SF	*$131.60*	$10,645
Subtotal	80.89			$10,645
METALS:				
Influent Channel:				
Grating	185.56	SF	*$72.38*	$13,431
Surge Basin:				
Grating	4.00	SF	*$72.38*	$290
Backwash Recycle Sump:				
Grating	4.00	SF	*$72.38*	$290
Backwash Sludge Sump:				
Grating	4.00	SF	*$72.38*	$290
Dry Pit:				

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Ladder	27.60	VLF	*$99.36*	$2,742
Pipe Vault:				
Grating	4.00	SF	*$72.38*	$290
Stairs	16.00	RISERS	*$394.80*	$6,317
Allowance for Misc Items	10%		$23,647.47	$2,365
Subtotal				$26,012
DOORS & WINDOWS:				
Backwash Recycle Sump:				
Aluminum Access Hatch (10' x 5')	1.00	EA	*$4,400.75*	$4,401
Backwash Sludge Sump:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Dry Pit:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Pipe Vault:				
Aluminum Access Hatch (3' x 3')	2.00	EA	*$1,098.21*	$2,196
Allowance for Misc Items	5%		$8,793.60	$440
Subtotal				$9,233
EQUIPMENT:				
Floating Decanter Plate System	0.00	SF	*$72.94*	$0
Traveling Solids Removal Mechanism	2.00	EA	*$66,857.09*	$133,714
Washwater Decant Pump (Submersible Pump)	3.00	EA	*$18,993.38*	$56,980
Sludge Pump (Submersible Pump)	2.00	EA	*$12,409.63*	$24,819
Mixers	0.00	HP	*$1,580.26*	$0
Allowance for Misc Items	10%		$215,513.57	$21,551
Subtotal				$237,065
I&C:				
Instruments				
Backwash Waste Recycle Header Magmeter (BWRH, 12 inch)	1.00	EA	$10,573.93	$10,574
Isolation Valve Actuators (Electric)	5.00	EA	*$5,064.93*	$25,325
Level Transmitters	1.00	EA	*$7,120.57*	$7,121
Number of Analog I/O Counts	6.00	EA	*$208.82*	$1,253
Number of Digital I/O Counts	30.00	EA	*$49.46*	$1,484
Number of Local Panels	1.00	EA	*$10,331.10*	$10,331
Number of PLC's	1.00	EA	*$10,990.54*	$10,991
I&C Conduit Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$69,552.80	$3,478
Subtotal				$73,030
MECHANICAL:				
Pipe:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	LF	*$657.50*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	LF	*$123.32*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	16.22	LF	*$219.17*	$3,555
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	LF	*$219.17*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	81.00	LF	*$54.81*	$4,439
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	16.22	LF	*$109.58*	$1,778
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	LF	*$109.58*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	54.00	LF	*$109.58*	$5,917
Elbows:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$3,959.76*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$2,588.21*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	1.00	EA	*$1,319.92*	$1,320
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$1,319.92*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	6.00	EA	*$1,150.31*	$6,902
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$659.96*	$660
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$659.96*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	4.00	EA	*$659.96*	$2,640
Tee:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$9,021.82*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$4,297.65*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	2.00	EA	*$3,007.27*	$6,015

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Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$3,007.27*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	0.00	EA	*$1,910.07*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$1,503.64*	$1,504
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Valves:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$28,960.68*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$12,602.74*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	3.00	EA	*$5,601.22*	$16,804
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	2.00	EA	*$4,826.78*	$9,654
Allowance for Misc Items	5%		$61,186.86	$3,059
Subtotal				$64,246
ELECTRICAL:				
# MCC Sections	8.00	EA	*$6,783.10*	$54,265
Switchgear	0.00	EA	*$31,202.24*	$0
Adjustable Frequency Drives				
Basin Mixer	0.00	EA	*$4,125.89*	$0
Sludge Pumps (Active)	1.00	EA	*$4,871.14*	$4,871
Sludge Pumps (Standby)	1.00	EA	*$4,871.14*	$4,871
Recycle Pumps (Active)	2.00	EA	*$6,299.20*	$12,598
Recycle Pumps (Standby)	1.00	EA	*$6,299.20*	$6,299
Electrical Conduit & Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$85,380.01	$4,269
Subtotal				$89,649
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,335,206.98
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2%		$1,534,721	$30,694.41
I & C Allowance	3%		$1,534,720.67	$46,041.62
Mechanical Allowance	5%		$1,534,720.67	$76,736.03
Electrical Allowance	3%		$1,534,720.67	$46,041.62
Facility Cost	**2,519,600**	**Gallons**	**$0.61**	**$1,534,721**

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	B	C	D	E	F
317					
318	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
319	SITEWORK:				
320	Soil Excavation	7890.61	CY	***$5.35***	$42,233
321	Imported Structural Backfill	885.62	CY	***$40.56***	$35,916
322	Backfill	137.39	CY	***$6.58***	$904
323	Haul Excess	7753.22	CY	***$6.58***	$51,017
324	Stair Case:				
325	Soil Excavation	673.00	CY	***$5.35***	$3,602
326	Imported Structural Backfill	87.11	CY	***$40.56***	$3,533
327	Backfill	34.67	CY	***$6.58***	$228
328	Haul Excess	638.33	CY	***$6.58***	$4,200
329	Blower Room:				
330	Soil Excavation	91.90	CY	***$5.35***	$492
331	Imported Structural Backfill	116.44	CY	***$40.56***	$4,722
332	Backfill	4.42	CY	***$6.58***	$29
333	Haul Excess	87.48	CY	***$6.58***	$576
334	Electrical Room:				
335	Soil Excavation	16.29	CY	***$5.35***	$87
336	Imported Structural Backfill	19.63	CY	***$40.56***	$796
337	Backfill	1.46	CY	***$6.58***	$10
338	Haul Excess	14.83	CY	***$6.58***	$98
339	Allowance for Misc Items	5%		$148,442.48	$7,422
340	Subtotal				$155,865
341					
342	CONCRETE:				
343	Filters				
344	Foundation (Includes Filter, Gullet Channel, Filter Influent/Backwash Wastewater Channel) (FSOGW * FSOGL * FOSGT) / 27 *#TF	458.37	CY	***$382.16***	$175,171
345	Pipe Gallery Wall	278.19	CY	***$683.50***	$190,141
346	Gullet Wall	55.97	CY	***$683.50***	$38,257
347	Filter Influent / Backwash Waste Channel Walls	460.37	CY	***$683.50***	$314,665
348	Filter Influent / Backwash Waste Channel Lower Elevated Slab	26.67	CY	***$1,088.69***	$29,032
349	Filter Influent / Backwash Waste Channel Upper Elevated Slab	36.00	CY	***$1,088.69***	$39,193
350	End Walls	253.63	CY	***$683.50***	$173,357
351	Common Filter Influent				
352	Slab on Grade	62.48	CY	***$345.93***	$21,615
353	Common Influent Channel Wall	213.70	CY	***$683.50***	$146,067
354	Common Influent Channel Elevated Slab	27.81	CY	***$1,088.69***	$30,276
355	Filter Gallery				
356	Slab on Grade	567.17	CY	***$345.93***	$196,201
357	Filter Gallery Elevated Slab	75.62	CY	***$1,088.69***	$82,330
358	Pipe Supports	2.24	CY	***$32.90***	
359	Blower Room				
360	Slab on Grade	63.66	CY	***$345.93***	$22,023
361	Blower Room Walls	31.79	CY	***$683.50***	$21,730
362	Stair Case				
363	Slab on Grade	46.22	CY	***$345.93***	$15,990
364	Stair Case Walls	25.58	CY	***$683.50***	$17,481
365	Electrical Room				
366	Slab on Grade	3.04	CY	***$345.93***	$1,051
367	Electrical Room Walls	9.71	CY	***$683.50***	$6,638
368	Allowance for Misc Items	5%		$1,521,216.81	$76,061
369	Subtotal				$1,597,278
370					
371	MASONRY:	**Moderate**			
372	CMU Filter Building	10239.03	SF	***$131.60***	$1,347,470
373	Blower Room	793.33	SF	***$131.60***	$104,404
374	Electrical Room	82.00	SF	***$131.60***	$10,791
375	Subtotal				$1,462,665
376					
377	METALS:				

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	B	C	D	E	F
378	Metal Guardrail with Pickets	517.33	LF	*$72.38*	$37,445
379	Filter Access Hatch	20.25	SF	*$109.91*	
380	Stairs (FBD * 12/8)	32.00	Risers	*$394.80*	$12,634
381	Allowance for Misc Items	10%		$50,078.70	$5,008
382	Subtotal				$55,087
383					
384	THERMAL & MOISTURE PROTECTION:				
385	Concrete Liner	0	SF	*$16.00*	$0
386	Allowance for Misc Items	10%		$0.00	$0
387	Subtotal				$0
388					
389	EQUIPMENT:				
390	Fabricated Slide Gates, 42-inch	2	EA	*$7,111.04*	$14,222
391	Underdrain - Leopold Type S	3,083	SF	*$69.90*	$215,466
392	Wash Troughs				
393	Conventional	0	LF	*$234.61*	$0
394	Media Retaining	379	LF	*$531.99*	$201,446
395	Media				
396	Bottom Media - Sand (ES=0.5 UC=1.4)	3,083	CF	*$17.47*	$53,867
397	Middle Media - Coal (ES=0 UC=0)	0	CF	*$23.30*	$0
398	Top Media - Coal (ES=1 UC=1.4)	12,331	CF	*$23.30*	$287,288
399	Air Scour Blowers (147 hp each)	2	EA	*$80,692.87*	$161,386
400	Allowance for Misc Items	10%		$933,675.01	$93,368
401	Subtotal				$1,027,043
402					
403	INSTRUMENTS & CONTROLS:				
404	Instruments				
405	Filter Effluent Magmeter (20-inch)	4.00	EA	*$17,150.92*	$68,604
406	Combined Filter Effluent Magmeter (36-inch)	0.00	EA	*$28,001.02*	$0
407	Isolation Valve Actuators	24.00	EA	*$5,064.93*	$121,558
408	Control Valve Actuators	4.00	EA	*$5,064.93*	$20,260
409	Turbidimeters	4	EA	*$3,133.05*	$12,532
410	Particle Counters	4	EA	*$6,764.54*	$27,058
411	Level Transmitters	4	EA	*$7,120.57*	$28,482
412	Differential Pressure Transmitters	4	EA	*$7,120.57*	$28,482
413	Filter Influent Level Transmitter	2	EA	*$7,120.57*	$14,241
414	Air Scour Differential Pressure Transmitter	2	EA	*$7,120.57*	$14,241
415	Air Scour Discharge Pressure Indicator Transmitter	2	EA	*$7,120.57*	$14,241
416	Number of Analog I/O Counts	53	EA	*$208.82*	$11,026
417	Number of Digital I/O Counts	149	EA	*$49.46*	$7,359
418	Number of PLC's	1	EA	*$10,331.10*	$10,331
419	I&C Conduit & Wire	4,266	LF	*$9.53*	$40,650
420	Allowance for Misc Items	10%		$419,065.93	$41,907
421	Subtotal				$460,973
422					
423	CONVEYING SYSTEMS:				
424	Monorail Hoist (3 Ton)	1	EA	*$3,257.13*	$3,257
425	Hoist Rail	190	LF	*$32.90*	$6,259
426	Allowance for Misc Items	5%		$9,515.98	$476
427	Subtotal				$9,992
428					
429	MECHANICAL:				
430	Pipe				
431	Air Scour Pipe-BAW (16-inch , Exposed , Steel , None , None)	268	LF	*$264.60*	$70,861

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	B	C	D	E	F
432	Filter Influent Header Pipe-FIH (36-inch , Buried , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$657.50*	$0
433	Filter Influent Pipe-FIH (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$547.92*	$0
434	Filter Effluent Pipe-FE (20-inch , Exposed , Steel , Cement Mortar , Paint)	56	LF	*$365.28*	$20,385
435	Filter Effluent Pipe-FE (20-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	56	LF	*$365.28*	$20,385
436	Filter Control Valve Pipe-FCV (16-inch , Exposed , Steel , None , None)	43	LF	*$264.60*	$11,290
437	Filter Effluent Header Pipe-FEH (36-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	79	LF	*$657.50*	$51,942
438	Filter to Waste-FTW (20-inch , Exposed , Steel , Cement Mortar , Paint)	43	LF	*$365.28*	$15,765
439	Filter to Waste-FTW (20-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	184	LF	*$365.28*	$67,211
440	Backwash Supply Pipe-BWS (36-inch , Exposed , Steel , Cement Mortar , Paint)	201	LF	*$657.50*	$131,986
441	Backwash Supply Pipe-BWS (36-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	48	LF	*$657.50*	$31,560
442	Backwash Waste Pipe-BWW (36-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	10	LF	*$657.50*	$6,575
443	Elbows				
444	Air Scour Pipe-BAW (16-inch , Steel)	16	EA	*$1,759.89*	$28,158
445	Filter Influent Header Pipe-FIH (36-inch , Steel)	0	EA	*$3,959.76*	$0
446	Filter Influent Pipe-FIH (30-inch , Steel)	0	EA	*$3,299.80*	$0
447	Filter Effluent Pipe-FE (20-inch , Steel)	4	EA	*$2,199.87*	$8,799
448	Filter Effluent Pipe-FE (20-inch , Steel)	4	EA	*$2,199.87*	$8,799
449	Filter Control Valve Pipe-FCV (16-inch , Steel)	0	EA	*$1,759.89*	$0
450	Filter Effluent Header Pipe-FEH (36-inch , Steel)	0	EA	*$3,959.76*	$0
451	Filter to Waste-FTW (20-inch , Steel)	6	EA	*$2,199.87*	$13,199
452	Filter to Waste-FTW (20-inch , Steel)	0	EA	*$2,199.87*	$0
453	Backwash Supply Pipe-BWS (36-inch , Steel)	2	EA	*$3,959.76*	$7,920
454	Backwash Supply Pipe-BWS (36-inch , Steel)	2	EA	*$3,959.76*	$7,920
455	Backwash Waste Pipe-BWW (36-inch , Steel)	0	EA	*$3,959.76*	$0
456	Tees				
457	Air Scour Pipe-BAW (16-inch , Steel)	4	EA	*$4,009.70*	$16,039
458	Filter Influent Header Pipe-FIH (36-inch , Steel)	0	EA	*$9,021.82*	$0
459	Filter Influent Pipe-FIH (30-inch , Steel)	0	EA	*$7,518.19*	$0
460	Filter Effluent Pipe-FE (20-inch , Steel)	4	EA	*$5,012.12*	$20,048
461	Filter Effluent Pipe-FE (20-inch , Steel)	0	EA	*$5,012.12*	$0
462	Filter Control Valve Pipe-FCV (16-inch , Steel)	0	EA	*$4,009.70*	$0
463	Filter Effluent Header Pipe-FEH (36-inch , Steel)	0	EA	*$9,021.82*	$0
464	Filter to Waste-FTW (20-inch , Steel)	0	EA	*$5,012.12*	$0
465	Filter to Waste-FTW (20-inch , Steel)	2	EA	*$5,012.12*	$10,024
466	Backwash Supply Pipe-BWS (36-inch , Steel)	6	EA	*$9,021.82*	$54,131
467	Backwash Supply Pipe-BWS (36-inch , Steel)	0	EA	*$9,021.82*	$0
468	Backwash Waste Pipe-BWW (36-inch , Steel)	0	EA	*$9,021.82*	$0
469	Crosses				
470	Air Scour Pipe-BAW (16-inch , Steel)	2	EA	*$5,346.27*	$10,693
471	Filter Influent Header Pipe-FIH (36-inch , Steel)	0	EA	*$12,029.10*	$0
472	Filter Influent Pipe-FIH (30-inch , Steel)	0	EA	*$10,024.25*	$0
473	Filter Effluent Pipe-FE (20-inch , Steel)	0	EA	*$6,682.83*	$0
474	Filter Effluent Pipe-FE (20-inch , Steel)	0	EA	*$6,682.83*	$0
475	Filter Control Valve Pipe-FCV (16-inch , Steel)	0	EA	*$5,346.27*	$0
476	Filter Effluent Header Pipe-FEH (36-inch , Steel)	2	EA	*$12,029.10*	$24,058
477	Filter to Waste-FTW (20-inch , Steel)	0	EA	*$6,682.83*	$0
478	Filter to Waste-FTW (20-inch , Steel)	0	EA	*$6,682.83*	$0
479	Backwash Supply Pipe-BWS (36-inch , Steel)	0	EA	*$12,029.10*	$0
480	Backwash Supply Pipe-BWS (36-inch , Steel)	0	EA	*$12,029.10*	$0
481	Backwash Waste Pipe-BWW (36-inch , Steel)	0	EA	*$12,029.10*	$0
482	Valves				
483	Air Scour Pipe-BAW (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
484	Filter Influent Header Pipe-FIH (36-inch ,V500 - BFV)	0	EA	*$28,960.68*	$0

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	B	C	D	E	F
485	Filter Influent Pipe-FIH (30-inch ,V500 - BFV)	4	EA	*$24,133.90*	$96,536
486	Filter Effluent Pipe-FE (20-inch ,V500 - BFV)	4	EA	*$16,089.26*	$64,357
487	Filter Effluent Pipe-FE (20-inch ,V500 - BFV)	0	EA	*$16,089.26*	$0
488	Filter Control Valve Pipe-FCV (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
489	Filter Effluent Header Pipe-FEH (36-inch ,V500 - BFV)	0	EA	*$28,960.68*	$0
490	Filter to Waste-FTW (20-inch ,V500 - BFV)	4	EA	*$16,089.26*	$64,357
491	Filter to Waste-FTW (20-inch ,V500 - BFV)	0	EA	*$16,089.26*	$0
492	Backwash Supply Pipe-BWS (36-inch ,V500 - BFV)	4	EA	*$28,960.68*	$115,843
493	Backwash Supply Pipe-BWS (36-inch ,V500 - BFV)	0	EA	*$28,960.68*	$0
494	Backwash Waste Pipe-BWW (36-inch ,V500 - BFV)	4	EA	*$28,960.68*	$115,843
495	Allowance for Misc Items	5%		$1,197,655.76	$59,883
496	Subtotal				$1,257,539
497					
498	ELECTRICAL:				
499	MCC's				
500	Sections	5	EA	*$6,783.10*	$33,915
501	AFD's				
502	Air Scour Blowers (147 hp each)	-	EA	*$22,201.95*	$0
503	Switchgear				
504	Units	-	EA	*$31,202.24*	$0
505	Electrical Conduit & Wire	158	LF	*$9.53*	$1,506
506	Allowance for Misc Items	5%		$35,421.03	$1,771
507	Subtotal				$37,192
508					
509	USER DEFINED ESTIMATE ITEMS	QUANT	UNIT	$/UNIT	TOTAL COST
510	Item 1 Description	0.00		0.00	$0
511	Item 2 Description	0.00		0.00	$0
512	Item 3 Description	0.00		0.00	$0
513	Item 4 Description	0.00		0.00	$0
514	Item 5 Description	0.00		0.00	$0
515	Item 6 Description	0.00		0.00	$0
516	Item 7 Description	0.00		0.00	$0
517	Item 8 Description	0.00		0.00	$0
518	Item 9 Description	0.00		0.00	$0
519	Item 10 Description	0.00		0.00	$0
520	Item 11 Description	0.00		0.00	$0
521	Item 12 Description	0.00		0.00	$0
522	Item 13 Description	0.00		0.00	$0
523	Item 14 Description	0.00		0.00	$0
524	Item 15 Description	0.00		0.00	$0
525	Subtotal				$0
526					
527	Subtotal				$6,063,631.57
528					
529	ALLOWANCES:		**User Over-write**		
530	Finishes Allowance	2%		$6,590,904	$131,818.08
531	Mechanical Allowance	2%		$6,590,903.88	$131,818.08
532	I&C Allowance	2%		$6,590,903.88	$131,818.08
533	Electrical Allowance	2%		$6,590,903.88	$131,818.08
534					
535	**Facility Cost**	**20,000,000**	**GPD**	**$0.33**	**$6,590,904**

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	B	C	D	E	F
180					
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
182					
183	SITEWORK:				
184	Excavation	4,742	CY	$ 5.35	$25,383
185	Imported Structural Backfill	747	CY	$ 40.56	$30,305
186	Native Backfill	1,245	CY	$ 6.58	$8,194
187	Haul Excess	3,497	CY	$ 6.58	$23,011
188	Allowance for Misc Items	5%		$86,893	$4,345
189	Subtotal				$91,237
190					
191	CONCRETE:				
192	Influent Channel:				
193	Foundation	42	CY	$ 382.16	$16,188
194	Channel Walls	88	CY	$ 683.50	$60,363
195	Elevated Slab	26	CY	$ 1,088.69	$28,234
196	Basin				
197	Foundation	160	CY	$ 382.16	$61,282
198	Channel Walls	286	CY	$ 683.50	$195,325
199	Elevated Slab	38	CY	$ 1,088.69	$41,369
200	Concrete Curb (8" X 8")	86	LF	$ 32.90	$2,829
201	Effluent Channel:				
202	Foundation	42	CY	$ 382.16	$16,188
203	Walls	88	CY	$ 683.50	$60,363
204	Elevated Slab	26	CY	$ 1,088.69	$28,234
205	Electrical Room				
206	Slab on Grade	2	CY	$ 345.93	$737
207	Allowance for Misc Items	5%		$511,114	$25,556
208	Subtotal				$536,669
209					
210	MASONRY:	Moderate			
211	CMU Building	5,514	SF	$ 131.60	$725,698
212	Electrical Room	58	SF	$ 131.60	$7,574
213	Subtotal	5,572			$733,272
214					
215	METALS:				
216	Aluminum Handrail	295	LF	$ 72.38	$21,352
217	Allowance for Misc Items	10%		$ 21,352.07	$2,135
218	Subtotal				$23,487
219					
220	WOODS & PLASTICS:				
221	FRP Ladder	4	EA	$ 1,443.20	$5,773
222	Allowance for Misc Items	5%		$ 5,772.82	$289
223	Subtotal				$6,061
224					
225	THERMAL & MOISTURE PROTECTION:				
226	Concrete Liner	0	SF	$16.00	$0
227	Allowance for Misc Items	10%		$0.00	$0
228	Subtotal				$0
229					
230	EQUIPMENT:				
231	Lamella Clarifier [WPL * PW * #P/T *# * COS(PAR)]	41,771	PLATE AREA (SF)	$ 19.45	$812,420
232	Fabricated Slide Gate	2	EA	$ 6,077.92	$12,156
233	Hoseless Sludge Collector	4	EA	$ 66,857.09	$267,428
234	Allowance for Misc Items	10%		$ 1,092,003.71	$109,200
235	Subtotal				$1,201,204
236					
237	INSTRUMENTS & CONTROLS:				
238	Instruments				
239	Turbidimeters	4	EA	$ 3,133.05	$12,532
240	Number of Analog I/O Counts	5	each	$208.82	$1,002.34
241	Number of Digital I/O Counts	24	each	$49.46	$1,186.98
242	Number of PLC's	1	each	$10,331.10	$10,331.10
243	I&C Conduit & Wire	373	LF	$9.53	$3,557.42
244	Allowance for Misc Items	10%		$28,610	$2,861.00
245	Subtotal				$31,471
246					

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	B	C	D	E	F
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
247	MECHANICAL:				
248	Solids Collection Pipe (4-inch, USL , Immersed , Steel)	343	LF	*$66.15*	$22,689
249	Solids Collection Pipe Elbows	16	each	*$439.97*	$7,040
250	Mud Valves	4	EA	*$1,974.02*	$7,896
251	Allowance for Misc Items	10%		$37,625	$3,762
252	Subtotal				$41,387
253					
254	ELECTRICAL:				
255	MCC's				
256	Sections	5	each	*$6,783.10*	$33,915
257	AFD's				
258	Sludge Collectors (total facility) (1 hp each)	-	each	*$4,248.86*	$0
259	Switchgear				
260	Units	-	each	*$31,202.24*	$0
261	Electrical Conduit & Wire	187	LF	*$9.53*	$1,778.71
262	Allowance for Misc Items	10%		$35,694	$3,569.42
263	Subtotal				$39,264
264					
265	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
266	Item 1 Description	0.00		0.00	$0
267	Item 2 Description	0.00		0.00	$0
268	Item 3 Description	0.00		0.00	$0
269	Item 4 Description	0.00		0.00	$0
270	Item 5 Description	0.00		0.00	$0
271	Item 6 Description	0.00		0.00	$0
272	Item 7 Description	0.00		0.00	$0
273	Item 8 Description	0.00		0.00	$0
274	Item 9 Description	0.00		0.00	$0
275	Item 10 Description	0.00		0.00	$0
276	Item 11 Description	0.00		0.00	$0
277	Item 12 Description	0.00		0.00	$0
278	Item 13 Description	0.00		0.00	$0
279	Item 14 Description	0.00		0.00	$0
280	Item 15 Description	0.00		0.00	$0
281	Subtotal				$0
282					
283	Subtotal				$2,704,054
284					
285	ALLOWANCES:		**User Over-write**		
286	Finishes Allowance	2.0%		$2,939,189	$58,784
287	I & C Allowance	2%		$2,939,189	$58,784
288	Mechanical Allowance	2%		$2,939,189	$58,784
289	Electrical Allowance	2%		$2,939,189	$58,784
290					
291	Facility Cost	**20,000,000**	**GPD**	**$0.15**	**$2,939,189**

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	B	C	D	E	F
188					
189	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
190					
191	SITEWORK:				
192	Excavation	4,462	CY	***$5.35***	$23,882
193	Imported Structural Backfill	743	CY	***$40.56***	$30,115
194	Native Backfill	1,137	CY	***$6.58***	$7,485
195	Haul Excess	3,325	CY	***$6.58***	$21,876
196	Allowance for Misc Items	5%		$83,357.26	$4,168
197	Subtotal				$87,525
198					
199	CONCRETE:				
200	Influent Channel:				
201	Foundation	42	CY	***$382.16***	$16,188
202	Channel Walls (Only 3 walls are covered here. The 4th wall is covered in the Flocc Basin.)	88	CY	***$683.50***	$60,362
203	Elevated Slab	25	CY	***$1,088.69***	$27,007
204	Flocc Basin				
205	Foundation	275	CY	***$382.16***	$105,198
206	Basin Walls (Only 3 walls are covered here. The Effluent wall is covered in the Influent Channel of the Lamella Clarifier)	178	CY	***$683.50***	$121,487
207	Under Baffle Wall	48	CY	***$683.50***	$32,761
208	Over Baffle Wall	48	CY	***$683.50***	$32,761
209	Elevated Slab	91	CY	***$1,088.69***	$99,593
210	Flocc Bearing Supports	42	EA	$0.00	$0
211	Electrical Room				
212	Slab on Grade	4	CY	***$345.93***	$1,435
213	Allowance for Misc Items	5%		$496,789.26	$24,839
214	Subtotal				$521,629
215					
216	MASONRY:	Moderate			
217	CMU Building	5,292	SF	***$131.60***	$696,495
218	Electrical Room	112	SF	***$131.60***	$14,739
219	Subtotal	5,404			$711,234
220					
221	METALS:				
222	Aluminum Handrail	276	LF	***$72.38***	$19,962
223	Additional Handrail with NO Building	0	LF	***$72.38***	$0
224	Stairs (1 per basin)	27	RISERS	***$394.80***	$10,507
225	Allowance for Misc Items	10%		$30,468.67	$3,047
226	Subtotal				$33,516
227					
228	WOODS & PLASTICS:				
229	FRP Weir	9	LF	$32.90	$306
230	FRP Ladder	4	EA	$1,443.17	$5,773
231	Allowance for Misc Items	5%		$6,078.43	$304
232	Subtotal				$6,382
233					
234	THERMAL & MOISTURE PROTECTION:				
235	Concrete Liner	0	SF	$16.00	$0
236	Allowance for Misc Items	10%		$0.00	$0
237	Subtotal				$0
238					
239	DOORS & WINDOWS:				
240	O/U Baffling ON/OFF Factor	*0*			
241	Serpentine Baffling ON/OFF Factor	*1*			$0
242	Stainless Steel Door (2' x 2') for O/U Baffling	0	EA	$1,052.81	$0
243	Stainless Steel Door (2' x 2') for Serpentine Baffling	4	EA	$1,052.81	$4,211
244	Stainless Steel Door (7' x 2.5')	0	EA	$4,606.05	$0
245	Allowance for Misc Items	5%		$4,211.24	$211
246	Subtotal				$4,422
247					

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	B	C	D	E	F
248	EQUIPMENT:				
249	Horizontal Paddle Wheel Flocculation Mechanism (Paddles & Drives)	0	LF	***$0.00***	$0
250	Vertical Paddle Wheel Flocculation Mechanism (Paddles & Drives)	18	EA	***$0.00***	$0
251	Vertical Turbine Flocculation Mechanism (Turbines & Drives)	24	HP	***$1,345.03***	$32,281
252	Vertical Turbine Flocculator VFD's	24	HP	***$533.15***	$12,796
253	Fabricated Slide Gate	2	EA	***$6,077.92***	$12,156
254	Allowance for Misc Items	10%		$57,232.18	$5,723
255	Subtotal				$62,955
256					
257	ELECTRICAL:				
258	*MCC's*				
259	Sections	12	each	***$6,783.10***	$81,397
260	*AFD's*				
261	Flocculation Mixers Stage 1 (total facility) (2 hp each)	6	each	***$4,371.83***	$26,231
262	Flocculation Mixers Stage 2 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
263	Flocculation Mixers Stage 3 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
264	Flocculation Mixers Stage 4 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
265	Flocculation Mixers Stage 5 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
266	Flocculation Mixers Stage 6 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
267	*Switchgear*				
268	Units	0	each	***$31,202.24***	$0
269	Electrical Conduit & Wire	1,752	lf	*$9.53*	$16,694
270	Allowance for Misc Items	10%		$175,308.86	$17,531
271	Subtotal				$192,840
272					
273	INSTRUMENTS & CONTROLS:				
274	Instruments				
275	Level Switch	2	each	*$549.53*	$1,099
276	Number of Analog I/O Counts	43	each	*$208.82*	$9,021
277	Number of Digital I/O Counts	108	each	*$49.46*	$5,341
278	Number of PLC's	1	each	*$10,331.10*	$10,331
279	I&C Conduit & Wire	1,827	lf	*$9.53*	$17,406
280	Allowance for Misc Items	10%		$43,198.52	$4,320
281	Subtotal				$47,518
282					
283	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
284	Item 1 Description	0.00		0.00	$0
285	Item 2 Description	0.00		0.00	$0
286	Item 3 Description	0.00		0.00	$0
287	Item 4 Description	0.00		0.00	$0
288	Item 5 Description	0.00		0.00	$0
289	Item 6 Description	0.00		0.00	$0
290	Item 7 Description	0.00		0.00	$0
291	Item 8 Description	0.00		0.00	$0
292	Item 9 Description	0.00		0.00	$0
293	Item 10 Description	0.00		0.00	$0
294	Item 11 Description	0.00		0.00	$0
295	Item 12 Description	0.00		0.00	$0
296	Item 13 Description	0.00		0.00	$0
297	Item 14 Description	0.00		0.00	$0
298	Item 15 Description	0.00		0.00	$0
299	Subtotal				$0
300					
301	Subtotal				$1,668,021
302					
303	ALLOWANCES:		**User Over-write**		

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	B	C	D	E	F
304	Finishes Allowance	2.0%		$1,813,066	$36,261
305	I & C Allowance	2%		$1,813,066	$36,261
306	Mechanical Allowance	2%		$1,813,066	$36,261
307	Electrical Allowance	2%		$1,813,066	$36,261
308					
309	**Facility Cost**	**20,000,000**	**GPD**	**$0.09**	**$1,813,066**

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	B	C	D	E	F
132					
133	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
134					
135	SITEWORK:				
136	Excavation	164.17	CY	$ 5.35	$879
137	Imported Structural Backfill	97.72	CY	$ 40.56	$3,963
138	Native Backfill	0.00	CY	$ 6.58	$0
139	Haul Excess	164.17	CY	$ 6.58	$1,080
140	Allowance for Misc Items	5%		$ 5,921.92	$296
141	Subtotal				$6,218
142					
143	CONCRETE:				
144	Wall Footing	10.34	CY	$ 345.93	$3,576
145	Stem Walls	0.00	CY	$ 683.50	$0
146	Slab on Grade	32.91	CY	$ 345.93	$11,385
147	Pipe Supports	14.00	EA	$ 438.67	$6,141
148	Electrical Room Slab on Grade	2.13	CY	$ 345.93	$737
149	Allowance for Misc Items	5%		$21,839	$1,092
150	Subtotal				$22,931
151					
152	MASONRY:	Moderate			
153	CMU Building	1024.14	SF	$ 131.60	$134,778
154	Electrical Room	57.56	SF	$ 131.60	$7,574
155	Subtotal	1081.69			$142,352
156					
157	EQUIPMENT:				
158	Inline Mixer (24-inch)	2.00	EA	$ 33,734.86	$67,470
159	Allowance for Misc Items	10%		$ 67,469.72	$6,747
160	Subtotal				$74,216.70
161					
162	INSTRUMENTS & CONTROLS:				
163	Instruments				
164	Mag Meter (14-inch)	2.00	EA	$ 11,797.27	$23,595
165	pH / Temperature	1.00	EA	$ 2,093.45	$2,093
166	Turbidity	1.00	EA	$ 3,133.05	$3,133
167	Streaming Current Detector	0.00	EA	$ 10,680.85	$0
168	UV Absorbance	1.00	EA	$ 21,794.63	$21,795
169	Conductivity	0.00	EA	$ 2,057.84	$0
170	Sample Panels	2.00	EA	$ 3,948.04	$7,896
171	Isolation Valve Actuators	4.00	each	$5,064.93	$20,260
172	Flow Control Valve Actuators	2.00	each	$5,064.93	$10,130
173	Number of Analog I/O Counts	12.00	each	$208.82	$2,506
174	Number of Digital I/O Counts	33.60	each	$49.46	$1,662
175	Number of PLC's	1.00	each	$10,331.10	$10,331
176	I&C Conduit & Wire	633.99	lf	$9.53	$6,041
177	Allowance for Misc Items	10%		$ 109,441.19	$10,944
178	Subtotal				$120,385
179					
180	CONVEYING SYSTEMS:				
181	Monorail Hoist (3 Ton)	1.00	EA	$ 55,749.49	$55,749
182	Hoist Rail	118.04	LF	$ 28.96	$3,418
183	Allowance for Misc Items	10%		$ 59,167.41	$5,917
184	Subtotal				$65,084
185					
186	MECHANICAL:				
187	Pipe:				
188	Rapid Mix Pipe (24-inch, RW, Exposed ,Steel ,Cement Mortar ,Paint)	40.00	lf	$438.33	$17,533

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	B	C	D	E	F
189	Flow Control Pipe (14-inch, FCP, Exposed ,Steel ,Cement Mortar ,Paint)	18.67	lf	*$255.69*	$4,773
190	Elbows:				
191	Rapid Mix Pipe (24-inch)	4.00	each	*$2,639.84*	$10,559
192	Valves:				
193	Rapid Mix Isolation Valves (24-inch)	4.00	each	*$19,307.12*	$77,228
194	Flow Control Valve (14-inch)	2.00	each	*$11,262.48*	$22,525
195	Allowance for Misc Items	10%		$132,619.04	$13,262
196	Subtotal				$145,881
197					
198	ELECTRICAL:				
199	MCC's				
200	Sections	5.00	each	*$6,783.10*	$33,915
201	AFD's				
202	Mechanical Mixers (4 hp each)	0.00	each	*$4,617.76*	$0
203	Switchgear				
204	Units	0.00	each	*$31,202.24*	$0
205	Electrical Conduit & Wire	97.54	lf	*$9.53*	$929
206	Allowance for Misc Items	10%		$34,845	$3,484
207	Subtotal				$38,329
208					
209	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
210	Item 1 Description	0.00		0.00	$0
211	Item 2 Description	0.00		0.00	$0
212	Item 3 Description	0.00		0.00	$0
213	Item 4 Description	0.00		0.00	$0
214	Item 5 Description	0.00		0.00	$0
215	Item 6 Description	0.00		0.00	$0
216	Item 7 Description	0.00		0.00	$0
217	Item 8 Description	0.00		0.00	$0
218	Item 9 Description	0.00		0.00	$0
219	Item 10 Description	0.00		0.00	$0
220	Item 11 Description	0.00		0.00	$0
221	Item 12 Description	0.00		0.00	$0
222	Item 13 Description	0.00		0.00	$0
223	Item 14 Description	0.00		0.00	$0
224	Item 15 Description	0.00		0.00	$0
225	Subtotal				$0
226					
227	Subtotal				$615,398
228					
229	ALLOWANCES:		**User Over-write**		
230	Finishes Allowance	2.0%		$699,316	$13,986
231	I & C Allowance	5%		$699,316	$34,966
232	Mechanical Allowance	0%		$699,316	$0
233	Electrical Allowance	5%		$699,316	$34,966
234					
235	Facility Cost	**20,000,000**	**GPD**	**$0.03**	**$699,316**

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Alternative 2 Finished Water pipeline

Pipelines		**$25,322,000**
10% allowance for pipeline valves & appurtenances		**$2,533,000**
Pipeline Construction Cost		**$27,855,000**
Pipeline Construction Cost		**$27,855,000**
3% markup for Bonds & Insurance	$836,000	
5% markup for Mob/Demob	$1,393,000	
8% markup for Contractors Overhead	$2,340,000	
4% markup for Contractors profit	$1,264,000	
25% Contingency	$8,422,000	
Subtotal Markups and Contingency		**$14,255,000**
Total Project Construction Costs		**$42,110,000**
8% allowance for pipeline engineering and design	3,369,000	
12% allowance for permitting, legal and administration	5,054,000	
8% allowance for pipeline engr services during construction	3,369,000	
Subtotal Other Project Costs		**$11,792,000**
GRAND TOTAL PROJECT COST		**$53,902,000**

Alternative 2 - Shallow Aquifer Finished Water Transmission Main

Water Forcemain		
Segment	Miles	Diameter
A	6	36
B	5	36

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$2,194,284	Co. Rd I, wetland
2	$2,965,248	In Co HWY H
3	$2,280,960	In Oakdale
4	$2,335,133	In Oakdale, cross Les Paul
5	$2,302,629	In Sunset Drive, cross SW Ave
6	$2,734,871	In NW Ave, cross College
7	$4,023,920	NW Ave to Main, at Fox River
8	$7,234	Main Street, businesses
9	$4,492,693	In Co. Road Y, wetland, cross 164
10	$1,984,435	City streets, Open country to Hillcrest
subtotal	**$25,321,406**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	320	320
Low urban	1.00	432	432
Medium urban	1.19	514	514
High urban	1.37	592	592
Groundwater	**1.30**	**562**	**562**
Forest	1.15	497	497
Gravel roads	0.85	367	367
Creek crossing	2.00	864	864
HWY crossing	4.00	1728	1728

miles	0.13	0.25	0.5
feet	660	1320	2640
	4620	3960	2640

Alternative 2 - Distribution

Pipelines		**$7,695,000**
10% allowance for pipeline valves & appurtenances		**$770,000**
Pipeline Construction Cost		**$8,465,000**
Pipeline Construction Cost		**$8,465,000**
3% markup for Bonds & Insurance	$254,000	
5% markup for Mob/Demob	$424,000	
8% markup for Contractors Overhead	$712,000	
4% markup for Contractors profit	$385,000	
25% Contingency	$2,560,000	
Subtotal Markups and Contingency		**$4,335,000**
Total Project Construction Costs		**$12,800,000**
5% allowance for pipeline engineering and design	768,000	
12% allowance for permitting, legal and administration	640,000	
08% allowance for pipeline engr services during construction	1,024,000	
Subtotal Other Project Costs		**$2,432,000**
GRAND TOTAL PROJECT COST		**$15,232,000**

O&M Costs Alternative 2 - Shallow and Fox River Alluvium

Source of Supply	Units	Quantity	Unit Cost	Ext. Cost	$/yr	Totals
Well pumping/maintenance	$/1000 gal	3,978,500	$ 0.140	$ 556,990	$ 556,990	
Total Supply						$ 556,990

Treatment/Pumping	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
Treatment Plant/Pump station					$3,558,904	
Residuals	$/1000 gal	79570	$ 4	$ 318,280	$ 318,280	
Total Treatment/Pumping						$ 3,877,184

Transmission	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
O&M	$/lf/yr	108,281	$ 0.52	$ 56,306	$ 56,306	
Total Transmission						$ 56,306

Home Softening	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
Salt/Equipment/Replacment	1				$ 2,863,894	
						$ 2,863,894

Alternative Total O&M ($/yr.)	**$ 7,400,000**
PRESENT WORTH (6%, 20 yrs)	**$ 85,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 117,000,000**

C H2M HILL P arametric Cost E stimating S ystem (CPES)

FACILITIES LIFE CYCLE COST ANALYSIS

File Version: 1/5/2010

Import File: C:\Documents and Settings\tnading\Desktop\waukesha\Waukesha WTP.xls

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Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months)	24
Mid-Point of Construction:	Jan/2012

Life Cycle Analysis:
i = 6.00%
n = 25
Annual Inflation %: 4.50%

To Global Life Cycle Data Sheet

To Annual O & M Cost Summary Sheet

☑ This Report is for INTERNAL Distribution
☐ This Report is for EXTERNAL Distribution

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Construction Cost	Annual O&M Cost (Escalated)	Life Cycle Cost (NPV)
	Yes	Inline Rapid Mix: RMX	$1,224,509	$11,448	$1,370,850
	Yes	Flocculation: FLOC	$3,174,699	$29,495	$3,551,743
	Yes	Lamella Clarifier: LAM	$5,146,551	$85,072	$6,234,044
	Yes	Filters: FILT	$11,540,743	$87,491	$12,659,160
	Yes	Surge Basin-Decanter: BWW	$2,687,313	$33,462	$3,115,069
	Yes	UV Disinfection: UVD	$2,348,574	$82,195	$3,399,292
	Yes	Concrete Clearwell: FWT	$2,297,940	$1,092	$2,311,899
	No	Steel Clearwell: FWT	$0	$0	$0
	No	In-Plant PS: FWPS	$0	$0	$0
	Yes	Vertical Turbine PS: FWPS	$7,410,535	$1,119,793	$21,725,243
	Yes	Filter BW PS: BWSPS	$1,927,296	$37,318	$2,404,344
	Yes	U.D. Facility: GEN	$0	$0	$0
	Yes	Liquid Chemical: FeCl3	$692,505	$361,992	$5,319,976
	Yes	Liquid Chemical: NaOCl	$518,039	$156,934	$2,524,178
	Yes	Liquid Chemical: FLUOR	$330,287	$11,746	$480,429
	Yes	Liquid Chemical: POLYPHOS	$362,245	$63,504	$1,174,039
	Yes	O&M Building: OMB	$8,312,125	$157,639	$10,327,270
		Additional Project Costs:			
		Biosolids Disposal	$0	$0	$0
		Standard Items	$17,422,556	$499,001	$23,801,456
		User Defined Items	$0	$0	$0
		Plant O & M Labor		$782,831	$10,007,198
TOTAL - Life Cycle Analysis			$65,395,917	$3,521,013	$110,406,190

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Rapid Mixing (Inline)

To Summary Sheet

Construction Cost:					$1,224,509
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	8	50%	8,760	$ 0.06	$ 1,463
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,082	2.00	8,760	$ 0.06	$ 1,062
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 3,267
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 5,792	10.0%	$ 579
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 6,371
Contingency				10%	$ 637
Total Annual O&M Cost					$ 7,008

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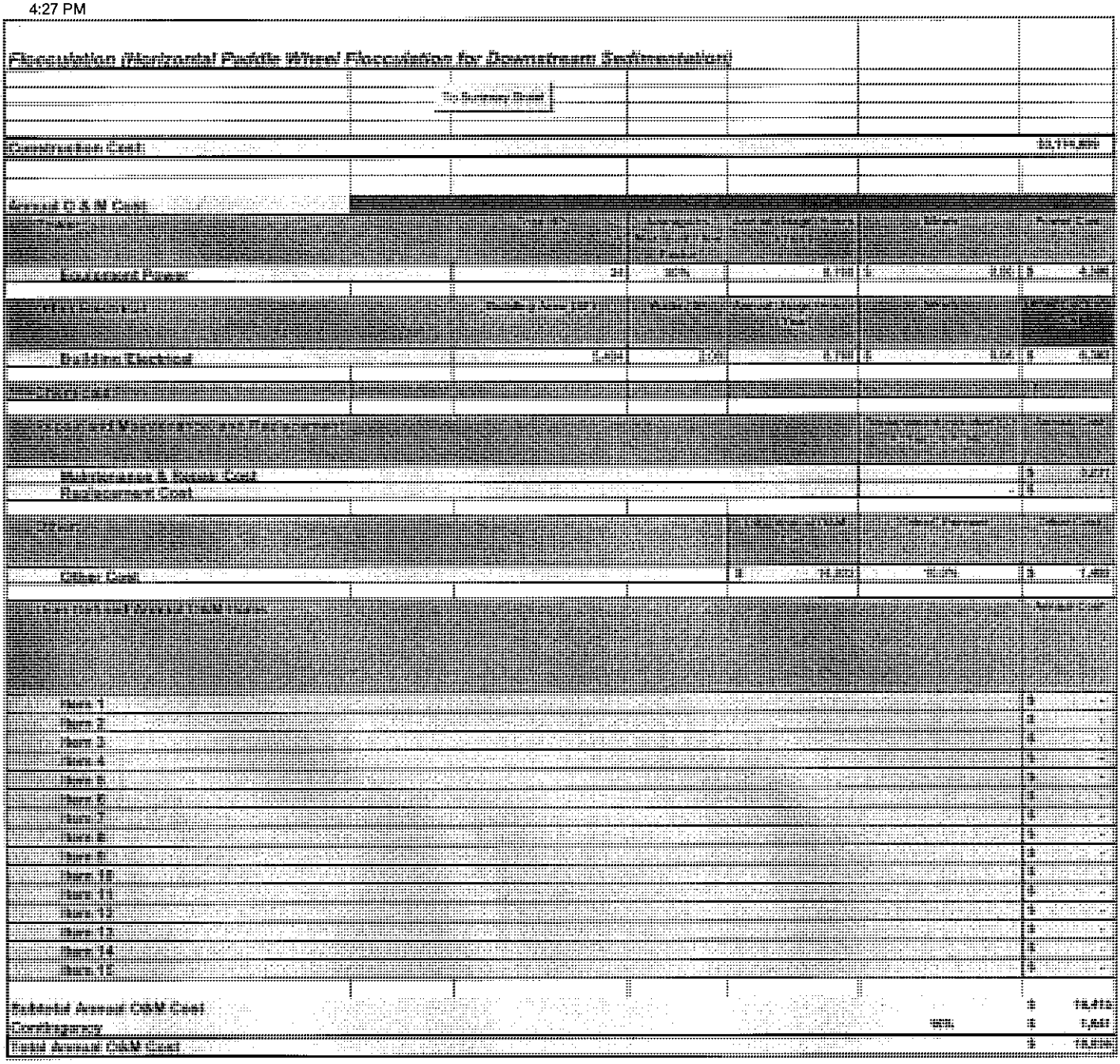

Flocculation (Horizontal Paddle Wheel Flocculation for Downstream Sedimentation)

To Summary Sheet

Construction Cost:						[illegible]
Annual O & M Cost:						
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Equipment Power		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Building Electrical		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]						
[illegible]					[illegible]	[illegible]
Maintenance & Repair Cost						[illegible]
Replacement Cost					-	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]
Other Cost				[illegible]	[illegible]	[illegible]
[illegible]						[illegible]
Item 1						[illegible]
Item 2						[illegible]
Item 3						[illegible]
Item 4						[illegible]
Item 5						[illegible]
Item 6						[illegible]
Item 7						[illegible]
Item 8						[illegible]
Item 9						[illegible]
Item 10						[illegible]
Item 11						[illegible]
Item 12						[illegible]
Item 13						[illegible]
Item 14						[illegible]
Item 15						[illegible]
Subtotal Annual O&M Cost						[illegible]
Contingency					[illegible]	[illegible]
Total Annual O&M Cost						[illegible]

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Lamella Clarifier

To Summary Sheet

Construction Cost:					$5,146,551
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	4	50%	8,760	$ 0.06	$ 732
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	5,572	2.00	8,760	$ 0.06	$ 5,467
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 36,842
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 43,040	10.0%	$ 4,304
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 47,344
Contingency				10%	$ 4,734
Total Annual O&M Cost					$ 52,079

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Filters

To Summary Sheet

Construction Cost: $11,540,742

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	8	50%	8,760	$ 0.06	$ 1,463

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	10,239	2.00	8,760	$ 0.06	$ 10,046

Chemicals:	Annual Usage (tons)	Annual Facility Usage (% of year)	$/ton	Chemical Cost
GAC	-	100%	$ 2,400.00	$ -
Total Chemical Cost				$ -

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 32,755
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 44,264	10.0%	$ 4,426

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

Subtotal Annual O&M Cost		$ 48,691
Contingency	10%	$ 4,869
Total Annual O&M Cost		$ 53,560

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Large System Combination Wastewater Surge Basin and Floating Tube Decanter Clarification (>= 5 MGD)

To Summary Sheet

Construction Cost:					**$2,687,312**
Annual O & M Cost:					
Power:	**Total HP**	**Average-to-Maximum Flow Factor**	**Annual Usage (Hours / Year)**	**$/kwh**	**Power Cost**
Equipment Power	43	50%	8,760	$ 0.06	$ 7,865
Other Electrical:	**Building Area (SF)**	**Watts / SF**	**Annual Usage (Hours / Year)**	**$/kwh**	**Other Electrical Cost**
Building Electrical	81	2.00	8,760	$ 0.06	$ 79
Chemicals:					$ -
Repair and Maintenance, and Replacement:				**Replacement Included? (1 = "Yes", 0 = "No")**	**Annual Cost**
Maintenance & Repair Cost					$ 8,985
Replacement Cost				-	$ -
Other:			**Total Annual O&M Cost**	**"Other" Percent**	**Other Cost**
Other Cost			$ 16,930	10.0%	$ 1,693
User Defined Annual O&M Items:					**Annual Cost**
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 18,622
Contingency				10%	$ 1,862
Total Annual O&M Cost					$ 20,485

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UV Disinfection

To Summary Sheet

Construction Cost:					$2,348,574
Annual O & M Cost:					
Power:	Total kw	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	42	50%	8,760	$ 0.06	$ 10,400
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,547	2.00	8,760	$ 0.06	$ 1,517
Specialty Items:				Number per Replacement / Recalibration	Cost
Lamp Replacement				8	$ 6,017
Lamp Replacement Frequency (hrs)	4,000	Fixed			
Input Lamp Cost	$ 350.00	Default = $350			
Ballast Replacement				8	$ 2,178
Input Ballast Replacement Frequency (yrs)	10	Typically 10 years			
Input Ballast Cost	$ 4,000.00	Default = $4,000			
Sleeve Replacement				8	$ 432
Input Sleeve Replacement Frequency (yrs)	3	Typically 3 to 5 years			
Input Sleeve Cost	$ 175.00	Default = $175			
Intensity Sensor Replacement				8	$ 3,502
Input Intensity Sensor Replacement Frequency (yrs)	5	Typically 3 to 5 years			
Input Intensity Sensor Cost	$ 2,750.00	Default = $2,750			
Intensity Sensor Recalibration		Annual Calibration except during Replacement Years			$ 3,363
Input Cost of Single Sensor Recalibration (each)	$ 500.00	Default = $500			
Total Specialty Items					$ 15,492
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 14,175
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			41,585	10.0%	$ 4,158
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -

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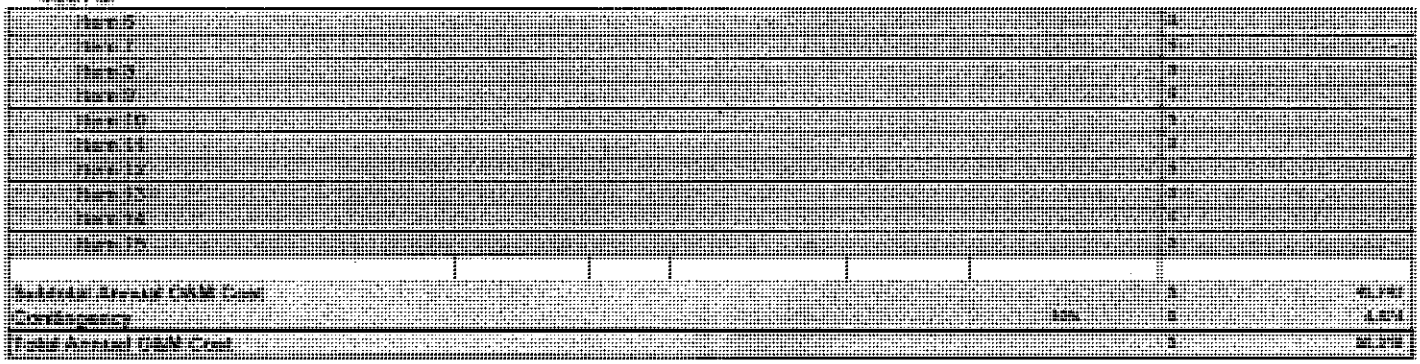

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Concrete Tank

To Summary Sheet

Construction Cost:						$2,297,940
Annual O & M Cost:						
Power:		Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
	Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:		Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
	Building Electrical	-	2.00	8,760	$ 0.06	$ -
Chemicals:						$ -
Repair and Maintenance, and Replacement:					Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
	Maintenance & Repair Cost					$ 552
	Replacement Cost				-	$ -
Other:				Total Annual O&M Cost	"Other" Percent	Other Cost
	Other Cost			$ 552	10.0%	$ 55
User Defined Annual O&M Items:						Annual Cost
	Item 1					$ -
	Item 2					$ -
	Item 3					$ -
	Item 4					$ -
	Item 5					$ -
	Item 6					$ -
	Item 7					$ -
	Item 8					$ -
	Item 9					$ -
	Item 10					$ -
	Item 11					$ -
	Item 12					$ -
	Item 13					$ -
	Item 14					$ -
	Item 15					$ -
Subtotal Annual O&M Cost						$ 608
Contingency					10%	$ 61
Total Annual O&M Cost						$ 668

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Vertical Turbine Pump Station

To Summary Sheet

Construction Cost:					$7,410,535
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2,800	50%	8,760	$ 0.06	$ 512,135
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	4,513	2.00	8,760	$ 0.06	$ 4,428
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 49,977
Replacement Cost			-	-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 566,540	10.0%	$ 56,654
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 623,194
Contingency				10%	$ 62,319
Total Annual O&M Cost					$ 685,513

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Granular Media Filter Backwash Supply Pump Station

To Summary Sheet

Construction Cost:	**$1,927,295**

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	21	50%	8,760	$ 0.06	$ 3,841

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	988	2.00	8,760	$ 0.06	$ 969
Chemicals:					$ -

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 14,070
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 18,880	10.0%	$ 1,888

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

Subtotal Annual O&M Cost		$ 20,768
Contingency	10%	$ 2,077
Total Annual O&M Cost		$ 22,845

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $692,504

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	3	50%	8,760	$ 0.06	$ 549

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,226	2.00	8,760	$ 0.06	$ 1,203

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	457	$ 782.93	$ 178,749
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 178,749

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 2,643
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 183,144	10.0%	$ 18,314

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$ 201,458
Contingency					10%	$ 20,146
Total Annual O&M Cost						$ 221,604

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $518,038

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,050	2.00	8,760	$ 0.06	$ 1,030

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	91	$ 1,672.13	$ 76,352
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 76,352

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 1,650
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 79,398	10.0%	$ 7,940

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$ 87,338
Contingency					10%	$ 8,734
Total Annual O&M Cost						$ 96,071

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost:	$330,287

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	714	2.00	8,760	$ 0.06	$ 701

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	24	$ 360.00	$ 4,384
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 4,384

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 492
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 5,942	10.0%	$ 594

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$ 6,536
Contingency					10%	$ 654
Total Annual O&M Cost						$ 7,190

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $362,245

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	840	2.00	8,760	$ 0.06	$ 824

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	30	$ 2,000.00	$ 30,441
Total Chemical Cost					$ 30,441

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 498
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 32,129	10.0%	$ 3,213

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost						$	35,342
Contingency					10%	$	3,534
Total Annual O&M Cost						$	38,876

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O & M Building

To Summary Sheet

Construction Cost:					**$8,312,124**
Annual O & M Cost:					
Power:	**Total HP**	**Average-to-Maximum Flow Factor**	**Annual Usage (Hours / Year)**	**$/kwh**	**Power Cost**
Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:	**Building Area (SF)**	**Watts / SF**	**Annual Usage (Hours / Year)**	**$/kwh**	**Other Electrical Cost**
Building Electrical	10,000	2.00	8,760	$ 0.06	$ 9,811
Chemicals:					$ -
Repair and Maintenance, and Replacement:				**Replacement Included? (1 = "Yes", 0 = "No")**	**Annual Cost**
Maintenance & Repair Cost					$ 69,943
Replacement Cost				-	$ -
Other:			**Total Annual O&M Cost**	**"Other" Percent**	**Other Cost**
Other Cost			$ 79,754	10.0%	$ 7,975
User Defined Annual O&M Items:					**Annual Cost**
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 87,730
Contingency				10%	$ 8,773
Total Annual O&M Cost					$ 96,503

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To Summary Sheet

Standard Additional Project Costs

Standard Additional Project Cost Item	Total Construction Cost	Total Construction Cost Appropriate Repair & Maintenance
Demolition	$ -	
Overall Sitework	$ [illegible]	
Plant Computer System	$ [illegible]	$ [illegible]
Yard Electrical	$ [illegible]	$ [illegible]
Yard Piping	$ [illegible]	$ [illegible]
Total	$ [illegible]	$ [illegible]

Annual O & M Cost			
Repair and Maintenance	[illegible]	[illegible]	[illegible]
Repair and Maintenance Cost	$ [illegible]	[illegible]	$ [illegible]
Replacement Cost		[illegible]	$

Other	[illegible]	[illegible]	[illegible]
Other Cost	$ [illegible]	[illegible]	$ [illegible]

User Defined Annual O&M Items		Annual Cost
Item 1		$ -
Item 2		$ -
Item 3		$ -
Item 4		$ -
Item 5		$ -
Item 6		$ -
Item 7		$ -
Item 8		$ -
Item 9		$ -
Item 10		$ -
Item 11		$ -
Item 12		$ -
Item 13		$ -
Item 14		$ -
Item 15		$ -

Subtotal Annual O&M Cost		$	277,707
Contingency	10%	$	27,771
Total Annual O&M Cost		$	305,477

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Alternative 3:
Lake Michigan Water

Alternative 3 - Lake Michigan Water		
Supply Pipeline		**$35,020,000**
10% allowance for pipeline valves & appurtenances		**$3,502,000**
Subtotal Pipeline Construction Cost		**$38,522,000**
Parkway Booster Station		**$8,573,000**
Subtotal Supply System Construction Cost		**$47,095,000**
Return Pipeline/Pump station to Underwood Creek		**$ 29,023,000**
Distribution System Improvements		**$ 8,465,000**
Subtotal Construction Cost		**$ 84,583,000**
3% markup for Bonds & Insurance	$2,538,000	
5% markup for Mob/Demob	$4,230,000	
8% markup for Contractors Overhead	$7,309,000	
4% markup for Contractors profit	$3,655,000	
25% Contingency	$25,579,000	
Subtotal Markups and Contingency		**$43,311,000**
Total Project Construction Costs		**$127,894,000**
8% allowance for pipeline engineering and design	10,232,000	
12% allowance for permitting, legal and administration	15,348,000	
8% allowance for pipeline engr services during constructio	10,232,000	
Subtotal Other Project Costs		**$35,812,000**
TOTAL PROJECT CAPITAL COST		**$164,000,000**

Alternative 3 - Milwaukee Water Supply

Pipeline Segment	Miles	Diameter	
A	9	36	432
B	3	36	432

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$3,991,680	In Howard Ave, cross HWY 894, 60th
2	$2,335,133	In Howard Ave, cross 76th, cross 84th, cross 92nd
3	$3,190,493	In Howard Ave, cross HWY 45, cross 104th
4	$2,720,045	In Howard Ave, cross HWY 100, cross Beliot Rd, in pkwy, cross Morgan Ave
5	$3,736,212	In pkwy, cross Oklahoma, cross National, cross Cleveland
6	$3,024,553	0.5 mi pkwy, 0.5 mi in 124th Street
7	$1,984,435	In 124th, cross 124th street, Utility corridor (Oak Leaf)
8	$2,047,162	Utility corridor, cross Sunnyslope, cross Moorland
9	$1,816,214	Utility corridor, cross Calhoun
10	$2,194,284	Utility corridor
11	$2,194,284	Utility corridor
12	$1,816,214	Utility corridor, cross Springdale
13	$2,280,960	Cotton Crt
14	$1,687,910	Open country
subtotal	**$35,019,579**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	320	320
Low urban	1.00	432	432
Medium urban	1.19	514	514
High urban	1.37	592	592
Groundwater	1.30	562	562
Forest	1.15	497	497
Gravel roads	0.85	367	367
Creek crossing	2.00	864	864
HWY crossing	4.00	1728	1728

miles	0.13	0.25	0.5
feet	660	1320	2640
	4620	3960	2640

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	455.19	CY	***$5.35***	$2,436
Imported Structural Backfill	576.89	CY	***$40.56***	$23,396
Native Backfill	21.83	CY	***$6.58***	$144
Haul Excess	433.36	CY	***$6.58***	$2,852
Forebay:				
Excavation	943.32	CY	***$5.35***	$0
Imported Structural Backfill	575.02	CY	***$40.56***	$0
Native Backfill	75.56	CY	***$6.58***	$0
Haul Excess	867.76	CY	***$6.58***	$0
Office:				
Excavation	0.00	CY	***$5.35***	$0
Imported Structural Backfill	0.00	CY	***$40.56***	$0
Native Backfill	0.00	CY	***$6.58***	$0
Haul Excess	0.00	CY	***$6.58***	$0
Surge Protection:				
Excavation	266.84	CY	***$5.35***	$1,428
Imported Structural Backfill	146.42	CY	***$40.56***	$5,938
Native Backfill	43.02	CY	***$6.58***	$283
Haul Excess	223.81	CY	***$6.58***	$1,473
Allowance for Misc Items	5%		$37,949.28	$1,897
Subtotal				$39,847
CONCRETE:				
Pump Station				
Foundation	342.13	CY	***$382.16***	$130,747
Support Walls	0.00	CY	***$683.50***	$0
Support Columns	0.00	CY	***$683.50***	$0
Pump Pad Epoxy	2.48	CY	$3,412.56	$8,449
Pump Pad Support	50.52	CY	***$345.93***	$17,476
Pipe Supports	2.74	CY	***$345.93***	$950
Mezzanine				
Elevated Slab	0.00	CY	***$1,088.69***	$0
Electrical Room				
Foundation	58.69	CY	***$345.93***	$20,303
Surge Protection				
Foundation	75.51	CY	***$345.93***	$26,120
Office				
Foundation	0.00	CY	***$345.93***	$0
Pump Station Forebay				
Slab on Grade for Steel Tank	346.49	CY	***$345.93***	$0
Prestressed Concrete Tank (654765 gallons)	0.00	EA	***$0.00***	$0
Outlet Box	5.91	CY	***$382.16***	$2,258
Allowance for Misc Items	5%		$206,302.68	$10,315
Subtotal				$216,618
MASONRY:	**Moderate**			
Pump Station Building	4077.42	SF	***$197.40***	$804,890
Office Building	0.00	SF	***$131.60***	$0
Surge Building	1019.35	SF	***$131.60***	$134,148
Electrical Room	1584.66	SF	***$131.60***	$208,543
Subtotal	6681.43			$1,147,582

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METALS:				
Metal Guardrail with Pickets	0.00	LF	***$72.38***	$0
Stairs = IF Mezzanine = 10 * 12/8	0.00	Risers	***$394.80***	$0
Pump Removal Hatches	191.04	SF	***$109.91***	$20,997
Ladder	0.00	VLF	***$99.36***	$0
Allowance for Misc Items	10%		$20,996.63	$2,100
Subtotal				$23,096
THERMAL & MOISTURE PROTECTION:				
Wet Well Liner	0.00	SF	***$16.00***	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	1000.00	HP	***$249.00***	$249,000
Active Pump # 2	1000.00	HP	***$249.00***	$249,000
Active Pump # 3	1000.00	HP	***$249.00***	$249,000
Active Pump # 4	0.00	HP	***$0.00***	$0
Active Pump # 5	0.00	HP	***$0.00***	$0
Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	1000.00	HP	***$249.00***	$249,000
Steel Forebay Tank (654765 gallons)	1.00	EA	*$278,348.80*	$0
Allowance for Misc Items	10%		$996,000.47	$99,600
Subtotal				$1,095,601
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	8.00	each	***$5,064.93***	$40,519
Control Valve Actuators	4.00	each	***$5,064.93***	$20,260
Level Indicator Transmitters	2.00	each	*$6,764.54*	$13,529
Level Swithces	2.00	each	*$7,120.57*	$14,241
Pressure Indicator Transmitters	5.00	each	*$7,120.57*	$35,603
Pressure Switches	8.00	each	*$7,120.57*	$56,965
Number of Analog I/O Counts	31.20	each	*$208.82*	$6,515
Number of Digital I/O Counts	84.00	each	*$49.46*	$4,154
Number of PLC's	4.00	each	*$10,331.10*	$41,324
I&C Conduit & Wire	2347.84	lf	*$9.53*	$22,372
Allowance for Misc Items	10%		$ 255,482.85	$25,548
Subtotal				$281,031
CONVEYING SYSTEMS				
Bridge Crane	0.00	EA	*$55,749.49*	$0
Bridge Crane Rail	0.00	LF	*$28.96*	$0
Allowance for Misc Items	10%		$ -	$0
Subtotal				$ -
MECHANICAL:				
Pipe:				
Suction Header Pipe (30-inch,SUC, Buried, Steel, Cement Mortar, Tape Coating)	66.96	LF	*$744.31*	$49,839
Suction Lateral Pipe (20-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	46.67	LF	*$491.38*	$22,931

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Discharge Lateral Pipe (18-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	36.00	LF	*$440.79*	$15,868
Discharge Header Pipe (30-inch,DIS, Buried, Steel, Cement Mortar, Tape Coating)	66.96	LF	*$744.31*	$49,839
Pump Suction Pipe (12-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	4.00	LF	*$289.03*	$1,156
Pump Discharge Pipe (8-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	2.67	LF	*$187.86*	$501
Elbows:				
Discharge Lateral Pipe (18-inch)	4.00	EA	*$1,597.76*	$6,391
Discharge Header Pipe (30-inch)	2.00	EA	*$2,831.95*	$5,664
Tees:				
Suction Header Pipe (30-inch)	4.00	EA	*$5,509.28*	$22,037
Discharge Header Pipe (30-inch)	4.00	EA	*$5,509.28*	$22,037
Valves:				
Suction Header Isolation Valve (30-inch, BFV)	1.00	EA	*$5,934.12*	$5,934
Suction Lateral Isolation Valve (20-inch, BFV)	4.00	EA	*$3,545.34*	$14,181
Discharge Lateral Isolation Valve (18-inch, BFV)	4.00	EA	*$2,759.13*	$11,037
Pump Control Valve (18-inch, Butterfly Valve)	4.00	EA	*$2,759.13*	$11,037
Discharge Header Isolation Valve (30-inch, BFV)	1.00	EA	*$5,934.12*	$5,934
Air Release Vacuum Valves	12.00	EA	*$3,297.16*	$39,566
Allowance for Misc Items	10%		$283,952.56	$28,395
Subtotal				$312,348
ELECTRICAL:				
MCC's				
Sections	3.00	each	*$6,783.10*	$20,349
AFD's				
Active Pump # 1	1000.00	HP	*$127.09*	$127,092
Active Pump # 2	1000.00	HP	*$127.09*	$127,092
Active Pump # 3	1000.00	HP	*$127.09*	$127,092
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	1000.00	HP	*$127.09*	$127,092
Switchgear				
Units	7.00	each	*$31,202.24*	$218,416
Electrical Conduit & Wire	323.84	lf	*$9.53*	$3,086
Allowance for Misc Items	5%		$750,220	$37,511
Subtotal				$787,731
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
75,000 gallon welded steel tank, foundation	1.00		150000.00	$150,000
Standby Generator	1.00		1000000.00	$1,000,000
Land	1.00		250000.00	$250,000
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$1,400,000
Subtotal				$5,303,853

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ALLOWANCES:		User Over-write		
Finishes Allowance	2%		$8,578,122	$171,562
I & C Allowance	2%	4%	$8,578,122	$349,130
Surge Allowance	5%	10%	$8,578,122	$857,812
Mechanical Allowance	2%	15%	$8,578,122	$1,286,718
Electrical Allowance	5%	7%	$8,578,122	$609,047
Facility Cost	**4,000**	**Total Pump HP**	**$2,144.53**	**$8,578,122**

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	Return Flow Underwood Creek (18.5 mgd, 36" dia)		
	Pipelines		**$23,195,000**
	10% allowance for pipeline valves & appurtenances		**$2,320,000**
	Pipeline Construction Cost		**$25,515,000**
	WWTP Effluent Pump Station		**$3,508,000**
	Conveyance System Construction Cost		**$29,023,000**
	3% markup for Bonds & Insurance	$871,000	
	5% markup for Mob/Demob	$1,452,000	
	8% markup for Contractors Overhead	$2,508,000	
	4% markup for Contractors profit	$1,254,000	
	25% Contingency	$8,777,000	
	Subtotal Markups and Contingency		**$14,862,000**
	Total Project Construction Costs		**$43,885,000**
	8% allowance for pipeline engineering and design	3,511,000	
	12% allowance for permitting, legal and administration	5,267,000	
	8% allowance for pipeline engr services during construction	3,511,000	
	Subtotal Other Project Costs		**$12,289,000**
	GRAND TOTAL PROJECT COST		**$56,174,000**

Alternative 3 - Underwood Creek Return Flow

Pipeline Segment		Diameter
A		36
B		36

Unit cost	$/dia-in	12

Mile	Cost		Comments
1	$2,389,306		0.75 mi follows river, crosses Prairie ave, Marshall and Dunbar, 0.25 under alley to NW ave
2	$2,389,306		Cross Maple, Grand, Barstow, East, Barney, Hartwell, crossing of E Broadway (major street); end at Oakland
3	$3,290,285		follows path (cross Greendale and Frederick), cross East Side bypass HYW 59 (MAJOR)
4	$1,836,971	70%	Follows New Berlin trail/utility corridor, cross Springdale;also a stream crossing, some forest; ends near stream crossing
5	$1,555,159	70%	Follows trail, open country mostly, some forest, wetlands for 0.5 mi; assume groundwater; ends near wetlands/open water pond
6	$1,247,001	70%	Follows trail, open country mostly, some forest (assume 10%)
7	$1,700,456	70%	Begins near Calhoun, one stream crossing; becoming urban again but still follows trail and is mostly open, crosses Calhoun and ends near Moorland, assume 10% forest
8	$1,181,537	70%	Still in trail, no crossings; very open; Ends near Sunnyslope Rd
9	$1,181,537	70%	Still in trail, no crossings; very open; Ends at 124th st
10	$2,623,104		Going north under 124th st, crosses Greenfield (hwy 59), ends near 124th and Zinke Dr
11	$3,800,079		Last section follows Underwood Creek, Crosses I-94
subtotal	**$23,194,740**		

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf
Open country	0.74	320
Low urban	1.00	432
Medium urban	1.19	514
High urban	1.37	592
Groundwater	**1.30**	**562**
Forest	1.15	497
Gravel roads	0.85	367
Creek crossing	2.00	864
HWY crossing	4.00	1728

miles	0.13	0.25
feet	660	1320
	4620	3960

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	639.92	CY	***$5.28***	$3,381
Imported Structural Backfill	532.57	CY	***$40.04***	$21,322
Native Backfill	38.78	CY	***$6.50***	$252
Haul Excess	601.13	CY	***$6.50***	$3,905
Forebay:				
Excavation	0.00	CY	***$5.28***	$0
Imported Structural Backfill	0.00	CY	***$40.04***	$0
Native Backfill	0.00	CY	***$6.50***	$0
Haul Excess	0.00	CY	***$6.50***	$0
Office:				
Excavation	0.00	CY	***$5.28***	$0
Imported Structural Backfill	0.00	CY	***$40.04***	$0
Native Backfill	0.00	CY	***$6.50***	$0
Haul Excess	0.00	CY	***$6.50***	$0
Surge Protection:				
Excavation	385.95	CY	***$5.28***	$2,039
Imported Structural Backfill	201.65	CY	***$40.04***	$8,073
Native Backfill	75.73	CY	***$6.50***	$492
Haul Excess	310.22	CY	***$6.50***	$2,015
Allowance for Misc Items	5%		$41,478.65	$2,074
Subtotal				$43,553
CONCRETE:				
Pump Station				
Foundation	482.04	CY	***$382.16***	$184,218
Support Walls	0.00	CY	***$683.50***	$0
Support Columns	10.37	CY	***$683.50***	$7,088
Pump Pad Epoxy	2.20	CY	$3,368.81	$7,401
Pump Pad Support	24.15	CY	***$345.93***	$8,354
Pipe Supports	29.63	CY	***$345.93***	$10,250
Mezzanine				
Elevated Slab	0.00	CY	***$1,088.69***	$0
Electrical Room				
Foundation	13.23	CY	***$345.93***	$4,577
Surge Protection				
Foundation	108.47	CY	***$345.93***	$37,524
Office				
Foundation	0.00	CY	***$345.93***	$0
Pump Station Forebay				
Slab on Grade for Steel Tank	0.00	CY	***$345.93***	$0
Prestressed Concrete Tank (0 gallons)	0.00	EA	***$0.00***	$0
Outlet Box	9.91	CY	***$382.16***	$3,786
Allowance for Misc Items	5%		$263,196.94	$13,160
Subtotal				$276,357
MASONRY:	Moderate			
Pump Station Building	5857.49	SF	***$194.87***	$1,141,458
Office Building	0.00	SF	***$129.91***	$0
Surge Building	1464.37	SF	***$129.91***	$190,243
Electrical Room	357.23	SF	***$129.91***	$46,409
Subtotal	7679.09			$1,378,109

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METALS:				
Metal Guardrail with Pickets	0.00	LF	*$71.45*	$0
Stairs = IF Mezzanine = 10 * 12/8	0.00	Risers	*$389.74*	$0
Pump Removal Hatches	0.00	SF	*$108.50*	$0
Ladder	0.00	VLF	*$98.09*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	200.00	HP	*$323.10*	$64,619
Active Pump # 2	200.00	HP	*$323.10*	$64,619
Active Pump # 3	200.00	HP	*$323.10*	$64,619
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	200.00	HP	*$323.10*	$64,619
Steel Forebay Tank (0 gallons)	0.00	EA	*$0.00*	$0
Allowance for Misc Items	10%		$258,477.39	$25,848
Subtotal				$284,325
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	8.00	each	*$2,169.93*	$17,359
Control Valve Actuators	4.00	each	*$2,169.93*	$8,680
Level Indicator Transmitters	2.00	each	*$6,677.82*	$13,356
Level Swithces	2.00	each	*$7,029.28*	$14,059
Pressure Indicator Transmitters	5.00	each	*$7,029.28*	$35,146
Pressure Switches	8.00	each	*$7,029.28*	$56,234
Number of Analog I/O Counts	31.20	each	*$206.14*	$6,432
Number of Digital I/O Counts	84.00	each	*$48.82*	$4,101
Number of PLC's	4.00	each	*$10,198.66*	$40,795
I&C Conduit & Wire	2896.62	lf	*$9.41*	$27,247
Allowance for Misc Items	10%		$ 223,408.90	$22,341
Subtotal				$245,750
CONVEYING SYSTEMS				
Bridge Crane	1.00	EA	*$55,034.79*	$55,035
Bridge Crane Rail	207.77	LF	*$28.59*	$5,939
Allowance for Misc Items	10%		$ 60,974	$6,097
Subtotal				$ 67,071
MECHANICAL:				
Pipe:				
Suction Header Pipe (42-inch,SUC, Buried, Steel, Cement Mortar, Tape Coating)	65.88	LF	*$1,034.40*	$68,150
Suction Lateral Pipe (24-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	56.00	LF	*$584.96*	$32,757
Discharge Lateral Pipe (24-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	48.00	LF	*$584.96*	$28,078
Discharge Header Pipe (42-inch,DIS, Buried, Steel, Cement Mortar, Tape Coating)	65.88	LF	*$1,034.40*	$68,150

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Pump Suction Pipe (12-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	4.00	LF	*$285.33*	$1,141
Pump Discharge Pipe (8-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	2.67	LF	*$278.51*	$743
Elbows:				
Discharge Lateral Pipe (24-inch)	4.00	EA	*$2,186.46*	$8,746
Discharge Header Pipe (42-inch)	2.00	EA	*$4,014.02*	$8,028
Tees:				
Suction Header Pipe (42-inch)	4.00	EA	*$7,836.34*	$31,345
Discharge Header Pipe (42-inch)	4.00	EA	*$7,836.34*	$31,345
Valves:				
Suction Header Isolation Valve (42-inch, BFV)	1.00	EA	*$8,726.52*	$8,727
Suction Lateral Isolation Valve (24-inch, BFV)	4.00	EA	*$5,390.47*	$21,562
Discharge Lateral Isolation Valve (24-inch, BFV)	4.00	EA	*$5,390.47*	$21,562
Pump Control Valve (24-inch, Full Port Valve)	4.00	EA	*$5,390.47*	$21,562
Discharge Header Isolation Valve (42-inch, BFV)	1.00	EA	*$8,726.52*	$8,727
Air Release Vacuum Valves	12.00	EA	*$3,254.89*	$39,059
Allowance for Misc Items	10%		$399,680.68	$39,968
Subtotal				$439,649
ELECTRICAL:				
MCC's				
Sections	8.00	each	*$6,696.14*	$53,569
AFD's				
Active Pump # 1	200.00	HP	*$180.66*	$36,132
Active Pump # 2	200.00	HP	*$180.66*	$36,132
Active Pump # 3	200.00	HP	*$180.66*	$36,132
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	200.00	HP	*$180.66*	$36,132
Switchgear				
Units	0.00	each	*$30,802.24*	$0
Electrical Conduit & Wire	399.53	lf	*$9.41*	$3,758
Allowance for Misc Items	5%		$201,856	$10,093
Subtotal				$211,949
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$2,946,763
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2%		$3,508,051	$70,161
I & C Allowance	2%		$3,508,051	$70,161
Surge Allowance	5%		$3,508,051	$175,403

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Mechanical Allowance	2%		$3,508,051	$70,161
Electrical Allowance	5%		$3,508,051	$175,403
Facility Cost	**800**	**Total Pump HP**	**$4,385.06**	**$3,508,051**

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Alternative 3 - Distribution

Pipelines		**$7,695,000**
10% allowance for pipeline valves & appurtenances		**$770,000**
Pipeline Construction Cost		**$8,465,000**
Pipeline Construction Cost		**$8,465,000**
3% markup for Bonds & Insurance	$254,000	
5% markup for Mob/Demob	$424,000	
8% markup for Contractors Overhead	$712,000	
4% markup for Contractors profit	$385,000	
25% Contingency	$2,560,000	
Subtotal Markups and Contingency		**$4,335,000**
Total Project Construction Costs		**$12,800,000**
5% allowance for pipeline engineering and design	768,000	
12% allowance for permitting, legal and administration	640,000	
08% allowance for pipeline engr services during construction	1,024,000	
Subtotal Other Project Costs		**$2,432,000**
GRAND TOTAL PROJECT COST		**$15,232,000**

Alternative 3 - Lake Michigan Distribution System Improvements

Water Forcemain		
Segment	Miles	Diameter
A	2.8	20
B	2	16

Unit cost	$/dia-in	12

Mile	Cost	Comments
1 mi of 20"	$1,736,064	Assume High Urban
1 mi of 16"	$1,388,851	Assume High Urban
subtotal	**$7,694,380**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	178	142
Low urban	1.00	240	192
Medium urban	1.19	286	228
High urban	1.37	329	263
Groundwater	**1.30**	**312**	**250**
Forest	1.15	276	221
Gravel roads	0.85	204	163
Creek crossing	2.00	480	384
HWY crossing	4.00	960	768

miles	0.13	0.25	0.5
feet	660	1320	2640

Lake Michigan O&M Costs							
Source of Supply		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	**Totals**
	Purchased water	1000 gals	3,978,500	$ 1.40	$ 5,569,900	$ 5,569,900	
	Total Supply						$ 5,569,900
Pumping Supply		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	Energy	mgd	10.9			$ 179,759	
	O&M		2% of Capital cost of pump station	$ 0.0200	$ 8,573,000	$ 171,460	
	Total Pumping Supply						$ 351,219
Return Flow		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	Energy	mgd	10.9			$ 118,712	
	O&M		2% of Capital cost of pump station	$ 0.0200	$ 3,508,000	$ 70,160	
	Total Return Flow						$ 188,872
Transmission		**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**	
	O&M	$/lf/yr	132,000	$ 0.52	$ 68,640	$ 68,640	
	Total Transmission						$ 68,640
Alternative Total O&M ($/yr.)							**$ 6,200,000**
PRESENT WORTH (6%, 20 yrs)							**$ 71,000,000**
PRESENT WORTH (6%, 50 yrs)							**$ 98,000,000**

Milwaukee Water Supply - 36" the entire alignment

Pipeline					
Segment	Miles	Diameter	60th & Howard Ground Elevation	780	
A	7	36	Hillcrest WSE	1000	
B	7	36	Segment A Piping K	6.85	(one K=1.0 entr, ten K=0.30 90-elb, 3 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
			Segment B Piping K	5.65	(one flow thru tee K=0.6, five K=0.3 90-elb, one bend thru tee K=1.80, three open bfly valve K=0.25, one exit K=0.5)
			Piping Friction Factor	0.015	
			Power cost, $/kw	0.06	
			Power efficiency	0.9	
			GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	B RW Velocity	B Pipeline Frict Loss	Total FW Piping Fric Loss	Total Static Loss	Total Friction Head	Available Suction Head	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost
	mgd	gpm	ft/s	ft	ft	ft/s	ft	ft	ft	ft	ft	ft	psi	hp	kw	kw	$
	8	5552	1.75	8.77	0.33	1.75	8.80	18.16	220	238	81	157	68	276	228	2001032	$120,062
ADD	10.9	7565	2.39	16.28	0.61	2.39	16.33	33.72	220	254	81	173	75	413	342	2995986	$179,759
MDD	18.5	12839	4.05	46.90	1.74	4.05	47.05	97.13	220	317	81	236	102	958	793	6950168	$417,010

Underwood Creek Return Flow - 36" the entire alignment

Pipeline		
Segment	Miles	Diameter
A	11.4	36

Waukesha WWTP
elevation at watershed divide
Discharge at Underwood Creek
Segment A Piping K
Segment B Piping K
Piping Friction Factor
Power cost, $/kw
Power efficiency
GHG, lbs CO2/Mwhr

[redacted] earth elevation at WWTP

[redacted] K=1.0 entr, ten K=0.30 90-elb, 3 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)

[redacted] flow thru tee K=0.6, five K=0.3 90-elb, one bend thru tee K=1.80, three open bfly valve K=0.25, one

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	Total Friction Head	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost
	mgd	gpm	ft/s	ft	ft	ft	ft	ft	ft	psi	hp	kw	kw	$
ADD	10	6940	2.19	22.25	0.51	22.76	102	124	124	54	273	226	1978537	$118,712
MDD	14	9716	3.06	43.60	1.00	44.60	102	146	146	63	449	372	3256229	$195,374

Underwood Creek Return Flow

Pipeline		
Segment	Miles	Diameter
A	11.4	36

Waukesha WWTP	794	Google earth elevation at WWTP
elevation at watershed divide	895	
Discharge at Underwood Creek	718	
Segment A Piping K	6.85	(one K=1.0 entr, ten K=0.30 90-elb, 3 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
Segment B Piping K	5.65	(one flow thru tee K=0.6, five K=0.3 90-elb, one bend thru tee K=1.80, three open bfly valve K=0.25, one exit K=0.5)
Piping Friction Factor	0.015	
Power cost, $/kw	0.06	
Power efficiency	0.9	
GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	Total Friction Head	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost	Annual GHG Produced
	mgd	gpm	ft/s	ft	ft	ft	ft	ft	ft	psi	hp	kw	kw	$	tons CO2
ADD	10	6940	2.19	22.25	0.51	22.76	102	124	124	54	273	226	1978537	$118,712	1839
MDD	14	9716	3.06	43.60	1.00	44.60	102	146	146	63	449	372	3256229	$195,374	3027

WWTP Effluent Pump Station

Approx. Topo EL 794

Design TDH	146	ft	must be designed to pump up to the watershed divide;
	63	psi	
No. of pumps	3		3 active, 1 standby
Capacity, mgd (each)	3.33		
HP (each)	122		nominal 150 hp
Drive	variable frequency		

Underwood Creek Return Flow

Pipeline		
Segment		Diameter
A		36
B		36

Unit cost	$/dia-in	12

432
432

Mile	Cost		Comments
1	$2,389,306		0.75 mi follows river, crosses Prairie ave, Marshall and Dunbar, 0.25 under alley to NW ave
2	$2,389,306		Cross Maple, Grand, Barstow, East, Barney, Hartwell, crossing of E Broadway (major street); end at Oakland follows path (cross Greendale and Frederick), cross
3	$3,290,285		East Side bypass HYW 59 (MAJOR)
4	$1,836,971	70%	Follows New Berlin trail/utility corridor, cross Springdale;also a stream crossing, some forest (assume 20%); ends near stream crossing
5	$1,555,159	70%	Follows trail, open country mostly, some forest (assume 30%), wetlands for 0.5 mi; assume groundwater; ends near wetlands/open water pond
6	$1,247,001	70%	Follows trail, open country mostly, some forest (assume 10%)
7	$1,700,456	70%	Begins near Calhoun, one stream crossing; becoming urban again but still follows trail and is mostly open, crosses Calhoun and ends near Moorland, assume 10% forest
8	$1,181,537	70%	Still in trail, no crossings; very open; Ends near Sunnyslope Rd
9	$1,181,537	70%	Still in trail, no crossings; very open; Ends at 124th st
10	$2,623,104		Going north under 124th st, crosses Greenfield (hwy 59), ends near 124th and Zinke Dr
11	$3,800,079		Last section follows Underwood Creek, Crosses I-94
subtotal	**$23,194,740**		

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf
Open country	0.74	320
Low urban	1.00	432
Medium urban	1.19	514
High urban	1.37	592
Groundwater	**1.30**	**562**
Forest	1.15	497
Gravel roads	0.85	367
Creek crossing	2.00	864
HWY crossing	4.00	1728

Underwood Creek Return Flow

Pipelines		**$23,195,000**
10% allowance for pipeline valves & appurtenances		**$2,320,000**
Pipeline Construction Cost		**$25,515,000**
WWTP Effluent Pump Station		**$3,508,000**
Conveyance System Construction Cost		**$29,023,000**
3% markup for Bonds & Insurance	$871,000	
5% markup for Mob/Demob	$1,452,000	
8% markup for Contractors Overhead	$2,508,000	
4% markup for Contractors profit	$1,254,000	
25% Contingency	$8,777,000	
Subtotal Markups and Contingency		**$14,862,000**
Total Project Construction Costs		**$43,885,000**
8% allowance for pipeline engineering and design	3,511,000	
12% allowance for permitting, legal and administration	5,267,000	
8% allowance for pipeline engr services during construction	3,511,000	
Subtotal Other Project Costs		**$12,289,000**
GRAND TOTAL PROJECT COST		**$56,174,000**

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	639.92	CY	***$5.28***	$3,381
Imported Structural Backfill	532.57	CY	***$40.04***	$21,322
Native Backfill	38.78	CY	***$6.50***	$252
Haul Excess	601.13	CY	***$6.50***	$3,905
Forebay:				
Excavation	0.00	CY	***$5.28***	$0
Imported Structural Backfill	0.00	CY	***$40.04***	$0
Native Backfill	0.00	CY	***$6.50***	$0
Haul Excess	0.00	CY	***$6.50***	$0
Office:				
Excavation	0.00	CY	***$5.28***	$0
Imported Structural Backfill	0.00	CY	***$40.04***	$0
Native Backfill	0.00	CY	***$6.50***	$0
Haul Excess	0.00	CY	***$6.50***	$0
Surge Protection:				
Excavation	385.95	CY	***$5.28***	$2,039
Imported Structural Backfill	201.65	CY	***$40.04***	$8,073
Native Backfill	75.73	CY	***$6.50***	$492
Haul Excess	310.22	CY	***$6.50***	$2,015
Allowance for Misc Items	5%		$41,478.65	$2,074
Subtotal				$43,553
CONCRETE:				
Pump Station				
Foundation	482.04	CY	***$382.16***	$184,218
Support Walls	0.00	CY	***$683.50***	$0
Support Columns	10.37	CY	***$683.50***	$7,088
Pump Pad Epoxy	2.20	CY	$3,368.81	$7,401
Pump Pad Support	24.15	CY	***$345.93***	$8,354
Pipe Supports	29.63	CY	***$345.93***	$10,250
Mezzanine				
Elevated Slab	0.00	CY	***$1,088.69***	$0
Electrical Room				
Foundation	13.23	CY	***$345.93***	$4,577
Surge Protection				
Foundation	108.47	CY	***$345.93***	$37,524
Office				
Foundation	0.00	CY	***$345.93***	$0
Pump Station Forebay				
Slab on Grade for Steel Tank	0.00	CY	***$345.93***	$0
Prestressed Concrete Tank (0 gallons)	0.00	EA	***$0.00***	$0
Outlet Box	9.91	CY	***$382.16***	$3,786
Allowance for Misc Items	5%		$263,196.94	$13,160
Subtotal				$276,357
MASONRY:	Moderate			
Pump Station Building	5857.49	SF	***$194.87***	$1,141,458
Office Building	0.00	SF	***$129.91***	$0
Surge Building	1464.37	SF	***$129.91***	$190,243
Electrical Room	357.23	SF	***$129.91***	$46,409
Subtotal	7679.09			$1,378,109

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METALS:				
Metal Guardrail with Pickets	0.00	LF	*$71.45*	$0
Stairs = IF Mezzanine = 10 * 12/8	0.00	Risers	*$389.74*	$0
Pump Removal Hatches	0.00	SF	*$108.50*	$0
Ladder	0.00	VLF	*$98.09*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	200.00	HP	*$323.10*	$64,619
Active Pump # 2	200.00	HP	*$323.10*	$64,619
Active Pump # 3	200.00	HP	*$323.10*	$64,619
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	200.00	HP	*$323.10*	$64,619
Steel Forebay Tank (0 gallons)	0.00	EA	*$0.00*	$0
Allowance for Misc Items	10%		$258,477.39	$25,848
Subtotal				$284,325
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	8.00	each	*$2,169.93*	$17,359
Control Valve Actuators	4.00	each	*$2,169.93*	$8,680
Level Indicator Transmitters	2.00	each	*$6,677.82*	$13,356
Level Swithces	2.00	each	*$7,029.28*	$14,059
Pressure Indicator Transmitters	5.00	each	*$7,029.28*	$35,146
Pressure Switches	8.00	each	*$7,029.28*	$56,234
Number of Analog I/O Counts	31.20	each	*$206.14*	$6,432
Number of Digital I/O Counts	84.00	each	*$48.82*	$4,101
Number of PLC's	4.00	each	*$10,198.66*	$40,795
I&C Conduit & Wire	2896.62	lf	*$9.41*	$27,247
Allowance for Misc Items	10%		$ 223,408.90	$22,341
Subtotal				$245,750
CONVEYING SYSTEMS				
Bridge Crane	1.00	EA	*$55,034.79*	$55,035
Bridge Crane Rail	207.77	LF	*$28.59*	$5,939
Allowance for Misc Items	10%		$ 60,974	$6,097
Subtotal				$ 67,071
MECHANICAL:				
Pipe:				
Suction Header Pipe (42-inch,SUC, Buried, Steel, Cement Mortar, Tape Coating)	65.88	LF	*$1,034.40*	$68,150
Suction Lateral Pipe (24-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	56.00	LF	*$584.96*	$32,757
Discharge Lateral Pipe (24-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	48.00	LF	*$584.96*	$28,078
Discharge Header Pipe (42-inch,DIS, Buried, Steel, Cement Mortar, Tape Coating)	65.88	LF	*$1,034.40*	$68,150

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Pump Suction Pipe (12-inch,SUC, Exposed, Steel, Cement Mortar, Paint)	4.00	LF	*$285.33*	$1,141
Pump Discharge Pipe (8-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	2.67	LF	*$278.51*	$743
Elbows:				
Discharge Lateral Pipe (24-inch)	4.00	EA	*$2,186.46*	$8,746
Discharge Header Pipe (42-inch)	2.00	EA	*$4,014.02*	$8,028
Tees:				
Suction Header Pipe (42-inch)	4.00	EA	*$7,836.34*	$31,345
Discharge Header Pipe (42-inch)	4.00	EA	*$7,836.34*	$31,345
Valves:				
Suction Header Isolation Valve (42-inch, BFV)	1.00	EA	*$8,726.52*	$8,727
Suction Lateral Isolation Valve (24-inch, BFV)	4.00	EA	*$5,390.47*	$21,562
Discharge Lateral Isolation Valve (24-inch, BFV)	4.00	EA	*$5,390.47*	$21,562
Pump Control Valve (24-inch, Full Port Valve)	4.00	EA	*$5,390.47*	$21,562
Discharge Header Isolation Valve (42-inch, BFV)	1.00	EA	*$8,726.52*	$8,727
Air Release Vacuum Valves	12.00	EA	*$3,254.89*	$39,059
Allowance for Misc Items	10%		$399,680.68	$39,968
Subtotal				$439,649
ELECTRICAL:				
MCC's				
Sections	8.00	each	*$6,696.14*	$53,569
AFD's				
Active Pump # 1	200.00	HP	*$180.66*	$36,132
Active Pump # 2	200.00	HP	*$180.66*	$36,132
Active Pump # 3	200.00	HP	*$180.66*	$36,132
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	200.00	HP	*$180.66*	$36,132
Switchgear				
Units	0.00	each	*$30,802.24*	$0
Electrical Conduit & Wire	399.53	lf	*$9.41*	$3,758
Allowance for Misc Items	5%		$201,856	$10,093
Subtotal				$211,949
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$2,946,763
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2%		$3,508,051	$70,161
I & C Allowance	2%		$3,508,051	$70,161
Surge Allowance	5%		$3,508,051	$175,403

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Mechanical Allowance	2%		$3,508,051	$70,161
Electrical Allowance	5%		$3,508,051	$175,403
Facility Cost	**800**	**Total Pump HP**	**$4,385.06**	**$3,508,051**

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Root River Return Flow

Pipeline		
Segment	Miles	Diameter
A	15.5	36

Waukesha WWTP	794	Google earth elevation at WWTP
elevation at watershed divide	895	
Discharge at Root River	705	
Segment A Piping K	10.35	(one K=1.0 entr, twenty K=0.30 90-elb, 5 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
Segment B Piping K	8.15	(one flow thru tee K=0.6, ten K=0.3 90-elb, one bend thru tee K=1.80, five open bfly valve K=0.25, one exit K=0.5)
Piping Friction Factor	0.015	
Power cost, $/kw	0.06	
Power efficiency	0.9	
GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost	Annual GHG Produced
	mgd	gpm	ft/s	ft	ft	ft	ft	ft	psi	hp	kw	kw	$	tons CO2
ADD	10	6940	2.19	30.34	0.77	31	102	133	57	332	275	2413060	$144,784	2243
MDD	14	9716	3.06	59.47	1.51	61	102	163	70	570	472	4138149	$248,289	3846

WWTP Effluent Pump Station

Approx. Topo EL	794		
Design TDH	163	ft	must be designed to pump up to the watershed divide;
	70	psi	
No. of pumps	3	3 active, 1 standby	
Capacity, mgd (each)	3.33		
HP (each)	136		nominal 150 hp
Drive	variable frequency		

Root River Return Flow

Pipeline		
Segment		Diameter
A		36
B		36

Unit cost	$/dia-in	12

Mile	Cost		Comments
1	$2,389,306	0%	0.75 mi follows river, crosses Prairie ave, Marshall and Dunbar, 0.25 under alley to NW ave
2	$2,389,306	0%	Cross Maple, Grand, Barstow, East, Barney, Hartwell, crossing of E Broadway (major street); end at Oakland
3	$3,290,285	0%	follows path (cross Greendale and Frederick), cross East Side bypass HYW 59 (MAJOR)
4	$1,836,971	70%	Follows New Berlin trail/utility corridor, cross Springdale;also a stream crossing, some forest (assume 20%); ends near stream crossing
5	$1,555,159	70%	Follows trail, open country mostly, some forest (assume 30%), wetlands for 0.5 mi; assume groundwater; ends near wetlands/open water pond
6	$1,247,001	70%	Follows trail, open country mostly, some forest (assume 10%)
7	$1,700,456	70%	Begins near Calhoun, one stream crossing; becoming urban again but still follows trail and is mostly open, crosses Calhoun and ends near Moorland, assume 10% forest
8	$1,181,537	70%	Still in trail, no crossings; very open; Ends near Sunnyslope Rd
9	$1,181,537	70%	Still in trail, no crossings; very open; Ends at 124th st
10	$2,584,328		Going south, 0.7 mi under 124th st. 0.3 mi along Root River pkwy; ends near Cleveland Ave.
11	$2,623,104		Follows Root River Parkway, crosses Oklahoma (major crossing), ends near S 116th St
12	$1,806,520		Follows Root River Parkway 0.2 mi, crosses Morgan, follows oak leaf bike trail, crosses Beloit Rd, ends between Beloit Rd and S 108th St
13	$2,431,503		Follows Oak Leaf Bike Trail, crosses Hwy 100, crosses Coldspring, ends at Hwy 45
14	$3,649,536		In Root River pkwy, cross HWY 45, Layton Ave, ends at Forest Home Ave
15	$2,623,104		In Root River pkwy, crosses Forest Home Ave (Hwy 24) and 84th st, discharges to Root River
subtotal	**$32,489,652**		

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES	Seg A cost $/lf
Open country	0.74	320
Low urban	1.00	432
Medium urban	1.19	514
High urban	1.37	592
Groundwater	**1.30**	**562**
Forest	1.15	497
Gravel roads	0.85	367
Creek crossing	2.00	864
HWY crossing	4.00	1728

Root River Return Flow

Pipelines		**$32,490,000**
10% allowance for pipeline valves & appurtenances		**$3,249,000**
Pipeline Construction Cost		**$35,739,000**
WWTP Effluent Pump Station		**$3,508,000**
Conveyance System Construction Cost		**$39,247,000**
3% markup for Bonds & Insurance	$1,178,000	
5% markup for Mob/Demob	$1,963,000	
8% markup for Contractors Overhead	$3,392,000	
4% markup for Contractors profit	$1,696,000	
25% Contingency	$11,869,000	
Subtotal Markups and Contingency		**$20,098,000**
Total Project Construction Costs		**$59,345,000**
8% allowance for pipeline engineering and design	4,748,000	
12% allowance for permitting, legal and administration	7,122,000	
8% allowance for pipeline engr services during construction	4,748,000	
Subtotal Other Project Costs		**$16,618,000**
GRAND TOTAL PROJECT COST		**$75,963,000**

Lake Michigan Direct Return Flow

Pipeline		
Segment	Miles	Diameter
A	22.0	36

Waukesha WWTP	794	
elevation at watershed divide	895	
Discharge at Lake Michigan	580	
Segment A Piping K	10.35	(one K=1.0 entr, twenty K=0.30 90-elb, 5 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
Segment B Piping K	8.15	(one flow thru tee K=0.6, ten K=0.3 90-elb, one bend thru tee K=1.80, five open bfly valve K=0.25, one exit K=0.5)
Piping Friction Factor	0.015	
Power cost, $/kw	0.06	
Power efficiency	0.9	
GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost	Annual GHG Produced
	mgd	gpm	ft/s	ft	ft	ft	ft	ft	psi	hp	kw	kw	$	tons CO2
ADD	10	6940	2.19	43.07	0.77	44	102	146	63	364	302	2644286	$158,657	2458
MDD	14	9716	3.06	84.41	1.51	86	102	188	81	658	545	4772636	$286,358	4436

WWTP Effluent Pump Station

Approx. Topo EL 794

Design TDH	188	ft	must be designed to pump up to the watershed divide;
	81	psi	
No. of pumps	3	3 active, 1 standby	
Capacity, mgd (each)	3.33		
HP (each)	157		nominal 200 hp
Drive	variable frequency		

Lake Michigan Direct Return Flow

Pipeline		
Segment		Diameter
A		36
B		36

Unit cost	$/dia-in	12

Mile	Cost		Comments
1	$2,389,306	0%	0.75 mi follows river, crosses Prairie ave, Marshall and Dunbar, 0.25 under alley to NW ave
2	$2,389,306	0%	Cross Maple, Grand, Barstow, East, Barney, Hartwell, crossing of E Broadway (major street); end at Oakland
3	$3,290,285	0%	follows path (cross Greendale and Frederick), cross East Side bypass HYW 59 (MAJOR)
4	$1,836,971	70%	Follows New Berlin trail/utility corridor, cross Springdale;also a stream crossing, some forest (assume 20%); ends near stream crossing
5	$1,555,159	70%	Follows trail, open country mostly, some forest (assume 30%), wetlands for 0.5 mi; assume groundwater; ends near wetlands/open water pond
6	$1,247,001	70%	Follows trail, open country mostly, some forest (assume 10%)
7	$1,700,456	70%	Begins near Calhoun, one stream crossing; becoming urban again but still follows trail and is mostly open, crosses Calhoun and ends near Moorland, assume 10% forest
8	$1,181,537	70%	Still in trail, no crossings; very open; Ends near Sunnyslope Rd
9	$1,181,537	70%	Still in trail, no crossings; very open; Ends at 124th st
10	$2,059,707		Follows Trail, crosses S 16th St, ends at Hwy 100
11	$2,431,503		Follows Trail, crosses Hwy 45, ends at S 92nd St
12	$2,714,342		Follows train tracks, crosses National, 82nd, 80th, ends at 76th
13	$2,714,342		Follows train tracks, crosses 73rd, 71st, 68th, Becher, ends at Beloit Rd
14	$2,714,342		Follows train tracks, ends at 43rd st
15	$2,714,342		Follows train tracks, ends at 27th st
16	$2,714,342		Follows train tracks, ends at 16th st
17	$2,714,342		Follows train tracks, ends at Hwy 794
18	$2,714,342		Follows train tracks, crosses Hwy 794, Oklahoma, Chase, Howell, Whitman, ends near Clement
19	$2,714,342		Follows train tracks, ends near Lake pkwy
20	$2,714,342		Follows train tracks, crosses Lake pkwy, Howard, ends at KK
21	$2,714,342		Follows KK then turns east on Lunham and discharges to Lake
subtotal	**$48,406,191**		

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES	Seg A cost $/lf
Open country	0.74	320
Low urban	1.00	432
Medium urban	1.19	514
High urban	1.37	592
Groundwater	**1.30**	**562**
Forest	1.15	497
Gravel roads	0.85	367
Creek crossing	2.00	864
HWY crossing	4.00	1728

Lake Michigan Direct Return Flow

Pipelines		**$48,407,000**
10% allowance for pipeline valves & appurtenances		**$4,841,000**
Pipeline Construction Cost		**$53,248,000**
WWTP Effluent Pump Station		**$3,508,000**
Conveyance System Construction Cost		**$56,756,000**
3% markup for Bonds & Insurance	$1,703,000	
5% markup for Mob/Demob	$2,838,000	
8% markup for Contractors Overhead	$4,904,000	
4% markup for Contractors profit	$2,452,000	
25% Contingency	$17,164,000	
Subtotal Markups and Contingency		**$29,061,000**
Total Project Construction Costs		**$85,817,000**
8% allowance for pipeline engineering and design	6,866,000	
12% allowance for permitting, legal and administration	10,299,000	
8% allowance for pipeline engr services during construction	6,866,000	
Subtotal Other Project Costs		**$24,031,000**
GRAND TOTAL PROJECT COST		**$109,848,000**

Alternative 4:
Lake Michigan and Shallow Aquifer

Alternative 4 -Lake Michigan and Shallow Aquifers		
Shallow Aquifer Water Treatment Plant		**$29,864,000**
Shallow Aquifer Wellfield		**$12,800,000**
Shallow Aquifer Supply Pipeline to Waukesha		**$ 18,573,000**
Distribution System Improvements		**$ 8,465,000**
Wastewater Force Main		**$3,332,000**
Subtotal Shallow Aquifer Construction Cost		**$73,034,000**
Lake Michigan Supply Pipeline		**$25,682,000**
Parkway Booster Station		**$5,282,822**
Return Flow Pipeline/Pump Station		**$19,172,686**
Subtotal Lake Michigan Supply		**$50,137,508**
Subtotal Construction Cost		**$123,171,508**
3% markup for Bonds & Insurance	$3,696,000	
5% markup for Mob/Demob	$6,159,000	
8% markup for Contractors Overhead	$10,643,000	
4% markup for Contractors profit	$5,322,000	
25% Contingency	$37,248,000	
Subtotal Markups and Contingency		**$63,068,000**
Total Project Construction Costs		**$186,239,508**
8% allowance for engineering and design	14,900,000	
12% allowance for permitting, legal and admin	22,349,000	
8% allowance for engr services during constru	14,900,000	
Subtotal Other Project Costs		**$52,149,000**
TOTAL PROJECT CAPITAL COST		**$238,000,000**

CH2M HILL Parametric Cost Estimating System (CPES)

FACILITIES DESIGN & CONSTRUCTION COST MODULE

File Version: 1/5/2010

Click for CPES QA/QC | To Concrete Wall Thickness Help | To Cost Summary Matrix | To Unit Cost Database

Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months):	24
Mid-Point of Construction:	Jan/2012

Roundup to the nearest: $1,000

☐ This Report is for INTERNAL Distributio

☐ This Report is for EXTERNAL Distributio

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Cost
	Yes	Inline Rapid Mix: RMX	$623,000
	Yes	Flocculation: FLOC	$1,527,000
	Yes	Lamella Clarifier: LAM	$2,367,000
	Yes	Filters: FILT	$5,024,000
	Yes	Surge Basin-Decanter: BWW	$1,535,000
	No	UV Disinfection: UVD	$0
	Yes	Concrete Clearwell: FWT	$1,313,000
	No	Steel Clearwell: FWT	$0
	No	In-Plant PS: FWPS	$0
	Yes	Vertical Turbine PS: FWPS	$3,042,000
	Yes	Filter BW PS: BWSPS	$1,101,000
	Yes	U.D. Facility: GEN	$0
	Yes	Liquid Chemical: FeCl3	$393,000
	Yes	Liquid Chemical: NaOCl	$296,000
	Yes	Liquid Chemical: FLUOR	$186,000
	Yes	Liquid Chemical: POLYPHOS	$185,000
	Yes	O&M Building: OMB	$2,849,000
SUBTOTAL - PROJECT COST			$20,441,000
ADDITIONAL PROJECT COSTS:			
Demolition	0%		$0
Overall Sitework	10%		$2,045,000
Plant Computer System	5%		$1,023,000
Yard Electrical	7%		$1,493,000
Yard Piping	14%		$2,862,000
UD #1 Default Description	0%		$0
UD #2 Default Description	0%		$0
UD #3 Default Description	0%		$0
SUBTOTAL with Additional Project Costs			$27,864,000

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	B	C	D	E	F
132					
133	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
134					
135	SITEWORK:				
136	Excavation	140.81	CY	$ 5.35	$754
137	Imported Structural Backfill	83.82	CY	$ 40.56	$3,399
138	Native Backfill	0.00	CY	$ 6.58	$0
139	Haul Excess	140.81	CY	$ 6.58	$927
140	Allowance for Misc Items	5%		$ 5,079.48	$254
141	Subtotal				$5,333
142					
143	CONCRETE:				
144	Wall Footing	9.31	CY	$ 345.93	$3,220
145	Stem Walls	0.00	CY	$ 683.50	$0
146	Slab on Grade	27.50	CY	$ 345.93	$9,513
147	Pipe Supports	14.00	EA	$ 438.67	$6,141
148	Electrical Room Slab on Grade	2.13	CY	$ 345.93	$737
149	Allowance for Misc Items	5%		$19,613	$981
150	Subtotal				$20,593
151					
152	MASONRY:	Moderate			
153	CMU Building	864.20	SF	$ 131.60	$113,730
154	Electrical Room	57.56	SF	$ 131.60	$7,574
155	Subtotal	921.76			$121,304
156					
157	EQUIPMENT:				
158	Inline Mixer (20-inch)	2.00	EA	$ 27,983.82	$55,968
159	Allowance for Misc Items	10%		$ 55,967.63	$5,597
160	Subtotal				$61,564.39
161					
162	INSTRUMENTS & CONTROLS:				
163	Instruments				
164	Mag Meter (12-inch)	2.00	EA	$ 10,574.21	$21,148
165	pH / Temperature	1.00	EA	$ 2,093.45	$2,093
166	Turbidity	1.00	EA	$ 3,133.05	$3,133
167	Streaming Current Detector	0.00	EA	$ 10,680.85	$0
168	UV Absorbance	1.00	EA	$ 21,794.63	$21,795
169	Conductivity	0.00	EA	$ 2,057.84	$0
170	Sample Panels	2.00	EA	$ 3,948.04	$7,896
171	Isolation Valve Actuators	4.00	each	$5,064.93	$20,260
172	Flow Control Valve Actuators	2.00	each	$5,064.93	$10,130
173	Number of Analog I/O Counts	12.00	each	$208.82	$2,506
174	Number of Digital I/O Counts	33.60	each	$49.46	$1,662
175	Number of PLC's	1.00	each	$10,331.10	$10,331
176	I&C Conduit & Wire	552.52	lf	$9.53	$5,265
177	Allowance for Misc Items	10%		$ 106,218.79	$10,622
178	Subtotal				$116,841
179					
180	CONVEYING SYSTEMS:				
181	Monorail Hoist (3 Ton)	1.00	EA	$ 55,749.49	$55,749
182	Hoist Rail	105.17	LF	$ 28.96	$3,045
183	Allowance for Misc Items	10%		$ 58,794.83	$5,879
184	Subtotal				$64,674
185					
186	MECHANICAL:				
187	Pipe:				
188	Rapid Mix Pipe (20-inch, RW, Exposed ,Steel ,Cement Mortar ,Paint)	33.33	lf	$365.28	$12,176

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	B	C	D	E	F
189	Flow Control Pipe (12-inch, FCP, Exposed ,Steel ,Cement Mortar ,Paint)	16.00	lf	*$219.17*	$3,507
190	Elbows:				
191	Rapid Mix Pipe (20-inch)	4.00	each	*$2,199.87*	$8,799
192	Valves:				
193	Rapid Mix Isolation Valves (20-inch)	4.00	each	*$16,089.26*	$64,357
194	Flow Control Valve (12-inch)	2.00	each	*$9,653.56*	$19,307
195	Allowance for Misc Items	10%		$108,146.20	$10,815
196	Subtotal				$118,961
197					
198	ELECTRICAL:				
199	MCC's				
200	Sections	5.00	each	*$6,783.10*	$33,915
201	AFD's				
202	Mechanical Mixers (3 hp each)	0.00	each	*$4,494.79*	$0
203	Switchgear				
204	Units	0.00	each	*$31,202.24*	$0
205	Electrical Conduit & Wire	85.00	lf	*$9.53*	$810
206	Allowance for Misc Items	10%		$34,725	$3,473
207	Subtotal				$38,198
208					
209	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
210	Item 1 Description	0.00		0.00	$0
211	Item 2 Description	0.00		0.00	$0
212	Item 3 Description	0.00		0.00	$0
213	Item 4 Description	0.00		0.00	$0
214	Item 5 Description	0.00		0.00	$0
215	Item 6 Description	0.00		0.00	$0
216	Item 7 Description	0.00		0.00	$0
217	Item 8 Description	0.00		0.00	$0
218	Item 9 Description	0.00		0.00	$0
219	Item 10 Description	0.00		0.00	$0
220	Item 11 Description	0.00		0.00	$0
221	Item 12 Description	0.00		0.00	$0
222	Item 13 Description	0.00		0.00	$0
223	Item 14 Description	0.00		0.00	$0
224	Item 15 Description	0.00		0.00	$0
225	Subtotal				$0
226					
227	Subtotal				$547,469
228					
229	ALLOWANCES:		**User Over-write**		
230	Finishes Allowance	2.0%		$622,124	$12,442
231	I & C Allowance	5%		$622,124	$31,106
232	Mechanical Allowance	0%		$622,124	$0
233	Electrical Allowance	5%		$622,124	$31,106
234					
235	Facility Cost	**12,000,000**	**GPD**	**$0.05**	**$622,124**

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	B	C	D	E	F
188					
189	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
190					
191	SITEWORK:				
192	Excavation	3,805	CY	***$5.35***	$20,366
193	Imported Structural Backfill	617	CY	***$40.56***	$25,021
194	Native Backfill	1,032	CY	***$6.58***	$6,793
195	Haul Excess	2,773	CY	***$6.58***	$18,244
196	Allowance for Misc Items	5%		$70,423.45	$3,521
197	Subtotal				$73,945
198					
199	CONCRETE:				
200	Influent Channel:				
201	Foundation	42	CY	***$382.16***	$16,188
202	Channel Walls (Only 3 walls are covered here. The 4th wall is covered in the Flocc Basin.)	70	CY	***$683.50***	$47,563
203	Elevated Slab	25	CY	***$1,088.69***	$27,007
204	Flocc Basin				
205	Foundation	218	CY	***$382.16***	$83,323
206	Basin Walls (Only 3 walls are covered here. The Effluent wall is covered in the Influent Channel of the Lamella Clarifier)	119	CY	***$683.50***	$81,280
207	Under Baffle Wall	40	CY	***$683.50***	$27,065
208	Over Baffle Wall	40	CY	***$683.50***	$27,065
209	Elevated Slab	81	CY	***$1,088.69***	$88,341
210	Flocc Bearing Supports	42	EA	$0.00	$0
211	Electrical Room				
212	Slab on Grade	4	CY	***$345.93***	$1,435
213	Allowance for Misc Items	5%		$399,265.97	$19,963
214	Subtotal				$419,229
215					
216	MASONRY:	Moderate			
217	CMU Building	4,312	SF	***$131.60***	$567,498
218	Electrical Room	112	SF	***$131.60***	$14,739
219	Subtotal	4,424			$582,238
220					
221	METALS:				
222	Aluminum Handrail	233	LF	***$72.38***	$16,854
223	Additional Handrail with NO Building	0	LF	***$72.38***	$0
224	Stairs (1 per basin)	16	RISERS	***$394.80***	$6,270
225	Allowance for Misc Items	10%		$23,124.34	$2,312
226	Subtotal				$25,437
227					
228	WOODS & PLASTICS:				
229	FRP Weir	6	LF	$32.90	$183
230	FRP Ladder	4	EA	$1,137.15	$4,549
231	Allowance for Misc Items	5%		$4,732.07	$237
232	Subtotal				$4,969
233					
234	THERMAL & MOISTURE PROTECTION:				
235	Concrete Liner	0	SF	$16.00	$0
236	Allowance for Misc Items	10%		$0.00	$0
237	Subtotal				$0
238					
239	DOORS & WINDOWS:				
240	O/U Baffling ON/OFF Factor	*0*			
241	Serpentine Baffling ON/OFF Factor	*1*			$0
242	Stainless Steel Door (2' x 2') for O/U Baffling	0	EA	$1,052.81	$0
243	Stainless Steel Door (2' x 2') for Serpentine Baffling	4	EA	$1,052.81	$4,211
244	Stainless Steel Door (7' x 2.5')	0	EA	$4,606.05	$0
245	Allowance for Misc Items	5%		$4,211.24	$211
246	Subtotal				$4,422
247					

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	B	C	D	E	F
248	EQUIPMENT:				
249	Horizontal Paddle Wheel Flocculation Mechanism (Paddles & Drives)	0	LF	***$0.00***	$0
250	Vertical Paddle Wheel Flocculation Mechanism (Paddles & Drives)	18	EA	***$0.00***	$0
251	Vertical Turbine Flocculation Mechanism (Turbines & Drives)	18	HP	***$1,477.12***	$26,588
252	Vertical Turbine Flocculator VFD's	18	HP	***$596.65***	$10,740
253	Fabricated Slide Gate	2	EA	***$6,077.92***	$12,156
254	Allowance for Misc Items	10%		$49,483.61	$4,948
255	Subtotal				$54,432
256					
257	ELECTRICAL:				
258	*MCC's*				
259	Sections	12	each	***$6,783.10***	$81,397
260	*AFD's*				
261	Flocculation Mixers Stage 1 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
262	Flocculation Mixers Stage 2 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
263	Flocculation Mixers Stage 3 (total facility) (1 hp each)	6	each	***$4,248.86***	$25,493
264	Flocculation Mixers Stage 4 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
265	Flocculation Mixers Stage 5 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
266	Flocculation Mixers Stage 6 (total facility) (0 hp each)	0	each	***$4,125.89***	$0
267	*Switchgear*				
268	Units	0	each	***$31,202.24***	$0
269	Electrical Conduit & Wire	1,752	lf	***$9.53***	$16,694
270	Allowance for Misc Items	10%		$174,571.06	$17,457
271	Subtotal				$192,028
272					
273	INSTRUMENTS & CONTROLS:				
274	Instruments				
275	Level Switch	2	each	***$549.53***	$1,099
276	Number of Analog I/O Counts	43	each	***$208.82***	$9,021
277	Number of Digital I/O Counts	108	each	***$49.46***	$5,341
278	Number of PLC's	1	each	***$10,331.10***	$10,331
279	I&C Conduit & Wire	1,827	lf	***$9.53***	$17,406
280	Allowance for Misc Items	10%		$43,198.52	$4,320
281	Subtotal				$47,518
282					
283	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
284	Item 1 Description	0.00		0.00	$0
285	Item 2 Description	0.00		0.00	$0
286	Item 3 Description	0.00		0.00	$0
287	Item 4 Description	0.00		0.00	$0
288	Item 5 Description	0.00		0.00	$0
289	Item 6 Description	0.00		0.00	$0
290	Item 7 Description	0.00		0.00	$0
291	Item 8 Description	0.00		0.00	$0
292	Item 9 Description	0.00		0.00	$0
293	Item 10 Description	0.00		0.00	$0
294	Item 11 Description	0.00		0.00	$0
295	Item 12 Description	0.00		0.00	$0
296	Item 13 Description	0.00		0.00	$0
297	Item 14 Description	0.00		0.00	$0
298	Item 15 Description	0.00		0.00	$0
299	Subtotal				$0
300					
301	Subtotal				$1,404,217
302					
303	ALLOWANCES:		**User Over-write**		

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	B	C	D	E	F
304	Finishes Allowance	2.0%		$1,526,323	$30,526
305	I & C Allowance	2%		$1,526,323	$30,526
306	Mechanical Allowance	2%		$1,526,323	$30,526
307	Electrical Allowance	2%		$1,526,323	$30,526
308					
309	Facility Cost	12,000,000	GPD	$0.13	$1,526,323

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	B	C	D	E	F
180					
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
182					
183	SITEWORK:				
184	Excavation	4,244	CY	$ 5.35	$22,713
185	Imported Structural Backfill	653	CY	$ 40.56	$26,492
186	Native Backfill	1,176	CY	$ 6.58	$7,738
187	Haul Excess	3,068	CY	$ 6.58	$20,185
188	Allowance for Misc Items	5%		$77,128	$3,856
189	Subtotal				$80,985
190					
191	CONCRETE:				
192	Influent Channel:				
193	Foundation	37	CY	$ 382.16	$14,026
194	Channel Walls	77	CY	$ 683.50	$52,960
195	Elevated Slab	22	CY	$ 1,088.69	$24,216
196	Basin				
197	Foundation	138	CY	$ 382.16	$52,925
198	Channel Walls	264	CY	$ 683.50	$180,519
199	Elevated Slab	38	CY	$ 1,088.69	$41,369
200	Concrete Curb (8" X 8")	73	LF	$ 32.90	$2,402
201	Effluent Channel:				
202	Foundation	37	CY	$ 382.16	$14,026
203	Walls	77	CY	$ 683.50	$52,960
204	Elevated Slab	22	CY	$ 1,088.69	$24,216
205	Electrical Room				
206	Slab on Grade	2	CY	$ 345.93	$737
207	Allowance for Misc Items	5%		$460,355	$23,018
208	Subtotal				$483,373
209					
210	MASONRY:	Moderate			
211	CMU Building	4,746	SF	$ 131.60	$624,619
212	Electrical Room	58	SF	$ 131.60	$7,574
213	Subtotal	4,804			$632,193
214					
215	METALS:				
216	Aluminum Handrail	269	LF	$ 72.38	$19,470
217	Allowance for Misc Items	10%		$ 19,470.17	$1,947
218	Subtotal				$21,417
219					
220	WOODS & PLASTICS:				
221	FRP Ladder	4	EA	$ 1,443.20	$5,773
222	Allowance for Misc Items	5%		$ 5,772.82	$289
223	Subtotal				$6,061
224					
225	THERMAL & MOISTURE PROTECTION:				
226	Concrete Liner	0	SF	$16.00	$0
227	Allowance for Misc Items	10%		$0.00	$0
228	Subtotal				$0
229					
230	EQUIPMENT:				
231	Lamella Clarifier [WPL * PW * #P/T *# * COS(PAR)]	25,063	PLATE AREA (SF)	$ 19.45	$487,452
232	Fabricated Slide Gate	2	EA	$ 6,077.92	$12,156
233	Hoseless Sludge Collector	4	EA	$ 66,857.09	$267,428
234	Allowance for Misc Items	10%		$ 767,035.90	$76,704
235	Subtotal				$843,739
236					
237	INSTRUMENTS & CONTROLS:				
238	Instruments				
239	Turbidimeters	4	EA	$ 3,133.05	$12,532
240	Number of Analog I/O Counts	5	each	$208.62	$1,002.34
241	Number of Digital I/O Counts	24	each	$49.46	$1,186.98
242	Number of PLC's	1	each	$10,331.10	$10,331.10
243	I&C Conduit & Wire	321	LF	$9.53	$3,061.92
244	Allowance for Misc Items	10%		$28,115	$2,811.45
245	Subtotal				$30,926
246					

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	B	C	D	E	F
181	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
247	MECHANICAL:				
248	Solids Collection Pipe (4-inch, USL , Immersed , Steel)	317	LF	*$66.15*	$20,969
249	Solids Collection Pipe Elbows	16	each	*$439.97*	$7,040
250	Mud Valves	4	EA	*$1,974.02*	$7,896
251	Allowance for Misc Items	10%		$35,905	$3,590
252	Subtotal				$39,495
253					
254	ELECTRICAL:				
255	MCC's				
256	Sections	5	each	*$6,783.10*	$33,915
257	AFD's				
258	Sludge Collectors (total facility) (1 hp each)	-	each	*$4,248.86*	$0
259	Switchgear				
260	Units	-	each	*$31,202.24*	$0
261	Electrical Conduit & Wire	161	LF	*$9.53*	$1,530.96
262	Allowance for Misc Items	10%		$35,446	$3,544.64
263	Subtotal				$38,991
264					
265	**USER DEFINED ESTIMATE ITEMS:**	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
266	Item 1 Description	0.00		0.00	$0
267	Item 2 Description	0.00		0.00	$0
268	Item 3 Description	0.00		0.00	$0
269	Item 4 Description	0.00		0.00	$0
270	Item 5 Description	0.00		0.00	$0
271	Item 6 Description	0.00		0.00	$0
272	Item 7 Description	0.00		0.00	$0
273	Item 8 Description	0.00		0.00	$0
274	Item 9 Description	0.00		0.00	$0
275	Item 10 Description	0.00		0.00	$0
276	Item 11 Description	0.00		0.00	$0
277	Item 12 Description	0.00		0.00	$0
278	Item 13 Description	0.00		0.00	$0
279	Item 14 Description	0.00		0.00	$0
280	Item 15 Description	0.00		0.00	$0
281	Subtotal				$0
282					
283	Subtotal				$2,177,181
284					
285	ALLOWANCES:		**User Over-write**		
286	Finishes Allowance	2.0%		$2,366,502	$47,330
287	I & C Allowance	2%		$2,366,502	$47,330
288	Mechanical Allowance	2%		$2,366,502	$47,330
289	Electrical Allowance	2%		$2,366,502	$47,330
290					
291	Facility Cost	**12,000,000**	**GPD**	**$0.20**	**$2,366,502**

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	B	C	D	E	F
317	COST ESTIMATE				
318	**Description**	**Quantity**	**Unit**	**$/Unit**	**Total Cost**
319	SITEWORK:				
320	Soil Excavation	5429.67	CY	***$5.35***	$29,061
321	Imported Structural Backfill	640.14	CY	***$40.56***	$25,961
322	Backfill	110.89	CY	***$6.58***	$730
323	Haul Excess	5318.78	CY	***$6.58***	$34,998
324	Stair Case:				
325	Soil Excavation	638.48	CY	***$5.35***	$3,417
326	Imported Structural Backfill	87.11	CY	***$40.56***	$3,533
327	Backfill	32.89	CY	***$6.58***	$216
328	Haul Excess	605.59	CY	***$6.58***	$3,985
329	Blower Room:				
330	Soil Excavation	81.35	CY	***$5.35***	$435
331	Imported Structural Backfill	102.89	CY	***$40.56***	$4,173
332	Backfill	4.04	CY	***$6.58***	$27
333	Haul Excess	77.31	CY	***$6.58***	$509
334	Electrical Room:				
335	Soil Excavation	16.29	CY	***$5.35***	$87
336	Imported Structural Backfill	19.63	CY	***$40.56***	$796
337	Backfill	1.46	CY	***$6.58***	$10
338	Haul Excess	14.83	CY	***$6.58***	$98
339	Allowance for Misc Items	5%		$108,034.91	$5,402
340	Subtotal				$113,437
341					
342	CONCRETE:				
343	Filters				
344	Foundation (Includes Filter, Gulllet Channel, Filter Influent/Backwash Wastewater Channel) (FSOGW * FSOGL * FOSGT) / 27 *#TF	314.52	CY	***$382.16***	$120,198
345	Pipe Gallery Wall	214.75	CY	***$683.50***	$146,779
346	Gullet Wall	42.53	CY	***$683.50***	$29,069
347	Filter Influent / Backwash Waste Channel Walls	362.33	CY	***$683.50***	$247,653
348	Filter Influent / Backwash Waste Channel Lower Elevated Slab	20.99	CY	***$1,088.69***	$22,849
349	Filter Influent / Backwash Waste Channel Upper Elevated Slab	28.33	CY	***$1,088.69***	$30,846
350	End Walls	221.13	CY	***$683.50***	$151,141
351	Common Filter Influent				
352	Slab on Grade	55.14	CY	***$345.93***	$19,076
353	Common Influent Channel Wall	179.54	CY	***$683.50***	$122,718
354	Common Influent Channel Elevated Slab	24.54	CY	***$1,088.69***	$26,719
355	Filter Gallery				
356	Slab on Grade	389.93	CY	***$345.93***	$134,890
357	Filter Gallery Elevated Slab	57.77	CY	***$1,088.69***	$62,891
358	Pipe Supports	1.84	CY	***$32.90***	
359	Blower Room				
360	Slab on Grade	55.50	CY	***$345.93***	$19,201
361	Blower Room Walls	29.08	CY	***$683.50***	$19,879
362	Stair Case				
363	Slab on Grade	46.22	CY	***$345.93***	$15,990
364	Stair Case Walls	25.58	CY	***$683.50***	$17,481
365	Electrical Room				
366	Slab on Grade	3.04	CY	***$345.93***	$1,051
367	Electrical Room Walls	9.71	CY	***$683.50***	$6,638
368	Allowance for Misc Items	5%		$1,195,069.53	$59,753
369	Subtotal				$1,254,823
370					
371	MASONRY:	Moderate			
372	CMU Filter Building	7599.82	SF	***$131.60***	$1,000,147
373	Blower Room	691.67	SF	***$131.60***	$91,024
374	Electrical Room	82.00	SF	***$131.60***	$10,791
375	Subtotal				$1,101,963
376					
377	METALS:				

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	B	C	D	E	F
378	Metal Guardrail with Pickets	415.33	LF	*$72.38*	$30,062
379	Filter Access Hatch	13.44	SF	*$109.91*	
380	Stairs (FBD * 12/8)	32.00	Risers	*$394.80*	$12,634
381	Allowance for Misc Items	10%		$42,695.87	$4,270
382	Subtotal				$46,965
383					
384	THERMAL & MOISTURE PROTECTION:				
385	Concrete Liner	0	SF	$16.00	$0
386	Allowance for Misc Items	10%		$0.00	$0
387	Subtotal				$0
388					
389	EQUIPMENT:				
390	Fabricated Slide Gates, 42-inch	2	EA	*$7,111.04*	$14,222
391	Underdrain - Leopold Type S	1,852	SF	*$69.90*	$129,455
392	Wash Troughs				
393	Conventional	0	LF	*$234.61*	$0
394	Media Retaining	223	LF	*$531.99*	$118,633
395	Media				
396	Bottom Media - Sand (ES=0.5 UC=1.4)	1,852	CF	*$17.47*	$32,364
397	Middle Media - Coal (ES=0 UC=0)	0	CF	*$23.30*	$0
398	Top Media - Coal (ES=1 UC=1.4)	7,408	CF	*$23.30*	$172,607
399	Air Scour Blowers (88 hp each)	2	EA	*$71,524.98*	$143,050
400	Allowance for Misc Items	10%		$610,331.42	$61,033
401	Subtotal				$671,365
402					
403	INSTRUMENTS & CONTROLS:				
404	Instruments				
405	Filter Effluent Magmeter (16-inch)	4.00	EA	*$14,438.40*	$57,754
406	Combined Filter Effluent Magmeter (30-inch)	0.00	EA	*$23,932.23*	$0
407	Isolation Valve Actuators	24.00	EA	*$5,064.93*	$121,558
408	Control Valve Actuators	4.00	EA	*$5,064.93*	$20,260
409	Turbidimeters	4	EA	*$3,133.05*	$12,532
410	Particle Counters	4	EA	*$6,764.54*	$27,058
411	Level Transmitters	4	EA	*$7,120.57*	$28,482
412	Differential Pressure Transmitters	4	EA	*$7,120.57*	$28,482
413	Filter Influent Level Transmitter	2	EA	*$7,120.57*	$14,241
414	Air Scour Differential Pressure Transmitter	2	EA	*$7,120.57*	$14,241
415	Air Scour Discharge Pressure Indicator Transmitter	2	EA	*$7,120.57*	$14,241
416	Number of Analog I/O Counts	53	EA	*$208.82*	$11,026
417	Number of Digital I/O Counts	149	EA	*$49.46*	$7,359
418	Number of PLC's	1	EA	*$10,331.10*	$10,331
419	I&C Conduit & Wire	3,438	LF	*$9.53*	$32,760
420	Allowance for Misc Items	10%		$400,325.99	$40,033
421	Subtotal				$440,359
422					
423	CONVEYING SYSTEMS:				
424	Monorail Hoist (3 Ton)	1	EA	*$3,257.13*	$3,257
425	Hoist Rail	162	LF	*$32.90*	$5,324
426	Allowance for Misc Items	5%		$8,581.61	$429
427	Subtotal				$9,011
428					
429	MECHANICAL:				
430	Pipe				
431	Air Scour Pipe-BAW (12-inch , Exposed , Steel , None , None)	216	LF	*$198.45*	$42,899

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	B	C	D	E	F
432	Filter Influent Header Pipe-FIH (30-inch , Buried , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$547.92*	$0
433	Filter Influent Pipe-FIH (20-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	0	LF	*$365.28*	$0
434	Filter Effluent Pipe-FE (16-inch , Exposed , Steel , Cement Mortar , Paint)	50	LF	*$292.22*	$14,613
435	Filter Effluent Pipe-FE (16-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	50	LF	*$292.22*	$14,613
436	Filter Control Valve Pipe-FCV (12-inch , Exposed , Steel , None , None)	32	LF	*$198.45*	$6,350
437	Filter Effluent Header Pipe-FEH (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	64	LF	*$547.92*	$34,884
438	Filter to Waste-FTW (16-inch , Exposed , Steel , Cement Mortar , Paint)	43	LF	*$292.22*	$12,612
439	Filter to Waste-FTW (16-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	153	LF	*$292.22*	$44,807
440	Backwash Supply Pipe-BWS (30-inch , Exposed , Steel , Cement Mortar , Paint)	170	LF	*$547.92*	$93,186
441	Backwash Supply Pipe-BWS (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	48	LF	*$547.92*	$26,300
442	Backwash Waste Pipe-BWW (30-inch , Encased , Steel , Cement Mortar , Fusion Bonded Epoxy)	10	LF	*$547.92*	$5,479
443	Elbows				
444	Air Scour Pipe-BAW (12-inch , Steel)	16	EA	*$1,319.92*	$21,119
445	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$3,299.80*	$0
446	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$2,199.87*	$0
447	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$1,759.89*	$7,040
448	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$1,759.89*	$7,040
449	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$1,319.92*	$0
450	Filter Effluent Header Pipe-FEH (30-inch , Steel)	0	EA	*$3,299.80*	$0
451	Filter to Waste-FTW (16-inch , Steel)	6	EA	*$1,759.89*	$10,559
452	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$1,759.89*	$0
453	Backwash Supply Pipe-BWS (30-inch , Steel)	2	EA	*$3,299.80*	$6,600
454	Backwash Supply Pipe-BWS (30-inch , Steel)	2	EA	*$3,299.80*	$6,600
455	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$3,299.80*	$0
456	Tees				
457	Air Scour Pipe-BAW (12-inch , Steel)	4	EA	*$3,007.27*	$12,029
458	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$7,518.19*	$0
459	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$5,012.12*	$0
460	Filter Effluent Pipe-FE (16-inch , Steel)	4	EA	*$4,009.70*	$16,039
461	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$4,009.70*	$0
462	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$3,007.27*	$0
463	Filter Effluent Header Pipe-FEH (30-inch , Steel)	0	EA	*$7,518.19*	$0
464	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$4,009.70*	$0
465	Filter to Waste-FTW (16-inch , Steel)	2	EA	*$4,009.70*	$8,019
466	Backwash Supply Pipe-BWS (30-inch , Steel)	6	EA	*$7,518.19*	$45,109
467	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$7,518.19*	$0
468	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$7,518.19*	$0
469	Crosses				
470	Air Scour Pipe-BAW (12-inch , Steel)	2	EA	*$4,009.70*	$8,019
471	Filter Influent Header Pipe-FIH (30-inch , Steel)	0	EA	*$10,024.25*	$0
472	Filter Influent Pipe-FIH (20-inch , Steel)	0	EA	*$6,682.83*	$0
473	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$5,346.27*	$0
474	Filter Effluent Pipe-FE (16-inch , Steel)	0	EA	*$5,346.27*	$0
475	Filter Control Valve Pipe-FCV (12-inch , Steel)	0	EA	*$4,009.70*	$0
476	Filter Effluent Header Pipe-FEH (30-inch , Steel)	2	EA	*$10,024.25*	$20,048
477	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$5,346.27*	$0
478	Filter to Waste-FTW (16-inch , Steel)	0	EA	*$5,346.27*	$0
479	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$10,024.25*	$0
480	Backwash Supply Pipe-BWS (30-inch , Steel)	0	EA	*$10,024.25*	$0
481	Backwash Waste Pipe-BWW (30-inch , Steel)	0	EA	*$10,024.25*	$0
482	Valves				
483	Air Scour Pipe-BAW (12-inch ,V500 - BFV)	4	EA	*$9,653.56*	$38,614
484	Filter Influent Header Pipe-FIH (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0

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	B	C	D	E	F
485	Filter Influent Pipe-FIH (20-inch ,V500 - BFV)	4	EA	*$16,089.26*	$64,357
486	Filter Effluent Pipe-FE (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
487	Filter Effluent Pipe-FE (16-inch ,V500 - BFV)	0	EA	*$12,871.41*	$0
488	Filter Control Valve Pipe-FCV (12-inch ,V500 - BFV)	4	EA	*$9,653.56*	$38,614
489	Filter Effluent Header Pipe-FEH (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0
490	Filter to Waste-FTW (16-inch ,V500 - BFV)	4	EA	*$12,871.41*	$51,486
491	Filter to Waste-FTW (16-inch ,V500 - BFV)	0	EA	*$12,871.41*	$0
492	Backwash Supply Pipe-BWS (30-inch ,V500 - BFV)	4	EA	*$24,133.90*	$96,536
493	Backwash Supply Pipe-BWS (30-inch ,V500 - BFV)	0	EA	*$24,133.90*	$0
494	Backwash Waste Pipe-BWW (30-inch ,V500 - BFV)	4	EA	*$24,133.90*	$96,536
495	Allowance for Misc Items	5%		$901,593.08	$45,080
496	Subtotal				$946,673
497					
498	ELECTRICAL:				
499	MCC's				
500	Sections	5	EA	*$6,783.10*	$33,915
501	AFD's				
502	Air Scour Blowers (88 hp each)	-	EA	*$14,946.94*	$0
503	Switchgear				
504	Units	-	EA	*$31,202.24*	$0
505	Electrical Conduit & Wire	127	LF	*$9.53*	$1,213
506	Allowance for Misc Items	5%		$35,128.81	$1,756
507	Subtotal				$36,885
508					
509	USER DEFINED ESTIMATE ITEMS	QUANT	UNIT	$/UNIT	TOTAL COST
510	Item 1 Description	0.00		0.00	$0
511	Item 2 Description	0.00		0.00	$0
512	Item 3 Description	0.00		0.00	$0
513	Item 4 Description	0.00		0.00	$0
514	Item 5 Description	0.00		0.00	$0
515	Item 6 Description	0.00		0.00	$0
516	Item 7 Description	0.00		0.00	$0
517	Item 8 Description	0.00		0.00	$0
518	Item 9 Description	0.00		0.00	$0
519	Item 10 Description	0.00		0.00	$0
520	Item 11 Description	0.00		0.00	$0
521	Item 12 Description	0.00		0.00	$0
522	Item 13 Description	0.00		0.00	$0
523	Item 14 Description	0.00		0.00	$0
524	Item 15 Description	0.00		0.00	$0
525	Subtotal				$0
526					
527	Subtotal				$4,621,479.61
528					
529	ALLOWANCES:		**User Over-write**		
530	Finishes Allowance	2%		$5,023,347	$100,466.95
531	Mechanical Allowance	2%		$5,023,347.40	$100,466.95
532	I&C Allowance	2%		$5,023,347.40	$100,466.95
533	Electrical Allowance	2%		$5,023,347.40	$100,466.95
534					
535	Facility Cost	**12,000,000**	**GPD**	**$0.42**	**$5,023,347**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation				
Influent Channel, Surge Basin & Decant Pump	5311.63	CY	*$5.35*	$28,429
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1502.22	CY	*$5.35*	$8,040
Pipe Vault	351.82	CY	*$5.35*	$1,883
Imported Structural Backfill				
Influent Channel, Surge Basin & Decant Pump	426.72	CY	*$40.56*	$17,306
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	80.20	CY	*$40.56*	$3,252
Pipe Vault	70.17	CY	*$40.56*	$2,846
Native Backfill				
Influent Channel, Surge Basin & Decant Pump	1115.38	CY	*$6.58*	$7,339
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	32.00	CY	*$6.58*	$211
Pipe Vault	103.39	CY	*$6.58*	$680
Haul Excess				
Influent Channel, Surge Basin & Decant Pump	4196.25	CY	*$6.58*	$27,612
Dry Pit, Backwash Waste Sludge Wet Well, & Backwash Waste Recycle Wet Well	1470.22	CY	*$6.58*	$9,674
Pipe Vault	248.42	CY	*$6.58*	$1,635
Allowance for Misc Items	5%		$108,907.43	$5,445
Subtotal				$114,353
CONCRETE:				
Surge Basin:				
Foundation	308.85	CY	*$382.16*	$118,028
Perimeter Walls	382.34	CY	*$683.50*	$261,329
Influent Channel Wall	62.23	CY	*$683.50*	$42,536
Concrete Curb (8" X 8")	76.89	LF	*$32.90*	$2,530
Backwash Recycle Sump:				
Slab on Grade	18.89	CY	*$345.93*	$6,534
Walls	90.62	CY	*$683.50*	$61,940
Elevated Slab	9.23	CY	*$1,088.69*	$10,045
Backwash Sludge Sump:				
Slab on Grade	13.33	CY	*$345.93*	$4,612
Walls	66.77	CY	*$683.50*	$45,640
Elevated Slab	6.88	CY	*$1,088.69*	$7,491
Dry Pit:				
Slab on Grade	5.31	CY	*$345.93*	$1,836
Walls	32.33	CY	*$683.50*	$22,096
Elevated Slab	3.49	CY	*$1,088.69*	$3,802
Pipe Vault:				
Lower Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Upper Elevated Slab	29.64	CY	*$1,088.69*	$32,271
Walls	32.67	CY	*$683.50*	$22,333
Electrical Room Slab on Grade	5.27	CY	*$345.93*	$1,822
Allowance for Misc Items	5%		$677,117.15	$33,856
Subtotal				$710,973
MASONRY:	Moderate			
Pump Sumps and Pipe Vault	0.00	SF	*$131.60*	$0
Electrical Room	80.89	SF	*$131.60*	$10,645
Subtotal	80.89			$10,645
METALS:				
Influent Channel:				
Grating	185.56	SF	*$72.38*	$13,431
Surge Basin:				
Grating	4.00	SF	*$72.38*	$290
Backwash Recycle Sump:				
Grating	4.00	SF	*$72.38*	$290
Backwash Sludge Sump:				
Grating	4.00	SF	*$72.38*	$290
Dry Pit:				

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Ladder	27.60	VLF	*$99.36*	$2,742
Pipe Vault:				
Grating	4.00	SF	*$72.38*	$290
Stairs	16.00	RISERS	*$394.80*	$6,317
Allowance for Misc Items	10%		$23,647.47	$2,365
Subtotal				$26,012
DOORS & WINDOWS:				
Backwash Recycle Sump:				
Aluminum Access Hatch (10' x 5')	1.00	EA	*$4,400.75*	$4,401
Backwash Sludge Sump:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Dry Pit:				
Aluminum Access Hatch (3' x 3')	1.00	EA	*$1,098.21*	$1,098
Pipe Vault:				
Aluminum Access Hatch (3' x 3')	2.00	EA	*$1,098.21*	$2,196
Allowance for Misc Items	5%		$8,793.60	$440
Subtotal				$9,233
EQUIPMENT:				
Floating Decanter Plate System	0.00	SF	*$72.94*	$0
Traveling Solids Removal Mechanism	2.00	EA	*$66,857.09*	$133,714
Washwater Decant Pump (Submersible Pump)	3.00	EA	*$18,993.38*	$56,980
Sludge Pump (Submersible Pump)	2.00	EA	*$12,409.63*	$24,819
Mixers	0.00	HP	*$1,580.26*	$0
Allowance for Misc Items	10%		$215,513.57	$21,551
Subtotal				$237,065
I&C:				
Instruments				
Backwash Waste Recycle Header Magmeter (BWRH, 12 inch)	1.00	EA	$10,573.93	$10,574
Isolation Valve Actuators (Electric)	5.00	EA	*$5,064.93*	$25,325
Level Transmitters	1.00	EA	*$7,120.57*	$7,121
Number of Analog I/O Counts	6.00	EA	*$208.82*	$1,253
Number of Digital I/O Counts	30.00	EA	*$49.46*	$1,484
Number of Local Panels	1.00	EA	*$10,331.10*	$10,331
Number of PLC's	1.00	EA	*$10,990.54*	$10,991
I&C Conduit Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$69,552.80	$3,478
Subtotal				$73,030
MECHANICAL:				
Pipe:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	LF	*$657.50*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	LF	*$123.32*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	16.22	LF	*$219.17*	$3,555
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	LF	*$219.17*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	81.00	LF	*$54.81*	$4,439
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	16.22	LF	*$109.58*	$1,778
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	LF	*$109.58*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	54.00	LF	*$109.58*	$5,917
Elbows:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$3,959.76*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$2,588.21*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	1.00	EA	*$1,319.92*	$1,320
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$1,319.92*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	6.00	EA	*$1,150.31*	$6,902
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$659.96*	$660
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$659.96*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	4.00	EA	*$659.96*	$2,640
Tee:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$9,021.82*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$4,297.65*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	2.00	EA	*$3,007.27*	$6,015

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Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$3,007.27*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	0.00	EA	*$1,910.07*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	1.00	EA	*$1,503.64*	$1,504
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	0.00	EA	*$1,503.64*	$0
Valves:				
Backwash Waste (BWW, 36 inch, Steel)	0.00	EA	*$28,960.68*	$0
Filter to Waste (FTW, 18 inch, DI)	0.00	EA	*$12,602.74*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Header (BWRH, 12 inch, Steel)	0.00	EA	*$9,653.56*	$0
Backwash Waste Recycle Lateral (BWRL, 8 inch, DI)	3.00	EA	*$5,601.22*	$16,804
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Header (BWSH, 6 inch, Steel)	0.00	EA	*$4,826.78*	$0
Backwash Waste Sludge Lateral (BWSL, 6 inch, Steel)	2.00	EA	*$4,826.78*	$9,654
Allowance for Misc Items	5%		$61,186.86	$3,059
Subtotal				$64,246
ELECTRICAL:				
# MCC Sections	8.00	EA	*$6,783.10*	$54,265
Switchgear	0.00	EA	*$31,202.24*	$0
Adjustable Frequency Drives				
Basin Mixer	0.00	EA	*$4,125.89*	$0
Sludge Pumps (Active)	1.00	EA	*$4,871.14*	$4,871
Sludge Pumps (Standby)	1.00	EA	*$4,871.14*	$4,871
Recycle Pumps (Active)	2.00	EA	*$6,299.20*	$12,598
Recycle Pumps (Standby)	1.00	EA	*$6,299.20*	$6,299
Electrical Conduit & Wire	259.78	lf	*$9.53*	$2,475
Allowance for Misc Items	5%		$85,380.01	$4,269
Subtotal				$89,649
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,335,206.98
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2%		$1,534,721	$30,694.41
I & C Allowance	3%		$1,534,720.67	$46,041.62
Mechanical Allowance	5%		$1,534,720.67	$76,736.03
Electrical Allowance	3%		$1,534,720.67	$46,041.62
Facility Cost	**2,519,600**	**Gallons**	**$0.61**	**$1,534,721**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Circular Clearwell				
Excavation	14,515	CY	*$5.35*	$77,691
Imported Structural Backfill	1,523	CY	*$40.56*	$61,784
Native Backfill	2,973	CY	*$6.58*	$19,563
Haul Excess	11,542	CY	*$6.58*	$75,949
Rectangular Clearwell				
Excavation	0	CY	*$5.35*	$0
Imported Structural Backfill	0	CY	*$40.56*	$0
Native Backfill	0	CY	*$6.58*	$0
Haul Excess	0	CY	*$6.58*	$0
Allowance for Misc Items	5%		$234,986.14	$11,749
Subtotal				$246,735
CONCRETE:				
Circular Clearwell				
Prestressed Concrete Tank (2000000 gallons)	1	EA	*$872,030.58*	$872,031
Rectangular Clearwell				
Foundation	0	CY	*$382.16*	$0
Columns	0	CY	*$683.50*	$0
Walls	0	CY	*$683.50*	$0
Elevated Slab	0	CY	*$1,088.69*	$0
Concrete Baffling	0	CY	*$683.50*	$0
Allowance for Misc Items	5%		$872,030.58	$43,602
Subtotal				$915,632
METALS & PLASTICS:				
Polypropylene Baffling	0	SF	*$10.99*	$0
Stainless Steel Baffling	0	SF	*$45.79*	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
THERMAL & MOISTURE PROTECTION:				
Concrete Liner	0	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$1,162,368
ALLOWANCES:		**User Over-write**		
Metals Allowance	1.0%		$1,249,858	$12,499
Finishes Allowance	2.0%		$1,249,858	$24,997

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Equipment Allowance	1.0%		$1,249,858	$12,499
I & C Allowance	2%		$1,249,858	$24,997
Mechanical Allowance	5%		$1,249,858	$62,493
Electrical Allowance	1%		$1,249,858	$12,499
Facility Cost	**2,000,000**	**Gallons**	**$0.66**	**$1,312,350**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Pump Station:				
Excavation	701.75	CY	*$5.35*	$0
Imported Structural Backfill	358.27	CY	*$40.56*	$0
Native Backfill	89.16	CY	*$6.58*	$0
Haul Excess	612.60	CY	*$6.58*	$0
Forebay:				
Excavation	7114.29	CY	*$5.35*	$0
Imported Structural Backfill	437.87	CY	*$40.56*	$0
Native Backfill	1838.49	CY	*$6.58*	$0
Haul Excess	5275.80	CY	*$6.58*	$0
Office:				
Excavation	0.00	CY	*$5.35*	$0
Imported Structural Backfill	0.00	CY	*$40.56*	$0
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	0.00	CY	*$6.58*	$0
Surge Protection:				
Excavation	117.15	CY	*$5.35*	$627
Imported Structural Backfill	86.04	CY	*$40.56*	$3,489
Native Backfill	18.55	CY	*$6.58*	$122
Haul Excess	98.59	CY	*$6.58*	$649
Allowance for Misc Items	5%		$4,887.33	$244
Subtotal				$5,132
CONCRETE:				
Pump Station				
Foundation	256.01	CY	*$382.16*	$0
Pump Pad Epoxy	0.74	CY	$3,412.56	$2,528
Pump Pad Support	7.78	CY	*$345.93*	$2,692
Pipe Supports	4.19	CY	*$345.93*	$1,448
Electrical Room				
Foundation	14.61	CY	*$345.93*	$5,055
Surge Protection				
Foundation	20.70	CY	*$345.93*	$7,161
Office				
Foundation	0.00	CY	*$345.93*	$0
Pump Station Forebay				
Slab on Grade for Rectangular Tank	231.48	CY	*$345.93*	$0
Support Walls for Rectangular	342.22	CY	*$683.50*	$0
Support Columns for Rectangular	16.50	CY	*$683.50*	$0
Elevated Slab for Rectangular	91.36	CY	*$1,088.69*	$0
Pump Baffling (for all cases)	16.43	CY	*$683.50*	$0
Sump Walls	86.37	CY	*$683.50*	$0
Sump Concrete Fill	184.06	CY	*$382.16*	$0
Prestressed Concrete Tank (422429 gallons)	0.00	EA	$0.00	$0
Allowance for Misc Items	5%		$18,883.83	$944
Subtotal				$19,828
MASONRY:	Moderate			
Pump Station Building	2235.55	SF	*$197.40*	$441,303
Office Building	0.00	SF	*$131.60*	$0
Surge Building	558.89	SF	*$131.60*	$73,551
Electrical Room	394.53	SF	*$131.60*	$51,921
Subtotal	3188.98			$566,775
METALS:				
Pump Removal Hatches	73.33	SF	*$109.91*	$8,060
Allowance for Misc Items	10%		$8,059.73	$806
Subtotal				$8,866
THERMAL & MOISTURE PROTECTION:				
Wet Well Liner	0.00	SF	$16.00	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
EQUIPMENT:				
Pumps				
Active Pump # 1	1.00	EA	*$167,150.63*	$167,151
Active Pump # 2	1.00	EA	*$167,150.63*	$167,151
Active Pump # 3	1.00	EA	*$167,150.63*	$167,151

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Active Pump # 4	1.00	EA	*$167,150.63*	$167,151
Active Pump # 5	0.00	EA	*$0.00*	$0
Active Pump # 6	0.00	EA	*$0.00*	$0
Active Pump # 7	0.00	EA	*$0.00*	$0
Active Pump # 8	0.00	EA	*$0.00*	$0
Active Pump # 9	0.00	EA	*$0.00*	$0
Active Pump # 10	0.00	EA	*$0.00*	$0
Standby Pump	1.00	EA	*$167,150.63*	$167,151
Allowance for Misc Items	10%		$835,753.14	$83,575
Subtotal				$919,328
INSTRUMENTATION & CONTROLS:				
Instruments				
Isolation Valve Actuators	10.00	each	*$5,064.93*	$50,649
Control Valve Actuators	5.00	each	*$5,064.93*	$25,325
Level Indicator Transmitters	2.00	each	*$6,764.54*	$13,529
Level Swithces	2.00	each	*$7,120.57*	$14,241
Pressure Indicator Transmitters	6.00	each	*$7,120.57*	$42,723
Pressure Switches	10.00	each	*$7,120.57*	$71,206
Number of Analog I/O Counts	37.20	each	*$208.82*	$7,768
Number of Digital I/O Counts	104.40	each	*$49.46*	$5,163
Number of PLC's	5.00	each	*$10,331.10*	$51,656
I&C Conduit & Wire	2380.06	lf	*$9.53*	$22,679
Allowance for Misc Items	10%		$ 304,939.30	$30,494
Subtotal				$335,433
MECHANICAL:				
Pipe:				
Discharge Lateral Pipe (14-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	35.00	LF	*$53.41*	$1,869
Discharge Header Pipe (30-inch,DIS, Exposed/Buried, Steel, Cement Mortar, Cement Mortar)	42.50	LF	*$744.31*	$31,633
Pump Discharge Pipe (10-inch,DIS, Exposed, HDPE, Cement Mortar, Cement Mortar)	4.17	LF	*$55.90*	$233
Elbows:				
Discharge Header Pipe (30-inch)	2.00	EA	*$2,831.95*	$5,664
Tees:				
Discharge Header Pipe (30-inch)	5.00	EA	*$5,509.28*	$27,546
Valves:				
Discharge Lateral Isolation Valve (14-inch, BFV)	5.00	EA	*$1,529.44*	$7,647
Pump Control Valve (14-inch, Check Valve)	5.00	EA	*$1,529.44*	$7,647
Discharge Header Isolation Valve (30-inch, BFV)	1.00	EA	*$5,934.12*	$5,934
Air Release Vacuum Valves	15.00	EA	*$3,297.16*	$49,457
Allowance for Misc Items	10%		$137,631.79	$13,763
Subtotal				$151,395
ELECTRICAL:				
MCC's				
Sections	7.00	each	*$6,783.10*	$47,482
AFD's				
Active Pump # 1	450.00	HP	*$132.14*	$59,461
Active Pump # 2	450.00	HP	*$132.14*	$59,461
Active Pump # 3	450.00	HP	*$132.14*	$59,461
Active Pump # 4	450.00	HP	*$132.14*	$59,461
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	450.00	HP	*$132.14*	$59,461
Switchgear				
Units	0.00	each	*$31,202.24*	$0
Electrical Conduit & Wire	340.01	lf	*$9.53*	$3,240
Allowance for Misc Items	5%		$348,025	$17,401
Subtotal				$365,427
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0

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	Item 7 Description	0.00		0.00	$0
	Item 8 Description	0.00		0.00	$0
	Item 9 Description	0.00		0.00	$0
	Item 10 Description	0.00		0.00	$0
	Item 11 Description	0.00		0.00	$0
	Item 12 Description	0.00		0.00	$0
	Item 13 Description	0.00		0.00	$0
	Item 14 Description	0.00		0.00	$0
	Item 15 Description	0.00		0.00	$0
Subtotal					$0
Subtotal					$2,372,183
ALLOWANCES:			User Over-write		
Finishes Allowance		5%		$3,041,261	$152,063
I & C Allowance		2%		$3,041,261	$60,825
Surge Allowance		5%		$3,041,261	$152,063
Mechanical Allowance		5%		$3,041,261	$152,063
Electrical Allowance		5%		$3,041,261	$152,063
Facility Cost		**2,250**	**Total Pump HP**	**$1,351.67**	**$3,041,261**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	1575.42	CY	*$5.35*	$0
Imported Structural Backfill	86.68	CY	*$40.56*	$0
Native Backfill	828.79	CY	*$6.58*	$0
Haul Excess	746.63	CY	*$6.58*	$0
Allowance for Misc Items	5%		$0.00	$0
Subtotal				$0
CONCRETE:				
Wet Well:				
Foundation	28.89	CY	*$382.16*	$0
Perimeter Walls	64.42	CY	*$683.50*	$0
Operating Floor:				
Elevated Slab (Including floor over Discharge Header Vault)	36.61	CY	*$1,088.69*	$0
Pump Pads	1.63	CY	*$345.93*	$565
Other Equipment Pads	1.00	CY	*$345.93*	$346
Discharge Pipe Vault:				
Slab on Grade	13.66	CY	*$345.93*	$4,725
Walls	17.16	CY	*$683.50*	$11,727
Allowance for Misc Items	5%		$17,362.33	$868
Subtotal				$18,230
MASONRY:	Moderate			
CMU Building	988.44	SF	*$131.60*	$130,080
Subtotal				$130,080
METALS:				
Checker Plate Over Intake Pipe Gate = (Diameter of Influent Pipe +2') * (2 Feet Wide) (sf)	10.00	SF	*$72.38*	$724
Checker Plate Over Discharge Pipe Header = ((Discharge Pipe Diameter * 2) * ("S" * Total Number of Pumps)	57.98	SF	*$72.38*	$4,197
Ladder	15.55	VLF	*$99.36*	$1,545
Allowance for Misc Items	10%		$6,464.96	$646
Subtotal				$7,111
EQUIPMENT:				
Size of Sluice Gate (per side in inches)	36.00	Inches		
Sluice Gate	1.00	EA	*$6,330.27*	$6,330
Pumps:				
Active Pump # 1	124.39	HP	*$790.52*	$98,332
Active Pump # 2	124.39	HP	*$790.52*	$98,332
Active Pump # 3	0.00	HP	*$0.00*	$0
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0
Active Pump # 6	0.00	HP	*$0.00*	$0
Active Pump # 7	0.00	HP	*$0.00*	$0
Active Pump # 8	0.00	HP	*$0.00*	$0
Active Pump # 9	0.00	HP	*$0.00*	$0
Active Pump # 10	0.00	HP	*$0.00*	$0
Standby Pump	124.39	HP	*$790.52*	$98,332
AFD's				
Active Pump # 1	124.39	HP	*$156.14*	$19,422
Active Pump # 2	124.39	HP	*$156.14*	$19,422
Active Pump # 3	0.00	HP	*$0.00*	$0
Active Pump # 4	0.00	HP	*$0.00*	$0
Active Pump # 5	0.00	HP	*$0.00*	$0

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Active Pump # 6	0.00	HP	***$0.00***	$0
Active Pump # 7	0.00	HP	***$0.00***	$0
Active Pump # 8	0.00	HP	***$0.00***	$0
Active Pump # 9	0.00	HP	***$0.00***	$0
Active Pump # 10	0.00	HP	***$0.00***	$0
Standby Pump	124.39	HP	***$156.14***	$19,422
Allowance for Misc Items	10%		$353,259.39	$35,326
Subtotal				$394,916
USER DEFINED ESTIMATE ITEMS:	**QUANT**	**UNIT**	**$/UNIT**	**TOTAL COST**
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$550,338
ALLOWANCES:		**User Over-write**		
Finishes Allowance	2.0%		$1,100,676	$22,014
I & C Allowance	8.0%		$1,100,676	$88,054
Mechanical Allowance	25.0%		$1,100,676	$275,169
Electrical Allowance	15.0%		$1,100,676	$165,101
Facility Cost	**373**	**Total Pump HP**	**$2,949.56**	**$1,100,676**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	89.00	CY	*$5.35*	$476
Imported Structural Backfill	45.41	CY	*$40.56*	$1,842
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	89.00	CY	*$6.58*	$586
Allowance for Misc Items	5%		$2,903.46	$145
Subtotal				$3,049
CONCRETE:				
Slab on Grade	31.46	CY	*$345.93*	$10,882
Containment Walls	6.37	CY	*$683.50*	$4,356
Bulk Tank Pads	29.50	CY	*$345.93*	$10,204
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	2.00	CY	*$345.93*	$692
Corridor				
Slab on Grade	7.50	CY	*$345.93*	$2,594
Electrical Room				
Slab on Grade	3.41	CY	*$345.93*	$1,179
Allowance for Misc Items	5%		$29,906.78	$1,495
Subtotal				$31,402
MASONRY:	Moderate			
CMU Building	1226.00	SF	*$131.60*	$161,343
Subtotal				$161,343
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$16,973.34*	$33,947
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	3.00	EA	*$6,737.98*	$20,214
Allowance for Misc Items	10%		$54,160.63	$5,416
Subtotal				$59,577
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	3.00	each	*$549.53*	$1,649
Magmeter	2.00	each	*$549.53*	$1,099
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	9.00	each	*$208.82*	$1,879
Number of Digital I/O Counts	26.00	each	*$49.46*	$1,286
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	297.00	lf	*$9.53*	$2,830
Allowance for Misc Items	10%		$34,460.81	$3,446
Subtotal				$37,907
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	61.00	lf	*$10.36*	$632
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	61.00	lf	*$11.98*	$731
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	12.00	each	*$7.95*	$95
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	12.00	each	*$63.16*	$758
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	3.00	each	*$8.27*	$25
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	3.00	each	*$109.33*	$328
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	6.00	each	*$45.15*	$271
Allowance for Misc Items	10%		$3,184.53	$318
Subtotal				$3,503
ELECTRICAL:				
# MCC Sections	6.00	#	*$6,783.10*	$40,699
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	243.00	lf	*$9.53*	$2,315
Allowance for Misc Items	10%		$43,014.07	$4,301
Subtotal				$47,315
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$353,071
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$392,301	$7,846
I & C Allowance	2%		$392,301	$7,846
Mechanical Allowance	4%		$392,301	$15,692
Electrical Allowance	2%		$392,301	$7,846
Facility Cost	**1,226**	**Building SF**	**$319.98**	**$392,301**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	76.22	CY	*$5.35*	$408
Imported Structural Backfill	38.89	CY	*$40.56*	$1,577
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	76.22	CY	*$6.58*	$502
Allowance for Misc Items	5%		$2,486.65	$124
Subtotal				$2,611
CONCRETE:				
Slab on Grade	28.07	CY	*$345.93*	$9,711
Containment Walls	4.73	CY	*$683.50*	$3,232
Bulk Tank Pads	25.13	CY	*$345.93*	$8,694
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	6.94	CY	*$345.93*	$2,402
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$24,500.49	$1,225
Subtotal				$25,726
MASONRY:	Moderate			
CMU Building	1050.00	SF	*$131.60*	$138,181
Subtotal				$138,181
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	2.00	EA	*$17,367.52*	$34,735
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$48,211.01	$4,821
Subtotal				$53,032
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	2.00	each	*$824.29*	$1,649
Chemical Tank Beacons	2.00	each	*$824.29*	$1,649
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	0.00	each	*$1,099.05*	$0
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	6.00	each	*$208.82*	$1,253
Number of Digital I/O Counts	20.00	each	*$49.46*	$989
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	225.00	lf	*$9.53*	$2,144
Allowance for Misc Items	10%		$31,752.48	$3,175
Subtotal				$34,928
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	59.00	lf	*$10.36*	$611
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	59.00	lf	*$11.98*	$707
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,557.19	$256
Subtotal				$2,813
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$266,266
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$295,851	$5,917
I & C Allowance	2%		$295,851	$5,917
Mechanical Allowance	4%		$295,851	$11,834
Electrical Allowance	2%		$295,851	$5,917
Facility Cost	**1,050**	**Building SF**	**$281.76**	**$295,851**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	51.83	CY	*$5.35*	$277
Imported Structural Backfill	26.44	CY	*$40.56*	$1,072
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	51.83	CY	*$6.58*	$341
Allowance for Misc Items	5%		$1,690.92	$85
Subtotal				$1,775
CONCRETE:				
Slab on Grade	20.15	CY	*$345.93*	$6,969
Containment Walls	3.83	CY	*$683.50*	$2,617
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	4.72	CY	*$345.93*	$1,634
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$11,680.12	$584
Subtotal				$12,264
MASONRY:	Moderate			
CMU Building	714.00	SF	*$131.60*	$93,963
Subtotal				$93,963
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	2.20	each	*$1,099.05*	$2,422
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	7.00	each	*$208.82*	$1,462
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	122.47	lf	*$9.53*	$1,167
Allowance for Misc Items	10%		$29,861.98	$2,986
Subtotal				$32,848
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	51.00	lf	*$10.36*	$528
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	51.00	lf	*$11.98*	$611
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,378.44	$238
Subtotal				$2,616
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$167,266
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$185,851	$3,717
I & C Allowance	2%		$185,851	$3,717
Mechanical Allowance	4%		$185,851	$7,434
Electrical Allowance	2%		$185,851	$3,717
Facility Cost	**714**	**Building SF**	**$260.30**	**$185,851**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
SITEWORK:				
Excavation	51.83	CY	*$5.35*	$277
Imported Structural Backfill	26.44	CY	*$40.56*	$1,072
Native Backfill	0.00	CY	*$6.58*	$0
Haul Excess	51.83	CY	*$6.58*	$341
Allowance for Misc Items	5%		$1,690.92	$85
Subtotal				$1,775
CONCRETE:				
Slab on Grade	20.15	CY	*$345.93*	$6,969
Containment Walls	3.83	CY	*$683.50*	$2,617
Bulk Tank Pads	0.00	CY	*$345.93*	$0
Day Tank Pads	0.00	CY	*$345.93*	$0
Transfer Pump Pads	0.00	CY	*$345.93*	$0
Metering Pump Pads	1.33	CY	*$345.93*	$461
Corridor				
Slab on Grade	4.72	CY	*$345.93*	$1,634
Electrical Room				
Slab on Grade	0.00	CY	*$345.93*	$0
Allowance for Misc Items	5%		$11,680.12	$584
Subtotal				$12,264
MASONRY:	Moderate			
CMU Building	714.00	SF	*$131.60*	$93,963
Subtotal				$93,963
METALS:				
Metal Stairway	1.00	EA	$6,580.07	$6,580
Grating	1.00	EA	$1,579.22	$1,579
Allowance for Misc Items	10%		$8,159.28	$816
Subtotal				$8,975
EQUIPMENT:				
Bulk Tank	0.00	EA	*$0.00*	$0
Day Tank	0.00	EA	*$0.00*	$0
Transfer Pump	0.00	EA	*$0.00*	$0
Metering Pump	2.00	EA	*$6,737.98*	$13,476
Allowance for Misc Items	10%		$13,475.96	$1,348
Subtotal				$14,824
INSTRUMENTS & CONTROLS:				
Instruments				
Chemical Tank Radar Level Transmitters	0.00	each	*$824.29*	$0
Chemical Tank Beacons	0.00	each	*$824.29*	$0
Day Tank Differential Pressure Transmitter	0.00	each	*$824.29*	$0
Drum or Tote Weigh Scale	1.37	each	*$1,099.05*	$1,501
Metering Pump Discharge Pressure Switch	2.00	each	*$549.53*	$1,099
Magmeter	1.00	each	*$549.53*	$550
Sump Pump Float Switch	1.00	each	*$274.76*	$275
Eyewash	1.00	each	*$824.29*	$824
Number of Analog I/O Counts	6.00	each	*$208.82*	$1,253
Number of Digital I/O Counts	15.00	each	*$49.46*	$742
Number of Local Panels	1.00	each	*$10,331.10*	$10,331
Number of PLC's	1.00	each	*$10,990.54*	$10,991
I&C Conduit & Wire	108.22	lf	*$9.53*	$1,031
Allowance for Misc Items	10%		$28,596.74	$2,860
Subtotal				$31,456
MECHANICAL:				
Pipe				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	lf	*$10.36*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	lf	*$11.98*	$0

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Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	51.00	lf	*$10.36*	$528
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	51.00	lf	*$11.98*	$611
Elbows				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$7.95*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$63.16*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	8.00	each	*$7.95*	$64
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	8.00	each	*$63.16*	$505
Tees				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$8.27*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$109.33*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$8.27*	$17
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$109.33*	$219
End Caps				
Chemical Transfer Pump Suction Header Piping-CTSH (1-inch, Exposed, PVC)	0.00	each	*$4.46*	$0
Chemical Transfer Pump Discharge Header Piping-CTDH (1-inch, Exposed, FRP)	0.00	each	*$32.34*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC)	2.00	each	*$4.46*	$9
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP)	2.00	each	*$32.34*	$65
Valves				
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	0.00	each	*$45.15*	$0
Chemical Metering Pump Suction Header Piping-LCSH (1-inch, Exposed, PVC, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Chemical Metering Pump Discharge Header Piping-LCDH (1-inch, Exposed, FRP, V-902, Diaphragm)	4.00	each	*$45.15*	$181
Allowance for Misc Items	10%		$2,378.44	$238
Subtotal				$2,616
ELECTRICAL:				
# MCC Sections	0.00	#	*$6,783.10*	$0
Switchgear	0.00	each	*$31,202.24*	$0
Adjustable Frequency Drives				
Metering Pumps	0.00	each	*$4,187.38*	$0
User Defined Item #1	0.00	each	*$4,125.89*	$0
User Defined Item #2	0.00	each	*$4,125.89*	$0
User Defined Item #3	0.00	each	*$4,125.89*	$0
Electrical Conduit & Wire	0.00	lf	*$9.53*	$0
Allowance for Misc Items	10%		$0.00	$0
Subtotal				$0
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0

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Subtotal				$0
Subtotal				$165,874
ALLOWANCES:		User Over-write		
Finishes Allowance	2.0%		$184,305	$3,686
I & C Allowance	2%		$184,305	$3,686
Mechanical Allowance	4%		$184,305	$7,372
Electrical Allowance	2%		$184,305	$3,686
Facility Cost	**714**	**Building SF**	**$258.13**	**$184,305**

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COST ESTIMATE

Description	Quantity	Unit	$/Unit	Total Cost
O&M BUILDING	6000.00	SF	$474.70	$2,848,226
Subtotal				$2,848,226
USER DEFINED ESTIMATE ITEMS:	QUANT	UNIT	$/UNIT	TOTAL COST
Item 1 Description	0.00		0.00	$0
Item 2 Description	0.00		0.00	$0
Item 3 Description	0.00		0.00	$0
Item 4 Description	0.00		0.00	$0
Item 5 Description	0.00		0.00	$0
Item 6 Description	0.00		0.00	$0
Item 7 Description	0.00		0.00	$0
Item 8 Description	0.00		0.00	$0
Item 9 Description	0.00		0.00	$0
Item 10 Description	0.00		0.00	$0
Item 11 Description	0.00		0.00	$0
Item 12 Description	0.00		0.00	$0
Item 13 Description	0.00		0.00	$0
Item 14 Description	0.00		0.00	$0
Item 15 Description	0.00		0.00	$0
Subtotal				$0
Subtotal				$2,848,226
ALLOWANCES:				
Finishes Allowance	0.0%		$2,848,226	$0
I & C Allowance	0%		$2,848,226	$0
Mechanical Allowance	0%		$2,848,226	$0
Electrical Allowance	0%		$2,848,226	$0
Facility Cost	**6,000**	**SF**	**$474.70**	**$2,848,226**

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Alternative 1 - Deep and Shallow Aquifer

Shallow Well Capital Costs						
Shallow Well	Shallow Well Capacity, mgd	Land	Wells and Pumphouses	Sitework Electric Utility	Shallow well Treatment Facility	Interconnecting Piping
Vernon 1	0.75	$160,000	$300,000	$750,000		$ 907,200
Vernon 2	0.75	$160,000	$300,000	$644,000		$ 132,000
Vernon 3	0.75	$160,000	$300,000			$ 662,400
Vernon 4	0.75	$160,000	$300,000			$ 1,152,000
Vernon 5	0.75	$160,000	$300,000			$ 2,112,000
Vernon 6	0.75	$160,000	$300,000			
Vernon 7	0.75	$160,000	$300,000			
Lather 1	0.75	$160,000	$300,000			
Lather 2	0.75	$160,000	$300,000			
Lather 3	0.75	$160,000	$300,000			
Lather 4	0.75	$160,000	$300,000			
Lather 5	0	$160,000	$300,000			
Vernon 8	0.75	$160,000	$300,000			
Vernon 9	0.75	$160,000	$300,000			
Wells 11-13 firm	1.2	$2,240,000	$4,200,000	$1,394,000	$29,864,000 Includes $2 million for Land	$4,965,600
	10.95					
	Total Wellfield	**$12,799,600**				

Alternative 1 Finished Water pipeline		
Pipelines		**$16,884,000**
10% allowance for pipeline valves & appurtenances		**$1,689,000**
Pipeline Construction Cost		**$18,573,000**
Pipeline Construction Cost		**$18,573,000**
3% markup for Bonds & Insurance	$558,000	
5% markup for Mob/Demob	$929,000	
8% markup for Contractors Overhead	$1,561,000	
4% markup for Contractors profit	$843,000	
25% Contingency	$5,616,000	
Subtotal Markups and Contingency		**$9,507,000**
Total Project Construction Costs		**$28,080,000**
8% allowance for pipeline engineering and design	2,247,000	
12% allowance for permitting, legal and administration	3,370,000	
8% allowance for pipeline engr services during construction	2,247,000	
Subtotal Other Project Costs		**$7,864,000**
GRAND TOTAL PROJECT COST		**$35,944,000**

Alternative 3 - Distribution

Pipelines		**$7,695,000**
10% allowance for pipeline valves & appurtenances		**$770,000**
Pipeline Construction Cost		**$8,465,000**
Pipeline Construction Cost		**$8,465,000**
3% markup for Bonds & Insurance	$254,000	
5% markup for Mob/Demob	$424,000	
8% markup for Contractors Overhead	$712,000	
4% markup for Contractors profit	$385,000	
25% Contingency	$2,560,000	
Subtotal Markups and Contingency		**$4,335,000**
Total Project Construction Costs		**$12,800,000**
5% allowance for pipeline engineering and design	768,000	
12% allowance for permitting, legal and administration	640,000	
08% allowance for pipeline engr services during construction	1,024,000	
Subtotal Other Project Costs		**$2,432,000**
GRAND TOTAL PROJECT COST		**$15,232,000**

Alternative 3 - Lake Michigan Distribution System Improvements

Water Forcemain		
Segment	Miles	Diameter
A	2.8	20
B	2	16

Unit cost	$/dia-in	12

Mile	Cost	Comments
1 mi of 20"	$1,736,064	Assume High Urban
1 mi of 16"	$1,388,851	Assume High Urban
subtotal	**$7,694,380**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	178	142
Low urban	1.00	240	192
Medium urban	1.19	286	228
High urban	1.37	329	263
Groundwater	**1.30**	**312**	**250**
Forest	1.15	276	221
Gravel roads	0.85	204	163
Creek crossing	2.00	480	384
HWY crossing	4.00	960	768

miles	0.13	0.25	0.5
feet	660	1320	2640

Alternative 1&2 Wastewater Forcemain		
Pipelines		**$3,029,000**
10% allowance for pipeline valves & appurtenances		**$303,000**
Pipeline Construction Cost		**$3,332,000**
Pipeline Construction Cost		**$3,332,000**
3% markup for Bonds & Insurance	$100,000	
5% markup for Mob/Demob	$167,000	
8% markup for Contractors Overhead	$280,000	
4% markup for Contractors profit	$152,000	
25% Contingency	$1,008,000	
Subtotal Markups and Contingency		**$1,707,000**
Total Project Construction Costs		**$5,039,000**
5% allowance for pipeline engineering and design	303,000	
12% allowance for permitting, legal and administration	252,000	
08% allowance for pipeline engr services during construction	404,000	
Subtotal Other Project Costs		**$959,000**
GRAND TOTAL PROJECT COST		**$5,998,000**

Alternative 1 & 2 - Wastewater Force Main

Wastewater Forcemain		
Segment	Miles	Diameter
A	2	6
B	3	6

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$416,275	In Sentry Dr., Cross 2 access roads, Chapman Dr, Spring city Dr, W. Sunset Dr
2	$452,390	In Sunset Dr, cross access road, dozens of residential drive ways, Oakdale Dr, Wisteria, School Dr. Burr Oak, HWY 59
3	$452,390	Cross Foxwood Trail, River Plain, Dale, Mary Ann, Red Oak
4	$833,026	In HWY H, cross HWY, Red clover, 0.5 mi wetland
5	$874,368	In Co Rd I, wetland
subtotal	**$3,028,450**	

Alignment Category	Pipeline Construction Difficulty Factors (source: C	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	53	53
Low urban	1.00	72	72
Medium urban	1.19	86	86
High urban	1.37	99	99
Groundwater	1.30	94	94
Forest	1.15	83	83
Gravel roads	0.85	61	61
Creek crossing	2.00	144	144
HWY crossing	4.00	288	288

miles	0.13	0.25	0.5	0.05
feet	660	1320	2640	264

Alternative 4 - Lake Michigan and Shallow Aquifer

Pipeline Segment	Miles	Diameter
A	9	24
B	3	24

Unit cost	$/dia-in	12

Mile	Cost	Comments
1	$2,661,120	In Howard Ave, cross HWY 894, 60th
2	$1,556,755	In Howard Ave, cross 76th, cross 84th, cross 92nd
3	$2,126,995	In Howard Ave, cross HWY 45, cross 104th
4	$1,613,363	In Howard Ave, cross HWY 100, cross Beliot Rd, in pkwy, cross Morgan Ave
5	$2,490,808	In pkwy, cross Oklahoma, cross National, cross Cleveland
6	$2,016,369	0.5 mi pkwy, 0.5 mi in 124th Street
7	$1,322,957	In 124th, cross 124th street, Utility corridor (Oak Leaf)
8	$1,364,774	Utility corridor, cross Sunnyslope, cross Moorland
9	$1,210,810	Utility corridor, cross Calhoun
10	$1,462,856	Utility corridor
11	$1,462,856	Utility corridor
12	$1,210,810	Utility corridor, cross Springdale
13	$1,520,640	Cotton Crt
14	$1,125,274	Open country
subtotal	**$23,346,386**	
10% Valves	$2,334,639	
Total	**$25,681,025**	

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES	Seg A cost $/lf	Seg B cost $/lf
Open country	0.74	213	213
Low urban	1.00	288	288
Medium urban	1.19	343	343
High urban	1.37	395	395
Groundwater	1.30	374	374
Forest	1.15	331	331
Gravel roads	0.85	245	245
Creek crossing	2.00	576	576
HWY crossing	4.00	1152	1152

miles	0.13	0.25	0.5
feet	660	1320	2640
	4620	3960	2640

Alternative 4 - Lake Michigan and Shallow Aquifer Return Flow Underwood Creek (7.6 mgd, 24" dia)

Pipelines	$15,463,160
10% allowance for pipeline valves &	$1,547,000
Pipeline Construction Cost	$17,011,000
WWTP Effluent Pump Station	$2,161,686
Conveyance System Construction C	$19,172,686

Alternative 4 - Underwood Creek Return Flow

Pipeline Segment		Diameter
A		24
B		24

Unit cost	$/dia-in	12

Mile	Cost		Comments
1	$1,592,870		0.75 mi follows river, crosses Prairie ave, Marshall and Dunbar, 0.25 under alley to NW ave
2	$1,592,870		Cross Maple, Grand, Barstow, East, Barney, Hartwell, crossing of E Broadway (major street); end at Oakland follows path (cross Greendale and Frederick), cross
3	$2,193,523		East Side bypass HYW 59 (MAJOR)
4	$1,224,647	70%	Follows New Berlin trail/utility corridor, cross Springdale;also a stream crossing, some forest; ends near stream crossing
5	$1,036,772	70%	Follows trail, open country mostly, some forest, wetlands for 0.5 mi; assume groundwater; ends near wetlands/open water pond
6	$831,334	70%	Follows trail, open country mostly, some forest (assume 10%)
7	$1,133,637	70%	Begins near Calhoun, one stream crossing; becoming urban again but still follows trail and is mostly open, crosses Calhoun and ends near Moorland, assume 10% forest
8	$787,692	70%	Still in trail, no crossings; very open; Ends near Sunnyslope Rd
9	$787,692	70%	Still in trail, no crossings; very open; Ends at 124th st
10	$1,748,736		Going north under 124th st, crosses Greenfield (hwy 59), ends near 124th and Zinke Dr
11	$2,533,386		Last section follows Underwood Creek, Crosses I-94
subtotal	**$15,463,160**		
10% Valves	**$1,547,862**		
Total	**$17,011,022**		

288
288

Alignment Category	Pipeline Construction Difficulty Factors (source: CPES)	Seg A cost $/lf
Open country	0.74	213
Low urban	1.00	288
Medium urban	1.19	343
High urban	1.37	395
Groundwater	1.30	374
Forest	1.15	331
Gravel roads	0.85	245
Creek crossing	2.00	576
HWY crossing	4.00	1152

miles	0.13	0.25
feet	660	1320

4620 3960

O&M Cost Alternative 4 - Lake Michigan and Shallow wells

Source of Supply	Units	Quantity	Unit Cost	Ext. Cost	$/yr	Total
Shallow Well Pumping/Maintenance	$/1000 gal	2,007,500	$ 0.140	$ 281,050	$ 281,050	
Purchased water	1000 gals	1,591,400	$ 1.40	$ 2,227,960	$ 2,227,960	
Total Supply						$ 2,509,010

Treatment/Pumping	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
Shallow Wells					$ 2,226,000	
Residuals		144175	$ 4	$ 576,700	$ 576,700	
Lake MI Energy	mgd	4.4			$ 75,732	
Lake MI O&M		2% of Capital cost of pump station	$ 0.0200	$ 5,300,000	$ 106,000	
Return Flow Energy	mgd	4.4			$ 56,619	
Return O&M		2% of Capital cos	$ 0.0200	$ 2,200,000	$ 44,000	
Total Treatment/Pumping						$ 3,085,051

Home Softening	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
Salt/Equipment/Replacment	1				$ 1,804,253	
						$ 1,804,253

Transmission	Units	Quantity	Unit Cost	Ext. Cost	$/yr	
Shallow Aquifer	$/lf/yr	137,280	$ 0.52	$ 71,386	$ 71,386	
Total Transmission						$ 71,386

Alternative Total O&M ($/yr.)	**$ 7,500,000**
PRESENT WORTH (6%, 20 yrs)	**$ 86,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 118,000,000**

C H2M HILL P arametric Cost E stimating S ystem (CPES)

FACILITIES LIFE CYCLE COST ANALYSIS

File Version: 1/5/2010

Import File: \\Gecko\wbg\Curl\WaukeshaWI\Treatment plant Surface water alt 1.xls Brows

Click for CPES QA/QC

Project Name:	Waukesha WTP
Project Number:	
Project Manager:	Linda Mohr
Estimator:	Jason Curl
Project Description:	Fox River Alluvium and Shallow Groundwater
Project Location (City):	Milwaukee
Project Location (State):	WISCONSIN
Project Location (Country):	USA
Construction Start (Month):	Jan
Construction Start (Year):	2011
Construction Duration (months)	24
Mid-Point of Construction:	Jan/2012

Life Cycle Analysis:
i = 6.00%
n = 25
Annual Inflation %: 4.50%

To Global Life Cycle Data Sheet

To Annual O&M Cost Summary Sheet

This Report is for INTERNAL Distribution

This Report is for EXTERNAL Distribution

Item	Is This Facility Included in Project? (Yes or No)	SCOPE OF PROJECT	Construction Cost	Annual O&M Cost (Escalated)	Life Cycle Cost (NPV)
	Yes	Inline Rapid Mix: RMX	$1,124,218	$10,054	$1,252,729
	Yes	Flocculation: FLOC	$2,758,162	$20,477	$3,019,917
	Yes	Lamella Clarifier: LAM	$4,276,418	$99,959	$5,554,216
	Yes	Filters: FILT	$9,077,505	$74,615	$10,031,332
	Yes	Surge Basin-Decanter: BWW	$2,773,337	$38,555	$3,266,193
	No	UV Disinfection: UVD	$0	$0	$0
	Yes	Concrete Clearwell: FWT	$2,371,500	$1,111	$2,385,692
	No	Steel Clearwell: FWT	$0	$0	$0
	No	In-Plant PS: FWPS	$0	$0	$0
	Yes	Vertical Turbine PS: FWPS	$5,495,750	$738,581	$14,937,283
	Yes	Filter BW PS: BWSPS	$1,988,991	$44,586	$2,558,947
	Yes	U.D. Facility: GEN	$0	$0	$0
	Yes	Liquid Chemical: FeCl3	$708,914	$220,946	$3,533,337
	Yes	Liquid Chemical: NaOCl	$534,622	$98,204	$1,789,986
	Yes	Liquid Chemical: FLUOR	$335,846	$8,675	$446,737
	Yes	Liquid Chemical: POLYPHOS	$333,051	$39,577	$838,978
	Yes	O&M Building: OMB	$5,146,925	$11,636	$5,295,664
		Additional Project Costs:			
		Biosolids Disposal	$0	$0	$0
		Standard Items	$13,413,828	$384,177	$18,324,898
		User Defined Items	$0	$0	$0
		Plant O & M Labor		$434,906	$5,559,555
		TOTAL - Life Cycle Analysis	$50,339,067	$2,226,059	$78,795,464
		Construction Cost per GPD (based on Maximum Daily Flow Rate)	$4.19 / GPD		
		Non-Construction Cost			
		Capital Cost per GPD (based on Maximum Daily Flow Rate)	$4.19 / GPD		(Note: "Capital Cost" equals Construction Cost plus Non-Construction Cost)
		Annual O & M Cost per 1,000 Gallons (based on Average Annual Daily Flow Rate)		$ 1.016 / Thousand Gallons	

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Rapid Mixing (Inline)

To Summary Sheet

Construction Cost:					$1,124,217
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	6	50%	8,760	$ 0.06	$ 1,097
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	922	2.00	8,760	$ 0.06	$ 905
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 3,084
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 5,086	10.0%	$ 509
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 5,595
Contingency				10%	$ 559
Total Annual O&M Cost					$ 6,154

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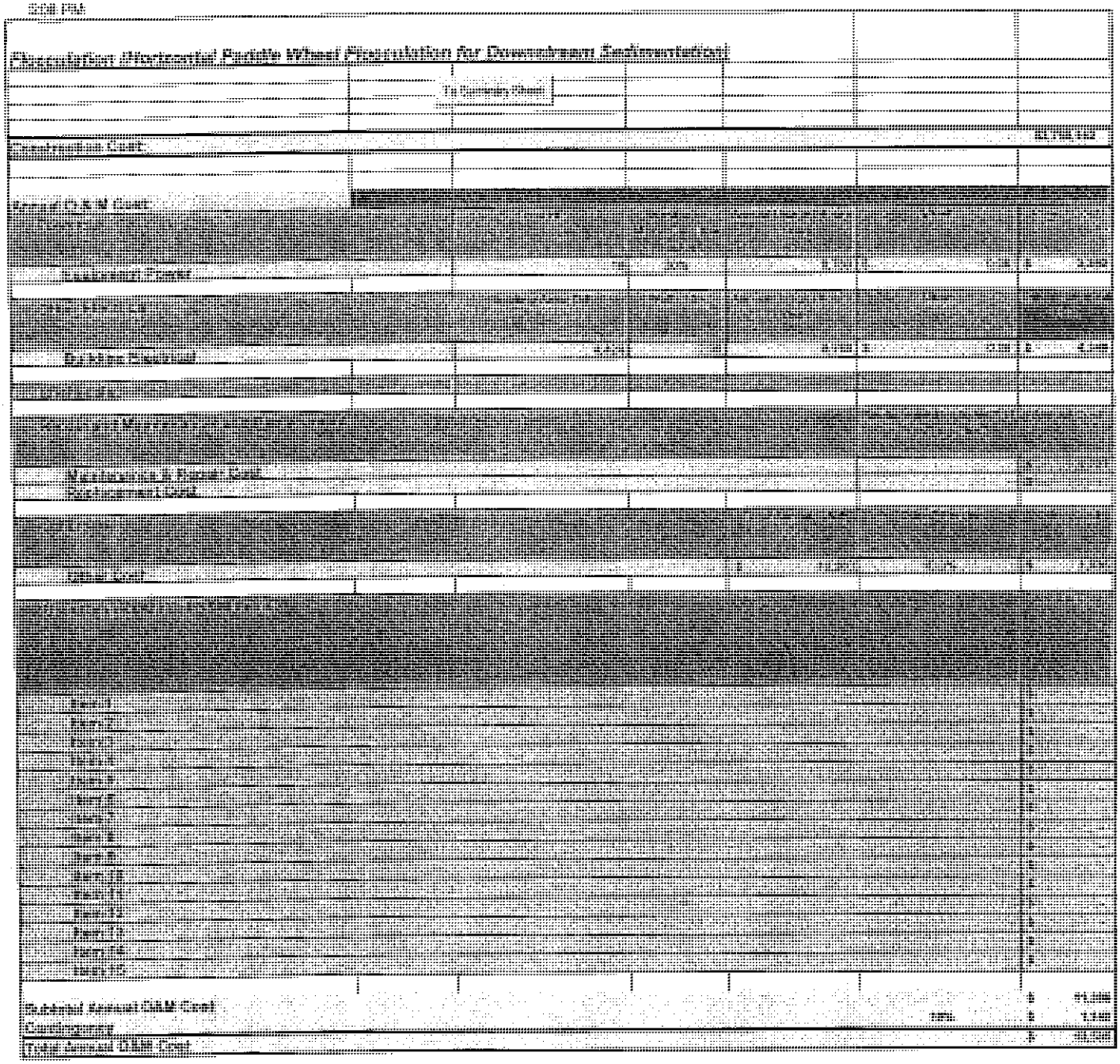

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Lamella Clarifier

To Summary Sheet

Construction Cost:					$4,276,417
Annual O & M Cost:					
Power:	Total HP	Average to Maximum Flow Factor	Annual Usage (Hours /Year)	$/kwh	Power Cost
Equipment Power	4	50%	8,760	$ 0.06	$ 732
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours /Year)	$/kwh	Other Electrical Cost
Building Electrical	4,804	2.00	8,760	$ 0.06	$ 4,713
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 45,127
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	Other, Percent	Other Cost
Other Cost			$ 50,572	10.0%	$ 5,057
User Defined Annual O&M Items					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 55,629
Contingency				10%	$ 5,563
Total Annual O&M Cost					$ 61,192

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Filters

To Summary Sheet

Construction Cost:					$9,077,505
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	5	50%	8,760	$ 0.06	$ 915
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	7,600	2.00	8,760	$ 0.06	$ 7,457
Chemicals:		Annual Usage (tons)	Annual Facility Usage (% of year)	$/ton	Chemical Cost
GAC		-	100%	$ 2,400.00	$ -
Total Chemical Cost					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = Yes, 0 = No?)	Annual Cost
Maintenance & Repair Cost					$ 29,379
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 37,750	10.0%	$ 3,775
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 41,525
Contingency				10%	$ 4,153
Total Annual O&M Cost					$ 45,678

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Large System Combination Wastewater Surge Basin and Floating Tube Decanter Clarification (>= 5 MGD)

To Summary Sheet

Construction Cost:					$2,773,337
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	43	50%	8,760	$ 0.06	$ 7,865
Other Electrical	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	81	2.00	8,760	$ 0.06	$ 79
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 11,562
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 19,506	10.0%	$ 1,951
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 21,457
Contingency				10%	$ 2,146
Total Annual O&M Cost					$ 23,602

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Concrete Tank

To Summary Sheet

Construction Cost:					$2,371,500
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	-	2.00	8,760	$ 0.06	$ -
Chemicals:					$ -
Repair and Maintenance and Replacement:				Replacement Included? (1= "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 562
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 562	10.0%	$ 56
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 618
Contingency				10%	$ 62
Total Annual O&M Cost					$ 680

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In-Plant Pump Station

To Summary Sheet

Construction Cost: $6,620,228

Annual O & M Cost:

Power:

	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2,666	50%	8,760	$ 0.06	$ 487,626

Other Electrical:

	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,022	2.00	8,760	$ 0.06	$ 1,003

Chemicals: $ -

Repair and Maintenance, and Replacement:

	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 74,141
Replacement Cost	-	$ -

Other:

	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 562,769.52	10.0%	$ 56,277

User Defined Annual O&M Items:

	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

Subtotal Annual O&M Cost		$ 619,046
Contingency	10%	$ 61,905
Total Annual O&M Cost		$ 680,951

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Vertical Turbine Pump Station

To Summary Sheet

Construction Cost:					$5,495,750
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	1,800	50%	8,760	$ 0.06	$ 329,230
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	3,189	2.00	8,760	$ 0.06	$ 3,129
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 41,314
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 373,672	10.0%	$ 37,367
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 411,039
Contingency				10%	$ 41,104
Total Annual O&M Cost					$ 452,143

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Granular Media Filter Backwash Supply Pump Station

To Summary Sheet

Construction Cost:					$1,988,991
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	21	50%	8,760	$ 0.06	$ 3,841
Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	988	2.00	8,760	$ 0.06	$ 969
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ 17,747
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 22,557	10.0%	$ 2,256
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 24,813
Contingency				10%	$ 2,481
Total Annual O&M Cost					$ 27,294

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost:	$708,913

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	3	50%	8,760	$ 0.06	$ 549

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,226	2.00	8,760	$ 0.06	$ 1,203

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	274	$ 782.93	$ 107,249
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 107,249

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 2,783
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 111,783	10.0%	$ 11,178

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$	122,962
Contingency	10%	$	12,296
Total Annual O&M Cost		$	135,258

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost:	$534,621

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	1,050	2.00	8,760	$ 0.06	$ 1,030

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	55	$ 1,672.13	$ 45,811
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 45,811

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 2,477
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 49,684	10.0%	$ 4,968

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$	54,653
Contingency	10%	$	5,465
Total Annual O&M Cost		$	60,118

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $335,845

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	714	2.00	8,760	$ 0.06	$ 701

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	15	$ 360.00	$ 2,630
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	-	$ -	$ -
Total Chemical Cost					$ 2,630

Repair and Maintenance, and Replacement:	Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost		$ 692
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 4,389	10.0%	$ 439

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$	4,828
Contingency	10%	$	483
Total Annual O&M Cost		$	5,310

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Liquid Chemical Storage & Feed

To Summary Sheet

Construction Cost: $333,051

Annual O & M Cost:

Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	2	50%	8,760	$ 0.06	$ 366

Other Electrical:	Building Area (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	714	2.00	8,760	$ 0.06	$ 701

Liquid Chemicals:	Annual Usage (% of year)	Average-to-Maximum Flow Factor	Annual Usage (dry tons / year)	Cost ($/dry ton)	Chemical Cost
Aluminum Sulfate (Alum)	100%	50%	-	$ 644.17	$ -
Aqueous Ammonia	100%	50%	-	$ 404.57	$ -
Ferric Chloride	100%	50%	-	$ 782.93	$ -
Hydrofluorosilicic Acid	100%	50%	-	$ 360.00	$ -
Hyrogen Peroxide (35%)	100%	50%	-	$ 1,734.23	$ -
Liquid Polymer	100%	50%	-	$ 3,140.89	$ -
Sodium Bisulfite	100%	50%	-	$ 920.91	$ -
Sodium Hydroxide (50%)	100%	50%	-	$ 825.32	$ -
Sodium Hypochlorite (12.5%)	100%	50%	-	$ 1,672.13	$ -
Sulfuric Acid	100%	50%	-	$ 138.09	$ -
Other Chemical	100%	50%	18	$ 2,000.00	$ 18,265
Total Chemical Cost					$ 18,265

Repair and Maintenance, and Replacement:	Replacement Included? (1= "Yes", 0= "No")	Annual Cost
Maintenance & Repair Cost		$ 692
Replacement Cost	-	$ -

Other:	Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost	$ 20,023	10.0%	$ 2,002

User Defined Annual O&M Items:	Annual Cost
Item 1	$ -
Item 2	$ -
Item 3	$ -
Item 4	$ -
Item 5	$ -
Item 6	$ -
Item 7	$ -
Item 8	$ -
Item 9	$ -
Item 10	$ -
Item 11	$ -
Item 12	$ -
Item 13	$ -
Item 14	$ -
Item 15	$ -

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Subtotal Annual O&M Cost		$ 22,026
Contingency	10%	$ 2,203
Total Annual O&M Cost		$ 24,228

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O & M Building

To Summary Sheet

Construction Cost:					$5,146,924
Annual O & M Cost:					
Power:	Total HP	Average-to-Maximum Flow Factor	Annual Usage (Hours / Year)	$/kwh	Power Cost
Equipment Power	-	50%	8,760	$ 0.06	$ -
Other Electrical:	Building Area, (SF)	Watts / SF	Annual Usage (Hours / Year)	$/kwh	Other Electrical Cost
Building Electrical	6,000	2.00	8,760	$ 0.06	$ 5,887
Chemicals:					$ -
Repair and Maintenance, and Replacement:				Replacement Included? (1 = "Yes", 0 = "No")	Annual Cost
Maintenance & Repair Cost					$ -
Replacement Cost				-	$ -
Other:			Total Annual O&M Cost	"Other" Percent	Other Cost
Other Cost			$ 5,887	10.0%	$ 589
User Defined Annual O&M Items:					Annual Cost
Item 1					$ -
Item 2					$ -
Item 3					$ -
Item 4					$ -
Item 5					$ -
Item 6					$ -
Item 7					$ -
Item 8					$ -
Item 9					$ -
Item 10					$ -
Item 11					$ -
Item 12					$ -
Item 13					$ -
Item 14					$ -
Item 15					$ -
Subtotal Annual O&M Cost					$ 6,475
Contingency				10%	$ 648
Total Annual O&M Cost					$ 7,123

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Milwaukee Water Supply - 24" the entire alignment

Pipeline Segment	Miles	Diameter
A	7	24
B	7	24

60th & Howard Ground Elevation	780	
Hillcrest WSE	1000	
Segment A Piping K	6.85	(one K=1.0 entr, ten K=0.30 90-elb, 3 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
Segment B Piping K	5.65	(one flow thru tee K=0.6, five K=0.3 90-elb, one bend thru tee K=1.80, three open bfly valve K=0.25, one exit K=0.5)
Piping Friction Factor	0.015	
Power cost, $/kw	0.06	
Power efficiency	0.9	
GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	B RW Velocity	B Pipeline Frict Loss	B Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	Total Friction Head	Available Suction Head	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost
	mgd	gpm	ft/s	ft	ft	ft/s	ft	ft	ft	ft	ft	ft	ft	psi	hp	kw	kw	$
	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	220	220	81	139	60	0	0	0	$0
ADD	4.4	3054	2.17	20.15	0.50	2.17	20.21	0.41	41.27	220	261	81	180	78	174	144	1262200	$75,732

Underwood Creek Return Flow - 24" the entire alignment

Pipeline Segment	Miles	Diameter
A	11.4	24

Waukesha WWTP	794	google earth elevation at WWTP
elevation at watershed divide	895	
Discharge at Underwood Creek	718	
Segment A Piping K	6.85	(one K=1.0 entr, ten K=0.30 90-elb, 3 open bfly valve K=0.25,one bend thru rdcr tee K=1.80+0.3)
Segment B Piping K	5.65	(one flow thru tee K=0.6, five K=0.3 90-elb, one bend thru tee K=1.80, three open bfly valve K=0.25, one
Piping Friction Factor	0.015	
Power cost, $/kw	0.06	
Power efficiency	0.9	
GHG, lbs CO2/Mwhr	1859	

	Supply Flow Rate	Supply Flow Rate	A Pipeline Velocity	A Pipeline Frict Loss	A Piping Misc K Loss	Total FW Piping Fric Loss	Total Static Loss	Total Friction Head	TDH	TDH	Power	Power	Annual Power Usage	Annual Power Cost
	mgd	gpm	ft/s	ft	ft	ft	ft	ft	ft	psi	hp	kw	kw	$
ADD	4.4	3054	2.17	32.70	0.50	33.20	102	135	135	58	130	108	943656	$56,619

Appendix N
Environmental Report

Environmental Impact Report

City of Waukesha Water Supply

Prepared for

City of Waukesha Water Utility

May 2010

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Environmental Impact Report

City of Waukesha Water Supply

Prepared for

City of Waukesha Water Utility

May 2010

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GUIDE TO ER CONTENT IN DNR OUTLINE

DNR Environmental Impact Statement Outline for City of Waukesha Municipal Water Supply Lake Michigan Diversion Application

i. Summary of environmental analysis process ("To the reader")
ii. Table of contents, tables, figures, contributors
iii. Executive summary

I. Proposed Project Overview

A. Need
Please refer to Environmental Report (ER) Chapter 1.

B. Project location
Please refer to ER Chapter 1.2 and ER Chapter 1 figures.

C. Diversion proposal
Please refer to the Application.

II. System Alternatives

A. Lake Michigan basin source/return system alternatives

1. Surface water
Please see Application Section 4 and ER Chapter 1.

2. Groundwater
Please see Application Section 4 and ER Chapter 1.

B. Mississippi River basin source/return system alternatives

1. Surface water
Please see Application Section 4 and ER Chapter 1.

2. Groundwater
Please see Application Section 4 and ER Chapter 1.

C. Conservation alternatives (as applied to existing and future water supplies)
Please see Application Section 2, "Waukesha Water Conservation and Efficiency" for information on the City of Waukesha's water conservation program. Water conservation continues to be part of all the water supply alternatives.

D. No-Action Alternative
The City of Waukesha currently obtains water from the deep and shallow aquifers. The "no action" alternative is represented by the Deep and Shallow Aquifer alternative which continues to use both the deep and shallow aquifers.

III. Proposed Project

A. Water supply

Please refer to the Lake Michigan water supply alternative in Application Section 4, and Lake Michigan water supply pipeline information in ER Chapter 1. All of the potential Lake Michigan water suppliers already operate drinking water treatment plants. Please refer to Application Section 2 and the Water Service Area Plan in Appendix D of the Application for information on the water service area plan and projected future water demand.

1. Lake Michigan intake

Included in reference above.

2. Supply pipeline

Included in reference above.

3. Water supply treatment

Included in reference above.

4. Water distribution and use: domestic, industrial, agricultural (including area served, projected future water needs)

Included in reference above.

B. Water return (including wastewater volume and I/I issues)

Please refer to the return flow alternatives in Application Section 5 and ER Chapter 2.3.2.4, Water Quality for information on pipelines and return flow quality. Return flow pipeline information is also provided in ER Chapter 1. Please refer to the Waste Water Facility Plan Amendment in Appendix E of the Application for further details on the evaluation of these alternatives.

1. Wastewater treatment

Included in reference above.

2. Return flow pipeline

Included in reference above.

3. Effluent discharge (including anticipated quality and applicable standards)

Included in reference above.

IV. Authorities and Approvals

The project will be reviewed as required under the Great Lakes-St. Lawrence River Basin Water Resource Compact (Compact).

In Wisconsin, the Compact implementing legislation is Wisconsin Act 227.

Please see ER Chapter 1.5 for additional Federal, State, and local approvals required for the project from the list of entities included below.

A. DNR

B. Great Lakes Compact

C. Other Wisconsin

D. Federal

E. Local

V. Affected Environment and Environmental Effects of the Proposed Project

A. Physical and biological environment

1. Aquatic resources

a. Lake Michigan

1 Location, existing designations/classifications
Lake Michigan background information is found in ER Chapter 2.3.1.7, Lake Michigan.

2 Size, volume, and floodplain
Lake Michigan background information is found in ER Chapter 2.3.1.7, Lake Michigan.

3 Water quality
Lake Michigan water quality impacts from all alternatives are discussed in ER Chapter 2.3.2.4, Water Quality.

4 Geomorphology and sediments
Lake Michigan geomorphology is discussed in ER Chapter 2.3.2.1, Flow and Geomorphology.

5 Flora (including threatened/endangered/special concern)
Vegetation is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.

b. Fauna (including threatened/endangered/special concern)
Wildlife is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species. Inland waterways (including all affected surface waters)
Background information for inland waterways is found in ER Chapter 2.3, Surface Water Resources.

1 Location, existing designations/classifications
Included in reference above.

2 Size, flows, and floodplain
Included in reference above.

3 Water quality
Water quality is discussed in ER Chapter 2.3.2.4, Water Quality.

4 Geomorphology and sediments (including channel morphology)
Geomorphology and sediments is discussed in ER Chapter 2.3.2, Flow and Geomorphology.

5 Flora (including threatened/endangered/special concern)
Vegetation is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.

6 Fauna (including threatened/endangered/special concern)
Wildlife is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.

c. Wetlands
Wetlands are discussed in ER Chapter 2.4, Wetlands.

1 Location, type, size
Included in reference above.

2 Flora (including threatened/endangered/special concern)
Vegetation is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.
3 Fauna (including threatened/endangered/special concern)
Wildlife is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.
4 Functional values

d. Groundwater
Groundwater is discussed in ER Chapter 2.1, Groundwater Resources.
1 Occurrence
See above reference.
(i) Bedrock
(ii) Unconsolidated materials
2 Use
Groundwater use is discussed in ER Chapter 2.1, Groundwater Resources and Application Section 3, Waukesha Water Supply Sources.
3 Water Quality
Groundwater quality is discussed in ER Chapter 2.1, Groundwater Resources, Application Section 3, Waukesha Water Supply Sources, and Application Section 4, Water Supply Alternative 2: Shallow Aquifer and Fox River Alluvium.

2. Terrestrial resources

a. Geomorphology and soils
Soils is discussed in ER Chapter 6, Soils.

b. Flora (including threatened/endangered/special concern)
Vegetation is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.

c. Fauna (including threatened/endangered/special concern)
Wildlife is discussed in ER Chapter 3.2, Wildlife Resources, and species is discussed in ER Chapter 3.4, Endangered and Threatened Species.

3. Air Quality
Air quality in terms of carbon dioxide generation from each of the alternatives considered is discussed in ER Chapter 5.4, Energy Use.

B. Socioeconomic environment (community and region)

1. Population (including age, ethnicity, health, and trends)
Population is discussed in ER Chapter 5.2, Population.

2. Economy (including industries, employment, tax base, and trends)
Economy is discussed in ER Chapter 5.3, Economy.

3. Land use, zoning, and transportation
Land use is discussed in ER Chapter 7, Land Use.

4. Energy use
Energy Use is discussed in ER Chapter 5.4, Energy Use.

5. Recreation and aesthetic resources
Recreation and aesthetic resources are discussed in ER Chapter 7.4, Public Land, Recreation, and Other Designated Areas and ER Chapter 7.6, Visual Resources.

6. Archeological and historical resources
Archeological and historical resources are discussed in ER Chapter 5, Cultural Resources.

7. Public water supplies and uses
Public water supplies and uses for the items listed below are discussed in ER Chapter 1.2.2, Existing Conditions, and Application Section 3, Waukesha Water Supply Sources.

a. Supplies

b. Uses
   1 Residential
   2 Industrial
   3 Recreational
   4 Commercial

VI. Alternatives to the Proposed Project

Impacts to environmental resources for water supply and return flow alternatives are found under the same ER Chapters as the proposed project.

A. Water source
Alternatives to the water supply source are described in ER Chapter 1.2, Proposed Facilities, and Application Section 4.

1. Lake Michigan intake
See reference above.

2. Other surface water sources
See reference above.

3. Groundwater sources
See reference above.

B. Supply pipeline
Alternatives to the water supply source are described in ER Chapter 1.2, Proposed Facilities, and Application Section 4.

C. Water supply treatment
Alternatives to the water supply source are described in ER Chapter 1.2, Proposed Facilities, and Application Section 4.

D. Water distribution and use (domestic, industrial, agricultural, including additional conservation measures)
Water conservation is discussed in Application Section 2, "Waukesha Water Conservation and Efficiency".

E. Wastewater treatment
Wastewater treatment is discussed in ER Chapter 2.3.2.4, Water Quality, and Application Section 5.

F. Return flow pipeline
Return flow pipelines are discussed in ER Chapter 1.2, Proposed Facilities, and Application Section 5.

G. Effluent discharge
Effluent discharged is discussed in ER Chapter 2.3.2.4, Water Quality, and Application Section 5.

VII. Evaluation of project significance

A. Long-term versus short-term effects

Please see Table 8-2, Chapter 8 of the ER. Long term and short term effects have been considered in the evaluation criteria used in Chapter 8 of the ER to determine significant impacts. The Lake Michigan water supply alternative with Underwood Creek return flow has minor adverse impact.

B. Effects on geographically scarce resources

Please see Table 8-2, Chapter 8 of the ER. Relative effects on geographically scarce resources for each of the alternatives is further detailed in other chapters of the ER as described in Table 8-1, Chapter 8 of the ER.

C. Reversibility of effects

Please see Table 8-2, Chapter 8 of the ER. The impacts identified for the Lake Michigan water supply and return flow alternatives are either no adverse impact or minor adverse impacts. The minor adverse impacts for Lake Michigan water supply are for temporary wetland construction impacts (ER Chapter 2.4, Wetlands). These impacts will be eliminated after construction of the pipeline as wetlands affected by the pipeline construction are restored.

The minor adverse impacts for return flow to a Lake Michigan tributary are for water quality changes in the receiving water body (ER Chapter 2.3.2.4, Water Quality), and for temporary wetland construction impacts (ER Chapter 2.4, Wetlands). These minor adverse impacts for water quality will in part lesson over time as more stringent phosphorus standards are regulated by the WDNR. The minor adverse impacts to wetlands during construction will also lesson over time as wetlands affected by pipeline construction as growth is restored after construction. Return flow directly to Lake Michigan in addition to the minor adverse impacts described above for return flow to a tributary also has minor adverse impacts to geomorphology and aquatic habitat. These additional minor adverse impacts are associated with construction in Lake Michigan which is not reversible.

The adverse effects such as groundwater use, aquatic habitat, wetlands, water quality, vegetation and wildlife, and soils from the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium alternatives are not reversible because they are associated with construction of above ground structures and on-going operation of these alternatives (e.g. continued pumping of the shallow groundwater). These impacts are not reversible for a water supply alternative that includes pumping shallow groundwater.

D. Cumulative effects

No significant cumulative effects to the chemical, physical, or biological integrity of the Great Lakes basin natural resources occurs with the proposed Lake Michigan diversion as summarized in ER Chapter 8, Table 8-2 and Application Section 6.

E. Risk (including unknowns and problems due to installation and operation)
Risk to public health is minimized with the Lake Michigan water supply alternative compared to the Deep and Shallow Aquifer and the Shallow Aquifer and Fox River Alluvium alternatives as discussed in Section 4 of the Application.

F. Precedence
Please see Section 6 of the Application.

G. Public controversy
The proposed project is the first straddling county diversion application under the Compact and Wisconsin Act 227. Consequently, the project is expected to be closely followed by interested stakeholders throughout the Great Lakes basin. The Compact was developed to allow straddling counties to obtain Great Lakes water, and it was approved by eight states and the U.S. Congress with a parallel approval process in Canada. Consequently, public interest is expected to be high, but many stakeholders across the Great Lakes basin have already developed the process whereby such an application can be proposed.

In Wisconsin, the City of Waukesha has been evaluating water supply alternatives for radium compliance for over 20 years. In recent years, the City of Waukesha has publicly communicated efforts to evaluate Lake Michigan as a water supply source and has communicated with potential Lake Michigan water suppliers and communities that may be affected with a return flow. The City has continued an aggressive public education program that has allowed the public to obtain detailed information about the future water supply alternatives, to ask questions and to provide comments. The City of Waukesha's future water supply will be the single largest capital project ever completed by the City and will subsequently have high public interest. The Compact provides the process for a straddling county diversion evaluation and there are established means for working with neighboring municipalities, obtaining public input, and resolving disputes.

The preparation of the ER is in response to the public interest over this project to provide a method to evaluate impacts to environmental resources comprehensively. This process provides for a method for the public to have an opportunity for input, review, and comment.

VIII. Appendixes

Please refer to ER Chapter 1 Appendix 1-A for information on Example Wetland and Waterway Pipeline Construction Crossing Impact Minimization Techniques.

A. Typical pipeline construction techniques and impacts.

Executive Summary

Overview of Waukesha Water Supply

Current Supply and Issues

The City currently obtains more than 87 percent of its water supply from the deep St. Peter Sandstone Aquifer. Near and beyond the City of Waukesha, this aquifer is confined by a geological feature—the Maquoketa shale layer—that limits natural recharge of the aquifer. Continued use of the aquifer by the City and surrounding communities since the 19th century and the presence of the Maquoketa shale have led to the 500- to 600-foot decline in aquifer water levels.[1] These levels continue to drop 5 to 9 feet per year.[2]

Reduced groundwater levels in southeastern Wisconsin have in turn affected regional surface waters, which now receive about 18 percent[3] less in groundwater contribution as water migrates toward the deep aquifer. Significant water quality issues occur with declining water levels in the deep aquifer, including increased levels of salts and radium (a naturally occurring element in the deep aquifer that can cause cancer). To provide drinking water with low levels of radium, the City treats some deep aquifer water to remove radium and blends some deep aquifer water with water from the shallow Troy Bedrock aquifer.

The City obtains less than 13 percent of its water supply from the shallow aquifer. Increased pumping of it will stress surface water resources by reducing base flows to local streams and wetlands.[4]

Program to Address Issues

The City of Waukesha as studied water supply options for many years and has been working to address the radium contamination for over 20 years. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has also conducted a regional water supply study that examined the impacts of water supply for the region on the deep and shallow aquifers as well as the use of Lake Michigan as a water supply source. The recommended water supply alternative from SEWRPC's study for the City of Waukesha includes Lake Michigan as a water supply. A Lake Michigan supply is regulated under the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact) and requires return flow be sent back to the Great Lakes basin.

The City of Waukesha has continued to explore water supply alternatives, including use of the deep aquifer, shallow aquifer wells, water conservation, and a Lake Michigan water supply source. This Environmental Report (ER) examines the environmental impacts associated with the water supply and return flow alternatives.

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[1] *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Southeastern Regional Planning Commission, 2008, pp.102–103.

[2] Waukesha Water Utility 2009 operating data.

[3] U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

[4] *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* SEWPRC, 2008, pp. 8–14.

As part of water supply planning process, the City of Waukesha has conducted meetings to solicit comment from City of Waukesha residents and the general public. Four public meetings have been held in 2010 alone, including one in a neighboring community potentially affected by a Lake Michigan return flow alternative, where the public has been asked to provide verbal or written comment regarding Waukesha's water supply alternatives. Many more public meetings have been conducted in prior years. The information gathered from these public meetings and comments from the public has been used to identify issues of concern which have been addressed in this ER. A compilation of comments received from the 2010 meetings and other public involvement processes will be provided to the WDNR as a separate submittal.

Environmental Report

Reason for Preparing

This ER has been developed to meet the Wisconsin Environmental Policy Act (WEPA) as required by the Wisconsin Department of Natural Resources (WDNR) and regulated under NR 150 Environmental Analysis and Review Procedures for Department Actions. The WDNR has indicated they will follow the WEPA process for evaluating the City of Waukesha water supply alternatives considered under the City's Great Lakes Diversion Application.

The WDNR issued a formal scoping request for this ER on February 5, 2010. This request has been issued to interested parties and resources agencies and has also been made available to the general public on the WDNR's website.

Relationship to Other Documents and Programs

The WEPA process calls for interagency coordination, including federal agencies, and references developing reviews consistent with National Environmental Policy Act (NEPA) where multiple agencies are involved. This document is intended to meet the NEPA process should it be required in the future. The City of Waukesha is evaluating water supply alternatives to secure a sustainable, reliable water supply that is protective of public health and provides regional environmental benefits. Despite significant success with an aggressive water conservation program, the City is faced with a declining groundwater supply and worsening water quality conditions. Consequently, the City has been studying water supply alternatives. This ER evaluates the environmental impacts of the water supply alternatives.

This ER references other documents for background purposes, notably the Application for Lake Michigan Water Supply (Application) and Application supporting documents.

Purpose and Need

The City of Waukesha needs a long-term water source that can meet water supply demands, is protective of human health and the environment, and is sustainable. The water supply source will be used for public water supply and consider year 2035 and ultimate build-out water demand.

Alternatives

Water Supply

Water supply alternatives have been studied for the City of Waukesha for many years. In March 2002, the Waukesha Water Utility completed a future water supply study.[5] Stakeholders in this study included representatives from the Utility, City of Waukesha, Wisconsin Department of Natural Resources (WDNR), SEWRPC, U.S. Geological Survey, Wisconsin Geological and Natural History Survey, and the University of Wisconsin–Madison. The study looked at the following 14 water supply sources and combinations of them:

- Deep (confined) aquifer near Waukesha
- Deep (unconfined) aquifer west of Waukesha
- Shallow groundwater south of Waukesha
- Shallow groundwater west of Waukesha
- Dolomite aquifer
- Fox River
- Rock River
- Lake Michigan
- Dam on the Fox or Rock River
- Waukesha quarry
- Waukesha springs
- Pewaukee Lake
- Milwaukee River
- Wastewater reuse

Nine water supply sources were eliminated for various technical reasons. Combinations of alternatives have also been evaluated and screened out. The Application considered four water supply alternatives in detail, chosen on the basis of previous screening[6] and stakeholder feedback. The Application evaluated and compared the following alternatives in detail:

- Deep and shallow aquifers
- Shallow aquifer and Fox River alluvium
- Lake Michigan and shallow aquifer
- Lake Michigan

As discussed in Section 4 of the Application, the *Lake Michigan and shallow aquifer* water supply alternative would utilize the same quantity of shallow groundwater as the *deep and shallow aquifers* water supply alternative. The *Lake Michigan and shallow aquifer* alternative would consequently have the same shallow groundwater impacts as the *deep and shallow aquifers* alternative. The *Lake Michigan and shallow aquifer* alternative would also have similar impacts as the *Lake Michigan* alternative because pipeline construction and the return flow impacts would still occur. Consequently, the impacts of a *Lake Michigan and shallow aquifer* alternative will be greater than the individual impacts of the *deep and shallow aquifers* or the *Lake Michigan* alternatives. The *Lake Michigan and shallow aquifer* alternative will instead have

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[5] *Future Water Supply Report for the Waukesha Water Utility*, CH2M HILL with Ruekert & Mielke, 2002.

[6] SEWRPC (2008); CH2M HILL et al. (2002).

a similar impact as adding the impacts of these two alternatives together. Because the *Lake Michigan and shallow aquifer* alternative has greater impacts, it is not evaluated further in this ER.

The three remaining water supply alternatives have been further divided into five specific sources/corridors including the following:

- Deep and Shallow Aquifers
- Shallow Aquifer and Fox River Alluvium
- Lake Michigan supply—Milwaukee
- Lake Michigan supply—Oak Creek
- Lake Michigan supply—Racine

Return Flow

Five alternatives were considered for return flow to the Lake Michigan source watershed. All of the alternatives are able to return the required quantities back to the Lake Michigan basin.

- Underwood Creek, a tributary to the Menomonee River that flows to Lake Michigan.
- Root River, a tributary to Lake Michigan.
- Directly to Lake Michigan.

Two alternatives were also considered to discharge to the Milwaukee Metropolitan Sewerage District (MMSD). These alternatives were screened out due to operational considerations of the current Waukesha WWTP.

Note that the existing discharge location into the Fox River from the Waukesha WWTP will continue to be used at times and continue to meet existing discharge limits. When flow available at the WWTP exceeds the amount to be returned, the excess flow from the WWTP will be conveyed through the existing outfall to the Fox River.

Similar infrastructure (a pump station and a pipeline of varying length depending on the alternative) was included for each alternative. Additional specific information regarding the various alternatives is included below and in the Application.

Major Issues in Evaluating Alternatives

Exacerbating Existing Groundwater Problems

All water supply sources were reviewed for their ability to not continue to deplete the deep aquifer currently used by the City of Waukesha. Continued use of the aquifer by the City and surrounding communities since the 19th century and the presence of the Maquoketa shale have led to the 500- to 600-foot decline in aquifer water levels.[8] These levels continue to drop 5 to 9 feet per year.[9] Reduced groundwater levels in southeastern Wisconsin have in turn affected regional surface waters, which now receive about 18 percent[10] less in groundwater contribution as water migrates toward the deep aquifer. Significant water

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8 *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin*, Southeastern Regional Planning Commission, 2008, pp.102–103.

9 Waukesha Water Utility 2009 operating data.

10 U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

quality issues occur with declining water levels in the deep aquifer, including increased levels of salts and radium (a naturally occurring element in the deep aquifer that can cause cancer). To provide drinking water with low levels of radium, the City treats some deep aquifer water to remove radium and blends some deep aquifer water with water from the shallow Troy Bedrock aquifer.

Groundwater Drawdown Impacts

Groundwater drawdown from the shallow aquifer and associated impacts to surface waters and other environmental resources is considered in the water supply alternative evaluation. Pumping groundwater from shallow aquifers changes the surface water and groundwater interaction. Previous studies have identified stream baseflow reductions will occur to surface waters, including baseflow reductions to cold water trout streams, when using more shallow groundwater for water supply. Groundwater drawdown from shallow aquifers can also affect wetland and other aquatic resources that depend upon groundwater hydrology for maintaining wetland habitat. The City of Waukesha has utilized a groundwater model to simulate the groundwater drawdown expected with water supply alternatives that use the shallow aquifer.

Wetlands

Wetland impacts occur from temporary construction impacts from pipeline construction, above ground structure construction, and groundwater drawdown. Construction impacts are temporary during construction and are avoided or mitigated through construction or restoration techniques. Operational impacts from above ground structures occur where roads, treatment plants, or well house locations occur in wetlands. Operational impacts also occur from shallow aquifer pumping and resulting groundwater drawdown. Because a wetland is designated by the type of plants, hydrology, and soil type, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. The City of Waukesha has utilized a groundwater model to simulate the groundwater drawdown expected with water supply alternatives that use the shallow aquifer. The groundwater modeling results were used to determine the wetland acreage that would experience of 5 foot or greater drawdown and the wetland acreage that would experience a 1 foot or greater drawdown.

Aquatic Habitat

Aquatic habitat impacts occur when flows change in surface streams. Flows change in surface streams under all alternatives considered. Shallow groundwater pumping alternatives change the surface water and groundwater interaction. Previous studies have identified stream baseflow reductions will occur to surface waters, including baseflow reductions to the Fox River and cold water trout streams, when using more shallow groundwater for water supply. Flow changes also occur with return flow alternatives where flow is no longer discharged to the Fox River and is discharged instead to a Lake Michigan tributary or directly to Lake Michigan. Return flow to a Lake Michigan tributary can increase aquatic habitat quantity and availability. Each of these flow changes has been considered to evaluate reductions or increases to aquatic habitat.

Vegetation and Wildlife

The Vernon Wildlife Area (VWA) is a 4,655-acre property in eastern Waukesha County consisting of wetlands and flowages associated with the Fox River and including a calcareous fen in the southern portion of the property. WDNR documents indicate the VWA provides significant wildlife habitat, especially for migrating and nesting waterfowl. Groundwater drawdown from shallow aquifer pumping could result in habitat type change. The City of Waukesha has utilized a groundwater model to simulate the groundwater drawdown expected with water supply alternatives that use the shallow aquifer. The groundwater modeling results were used to determine acreage of the VWA that would experience of 5 foot or greater drawdown and the VWA acreage that would experience a 1 foot or greater drawdown.

Lake Michigan Return Flow

For the Lake Michigan water supply source alternative, the Great Lakes-St. Lawrence River Basin Water Resources Compact requires return flow be sent back to the Great Lakes basin. Environmental issues related to return flow alternatives include: geomorphic stability changes caused by increases in stream flows, aquatic habitat change, impacts to flooding, and water quality impacts. Each of these areas is reviewed for all alternatives.

Construction Impacts for Conveyance

Each of the water supply and return flow alternatives involves construction of long linear pipelines to convey the water supply or convey the return flow. These long linear projects will cross water bodies, wetlands, public lands, and other features. The impacts that these pipelines may have on environmental resources is reviewed and compared.

Areas Covered by ER with No Significant Impacts or Issues

The ER review compares each of the water supply and return flow alternatives for environmental impacts. Chapter 8 provides a comparison of all alternatives. In reviewing the impacts, it was found that no adverse impacts were common among all alternatives for the following:

- Cultural Resources
- Socioeconomics

Details of these resource alternatives are found in their respective ER chapters.

Comparison of Alternatives

The following table compares the environmental impacts of each of the alternatives. This table and supporting conclusions is found in Chapter 8, Table 8-2.

Selection and Description of Preferred Plan

The Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium alternatives would have significant adverse environmental impacts to natural resources particularly wetlands and the Vernon Wildlife Area. The Lake Michigan water supply and

return flow alternatives would have only minor adverse environmental impacts to natural resources. Lake Michigan is the preferred water supply alternative as a result.

Of the return flow alternatives, the Underwood Creek and Root River alternatives both would have minor adverse impacts in two categories, whereas the Lake Michigan alternative would have minor adverse impacts in four categories. The costs of the Underwood Creek and Root River alternatives, were compared, and the Underwood Creek alternative is the preferred return flow alternative.

Once a water supplier and return flow location have been reviewed and approved, the City will work with the regulatory agencies during final design to conduct any necessary field surveys, location refinements, mitigation planning, and to obtain required permits.

TABLE ES-1
Water Supply and Return Flow Alternative Environmental Impact Comparison Summary
City of Waukesha Water Supply

Water Supply Alternative	Groundwater Resources	Flow and Geomorphology	Flooding	Aquatic Habitat	Water Quality	Wetlands	Vegetation and Wildlife Resources	Soils	Land Use
Deep and shallow aquifers	Significant adverse impact	No adverse impact	No adverse impact	Significant adverse impact	Minor adverse impact	Significant adverse impact	Significant adverse impact	Minor adverse impact	No adverse impact
Shallow aquifer and Fox River alluvium	Significant adverse impact	No adverse impact	No adverse impact	Significant adverse impact	Minor adverse impact	Significant adverse impact	Significant adverse impact	Minor adverse impact	No adverse impact
Lake Michigan – Milwaukee	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Lake Michigan – Oak Creek	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Lake Michigan – Racine	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Return Flow Alternatives									
Underwood Creek	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Root River	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Direct to Lake Michigan	No adverse impact	Minor adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact

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Chapter 1
Introduction

CHAPTER 1

Introduction

1.1 Introduction

This Environmental Report (ER) has been developed to meet the Wisconsin Environmental Policy Act (WEPA) as required by the Wisconsin Department of Natural Resources (WDNR) and regulated under NR 150 Environmental Analysis and Review Procedures for Department Actions. The WDNR has indicated they will follow the WEPA process for evaluating the City of Waukesha water supply alternatives considered under the City's Great Lakes Diversion Application.

The WEPA process calls for interagency coordination, including federal agencies, and references developing reviews consistent with National Environmental Policy Act (NEPA) where multiple agencies are involved. This document is intended to meet the NEPA process should it be required in the future. The City of Waukesha is evaluating water supply alternatives to secure a sustainable, reliable water supply that is protective of public health and provides regional environmental benefits. Despite significant success with an aggressive water conservation program, the City is faced with a declining groundwater supply and worsening water quality conditions. Consequently, the City has been studying water supply alternatives. This ER evaluates the environmental impacts of the water supply alternatives.

The WDNR issued a formal scoping request for this ER on February 5, 2010. This request has been issued to interested parties and resources agencies and has also been made available to the general public on the WDNR's website.

As part of water supply planning process, the City of Waukesha has conducted meetings to solicit comment from City of Waukesha residents and the general public. Four public meetings have been held in 2010 alone, including one in a neighboring community potentially affected by a Lake Michigan return flow alternative, where the public has been asked to provide verbal or written comment regarding Waukesha's water supply alternatives. Many more public meetings have been conducted in prior years. The information gathered from these public meetings and comments from the public has been used to identify issues of concern which have been addressed in this ER. A compilation of comments received from the 2010 meetings and other public involvement processes will be provided to the WDNR as a separate submittal.

A variety of water supply alternatives have been evaluated, including groundwater, surface water sources in the Mississippi River basin, and Lake Michigan. The Great Lakes-St. Lawrence River Basin Water Resources Compact regulates Lake Michigan as a water supply as a diversion for the City of Waukesha and requires return flow back to the Great Lakes Basin. Consequently, the Lake Michigan water supply alternative also has included an evaluation of return flow alternatives.

This ER evaluates water supply alternatives and the environmental impacts of a City of Waukesha long-term water supply.

ER Chapter 1 introduces the Project in several subsections, which provide an overview of the proposed Project facilities (Chapter 1.2), describe the land requirements for construction and operation (Chapter 1.3), provide information on operation and maintenance procedures for the Project alternatives (Chapter 1.4), and identify agencies contacted and permits required (Chapter 1.5).

1.2 Proposed Facilities

1.2.1 Purpose and Need

The City of Waukesha needs a long-term water source that can meet water supply demands, is protective of human health and the environment, and is sustainable. The water supply source will be used for public water supply and consider year 2035 and ultimate build-out water demand.

1.2.2 Existing Conditions

The City currently obtains more than 87 percent of its water supply from the deep St. Peter Sandstone Aquifer. Near and beyond the City of Waukesha, this aquifer is confined by a geological feature—the Maquoketa shale layer—that limits natural recharge of the aquifer. Continued use of the aquifer by the City and surrounding communities since the 19th century and the presence of the Maquoketa shale have led to the 500- to 600-foot decline in aquifer water levels.[1] These levels continue to drop 5 to 9 feet per year.[2] Reduced groundwater levels in southeastern Wisconsin have in turn affected regional surface waters, which now receive about 18 percent[3] less in groundwater contribution as water migrates toward the deep aquifer. Significant water quality issues occur with declining water levels in the deep aquifer, including increased levels of salts and radium (a naturally occurring element in the deep aquifer that can cause cancer). To provide drinking water with low levels of radium, the City treats some deep aquifer water to remove radium and blends some deep aquifer water with water from the shallow Troy Bedrock aquifer.

The City obtains less than 13 percent of its water supply from the shallow aquifer. Increased pumping of it will stress surface water resources by reducing base flows to local streams and wetlands.[4]

Additional detail on existing water supply conditions and background on the City of Waukesha is found in Application Sections 1 and 2.

1.2.3 Location and Description of Alternatives

The City seeks a water supply of 10.9 million gallons per day (mgd) to meet future average day water supply demand of the City's projected water service area as delineated by the local planning authority, the Southeastern Wisconsin Regional Planning Commission

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[1] *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* Southeastern Regional Planning Commission, 2008, pp.102–103.

[2] Waukesha Water Utility 2009 operating data.

[3] U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

[4] *Draft Planning Report on Regional Water Supply Plan for Southeastern Wisconsin,* SEWPRC, 2008, pp. 8–14.

(SEWRPC). The City seeks sufficient water to serve customers within its delineated service area. Section 2 of the Application documents the water supply needed under the planning horizon.

The City evaluated several water supply and return flow alternatives.

1.2.3.1 Water Supply Alternatives

Water supply alternatives included continued use of the deep and shallow aquifer, increased withdrawal from the shallow aquifer, local river supplies, local lake supplies, and wastewater reuse. These alternatives have been developed and analyzed by multiple studies, the findings of which are included in Section 4 of the Application and summarized below. The Application and this Environmental Report (ER) present a comprehensive review of the three most feasible alternatives: continued use of the deep and shallow aquifers, use of shallow aquifer resources alone, and use of Great Lakes water.

In March 2002, the Waukesha Water Utility completed a future water supply study.[5] Stakeholders in this study included representatives from the Utility, City of Waukesha, Wisconsin Department of Natural Resources (WDNR), SEWRPC, U.S. Geological Survey, Wisconsin Geological and Natural History Survey, and the University of Wisconsin–Madison. The study looked at the following 14 water supply sources and combinations of them:

- Deep (confined) aquifer near Waukesha
- Deep (unconfined) aquifer west of Waukesha
- Shallow groundwater south of Waukesha
- Shallow groundwater west of Waukesha
- Dolomite aquifer
- Fox River
- Rock River
- Lake Michigan
- Dam on the Fox or Rock River
- Waukesha quarry
- Waukesha springs
- Pewaukee Lake
- Milwaukee River
- Wastewater reuse

Nine water supply sources were eliminated for the reasons listed in Exhibit 4-1 of the Application. Summary information on these previous studies is included in Section 4 of the Application. Combinations of alternatives have also been evaluated and screened out, as described in Section 4 of the Application. The following water supply alternatives passed the initial screening process:

- Deep confined aquifer
- Deep unconfined aquifer
- Shallow groundwater near Waukesha
- Shallow groundwater and deep confined aquifer
- Lake Michigan

[5] *Future Water Supply Report for the Waukesha Water Utility*, CH2M HILL with Ruekert & Mielke, 2002.

The Application considered four water supply alternatives in detail, chosen on the basis of previous screening[6] and stakeholder feedback. The Application evaluated and compared the following alternatives in detail:

- Deep and shallow aquifers
- Shallow aquifer and Fox River alluvium
- Lake Michigan and shallow aquifer
- Lake Michigan

As discussed in Section 4 of the Application, the *Lake Michigan and shallow aquifer* water supply alternative would utilize the same quantity of shallow groundwater as the *deep and shallow aquifers* water supply alternative. The *Lake Michigan and shallow aquifer* alternative would consequently have the same shallow groundwater impacts as the *deep and shallow aquifers* alternative. The *Lake Michigan and shallow aquifer* alternative would also have similar impacts as the *Lake Michigan* alternative because pipeline construction and the return flow impacts would still occur. Consequently, the impacts of a *Lake Michigan and shallow aquifer* alternative will be greater than the individual impacts of the *deep and shallow aquifers* or the *Lake Michigan* alternatives. The *Lake Michigan and shallow aquifer* alternative will instead have a similar impact as adding the impacts of these two alternatives together. Because the *Lake Michigan and shallow aquifer* alternative has greater impacts, it is not evaluated further in this ER.

The three remaining water supply alternatives have been further divided into five specific sources/corridors including the following:

- Deep and shallow aquifers
- Shallow aquifer and Fox River alluvium
- Lake Michigan supply—Milwaukee
- Lake Michigan supply—Oak Creek
- Lake Michigan supply—Racine

The City of Waukesha currently obtains water from the deep and shallow aquifers. The "No Action" alternative is represented by the Deep and Shallow Aquifers water supply alternative which continues to use both the deep and shallow aquifers for the City of Waukesha's water supply.

1.2.3.2 Return Flow Alternatives

Five alternatives were considered for return flow to the Lake Michigan source watershed. All of the alternatives are able to return the required quantities back to the Lake Michigan basin.

- Underwood Creek, a tributary to the Menomonee River that flows to Lake Michigan.
- Root River, a tributary to Lake Michigan.
- Directly to Lake Michigan.
- The Milwaukee Metropolitan Sewerage District (MMSD) system and water reclamation facility, which would then return flow to Lake Michigan. Two subalternatives were considered for return flow to MMSD.

[6] SEWRPC (2008); CH2M HILL et al. (2002).

Note that the existing discharge location into the Fox River from the Waukesha WWTP will continue to be used at times and continue to meet existing discharge limits. When flow available at the WWTP exceeds the amount to be returned, the excess flow from the WWTP will be conveyed through the existing outfall to the Fox River. Because this Fox River outfall is currently in use, no new impacts are anticipated with its continued use, and thus discharge to the Fox River was not evaluated as part of this ER. Additional information on when discharge to the Fox River will occur is included in Section 5 of the Application. Information on flow changes to the Fox River with a Lake Michigan return flow is included in Chapter 2 of this ER.

Each alternative includes a corridor for the pipeline and associated infrastructure along the pipeline alignment (e.g., pump station, service manholes). The pipeline corridors and the supply and return flow discharge locations were selected to protect public health and safety, to provide long-term sustainability, to minimize environmental impacts, to provide feasible implementation (constructability), to use previously disturbed areas and existing utility corridors, to be consistent with the SEWRPC alignments, to allow the return flow to be used as a resource to the Lake Michigan basin, and to minimize cost.

The supply and return flow pipeline alignments selected follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands. The alignments are discussed below for each return flow alternative. The alignments were developed to a limited level of detail that allows for screening and comparison of alternatives. The concepts do not include the details that will be identified and evaluated in subsequent engineering design phases for the actual project once an alignment is approved.

Similar infrastructure (a pump station and a pipeline of varying length depending on the alternative) was included for each alternative. Additional specific information regarding the various alternatives is included below and in the Application.

1.2.3.3 Location Maps, Detailed Route Maps

The regional location of the supply and return route alternatives is illustrated in the attached figures. Aerial-photo-based maps of the alternative routes are provided as Figures attached to this ER Chapter.

1.2.4 Pipeline Facilities

The various supply and return flow corridors evaluated in this ER are summarized in Table 1-1. Details of each of the alternatives considered and rationales for further evaluation or disqualification are included in Application Sections 4, Water Supply Alternatives, and 5, Return Flow. As a result of the information presented in the Application, only the following alternatives have been included in this ER:

1.2.4.1.1 Supply Alternatives

- Deep and shallow aquifers
- Shallow aquifer and Fox River alluvium
- Lake Michigan—Milwaukee supply
- Lake Michigan—Oak Creek supply
- Lake Michigan—Racine supply

1.2.4.1.2 Return Flow Alternatives

- Underwood Creek to Lake Michigan
- Root River to Lake Michigan
- Directly to Lake Michigan

Proposed pipeline facilities information is summarized in Table 1-1.

TABLE 1-1
Proposed Pipeline Facilities
City of Waukesha Water Supply

Alternative	Diameter (In.)	Length (miles)	Counties
Supply Alternatives			
Deep and Shallow Aquifers	8 to 36	13.9	Waukesha
Shallow Aquifer and Fox River Alluvium	8 to 36	14.7	Waukesha
Lake Michigan—Milwaukee Supply	36	15	Milwaukee and Waukesha
Lake Michigan—Oak Creek Supply	36	27	Milwaukee and Waukesha
Lake Michigan—Racine Supply	36	38	Racine and Waukesha
Return Flow Alternatives			
Underwood Creek to Lake Michigan	36	11.5	Milwaukee and Waukesha
Root River to Lake Michigan	36	15.5	Milwaukee and Waukesha
Direct to Lake Michigan	36	23.5	Milwaukee and Waukesha

1.2.5 Aboveground Facilities

The number and type of aboveground facilities differ for each of the various supply and return flow alternatives. A summary of the proposed aboveground facility is summarized in Table 1-2.

TABLE 1-2
Proposed Aboveground Facilities
City of Waukesha Water Supply

Project Component	Description	Township	County
Supply Alternatives			
Deep and Shallow Aquifers	1 water treatment plant, 11 well houses [a]	Waukesha	Waukesha
Shallow Aquifer and Fox River Alluvium	1 water treatment plant, 15 well houses [b]	Waukesha	Waukesha
Lake Michigan—Milwaukee Supply	— [c]	—	—
Lake Michigan—Oak Creek Supply	— [c]	—	—
Lake Michigan—Racine Supply	— [c]	—	—

TABLE 1-2
Proposed Aboveground Facilities
City of Waukesha Water Supply

Project Component	Description	Township	County
Return Flow Alternatives			
Underwood Creek to Lake Michigan	—[c]	—	—
Root River to Lake Michigan	—[c]	—	—
Direct to Lake Michigan	—[c]	—	—

[a]Includes 1.65 miles of new, 15-foot-wide access roads between well houses discussed in Chapter 7.
[b]Includes 2.78 miles of new, 15-foot-wide access roads between well houses discussed in Chapter 7.
[c]No new aboveground facilities required.

1.3 Land Requirements

Chapter 7 of this ER discusses the potential land acreage totals affected during construction for each of the supply and return flow alternatives being evaluated. These totals are based upon a typical 75-foot-wide construction corridor over the length of the respective alternatives. Land requirements for the pipeline facilities will generally be temporary during construction while land requirements for above ground facilities will generally have long-term operational requirements. A detailed discussion on the current types of land uses along each of the routes, acreage totals of these land uses, and long-term maintenance and aboveground structures impacts are included in ER Chapter 7.

1.3.1 Pipeline Facilities

A summary of land requirements for pipeline facilities is summarized in ER Chapter 7.

1.3.2 Aboveground Facilities

A summary of land requirements for aboveground facilities is summarized in ER Chapter 7.

1.3.3 Access Roads

Existing roads and highways would be used for primary access to the construction workspace for the various supply and return alternatives. Additional temporary access roads would be required during construction in order to facilitate transport of equipment and materials along the construction corridor, but these areas will be restored as agreed upon by the regulatory agencies and consequently resource impacts related to these roads are anticipated to be minor and will not result in any significant long-term impacts.

Construction of new permanent access roads would be required for the Deep and Shallow Aquifers or Shallow Aquifer and Fox River Alluvium alternatives if either were selected as the final supply option. These new permanent access roads would be used to connect the proposed water treatment plant, pump stations, and well houses that would be installed as part of those alternatives and allow for routine maintenance and any repairs that would be necessary. For the purposes of this ER, it was assumed that the access roads would be graveled. A more-detailed discussion on the potential area of impact associated with the development of the access roads is provided in ER Chapter 7, Land Use. The locations of the

potential access roads are indicated on the maps provided as Figures attached to this Chapter.

1.3.4 Schedule

The development of a new water supply and return flow discharge for the City is being driven by a June 30, 2018, deadline to achieve public health protection standards for radium in drinking water. This project will be a multiyear effort consisting of the following major efforts:

- Draft Application made available for public comment—January 28, 2010
- WDNR public scoping process begins for NR 150—February 1, 2010
- Public presentations and meetings—February-April 2008
- Application and Environmental Report submitted to WDNR— May 2010
- WDNR Public Hearing for NR 150—estimated June 2010
- WDNR review completed—estimated August 2010
- Submittal to Great Lakes governors—estimated August 2010
- Approval from Great Lakes governors—estimated fall 2010
- Permitting, fieldwork, design start—estimated January 2011
- Start construction—estimated July 2013
- Completed construction—estimated December 2016

This schedule provides a buffer of approximately 18 months, which may be needed to address longer review times, construction delays, or other unanticipated events.

1.4 Operation and Maintenance

Operation and maintenance will begin upon completion of the construction phase. Regularly scheduled maintenance will ensure that the constructed facilities meet standard service requirements. For aboveground project features and service roads, land use will change with construction and continue for the operation and maintenance phase. For pipelines, land use will change with construction will have primarily temporary impacts; during operation and maintenance, land use impacts, such as those from occasional mowing, will be low.

Where the pipelines are not under pavement, erosion control devices and seeded areas installed during construction will be periodically monitored, and defects will be repaired until a condition similar to approximately adjacent off-right-of-way land is achieved. Monitoring will continue regularly with ground surveys to detect potential mechanical damage caused by natural processes or third-party activities. Wetland and water body crossings will be routinely inspected during a monitoring period to ensure that erosion and sedimentation control practices are effective and to remedy nonconforming situations.

In previously unmaintained areas, a cleared herbaceous condition will be maintained over a 10-foot-wide corridor directly over the supply and return flow pipelines. Ten feet is the minimum right-of-way necessary to allow for periodic pipeline inspection; trees that reach a height of 15 feet and stand within 15 feet of the pipe centerline will be selectively cut. The remaining workspace will revert to its preconstruction land use/land cover once construction is complete. Preconstruction habitat suitable for wildlife will be allowed to reestablish where practicable. Agricultural fields will revert to crop production or pasture.

Mechanical mowing will be performed as required to maintain access and to allow for greater visibility of the line. Brush removal typically will be completed using mechanical equipment.

1.5 Permits and Approvals

Implementing a Lake Michigan water supply alternative would require review and approval under the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact) and Wisconsin Act 227.

Besides Compact review, construction, operation, and maintenance will be in accordance with applicable federal, state, and local permit requirements. The environmental permits, reviews, and clearances that are anticipated to be applicable are identified in Table 1-3.

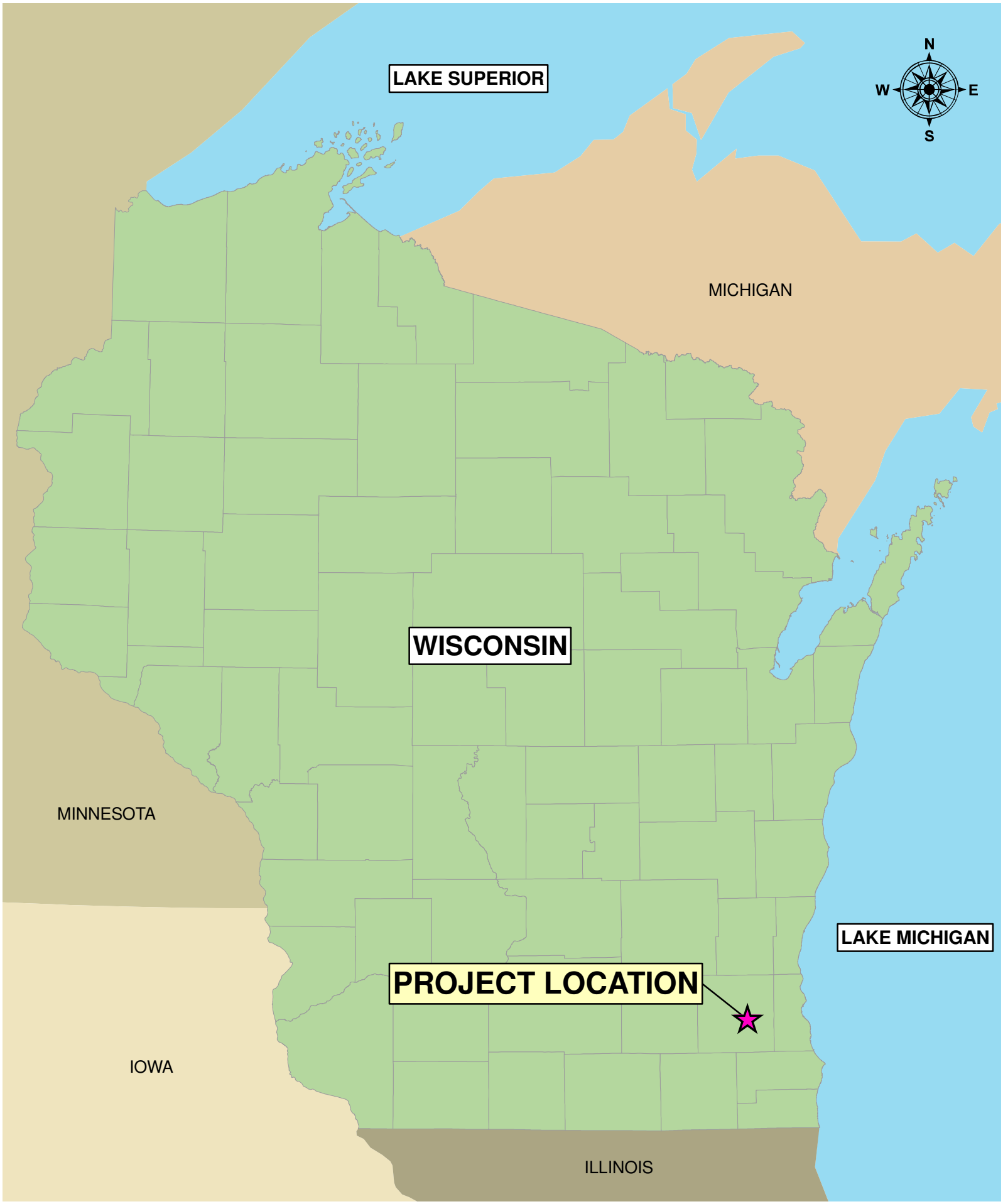
To date, consultations with federal, state, and local regulatory officials and government agencies regarding clearances and data consultations for this Project have been limited to preliminary or screening-level discussions. In-depth coordination regarding project specific permits, approval, and conditions will be completed once approvals for Lake Michigan water have been obtained and the water supplier has been finalized.

TABLE 1-3
Permits, Licenses, Approvals, and Certificates Required for Construction, Operation, and Maintenance
City of Waukesha Water Supply

Permit/Approval (Statute/Reg.)	Administering Agency	Status
Federal		
Endangered Species Section 7 Consultation (Endangered Species Act — 16 U.S.C.1531 et. seq.)	U.S. Fish and Wildlife Service, Green Bay ES Field Office	Initiated January 13, 2010
Section 404 Dredge and Fill Permit (Clean Water Act—33 U.S.C. 1344)	U.S. Army Corps of Engineers, St. Paul District	Pending selection of a preferred supply, return flow alternative, and governors' approval
Section 10 Navigable Waters (Rivers and Harbors Act of 1899- 33 U.S.C. 403)	U.S. Army Corps of Engineers, St. Paul District	Pending selection of a preferred supply, return flow alternative, and governors' approval
State		
Chapter 30 Stream Crossings Navigable Waters (Applications on County Basis; WI NR 199, 102, 103, 155, 117)	WDNR, Bureau of Fisheries Management and Habitat Protection	Pending selection of a preferred supply, return flow alternative, and governors' approval
WPDES Stormwater Discharge Permit (WI NR 216)	WDNR, Bureau of Watershed Management	Pending selection of a preferred supply, return flow alternative, and governors' approval
Hydrostatic Test Discharge General Permit (WI Chapter 283, 216)	WDNR, Bureau of Watershed Management	Pending selection of a preferred supply, return flow alternative, and governors' approval
Pit/Trench Dewatering General Permit (WI Chapter 283, 216)	WDNR, Bureau of Watershed Management	Pending selection of a preferred supply, return flow alternative, and governors' approval
Section 401 Water Quality Certification—Joint Application with COE Outside	Wisconsin Department of Natural Resources, Bureau of	Pending selection of a preferred supply, return flow alternative, and

TABLE 1-3
Permits, Licenses, Approvals, and Certificates Required for Construction, Operation, and Maintenance
City of Waukesha Water Supply

Permit/Approval (Statute/Reg.)	Administering Agency	Status
Navigable Waters (Applications on County Basis; see Stream Crossings in Section 2)	Fisheries Management and Habitat Protection	governors' approval
WDNR—Wastewater Facilities Plan Review (WI NR 110)	WDNR	Submitted with the Application
WDNR—Wisconsin Floodplain Management Program (WI NR 116)	WDNR	Pending selection of a return flow alternative and governors' approval
WDNR–Environmental Report (Statewide; WI NR 150)	WDNR, Bureau of Integrated Science Services	Spring 2010
Natural Heritage Inventory (Wisconsin Endangered Species Law—WI Stats. S. 29.415)	WDNR, Bureau of Endangered Resources	Initiated January 12, 2010
Incidental Take Permit (WI Stats. 29.604)	WDNR, Bureau of Endangered Resources	Pending selection of a preferred supply, return flow alternative, and governors' approval
WDNR—Water Quality Anti-Degradation (WI NR 207)	WDNR	Pending selection of a preferred supply, return flow alternative, and governors' approval
WDNR— WPDES Permit for Effluent Standards and Limitations (WI NR 217 and WI SS 283)	WDNR	October 16, 2008, WDNR letter provided initial information; additional review occurring with governors' approval
WDNR—Water Service Area Plan (WI NR 281)	WDNR	Submitted with the Application
Wastewater systems construction plan review	WDNR	Conducted at design completion and prior to construction
Water systems construction plan review	WDNR	Conducted at design completion and prior to construction
Cultural Resources Review (36 CFR Part 800; WI Chapter 285)	Wisconsin State Historic Preservation Office	Pending selection of a preferred supply, return flow alternative, and governors' approval
Agricultural Impact Statement (WI Statute 32.035)	Wisconsin Department of Agriculture, Trade, and Consumer Protection	Pending selection of a preferred supply, return flow alternative, and governors' approval
County		
Shoreland-Wetland Zoning Permit and Conditional Use Application	Varies by county	Pending selection of a preferred supply, return flow alternative, and governors' approval
Erosion and Sedimentation Control Permit	Varies by county/municipality	Pending selection of a preferred supply, return flow alternative, and governors' approval


LAKE SUPERIOR
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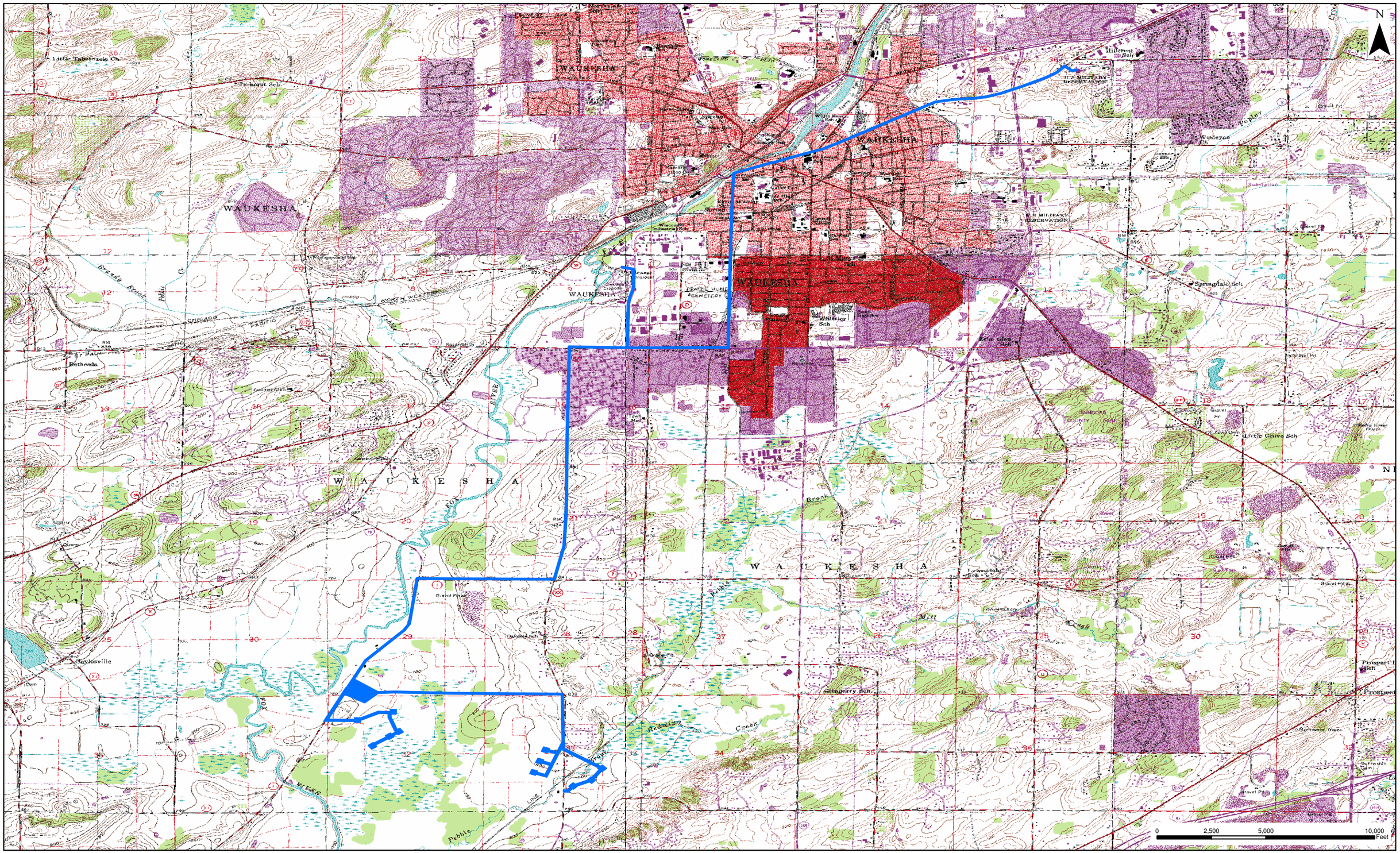
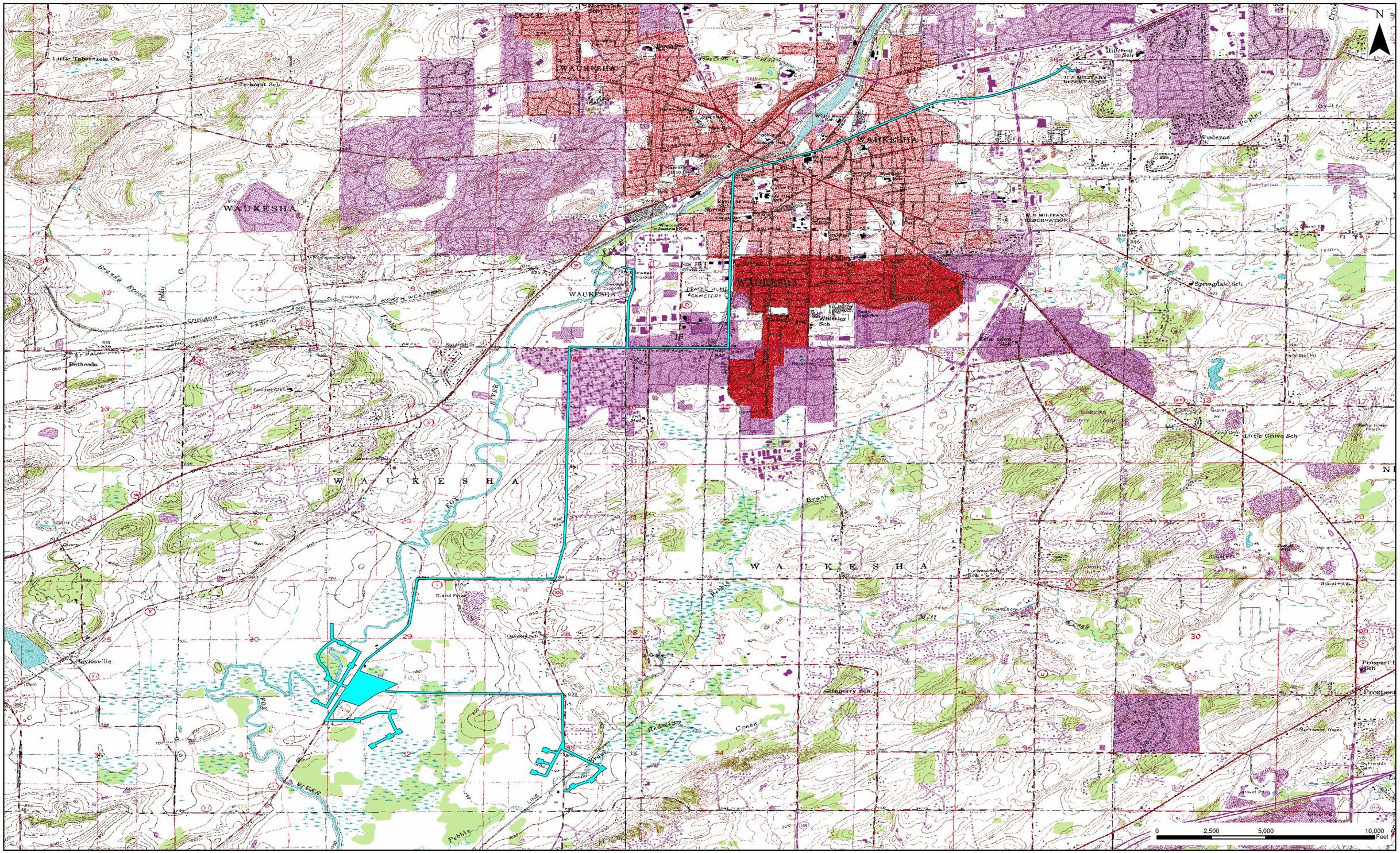
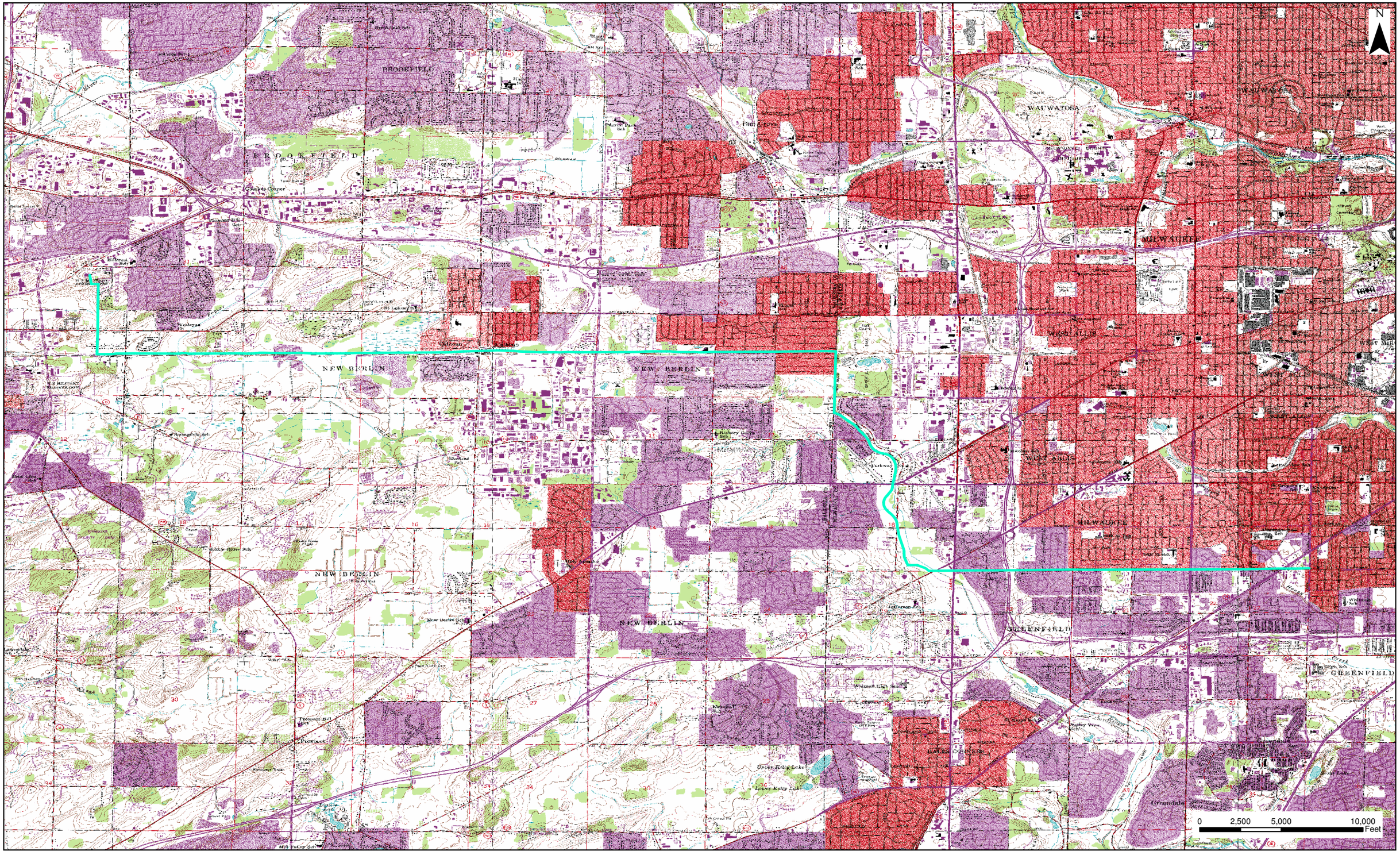
S
MICHIGAN
WISCONSIN
MINNESOTA
LAKE MICHIGAN
PROJECT LOCATION
IOWA
ILLINOIS

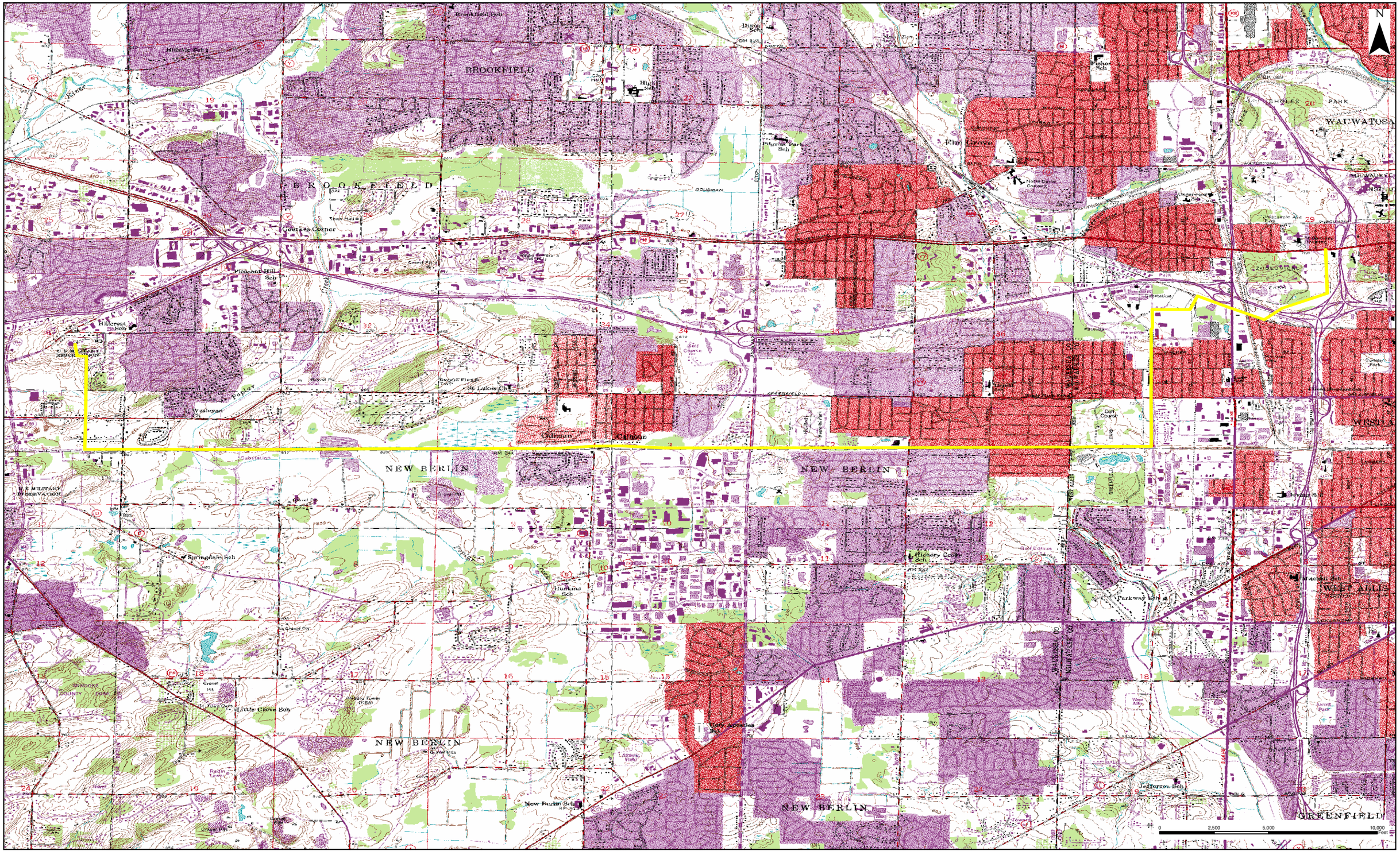

N
WAUKESHA
WAUKESHA
WAUKESHA
WAUKESHA
WAUKESHA
WAUKESHA
Little Tabernacle Ch.
Turnbrist Sch.
Hillcrest Sch.
Wesleyan Ch.
Springdale Sch.
Little Grove Sch.
Prospect Hill Sch.
Prospect Hill
Brandy Brook
Pebble Cr.
Fox River
Pebble Creek
Redwing Creek
Bonnie Brook
Rapids
Eastbrook
Gardner Glen
Bethesda
Guthrie Sch.
Oakdale Sch.
Glenn Pk.
Glenn Park
Glenn Hills
Glenn Hills Sch.
Glenview Manor
Glenview Terrace
Glenview Park
Glenview Pk.
Glenview Sch.
Glenwood Sch.
Glenwood Park
Glenwood Terrace
Glenwood Manor
Glenwood Hills
Glenwood Hills Sch.
Glenwood Hills Park
Glenwood Hills Pk.
Glenwood Hills Manor
Glenwood Hills Terrace
Glenwood Hills Estates
Glenwood Hills Subdivision
Glenwood Hills Addition
Glenwood Hills Addition No. 1
Glenwood Hills Addition No. 2
Glenwood Hills Addition No. 3
Glenwood Hills Addition No. 4
Glenwood Hills Addition No. 5
Glenwood Hills Addition No. 6
Glenwood Hills Addition No. 7
Glenwood Hills Addition No. 8
Glenwood Hills Addition No.



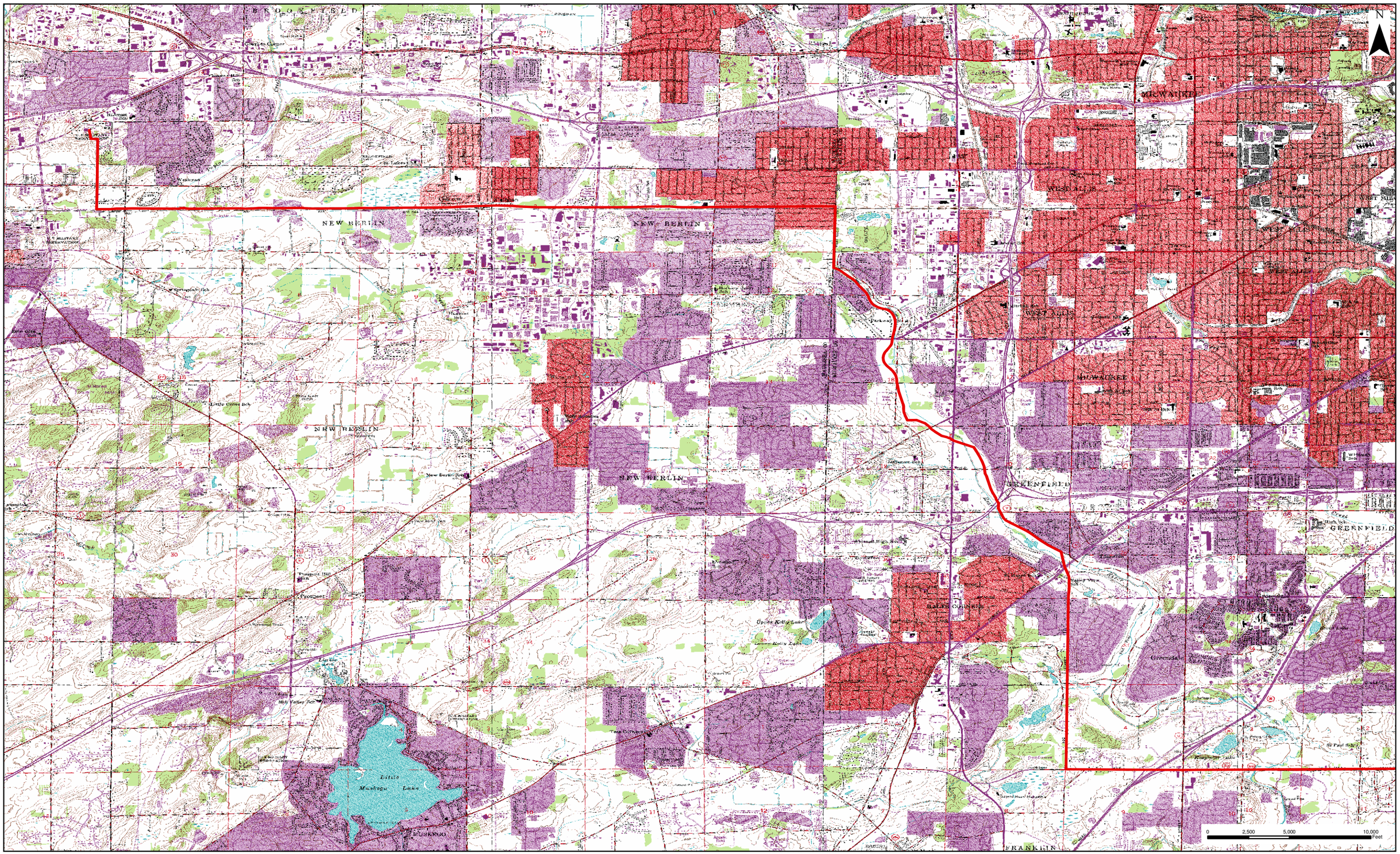
ALTERNATIVE 2 SHALLOW AQUIFER AND FOX RIVER ALLUVIUM



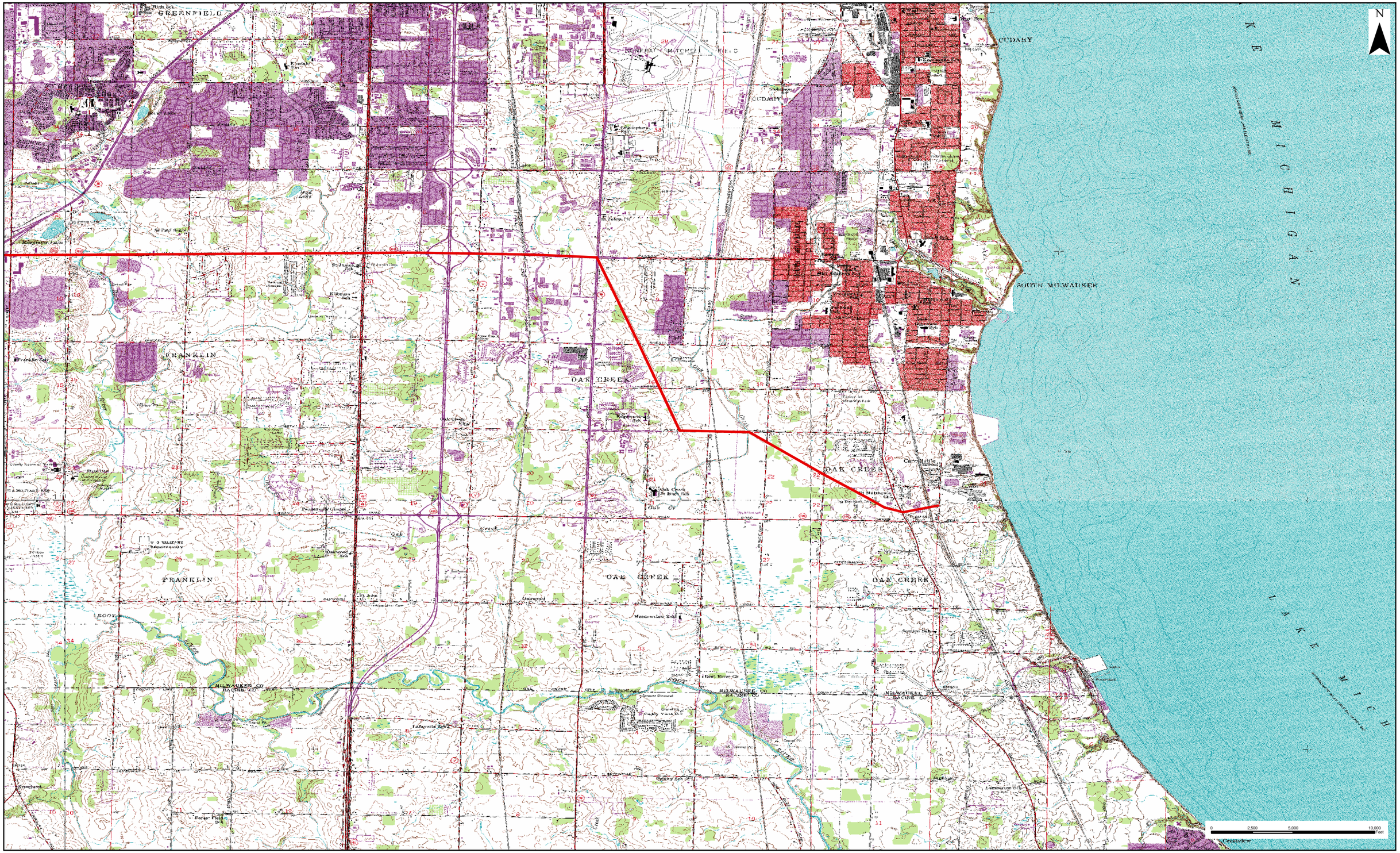
ALTERNATIVE 3-a1 MILWAUKEE SUPPLY



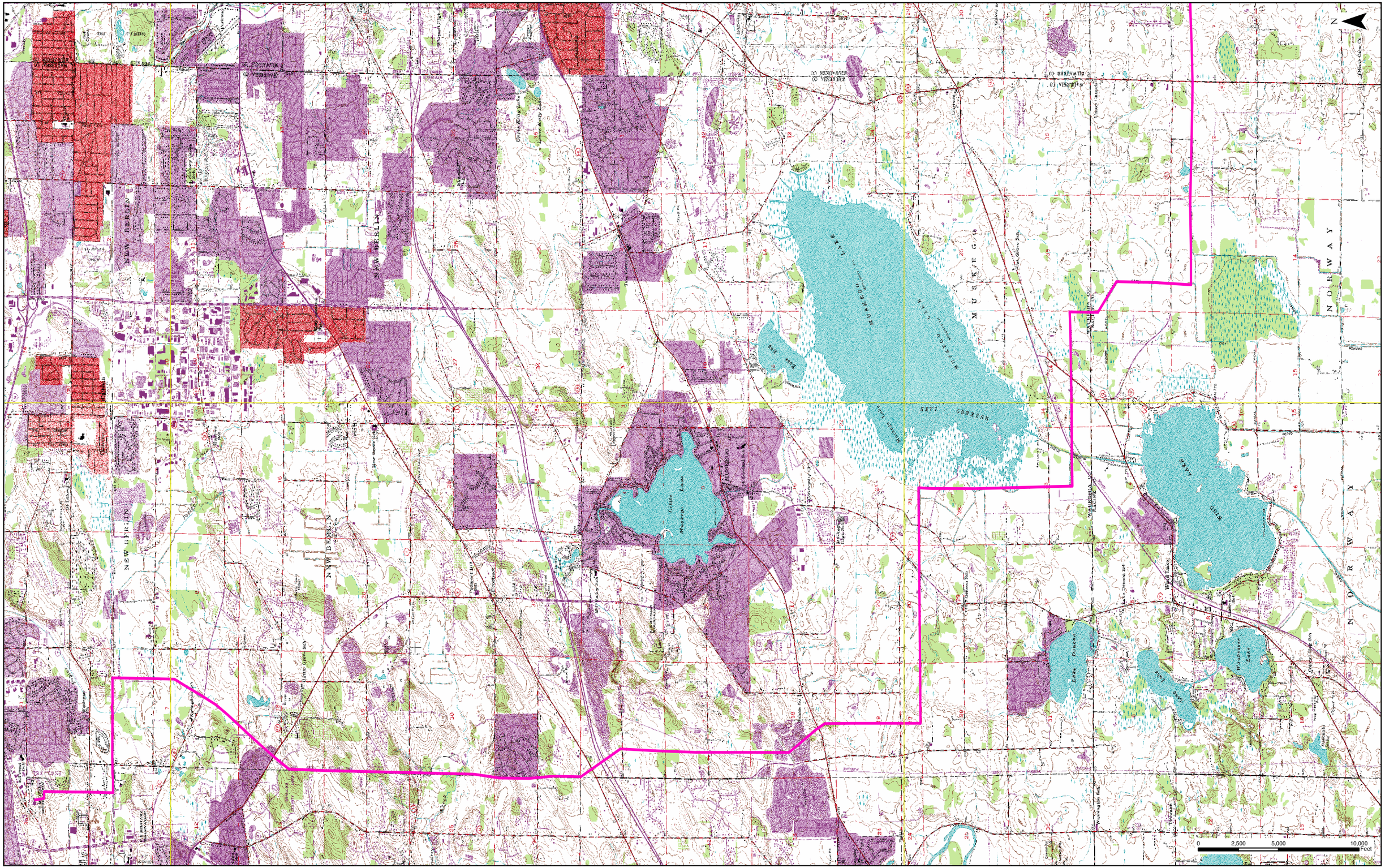
ALTERNATIVE 3-a2 MILWAUKEE SUPPLY 2



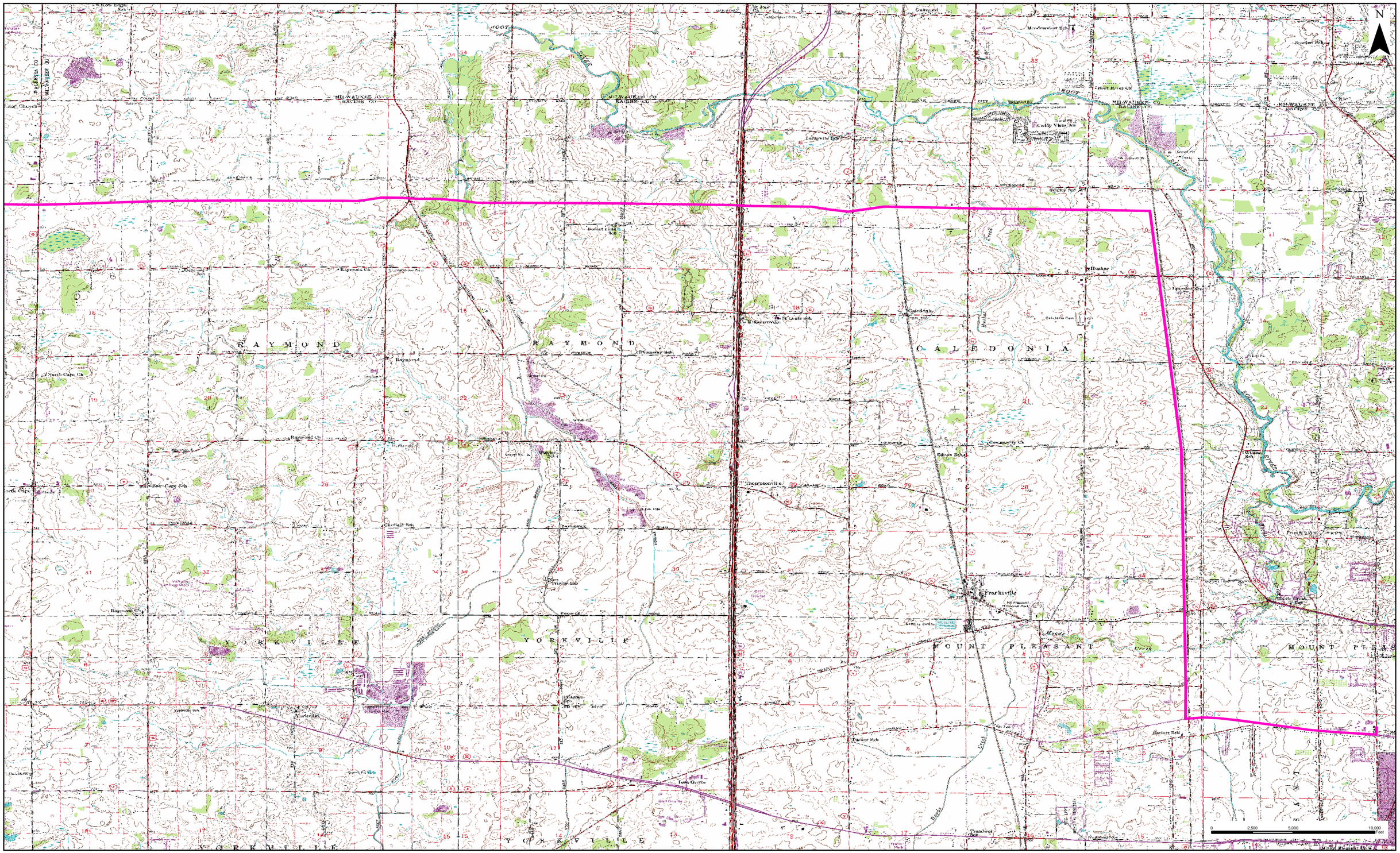
ALTERNATIVE 3-a3 OAK CREEK SUPPLY TILE 1



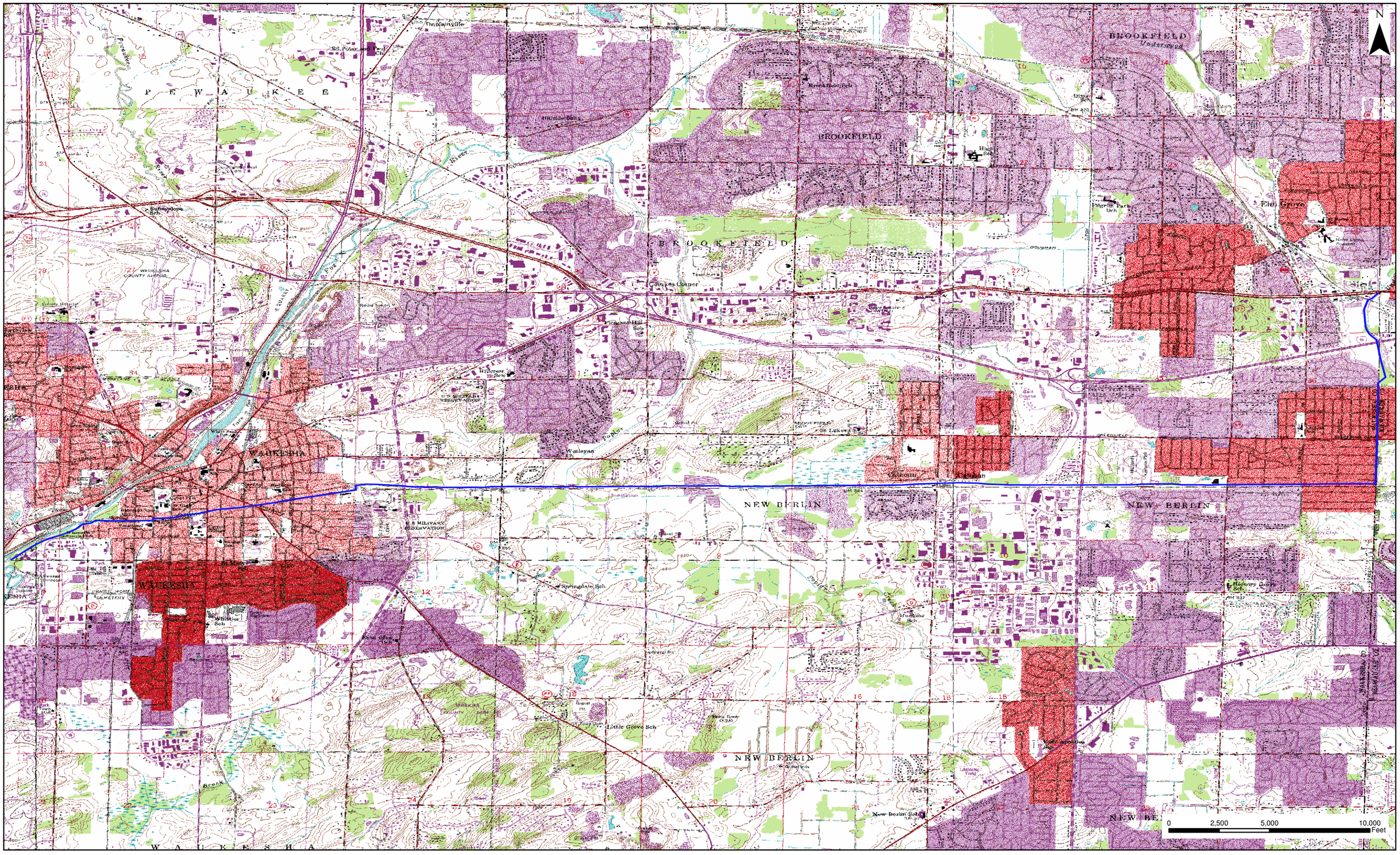
ALTERNATIVE 3-a3 OAK CREEK SUPPLY TILE 2

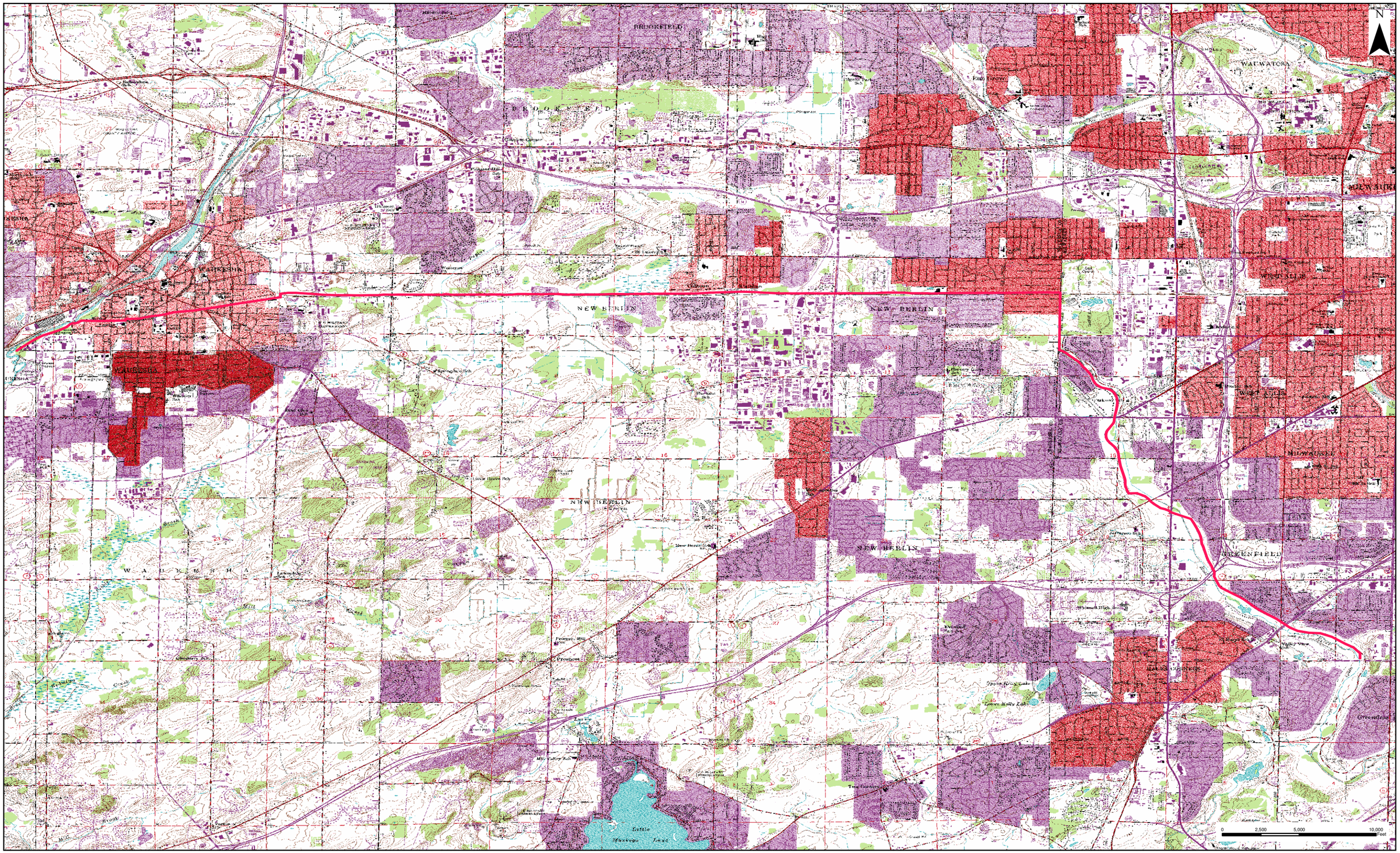


ALTERNATIVE 3-a4 RACINE SUPPLY TILE 1



ALTERNATIVE 3-a4 RACINE SUPPLY TILE 2


N
PEWAUKEE
BROOKFIELD
BROOKFIELD
BROOKFIELD
Underwood
Dunnsville
Sunnyslope Sch.
Pleasant Hill Sch.
Hillcrest Sch.
Brookfield Sch.
Hillside Sch.
Pilgrim Park Sch.
Elm Grove
Dolyman
Courtes Corner
Town Hall
Waukesha County Airport
Waukesha County Asylum
Waukesha County Home Cemetery
Wauk. Co. Militia Reservation
Wauk. Co. Militia Reservation
Wauk. Co. Militia Reservation



ALTERNATIVE 3-b2 ROOT RIVER

ALTERNATIVE 1 OVERVIEW MAP

N

Legend

- Alt 1 Deep and Shallow Wells Project Area
- Map Tiles
- Municipal Boundaries
- Freeway
- Highway
- Major Roads

0 4,000 8,000 Feet

TILE 4

TILE 3

TILE 2

TILE 1

PEWAUKEE

WAUKESHA

WALES

NEW BERLIN

MUSKEGO

Northview

Davidson

Cleveland

Coffee

Elmhurst

Meadowbrook

Grandview

Merrill Hills

Madison

Moreland

Delafield

Pewaukee

Main

Arcadian

Broadway

Springdale

Saint Paul

Mac Arthur

Prairie

East

Genesee

Sunset

Oakdale

Center

Cth X

National

Beloit

Racine

Martin

Small

College

18

59

164

83

43

TILE 1

Legend

Alt 1 Deep and Shallow Wells Project Area

0 1,000 2,000 Feet

N

Wood Lilly

Gruettner

Cartwr

CR I

Fox Vale

Glendale

Hazelhurst

Oakdale

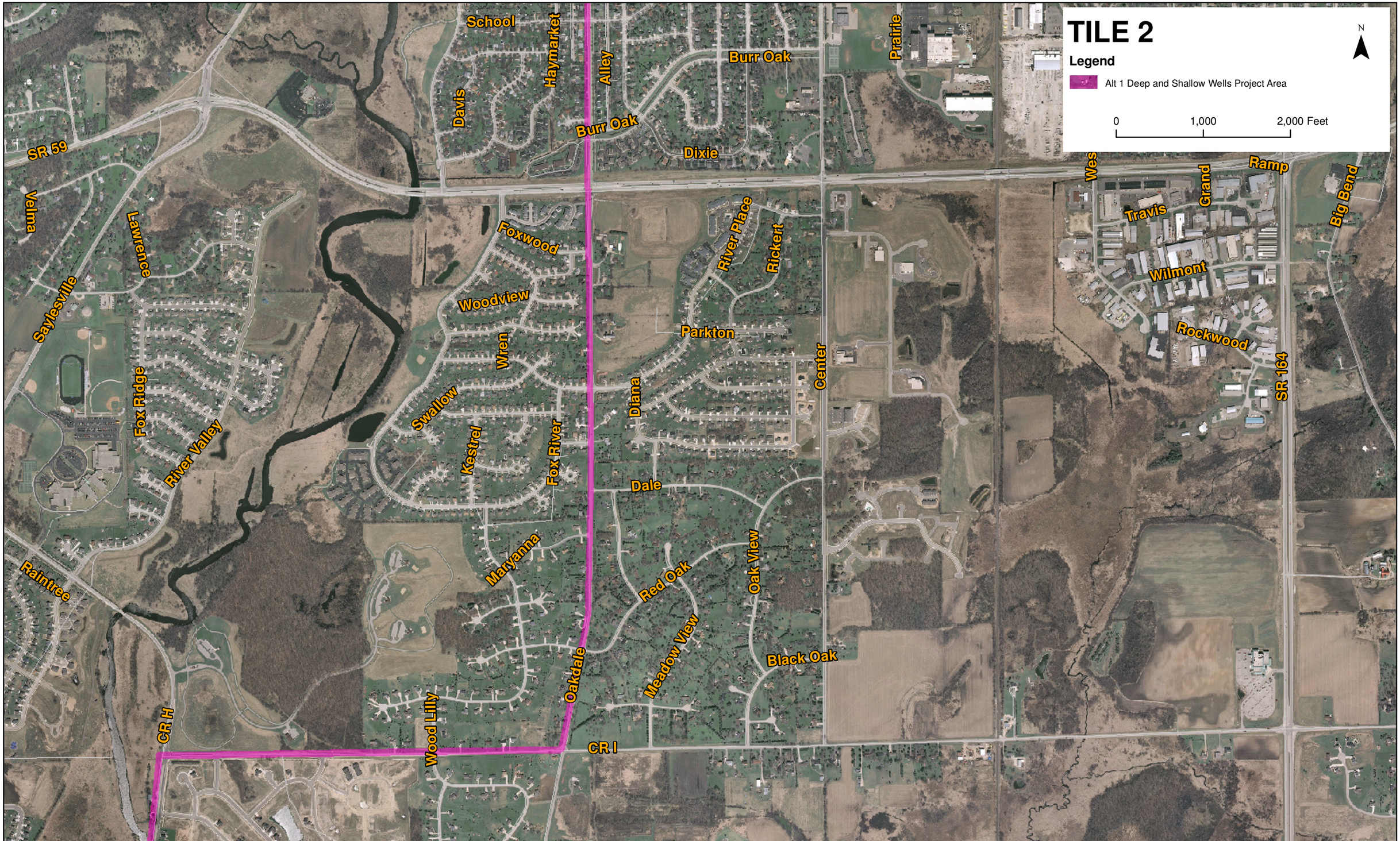
Lois

Crest

Misty Woods

Deerfield

Townline


TILE 2
Legend
Alt 1 Deep and Shallow Wells Project Area
0
1,000
2,000 Feet
N
School
Haymarket
Alley
Burr Oak
Prairie
Davis
Burr Oak
Dixie
SR 59
Velma
Lawrence
Foxwood
River Place
Rickert
Wes
Grand
Ramp
Big Bend
Travis
Wilmont
Sayiesville
Woodview
Parkton
Rockwood
Wren
Center
SR 164
Fox Ridge
Swallow
Diana
River Valley
Kestrel
Fox River
Dale
Maryanna
Red Oak
Oak View
Raintree
Meadow View
Black Oak
Oakdale
CR H
Wood Lilly
CR I

TILE 3

Legend

Alt 1 Deep and Shallow Wells Project Area

0 1,000 2,000 Feet

N

Minot
Cambridge
Saint Paul
Dunbar
Napa
Letko
Hamilton
Pendleton
Minaka
Phillip
West
Walton
Laflin
James
Windemere
Kensington
Newhall
Wilson
Luke
Scott
Arthur
Grandview
Mac Arthur
CR De
Oxford
Wabash
Prarie Home
Estberg
Brighton
Prairie
Grand
East
Badger
Hoover
Hickory
Poplar
Sentry
Progress
Tenny
Sunset
Genesee
Fox River
Garfield
Green Valley
Baird
View
Wisteria
Center
Big Bend
Genesee
Alley
Mulberry
Debbie
Richard
Sycamore
Dixie
School
Alley
Rivera

TILE 4

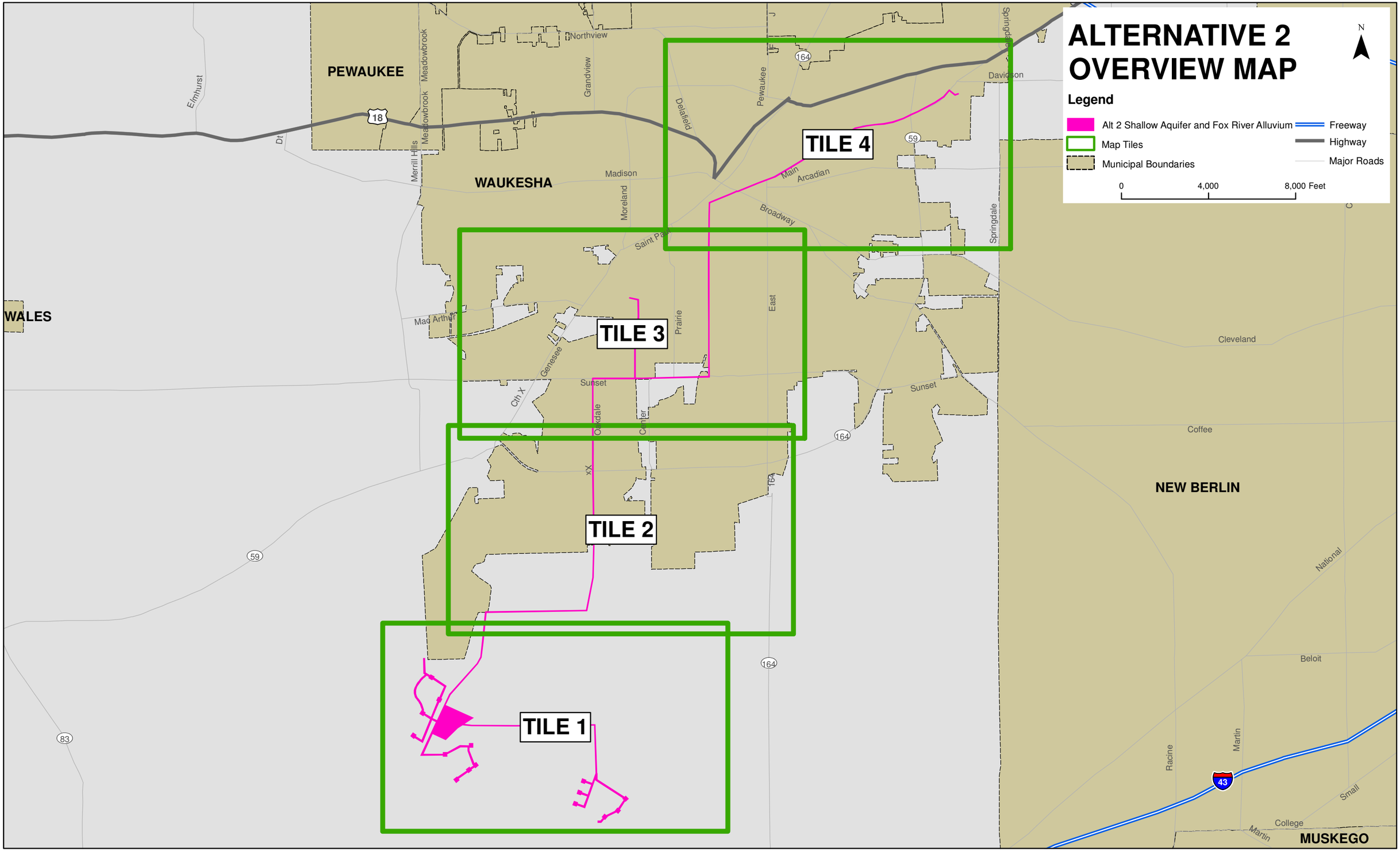
Legend

Alt 1 Deep and Shallow Wells Project Area

0 1,000 2,000 Feet

N

Moreland
CR J
SR 164
Davidson
Delafield
US 18
SR 164
Madison
Saint Paul
Broadway
Arcadian
SR 59
East
Broadway
Springdale
Prairie


ALTERNATIVE 2
OVERVIEW MAP
Legend
Alt 2 Shallow Aquifer and Fox River Alluvium
Map Tiles
Municipal Boundaries
Freeway
Highway
Major Roads
0
4,000
8,000 Feet
N
TILE 1
TILE 2
TILE 3
TILE 4
PEWAUKEE
WAUKESHA
WALES
NEW BERLIN
MUSKEGO
Northview
Grandview
Meadowbrook
Elmhurst
Merrill Hills
Madison
Moreland
Delafield
Pewaukee
Main
Arcadian
Broadway
Saint Paul
Springdale
Davidson
Mac Arthur
Prairie
East
Genesee
Sunset
Cth X
Oakdale
Center
Cleveland
Coffee
National
Beloit
Racine
Martin
College
Small
18
164
59
83
43

TILE 1

Legend

Alt 2 Shallow Aquifer and Fox River Alluvium

0 1,000 2,000 Feet

N

Wood Lilly

Gruettner

Cartwr

Fox Vale

Glendale

Wood Lilly

Hazelhurst

Lois

Crest

Oakdale

CR I

Misty Woods

Deerfield

Townline

TILE 2

Legend

Alt 2 Shallow Aquifer and Fox River Alluvium

0 1,000 2,000 Feet

N

Genesee
Valley View
Velma
Donald
Saylesville
Lawrence
Lavine
Campfire
River Valley
Raintree
CR H
School
Davis
Foxwood
Woodview
Swallow
Fox River
Maryanna
Wood Lilly
Oakdale
Alley
Burr Oak
Dixie
SR 59
River Place
Wesley
Parkton
Center
Dale
Red Oak
Oak View
CR I
Prairie
Travis
Wilmont
SR 164
Big Bend

TILE 3

N

Legend

Alt 2 Shallow Aquifer and Fox River Alluvium

0 1,000 2,000 Feet

Minot
Cambridge
Saint Paul
Dunbar
Marshall
Napa
Letko
Pendleton
Minaka
College
Apache
Phillip
West
Laflin
James
Windemere
Kensington
Walton
Newhall
Wilson
Scott
Arthur
Mac Arthur
Grandview
Oxford
CR De
Wabash
Prarie Home
Estberg
Brighton
Prairie
Grand
East
Badger
Hoover
Hickory
Poplar
Sentry
Progress
Tenny
Garfield
Sunset
Genesee
Fox River
Green Valley
Baird
View
Wisteria
Center
Big Bend
Genesee
Alley
Mulberry
Debbie
Richard
Sycamore
Dixie
School
Alley
Rivera

TILE 4

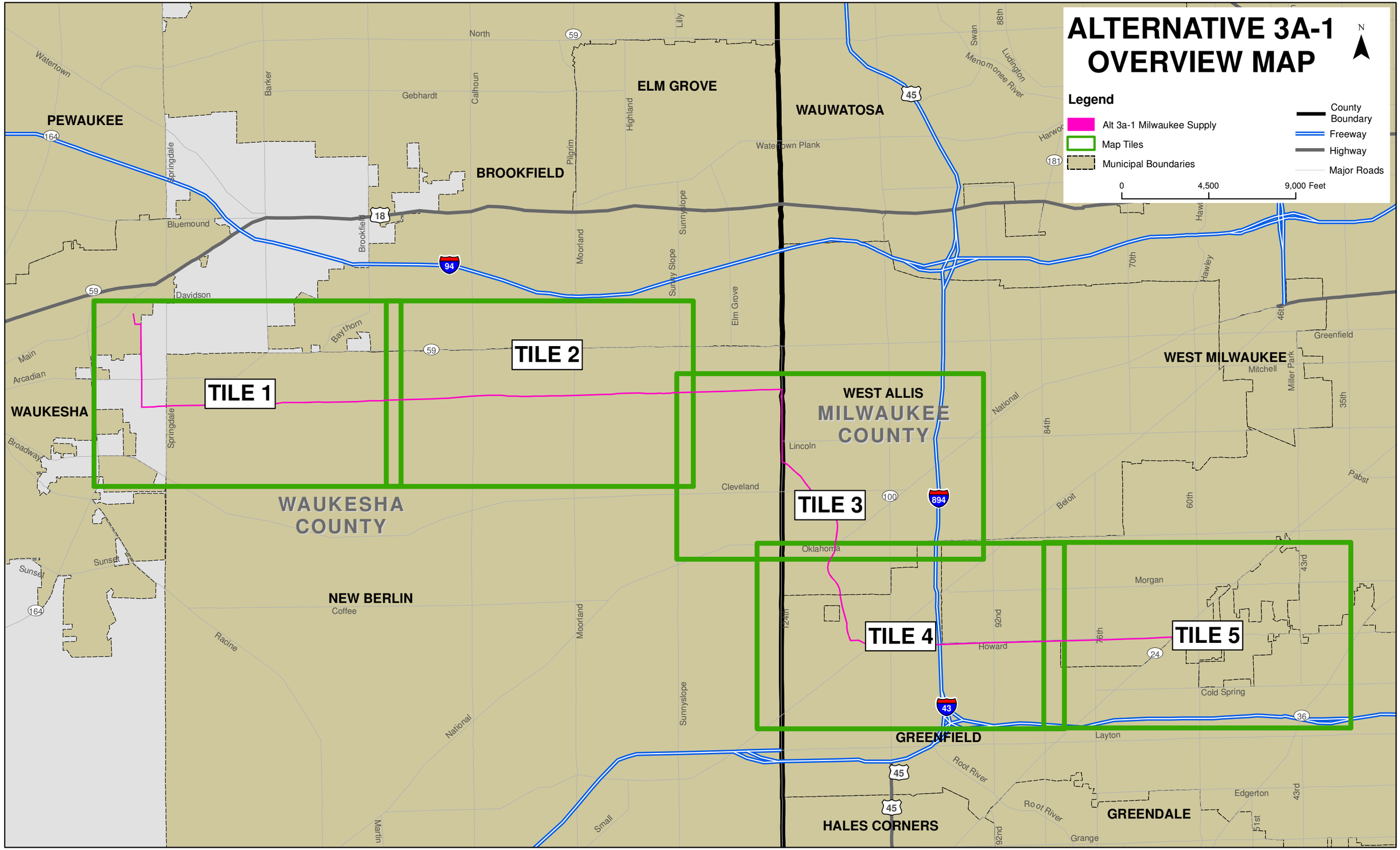
N

Legend

Alt 2 Shallow Aquifer and Fox River Alluvium

0 1,000 2,000 Feet

Moreland
CR J
SR 164
Davidson
Delafield
US 18
SR 164
Madison
Saint Paul
Broadway
Arcadian
SR 59
East
Broadway
Springdale
Prairie


ALTERNATIVE 3A-1
OVERVIEW MAP
N
Legend
Alt 3a-1 Milwaukee Supply
Map Tiles
Municipal Boundaries
County Boundary
Freeway
Highway
Major Roads
0
4,500
9,000 Feet
TILE 1
TILE 2
TILE 3
TILE 4
TILE 5
PEWAUKEE
ELM GROVE
WAUWATOSA
BROOKFIELD
WAUKESHA
WEST ALLIS
WEST MILWAUKEE
MILWAUKEE COUNTY
WAUKESHA COUNTY
NEW BERLIN
GREENFIELD
HALES CORNERS
GREENDALE
Watertown
North
Gebhardt
Calhoun
Barker
Lilly
Highland
Pilgrim
Watertown Plank
Swan
88th
Menomonee River
Ludingston
Bluemound
Springdale
Brookfield
Moorland
Sunnyslope
Sunny Slope
Elm Grove
Davidson
Baythorn
Main
Arcadian
Broadway
Sunset
Racine
Coffee
National
Martin
Small
Lincoln
Cleveland
Oklahoma
Howard
Morgan
Cold Spring
Layton
Root River
Grange
Edgerton
Greenfield
Mitchell
Miller Park
Pabst
Beloit
Hawley
70th
84th
92nd
76th
60th
46th
35th
43rd
51st
124th
164
59
18
94
45
181
100
894
24
43
36

TILE 1

Legend

Alt 3a-1 Milwaukee Supply

0 1,000 2,000 Feet

N

Davidson
Main
Belgren
Calico
Summit
Hi Ridge
Linden
Nike
Ridge
Plateau
Barker
Auburn
Dolphin
Marlin
Copenhill
Ashbourne
Cologne
Sunnycrest
Avondale
Coral
Pioneer
Greenhill
Westwoods
Pinecrest
SR 59
Whitehall
Downie
Norwood
Craftsman
Lilly
Lincoln
Anoka
Pearl
Springdale
Danny
Lincoln
SR 59
CR D
Rempe
Broadale
Johnson

TILE 2

Legend

Alt 3a-1 Milwaukee Supply

N

0 1,000 2,000 Feet

Kestrel
Tremont
Ridge
Norwood
Franklin
Michael
Lois
Burnet
Pinehurst
Moorland
Post
Pepper
Dover
Jewel
High Meadow
Davidson
Patti
SR 59
Ridgeway
Fullerton
Sherwood
Meadow
Prospect
Coachlight
164th
167th
Calhoun
Ridge
Ranch
Berlin
Oak
Kostner
Roosevelt
Sunny Slope
Honey
Rogers
West
Rogers
Rogers
Reservoir
Woodview
Westward
Crestview
Woodshire
Woodland
162nd
Lincoln
170th
171st
Commerce
Overland
Krahn
Ronke
Park
Parkside
Brookland
Lilac
Robin
Brittany

TILE 3

Legend

Alt 3a-1 Milwaukee Supply

0 1,000 2,000 Feet

N

Prospect
Forest
Forest
Conrad
Forest
Honey
Honey
Park
Graham
Ferguson
Paddock
Lilac
134th
Robin
Montana
133rd
132nd
130th
Lagoon
Montana
127th
124th
National
Oklahoma
Harrison
Cleveland
Waukesha
Root River
Main
South
116th
115th
Mitchell
106th
Manor Par
Rog
Becher
Grant
114th
107th
102nd
98th
94th
95th
Lincoln
118th
Arthur
117th
SR 100
Hayes
Arthur
100th
Hayes
99th
96th
Harrison
Rosedale
Montana
111th
109th
Montana
111th
Dakota
104th
101st
I 894
97th
94th
Oklahoma
Wollmer
106th
103rd
Euclid

TILE 4

Legend

Alt 3a-1 Milwaukee Supply

0 1,000 2,000 Feet

N

National
Lakefield
122nd
Root River
Toldt
114th
Oklahoma
105th
Euclid
98th
Burdick
Ohio
124th
Holt
113th
Wollmer
I 894
95th
Verona
85th
82nd
Morgan
Eden
White Oak
Russell
Wilbur
120th
116th
SR 100
103rd
96th
93rd
90th
86th
Warnimont
83rd
87th
84th
North
Wilbur
River Ridge
Howard
Tripoli
Howard
Van Beck
Norwich
106th
104th
99th
Waterford
Tesch
Stonewood
119th
117th
Beloit
Plainfield
112th
101st
97th
94th
91st
88th
Leroy
Cold Spring
Todd
Coldspring
SR 100
92nd
90th
Whitaker
Sunset
116th
113th
I 43
I 43

TILE 5

Legend

Alt 3a-1 Milwaukee Supply

N

0 1,000 2,000 Feet

60th

Morgan

43rd

SR 24

76th

Howard

SR 24

60th

84th

Coldspring

Coldspring

Coldspring

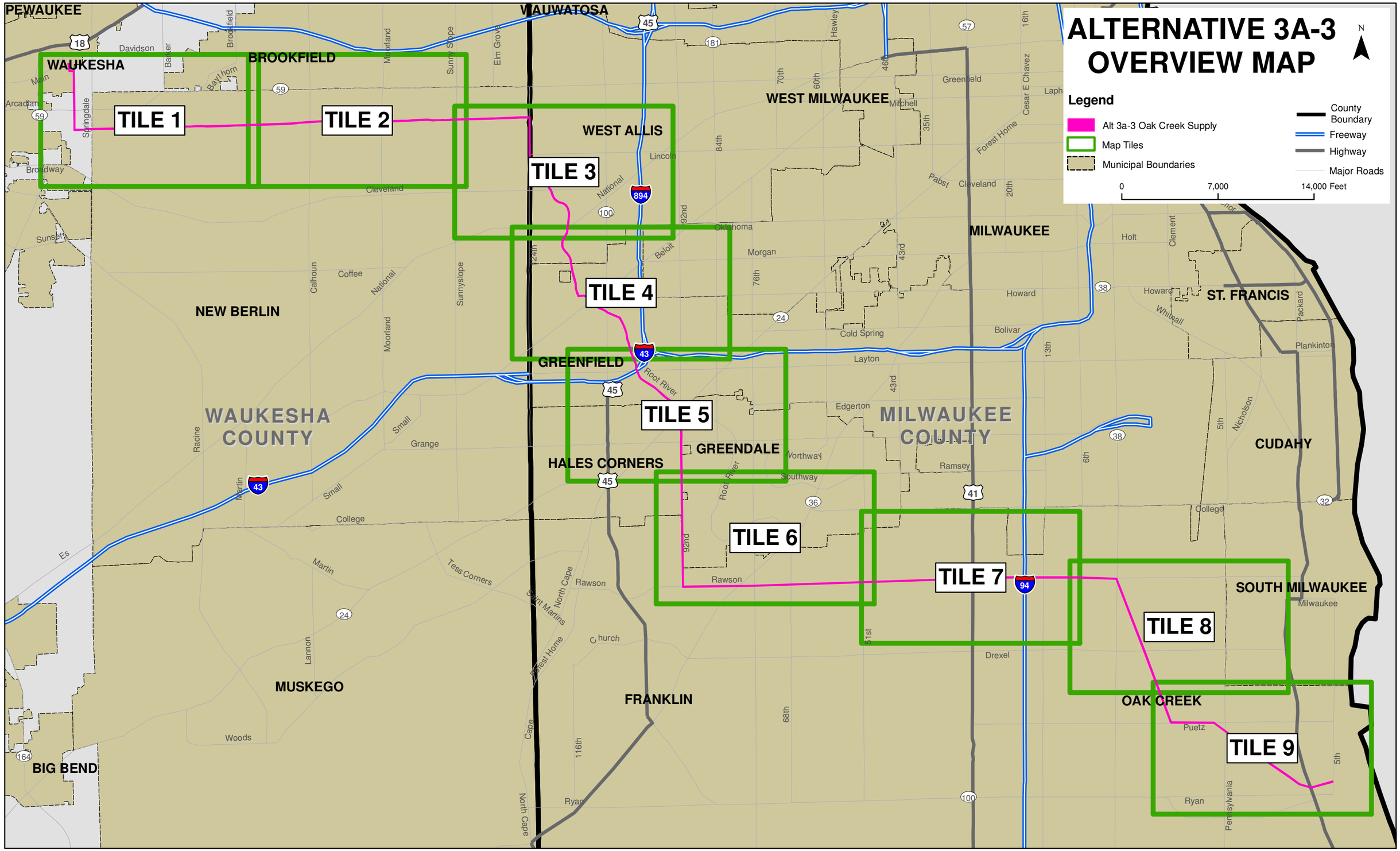
SR 36

SR 36

76th

I 43

I 43


ALTERNATIVE 3A-3
OVERVIEW MAP
N
Legend
Alt 3a-3 Oak Creek Supply
Map Tiles
Municipal Boundaries
County Boundary
Freeway
Highway
Major Roads
0
7,000
14,000 Feet
TILE 1
TILE 2
TILE 3
TILE 4
TILE 5
TILE 6
TILE 7
TILE 8
TILE 9
PEWAUKEE
WAUWATOSA
WAUKESHA
BROOKFIELD
WEST ALLIS
WEST MILWAUKEE
MILWAUKEE
NEW BERLIN
GREENFIELD
GREENDALE
HALES CORNERS
WAUKESHA COUNTY
MILWAUKEE COUNTY
ST. FRANCIS
CUDAHY
SOUTH MILWAUKEE
OAK CREEK
FRANKLIN
MUSKEGO
BIG BEND

TILE 1

Legend

Alt 3a-3 Oak Creek Supply

N

0 1,000 2,000 Feet

Davidson

Main

Barker

SR 59

Springdale

CR D

TILE 2

Legend

Alt 3a-3 Oak Creek Supply

N

0 1,000 2,000 Feet

SR 59

Calhoun

Moorland

Sunny Slope

Moorland

TILE 3

Legend

Alt 3a-3 Oak Creek Supply

N

0 1,000 2,000 Feet

Lincoln
SR 100
Cleveland
124th
National
Oklahoma
Oklahoma
114th
National
SR 100
I 894
I 894
Oklahoma
Oklahoma

TILE 4

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

National
Oklahoma
Oklahoma
124th
I 894
I 894
Morgan
SR 100
84th
Howard
Beloit
SR 100
92nd
I 43
I 43

TILE 5

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

I 894
I 43
I 43
SR 100
SR 100
Root River
92nd
SR 24
SR 24
84th
Edgerton
Root River
76th
US 45
US 45
92nd
Grange
76th
Westway

TILE 6

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

92nd

Root River

76th

76th

Westway

Southway

SR 36

College

SR 36

68th

Rawson

TILE 7

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

51st

US 41

I 94

Rawson

13th

TILE 8

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

Rawson

Nicholson

Pennsylvania

SR 38

Drexel

SR 32

TILE 9

Legend

Alt 3a-3 Oak Creek Supply

0 1,000 2,000 Feet

N

Puetz

SR 32

5th

Ryan

SR 100

Pennsylvania

SR 100

ALTERNATIVE 3A-4 OVERVIEW MAP

N

Legend

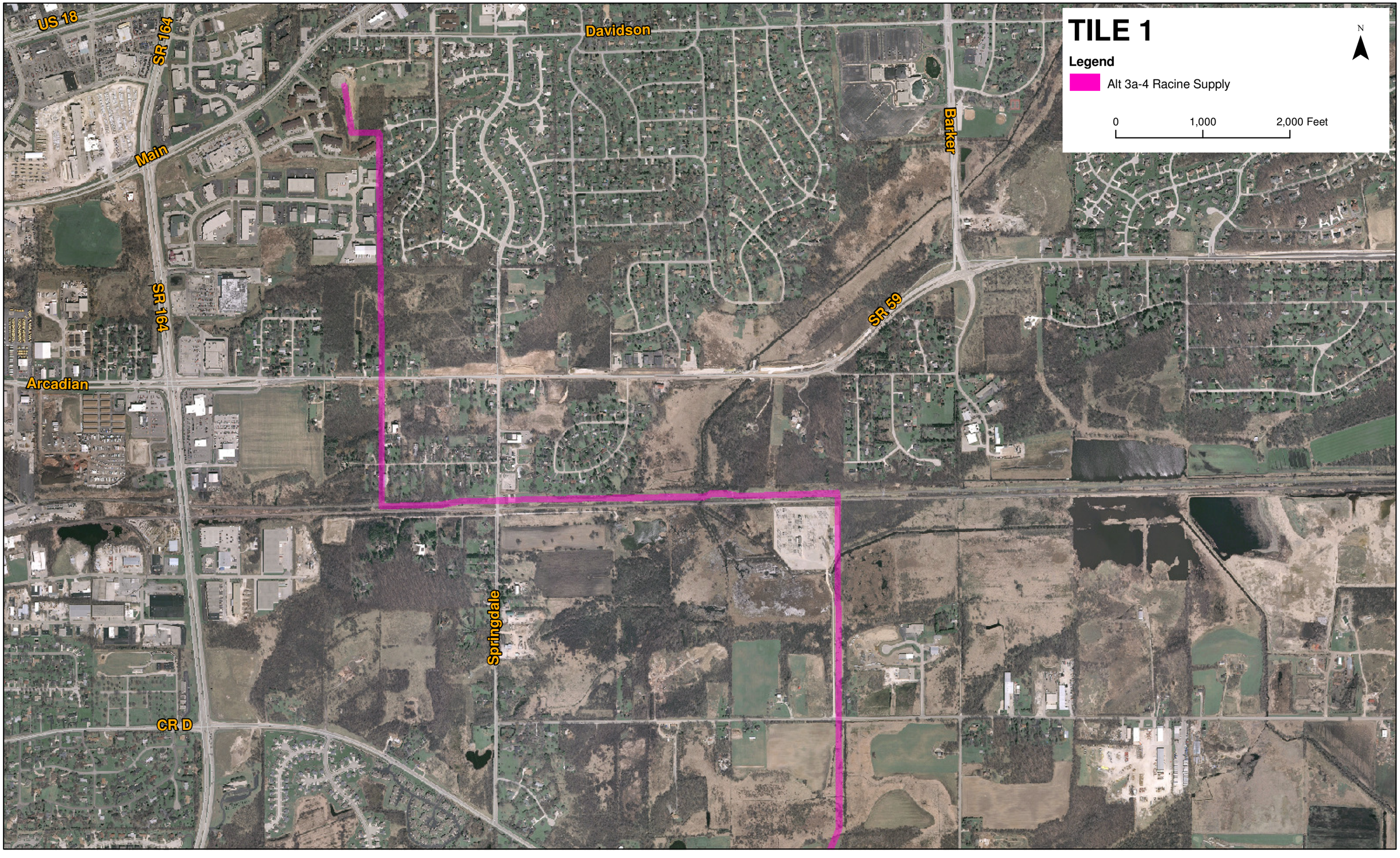
- Alt 3a-4 Racine Supply
- Map Tiles
- Municipal Boundaries
- County Boundary
- Freeway
- Highway
- Major Roads

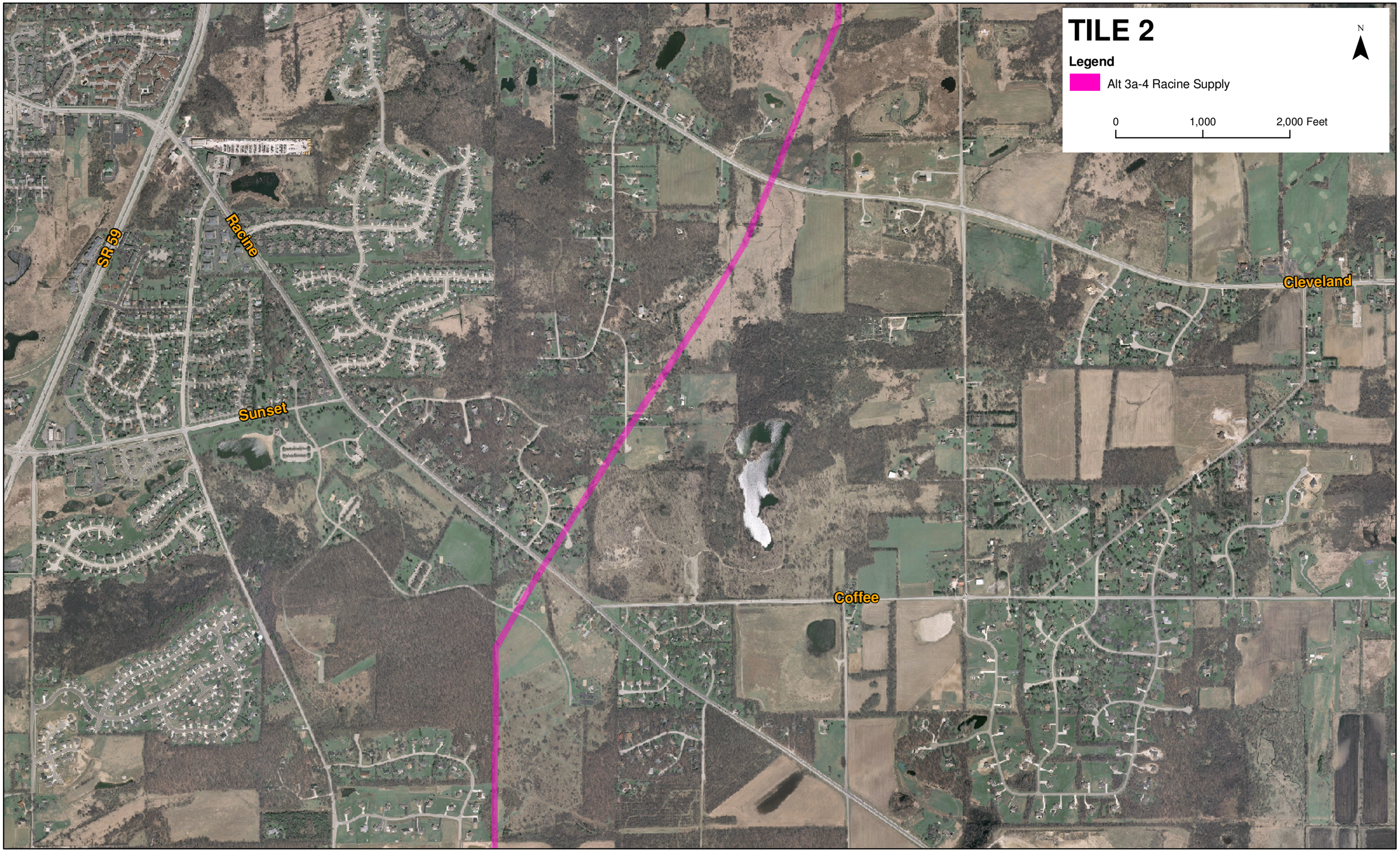
0 12,000 24,000 Feet

TILE 1
TILE 2
TILE 3
TILE 4
TILE 5
TILE 6
TILE 7
TILE 8
TILE 9
TILE 10
TILE 11
TILE 12
TILE 13
TILE 14
TILE 15

PEWAUKEE
WAUKESHA
WALES
BROOKFIELD
WEST ALLIS
MILWAUKEE
GREENFIELD
NEW BERLIN
GREENDALE
HALES CORNERS
CUDAHY
ST. FRANCIS
SOUTH MILWAUKEE
OAK CREEK
FRANKLIN
MUSKEGO
BIG BEND
MUKWONAGO
WATERFORD
ROCHESTER
STURTEVANT
WIND POINT
NORTH BAY
RACINE

WAUKESHA COUNTY
MILWAUKEE COUNTY
RACINE COUNTY
WALWORTH COUNTY


US 18
SR 164
Davidson
Main
Barker
SR 164
SR 59
Arcadian
Springdale
CR D
TILE 1
Legend
Alt 3a-4 Racine Supply
0
1,000
2,000 Feet
N


TILE 2
Legend
Alt 3a-4 Racine Supply
N
0
1,000
2,000 Feet
SR 59
Racine
Sunset
Cleveland
Coffee

TILE 3

N

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

Racine

National

TILE 4

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

N

National

I 43

I 43

College

CR Es

TILE 5

N

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

CR E s

I 43

I 43

SR 164

Racine

TILE 6

Legend

Alt 3a-4 Racine Supply

N

0 1,000 2,000 Feet

SR 164

CR L

Janesville

Woods

TILE 7

Legend

Alt 3a-4 Racine Supply

N

0 1,000 2,000 Feet

Parker

Christopher

Deback

Racine

Kelsey

Shore

Valerie

Driveway

Keiser

Muskego Dam

SR 36

TILE 8

Legend

Alt 3a-4 Racine Supply

N

0 1,000 2,000 Feet

CR G

Union Church

SR 36

CR S

Loomis

Sadler

Loomis

Wind Lake

Willow

Rasmussen

Windsong

Kurtz

7 Mile

CR G

TILE 9

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

N

Driveway

Adeline

7 Mile

CR G

CR K

Walczak

Allis

Norcine

US 45

122nd

CR G

100th

TILE 10

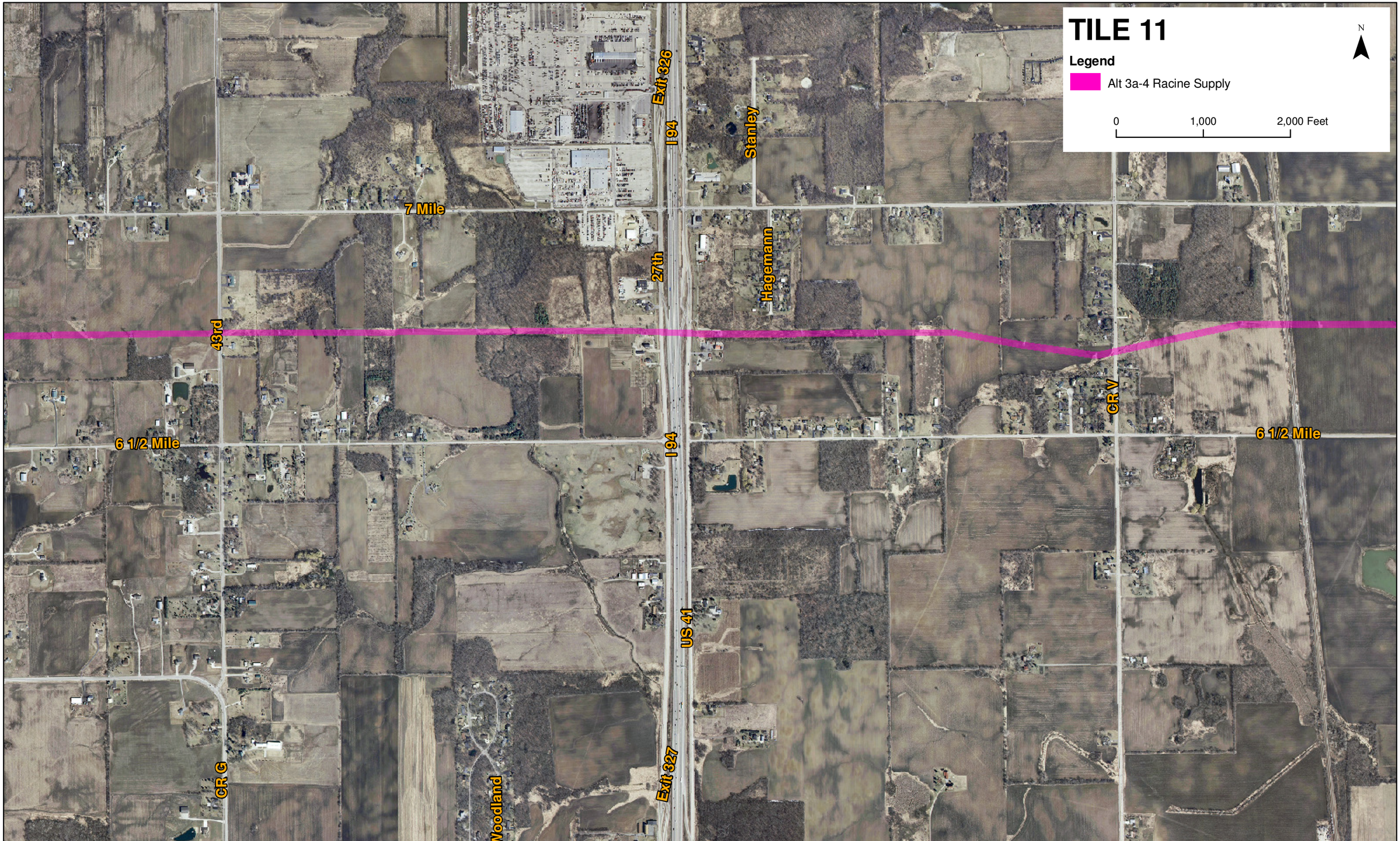
Legend

Alt 3a-4 Racine Supply

N

0 1,000 2,000 Feet

92nd
76th
7 Mile
60th
Sherwood
51st
6 1/2 Mile
CR U
CR G
76th
Waukesha


TILE 11
Legend
Alt 3a-4 Racine Supply
0
1,000
2,000 Feet
N
Exit 326
I 94
Stanley
7 Mile
27th
Hagemann
43rd
CR V
6 1/2 Mile
6 1/2 Mile
I 94
US 41
CR G
Woodland
Exit 327

TILE 12

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

N

Forest Hills

Brookside

6 1/2 Mile

Nicholson

River

SR 38

CR G

CR G

Linwood

Park

River

TILE 13

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

N

River

5 Mile

Nicholson

River Hills

Agatha

Alexander

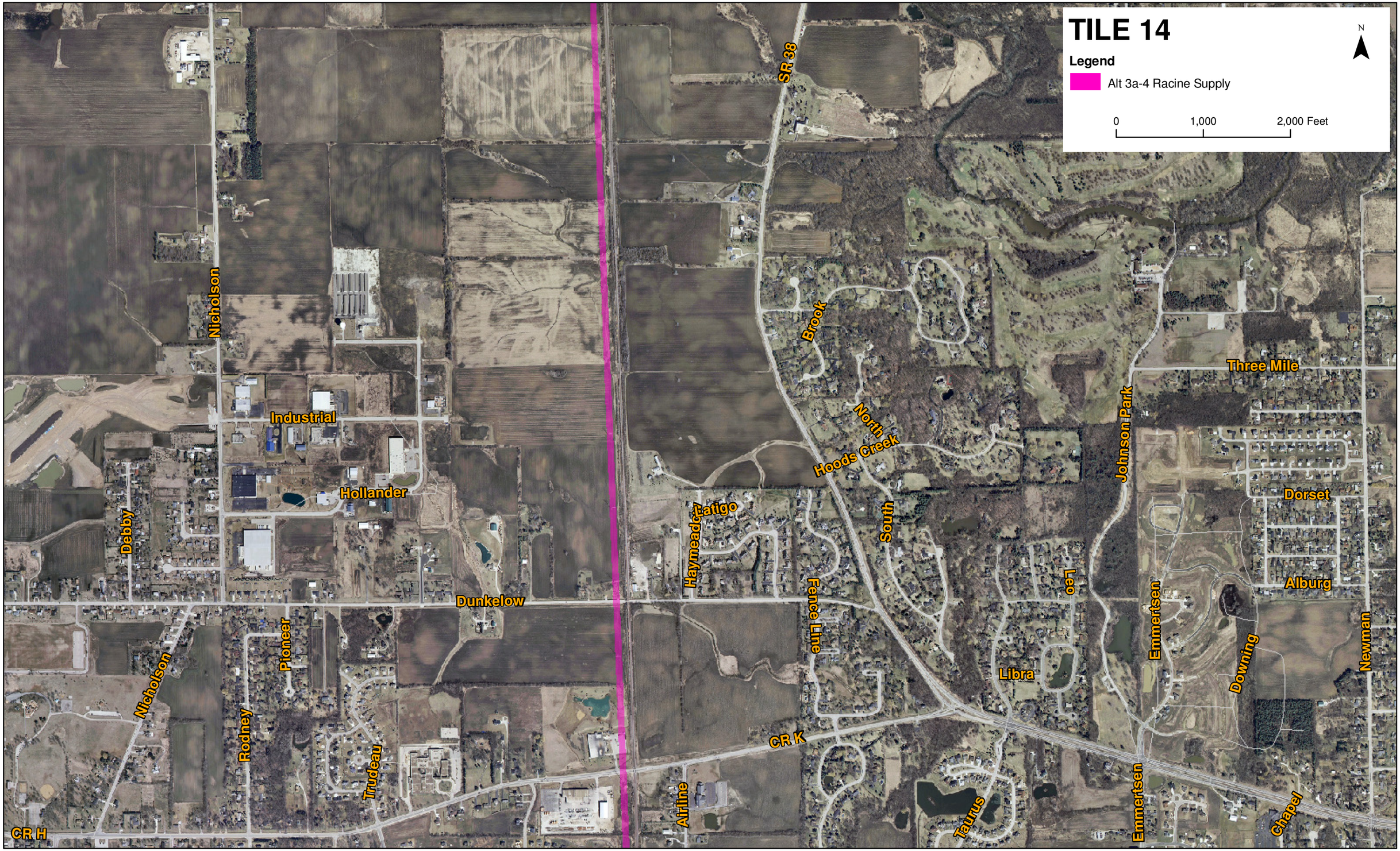
Old Farm

Short

4 Mile

SR 38

Bluffside


TILE 14
Legend
Alt 3a-4 Racine Supply
0
1,000
2,000 Feet
N
SR 38
Nicholson
Industrial
Hollander
Debby
Dunkelow
Pioneer
Nicholson
Rodney
Trudeau
CR H
Brook
North
Hoods Creek
Latigo
Haymeadow
South
Fence Line
Airline
CR K
Taurus
Libra
Leo
Johnson Park
Emmertsen
Emmertsen
Three Mile
Dorset
Alburg
Downing
Newman
Chapel

TILE 15

Legend

Alt 3a-4 Racine Supply

0 1,000 2,000 Feet

N

Taurus
Lincrest
Chapel
SR 38
Manor
Green Haze
Wexford
Berkshire
Newman
Sandy
Green Bay
Airline
Indian Hills
Carriage Hills
Percival
Gittings
Fieldview
Independence
Emmetsen
Gina
Spring Hill
Windsor
CR C
Daniel
Old Spring
Sunnyslope
Lindsay
Spring
Ohio
Timmer
Glenwood
Shirley
Summerset
Emerald Heather
Suzanne
Stuart
Pheasant Creek
SR 31
Cherry Hill
Illinois
Hilltop

ALTERNATIVE 3B-1 OVERVIEW MAP

N

Legend

- Alt 3b-1 Underwood Creek
- Map Tiles
- Municipal Boundaries
- County Boundary
- Freeway
- Highway
- Major Roads

0 4,500 9,000 Feet

TILE 1

TILE 2

TILE 3

TILE 4

TILE 5

PEWAUKEE

BROOKFIELD

ELM GROVE

WAUWATOSA

WAUKESHA

NEW BERLIN

WEST ALLIS

MILWAUKEE

GREENFIELD

WAUKESHA COUNTY

MILWAUKEE COUNTY

Capitol

Wisconsin

Main

Prospect

Bluemound

Watertown

Springdale

Barker

North

Burleigh

Lily

Gebhardt

Highland

Pilgrim

Moorland

Sunnyslope

Elm Grove

Watertown Plank

Harwood

State

70th

Milwaukee

Wisconsin

Brookfield

Northview

Grandview

Delafield

Pewaukee

Davidson

Bayhorn

Madison

Moreland

Main

Arcadian

Saint Paul

Broadway

Mac Arthur

Prairie

East

Genesee

Cth X

Sunset

Oakdale

Center

Racine

Coffee

Calhoun

Cleveland

Lincoln

National

84th

92nd

Beloit

Oklahoma

Morgan

76th

Howard

124th

Sunnyslope

Moorland

164

190

59

18

94

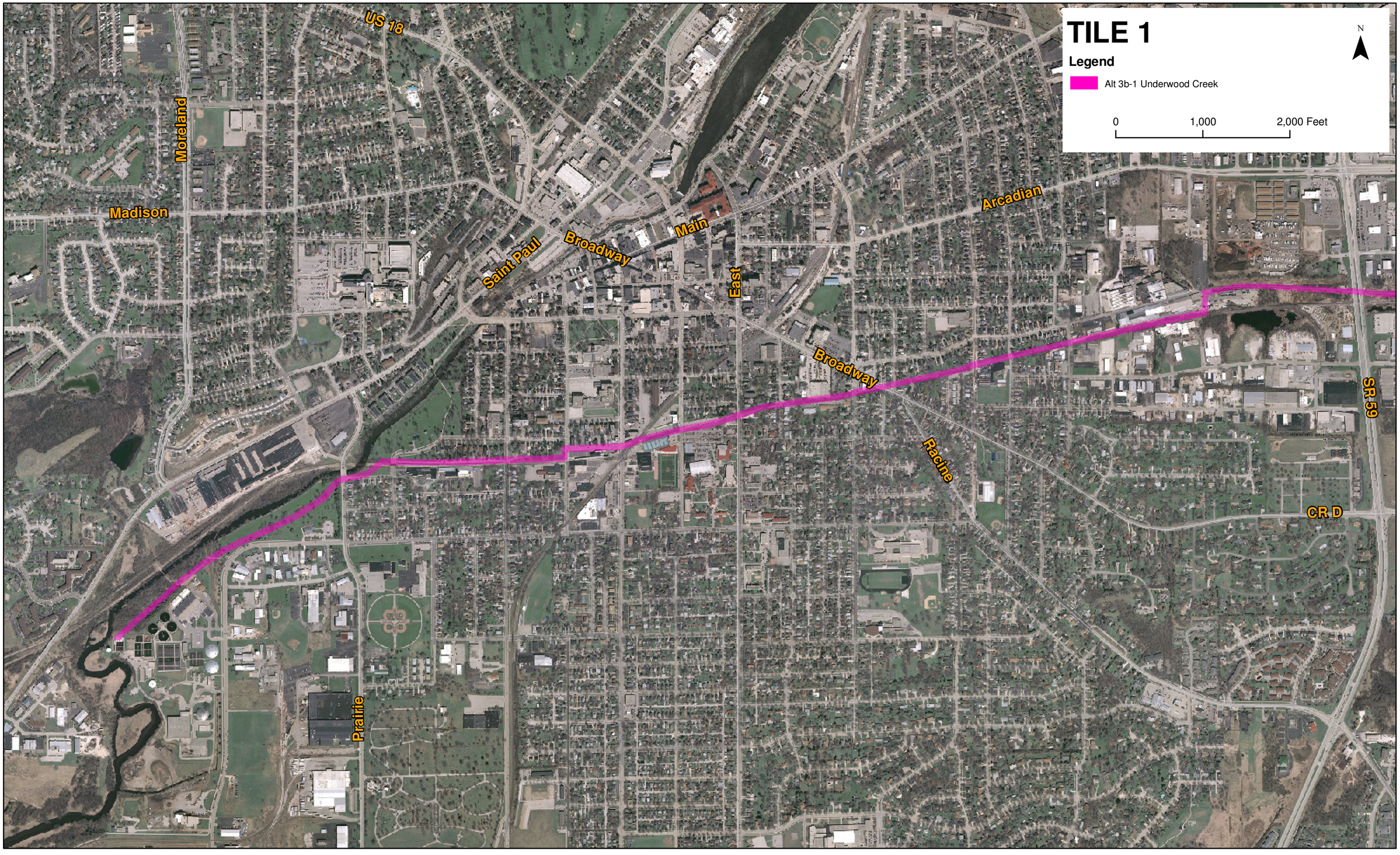
100

894

43

24

181


TILE 1
Legend
Alt 3b-1 Underwood Creek
N
0
1,000
2,000 Feet
US 18
Moreland
Madison
Saint Paul
Broadway
Main
East
Arcadian
Broadway
Racine
SR 59
CR D
Prairie

TILE 2

Legend

Alt 3b-1 Underwood Creek

0 1,000 2,000 Feet

N

Main

SR 164

SR 59

Barker

Springdale

CR D

Cleveland

Racine

TILE 3

Legend

Alt 3b-1 Underwood Creek

0 1,000 2,000 Feet

N

SR 59

Calhoun

Moorland

Moorland

Sunny Slope

TILE 4

Legend

Alt 3b-1 Underwood Creek

0 1,000 2,000 Feet

N

Elm Grove
SR 59
Sunny Slope
124th
SR 100
SR 100
Lincoln
National
I 894
Cleveland

TILE 5

Legend

Alt 3b-1 Underwood Creek

0 1,000 2,000 Feet

N

Watertown Plank

US 18

US 18

Wisconsin

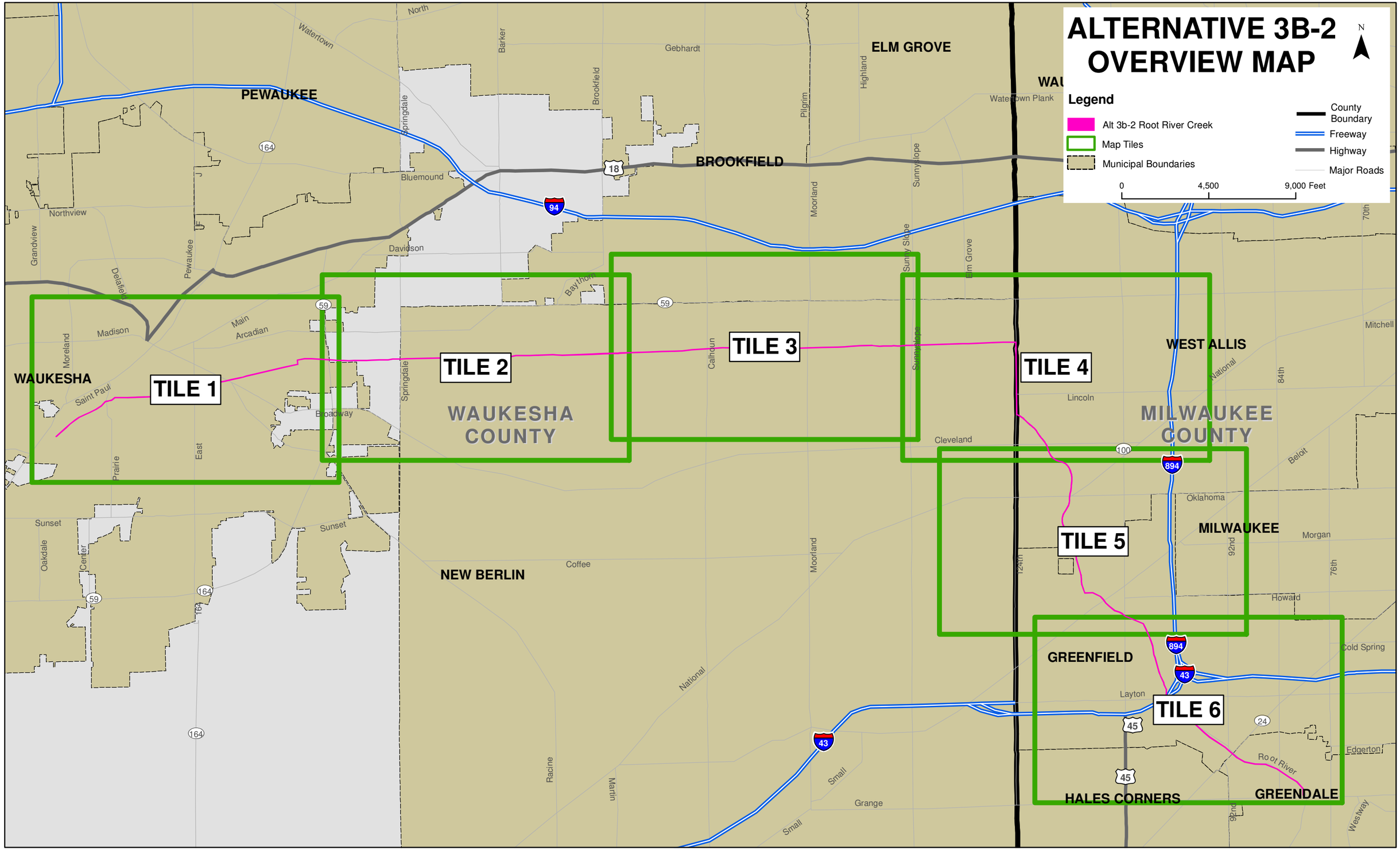
Elm Grove

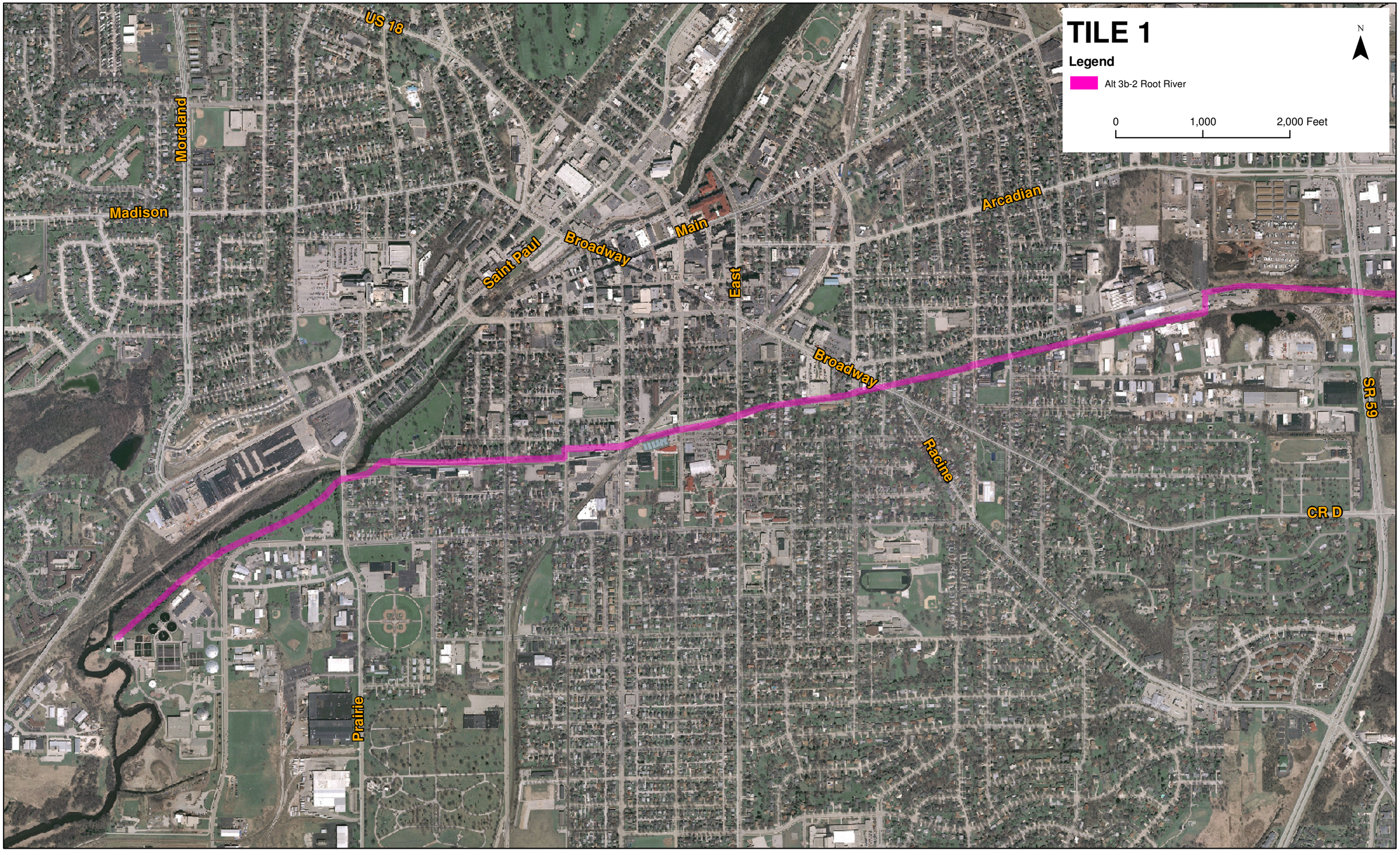
I 94

I 94

SR 100

Sunny Slope


ALTERNATIVE 3B-2
OVERVIEW MAP
N
Legend
Alt 3b-2 Root River Creek
Map Tiles
Municipal Boundaries
County Boundary
Freeway
Highway
Major Roads
0
4,500
9,000 Feet
TILE 1
TILE 2
TILE 3
TILE 4
TILE 5
TILE 6
WAUKESHA COUNTY
MILWAUKEE COUNTY
PEWAUKEE
BROOKFIELD
ELM GROVE
WAUKESHA
WEST ALLIS
MILWAUKEE
NEW BERLIN
GREENFIELD
HALES CORNERS
GREENDALE
Watertown Plank
Gebhardt
Bluemound
Davidson
Northview
Madison
Main
Arcadian
Saint Paul
Broadway
Lincoln
Cleveland
Oklahoma
Morgan
Howard
Cold Spring
Layton
Edgerton
Root River
Coffee
Sunset
Grange
Small
Racine
Martin
Moorland
Springdale
Brookfield
Barker
Pilgrim
Highland
Sunnyslope
Elm Grove
Calhoun
Bay Thorn
Pewaukee
Delafield
Grandview
Moreland
Prairie
East
Oakdale
Center
National
Beloit
Mitchell
Westway
84th
92nd
76th
70th
124th
North
Watertown
164
18
94
59
100
894
43
45
24


TILE 1
Legend
Alt 3b-2 Root River
N
0
1,000
2,000 Feet
US 18
Moreland
Madison
Saint Paul
Broadway
Main
East
Arcadian
Broadway
Racine
SR 59
CR D
Prairie

TILE 2

Legend

Alt 3b-2 Root River

0 1,000 2,000 Feet

N

Main

SR 164

SR 59

Barker

Springdale

CR D

Cleveland

Racine

TILE 3

Legend

Alt 3b-2 Root River

0 1,000 2,000 Feet

N

SR 59

Calhoun

Moorland

Moorland

Sunny Slope

TILE 4

Legend

Alt 3b-2 Root River

0 1,000 2,000 Feet

N

Elm Grove
SR 59
Sunny Slope
124th
SR 100
Lincoln
National
I 894
Cleveland

TILE 5

Legend

Alt 3b-2 Root River

0 1,000 2,000 Feet

N

National

124th

National

National

Oklahoma

114th

Oklahoma

Oklahoma

SR 100

I 894

I 894

Morgan

Howard

SR 100

Beloit

TILE 6

Legend

Alt 3b-2 Root River

0 1,000 2,000 Feet

N

Beloit
I 894
SR 100
I 894
Layton
SR 24
76th
I 43
I 43
SR 100
Root River
92nd
US 45
US 45
SR 24
Root River
92nd
76th
Grange

ALTERNATIVE 3B-3 OVERVIEW MAP

N

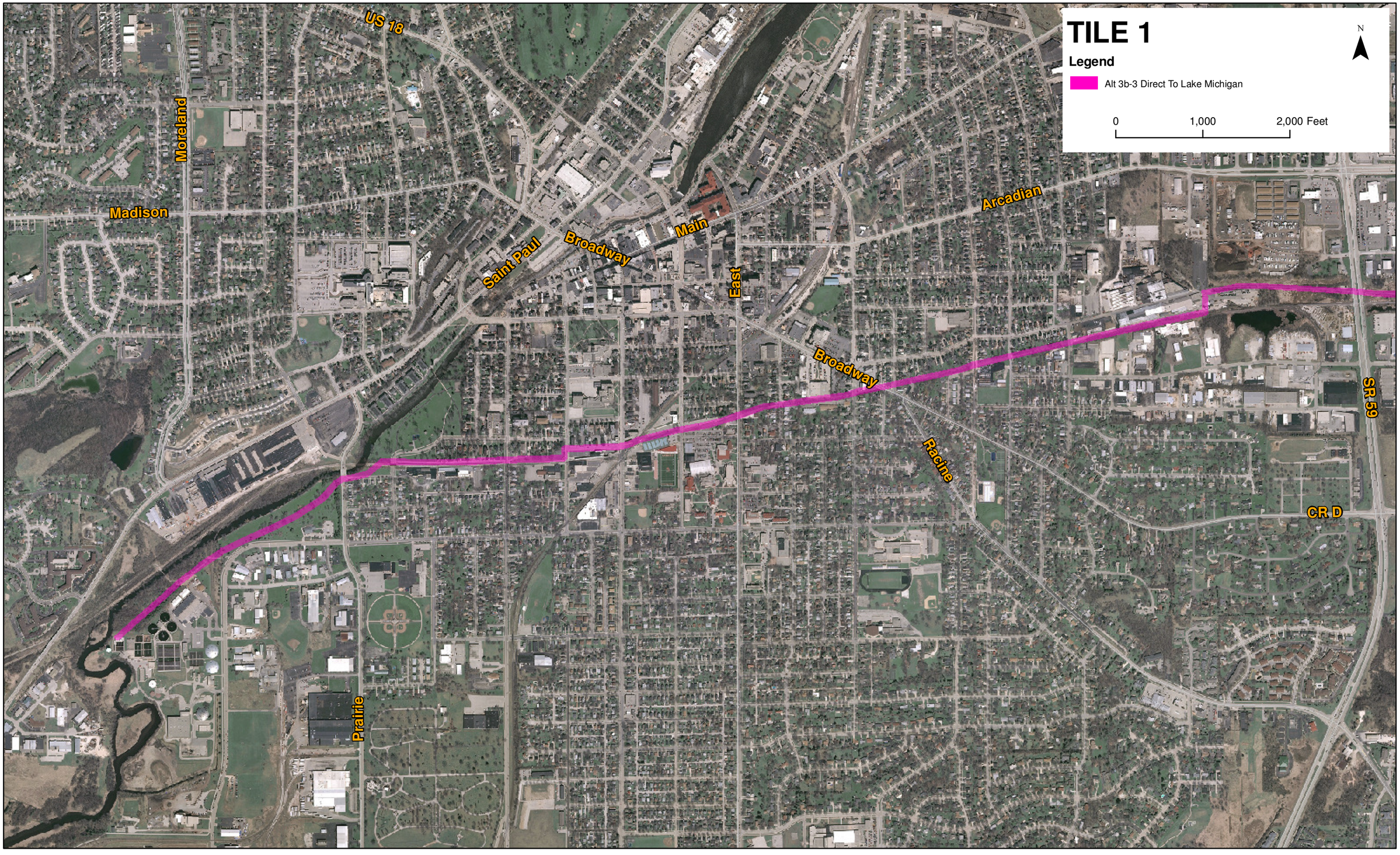
Legend

- Alt 3b-3 Direct To Lake Michigan
- Map Tiles
- Municipal Boundaries
- County Boundary
- Freeway
- Highway
- Major Roads

0 8,000 16,000 Feet

TILE 1
TILE 2
TILE 3
TILE 4
TILE 5
TILE 6
TILE 7
TILE 8

PEWAUKEE
BROOKFIELD
ELM GROVE
WAUWATOSA
WEST ALLIS
WEST MILWAUKEE
MILWAUKEE
WAUKESHA
WAUKESHA COUNTY
MILWAUKEE COUNTY
NEW BERLIN
GREENFIELD
HALES CORNERS
GREENDALE
FRANKLIN
MUSKEGO
BIG BEND
OAK CREEK
ST. FRANCIS
CUDAHY
SOUTH MILWAUKEE


TILE 1
Legend
Alt 3b-3 Direct To Lake Michigan
0
1,000
2,000 Feet
N
US 18
Moreland
Madison
Saint Paul
Broadway
Main
East
Arcadian
Broadway
Racine
SR 59
CR D
Prairie

TILE 2

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

Main

SR 164

SR 59

Barker

Springdale

CR D

Cleveland

Racine

TILE 3

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

SR 59

Calhoun

Moorland

Sunny Slope

Moorland

TILE 4

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

Elm Grove
SR 59
Sunny Slope
124th
SR 100
SR 100
Lincoln
National
I 894
Cleveland

TILE 5

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

SR 181
84th
70th
National
Mitchell
92nd
60th
National
Lincoln
Beloit
76th

TILE 6

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

Miller
US 41
Becher
Forest Home
Lincoln
35th
SR 24
Pabst
Cleveland
6th
SR 24
43rd
US 41
20th
Oklahoma

TILE 7

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

SR 32
I 794
Superior
Shore
I 43
6th
I 794
Oklahoma
SR 62
SR 38
Holt
Clement
SR 38
Howard
Howard
I 43
Whitnall

TILE 8

Legend

Alt 3b-3 Direct To Lake Michigan

0 1,000 2,000 Feet

N

Howard

Howard

Packard

SR 62

Lake Michigan

Plankinton

Layton

Whitnall

SR 32

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Chapter 2
Water Use and Quality

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2-6 Deep and Shallow Aquifers One Foot Drawdown Area and Springss

CHAPTER 2

Water Use and Quality

2.1 Introduction

This chapter contains information necessary to identify and quantify the construction and operational impacts of the supply and return flow alternatives on water use and quality.

2.2 Groundwater Resources

2.2.1 Existing Resources

The impact of groundwater withdrawals on surface water is a concern in Wisconsin and human-induced and natural groundwater shortages occur. Regional aquifers and groundwater resources were identified for the areas underlying the supply and return flow alternatives. Data for the aquifers present are provided by county where available from published reports. Groundwater quality data are provided on a regional basis and should be considered summary data.

Potential impacts to the aquifers present near the supply and return flow alternatives being considered can be divided in to two categories: temporary construction-related impacts and long-term operational impacts. Construction impacts to shallow aquifers as a result of the construction and placement of a 36-inch water main from the new water treatment plants to the City and pipelines from 8 to 20 inches in diameter in the well field to the water treatment plant at shallow depths of generally less than 10 feet are not expected to be significant. Temporary impacts may include short-duration trench-dewatering efforts. It is anticipated that the shallow aquifers would return to preconstruction conditions once construction has been completed.

Long-term impacts related to the operation of the supply or return flow alternatives may involve long-term water withdrawal from deep and shallow aquifers and from alluvial soils adjacent to the Fox River or replenishment of the deep aquifer system if a Lake Michigan water supply source is approved. Similarly, return flow alternatives will result in the discharge of treated water to Underwood Creek or Root River, which ultimately drains to Lake Michigan, or discharge directly to Lake Michigan itself.

The U.S. Environmental Protection Agency (EPA) designates sole-source aquifers as part of their Wellhead Protection Program. There are no designated sole-source aquifers in the State of Wisconsin (EPA, 2010a).

2.2.1.1 Aquifers and Existing Use

The major aquifers in Waukesha and Milwaukee counties are the Quaternary and Late Tertiary unconsolidated sand and gravel aquifer, Silurian-Devonian dolomite aquifer, and Cambrian-Ordovician sandstone aquifer. Historical use of the aquifers is discussed in Application Section 3, “Waukesha Water Supply Sources.”

Shallow Aquifer. The unconsolidated sand-and-gravel aquifer is not continuous but consists of lenses and layers of sand and gravel interspersed with other fine-grained or other low-permeability deposits. Therefore, well yields vary and are dependent on the permeability and thickness of the sand and gravel at a particular location. Recharge occurs through infiltration through surface soils and directly into the aquifer. Additional information in Section 3 of the Application, "Shallow Aquifer," describes how the aquifer known locally at the Troy Bedrock Valley Aquifer is used for water supply. Additional information on water quality in the shallow aquifer is found in Application Section 3, "Shallow Troy Bedrock Valley Aquifer."

Fox River Alluvium. The Fox River Alluvium, geology under and around the Fox River, consists of sands and gravels as well as clay layers. The geology varies spatially based upon past geologic activity and river geomorphic processes. The Fox River Alluvium may in some locations be connected with the shallow aquifer system. Wells designed to access river alluvium water typically draw water from the river and from adjacent shallow aquifers. Current water supply wells have not been sited to specifically tap the Fox River Alluvium as a water supply source to avoid treatment to surface water regulations. Potential water quality considerations of groundwater under the influence of surface water are discussed in Application Section 4, "Water Supply Alternative 2: Shallow Aquifer and Fox River Alluvium."

Deep Aquifer. The sandstone aquifer consists of alternating sequences of Cambrian- and Ordovician-age sandstone and dolomite, along with some shale. The sandstone aquifer underlies the dolomite aquifer and the Maquoketa shale. Due to the thickness of the sandstone aquifer, large water quantities can be produced from wells within the aquifer. Near Waukesha, recharge of this aquifer occurs further west where the Maquoketa shale does not exist. Exhibits 3-2 and 3-3 of the Application illustrate the constraints limiting recharge of the deep aquifer.

The City of Waukesha's groundwater supply has radium levels up to three times the United States Environmental Protection Agency's (USEPA's) drinking water maximum contaminant level (MCL) of 5 picocuries per liter (piC/L). The naturally occurring radioactive isotopes radium-226 and radium-228 are present in the aquifer because of parent elements in the sandstone. The radioactive isotopes are known to be carcinogenic. The concentration of radium in the City's groundwater supply is as high as 15 piC/L, among the highest in the country for a potable water supply. Additional information on deep aquifer water quality is found in Application Section 3, "Deep Aquifer Groundwater Quality."

The Precambrian aquifer is also present throughout Wisconsin, including Waukesha County. The Precambrian crystalline bedrock aquifer consists of all rocks of Precambrian age that underlie the state of Wisconsin, primarily granitic and metamorphic rocks. The crystalline bedrock aquifer directly underlies the sandstone aquifer. Groundwater comes from fractures that exist in the crystalline rocks and yield small quantities of water (USGS, 2000, 2010; WDNR, 2010a).

Additional information in Application Section 3, "Deep Aquifer," describes water quality and quantity problems the county is facing, such as historical drawdowns of over 500 to 600 feet, current declining levels of 5 to 9 feet per year, and decreasing water quality.

Springs. Springs are known to exist in Waukesha County. The Wisconsin Geological and Natural History Survey maintains an inventory of springs. This inventory was consulted and multiple springs exist near the groundwater alternative area (WGNHS, 2010). Wisconsin regulates groundwater pumping that may affect large springs under Act 310. Act 310 requires an environmental review of wells that may have a significant impact on springs that have a flow of at least 1 cubic feet per second for at least 80 percent of the time.

2.2.1.2 Existing Contamination Sites

Areas in Wisconsin where groundwater is most susceptible to contamination are those where most of the groundwater is stored in shallow aquifers (Schmidt, 1987). The WDNR Bureau of Remediation and Redevelopment (BRR) oversees the Remediation and Redevelopment (RR) Program and has a Web-based mapping system, RR Sites Map,[1] which contains information about contaminated properties and other activities related to the investigation and cleanup of contaminated soil or groundwater in Wisconsin. The WDNR BRR RR Sites Map Geographic Information System (GIS) registry layers contain groundwater contamination sites and groundwater and soil contamination sites. Based on information obtained from the WDNR GIS Registry, there appears to be two closed (cleaned up) groundwater-contamination sites and three closed (cleaned up) groundwater- and soil-contamination sites along the routes for the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium alternatives; one open groundwater-contamination site and four closed groundwater- and soil-contamination sites along the Lake Michigan—Milwaukee Supply; only three closed groundwater and soil contamination sites along the Oak Creek supply alternative; one closed groundwater and soil contamination site along the Racine supply alternative; one closed groundwater-contamination site and four closed groundwater- and soil-contamination sites along the Underwood Creek to Lake Michigan alternative; four closed groundwater and soil contamination sites; and five closed groundwater contamination sites and 14 closed groundwater and soil contamination sites along the return flow direct to Lake Michigan (WDNR, 2010b).

According to the WDNR's online BRR Tracking System, which is part of the WDNR Contaminated Lands Environmental Action Network (CLEAN), Milwaukee County has approximately 5,070 environmental repair (ERP) and leaky underground storage tank (LUST) sites, Racine County has approximately 792 ERP and LUST sites, and Waukesha County has approximately 1,616 ERP and LUST sites (WDNR, 2010c). Owing to the significant number of ERP and LUST sites within the counties of the supply and return flow alternatives, there is a potential that contaminated groundwater could be encountered during construction and operation activities. For final design, the City will work with WDNR to appropriately manage crossing any contaminated-groundwater areas. If groundwater contamination is encountered during construction or operation activities, the City will work with the appropriate agencies to handle it appropriately.

2.2.2 Impacts and Mitigation

Environmental effects on groundwater for each of the water supply and return flow alternatives could occur either from the construction process or from operation and maintenance. The potential impacts from operation and maintenance vary depending upon

[1] http://www.dnr.state.wi.us/org/aw/rr/gis/.

the specific water supply alternative and are described individually below. The potential construction impacts are consistent for all alternatives and are described in this section.

Construction of a new water main or return flow pipe will all involve the installation of 8- to 36-inch water main pipe at shallow depths of generally less than 10 feet and will not require any long-term water withdrawal or discharges. Therefore, impacts to groundwater sources as a result of construction activities will be limited.

Potential groundwater impacts from heavy equipment fuel, lubrication oil, or hydraulic oil spills as a result of the construction of any of the alternatives will be minimized by implementing best management practices (BMPs) for storing such materials, refueling equipment, developing and implementing a spill prevention plan, and cleaning up of any lost materials that may present a danger to the aquifer. Preventative measures will be implemented to avoid such spills, including compliance with refueling zone practices. While BMPs will be used to prevent spills from occurring, if one were to occur, the material will be cleaned up to meet WDNR requirements. The volumes of petroleum-based fluids used during construction are likely to be minor. As a result, the construction of a preferred supply and return flow alternative is not anticipated to represent a significant impact to regional aquifers. Prior to construction, the City will work with the applicable resource and municipal agency stakeholders to identify any high-risk areas for petroleum fluid spills and coordinate the development of appropriate BMPs to protect important resources.

2.2.2.1 Water Supply Alternatives

Deep and Shallow Aquifers. The Deep and Shallow Aquifers supply alternative is entirely within Waukesha County. The aquifers used for water supply with this alternative include the Quaternary and Late Tertiary unconsolidated sand-and gravel-aquifer (shallow aquifer) and the Cambrian-Ordovician sandstone aquifer (deep aquifer). Water withdrawals between these two aquifers are described in detail in Section 4 of the Application.

As discussed in the Application, long-term water withdrawal from the deep and shallow aquifers and from alluvial soils adjacent to the Fox River in Waukesha County will result in a continued draw down of the aquifer levels and increased treatment of the water to ensure a safe drinking water supply. This drawdown of the deep aquifer will continue to cause water to migrate toward Waukesha County away from Lake Michigan, as the aquifers attempt to fill the cone of depression in the deep aquifer from nearby aquifer sources.

A groundwater model was developed to simulate the groundwater flow and capacity of shallow aquifer used in this alternative. Deep aquifer modeling was not conducted because that aquifer is currently used by the City of Waukesha and the performance is well known. The detailed results can be found in Appendix O, Groundwater Modeling, of the Application. The results indicate a maximum groundwater drawdown of about 50 feet. Groundwater impacts to surface waters and other natural resources are described in Chapter 2.3, Surface Water Resources, and Chapter 2.4, Wetlands.

Groundwater flows to the Fox River are eliminated and flow from the Fox River is reduced for a total change of 2.4 mgd in this reach of the river. Groundwater reductions to three cold water trout streams (Pebble Brook, Pebble Creek, and Mill Brook) also occur. For example, groundwater baseflow to Pebble Brook would be reduced by 61 percent, Pebble Creek would

be reduced by 9 percent, and Mill Book would be reduced by 29 percent. The largest reduction of groundwater flow to a trout stream is 2.1 mgd from Pebble Brook.

The spatial extent over which groundwater drawdown of 5 feet or greater and of 1 foot or greater is shown in the figures at the end of this section. Within this groundwater drawdown footprint, several springs are known to exist. Maps depicting the Wisconsin Geological and Natural History Service spring inventory were reviewed and compared to the groundwater drawdown to see which springs may be affected (WGNHS, 2010). Figures at the end of the Chapter show the spring locations. The 1-foot drawdown affects 7 springs that range in known flow rate from 5 to 50 gallons per minute (gpm) (0.11 cfs).

Additional details on the specific impacts from operation of this groundwater supply alternative is provided in Application Section 3, "Need for a New Water Supply"; Section 4, "Water Supply Alternatives"; and in the Groundwater Modeling Results in Appendix O of the Application.

Shallow Aquifer and Fox River Alluvium—Waukesha County. The Shallow Aquifer and Fox River Alluvium alternative is entirely within Waukesha County. The aquifer used for this water supply alternative is the Quaternary and Late Tertiary unconsolidated sand-and-gravel aquifer (shallow aquifer) and alluvium under and around the Fox River. Water withdrawal from this aquifer is described in detail in Section 4 of the Application. Under this alternative, the deep aquifer would no longer be used. No longer using the deep aquifer will result in a beneficial partial rebound of the deep aquifer groundwater level because no more pumping would be occurring from the City of Waukesha.

A groundwater model was developed to simulate the groundwater flow and capacity of shallow aquifer used in this alternative. The detailed results can be found in Appendix O, Groundwater Modeling, of the Application. Under this alternative, more water is pumped out of the shallow aquifer because the deep aquifer is no longer used as a source of water supply. The results indicate a maximum groundwater drawdown of about 105 feet. Groundwater impacts to surface waters and other natural resources are described in Chapter 2.3, Surface Water Resources, and Chapter 2.4, Wetlands.

Groundwater flows to the Fox River are eliminated and flow from the Fox River is reduced for a total change of 5.9 mgd in this reach of the river. Groundwater reductions to three cold water trout streams (Pebble Brook, Pebble Creek, and Mill Brook) also occur. For example, groundwater baseflow to Pebble Brook would be reduced by 58 percent, Pebble Creek would be reduced by 23 percent, and Mill Book would be reduced by 30 percent. The largest reduction of groundwater flow to a trout stream is 2.0 mgd from Pebble Brook. Groundwater flow reduction to Mill Brook is roughly the same, and flow reduction to Pebble Creek increases under this alternative as compared to the Deep and Shallow Aquifers alternative.

The spatial extent over which groundwater drawdown of 5 feet or greater and of 1 foot or greater is shown in the figures at the end of this Chapter. Within this groundwater drawdown footprint, several springs are known to exist. Maps depicting the Wisconsin Geological and Natural History Service spring inventory were reviewed and compared to the groundwater drawdown to see which springs may be affected (WGNHS, 2010). Figures at the end of the Chapter show the spring locations. The 1-foot drawdown affects 12 springs that range in known flow rate from 0 at the time of survey to 50 gallons per minute (gpm) (0.11 cfs).

Additional details on the specific impacts from operation of this groundwater supply alternative is provided in Application Section 3, "Need for a New Water Supply"; Section 4, "Water Supply Alternatives"; and in the Groundwater Modeling Results in Appendix O of the Application.

Lake Michigan–Milwaukee Supply. Withdrawal from Lake Michigan for the Lake Michigan–Milwaukee Supply alternative would mean withdrawal of surface waters from Lake Michigan and therefore would not involve groundwater withdrawals, except for the emergency purposes described in Application Section 4. As a result, no adverse impacts to groundwater aquifers would occur. Under any Lake Michigan supply alternative, the deep aquifer would no longer be used. No longer using the deep aquifer would have the benefit of a partial rebound of the deep aquifer groundwater level because there would be no more pumping by the City of Waukesha.

Due to the volume of water present, withdrawal from Lake Michigan with return flow will result in an insignificant change in lake water levels and therefore is not anticipated to result in adverse affects to regional aquifer supplies that are influenced by Lake Michigan.

Lake Michigan–Oak Creek Supply. The Lake Michigan–Oak Creek Supply alternative will have the same effects on groundwater resources as the Lake Michigan–Milwaukee Supply alternative.

Lake Michigan–Racine Supply. The Lake Michigan–Racine Supply alternative will have the same effects on groundwater resources as the Lake Michigan–Milwaukee Supply alternative.

2.2.2.2 Return Flow Alternatives

Underwood Creek to Lake Michigan. The Underwood Creek to Lake Michigan return flow alternative impacts to groundwater are expected to be insignificant. Because of the small change in a Lake Michigan tributary water depth from return flow, this alternative is not expected to result in adverse affects to regional aquifer supplies that are influence by a Lake Michigan tributary.

Root River to Lake Michigan. The Root River to Lake Michigan return flow alternative will have the same effects on regional groundwater resources as the Underwood Creek return flow alternative.

Direct to Lake Michigan. The Direct to Lake Michigan return flow alternative impacts to groundwater are expected to be insignificant because the alternative will result in an insignificant change in lake water levels and therefore is not anticipated to result in adverse affects to regional aquifer supplies that are influence by Lake Michigan.

2.3 Surface Water Resources

2.3.1 Existing Resources

Surface waters within the affected environment are summarized below. The types of information included within each of these affected environments vary because the effects the various water supply and return flow alternatives have on these surface waters also vary. Consequently, detailed information on water quality and aquatic habitat is provided

for surface waters potentially receiving the return flow while such information is not provided for surface waters where new discharges do not occur within any of the alternatives.

According to the Wisconsin Administrative Code (WAC), Chapter NR 102 Water Quality Standards for Wisconsin Surface Waters, Wisconsin categorizes surface waters into one of five fishery "use" subcategories (WDNR, 2010d). Stream use is determined by the fish species or other aquatic organisms capable of being supported by a natural stream system. The designation of an appropriate use class is based on the ability of a stream to supply habitat and water quality requirements for a class of organisms:

- Cold water communities (COLD)—capable of supporting cold water sport fish
- Warm water sport fish communities (WWSF)—capable of supporting warm water sport fish
- Warm water forage fish communities (WWFF)—capable of supporting an abundant diverse community of warm water forage fish
- Limited forage fish communities (LFF)—capable of supporting limited tolerant or very tolerant forage or rough fish, or tolerant macroinvertebrates
- Limited aquatic life (LAL)—capable of supporting very tolerant macroinvertebrates or no aquatic life

Wisconsin NR Code 104 classifies all LFF and LAL water bodies as "variance" waters. Streams without a known designation are, by default, classified as warm water sport fisheries and are considered WWSF or WWFF waters (WDNR, 2010e).

According to Wisconsin NR Code 102.10 and 102.11, no Outstanding Resource Waters or Exceptional Resource Waters (ERWs) are located along the proposed supply or return flow alternatives. Genesee Creek in Waukesha County west of Vernon Marsh is listed as an Exceptional Resource Water upstream of State Highway 59, but this area is outside of the influence of the project and 1-foot groundwater drawdown.

An Outstanding Resource Water is "a lake or stream having excellent water quality, high recreational and aesthetic value, high-quality fishing and is free from point source or nonpoint source pollution." An Exceptional Resource Waters is "a stream exhibiting the same high quality resource values as outstanding waters, but may be impacted by point source pollution or have the potential for future discharge from a small sewer community."

2.3.1.1 Fox River

The Fox River will be affected by all the water supply alternatives considered. The Fox River currently receives the flow from the Waukesha Wastewater Treatment Plant (WWTP) discharge. A change in discharge location will affect the Fox River. Two of the water supply alternatives include pumping from shallow wells near the Fox River which may change baseflows in the river.

The Fox River receives the WWTP discharge and drains 151 square miles at the southern end of the City of Waukesha. The upper Fox River, flowing through the City of Waukesha, is a perennial stream (WDNR, 2002a). At the USGS Fox River stream gage 05543830 in the

City of Waukesha, average annual stream flow is 110 cfs (71 mgd) over the period of record from 1963 to 2009.[2] The Fox River is designated by the WDNR as a WWSF, which includes the following uses: fish and aquatic life, recreation, public health and welfare, and fish consumption.

The Fox River near the WWTP outfall is on the 303(d) list for several impairments, including PCBs for fish consumption advisories, phosphorous for low dissolved oxygen concentration, and sediment for habitat impairment.[3]

Just downstream of the City of Waukesha are several perennial Fox River tributaries, including Genesee Creek, Mill Brook, Brandy Brook, Pebble Creek, Pebble Brook, Mill Creek, and Spring Creek, all of which are listed as supporting cold water communities. The Fox River is on the 303(d) list for fish consumption advisories due to PCBs. The potential sources of impairments in the watershed are non-point-source discharges, contaminated sediments, and discharges from municipal separate storm sewer systems (WDNR, 2010f).

2.3.1.2 Pebble Brook

Pebble Brook will only potentially be affected by the alternatives that pump shallow groundwater that may otherwise flow into Pebble Brook. Pebble Brook is not affected by the Lake Michigan water supply and return flow alternatives.

Pebble Brook is a narrow 9-mile-long perennial trout stream located in southeastern Waukesha County. It is a tributary to the Fox River south of the City of Waukesha. The WDNR has classified Pebble Brook as a Cold water fishery. Cold water fisheries are classified by NR102(04)(3) as surface waters capable of supporting a community of cold water fish and other aquatic life or serving as a spawning area for cold water fish species. Cold water streams receive much of their flow from groundwater entering the stream which enables their temperature to remain cold. Pebble Brook is not listed for use impairments (WDNR, 2002a).

2.3.1.3 Pebble Creek

Pebble Creek will only potentially be affected by the alternatives that pump shallow groundwater that may otherwise flow into Pebble Creek. Pebble Creek is not affected by the Lake Michigan water supply and return flow alternatives.

Pebble Creek is a narrow, 6-mile-long perennial trout stream in southeastern Waukesha County. It is a tributary to the Fox River south of the City of Waukesha. The WDNR has classified Pebble Creek as a Cold water fishery. Cold water fisheries are classified by NR102(04)(3) as surface waters capable of supporting a community of cold water fish and other aquatic life or serving as a spawning area for cold water fish species. Cold water streams receive much of their flow from groundwater entering the stream which enables their temperature to remain cold.

Use impairments to Pebble Creek include unspecified non-point-source contamination, sedimentation, and beaver dams. These impairments result in a loss of habitat within the waterway and water temperature fluctuations (WDNR, 2002a).

[2] http://waterdata.usgs.gov/wi/nwis/rt, gage number 05543830 accessed April, 2010.

[3] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html. Accessed January 19, 2010.

2.3.1.4 Mill Brook

Mill Brook will only potentially be affected by the alternatives that pump shallow groundwater that may otherwise flow into Mill Brook. Mill Brook is not affected by the Lake Michigan water supply and return flow alternatives.

Mill Brook is a narrow, 5-mile-long perennial trout stream in southeastern Waukesha County. It is a tributary to the Fox River south of the City of Waukesha. The WDNR has classified Mill Brook as a Cold water fishery. Cold water fisheries are classified by NR102(04)(3) as surface waters capable of supporting a community of cold water fish and other aquatic life or serving as a spawning area for cold water fish species. Cold water streams receive much of their flow from groundwater entering the stream which enables their temperature to remain cold.

Use impairments to Mill Brook include construction erosion, unspecified non-point-source contamination, sedimentation, and beaver dams. These impairments result in water temperature fluctuations (WDNR, 2002a).

2.3.1.5 Underwood Creek and Menomonee River

Underwood Creek and the Menomonee River will only be affected by the Lake Michigan water supply alternatives for return flow to Underwood Creek. The groundwater supply alternatives do not affect Underwood Creek or the Menomonee River.

Underwood Creek is a tributary stream to the Menomonee River, which in turn ultimately flows to Lake Michigan. Discharge of return flows to Underwood Creek is expected to occur in Waukesha County, near the crossing of Underwood Creek and Bluemound Road. At that location, Underwood Creek flows about 2.6 river miles to its confluence with the Menomonee River in Wauwatosa. All of Underwood Creek, except for 2,400-foot=long reach that was rehabilitated in 2009 to a natural channel, is concrete lined. Future concrete channel rehabilitation of additional sections of the stream has been proposed. The Menomonee River from the Underwood Creek confluence flows another 10 river miles to Lake Michigan in the City of Milwaukee.

Underwood Creek is designated for WDNR fish and aquatic life standards. Underwood Creek also has a variance in Milwaukee County for dissolved oxygen and fecal coliform.[4] At the USGS Underwood Creek stream gage 04087088 in the City of Wauwatosa downstream of the return flow location, the average annual stream flow is 15.1 cfs (9.8 mgd) over the period of record from 1974 to 2009.[5]

The Menomonee River downstream of Underwood Creek is classified for WDNR fish and aquatic life standards, but it has the same dissolved oxygen and fecal coliform variances from Honey Creek to the mouth of the river (about 5 miles downstream of the proposed return flow location).[6] At the USGS Menomonee River stream gage 04087120 in the City of Wauwatosa downstream of the return flow location, the average annual stream flow is 108 cfs (69 mgd) over the period of record from 1961 to 2009.[7]

[4] NR 104.06(2) Water Quality Standards for Wisconsin Surface Waters.

[5] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087088 accessed April, 2010.

[6] NR 104.06(2) Water Quality Standards for Wisconsin Surface Waters.

[7] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087120 accessed April, 2010.

A reach of Underwood Creek upstream of the discharge in Waukesha County is proposed to be included on the 2010 303(d) list for fecal coliform as a recreational restriction.[8] The last 2.67 miles of the Menomonee River is proposed to be included on the 2010 303(d) list for fecal coliform as recreational restrictions. The Menomonee River is on the 303(d) list in the same stretch of river for PCBs from contaminated sediment, *E. coli* bacteria for recreational restrictions, total phosphorus for low dissolved oxygen, and unspecified metals for chronic aquatic toxicity. These listings were made in 1998.

Water quality information is gathered by a number of organizations in the Underwood Creek and Menomonee River watersheds. The USGS and the Milwaukee Metropolitan Sewerage District (MMSD) have obtained water quality data and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) has done extensive water quality modeling of the watersheds.

Water quality standards for dissolved oxygen are 5.0 milligrams per liter (mg/L) and recreational use fecal coliform standards are 200 counts/100 mL monthly geometric mean and are not to exceed 400 counts/100 mL in more than 10 percent of all samples during any month.[9] Dissolved oxygen variances are also applicable to these waters in some areas. The dissolved oxygen variance is 2.0 mg/L and the fecal coliform variances are 1,000 counts/100 mL monthly geometric mean and is not to exceed 2,000 counts/100 mL in more than 10 percent of all samples during any month.[10]

There are no numeric phosphorus water quality standards in Wisconsin, but a planning guideline of 0.1 mg/L was used in SEWRPC's Regional Water Quality Management Plan Update. There are no numeric total suspended solids standards in Wisconsin, however a reference background concentration of 17.2 mg/L was used in SEWRPC's Regional Water Quality Management Plan Update.[11]

The USGS water quality sampling occurred at USGS gage 04087088 on Underwood Creek at Wauwatosa with data obtained from February 2004 through August 2005.[12] Dissolved oxygen, phosphorus, and fecal coliform concentration ranges are included in Table 2-1.

TABLE 2-1
Underwood Creek Water Quality Data (USGS 2004, 2005)
City of Waukesha Water Supply

Parameter	Dissolved Oxygen (mg/L)	Phosphorus of Unfiltered Water (mg/L as P)	Fecal Coliform (Counts/100 mL)
Number of samples	12	12	12
Minimum	8.3	0.020	120
Maximum	14.2	0.350	16,000
Mean	11.8	0.114	3,018

[8] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html accessed January 19, 2010.
[9] WDNR NR 102.04(4).
[10] WDNR NR 102.06.
[11] SEWRPC. 2008. *A Regional Water Supply Plan for Southeastern Wisconsin.* Planning Report No. 52.
[12] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087088 accessed February 2010.

The USGS water quality sampling occurred at USGS gage 04087120 on the Menomonee River at Wauwatosa with data obtained primarily from 1991to 1993 and again from 2004 to 2009.[13] Dissolved oxygen, phosphorus, and fecal coliform concentration ranges are included in Table 2-2.

TABLE 2-2
Menomonee River Water Quality Data (USGS 1991–1993, 2004–2009)
City of Waukesha Water Supply

Parameter	Dissolved Oxygen (mg/L)	Phosphorus of Unfiltered Water (mg/L as P)	Fecal Coliform (counts/100 mL)
Number of samples	429	380	47
Minimum	7.5	0.020	10
Maximum	16.0	1.400	800,000
Mean	11.7	0.228	21,793

Note: Dissolved oxygen samples are from gage operation; phosphorus and fecal coliform are from field samples.

The MMSD (2008) water quality sampling produced a report Underwood Creek Water Quality Baseline Report. Generally, eight samples were taken each year from 2003 through 2005. The sampling was conducted for a variety of parameters and throughout the Underwood Creek watershed. The average of annual sample results at locations downstream of the expected return flow location is summarized in Table 2-3.

TABLE 2-3
MMSD Underwood Creek 2003–2005 Average Water Quality Range
City of Waukesha Water Supply

Dissolved Oxygen (mg/L)	Phosphorus (mg/L)	Fecal Coliform (counts/100 mL)
11.8 to 17.8	0.102 to 0.203	1,915 to 23,677

Water quality in Underwood Creek and the Menomonee River was extensively studied in SEWRPC's (2007) *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*. Findings for the 11-year period of record simulation under SEWRPC's existing condition scenario are summarized below for three points closest to the proposed return flow location (SEWRPC, 2007, Appendix N).

TABLE 2-4
Average Water Quality Data Downstream of Underwood Creek Return Flow Location
City of Waukesha Water Supply

Dissolved Oxygen (mg/L)	Phosphorus (mg/L)	Fecal Coliform Summer Season Geometric Mean (Count/100 mL)	Total Suspended Solids (mg/L)
11.0 to 11.1	0.066 to 0.111	351 to 496	15.6 to 16.8

Underwood Creek and Menomonee River Fisheries and Habitat. Fisheries and habitat information for Underwood Creek and the Menomonee River is summarized in Section 5 of the Application and reiterated here. Game and nongame fish species are regulated and protected under state and federal legislation, including the Fish and Wildlife Conservation

[13] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087120 accessed February 2010.

Act of 1980 (16 USC 2901-2911) and the Fish and Wildlife Coordination Act of 1958 (16 USC 661 et seq.).

Underwood Creek, along with the Menomonee River, is a WWSF, with an imbalance in number and type of species, which is indicative of a poor-quality fishery. Although macroinvertebrate communities within the watershed have improved substantially since 1993, the USGS macroinvertebrate data collected in 2007 concluded that Underwood Creek and the Menomonee River range from fairly poor to fair–to-good, in terms of relative quality based on the presence of specific macroinvertebrates. Fish and macroinvertebrate communities are summarized in Appendix L of the Application.

Fisheries data for the Menomonee River watershed show an apparent net gain of fish species within the watershed. For example, 10 new species have been identified since 1986, and the most recent fishery surveys conducted by the USGS in 2004 and 2007 noted that 12 of the 20 species found in the Menomonee River watershed occurred within Underwood Creek (SEWRPC, 2007, pp. 200–214). Underwood Creek is predominantly a concrete channel with little habitat for fish, but the creek provides minimal substrate for macroinvertebrates. The part of the concrete channel removed in 2009 and rehabilitated to a meandering stream channel has numerous pools and riffles, and a substrate composed of gravel, sand, and silt.

With the potential presence of two state-listed threatened fish species in the Menomonee River watershed, there appear to be areas of good river quality within limited parts of the watershed. The poor quality of the fish communities in the watershed is caused mostly by habitat loss. The rehabilitated channel of Underwood Creek contains habitat features that fish and macroinvertebrates can use. Although habitat conditions in Underwood Creek are limiting for the fish and benthic communities, those conditions could be improved by providing more or higher quality habitat.

Additional summary background information on flood control projects, geomorphology, and flow for Underwood Creek is included in Section 5, “Return Flow,” of the Application Document.

2.3.1.6 Root River

Root River will only be affected by the Lake Michigan water supply alternatives for return flow to the Root River and by Lake Michigan water supply or return flow pipeline alignments that cross the Root River. The groundwater supply alternatives do not affect the Root River.

The Root River flows through parts of Milwaukee and Racine counties, and into Lake Michigan at Racine, Wisconsin. The river has more natural channel (e.g., natural bottom substrate and vegetated river banks) than does Underwood Creek, and it has a mixture of land uses between its headwaters and Lake Michigan. The headwaters of the Root River are heavily urbanized, the middle reaches are primarily agriculture and lower density development, and the lower parts of the watershed near Lake Michigan are heavily urbanized.

The Root River is classified for WDNR fish and aquatic life standards and is a WWSF community (WDNR, 2002b). At the USGS Fox River stream gage 04087214 in the City of Greenfield close to the return flow location, the average annual stream flow is 17.5 cfs

(11.3 mgd) over the period of record from 2004 to 2009.[14] The Root River at the potential discharge location is on the 303(d) list for low dissolved oxygen with reported causes from sediment and phosphorus.[15] In addition, the last roughly 6 miles of the Root River upstream of Lake Michigan is on the 303(d) list for PCBs. These listings were all made in 1998.[16]

Water quality information is gathered by a number of organizations in the Root River watershed. The USGS has obtained water quality data, and SEWRPC has done extensive water quality modeling of the watersheds.

Water quality standards for dissolved oxygen are 5.0 milligrams per liter (mg/L) and recreational use fecal coliform standards are 200 counts/100 mL monthly geometric mean and are not to exceed 400 counts/100 mL in more than 10 percent of all samples during any month.[17]

There are no numeric phosphorus water quality standards in Wisconsin, but a planning guideline of 0.1 mg/L was used in SEWRPC's Regional Water Quality Management Plan Update. There are no numeric total suspended solids standards in Wisconsin, however a reference background concentration of 17.2 mg/L was used in SEWRPC's Regional Water Quality Management Plan Update.[18]

The USGS water quality sampling occurred at USGS gage 04087214 on the Root River at Grange Avenue in Greenfield, with data obtained from 2004 through 2009.[19] Dissolved oxygen, phosphorus, and fecal coliform concentration ranges are included in Table 2-5.

Water quality in the Root River was extensively studied in SEWRPC's *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*. Findings for the 11-year period of record simulation under SEWRPC's existing condition scenario are summarized below for three points closest to the proposed return flow location (SEWRPC, 2007, pp. 200–214).

TABLE 2-5
Average Water Quality Data Downstream of Root River Return Flow Location
City of Waukesha Water Supply

Parameter	Dissolved Oxygen (mg/L)	Phosphorus of Unfiltered Water (mg/L as P)	Fecal Coliform (counts/100 mL)
Number of Samples	21	12	13
Minimum	2.5	0.03	110
Maximum	20.3	0.16	7,500
Mean	8.5	0.11	1,395

Root River Fisheries and Habitat. Fisheries and habitat information for Underwood Creek and the Menomonee River is summarized in Section 5 of the Application and reiterated here.

Fishery data for in the Root River watershed show that 10 new species have been identified, but 10 of 64 recorded species have not been observed since 1986 (SEWRPC, 2007, pp. 200–214).

[14] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087214 accessed April, 2010.
[15] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html accessed January 19, 2010.
[16] http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html accessed January 19, 2010.
[17] WDNR NR 102.04(4).
[18] SEWRPC. 2008.
[19] http://waterdata.usgs.gov/wi/nwis/rt, gage number 04087120 accessed February, 2010.

The most recent fishery surveys, conducted in 2004 and 2007 by the USGS, identified 17 species in the Root River near the proposed return flow location. Some of the new species were observed in reaches of the Root River between the confluence with Lake Michigan and the first dam, suggesting that Lake Michigan's fish community may be influencing the fish community of the lower reaches of the watershed. The Root River is a warm-water habitat, where the balance of fish species indicates a fair quality fishery overall in the watershed that is higher in quality than that of the Menomonee River watershed. Macroinvertebrate data collected within the Root River watershed suggest that the river is dominated by species tolerant of a low-quality habitat. Most species within the fish and macroinvertebrate communities generally indicate fair habitat quality.

With the potential presence of one state-listed endangered and three state-listed threatened fish species, there appear to be areas of good quality within parts of the watershed, but there is also impairment because of the agricultural and urban development. The Root River watershed has relatively few streambed and bank modifications, with less than 1 percent of the stream channel observed being in conduit and none lined with concrete. Although habitat conditions in the Root River are fair to good, habitat could be improved by providing more or higher quality habitat.

2.3.1.7 Lake Michigan

Lake Michigan will only be affected by the Lake Michigan water supply alternatives for return flow to Underwood Creek. The groundwater supply alternatives do not affect Underwood Creek or the Menomonee River.

Lake Michigan is bordered by four states and connected through the other Great Lakes to the other four Great Lakes states and two Canadian provinces. Lake Michigan is the second largest of the Great Lakes and is the only Great Lake entirely within the borders of the U.S.[20]

TABLE 2-6
Average Water Quality Data at Select Locations in Lake Michigan near the Greater Milwaukee Watersheds
City of Waukesha Water Supply

Dissolved Oxygen (mg/L)	Phosphorus (mg/L)	Fecal Coliform Summer Season Geometric Mean (Count/100 mL)	Total Suspended Solids (mg/L)
9.6 to 11.5	0.062 to 0.087	603 to 770	10.3 to 19.4

Lake Michigan Water Quality. SEWRPC and the MMSD have been measuring water quality in the Greater Milwaukee area since the 1960s (SEWRPC, 2007, p. 149). Notable water quality improvements have been documented since the MMSD's deep tunnel system came online in 1994 to reduce the number of combined sewer overflows (CSOs). Water quality trends at sampling stations in the Milwaukee outer harbor and nearshore Lake Michigan areas over this historical monitoring period have indicted (SEWRPC, 2007, p. 155):

- Fecal coliform concentration has trended down.
- Biological oxygen demand has trended down.
- Dissolved oxygen concentration has trended down or stayed the same and generally meets standards.

[20] http://www.dnr.state.wi.us/org/water/greatlakes/discover/lakemichigan.htm. Accessed March 4, 2010.

- Total suspended solids concentration trends varied with some stations increasing and others staying the same.
- Total phosphorus concentration has trended down in the outer harbor and up in the nearshore area; since 1986 average annual concentrations have been less than 0.1 mg/L, except for one year.

Annual pollutant loadings to Lake Michigan from the Greater Milwaukee watersheds have been documented in SEWRPC's *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (2007). The average annual loadings for select parameters are included below:

- Fecal coliform: 83,435 trillion cells
- Total phosphorus: 767,230 pounds
- Total suspended solids: 184,435,700 pounds

Additional detail on these and other water quality parameters is found in SEWRPC's *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (2007).

Nearshore Lake Michigan Fisheries and Habitat. In recent years, nuisance algae (cladophora) growth has been observed along the Lake Michigan shoreline. The algae grows underwater attached to rocks and is dislodged by waves and then washes up on shore. The rotting algae creates nuisance odors. Similar algae growths were observed in the mid-1950s and again during the 1960s and 1970s, before this most recent occurrence. The cause of this latest resurgence in algae growth is uncertain, but it may be due in part from changes in water clarity and phosphorous availability brought on by the prevalence of invasive zebra and quagga mussels.[21]

The Milwaukee Harbor estuary is designated a Great Lakes Area of Concern (AOC) due to legacy contaminants present and other impairments. The Milwaukee Harbor suffers from urban stresses similar to those that the other 42 AOCs throughout the Great Lakes experience from highly urban areas. The priorities of the Milwaukee AOC include remediation of contaminated sediments in tributaries and nearshore waters of Lake Michigan, prevention of eutrophication, non-point-source pollution control, improvement of beach water quality, enhancement of fish and wildlife populations, and habitat restoration.[22]

Even though the Milwaukee Harbor estuary has these stresses, the fishery is reported to contain a high abundance and diversity of species because the fishery is connected to the rest of Lake Michigan and the portions of the Milwaukee, Menomonee, and Kinnickinnic Rivers, which achieve full fish and aquatic life standards (SEWRPC, 2007, p. 205).

2.3.1.8 Other Surface Waters

Other surface waters within the affected environment are those that are crossed with a water supply or return flow pipeline and receive only temporary construction impacts. These surface waters are summarized below.

[21] http://www.dnr.state.wi.us/ORG/water/greatlakes/cladophora/. Accessed March 3, 2010.
[22] http://www.epa.gov/glnpo/aoc/milwaukee.html. Accessed March 3, 2010.

2.3.2 Impacts and Mitigation

An assessment of the environmental effects for the water supply alternatives, and associated return flow for the Lake Michigan alternative, was completed and is discussed below for the affected environments.

2.3.2.1 Flow and Geomorphology

Impacts to flow and geomorphology to the surface waters potentially affected by the water supply and return flow alternatives are discussed below. Impacts to flow were assessed for potential changes to the existing flow within the surface water, to the surface water, or away from the surface water (e.g., baseflow changes within a creek). Where flow data exist to make numerical comparisons between alternatives, the impacts are quantified. However, where flow data are limited, such as on an ungauged creek like Mill Brook, qualitative assessments of impacts are discussed.

The geomorphology of the surface waters are assessed based on the impact to the surface water geomorphic stability, change in erosion potential, or change in vertical or lateral stability.

Fox River. Impacts to the Fox River for each water supply and return flow alternative are discussed below. As described in the background information on the Fox River, the average annual stream flow is 110 cfs (71 mgd) over the period of record.

Deep and Shallow Aquifers Water Supply. The shallow groundwater pumping with this alternative causes a drawdown in the aquifer and intercepts groundwater flow to surface waters. This potential surface water flow change from pumping the shallow aquifer has been documented by prior studies and groundwater modeling for this specific alternative.

SEWRPC identified adverse impacts from baseflow reduction to the Fox River. For a similar water supply alternative mixing deep and shallow groundwater sources, SEWRPC identified parts of the Fox River could experience a baseflow decrease greater than 10 percent.[23] A subsequent study estimated significant baseflow reductions near Waukesha when only 3.9 mgd of shallow groundwater was pumped and artificial recharge was used.[24]

The shallow groundwater pumping in this alternative causes a drawdown in the aquifer and intercepts groundwater flow to the Fox River. Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to the river could reduce significantly. For example, compared to the base scenario, groundwater baseflow to the river would be reversed, where groundwater pumping in this alternative is expected to draw water away from the Fox River. In the base scenario, groundwater flow *to the river* is estimate to be about 1.7 mgd in the study area. By implementing the groundwater pumping in this alternative, 0.7 mgd of groundwater would be withdrawn *from* the Fox River. This results in a 2.4 mgd flow reduction in groundwater baseflow to the river.

Because the WWTP discharges to the Fox River upstream of most of the affected areas of the river, this baseflow reduction is not anticipated to have significant adverse impacts between

[23] SEWRPC. 2008. Planning Report on Regional Water Supply Plan for Southeastern Wisconsin, Preliminary Draft.
[24] Cherkauer. 2009.

the WWTP discharge and the downstream extent of the groundwater drawdown (groundwater drawdown maps shown in Appendix O). However, the groundwater pumping will have an adverse impact on the flow in the Fox River downstream of the areas affected by the groundwater drawdown (downstream of the Vernon Marsh) because 2.4 mgd baseflow is removed from the Fox River (i.e., 2.4 mgd would be continuously intercepted between groundwater pumping and the WWTP and therefore would be removed from the flow in the river in the downstream reaches).

Geomorphic changes with reduced baseflows could result in a smaller channel over time but because channel stability is less associated with baseflow and more influenced by larger channel-forming flows generally in the 1- to 2-year return period flow range, baseflow reduction is not expected to cause a significant change in channel stability from existing conditions. The 2.4 mgd is only about 3 percent of the 71 mgd annual average flow in the river and even less than the channel-forming flow rate. The baseflow reductions from groundwater pumping will reduce flow in the river, but it is not expected to have a significant adverse impact to the flow in the river because the flow is small compared to the river flow, and flow in the Fox River includes baseflow along upstream segments of the river, other tributaries, and two WWTPs upstream of Waukesha.

Shallow Aquifer and Fox River Alluvium Water Supply. The shallow groundwater pumping with this alternative causes a drawdown in the aquifer and intercepts groundwater flow to the Fox River. This potential habitat impact from pumping the shallow aquifer has been documented by prior studies and groundwater modeling for this specific alternative.

Similarly to the Deep and Shallow Aquifer alternative, groundwater is pumped from the shallow aquifer and baseflow reduction impacts to the Fox River are expected. The baseflow reduction impacts to the Fox River would be expected to be more or similar to those documented in previous studies by SEWRPC and Cherkaur as described under the Deep and Shallow Aquifers alternative.

Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to the river could reduce significantly. For example, compared to the base scenario, groundwater baseflow to the river would be reversed, where groundwater pumping in this alternative is expected to draw water away from the Fox River. In the base scenario, groundwater flow *to the river* is estimate to be about 1.7 mgd in the study area. By implementing the groundwater pumping in this alternative, 4.2 mgd of groundwater would be withdrawn *from* the Fox River. This results in a 5.9 mgd flow reduction in groundwater baseflow to the river.

Because the WWTP discharges to the Fox River upstream of most of the affected areas of the river, this baseflow reduction is not anticipated to have significant adverse impacts between the WWTP discharge and the downstream extent of the groundwater drawdown (groundwater drawdown maps shown in Appendix O). However, the groundwater pumping will have an adverse impact on the flow in the Fox River downstream of the areas affected by the groundwater drawdown (downstream of the Vernon Marsh) because 5.9 mgd baseflow is removed from the Fox River (i.e., 5.9 mgd would be continuously intercepted between groundwater pumping and the WWTP and therefore would be removed from the flow in the river in the downstream reaches).

Geomorphic changes with reduced baseflows could result in a smaller channel over time but because channel stability is less associated with baseflow and more influenced by larger channel-forming flows generally in the 1- to 2-year return period flow range, baseflow reduction is not expected to cause a significant change in channel stability from existing conditions. The 5.9 mgd is about 8 percent of the 71 mgd annual average flow in the river and even less than the channel-forming flow rate. The baseflow reductions from groundwater pumping will reduce flow in the river, but it is not expected to have a significant adverse impact to the flow in the river because the flow is small compared to the river flow, and flow in the Fox River includes baseflow along upstream segments of the river, other tributaries, and two WWTPs upstream of Waukesha.

Lake Michigan Water Supply. A Lake Michigan water supply, regardless of its supply location from Milwaukee, Oak Creek, or Racine, will not adversely affect the Fox River with respect to geomorphology. This is because groundwater pumping would stop. A Lake Michigan supply and cessation of shallow groundwater pumping would improve the subsurface flow to the Fox River, and allow the baseflow to be at least partially restored to conditions similar to pre-well conditions, by allowing the groundwater to contribute more baseflow to the river. This will improve the baseflow under current shallow groundwater pumping conditions and will have the greatest benefit in the future when projected water demands are greater.

A Lake Michigan supply will affect the Fox River the same, regardless of the return flow location to Underwood Creek, Root River or direct to Lake Michigan. A Lake Michigan supply will require a shift of most of the WWTP discharge from the Fox River to the Lake Michigan basin, but a return flow will not eliminate discharge to the Fox River.

The Compact requires that the minimum return flow be at least the water withdrawn less an allowance for consumptive use. The Compact also requires that the return flow minimize out-of-basin water sent into the Great Lakes basin. These two requirements established minimum and maximum return flow rates to provide the water balance between the withdrawal and return, as described in Section 5 of the Application. As a result, WWTP flow will still occur at times to the Fox River with any Lake Michigan water supply alternative.

A study by the USGS and University of Milwaukee reports that wastewater flow from Sussex, Brookfield and Waukesha contributes 40 percent of the total Fox River flow during annual low flows.[25] The City of Waukesha's average annual WWTP flow is about 10 mgd, or 50 percent of the WWTP flow from the three communities. Using this percentage, the City of Waukesha WWTP contributes about 25 percent of the Fox River flow during annual low flow conditions. Thus, during the low flow periods when return flow (WWTP flow) would likely be entirely to the Lake Michigan basin, a 25 percent reduction in the Fox River flow is estimated. Baseflow conditions generally do not adversely affect the geomorphic conditions in the river, so no significant impacts are expected to the geomorphic conditions of the Fox River with this change.

Because of higher river flows, the Waukesha WWTP discharge is even a smaller fraction of the total river flow. For example, over the period of record for the USGS stream gage near

[25] Doug Cherkauer, D. Feinstein, T. Grundl, W. Kean. "Is riverbank filtration a viable means of extending groundwater supplies?" Presentation to the Compact Implementation Coalition and Sweet Water NGO Team, February 18, 2010, Great Lakes Water Institute, Milwaukee, Wisconsin.

the Waukesha WWTP (Gage ID 05543830 for water years 1964–2008) the average annual river flow was 71 mgd and the average annual peak river flow was 644 mgd. With an average annual Waukesha WWTP discharge of 10 mgd, the WWTP discharge represents 14 percent of the annual average river flow and only 1.6 percent of the average annual peak river flow. This small amount of flow reduction in the river would not be expected to have a significant adverse affect on the flow or geomorphic conditions in the river. In addition, during times when the Fox River has these higher flows, the Waukesha WWTP effluent will likely exceed the maximum return flow rate as discussed in Section 5 of the Application, and WWTP effluent will return flow to the Lake Michigan basin and discharge to the Fox River. During these times, the impact to the Fox River will be even less because the WWTP would continue to supplement the Fox River flows.

Return Flow Alternatives. Because a Lake Michigan supply will require return flow, any impacts to the Fox River are assigned to the Lake Michigan water supply alternatives. Impacts with return flow alternatives are compared to Lake Michigan tributaries and are described in the sections below discussing Lake Michigan tributary watersheds in detail.

2.3.2.2 Pebble Brook, Pebble Creek, and Mill Brook

Deep and Shallow Aquifers Water Supply. The shallow groundwater pumping in this alternative causes a drawdown in the aquifer and intercepts groundwater flow to these cold water streams. Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to these cold water streams could reduce significantly. For example, groundwater baseflow to Pebble Brook would be reduced by 61 percent, Pebble Creek would be reduced by 9 percent, and Mill Book would be reduced by 29 percent. Geomorphic changes with reduced baseflows could result in a smaller channel over time. Because channel stability is less associated with baseflow and more influenced by larger channel-forming flows generally in the 1- to 2-year return period flow range, baseflow reduction is not expected to cause a significant change in channel stability from what currently exists. The baseflow reductions could however, have a significant adverse impact to the flow in the channels (especially Pebble Brook because of its 61 percent baseflow reduction) during low flow periods when groundwater baseflow accounts for most of the flow in the channels.

Shallow Aquifer and Fox River Alluvium Water Supply. The shallow groundwater pumping in this alternative causes a drawdown in the aquifer and intercepts groundwater flow to these cold water streams. Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to these cold water streams could reduce significantly, and greater than the Deep and Shallow Aquifer alternative. For example, groundwater baseflow to Pebble Brook would be reduced by 58 percent, Pebble Creek would be reduced by 23 percent, and Mill Book would be reduced by 30 percent. Geomorphic changes with reduced baseflows could result in a smaller channel over time. Because channel stability is less associated with baseflow and more influenced by larger channel forming flows generally in the 1- to 2-year return period flow range, baseflow reduction is not expected to cause a significant change in channel stability from what exists. The baseflow reductions could however, have a significant adverse impact to the flow in the channels during low flow periods when groundwater baseflow accounts for most of the flow in the channels.

Lake Michigan Water Supply and Return Flow. There is no shallow groundwater pumping with this alternative and consequently the cold water streams are not affected with these alternatives.

Underwood Creek and Menomonee River. The flow and geomorphology in Underwood Creek and the Menomonee River will only be affected by a Lake Michigan water supply with return flow to Underwood Creek. All of the other water supply and return flow alternatives will not affect these watercourses. As described in the background information on Underwood Creek and the Menomonee River, the average annual stream flow is 15.1 cfs (9.8 mgd) over the period of record for Underwood Creek and 108 cfs (69 mgd) over the period of record for the Menomonee River.

A detailed analysis of the flow and geomorphic conditions is included in Section 5 and Appendixes G and L of the Application. In summary, return flow to Underwood Creek will increase the flow in the creek and river downstream of the return flow location. Underwood Creek experiences periods of no-flow and therefore a return flow could constitute 100 percent of the creek flow during these times. During less frequent flow events, such as a 2-year flow, a return flow is less than 2 percent of the creek flow and even less than the river flow. Due to the small percentage of return flow in the creek and river, a return flow will not adversely impact the flow or geomorphic conditions in either watercourse. Instead, the return flow will benefit Underwood Creek flow during low and no-flow periods because the return flow will provide a baseflow in the creek at all times.

Root River. The flow and geomorphology in the Root River will only be affected by a Lake Michigan water supply with return flow to the Root River. All of the other water supply and return flow alternatives will not affect this watercourse. As described in the background information on the Fox River, the average annual stream flow is 17.5 cfs (11.3 mgd) over the period of record.

A more detailed analysis of the flow and geomorphic conditions is included in Section 5 of the Application. In summary, return flow to the Root River is expected to have a similar insignificant impact as return flow to Underwood Creek. Similar to Underwood Creek, flow in the Root River sometimes is very low, and the functional habitat in the river is limited by the river flow. Augmentation of the return flow would eliminate the very low flow periods. Because the return flow rate is small compared to the higher flows in the river, return flow is not expected to affect the geomorphic stability of the river. For example, a return flow is about 5 percent of the 2-year river flow near the discharge location, and about 2.2 percent at the next reach about 1.3 miles downstream of the return flow outfall location.[26] These are similar to the Underwood Creek flow, where a detailed evaluation concluded that the return flow would not affect the geomorphic stability of the rehabilitated parts of the creek. A recent sediment transport study of the Root River concluded that the river stability is relatively insensitive to changes in flows because of the erosion resistance of the channel boundary materials, the relatively flat channel gradient, and the presence of a functional floodplain.[27] For these reasons, a return flow will not adversely impact the flow or geomorphic conditions in the

[26] MMSD. *Root River Sediment Transport Planning Study.* May 4, 2007. Hydraulics Technical Memorandum 3. HEC-RAS model from enclosed CD.

[27] MMSD. *Root River Sediment Transport Planning Study.* May 4, 2007. Hydraulics Technical Memorandum 6. Page 1.

river. Instead, the return flow will benefit Root River flow during low-flow periods because the return flow will provide additional baseflow in the river.

Lake Michigan. Impacts to Lake Michigan for each water supply and return flow alternative are discussed below.

Deep and Shallow Aquifers Water Supply. This water supply alternative will have an impact to the flow within Lake Michigan because increased pumping of the deep aquifer will continue to draw groundwater from under Lake Michigan. Because this water supply alternative includes discharging the water to the Fox River through the City of Waukesha WWTP, this volume of water is lost from the Great Lakes Basin. The volume from the Lake Michigan basin is considered to have no adverse impact. This alternative is not expected to affect the geomorphology of Lake Michigan.

Shallow Aquifer and Fox River Alluvium Water Supply. This water supply alternative will stop pumping of the deep aquifer for the City of Waukesha and consequently some minor decrease in groundwater flow away from Lake Michigan will occur. This will have a small benefit to the Lake Michigan basin. There is no adverse impact on the flow or geomorphology of Lake Michigan with this alternative.

Lake Michigan Supply and Return Flow. Flow within Lake Michigan will not be affected by a Lake Michigan water supply or return flow alternative. This is because the City of Waukesha has a goal of returning 100 percent of the withdrawn water. Details of how the City plans to accomplish this are included in Section 5 of the Application.

The geomorphology of Lake Michigan will not be adversely affected by the Lake Michigan water supply alternative because regardless of a Milwaukee, Oak Creek or Racine supply, the supply will utilize existing treatment plant intakes in the Lake and no construction is expected to occur within the Lake for a water supply.

The geomorphology of the Lake will not be affected by the return flow alternatives except for a return flow directly to Lake Michigan. For this return flow alternative, an outfall will be required on the bottom of the Lake to provide an offshore discharge. The pipe in the Lake will change the Lake substrate composition along the pipe alignment. The area in Lake Michigan affected by the pipeline is summarized in the land use changes documented in Section 7 of this ER and is expected to have a minor adverse impact to the Lake's geomorphology.

2.3.2.3 Flooding

Flooding is a concern in each urbanized community, and especially in southeastern Wisconsin where extensive flood mitigation projects have been constructed, and more are planned. The water supply and return flow alternatives were evaluated based on their impact to flooding along affected surface water resources. A summary of the analysis is discussed below for each water resource.

Fox River. Impacts to the Fox River for each water supply and return flow alternative are discussed below.

Deep and Shallow Aquifer Water Supply. The Deep and Shallow Aquifers supply alternative will not affect flooding on the Fox River because there are no floodplain changes and this alternative would continue to use the existing City of Waukesha WWTP for the discharge of

treated wastewater. This alternative has a number of above ground structures. The buildings associated with this alternative will be located outside the regulatory floodplain, so they will not be damaged by the 100-year return period flood.

Shallow Aquifer and Fox River Alluvium Water Supply. The Shallow Aquifer and Fox River Alluvium supply alternative will also not affect the Fox River flooding for the same reasons discussed for the Deep and Shallow Aquifer alternative. This alternative has a number of aboveground structures. The buildings associated with this alternative will be located outside the regulatory floodplain, so they will not be damaged by the 100-year return period flood.

Lake Michigan Water Supply and Return Flow. A Lake Michigan water supply from either the City of Milwaukee, Oak Creek or Racine will not affect flooding on the Fox River. This is because Lake Michigan is in a different watershed.

The return flow to either Underwood Creek, Root River or directly to Lake Michigan will not affect flooding on the Fox River. As discussed in Section 5 of the Application, return flow to the Lake Michigan basin will be temporarily paused during flooding events downstream of the return flow discharge location and flow from the WWTP would be conveyed to the Fox River. This will maintain the same flow in the Fox River during flooding events as the groundwater supply alternatives. Therefore, a Lake Michigan water supply with the return flow as described in Section 5 of the Application will not adversely change flooding on the Fox River.

This alternative has two small aboveground pump stations, one for water from a Lake Michigan water supplier and one at the existing Waukesha WWTP for return flow. These pump stations will be located and designed so there is no damage from the 100-year return period flood.

Pebble Brook, Pebble Creek and Mill Brook. None of the water supply or return flow alternatives impact flooding on these watercourses because flows do not increase to these watercourses.

Underwood Creek, Menomonee River, and Root River. The groundwater supply alternatives will not affect flooding in these watercourses because the water supply and discharge from the Waukesha WWTP will not be located in these watersheds under those water supply alternatives. A Lake Michigan water supply, regardless of a City of Milwaukee, Oak Creek, or Racine supply will not affect flooding in these watercourses because the water intake at each location is within Lake Michigan.

The return flow to any of the watercourses will not affect flooding or the floodplain delineations. As discussed in Section 5 of the Application, return flow to Underwood Creek (Menomonee River) or Root River will be temporarily paused during flooding events that threaten personal or public property.

Lake Michigan. The groundwater supply alternatives will not affect flooding in these watercourses because the water supply and discharge from the Waukesha WWTP will not be located in these watercourse watersheds. A Lake Michigan water supply and return flow, regardless of supply and return flow locations, will not affect flooding in the Lake because as discussed in Section 5 of the Application, a Lake Michigan water supply with return flow will provide a water balance. A water balance will prevent excess volume from being transferred into Lake Michigan, which eliminates flooding impacts in the lake.

2.3.2.4 Aquatic Habitat

Aquatic habitat in the surface water resources will be affected as a result of the water supply and return flow alternatives. The impacts are generally beneficial for the surface waters in the Lake Michigan basin but the surface waters in the Fox River watershed generally have a minor adverse impact.

The pipeline alignments water body crossings that could cause temporary construction impacts to aquatic habitat are listed below in Table 2-7. During the design phase, the City of Waukesha will work with the resource agencies to determine the appropriate construction techniques for each crossing to minimize and mitigate temporary impacts. Example techniques that could be used are included in Appendix 2-A, Example Wetland and Waterway Pipeline Construction Crossing Impact Minimization Techniques.

Temporary construction impacts on in-stream and shoreline vegetative cover may include alteration or temporary loss at pipeline water crossings. Submergent and emergent vegetation, in-stream logs and rocks, and undercut banks provide cover for fish and other aquatic biota. Fish that normally live in these areas may be displaced during construction. However, this habitat alteration will be relatively insignificant because of the small area affected at each crossing location and stream bank restoration techniques will be designed to promote regrowth of riparian vegetation.

The aquatic habitat impacts resulting from the operations (i.e., post-construction) of each water supply and return flow alternative is described below.

Fox River. Aquatic habitat impacts to the Fox River for each water supply and return flow alternative are discussed below. As described in the background information on the Fox River, the average annual stream flow is 110 cfs (71 mgd) over the period of record.

Deep and Shallow Aquifers Water Supply. Baseflow reductions to the Fox River are expected for this alternative water supply because of the shallow groundwater pumping. The City of Waukesha WWTP will continue to discharge treated wastewater to the Fox River. The WWTP discharges are larger than the baseflow reduction, so the WWTP discharges are expected to partially supplement the baseflow reduction caused by the pumping. However, as discussed above in the Flow and Geomorphology section, the groundwater pumping will reduce the volume of water in the Fox River compared to current conditions because the groundwater pumping draws baseflow from the river. Because there is less flow in the river for this alternative, there will be less aquatic habitat. The Deep and Shallow Aquifers supply alternative will not have significant adverse impacts on the aquatic habitat in the Fox River, but minor adverse impacts are possible from the flow reduction.

Shallow Aquifer and Fox River Alluvium Water Supply. The Shallow Aquifer and Fox River Alluvium alternative has greater reductions to Fox River baseflow. This alternative would continue to use the existing City of Waukesha WWTP for the discharge of treated wastewater. The WWTP discharges are larger than the baseflow reduction, so the WWTP discharges are expected to partially supplement the baseflow reduction caused by the groundwater pumping. However, as discussed above in the Flow and Geomorphology section, the groundwater pumping will reduce the volume of water in the Fox River compared to current conditions because the groundwater pumping draws baseflow from the river. Because there is less flow in the river for this alternative, there will be less aquatic

habitat. The Shallow Aquifer and Fox River Alluvium supply alternative will not have significant adverse impacts on the aquatic habitat in the Fox River, but minor adverse impacts are possible.

Lake Michigan Water Supply. A Lake Michigan water supply from either Milwaukee, Oak Creek, or Racine will have an effect on the aquatic habitat in the Fox River. As discussed in Section 5 of the Application, flow from the City of Waukesha WWTP will be returned to the Lake Michigan basin with a Lake Michigan supply. The return flow will generally be to the Lake Michigan basin, but there will be times when WWTP flow is discharged to the Fox River. As discussed in Section 5 of the Application, "Return Flow Management Plan," flow to the Fox River will occur when the WWTP flow exceeds the maximum return flow rate or during extreme flooding conditions in a Lake Michigan tributary (for a tributary return flow location). Because the WWTP flow to the Fox River will be reduced with a Lake Michigan supply, less water will be available in the river, reducing the amount of aquatic habitat. As discussed above, the City of Waukesha WWTP contributes about 25 percent of the Fox River flow during annual low flow conditions. This reduction in flow and aquatic habitat will have a minor adverse impact on the river during annual low flow conditions.*Return Flow Alternatives.* Because a Lake Michigan supply will require return flow, any impacts to the Fox River are assigned to the Lake Michigan water supply alternatives. Impacts with return flow alternatives are compared to Lake Michigan tributaries and are described in the sections below discussing Lake Michigan tributary watersheds in detail.

Pebble Brook, Pebble Creek and Mill Brook. Aquatic habitat impacts to Pebble Brook, Pebble Creek, and Mill Brook for each water supply and return flow alternative are discussed below.

Deep and Shallow Aquifers Water Supply. The shallow groundwater pumping with this alternative causes a drawdown in the aquifer and intercepts groundwater flow to these cold water streams. This potential habitat impact from pumping the shallow aquifer has been documented by prior studies and groundwater modeling for this specific alternative.

SEWRPC identified adverse impacts from baseflow reduction to Pebble Brook and Pebble Creek. For a similar water supply alternative mixing deep and shallow groundwater sources, SEWRPC identified parts of Pebble Creek could experience a baseflow decrease greater than 25 percent.[28] A subsequent study estimated significant baseflow reductions near Waukesha when only 3.9 mgd of shallow groundwater was pumped and artificial recharge was used.[29]

Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to these cold water streams could reduce significantly. For example, groundwater baseflow to Pebble Brook would be reduced by 61 percent, Pebble Creek would be reduced by 9 percent, and Mill Book would be reduced by 29 percent. Baseflow reductions will reduce the quantity and amount of time habitat is available in these channels.

The baseflow reductions could have a significant adverse impact to aquatic habitat in the channels (especially Pebble Brook because of its 61 percent baseflow reduction) during low flow periods when groundwater baseflow is the majority of the flow in the channels. During

[28] SEWRPC. 2008. Planning Report on Regional Water Supply Plan for Southeastern Wisconsin, Preliminary Draft.
[29] Cherkauer. 2009.

higher flow periods, the baseflow reduction is not anticipated to have a significant adverse impact because the reduction in baseflow is a very small percentage of the flood flow rate in the channels. Because these baseflow reduction numbers represent steady state average conditions, actual baseflow percent reduction will be greater during droughts when water demand is higher and stream baseflows are lower.

Shallow Aquifer and Fox River Alluvium Water Supply. The shallow groundwater pumping with this alternative causes a drawdown in the aquifer and intercepts groundwater flow to these cold water streams. This potential habitat impact from pumping the shallow aquifer has been documented by prior studies and groundwater modeling for this specific alternative.

Similarly to the Deep and Shallow Aquifer alternative, groundwater is pumped from the shallow aquifer and baseflow reduction impacts to cold water streams are expected. The baseflow reduction impacts to cold water streams would be expected to be more or similar to those documented in previous studies by SEWRPC and Cherkaur as described under the Deep and Shallow Aquifer alternative.

Detailed groundwater modeling (Appendix O of the Application) of this alternative found average groundwater baseflows to these cold water streams could reduce significantly, and greater than the Deep and Shallow Aquifer alternative. For example, groundwater baseflow to Pebble Brook would be reduced by 58 percent, Pebble Creek would be reduced by 23 percent, and Mill Book would be reduced by 30 percent. Baseflow reductions will reduce the quantity and amount of time habitat is available in these channels.

The baseflow reductions could have a significant adverse impact to aquatic habitat in all three channels during low flow periods when groundwater baseflow is the majority of the flow in the channels. During higher flow periods, the baseflow reduction is not anticipated to have a significant adverse impact because the reduction in baseflow is a very small percentage of the flood flow rate in the channels. Because these baseflow reduction numbers represent steady state average conditions, actual baseflow percent reduction will be greater during droughts when water demand is higher and stream baseflows are lower.

Lake Michigan Water Supply and Return Flow. There is no shallow groundwater pumping with this alternative and consequently these cold water streams are not affected by these alternatives.

Underwood Creek and Menomonee River. None of the water supply alternatives will affect the aquatic habitat in Underwood Creek and the Menomonee River. The aquatic habitat in these watercourses will only be affected with a return flow discharge location to Underwood Creek. As discussed in Section 5 and Appendix L of the Application, a return flow to Underwood Creek is expected to improve the aquatic habitat in Underwood Creek and the Menomonee River. The greatest benefits will occur during low flow conditions in the creek and river, when the return flow contributes the greatest portion of flow. A summary of the habitat improvements to the creek and river discussed in detail in Appendix L includes:

- The habitat of dominant fish and macroinvertebrates could be improved with additional flow, especially in the rehabilitated segment of the creek and during periods when the creek flows are low (baseflow flow conditions).
- Underwood Creek often experiences extended periods when there is no flow in the creek because of ice or dry conditions when there is little precipitation. At those times,

return flow would provide the greatest habitat improvement because periods of no flow could be eliminated.

- During baseflow and low flow periods, return flow would provide additional water depth to improve fish passage through the riffle and concrete parts of the creek, to deepen pools within the restored reach, and to provide more wetted perimeter habitat near the creek banks and overhanging vegetation.
- Return flow is expected to slightly increase shear stresses in the creek, which are insignificant to the geomorphic stability of the creek, but could improve the bottom substrate habitat by reducing embeddedness (fine sediment accumulation in coarse substrates) to support coarse (e.g., gravel) sediment habitat.
- Most of the creek is concrete lined, but the areas that have already been rehabilitated or that will be rehabilitated in the future will benefit the most from additional flow.
- When creek flow is high (e.g., flow events greater than a 2-year flow), return flow is a small portion of the total creek flow. During these times, return flow is not expected to have a significant effect on the creek habitat.
- Return flow influence on the larger Menomonee River is expected to benefit the habitat downstream of its confluence with Underwood Creek for the same reasons. Because the return flow will be a smaller percentage of the total river flow, it will improve fish passage, submerged habitat, and embeddedness to a lesser degree. When river flows are high, return flow is not expected to have a significant effect on river habitat because it will be a very small percentage of the total river flow.

A return flow to Underwood Creek and Menomonee River will have a beneficial effect on the aquatic habitat, especially during low flow conditions in the creek and river.

Root River. None of the water supply alternatives will affect the aquatic habitat in the Root River. The aquatic habitat will only be affected with a return flow discharge location to the Root River. As discussed in Section 5 of the Application, a return flow to Underwood Creek is expected to improve the aquatic habitat, similar to an Underwood Creek discharge location. The greatest benefits will occur during low flow conditions in the river, when the return flow contributes the greatest portion of flow. The same as an Underwood Creek return flow, a return flow to the Root River will have a beneficial effect on the aquatic habitat, especially during low flow conditions in the river.

Lake Michigan. None of the water supply alternatives will affect the aquatic habitat in Lake Michigan. The aquatic habitat will only be affected with a return flow discharge location direct to Lake Michigan because this return flow alternative includes construction of a pipeline in Lake Michigan to provide an offshore discharge (as discussed in Section 5 of the Application). The pipeline within Lake Michigan will likely change the bottom substrate of the lake along the alignment from natural substrate. This change in natural substrate for the pipeline alignment is expected to have a minor adverse impact on the Lake Michigan aquatic habitat.

2.3.2.5 Water Quality

Water quality environmental effects will occur both during construction as well during operation and maintenance. Potential impacts to aquatic resources generally associated with

construction can be both direct and indirect. They will depend primarily upon the physical characteristics of the streams and time of year.

The primary impact of temporary construction impacts to surface waters can be associated with elevated loads of suspended sediment resulting from in-stream trenching activities and erosion of cleared stream banks and rights-of-way from pipeline construction. Impact severity is a function of sediment load, particle size, stream bank and streambed composition, flow velocity, turbulence, and duration of construction activities. Since the impacts will be temporary and will be crossed using BMPs designed to reduce the impact, turbidity, and erosion created by construction will be minimal.

Temporary construction impacts can also elevate suspended sediment levels that increase turbidity and consequently reduce primary photosynthetic production, flocculate plankton, decrease visibility and food availability, and produce effects that are aesthetically displeasing (USFWS, 1982). However, Long (1975) concluded that most fish avoid turbid water and can survive for several days in waters where a stream has caused turbidity. Since the construction impacts will be temporary and river crossings will use BMPs designed to reduce the impact, turbidity and erosion created by construction will be minimal.

Construction effects on water quality will be minimized by using best management practices as described in Appendix 2-A, "Example Wetland and Waterway Pipeline Construction Crossing Impact Minimization Techniques."

Operational and maintenance effects on water quality are described below for each water supply and return flow alternative.

Deep and Shallow Aquifers Water Supply. The Deep and Shallow Aquifers supply alternative includes new aboveground impacts to over 30 acres (see Table 7-1) that will produce stormwater pollution runoff from previously undeveloped land. The increased runoff will have stormwater water quality impacts that drain to the Fox River. The runoff will be managed to meet the WDNR's stormwater quality management requirements for new development NR 151 *Runoff Management* (WDNR, 2010g) as well as local stormwater management requirements.

Operational and maintenance effects on water quality are associated with WWTP discharge to the Fox River for this groundwater supply alternative. Existing WWTP permit limits from the WDNR and performance for many water quality parameters has been documented in Appendix H of the Application. The WDNR commonly provides allowances for permitted discharges in the form of interim limits, variances, or other allowances when background levels are higher than water quality standards, when the water quality constituent cannot be removed by municipal WWTP best available technology permitted in Wisconsin, or water quality standards can be met after mixing or other processes in the receiving water.

The Waukesha WWTP currently has an allowance for chloride discharge in the form of an interim limit governed by NR 106.83(2)(b). A significant source of chloride in the Waukesha WWTP is residential water softening. Residential water softening would continue with the groundwater alternatives. The allowance for an interim chloride limit would also consequently be needed. The Waukesha WWTP also currently has an allowance for mercury in the form of an interim limit governed under NR 106.145(4) which requires a mercury minimization plan that Waukesha is implementing. The water supply source is not expected

to have an effect on mercury at the WWTP. Other water quality parameters may be addressed by similar regulatory approaches for allowances under current or future regulations for all discharge location alternatives.

The groundwater draw down will also effect baseflow in Pebble Brook, Pebble Creek, and Mill Brook, three cold water streams south of Waukesha tributary to the Fox River as described above in Aquatic Habitat. Lower baseflows in these cold water streams will lead to warmer temperatures and potential temperature impairment. Pebble Creek is already listed for water temperature fluctuation and this impairment would be expected to worsen.

Shallow Aquifer and Fox River Alluvium Water Supply. The Shallow Aquifer and Fox River Alluvium supply alternative includes new aboveground impacts to over 50 acres (see Table 7-1), which will produce stormwater pollution runoff from previously undeveloped land. The increased runoff will have stormwater water quality impacts that drain to the Fox River. The runoff will be managed to meet the WDNR's stormwater quality management requirements for new development NR 151 *Runoff Management* as well as local stormwater management requirements.

This groundwater water supply alternative continues WWTP discharge to the Fox River. The Waukesha WWTP meets permit requirements currently, so no change in the plant permit limits is expected with a switch in water sources. The same approach to permit allowances for discharge to the Fox River as currently occurs would be expected with this water supply alternative.

The groundwater draw down will also effect baseflow in Pebble Brook, Pebble Creek, and Mill Brook, three cold water streams south of Waukesha tributary to the Fox River as described above in Aquatic Habitat. Lower baseflows in these cold water streams will lead to warmer temperatures and potential temperature impairment. Pebble Creek is already listed for water temperature fluctuation and this impairment would be expected to worsen.

Lake Michigan–Milwaukee Supply, –Oak Creek Supply, and –Racine Water Supply. A Lake Michigan supply regardless of the water source includes new aboveground impacts that are limited to only a new pump station less than a quarter acre in size; consequently, operational stormwater quality impacts will be insignificant. All Lake Michigan supply options will also include return flow water quality impacts, which are described below.

Underwood Creek–Lake Michigan, Root River–Lake Michigan, and Direct-to-Lake-Michigan Return Flow Alternatives. All water returned to the Lake Michigan watershed, will meet WDNR water quality permit requirements. All return flow alternatives are assumed to share in common expected effluent limits for the purpose of this analysis. A summary of proposed discharge limits from the WDNR and a comparison to historical Waukesha WWTP performance are detailed in Application Section 5, "Water Quality." It is important to note that the Waukesha WWTP historical effluent (October 1, 2002, to August 31, 2009) already consistently produces an effluent quality better than the proposed permit limits.

While the groundwater alternatives would continue the need for water softening, water softening would no longer be needed with a Lake Michigan water supply source. Consequently, a reduction in chloride concentration in return flow over time is expected. The same approach to permit allowances for discharge to the Fox River would be expected to be required for return flow.

Return flow will switch discharge up to a maximum amount from the Fox River to the Lake Michigan watershed. The return flow management plan is discussed in detail in Section 5 of the Application. In general, the return flow management plan provides return flow up to a value of 115 percent of the average day water demand if sufficient water is available at the WWTP. Water at the WWTP in excess of this amount will continue to be discharged into the Fox River and meet permit limits. The Wisconsin Pollutant Discharge Elimination System (WPDES) values are intended to protect receiving streams. Consequently, significant water quality impacts to the Fox River are not anticipated with return flow to the Lake Michigan watershed instead of continuous discharge to the Fox River.

Flow from all return flow alternatives ultimately ends up in Lake Michigan. Consequently, the findings for all return flow alternatives with respect to Lake Michigan water quality inputs are the same and are listed here prior to discussing individual alternatives. Water quality information was reviewed for overall water quality parameter loadings from the greater Milwaukee watersheds tributary to Lake Michigan. SEWRPC compiled total annual water quality parameter loadings for all the greater Milwaukee watersheds (SEWRPC, 2007, Tables 54–56). The contribution of the City of Waukesha return flow loadings was calculated using the information from the water quality modeling documented in Appendix H of the Application and then compared to the SEWRPC annual average load findings. The analysis indicates the following:

- Fecal coliform contribution in the return flow under very conservative, worst-case conditions is only 0.20 percent of all fecal coliform loading from the greater Milwaukee watersheds.
- Total suspended solids contribution in the return flow under very conservative, worst-case conditions is only 0.21 percent of all total suspended solids loading from the greater Milwaukee watersheds.
- Phosphorus contribution in the return flow is only 1.23 percent of all phosphorus loading under worst-case conditions and only 0.62 percent of all phosphorus loading given the City of Waukesha's WWTP historic performance. These contributions could be even less because the WDNR is considering new phosphorus regulations that could require more stringent phosphorus discharge limitations.

The Underwood Creek to Lake Michigan return flow alternative considered water quality changes to Underwood Creek and downstream reaches of the Menomonee River.

The 303(d) listing for Underwood Creek and the Menomonee River will not become worse with return flow. The fecal coliform recreational restriction 303(d) listing for Underwood Creek will not be exacerbated with return flow because the fecal coliform concentration in the discharge has averaged between 2 and 49 cells/100 mL during the recreational season, which is well below the standard of 400 cells/100 mL.

The 303(d) listings or proposed listings on the last 2.67 miles of the Menomonee River will not be exacerbated with return flow. The proposed fecal coliform listing will not be exacerbated with return flow because the fecal coliform concentration in the discharge has averaged between 2 and 49 cells/100 mL during the recreational season, which is well below the standard of 400 cells/100 mL.

The listing for PCBs from contaminated sediment will not become worse because the return flow does not include this chemical. The listing for *E. coli* bacteria for recreational restrictions will not become worse because disinfection at the WWTP works so well that only between 2 and 49 cells/100 mL of fecal coliform occur during the recreational season, and a similar high quality would be expected for other bacteria such as *E. coli*. The listing of total phosphorus for low dissolved oxygen does not appear accurate because this listing goes all the way back to 1998, and a more-recent SEWRPC detailed analysis of water quality in the Menomonee River found that the dissolved oxygen variance standard was always met for the 11-year period of record analyzed (SEWRPC, 2007, Appendix N).

Subsequent modeling of the Menomonee River also found no change in dissolved oxygen standard compliance with return flow. No change in dissolved oxygen standard compliance is in part due to the very good performance of the Waukesha WWTP which produces effluent with a very low biological oxygen demand (BOD) concentration. As described in Appendix H of the Application, historical WWTP performance has produced a BOD concentration less than 2 mg/L on average. Finally, the listing of unspecified metals for chronic aquatic toxicity will not be exacerbated because the WWTP WPDES permit process has analyzed metals concentrations and found that they are below toxic levels.

Water quality analysis for these water bodies is summarized in Section 5 of the Application with additional detailed information in Appendix H to the Application.

The Root River to Lake Michigan return flow alternative considered water quality changes to the Root River. The 303(d) listings in the Root River should not be exacerbated with return flow. Near the potential discharge location, the Root River was originally listed for low dissolved oxygen from sediment and phosphorus in 1998. However, more recent SEWRPC water quality modeling found that dissolved oxygen concentrations met the standard between 95 and 100 percent of the time for the 11-year period of record analyzed (SEWRPC, 2007, Appendix N). No or little change in dissolved oxygen standard compliance would be expected with return flow to the Root River because historical WWTP performance has produced a BOD concentration less than 2 mg/L on average as described in Appendix H of the Application.

The Root River PCB 303(d) listing in the 6 miles of the river upstream of Lake Michigan will not be exacerbated because this chemical is not found in the return flow. Water quality analysis for this water body is summarized in Section 5 of the Application.

The Direct to Lake Michigan return flow alternative has the same water quality affects as those listed for the other return flow alternatives.

2.3.3 Perennial and Intermittent Surface Water Crossings

All water supply alternatives have pipelines that cross surface waters. The extents of the surface water crossings are listed in Tables 2-7 to 2-9 for each alternative. Please see Chapter 1 for figures associated with each of the alternatives. All of these crossings will have temporary impacts during construction. Once the construction is complete, the surface water crossing will be restored. Operational and maintenance impacts are expected to be negligible.

TABLE 2-7
Water Body Crossings
City of Waukesha Water Supply

Alternative	Water Body/ Stream No.	Water Body Name	Water Body Type	Approximate Crossing Width (ft)	Crossing Area (acres)	Fisheries Classification[a]
Supply						
Deep and Shallow Aquifers	3	Fox River	Perennial	139.4	0.24	WWSF
	2855	Unnamed	Intermittent/ephemeral	17.4	0.03	—
	2931	Pebble Brook	Perennial	46.5	0.08	Unknown
	2973	Unnamed	Intermittent/ephemeral	11.6	0.02	—
Shallow Aquifer and Fox River Alluvium	3	Fox River	Perennial	342.7	0.59	WWSF
	2855	Unnamed	Intermittent/ephemeral	17.4	0.03	—
	2931	Pebble Brook	Perennial	46.5	0.08	Unknown
	2973	Unnamed	Intermittent/ephemeral	11.6	0.02	—
Lake Michigan—Milwaukee Supply	1845	Poplar Creek	Perennial	16.8	0.03	Unknown
	3294	Unnamed	Intermittent/ephemeral	—	0.002	—
	3305	Unnamed	Intermittent/ephemeral	—	0.005	—
	3315	Deer Creek	Perennial	—	0.019	WWSF
	4310	Honey Creek	Perennial	26	0.04	—
	21136	Deer Creek	—	77.4	0.02	—
	22799	North Branch Root River	—	23.2	0.04	—
	22800	North Branch Root River	—	23.2	0.04	—
Lake Michigan—Oak Creek Supply	1845	Poplar Creek	Perennial	16.8	0.0	Unknown
	3294	Unnamed	Intermittent/ephemeral	1.7	0.003	—
	3305	Unnamed	Intermittent/ephemeral	2.9	0.005	—
	3315	Deer Creek	Perennial	11.6	0.02	WWSF
	4671	East Branch Root River	—	81.6	0.06	—
	4887	North Branch Root River	—	93.3	0.04	—
	5210	Oak Creek	Perennial	77.9	0.10	—
	6272	North Branch Root River	—	89.9	0.06	—
	6929	North Branch Oak Creek	—	75.0	0.05	—
	21136	Deer Creek	—	77.4	0.02	—
	22799	North Branch Root River	—	220.3	0.08	—

TABLE 2-7
Water Body Crossings
City of Waukesha Water Supply

Alternative	Water Body/ Stream No.	Water Body Name	Water Body Type	Approximate Crossing Width (ft)	Crossing Area (acres)	Fisheries Classification[a]
Lake Michigan—Racine Supply	1845	Poplar Creek	Perennial		0.03	Unknown
	3280	Poplar Creek	Perennial	—	1.09	Unknown
	3333	Unnamed	Intermittent/ephemeral	—	0.07	—
	3335	Unnamed	Intermittent/ephemeral	—	0.05	—
	3408	Unnamed	Intermittent/ephemeral	—	0.02	—
	3413	Unnamed	Intermittent/ephemeral	—	0.08	—
	3432	Muskego Drainage Canal	Perennial	—	0.51	Unknown
	3459	Unnamed	Intermittent/ephemeral	—	0.20	—
	3484	Unnamed	Intermittent/ephemeral	—	0.02	—
	3486	Unnamed	Intermittent/ephemeral	—	0.06	—
	8339	Unnamed	Intermittent/ephemeral	—	0.24	—
	210	Husher Creek	—	164.9	0.03	—
	668	Hoods Creek	—	81.5	0.04	—
	1827	Goose Lake Branch Canal	—	4411.8[b]	2.23	—
	2282	Root River Canal	—	75.3	0.07	—
	20172	Mill Creek	—	98.0	0.01	—
Return						
Underwood Creek to Lake Michigan	1738	Unnamed	Intermittent/ephemeral	—	0.002	—
	1845	Poplar Creek	Perennial	—	0.032	Unknown
	3052	Unnamed	Intermittent/ephemeral	—	0.012	—
	3054	Unnamed	Intermittent/ephemeral	—	0.082	—
	3055	Unnamed	Intermittent/ephemeral	—	0.001	—
	3294	Unnamed	Intermittent/ephemeral	—	0.003	—
	3305	Unnamed	Intermittent/ephemeral	—	0.005	—
	3315	Deer Creek	Perennial	—	0.02	WWSF
	21136	Deer Creek	—	77.4	0.02	
Root River to Lake Michigan	1845	Poplar Creek	Perennial	—	0.03	Unknown
	3052	Unnamed	Intermittent/ephemeral	—	0.01	—
	3054	Unnamed	Intermittent/ephemeral	—	0.08	—

TABLE 2-7
Water Body Crossings
City of Waukesha Water Supply

Alternative	Water Body/ Stream No.	Water Body Name	Water Body Type	Approximate Crossing Width (ft)	Crossing Area (acres)	Fisheries Classification[a]
	3055	Unnamed	Intermittent/ephemeral	—	0.001	—
	3294	Unnamed	Intermittent/ephemeral	—	0.003	—
	3305	Unnamed	Intermittent/ephemeral	—	0.005	—
	3315	Deer Creek	Perennial	—	0.02	WWSF
	4887	North Branch Root River	—	93.3	0.04	—
	5985	North Branch Root River	—	42.8	0.03	—
	21136	Deer Creek	—	77.4	0.02	—
	22799	North Branch Root River	—	496.2	0.16	—
Direct to Lake Michigan	1845	Poplar Creek	Perennial	—	0.03	Unknown
	3052	Unnamed	Intermittent/ephemeral	—	0.01	—
	3054	Unnamed	Intermittent/ephemeral	—	0.08	—
	3055	Unnamed	Intermittent/ephemeral	—	0.001	—
	3294	Unnamed	Intermittent/ephemeral	—	0.003	—
	3305	Unnamed	Intermittent/ephemeral	—	0.005	—
	3315	Deer Creek	Perennial	—	0.02	WWSF
	5428	Lake Michigan	Lake	—	6.24	—
	21136	Deer Creek	—	77.4	0.02	—

[a]WDNR (2010f).

[b] The current theoretical project alignment for Lake Michigan-Racine Supply is parallel to the Goose Lake Branch Canal, but the actual construction corridor would be narrowed to avoid impacts to the waterbody.

TABLE 2-8
Summary of Acres of Water Body Crossings
City of Waukesha Water Supply

Name	Deep and Shallow Wells	Shallow Aquifer and Fox River Alluvium	Lake Michigan–Milwaukee Supply	Lake Michigan-Oak Creek Supply	Lake Michigan–Racine Supply	Underwood Creek to Lake Michigan	Root River to Lake Michigan	Direct To Lake Michigan
Deer Creek	—	—	0.02	0.02	—	0.02	0.02	0.02
Lake Michigan	—	—	—	—	—	—	—	6.24
Muskego Drainage Canal	—	—	—	—	0.51	—	—	—
Fox River	0.24	0.59	—	—	—	—	—	—
Pebble Brook	0.08	0.08	—	—	—	—	—	—
Poplar Creek	—	—	0.03	0.03	1.12	0.03	0.03	0.03
Honey Creek	—	—	—	—	—	—	—	—
North Branch Root River	—	—	—	—	—	—	—	—
East Branch Root River	—	—	—	—	—	—	—	—
Husher Creek	—	—	—	—	—	—	—	—
Hoods Creek	—	—	—	—	—	—	—	—
Oak Creek	—	—	—	—	—	—	—	—
North Branch Oak Creek	—	—	—	—	—	—	—	—
Goose Lake Branch Canal	—	—	—	—	—	—	—	—
Root River Canal	—	—	—	—	—	—	—	—
Mill Creek	—	—	—	—	—	—	—	—
Unnamed	0.04	0.04	0.01	0.01	0.72	0.11	0.10	0.10
Grand Total	**0.36**	**0.71**	**0.06**	**0.06**	**2.35**	**0.16**	**0.15**	**6.39**

TABLE 2-9
Summary of Number of Water Body Crossings
City of Waukesha Water Supply

Alt 1 Deep and Shallow Wells	Alt 2 Shallow Aquifer and Fox River Alluvium	Alt 3a-1 Milwaukee	Alt 3a-2 Oak Creek	Alt 3a-3 Racine	Alt 3b-1 Underwood Creek	Alt 3b-2 Root River	Alt 3b-3 Direct To Lake Michigan
4	4	8	11	16	9	11	9

The City will minimize construction impacts to surface waters during construction. The specific practices for individual surface water crossings will be developed once the final pipeline alternative has been selected. Then the City will work with applicable federal, state, and local stakeholder agencies to select the construction measures and mitigation plans necessary on a case by case basis to minimize impacts to local surface water resources to the extent feasible.

Typical pipeline construction surface-water-crossing BMPs are included in Appendix 2-A.

2.4 Wetlands

Most wetlands are classified as "waters of the United States," which are protected under Section 404 of the Clean Water Act (34 USC 1344). The term "waters of the United States" covers both deepwater aquatic habitats and six categories of special aquatic sites (of which wetlands are one category) designated by the EPA in its Section 404(b)(1) guidelines (EPA, 2010b).

The USACE and EPA jointly define wetlands as "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that in normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Wetlands generally include swamps, marshes, bogs, and similar areas.

For an area to be defined as a jurisdictional wetland, it must, under normal circumstances, possess positive indicators of each of three parameters: hydrophytic vegetation, hydric soils, and wetland hydrology, described below.

- *Hydrophytic vegetation.* The prevalent vegetation must consist of plants adapted to life in hydric soils. These species, due to morphological, physiological, or reproductive adaptations, can and do persist in anaerobic soil conditions.
- *Hydric soils.* Soils in wetlands must be classified as hydric or they must possess characteristics that are associated with reducing soil conditions. Hydric soils are soils that are "saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation" (USACE, 1987).
- *Wetland hydrology.* The area must be permanently or periodically inundated or have soils that are saturated to the surface for some time during the growing season.

2.4.1 Existing Resources

Wetlands crossed by the supply and return flow alternatives, located at the proposed aboveground structures (including well houses and water treatment plant), and affected by groundwater drawdown were identified from the 2005 Wetlands Inventory provided by

SEWRPC and WDNR (2005) to produce the an accurate and comprehensive desktop wetlands inventory.

Wetlands affected by groundwater pumping were determined from groundwater modeling results. Groundwater modeling is documented in Appendix O of the Application. The impact to wetlands from a 5 foot or greater and 1 foot or greater groundwater drawdown is shown in the figures at the end of this Chapter. Because a wetland is designated by the type of plants, hydrology, and soil type, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. Table 2-10 lists the total wetlands affected by various groundwater drawdown depths for each groundwater supply alternative.

TABLE 2-10
Wetland Impacts from Groundwater Drawdown (Acres)
City of Waukesha Water Supply

	Emergent or Wet Meadow	Filled or Drained Wetland	Flats or Unvegetated Wet Soil	Forested	Open Water & Aquatic Bed	Scrub/ Shrub	Grand Total
Deep and Shallow Aquifers 5 foot or greater groundwater drawdown	240.6	1.8	12.1	307.5	11.1	419.0	992.1
Deep and Shallow Aquifers 1 foot or greater groundwater drawdown	710.2	11.3	50.5	932.2	88.6	1,294.4	3,087.2
Shallow Aquifer and Fox River Alluvium 5 foot or greater groundwater drawdown	475.0	2.4	30.4	547.9	37.0	871.3	1,964.0
Shallow Aquifer and Fox River Alluvium 1 foot or greater groundwater drawdown	1,079.2	12.5	74.5	1,278.7	103.4	1,558.2	4,106.5

Table 2-11 lists the wetlands crossed by the supply and return flow alternatives. Please see Chapter 1 for figures associated with each of the alternatives. There is some overlap between the wetlands potentially affected by groundwater drawdown and wetlands only affected by supply and return flow route alternative pipeline or aboveground structure construction. Consequently, only wetlands affected by the pipeline or aboveground structure construction are listed in Table 2-11.

Wetland quality is decreased by various disturbances, including agricultural activities, silviculture, residential development, transportation and utility easements, drainage modifications (ditches, dams, drain tiles, stream channelization, etc.), and the invasion of exotic or nuisance plants. These disturbances usually alter the plant species composition or hydrological regime of an area, which in turn alter wetland quality.

2.4.2 Impacts and Mitigation

A discussion regarding wetland crossing acreages associated with each of the alternatives has been included below and is summarized in Table 2-11. Additional analysis on the significance of wetland acreages affected for each alternative in comparison to other land use types crossed can be found in ER Chapter 7, "Land Use." Potential wetlands impacts are described in terms of temporary construction and operational impacts. Pipeline construction impacts to wetlands are expected to be temporary in nature while operational impacts are

expected to be ongoing permanent impacts. Operational impacts are subdivided into aboveground structure impacts and impacts from groundwater level drawdown.

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
Supply				
Deep and Shallow Aquifers	7963	Emergent/wet meadow	556.9	1.60
	7982	Emergent/wet meadow	597.2	1.83
	8111	Flats/unvegetated wet soil	—	0.01
	8122	Scrub/shrub	—	0.13
	8129	Scrub/shrub	474.7	1.34
	8146	Scrub/shrub	872.4	1.50
	8178	Scrub/shrub	480.3	0.83
	8197	Scrub/shrub	526.8	0.71
	8246	Scrub/shrub	—	0.07
	8263	Scrub/shrub	283.3	0.58
	8315	Forested	—	0.02
	8325	Forested	—	0.02
	8392	Forested	—	0.84
	8395	Forested	235.7	0.40
	8399	Forested	611.9	0.95
	8401	Forested	—	0.01
Shallow Aquifer and Fox River Alluvium	7963	Emergent/wet meadow	556.9	1.60
	7982	Emergent/wet meadow	597.2	1.83
	8044	Emergent/wet meadow	—	0.52
	8089	Emergent/wet meadow	58.6	0.28
	8111	Flats/unvegetated wet soil	—	0.01
	8122	Scrub/shrub	—	0.13
	8129	Scrub/shrub	474.7	1.34
	8146	Scrub/shrub	872.4	1.50
	8178	Scrub/shrub	480.3	0.83
	8179	Scrub/shrub	45.8	0.31
	8184	Scrub/shrub	220.8	1.09
	8197	Scrub/shrub	526.8	0.71
	8246	Scrub/shrub	—	0.07
	8249	Scrub/shrub	—	0.11
	8263	Scrub/shrub	283.3	0.58

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	8266	Scrub/shrub	—	0.15
	8303	Forested	782.9	1.34
	8315	Forested	—	0.02
	8324	Forested	—	1.23
	8325	Forested	902.8	2.06
	8392	Forested	—	0.84
	8395	Forested	235.7	0.40
	8399	Forested	611.9	0.95
	8401	Forested	248.5	1.59
	8402	Forested	213.5	2.42
Lake Michigan—Milwaukee Supply	4965	Scrub/shrub	216.7	0.38
	7962	Emergent/wet meadow	—	0.37
	8145	Scrub/shrub	—	0.16
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49
	8465	Forested	—	0.12
	8723	Emergent/wet meadow	—	0.08
	8909	Scrub/shrub	—	0.30
	8911	Scrub/shrub	—	0.17
	8915	Scrub/shrub	—	0.001
	8920	Scrub/shrub	—	0.11
	8921	Scrub/shrub	—	0.14
	8923	Scrub/shrub	—	0.07
	9184	Forested	—	0.01
	9306	Open water	—	0.01
	10454	Emergent/wet meadow	—	0.02
	11047	Emergent/wet meadow	313.4	0.50
	11672	Scrub/shrub	—	0.02
	11796	Forested	637.4	1.08
	11799	Forested	1286.9	2.53
	11973	Forested	—	0.002
	12645	Forested	—	0.02
	12650	Forested	—	0.15
	12660	Forested	—	0.01

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
Lake Michigan—Oak Creek Supply	4965	Scrub/shrub	—	0.38
	7962	Emergent/wet meadow	—	0.37
	8145	Scrub/shrub	—	0.16
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49
	8465	Forested	—	0.12
	8723	Emergent/wet meadow	—	0.08
	8909	Scrub/shrub	—	0.30
	8911	Scrub/shrub	—	0.17
	8915	Scrub/shrub	—	0.001
	8920	Scrub/shrub	—	0.11
	8921	Scrub/shrub	—	0.14
	8923	Scrub/shrub	—	0.07
	9184	Forested	—	0.01
	9306	Open water	—	0.01
	10454	Emergent/wet meadow	—	0.02
	10748	Emergent/wet meadow	—	0.03
	10753	Emergent/wet meadow	—	0.52
	10810	Emergent/wet meadow	—	0.17
	10822	Emergent/wet meadow	—	0.13
	10931	Emergent/wet meadow	—	0.72
	11026	Emergent/wet meadow	—	0.04
	11030	Emergent/wet meadow	—	0.07
	11031	Emergent/wet meadow	—	0.28
	11047	Emergent/wet meadow	—	0.50
	11273	Scrub/shrub	—	0.01
	11346	Scrub/shrub	—	0.09
	11363	Scrub/shrub	—	0.10
	11381	Scrub/shrub	—	0.04
	11433	Scrub/shrub	—	0.15
	11437	Scrub/shrub	—	0.001
	11548	Scrub/shrub	—	0.19
	11564	Scrub/shrub	—	1.82
	11586	Scrub/shrub	—	0.02

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	11638	Scrub/shrub	—	0.01
	11672	Scrub/shrub	—	0.02
	11772	Forested	—	0.40
	11796	Forested	—	0.01
	11799	Forested	—	2.49
	11970	Forested	—	0.16
	11972	Forested	—	1.14
	11973	Forested	—	0.002
	12265	Forested	—	0.09
	12285	Forested	—	0.04
	12294	Forested	—	0.47
	12299	Forested	—	0.26
	12384	Forested	—	0.43
	12505	Forested	—	0.09
	12645	Forested	—	0.02
	12650	Forested	—	0.15
	12660	Forested	—	0.01
	13168	Open water	—	0.03
	13185	Open water	—	0.02
Lake Michigan—Racine Supply	3	Emergent/wet meadow	—	0.61
	4965	Scrub/shrub	—	0.38
	7512	Scrub/shrub	—	0.02
	7895	Open water	—	0.39
	7962	Emergent/wet meadow	—	0.37
	8050	Emergent/wet meadow	—	1.94
	8126	Scrub/shrub	—	0.51
	8139	Scrub/shrub	—	0.09
	8145	Scrub/shrub	—	0.16
	8168	Scrub/shrub	—	0.43
	8183	Scrub/shrub	—	0.96
	8188	Scrub/shrub	—	0.54
	8192	Scrub/shrub	—	0.70
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	8338	Forested	—	1.14
	8382	Forested	—	0.03
	8383	Forested	—	0.05
	8436	Forested	—	0.20
	8465	Forested	—	0.12
	8625	Filled/drained wetland	—	0.17
	8632	Filled/drained wetland	—	0.37
	8766	Emergent/wet meadow	—	3.23
	8872	Scrub/shrub	—	3.46
	8873	Scrub/shrub	—	2.72
	8901	Scrub/shrub	—	0.47
	9139	Forested	—	0.06
	9184	Forested	—	0.01
	9309	Scrub/shrub	—	2.25
	9336	Emergent/wet meadow	—	0.22
	9337	Emergent/wet meadow	—	0.36
	9345	Emergent/wet meadow	—	0.40
	9353	Emergent/wet meadow	—	0.81
	9358	Emergent/wet meadow	—	0.001
	9366	Emergent/wet meadow	—	0.43
	9378	Emergent/wet meadow	—	1.85
	9381	Emergent/wet meadow	—	0.12
	9382	Emergent/wet meadow	—	0.10
	9395	Emergent/wet meadow	—	0.26
	9396	Emergent/wet meadow	—	0.55
	9406	Emergent/wet meadow	—	0.45
	9408	Emergent/wet meadow	—	0.15
	9423	Flats/unvegetated wet soil	—	0.21
	9432	Flats/unvegetated wet soil	—	0.61
	9434	Flats/unvegetated wet soil	—	0.44
	9450	Flats/unvegetated wet soil	—	1.84
	9451	Flats/unvegetated wet soil	—	0.63
	9457	Scrub/shrub	—	1.26
	9459	Scrub/shrub	—	0.54

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	9461	Scrub/shrub	—	0.42
	9464	Scrub/shrub	—	1.22
	9477	Scrub/shrub	—	0.75
	9503	Forested	—	0.51
	9531	Forested	—	0.03
	9552	Open water	—	0.20
	9556	Open water	—	0.50
	9559	Open water	—	0.22
	9561	Open water	—	0.05
	9592	Emergent/wet meadow	—	0.46
	9597	Emergent/wet meadow	—	0.26
	10058	Emergent/wet meadow	—	0.72
	10090	Emergent/wet meadow	—	0.26
	10164	Scrub/shrub	—	0.02
	10195	Forested	—	1.31
	13701	Filled/drained wetland	—	0.05
	13719	Filled/drained wetland	—	0.07
	14241	Emergent/wet meadow	—	0.02
	14301	Emergent/wet meadow	—	0.23
	14655	Flats/unvegetated wet soil	—	0.12
	15492	Emergent/wet meadow	—	0.21
	15519	Emergent/wet meadow	—	0.32
	15593	Emergent/wet meadow	—	0.12
	15606	Emergent/wet meadow	—	0.26
	15748	Emergent/wet meadow	—	0.36
	15821	Emergent/wet meadow	—	0.73
	16339	Flats/unvegetated wet soil	—	0.05
	16468	Flats/unvegetated wet soil	—	0.66
	16601	Scrub/shrub	—	2.03
	16870	Scrub/shrub	—	0.68
	16945	Scrub/shrub	—	0.86
	16956	Scrub/shrub	—	0.001
	16957	Scrub/shrub	—	0.26
	16973	Scrub/shrub	—	0.14

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	17124	Scrub/shrub	—	0.72
	17253	Scrub/shrub	—	0.18
	17860	Forested	—	0.85
	18252	Forested	—	0.30
	18661	Forested	—	0.02
	18669	Forested	—	0.75
	18679	Forested	—	1.47
	20167	Open water	—	0.26
Return				
Underwood Creek to Lake Michigan	6807	Emergent/wet meadow	187.0	0.30
	6934	Forested	20.0	0.04
	6937	Forested	1380.9	2.52
	7003	Forested	—	0.05
	7962	Emergent/wet meadow	—	1.38
	7970	Emergent/wet meadow	—	0.00
	8015	Emergent/wet meadow	—	0.17
	8125	Scrub/shrub	—	0.75
	8145	Scrub/shrub	—	0.16
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49
	8463	Forested	—	0.11
	8723	Emergent/wet meadow	—	0.08
	8909	Scrub/shrub	—	0.30
	8911	Scrub/shrub	—	0.17
	8915	Scrub/shrub	—	0.00
	8920	Scrub/shrub	—	0.11
	8921	Scrub/shrub	—	0.14
	8923	Scrub/shrub	—	0.07
	9184	Forested	—	0.01
	9306	Open water	—	0.01
	12683	Forested	1454.2	2.38
Root River to Lake Michigan	7962	Emergent/wet meadow	—	1.38
	7970	Emergent/wet meadow	—	0.00
	8015	Emergent/wet meadow	—	0.17

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
	8125	Scrub/shrub	—	0.75
	8145	Scrub/shrub	—	0.16
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49
	8463	Forested	—	0.11
	8723	Emergent/wet meadow	—	0.08
	8909	Scrub/shrub	—	0.30
	8911	Scrub/shrub	—	0.17
	8915	Scrub/shrub	—	0.00
	8920	Scrub/shrub	—	0.11
	8921	Scrub/shrub	—	0.14
	8923	Scrub/shrub	—	0.07
	9184	Forested	—	0.01
	9306	Open water	—	0.01
	11029	Emergent/wet meadow	—	0.01
	11030	Emergent/wet meadow	90.5	0.11
	11031	Emergent/wet meadow	175.3	0.30
	11047	Emergent/wet meadow	—	0.18
	11433	Scrub/shrub	114.5	0.20
	11638	Scrub/shrub	14.5	0.04
	11672	Scrub/shrub	—	0.10
	11794	Forested	—	0.00
	11796	Forested	15.3	0.03
	11799	Forested	2261.4	3.58
	11970	Forested	—	0.01
	11972	Forested	503.7	0.92
	12578	Forested	304.8	0.52
	12581	Forested	—	0.22
	12585	Forested	82.7	0.13
	12587	Forested	—	0.00
	12645	Forested	—	0.72
	12650	Forested	284.7	0.69
	12656	Forested	—	0.25
	12660	Forested	—	0.28

TABLE 2-11
Wetland Crossings
City of Waukesha Water Supply

Alternative	Wetland No.	Wetland Type	Crossing Width (ft)	Crossing Area (acres)
Direct to Lake Michigan	7962	Emergent/wet meadow	—	1.38
	7970	Emergent/wet meadow	—	0.00
	8015	Emergent/wet meadow	—	0.17
	8125	Scrub/shrub	—	0.75
	8145	Scrub/shrub	—	0.16
	8239	Scrub/shrub	—	0.13
	8290	Scrub/shrub	—	0.49
	8463	Forested	—	0.11
	8723	Emergent/wet meadow	—	0.08
	8909	Scrub/shrub	—	0.30
	8911	Scrub/shrub	—	0.17
	8915	Scrub/shrub	—	0.00
	8920	Scrub/shrub	—	0.11
	8921	Scrub/shrub	—	0.14
	8923	Scrub/shrub	—	0.07
	9184	Forested	—	0.01
	9306	Open water	—	0.01
	10321	Filled/drained wetland	121.6	0.13
	11046	Emergent/wet meadow	270.9	0.45
	11053	Emergent/wet meadow	—	0.19
	11054	Emergent/wet meadow	—	0.10
	11676	Scrub/shrub	—	0.01
	12613	Forested	—	0.08
	12627	Forested	—	0.08
	12628	Forested	—	0.01
	12643	Forested	193.6	0.32

2.4.2.1 Supply Alternatives

Deep and Shallow Aquifers. Two palustrine emergent (PEM) wetlands, seven palustrine scrub-shrub (PSS) wetlands, six palustrine forested (PFO) wetlands, and one flats/unvegetated wetlands are located along this alternative and affected by the pipeline construction or aboveground structures. As shown in Table 2-12, this supply route may affect 10.83 acres of wetlands. The breakdown of temporary and potential permanent impacts are described below, where permanent aboveground structures are discussed.

TABLE 2-12
Summary of Wetland Types Impacted (Acres)
City of Waukesha Water Supply

	Emergent or Wet Meadow	Flats or Unvegetated Wet Soil	Forested	Scrub/ Shrub	Filled or Drained Wetland	Open Water	Grand Total
Deep and Shallow Aquifers	3.42	0.01	2.24	5.16	—	—-	10.83
Shallow Aquifer and Fox River Alluvium	4.22	0.01	10.85	6.81	—-	—-	21.88
Lake Michigan-Milwaukee Supply	0.83	—-	3.9	14.82	—-	—-	19.55
Lake Michigan-Oak Creek Supply	2.91	—-	5.86	4.39	—-	0.06	13.22
Lake Michigan-Racine Supply	15.8	4.57	6.85	22.36	0.66	1.62	51.85
Underwood Creek to Lake Michigan	1.42	—-	5.11	7.32	—-	—-	13.85
Root River to Lake Michigan	2.22	—-	7.48	2.66	—-	0.01	12.37
Direct To Lake Michigan	2.36	—-	0.6	2.33	0.13	0.01	5.43

Note: Not all impacts are permanent. Permanent versus temporary construction impacts are discussed below.

The groundwater drawdown from pumping provides significant additional operational impacts as shown in Table 2-10. Nearly 1,000 acres of wetlands experience a 5 foot or greater groundwater drawdown. A 1-foot or greater groundwater drawdown occurs for over 3,000 wetland acres.

Because a wetland is designated by the type of plants, hydrology, and soil type, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. Species change, habitat change, or destruction of habitat could occur when the groundwater level is lowered below what is needed for plant species that have colonized areas based upon current groundwater levels. Vernal pool habitat is also very susceptible to changes in water depth and lowering groundwater levels could reduce the occurrence or duration of this seasonal habitat where it exists within the groundwater drawdown zone.

Shallow Aquifer and Fox River Alluvium. Four PEM, 11 PSS, and nine PFO wetlands are located along this alternative and affected by the pipeline construction or aboveground structures. As shown in Table 2-12, this supply route may affect 21.88 acres of wetlands. The breakdown of temporary and potential permanent impacts is described below, where permanent aboveground structures are discussed.

The groundwater drawdown provides significant additional operational impacts, as shown in Table 2-10. Nearly 2,000 acres of wetlands experience a 5-foot or greater groundwater drawdown. A 1-foot or greater groundwater drawdown occurs for over 4,000 wetland acres. The same potential habitat changes from groundwater drawdown described for the Deep and Shallow Aquifer alternative also apply to this alternative.

Lake Michigan–Milwaukee Supply. Four PEM, 11 PSS, and 11 PFO wetlands are located along this alternative and affected by the pipeline construction. As shown in Table 2-12, this supply route may affect 19.55 acres of wetlands; however, all impacts will be temporary in nature.

Lake Michigan–Oak Creek Supply. Twelve PEM, 21 PSS, 20 PFO, and three open-water wetlands are located along this alternative and affected by the pipeline construction. As shown in

Table 2-12, this supply route may affect 13.22 acres of wetlands; however, all impacts will be temporary in nature.

Lake Michigan–Racine Supply. Twenty-nine PEM, 29 PSS, 16 PFO, 4 filled/drained, 8 flat/unvegetated soil, and 6 open-water wetlands are located along this alternative and affected by the pipeline construction. As shown in Table 2-12, this supply route may affect 51.85 acres of wetlands; however, all impacts will be temporary in nature.

2.4.2.2 Return Flow Alternatives

Underwood Creek to Lake Michigan. Five PEM, 10 PSS, and six PFO wetlands are located along this alternative and affected by the pipeline construction. As shown in Table 2-12, this return flow alternative may affect 13.85 acres of wetlands, but all impacts will be temporary in nature.

Root River to Lake Michigan. Eight PEM, 13 PSS, 15 PFO, and one open-water wetland are located along this alternative and affected by the pipeline construction. As shown in Table 2-12, this return flow alternative may affect 12.37 acres of wetlands; however, all impacts will be temporary in nature.

Direct to Lake Michigan. Seven PEM, 11 PSS, six PFO wetlands, one open-water wetland, and one filled/drained wetland are located along this alternative and affected by the pipeline construction. As shown in Table 2-12, this return flow alternative may affect 5.43 acres of wetlands; however, all impacts will be temporary in nature.

2.4.2.3 Aboveground Structures

Aboveground structures associated with the various alternatives represent potential permanent impacts to wetland resources. Permanent structures that may be necessary, depending on the final alternative selected, include, but are not limited to, pump houses, access roads, and water treatment plants. Preliminary siting of aboveground resources has been completed and is associated primarily with the Deep and Shallow Aquifers alternative and the Shallow Aquifer and Fox River Alluvium alternative. The potential permanent impacts to wetland resources for these two alternatives are included below. The remaining pipeline alternatives have minimal aboveground structures.

Deep and Shallow Aquifers. Of the 10.83 acres of wetlands potentially temporarily affected by this alternative, 6.31 acres, or 58 percent, are affected by the 11 proposed well houses and corresponding access roads. No wetland impacts are anticipated as a result of the proposed water treatment plant for this alternative.

Shallow Aquifer and Fox River Alluvium. This alternative would affect 21.88 acres of wetlands, of which 17.26 acres are the result of the 15 proposed well houses. Approximately 0.11 acre will be as a result of the proposed water treatment plant.

2.4.2.4 Mitigation

Based on the results of the groundwater modeling study completed (Appendix O to the Application), approximately 1,000 to 2,000 acres of wetlands could be affected by a 5-foot groundwater drawdown, depending upon the groundwater water supply alternative. For 1 foot of drawdown, approximately 3,000 to 4,000 wetland acres could be affected. As described in the groundwater modeling results in Appendix O to the Application, an alternative groundwater well location option, which involved altering and adding well

locations to spread them farther apart to reduce the potential environmental impacts, was analyzed for the Shallow Aquifer and Fox River Alluvium alternative. A review of the modeling drawdown for that alternative (see Section 4 of the Application and the figures in this chapter) indicated the 5-foot drawdown would reduce the wetland impact to 1,783 acres and the 1-foot drawdown would reduce the wetland impact to 4,063 acres. The wetland impacts from this variation only reduced the impacts from the base case 1 to 9 percent. As a result, it appears that any shallow groundwater supply alternative in the Troy Bedrock aquifer near the City of Waukesha will result in potentially significant impacts.

The construction for supply and return flow pipeline alternatives are co-located with existing infrastructure to the greatest extent feasible in order to minimize wetland impacts by utilizing previously disturbed land and reducing habitat fragmentation. The Deep and Shallow Aquifers and Shallow and Fox River Alluvium alternatives will require impacts to previously undisturbed wetland areas due to the need to drill wells in rural, undeveloped locations. With the exception of proposed aboveground structures and groundwater drawdown, construction impacts will be temporary in nature.

Temporary construction impacts in wetlands may include loss of herbaceous and scrub-shrub vegetation, wildlife habitat disruption, soil disturbance associated with grading, trenching, and stump removal, sedimentation and turbidity increases, and hydrological profile changes. Impacts will be minimized by adherence to BMPs developed by coordination among the City and agency stakeholders, and state and local permit requirements.

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FIGURE 2-1 SHALLOW AQUIFER WITH FOX RIVER ALLUVIUM ONE FOOT DRAWDOWN AREA

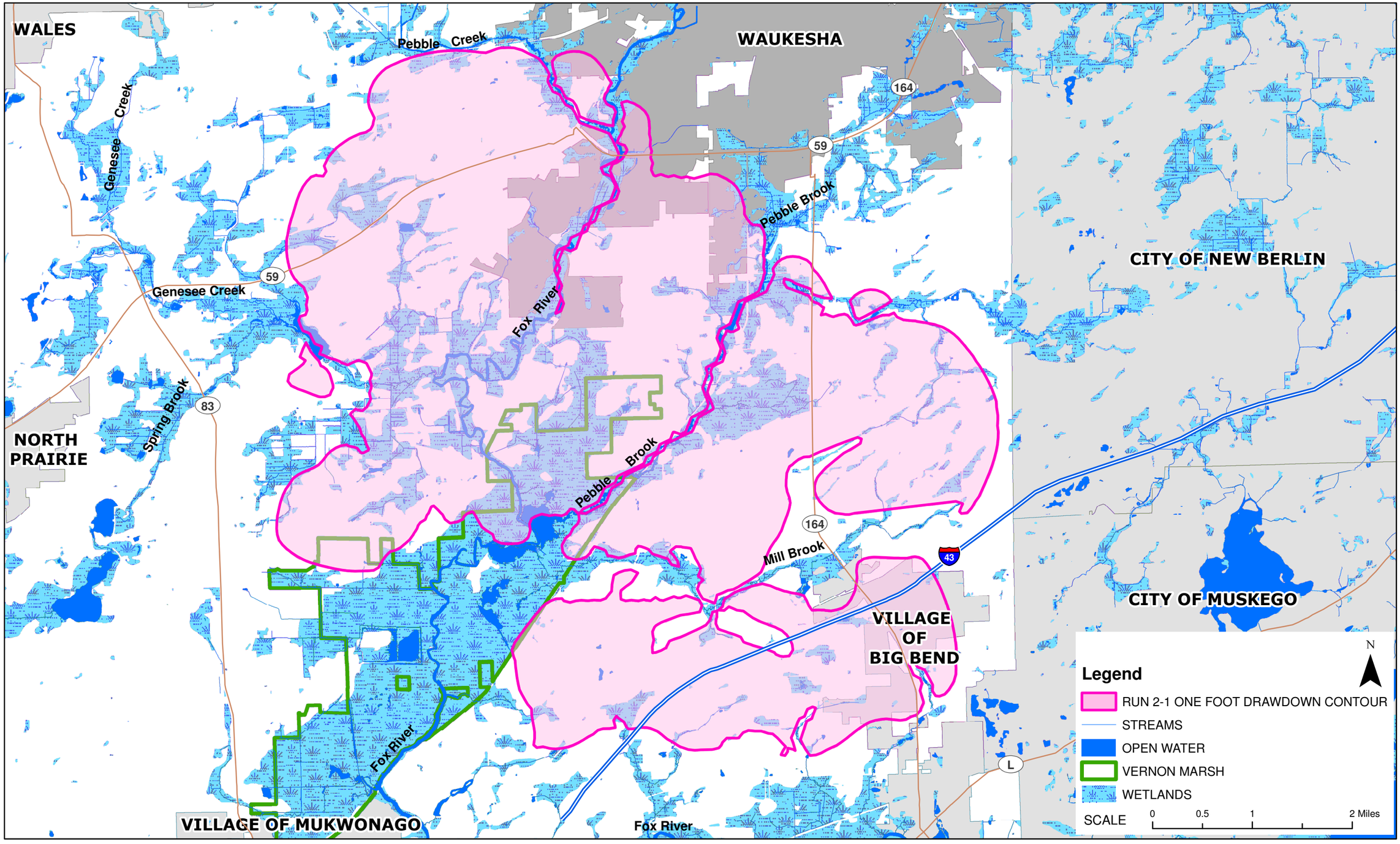


FIGURE 2-2 SHALLOW AQUIFER WITH FOX RIVER ALLUVIUM
FIVE FOOT DRAWDOWN AREA

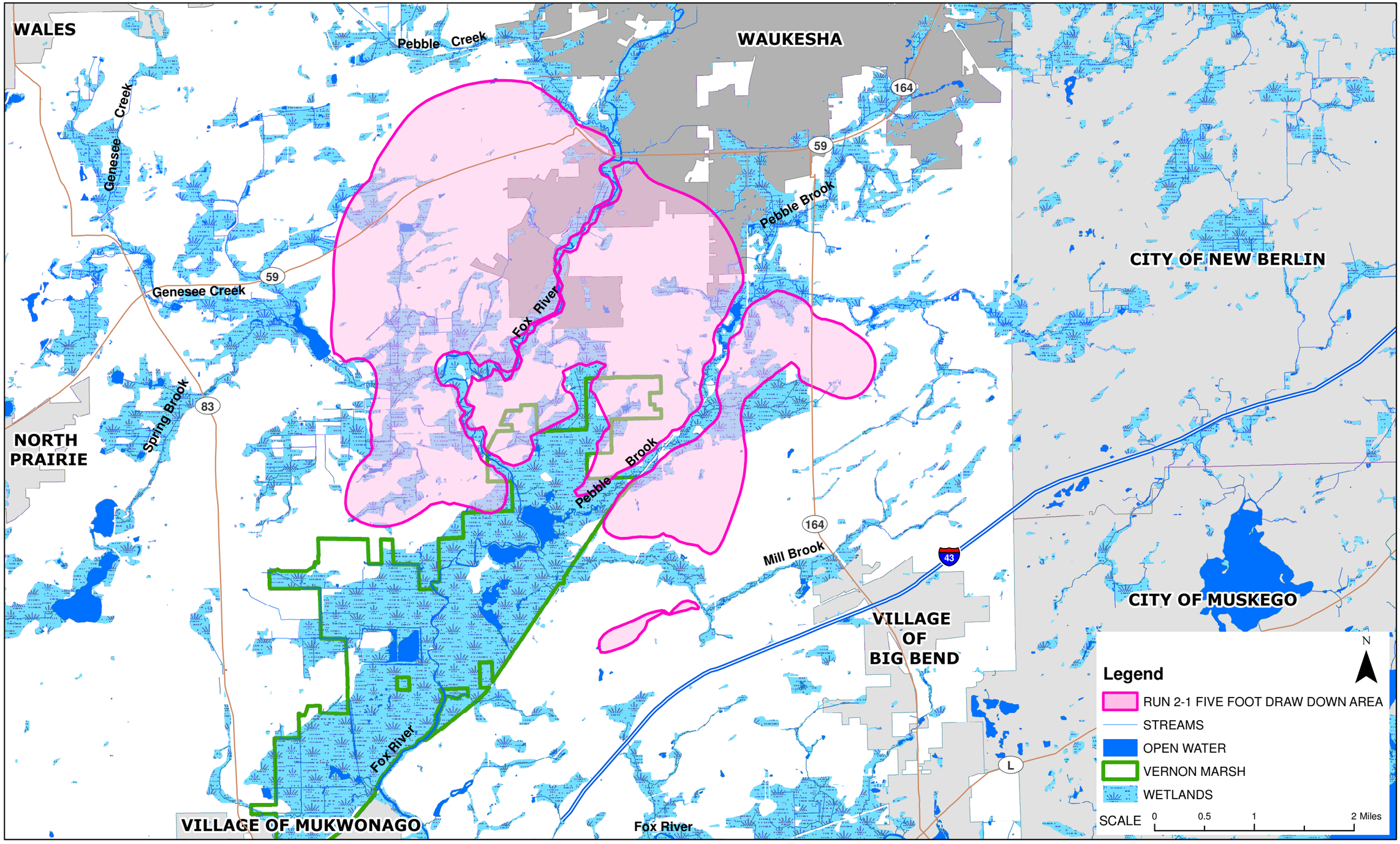


FIGURE 2-3 DEEP AND SHALLOW AQUIFERS
ONE FOOT DRAWDOWN AREA

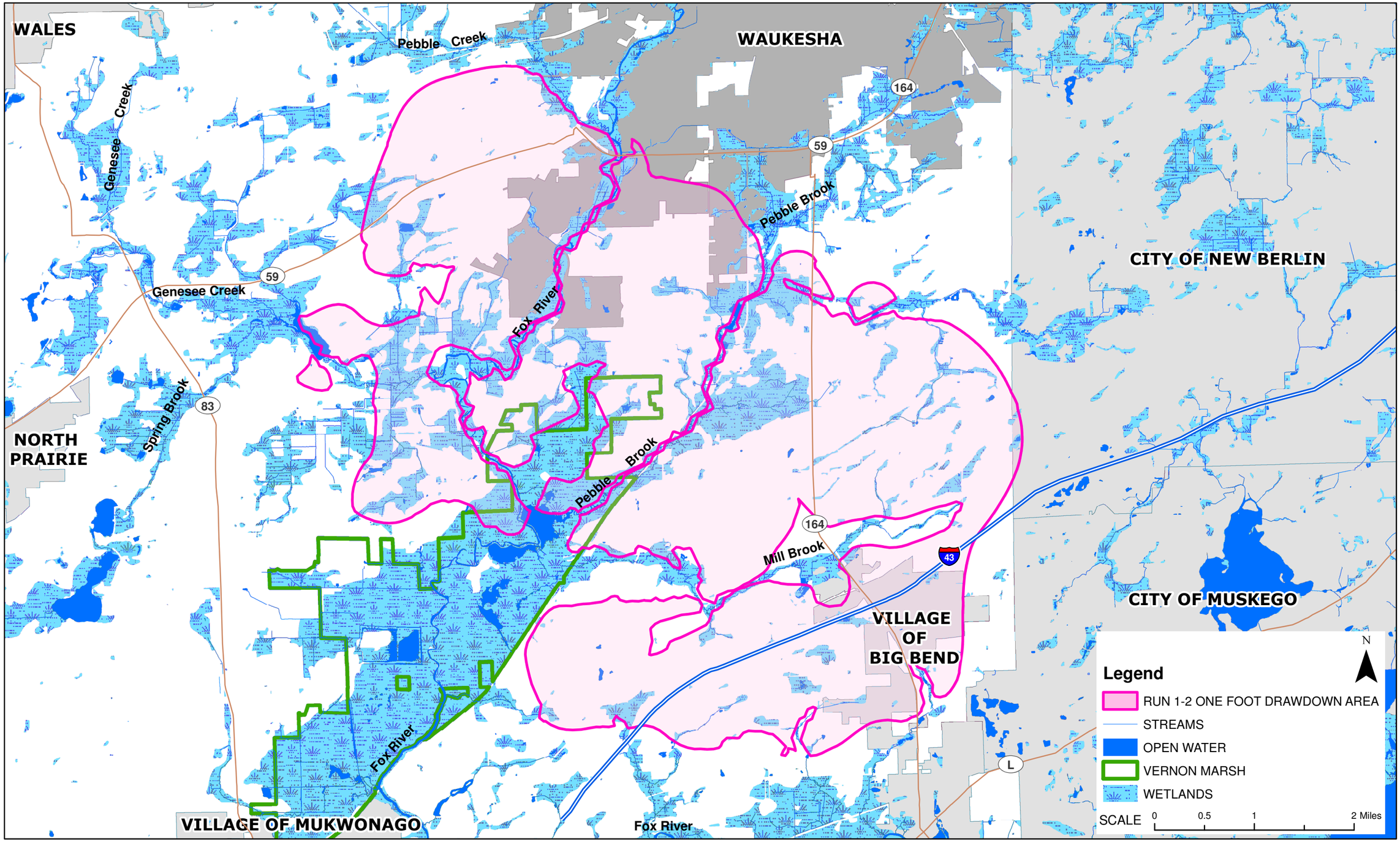


FIGURE 2-4 DEEP AND SHALLOW AQUIFERS
FIVE FOOT DRAWDOWN AREA

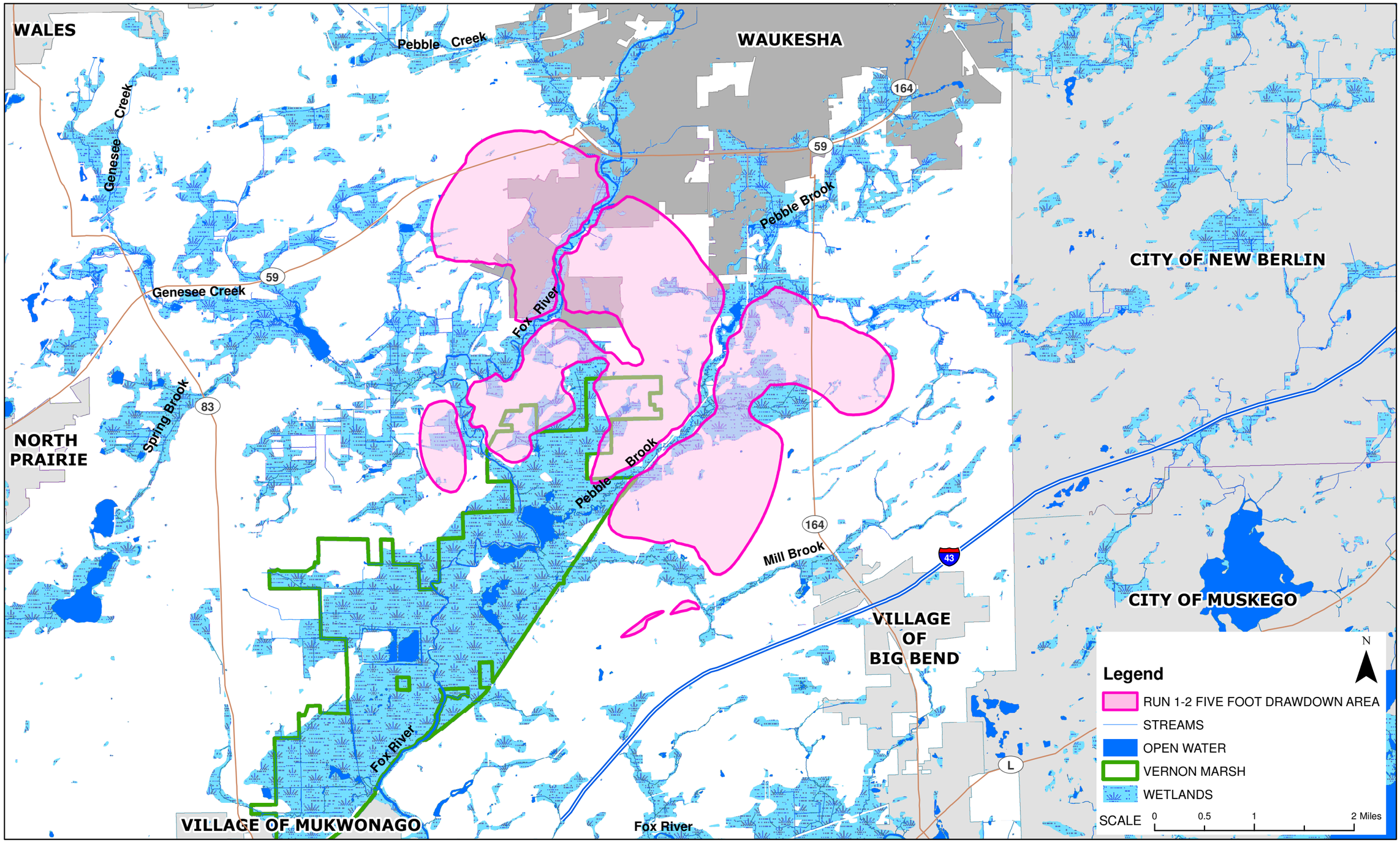


FIGURE 2-5 SHALLOW AQUIFER WITH FOX RIVER ALLUVIUM ONE FOOT DRAWDOWN AREA AND SPRINGS

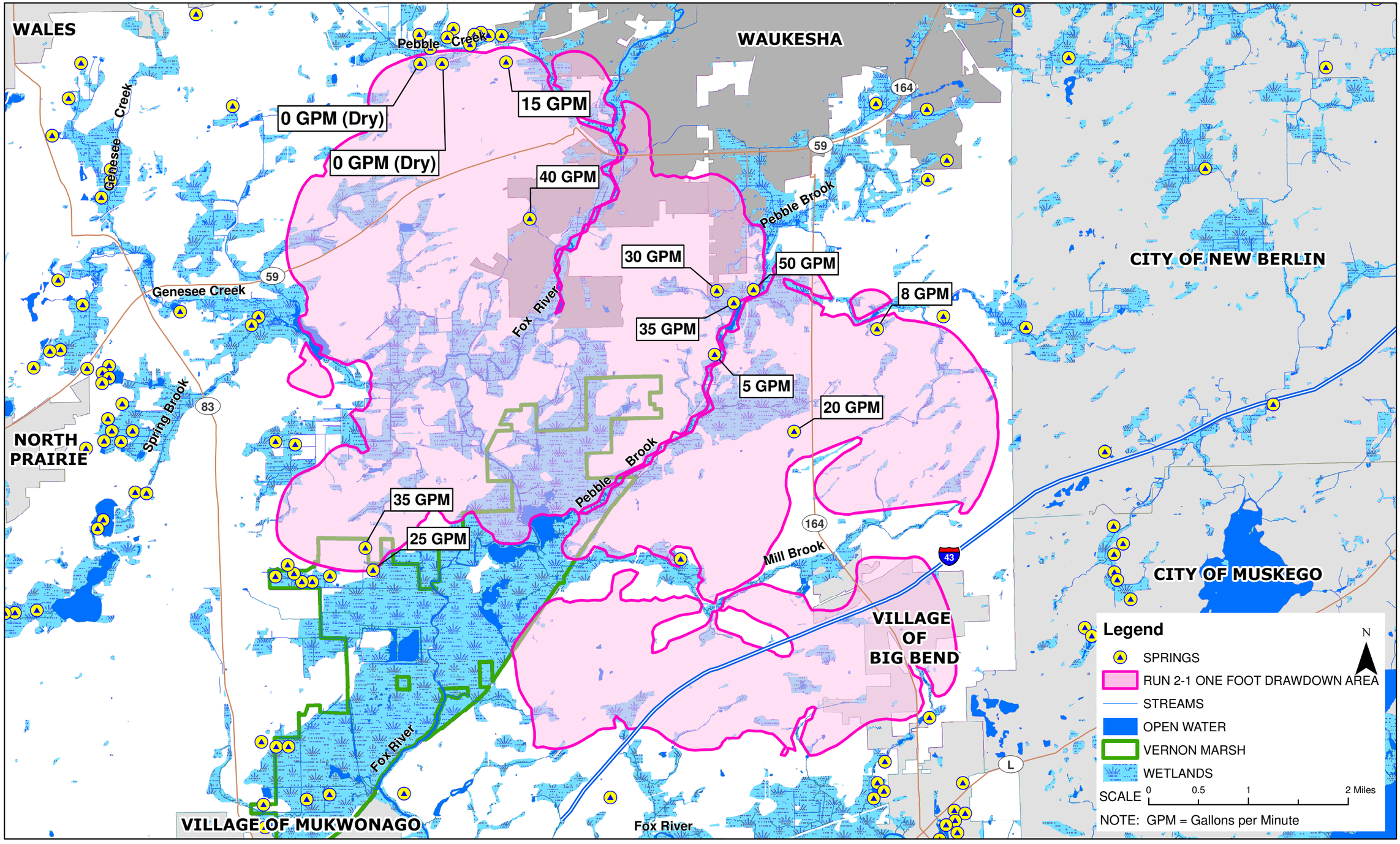
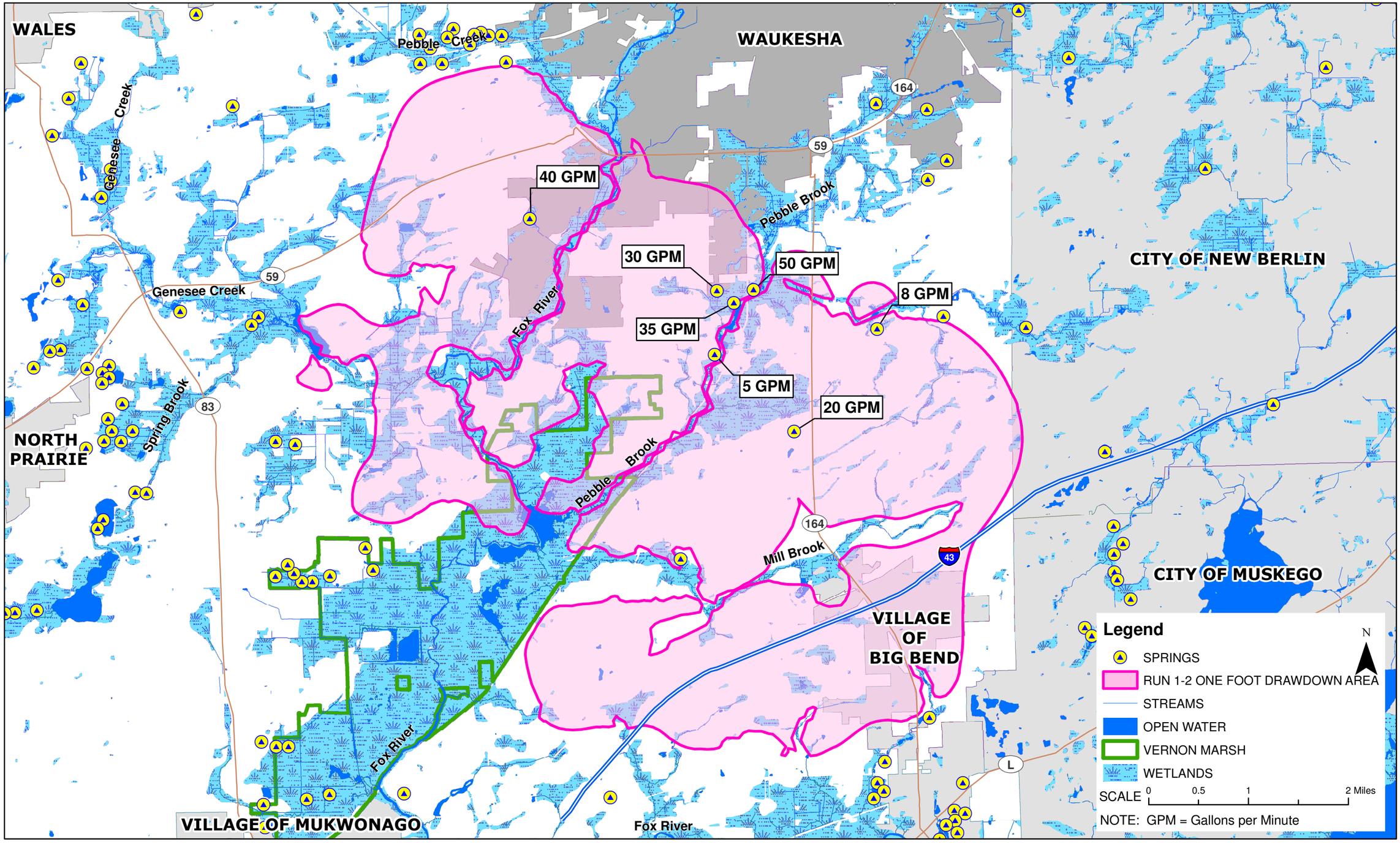


FIGURE 2-6 DEEP AND SHALLOW AQUIFERS ONE FOOT DRAWDOWN AREA AND SPRINGS



Appendix 2-A

Example Wetland and Waterway Pipeline Construction Crossing Impact Minimization Techniques

APPDENDIX 2-A

Example Wetland and Waterbody Pipeline Construction and Mitigation Procedures

This appendix outlines common practices that can be used to minimize the impact of constructing long pipelines through waterways or wetlands. The process of providing Lake Michigan water to the City of Waukesha, as discussed in the Environmental Report, will require the construction of pipelines crossing water bodies and wetlands. All of the preliminary design alternatives analyzed in the study have shown that they will cross a wetland or waterway of some kind (wetland, stream, etc.).

The list below provides examples of the techniques that may be used during construction of the pipeline. These techniques were identified from typical practices used for prior long pipeline construction projects in Wisconsin, including Federal Energy Regulatory Commission pipeline projects, among others. The actual procedures that will be implemented during construction will be agreed upon by the regulatory agencies during the final design of this project and may include some of these techniques as well as others.

1.01 INSTALLATION OF WATERBODY CROSSINGS

A. General Crossing Procedures:

1. Comply with the Corps of Engineers (COE), or its delegated agency, permit terms and conditions.
2. Construct crossings as close to perpendicular to the axis of the waterbody channel as engineering and routing conditions permit.
3. If the pipeline parallels a waterbody, attempt to maintain at least 15 feet of undisturbed vegetation between the waterbody (and any adjacent wetland) and the construction right-of-way.
4. Where waterbodies meander or have multiple channels, route the pipeline to minimize the number of waterbody crossings.
5. Maintain adequate flow rates to protect aquatic life, and prevent the interruption of existing downstream uses.
6. Waterbody buffers (extra work area setbacks, refueling restrictions, etc.) must be clearly marked in the field with signs and/or highly visible flagging until construction-related ground disturbing activities are complete.

B. Spoil Pile Placement and Control:

1. All spoil from minor and intermediate waterbody crossings, and upland spoil from major waterbody crossings, must be placed in the construction right-of-way at least 10 feet from the water's edge or in additional extra work areas as described in section V.B.2.

2. Use sediment barriers to prevent the flow of spoil or heavily silt laden water into any waterbody.

C. Equipment Bridges:

1. Only clearing equipment and equipment necessary for installation of equipment bridges may cross waterbodies prior to bridge installation. Limit the number of such crossings of each waterbody to one per piece of clearing equipment.
2. Construct equipment bridges to maintain unrestricted flow and to prevent soil from entering the waterbody. Examples of such bridges include:
   a. Equipment pads and culvert(s).
   b. Equipment pads or railroad car bridges without culverts.
   c. Clean rock fill and culvert(s); and
   d. Flexi-float or portable bridges.
3. Additional options for equipment bridges may be utilized that achieve the performance objectives noted above. Do not use soil to construct or stabilize equipment bridges.
4. Design and maintain each equipment bridge to withstand and pass the highest flow expected to occur while the bridge is in place. Align culverts to prevent bank erosion or streambed scour. If necessary, install energy dissipating devices downstream of the culverts.
5. Design and maintain equipment bridges to prevent soil from entering the waterbody.
6. Remove equipment bridges as soon as possible after permanent seeding unless the COE, or its delegated agency, authorizes it as a permanent bridge.
7. If there will be more than 1 month between final cleanup and the beginning of permanent seeding and reasonable alternative access to the right-of-way is available, remove equipment bridges as soon as possible after final cleanup.

D. Dry-Ditch Crossing Methods:

1. Unless approved otherwise by the appropriate state agency, install the pipeline using one of the dry-ditch methods outlined below for crossings of waterbodies up to 30 feet wide (at the water's edge at the time of construction) that are state-designated as either coldwater or significant coolwater or warmwater fisheries.
2. Dam and Pump:
   a. The dam-and-pump method may be used without prior approval for crossings of waterbodies where pumps can adequately transfer streamflow volumes around the work area, and there are no concerns about sensitive species passage.
   b. Implementation of the dam-and-pump crossing method
   c. Must meet the following performance criteria:
      1) Use sufficient pumps, including on-site backup pumps, to maintain downstream flows;
      2) Construct dams with materials that prevent sediment and other pollutants from entering the waterbody (e.g., sandbags or clean gravel with plastic liner);
      3) Screen pump intakes;
      4) Prevent streambed scour at pump discharge; and

5) Monitor the dam and pumps to ensure proper operation throughout the waterbody crossing.

3. Flume Crossing: The flume crossing method requires implementation of the following steps:
   a. Install flume pipe before any trenching;
   b. Use sand bag or sand bag and plastic sheeting diversion structure or equivalent to develop an effective seal and to divert stream flow through the flume pipe (some modifications to the stream bottom may be required in to achieve an effective seal);
   c. Properly align flume pipe(s) to prevent bank erosion and streambed scour;
   d. Do not remove flume pipe during trenching, pipelaying, or backfilling activities, or initial streambed restoration efforts; and;
   e. Remove all flume pipes and dams that are not also part of the equipment bridge as soon as final cleanup of the stream bed and bank is complete.
4. Horizontal Directional Drill (HDD): To the extent they were not provided as part of the pre-certification process, for each waterbody or wetland that would be crossed using the HDD method, provide a plan that includes:
   a. Site-specific construction diagrams that show the location of mud pits, pipe assembly areas, and all areas to be disturbed or cleared for construction;
   b. A description of how an inadvertent release of drilling mud would be contained and cleaned up; and
   c. A contingency plan for crossing the waterbody or wetland in the event the directional drill is unsuccessful and how the abandoned drill hole would be sealed, if necessary.

E. Crossings of Minor Waterbodies: Where a dry-ditch crossing is not required, minor waterbodies may be crossed using the open-cut crossing method, with the following restrictions:

1. Except for blasting and other rock breaking measures (if applicable), complete instream construction activities (including trenching, pipe installation, backfill, and restoration of the streambed contours) within 24 hours. Streambanks and unconsolidated streambeds may require additional restoration after this period;
2. Limit use of equipment operating in the waterbody to that needed to construct the crossing; and
3. Equipment bridges are not required at minor waterbodies that do not have a state-designated fishery classification (e.g., agricultural or intermittent drainage ditches). However, if an equipment bridge is used it must be constructed as described.

F. Crossings of Intermediate Waterbodies: Where a dry-ditch crossing is not required, intermediate waterbodies may be crossed using the open-cut crossing method, with the following restrictions:

1. Complete instream construction activities (not including blasting and other rock breaking measures, if applicable) within 48 hours, unless site specific conditions make completion within 48 hours infeasible;
2. Limit use of equipment operating in the waterbody to that needed to construct the crossing; and

3. All other construction equipment must cross on an equipment bridge as specified.

G. Crossings of Major Waterbodies: Before construction, the project sponsor shall develop a plan for each major water body crossing. This plan should be developed in consultation with the appropriate state and Federal agencies and should include extra work areas, spoil storage areas, sediment control structures, etc., as well as mitigation for navigational issues.

1.02 INSTALLATION OF WETLAND CROSSINGS

A. Extra Work Areas and Access Roads:

1. Locate all extra work areas (such as staging areas and additional spoil storage areas) at least 50 feet away from wetland boundaries, unless site constraints require a narrower buffer, except where the adjacent upland consists of actively cultivated or rotated cropland or other disturbed land.
2. The project sponsor shall develop a site-specific construction plan for each extra work area with a less than 50-foot setback from wetland boundaries (except where adjacent upland consists of actively cultivated or rotated cropland or other disturbed land) and a site-specific explanation of the conditions that will not permit a 50-foot setback.
3. Limit clearing of vegetation between extra work areas and the edge of the wetland to the certificated construction right-of-way.
4. The construction right-of-way may be used for access when the wetland soil is firm enough to avoid rutting or the construction right-of-way has been appropriately stabilized to avoid rutting (e.g., with timber riprap, prefabricated equipment mats, or terra mats). In wetlands that cannot be appropriately stabilized, all construction equipment other than that needed to install the wetland crossing shall use access roads located in upland areas. Where access roads in upland areas do not provide reasonable access, limit all other construction equipment to one pass through the wetland using the construction right-of-way.
5. The only access roads, other than the construction right-of-way, that can be used in wetlands, are those existing roads that can be used with no modification and no impact on the wetland.

B. Crossing Procedures:

1. Comply with COE, or its delegated agency, permit terms and conditions.
2. Assemble the pipeline in an upland area unless the wetland is dry enough to adequately support skids and pipe or pipe material necessitates a different implementation approach.
3. Use "directional drill” or “floating mat” techniques to place the pipe in the trench where water and other site conditions allow.
4. Minimize the length of time that topsoil is segregated and the trench is open.
5. Limit construction equipment operating in wetland areas to that needed to clear the construction right-of-way, dig the trench, fabricate and install the pipeline, backfill the trench, and restore the construction right-of-way.

6. Cut vegetation just above ground level, leaving existing root systems in place, and remove it from the wetland for disposal.
7. Limit pulling of tree stumps and grading activities to directly over the trenchline. Do not grade or remove stumps or root systems from the rest of the construction right-of-way in wetlands unless safety-related construction constraints require grading or the removal of tree stumps from under the working side of the construction right-of-way.
8. Segregate the top 1 foot of topsoil from the area disturbed by trenching, except in areas where standing water is present or soils are saturated or frozen. Immediately after backfilling is complete, restore the segregated topsoil to its original location.
9. Do not use rock, soil imported from outside the wetland, tree stumps, or brush riprap to support equipment on the construction right-of-way.
10. If standing water or saturated soils are present, or if construction equipment causes ruts or mixing of the topsoil and subsoil in wetlands, use low-ground-weight construction equipment, or operate normal equipment on timber riprap, prefabricated equipment mats, or terra mats.
11. Do not cut trees outside of the approved construction work area to obtain timber for riprap or equipment mats.
12. Attempt to use no more than two layers of timber riprap to support equipment on the construction right-of-way.
13. Remove all project-related material used to support equipment on the construction right-of-way upon completion of construction.

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Chapter 3
Vegetation and Wildlife Resources

CHAPTER 3

Vegetation and Wildlife Resources

3.1 Introduction

This section describes existing fish and wildlife resources, plant communities, sensitive species, special status species and habitats that may be directly or indirectly affected by the supply and return flow alternatives being evaluated. It considers anticipated impacts related to construction and operation. Information was derived from two principal sources: communication with federal and state agencies and published and unpublished natural resources data pertaining to the regional area. Due to the preliminary nature of the project, field surveys on the proposed corridor options have not yet been completed. A field review will be completed to delineate wetlands and survey habitats within proposed construction workspaces once a final supply and return flow route has been chosen. Based on the field review, measures will be taken to mitigate any identified impacts to vegetation and wildlife resources.

3.2 Wildlife Resources

Game and nongame wildlife species are regulated and protected under various legislation including the State of Wisconsin's wild game regulations, Wisconsin's Endangered and Threatened Species regulations (NR 27); and the federal Fish and Wildlife Conservation Act of 1980 (16 U.S.C. 2901-2911), the Endangered Species Act, and the Fish and Wildlife Coordination Act of 1958.

3.2.1 Existing Resources

Wildlife species require adequate food, water, cover, and living space for the survival of individuals and to maintain population viability. The various habitats within the project area support a variety of widespread and tolerant mammals, birds, reptiles, amphibians, and invertebrates. A aerial view of the alternative alignments is shown with the figures in ER Chapter 1. The wildlife habitats along the proposed workspace fall into four categories and several subcategories:

- *Open Unforested Areas* affected by the supply and return flow alternatives generally include cropland (fallow and active), undeveloped nonforested areas, and scrub-shrub land. Farm crops may serve as a food source for certain species, including whitetail deer and Canada goose. Uncultivated grasslands, pasture, scrub-shrub land, and maintained rights-of-way may support herbaceous and low-level woody vegetation, offering protective cover and forage food sources. Open areas may function as travel corridors where adjacent land is wooded or developed. Open, uncultivated areas may sustain abundant populations of small mammals, such as deer mouse and meadow vole, larger herbivorous mammals, such as woodchuck and eastern cottontail rabbit, and predatory omnivores or carnivores, such as opossum, striped skunk, and red fox. Open areas may provide suitable habitat for bird species, including red-winged blackbird, Canada goose, meadowlark, mourning dove, American crow, American robin, European starling, common grackle, and various sparrows. Open areas bordered by woodland habitats or

hedgerows are of particular value to birds and other wildlife because of the nesting and refuge opportunities they afford. Reptiles and amphibians that frequent open grassy areas include the eastern garter snake, blue racer, and American toad.

- *Wooded Areas* affected by the supply and return route options generally consist of deciduous upland forests. Forested areas exhibit a more complex structure than open areas and generally provide a higher-quality wildlife habitat. Large unfragmented tracts of forested land can provide important habitat for larger, territorial mammals (coyote, deer) and may provide habitat for migratory birds. Food sources from mature trees, as well as berries and other fruits from some understory shrubs and woody vines, are an important wildlife food source. Secondary canopy shrubs and saplings, brush piles, and fallen logs provide cover for various small- to medium-sized mammals. There will be little change in permanent forested riparian areas affected by the aboveground structures anticipated with the project as shown in the figures in ER Chapter 1. While impacts to forested riparian areas and wetlands may occur as a result of pipeline installation, these impacts are temporary in nature and will be managed by avoidance, minimization, and mitigation measures developed in coordination with the appropriate regulatory agencies. As a result, temporary impacts do not represent a significant resource concern.

- *Aquatic Areas* affected by the supply and return route options consist generally of streams and wetlands from pipeline construction and return flow receiving waters which includes Lake Michigan tributaries and Lake Michigan. Aquatic areas can provide habitat to a diverse wildlife population, and a number of common species (beaver, muskrat, herons, etc.) are dependent on aquatic habitat for food and shelter. Some animals and birds (beaver, muskrat, herons) are dependent on aquatic habitats for food and shelter. Others (e.g., raccoon) are less restricted but prefer to be close to water. Amphibians and many reptiles favor aquatic habitats; representative species include bullfrog and northern water snake. Aquatic habitat is discussed further in ER Chapter 2.

- *Developed Areas* affected by the Project generally consist of residential, commercial, and industrial land, and active recreational parks. These areas generally consist of asphalt and concrete surfaces, maintained turf grass, and landscape trees and shrubs. In general, these areas provide poor wildlife habitat. However, several opportunistic species (raccoon, opossum, squirrel, American crow, American robin, European starling, common grackle, various sparrows, etc.) have adapted well and thrive in urban and suburban settings.

3.2.2 Significant Habitat: Vernon Wildlife Area

Significant wildlife habitats typically include state game refuges, wildlife management areas, National Wildlife Refuges, and other unique or sensitive areas. A single state wildlife management area, Vernon Wildlife Area (VWA), is located within the proposed construction workspace for the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives. VWA is a 4,655-acre property in eastern Waukesha County consisting of wetlands and flowages associated with the Fox River and including a calcareous fen in the southern portion of the property. Adjacent uplands are dominated by grassland habitats with interspersed areas of limited hardwoods. The VWA provides significant wildlife habitat, especially for migrating and nesting waterfowl (WDNR, 2010d).

3.2.3 Construction and Operation Impacts and Mitigation

3.2.3.1 Impacts Outside of Vernon Wildlife Area

In general, impacts to wildlife resources as a result of constructing new supply and return flow water mains are anticipated to be minor and limited to temporary impacts during construction to tolerant opportunistic species. Clearing and grading the construction areas will result in loss of vegetative cover and may result in the mortality of less mobile fauna, such as small rodents, reptiles, and invertebrates, which may be unable to escape the construction area.

Construction disturbance will likely cause the temporary displacement of more mobile wildlife from the construction workspace and adjacent areas. Wooded habitat removed by construction will be replaced initially by nonwoody vegetation, which may provide food, shelter, and breeding space for small mammals and birds. Trees will be allowed to grow back on cleared workspace beyond the maintained maintenance corridor. Surface restoration will include coordination with regulatory agencies to provide preferred habitat vegetation applicable to adjacent land use and operational considerations.

After construction, wildlife is expected to return and colonize postconstruction habitats. Because the pipeline routes follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands, no permanent or long-term impacts to wildlife resources are anticipated other than those associated with permanent above ground structures predominantly associated with the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives (see Chapter 7, Table 7-1). Plans will accommodate general and site-specific protective measures for any sensitive wildlife habitat and species identified during the course of construction. Seasonal timing to account for reproductive and migratory patterns will be coordinated with state and federal agencies, as necessary.

Siting for the supply and return flow alternatives was chosen to minimize the overall land use impact by utilizing land already in use as roadways, utility corridors, or previously disturbed areas.

Stream crossings will be constructed as quickly as possible and stream habitats restored upon completion of construction. State-approved BMPs will be used to minimize sedimentation, turbidity, and other impacts that may temporarily affect stream vegetation and wildlife.

The City will continue to work with local, state, and federal agencies, landowners, and soil conservation authorities so that construction and mitigation procedures are compatible with both site-specific and regional environmental protection objectives.

3.2.3.2 Impacts to Vernon Wildlife Area (VWA)

A total of 1.25 acres of the VWA would be affected by the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives if either were constructed as currently proposed (see ER Chapter 7, Table 7-5). These impacts would consist of temporary, construction-type impacts.

In addition, due to the volume of water proposed to be withdrawn from the deep and shallow aquifers for the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium alternatives, there is the potential for a drawdown of the groundwater table

within the VWA. Groundwater modeling shows groundwater level drawdown associated with these alternatives and is discussed in Appendix O to the Application. The groundwater drawdown relative to the VWA is shown in ER Chapter 2 figures.

Groundwater drawdowns were compared for overlap to the VWA. The Deep and Shallow Aquifers alternative has a 5 foot or greater depth of groundwater drawdown affecting 291 acres, or a 1 foot or greater depth of groundwater drawdown affecting 609 acres. This level of groundwater drawdown is a significant impact upon the VWA habitat because much of the VWA is wetland and this level of drawdown could result in habitat type change. Wetland impacts are described in ER Chapter 2.4.

The Shallow Aquifer and Fox River Alluvium alternative has a 5 foot or greater depth of groundwater drawdown affecting 343 acres, or a 1 foot or greater depth of groundwater drawdown affecting 1,106 acres. This level of groundwater drawdown is a significant impact upon the VWA habitat because much of the VWA is wetland and this level of drawdown could result in habitat type change. Wetland impacts are described in ER Chapter 2.4.

The Lake Michigan water supply and return flow alternatives do not affect the VWA.

3.3 Vegetation

The figures in Chapter 1 show an aerial view of the alternative alignments which portray the land use and general vegetation along the routes for each alternative. Table 7-2 in ER Chapter 7, Land Use, provides a comprehensive breakdown of land use affected by each of the supply and return flow alternatives. (Note that there may be differences between land use types discussed in Chapter 7 and the vegetation and habitat types discussed here, in Chapter 3.)

3.3.1 Existing Resources

U.S. Department of Agriculture's *Descriptions of the Ecoregions of the United States* (USDA, 1995) describes a hierarchical classification system for ecological units on national and regional scales. Areas of the country are described as being within a specific domain, division, province, section, subsection, and landscape. Southeast Wisconsin is within the Humid Temperate Domain, Hot Continental Division, and Eastern Broadleaf Forest Province (USDA, 2010). Descriptions of these ecoregions are as follows:

3.3.1.1 Humid Temperate Domain

The climate of the Humid Temperate Domain, located in the middle latitudes (30° to 60°N), is governed by both tropical and polar air masses. The middle latitudes are subject to cyclones. Much of the precipitation in this belt comes from rising moist air along fronts within these cyclones. Pronounced seasons are the rule, with strong annual cycles of temperature and precipitation. Climates of the middle latitudes have a distinctive winter season, which tropical climates do not.

The Humid Temperate Domain contains forests of broadleaf deciduous and needleleaf evergreen trees. The variable importance of winter frost determines six divisions: warm continental, hot continental, subtropical, marine, prairie, and Mediterranean (USDA, 2010).

3.3.1.2 Hot Continental Division

The Hot Continental Division is characterized by hot summers and cool winters. In the warmer sections of the Hot Continental Division, the frost-free, or growing, season continues for 5 to 6 months and in the colder sections only 3 to 5 months. Snow cover is deeper and lasts longer in the northerly areas.

Vegetation in this climate division is winter deciduous forest, dominated by tall broadleaf trees that provide a continuous dense canopy in summer but shed their leaves completely in winter. Lower layers of small trees and shrubs are weakly developed. In spring, a ground cover of herbs quickly develops, but is greatly reduced after trees reach full foliage and shade the ground.

Soils are chiefly inceptisols, ultisols, and alfisols, which are rich in humus and moderately leached, with a distinct light-colored leached zone under the dark upper layer. The ultisols have a low supply of bases and a horizon in which clay has accumulated. Where topography is favorable, diversified farming and dairying are the most successful agricultural practices.

Rainfall decreases with distance from the ocean. Therefore, this division is subdivided into moist oceanic and dry continental provinces (USDA, 2010).

3.3.1.3 Eastern Broadleaf Forest Province

Most of the Eastern Broadleaf Forest Province has rolling hills, but some parts have close to flat topography. In Wisconsin the province has been glaciated. Broadleaf deciduous forests dominate the province and, owing to lower precipitation, the province also supports the oak-hickory association. The Eastern Broadleaf Forest in the northern states, such as Wisconsin, also supports the maple-basswood association (USDA, 2010).

3.3.2 Vegetation Communities of Special Concern

According to correspondence from the USFWS (2010), no vegetation communities of special concern or critical habitat occur within the construction workspaces associated with the supply and return flow alternatives.

WDNR (2010c) identified several vegetation communities of special concern (referred to in Wisconsin as "Natural Communities") that may be in the area of the supply and return flow alternatives. The pipeline alignments follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands, so few, if any impacts to Natural Communities are expected. Any project alignment impacts to these Natural Communities will be coordinated with the appropriate state and federal agencies and will be avoided and minimized. Potential Natural Communities include:

- Southern Dry Mesic Forest
- Southern Mesic Forest
- Mesic Prairie
- Wet Prairie
- Emergent Marsh
- Southern Sedge Meadow
- Calcareous Fen
- Shrub-Carr
- Northern Wet Forest
- Floodplain Forest
- Springs and Spring Runs

3.3.3 Construction and Operation Impacts and Mitigation

The City has selected pipeline routes to primarily follow areas that have already been developed or disturbed to minimize impacts to vegetation communities of special concern. The City will work with regulatory agencies to identify specific locations where vegetation communities of special concern exist and to minimize and mitigate impacts. The majority of the project footprint for all alternatives is associated with pipeline construction, the impacts of which will primarily be temporary during construction.

Operational impacts are associated both with above ground structures which are predominantly associated with the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives and groundwater drawdown which is only associated with the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives. The operational impacts from groundwater drawdown from pumping are described above under Chapter 3.2 Wildlife Resources. The Lake Michigan water supply and return flow alternatives have insignificant operational surface impacts. The temporary construction and operational surface impacts are summarized in Chapter 7, Table 7-1.

Construction will necessitate removing surface vegetation from workspaces. The ground surface will be graded to facilitate pipeline installation and to allow safe operation of equipment. During grading, the root systems of herbs, shrubs, and small trees will be disturbed.

Vegetation removal can increase wind and water erosion of exposed soil. It can also increase soil temperature and allow greater light penetration into fringing woodland where new workspace is cleared in forested areas. Changes in light and temperature regimes may influence the species profile of plant communities within and adjacent to the workspace. The City will minimize soil erosion by adherence to BMPs.

Most impacts to vegetation are expected to be minor and short-term. In open areas with herbaceous cover, recolonization of disturbed ground by annual and perennial species is characteristically rapid and occurs within one growing season. Where necessary, the City will develop area-specific revegetation and restoration plans in consultation with the appropriate federal, state, and local agencies.

Clearing of woody shrubs and trees will have more significant, long-term impacts because shrubs and trees take longer to regrow than herbaceous vegetation. During recolonization, a shrub- or tree-dominated community will evolve through several successional stages before assuming its original profile.

Tree removal will be minimized to the extent practicable and replanting will be in accordance with local, state, and federal agency requirements. Woody shrubs and trees will be allowed to regrow in previously forested areas, but the permanent pipeline maintenance corridor will be maintained with low vegetative cover to facilitate access and inspection of the water main. Mechanical methods, such as a brush hog, will be used as necessary to keep the maintenance corridor clear of excessive woody vegetation.

Table 8-2 shows the potential acreage of various land use affected along the proposed workspace. Further details are provided in ER Chapter 7, Land Use.

3.4 Endangered and Threatened Species

The Endangered Species Act of 1973 (16 U.S. Code (USC) 1531-1543, Public Law 93-205) states that threatened and endangered plant and animal species are of aesthetic, ecological, educational, historic, and scientific value to the United States and that protection of these species and their habitats is required. The Act protects fish, wildlife, plants, and invertebrates that are federally listed as endangered or threatened.

A federally endangered species is any species that is in danger of extinction throughout all or a significant portion of its range, with exceptions for certain insect pests. A federally threatened species is any species that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. Species likely to become endangered or threatened in the foreseeable future may be listed as proposed endangered or threatened, or of special concern. In addition to protection of individual species, federal regulatory protection is also afforded to certain rare, natural vegetation communities, or critical habitats.

In Wisconsin, WDNR describes threatened and endangered species as one of three categories. An "endangered" species is one whose continued existence as a viable component of this state's wild animals or wild plants is determined by WDNR to be in jeopardy on the basis of scientific evidence. A "threatened" species is one that appears likely, within the foreseeable future and on the basis of scientific evidence, to become endangered. A "special concern" species is one about which some problem of abundance or distribution is suspected but not yet proved. The main purpose of this category is to focus attention on certain species before they become endangered or threatened.

Endangered and threatened species are characteristically in jeopardy because of ecosystem disruptions, including the destruction, alteration, or curtailment of habitats; overexploitation; and the effects of disease, pollution, and predation. An individual species may be both state and federally listed.

3.4.1 Existing Resources

3.4.1.1 Federally Listed Species

According to correspondence from the USFWS (2010), no federally listed threatened or endangered species occur within the vicinity of the supply and return flow alternatives being evaluated. Since construction is not proposed until midyear 2013, the City is planning to consult with the USFWS in spring 2013 to verify that no new federally listed species have been identified within the selected supply and return flow construction workspace.

3.4.1.2 State-Listed Species

The City initiated consultation with WDNR Office of Energy, which assumes responsibility for endangered resources review of utility projects and works closely with the Bureau of Endangered Resources to implement the WDNR's endangered resources protection policies and regulations. WDNR (2010c) identified multiple listed species as potentially occurring within the vicinity of the proposed supply and return flow alternatives. A summary of the listed species associated with each of the supply and return flow alternatives is included in the following tables 3-1 through 3-7.

Consultation with SEWRPC was also conducted by the City at the request of the WDNR to inquire about any threatened or endangered species or species of concern information SEWRPC may have available. The information from SEWRPC is available in several reports on a watershed basis and is consistent with information on listed species received from the WDNR. However, a recent SEWRPC report, Community Assistance Planning Report No. 284, Pebble Creek Watershed Protection Plan documented the presence of a state threatened species, the Longear Sunfish (*Lepomis megalotis)* in 1999-2005 surveys in Pebble Creek. As discussed in Chapter 2.3.2.2, base groundwater flows to Pebble Creek could be significantly affected by the Deep and Shallow Aquifer and Shallow Aquifer and Fox River Alluvium alternatives and as a result, these alternatives have the potential to adversely impact habitats for documented listed species. Other species were found in Pebble Creek or at the confluence with the Fox River that are species of special concern in Wisconsin. However, the historical presence of these species in the watershed does not indicate the species occur in the alternative corridor.

Due to the preliminary nature of the project, no field surveys have been completed at this time. Once a final water supplier has been negotiated and a return flow location have been approved, field surveys will be completed to along the selected route to confirm the presence or absence of the species listed by the WDNR.

3.4.2 Construction and Operation Impacts and Mitigation

Based on the consultation response from USFWS (2010), no impacts to federally listed species or critical habitat are anticipated. However, USFWS does state that "if there is a lag between plan completion and construction this office should be contacted for updated species and critical habitat information [which is] updated every 6 months." The City will reinitiate consultation with the USFWS to comply with their request and to prevent impacts to federally listed species or critical habitat.

The City has selected pipeline routes to primarily follow areas that have already been developed or disturbed to minimize impacts to endangered and threatened species. The City will work with regulatory agencies to identify specific locations where such species may potentially be impacted and take measure to to minimize impacts. The majority of the project footprint for all alternatives is associated with pipeline construction, the impacts of which will primarily be temporary during construction.

Operational impacts are associated both with above ground structures which are predominantly associated with the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives and groundwater drawdown which is only associated with the Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium supply alternatives. The Lake Michigan water supply and return flow alternatives have insignificant operational surface impacts. The temporary construction and operational surface impacts are summarized in Chapter 7, Table 7-1.

The City is currently coordinating with the WDNR to conduct a habitat assessment at locations along alternative infrastructure alignments in the summer of 2010. The information gained from the habitat assessment will be shared with the WDNR. Once a final water supplier has been negotiated and a return flow location have been approved, field surveys will be completed to confirm the presence or absence of the species listed by the

WDNR. The City will continue to work closely with the WDNR to avoid, minimize, or mitigate impacts to threatened or endangered species.

Should a threatened or endangered species be positively identified within the construction workspace, the City will:

- Avoid or minimize impacts to the species wherever it is feasible
- Stage construction to limit disturbance during sensitive time periods
- Conduct temporary removal by an approved scientist following established protocols

3.5 References

SEWRPC (Southeastern Wisconsin Regional Planning Commission). 2008. Community Assistance Planning Report No. 284, Pebble Creek Watershed Protection Plan.

SEWRPC (Southeastern Wisconsin Regional Planning Commission). 2007. Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds. Technical Report No. 39.

USDA (U.S. Department of Agriculture). 1995. Descriptions of the Ecoregions the United States. Compiled by R. G. Baily.

USDA (U.S. Department of Agriculture). 2010. USDA Humid Temperate Domain. http://www.fs.fed.us/land/ecosysmgmt/index.html. Accessed Feb. 25, 2010.

USFWS (U.S. Fish and Wildlife Service). 2010. Correspondence from Jill Utrupp/USFWS to Corey Wilcox/CH2M HILL. January 26.

WDNR (Wisconsin Department of Natural Resources). 2010c. E-mails from Shari Koslowsky/WDNR to Corey Wilcox/CH2M HILL. January 29, April 6, and April 8.

WDNR (Wisconsin Department of Natural Resources). 2010d. Vernon Wildlife Area. http://www.dnr.state.wi.us/org/land/wildlife/wildlife_areas/vernon.htm. Accessed February 25, 2010.

TABLE 3-1
Lake Michigan—Milwaukee Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat	—	Southern dry-mesic forest	N/A	—	5/1/1992 9/3/1997 5/23/2002
	—	Bird Rookery	NA	-—	NA
	—	Southern mesic forest	N/A	—	2/8/1988
Plants	*Asclepias purpurascens*	Purple milkweed	E	—	7/13/1912
	Astragalus neglectus	Cooper's milkvetch	E	—	6/22/1939
	Carex crus-corvi	Ravenfoot sedge	E	—	6/22/1988
	Carex lupuliformis	False hop sedge	E	—	7/22/1988 1995
	Conioselinum chinense	Hemlock parsley	E	—	8/25/1897
	Platanthera leucophaea	Prairie white-fringed orchid	E	T	7/9/1890
	Erigenia bulbosa	Harbinger-of-spring	E	—	4/25/1897
	Prenanthes aspera	Rough rattlesnake root	E	—	1845
	Cypripedium arietinum	Ram's-head lady's slipper	T	—	6/1897
	Cypripedium candidum	Small white lady's slipper	T	—	1850
	Aster furcatus	Forked aster	T	—	6/7/1999
	Cacalia muehlenbergii	Great Indian plantain	SC	—	7/1/1937
	Lithospermum latifolium	American gromwell	SC	—	5/29/1976 4/30/1992 5/11/1992
	Platanthera hookeri	Hooker orchid	SC	—	7/9/1899

TABLE 3-1
Lake Michigan—Milwaukee Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Scutellaria ovata	Heart-leaved skullcap	SC	—	5/12/1980 8/1/2000
	Trillium recurvatum	Reflexed trillium	SC	—	5/28/2000 5/23/2002
	Calamagrostis stricta	Slim-stem small reedgrass	SC	—	6/30/1940
	Carex tenuiflora	Sparse-flowered sedge	SC	—	6/3/1882
	Cypripedium parviflorum	Northern yellow lady's slipper	SC	—	6/3/1932
	Liatris spicata	Marsh blazing star	SC	—	9/1875
	Thalictrum revolutum	Waxleaf meadowrue	SC	—	8/8/1933 6/30/1940
	Triglochin maritime	Common bog arrow-grass	SC	—	1800s
	Ptelea trifoliate	Wafer-ash	SC	—	10/3/2000
	Viburnum prunifolium	Smooth black-haw	SC	—	12/2/1999
	Platanthera dilatata	Leafy white orchid	SC	—	7/1884
Reptiles & Amphibians	*Acris crepitans*	Northern cricket frog	E	—	5/10/1946 5/1/1955
	Thamnophis butleri	Butler's gartersnake	T	—	7/13/2007 10/23/2007 6/2008 10/23/2008

TABLE 3-1
Lake Michigan—Milwaukee Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Emydoidea blandingii	Blanding's turtle	T	—	5/3/1988 6/26/1996 2002
	Lithobates catesbeianus	American bullfrog	SC	—	7/20/1988
Fish	*Luxilus chrysocephalus*	Striped shiner	E	—	1920
	Lythrurus umbratilis	Redfin shiner	T	—	7/11/1924
	Clinostomus elongates	Redside dace	SC	—	3/20/1910
	Erimyzon sucetta	Lake chubsucker	SC	—	3/29/1977 5/10/1979
Insects	*Pompeius verna*	Little glassy wing	SC	—	7/12/1988
	Archilestes grandis	Great spreadwing	SC	—	9/20/1984
Crustaceans	*Procambarus gracilis*	Prairie crayfish	SC	—	3/28/1910 5/11/1970

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected).

TABLE 3-2
Lake Michigan—Oak Creek Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat	—	Southern dry mesic forest	N/A	—	6/11/1991 5/1/1992 9/30/1997 7/24/2001 5/23/2002 5/1/2003
	—	Southern mesic forest	N/A	—	2/8/1988 6/16/1991 6/22/1995 7/29/1999
	—	Mesic prairie	N/A	—	8/17/1992
	—	Wet prairie	N/A	—	7/1985
	—	Emergent marsh	N/A	—	7/1985
	—	Southern sedge meadow	N/A	—	7/1985
	—	Calcareous fen	N/A	—	9/9/1991
	—	Shrub-carr	N/A	—	7/1985
	—	Northern wet forest	N/A	—	7/1985
	—	Floodplain forest	N/A	—	6/2/1995
	—	Springs and spring runs (hard)	N/A	—	7/1985
Plants	*Asclepias purpurascens*	Purple milkweed	E	—	8/20/1905 7/13/1912 7/4/1928

TABLE 3-2
Lake Michigan—Oak Creek Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Solidago caesia	Bluestem goldenrod	E	—	9/16/1991 8/30/2000 6/4/2003 9/20/2003
	Platanthera leucophaea	Prairie white-fringed orchid	E	T	7/9/1890
	Carex lupuliformis	False hop sedge	E	—	1995 5/1/2003
	Carex crus-corvi	Ravenfoot sedge	E	—	6/22/1988
	Trisetum melicoides	Purple false oats	E	—	8/4/1940
	Astragalus neglectus	Cooper's milkvetch	E	—	6/22/1939
	Conioselinum chinense	Hemlock parsley	E	—	8/25/1897
	Erigenia bulbosa	Harbinger-of-spring	E	—	4/25/1897
	Prenanthes aspera	Rough rattlesnake root	E	—	1845
	Aster furcatus	Forked aster	T	—	5/1/1992 1997
	Tofieldia glutinosa	Sticky false-asphodel	T	—	7/31/2003
	Cypripedium arietinum	Ram's-head lady's slipper	T	—	6/1897
	Cypripedium candidum	Small white lady's slipper	T	—	1850
	Scutellaria ovata	Heart-leaved skullcap	SC	—	5/12/1980 8/1/2000
	Carex tenuiflora	Sparse-flowered sedge	SC	—	6/3/1882
	Cacalia muehlenbergii	Great Indian plantain	SC	—	7/1/1937
	Medeola virginiana	Indian cucumber-root	SC	—	6/6/1908
	Platanthera hookeri	Hooker orchid	SC	—	7/9/1899

TABLE 3-2
Lake Michigan—Oak Creek Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Trillium recurvatum	Reflexed trillium	SC	—	5/18/1941 5/11/1992 4/30/1999 5/28/2000 7/11/2000 5/23/2002 5/1/2003
	Viburnum prunifolium	Smooth black-haw	SC	—	9/16/1991 4/26/2000 7/11/2000 5/1/2003
	Cypripedium parviflorum	Northern yellow lady's slipper	SC	—	5/30/1889 7/9/1890 6/3/1932
	Liatris spicata	Marsh blazing star	SC	—	9/1875
	Epilobium strictum	Downy willow-herb	SC	—	8/19/1983
	Triglochin maritime	Common bog arrow-grass	SC	—	1800s
	Platanthera dilatata	Leafy white orchid	SC	—	7/1884
	Glycyrrhiza lepidota	Wild licorice	SC	—	8/13/1940
	Thalictrum revolutum	Waxleaf meadowrue	SC	—	6/30/1940 7/5/1963 6/15/2000
	Lithospermum latifolium	American gromwell	SC	—	5/27/1897 5/29/1976 4/30/1992 5/11/1992

TABLE 3-2
Lake Michigan—Oak Creek Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					10/19/2005
	Calamagrostis stricta	Slim-stem small reedgrass	SC	—	6/30/1940
	Cakile lacustris	American sea-rocket	SC	—	7/26/1975
	Cypripedium reginae	Showy lady's slipper	SC	—	6/17/1939
	Equisetum variegatum	Variegated horsetail	SC	—	6/30/1995
	Gentianopsis procera	Lesser fringed gentian	SC	—	9/22/2000
	Solidago ohioensis	Ohio goldenrod	SC	—	10/20/2000
	Triglochin palustris	Slender bog arrow-grass	SC	—	8/11/1981
	Ptelea trifoliata	Wafer-ash	SC	—	10/3/2000
Birds	*Sterna forsteri*	Forster's tern	E	—	2004
	Nycticorax nyticorax	Black-crowned night heron	SC	—	1962
	Pandion haliaetus	Osprey	SC	—	5/2008
	Spiza Americana	Dickissel	SC	—	7/7/2000
Reptiles & Amphibians	*Acris crepitans*	Northern cricket frog	E	—	5/10/1946 5/1/1955
	Thamnophis butleri	Butler's gartersnake	T	—	7/14/2006 5/14/2007 7/13/2007 10/23/2007 4/2008 6/2008 10/23/2008
	Emydoidea blandingii	Blanding's turtle	T	—	5/3/1988 6/4/1996

TABLE 3-2
Lake Michigan—Oak Creek Supply: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					5/9/2000
					2002
	Lithobates catesbeianus	American bullfrog	SC	—	7/20/1988
Fish	*Luxilus chrysocephalus*	Striped shiner	E	—	1920
	Lythrurus umbratilis	Redfin shiner	T	—	7/11/1974
	Lepomis megalotis	Longear sunfish	T	—	4/4/2000
	Etheostoma microperca	Least darter	SC	—	7/11/1924
	Erimyzon sucetta	Lake chubsucker	SC	—	3/29/1977
					5/10/1979
Insects	*Somatochlora ensigera*	Lemon-faced emerald	SC	—	6/25/1978
	Pompeius verna	Little glassy wing	SC	—	7/12/1988
Crustaceans	*Procambarus gracilis*	Prairie crayfish	SC	—	5/11/1970
					8/7/1982

[a]E, Endangered; T, Threatened; SC, Spaecies of Concern (not legally protected).

TABLE 3-3
Underwood Creek Return: State-Listed Endangered and Threatened Species, Natural Heritage Inventory Data—WDNR
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat	—	Southern dry-mesic forest	N/A	—	9/30/1997 10/9/1998 5/23/2002
	—	Southern mesic forest	N/A	—	2/8/1988 4/28/1993
	—	Floodplain forest	N/A	—	5/23/1992
	—	Southern sedge meadow	N/A	—	9/26/1990
	—	Mesic prairie	N/A	—	7/26/2002
Plants	*Asclepias purpurascens*	Purple milkweed	E	—	7/13/1912
	Astragalus neglectus	Cooper's milkvetch	E	—	6/22/1939
	Carex crus-corvi	Ravenfoot sedge	E	—	6/22/1988
	Carex lupuliformis	False hop sedge	E	—	1995
	Conioselinum chinense	Hemlock parsley	E	—	8/25/1897
	Platanthera leucophaea	Prairie white-fringed orchid	E	T	7/9/1890
	Erigenia bulbosa	Harbinger-of-spring	E	—	4/25/1897
	Prenanthes aspera	Rough rattlesnake root	E	—	1845
	Cypripedium arietinum	Ram's-head lady's slipper	T	—	6/1897
	Aster furcatus	Forked aster	T	—	1997
	Cypripedium candidum	Small white lady's slipper	T	—	1850
	Cacalia muehlenbergii	Great Indian plantain	SC	—	7/1/1937
	Lithospermum latifolium	American gromwell	SC	—	5/27/1897 5/29/1976 4/30/1992 4/28/1993

TABLE 3-3
Underwood Creek Return: State-Listed Endangered and Threatened Species, Natural Heritage Inventory Data—WDNR
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Platanthera hookeri	Hooker orchid	SC	—	7/9/1899
	Scutellaria ovata	Heart-leaved skullcap	SC	—	5/12/1980 8/1/2000
	Trillium recurvatum	Reflexed trillium	SC	—	5/12/2002 5/23/2002
	Calamagrostis stricta	Slim-stem small reedgrass	SC	—	6/30/1940
	Carex tenuiflora	Sparse-flowered sedge	SC	—	6/3/1882
	Cypripedium parviflorum	Northern yellow lady's slipper	SC	—	6/3/1932 8/11/1992
	Liatris spicata	Marsh blazing star	SC	—	9/1875
	Thalictrum revolutum	Waxleaf meadowrue	SC	—	6/30/1940
	Triglochin maritime	Common bog arrow-grass	SC	—	1800s
	Platanthera dilatata	Leafy white orchid	SC	—	7/1884
	Calylophus serrulatus	Yellow evening primose	SC	—	7/26/2002
	Thaspium trifoliatum	Purple meadow parsnip	SC	—	5/30/1930
	Jeffersonia diphylla	Twinleaf	SC	—	4/28/1993
Birds	*Nycticorax nycticorax*	Black-crowned night heron	SC	—	1974
Reptiles & Amphibians	*Acris crepitans*	Northern cricket frog	E	—	5/10/1946 5/1/1955
	Thamnophis butleri	Butler's gartersnake	T	—	7/2007 10/23/2007 2008
	Emydoidea blandingii	Blanding's turtle	T	—	5/3/1988

TABLE 3-3
Underwood Creek Return: State-Listed Endangered and Threatened Species, Natural Heritage Inventory Data—WDNR
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					6/26/1996
	Lithobates catesbeianus	American bullfrog	SC	—	7/20/1988
Fish	*Luxilus chrysocephalus*	Stride shiner	E	—	1920
	Lythrurus umbratilis	Redfin shiner	T	—	7/11/1924
	Etheostoma microperca	Least darter	SC	—	11/17/1901
	Erimyzon sucetta	Lake chubsucker	SC	—	3/29/1977
	Clinostomus elongates	Redside dace	SC	—	11/17/1901
Insects	*Pompeius verna*	Little glassy wing	SC	—	7/12/1988
Crustaceans	*Procambarus gracilis*	Prairie crayfish	SC	—	5/11/1970

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected).

TABLE 3-4
Direct to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat	—	Calcareous fen	NA		9/9/1991
	—	Southern dry mesic forest	N/A	—	5/14/1991
	—	Southern mesic forest	N/A	—	9/9/1991
	—	Springs and spring runs (hard)	N/A	—	7/1985
Plants	*Asclepias purpurascens*	Purple milkweed	E	—	8/20/1905 7/13/1912 7/4/1928
	Aster furcatus	Forked aster	T	—	8/19/2001 1997
	Astragalus neglectus	Cooper's milkvetch	E	—	6/22/1939
	Cacalia muehlenbergii	Great Indian plantain	SC	—	7/1/1937
	Cakile lacustris	American sea-rocket	SC	—	1950s?
	Calamagrostis stricta	Slim-stem small reedgrass	SC	—	6/30/1940
	Carex tenuiflora	Sparse-flowered sedge	SC	—	6/3/1882
	Conioselinum chinense	Hemlock parsley	E	—	8/25/1897
	Cypripedium arietinum	Ram's-head lady's slipper	T	—	6/1897
	Cypripedium candidum	Small white lady's slipper	T	—	1850
	Cypripedium parviflorum	Northern yellow lady's slipper	SC	—	5/30/1889 7/9/1890 6/3/1932
	Cypripedium reginae	Showy lady's slipper	SC	—	6/17/1939
	Equisetum variegatum	Variegated horsetail	SC	—	6/30/1995

TABLE 3-4
Direct to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Erigenia bulbosa	Harbinger-of-spring	E	—	1850 1920
	Euphorbia polygonifolia	Seaside Spurge	SC		1872
	Gentianopsis procera	Lesser fringed gentian	SC	—	9/9/1991
	Glycyrrhiza lepidota	Wild licorice	SC	—	8/19/1940
	Liatris spicata	Marsh blazing star	SC	—	9/1875 1872
	Lithospermum latifolium	American gromwell	SC	—	5/27/1897
	Medeola virginiana	Indian cucumber-root	SC	—	6/6/1908
	Penstemon hirsutus	Hairy Beardtongue	SC		6/18/1939
	Platanthera dilatata	Leafy white orchis	SC	—	7/1884
	Platanthera hookeri	Hooker orchis	SC	—	7/9/1899
	Platanthera leucophaea	Prairie white-fringed orchid	E	T	7/9/1890
	Solidago caesia	Bluestem goldenrod	E	—	9/20/1872 9/25/2001 12/10/2000
	Solidago ohioensis	Ohio goldenrod	SC	—	9/20/1975 9/9/1991
	Thalictrum revolutum	Waxleaf meadowrue	SC	—	8/8/1933 6/30/1940
	Tofieldia glutinosa	Sticky false-asphodel	T	—	6/30/1995
	Triglochin maritime	Common bog arrow-grass	SC	—	1800s

TABLE 3-4
Direct to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Triglochin palustris	Slender bog arrow-grass	SC	—	8/11/1981
	Trillium recurvatum	Reflexed trillium	SC	—	5/14/1991 1846 5/23/1945 5/17/1963 5/28/2000 5/11/1938
	Trisetum melicoides	Purple false oats	E	—	8/4/1940
Birds	*Spiza Americana*	Dickissel	SC	—	2/8/2000
Reptiles & Amphibians	*Acris crepitans*	Northern cricket frog	E	—	5/10/1946 5/1/1955
	Thamnophis butleri	Butler's gartersnake	T	—	10/25/1915 4/14/1910 2003 5/14/2007 10/10/1938 10/18/1987
	Emydoidea blandingii	Blanding's turtle	T	—	5/3/1988 6/4/1996 5/9/2000 2002
	Lithobates catesbeianus	American bullfrog	SC	—	7/20/1988
Fish	*Luxilus chrysocephalus*	Striped shiner	E	—	3/2/1910

TABLE 3-4
Direct to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Lythrurus umbratilis	Redfin shiner	T	—	7/11/1974
	Moxostoma valenciennesi	Greater Redhorse	T		9/13/1996
	Fundulus diaphanus	Banded Killfish	SC	—	4/20/1902
	Pompeius verna	Little glassy wing	SC	—	7/12/1988
Crustaceans	*Procambarus gracilis*	Prairie crayfish	SC	—	3/28/1910 5/2/1910 7/9/1983 2/7/1982 7/11/1982 7/8/1982

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected).

TABLE 3-5
Deep and Shallow Wells & Shallow Aquifer and Fox River Alluvium - State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat/Other	—	Bird Rookery	SC	—	1994
	—	Calcerous Fen	NA	—	9/10/1992
	—	Emergent Marsh	N/A	—	5/30/1992
	—	Mesic Prairie	N/A	—	7/26/2002
	—	Southern dry forest	N/A	—	4/30/1992
	—	Southern dry-mesic forest	N/A	—	4/30/1992
	—	Southern mesic forest	N/A	—	4/29/1992
Plants	*Agrimonia parviflora*	Swamp Agrimony	SC	—	6/3/1882 1999
	Asclepias Purpurascens	Purple Milkweed	E	—	4/7/1928
	Aster furcatus	Forked aster	T	—	6/8/1999 8/18/1998
	Cacalia tuberosa	Prairie Indian plantain	T	—	7/25/1925
	Carex Crawei	Crawe Sedge	SC	—	1852
	Cypripedium candidum	Small White Lady's Slipper	T	—	6/9/1997 6/10/1898 5/31/1948
	Cypripedium parviflorum	Northern yellow lady's slipper	SC	—	8/11/1982
	Gentiana alba	Yellow Gentain	T	—	8/30/1938
	Gentianopsis procera	Lesser Fringed Gentain	SC	—	9/10/1992
	Jeffersonia diphylla	Twinleaf	SC	—	1852

TABLE 3-5
Deep and Shallow Wells & Shallow Aquifer and Fox River Alluvium - State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					6/24/1930
	Liatris spicata	Marsh blazing star	SC	—	7/8/1933 10/8/1897
	Myriophyllum farewelii	Farwell's Water-milfoil	SC	—	5/31/1931
	Polygala cruciata	Crossleaf Milkwort	SC	—	8/1875
	Prenanthes aspera	Rough rattlesnake root	E	—	1845
	Ptelea trifoliata	Wafer ash	SC	—	9/10/1992
	Solidago ohioensis	Ohio Goldenrod	SC	—	8/30/1928 9/10/1992 6/9/1997
	Thaspium trifoliatum var. flavum	Purple Meadow-Parsnip	SC	—	5/30/1930
Reptiles & Amphibians	*Acris crepitans*	Northern cricket frog	E	—	5/1/1955
	Emydoidea blandingii	Blanding's turtle	T	—	5/1993
	Thamnophis butleri	Butler's gartersnake	T	—	4/5/1955 4/17/1998 6/7/2007 2/10/2007 10/2007 2004 2003 4/17/1998

TABLE 3-5
Deep and Shallow Wells & Shallow Aquifer and Fox River Alluvium - State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Fish and Mussels	*Alasmidonta marginata*	Elktoe	SC	—	8/15/2001
	Alasmidonta virdis	Slippershell Mussel	T	—	8/15/2001
	Erimyzon sucetta	Lake chubsucker	SC	—	11/7/1978 7/13/1978
	Lepomis megalotis	Longear Sunfish	T	—	3/10/1996
	Luxilus chrysocephalus	Striped shiner	E	—	1920
Birds	*Chlidonias niger*	Black tern	SC	—	5/30/1992
	Gallinula Chloropus	Common Moorhen	SC	—	5/30/1992
Mammals	*Spermophilus frankilinii*	Franklin's ground Squirrel	SC	—	1980

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected).

TABLE 3-6
Root River to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat	—	Mesic Prairie	N/A	—	7/26/2002
	—	Southern Dry Mesic Forest	N/A	—	5/14/1991 6/11/1991 5/1/1992 5/23/2002
	—	Southern Mesic Forest	N/A	—	2/8/1988
Plants	*Asclepias purpurascens*	Purple Milkweed	E		8/20/1905 7/13/1912
	Aster furcatus	Forked Aster	T	—	5/1/1992
	Astragalus neglectus	Cooper's Milkvetch	E	—	6/22/1939
	Cacalia muehlenbergii	Great Indian Plantain	SC	—	7/1/1937
	Calamagrostis stricta	Slim-stem Small reedgrass	SC	—	6/30/1940
	Carex lupuliformis	False Hop Sedge	E	—	1995
	Carex tenuiflora	Sparse-flowered Sedge	SC	—	6/3/1882
	Conioselinum chinense	Hemlock parsley	E	—	8/25/1897
	Cypripedium arietinum	Ram's-head Lady's slipper	T	—	6/1897
	Cypripedium parviflorum	Northern Yellow Lady's slipper	SC	—	6/3/1932 8/11/1992
	Liatris spicata	Marsh Blazing Star	SC	—	9/1875
	Lithospermum latifolium	American Gromwell	SC	—	5/27/1897 6/11/1991 4/30/1992 5/11/1992
	Platanthera dilatata	Leafy white orchid	SC	—	7/1884

TABLE 3-6
Root River to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Platanthera hookeri	Hooker orchid	SC	—	7/9/1899
	Platanthera leucophaea	Prairie white-fringed orchid	E	T	7/9/1890
	Prenanthes aspera	Rough Rattlesnake-root	E	—	1845
	Ptelea trifoliata	Wafer-ash	SC	—	10/3/2000
	Scutellaria ovata	Heart-leaved skullcap	SC	—	8/1/2000
	Solidago caesia	Bluestem goldenrod	E	—	9/20/2003
	Thalictrum revolutum	Waxleaf Meadowrue	SC	—	8/8/1933 6/30/1940
	Triglochin maritime	Common Bog Arrow-grass	SC	—	1800s
	Trillium recurvatum	Reflexed Trillium	SC	—	1846 5/18/1941 5/23/1944 5/23/1945 5/14/1991 5/1/1992 5/28/2000 5/12/2002 5/23/2002
	Viburnum prunifolium	Smooth black-haw	SC	—	6/11/1991
Birds	*Spiza Americana*	Dickcissel	SC	—	7/7/2000
Reptiles & Amphibians	*Acris crepitans*	Northern Cricket Frog	E	—	5/10/1946 5/1/1955
	Emydoidea blandingii	Blanding's Turtle	T	—	5/3/1988 5/9/2000
	Lithobates catesbeianus	American Bullfrog	SC	—	7/20/1988

TABLE 3-6
Root River to Lake Michigan: State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Thamnophis butleri	Butler's Gartersnake	T	—	4/5/1955
					2003
					6/30/2003
					10/2003
					2004
					7/13/2006
					7/18/2006
					5/14/2007
					6/7/2007
					6/13/2007
					7/2007
					10/2/2007
					2008
					6/2008
Fish	*Luxilus chrysocephalus*	Striped shiner	E	—	1920
	Lythrurus umbratilis	Redfin shiner	T	—	7/11/1924
	Lepomis megalotis	Longear sunfish	T	—	4/4/2000
	Etheostoma microperca	Least darter	SC	—	7/11/1924
	Erimyzon sucetta	Lake chubsucker	SC	—	5/10/1979
Insects	*Pompeius verna*	Little Glassy Wing	SC	—	7/12/1988
Crustaceans	*Procambarus gracilis*	Prairie Crayfish	SC	—	3/28/1910
					5/11/1970

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected).

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
Habitat		Bird Rookery	SC	—	10/18/1991
					6/16/1905
		Calcareous Fen	NA	—	8/11/1993
					10/2/1992
		Emergent Marsh	NA	—	3/9/1985
		Floodplain Forest	NA	—	5/6/1993
					7/22/1991
					10/1/1991
					12/11/1993
					7/1985
					7/10/1991
					7/1976
		Lake--Oxbow	NA	—	7/1976
		Mesic Prairie	NA	—	7/19/1991
		Northern Wet Forest	NA	—	6/19/1992
		Southern Dry Forest	NA	—	4/30/1993
		Southern Dry-mesic Forest	NA	—	10/7/1991
					10/2/1991

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					5/20/1991
					4/1999
					9/30/1997
		Southern Mesic Forest	NA	—	7/1976
					10/7/1991
					10/1/1991
					5/8/1992
					7/1976
					5/20/1991
					5/18/2004
					4/29/1992
					2/8/1988
		Stream--Slow, Hard, Warm	NA	—	7/1985
Plants	*Adlumia fungosa*	Climbing Fumitory	SC	—	1861?
	Arethusa bulbosa	Swamp-pink	SC	—	6/13/1888
	Asclepias purpurascens	Purple Milkweed	E	—	7/19/1879
					7/4/1928
					8/20/1905
	Asclepias sullivantii	Prairie Milkweed	T	—	6/14/1905

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					9/1880
	Aster furcatus	Forked Aster	T	—	6/12/1905
					9/10/1992
					8/29/1990
	Cacalia muehlenbergii	Great Indian-plantain	SC	—	6/16/1905
	Cacalia tuberosa	Prairie Indian Plantain	T	—	7/1995
					7/30/1898
	Calamintha arkansana	Low Calamint	SC	—	10/3/1891
	Carex crawei	Crawe Sedge	SC	—	6/15/1901
					1/25/1905
	Carex crus-corvi	Ravenfoot Sedge	E	—	9/9/1996
	Carex formosa	Handsome Sedge	T	—	1980s
	Carex lupuliformis	False Hop Sedge	E	—	6/12/1905
	Carex richardsonii	Richardson Sedge	SC	—	6/12/1901
	Carex tenuiflora	Sparse-flowered Sedge	SC	—	7/1/1932
	Cirsium hillii	Hill's Thistle	T	—	8/17/1897
	Cypripedium candidum	Small White Lady's-slipper	T	—	6/1876

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Cypripedium parviflorum var. makasin	Northern Yellow Lady's-slipper	SC	—	5/23/1897
					3/14/1905
					5/30/1889
					5/7/1938
					6/3/1932
	Cypripedium reginae	Showy Lady's-slipper	SC	—	3/17/1905
	Deschampsia cespitosa	Tufted Hairgrass	SC	—	6/30/1900
	Echinacea pallida	Pale-purple Coneflower	T	—	6/9/1905
	Etheostoma microperca	Least Darter	SC	—	7/10/1924
	Festuca paradoxa	Cluster Fescue	SC	—	1930s?
	Fraxinus quadrangulata	Blue Ash	T	—	7/9/1995
	Gentiana alba	Yellow Gentian	T	—	8/1992
	Gentianopsis procera	Lesser Fringed Gentian	SC	—	5/9/1897
					9/28/1968
	Jeffersonia diphylla	Twinleaf	SC	—	6/24/1930
	Liatris spicata	Marsh Blazing Star	SC	—	9/5/1990
					6/12/1905
	Lithospermum latifolium	American Gromwell	SC	—	5/8/1992

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					10/2/1991
					5/29/1976
					10/21/2000
					12/11/1993
	Medeola virginiana	Indian Cucumber-root	SC	—	6/6/1908
	Pandion haliaetus	Osprey	SC	—	6/30/1905
	Panicum wilcoxianum	Wilcox Panic Grass	SC	—	7/23/1944
	Parthenium integrifolium	American Fever-few	T	—	9/25/1900
					6/12/1905
	Plantago cordata	Heart-leaved Plantain	E	—	7/17/2002
	Platanthera leucophaea	Prairie White-fringed Orchid	E	—	7/9/1980
	Polystichum acrostichoides	Christmas Fern	SC	—	1861?
	Prenanthes aspera	Rough Rattlesnake-root	E	—	1/18/1905
	Ptelea trifoliata	Wafer-ash	SC	—	10/17/ 1940
					7/6/1966
	Ranunculus cymbalaria	Seaside Crowfoot	T	—	7/1/1898
					8/1878
	Scutellaria ovata	Heart-leaved Skullcap	SC	—	5/24/2000

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
	Solidago caesia	Bluestem Goldenrod	E	—	10/21/2000
					10/18/1991
					9/10/1992
					9/25/2001
	Solidago ohioensis	Ohio Goldenrod	SC	—	9/5/1990
					6/12/1905
					9/13/1991
					10/2/1992
					8/30/1928
					9/13/1991
					10/2/1992
					9/10/1992
	Thalictrum revolutum	Waxleaf Meadowrue	SC	—	7/6/1906
					9/5/1990
					6/12/1905
	Tofieldia glutinosa	Sticky False-asphodel	T	—	7/2/1898
	Tomanthera auriculata	Earleaf Foxglove	SC	—	8/18/1900
	Triglochin maritima	Common Bog Arrow-grass	SC	—	1800s
	Trillium recurvatum	Reflexed Trillium	SC	—	5/6/1993

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					6/3/1991
					5/24/2000
					6/6/1991
					10/1/1991
					4/6/1962
					5/20/1991
					8/18/2004
					5/14/1933
					5/12/1980
					5/10/1988
					5/15/2001
					5/20/1990
					6/15/1960
					4/28/1998
	Viburnum prunifolium	Smooth Black-haw	SC	—	5/6/1993
					5/8/1992
					12/11/1993
					5/24/2000
					10/2/1991
					9/1/1985

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					10/1/1991
					5/25/1992
					10/7/1991
					7/22/1998
Reptiles & Amphibians	*Emydoidea blandingii*	Blanding's Turtle	T	—	7/1/1989
					5/3/2006
	Thamnophis butleri	Butler's Gartersnake	T	—	6/26/1905
					10/2/2010
					4/5/1955
					6/7/2005
					7/2007
					6/13/2006
					6/30/2003
					4/5/1955
					7/13/2007
	Regina septemvittata	Queensnake	E	—	8/21/1971
	Acris crepitans	Northern Cricket Frog	E	—	5/1/1955
Birds	*Haliaeetus leucocephalus*	Bald Eagle	SC	R	5/2008
	Nycticorax nycticorax	Black-crowned Night-heron	SC	—	1950s

TABLE 3-7
Lake Michigan - Racine; State-Listed Endangered and Threatened Species and Communities
City of Waukesha Water Supply

Species Group	Scientific Name	Common Name	State Status[a]	Federal Status[a]	Date Last Observed
					5/15/1905
	Buteo lineatus	Red-shouldered Hawk	T	—	4/1982
	Bartramia longicauda	Upland Sandpiper	SC		6/10/1987
Fish and Mussels	*Fundulus diaphanus*	Banded Killifish	SC	—	6/20/1995
					7/11/1978
					11/9/1978
	Opsopoeodus emiliae	Pugnose Minnow	SC	—	6/26/1995
	Notropis anogenus	Pugnose Shiner	T	—	10/8/1971
	Luxilus chrysocephalus	Striped Shiner	E	—	7/12/1978
	Erimyzon sucetta	Lake Chubsucker	SC	—	7/11/1978
					3/29/1977
	Lythrurus umbratilis	Redfin Shiner	T	—	7/11//1924
					7/10/1924
	Lepomis megalotis	Longear Sunfish	T	—	1/9/1900
					7/10/1924
					11/9/1978

[a]E, Endangered; T, Threatened; SC, Species of Concern (not legally protected); R, Recovery

Appendix 3-A

Volume 1: Public Agency Correspondence

CH2M HILL
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January 12, 2010

Shari Koslowsky
Office of Energy SS/7
Wisconsin Department of Natural Resources
P.O. Box 7921
Madison, WI 53707-7921
Phone: (608) 261-4382

Subject: Threatened and Endangered Species Review Request
City of Waukesha Municipal Water Supply – Lake Michigan Diversion

Dear Ms. Koslowsky:

On behalf of the City of Waukesha (the City), CH2M HILL is requesting your verification that no threatened, endangered, proposed or candidate species, and/or unique habitats or natural areas exist in locations where infrastructure associated with obtaining a new water source for the City may be located. As requested by the Wisconsin DNR, the City is completing an environmental report that is evaluating the impacts of several alternatives to meet the current and future water supply needs of the City. These water supply alternatives include expanding existing groundwater sources, developing new groundwater sources, and obtaining and returning Lake Michigan water. This review will assist the City with evaluating the impacts of each alternative.

All of the proposed areas that may be impacted by water supply alternatives are located in the Counties of Waukesha, Milwaukee, or Racine, Wisconsin. The township, range, and section data for each proposed route is provided in tabular format in Attachment 1, which is included with this letter for your convenience. Attachment 2 is a map depicting the quarter sections from Attachment 1 that intersect with the alternatives.

CH2M HILL is requesting your concurrence that no state protected resources will be affected by or is located within one (1) mile of the water supply alternatives described above.

Because we are evaluating and comparing the alternatives, it is important that the potential impacts be identified for each alternative. We respectfully request that if potential impacts are identified in your review, that you please indicate which alignment ID and quarter section is impacted.

If you have any questions regarding this request or need additional information, please do not hesitate to contact me at (414) 272-2426, ext. 40356. Thank you.

Sincerely,

CH2M HILL



Corey Wilcox
Associate Scientist

Attachments:
(1) Tables 1 – 3. Township, Range, and Section Data for Water Supply Alternatives
(2) Map Depicting Quarter-Sections Impacted by Proposed Water Supply Alternatives

Cc: Mark Mittag/CH2M HILL
Brent Brown/CH2M HILL

TABLE 2A – 2D – TRS Data

TABLE 2A

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RB	06	19	01	2
RB	06	19	01	3
RB	06	19	02	3
RB	06	19	02	4
RB	06	19	03	3
RB	06	19	03	4
RB	06	19	04	4
RB	06	19	09	1
RB	06	19	01	1
RB	06	19	01	4
RB	06	20	01	1
RB	06	20	01	2
RB	06	20	01	3
RB	06	20	01	4
RB	06	20	02	1
RB	06	20	02	2
RB	06	20	02	3
RB	06	20	02	4
RB	06	20	03	1
RB	06	20	03	2
RB	06	20	03	3
RB	06	20	03	4
RB	06	20	04	1
RB	06	20	04	2
RB	06	20	04	3
RB	06	20	04	4
RB	06	20	05	1
RB	06	20	05	2
RB	06	20	05	3
RB	06	20	05	4
RB	06	20	06	1
RB	06	20	06	2

TABLE 2A

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RB	06	20	06	3
RB	06	20	06	4

TABLE 2B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RLM	06	21	02	3
RLM	06	21	02	4
RLM	06	21	03	1
RLM	06	21	03	2
RLM	06	21	03	3
RLM	06	21	03	4
RLM	06	21	04	1
RLM	06	21	04	2
RLM	06	21	04	3
RLM	06	21	04	4
RLM	06	21	05	1
RLM	06	21	05	2
RLM	06	21	05	3
RLM	06	21	05	4
RLM	06	21	06	1
RLM	06	21	06	4
RLM	06	21	11	1
RLM	06	21	12	1
RLM	06	21	12	2
RLM	06	21	12	4
RLM	06	22	07	3
RLM	06	22	07	4
RLM	06	22	08	3
RLM	06	22	08	4
RLM	06	22	15	2
RLM	06	22	15	3

TABLE 2B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RLM	06	22	15	4
RLM	06	22	16	1
RLM	06	22	16	2
RLM	06	22	17	1
RLM	06	22	22	1
RLM	06	22	23	1
RLM	06	22	23	2
RLM	06	22	23	3
RLM	06	22	23	4
RLM	06	22	24	2
RLM	06	22	24	3
RLM	06	20	01	1
RLM	06	20	01	4
RLM	06	21	06	2
RLM	06	21	06	3

TABLE 2C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RRG	06	20	12	1
RRG	06	21	06	3
RRG	06	21	07	2
RRG	06	21	07	3
RRG	06	21	07	4
RRG	06	21	18	1
RRG	06	21	18	2
RRG	06	21	18	3
RRG	06	21	18	4
RRG	06	21	19	1
RRG	06	21	20	2
RRG	06	21	20	3
RRG	06	21	28	2

TABLE 2C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RRG	06	21	28	3
RRG	06	21	28	4
RRG	06	21	29	1
RRG	06	21	29	2
RRG	06	21	29	4
RRG	06	20	01	4

TABLE 2D

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RUB	06	21	06	2
RUB	07	20	25	4
RUB	07	20	36	1
RUB	07	20	36	4
RUB	07	21	31	2
RUB	07	21	31	3
RUB	06	20	01	1

TABLE 3A – 3F – TRS Data

TABLE 3A

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SSWF	05	19	04	1
SSWF	05	19	04	2
SSWF	06	19	28	3
SSWF	06	19	28	4
SSWF	06	19	33	1
SSWF	06	19	33	2
SSWF	06	19	33	3
SSWF	06	19	33	4

TABLE 3B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SAWTP	06	19	29	3
SAWTP	06	19	32	2

TABLE 3C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
VMWTPHR	06	19	01	1
VMWTPHR	06	19	01	4
VMWTPHR	06	19	13	1
VMWTPHR	06	19	13	4
VMWTPHR	06	19	20	3
VMWTPHR	06	19	20	4
VMWTPHR	06	19	21	3
VMWTPHR	06	19	21	4
VMWTPHR	06	19	22	3
VMWTPHR	06	19	22	4
VMWTPHR	06	19	23	3
VMWTPHR	06	19	23	4

TABLE 3C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
VMWTPHR	06	19	24	1
VMWTPHR	06	19	24	2
VMWTPHR	06	19	24	3
VMWTPHR	06	19	24	4
VMWTPHR	06	19	25	1
VMWTPHR	06	19	25	2
VMWTPHR	06	19	26	1
VMWTPHR	06	19	26	2
VMWTPHR	06	19	27	1
VMWTPHR	06	19	27	2
VMWTPHR	06	19	28	1
VMWTPHR	06	19	28	2
VMWTPHR	06	19	29	1
VMWTPHR	06	19	29	2
VMWTPHR	06	19	29	3
VMWTPHR	06	20	06	1
VMWTPHR	06	20	06	2
VMWTPHR	06	20	06	3
VMWTPHR	06	20	06	4
VMWTPHR	06	20	07	1
VMWTPHR	06	20	07	3
VMWTPHR	06	20	07	4
VMWTPHR	06	20	18	2
VMWTPHR	06	20	18	3
VMWTPHR	06	19	36	4

TABLE 3D

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SWSWF	06	19	29	1
SWSWF	06	19	29	2

TABLE 3D

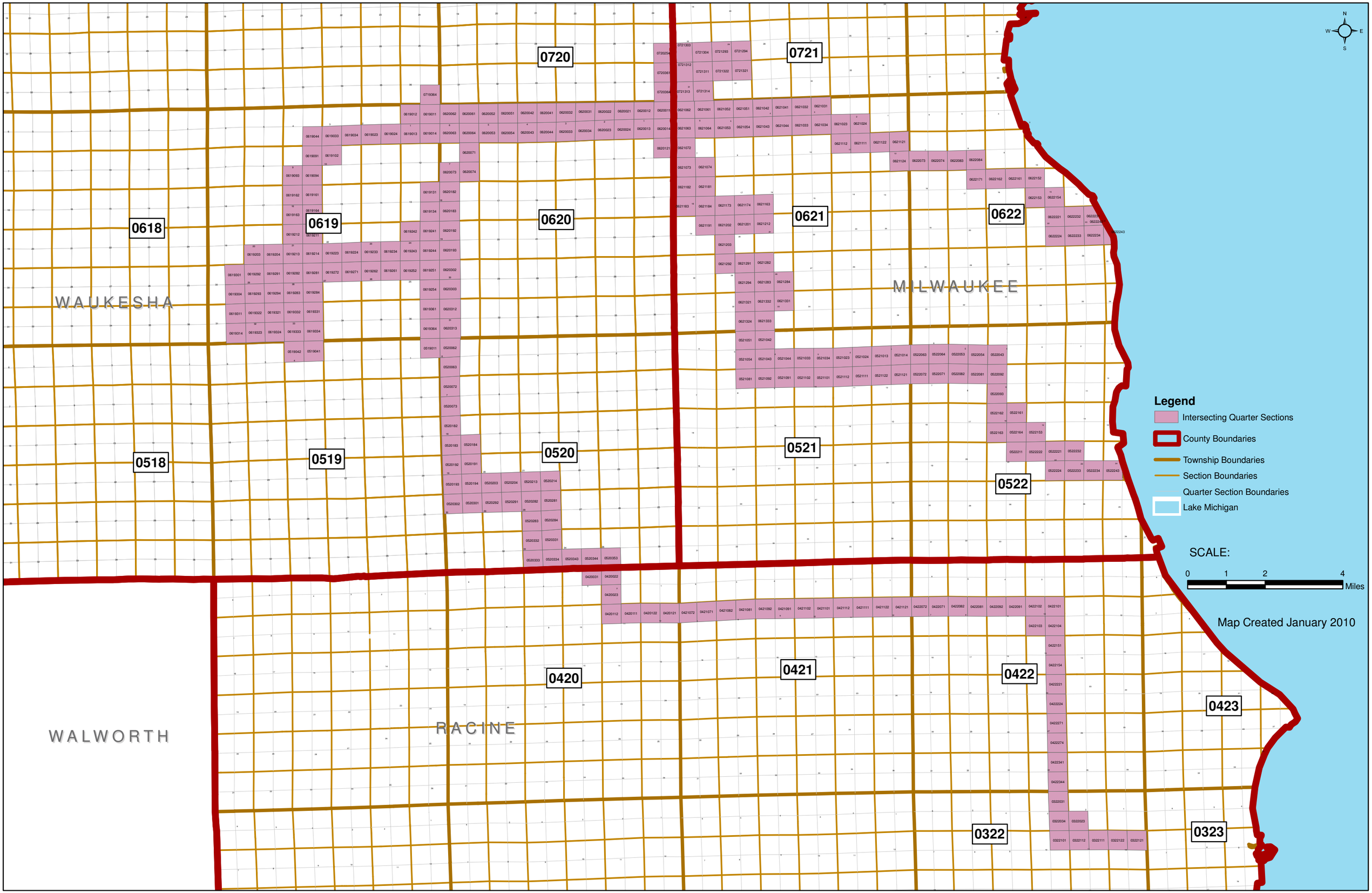
ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SWSWF	06	19	29	3
SWSWF	06	19	29	4
SWSWF	06	19	30	1
SWSWF	06	19	30	4
SWSWF	06	19	31	1
SWSWF	06	19	32	1
SWSWF	06	19	32	2

TABLE 3E

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
WTPSWWTP	06	19	09	1
WTPSWWTP	06	19	09	3
WTPSWWTP	06	19	09	4
WTPSWWTP	06	19	10	2
WTPSWWTP	06	19	16	1
WTPSWWTP	06	19	16	2
WTPSWWTP	06	19	16	3
WTPSWWTP	06	19	16	4
WTPSWWTP	06	19	20	3
WTPSWWTP	06	19	20	4
WTPSWWTP	06	19	21	1
WTPSWWTP	06	19	21	2
WTPSWWTP	06	19	21	3
WTPSWWTP	06	19	21	4
WTPSWWTP	06	19	28	1
WTPSWWTP	06	19	28	2
WTPSWWTP	06	19	29	1
WTPSWWTP	06	19	29	2
WTPSWWTP	06	19	29	3

TABLE 3F

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
WWURLLS	06	19	29	3
WWURLLS	06	19	29	4
WWURLLS	06	19	30	4
WWURLLS	06	19	31	1
WWURLLS	06	19	31	4
WWURLLS	06	19	32	1
WWURLLS	06	19	32	2
WWURLLS	06	19	32	3
WWURLLS	06	19	32	4



0720
0721
0618
0619
0620
0621
0622
WAUKESHA
MILWAUKEE
0518
0519
0520
0521
0522
0420
0421
0422
0423
WALWORTH
RACINE
0322
0323
Legend
Intersecting Quarter Sections
County Boundaries
Township Boundaries
Section Boundaries
Quarter Section Boundaries
Lake Michigan
SCALE:
0
1
2
4
Miles
Map Created January 2010

CH2M HILL
135 S. 84th Street
Suite 325
Milwaukee, WI 53214
Tel 414-272-2426
Fax 414-272-4408

January 13, 2010

Ms. Louise Clemency
Ecological Services Office – Green Bay
U.S. Fish and Wildlife Service
2661 Scott Tower Drive
New Franken, WI 54229
Phone: (920) 866-1717

Subject: Threatened and Endangered Species Review Request
City of Waukesha, Wisconsin Application for Lake Michigan Water Supply

Dear Ms. Clemency:

On behalf of the City of Waukesha (the City), CH2M HILL is requesting your verification that no threatened, endangered, proposed or candidate species, and/or unique habitats or natural areas exist in locations where infrastructure associated with obtaining a new water source for the City may be located. As requested by the Wisconsin DNR, the City is completing an environmental report that is evaluating the impacts of several alternatives to meet the current and future water supply needs of the City. These water supply alternatives include expanding existing groundwater sources, developing new groundwater sources, and obtaining and returning Lake Michigan water. This review will assist the City with evaluating the impacts of each alternative.

All of the proposed areas that may be impacted by water supply alternatives are located in the Counties of Waukesha, Milwaukee, or Racine, Wisconsin. The township, range, and section data for each proposed route is provided in tabular format in Attachment 1, which is included with this letter for your convenience. Attachment 2 is a map depicting the quarter sections from Attachment 1 that intersect with the alternatives.

CH2M HILL reviewed the online U.S. Fish and Wildlife Service (USFWS), Midwest Region's *County Distribution of Federally-listed Endangered, Threatened, Proposed, and Candidate Species* list for the state of Wisconsin, and found that no species are listed for either Milwaukee or Racine County. However, there is one threatened species listed for Waukesha County: the eastern prairie fringed orchid (*Platanthera leucophaea*). According to the USFWS, the eastern prairie fringed orchid typically occurs in wet grassland habitats.

CH2M HILL is requesting your concurrence that no federally protected resources will be affected by or is located within one (1) mile of the water supply alternatives described above.

Because we are evaluating and comparing the alternatives, it is important that the potential impacts be identified for each alternative. We respectfully request that if potential impacts are identified in your review, that you please indicate which alignment ID and quarter section is impacted.

If you have any questions regarding this request or need additional information, please do not hesitate to contact me at (414) 272-2426, ext. 40356. Thank you.

Sincerely,

CH2M HILL

Corey Wilcox
Associate Scientist

Attachments:
(1) Tables 1 – 3. Township, Range, and Section Data for Water Supply Alternatives
(2) Map Depicting Quarter-Sections Impacted by Proposed Water Supply Alternatives

Cc: Mark Mittag/CH2M HILL
Brent Brown/CH2M HILL

TABLE 1A – 1H – TRS Data

TABLE 1A

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
MS	06	21	17	3
MS	06	21	17	4
MS	06	21	20	1
MS	06	20	01	4
MS	06	20	12	1
MS	06	21	06	3
MS	06	21	07	2
MS	06	21	07	3
MS	06	21	18	1
MS	06	21	18	2
MS	06	21	18	3
MS	06	21	18	4
MS	06	21	19	1
MS	06	21	20	2

TABLE 1B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
OCS	05	21	01	3
OCS	05	21	01	4
OCS	05	21	02	3
OCS	05	21	02	4
OCS	05	21	03	3
OCS	05	21	03	4
OCS	05	21	04	2
OCS	05	21	04	3
OCS	05	21	04	4
OCS	05	21	05	1
OCS	05	21	05	4
OCS	05	21	08	1
OCS	05	21	09	1

TABLE 1B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
OCS	05	21	09	2
OCS	05	21	10	1
OCS	05	21	10	2
OCS	05	21	11	1
OCS	05	21	11	2
OCS	05	21	12	1
OCS	05	21	12	2
OCS	05	22	04	3
OCS	05	22	05	3
OCS	05	22	05	4
OCS	05	22	06	3
OCS	05	22	06	4
OCS	05	22	07	1
OCS	05	22	07	2
OCS	05	22	08	1
OCS	05	22	08	2
OCS	05	22	09	2
OCS	05	22	09	3
OCS	05	22	15	3
OCS	05	22	16	1
OCS	05	22	16	2
OCS	05	22	16	4
OCS	05	22	21	1
OCS	05	22	22	1
OCS	05	22	22	2
OCS	05	22	22	4
OCS	05	22	23	2
OCS	05	22	23	3
OCS	05	22	23	4
OCS	06	21	32	1
OCS	06	21	32	4
OCS	06	21	33	2
OCS	06	21	33	3

TABLE 1B

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
OCS	06	20	01	4
OCS	06	20	12	1
OCS	06	21	06	3
OCS	06	21	07	2
OCS	06	21	07	3
OCS	06	21	18	1
OCS	06	21	18	2
OCS	06	21	18	3
OCS	06	21	18	4
OCS	06	21	19	1
OCS	06	21	20	2
OCS	06	21	20	3
OCS	06	21	28	3
OCS	06	21	29	1
OCS	06	21	29	2
OCS	06	21	29	4

TABLE 1C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RS	03	22	03	1
RS	03	22	03	4
RS	03	22	10	1
RS	03	22	11	1
RS	03	22	11	2
RS	03	22	12	1
RS	03	22	12	2
RS	04	20	02	2
RS	04	20	02	3
RS	04	20	03	1
RS	04	20	11	1
RS	04	20	11	2

TABLE 1C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RS	04	20	12	1
RS	04	20	12	2
RS	04	21	07	1
RS	04	21	07	2
RS	04	21	08	1
RS	04	21	08	2
RS	04	21	09	1
RS	04	21	09	2
RS	04	21	10	1
RS	04	21	10	2
RS	04	21	11	1
RS	04	21	11	2
RS	04	21	12	1
RS	04	21	12	2
RS	04	22	07	1
RS	04	22	07	2
RS	04	22	08	1
RS	04	22	08	2
RS	04	22	09	1
RS	04	22	09	2
RS	04	22	10	1
RS	04	22	10	2
RS	04	22	10	4
RS	04	22	15	1
RS	04	22	15	4
RS	04	22	22	1
RS	04	22	22	4
RS	04	22	27	1
RS	04	22	27	4
RS	04	22	34	1
RS	04	22	34	4
RS	05	19	01	1
RS	05	20	06	2

TABLE 1C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RS	05	20	06	3
RS	05	20	07	2
RS	05	20	07	3
RS	05	20	18	2
RS	05	20	18	3
RS	05	20	18	4
RS	05	20	19	1
RS	05	20	19	2
RS	05	20	19	3
RS	05	20	19	4
RS	05	20	20	3
RS	05	20	20	4
RS	05	20	21	3
RS	05	20	21	4
RS	05	20	28	1
RS	05	20	28	2
RS	05	20	28	3
RS	05	20	28	4
RS	05	20	29	1
RS	05	20	29	2
RS	05	20	30	1
RS	05	20	30	2
RS	05	20	33	1
RS	05	20	33	2
RS	05	20	33	3
RS	05	20	33	4
RS	05	20	34	3
RS	05	20	34	4
RS	05	20	35	3
RS	06	19	24	1
RS	06	19	24	4
RS	06	19	25	1
RS	06	19	25	4

TABLE 1C

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
RS	06	19	36	1
RS	06	19	36	4
RS	06	20	19	2
RS	06	20	19	3
RS	06	20	30	2
RS	06	20	30	3
RS	06	20	31	2
RS	06	20	31	3

TABLE 1D

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SB	06	20	01	1
SB	06	20	01	2
SB	06	20	01	3
SB	06	20	01	4
SB	06	20	02	1
SB	06	20	02	2
SB	06	20	02	3
SB	06	20	02	4
SB	06	20	03	1
SB	06	20	03	2
SB	06	20	03	3
SB	06	20	03	4
SB	06	20	04	1
SB	06	20	04	2
SB	06	20	04	3
SB	06	20	04	4
SB	06	20	05	1
SB	06	20	05	2
SB	06	20	05	3
SB	06	20	05	4

TABLE 1D

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SB	06	20	06	1
SB	06	20	06	4

TABLE 1E

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SNEWHR	06	19	01	1
SNEWHR	06	19	01	4
SNEWHR	06	20	06	1
SNEWHR	06	20	06	2
SNEWHR	06	20	06	3
SNEWHR	07	19	36	4
SNEWHR	06	20	06	4

TABLE 1F

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
SSEWHT	06	19	13	4
SSEWHT	06	20	06	4
SSEWHT	06	20	07	1
SSEWHT	06	20	07	3
SSEWHT	06	20	07	4
SSEWHT	06	20	18	2
SSEWHT	06	20	18	3

TABLE 1G

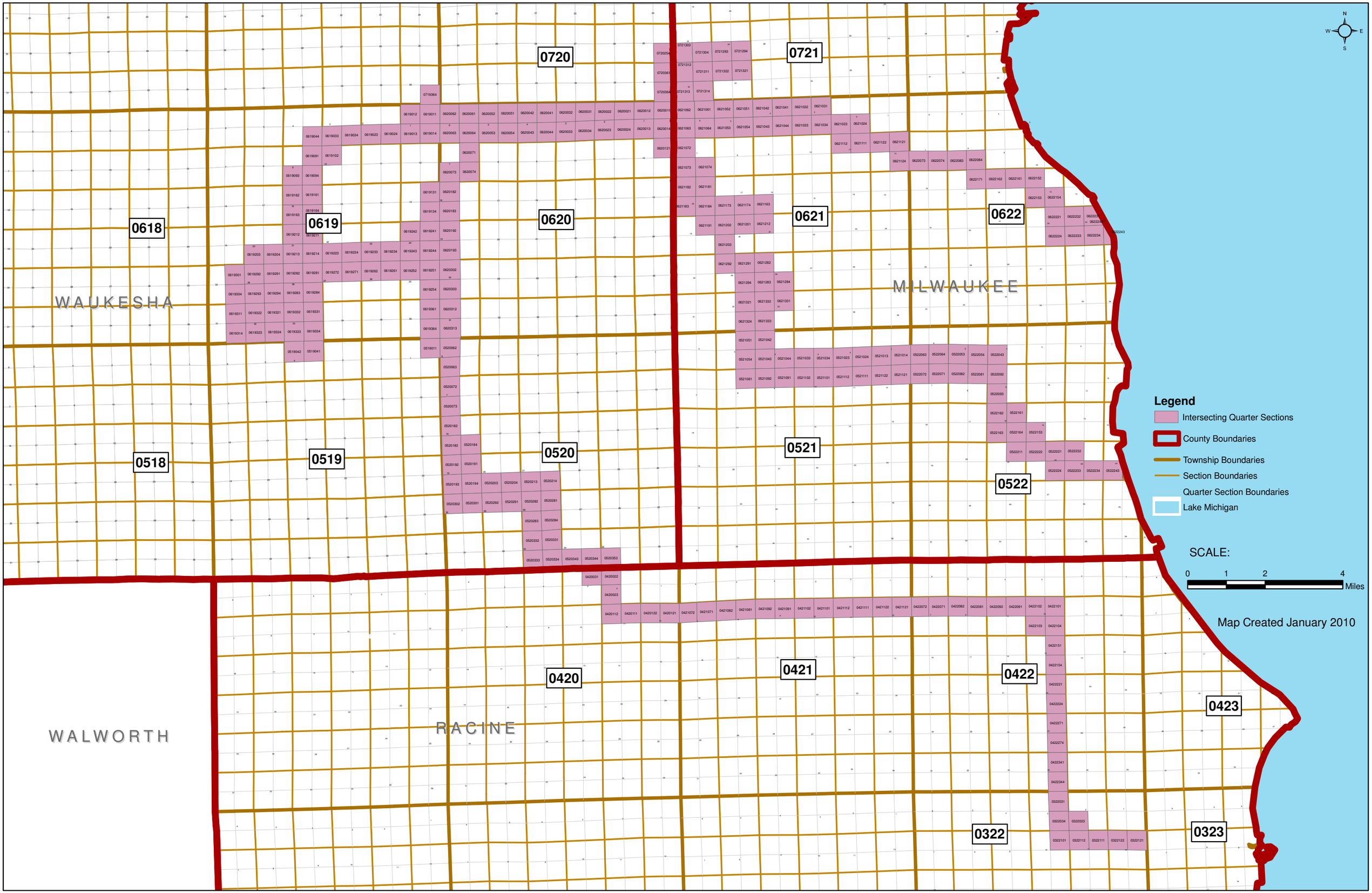
ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
EVSWS	06	19	28	3
EVSWS	06	19	28	4

TABLE 1G

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
EVSWS	06	19	29	3
EVSWS	06	19	29	4
EVSWS	06	19	32	1
EVSWS	06	19	32	2
EVSWS	06	19	33	1
EVSWS	06	19	33	2

TABLE 1H

ALIGNMENT	TWN	RNG	SEC	QUARTER_SEC_ID
MSZ	06	21	06	2
MSZ	07	21	29	3
MSZ	07	21	29	4
MSZ	07	21	30	4
MSZ	07	21	31	1
MSZ	07	21	31	2
MSZ	07	21	31	3
MSZ	07	21	31	4
MSZ	07	21	32	1
MSZ	07	21	32	2



0720
0721
0618
0619
0620
0621
0622
WAUKESHA
MILWAUKEE
0518
0519
0520
0521
0522
0420
0421
0422
0423
WALWORTH
RACINE
0322
0323
Legend
Intersecting Quarter Sections
County Boundaries
Township Boundaries
Section Boundaries
Quarter Section Boundaries
Lake Michigan
SCALE:
0
1
2
4
Miles
Map Created January 2010
N
S
E
W

CH2MHILL TRANSMITTAL

To: Wisconsin Dept. of Natural Resources
Office of Energy, OE/7
101 S. Webster S., P.O. Box 7921
Madison, WI 53707-7921

From: Corey Wilcox
135 S. 84th Street, Suite 325
Milwaukee, WI 53076

Attn: Shari Koslowsky

Date: January 20, 2010

Re: City of Waukesha, Wisconsin- Application for Lake Michigan Water Supply

We Are Sending You:

[Attached]
Shop Drawings
Prints
Copy of letter

Method of shipment:

Under separate cover via
Documents
Specifications
Other:

Tracings
Catalogs

Quantity	Description
1	CD containing shapefiles of the alternative routes being evaluated

If the material received is not as listed, please notify us at once.

Shari,

As we discussed on the phone on Tuesday, Jan. 19, we would like your help in evaluating T/E concerns along the potential water supply and return options included in the January 12, 2010 letter sent to you via email. In order to help facilitate your review I have enclosed a CD containing shape files that show each of the routes currently being evaluated. Of the multiple routes being evaluated, we would prefer your review and comment on 4 in particular by close of business on Monday, January 25 in order to prepare for a public meeting on the project on January 26. These four routes are designated as:

Alt 1 Deep and Shallow Wells
Alt 2 Shallow Aquifer and Fox River Alluvium
Alt 3a-1 Milwaukee
Alt 3b-2 Underwood Creek

We understand you have a busy schedule and for the purposes of the January 26 public meeting we are only looking for a list of T/E species for each of the four routes listed above. A more detailed discussion on the specific impacts that may be anticipated can be provided as follow up material.

Thank you.

Corey Wilcox

Copy To:
Mark Mittag / CH2M HILL

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CH2M HILL
135 S. 84th Street
Suite 325
Milwaukee, WI 53214
Tel 414-272-2426
Fax 414-272-4408

February 2, 2010

Ms. Jill Utrupp
Ecological Services Office – Green Bay
U.S. Fish and Wildlife Service
2661 Scott Tower Drive
New Franken, WI 54229

Subject: Environmental Review
City of Waukesha Municipal Water Supply – Lake Michigan Diversion

Dear Ms. Utrupp:

This letter is a follow-up to the initial threatened and endangered (T&E) species review request letter sent on January 13, 2010, and subsequent phone and email correspondence on January 21 and 26, 2010 regarding several alternatives being considered to meet future water supply needs of the City of Waukesha (City).

On behalf of the City, CH2M HILL is requesting a more detailed environmental impact review for the locations where the alternatives are proposed, to further identify and evaluate any potential impacts the alternatives may have on federal-listed species, federal-managed lands, and/or sensitive habitats. The township, range, and section data for each proposed alternative is provided in tabular format in Attachment 1, which is included with this letter for your convenience. In addition, a copy of the Draft Application for Lake Michigan Water Supply, which provides a explanation of the nature, location, and general impacts resulting from the proposed project, has been included (Attachment 2) to provide you with more detailed information regarding the proposed alternatives.

Due to the need to compare each of the alternatives, we would appreciate if you would provide a separate review and analysis of the potential impacts for each alternative. Accordingly, we respectfully request that you please indicate the corresponding alternative name and which section /quarter section(s) the resource may be present.

If you have any questions regarding this request or need additional information, please do not hesitate to contact me at (414) 272-2426, ext. 40356. Thank you.

Sincerely,

CH2M HILL

Corey Wilcox

Corey Wilcox
Associate Scientist

Attachments:
Tables 1 – 8. Township, Range, and Section Data for Proposed Water Supply and Return Alternatives

DRAFT Application Lake Michigan Water Supply

Cc: Mark Mittag/CH2M HILL
Brent Brown/CH2M HILL

CH2M HILL
135 S. 84th Street
Suite 325
Milwaukee, WI 53214
Tel 414-272-2426
Fax 414-272-4408

February 2, 2010

Shari Koslowsky
Office of Energy SS/7
Wisconsin Department of Natural Resources
P.O. Box 7921
Madison, WI 53707-7921

Subject: Environmental Review
City of Waukesha Municipal Water Supply – Lake Michigan Diversion

Dear Ms. Koslowsky:

This letter is a follow-up to the initial threatened and endangered (T&E) species review request letter sent on January 13, 2010, and subsequent phone and email correspondence on January 19, 2010 regarding several alternatives being considered to meet future water supply needs of the City of Waukesha (City).

On behalf of the City, CH2M HILL is requesting a more detailed environmental impact review for the locations where the alternatives are proposed, to further identify and evaluate any potential impacts the alternatives may have on state-listed species, state-managed lands, and/or sensitive habitats. The township, range, and section data for each proposed alternative is provided in tabular format in Attachment 1, which is included with this letter for your convenience. In addition, a copy of the Draft Application for Lake Michigan Water Supply, which provides a explanation of the nature, location, and general impacts resulting from the proposed project, has been included (Attachment 2) to provide you with more detailed information regarding the proposed alternatives.

Due to the need to compare each of the alternatives, we would appreciate if you would provide a separate review and analysis of the potential impacts for each alternative. Accordingly, we respectfully request that you please indicate the corresponding alternative name and which section /quarter section(s) the resource may be present.

If you have any questions regarding this request or need additional information, please do not hesitate to contact me at (414) 272-2426, ext. 40356. Thank you.

Sincerely,

CH2M HILL

Corey Wilcox

Corey Wilcox
Associate Scientist

Attachments:
Tables 1 – 8. Township, Range, and Section Data for Proposed Water Supply and Return Alternatives

DRAFT Application Lake Michigan Water Supply

Cc: Mark Mittag/CH2M HILL
Brent Brown/CH2M HILL

TRS Data for Proposed Supply and Return Routes

TABLE 1
Alternative 1
Deep and Shallow Wells (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	16	2
06	19	16	1
06	19	15	2
06	19	15	1
06	19	16	3
06	19	16	4
06	19	30	4
06	19	29	3
06	19	29	4
06	19	28	3
06	19	28	4
06	19	03	3
06	19	03	4
07	19	35	3
07	19	35	4
07	19	36	3
07	19	36	4
06	19	09	3
06	19	09	4
06	19	10	3
06	19	10	4
06	19	09	1
06	19	10	2
06	19	10	1
06	19	03	2
06	19	03	1
06	19	02	2
06	19	02	1
06	19	31	1
06	19	32	2
06	19	32	1

TABLE 1
Alternative 1
Deep and Shallow Wells (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	33	2
06	19	33	1
06	19	31	4
06	19	32	3
06	19	32	4
06	19	33	3
06	19	33	4
06	19	29	2
06	19	29	1
06	19	28	2
06	19	28	1
06	19	20	3
06	19	20	4
06	19	21	3
06	19	21	4
06	19	21	2
06	19	21	1

TABLE 2
Alternative 2
Shallow Aquifer and Fox River Alluvium (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	16	2
06	19	16	1
06	19	15	2
06	19	15	1
06	19	16	3
06	19	16	4
06	19	30	4
06	19	29	3
06	19	29	4
06	19	28	3
06	19	28	4
06	19	03	3
06	19	03	4
07	19	35	3
07	19	35	4
07	19	36	3
07	19	36	4
06	19	09	3
06	19	09	4
06	19	10	3
06	19	10	4
06	19	09	1
06	19	10	2
06	19	10	1
06	19	03	2
06	19	03	1
06	19	02	2
06	19	02	1
06	19	31	1
06	19	32	2
06	19	32	1
06	19	33	2

TABLE 2
Alternative 2
Shallow Aquifer and Fox River Alluvium (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	33	1
06	19	31	4
06	19	32	3
06	19	32	4
06	19	33	3
06	19	33	4
06	19	30	1
06	19	29	2
06	19	29	1
06	19	28	2
06	19	28	1
06	19	20	3
06	19	20	4
06	19	21	3
06	19	21	4
06	19	21	2
06	19	21	1

TABLE 3
Alternative 3a-1
Milwaukee Supply

TWN	RNG	SEC	QUARTER_SEC_ID
06	21	06	2
06	21	06	3
06	21	07	1
06	21	07	2
06	21	07	3
06	21	07	4
06	21	14	3
06	21	15	3
06	21	15	4
06	21	16	3
06	21	16	4
06	21	17	3
06	21	17	4
06	21	18	1
06	21	18	2
06	21	18	3
06	21	18	4
06	21	19	1
06	21	19	2
06	21	20	1
06	21	20	2
06	21	21	1
06	21	21	2
06	21	22	1
06	21	22	2
06	21	23	2
06	20	06	3
06	20	06	4
06	20	05	3
06	20	05	4
06	20	04	3
06	20	04	4

TABLE 3
Alternative 3a-1
Milwaukee Supply

TWN	RNG	SEC	QUARTER_SEC_ID
06	20	03	3
06	20	03	4
06	20	02	3
06	20	02	4
06	20	01	3
06	20	01	4
06	19	01	4
07	19	36	4
06	20	10	1
06	20	11	2
06	20	11	1
06	20	12	2
06	20	12	1
06	19	01	1
06	20	06	2
06	20	06	1
06	20	05	2
06	20	05	1
06	20	04	2
06	20	04	1
06	20	03	2
06	20	03	1
06	20	02	2
06	20	02	1
06	20	01	2
06	20	01	1

TABLE 4
Alternative 3a-2
Oak Creek (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
05	21	01	3
05	21	01	4
05	21	02	3
05	21	02	4
05	21	03	3
05	21	03	4
05	21	04	2
05	21	04	3
05	21	04	4
05	21	05	1
05	21	05	4
05	21	08	1
05	21	09	1
05	21	09	2
05	21	10	1
05	21	10	2
05	21	11	1
05	21	11	2
05	21	12	1
05	21	12	2
05	22	04	3
05	22	05	3
05	22	05	4
05	22	06	3
05	22	06	4
05	22	07	1
05	22	07	2
05	22	08	1
05	22	08	2
05	22	09	2
05	22	09	3
05	22	15	3

TABLE 4
Alternative 3a-2
Oak Creek (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
05	22	16	1
05	22	16	2
05	22	16	3
05	22	16	4
05	22	21	1
05	22	22	1
05	22	22	2
05	22	22	4
05	22	23	2
05	22	23	3
05	22	23	4
05	22	24	3
06	20	01	4
06	20	12	1
06	21	06	3
06	21	07	2
06	21	07	3
06	21	18	1
06	21	18	2
06	21	18	3
06	21	18	4
06	21	19	1
06	21	20	2
06	21	20	3
06	21	28	3
06	21	29	1
06	21	29	2
06	21	29	4
06	21	32	1
06	21	32	4
06	21	33	2
06	21	33	3

TABLE 4
Alternative 3a-2
Oak Creek (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	20	01	1
06	20	01	2
06	20	01	3
06	20	01	4
06	20	02	1
06	20	02	2
06	20	02	3
06	20	02	4
06	20	03	1
06	20	03	2
06	20	03	3
06	20	03	4
06	20	04	1
06	20	04	2
06	20	04	3
06	20	04	4
06	20	05	1
06	20	05	2
06	20	05	3
06	20	05	4
06	20	06	1
06	20	06	4
06	19	01	1
06	19	01	4
06	20	06	1
06	20	06	2
06	20	06	3
06	20	06	4
07	19	36	4

TABLE 5
Alternative 3a-3
Racine (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
03	22	02	3
03	22	03	1
03	22	03	4
03	22	10	1
03	22	11	1
03	22	11	2
03	22	12	1
03	22	12	2
04	20	02	2
04	20	02	3
04	20	03	1
04	20	11	1
04	20	11	2
04	20	12	1
04	20	12	2
04	21	07	1
04	21	07	2
04	21	08	1
04	21	08	2
04	21	09	1
04	21	09	2
04	21	10	1
04	21	10	2
04	21	11	1
04	21	11	2
04	21	12	1
04	21	12	2
04	22	07	1
04	22	07	2
04	22	08	1
04	22	08	2
04	22	09	1

TABLE 5
Alternative 3a-3
Racine (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
04	22	09	2
04	22	10	1
04	22	10	2
04	22	10	3
04	22	10	4
04	22	15	1
04	22	15	4
04	22	22	1
04	22	22	4
04	22	27	1
04	22	27	4
04	22	34	1
04	22	34	4
05	19	01	1
05	20	06	2
05	20	06	3
05	20	07	2
05	20	07	3
05	20	18	2
05	20	18	3
05	20	18	4
05	20	19	1
05	20	19	2
05	20	19	3
05	20	19	4
05	20	20	3
05	20	20	4
05	20	21	3
05	20	21	4
05	20	28	1
05	20	28	2
05	20	28	3

TABLE 5
Alternative 3a-3
Racine (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
05	20	28	4
05	20	29	1
05	20	29	2
05	20	30	1
05	20	30	2
05	20	33	1
05	20	33	2
05	20	33	3
05	20	33	4
05	20	34	3
05	20	34	4
05	20	35	3
06	19	24	1
06	19	24	4
06	19	25	1
06	19	25	4
06	19	36	1
06	19	36	4
06	20	19	2
06	20	19	3
06	20	30	2
06	20	30	3
06	20	31	2
06	20	31	3
06	19	01	1
06	19	01	4
06	20	06	1
06	20	06	2
06	20	06	3
06	20	06	4
07	19	36	4
06	19	13	1

TABLE 5
Alternative 3a-3
Racine (Supply)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	13	4
06	20	06	4
06	20	07	1
06	20	07	3
06	20	07	4
06	20	18	2
06	20	18	3

TABLE 6
Alternative 3b-1
Underwood Creek (Return Route)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	01	1
06	19	01	2
06	19	01	3
06	19	01	4
06	19	02	3
06	19	02	4
06	19	03	3
06	19	03	4
06	19	04	4
06	19	09	1
06	19	10	2
06	20	01	1
06	20	01	2
06	20	01	3
06	20	01	4
06	20	02	1
06	20	02	2
06	20	02	3
06	20	02	4
06	20	03	1
06	20	03	2
06	20	03	3
06	20	03	4
06	20	04	1
06	20	04	2
06	20	04	3
06	20	04	4
06	20	05	1
06	20	05	2
06	20	05	3
06	20	05	4
06	20	06	1

TABLE 6
Alternative 3b-1
Underwood Creek (Return Route)

TWN	RNG	SEC	QUARTER_SEC_ID
06	20	06	2
06	20	06	3
06	20	06	4
06	20	01	1
06	21	06	2
07	20	25	4
07	20	36	1
07	20	36	4
07	21	30	3
07	21	31	2
07	21	31	3

TABLE 7
Alternative 3b-2
Root River (Return)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	01	1
06	19	01	2
06	19	01	3
06	19	01	4
06	19	02	3
06	19	02	4
06	19	03	3
06	19	03	4
06	19	04	4
06	19	09	1
06	19	10	2
06	20	01	1
06	20	01	2
06	20	01	3
06	20	01	4
06	20	02	1
06	20	02	2
06	20	02	3
06	20	02	4
06	20	03	1
06	20	03	2
06	20	03	3
06	20	03	4
06	20	04	1
06	20	04	2
06	20	04	3
06	20	04	4
06	20	05	1
06	20	05	2
06	20	05	3
06	20	05	4
06	20	06	1

TABLE 7
Alternative 3b-2
Root River (Return)

TWN	RNG	SEC	QUARTER_SEC_ID
06	20	06	2
06	20	06	3
06	20	06	4
06	20	01	4
06	20	12	1
06	21	06	3
06	21	07	2
06	21	07	3
06	21	07	4
06	21	18	1
06	21	18	2
06	21	18	3
06	21	18	4
06	21	19	1
06	21	20	2
06	21	20	3
06	21	28	2
06	21	28	3
06	21	28	4
06	21	29	1
06	21	29	2
06	21	29	4
06	21	33	1

TABLE 8
Alternative 3b-3
Direct to Lake Michigan (Return)

TWN	RNG	SEC	QUARTER_SEC_ID
06	19	01	1
06	19	01	2
06	19	01	3
06	19	01	4
06	19	02	3
06	19	02	4
06	19	03	3
06	19	03	4
06	19	04	4
06	19	09	1
06	19	10	2
06	20	01	1
06	20	01	2
06	20	01	3
06	20	01	4
06	20	02	1
06	20	02	2
06	20	02	3
06	20	02	4
06	20	03	1
06	20	03	2
06	20	03	3
06	20	03	4
06	20	04	1
06	20	04	2
06	20	04	3
06	20	04	4
06	20	05	1
06	20	05	2
06	20	05	3
06	20	05	4
06	20	06	1

TABLE 8
Alternative 3b-3
Direct to Lake Michigan (Return)

TWN	RNG	SEC	QUARTER_SEC_ID
06	20	06	2
06	20	06	3
06	20	06	4
06	20	01	1
06	20	01	4
06	21	02	3
06	21	02	4
06	21	03	1
06	21	03	2
06	21	03	3
06	21	03	4
06	21	04	1
06	21	04	2
06	21	04	3
06	21	04	4
06	21	05	1
06	21	05	2
06	21	05	3
06	21	05	4
06	21	06	1
06	21	06	2
06	21	06	3
06	21	06	4
06	21	11	1
06	21	11	2
06	21	12	1
06	21	12	2
06	21	12	4
06	22	07	3
06	22	07	4
06	22	08	3
06	22	08	4

TABLE 8
Alternative 3b-3
Direct to Lake Michigan (Return)

TWN	RNG	SEC	QUARTER_SEC_ID
06	22	15	2
06	22	15	3
06	22	15	4
06	22	16	1
06	22	16	2
06	22	17	1
06	22	22	1
06	22	22	4
06	22	23	1
06	22	23	2
06	22	23	3
06	22	23	4
06	22	24	2
06	22	24	3

CH2MHILL TRANSMITTAL

To: Office of Energy SS/7
Wisconsin DNR
101 S Webster Street - OE/7
P.O. Box 7921
Madison, WI 53707-7921

From: Corey Wilcox

135 South 84th Street
Suite 325
Milwaukee, WI 53214135 S. 84th Street, Suite 325
Milwaukee, WI 53076

Attn: Shari Koslowsky

Date: March 19, 2010

Re: Environmental Review - City of Waukesha Municipal Water Supply – Lake Michigan Diversion

We Are Sending You:

Method of shipment: FedEx

Attached	Under separate cover via	
Shop Drawings	Documents	Tracings
Prints	Specifications	Catalogs
Copy of letter	(Other:) CD containing Draft Application Document	

Quantity	Description
1	CD containing Aerial Photographs of the Supply and Return Flow Alternatives being evaluated as part of the Waukesha Water Utility- Lake Michigan Water Supply Application

If the material received is not as listed, please notify us at once.

Copy To: Mark Mittag/CH2M HILL

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Appendix

4A Public Service Archaeology and Architecture Program Archival Investigation Report (Confidential Information)

Tables

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Chapter 4
Cultural Resources

CHAPTER 4

Cultural Resources

4.1. Introduction

Section 106 of the National Historic Preservation Act (NHPA; 16 USC 470)) and its implementing regulations (36 CFR 800) require federal agencies (such as the U.S. Army Corps of Engineers [USACE] when issuing a Section 404 permit) to take into account the effects of their undertakings on historic properties listed in or eligible for listing in the National Register of Historic Places (NRHP; 36 CFR 60). Each of the water supply alternatives being considered will likely trigger federal permit requirements and subsequent Section 106 compliance. The NHPA and the regulations also require federal agencies to consult with the appropriate State Historic Preservation Officers (SHPOs) and federally-recognized Native American tribes for undertakings with the potential to affect NRHP-listed or -eligible properties. In order to comply with NHPA, the City will initiate the necessary consultations and conduct cultural resources surveys once the construction workspace has been determined. The construction workspace will be determined once the water supply provider and return flow alternative have been determined and approved.

In addition, if the City applies for a Chapter 30 Wetland Water Quality Certification and/or a Wisconsin Pollutant Discharge Elimination System (WPDES) permit from the WDNR, then a cultural resource review will also be triggered. The permit review process involves a preliminary desktop cultural resources review by the WDNR to identify cultural resources or sites potentially impacted by the proposed supply and return flow alternatives. A request for cultural resource surveys may be initiated and required by the WDNR if the preliminary review results in cultural resources or sites being located along or within the construction workspace. If cultural resource surveys are required by the WDNR or SHPO in order to be in compliance with Section 106 of the National Historic Preservation Act, the City will work with an archeologist to conduct the necessary cultural resource surveys.

A majority of each alternative co-locates along previously disturbed utility corridors, roadways, railroad ROWs, or recreational trails, which is likely to minimize impacts to previously undisturbed resources. The City will follow any applicable requirements to protect cultural resources regardless of what alternative is chosen, and the City will implement minor adjustments to alignments or other disturbance minimization measures, if necessary, in order to avoid potential impacts. Consequently, no significant impacts to known cultural resources will occur.

Archival investigations were conducted by The Public Service Archaeology & Architecture Program of the University of Illinois at Urbana-Champaign (PSAAP) to identify significant cultural resources within or adjacent to potential construction corridors of the proposed supply and return flow alternatives. The investigations included a review of the known archaeological sites and previous cultural resource surveys within 100 meters of each alternative's potential corridor. These findings contain archeologically sensitive and confidential information and are not intended for public release.

Although some of the alternatives evaluated share project corridors and thus have the potential to disturb the same cultural sites, most alternatives' corridors are separate, and therefore each alternative was investigated separately. The results of the archival investigations are listed below and summarized below.

Supply Alternatives
- Deep and Shallow Aquifers: 9 sites and 2 surveys
- Shallow Aquifer and Fox River Alluvium: 10 sites and 2 surveys
- Lake Michigan—Milwaukee Supply: 5 sites and 6 surveys
- Lake Michigan—Oak Creek Supply: 11 sites and 11 surveys
- Lake Michigan—Racine Supply: 2 sites and 7 surveys

Return Flow Alternatives
- Underwood Creek to Lake Michigan: 6 sites and 7 surveys
- Root River to Lake Michigan: 9 sites and 2 surveys
- Direct to Lake Michigan: 17 sites and 7 surveys

4.2. Archaeological Sites

4.2.1. Supply Alternatives

4.2.1.1. Deep and Shallow Aquifers

According to the archival investigations, nine archaeological sites exist within 100 m (328 feet) of the centerline of this proposed supply route. Table 4-1 provides the locations and descriptions of these nine sites.

4.2.1.2. Shallow Aquifer and Fox River Alluvium

According to the archival investigations, 10 archaeological sites exist within 100 m (or 328 feet) of the centerline of this proposed supply route. Table 4-2 provides the locations and descriptions of these 10 sites.

4.2.1.3. Lake Michigan—Milwaukee Supply

According to the archival investigations, five archaeological sites exist within 100 m (328 feet) of the centerline of this proposed supply route. Table 4-3 provides the locations and descriptions of these five sites.

4.2.1.4. Lake Michigan Supply—Oak Creek

According to the archival investigations, 11 archaeological sites exist within 100 m (328 feet) of the centerline of this proposed supply route. Table 4-4 provides the locations and descriptions of these 11 sites.

4.2.1.5. Lake Michigan Supply—Racine

According to the archival investigations, two archaeological sites exist within 100 m (328 feet) of the centerline of this proposed supply route. Table 4-5 provides the locations and descriptions of these two sites.

TABLE 4-1
Archaeological Sites within 100 m of Centerline of a Supply Alternative: Deep and Shallow Aquifers[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Ludy Jan Site	6N	19E	Unknown Historic Indian campsite/ village/workshop. A large amount of archaeological material is distributed on a sandy ridge. It appears to be a multicomponent site with a variety of material ranging from Archaic to Historic.	Update 1979: Following Phase II investigations, the site was determined *not* to be eligible for listing on the National/State Register of Historic Places. Current recommendations may differ from the original findings, and site status should be confirmed with WHS.
Gienke #3	6N	19E	Unknown prehistoric campsite/village/ workshop adjacent to the Fox River.	The current status is unknown, and additional investigations may need to be completed. Consultation with WHS is necessary.
Gienke #1	6N	19E	Unknown prehistoric campsite/village/ workshop. This site consists of a scatter of fire-cracked rock, debitage, and nondiagnostic lithic tools.	Update 2007: Intensive surface survey failed to relocate this site. The extended cultivation of this land has likely disturbed and deflated the site. The current status is unknown and additional investigations may be necessary. Consultation with WHS is necessary.
Gienke #2	6N	19E	Late Archaic to Middle Woodland campsite/village/workshop. The distribution of material was widely scattered.	The current status is unknown, and additional investigations may need to be completed. Consultation with WHS is necessary.
Stephen Peet's Mounds	6N	19E	A group of mounds. Due to the vague nature of the report, the site is not mapped. No other information is available.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Prairie Home Cemetery	6N	19E	A Historic Euro-American cemetery/burial. This site consists of a marked Euro-American cemetery established 1841 and possibly as early as 1835. The site occupies an 8-acre parcel and has expanded to 80 acres, due to transfers from other, smaller cemeteries. Prairie Home also has a potter's field.	This burial site is catalogued and subject to the provisions of Wis. Stats 157.70. Consultation with WHS is required.
Tcheegascoutak	6N	19E	Historic Indian campsite/village. The Potawatomi settlement of Tcheegascoutak is reported for this location. Historic records indicate that the large village may have been inhabited by as many as 4,000 people around 1827.	This site is listed on the National/State Register of Historic Places and may be afforded special consideration pursuant to state and/or federal law. Consultation with WHS is necessary.
Main Street Mounds	6N	19E	Late Woodland mounds–conical, effigy, linear. The site consists of a group of one panther effigy, one linear, and one conical mound. No other information is available.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Court House Mounds	6N	19E	Late Woodland mounds–conical, effigy, linear, and historic Indian, historic Euro-American trading/fur post. The Waukesha Museum was erected over the location of the turtle mound, and two mounds were located in the middle of modern Main St. This site consists of a group of mounds. A postcontact grave had been excavated into one of the turtle mounds.	Update 2000: The Vieau-Juneau Trading Post has been reported at this location. This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Lapham (1836, 1855); Brown (1906b, 1906c, 1923b, 1923d, 1925, 1930a, 1930b); Overstreet and Brazeau (1978a, 1978b, 1978c, 1978d, 1979); Becker (1988); Holliday (1989); Goldstein (1994); Van Dyke (2008).

TABLE 4-2
Archaeological Sites within 100 m of Centerline of a Supply Alternative: Shallow Aquifer and Fox River Alluvium[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Dreger Site	6N	19E	Unknown prehistoric campsite/ village/workshop.	Current status unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Ludy Jan Site	6N	19E	Unknown Historic Indian campsite/village/workshop. It appears to be a multicomponent site with a variety of material ranging from Archaic to Historic.	Update 1979: Following Phase II investigations, the site was determined *not* to be eligible for listing on the National/State Register of Historic Places. Current recommendations may differ from the original findings, and site status should be confirmed with WHS.
Gienke #3	6N	19E	Unknown prehistoric campsite/village/ workshop.	The current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Gienke #1	6N	19E	Unknown prehistoric campsite/village/ workshop. This site consists of a scatter of fire-cracked rock, debitage, and nondiagnostic lithic tools.	Update 2007: Intensive surface survey failed to relocate this site. The extended cultivation of this land has likely disturbed and deflated the site. The current status is unknown and additional investigations may be necessary. Consultation with WHS is necessary.
Gienke #2	6N	19E	Late Archaic to Middle Woodland campsite/ village/workshop. The distribution of material was widely scattered.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Stephen Peet's Mounds	6N	19E	A group of mounds. Due to the vague nature of the report, the site is not mapped. No other information is available.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Prairie Home Cemetery	6N	19E	Historic Euro-American cemetery/burial. This site consists of a marked Euro-American cemetery established 1841 and possibly as early as 1835. The site occupies an 8-acre parcel and has expanded to 80 acres, due to transfers from other, smaller cemeteries. Prairie Home also has a potter's field.	This Burial Site is catalogued and subject to the provisions of Wis. Stats 157.70. Consultation with WHS is required.
Tcheegascoutak	6N	19E	Historic Indian campsite/ village. The Potawatomi settlement of Tcheegascoutak is reported for this location. Historic records indicate that the large village may have been inhabited by as many as 4,000 people around 1827.	Listed on the National/State Register of Historic Places and may be afforded special consideration pursuant to state and/or federal law. Consultation with WHS is necessary.
Main Street Mounds	6N	19E	Late Woodland mounds–conical, effigy, linear. The site consists of a group of one panther effigy, one linear and one conical mound. No other information is available.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

TABLE 4-2
Archaeological Sites within 100 m of Centerline of a Supply Alternative: Shallow Aquifer and Fox River Alluvium[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Court House Mounds	6N	19E	Late Woodland mounds–conical, effigy, linear, and historic Indian, historic EuroAmerican trading/fur post. The Waukesha Museum was erected over the location of the turtle mound, and two mounds were located in the middle of modern Main St. This site consists of a group of mounds. A postcontact grave had been excavated into one of the turtle mounds.	Update 2000: The Vieau-Juneau Trading Post has been reported at this location. This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Lapham (1836, 1855); Brown (1906b, 1906c, 1923b, 1923d, 1925, 1930a, 1930b); Overstreet and Brazeau (1978a, 1978b, 1978c, 1978d, 1979); Becker (1988); Holliday (1989); Goldstein (1994); Van Dyke (2008).

TABLE 4-3
Archaeological Sites within 100 m of Centerline of a Supply Alternative: Lake Michigan—Milwaukee Supply[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Calhoun Mounds	6N	20E	This site was located on the J. Elger property south of Calhoun Station and consists of two conical mounds (Woodland Mounds-Conical). They had disappeared through cultivation of the land by July 8, 1903.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Highland Memorial Park	6N	20E	Historic Euro-American cemetery/ burial. Records for this cemetery are complete but are not available to the public.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Root River Parkway	6N	21E	Unknown prehistoric isolated finds.	The current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Beloit Corners Burials	6N	21E	Middle Archaic cemetery/burial.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Blessed Sacrament Cemetery	6N	21E	Historic Euro-American cemetery/burial. This is a very small cemetery, with many fallen stones.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Brown (1906a, 1916b, 1923a, 1924); Benchley (1981); Becker (1988); Herzfeld (1995); McMullen and Hammerberg (1998); Van Dyke (2007).

TABLE 4-4
Archaeological Sites within 100 m of Centerline of a Supply Alternative: Lake Michigan Supply—Oak Creek[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Calhoun Mounds	6N	20E	Consists of two conical mounds (Woodland Mounds–Conical). They had disappeared through cultivation of the land by July 8, 1903.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Highland Memorial Park	6N	20E	Historic Euro-American cemetery/ burial. Records for this cemetery are complete, but are not available to the public.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Root River Parkway	6N	21E	Unknown prehistoric isolated finds.	Current status is unknown, and additional investigations may need to be completed. Consultation with WHS is necessary.
Beloit Corners Burials	6N	21E	Middle Archaic cemetery/burial.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Jungblut Gravel Pit	6N	21E	Campsite/ village, cemetery/burial. This site consists of a Menominee habitation area and a cemetery.	The site may or may not be on the Jungblut farm. Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Whitnall Park Burial	6N	21E	Late Archaic, Early Woodland cemetery/burial.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Unnamed Site #1	5N	21E	Located along the banks of the Root River. Culture unknown.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Unnamed Site #2	5N	21E	The site, an unknown Prehistoric campsite/ village.	Current status site is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Chicago Short	5N	21E	Unknown Prehistoric campsite/ village.	Determined not eligible. Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Unnamed Site #3	5N	22E	Unknown Prehistoric site. Contains lithics scatter. Patricia B. Richards investigated the site in 1993. No artifacts were recovered within the survey corridor.	Due to previous road construction and maintenance activities, all deposits within the right-of-way probably have been extensively disturbed.
St. Matthews Cemetery	5N	22E	The site is a Euro-American cemetery/burial.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Jungblut (1903); *Milwaukee Sentinel* (1903); Brown (1906a, 1916b, 1923a, 1924); Milwaukee Newspaper (1922); Benchley et al. (1979); Penman (1979); Benchley (1981); Becker (1988); Keene (1995); McMullen and Hammerberg (1998); Van Dyke (2008).

TABLE 4-5
Archaeological Sites within 100 m of Centerline of Supply Alternative: Lake Michigan Supply—Racine [a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Tews Site	5N	20E	Unknown Prehistoric campsite/village/workshop.	Current status is unknown and additional investigations may need to be completed. Consultation with Wisconsin Historical Societyis necessary.
Heinrich	5N	20E	Middle-Late woodland campsite/village/ workshop.	Current status is unknown and additional investigations may need to be completed. Consultation with Wisconsin Historical Society is necessary.

[a]To protect cultural resources, section and quarter section locations have been omitted.

4.2.2. Return Flow Alternatives

4.2.2.1. Underwood Creek

According to the archival investigations, six archaeological sites exist within 100 m (328 feet) of the centerline of this proposed flow return route. Table 4-6 provides the locations and descriptions of these six sites.

TABLE 4-6
Archaeological Sites within 100 m of Centerline of a Flow Return Alternative: Underwood Creek [a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Stephen Peet's Mounds	6N	19E	A group of mounds. Due to the vague nature of the report, the site is not mapped. No other information is available.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Industrial School Mound	6N	19E	This site consists of a single conical mound 40 feet in diameter and one and a half feet high.	Updated 1995: No surface indications of a mound were found during a 1994 field check. This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Dwell's Cornfields	6N	19E	Historic Indian campsite/village/corn hills/garden beds. The site is associated with the early 19th century Potawatomi occupation of Waukesha.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Charles Street Mounds	6N	19E	Woodland, Late Woodland conical and linear mounds. This site consists of a group of five conical mounds and one linear mound, destroyed prior to 1906.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with the Wisconsin Historical Society is required.
Calhoun Mounds	6N	20E	This site consists of two conical mounds (Woodland Mounds-Conical). They had disappeared through cultivation of the land by July 8, 1903.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with the Wisconsin Historical Society (WHS) is required.
Highland Memorial Park	6N	20E	Historic Euro-American cemetery/burial. Records for this cemetery are complete, but are not available to the public.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Dwelle (1836); Lapham (1855); Brown (1906a, 1906b, 1923a, 1923b, 1923c, 1925); Philips (1923); Becker (1988); Goldstein (1994); Sasso (1998).

4.2.2.2. Root River

According to the archival investigations, nine archaeological sites exist within 100 m (328 feet) of the centerline of this proposed flow return route. Table 4-7 provides the locations and descriptions of these nine sites.

TABLE 4-7
Archaeological Sites within 100 m of Centerline of a Flow Return Alternative: Root River[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Stephen Peet's Mounds	6N	19E	A group of mounds. Due to the vague nature of the report, the site is not mapped. No other information is available.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Industrial School Mound	6N	19E	Consists of a single conical mound forty feet in diameter and one and a half feet high.	Updated 1995: No surface indications of a mound were found during a 1994 field check. This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Dwell's Cornfields	6N	19E	Historic Indian campsite/village/ cornhills/garden beds. The site is associated with the early 19th century Potawatomi occupation of Waukesha.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Charles Street Mounds	6N	19E	Woodland, Late Woodland conical and linear mounds. This site consists of a group of five conical mounds and one linear mound, destroyed prior to 1906.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with the Wisconsin Historical Society is required.
Calhoun Mounds	6N	20E	Consists of two conical mounds (Woodland Mounds–Conical). They had disappeared through cultivation of the land by July 8, 1903.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with the Wisconsin Historical Society (WHS) is required.
Highland Memorial Park	6N	20E	Historic Euro-American cemetery/burial. Records for this cemetery are complete, but are not available to the public.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Root River Parkway	6N	21E	Unknown prehistoric isolated finds.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Beloit Corners Burials	6N	21E	Middle Archaic cemetery/burial.	This burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Jungblut Gravel Pit	6N	21E	Campsite/village, cemetery/burial. This site consists of a Menominee habitation area and a cemetery.	The Jungblut farm is listed in Section 29 on archival plats. However, the site may or may not be on the Jungblut farm.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Dwelle (1836); Lapham (1855b); Jungblut (1903); *Milwaukee Sentinel* (1903); Brown (1906a, 1906b, 1916b, 1923a, 1923b, 1923c, 1924, 1925); Philips (1923); Benchley (1981); Becker (1988); Goldstein (1994); McMullen and Hammerberg (1998); Sasso (1998); Van Dyke (2007).

4.2.2.3. Direct to Lake Michigan

According to the archival investigations, 17 archaeological sites exist within 100 m (328 feet) of the centerline of this proposed flow return route. Table 4-8 provides the locations and descriptions of these 17 sites.

TABLE 4-8
Archaeological Sites within 100 m of Centerline of a Flow Return Alternative: Direct to Lake Michigan[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Stephen Peet's Mounds	6N	19E	A group of mounds. Due to the vague nature of the report, the site is not mapped. No other information is available.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Industrial School Mound	6N	19E	Consists of a single conical mound forty feet in diameter and one and a half feet high.	Updated 1995: No surface indications of a mound were found during a 1994 field check. This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Dwell's Cornfields	6N	19E	Historic Indian campsite/village/corn hills/garden beds. The site is associated with the early 19th century Potawatomi occupation of Waukesha.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Charles Street Mounds	6N	19E	Woodland, Late Woodland conical and linear mounds. This site consists of a group of five conical mounds and one linear mound, destroyed prior to 1906.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with the Wisconsin Historical Society is required.
Calhoun Mounds	6N	20E	This site consists of two conical mounds (Woodland Mounds–Conical). They had disappeared through cultivation of the land by July 8, 1903.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Highland Memorial Park	6N	20E	Historic Euro-American cemetery/burial. Records for this cemetery are complete, but are not available to the public.	This Burial Site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Indian Fields	6N	21E	Consists of a habitation area and a large group of mounds. In 1836, the site was described as showing "recent signs of Indian occupancy and cultivation." The mounds were probably segregated into several distinct groups, but the site is so vaguely described that little can be said about its structure.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Pilgrims' Rest Cemetery	6N	21E	Historic Euro-American cemetery/burial. Pilgrims' Rest Cemetery was established in 1880 by St. Stephen's Congregation and was managed by a church cemetery committee. It was sold in June 1996 to Good Hope Pilgrims Rest Cemetery corp.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Jackson Park Burial	6N	21E	Unknown Prehistoric campsite/village, Woodland cemetery/burial.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Jackson Park	6N	21E	Unknown Prehistoric isolated finds.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.

TABLE 4-8
Archaeological Sites within 100 m of Centerline of a Flow Return Alternative: Direct to Lake Michigan[a]
City of Waukesha Water Supply

Site Name	Township	Range	Description	Consultation Requirements
Unnamed Site #1	6N	22E	Unknown Prehistoric campsite/village.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Unnamed Site #2	6N	22E	Unknown enclosure/earthworks.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.
Greenwood Cemetery	6N	22E	Historic Euro-American cemetery.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Forest Home Cemetery	6N	22E	Historic Euro-American cemetery. This is a large cemetery that has early burial records on microfilm.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Austin's Gravel Pit Burials	6N	22E	Unknown cemetery/burial. Various references place this site in different sections.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Unnamed Site #3	6N	22E	Historic Euro-American cemetery/burial site.	This Burial site is not catalogued, but is protected under Wis. Stats 157.70. Consultation with WHS is required.
Unnamed Site #4	6N	22E	Unknown site.	Current status is unknown and additional investigations may need to be completed. Consultation with WHS is necessary.

[a]To protect cultural resources, section and quarter section locations have been omitted.
WHS, Wisconsin Historical Society.
Sources: Dwelle (1836); Lapham (1855a, 1855b); Jungblut (1903); Brown (1906a, 1906b, 1906d, 1908, 1916a, 1916c, 1916d, 1923b, 1923c, 1925); Philips (1923); Benchley et al. (1979); Gregory and Benchley (1980); Benchley (1981); Becker (1988); Goldstein (1994); Herzfeld (1995); Sasso (1998).

4.3. Previous Cultural Resource Surveys

The archival investigations of the supply and return flow alternatives involved an evaluation of previous cultural resource surveys within 100 meters of the proposed alignments. Documentary research was conducted using a variety of historical references. Due to the fact that the results of the archival investigations are based on existing records the number of sites identified along each alternative does not reflect potential resources that may be present in previously unsurveyed areas. The results of the archival investigations for previous cultural resource surveys are summarized below by study location.

4.3.1. Supply Alternatives

4.3.1.1. Deep and Shallow Wells

Two previous surveys were conducted along this alternative in Waukesha County. Details of these past surveys are provided in Appendix 4A.

4.3.1.2. Shallow Aquifer and Fox River Alluvium

Two previous surveys were conducted along this alternative in Waukesha County. Details of these past surveys are provided in Appendix 4A.

4.3.1.3. Lake Michigan—Milwaukee Supply

Six previous surveys were conducted along this alternative in Milwaukee and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

4.3.1.4. Lake Michigan—Oak Creek Supply

Eleven previous surveys were conducted along this alternative in Milwaukee and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

4.3.1.5. Lake Michigan—Racine Supply

Seven previous surveys were conducted along this alternative in Racine and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

4.3.2. Return Flow Alternatives

4.3.2.1. Underwood Creek to Lake Michigan

Seven previous surveys were conducted along this alternative in Milwaukee and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

4.3.2.2. Root River to Lake Michigan

Two previous surveys were conducted along this alternative in Milwaukee and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

4.3.2.3. Direct to Lake Michigan

Seven previous surveys were conducted along this alternative in Milwaukee and Waukesha Counties. Details of these past surveys are provided in Appendix 4A.

For additional information, refer to archival investigation results provided by PSAAP, included as Appendix 4A.These findings contain archeologically sensitive and confidential information and are not intended for public release.

4.4. National Register of Historic Places

The National Parks Service's (NPS) National Register of Historic Places (NRHP) was authorized under the National Historic Preservation Act of 1966. The NRHP is the official list of historic places throughout the United States and is part of a national program to coordinate and support efforts to identify, evaluate, and protect historic and archeological resources (NRHP, 2010a).

The NRHP database, which can be used through Google Earth©, provides the locations of NRHP sites for the Midwest Region, including Wisconsin. No NRHP sites are located within 0.10 mile of the Lake Michigan—Milwaukee Supply, Lake Michigan—Oak Creek Supply, or Lake Michigan—Racine Supply alternatives.

There are 25 NRHP sites within 0.10 mile of the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium supply alternatives in Waukesha County (Google Earth, 2010; NHRP, 2010b).

Thirteen NRHP sites were identified within 0.10 mile of the Underwood Creek to Lake Michigan return flow alternative, all within Waukesha County; no NRHP sites were identified within the Milwaukee County portion of the Underwood Creek to Lake Michigan return flow alternative.

There are 10 NRHP sites within 0.10 mile of the Root River to Lake Michigan return flow alternative, of which all are within Waukesha County.

There are 10 NRHP sites within 0.10 mile of the Direct to Lake Michigan return flow alternative within Waukesha County and two NRHP sites within Milwaukee County (Google Earth, 2010; NHRP, 2010b).

No NRHP sites will be impacted by permanent structures associated with the project. .

Regardless of the alternatives selected, the City will follow regulatory requirements to prevent any significant impacts and mitigate impacts to known or potential NRHP sites.

4.5. Impacts and Mitigation

The cultural resources affected environment is the cultural resources that exist within the area of potential effect of the alternatives. Regardless of the alternatives selected, the City will meet regulatory requirements regarding cultural resources during the design and construction phases to prevent any significant impacts and mitigate impacts to known or potential NRHP sites. During operation, there will be no ground disturbance and no impacts will occur to cultural resources.

4.6. Status of Native American Consultation

Research regarding the various supply and return flow alternatives was based on a desktop-level analysis using available survey data in order to preliminarily quantify the extent and nature of cultural resources that may be present. In order to comply with Section 106 of the NHPA, and to determine whether or not the Project affects any cultural properties of a Native American Nation or Tribe, consultation will be conducted with Native American groups. Coordination will occur once a Lake Michigan water supplier has been determined and a return flow location has been approved.

4.7. Consultation with the State Historic Preservation Office and Cultural Resources Survey

The City will conduct comprehensive field surveys of all proposed work spaces as required by Section 106 of the NHPA, to protect archeological resources and coordinate appropriately with the SHPO regarding potential impacts from construction once a defined Lake Michigan water supplier has been determined and a return flow location has been approved. At that time, should eligible historic properties be identified in association with the alternative to be

implemented the City will work with a qualified archeologist to prepare the appropriate evaluation reports and corresponding SHPO-approved cultural resource protection plan.

4.8. References

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Brown, C. E. 1906a. State Historical Society of Wisconsin, Record of Wisconsin Antiquities. WA (OS) 5(3–4): 408.

Brown, C. E. 1906b. State Historical Society of Wisconsin, Record of Wisconsin Antiquities. WA (OS) 5(3–4): 405.

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Chapter 5
Socioeconomic Environment

CHAPTER 5

Socioeconomic Environment

5.1 Introduction

This section describes socioeconomic resources that could be affected by the water supply and return flow alternatives described in Chapter 1 and also the potential impacts. Socioeconomic impacts associated with water supply result primarily from variations in supply quantity; supply quality; and cost of supply. Since all alternatives evaluated in the Application have comparable quantity, quality, and cost of potable water, the socioeconomic impacts among alternatives considered in this report are very similar.

The University of Wisconsin–Milwaukee prepared an evaluation of the socioeconomic implications of water supply alternatives in support of SEWRPCs regional water supply plan. Based on recommendations by SEWRPC's Environmental Justice Task Force, SEWRPC contracted with the University of Wisconsin–Milwaukee Center for Economic Development (CED) in 2009 as a nonpartisan agency to evaluate the recommendations set forth in the regional water supply plan and the socioeconomic impact of the recommendations. *A Socio-Economic Impact Analysis of SEWRPC's Regional Water Supply Plan* (March 2010) has been released in draft form. The analysis included extensive interviews with planners and utility personnel from the communities and considered a wide range of socioeconomic attributes. The analysis in this chapter summarizes the findings of the draft report.

5.2 Population

5.2.1 Existing Resources

Waukesha county population has more than doubled between 1960 and 2007. This growth is much greater than that in the region. whereas Waukesha accounted for only 10 percent of the regional population, it now represents almost 20 percent (Table 5-1). The City of Waukesha has experienced a similar population growth, increasing from 30,000 in 1960 to more than 64,000 in 2000. The rate of growth in the City Waukesha is expected to decline over the next 25, reaching a projection a total of 88,500 in 2035 (36 percent increase). The water supply needs for the City are based on these population projections.

TABLE 5-1
Waukesha and Regional Population

	1960		2007		Change	
County	Number	% of Region	Number	% of Region	Number	%
Waukesha	158,249	10.1	376,978	18.9	218,729	138.2
Region	1,573,614	100.0	1,995,901	100.0	422,287	26.8

Source: US Census Bureau as reported in UW Milwaukee 2010

The City of Waukesha is predominately white, but racial diversity has risen since 1960. The percent of nonwhites increased from 0.5 percent in 1960 to almost 9 percent in 2000, more than 5,500 nonwhite residents in the City over the period. The percent increase in nonwhites is similar to other that in communities in the region. The percent of Waukesha County nonwhite population is projected to almost double by 2035 to almost 17 percent of the total.

5.2.2 Impacts and Mitigation

The demand projections used to specify the water supply quantities for all sources (groundwater and Lake Michigan) were based on the population projections discussed above, and all alternative sources can meet the projected demand. Thus meeting the demand using any alternative source would not have any impact on population. Any sources also can support the projected increase in nonwhite population in the Waukesha. This is consistent with conclusions in the CED socioeconomic study, where planners and utilities managers reported that the water supply source will not affect population growth or distribution.

5.3 Economy

5.3.1 Existing Resources

The economy in Waukesha County also has grown over the last 20 years. Economic growth in Waukesha has been much greater than the overall region, increasing from nearly 5 percent of the total in 1960 to more than 22 percent in 2000 (Table 5-2). This is consistent with the regional trend of employment migration from the urban areas to the more suburban areas and the shift from manufacturing to service sector jobs.

TABLE 5-2
Waukesha and Regional Economy

	1960		1970		1980		1990		2000	
County	Jobs	%	Jobs	%	Jobs	%	Jobs	%	Jobs	%
Waukesha	32,600	4.8	81,000	10.3	132,800	14.0	189,700	16.6	270,800	22.1
Region	673,000	100.0	784,900	100	948,200	100	1,143,700	100	1,222,800	100

Source: Bureau of Labor Statistics and the US Census Bureau as reported in UW Milwaukee 2010.

The economy in Waukesha County is projected to increase by 67,000 jobs, or 25 percent, by 2035. This is considerably higher than for Milwaukee County (7 percent increase) but similar to the surrounding counties.

Much of the industry in the region is considered to be water-intensive, and thus potentially affected by water supply. However, many of the large industrial water users do not rely on municipal water but on private high-capacity groundwater wells. A review of the large businesses in Waukesha county indicates that there are no known major water-intensive businesses or industries using municipal supplies (UW Madison 2010).[1]

[1] University of Wisconsin Milwaukee, Center for Economic Development. 2010. Chapter 3, page 15.

5.3.2 Impacts and Mitigation

The projections of water demand take into account the increase in the Waukesha economy discussed above as it relates to the City's water supply service area (see Appendix xx in the Application). By serving the projected demand, water supply would not constrain or otherwise affect economic growth. The source of the supply does not affect the quantity, thus all supply source alternatives are similar with respect to quantity and do not impact the economy. Also the cost of all alternatives is similar, so there is no advantage to employment or other economic factors for one supply source over another.

The CED study found that the source of water is not a differentiating factor on development within a municipal service area.[2] The only exception to this view is related to perceptions surrounding groundwater quality. The study found some planners and utility managers in the region understood groundwater quality problems to be associated with contamination (particularly radium). There were no concerns expressed for surface water sources.

5.4 Energy Use

5.4.1 Existing Resources

Water intake, treatment, and distribution in Waukesha is accomplished from the existing power grid. The supply is adequate and expected to accommodate projected population and economic growth.

5.4.2 Impacts and Mitigation

As described in the Section 4 of the Application and summarized in Table 5-3, energy use would be substantially lower for the Lake Michigan water supply than either groundwater supply alternative. The return flow alternatives associated with the Lake Michigan supply have similar energy requirements.

TABLE 5- 3
Energy Use for Water Supply Alternatives

Alternative	Est. Annual Energy Usage (MWh)
Alt 1: Deep and Shallow Aquifer Water Supply	33,400
Alt 2: Shallow Aquifer and Fox River Alluvium Water Supply	20,500
Alt 3: Lake Michigan Water Supply with Return Flow	16,200
Return Flow to Underwood Creek	2,000
Return Flow to Root River	2,500
Return Flow Direct to Lake Michigan	2,700

5.5 References

University of Wisconsin Milwaukee, Center for Economic Development. 2010. http://www4.uwm.edu/ced/sewrpc/index.cfm

[2] University of Wisconsin Milwaukee, Center for Economic Development. 2010. Chapter 3, page 19.

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Chapter 6
Soils

CHAPTER 6

Soils

6.1 Introduction

This section provides information about soil conditions along the routes of the supply and return flow alternatives evaluated. Chapter 2 discusses geomorphology and channel stability. Consequently, this Chapter focuses upon soil productivity for agricultural production. Chapter 7, Land Use communicates additional information on how much of the alternative alignments support active agriculture. The water supply or return flow pipeline routes follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands. As a result potential impacts to active agricultural areas are minimized.

6.2 Identification of Prime Farmland

6.2.1 Background and Methodology

Prime farmland soils crossed by the supply and return flow alternatives were identified and characterized using the Natural Resource Conservation Service (NRCS) 2009 Soil Survey Geographic (SSURGO) database (NRCS, 2009). The prime farmland soils series were identified in a linear progression along the proposed routes.

6.2.2 Prime Farmland Soils

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses. It has the soil quality, growing season, and moisture supply needed to produce economically sustained high yields of crops when treated and managed according to acceptable farming methods, including water management. In general, prime farmlands have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, acceptable salt and sodium content, and few or no rocks.

Prime farmlands are not excessively erodible or saturated with water for long periods, and either they do not flood frequently or they are protected from flooding. It may be, however, that not all of the areas designated as prime farmland are currently active agriculturally, but instead there may be locations that exhibit extensive historical disturbance due to development, such as residential or roadway construction. Based upon a review of current land use classifications, observations as to whether active agricultural areas are present is included for each water supply and return flow alternative and is discussed below.

6.3 Prime Farmland Soils

The soil series and associated descriptions were obtained through the SSURGO database (NRCS, 2009). Descriptions provided are based on information available at the county level

for soil series. Specific information on soil characteristics and limitations for the supply and return flow alternatives are provided in Tables 6-1 through 6-8.

6.3.1 Supply Alternatives

6.3.1.1 Deep and Shallow Aquifers

The operational and maintenance impacts to soils are those that occur from the facilities which will permanently alter the land use, such as the water treatment plant (WTP), wells, and service roads. The WTP proposed for the Deep and Shallow Wells Alternative impacts 33.20 acres, of which all impacts prime farmland soils. The 11 well houses proposed for the Deep and Shallow Wells Proposed Alternative impact approximately 38.41 acres, of which 30.96 acres, or 80.6 percent, is prime farmland soils. Table 6-1 below includes these operational and maintenance impacts as well as those associated with pipeline construction, where agricultural use could continue after construction is completed.

While this alternative effects soil classified as prime agricultural land as listed in Table 6-1, current land use designated as active agriculture is much less as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural use currently exist on a majority of the remaining soil that is classified as prime farmland.

6.3.1.2 Shallow Aquifer and Fox River Alluvium

The operational and maintenance impacts to soils are those that occur from the facilities which will permanently alter the land use, such as the WTP, wells, and service roads. The WTP proposed for the Shallow Aquifer and Fox River Alluvium Alternative impacts approximately 14.74 acres, of which all is classified as prime farmland soils. The 15 well houses proposed for the Shallow Aquifer and Fox River Alluvium Alternative impact approximately 51.26 acres, of which 50.62 acres, or 99 percent, are designated as prime farmland soils. Table 6-2 below includes these operational and maintenance impacts, as well as those associated with pipeline construction where agricultural use could continue after construction is completed.

While this alternative effects soil classified as prime agricultural land as listed in Table 6-2 below, current land use designated as active agriculture is much less, as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural exist on a majority of the remaining soil that is classified as prime farmland.

6.3.1.3 Lake Michigan—Milwaukee Supply

While this alternative impacts soil classified as prime farmland, as listed in Table 6-3 below, there is no current land use designated as active agriculture, as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently occur on all of the remaining soil classified as prime farmland.

6.3.1.4 Lake Michigan Supply—Oak Creek

There are negligible facilities that alter the land use associated with this alternative. Any impacts to active agricultural lands would be from pipeline construction, which would all be temporary in nature and would allow agricultural activities to continue after construction is completed.

TABLE 6-1
Prime Farmlands Crossed by the Deep and Shallow Aquifers Supply Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AzA	Aztalan loam, 0 to 2 percent slopes	4.55
CeB	Casco loam, 2 to 6 percent slopes	2.55
Dt	Drummer silt loam, gravelly substratum	1.42
FmA	--	11.24
FmB	Fox sandy loam, 1 to 6 percent slopes	1.10
FoA	Fox loam, 0 to 2 percent slopes	16.33
FoB	Fox loam, 2 to 6 percent slopes	1.77
FoC2	Fox loam, 6 to 12 percent slopes, eroded	0.33
FsA	Fox silt loam, 0 to 2 percent slopes	3.34
FsB	Fox silt loam, 2 to 6 percent slopes	0.76
HeA	Hebron loam, 0 to 2 percent slopes	3.88
HeB	Hebron loam, 2 to 6 percent slopes	0.86
HmB	Hochheim loam, 2 to 6 percent slopes	4.30
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	4.39
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	7.59
HtA	Houghton muck, 0 to 2 percent slopes	0.59
KeA	Kane silt loam, 1 to 3 percent slopes	3.29
LyB2	Lorenzo loam, 2 to 6 percent slopes, eroded	0.09
MgA	Martinton silt loam, 1 to 3 percent slopes	0.41
MmA	Matherton silt loam, 1 to 3 percent slopes	6.89
MoB	Mayville silt loam, 2 to 6 percent slopes	0.73
Na	Navan silt loam	2.74
Oc	Ogden muck	0.07
OmB	Oshtemo loamy sand, 1 to 6 percent slopes	9.68
Pa	Palms muck	3.59
Ph	Pella silt loam	4.09
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.12
Sm	Sebewa silt loam	1.23
ThB	Theresa silt loam, 2 to 6 percent slopes	2.69
WeA	Warsaw loam, 0 to 2 percent slopes	1.36
WeB	Warsaw loam, 2 to 6 percent slopes	21.24
WhA	Warsaw silt loam, 0 to 2 percent slopes	16.29
	Total	**139.53**

TABLE 6-2
Prime Farmlands Crossed by the Shallow Aquifer and Fox River Alluvium Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AzA	Aztalan loam, 0 to 2 percent slopes	4.55
CeB	Casco loam, 2 to 6 percent slopes	2.55
Dt	Drummer silt loam, gravelly substratum	2.33
FmA	—	14.98
FmB	Fox sandy loam, 1 to 6 percent slopes	4.54
FoA	Fox loam, 0 to 2 percent slopes	25.47
FoB	Fox loam, 2 to 6 percent slopes	4.07
FoC2	Fox loam, 6 to 12 percent slopes, eroded	0.33
FsA	Fox silt loam, 0 to 2 percent slopes	3.34
FsB	Fox silt loam, 2 to 6 percent slopes	0.76
HeA	Hebron loam, 0 to 2 percent slopes	5.16
HeB	Hebron loam, 2 to 6 percent slopes	0.86
HmB	Hochheim loam, 2 to 6 percent slopes	4.31
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	5.05
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	7.59
HtA	Houghton muck, 0 to 2 percent slopes	4.21
KeA	Kane silt loam, 1 to 3 percent slopes	3.29
LyB2	Lorenzo loam, 2 to 6 percent slopes, eroded	0.09
MgA	Martinton silt loam, 1 to 3 percent slopes	0.41
MmA	Matherton silt loam, 1 to 3 percent slopes	9.61
MoB	Mayville silt loam, 2 to 6 percent slopes	0.73
MtA	Mequon silt loam, 1 to 3 percent slopes	0.00
Na	Navan silt loam	2.74
Oc	Ogden muck	0.07
OmB	Oshtemo loamy sand, 1 to 6 percent slopes	12.89
Pa	Palms muck	3.72
Ph	Pella silt loam	4.92
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.12
Sm	Sebewa silt loam	1.23
ThB	Theresa silt loam, 2 to 6 percent slopes	2.69
WeA	Warsaw loam, 0 to 2 percent slopes	1.36
WeB	Warsaw loam, 2 to 6 percent slopes	23.88
WhA	Warsaw silt loam, 0 to 2 percent slopes	16.29
Ww	Wet alluvial land	3.15
	Total	**177.29**

TABLE 6-3
Prime Farmlands Crossed by the Lake Michigan—Milwaukee Supply Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	5.37
AzB	Aztalan loam, 2 to 6 percent slopes	1.08
FoB	Fox loam, 2 to 6 percent slopes	1.07
FsB	Fox silt loam, 2 to 6 percent slopes	1.00
FsC2	Fox silt loam, 6 to 12 percent slopes, eroded	0.10
HmB	Hochheim loam, 2 to 6 percent slopes	0.93
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	0.91
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	3.63
HtA	Houghton muck, 0 to 2 percent slopes	13.24
LmB	Lamartine silt loam, 1 to 4 percent slopes	1.49
Lo	Lawson silt loam	8.70
MgA	Martinton silt loam, 1 to 3 percent slopes	0.75
MmA	Matherton silt loam, 1 to 3 percent slopes	2.93
MtA	Mequon silt loam, 1 to 3 percent slopes	20.41
Mzb	Montgomery silty clay loam	1.23
Na	Navan silt loam	0.08
Oc	Ogden muck	5.07
OuB	Ozaukee silt loam, 2 to 6 percent slopes	8.96
OuB2	Ozaukee silt loam, 2 to 6 percent slopes, eroded	9.38
OuC2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	1.68
Ph	Pella silt loam	2.32
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.31
ShC2	Saylesville silt loam, 6 to 12 percent slopes, eroded	0.08
Sm	Sebewa silt loam	9.42
ThB	Theresa silt loam, 2 to 6 percent slopes	0.33
Wa	Wallkill silt loam	0.35
Ww	Wet alluvial land	7.58
	Total	**108.42**

TABLE 6-4
Prime Farmlands Crossed by the Lake Michigan—Oak Creek Supply Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	7.58
AzB	Aztalan loam, 2 to 6 percent slopes	5.17
BlA	Blount silt loam, 1 to 3 percent slopes	19.75
CeB	Casco loam, 2 to 6 percent slopes	0.06
Dt	Drummer silt loam, gravelly substratum	11.38
FoB	Fox loam, 2 to 6 percent slopes	1.91
FsB	Fox silt loam, 2 to 6 percent slopes	1.00
FsC2	Fox silt loam, 6 to 12 percent slopes, eroded	0.79
GrB	Grays silt loam, 2 to 6 percent slopes	1.79
HeB	Hebron loam, 2 to 6 percent slopes	1.21
HmB	Hochheim loam, 2 to 6 percent slopes	0.93
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	0.91
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	3.63
HtA	Houghton muck, 0 to 2 percent slopes	13.77
KwB	Knowles silt loam, 2 to 6 percent slopes	6.10
LmB	Lamartine silt loam, 1 to 4 percent slopes	1.49
Lo	Lawson silt loam	10.77
MgA	Martinton silt loam, 1 to 3 percent slopes	2.16
MmA	Matherton silt loam, 1 to 3 percent slopes	6.21
MtA	Mequon silt loam, 1 to 3 percent slopes	13.80
Mzb	Montgomery silty clay loam	1.23
MzdB	Morley silt loam, 2 to 6 percent slopes	6.82
MzdB2	Morley silt loam, 2 to 6 percent slopes, eroded	41.90
MzdC2	Morley silt loam, 6 to 12 percent slopes, eroded	4.30
MzfA	Mundelein silt loam, 1 to 3 percent slopes	0.16
Na	Navan silt loam	1.80
Oc	Ogden muck	5.97
OuB	Ozaukee silt loam, 2 to 6 percent slopes	9.88
OuB2	Ozaukee silt loam, 2 to 6 percent slopes, eroded	5.54
OuC2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	0.40
Ph	Pella silt loam	2.32
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.31
RkB	Ritchey silt loam, 1 to 6 percent slopes	1.39
ShB	Saylesville silt loam, 2 to 6 percent slopes	1.17
ShC2	Saylesville silt loam, 6 to 12 percent slopes, eroded	0.08
Sm	Sebewa silt loam	14.26
ThB	Theresa silt loam, 2 to 6 percent slopes	0.33
Wa	Wallkill silt loam	0.35
Ww	Wet alluvial land	8.89
	Total	**217.51**

TABLE 6-5
Prime Farmlands Crossed by the Lake Michigan—Racine Supply Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
Am	Alluvial land	0.11
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	6.01
AtA	Ashkum silty clay loam, 0 to 3 percent slopes	21.08
AzB	Aztalan loam, 2 to 6 percent slopes	2.44
BcA	Beecher silt loam, 1 to 3 percent slopes	13.17
BlA	Blount silt loam, 1 to 3 percent slopes	14.36
BnB	Boyer sandy loam, 2 to 6 percent slopes	0.33
BsA	Brookston silt loam, 0 to 3 percent slopes	4.17
CeB	Casco loam, 2 to 6 percent slopes	0.02
Cw	Colwood silt loam	0.92
EtA	Elliott silty clay loam, 0 to 2 percent slopes	7.77
EtB	Elliott silty clay loam, 2 to 6 percent slopes	6.80
FoB	Fox loam, 2 to 6 percent slopes	1.07
FrB	Fox loam, clayey substratum, 2 to 6 percent slopes	1.08
FsB	Fox silt loam, 2 to 6 percent slopes	1.00
FtB	Fox silt loam, loamy substratum, 2 to 6 percent slopes	0.41
GrB	Grays silt loam, 2 to 6 percent slopes	0.18
HeA	Hebron loam, 0 to 2 percent slopes	0.69
HeB	Hebron loam, 2 to 6 percent slopes	0.34
HeB2	Hebron loam, 2 to 6 percent slopes, eroded	0.64
HeC2	Hebron loam, 6 to 12 percent slopes, eroded	0.09
HmB	Hochheim loam, 2 to 6 percent slopes	10.72
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	7.70
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	11.35
HoC3	Hochheim soils, 6 to 12 percent slopes, severely eroded	0.20
Ht	Houghton muck	5.12
HtA	Houghton muck, 0 to 2 percent slopes	17.75
HtB	Houghton muck, 2 to 6 percent slopes	1.16
JuA	Juneau silt loam, 1 to 3 percent slopes	0.20
KaA	Kane loam, 1 to 3 percent slopes	0.95
KhA	Kane silt loam, clayey substratum, 1 to 3 percent slopes	7.01
LmB	Lamartine silt loam, 1 to 4 percent slopes	6.52
MeB	Markham silt loam, 2 to 6 percent slopes	21.10
MeB2	Markham silt loam, 2 to 6 percent slopes, eroded	9.56
MeC2	Markham silt loam, 6 to 12 percent slopes, eroded	0.34

TABLE 6-5
Prime Farmlands Crossed by the Lake Michigan—Racine Supply Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
MgA	Martinton silt loam, 1 to 3 percent slopes	6.13
MkA	Matherton loam, 1 to 3 percent slopes	2.35
MmA	Matherton silt loam, 1 to 3 percent slopes	2.24
MoB	Mayville silt loam, 2 to 6 percent slopes	2.83
Mzb	Montgomery silty clay loam	3.17
Mzc	Montgomery silty clay	4.35
MzdB	Morley silt loam, 2 to 6 percent slopes	33.02
MzdB2	Morley silt loam, 2 to 6 percent slopes, eroded	14.62
MzdC2	Morley silt loam, 6 to 12 percent slopes, eroded	12.51
MzfA	Mundelein silt loam, 1 to 3 percent slopes	0.28
Na	Navan silt loam	4.07
Oc	Ogden muck	18.37
Ph	Pella silt loam	3.56
PrA	Pistakee silt loam, 1 to 3 percent slopes	1.81
RaA	Radford silt loam, 0 to 3 percent slopes	0.92
ScB	St. Charles silt loam, 2 to 6 percent slopes	0.28
Sg	Sawmill silt loam, calcareous variant	0.62
ShA	Saylesville silt loam, 0 to 2 percent slopes	1.36
ShB	Saylesville silt loam, 2 to 6 percent slopes	4.93
ShB2	Saylesville silt loam, 2 to 6 percent slopes, eroded	1.21
ShC2	Saylesville silt loam, 6 to 12 percent slopes, eroded	1.53
Sm	Sebewa silt loam	1.68
So	Sebewa silt loam, clayey substratum	0.38
ThA	Theresa silt loam, 0 to 2 percent slopes	0.55
ThB	Theresa silt loam, 2 to 6 percent slopes	6.03
ThB2	Theresa silt loam, 2 to 6 percent slopes, eroded	1.56
ThC2	Theresa silt loam, 6 to 12 percent slopes, eroded	0.51
VaB	Varna silt loam, 2 to 6 percent slopes	7.53
Wa	Wallkill silt loam	1.11
WgB	Warsaw loam, clayey substratum, 2 to 6 percent slopes	0.02
	Total	**321.89**

TABLE 6-6
Prime Farmlands Crossed by the Underwood Creek to Lake Michigan Return Flow Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	4.88
CeB	Casco loam, 2 to 6 percent slopes	0.54
FoA	Fox loam, 0 to 2 percent slopes	0.08
FsC2	Fox silt loam, 6 to 12 percent slopes, eroded	0.10
GrB	Grays silt loam, 2 to 6 percent slopes	0.43
HmB	Hochheim loam, 2 to 6 percent slopes	8.97
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	0.57
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	0.73
HtA	Houghton muck, 0 to 2 percent slopes	17.74
KeA	Kane silt loam, 1 to 3 percent slopes	0.66
LmB	Lamartine silt loam, 1 to 4 percent slopes	0.66
LyB2	Lorenzo loam, 2 to 6 percent slopes, eroded	0.92
MgA	Martinton silt loam, 1 to 3 percent slopes	0.75
MmA	Matherton silt loam, 1 to 3 percent slopes	3.82
MtA	Mequon silt loam, 1 to 3 percent slopes	12.36
Mzb	Montgomery silty clay loam	1.23
MzfA	Mundelein silt loam, 1 to 3 percent slopes	0.79
Oc	Ogden muck	5.07
OuB	Ozaukee silt loam, 2 to 6 percent slopes	9.34
OuB2	Ozaukee silt loam, 2 to 6 percent slopes, eroded	4.93
OuC2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	1.01
Ph	Pella silt loam	13.14
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.31
Sm	Sebewa silt loam	2.37
WeB	Warsaw loam, 2 to 6 percent slopes	9.08
WeC2	Warsaw loam, 6 to 12 percent slopes, eroded	0.33
Ww	Wet alluvial land	1.93
	Total	**102.75**

TABLE 6-7
Prime Farmlands Crossed by the Root River to Lake Michigan Return Flow Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	4.21
AzB	Aztalan loam, 2 to 6 percent slopes	0.85
CeB	Casco loam, 2 to 6 percent slopes	0.72
Dt	Drummer silt loam, gravelly substratum	15.71
FoA	Fox loam, 0 to 2 percent slopes	0.08
FsC2	Fox silt loam, 6 to 12 percent slopes, eroded	0.10
HmB	Hochheim loam, 2 to 6 percent slopes	8.97
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	0.57
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	0.73
HtA	Houghton muck, 0 to 2 percent slopes	17.86
KeA	Kane silt loam, 1 to 3 percent slopes	0.66
LmB	Lamartine silt loam, 1 to 4 percent slopes	0.66
Lo	Lawson silt loam	9.97
LyB2	Lorenzo loam, 2 to 6 percent slopes, eroded	0.92
MgA	Martinton silt loam, 1 to 3 percent slopes	0.75
MmA	Matherton silt loam, 1 to 3 percent slopes	5.99
MtA	Mequon silt loam, 1 to 3 percent slopes	13.65
Mzb	Montgomery silty clay loam	1.23
Na	Navan silt loam	0.04
Oc	Ogden muck	5.07
OuB	Ozaukee silt loam, 2 to 6 percent slopes	7.95
OuB2	Ozaukee silt loam, 2 to 6 percent slopes, eroded	3.70
OuC2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	0.47
Ph	Pella silt loam	3.06
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.34
ShC2	Saylesville silt loam, 6 to 12 percent slopes, eroded	0.02
Sm	Sebewa silt loam	11.40
WeB	Warsaw loam, 2 to 6 percent slopes	9.08
WeC2	Warsaw loam, 6 to 12 percent slopes, eroded	0.33
Ww	Wet alluvial land	11.01
	Total	**136.13**

TABLE 6-8
Prime Farmlands Crossed by the Direct to Lake Michigan Return Flow Alternative
City of Waukesha Water Supply

Prime Farmland Soil Series	Soil Series Description	Acres Crossed
AsA	Ashkum silty clay loam, 0 to 3 percent slopes	4.21
CeB	Casco loam, 2 to 6 percent slopes	0.91
FoA	Fox loam, 0 to 2 percent slopes	0.08
FsC2	Fox silt loam, 6 to 12 percent slopes, eroded	0.10
GrB	Grays silt loam, 2 to 6 percent slopes	1.47
HmB	Hochheim loam, 2 to 6 percent slopes	8.97
HmB2	Hochheim loam, 2 to 6 percent slopes, eroded	0.57
HmC2	Hochheim loam, 6 to 12 percent slopes, eroded	0.73
HtA	Houghton muck, 0 to 2 percent slopes	17.74
KeA	Kane silt loam, 1 to 3 percent slopes	0.66
LmB	Lamartine silt loam, 1 to 4 percent slopes	0.66
LyB2	Lorenzo loam, 2 to 6 percent slopes, eroded	0.92
MgA	Martinton silt loam, 1 to 3 percent slopes	0.75
MmA	Matherton silt loam, 1 to 3 percent slopes	7.20
MtA	Mequon silt loam, 1 to 3 percent slopes	12.35
Mzb	Montgomery silty clay loam	1.23
MzfA	Mundelein silt loam, 1 to 3 percent slopes	1.05
Oc	Ogden muck	5.07
OuB	Ozaukee silt loam, 2 to 6 percent slopes	7.95
OuB2	Ozaukee silt loam, 2 to 6 percent slopes, eroded	3.13
OuC2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	0.40
Ph	Pella silt loam	3.06
PrA	Pistakee silt loam, 1 to 3 percent slopes	0.31
Sm	Sebewa silt loam	2.54
WeB	Warsaw loam, 2 to 6 percent slopes	9.08
WeC2	Warsaw loam, 6 to 12 percent slopes, eroded	0.33
Ww	Wet alluvial land	1.93
	Total	**93.41**

While this alternative effects soil classified as prime farmland, as listed in Table 6-4 below, current land use classified as active agricultural is much less, as shown in the Table 6-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently exist on a majority of the remaining soil classified as prime farmland.

6.3.1.5 Lake Michigan Supply—Racine

There are negligible facilities that alter the land use associated with this alternative. Any impacts to active agricultural lands would be from pipeline construction, which would all be temporary in nature and would allow agricultural activities to continue after construction is completed.

While this alternative effects soil classified as prime farmland, as listed in Table 6-5 below, current land use classified as active agricultural is much less, as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently exist on a majority of the remaining soil classified as prime farmland.

6.3.2 Return Flow Alternatives

6.3.2.1 Underwood Creek

While this alternative impacts soil classified as prime farmland, as listed in Table 6-6 below, there is no current land use designated as active agriculture as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently occur on all of the remaining soil classified as prime farmland.

6.3.2.2 Root River

While this alternative impacts soil classified as prime farmland, as listed in Table 6-7 below, there is no current land use designated as active agriculture, as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently occur on all of the remaining soil classified as prime farmland.

6.3.2.3 Direct to Lake Michigan

While this alternative impacts soil classified as prime farmland, as listed in Table 6-8 below, there is no current land use designated as active agriculture, as shown in the Table 7-2 (see Chapter 7 of this Environmental Report). Land uses other than agricultural currently occur on all of the remaining soil classified as prime farmland.

6.4 Construction and Operation Impacts and Mitigation

Construction will result in both short-term and permanent impacts to the soils within a given supply or return flow alternative corridor. Potential impacts may include soil erosion on steep slopes by wind and water, mixing of topsoil and subsoil, soil compaction and rutting from construction equipment, and poor revegetation potential. However, these impacts will be mitigated by sustainable construction techniques and an aggressive re-vegetation program.

Because the pipeline routes follow previously disturbed areas including streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county

lands few impacts occur to active agricultural lands even if the soil is classified as prime agricultural land. Expected impacts to active agricultural lands are listed in Chapter 7 Land Use, Table 7-2. As noted in Table 7-2, the Lake Michigan Supply – Milwaukee and all of the return flow alternatives cross lands classified as prime farmland, but they have no impacts on active agricultural lands.

However, if an alternative includes impacts to active agricultural lands, crop production may be lost within temporary workspaces if construction takes place during the growing season. Losses would be short-term in areas where no permanent aboveground structures or access roads are proposed as the land would be returned to production for the growing season following completion of construction. Topsoil will be carefully managed during construction to ensure that the productive capacity of the land would be retained after construction.

In addition to topsoil management, the land disturbed during construction would be restored as nearly as practicable to pre-construction conditions. The City would employ BMPs, such as topsoil segregation, sediment and erosion control measures, and proper site restoration, to minimize long-term impacts to construction areas. Further information regarding specific BMPs and restoration measures proposed to be used will be provided to the appropriate agency stakeholders during the design process. Operational impacts to prime farmland occur for the Deep and Shallow Wells and Shallow Aquifer and Fox River Alluvium alternatives due to above ground structures required for the project. Acreage impacts are listed in the above descriptions.

6.5 References

NRCS (Natural Resources Conservation Service). 2009. U.S. Department of Agriculture, NRCS, Soil Survey Geographic (SSURGO) Database. Available at http://soils.usda.gov/survey/geography/ssurgo/. Accessed January and February 2010.

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Chapter 7
Land Use, Recreation, and Aesthetics

CHAPTER 7

Land Use, Recreation, and Aesthetics

7.1. Introduction

This section addresses existing land uses within the supply and return flow alternatives that could be affected by construction or operation of the routes. It identifies sensitive land uses near the route, including residential areas, hospitals, public lands, recreation areas, and other similar special use areas.

7.2. Land Use

Table 7-1 summaries the total land impacts anticipated for the various supply and return flow alternatives.

TABLE 7-1
Summary of Land Acreage Impacts
City of Waukesha Water Supply

Alternative Name	Land Affected (acres)	
	Overall[a]	During Operation[b]
Supply Alternatives		
Deep and Shallow Wells pipeline alignment	121.11	*0*
Aboveground structures and access roads[c]	*31.49*	*31.49*
Deep and Shallow Wells (Total)	152.6	31.49
Shallow Aquifer and Fox River Alluvium pipeline alignment	134.51	*0*
Aboveground structures and access roads[c]	*56.19*	*56.19*
Shallow Aquifer and Fox River Alluvium (Total)	190.7	56.19
Lake Michigan—Milwaukee Supply	122.4[d]	0
Lake Michigan—Oak Creek	230.2[d]	0
Lake Michigan—Racine	341.6[d]	0
Return Flow Alternatives		
Underwood Creek to Lake Michigan	104.8	0[e]
Root River to Lake Michigan	141.4	0[e]
Direct to Lake Michigan to Lake Michigan	206	0[e]

[a] Includes all areas impacted by the supply and return flow alternatives, both temporary and permanent.
[b] Includes land disturbed during construction that also will be regarded as permanent workspace, including new aboveground structures and new access roads .
[c] Includes new access roads (15 feet wide), well houses, and WTP.
[d] A pump station may be required from the water provider. If required, it will be constructed within a previously disturbed area.
[e] Aboveground structures may include only a single pump station which will be constructed within the existing Waukesha WWTP site, in a previously disturbed area.

Table 7-2 provides quantitative data for land use types affected by a combination of temporary construction impacts and operation impacts of the supply and return flow alternatives. Land use data was assembled from the 2000 SEWRPC Digital Land Use Inventory and 2005 SEWRPC Park and Open Space Sites, both produced by SEWRPC's Land Use and GIS Divisions (SEWRPC, 2000, 2005). The following descriptions were used in classifying land use in this section:

- *Residential*. Two-family and multifamily low-rise (up to three stories) and multifamily high-rise (four or more stories) buildings and low-, medium-, and high-density areas.
- *Commercial and Industrial*. Retail sales and service intensive areas; manufacturing, wholesaling and storage areas; and unused lands designated as commercial or industrial.
- *Transportation and Communication Utilities.* Motor-vehicle-related freeways, expressways, streets, and truck terminals; off-street parking areas; rail-related track ROWs; and communication and utility areas/structures.
- *Government and Institutional.* Administrative, safety, or assembly areas, both local and regional; educational areas (local and regional); and cemeteries.
- *Recreational Areas*. Land-related recreational areas, both public and nonpublic.
- *Agricultural Lands.* Cropland, pasture, lowland pasture, farm buildings, and other agricultural areas.
- *Open Lands*. Urban and rural open areas.
- *Woodlands*. Open lands that are forested.
- *Surface Water*. Open lands that are bodies of water.
- *Wetlands*. Wetland areas in designated open land, transportation, and communication/utility areas.

As illustrated in Table 7-2, most of the land impacted by each of the individual supply and return flow alternatives is categorized as transportation and communication utilities, the majority of which is made up of the roadways impacted by the routes. This emphasizes the fact that the pipelines associated with this project primarily use existing public right-of-way or utility corridors. The second largest land use category impacted for some individual routes was agricultural lands. Even though the Lake Michigan Supply – Milwaukee and all of the return flow alternatives cross lands classified as prime farmland (Chapter 6, Soil), they have no impacts on active agricultural lands. Combined, transportation and communication utilities and agricultural lands account for 75 percent of the total area affected by the various supply and return flow alternatives.

Once a final alternative has been selected and constructed, land with temporary impacts from pipeline construction will be allowed to revert or will be restored to its prior existing use. Land use change during the operational phase of the project would almost exclusively occur for either of the Deep and Shallow Wells alternative or the Shallow Aquifer and Fox River Alluvium alternative due to the need for a new water treatment plant, new access roads, and aboveground structures with these alternatives.

TABLE 7-2
Land Use Impacts in Acres
City of Waukesha Water Supply

Route	Residential	Commercial & Industrial	Transportation & Communication/ Utilities	Government. & Institutional	Recreational Areas	Agricultural Lands	Open Lands	Woodlands	Surface Water	Wetlands	Total[a]
Supply Routes											
Deep and Shallow Wells	10.84	2.18	77.57	0.82	0.66	46.53	6.31	0.00	0.24	7.46	**152.61**
Shallow Aquifer and Fox River Alluvium	10.70	2.18	77.70	0.82	0.66	73.72	6.31	0.00	0.55	18.10	**190.74**
Lake Michigan—Milwaukee Supply[b]	3.03	3.29	97.86	0.04	2.35	0.00	7.97	0.45	0.00	7.21	**122.2**
Lake Michigan—Oak Creek Supply[b]	10.25	2.60	160.16	0.59	5.16	4.24	31.37	2.12	0.16	13.54	**230.19**
Lake Michigan—Racine Supply	9.31	4.24	33.85	0.04	3.75	213.05	30.70	7.74	0.26	38.67	**341.61**
Return Route											
Underwood Creek to Lake Michigan[b]	2.38	3.92	74.85	0.92	3.08	0.00	6.03	0.00	0.17	13.44	**104.79**
Root River to Lake Michigan[b]	1.61	2.31	92.18	0.92	9.14	0.00	19.68	1.18	0.17	14.23	**141.42**
Direct to Lake Michigan[b]	4.80	9.81	154.77	4.29	4.51	0.00	11.33	0.08	0.17	10.03[b]	**199.79[c]**

Source: SEWRPC (2000).
[a] Represents the total land along each alternative that had a specific land use designation within the SEWRPC Digital Land Use Inventory.
[b] Lake Michigan Supply and Return flow options share the same workspace for approximately 6 miles. Actual land use totals would be less than reported if a Lake Michigan Supply and Return flow option were selected.

[C] Total does not include 6.2 acres of surface waters within Lake Michigan which were not included in the SEWRPC Digital Land Use Inventory.

7.2.1. Access Roads

Existing roads and highways would be used for primary access to the workspace along the supply and return flow alternatives, for both construction crews and delivery of pipe and equipment. Equipment would be moved across public roads that intersect the workspace as work progresses. This would be done in accordance with applicable safety requirements and with due regard for maintenance of existing road surface conditions. Use of access roads during the short-term construction period would have a similar effect as other construction activities on adjacent land uses.

The only new access roads proposed will be for the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium supply alternatives in Waukesha County. These new gravel access roads would be used for access to the well houses at the southern terminus of both supply routes, during both construction and operation.

No new access roads will be required for the various Lake Michigan supply alternatives or the return flow alternatives. Existing public or private roads will be used for these alternatives. Table 7-3 summarizes the number and acreages of proposed new access roads for each of the alternatives.

TABLE 7-3
Access Roads
City of Waukesha Water Supply

Alternative Name	Number of New Access Roads	Acreage Affected by New Access Road
Supply Alternatives		
Deep and Shallow Wells	2[a]	3.0[b]
Shallow Aquifer and Fox River Alluvium	3[a]	5.0[b]
Lake Michigan—Milwaukee Supply	None proposed[c]	—
Lake Michigan—Oak Creek	None proposed[c]	—
Lake Michigan—Racine	None proposed[c]	—
Return Flow Alternatives		
Underwood Creek to Lake Michigan	None proposed[c]	—
Root River to Lake Michigan	None proposed[c]	—
Direct to Lake Michigan	None proposed[c]	—

[a]Access will also include existing municipal roadways and trails

[b]Assumes access roads will be 15 feet wide, constructed only between well houses, and will not involve water body crossings.

[c]Access is anticipated to be from existing municipal roadways and trails.

7.2.2. Aboveground Structures

The supply and return flow alternatives will involve the construction of water main pipelines through Milwaukee, Racine, or Waukesha Counties, Wisconsin. Permanent impacts associated with aboveground structures will depend on the alternative(s) selected,

and will include the construction of well houses, pump stations, and new water treatment plant (WTP) for the two shallow aquifer alternatives.

A summary of the proposed aboveground structures and acreages associated with each of the alternatives is depicted in Table 7-4. The above ground structures are primarily associated with the Deep and Shallow Aquifer and Shallow Aquifer and Fox River Alluvium alternatives. Lake Michigan water supply and return flow alternatives have an insignificant impact for above ground structures.

TABLE 7-4
Aboveground Structures
City of Waukesha Water Supply

Alternative Name	Description & Number of Structures	Acres
Supply Alternatives		
Deep and Shallow Aquifers	11 well houses	13.75
	WTP	14.74
Shallow Aquifer and Fox River Alluvium	15 well houses	17.99
	WTP	33.20[a]
Lake Michigan—Milwaukee Supply	None proposed[b]	—
Lake Michigan—Oak Creek	None proposed[b]	—
Lake Michigan—Racine	None proposed[b]	—
Return Flow Alternatives		
Underwood Creek to Lake Michigan	Pump Station[c]	—
Root River to Lake Michigan	Pump Station[c]	—
Direct to Lake Michigan	Pump Station[c]	—

[a] Includes the same 14.74 acres listed for the Deep and Shallow Aquifers alternative, plus additional 18.46 acres for more expansive plant needed for treatment of groundwater under the influence of surface water.
[b] A pump station may be required from the water provider. If required, it will be constructed within a previously disturbed area.
[c] Will be constructed within the existing Waukesha WWTP site, in a previously disturbed area.

7.3. Residential and Commercial Areas

7.3.1. Existing Residences and Buildings

No private residences would be affected by the supply and return flow alternatives being considered. A single private building is located within the proposed 75-foot-wide construction corridor for the Lake Michigan—Milwaukee, —Oak Creek, and —Racine supply alternatives. The building is located in Waukesha County near the terminus of the Lake Michigan supply alternatives and based on a review of aerial photography, appears to be used as a storage structure. The City will coordinate with the owner of the building further if the final alternative chosen is a Lake Michigan supply option. Appropriate mitigation measures will be taken to restore properties disturbed during construction.

7.4. Public Land, Recreation, and Other Designated Areas

7.4.1. Public or Conservation Land and Natural, Recreational, or Scenic Areas

A review of alternatives being evaluated was completed to identify Public or Conservation Land and Natural, Recreational, or Scenic Areas within 0.10 mile of the respective alternative alignments. Public or Conservation Land and Natural, Recreational, or Scenic Areas may include the following:

- Federal or state wild and scenic rivers
- USFWS designated areas, USDA Forest Service areas
- U.S. National Parks
- National Wilderness Areas
- National Trails System
- National Historic Landmarks
- Critical habitat areas of NOAA Fisheries
- State designated natural areas and state managed lands
- State , county, and/or city parks
- Golf courses and athletic fields
- Designated greenspace corridors
- School properties

According to a review of Google Earth (Google Earth, 2009) and the SEWRPC Land Use Division and GIS Division , Park and Open Spaces Sites data (SEWRPC, 2005), no federally designated or managed Public or Conservation Land and Natural, Recreational, or Scenic Areas are impacted by the supply and return flow alternatives.

Limited temporary construction impacts may occur to state and local Public or Conservation Land and Natural, Recreational, or Scenic Areas as a result of construction depending on which supply and return flow alternative is ultimately selected. Impacts to state and local resources can be divided into two main categories; construction related impacts and impacts resulting from groundwater table drawdown. Construction related impacts to resources can be further divided into temporary and permanent impacts. Temporary construction related impacts resulting from the project are anticipated to be short in duration and will be minimized by implementing BMPs designed to reduce impacts to sensitive resources. No permanent aboveground structures will be built within areas designated as state or local Public or Conservation Land and Natural, Recreational, or Scenic Areas and as a result, no permanent construction related impacts will occur.

Permanent impacts resulting from a potential drawdown of the groundwater table are only applicable to the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium Alternatives. The groundwater drawdown affects the Vernon Wildlife Area and is described in Chapter 2.4 Wetlands, and Chapter 3, Vegetation and Wildlife Resources .

Table 7-5 summarizes the Public or Conservation Land and Natural, Recreational, or Scenic Areas located within or adjacent to the proposed workspaces for the supply and return flow alternatives.

TABLE 7-5
Public or Conservation Lands within or Adjacent to the Alternatives
City of Waukesha Water Supply

Alternative Name	Name of Resource	Acres Within Proposed 75-ft Construction Workspace
Supply Alternatives		
Deep and Shallow Aquifers	Vernon Marsh Wildlife Area	1.25
	American Legion Memorial Park	0.10
	Fox River Park	1.40
	Hillcrest Park	0.06
	Spring City Soccer Club Athletic Fields	0.72
Shallow Aquifer and Fox River Alluvium	Vernon Marsh Wildlife Area	1.25
	American Legion Memorial Park	0.10
	Fox River Park	1.41
	Hillcrest Park	0.06
	Spring City Soccer Club Athletic Fields	0.72
Lake Michigan—Milwaukee Supply	Greenfield Park	0.17
	Hillcrest Park	1.16
	New Berlin Golf Course	1.51
	Root River Parkway	21.28
Lake Michigan—Oak Creek	Former North Shore ROW	9.38
	Greenfield Park	0.17
	Greenlawn Park	0.05
	Hillcrest Park	1.16
	Milwaukee Metropolitan Sewerage District Conservation Plan area	0.54
	New Berlin Hills Golf Course	1.51
	Oak Creek Parkway	1.10
	Root River Parkway	39.40
	Whitnall Park	5.41
Lake Michigan—Racine	WDNR designated Big Muskego Lake Wildlife Area	2.64
	Cheska Farms Riding Stables WDNR site	2.29
	WDNR designated area	5.66
	Hillcrest Park	1.16
	Minooka Park	8.64

TABLE 7-5
Public or Conservation Lands within or Adjacent to the Alternatives
City of Waukesha Water Supply

Alternative Name	Name of Resource	Acres Within Proposed 75-ft Construction Workspace
Return Flow Alternatives		
Underwood Creek	Bethesda Springs Park	0.30
	Carroll College athletic fields	0.28
	Fox River Sanctuary	2.48
	Greenfield Park	0.17
	Krueger Park (which becomes Rainbow Park on the south side of Interstate 94)	0.89
	Underwood Creek Parkway and Corridor	3.83
Root River	Bethesda Springs Park	0.30
	Carroll College athletic fields	0.28
	Fox River Sanctuary	2.48
	Greenfield Park	0.17
	New Berlin Hills Golf Course	1.00
	Root River Parkway	43.99
Direct to Lake Michigan	Bethesda Springs Park	0.30
	Carroll College athletic fields	0.28
	Fox River Sanctuary	2.48
	Greene Park	0.61
	Greenfield Park	0.64
	Kinnickinnic River Parkway	0.35
	Sheridan Park	0.60
	Saint Francis High School	0.49
	Saint Francis Property	0.30

Sources: Google Earth (2009); SEWRPC (2005).

7.4.2. Coastal Zone Management Areas

Coastal Zone Management Areas are enforced within Wisconsin counties that border the Great Lakes, including Milwaukee County. The Lake Michigan—Milwaukee supply, Lake Michigan—Oak Creek supply, Lake Michigan—Racine supply, Underwood Creek return flow, and Root River return flow alternatives are located within Milwaukee County but do not affect coastal areas.

The Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium alternatives and their associated aboveground structures (well houses and WTP) are located entirely within Waukesha County and therefore will not impact a Coastal Zone Management Area.

The Direct to Lake Michigan return flow alternative is located within the designated Wisconsin Coastal Zone (DOA, 2010). If this alternative is utilized, the City will coordinate with the WDNR, USACE, and applicable agencies regarding avoidance and minimization of impacts to the Wisconsin Coastal Zone.

7.5. Agricultural Lands

Construction may result in a reduction of agricultural production if the alternative affects agricultural land. According to Table 7-2 in, the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium alternatives have permanent impacts on prime farmland soils. The Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium alternatives, Lake Michigan – Oak Creek, and Lake Michigan – Racine all have temporary construction agricultural impacts (Table 7-2) while the Lake Michigan- Milwaukee, and all the return flow alternatives have no agricultural land use impacts. Further discussion on impacts to prime farmland soils is included in Chapter 6, Soils.

7.6. Visual Resources

Construction will not affect any areas subject to federal visual resource management standards, and no designated sensitive viewpoints are known to occur along the supply and return flow alternatives.

The aboveground structures (well houses and WTP for the Deep and Shallow Aquifers and Shallow Aquifer and Fox River Alluvium alternatives) would be located within primarily agricultural areas, with a small amount of wetlands and very limited residential areas (approximately 1.0 acre) impacted. None of the proposed aboveground structures is located in any visually sensitive areas.

Visual impacts of the supply and return flow alternatives are anticipated to be minor and temporary. In agricultural areas, previously disturbed easements, roadway corridors, and residential properties, the visual disturbance would be difficult to detect by the first growing season following completion of construction due to surface restoration efforts.

7.7. References

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Chapter 8
Comparison of Alternatives

CHAPTER 8

Comparison of Alternatives

This section compares impacts of the alternatives considered relative to each other. Impacts could result from construction (short term) or operation (long term).

8.1 Environmental Impact Category Description

Table 8-1 describes the level of impact (no adverse impact, minor adverse impact, etc.) for the various environmental resource categories reviewed in this ER. Each category has been detailed in previous sections of this report; this chapter compares the alternatives on the basis of these relative impact classifications. The text below describes the impacts of each alternative, and Table 8-2 summarizes the findings.

TABLE 8-1
Environmental Impact Category Description
City of Waukesha Water Supply

Category	No Adverse Impact	Minor Adverse Impact	Moderate Adverse Impact	Significant Adverse Impact
Groundwater Resources (Chapter 2)	Causes rebound of the deep aquifer in City of Waukesha and no drawdown of the shallow aquifer or temporary impacts from construction. Does not reduce stream at any time.	Stabilizes draw down of the deep aquifer in City of Waukesha and shallow aquifer draw down of 5 feet or less affects fewer than 5 acres of wetlands. Reduced baseflow in warm water streams of up to 25% causing habitat loss.	Draw down of the deep aquifer continues and shallow aquifer draw down of 5 feet or more affects greater than 5 but less than 10 acres of wetlands. Reduced baseflow in warm water streams of greater than 25% but less than 50%, causing habitat loss. Reduced baseflow to cold water streams, but less than 25%.	Draw down of the deep aquifer continues or shallow aquifer draw down of 5 feet or more affects greater than 10 acres of wetlands. Reduced baseflow in cold water streams of 25% or more or reduced baseflow in warm water streams of 50% or more.
Flow and Geomorphology (Chapter 2)	With return flow, channel is stable for flows up to the 2-year return where the channel is currently stable. No substrate change to Lake Michigan from construction.	With return flow, channel has some instability for flows up to the 2-year return where the channel is currently stable. Substrate change to Lake Michigan of fewer than 10 acres.	With return flow, channel has frequent instability for flows up to the 2-year return where the channel is currently stable. Substrate change to Lake Michigan of greater than 10 but less than 20 acres.	With return flow, channel is unstable at most flows where the channel is currently stable. Substrate change to Lake Michigan of greater than 20 acres.
Water Quality (Chapter 2)	Temporary impacts from construction; during operation water quality numeric standards compliance improves or stays approximately the same based upon expected water quality from historical wastewater treatment plant performance. Contributes a de minimis change (<1%) in total water quality parameter average annual loading to Lake Michigan near Milwaukee based upon expected water quality from historical wastewater treatment plant performance. Operational changes in stormwater runoff quality occur due to new above ground structures.	Water quality numeric standards compliance improves or stays approximately the same based upon expected water quality from historical wastewater treatment plant performance and recognizing allowances commonly provided in other municipal discharge permits. Contributes a minor change (>1%, but less than 10%) in total water quality parameter average annual loading to Lake Michigan near Milwaukee based upon expected water quality from historical wastewater treatment plant performance.	Lowering of in-stream water quality, but no numeric water quality standard exceedences for water quality parameters that were not exceeded without return flow based upon historical wastewater treatment plant performance and recognizing allowances commonly provided in other municipal discharge permits. Numeric water quality standard exceedences for water quality parameters that were already exceeded without return flow based upon historical wastewater treatment plan performance. Contributes a moderate change (>10%, but less than 25%) in total water quality parameter average annual loading to Lake Michigan near Milwaukee based upon expected water quality from historical wastewater treatment plant performance.	New exceedence of numeric water quality standards occurs for water quality parameters that were not exceeded without return flow based upon historical wastewater treatment plant performance and recognizing allowances commonly provided in other municipal discharge permits. Contributes a substantial change (>25%) in total water quality parameter average annual loading to Lake Michigan near Milwaukee based upon expected water quality from historical wastewater treatment plant performance.

TABLE 8-1
Environmental Impact Category Description
City of Waukesha Water Supply

Category	No Adverse Impact	Minor Adverse Impact	Moderate Adverse Impact	Significant Adverse Impact
Flooding (Chapter 2)	No increase in flooding depth for the 100-year return period storm.	Causes an increase in flooding depth of greater than 0.01 but less than 0.1 foot at buildings for the 100-year return period storm.	Causes an increase in flooding depth of greater than 0.1 but less than 1.0 foot at buildings for the 100-year return period storm.	Causes an increase in flooding depth of greater than 1.0 foot at buildings for the 100-year return period storm.
Aquatic Habitat (Chapter 2)	Temporary impacts from construction; neutral or improved habitat creation and frequency of availability from operation.	Reduced baseflow in warm water streams of up to 25%, causing habitat loss. Substrate change to Lake Michigan of fewer than 10 acres.	Reduced baseflow in warm water streams of greater than 25% but less than 50%, causing habitat loss. Reduced baseflow to cold water streams, but less than 25%. Substrate change to Lake Michigan of greater than 10 but less than 20 acres.	Reduced baseflow in cold water streams of 25% or more or reduced baseflow in warm water streams of 50% or more, causing habitat loss. Substrate change to Lake Michigan of greater than 20 acres.
Wetlands (Chapter 2)	No temporary or operational impacts to existing wetlands greater than 0.1 acre.	Temporary construction impacts to wetlands. Operational impacts of greater than 0.1 acre but less than 5 acres of existing wetlands.	Operational impacts of greater than 5 but less than 10 acres of existing wetlands.	Operational impacts of more than 10 acres of existing wetlands.
Vegetation and Wildlife Resources (Chapter 3)	No long-term, operational impacts.	Operational impacts occur from new above ground structures to areas without special wildlife area protection. Groundwater drawdown to areas with special wildlife protection areas impact is less than 5 acres.	Groundwater drawdown to areas with special wildlife protection areas impact is greater than 5 but less than 10 acres.	Groundwater drawdown to areas with special wildlife protection areas impact is greater than 10 acres.
Cultural Resources (Chapter 4)	Cultural resources will be protected for all alternatives and thus the same for all alternatives. Any impacts to known cultural resources will follow applicable regularly requirements and will consequently be insignificant.	See No Adverse Impact definition.	See No Adverse Impact definition.	See No Adverse Impact definition.

TABLE 8-1
Environmental Impact Category Description
City of Waukesha Water Supply

Category	No Adverse Impact	Minor Adverse Impact	Moderate Adverse Impact	Significant Adverse Impact
Socioeconomics (Chapter 5)	Future growth planning in the City of Waukesha has not been contingent upon water supply source. Consequently, socioeconomic impacts are insignificant for all alternatives.	See Insignificant Impact definition.	See Insignificant Impact definition.	See Insignificant Impact definition.
Soils (Chapter 6)	No operational impacts and only temporary construction impacts.	Operational impacts are limited to soil types frequently found in the area.	Operational impacts occur to soil types infrequently occurring in the area.	Operational impacts occur to soil types rarely occurring in the area.
Land Use (Chapter 7)	Temporary construction impacts and operational impacts that result in land use changes already frequently occurring in the area.	Operational impacts result in land use changes to Public or Conservation Land and Natural, Recreational, or Scenic Areas less than 5 acres.	Operational impacts result in land use changes to Public or Conservation Land and Natural, Recreational, or Scenic Areas greater than 5, but less than 50 acres.	Operational impacts result in land use changes to Public or Conservation Land and Natural, Recreational, or Scenic Areas greater than 50 acres.

8.2 Alternative Comparison

Each alternative is compared below for relative environmental impacts for each category in Table 8-1. Table 8-2 is a comparison summary of the impacts for each alternative.

8.2.1 Groundwater Resources

Please refer to Chapter 2.2.2 for detailed information on each alternative.

8.2.1.1 Deep and Shallow Aquifers

This alternative would reduce existing impacts to the deep aquifer because there would be less pumping of the deep aquifer and thus some rebound of the deep aquifer in the City of Waukesha over time. Increased pumping of the shallow aquifer, however, would decrease baseflow to various streams. Groundwater modeling of the alternative indicates that the Fox River would experience 2.4 mgd less flow. The reduction of baseflow to the Fox River from groundwater pumping would be a minor adverse impact.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would experience baseflow reduction from groundwater pumping, with a 61 percent reduction in Pebble Brook on average, and an even greater reduction during low flow conditions. The baseflow reduction to the cold water streams would be a significant adverse impact.

Groundwater pumping would reduce the groundwater level by 5 feet or more for nearly 1,000 wetland acres. Drawdown of 1 foot or greater would occur for over 3,000 wetland acres. Because a wetland is designated by the type of plants, hydrology, and soil, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. The groundwater drawdown to wetlands from groundwater pumping would be a significant adverse impact.

8.2.1.2 Shallow Aquifer and Fox River Alluvium

Impacts to the deep aquifer are further reduced with this alternative because there would be no pumping of the deep aquifer for the City of Waukesha water supply, which will lead to some rebound of the deep aquifer in the City of Waukesha over time. However, increased pumping from the shallow aquifer further decreases baseflow to various streams. Groundwater modeling of this alternative indicates that the Fox River would experience 5.9 mgd less flow. The baseflow reduction to the Fox River from groundwater pumping would be a minor adverse impact.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would also experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 58 percent on average, and an even greater reduction during low flow conditions. The baseflow reduction to the cold water streams would be a significant adverse impact.

Groundwater pumping would reduce the groundwater level by 5 feet or more for nearly 2,000 wetland acres. A 1-foot or greater groundwater drawdown would occur for over 4,000 wetland acres. Because a wetland is designated by the type of plants, hydrology, and soil, groundwater drawdown in wetlands can reduce or eliminate the hydrology element

required to sustain wetland conditions. The groundwater drawdown to wetlands from groundwater pumping would be a significant adverse impact.

8.2.1.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

The Lake Michigan water supply alternatives would eliminate the need for pumping the deep aquifer, which would cause a partial rebound in the deep aquifer in the City of Waukesha. Due to the volume of water present, withdrawal from Lake Michigan with return flow would result in no changes in lake volume, and therefore it is not anticipated that withdrawal from the lake would result in adverse effects to regional aquifer supplies that are influenced by Lake Michigan. Lake Michigan water supply consequently produces no adverse impact on groundwater resources.

8.2.1.4 Return Flow—Underwood Creek to Lake Michigan

Due to the small change in this Lake Michigan tributary water depth with return flow, this alternative is not anticipate to result in adverse impacts to regional aquifer supplies that are influenced by a Lake Michigan tributary. Return flow to Underwood Creek consequently would produce no adverse impact on groundwater resources.

8.2.1.5 Return Flow—Root River to Lake Michigan

Due to the small change in this Lake Michigan tributary water depth with return flow, this alternative is not anticipate to result in adverse impacts to regional aquifer supplies that are influenced by a Lake Michigan tributary. Return flow to the Root River consequently would produce no adverse impact on groundwater resources.

8.2.1.6 Return Flow—Direct to Lake Michigan

Due to the volume of water present, withdrawal from Lake Michigan with return flow will result in an insignificant change in lake water levels and therefore is not anticipated to result in adverse effects to regional aquifer supplies that are influenced by Lake Michigan. Direct to Lake Michigan return flow consequently would produce no adverse impact on groundwater resources.

8.2.2 Flow and Geomorphology

Please refer to Chapter 2.3.2.1 for detailed information on each of these alternatives.

8.2.2.1 Deep and Shallow Aquifers

Impacts to the flow and geomorphology of surface water resources would occur from shallow groundwater pumping with this water supply alternative. Groundwater modeling of this alternative indicates that the Fox River would experience 2.4 mgd less flow. The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would also experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 61 percent on average and an even greater reduction during low flow conditions. Geomorphic changes with reduced baseflows could result in a smaller channel over time, but because channel stability is associated less with baseflow and influenced more by larger channel-forming flows, baseflow reduction is not expected to cause a significant change in channel stability from existing conditions. The baseflow reduction to

surface waters from groundwater pumping would produce no adverse impact to geomorphology.

8.2.2.2 Shallow Aquifer and Fox River Alluvium

Impacts to the flow and geomorphology of surface water resources would occur from shallow groundwater pumping with this water supply alternative. Groundwater modeling of this alternative indicates the Fox River would experience 5.9 mgd less flow. The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would also experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 58 percent on average and an even greater reduction during low flow conditions. Geomorphic changes with reduced baseflows could result in a smaller channel over time, but because channel stability is associated less with baseflow and influenced more by larger channel-forming flows, baseflow reduction is not expected to cause a significant change in channel stability from existing conditions. The baseflow reduction to surface waters from groundwater pumping would produce no adverse impact to geomorphology.

8.2.2.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

The Lake Michigan water supply alternatives prevent the need for baseflow reduction from groundwater pumping. The flow and geomorphology changes to the environment are dependent upon only the return flow location. Consequently, the Lake Michigan water supply would produce no adverse impacts to flow and geomorphology.

8.2.2.4 Return Flow—Underwood Creek to Lake Michigan

Impacts to the flow and geomorphology of surface water resources occur with this return flow alternative. Return flow to Underwood Creek would reduce the baseflow in the Fox River by approximately 10 mgd, based upon historical WWTP operation. Geomorphic changes with reduced baseflows could result in channel change over time, but because channel stability is associated less with baseflow and influenced more by larger channel-forming flows, baseflow reduction is not expected to cause a significant change in channel stability from existing conditions. Consequently, flow and geomorphology changes to the Fox River are expected to have no adverse impact.

The flow that used to discharge to the Fox River instead increases baseflow in Underwood Creek and the Menomonee River. A geomorphic study was conducted analyzing channel stability of return flow to Underwood Creek and found that the increased baseflows do not adversely impact the channel stability. Return flow to Underwood Creek consequently would produce no adverse impact on flow and geomorphology.

8.2.2.5 Return Flow—Root River to Lake Michigan

Impacts to the flow and geomorphology of surface water resources occur with this return flow alternative. The changes to the Fox River would be the same as those listed for the Underwood Creek return flow alternative.

The flow that used to discharge to the Fox River instead would increase baseflow in the Root River. A recent sediment transport study of the Root River concluded that the river stability is relatively insensitive to changes in flows because of the erosion resistance of the

channel boundary materials, the relatively flat channel gradient, and the presence of a functional floodplain. Return flow to Root River consequently would produce no adverse impact on flow and geomorphology.

8.2.2.6 Return Flow—Direct to Lake Michigan

Impacts to the flow and geomorphology of surface water resources occur with this return flow alternative. The changes to the Fox River would be the same as those listed for the Underwood Creek return flow alternative.

The flow that used to discharge to the Fox River instead would discharge directly to Lake Michigan. To send the water directly into Lake Michigan, a new outfall would be required on the bottom of the Lake. The pipe in the Lake would change the Lake substrate composition along the pipe alignment. A total of 6.2 acres is estimated to be potentially affected. Return flow direct to Lake Michigan consequently would produce a minor adverse impact on geomorphology.

8.2.3 Flooding

Please refer to Chapter 2.3.2.2 for detailed information on each of these alternatives.

8.2.3.1 Deep and Shallow Aquifers

Flooding impacts would not change under this alternative, because flow would continue to be discharged to the Fox River. Consequently, groundwater pumping would produce no adverse impact to flooding.

8.2.3.2 Shallow Aquifer and Fox River Alluvium

Flooding impacts would not change under this alternative, because flow would continue to be discharged to the Fox River. Consequently, groundwater pumping would produce no adverse impact to flooding.

8.2.3.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

A Lake Michigan supply would not affect flooding in any surface waters. Consequently, a Lake Michigan supply would cause no adverse impact to flooding.

8.2.3.4 Return Flow—Underwood Creek, Root River, or Direct to Lake Michigan

The return flow to any location would not impact flooding. Return flow would be temporarily paused during flooding events downstream of the return flow discharge location, and flow from the WWTP would be conveyed to the Fox River. This would maintain the same flow in the Fox River during flooding events as the groundwater supply alternatives. Consequently, any return flow alternative would cause no adverse impact to flooding.

8.2.4 Aquatic Habitat

Please refer to Chapter 2.3.2.3 for detailed information on each of these alternatives.

8.2.4.1 Deep and Shallow Aquifers

Impacts to aquatic habitat would occur with this alternative because increased pumping of the shallow aquifer would decrease baseflow to various streams. Reduced baseflow can decrease the frequency and availability of aquatic habitat, including wetlands. Groundwater modeling of this alternative indicates the Fox River would experience 2.4 mgd less flow. The aquatic habitat change from baseflow reduction to the Fox River would be a minor adverse impact.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would also experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 61 percent on average, with an even greater reduction during low flow conditions. These baseflow reductions would decrease habitat in these streams. The baseflow reduction to the cold water streams would be a significant adverse impact to aquatic habitat.

8.2.4.2 Shallow Aquifer and Fox River Alluvium

Impacts to aquatic habitat would occur with this alternative because increased pumping of the shallow aquifer would decrease baseflow to various streams. Reduced baseflow can decrease the frequency and availability of aquatic habitat. Groundwater modeling of this alternative indicates the Fox River would experience 5.9 mgd less flow. The aquatic habitat change from baseflow reduction to the Fox River from would be a minor adverse impact.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would also experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 58 percent on average, with an even greater reduction during low flow conditions. These baseflow reductions would decrease habitat in these streams. The baseflow reduction to the cold water streams would be a significant adverse impact to aquatic habitat.

8.2.4.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

The Lake Michigan water supply alternatives would not change habitat in Lake Michigan or other surface water resources. Lake Michigan water supply consequently would produce no adverse impact on aquatic habitat.

8.2.4.4 Return Flow—Underwood Creek to Lake Michigan

Return flow to Underwood Creek would increase baseflow and consequently the quantity and availability of aquatic habitat. The greatest habitat benefits would occur during low flow conditions. Return flow to Underwood Creek consequently would improve the aquatic habitat and produce no adverse impact on aquatic habitat.

8.2.4.5 Return Flow—Root River to Lake Michigan

Return flow to the Root River would increase baseflow and consequently the quantity and availability of aquatic habitat. The greatest habitat benefits would occur during low flow conditions. Return flow to the Root River consequently would improve the aquatic habitat and produce no adverse impact on aquatic habitat.

8.2.4.6 Return Flow—Direct to Lake Michigan

Return flow directly to Lake Michigan would have no volume change in flow. Aquatic habitat changes to Lake Michigan with this alternative would occur only with the return flow pipeline on the bottom of Lake Michigan, which would change the bottom substrate. An estimated 6.2 acres could be affected by this alternative. A change in bottom substrate of this magnitude would be expected to have only a minor adverse impact.

8.2.5 Water Quality

Please refer to Chapter 2.3.2.4 for detailed information on each of these alternatives.

8.2.5.1 Deep and Shallow Aquifers

This alternative would maintain WWTP discharge to the Fox River as currently occurs. Discharge permit requirements are currently met and would be met under this future groundwater supply alternative. The existing WDNR discharge permit includes allowances for chloride and mercury. These allowances are expected to continue under this water supply source. Consequently, the water quality impacts to the Fox River are expected to be minor adverse impacts.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 61 percent on average, with an even greater reduction during low flow conditions. Lower baseflows in these cold water streams would lead to warmer temperatures and potential temperature impairment. Pebble Creek's water temperature already fluctuates, and this would be expected to worsen. The water quality impacts to the cold water streams are expected to be minor adverse impacts.

8.2.5.2 Shallow Aquifer and Fox River Alluvium

This alternative would maintain WWTP discharge to the Fox River as currently occurs. Impacts are expected to be the same to the Fox River as with the Deep and Shallow Aquifer alternative. Consequently, the water quality impacts to the Fox River would be expected to be minor adverse impacts.

The small cold water streams Pebble Brook, Pebble Creek, and Mill Brook would experience baseflow reduction from groundwater pumping, with Pebble Brook experiencing a baseflow reduction of 59 percent on average, with an even greater reduction during low flow conditions. Lower baseflows in these cold water streams would lead to warmer temperatures and potential temperature impairment. Pebble Creek's water temperature already fluctuates, and this would be expected to worsen. The water quality impacts to the cold water streams would be expected to be minor adverse impacts.

8.2.5.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

The Lake Michigan water supply alternatives would not change water quality in Lake Michigan and have no adverse impact to other surface water resources. A Lake Michigan water supply source would eliminate the need for water softening, which would be necessary under both groundwater supply alternatives. Consequently, discharge of chlorides in the WWTP from water softener salts would be eliminated from discharge to the

environment over time. The Lake Michigan water supply consequently would produce no adverse impact on water quality.

8.2.5.4 Return Flow—Underwood Creek to Lake Michigan

Return flow to Underwood Creek would take flow currently discharged to the Fox River and send it to Underwood Creek instead. The current Fox River discharge includes a permit allowance for chloride, which would no longer be discharged daily to the Fox River. Consequently, changes to Fox River water quality would occur, but because WDNR discharge permits are designed to protect receiving waters, no significant change in impacts to the Fox River is expected.

Potential discharge permit requirements provided by the WNDR for return flow discharge have been reviewed, and the WWTP would currently meet these requirements based upon historical performance. Water quality modeling found water quality improved, continued to meet water quality standards, or did not cause higher algae growth. The allowances in the current WDNR discharge permit are expected to continue under this water supply source. Consequently, the water quality impacts to Underwood Creek would be expected to have minor adverse impacts.

Water quality loading to Lake Michigan from the watersheds around greater Milwaukee was reviewed and found to be only 0.2 percent of all fecal coliform loading and only 0.21 percent of all total suspended solids loading under conservative, worst-case conditions. Phosphorus loading was found to be only 0.62 percent of all phosphorous loading under past historical performance and only 1.23 percent of all phosphorus loading under worst-case conditions. These phosphorus contributions could be even less in the future because the WDNR is considering new phosphorus regulations that could require more stringent phosphorus discharge limitations. Consequently, the water quality impacts to Lake Michigan would be expected to have minor adverse impacts.

8.2.5.5 Return Flow—Root River to Lake Michigan

Return flow to the Root River would have the same impacts to the Fox River as described for return flow to Underwood Creek.

Potential discharge permit requirements provided by the WNDR for return flow discharge have been reviewed, and the WWTP would currently meet these requirements based upon historical performance. The allowances in the current WDNR discharge permit are expected to continue under this water supply source. Consequently, the water quality impacts to the Root River would be expected to have minor adverse impacts.

Water quality impacts to Lake Michigan would be the same as those described for return flow to Underwood Creek: minor adverse impacts.

8.2.5.6 Return Flow—Direct to Lake Michigan

Return flow directly to Lake Michigan would have the same impacts to the Fox River as described for return flow to Underwood Creek.

Water quality impacts to Lake Michigan would be the same as those described for return flow to Underwood Creek: minor adverse impacts.

8.2.6 Wetlands

Please refer to Chapter 2.4.2 for detailed information on each of these alternatives.

8.2.6.1 Deep and Shallow Aquifers

Temporary construction-related impacts to wetlands are associated with all alternatives. Consequently, this summary focuses upon operational impacts to wetlands from this alternative that occur from aboveground structures and groundwater drawdown.

A total of 6.31 acres of wetlands could be impacted from operational impacts associated with aboveground structures. This alternative would have a moderate adverse impact on wetlands from aboveground structures.

The groundwater-pumping operation would reduce the groundwater level by 5 feet or more for nearly 1,000 wetland acres. A 1-foot or greater groundwater drawdown would occur for over 3,000 wetland acres. Because a wetland is designated by the type of plants, hydrology, and soil, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. The groundwater drawdown to wetlands from groundwater pumping would be a significant adverse impact.

8.2.6.2 Shallow Aquifer and Fox River Alluvium

Temporary construction-related impacts to wetlands are associated with all alternatives. Consequently, this summary focuses upon operational impacts to wetlands from this alternative that occur from aboveground structures and groundwater drawdown.

A total of 17.26 acres of wetlands could be impacted from operational impacts associated with aboveground structures. This alternative would have a significant adverse impact on wetlands from aboveground structures.

The groundwater pumping would reduce the groundwater level by 5 feet or more for nearly 2,000 wetland acres. A 1-foot or greater groundwater drawdown would occur for over 4,000 wetland acres. Because a wetland is designated by the type of plants, hydrology, and soil, groundwater drawdown in wetlands can reduce or eliminate the hydrology element required to sustain wetland conditions. The groundwater drawdown to wetlands from groundwater pumping would be a significant adverse impact.

8.2.6.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

Temporary construction-related impacts to wetlands are associated with all alternatives. Consequently, this summary focuses upon operational impacts to wetlands from this alternative that would occur from aboveground structures. There would be no operational impacts to wetlands from aboveground structures associated with these alternatives. These alternatives would have only minor adverse impacts to wetlands from temporary construction impacts.

8.2.6.4 Return Flow—Underwood Creek, Root River, or Direct to Lake Michigan

Temporary construction-related impacts to wetlands are associated with all alternatives. Consequently, this summary focuses upon operational impacts to wetlands from this alternative that would occur from aboveground structures. There would be no operational

impacts to wetlands from aboveground structures associated with these alternatives. These alternatives would have only minor adverse impacts to wetlands from temporary construction impacts.

8.2.7 Vegetation and Wildlife

Please refer to Chapters 3.2.3, 3.3.3, and 3.4.2 for detailed information on each of these alternatives. The City is currently coordinating with the WDNR to conduct a habitat assessment at locations along alternative infrastructure alignments in the summer of 2010. The information gained from the habitat assessment will be shared with the WDNR.

8.2.7.1 Deep and Shallow Aquifers

Temporary construction-related impacts to vegetation are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. The City will work closely with resource agencies to avoid, minimize, and mitigate impacts, if any, to threatened and endangered species. Consequently, this summary focuses upon operational impacts to vegetation and wildlife from this alternative that would occur from aboveground structures and groundwater drawdown.

The groundwater pumping operation reduces the groundwater level by 5 feet or more over 291 acres of the Vernon Wildlife Area (VWA). A 1-foot or greater groundwater drawdown over the VWA occurs for over 609 acres. This groundwater level drawdown could result in habitat type change in this specially regulated area. The groundwater drawdown to VWA regulated lands from groundwater pumping would be a significant adverse impact.

8.2.7.2 Shallow Aquifer and Fox River Alluvium

Temporary construction-related impacts to vegetation are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. The City will work closely with resource agencies to avoid, minimize, and mitigate impacts, if any, to threatened and endangered species. Consequently, this summary focuses upon operational impacts to vegetation and wildlife from this alternative that would occur from aboveground structures and groundwater drawdown.

The groundwater-pumping operation reduces the groundwater level by 5 feet or more over 343 acres of the VWA. A 1-foot or greater groundwater drawdown over the VWA would occur for over 1,106 acres. This groundwater level drawdown could result in habitat type change in this specially regulated area. The groundwater drawdown to VWA-regulated lands from groundwater pumping would be a significant adverse impact.

8.2.7.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

Temporary construction-related impacts to vegetation are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. The City will work closely with resource agencies to avoid, minimize, and mitigate impacts, if any, to threatened and endangered species. Consequently, this summary focuses upon

operational impacts to vegetation and wildlife from this alternative that would occur from aboveground structures.

There would be no operational impacts to wildlife areas with these alternatives. Consequently, there would be no adverse impact to vegetation and wildlife with these alternatives.

8.2.7.4 Return Flow—Underwood Creek, Root River, or Direct to Lake Michigan

Temporary construction-related impacts to vegetation are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. The City will work closely with resource agencies to avoid, minimize, and mitigate impacts, if any, to threatened and endangered species. Consequently, this summary focuses upon operational impacts to vegetation and wildlife from this alternative that would occur from aboveground structures.

There would be no operational impacts to wildlife areas with these alternatives. Consequently, there would be no adverse impact to vegetation and wildlife with these alternatives.

8.2.8 Cultural Resources

Please refer to Chapter 4.5 for detailed information on each of these alternatives.

Regardless of the alternatives selected, the City will meet regulatory requirements regarding cultural resources during the design and construction phases to prevent any significant impacts and mitigate impacts to known or potential NRHP sites. During operation, there would be no ground disturbance and thus no impacts to cultural resources. Consequently, no adverse impacts to cultural resources are expected.

Because there would be no adverse impacts to cultural resources for any alternative, Table 8-2 does not include cultural resources in the comparison summary.

8.2.9 Socioeconomics

Please refer to Chapters 5.2.2, 5.3.2, and 5.4.2 for detailed information on each of these alternatives.

Regardless of the alternatives selected, socioeconomic impacts would be similar for all alternatives. A draft socioeconomic study of SEWRPC's Regional Water Supply concludes that given similar costs and quantity, the source of water is not a differentiating factor in development, population, economics, or other socioeconomic attributes within a municipal service area. Consequently, since all alternatives are capable of delivering the projected water demand at similar costs, there would be no adverse impact differences with population or land use and the associated economic outcomes that depend upon these factors with any alternative.

Energy use would be less with a Lake Michigan water supply and return flow pipeline than what is expected with the two groundwater supplies.

Because there are no adverse socioeconomic impacts differentiating the alternative, Table 8-2 does not include socioeconomics in the comparison summary.

8.2.10 Soils

Please refer to Chapter 6.4 for detailed information on each of these alternatives.

8.2.10.1 Deep and Shallow Aquifers

Temporary construction-related impacts to soils are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. Consequently, this summary focuses upon operational impacts to soils from this alternative that would occur from aboveground structures.

The aboveground structures would affect prime farmland soils. Prime farmland soil is commonly found in the project vicinity. The drinking water treatment plant (WTP) proposed for this alternative would impact 33.20 acres, all of which are prime farmland soils. The 11 well houses proposed would impact approximately 38.41 acres, of which 30.96 acres, or 80.6 percent, are prime farmland soils. These impacts would be limited to soil types frequently found in the area and consequently would be minor adverse impacts.

8.2.10.2 Shallow Aquifer and Fox River Alluvium

Temporary construction-related impacts to soils are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. Consequently, this summary focuses upon operational impacts to soils from this alternative that would occur from aboveground structures.

The aboveground structures would affect prime farmland soils. Prime farmland soil is commonly found in the project vicinity. The WTP proposed for this alternative would impact approximately 14.74 acres, of which all is classified as prime farmland soils. The 15 well houses proposed for this alternative would impact approximately 51.26 acres, of which 50.62 acres, or 99 percent, are designated prime farmland soils. These impacts would be limited to soil types frequently found in the area and consequently would be minor adverse impacts.

8.2.10.3 Lake Michigan—Milwaukee Supply, Oak Creek Supply, or Racine Supply

Temporary construction-related impacts to soils are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. Consequently, this summary focuses upon operational impacts to soils from this alternative that would occur from aboveground structures.

There would be no significant aboveground structures with these alternatives and thus insignificant impacts to prime farmland. Consequently, there would be no adverse impacts with these alternatives.

8.2.10.4 Return Flow—Underwood Creek, Root River, or Direct to Lake Michigan

Temporary construction-related impacts to soils are associated with all alternatives. All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to vegetation and species of concern. Consequently, this summary focuses upon operational impacts to soils from this alternative that would occur from aboveground structures.

There would be no significant aboveground structures with these alternatives and thus insignificant impacts to prime farmland. Consequently, there would be no adverse impacts with these alternatives.

8.2.11 Land Use

Please refer to Chapters 7.3, 7.4, and 7.6 for detailed information on each of these alternatives.

All alternatives have selected pipeline routes that focus primarily upon areas that have been already developed or disturbed to minimize impacts to existing Public or Conservation Land and Natural, Recreational, or Scenic Areas. These pipeline routes would be disturbed only temporarily during construction. No alternative would have ongoing operational impacts to these resources. Consequently, all alternatives are similar and would have no adverse operational impacts to public or conservation land or to natural, recreational, or scenic areas.

TABLE 8-2
Water Supply and Return Flow Alternative Environmental Impact Comparison Summary
City of Waukesha Water Supply

Water Supply Alternative	Groundwater Resources	Flow and Geomorphology	Flooding	Aquatic Habitat	Water Quality	Wetlands	Vegetation and Wildlife Resources	Soils	Land Use
Water Supply Alternatives									
Deep and shallow aquifers	Significant adverse impact	No adverse impact	No adverse impact	Significant adverse impact	Minor adverse impact	Significant adverse impact	Significant adverse impact	Minor adverse impact	No adverse impact
Shallow aquifer and Fox River alluvium	Significant adverse impact	No adverse impact	No adverse impact	Significant adverse impact	Minor adverse impact	Significant adverse impact	Significant adverse impact	Minor adverse impact	No adverse impact
Lake Michigan – Milwaukee	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Lake Michigan – Oak Creek	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Lake Michigan – Racine	No adverse impact	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Return Flow Alternatives									
Underwood Creek	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Root River	No adverse impact	No adverse impact	No adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact
Direct to Lake Michigan	No adverse impact	Minor adverse impact	No adverse impact	Minor adverse impact	Minor adverse impact	Minor adverse impact	No adverse impact	No adverse impact	No adverse impact

8.3 Conclusion

The Deep and Shallow Aquifers and the Shallow Aquifer and Fox River Alluvium alternatives would have significant adverse environmental impacts to natural resources. The Lake Michigan water supply and return flow alternatives would have only minor adverse environmental impacts to natural resources. Lake Michigan is the preferred water supply alternative as a result.

Of the return flow alternatives, the Underwood Creek and Root River alternatives both would have minor adverse impacts in two categories, whereas the Lake Michigan alternative would have minor adverse impacts in four categories. The costs of the Underwood Creek and Root River alternatives were compared, and the Underwood Creek alternative is the preferred return flow alternative.

Once a water supplier and return flow location have been reviewed and approved, the City will work with the regulatory agencies during final design to conduct any necessary field surveys, location refinements, mitigation planning, and to obtain required permits.

Appendix O

Results of Groundwater Modeling Study Shallow Groundwater Source Fox River & Vernon Marsh Area Waukesha Water Utility

RESULTS OF GROUNDWATER MODELING STUDY
SHALLOW GROUNDWATER SOURCE
FOX RIVER & VERNON MARSH AREA
WAUKESHA WATER UTILITY

Prepared by RJN Environmental Services, LLC

April 2010

Objective

The Troy Bedrock Valley Aquifer Model ("model" – Southeastern Wisconsin Regional Planning Commission Memorandum Report Number 188) was utilized to simulate various shallow aquifer pumping scenarios for the Waukesha Water Utility. The objective of this work was to assess the potential impact to surface waters and wetlands, as well as private wells, of groundwater extraction from the sand and gravel aquifer in the vicinity of Vernon Marsh, Waukesha County, Wisconsin.

Model Description

The construction and calibration of the model was funded by the City of Muskego, the Villages of Mukwonago and East Troy, and the Waukesha Water Utility to be used as a tool for the development of new water resources in the Troy Bedrock Valley. The model is a three-dimensional finite difference model (MODFLOW – United States Geological Survey). It consists of five layers, simulating the unconfined, unconsolidated deposits in the Troy Bedrock Valley. This model was rigorously reviewed by experts at the Wisconsin Geological and Natural History Survey, and is therefore considered to accurately simulate the groundwater flow within the model domain.

MODFLOW consists of a series of mathematic "modules," with each simulating an aspect of groundwater flow. With respect to groundwater interaction with surface waters, two modules were used. "Drains" are features into which groundwater discharges. In the event that the simulated aquifer level drops below the user-selected elevation of a drain, the drain goes dry. "Rivers" are similar to drains except that they can discharge water to the aquifer if the aquifer level drops below the user-defined elevation of the river. Unlike drains, river cells do not go dry, and can therefore act as a source of water.

The model itself covers a large portion of Waukesha and Walworth Counties. The area of concern is the northern portion of Vernon Marsh, including reaches of the Fox River, Pebble Brook and Mill Brook, all located in the central area of the model. Consequently, simulated impacts of wells are not influenced by model boundary conditions. Surface waters of the model are simulated as rivers, and wetlands are simulated as drains. In the river option, surface waters can receive groundwater from the aquifer, or lose water to the aquifer. Drains can only receive water from the aquifer.

Additionally, the model used simulates steady-state conditions. That is, the model assumes that simulated wells are operating all the time, with the simulated flow rate being spread over a 24-hour period.

Typically, the most productive layer of the unconfined aquifer in the Troy Bedrock Valley is at the base of the unconsolidated deposits. Consequently, pumping wells were simulated in layers 4 and 5 of the model, which is consistent with the layers utilized by existing wells that were placed in the model during its construction.

Modeling Approach

For this work, two primary impacts were evaluated: A reduction in the baseflow to streams and wetlands, caused by the wells, and the number of private wells potentially impacted by the wells. Although private wells are not plotted, the figures show the number of private wells on record at the Wisconsin Department of Natural Resources in each Section. Baseflow reduction was estimated by calculating the changes in cell-to-cell flow, and relating that to the base run, in which no wells are simulated in this area.

Based on projected needs, two groups of scenarios were simulated. In the first, a total of 6.5 million gallons per day (MGD) were simulated from shallow wells, assuming that this water would be blended with 4.4 MGD from deep wells, for a total desired amount of 10.9 MGD. Two scenarios which are representative of the results of this group are presented.

Tables 1 and 2 summarize the wells simulated in each of the presented model runs, as well as the simulated pumping rates. Simulated well locations were based on various considerations. Wells 11, 12 and 13 are existing Waukesha Water Utility wells. The "Lather" wells are potential well locations that have already been located by Waukesha. "Troy" wells refer to potential wells in the Troy Bedrock Valley. These well locations were selected in an attempt to minimize the impacts to sensitive surface water features and private wells, and based on the potential availability of well sites.

Results

Figure 1 shows the drawdown simulated by Scenario 1-1. This scenario produced a maximum drawdown of 105 feet. This scenario places the stress directly in the area of the Fox River, resulting in a 240 percent reduction in baseflow (see Table 3), meaning that no groundwater is being discharged to the river in this area, and the aquifer is drawing a significant amount of water out of the river.

Scenario 1-2 spreads the stress in the areas of the Fox River and Pebble Brook. Figure 2 shows the simulated drawdown from this scenario. Although the maximum drawdown is significantly reduced in this scenario (50 feet), the reductions in baseflow are still high. As Table 3 shows, the baseflow reduction in the Fox River is still over 100 percent; however, the reduction in Pebble Brook is 61 percent. Because Pebble Brook is a trout stream, it is given special protections by Wisconsin water laws.

Two sets of results are also presented to represent the second group of scenarios, in which the projected daily need of 10.9 MGD is drawn entirely from the unconfined aquifer of the Troy Bedrock Valley. In the first scenario, the stress is again concentrated on the Fox River area. Figure 3 shows the simulated drawdown resulting from this model run. Although more wells are utilized in this run than in Scenario 1-1, the maximum drawdown is still 105 feet, with a baseflow reduction in the Fox River of 346 percent. Additionally, the flow reduction to Pebble Brook, which is some distance from the simulated wells, is 58 percent, and the marsh and Mill Brook are also significantly impacted.

Scenario 2-2 presents an extreme condition, in which stress is removed from the Fox River, and many wells are added. Most of the new wells were placed a distance from Pebble Brook (e.g., a mile or more), in an effort to reduce the impact to the brook, while at the same time minimize, to the extent possible, the significant well and distribution system costs. As Figure 4 shows, the maximum drawdown in this scenario is reduced to 55 feet; however, the reductions in baseflow are still very high. The aquifer continues to draw water from the Fox River, with a baseflow reduction of 156 percent. Reductions in baseflow to Pebble Brook and Mill Brook are 82 and 94 percent, respectively, and there is a 51 percent reduction to the sensitive environments of Vernon Marsh.

Summary

Numerous model runs were completed in an effort to develop a scenario by which the Waukesha Water Utility can obtain sufficient water from the unconfined aquifer of the Troy Bedrock Valley. Although this is a very productive aquifer, it is also the home to some very sensitive environmental features, such as the Vernon Marsh and Pebble Brook. Because the marsh relies a great deal on input from the Fox River, this stream is also an important environmental feature.

The first group of scenarios was run to consider the possibility of blending the water from the shallow aquifer with bedrock aquifer water, which is of a poorer quality. Not only did these scenarios reduce the baseflow of water to the Fox River, they actually showed the wells drawing water from the River. Although the direct baseflow reductions to the Vernon Marsh was relatively low (6 to 7 percent), the loss of surface water from the Fox River means that the impact to the marsh would be much greater than that.

The impacts from the second group of scenarios are much larger, even with the addition of numerous wells. The resulting reductions in baseflow to the Fox River range from 156 to 346 percent, compounding the simulated reduced baseflow to the Vernon Marsh of 17 to 51 percent. The reduction in flow to Pebble Brook is also significant, ranging from 58 to 82 percent.

Conclusions

Because the Fox River, Pebble Brook and Mill Brook converge on Vernon Marsh from the north and northeast, the groundwater discharge from the small area between these streams is split between them. Consequently, most of the base flow to this section of the Fox River comes from the west, while base flow to Pebble Brook and Mill Brook comes primarily from the east. As a result, even the placement of wells thousands of feet east of the Pebble Brook results in the interception of much of its baseflow.

Although by spreading the impact to the aquifer to more wells than were simulated in this effort, it may be possible to obtain acceptable baseflow reductions, it is clear from these analyses that many wells would be required, spaced over a very large area.

TABLES

TABLE 1
SIMULATED WELLS AND
PUMPING RATES
GROUP 1 - DEEP AND SHALLOW
WAUKESHA WATER UTILITY

WELL	PUMPING RATE (MGD)
SCENARIO 1-1	
11	0.6
12	0.6
13	1.1
Lather 1	0.82
Lather 2	0.82
Lather 3	0.82
Lather 4	0.82
Lather 5	0.82
Total	**6.4**
SCENARIO 1-2	
11	0.376
12	0.376
13	0.376
Lather 1	0.376
Lather 2	0.376
Lather 3	0.376
Lather 4	0.376
Lather 5	0.376
Troy 1	0.376
Troy 2	0.376
Troy 3	0.376
Troy 4	0.376
Troy 5	0.376
Troy 6	0.376
Troy 7	0.376
Troy 8	0.376
Troy 9	0.376
Total	**6.4**

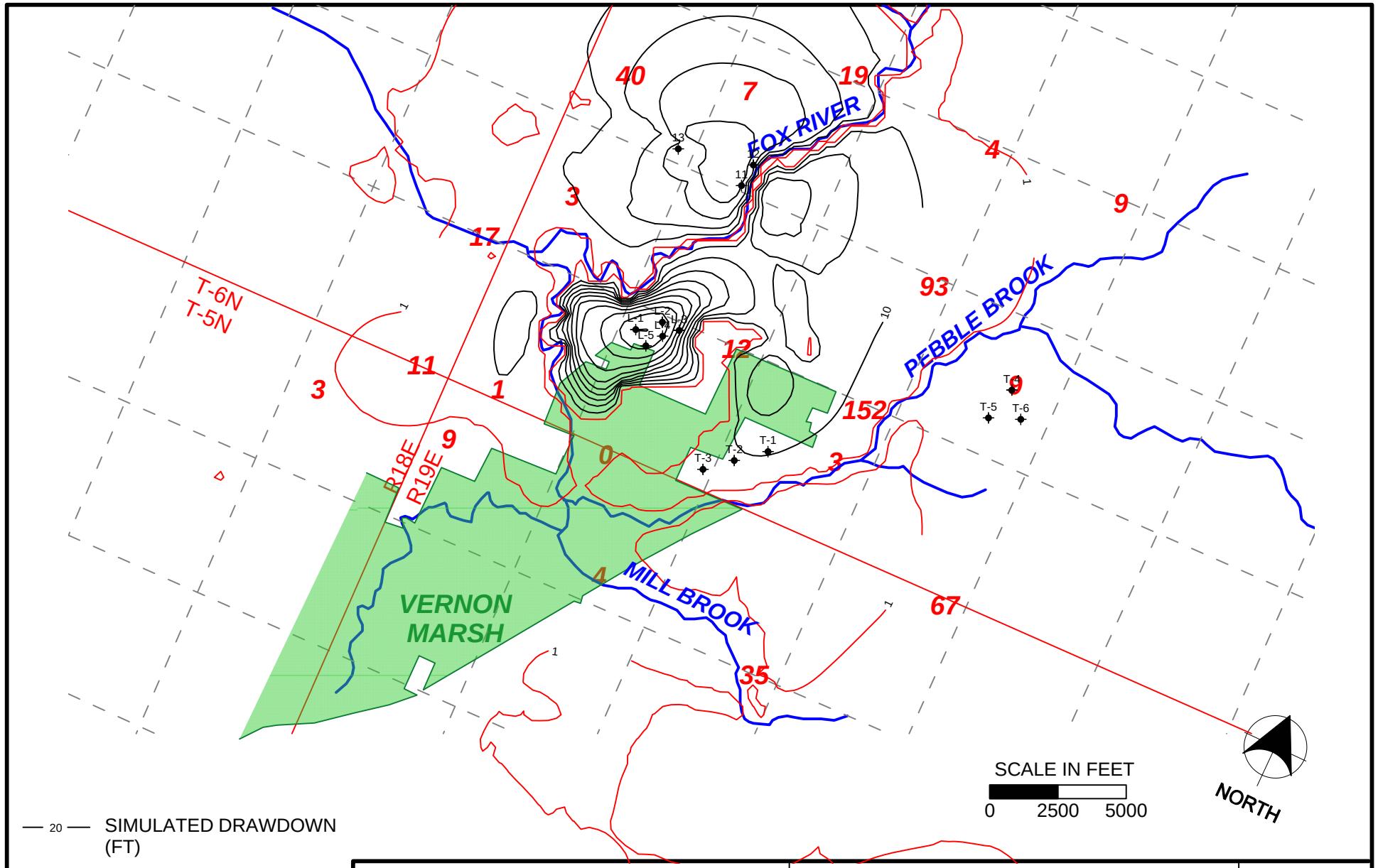
TABLE 2
SIMULATED WELLS AND
PUMPING RATES
GROUP2 - SHALLOW WELLS
WAUKESHA WATER UTILITY

WELL	PUMPING RATE (MGD)
SCENARIO 2-1	
11	0.6
13	0.6
Lather 1	1
Lather 3	1
Lather 5	1
Troy 2	0.55
Troy 3	0.55
Troy 5	0.55
Troy 6	0.55
Fox 1	1.5
Fox 3	1.5
Fox 4	1.5
TOTAL	**10.9**
SCENARIO 2-2	
11	0.389
12	0.389
13	0.389
Lather 1	0.389
Lather 2	0.389
Lather 3	0.389
Lather 4	0.389
Lather 5	0.389
Troy 1	0.389
Troy 2	0.389
Troy 3	0.389
Troy 4	0.389
Troy 5	0.389
Troy 6	0.389
Troy 7	0.389
Troy 8	0.389
Troy 9	0.389
Troy 10	0.389
Troy 11	0.389
Troy 12	0.389
Troy 13	0.389
Troy 14	0.389
Troy 15	0.389
Troy 16	0.389
Troy 17	0.389
Troy 18	0.389
Troy 19	0.389
Troy 20	0.389
Total:	**10.9**

TABLE 3
WAUKESHA WATER UTILITY
SUMMARY OF FLOWS

RESOURCE	BASEFLOWS								
	BASE SCENARIO	SCENARIO 1-1		SCENARIO 1-2		SCENARIO 2-1		SCENARIO 2-2	
	GPD	GPD	PERCENT REDUCTION	GPD	PERCENT REDUCTION	GPD	PERCENT REDUCTION	GPD	PERCENT REDUCTION
FOX RIVER	1,702,810	-2,384,868	240	-716,304	142	-4,188,052	346	-960,338	156
PEBBLE BROOK	3,399,693	2,969,633	13	1,328,516	61	1,443,515	58	617,102	82
VERNON MARSH	2,817,027	2,660,343	6	2,633,676	7	2,326,537	17	1,373,475	51
MILL BROOK	687,910	615,123	11	488,956	29	483,495	30	42,239	94
PEBBLE CREEK	553,948	440,009	21	503,946	9	424,346	23	501,104	10

FIGURES

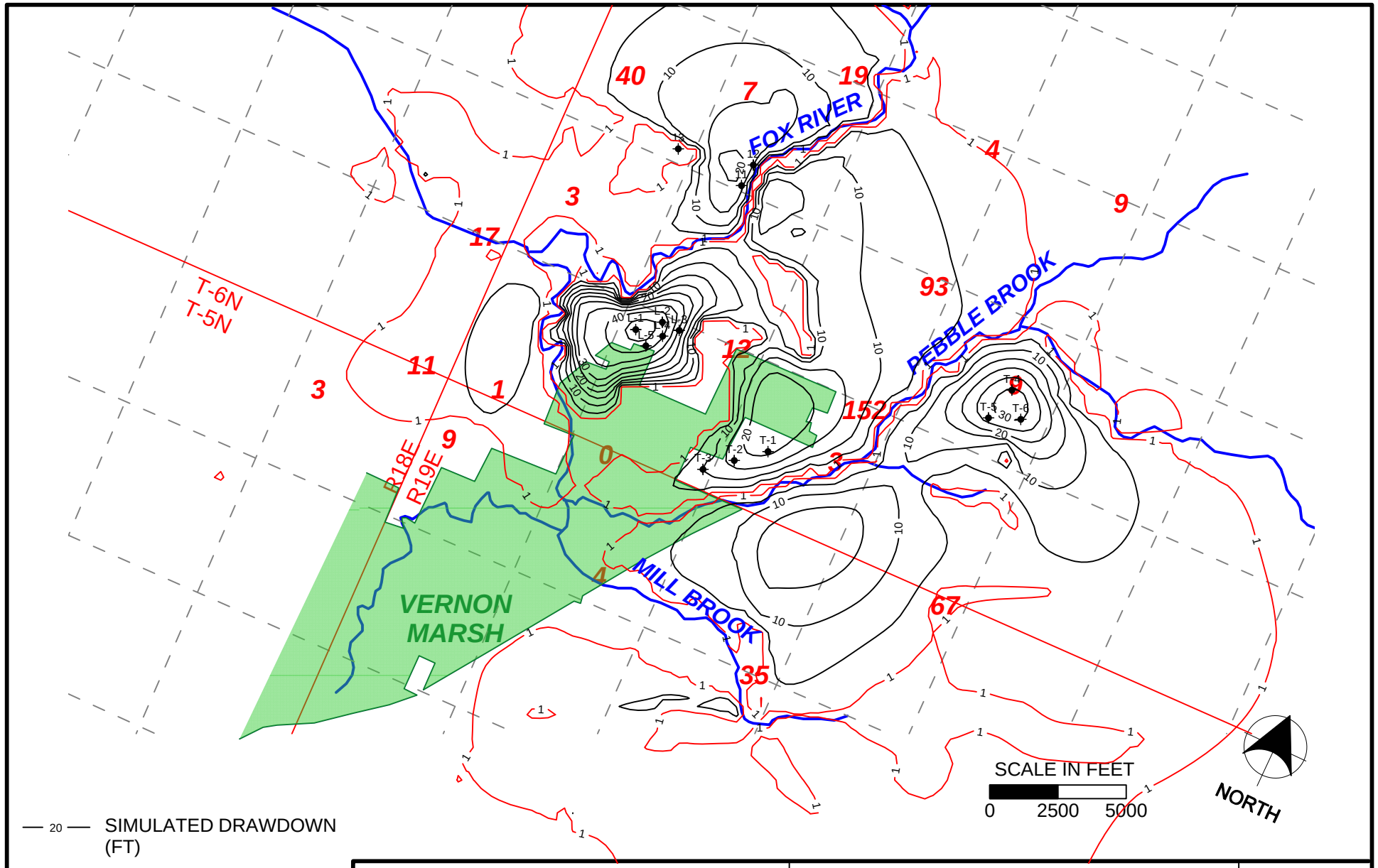


RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations
4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

CITY OF WAUKESHA
WAUKESHA, WISCONSIN
DRAWDOWN
SCENARIO 1-1

FIGURE 1

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	24 MAR 10	RUN 1-2 DDN



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Site Investigations
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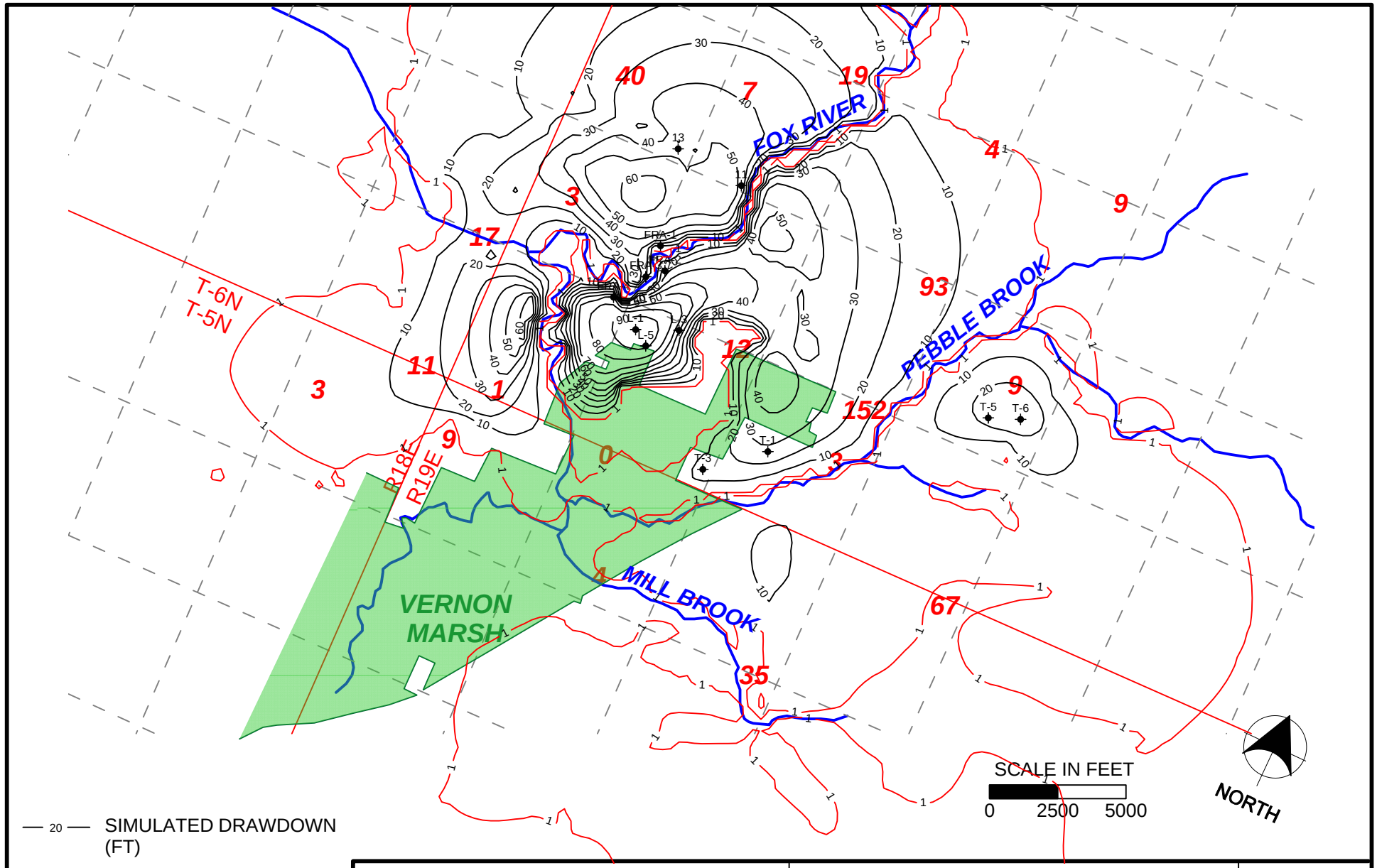
CITY OF WAUKESHA
WAUKESHA, WISCONSIN
DRAWDOWN
SCENARIO 1-2

FIGURE 2

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	24 MAR 10	RUN 1-2 DDN

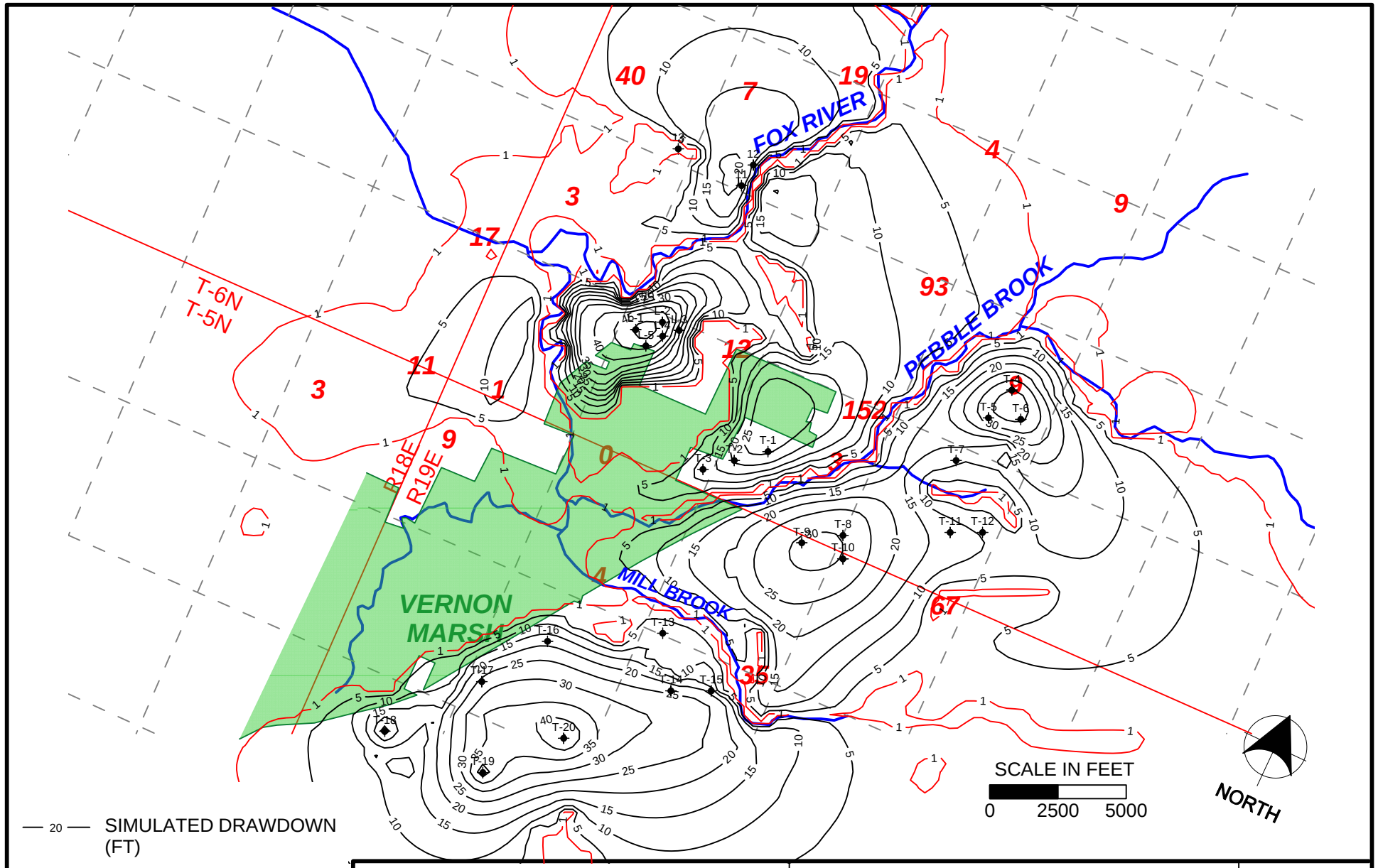


RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations
4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

CITY OF WAUKESHA
WAUKESHA, WISCONSIN
DRAWDOWN
SCENARIO 2-1

FIGURE 3

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	24 MAR 10	RUN 2-1 DDN



— 20 — SIMULATED DRAWDOWN (FT)

1-FOOT DRAWDOWN

SIMULATED NEW WELL

35 NUMBER OF PRIVATE WELLS IN SECTION

RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations
4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

CITY OF WAUKESHA
WAUKESHA, WISCONSIN
DRAWDOWN
SCENARIO 2-2

FIGURE 4

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	24 MAR 10	RUN 2-2 DDN

Appendix P

Potential Lake Michigan Water Suppliers Letters of Interest

Racine Water and Wastewater Utilities

Keith E. Haas, P.E.
General Manager

City of Racine, Wisconsin

Michael L. Gitter, P.E.
Chief of Operations

Charles A. Schweitzer, P.E.
Chief Engineer

Kenneth M. Scolaro, C.P.A.
Administrative Manager

October 28, 2009

Mayor Larry Nelson
City of Waukesha
201 Delafield Street
Waukesha, WI 53188-3615

Dear Mayor Nelson:

We understand that the City of Waukesha is considering an application for Lake Michigan water in accordance with provisions of the Great Lakes Compact. We further understand that the application to use and return the water may be filed in the near future. As part of that permitting process, s. 281.346(4)(b)4m, Wis. Stats., requires an applicant to provide letters or resolutions from potential water suppliers as evidence of their support for meeting the water supply needs of the City of Waukesha.

Please consider this communication to indicate the support of the City of Racine and its water utility for negotiations with the City of Waukesha for the potential sale of Lake Michigan water to meet your water supply needs.

The Racine Water Utility currently has sufficient capacity to meet the 20-year projections of the needs of the Waukesha Water Utility of 9.1 mgd in 2028 and a maximum day of 15.28 mgd. We do not anticipate that supplying the Waukesha Water Utility with water would cause Racine to exceed its 60 mgd baseline over the next 20 years.

The types of improvements that would be required would include a pipeline and booster station between Racine and Waukesha. It is anticipated that the costs of such improvements would be paid for by Waukesha. Operations and maintenance costs to the point of transfer of ownership would be as assigned by the Public Service Commission in accordance with laws and guidelines in the state of Wisconsin for wholesale water customers through rate-making policy.

We understand that this letter does not commit the City of Racine or its water utility to spend any of its money on studies or design alternatives to facilitate any negotiations that may occur in the future. We also understand that this letter does not commit the City of Racine to a water sale but indicates a willingness to negotiate on a potential sale.

Sincerely,

Keith E. Haas, P.E.
General Manager

c: D. Duchniak

800 Center Street, Room 227 Racine, Wisconsin 53403 262-636-9181 (Phone) 262-636-9933 (Fax)

OAK CREEK
WATER and SEWER UTILITY
170 West Drexel Avenue, Oak Creek, WI 53154
(414) 570-8210
Fax: (414) 570-8215

December 3, 2009

Mayor Larry Nelson
City of Waukesha
201 Delafield Street
Waukesha, WI 53188-3615

Dear Mayor Nelson:

We understand that the City of Waukesha is considering an application for Lake Michigan water in accordance with provisions of the Great Lakes Compact. We further understand that the application to use and return the water may be filed in the near future. As part of that permitting process, s. 281.346(4)(b)4m, Wis. Stats., requires an applicant to provide letters or resolutions from potential water suppliers as evidence of their support for meeting the water supply needs of the City of Waukesha.

Please consider this communication to indicate the support of the City of Oak Creek for negotiations with the City of Waukesha for the potential sale of Lake Michigan water to meet your water supply needs.

The available expansion capability of the Oak Creek treatment plant would have sufficient capacity to meet Waukesha Water Utility's 20-year projections of approximately 15 million gallons per day. We anticipate that supplying Waukesha Water Utility with water would cause the Oak Creek treatment plant to exceed its baseline between 2015 and 2020. Any costs for additional Great Lakes Compact compliance requirements, related to exceeding our baseline, are anticipated to be paid by Waukesha.

The types of improvements that would be required would include one additional flocculation/sedimentation basin, four filters, and a transmission main and booster station between Oak Creek and Waukesha. It is anticipated that the costs of such improvements would be paid for by Waukesha funding the initial project costs, or through wholesale rates that provide Oak Creek with adequate debt service for these improvements. Operations and maintenance costs to the point of transfer of ownership would be determined by a cost-of-service study approved by the Public Service Commission of Wisconsin.

We understand that this letter does not commit the City of Oak Creek or its water utility to spend any of its money on studies or design alternatives to facilitate any negotiations that may occur in the future. We also understand that this letter does not commit the City of Oak Creek to a water sale but indicates a willingness to negotiate on a potential sale.

Sincerely,

Steven N. Yttri, CPA
General Manager

cc: Daniel Duchniak

City of Milwaukee

Department of Public Works
Milwaukee Water Works

Jeffrey J. Mantes
Commissioner of Public Works

Preston D. Cole
Director of Operations

Carrie M. Lewis
Superintendent of Water Works

January 6, 2010

Honorable Larry Nelson, Mayor
City of Waukesha
City Hall - 201 Delafield Street
Waukesha, WI 53188

Dear Mayor Nelson:

We understand that the City of Waukesha is contemplating the submission of an application for Great Lakes water to the appropriate authorities. We further understand that as part of that application, you require expressions of interest from potential suppliers of that water.

Please be advised that pursuant to Common Council resolution #091017 (copy enclosed) adopted on December 22, 2009, the City of Milwaukee is willing to consider providing treated drinking water through our water utility to any community, including the City of Waukesha, that complies with all applicable local, state, national and international laws, regulations and compacts; has secured all required approvals; and which satisfies the requirements set forth in City of Milwaukee Resolution # 080457, which establishes the process by which the City of Milwaukee may provide drinking water to neighboring communities.

In addition, with respect to requests to provide Lake Michigan drinking water outside the Great Lakes Basin, the City of Milwaukee expects the City of Waukesha to present a detailed return flow plan to all affected communities prior to negotiations with the City of Milwaukee.

Very truly yours,

CLewis

Carrie Lewis, Superintendent
Milwaukee Water Works

CL: pa
Doc: Waukesha letter of intent language_100106

C: Mayor Tom Barrett
Ald. R. Bauman, W. Hines, W. Wade, M. Murphy

City of Milwaukee

Office of the City Clerk

200 E. Wells Street
Milwaukee, Wisconsin 53202

Certified Copy of Resolution

FILE NO: 091017

Title:
Substitute resolution expressing the City of Milwaukee's interest in exploring the potential sale of water to the City of Waukesha.

Body:
Whereas, The City of Waukesha is preparing its application for the Wisconsin Department of Natural Resources ("DNR") as a first, formal step in its petition for such a water diversion; and

Whereas, Section 281.346(4)(b)4m Wis., Stats., and the Wisconsin DNR indicate the City of Waukesha's DNR application must include letters or resolutions from possible water suppliers expressing the willingness of such suppliers to sell water to the City of Waukesha, under terms to be negotiated and mutually agreed upon at such time the City of Waukesha's application for a Lake Michigan water diversion is approved; and

Whereas, Resolution file #080457, adopted by the Milwaukee Common Council on July 30, 2008, establishes the process by which the City of Milwaukee may provide drinking water to neighboring communities; now, therefore, be it

Resolved, By the Common Council of the City of Milwaukee, that the Superintendent of Milwaukee Water Works is directed to issue a letter to the City of Waukesha that complies in form and substance to Exhibit A attached hereto and incorporated herein.

I, Ronald D. Leonhardt, City Clerk, do hereby certify that the foregoing is a true and correct copy of a(n) Resolution Passed by the COMMON COUNCIL of the City of Milwaukee, Wisconsin on December 22, 2009.

Ronald D. Leonhardt

Ronald D. Leonhardt

January 06, 2010

Date Certified

Resolution File #091017
Revised Exhibit A

Honorable Larry Nelson
Mayor
City of Waukesha
City Hall
201 Delafield Street
Waukesha, WI 53188

Dear Mayor Nelson,

We understand that the City of Waukesha is contemplating the submission of an application for Great Lakes water to the appropriate authorities. We further understand that as part of that application, you require expressions of interest from potential suppliers of that water.

Please be advised that pursuant to Common Council resolution #091017 adopted on _____, the City of Milwaukee is willing to consider providing treated drinking water through our water utility to any community, including the City of Waukesha, that complies with all applicable local, state, national and international laws, regulations and compacts; has secured all required approvals; and which satisfies the requirements set forth in City of Milwaukee Resolution #080457, which establishes the process by which the City of Milwaukee may provide drinking water to neighboring communities.

In addition, with respect to requests to provide Lake Michigan drinking water outside the Great Lakes Basin, the City of Milwaukee expects the City of Waukesha to present a detailed return flow plan to all affected communities prior to negotiations with the City of Milwaukee.

Very truly yours,