VOLUME 4 OF 5

City of Waukesha Return Flow Plan

OCTOBER 2013



Volume 4 of 5

City of Waukesha Return Flow Plan

Prepared for

City of Waukesha

October 2013

CH2MHILL®

Executive Summary

The return of water to the Lake Michigan basin after use is an important requirement of the Great Lakes–St. Lawrence River Basin Water Resources Compact and Wisconsin Statute (Wis. Stat. § 281.346) for obtaining a Lake Michigan water supply. In support of *The City of Waukesha Application for Lake Michigan Diversion with Return Flow*, alternatives for managing the return flow volume and the return flow location have been evaluated.

Return Flow Management

Compact Article 4, Section 4.9(4)c and Wis. Stat. §281.346(4)(f)3 require that the return flow be in an amount equal to the water demand—the amount of water withdrawn from Lake Michigan—less consumptive use. They do not have explicit requirements for the return flow timing or balancing of the requirement to maximize basin water and minimize out-of-basin water in return flow. Because there are no specific requirements, the City considered five alternatives for *managing* return flow:

- Alternative 1—Return all flow from the WWTP to the Lake Michigan basin.
- Alternative 2—Return flow from the WWTP with a maximum return flow rate up to 115 percent of average day water demand, and temporarily pause return flow when Lake Michigan receiving tributary exceeds 2-year return period flow.
- Alternative 3—Return flow from the WWTP with a maximum return flow rate up to the maximum day water demand, and reduce maximum return flow rate to average day water demand when Lake Michigan receiving tributary exceeds 2-year return period flow.
- Alternative 4—Return flow from the WWTP with a maximum return flow rate up to the previous day water demand.
- Alternative 5—Return flow from the WWTP with a maximum return flow rate up to the maximum day demand.

The City selects the Alternative 5 because it is protective of the water and water-dependent natural resources of the Lake Michigan basin and it will return no less than 100 percent of the volume of the water withdrawn, ensuring that the withdrawal and return flow will not affect lake levels.

Return Flow Location

The City evaluated several alternatives for the *location* where water withdrawn from Lake Michigan could be returned. The alternatives were evaluated based on their public health and safety, short- and long-term environmental impacts, ability to implement, and cost. The alternatives include abandoning the City's wastewater treatment plant (WWTP) and conveying return flow to the Milwaukee Metropolitan Sewerage District (MMSD), and maintaining the City's WWTP with return flow to a Lake Michigan tributary or directly to Lake Michigan. Four alternatives investigated in this Return Flow Plan include return flow to MMSD, two include return flow to Lake Michigan tributaries, and two include return flow directly to Lake Michigan.

Return flow to the Root River, which is tributary to Lake Michigan, is the preferred return flow *location*. The return flow to the Root River, together with the management plan, set a high standard and precedent for obtaining Lake Michigan water for the following reasons:

- The location on the Root River where return flow is proposed is well suited for the flow because it has similar watershed properties and is of similar size as that of the Fox River, where the City's WWTP has discharged since 1890.
- The Root River has greatest environmental benefit to the Lake Michigan tributary, Lake Michigan's ecosystem and water-dependent natural resources.
- The return flow management plan will go beyond the requirements of Compact Article 4, Section 4.9(4)c and Wis. Stat. §281.346(4)(f)3 because it returns no less than 100 percent of the water volume withdrawn. The

return flow will minimize the volume of out-of-basin water and it will not impact the water level of Lake Michigan. As a result, there will be no individual or cumulative impacts to the quantity of the waters or water-dependent natural resources of the Lake Michigan basin.

- Return flow to the Root River will environmentally benefit the fisheries in the Root River and Great Lakes because the additional flow will allow more fish to reach the Root River Steelhead Facility for egg collection and spawning. As a result, return flow to the Root River will contribute to protecting, sustaining, and improving the biological integrity of the Root River and Lake Michigan.
- The Root River return flow and flow augmentation will increase fishing opportunities in the Root River and support Wisconsin's fishing economy—$2.75 billion economic impact, 30,000 jobs, and $196 million in local and state tax revenue that fishing provided in 2009. Increased fishing opportunities will also support the 3.7 million days that Wisconsin anglers spent fishing the Great Lakes.
- Return flow to the Root River will protect water quality because the flow will meet all state and federal water quality limits. For some parameters such as phosphorus, the return flow to the Root River will improve water quality in the river, because the return flow water quality will be better than that of the river. Return flow water quality will also have limits more strict than those imposed on other Lake Michigan direct or tributary dischargers in the area. As a result, return flow will have no significant adverse individual or cumulative impacts on the quality of the waters and water-dependent natural resources of the Great Lakes basin. Returning flow though the Root River will protect, sustain, and for some parameters, improve the chemical integrity of the Root River.
- Return flow through the Root River will not introduce invasive species or VHS (viral hemorrhagic septicemia) from the Mississippi Basin to the Lake Michigan basin, because return flow will receive full treatment at the City's WWTP before being pumped to the River.
- There will be no risk of overflows or opportunities for partially treated or untreated wastewater in return flow because the water will be fully treated at the City's WWTP before being pumped to the Root River.
- The physical integrity of the Root River will be protected and sustained because return flow is small compared to flow rates experienced by the river (maximum return flow rate is less than 2.5 percent of the 2-year return period river flow and less than 0.6 percent of the 100-year return period river flow). A recent study concluded that the Root River 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.
- Compared to the other return flow alternatives considered implementable, return flow to the Root River has the least adverse environmental and construction impacts because the pipeline alignment follows a corridor that has been previously disturbed for roadway development.
- Return flow to the Root River returns the withdrawn water to the source watershed, near the place where it is withdrawn, as required by Wis. Stat. § 281.346(4)(f)3m.
- Compared to the other implementable return flow alternatives, return flow to the Root River is the least costly.

Contents

Executive Summary iii

Acronyms and Abbreviations ix

1. Introduction 1

2. Return Flow Management Plan 1
2.1 Return Flow Management Plan Alternatives 2
2.2 Return Flow Effects on Lake Levels 7
2.3 Minimizing Out-of-Basin Water in Return Flow 7

3. Return Flow Location Alternatives 8
3.1 Return Flow to Underwood Creek 9
3.1.1 Environmental Resources 10
3.1.2 Flow, Geomorphology, and Habitat 11
3.1.3 Fisheries 13
3.1.4 Flooding 14
3.1.5 Return Flow Water Quality 15
3.1.6 Underwood Creek and Menomonee River Water Quality 17
3.1.7 Return Flow Water Quality Modeling 18
3.1.8 Cost Estimate 19
3.2 Return Flow to the Root River 19
3.2.1 Environmental Resources 21
3.2.2 Flow, Geomorphology, and Habitat 22
3.2.3 Flow Augmentation 24
3.2.4 Fisheries 26
3.2.5 Flooding 26
3.2.6 Return Flow Water Quality 26
3.2.7 Root River Water Quality 27
3.2.8 Return Flow Water Quality Modeling 28
3.2.9 Cost Estimate 28
3.3 Return Flow Directly to Lake Michigan near Milwaukee and Oak Creek 28
3.3.1 Environmental Resources 29
3.3.2 Flow, Geomorphology, and Habitat 30
3.3.3 Fisheries 30
3.3.4 Flooding 30
3.3.5 Water Quality 30
3.3.6 Cost Estimate 30
3.4 Return Flow Directly to Lake Michigan near Racine 31
3.4.1 Environmental Resources 31
3.4.2 Flow, Geomorphology, and Habitat 32
3.4.3 Fisheries 32
3.4.4 Flooding 32
3.4.5 Water Quality 32
3.4.6 Cost Estimate 33
3.5 Return Flow through the Milwaukee Metropolitan Sewerage District 33
3.5.1 MMSD Alternative 1 33
3.5.2 MMSD Alternative 2 35
3.5.3 MMSD Alternative 3 36

3.5.4 Cost Estimate 36

4. Invasive Species Prevention 37

5. Preferred Return Flow Alternative 38
5.1 Return Flow Management 38
5.2 Return Flow Location 38

6. References 40

Appendixes

A Facility Plan Amendment—City of Waukesha Wastewater Treatment Plant Improvements for Returning Water Withdrawn from Lake Michigan
B City of Brookfield Co-applicant Letter for an Underwood Creek Return Flow Outfall Structure
C Technical Memorandum: Underwood Creek Effluent Return Evaluation, July 23, 2009
D Return Flow Effects on Habitat and Fisheries in Underwood Creek, Menomonee River, and Fox River
E Root River, Underwood Creek, and Fox River Flow Rates with Return Flow in Years 2005 and 2008
F Diurnal Return Flow Effects on Root River and Underwood Creek Flow Rates
G Return Flow Effects on Root River, Underwood Creek, and Fox River Flashiness Index
H Water Quality Model of Proposed Discharge to Underwood Creek
I Return Flow Plan Cost Estimates
J Option to Purchase for Root River Return Flow
K Return Flow Effects on Hydraulic Conditions within the Root River from a City of Waukesha Lake Michigan Water Supply
L Wisconsin Department of Natural Resources: Water Return to Root River from Waukesha
M Water Quality Model of Potential Return Flow Discharge to Root River

Exhibits

1 Flow Diagram of the City of Waukesha WWTP 2
2 Comparison of Future Water Demand and Waukesha Wastewater Treatment Plant Design Flow Rates 2
3 Summary of Return Flow Management Plan Alternatives 3
4 Estimated Annual Water Withdrawal and Return Flow Water Balances Between 2005-2012 for Return Flow Management Plan Alternatives 5
5 Flow Diagram of the City of Waukesha WWTP with Return Flow to Lake Michigan 6
6 Flow Chart of the Return Flow Operation 6
7 Water Supply and WWTP Flow Rates for 2012 7
8 Return Flow Pipeline Alignment to Underwood Creek 10
9 Potential Environmental Impacts for an Underwood Creek Return Flow Pipeline 10
10 Underwood Creek Near Proposed Return Flow Location 11
11 Rehabilitated Segment of Underwood Creek Downstream of Proposed Return Flow Location 11
12 City of Waukesha WWTP WPDES Effluent Permit Limits 15
13 Comparison of WDNR-Proposed WPDES Limits to Historical WWTP Performance and Other Direct and Tributary Lake Michigan Municipal Dischargers 16
14 Screening Level Cost Estimate for Return Flow to Underwood Creek 19
15 Root River Near Return Flow Location 20
16 Return Flow Pipeline Alignment to the Root River 21
17 Potential Environmental Impacts for a Root River Return Flow 22
18 The Root River Steelhead Facility Has an Important Role in Sustaining a Healthy Fishery in Lake Michigan 25
19 The Root River Flow Is Lowest When Egg Collection and Spawning Occur at the Root River Facility 25
20 Screening Level Cost Estimate for Return Flow to the Root River 28
21 Return Flow Pipeline Alignment Direct to Lake Michigan near Milwaukee and Oak Creek 29

22 Summary of Potential Environmental Impacts for Return Flow Direct to Lake Michigan near Milwaukee and Oak Creek....29
23 Screening Level Cost Estimate for Return Flow to Lake Michigan near Milwaukee and Oak Creek....30
24 Return Flow Pipeline Alignment Direct to Lake Michigan near Racine....31
25 Summary of Potential Environmental Impacts for Return Flow Direct to Lake Michigan near Racine....32
26 Screening Level Cost Estimate for Return Flow Direct to Lake Michigan near Racine....33
27 Alternatives for Return Flow to MMSD....34
28 MMSD Alternative 1: MMSD Return Flow Alignment to South Shore....34
29 MMSD Alternative 1: MMSD Return Flow Alignment to South Shore....35
30 MMSD Alternative 2: MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station....35
31 MMSD Alternative 2: MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station....36
32 MMSD Alternative 3: Pipeline and Biological High Rate Treatment at South Shore....36
33 Screening Level Cost Estimates for Return Flow Alternatives to MMSD....37
34 Summary of Potential Environmental Impacts for the Return Flow Pipeline Alignment Alternatives....38
35 Cost Comparison for Return Flow Alternatives....39

Acronyms and Abbreviations

cfs	cubic feet per second
CMOM	capacity, management, operation, and maintenance
I/I	infiltration and inflow
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
mL	milliliter
MMSD	Milwaukee Metropolitan Sewerage District
O&M	operation and maintenance
SEWRPC	Southeastern Wisconsin Regional Planning Commission
TMDL	total maximum daily load
USEPA	U.S. Environmental Protection Agency
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System
WWTP	wastewater treatment plant

1. Introduction

In support of The City of Waukesha Application for Lake Michigan Diversion with Return Flow, return flow alternatives were evaluated based on their public health and safety, short and long-term environmental impacts, ability to implement, and cost. This report documents the return flow alternatives evaluation and operational plan for returning water to Lake Michigan with a Lake Michigan water supply. It also summarizes impacts to the Fox River within the Mississippi watershed, because the City's existing WWTP discharge to the Fox River will be reduced by the amount of water returned to Lake Michigan.

The City has evaluated multiple water supply alternatives to secure a sustainable and 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 faces a declining groundwater supply and water quality conditions that do not meet regulatory requirements for radium and gross alpha. The City is under a consent order to bring its water into compliance with radium and gross alpha requirements by June 30, 2018. The City has evaluated various water supply alternatives consisting of groundwater and surface water sources in the Mississippi River and Lake Michigan basins (refer to Volume 2, City of Waukesha Water Supply Service Area Plan). After studying this issue for more than a decade, the City has determined that the only reasonable alternative is a Lake Michigan water supply. The Great Lakes–St. Lawrence River Basin Water Resources Compact and Wisconsin Statute (Wis. Stat. § 281.346) regulate Lake Michigan as a water supply diversion for the City and require flow to be returned to the Lake Michigan basin ("return flow").

The Compact and Wis. Stat. § 281.346 have similar minimum requirements for returning flow but the state statute is more strict than the Compact. For example Wis. Stat. § 281.346(4)(f)3m 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 (a) not economically feasible, (b) not environmentally sound, or (c) not in the interest of public health. The Compact does not contain a comparable requirement. Throughout this document, the Compact and Wisconsin Statute requirements are summarized and each return flow alternative is evaluated against them. As discussed below, the return flow will meet each of the Compact and Wisconsin Statute requirements.

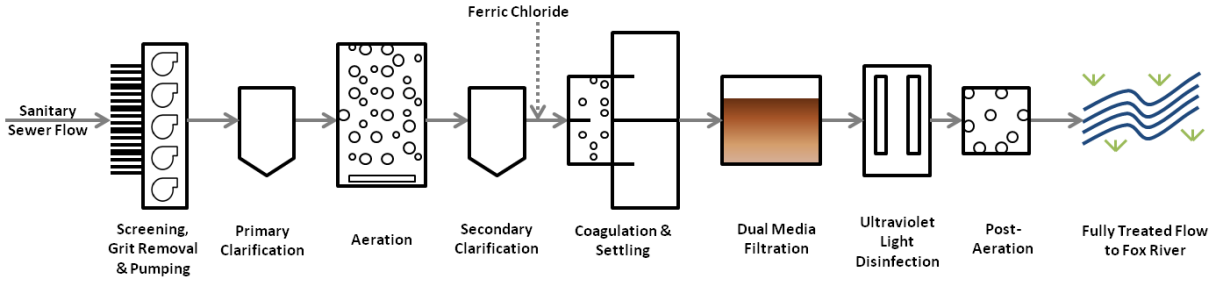
2. Return Flow Management Plan

The City will meet the requirements of Compact Article 4, Section 4.9(4)c and Wis. Stat. §281.346(4)(f)3 to return the volume of water withdrawn from Lake Michigan, less an allowance for consumptive use. In fact, the City proposes to exceed the requirements by returning no less than 100 percent of the volume withdrawn, providing a precedent of no negative impact on Great Lakes water levels.

The City has a separate sanitary sewer system that conveys wastewater from its service area. There are no combined storm and sanitary sewers in the City or its sewer service area. All of the sewers within the sewer service area and that are connected to the wastewater treatment plant (WWTP) are separate sanitary sewers. The WWTP is an advanced facility with primary, secondary, and tertiary treatment (dual media sand filters), and ultraviolet light disinfection processes (Exhibit 1). Few treatment plants in Wisconsin have effluent filtration, but the City installed these in 1982 and expanded their capacity in 1995.

The WWTP produces high quality water that currently flows to the Fox River, in the Mississippi watershed, but when the City switches its water supply to Lake Michigan, the WWTP will return fully treated water to the Lake Michigan basin. The City will continue to use the treatment facility and maintain or increase its high-quality treatment standards for future return flow. The return flow to Lake Michigan will have very similar permit limits as the WWTP flow to the Fox River according to the Wisconsin Department of Natural Resources (WDNR, 2011b; also included within Appendix A). Therefore, treatment process improvements specific for return flow are not anticipated but a pump station and pipeline to return the water will be constructed. The return flow will be conveyed from the WWTP after it receives full treatment and meets all state and federal permit limits. There will be no risk of overflows or opportunities for partially treated or untreated wastewater in return flow because the water will be fully treated at the City's WWTP before being returned to Lake Michigan.

EXHIBIT 1
Flow Diagram of the City of Waukesha WWTP



The average annual and maximum monthly flow from the WWTP is greater than that of the future water demand discussed in the Application Volume 2, City of Waukesha Water Supply Service Area Plan (Exhibit 2). Part of the flow difference is attributable to the fact that the City serves a few wastewater-only customers (57 accounts between 2007 and 2010) in its service area that contribute wastewater to the WWTP but do not receive water service. Between 2007 and 2010 the average flow from the wastewater-only customers ranged from 0.01 to 0.06 million gallons per day (mgd), or between 1.4 and 1.6 percent of the WWTP flow (Appendix A). The balance of the flow difference is due to infiltration and inflow (I/I) in the collection system. As in all communities with sanitary sewer collection systems, I/I occurs during wet periods and storms. I/I contributes to the collection system flows during these times and subsequently receives the same treatment as wastewater at the WWTP. The average dry and wet weather I/I flow in the City's collection system is not excessive based on guidance from the U.S. Environmental Protection Agency (USEPA) (Strand Associates, 05/2011, page 2-2), but the City is aggressively pursuing I/I reductions as discussed in Section 2.3. As a demonstration of the City's commitment to I/I reduction, the future flow rates used by the WWTP for facility planning and design are reduced by 14 to 34 percent from current criteria (Strand Associates, 05/2011, page 4-6).

EXHIBIT 2
Comparison of Future Water Demand and Waukesha Wastewater Treatment Plant Design Flow Rates

Flow	WWTP Design Criteria (mgd)[a]	Water Demand (mgd)
Average annual	11.7	10.1
Maximum day	26.2	16.7

[a]Strand Associates, Inc. 2011. City of Waukesha Wastewater Treatment Plant Facility Plan. Page 4-6. Addendum No. 1, October 5, 2012.

2.1 Return Flow Management Plan Alternatives

The Compact Article 4, Sections 4.9(4)c, 4.9.3.e, and 4.9.4.d and Wis. Stats. §281.346(4)(e)1.c, §281.346(4)(e)1.e, §281.346(4)(f)3, and §281.346(4)(f)4 include requirements for return flow, such as protecting water quality and water-dependent natural resources, returning the withdrawn water, less an allowance for consumptive use, and minimizing out-of-basin water in the return flow to the extent practicable, while maximizing the return of Great Lakes water. Those requirements do not specifically dictate *how* or *when* the withdrawn water must be returned to the Great Lakes basin. However, the timing, water volume balance, and minimization of return flow containing out-of-basin water into Lake Michigan are important considerations for the water supply and resulting return flow management plan in evaluating compliance with the Compact and Wisconsin Statutes. Because the Compact and Wisconsin Statutes do not specify the timing of return flow, the City considered five alternatives for *management* of the return flow. Each meets the requirements of the Compact and Wisconsin Statutes.

Exhibit 3 lists the advantages and disadvantages of each return flow management plan alternative for return flow from the City's WWTP to Lake Michigan. Each plan involves a different operation of the WWTP and return flow, and each results in a different volume of water returned to Lake Michigan. Exhibit 4 summarizes Lake Michigan water withdrawal and return volumes following each management plan alternative, using actual daily water demand and WWTP flow from the City between 2005 and 2012. Although the Lake Michigan water diversion with return flow did not exist during this time, these years were used as a surrogate to demonstrate how the management plan would operate. These years were chosen because they include multiple wet (2008 and 2010), dry (2005 and 2012) and average precipitation years that influence water demand and WWTP flow rates, and ultimately the water balance of the withdrawal volume that would be returned to Lake Michigan.

EXHIBIT 3
Summary of Return Flow Management Plan Alternatives
(*Disadvantages in bold are primary reasons for not being the proposed alternative.*)

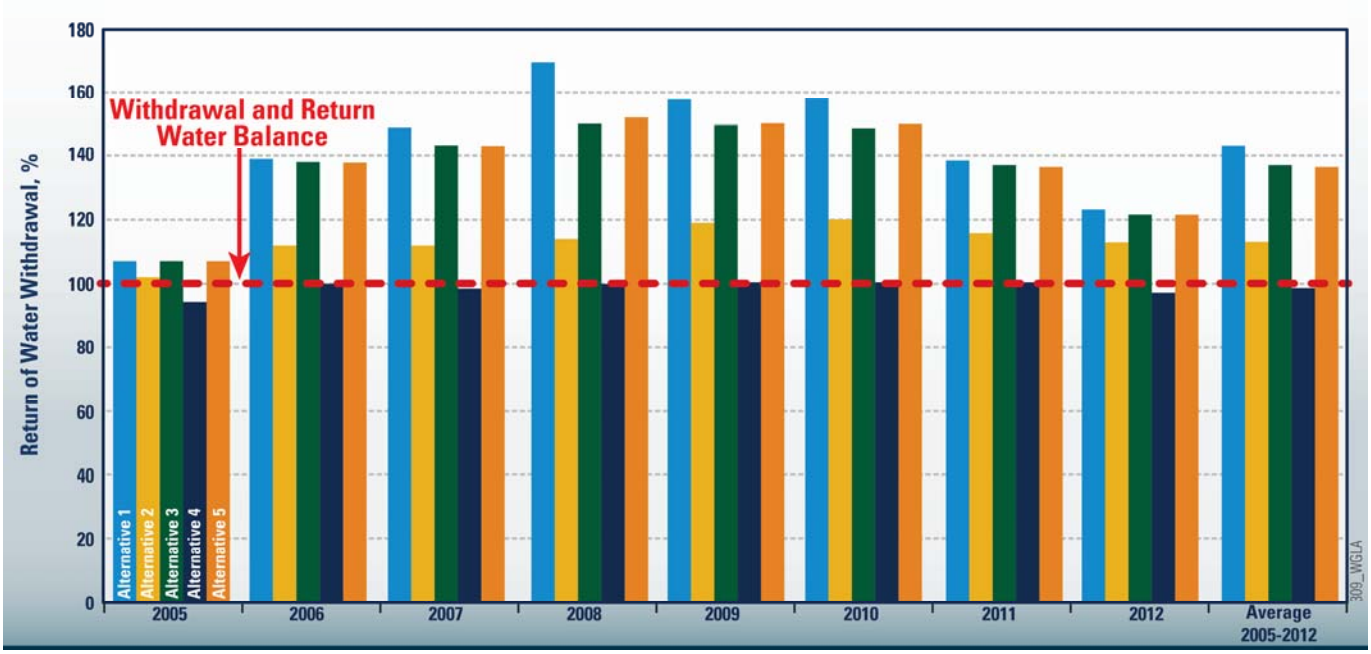
Alternative	Advantages	Disadvantages	Withdrawn Water Returned to Lake Michigan [a]	Return Flow that is Out-of-Basin Water [b]
1. Return all flow from WWTP to Lake Michigan.	Greatest volume of water returned to the lake because all WWTP flow would be returned. More water returned to the lake than withdrawn, even in drought years, because of I/I of stormwater and groundwater into the sanitary sewer system. Single discharge location makes permitting, monitoring, reporting, and operation straightforward. Provides greatest base flow increase for flow-limited Lake Michigan tributaries when return flow is to a tributary. Incentivizes I/I reduction to reduce pumping costs.	**Greatest excess of return flow volume compared to water supply volume, even during drought years.** **Fails to minimize out-of-basin water.** Requires high capacity return flow infra-structure for peak flows at WWTP from I/I. Higher capital cost and energy demands. Eliminates long-standing WWTP base flow to the Fox River.	112–169%	24–50%
2. Return flow from WWTP to Lake Michigan up to 115% of average day water demand (10.1 mgd × 1.15 = 13.0 mgd). Divert all WWTP to the Fox River when Lake Michigan receiving tributary exceeds 2-year return period flow.[c]	Provides water balance to Lake Michigan during most years, even in drought years, because of I/I of stormwater and groundwater into the sanitary sewer system. Prevents flow increases to Lake Michigan tributary during high flows when return flow is to a tributary. Limits infrastructure to 13.0 mgd return flow. Provides base flow increase for flow-limited Lake Michigan tributaries when return flow is to a tributary. Helps minimize out-of-basin water in return flow.	**Pausing return flow, even for only a few hours per year and even when an annual water balance is achieved, may not be preferred.** More water is returned to Lake Michigan than is withdrawn during wet years, because of I/I. Reduces long-standing WWTP base flow to the Fox River.	102–120%	17–29%
3. Return flow from WWTP up to maximum day water demand (16.7 mgd). Reduce maximum return flow to average day water demand (10.1 mgd) when Lake Michigan receiving tributary exceeds 2-year return period flow.	More water is returned to the lake than is withdrawn, even during drought years (also a disadvantage), due to I/I of stormwater and groundwater into the sanitary sewer system. Reduces flow increase during high flows on a Lake Michigan tributary when return flow is to a tributary. Limits infrastructure to 16.7 mgd return flow. Provides base flow increase for flow-limited Lake Michigan tributaries when return flow is to a tributary. Helps minimize out-of-basin water in return flow.	More water is returned to Lake Michigan than is withdrawn, even during drought years due to I/I. **Limiting return flow, even for only a few hours per year and even when an annual water balance is achieved, may not be preferred.** Reduces long-standing WWTP base flow to the Fox River.	112–150%	24–43%

EXHIBIT 3
Summary of Return Flow Management Plan Alternatives
(*Disadvantages in bold are primary reasons for not being the proposed alternative.*)

Alternative	Advantages	Disadvantages	Withdrawn Water Returned to Lake Michigan [a]	Return Flow that is Out-of-Basin Water [b]
4. Return flow from WWTP equal to previous day water demand (up to 100 percent of WWTP flow).	Most consistent with water demand on a *daily* basis. Provides water balance between water supply and return flow to Lake Michigan when considering an allowance for consumptive use. Closest alternative to water balance for Lake Michigan and Fox River Watersheds. Limits infrastructure for 16.7 mgd return flow. Incentivizes I/I reduction to reduce pumping costs. Provides base flow increase for flow-limited Lake Michigan tributaries when return flow is to a tributary. Minimizes out-of-basin water as return flow.	**Does not return 100 percent volume withdrawn and would result in a relatively small net loss of volume from Lake Michigan.** Requires highest degree of return flow control. Reduces long-standing WWTP base flow to the Fox River.	94–100%	10–15%
5. Return flow from WWTP up to the maximum day water demand (16.7 mgd).	Simplest pump station and pipeline operation and controls. Return flow is consistent with water demand on a *continuous* basis, because the maximum return flow would be the same as the maximum water demand. Balances requirements to maximize the return of Great Lakes water and minimize the return of out-of-basin water. Returns 100 percent of the withdrawn water volume, even in drought years (also a disadvantage), because of I/I of stormwater and groundwater into sanitary sewer system. Limits infrastructure for 16.7 mgd return flow. Incentivizes I/I reduction to reduce pumping costs. Provides base flow increase for flow-limited Lake Michigan tributaries when return flow is to a tributary. Simple strategy for permitting and system operation.	More water volume returned to Lake Michigan than withdrawn, even during drought year due to I/I. Reduces long-standing WWTP base flow to the Fox River.	112–152 %	24–44%

[a] Average and maximum day water demands based on historic values between 2005-2012.
[b] Includes an assumed 15 percent water consumption.
[c] Return flow management plan proposed in the draft May 2010 Application.

EXHIBIT 4
Estimated Annual Water Withdrawal and Return Flow Water Balances Between 2005-2012 for Return Flow Management Plan Alternatives
(Based on historical water demand and WWTP flow data)



Return flow management plan Alternative 2 (return flow from WWTP to Lake Michigan up to 115 percent of average and divert all WWTP to the Fox River when Lake Michigan receiving tributary exceeds 2-year return period flow) was the proposed management plan in the draft May 2010 Application. It is no longer proposed because feedback indicated that continuous return flow is preferred.

The return flow management plans have other advantages and disadvantages, but the return of all flow from the WWTP, up to the maximum day water demand of 16.7 mgd, is proposed (return flow management plan Alternative 5). That plan would return all the flow from the WWTP all the time, up to the maximum day water demand. Alternative 5 excludes from return flow water volumes that exceed the maximum day water demand. This helps minimize out-of-basin water in return flow and promotes a water balance between the Fox River and Lake Michigan.

The proposed return flow management plan has continuous return flow from the WWTP that is limited only by the maximum day water demand of 16.7 mgd. When peak water demands exceed the WWTP flow (e.g., at times during the summer), the return flow from the WWTP would still be equal to the water demand, less consumptive use. When peak water demands are less than WWTP flow (e.g., wet weather events), the return flow from the WWTP would be limited to the maximum day water demand. The proposed alternative is consistent with the preference for returning the Lake Michigan water on a continuous basis because, the return flow would be all the WWTP flow, limited only when discharge from the WWTP exceeds the maximum water demand. Some alternatives share these advantages, but their disadvantages are more significant (Exhibit 3).

The proposed management plan is summarized in a WWTP flow diagram (Exhibit 5) and in a flow chart (Exhibit 6). The Alternative 5 plan equalizes the maximum day water supply demand with the maximum return flow rates. This allows the water supply and return flow to meet the Compact and Wisconsin Statute requirement of returning the withdrawn water volume less allowance for consumptive use. It also allows the City to achieve 100 percent return flow because, based on historical water supply and WWTP flow records, the average WWTP flow is slightly greater than the water supply. Exhibit 7 summarizes the water supply and WWTP flow rates for 2012, a severe drought year in recent past. With the exception of a few days in April and December, the daily water demand and WWTP flows are similar where the average WWTP flow rates were less than 1.6 mgd greater than the water demand (less than 25 percent).

EXHIBIT 5

Flow Diagram of the City of Waukesha WWTP with Return Flow to Lake Michigan

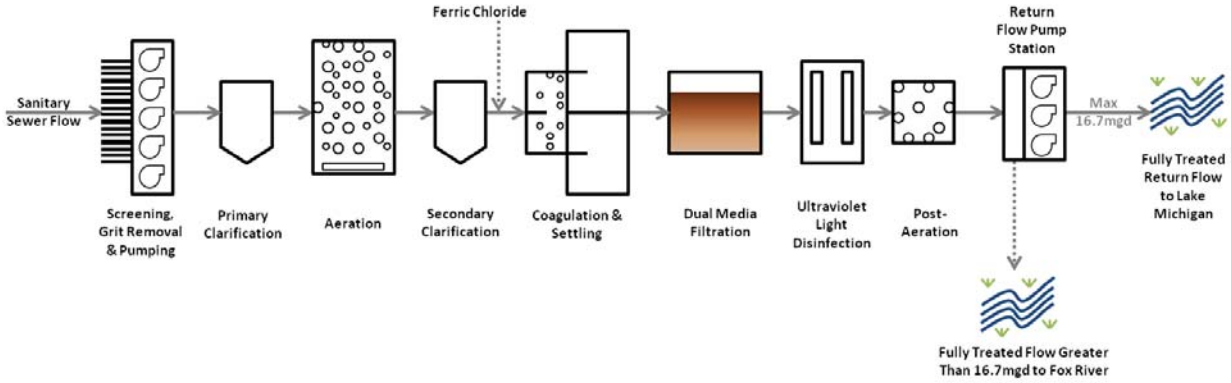
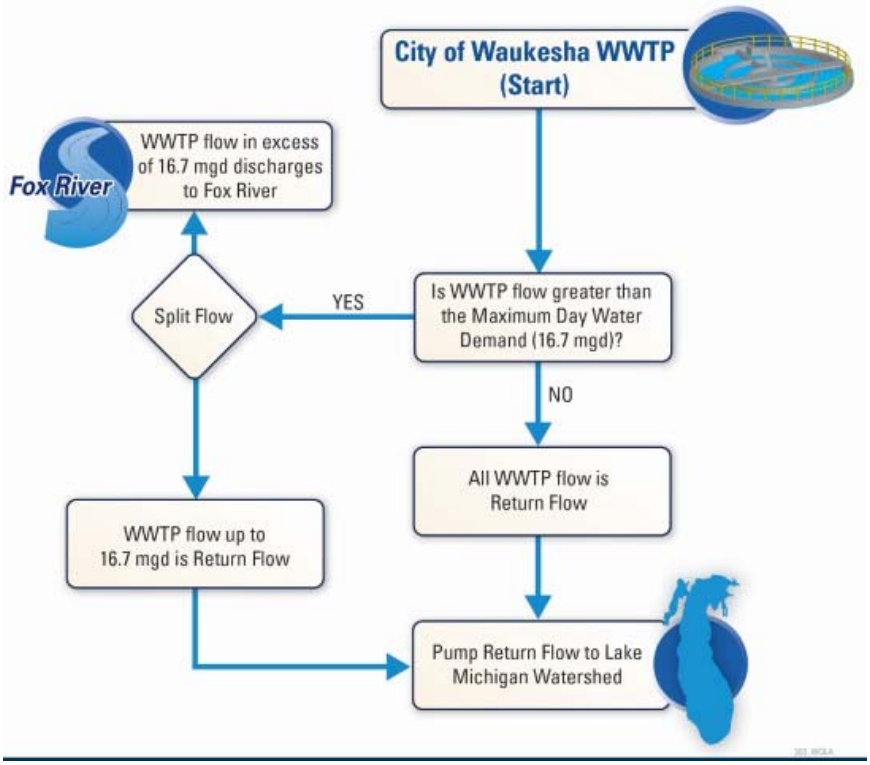


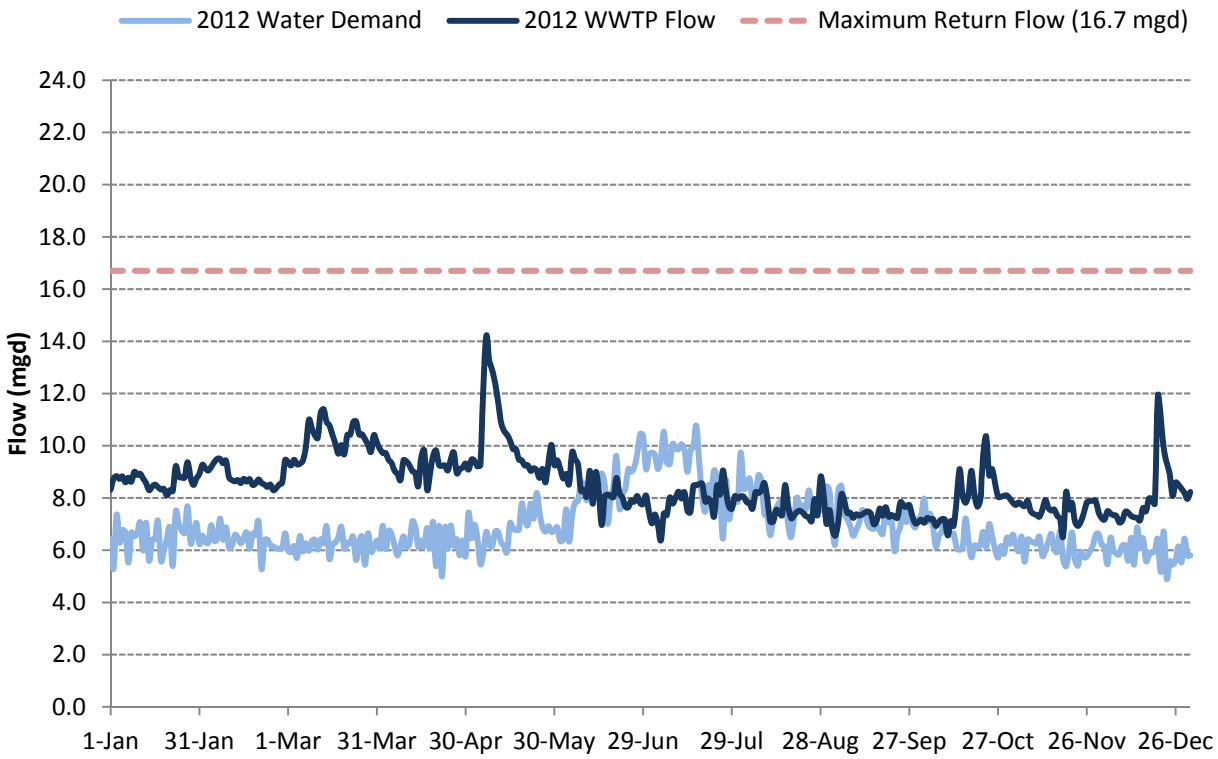
EXHIBIT 6

Flow Chart of the Return Flow Operation



Average WWTP flows exceed the water supply from Lake Michigan. The peak water supply and the peak WWTP flow rates are not likely to occur at the same time, since the highest water demand occurs during dry weather periods (summer) and the highest WWTP flow occurs during wet weather periods (spring or during rainfall events). However, the WWTP flow is greater than the water supply most of the time. For example, during the severe drought year 2012 when WWTP flow rates had their greatest difference from water demand, the 10 days with the greatest water demand had WWTP flows that averaged only 2.2 mgd less than the water supply. During this same year, the median (50th percentile) water demand and WWTP flow rates differed by only 1.7 mgd, where the water demand was 6.6 mgd and the WWTP had a flow rate of 8.3 mgd. This demonstrates that during dry years (Exhibit 7), there are times when the water demand is greater than the WWTP flow, but most of the time the two are similar. Consequently, return flow from the WWTP will go beyond the Compact and Wisconsin Statute requirements and allow the City to return 100 percent of the water volume withdrawn from Lake Michigan, even during dry years. This will also be true during wet years, although WWTP flows typically are greater than the water demand during those times. For example, during wet year 2008, the WWTP median flow was 3.2 mgd greater than the median water supply. The flow difference during 2008 was still similar to the average difference of 2.2 mgd in drought year 2012. Based on the historical values, the differences between future water withdrawal and return flow volumes are expected to remain similar or to decrease as the City continues its efforts to reduce I/I. This is demonstrated above and as part of WWTP facility planning, where the future average day water demand of 10.1 mgd is similar to the future 11.7 mgd average daily flow at the WWTP. Having an average WWTP flow greater than the average water demand will allow the City to achieve 100 percent return flow.

EXHIBIT 7
Water Supply and WWTP Flow Rates for 2012



2.2 Return Flow Effects on Lake Levels

Under the proposed return flow management plan, return flow to Lake Michigan would be continuous. The peak return flow rate is the same as the peak water demand. As shown in Exhibit 2, the average return flow rate (11.7 mgd) is slightly greater than but similar to the average future water demand (10.1 mgd), and so there will be 100 percent return flow of the withdrawn water volume. This will not affect the water level of Lake Michigan, and it sets a positive precedent for Great Lakes water diversions.

2.3 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.

As required by Compact Article 4, Section 4.9(4)(c)i and Wis. Stat. §281.346(4)(f)4a, the return flow will consist only of flow from the WWTP that originates within the sanitary sewer service area served by the City's WWTP, which is consistent with the water supply service area. Because sources of return flow outside the sewer service area will not be used for return flow, out-of-basin water in return flow will be minimized. The City also will minimize out-of-basin water through its proposed return flow management plan, which limits return flow to the maximum day demand of a Lake Michigan withdrawal. In addition, the City will minimize out-of-basin water in the return flow through continued implementation of an aggressive I/I reduction program that minimizes the amount of clear water entering the sanitary sewer collection system. The City's collection system and WWTP have adequate conveyance

and treatment capacity to provide treatment of the I/I, but the City continues to reduce I/I, minimize the treatment costs associated with the I/I, and minimize the I/I that could be part of the return flow through its Master Plans (Donohue & Associates, 2011a and 2011b) and Capacity, Management, Operation, and Maintenance (CMOM) Plan (Superior Engineering, Donohue & Associates, 2011). The City is performing annual self-audits (Superior Engineering, Donohue & Associates, 2011, page 54) and quarterly progress reports. Extensive inspection and maintenance measures are continuing to reduce I/I in the collection system. The following are examples of these measures (City of Waukesha, 2012a and 2012b):

- 475,000 linear feet of sewer televising with another 500,000 scheduled to be completed by 2013. At the end of 2013, 76 percent of the entire gravity sewer system will have been inspected.
- 37,280 feet of sanitary sewer pipe lining between 2011 and 2013.
- 12,726 feet of sanitary sewer pipe replacement between 2011 and 2012.
- 6,926 manhole inspections between 2011 and 2013. At the end of 2013, 79 percent of the City's manholes will have been inspected.
- Manhole rehabilitation measures including 462 cover replacements, 58 chimney linings, 200 chimney replacements, 5 chimney/cone replacements, 158 complete manhole linings, 31 total manhole replacements, grouting 3 manholes, and 202 invert rehabilitations by the end of 2012. In 2013, another 200 manholes are expected to be rehabilitated (City of Waukesha, 2012c, page 1).
- Inspection and maintenance work on force mains will include the replacement of 6,350 feet of ferrous pipe in 2012, with another 3,100 feet planned for 2013 (City of Waukesha, 2012c, page 1).

The City started implementing key elements of a CMOM program before the USEPA required it to do so, including sewer cleaning, pump station inspection and maintenance programs (Superior Engineering, Donohue & Associates, 2011, page 1). Completed projects that contribute to reducing I/I include 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 has an aggressive I/I reduction program and continues to investigate I/I throughout the collection system to prioritize projects that provide the most efficient I/I reduction and minimize out-of-basin water in return flow. By using the City's sanitary sewer system and the I/I reduction measures in combination with the return flow management plan, the Compact Article 4, Sections 4.9(3)b and Wis. Stats. §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.

3. Return Flow Location Alternatives

Five alternatives were considered for return flow to the Lake Michigan source watershed from a Lake Michigan water supply to the City. The alternatives include return flow to Lake Michigan:

- Through Underwood Creek, a tributary to Lake Michigan
- Through Root River, a tributary to Lake Michigan
- Direct to Lake Michigan near Milwaukee and Oak Creek
- Direct to Lake Michigan near Racine
- Through the Milwaukee Metropolitan Sewerage District (MMSD) sewer system and water reclamation facility, and then to Lake Michigan

Compact Article 4, Section 4.9(4)d and Wis. Stat. §281.346(4)(f)5 require that the return flow result in no significant adverse individual or cumulative impacts to the quantity or quality of the waters or water-dependent natural resources 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). The pipeline corridors and the return flow discharge locations were evaluated using the following criteria, listed in order from greatest to least weight: protect public health and safety; minimize environmental impacts; provide feasible implementation (an alignment that is constructible); use previously disturbed areas and existing utility corridors;

be consistent with and improve upon alignments identified by the Southeastern Wisconsin Regional Planning Commission (SEWRPC, 2010a) where practical; allow the return flow to be used as an environmental resource to the Lake Michigan Basin; and minimize cost.

The return flow alignments selected for evaluation follow previously disturbed areas, such as streets and alleys, bike paths, active and abandoned railroad corridors, utility corridors, and city and county lands. The alignments were developed to a planning level of detail that allows screening and comparison of alternatives. The concepts do not include the detail that will be identified and evaluated in subsequent engineering design phases for the actual project. Similar infrastructure (a pump station, appurtenances, and a pipeline of varying length depending on the alternative) was included for each alternative.

Each alternative is discussed below. The appendixes and the Environmental Report (refer to Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives) contain additional information and evaluation details. Return flow to the Root River is the preferred alternative because it is protective of public health and safety, it has no significant environmental impacts, it is the least costly of the implementable alternatives, and it provides the greatest environmental benefit to the fisheries in the Root River and Great Lakes. In the draft May 2010 Application, Underwood Creek was proposed as the preferred return flow location, and so it is the first alternative discussed below. Geomorphic, habitat, and fisheries assessments were completed as part of the Application because recent restoration projects have been implemented since planning reports by SEWRPC and MMSD were last updated. For some evaluation criteria, such as return flow impacts on in-stream habitat, there are similarities between the Underwood Creek and Root River alternatives. As a result, the evaluation of the Root River alternative uses some of the analyses on Underwood Creek. The Root River alternative was analyzed in detail, but the Underwood Creek alternative should also be reviewed in support of evaluating the Root River alternative.

3.1 Return Flow to Underwood Creek

Wisconsin Stat. § 281.346(4)(f)3m 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 returning the water at that place is (a) not economically feasible; (b) not environmentally sound; or (c) not in the interest of public health.

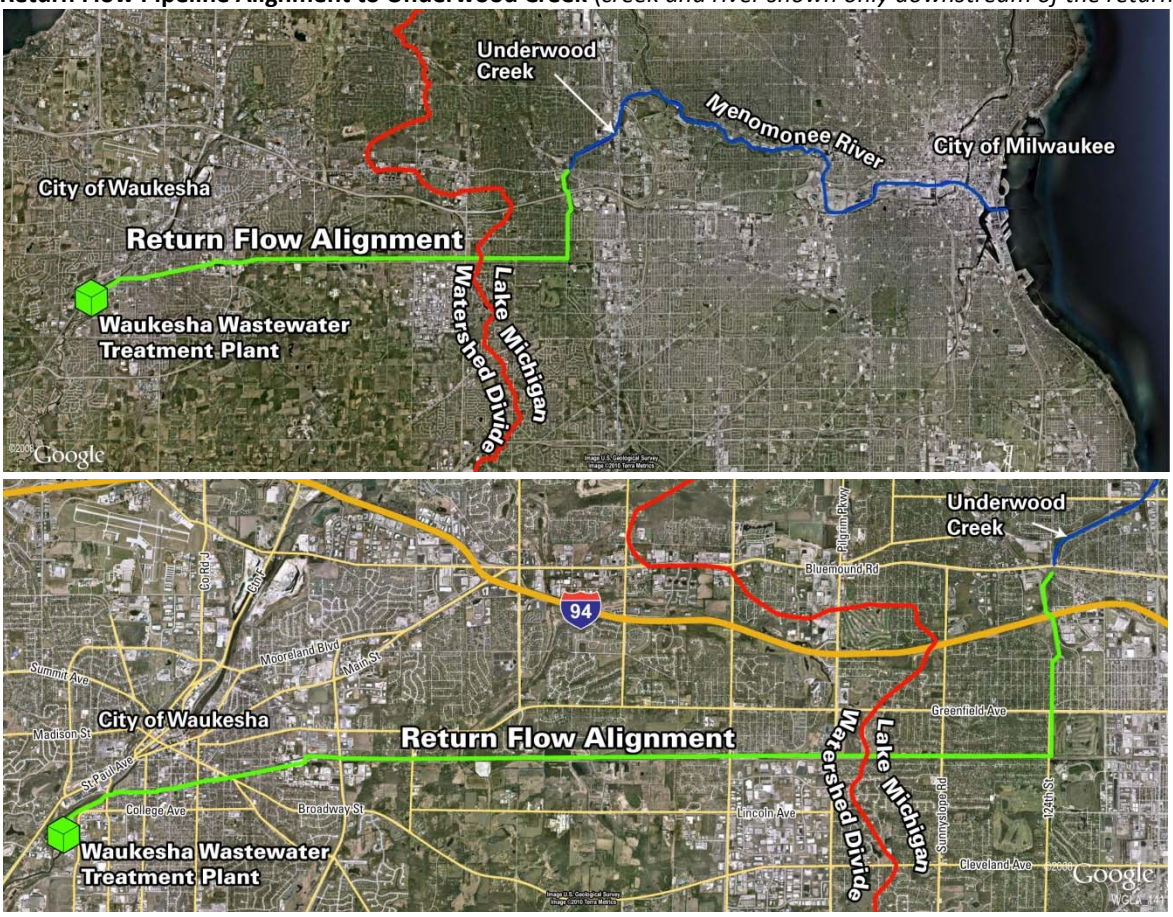
The City considered return flow to Lake Michigan through Underwood Creek near the crossing of Underwood Creek and Bluemound Road in Waukesha County. At that location, Underwood Creek flows about 2.6 river miles to its confluence with the Menomonee River in Wauwatosa (Milwaukee County) before flowing another 10 river miles to Lake Michigan.

A screening level layout was developed for the return flow pipeline to Underwood Creek (Exhibit 8). It would begin at the City WWTP and proceed north and east through a City park and along an alley and minor streets for about 1.3 miles. The pipeline would continue east for another 1.3 miles, following an abandoned railroad corridor planned for a future recreational trail, where it would join with an utility corridor and bike trail for 7 miles. The pipeline would continue 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 would be expected to be located at an elevation similar to the bed elevation of Underwood Creek, where the detailed design of the discharge structure will meet the requirements of Wis. Stat. §281.346(4)(f)4.c. The City of Brookfield owns the property where the pipeline would end. Appendix B includes a letter from the City of Brookfield supporting future permitting of a pipe and outfall for this alternative.

The return flow to Underwood Creek alternative would comply with Wis. Stat. § 281.346(4)(f)3m requirement that water be returned as close as practicable to the source because the Underwood Creek and Menomonee River watersheds are within the Lake Michigan source watershed and the location where the return flow would enter Lake Michigan is close to the withdrawal location, regardless of whether the water supply is from the City of Milwaukee, Oak Creek, or Racine. The Underwood Creek and Menomonee River watershed includes parts of the City of Milwaukee. Where the river flows into Lake Michigan, it is in the City of Milwaukee, it is within 10.5 miles of the City of Oak Creek withdrawal location. The Underwood Creek and Menomonee River watersheds are adjacent to the watersheds that include parts of Racine and Oak Creek.

EXHIBIT 8

Return Flow Pipeline Alignment to Underwood Creek (*creek and river shown only downstream of the return flow*)



3.1.1 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 cause 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 be no long-term significant adverse impacts because the return flow alignment follows an alignment previously disturbed with existing development (e.g., roadway, bike path, utility corridor). A 75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare impacts between alternatives. Exhibit 9 summarizes some of the impacts to environmental resource types for the return flow corridor.[1] The City of Waukesha Environmental Report for Water Supply Alternatives (refer to Volume 5) contains a detailed evaluation.

EXHIBIT 9

Potential Environmental Impacts for an Underwood Creek Return Flow Pipeline

Resource Type	Potential Temporary Impact of Pipeline Corridor
Stream and water body crossings	9
Water body crossing	0.16 acre
Wetlands	9 acres[a]

[a] Temporary Impacts 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 acres within the pipeline corridor between the Waukesha WWTP and the outfall to Underwood Creek. Most of the impacts occur in the last 0.9 mile of the alignment, where about 4 acres of land are classified as wetlands. The area was previously disturbed when the

[1] The impacts summarized are for the return flow pipeline alignment only. Some of the impacts summarized here are shared with the water supply pipeline alignments. For simplicity in evaluating the return flow alternatives, only the impacts of the return flow pipelines are summarized. For comparison of environmental impacts of complete combinations of water supply and return flow system alternatives, see Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives.

creek was lined with concrete and when a recreational trail was recently constructed. The pipeline corridor is located along the trail to minimize wetland impacts, but some temporary impacts are likely with a return flow outfall near Bluemound Road. To reduce impacts, the outfall could be located upstream of Bluemound Road 0.9 mile. This would reduce the potential temporary construction impacts from 9 to about 5 acres, but this location is not in the City of Brookfield, which has provided a letter of support for future permitting (Appendix B).

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.

3.1.2 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.

EXHIBIT 10
Underwood Creek Near Proposed Return Flow Location

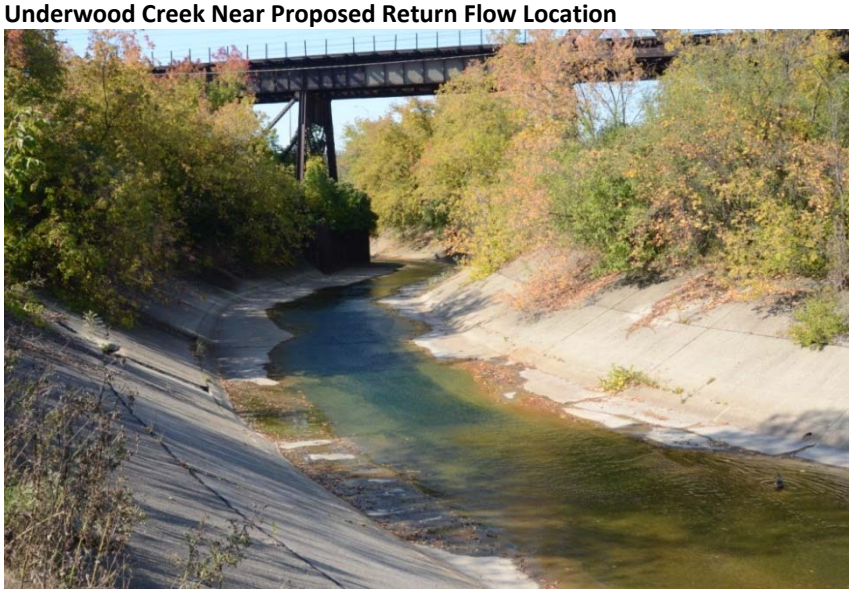


EXHIBIT 11
Rehabilitated Segment of Underwood Creek Downstream of Proposed Return Flow Location



Downstream of the return flow outfall, Underwood Creek is mostly concrete-lined (Exhibit 10), but in 2009 a 2,400-foot segment of lining was removed and the creek rehabilitated (Exhibit 11) with natural channel design features (MMSD, 2008a). The creek now 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. Appendix C contains a preliminary design for rehabilitating an additional 4,400-foot section of the creek. Final design of this segment is ongoing. When construction is completed, it is expected to provide similar environmental resource benefits.

The Underwood Creek design engineers conducted a hydraulic and geomorphic analysis for return flow (Appendix C). This analysis used a return flow rate of 20 cubic feet per second (cfs; 12.9 mgd), which is very similar to the average return flow and average daily flow projected at the City's WWTP of 18 cfs (11.7 mgd) (Strand Associates, 2011, page 4-6). 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.

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 storms. Return flow would provide all the flow in Underwood Creek during dry periods and would provide a very small portion of flow during storms. For example, a maximum return flow of 25.8 cfs (16.7 mgd) return flow is only 1.5 to 1.7 percent of the 2-year return period creek flow (for locations in the creek downstream of the potential return flow location) and 0.37 to 0.84 percent of the 100-year return period flow (SEWRPC, 2010b).

Return flow effects on the Menomonee River are similar to those on Underwood Creek. The Menomonee River is downstream of Underwood Creek, and so the river has a much larger watershed and base flow rate. Because of this, the return flow is an even smaller fraction of the river flow. Similarly to Underwood Creek, the return flow will not affect the geomorphic stability of the river. Comparing the same frequency storm events for the river, a maximum return flow rate of 25.8 cfs (16.7 mgd) is only 0.53 to 0.91 percent of the 2-year return period flow (for locations in the river downstream of the potential return flow location) and 0.16 to 0.28 percent of the 100-year return period flow (SEWRPC, 2010b).

A habitat assessment was completed for Underwood Creek and Menomonee River to determine 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 will not have a significant adverse effect on the in-stream habitat, but they are expected to benefit 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 augment low base flow to provide improved habitat. The return flow will have similar but less significant benefits for the Menomonee River, because the river flow is greater than the creek flow. Appendix D contains details of the habitat analysis completed for the Application for return flow rates of 20 and 30 cfs. The proposed maximum return flow rate of 25.8 cfs is within this range.

Return Flow Effect in 2005 and 2008. Return flow was simulated for 2005 and 2008 to demonstrate how return flow would have affected Underwood Creek and the Fox River flow rates during a recent dry year (2005) and wet year (2008) (Appendix E). Return flow to Underwood Creek noticeably increased Underwood Creek flows in 2005 during low flow periods observed throughout the year. Underwood Creek flow without return flow was often less than 5 cfs during 2005 and 2008. The return flow eliminated these very low flow periods with a relatively uniform return flow rate. In both 2005 and 2008, return flow was not significant when creek flows were above base flow because the return flow is a small percentage of river flow.

Average daily flow in the Fox River was reduced by an amount equal to the return flow rate. The reduction was more noticeable in 2005 than in 2008, but the average reduction was about 23 percent. During 2008, the average difference in the hydrographs of the Fox River with and without return flow was about 12 percent. In both 2005 and 2008, the absence of flow from the WWTP was not significant when river flows were above base flow, because the return flow is less than 5 percent of the river flow.

Diurnal Return Flow Effects. Hourly WWTP flow data and USGS 15-minute flow data from 2005 were used to simulate flow rates in Underwood Creek to evaluate the effect that diurnal return flows from the WWTP would have on the variability of the creek flows (Appendix F). The year 2005 was chosen because it was a relatively dry year in the recent past when return flow would have a greater influence on flow rates in the receiving water. The diurnal variations in the return flow are small and are within the range of existing flow fluctuations within Underwood Creek. The diurnal fluctuations of return flow in the creek are significantly less than that experienced during a runoff event, where a runoff event can be several orders of magnitude greater than the diurnal

fluctuation of return flow. For example, during the moderately high flow event on June 26, 2008, the creek flow increased from 2.6 to 374.1 cfs in 3 hours, whereas the return flow maximum diurnal fluctuation observed in the 2005 simulation was 10.5 cfs. As a result, the diurnal flow variation from return flow will not have a significant impact on the creek.

Return Flow Effects on Flashiness. Flashiness is the frequency and rapidity of short-term changes in stream flow (Baker et. al., 2004). The flashiness index was calculated with and without return flow for Underwood Creek and the Fox River for the dry year of 2005 and the wet year of 2008 (Appendix G). The simulations were completed to determine the effect that return flow has on the index. The flashiness index is lower for Underwood Creek when a Lake Michigan supply with return flow is compared to the creek flow without return flow. This is because the return flow adds base flow and is relatively uniform. The flashiness index slightly increases for the Fox River because WWTP flow that historically discharged to the Fox River is instead discharged to Underwood Creek through return flow. In other words, the base flow reduction in the Fox River raises the flashiness index.

The reduction in flashiness index for Underwood Creek is predicted to benefit the aquatic resources in the creek because of the improvement in base flow, as summarized in Appendix D. The change in the flashiness index for the Fox River will have a negligible effect on aquatic resources, because the change is very small and the proposed return flow management plan will not negatively affect the rate at which peak flow in the river occurs as compared to existing conditions.

Based on the above analysis for flow, geomorphology and habitat, the physical integrity of Underwood Creek and the Menomonee River will be protected and sustained as required by the Compact Article 4, Section 4.9(4)d and Wis. Stats. §281.346(4)(f)4m and §281.346(4)(f)5.

3.1.3 Fisheries

Fisheries data for the Menomonee River watershed show a recent 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, 2007a, pp. 200–14). Underwood Creek is predominantly a concrete channel with little habitat for fish, but the creek provides minimal substrate for macroinvertebrates. The reach that was rehabilitated to a meandering stream channel has numerous pools and riffles, and a substrate composed of gravel, sand, and silt. The downstream 4,400-foot reach of Underwood Creek for which a preliminary design has been completed is expected to have similar habitat features that would further improve the fisheries.

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 a limiting factor for the fish and benthic communities, those conditions could be improved by providing more or higher quality habitat. Because return flow could improve habitat, the fish and macroinvertebrate communities would also be expected to improve.

An example of improving fisheries with effluent flow from a WWTP occurs in southeast Michigan, where the Ypsilanti Community Utilities Authority uses wastewater effluent as an environmental resource. In 1995, the Lower Rouge River near Detroit began receiving flow augmentation from WWTP 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. Base flow enhancement has dramatically increased the fishery potential of the Lower Rouge, where flow augmentation demonstrates that base flow enhancement to low flow systems may be a particularly useful tool to enhance sport fish populations (Wiley et al., 04/1998, pp. 7, 13, and 18). Similarly, return flow to Underwood Creek

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 base flow in Underwood Creek and the Menomonee River to support an improved fishery. Return flow to the creek provides natural resource benefits, whereas pipe conveyance (for example, return flow direct to Lake Michigan) does not afford the opportunity to provide an environmental benefit.

Based on the above analysis, the biological integrity of Underwood Creek and the Menomonee River would be protected and sustained with the return flow. The same is true for the Fox River, which would have less flow due to the return flow to Lake Michigan. As summarized in Appendix D, the fish community in the Fox River is fairly diverse with several species indicative of cool water habitats. The cool water species were surveyed near the mouth of Genesee Creek, a known cold water fishery. State designated threatened or species of special concern also were present. Based on flow models of the Fox River, a maximum loss of water depth of about 2 inches or less is predicted during dry weather. The difference is even less during normal or wet conditions. These depth changes would have an insignificant impact on the Fox River fisheries. The biological integrity of the Fox River would also be protected and sustained with the return flow to Lake Michigan.

3.1.4 Flooding

To protect public and private property, various municipalities have invested and continue to invest in flood control projects. For example, downstream of the return flow location, the MMSD has invested in the Hart Park flood control project, completed in 2007 (MMSD, 2010a), and the Milwaukee County Grounds flood control project (MMSD, 2010b). Other projects completed or planned elsewhere in the watershed also provide flood protection to neighboring and downstream residents.

SEWRPC has updated flood flow projections for Underwood Creek and the Menomonee River that account for the Milwaukee County Grounds flood control project (SEWRPC, 10/14/2011). The 100-year return period flow rates in Underwood Creek range from 3,080 to 6,910 cfs between the proposed return flow discharge location and the confluence with the Menomonee River. The 100-year return period flow rates in the Menomonee River range from 9,300 to 16,000 cfs between the confluence with Underwood Creek and the mouth of the Menomonee River at Lake Michigan.

Return flow is a small fraction of the flood flow rates. Using a maximum return flow rate of 25.8 cfs (16.7 mgd), the fraction of return flow in Underwood Creek during flood flows ranges between 0.37 to 0.84 percent. For the Menomonee River, the fraction of the maximum return flow rate during flood flows is even lower, ranging between 0.16 to 0.28 percent.

A flooding analysis by the Wisconsin Department of Transportation (2012a) for the Zoo Interchange drainage improvements affecting Underwood Creek and the Menomonee River concluded that the interchange reconstruction and drainage reconfiguration would not have a statistically significant effect on regional flood flows. However, the analysis showed that the improvements would reduce the 100-year return period flow rates between 25 and 29 cfs along Underwood Creek downstream of the proposed return flow location. Further downstream along the Menomonee River where river flow rates are significantly larger, flow reductions ranged between 14 and 29 cfs. For all locations downstream of the return flow, the average flow reduction was 24 cfs. Although these flow reductions were determined not to be statistically significant, the modeled reduction in flow rates is similar to the anticipated maximum return flow rate of 25.8 cfs.

The MMSD's flood detention facility at the Milwaukee County Grounds originally was designed to receive 3,300 cfs of flow from Underwood Creek for the 100-year return period flood (MMSD, 2007a, Section 2.5.1.1, Page 2-13 and Table 2-6). Based on updated modeling by SEWRPC, the detention facility reduces flow by 3,830 cfs, which is 530 cfs greater than the design criteria. Consequently, return flow to Underwood Creek would not be anticipated to adversely affect the function of the detention facility.

3.1.5 Return Flow 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 will provide return flow with water quality that meets all requirements stipulated by the USEPA and the Wisconsin Pollutant Discharge Elimination System (WPDES). A WPDES permit for the WWTP was recently reissued with an effective date of August 1, 2013 for the current discharge location on the Fox River (Appendix A). Exhibit 12 summarizes the permit limits for the WWTP continuing to discharge to the Fox River. The WDNR has also provided the City with proposed effluent limits for discharge to a Lake Michigan tributary (WDNR, 2011b).[2] These limits are very similar to the permit limits for the Fox River.

Effluent limits for one direct to Lake Michigan municipal discharger and two in-basin municipal dischargers to Lake Michigan tributaries were obtained for comparison purposes. The WDNR-proposed effluent limits for return flow to a Lake Michigan tributary are more stringent than other currently permitted Lake Michigan direct and tributary dischargers (Exhibit 13).

EXHIBIT 12
City of Waukesha WWTP WPDES Effluent Permit Limits

Parameter	Permit Limit
BOD_5, total	≤ 8.2 to 10 mg/L weekly (varies by season)
Total suspended solids	≤ 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	≤ 0.7 mg/L monthly interim (≤ 0.075 mg/L future limit)
Fecal coliform	≤ 400#/100 mL monthly geometric mean (May–September)
Chlorides	690 mg/L weekly with a target value of 440 mg/L
Temperature	Compliance demonstrated through mixing analysis.

August 1, 2013 Permit for Existing Fox River Discharge.

Total maximum daily loads (TMDLs) for phosphorus, fecal coliform, and total suspended solids are being developed for Underwood Creek and the Menomonee River (see next section regarding impairments requiring development of TMDLs). A draft of the TMDLs is not expected until December 2013. Consequently, the WDNR-proposed limits in Exhibit 13 include 0.075 mg/L for phosphorus. This is equivalent to the water quality standard for return flow to Underwood Creek (and the Root River), and these standards are consistent with the facility planning completed by the WWTP in 2011. Because the City is committed to maintaining high quality effluent from its WWTP, all of the return flow location alternatives will meet TMDL and WPDES requirements.

Chlorides. Chloride concentrations from the City's WWTP were reviewed from March 2006 through May 2013 (Appendix A). The average weekly chloride concentration was 479 mg/L with a maximum weekly concentration of 690 mg/L and minimum weekly concentration of 310 mg/L. The average weekly chloride concentration for the months during which road salts are applied (December through April) was 497 mg/L with a maximum of 690 mg/L. The average for non-winter months was 465 mg/L with a maximum of 595 mg/L. The 90th percentile weekly chloride concentration was 590 mg/L.

The WWTP's WPDES permit includes chloride limits for a Fox River discharge that are more strict than those in the City's previous permit. The permit limit is 690 mg/L weekly average and it requires the City implement a chloride compliance plan to achieve a target value of 440 mg/L. The permit also included chloride limits of 395 mg/L for a return flow through Underwood Creek (and the Root River), which is the water quality criterion. The proposed chloride limit for Underwood Creek (and the Root River) is lower than their current target value (440 mg/L) for

[2] Chloride limit of 395 mg/L instead of 400 mg/L, to be consistent with water quality standard and permit. See Appendix A.

EXHIBIT 13

Comparison of WDNR-Proposed WPDES Limits to Historical WWTP Performance and Other Direct and Tributary Lake Michigan Municipal Dischargers

Water Quality Parameter	City of Waukesha Potential Return Flow		Lake Michigan Tributary WWTP Discharger #1[b]	Lake Michigan Tributary WWTP Discharger #2[c]	Discharger Direct to Lake Michigan[d]
	WDNR-Proposed Limit for Lake Michigan Tributary Return	Waukesha Historical Average[a]			
Biological oxygen demand, mg/L	≤ 5.7 to ≤ 10.0	1.8	≤ 10.0 to ≤ 15	≤ 30.0 monthly avg.	≤ 30.0 monthly avg.
Total suspended solids, mg/L	≤ 10.0	1.2	≤15.0	≤ 30.0 monthly avg.	≤ 30.0 monthly avg.
Dissolved oxygen, mg/L	≥ 7.0	9.2	≥ 6.0	≥ 6.0	No Limit
Phosphorus, mg/L	≤ 0.075[e]	0.16	≤ 1.0	≤ 1.0	≤ 1.0
Ammonia (NH_3-N), mg/L	≤ 1.3 to ≤ 4.3	< 1.0	≤ 3.3 to 6.4 monthly avg.	≤ 6.3 to 12.0 monthly avg.	pH dependent; ≤ 1.8 to 39 daily max.
Chlorides, mg/L	≤ 395	477	≤ 570	No limit	No limit
Temperature, °F (varies by month)	≤ 49 to 81	53 to 70	No Limit	No limit	No limit

[a]October 1, 2002, to August 31, 2009. March 15, 2006 to May 1, 2013 for Chlorides.
[b]WPDES Permit No. WI-0020222-08-0
[c]WPDES Permit No. WI-0020184-08-0
[d]WPDES Permit No. WI-0025194-07-1
[e]Water Quality Standard for Underwood Creek and the Root River.

discharge to the Fox River, but they are not significantly different. Consequently, achieving the return flow limits are likely to be achieved by meeting the Fox River limits.

The WPDES permit identified several chloride reduction measures that the City would have to implement for its Fox River discharge. The chloride reduction measures and additional measures identified as part of this Application were evaluated to estimate the effluent chloride concentrations for return flow (Appendix A). Several scenarios were evaluated that show concentrations of chloride in return flow can be reduced to below the requirements. Much of the chloride reduction is achieved by residential and commercial/industrial water softener removal because a Lake Michigan water supply will not require water softening (water softeners discharge chlorides to the WWTP). Using the 90th percentile historical weekly chloride concentration, less than a 60 percent reduction in residential and commercial/industrial water softening is estimated to be required to achieve an effluent limit of 395 mg/L. Complying with the return flow chloride limits will be achievable because it is expected that softening will be reduced by more than 60 percent and reduction of chlorides above the 90th percentile will be accomplished by chloride reduction measures that target winter events, such as deicing operations and salt water runoff from storage facilities.

Temperature. A preliminary thermal analysis of the City's return flow discharge to the Root River (Appendix A) is also applicable to Underwood Creek because some of the compliance options are the same. The purpose of the analysis was to identify one or more methods to comply with the WDNR thermal regulations in Wisconsin Administrative Code Chapters NR 102 and NR 106. The City's return flow is not "hot" and does not pose any acute thermal threat to aquatic life. Rather, like many WWTPs in Wisconsin, the return flow temperature is warmer than the ambient Underwood Creek temperature in late fall and winter, with the highest measured WWTP effluent temperatures ranging from 51 to 70 degrees Fahrenheit (October through January). The WDNR thermal sublethal standards during these months can be triggered by typical municipal wastewater effluent.

Underwood Creek is lined with concrete for 73 percent of its length between the return flow location and the Menomonee River (1.9 of the 2.6 miles). The lining continues 1.0 mile upstream of the return flow location to where Underwood Creek originates from a culvert that extends from its headwaters. The concrete channel supports a limited biological community for the 1.9 miles of concrete lining that is downstream of the return flow. As a result, the biological community may be tolerant of the thermal load from return flow and thermal limits may

not impact the return flow. However, based on the thermal analysis (Appendix A), the following options would allow the City to meet the thermal requirements on Underwood Creek:

- Thermal mixing analysis of Underwood Creek
- Using site-specific ambient temperatures to establish thermal limits
- Management techniques to lower the return flow temperature before discharge
- Combinations of the above techniques

Several options exist for the Underwood Creek return flow to achieve WDNR thermal rule compliance, if they are required. Return flow as it relates to thermal discharge would reasonably protect the chemical, physical, and biological integrity in Underwood Creek.

3.1.6 Underwood Creek and Menomonee River Water Quality

Under the WDNR fish and aquatic life standards, Underwood Creek is a warm water fishery, but it has a variance in Milwaukee County for dissolved oxygen and fecal coliform (Wisconsin Administrative Code, Chapter NR 104.06(2)). The Menomonee River downstream of Underwood Creek is also a warm water fishery under the WDNR 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).

A reach of Underwood Creek in Milwaukee and Waukesha counties was included on the 2010 303(d) list for fecal coliform as a recreational restriction and is proposed to be included on the 2012 303(d) list for total phosphorus as a fish and aquatic life community restriction (WDNR, 2012a). Similarly, the downstream 2.67 miles of the Menomonee River are on the 2010 303(d) list for PCBs from contaminated sediment, *E. coli* bacteria for recreational restrictions, total phosphorus for low dissolved oxygen, and unspecified for chronic aquatic toxicity. Up to river mile 6.27, the Menomonee River is listed for fecal coliform as a recreational restriction. 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 (SEWRPC, 2007a).

SEWRPC's *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* extensively studied water quality in Underwood Creek and the Menomonee River. 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. In addition, water quality analysis was completed for the current conditions in Underwood Creek and the Menomonee River, and for conditions with return flow (Section 3.1.7 below and Appendix H).

Fecal Coliform. Underwood Creek and the Menomonee River sometimes exceed the 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 (SEWRPC, 2007a).

The historical performance at the City's WWTP for the summer recreation season (May through October) had geometric mean fecal coliform concentration ranging from 2 to 49 cells/100 mL. A TMDL for fecal coliform is being developed for Underwood Creek and the Menomonee River, but a draft is not expected until at least December 2013. Because the return flow fecal coliform concentration is much lower than the existing conditions and water quality standards in Underwood Creek and the Menomonee River, the TMDL is not expected to affect the City's return flow effluent limit and the average fecal coliform concentration in the creek and river will improve.

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's WWTP historical performance for average dissolved oxygen concentration ranges from 7.9 to 10.5 mg/L. Modeling of the WWTP's effluent dissolved oxygen and oxygen demand was completed for a Root River return flow to determine if supplemental aeration would be required to meet a 7 mg/L permit limit (Appendix A). The Root River return flow was used because it is a much longer pipeline than that for Underwood Creek, which is considered a more conservative aeration requirement for an Underwood Creek return flow. Using conservative modeling assumptions of minimum flows, maximum temperatures, and the 95th percentile 5-day biochemical oxygen demand, model runs indicate an initial dissolved oxygen concentration of 7.48 mg/L at the WWTP would provide a dissolved oxygen

concentration of 7 mg/L at an Underwood Creek outfall. Under these conservative assumptions, only 0.48 mg/L dissolved oxygen would be depleted between the WWTP and discharge to Underwood Creek. A review of historical data shows that a dissolved oxygen concentration of 7.48 is achievable with the existing aeration system for the modeled scenario. With a new aeration system planned as part of the WWTP facility planning (Strand Associates, 05/2011), providing 7.48 mg/L is within the design guidelines, and supplemental aeration system at the Underwood Creek outfall is consequently not expected.

Because the return flow dissolved oxygen concentration is greater than that in Underwood Creek and it 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 after return flow.

Total Phosphorus. Underwood Creek and the Menomonee River meet the SEWRPC planning level goal of 0.1 mg/L 66 to 84 percent of the time (Appendix H). The City's WWTP historical performance for monthly average phosphorus concentration ranges from 0.10 to 0.24 mg/L. However, for a return flow to Underwood Creek, the return flow effluent concentration will be equal to or better than the Underwood Creek water quality standard of 0.075 mg/L. The water quality criterion for the Menomonee River is 0.1 mg/L. Discharging at or below the Underwood Creek water quality standard will result in an improvement to Underwood Creek and the Menomonee River because both will have a lower phosphorus concentration as a result of the return flow (Hedman, 07/25/2012).

A TMDL for phosphorus is being developed for Underwood Creek and the Menomonee River. It is possible that the TMDL may require stricter effluent limits, but it is also possible for the effluent concentration to be greater than the water quality standard. This will not be known until after the TMDL is further developed. The TMDL will include the return flow as part of its analysis, but the results of such modeling are not yet available. A draft of the TMDL is not expected until at least December 2013. A return flow to Underwood Creek would be implemented to meet the requirements of the TMDL and applicable WDNR administrative codes (e.g., NR 102 and NR 217). As part of the City's facility planning, the WWTP has been planning to meet an effluent limit of 0.075 mg/L (for its existing Fox River outfall), which is also the water quality standard for Underwood Creek.

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. The Underwood Creek and Menomonee River TMDL includes total suspended solids but because the return flow concentration is much lower than the background concentration, the TMDL is not expected to change the total suspended solids effluent limit. Consequently, the average total suspended solids concentration is expected to improve in Underwood Creek and the Menomonee River as a result of return flow.

3.1.7 Return Flow Water Quality Modeling

Additional evaluation was completed through detailed water quality modeling of the return flow water quality impacts on Underwood Creek and additional evaluation of water quality data for Lake Michigan.

Underwood Creek Water Quality. Water quality modeling was conducted for the Underwood Creek return flow alternative (see Appendix H). Modeling included existing conditions in Underwood Creek with return flow concentration based on past performance and also a "worst case" scenario having higher flows and higher concentrations in the discharge that were still within permit limits proposed by the WDNR at that time. This modeling analysis was completed before obtaining the WDNR's revised lower effluent limits in February 2013 (Appendix A) for phosphorus, ammonia, and total suspended solids. The modeling was also completed using a maximum return flow rate of 12.9 mgd (20 cfs), which is slightly less than the maximum return flow rate of 16.7 mgd (25.8 cfs) proposed in the Application. These changes would improve water quality beyond that which was modeled, because the water quality in the return flow would be higher quality than that in Underwood Creek and the Menomonee River.

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. Phosphorus concentrations were predicted to increase and were

more frequently higher than the planning level goal used in the SEWRPC modeling (0.1 mg/L). However, after the modeling was completed, the WDNR proposed return flow effluent limits (Appendix A) that would require phosphorus concentrations to be better than or equal to the water quality standard of 0.075 mg/L. This would improve phosphorus concentrations in Underwood Creek and Menomonee River, because it is much lower than the modeled return flow concentrations and lower than average existing concentrations in the creek and river.

Lake Michigan Water Quality. Return flow to Underwood Creek 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 (SEWRPC, 2007a, 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 and then compared to the SEWRPC annual average load findings. Because this comparison was for loadings calculated under higher effluent limits for phosphorus and total suspended solids, the analysis overestimates impacts. Lesser impacts will be observed because of the more recent WDNR proposed effluent limits, as reported below (see Appendix M). The analysis with higher limits indicates the following:

- Fecal coliform contribution in the return flow under very conservative worst case conditions is only 0.18 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 0.19 percent of all total suspended solids loading from the greater Milwaukee watersheds.
- Phosphorus contribution in the return flow is only 0.35 percent of all phosphorus loading even under very conservative worst case conditions. Both Underwood Creek and the Root River now have a phosphorus water quality standard of 0.075 mg/L. The interim limit for direct discharge to Lake Michigan is 0.6 mg/L.

Based on data within the SEWRPC study (Section 3.1.6) and the above analysis, the return flow would protect and sustain the chemical integrity of Underwood Creek and the Menomonee River, and there would be no individual or cumulative significant adverse impacts to the Lake Michigan basin (Compact Article 4, Section 4.9(4)d and Wis. Stats. §281.346(4)(f)4m and §281.346(4)(f)5). For some parameters, such as fecal coliform, the return flow would allow Underwood Creek and the Menomonee River to meet their water quality standards more often and would result in an environmental benefit. The water quality standards and the TMDL are inherently protective of water quality in Underwood Creek and the Menomonee River. The City would provide return flow with water quality that meets effluent requirements derived from the TMDL and WDNR WPDES process.

3.1.8 Cost Estimate

An estimate was prepared for capital, operation and maintenance (O&M), and present worth costs to allow comparison of alternatives. The estimate used information available at the time of the estimate but 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 will vary from the estimates presented here. Exhibit 14 summarizes the screening-level cost estimate, based on return flow to Underwood Creek through a pump station at the City's WWTP, a pipeline, and an outfall to the creek. Appendix I contains additional cost estimate details.

EXHIBIT 14
Screening Level Cost Estimate for Return Flow to Underwood Creek
(Costs include savings for corridor sharing with a Milwaukee water supply pipeline)

Capital cost[a]	$58,059,000
Annual O&M cost	$288,000
20-Year present worth	$61,059,000
50-Year present worth	$63,059,000

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

3.2 Return Flow to 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. Return flow is proposed to enter the Root River in the middle reaches, just downstream of the confluence with the Root River Canal. The watershed size at the return flow location is 126.2 square miles (Exhibit 15).

EXHIBIT 15
Root River Near Return Flow Location (*spring flow, May 2013*)



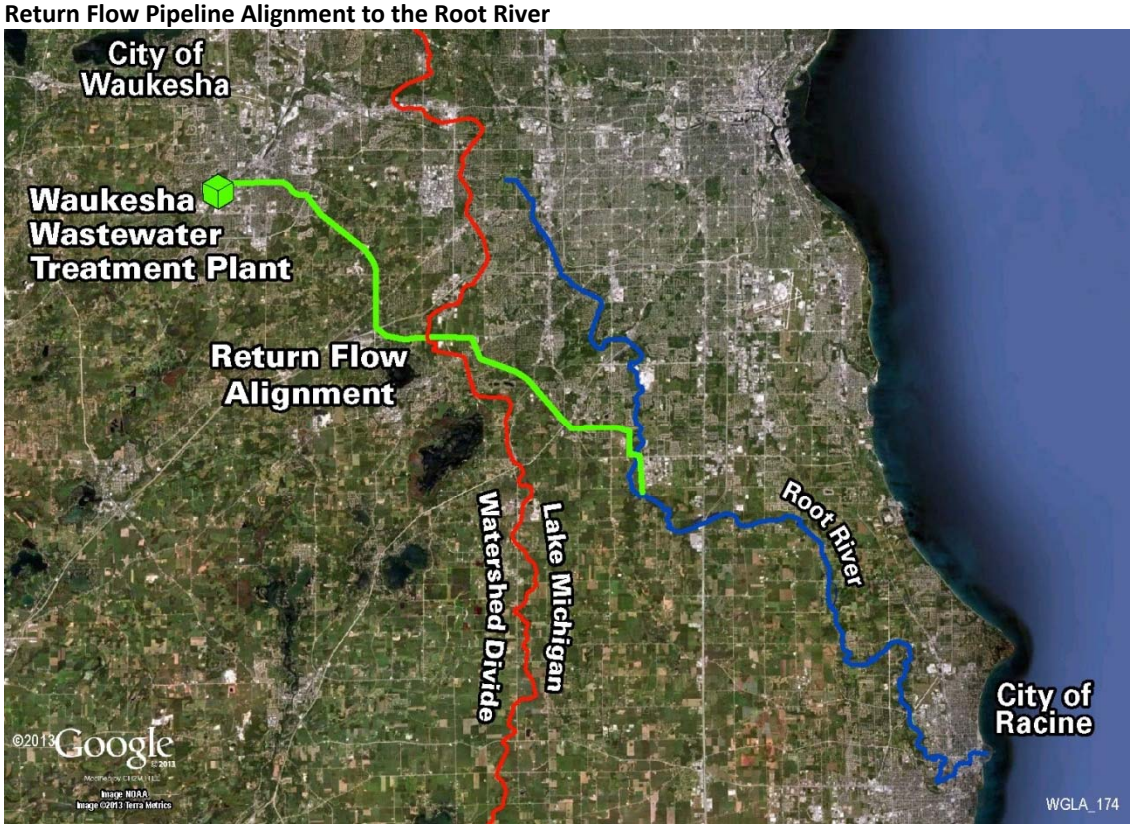
The conceptual pipeline alignment for return flow to the Root River is the same as the water supply pipeline from Oak Creek for most of its distance (refer to Volume 2, City of Waukesha Water Supply Service Area Plan). The length of the return flow pipeline is 20 miles (Exhibit 16). Leaving the WWTP, the first 3.5 miles of pipeline would follow urban streets to the southeast side of the City. From there, it would continue southeast an additional 8 miles following major roadway alignments through rural land use. The final 8.5 miles of pipeline would continue southeast through the City of Franklin, where the land use varies between medium and low density residential, agricultural and commercial land use. The entire proposed alignment follows previously disturbed areas such as roads and the City's WWTP grounds.

The outfall location for a Root River return flow would be farther downstream than the location previously considered by SEWRPC (SEWRPC, 2010a, Chapter 9, Map 115) and in the draft May 2010 Application because the return flow pipeline alignment would overlap with a water supply pipeline from Oak Creek (refer to Volume 2, City of Waukesha Water Supply Service Area Plan for water supply alignments). In addition, the City has executed an Option to Purchase (Appendix J) at the return flow location described herein so that for future permitting with the WDNR, it can complete its own permitting without a co-applicant, as was needed for an Underwood Creek return.

The return flow to the Root River alternative complies with Wis. Stat. § 281.346(4)(f)3m requirement that the place at which the water is returned to the source watershed be as close as practicable to the location of the water withdrawal because the Root River watershed is within the Lake Michigan source watershed and the location where the return flow enters Lake Michigan is close to the withdrawal location (regardless of whether the water supply is from Milwaukee, Oak Creek, or Racine). The Root River watershed includes parts of Milwaukee and Oak Creek, and most of the City of Racine. The river's confluence with Lake Michigan is within 10.5 miles of the Oak Creek withdrawal location and within 20 miles of the City of Milwaukee. The Root River watershed is also adjacent to the watersheds that include most of Milwaukee and Oak Creek.

EXHIBIT 16

Return Flow Pipeline Alignment to the Root River





3.2.1 Environmental Resources

Impacts to environmental resources were analyzed for the return flow pipeline corridor (refer to Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives). As with all return flow alternatives, a 75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare impacts between

alternatives. Exhibit 17 summarizes the impacts for some environmental resource types for the corridor to the Root River.[3]

EXHIBIT 17
Potential Environmental Impacts for a Root River Return Flow

Resource Type	Potential Temporary Impact of Pipeline Corridor
Stream and water body crossings	4
Water body crossings	0.30 acre
Wetlands	< 1 acre

The Root River alignment has slightly more environmental impacts for some parameters than does the Underwood Creek alignment, primarily because the Root River alignment is longer. However, the impacts are small (e.g. 0.30 acres of water body crossings) because the Root River alignment would follow corridors that are already disturbed through existing roadway developments and it avoids such environmental resources as wetlands and stream crossings as much as possible. The impacts would be temporary and because they would be associated with the pipeline construction. There will be no short-term or long-term significant adverse impacts.

The return flow *discharge* would not adversely affect the environmental resources along the pipeline corridor. Instead, the discharge was analyzed separately (below) for its impact on resources within the Root River and Lake Michigan. The Environmental Report (refer to Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives) contains a detailed evaluation.

3.2.2 Flow, Geomorphology, and Habitat

SEWRPC is developing a Root River Watershed Restoration Plan (SEWRPC, 2013) that expands on the recommendations developed through previous SEWRPC planning efforts, including *A Comprehensive Plan for the Root River Watershed* (Planning Report No. 9), *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000* (Planning Report No. 30), *Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds* (Technical Report No. 39), and *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (Planning Report No. 50). These reports have identified the need for improved habitat in the Root River, and some recommend flow augmentation to alleviate low flow conditions that adversely affect the river.

The MMSD completed a comprehensive study of the Root River in 2007 within its service area in Milwaukee County. The purpose of the study was to baseline the channel stability in the North Branch of the river and to provide hydrologic, hydraulic, and sediment transport predictions on the vertical and lateral stability of the river and tributary channels (MMSD, 2007b, Executive Summary). The study area included the watershed immediately upstream of where return flow is proposed.

The results of the MMSD and SEWRPC studies were used, in part, to evaluate the effect of a return flow discharge on the flow, geomorphology, and habitat within the Root River. The Root River has well vegetated river banks and a natural channel bottom for nearly all of its length. There are no concrete-lined parts of the Root River like there is on Underwood Creek and the Root River downstream of the proposed return flow location 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. Similarly 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. Flow change from return flow was evaluated at two locations along the Root River to understand the potential base flow benefits from return flow (Appendix K). One location is at the proposed the Root River return flow outfall and the other is about 150 feet downstream of the Root River Steelhead Facility, a WDNR egg harvesting and spawning facility in the City of Racine that is about 3.8 river miles upstream from Lake Michigan.

Flow rates developed by MMSD upstream of the return flow location and by USGS upstream of the Steelhead Facility were used to evaluate the return flow effects on river flow (Appendix K). At low flow conditions, the

[3] The impacts summarized are for the return flow pipeline alignment only. Some of the impacts summarized here are shared with the water supply pipeline alignments. For simplicity in evaluating the return flow alternatives, only the impacts of the return flow pipelines are summarized. For comparison of environmental impacts of complete combinations of water supply and return flow system alternatives, see the Environmental Report in Volume 5 of the Application.

average return flow of 18 cfs (11.7 mgd) would increase the water depth and the average velocity at these two locations between 0.51 to 0.66 foot and 0.30 and 0.24 foot per second, respectively. The increase in water depth in well within the low flow river bank and the increases in velocity are insignificant. The maximum return flow of 25.8 cfs (16.7 mgd) is about 2.5 percent of the 2-year return period river flow in the reach upstream of the return flow location and 1.34 percent upstream of the Steelhead Facility. For a 100-year return period river flow, the maximum return flow is 0.54 percent upstream of the return flow location and 0.44 percent upstream of the Steelhead Facility.

Return flow to the Root River would not adversely affect the river during low flows. Instead, it would provide a benefit to the water dependent resources through greater available habitat with additional flow, water depth, wetted area within the river. The increased flow would not adversely impact the geomorphic stability of the river because similarly to Underwood Creek, the changes would be small. 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. Consequently, the return flow will not adversely impact the physical integrity of the Root River.

Beneficial habitat effects in the Root River from the additional flow would include more functional habitat through reduced embeddedness and increased wetted area of in-stream habitat. Because the Root River is longer and has more natural channel (as compared to the concrete-lined channel in Underwood Creek) downstream of the return flow location, a return flow to the Root River would have more habitat benefits than the Underwood Creek alternative.

Return Flow Effect in 2005 and 2008. Return flow was simulated for 2005 and 2008 to demonstrate how return flow would have affected the Root River and the Fox River flow rates during a dry year (2005) and a wet year (2008) in the recent past (Appendix E). The simulated return flow to the Root River and the associated reduction of flow to the Fox River is different in 2005 and 2008. Flow in the Root River noticeably increased in 2005 during low flow periods June through October. Root River flow without return flow was often less than 5 cfs, which is much less than other times of that year or during low flow times in 2008. The return flow eliminated these very low flow periods with a relatively uniform return flow rate. In 2008, base flow in the Root River was also increased but was less noticeable. In both 2005 and 2008, return flow was not significant when river flows were above base flow because the return flow is a small percentage of river flow.

Average daily flow in the Fox River was reduced by an amount equal to the return flow rate. The reduction was more noticeable in 2005 than in 2008, but the average reduction was about 23 percent. During wet year 2008, the average difference in the hydrographs of the Fox River with and without return flow was about 12 percent. In both 2005 and 2008, the absence of flow from the WWTP was not significant when river flows were above base flow because the return flow is less than 5 percent river flow.

Diurnal Return Flow Effects. Hourly WWTP flow data and USGS 15-minute flow data from 2005 were used to simulate flow rates in the Root River to evaluate the effect that diurnal return flows from the WWTP would have on the variability of the creek flows (Appendix F). The year 2005 was chosen because it was a recent dry year when return flow would have a greater influence on flow rates in the receiving water. The diurnal variations in the return flow to the Root River are very small and significantly lower than the existing daily flow fluctuations within the Root River. The diurnal fluctuations of return flow in the river are significantly less than that experienced during a runoff event, where a runoff event can be several orders of magnitude greater than the diurnal fluctuation of return flow. For example, during the moderately high flow event on June 6, 2008, the river flow increased from 54.3 to 253.7 cfs in 6 hours. In comparison, the return flow maximum diurnal fluctuation in 2005 was 18.9 cfs.

The diurnal flow variation from return flow will not have a significant impact on the river. Even when accounting for the return flow rates' diurnal variations, return flow to the Root River would benefit water dependent resources in the river by creating additional habitat during all low flow conditions.

Return Flow Effects on Flashiness. Flashiness is the frequency and rapidity of short term changes in stream flow (Baker et. al., 2004). The flashiness index was calculated with and without return flow for the Root River and the Fox River for 2005 and 2008 (Appendix G). The simulations were completed to determine the effect that return

flow has on the index. The flashiness index is lower for the Root River when a Lake Michigan supply with return flow is compared to the river flow without return flow. This is because the return flow adds base flow but has an insignificant impact to peak storm runoff events. The flashiness index slightly increases for the Fox River because WWTP flow that historically discharged to the Fox River would instead discharge to the Root River through return flow.

The reduction in flashiness index for the Root River would have a beneficial effect on the aquatic resources in the river because of the improvement in base flow, which, as noted, has benefits to the aquatic resources similar to those for Underwood Creek (Appendix D). The change in flashiness index for the Fox River would have a negligible effect on aquatic resources because the change is very small and the proposed return flow management plan would not adversely affect the rate at which peak flow in the river occurs compared to existing conditions.

Based on the above analysis for flow, geomorphology and habitat, the physical integrity of the Root River would be protected and sustained as required by Compact Article 4, Section 4.9(4)d and Wis. Stats. §281.346(4)(f)4m and §281.346(4)(f)5.

3.2.3 Flow Augmentation

In 1964, the Root River watershed had 9 major sources of wastewater (SEWRPC, 1966, Table 12, page 60) that contributed a combined total of about 3.7 mgd average annual flow to the river. River flows fluctuated seasonally and with precipitation events, but low flows in the upper reaches of the river system consisted almost entirely of wastewater effluent (SEWRPC, 1966, page 65). During some periods, the entire Root River flow in the upper reaches flow was wastewater effluent. By 1975, 16 municipal and private wastewater treatment plants (SEWRPC, 1979, Volume 1, Table 37, page 304) had the ability to discharge a combined annual average flow to the Root River watershed of about 2.9 mgd (SEWRPC, 1979, Volume 1, Tables 119–120). After that time, the number of dischargers decreased as facilities closed and wastewater treatment operations were consolidated. The 1979 plan recommended that all public wastewater treatment plants be connected to MMSD. That was completed by 1985. The plan also recommended abandoning six private wastewater treatment plants, and that was completed by 1990 (SEWRPC, 2007b, page 771). By 2004, only three wastewater treatment facilities were permitted for discharge in the Root River watershed (SEWRPC, 2007b, Table 169, page 776).

As first documented throughout the 1966 Comprehensive Plan for the Root River Watershed, flow augmentation was needed in the Root River even with the wastewater discharges that were present at that time. Low-flow conditions in the Root River were enough of a concern that flow augmentation through reservoir storage in a 660-acre Oakwood Lake reservoir, use of Lake Michigan water, and groundwater pumping was conceptually explored by SEWRPC (SEWRPC, 1966, page 188). The need for low-flow augmentation and the multiple benefits associated with it was reaffirmed in the 1979 Regional Water Quality Management Plan because the Root River was observed to be adversely affected by low flows, and regional consolidation of WWTP discharges would further necessitate flow augmentation (SEWRPC, 1979, Volume 3, page 133).

In 1994, the WDNR constructed the Root River Steelhead Facility to support egg collection, fisheries stocking, spawning, hatchery, and fish monitoring operations in Lake Michigan and its tributaries. In peak years, the facility monitors more than 10,000 salmonids that provide angling opportunities that exceed more than 100,000 angling hours in Racine (Appendix L). However, the operation of the facility and public angling opportunities are greatly diminished with the current low flows observed in the Root River.

The Steelhead Facility is one of only three egg collection and spawning facilities in Wisconsin. It is Wisconsin's primary source of steelhead eggs and brood (parent) stock, and it is the backup facility for the egg collection of brown trout and Coho and Chinook salmon. Because successful natural reproduction of trout and salmon does not occur, the fishery is entirely dependent upon hatchery-raised fish (Exhibit 18) (WDNR, 07/17/2013). Fall fish migration and egg collection at the Steelhead Facility coincides with the lowest monthly flows of the year in the Root River (Exhibit 19). This has significant impact on the WDNR’s ability to meet egg collection goals and Great Lakes stocking quotas because sufficient numbers of fish are not able to reach the facility (WDNR, 2013c).

At the WDNR Strawberry Creek Spawning Facility along Lake Michigan (Exhibit 18), the facility was affected by inadequate flows that would not adequately support egg collection and spawning activities. As a result, the WDNR pumps water from the Sturgeon Bay ship canal (i.e. Lake Michigan) to augment flow in Strawberry Creek. The WDNR has considered augmenting the flow in the Root River with Lake Michigan water, but construction and energy costs were prohibitive (Appendix L). Augmenting flow in the Root River with return flow could eliminate reported low flow conditions, it would improve the operation of the Steelhead Facility, and it would improve angling opportunities in the Root River and Lake Michigan (Appendix L). The return flow and augmented flow would increase fishing opportunities in the river and support the $2.75 billion in economic impact, the 30,000 jobs, and the $196 million in local and state tax revenue that fishing provided throughout Wisconsin in 2009. Improved flow conditions will also support the 3.7 million days that Wisconsin anglers spent fishing the Great Lakes (WDNR, 2011a). This flow augmentation concept is similar to the Ypsilanti Community Utilities Authority in southeast Michigan, which uses wastewater effluent as an environmental resource (as with the Underwood Creek return flow alternative).

EXHIBIT 18

The Root River Steelhead Facility Has an Important Role in Sustaining a Healthy Fishery in Lake Michigan

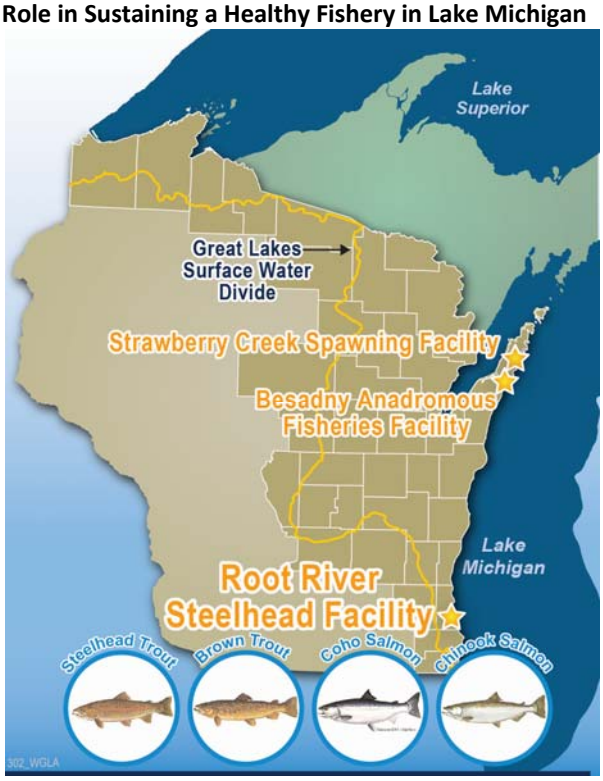
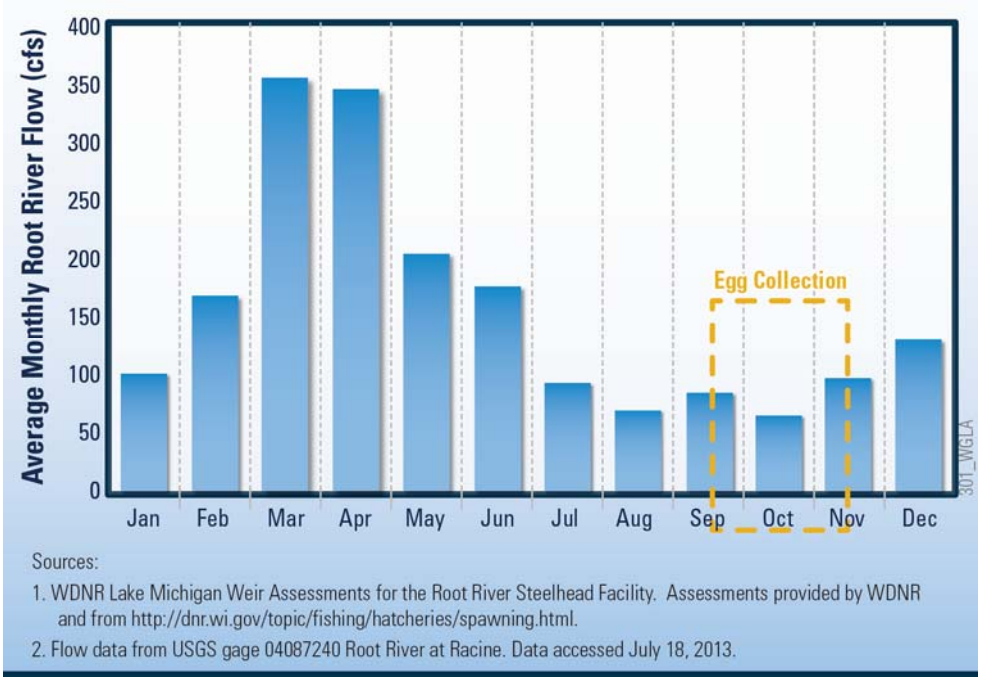


EXHIBIT 19

The Root River Flow Is Lowest When Egg Collection and Spawning Occur at the Root River Facility

(River Flow Data from September 1963 through September 2012)



3.2.4 Fisheries

According to fishery data for the Root River watershed, 10 new species have been identified, but 10 of 64 recorded species have not been observed since 1986 (SEWRPC, 2007a, pp. 200–14).[4] Fishery surveys conducted by the USGS in 2004 and 2007 identified 17 species in the Root River near the proposed return flow location. Some 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 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.

Biological indices have been developed for three stream reaches along the Root River (WDNR, 2012e). The indices use benthic macroinvertebrates and fish as indicators of the water quality and physical conditions within the stream. The MIBI (benthic macroinvertebrate index) and IBI (fish index) were developed within three stream reaches of the Root River. In general the MIBI and IBI for the lower reach of the Root River (river miles 0 to 5.82) suggests fair to good water quality and physical habitat condition. The middle reach (river miles 5.82 to 20.48) ranges from poor to good, with most of the data suggesting fair conditions. The upper reach (river miles 20.48 to 43.95) also ranges from poor to good). The data suggest some limitation in water quality or physical habitat in the middle and upper reaches.

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, conditions could be improved by providing more or higher quality habitat. Under current low flow conditions biological communities are limited in several reaches of the Root River. As noted, flow augmentation has been discussed by WDNR and SEWRPC for several years along the Root River as a means to improve the fisheries ecological function of the river. Based on the fisheries and macroinvertebrate data reported by the WDNR, an increase in flow may improve these conditions and promote a more diverse community structure by improving water quality and expanding available habitat. Based on the above analysis, the biological integrity of the Root River will be protected and sustained with the return flow.

As with an Underwood Creek return flow alternative, a Root River return flow would result in a maximum loss of water depth in the Fox River of about 2 inches or less during dry weather. These depth changes would have a minor impact on the Fox River fisheries, and the biological integrity of the Fox River would be protected and sustained with the return flow to Lake Michigan.

3.2.5 Flooding

Return flow to the Root River would be small compared to the 100-year return period flood flows. For a 100-year return period river flow, the maximum return flow is 0.54 percent upstream of the return flow location and 0.44 percent upstream of the Steelhead Facility (Appendix K). This equates to a water depth change of 0.02 foot at each location, or a change between 0.14 and 0.17 percent of the water depth. Return flow is also very small compared to more frequent events like the 10-year return period flow—between 0.05 and 0.03 foot water depth change.

3.2.6 Return Flow Water Quality

Water quality permit limits proposed by the WDNR for the Root River differ from those for Underwood Creek by only 0.1 mg/L for BOD and ammonia (Appendix A). These differences are insignificant, and so the same high quality return flow would occur to the Root River as that for Underwood Creek.

[4] Data compilation from MMSD, USGS, and WDNR.

Chlorides. Compliance with chloride limits for a Root River return flow is achievable and the same as for an Underwood Creek return flow.

Temperature. A preliminary thermal analysis of the City's return flow discharge to the Root River was completed to identify one or more methods by which to comply with the WDNR thermal regulations in NR 102 and NR 106 (Appendix A). The City's return flow would not be "hot" and thus not pose an acute thermal threat to aquatic life. Rather, like many WWTPs in Wisconsin, the return flow temperature would be warmer than the ambient Root River temperature in late fall and winter, with the highest measured WWTP effluent temperatures ranging from 51 to 70 degrees Fahrenheit (October through January). The WDNR thermal sublethal standards during those periods can be triggered by typical municipal wastewater effluent.

The analysis compares the physical riverine characteristics of the current WWTP Fox River discharge to that of the Root River return flow location. Preliminary indications are that natural mixing of the discharge within the Fox River would meet the thermal requirements, and would therefore satisfactorily meet the thermal discharge requirements to the Root River.

The analysis concludes that several options exist to meet the thermal requirements:

- Thermal mixing analysis of the Root River
- Using site-specific ambient temperatures to establish thermal limits
- Management techniques to lower the return flow temperature before discharge
- Combinations of the above techniques

There are several options for the Root River return flow to achieve WDNR thermal rule compliance. Return flow as it relates to thermal discharge can reasonably protect the chemical, physical, and biological integrity of the Root River. A successful Application would trigger more detailed data gathering and analysis for thermal and other water quality requirements for a Root River discharge permit.

3.2.7 Root River Water Quality

The Root River is classified 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 (Clean Water Act section 303(d), 33 U.S.C. § 1313(d)) for low dissolved oxygen with reported causes from sediment and phosphorus (WDNR, 2012b). In addition, the last 6 or so miles of the Root River upstream of Lake Michigan is on the 303(d) list for PCBs. Listings were first made in 1998 and are included on the proposed 2012 impaired waters list.

SEWRPC modeled water quality in the Root River in great detail (SEWRPC, 2007a). The water quality findings for SEWRPC's existing condition scenario are summarized below for three points near the proposed return flow location.

Fecal Coliform. The Root River meets fecal coliform single sample standards during the summer recreational season 58 to 66 percent of the time. The geometric mean fecal coliform concentration for summer ranges from 603 to 770 cells/100 mL (SEWRPC, 2007a). The historical performance at the City's WWTP for the summer recreation season (May through October) had geometric mean fecal coliform concentrations ranging from 2 to 49 cells/100 mL. Because the return flow fecal coliform concentration is much lower than those of 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's 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. This improvement will move the Root River towards delisting from the 303(d) impaired waters list.

Total Phosphorus. The Root River meets the SEWRPC planning level goal of 0.1 mg/L 73 to 84 percent of the time but less so for the water quality standard of 0.075 mg/L. However, similar to Underwood Creek, the City's

discharge would be below the receiving water quality criterion of 0.075 mg/L and therefore would improve phosphorus concentrations in the Root River. This improvement would move the Root River towards delisting from the 303(d) impaired waters list.

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's 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 the Root River as a result of return flow. This improvement would move the Root River towards delisting from the 303(d) impaired waters list.

Lake Michigan. Root River return flow ultimately reaches Lake Michigan. The comparison of the return flow water quality loading to that of the greater Milwaukee watersheds is the same as that for the Underwood Creek alternative. The return flow would contribute less than 1 percent of the annual load to Lake Michigan from the great Milwaukee watersheds for phosphorus, TSS, and bacteria.

3.2.8 Return Flow Water Quality Modeling

Additional evaluation was completed through detailed water quality modeling of the return flow to the Root River (Appendix M). A watershed water quality model developed by SEWRPC was obtained and updated to include a new point source for return flow. The updated model was used to simulate the SEWRPC existing condition and preferred alternative (recommended plan) scenarios and to include a discharge from the WWTP. The return flow characteristics were set to either represent average historical operating conditions (the expected discharge condition) based upon October 2002 through August 2009 data or to represent a conservative scenario based on higher flow rates and permit limit conditions (maximum potential discharge condition).

The water quality modeling found that average water quality would improve or continue to meet water quality standards or background reference concentrations for all water quality parameters. This includes fecal coliform, dissolved oxygen, total phosphorus and total suspended solids. Modeling results also indicate that with return flow, nuisance algae growth would decrease in the Root River.

The return flow would meet all state and federal water quality limits and exceed the limits for other Lake Michigan direct or tributary dischargers. Therefore, return flow to the Root River would protect water quality in the river. For some parameters such as phosphorus, the return flow to the Root River would improve water quality in the river because the return flow water quality will be better than that of the river. As a result, return flow will result in no significant adverse individual or cumulative impacts on the quality of the waters and water-dependent natural resources of the Great Lakes basin (Compact Article 4, Section 4.9(4)d and Wis. Stats. §281.346(4)(f)4m and §281.346(4)(f)5). Returning flow through the Root River will protect, sustain, and improve the chemical integrity of the Root River.

3.2.9 Cost Estimate

Exhibit 20 summarizes the screening-level cost estimate for this alternative. The costs are based on return flow to the Root River through a pump station at the City's WWTP, a pipeline, and an outfall to the river. Appendix I contains additional information.

EXHIBIT 20
Screening Level Cost Estimate for Return Flow to the Root River
(Costs include savings for corridor sharing with a City of Oak Creek water supply pipeline)

Capital cost[a]	$96,038,000
Annual O&M cost	$618,000
20-Year present worth	$103,038,000
50-Year present worth	$106,038,000

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

3.3 Return Flow Directly to Lake Michigan near Milwaukee and Oak Creek

The City of Waukesha developed a screening-level alignment to evaluate the environmental effects and costs of return flow directly to Lake Michigan near Milwaukee and Oak Creek (Exhibit 21). The conceptual pipeline alignment is the same as that for Underwood Creek 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

EXHIBIT 21

Return Flow Pipeline Alignment Direct to Lake Michigan near Milwaukee and Oak Creek



nears Lake Michigan, it continues east about 1.2 miles along a city street and then extends into Lake Michigan about 0.5 mile to provide an offshore outfall.

The alignment is similar to that developed by SEWRPC, except the last segment of pipe 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, but it has greater implementation challenges than the Underwood Creek and Root River return flow alternatives because it is longer, within a railroad corridor and industrial development for about 11.2 miles, and crosses multiple political jurisdictions, and the outfall located 0.5 mile offshore.

This alternative complies with the Wis. Stat. §281.346(4)(f)3m requirement that the place at which the water is returned to the source watershed be as close as practicable to the withdrawal because the return flow is direct to Lake Michigan at a location where the return flow enters Lake Michigan close to the withdrawal location, regardless of whether the water supply is from Milwaukee or Oak Creek. The return flow enters Lake Michigan within 3 miles of Milwaukee and 6 miles of Oak Creek.

3.3.1 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 would affect these resources temporarily because of construction associated with building the pipeline. A minor adverse impact may occur where the outfall is constructed within Lake Michigan for an offshore discharge.

EXHIBIT 22

Summary of Potential Environmental Impacts for Return Flow Direct to Lake Michigan near Milwaukee and Oak Creek

Resource Type	Potential Impact of Pipeline Corridor
Stream and water body crossings	9
Water body crossings	6.5 acres
Wetlands	5 acres

The impacts to environmental resources were analyzed for the return flow pipeline corridor (see detailed evaluation in Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives). The alignment has greater environmental impacts than the Underwood Creek and Root River return flow alternatives, primarily because it is much longer and includes construction of 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 22 summarizes the environmental impacts for some of the resource types evaluated in the Environmental Report along the return flow corridor.[5]

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

3.3.2 Flow, Geomorphology, and Habitat

As with the Underwood Creek and Root River alternatives, return flow directly to Lake Michigan would not have significant adverse impact on flow, geomorphology, or habitat in the lake. For discharges to Underwood Creek or the Root River, the return flow would 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 body whereby the additional flow could benefit water dependent natural resources in a Lake Michigan tributary. Consequently, return flow directly to Lake Michigan is not preferred as compared to return flow to a tributary that could benefit from flow augmentation.

Impacts to the Fox River would be the same as described in the Underwood Creek and Root River alternatives, because the return flow plan impacts to the Fox River are the same for all return flow alternatives.

3.3.3 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 would meet water quality standards. Consequently, there would be no significant adverse impact on Lake Michigan fisheries. Impacts to the Fox River fisheries are the same as described in the Underwood Creek and Root River alternatives, because the return flow management plan impacts to the Fox River are the same for all alternatives.

3.3.4 Flooding

The return flow would not have an impact on flooding because the discharge would be directly to Lake Michigan.

3.3.5 Water Quality

Under all return flow alternatives, flow is returned to Lake Michigan. The water quality loading for a direct to Lake Michigan alternative has been assumed to be the same as that summarized in the Underwood Creek and Root River alternatives. Due to the greater mixing available for a direct to Lake Michigan return flow (Appendix A), higher annual water quality limits for some parameters would be protective of the environment. It is estimated that the return flow would contribute less than 1 percent of the annual load of phosphorus, TSS, and bacteria from the greater Milwaukee watersheds to Lake Michigan.

3.3.6 Cost Estimate

Exhibit 23 summarizes the screening-level cost estimate for this alternative. Costs are based on return flow to Lake Michigan through a pump station at the City's WWTP, a pipeline, and an outfall to the lake. Appendix I contains additional information.

EXHIBIT 23
Screening Level Cost Estimate for Return Flow to Lake Michigan near Milwaukee and Oak Creek

Capital cost[a]	$117,247,000
Annual O&M cost	$423,000
20-Year present worth	$122,247,000
50-Year present worth	$124,247,000

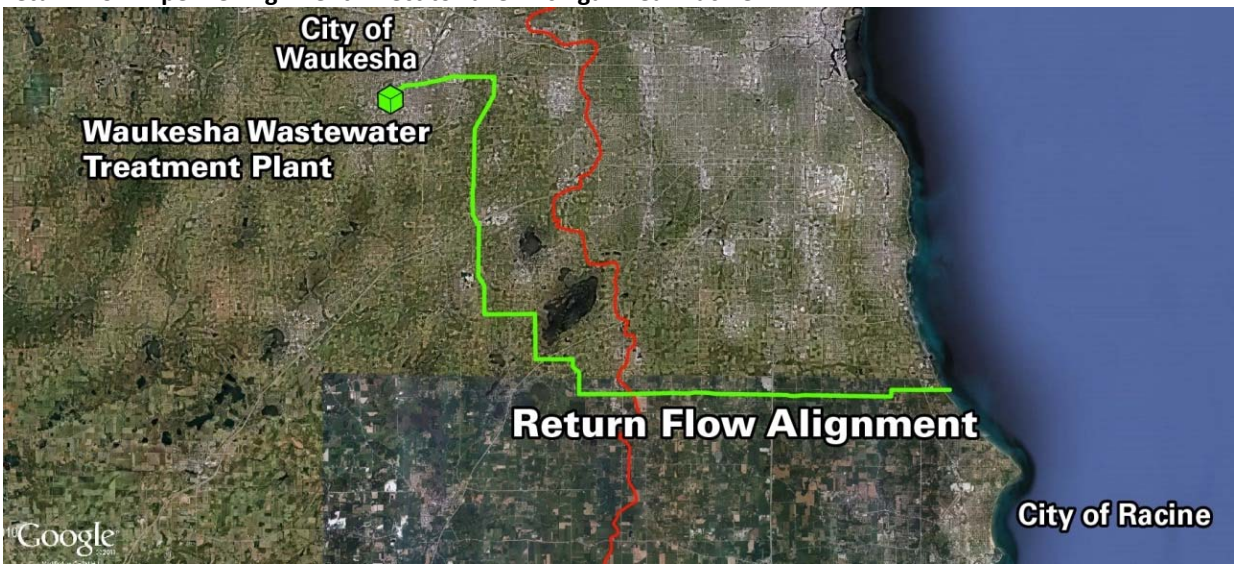
[a]Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision, etc.), 25% contingency, and costs for permitting, legal, engineering, administrative.

[5] Impacts are for the return flow pipeline alignment only. Some impacts discussed here are shared with water supply pipeline alignments. For simplicity in comparing return flow alternatives, only the impacts from return flow pipelines are discussed here. For comparison of environmental impacts of complete combinations of water supply and return flow system alternatives, see Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives.

3.4 Return Flow Directly to Lake Michigan near Racine

The City developed a screening-level alignment to evaluate the environmental effects and costs of a return flow directly to Lake Michigan near Racine (Exhibit 24). The conceptual pipeline alignment is the same as that for Underwood Creek for about the first 4.4 miles, after which the Lake Michigan near Racine alignment proceeds south following the same alignment as the Racine water supply alignment. The Racine water supply and Lake Michigan return alignments share a corridor for about 28 miles. In the eastern 4 miles of the shared corridor, the water supply and return flow alignments diverge, and the proposed water supply line continues south to connect with the Racine distribution system and the return flow alignment continues east toward Lake Michigan. The 4-mile return flow alignment was chosen because it allowed the discharge location to be near the City of Racine (within about 6.5 miles of the water treatment plant), and the alignment could follow a utility corridor and previously disturbed open space at the Lake Michigan shoreline. Sharing a corridor between the water supply and return flow alignments will minimize cost, construction, and environmental impacts for this alternative. The corridor follows previously disturbed lands that include agriculture, utility corridors, roads and recreational paths. As with the Lake Michigan near Milwaukee and Oak Creek return flow alternative, this alignment extends into Lake Michigan about 0.5 mile to provide an offshore outfall.

EXHIBIT 24
Return Flow Pipeline Alignment Direct to Lake Michigan near Racine



This alternative complies with the Wis. Stat. § 281.346(4)(f)3m requirement that the place at which the water is returned to the source watershed be as close as practicable to the withdrawal location because the return flow is direct to Lake Michigan at a location close to the withdrawal location at the City of Racine. The return flow enters Lake Michigan within 7 miles of the City of Racine.

3.4.1 Environmental Resources

Similar to the Underwood Creek, Root River, and Direct to Lake Michigan near the Milwaukee and Oak Creek alignments, this alignment follows previously disturbed corridors and avoids wetlands, stream crossings, and similar environmental resources land uses as much as possible. Some areas of the alignment would temporarily affect these resources because of constructing the pipeline. A minor adverse impact may occur where the outfall is constructed within Lake Michigan for an offshore discharge.

The environmental impacts associated with the direct to Lake Michigan near Racine return flow alignment would be similar to those reported for the Racine water supply alignment due to shared corridors for most of the alignment (see Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives). The alignment has greater environmental impacts than the other three return flow alignments, primarily, because it is much longer and includes construction of an outfall within Lake Michigan. As with the other return flow alternatives, a

75-foot-wide corridor was used along the centerline of the pipeline alignment to assess and compare impacts between alternatives. Exhibit 25 summarizes some environmental impacts along the water supply alignment corridor, which is used as a surrogate for the return flow alignment because the two corridors are very similar.[6]

The return flow *discharge* would not adversely impact the environmental resources along the pipeline corridor. Instead, a direct discharge was analyzed (below) for the potential impacts on Lake Michigan resources.

EXHIBIT 25
Summary of Potential Environmental Impacts for Return Flow Direct to Lake Michigan near Racine

Resource Type	Potential Impact of Pipeline Corridor
Stream and water body crossings	16
Water body crossings	4.7 acres
Wetlands	52 acres

Note: Impacts are for Racine water supply pipeline alignment. See footnote in text.

3.4.2 Flow, Geomorphology, and Habitat

As with the Underwood Creek, Root River and Direct to Lake Michigan near Milwaukee and Oak Creek return flow alternatives, return flow directly to Lake Michigan near Racine does not cause significant adverse impacts to the flow, geomorphology, or habitat in the lake. For discharges to Underwood Creek or the Root River, the return flow would able to provide a resource benefit by providing additional flow in the creek or river during periods when little or no flow is naturally present. The return flow to a Lake Michigan tributary could benefit habitats through flow augmentation without adversely affecting geomorphic stability. Return flow directly to Lake Michigan, however, would have no environmental benefit because the return flow would be conveyed in a pipe, instead of through a surface water body, where the additional flow could benefit the water dependent natural resources. Consequently, return flow directly to Lake Michigan is least preferred, compared to return flow to a tributary that could benefit from flow augmentation.

Impacts to the Fox River would be the same as those under the Underwood Creek and Root River alternatives, because the return flow management plan is the same among alternatives for impacts to the Fox River.

3.4.3 Fisheries

As with return flow directly to Lake Michigan near Milwaukee and Oak Creek, return flow directly to Lake Michigan near Racine would not have a significant adverse impact on 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 would be no significant adverse impact on Lake Michigan fisheries. Impacts on the Fox River would be the same as those under the Underwood Creek and Root River alternatives, because the impacts of return flow plan on the Fox River are the same for other alternatives.

3.4.4 Flooding

The return flow would not impact flooding because the discharge is directly to Lake Michigan.

3.4.5 Water Quality

Under all return flow alternatives, flow is returned to Lake Michigan. The water quality loading for a direct to Lake Michigan alternative has been assumed to be the same as that summarized in the Underwood Creek and Root River alternatives. Because of the greater mixing available for a direct to Lake Michigan return flow (Appendix A), higher annual water quality limits for some parameters would be protective of the environment. It is estimated that the return flow would contribute less than 1 percent of the annual load of phosphorus, TSS, and bacteria from the greater Milwaukee watersheds to Lake Michigan.

[6] Most of the impacts summarized are shared between the Racine water supply and Lake Michigan near Racine return flow pipeline alignments. The impacts summarized are for the water supply pipeline alignment, used as a surrogate for the return flow alignment. For simplicity in evaluating return flow alternatives against each other, only the impacts from return flow pipelines are summarized here. For comparison of environmental impacts of complete combinations of water supply and return flow system alternatives, see Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives.

3.4.6 Cost Estimate

Exhibit 26 summarizes the screening-level cost estimate for this alternative. Costs are based on return flow to Lake Michigan through a pump station at the City of Waukesha WWTP, a pipeline, a lift station at about the midpoint along the pipeline, and an outfall to the lake. The cost estimate includes cost savings for a shared corridor between the Racine water supply and return flow pipelines, and includes about 37 miles of 30-inch pipe. Appendix I contains additional information.

EXHIBIT 26

Screening Level Cost Estimate for Return Flow Direct to Lake Michigan near Racine

(Costs include savings for corridor sharing with Racine water supply pipeline)

Capital cost[a]	$166,708,000
Annual O&M cost	$947,000
20-Year present worth	$177,570,000
50-Year present worth	$181,634,000

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

3.5 Return Flow through the Milwaukee Metropolitan Sewerage District

The MMSD operates regional sewage collection and water reclamation systems for most communities in the Milwaukee metropolitan area within the Lake Michigan Basin. Under this return flow alternative, the City's 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. One method of returning flow through MMSD would be to continue to use the City's WWTP with return flow of treated water to MMSD, but this would amount to "treating" the return flow twice, roughly doubling treatment costs, energy use, and greenhouse gas emissions with no significant improvement in return flow water quality. As a result, this method was not evaluated in detail, and instead the alternative consists of abandoning the City's WWTP and providing treatment at MMSD.

SEWRPC evaluated return flow to MMSD as part of the Regional Water Supply Plan for Southeastern Wisconsin (SEWRPC, 2010a, Chapter 9, page 631). The analysis was based in part on an earlier evaluation completed by SEWRPC during the Regional Water Quality Management Plan Update (SEWRPC 2007a). Return flow to MMSD was retired from further consideration because it was significantly more costly than other return flow alternatives.

The City conducted economic analyses of three additional alternatives that included demolishing the WWTP for raw sewage return to MMSD. (Appendix A contains a detailed evaluation of this alternative.) Greater risk and potential public health impacts would be related to pumping raw wastewater as opposed to fully treated wastewater, so the City performed a screening-level analysis consistent with the other return flow alternatives. The MMSD treatment facilities have sufficient capacity for return flow during dry weather, but they are capacity limited in wet weather. Therefore, the City identified alternatives to providing wet weather equalization storage or additional treatment capacity at MMSD's South Shore Water Reclamation Facility. Previous MMSD and SEWRPC studies have identified South Shore as the facility at which to expand wet weather treatment capacity. The three alternatives shown in Exhibit 27 are:

- MMSD Alternative 1: Wet Weather Equalization and Pipeline to MMSD South Shore
- MMSD Alternative 2: Wet Weather Equalization and Pipeline to MMSD Interceptor near Greenfield Park Pump Station
- MMSD Alternative 3: Pipeline to MMSD South Shore and Biological High-Rate Treatment Facility at South Shore

Under each MMSD return flow alternative, the Waukesha WWTP would be decommissioned, and a new raw sewage pump station and pipeline would be constructed to convey flow to MMSD. The alternatives and their engineering features are summarized below; see also Appendix A.

3.5.1 MMSD Alternative 1

MMSD Alternative 1 assumes that new infrastructure is needed for wet weather equalization and for conveying dry and wet weather flow to South Shore. During wet weather, return flow would be stored in an underground

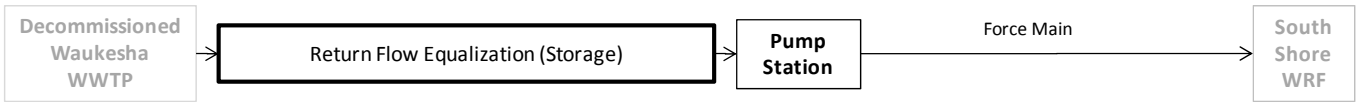
tunnel until sufficient treatment capacity were available at South Shore. Exhibit 28 shows the conceptual alignment of the storage tunnel and force main between the Waukesha WWTP and South Shore.

EXHIBIT 27

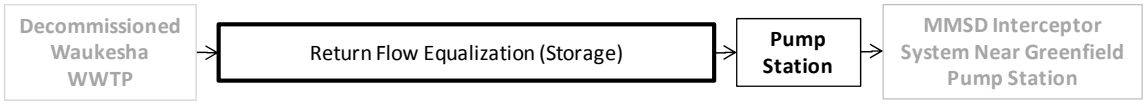
Alternatives for Return Flow to MMSD

(grey text is existing infrastructure; black text is new infrastructure)

MMSD Alternative 1: Wet Weather Equalization and New Pipeline to South Shore



MMSD Alternative 2: Wet Weather Equalization and Discharge to MMSD near Greenfield Pump Station

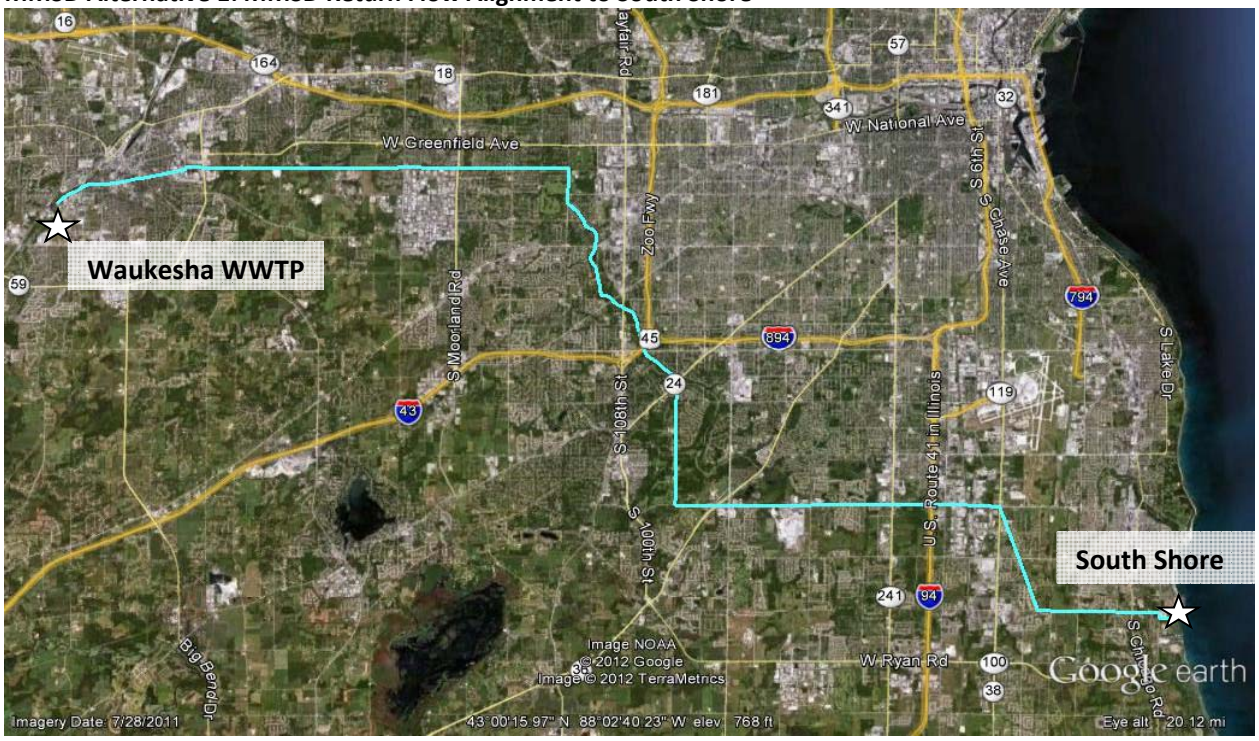


MMSD Alternative 3: Biological High Rate Treatment and New Pipeline to South Shore



EXHIBIT 28

MMSD Alternative 1: MMSD Return Flow Alignment to South Shore

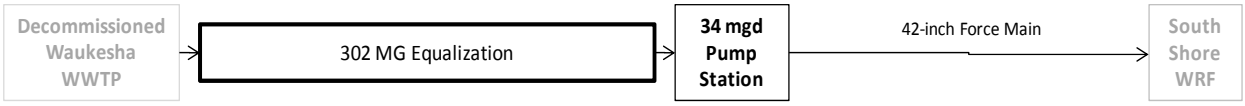


Wet Weather Equalization. South Shore has a maximum daily flow capacity of 250 mgd with a 300-mgd peak hourly flow capacity, but it frequently reaches its peak capacity for prolonged periods of time during storms. As a result, 302 million gallons (MG) of equalization is estimated to be needed based on historical operation of South Shore and the future return flow rates from Waukesha.

Pump Station and Force Main. A 34-mgd pump station at the downstream end of the equalization tunnel would dewater the tunnel and convey return flow through an estimated 17-mile, 42-inch force main to South Shore (28 total miles less the 11-mile storage tunnel). Based on the force main hydraulics, a single pump station would be sufficient to convey return flow to South Shore.

Existing Infrastructure. MMSD Alternative 1 includes the most amount of new infrastructure. It would use the South Shore Water Reclamation Facility but includes new infrastructure to store and convey flow from the Waukesha WWTP. Exhibit 29 is a schematic layout of MMSD Alternative 1.

EXHIBIT 29
MMSD Alternative 1: MMSD Return Flow Alignment to South Shore



3.5.2 MMSD Alternative 2

MMSD Alternative 2 consists of conveying return flow to the MMSD interceptor near MMSD's Greenfield Park Pump Station. MMSD identified this location for return flow discharge as the point in its system nearest the proposed return flow alignment corridor (Shafer, 01/20/2010). The pump station operates only during wet weather[7] and discharges to a 30-inch gravity sewer. The 30-inch sewer segment receiving the wet weather flow has a pipe-full flow capacity sufficient for Waukesha's return flow.[8] MMSD Alternative 2 assumes that return flow from the storage tunnel discharges into the same 30-inch sewer during dry weather periods, when the sewer is not receiving flow from the pump station. During wet weather, return flow would be stored in an underground tunnel until the return flow could be conveyed and treated once wet weather flows subside.

Exhibit 30 shows the conceptual alignment of the storage tunnel and force main between the Waukesha WWTP and 30-inch interceptor near the Greenfield Pump Station.

EXHIBIT 30
MMSD Alternative 2: MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station



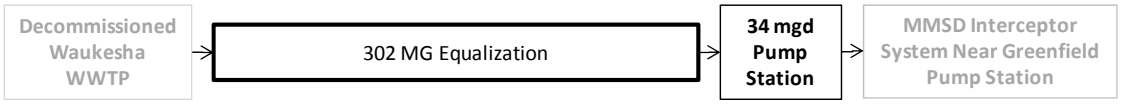
[7] Pump station capacity and sewer capacity obtained from the MMSD 2009 Comprehensive System Model.

[8] Detailed hydraulic modeling is required to determine pipe capacities farther downstream in the MMSD collection system to determine if there is sufficient capacity for return flow throughout the downstream system and with existing flow rates within the system.

Wet Weather Equalization. MMSD Alternative 2 includes an equalization tunnel that would extend from the Waukesha WWTP to the MMSD interceptor system near Greenfield Pump Station. Like MMSD Alternative 1, it includes 302 million gallons of underground tunnel storage for wet weather flow equalization.

Pump Station and Force Main. One new 34-mgd pump station at the downstream end of the equalization tunnel would dewater the tunnel and convey flow to the 30-inch interceptor. The interceptor near the pump station is about 11 miles from the Waukesha WWTP, which is the estimated length of the tunnel. Increasing the capacity or changing the operation of the pump station is not expected, because the return flow would be discharged to the MMSD collection system during dry weather. Exhibit 31 is a schematic layout of MMSD Alternative 2.

EXHIBIT 31
MMSD Alternative 2: MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station



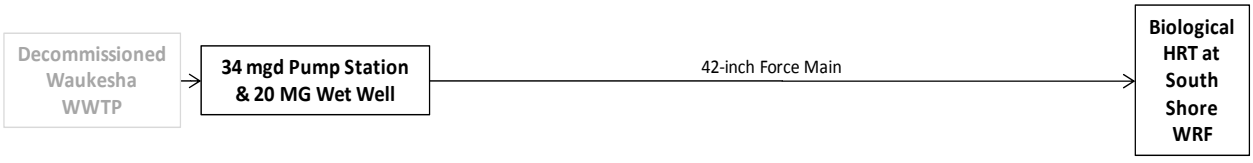
3.5.3 MMSD Alternative 3

MMSD Alternative 3 includes additional wet weather treatment capacity at South Shore in lieu of wet weather equalization storage. Equipment and operational assumptions are similar to those with SEWRPC's evaluation of the City's return to MMSD in its Regional Water Supply Plan. MMSD Alternative 3 is also consistent with MMSD's plans for expanding wet weather treatment capacity within its service area. MMSD Alternative 3 includes a pump station, a large wet well near the Waukesha WWTP site, and new force main to South Shore. A new biological high rate treatment facility would be constructed at South Shore with capacity equivalent to Waukesha's wet weather return flow rate. During dry weather, return flow would be treated at the South Shore facility. During wet weather, the high rate treatment facility would provide treatment for a flow rate equivalent to return flow. The conceptual alignment for MMSD Alternative 3 force main is the same as that for MMSD Alternative 1 (Exhibit 28).

Pump Station, Wet Well, and Force Main. Based on preliminary hydraulic analysis, MMSD Alternative 3 includes one 34 mgd pump station expected to be located near the site of the demolished Waukesha WWTP. The pump station would include a 20-million-gallon equalization wet well to buffer the peak hourly flows estimated in the Waukesha WWTP facility plan.

Increased Wet Weather Treatment Capacity at South Shore. MMSD is conducting studies to determine optimum wet weather treatment capacity at South Shore. MMSD Alternative 3 assumes that 34 mgd of biological high rate treatment and disinfection capacity is provided. (High rate treatment is also known as physical-chemical treatment, ballasted flocculation, or chemically enhanced clarification.) This flow rate is equivalent to Waukesha's maximum daily WWTP flow rate. Flows greater than the maximum daily WWTP flow rate would be temporarily stored in the equalization wet well. Exhibit 32 is a schematic layout of MMSD Alternative 3.

EXHIBIT 32
MMSD Alternative 3: Pipeline and Biological High Rate Treatment at South Shore



3.5.4 Cost Estimate

Exhibit 33 summarizes conceptual-level cost estimates for the MMSD return flow alternatives. The least expensive cost for return flow to MMSD is more than $96 million more than the most expensive option for treatment at the Waukesha WWTP with return flow to the Lake Michigan basin. The cost estimates do not include capital and O&M costs for MMSD's compliance with the state's future phosphorus standards. As a result, return flow to MMSD would likely be more expensive than estimated.

EXHIBIT 33
Screening Level Cost Estimates for Return Flow Alternatives to MMSD (*2009 Dollars*)

Return Flow Alternative	Capital Cost	Annual O&M Cost[b]	20-Year Present Worth
MMSD Alternative 1: Wet Weather Equalization and Force Main to South Shore [a]	$980,400,000	$1,444,000	$997,400,000
MMSD Alternative 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station [a]	$869,400,000	$1,300,000	$884,400,000
MMSD Alternative 3: Force Main and Biological High Rate Treatment at South Shore [a]	$262,400,000	$1,063,000	$274,400,000

[a] MMSD Alternatives 1, 2, and 3 include a $72.6 million capital cost "credit" for facility plan improvements that would not be required if the Waukesha WWTP were decommissioned. The $72.6 million credit is not specific to return flow; instead it represents improvements identified in the 2030 facility plan that would be required if the Waukesha WWTP were to remain, including meeting phosphorus water quality standards. This cost is not applied to the proposed return flow because the facility plan improvements would be required regardless of the WWTP's discharge location, but it is credited to the MMSD return flow alternatives so that the alternatives can be compared on a true cost basis.
[b] Does not include WWTP O&M costs, because they are virtually the same between Waukesha and MMSD, and therefore negligible when comparing cost differences between the three MMSD alternatives and the proposed return flow.

Because the cost for an MMSD return flow alternative is significantly greater than that for any other return flow alternatives, impacts to environmental resources, fisheries, habitat, geomorphology, flooding, and water quality under the MMSD alternatives were not evaluated in detail. However, the impacts likely would be similar to those of the Direct to Lake Michigan near Milwaukee and Oak Creek alternative because the pipeline lengths are similar and the alignments traverse similar land use types.

This economic evaluation corroborates the work conducted by SEWRPC in the Regional Water Supply Plan (SEWRPC, 2010a, Chapter 9, page 631) and the findings that return flow to MMSD would be significantly more expensive than other alternatives considered because of the additional infrastructure and treatment facilities required. Additional analyses might refine these alternatives and cost estimates, but the conclusions reached by this screening analysis will not change. Return flow to MMSD is not cost-effective compared to other alternatives and is thus eliminated from further consideration.

4. Invasive Species Prevention

Regardless of the return flow discharge location, the return flow will meet the Compact Article 4, Section 4.9(4)c and Wis. Stat. §281.346(4)(f)4.b requirements to prevent introduction of invasive species into the Great Lakes basin. The City will use construction best management practices and ongoing operation best practices to reduce the potential of introducing or spreading invasive species and viruses during construction and operation of the return flow.

During construction of the return flow (and water supply) pipelines, best management practices will be used to reduce the potential introduction or spread of invasive species. The Wisconsin Administrative Code Chapter NR 40 *Invasive Species Identification, Classification and Control*, will be consulted and followed where applicable to implement best practices to control the spread of invasive species. Practices that will be considered include washing equipment and timber mats before entering wetlands or watercourses, removing aquatic vegetation from equipment leaving waterways, steam cleaning and disinfecting equipment used in waterways where invasive species may exist, using noninvasive construction techniques, and others. Post-construction restoration methods will use only native species, and the City will consider methods to encourage those species to thrive to reduce the potential for invasive species to become established.

During operation of the pipelines, prevention of invasive species in the return flow will be a function of both water supply and return flow operations. A Lake Michigan water supply source will have multiple barriers to prevent the spread of invasive species through water delivered to the City's service area. Treatment at any of the three potential Lake Michigan drinking water suppliers includes filters and disinfection procedures to remove and inactivate viruses. This level of treatment will not allow transfer of invasive species through the water distribution system. Once the water is distributed in pipelines, the required disinfectant residual will be maintained to prevent microbial growth within the pipelines. Once the drinking water is used and is collected in the sanitary sewer

collection system, the City's WWTP will treat the water before it is returned to the Lake Michigan basin. The WWTP is an advanced facility with settling and biological treatment systems, dual media sand filters, and ultraviolet light disinfection designed to meet WDNR water quality requirements. The treated water is contained within the WWTP before return flow, and the return flow pipeline is proposed only to connect the WWTP directly to the return flow location. Consequently, there are no opportunities for invasive species or viral hemorrhagic septicemia from the Mississippi Basin to be introduced to the Lake Michigan basin (or vice versa) from the return flow discharge. 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.

5. Preferred Return Flow Alternative

As noted, the City of Waukesha considered five alternatives for managing return flow and five for the return flow location.

5.1 Return Flow Management

The City is committed to returning to Lake Michigan the water volume it seeks to withdraw from the lake for its public water supply. The proposed return flow management plan will provide continuous return flow after receiving full treatment from the City's WWTP. The treated water would be returned at the same maximum flow rate as that of the withdrawn water. The water volume withdrawn from Lake Michigan would be returned. This exceeds the requirement of the Compact to return the same volume, less consumptive use, because the average WWTP flow is greater than the average water supply.

5.2 Return Flow Location

Each return flow location alternative was evaluated in the screening level analysis. The Environmental Report (see Volume 5, City of Waukesha Environmental Report for Water Supply Alternatives) contains detailed evaluations of environmental, social, and historic resources for each return flow (and water supply) alternative. Based on the analysis herein and in the Environmental Report, the City identifies the Root River as the preferred return flow location alternative.

Exhibit 34 summarizes some of the construction-related environmental impacts for the return flow alternatives for a 75-foot-wide corridor along the pipeline alignments.

EXHIBIT 34
Summary of Potential Environmental Impacts for the Return Flow Pipeline Alignment Alternatives

Return Flow Alternative	Stream and Water Body Crossings	Water Body Crossings (acres)	Wetlands (acres)
Underwood Creek	9	0.16	9[a]
Root River	4	0.30	< 1
Direct to Lake Michigan near Milwaukee and Oak Creek	9	6.5	5
Direct to Lake Michigan near Racine[b]	16	4.7	52

[a] For an outfall near Bluemound Road. The impact would be about 5.0 acres for a discharge 0.9 mile upstream.
[b] Impacts are for Racine water supply pipeline alignment. See footnote in text.

Returning flow by means of Underwood Creek, the Root River, or the direct to Lake Michigan options meet the requirements of the Compact and Wisconsin Statute. However the direct to Lake Michigan returns are cost prohibitive (Exhibit 35) and these routes would not serve as an environmental resource to the Lake Michigan basin, and would have greater impacts during construction. Thus, direct returns are not preferred.

Return flow to Underwood Creek has no significant adverse environmental impacts, it maximizes use of existing utility corridors and previously disturbed areas, and the flow can be used as an environmental resource by improving the habitat and fisheries in Underwood Creek and the Menomonee River. Return flow to Underwood Creek is the least costly alternative because its pipeline is the shortest. However, because a TMDL was started

EXHIBIT 35
Cost Comparison for Return Flow Alternatives (*2013 dollars except as noted*)

Return Flow Alternative	Capital Cost	Annual O&M Cost	20-Year Present Worth	50-Year Present Worth
Underwood Creek	$58,059,000	$288,000	$61,059,000	$63,059,000
Root River	$96,038,000	$618,000	$103,038,000	$106,038,000
Direct to Lake Michigan near Milwaukee and Oak Creek	$117,247,000	$423,000	$122,247,000	$124,247,000
Direct to Lake Michigan near Racine	$166,708,000	$947,000	$177,570,000	$181,634,000
MMSD Alternative 1: Wet Weather Equalization and Force Main to South Shore [a]	$980,400,000	$1,444,000	$997,400,000	—
MMSD Alternative 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station [a]	$869,400,000	$1,300,000	$884,400,000	—
MMSD Alternative 3: Force Main and Biological High Rate Treatment at South Shore [a]	$262,400,000	$1,063,000	$274,400,000	—

Note: Includes direct construction cost, contractor administrative costs (insurance, bonds, supervision, etc.), 25% contingency, and costs for permitting, legal, engineering, administrative.
[a] 2009 dollars

after Underwood Creek was evaluated for return flow and an allocation has not yet been established for return flow, the WDNR has determined that an Underwood Creek return flow could not be approved. Consequently, this alternative cannot be implemented at this time and is therefore not the preferred return flow alternative.

The Root River return flow alternative is preferred. The return flow pipeline to the Root River would have no significant adverse environmental impact, because it follows an alignment previously disturbed by existing developments. The impacts of pipeline construction would be temporary. The Root River alternative maximizes the use of utility corridors and previously disturbed areas, and the flow can be used as an environmental resource by improving the habitat and fisheries in the river.

Return of flow to the Root River will benefit the Steelhead Facility by augmenting flow during critical low flow periods when the lack of water depth limits fish passage, which in turn limits the WDNR's ability to collect eggs for harvesting and stocking within the Root River, Lake Michigan, and its tributaries. There would be significant benefit to the Root River, Lake Michigan, and the entire Great Lakes, because the facility has been unable to harvest sufficient eggs in some years to meet the state's egg collection quotas. Fishing is a significant economy within Wisconsin and the Great Lakes, and a return flow to support egg collection, spawning, and hatchery operations would provide recreational, environmental and economic benefit to each of the Great Lakes states and Canadian provinces.

Return flow to the Root River will also protect public health by providing water that meets or exceeds the effluent limits proposed by the WDNR (as required by Compact Article 4, Section 4.9(4)c). This will contribute to protecting and sustaining the water and water-dependent natural resources of the Great Lakes basin, and the return flow will not have significant individual or cumulative adverse impacts.

Exhibit 35 summarizes the estimated costs of the return flow alternatives. Return flow to Underwood Creek is the least costly alternative because its pipeline is the shortest, but the alternative is not implementable at this time because the WDNR and the TMDL has not yet established a return flow allocation. The alternatives with return flow directly to Lake Michigan and MMSD are significantly more costly, the return flow would not serve as an environmental resource to the Lake Michigan basin, and some alternatives have greater environmental impacts during pipeline construction. These alternatives are not preferred when reviewed in light of the Root River alternative. The Root River return flow alternative meets the Compact and Wisconsin Statute requirements, it provides the greatest environmental benefit to the Great Lakes basin, and it is the least costly alternative that can be implemented at this time such that it is the most cost effective alternative. As a result, return flow to the Root River is the preferred alternative.

6. References

AECOM. 2009. Root River Flood Stage Relationship Study. Memorandum for City of Racine Director of Public Works. July 20.

AECOM. 2012. *City of Waukesha Interceptor Sewer Cost Comparison Analysis.* Final Report. April.

AECOM. 2013. Water Demand Projections. Technical memorandum, City of Waukesha. June 6.

Baker, David B., R. Peter Richards, Timothy T. Loftus, and Jack W. Kramer. April 2004. "A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams." *Journal of the American Water Resources Association.*

CH2M HILL. 2011. Response to WDNR Regarding Letter to Waukesha Water Utility on Application for Lake Michigan Water Supply.

CH2M HILL and Ruekert-Mielke. 2002, March. *Future Water Supply Report; City of* Waukesha - Water Utility.

City of Milwaukee Water Works. 2011. *Raw Water Annual Water Quality Report.*

City of Waukesha. 2012a. *Capacity, Management, Operations, and Maintenance Quarterly Collection System Progress Report.* March 31.

City of Waukesha. 2012b. *Capacity, Management, Operations, and Maintenance Quarterly Collection System Progress Report.* June 30.

City of Waukesha. 2012c. Capacity, Management, Operations, and Maintenance Donohue & Associates. 2011b. *Phase II Final Report Sanitary Sewer System Master Plan; City of Waukesha.*

Federal Emergency Management Agency. 2012. *Flood Insurance Study.* Racine County, Wisconsin and Incorporated Areas. May 2.

Federal Emergency Management Agency. 2012. Flood Insurance Study. Milwaukee County, Wisconsin and Incorporated Areas. September 26.

Hedman, Susan/U.S. EPA. 2012. Letter to Cathy Stepp/Secretary of Wisconsin DNR. U.S. EPA approval of NR 217. July 25.

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

Kinzelman, Julie, J. Maki, K. Abbott, T. Begotka, A. Koski. 2009. Improving Water Quality through Seasonal Assessments, Education, and Non-Point Source Pollution Controls. Final Report. December 31.

Kammerer, P. A. Jr., *Groundwater Quality Atlas of Wisconsin.* U.S. Geological Survey and University of Wisconsin-Extension, Wisconsin Geological and Natural History Survey, Information Circular 39-1981.

Milwaukee Metropolitan Sewerage District (MMSD). 2001. Sediment Transport Study of the Menomonee River Watershed. February 7.

Milwaukee Metropolitan Sewerage District. 2006. Underwood Creek Rehabilitation and Flood Management Project. Preliminary Engineering Design Report.

Milwaukee Metropolitan Sewerage District. 2007a. *Milwaukee County Grounds Floodwater Management Facility Final Design Report.*

Milwaukee Metropolitan Sewerage District. 2007b. *Root River Sediment Transport Planning Study.* September 5.

Milwaukee Metropolitan Sewerage District. 2008a. *Watercourse: Underwood Creek Rehabilitation and Flood Management—Phase 1.*

Milwaukee Metropolitan Sewerage District. 2008b. Underwood Creek Water Quality Baseline Report, 2003–2005.

Milwaukee Metropolitan Sewerage District. 2008. Water Quality in the Menomonee River Watershed. Watershed Restoration Plan.

Milwaukee Metropolitan Sewerage District. 2009. Comprehensive System Model.

Milwaukee Metropolitan Sewerage District. 2010a. http://v3.mmsd.com/hartparkproject.aspx. Accessed January 13.

Milwaukee Metropolitan Sewerage District. 2010b. http://v3.mmsd.com/milwaukeecogrounds.aspx. Accessed January 13.

SEH. 2009. *Underwood Creek Effluent Return Evaluation.* Prepared for the City of Waukesha Water Utility. July 23.

Shafer, Kevin/MMSD. 2010. Letter to Dan Duchniak/Waukesha Water Utility. January 20.

Southeastern Wisconsin Regional Planning Commission (SEWRPC). 1966. *A Comprehensive Plan for the Root River Watershed.* Planning Report No. 9.

Southeastern Wisconsin Regional Planning Commission. 1979. *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000.* Planning Report No. 30.

Southeastern Wisconsin Regional Planning Commission. 1990. *A Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District.* Community Assistance Planning Report No. 152.

Southeastern Wisconsin Regional Planning Commission. 1997. A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin. Planning Report No. 42.

Southeastern Wisconsin Regional Planning Commission. 1999. Sanitary Sewer Service Area for the City of Waukesha and Environs. Community Assistance Planning Report No 100. Second Edition. March 1999. (Amended February 2001, June 2002, September 2003, September 2004, September 2005, September 2006, and December 2007.)

Southeastern Wisconsin Regional Planning Commission. 2000. Analysis of Alternative Plans for Removal of the Concrete Lining in Underwood Creek in the City of Wauwatosa. Memorandum Report No. 141. Prepared with the Milwaukee Metropolitan Sewerage District.

Southeastern Wisconsin Regional Planning Commission. 2003. Sanitary Sewer Service Area for the City of Racine and Environs, Racine and Kenosha Counties, Wisconsin. Community Assistance Planning Report No. 147. Second Edition. June.

Southeastern Wisconsin Regional Planning Commission. 2007a. *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.* Planning Report No. 50.

Southeastern Wisconsin Regional Planning Commission. 2007b. *Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds.* Technical Report No. 39.

Southeastern Wisconsin Regional Planning Commission. 2010a. A Regional Water Supply Plan for Southeastern Wisconsin. Planning Report No. 52.

Southeastern Wisconsin Regional Planning Commission. 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 2. December.

Southeastern Wisconsin Regional Planning Commission. 2008a. Pebble Creek Watershed Protection Plan, Waukesha County, Wisconsin. Community Assistance Planning Report No. 284. June.

Southeastern Wisconsin Regional Planning Commission.2010b. *Preliminary Draft Flood Discharges for the Menomonee River Watershed.* MCAMLIS/MMSD/SEWRPC Floodplain Mapping Program. January 7.

Southeastern Wisconsin Regional Planning Commission. 2010c. Racine County Hazard Mitigation Plan Update: 2010-2015. Community Assistance Planning Report No. 266, 2nd edition.

Southeastern Wisconsin Regional Planning Commission. 2011. Menomonee River and Underwood Creek Flows with Milwaukee County Grounds Basin. Personal communication with Ronald Printz. E-mail with attached spreadsheets on 10-14-2011.

Southeastern Wisconsin Regional Planning Commission. 2012. *Estimated Buildout Population within the Planned Waukesha Water Supply Service Area by Community*. Analysis by William Stauber (WJS). January 25.

Southeastern Wisconsin Regional Planning Commission. 2013. A Restoration Plan for the Root River Watershed. Community Assistance Planning Report No. 316. Preliminary Draft, Meeting Minutes, Meeting Presentations. http://www.sewrpc.org/SEWRPC/Environment/Root-River-Watershed-Restoration-Plan.htm. Last Accessed August 29.

Strand Associates. May 2011. *City of Waukesha Wastewater Treatment Facilities Plan.* Amended October 5, 2012.

Superior Engineer and Donohue & Associates. 2011. Final Capacity, Management, Operations, and Maintenance Plan, City of Waukesha.

Wastewater Engineering: Treatment, Disposal and Reuse, 3rd Edition, Metcalf and Eddy, Inc., George Tchobanoglous and Franklin Burton, 1991. Page 74.

Wiley, Michael, 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.

Wisconsin Department of Natural Resources (WDNR). 2002. The State of the Root-Pike River Basin. May 2002. WDNR Publication No. WT-700-2002.

Wisconsin Department of Natural Resources. 2008. WPDES Effluent Limitations [for Return Flow from a Lake Michigan water supply]. October 16. Letter from Duane Schuettpelz/WDNR to Dan Duchniak/Waukesha Water Utility.

Wisconsin Department of Natural Resources. 2011a. *Comprehensive Study of Wisconsin's Fish Propagation System.* December 19.

Wisconsin Department of Natural Resources. 2011b. Limits for Waukesha Return Flow. December 13, 2011 correspondence from Jackie Fratrick/WDNR to Kristy Rogers/WDNR and Diane Figiel/WDNR. Provided to the City of Waukesha on February 5, 2013.

Wisconsin Department of Natural Resources. 2012a. http://dnr.wi.gov/water/impairedSearch.aspx. Accessed January 12.

Wisconsin Department of Natural Resources. 2012b. http://dnr.wi.gov/water/impairedSearch.aspx. Accessed June 25.

Wisconsin Department of Natural Resources. 2012c. Surface Water Data Viewer. http://www.dnr.state.wi.us/org/water/data_viewer.htm. Accessed March 26, 2012.

Wisconsin Department of Natural Resources. 2012e. Fish and macroinvertebrate data provided by Nicole Clayton/WDNR. June 25.

Wisconsin Department of Natural Resources. 2012d. Water return to Root River from Waukesha. Correspondence from Brad Eggold to Eric Ebersberger.

Wisconsin Department of Natural Resources. 2013a. Root River Steelhead Facility. http://dnr.wi.gov/topic/Fishing/lakemichigan/rootriver.html. Accessed July 17.

Wisconsin Department of Natural Resources. 2013b. Draft permit to discharge under the Wisconsin Pollutant Discharge Elimination System. Facility at 600 Sentry Drive, Waukesha, WI to the Southeastern Fox River in Waukesha County. WPDES Permit No. WI-0029971-08-0. April 17.

Wisconsin Department of Natural Resources. 2013c. Lake Michigan Weir Assessments for the Root River Steelhead Facility. Assessments provided by WDNR and from http://dnr.wi.gov/topic/fishing/hatcheries/spawning.html. Accessed July 17.

Wisconsin Department of Transportation. 2012a. Modeled Regional Flood Impacts to the Menomonee River Watercourses Due to Improvements of the Zoo Interchange, Highways 45, I-94, and I-894 and Associated Improvements to Highway 100 and Watertown Plank Road. Final Technical Memorandum. January 31.

Wisconsin Department of Transportation. 2012b. Zoo Interchange Preliminary Pollutant Load Analysis. Technical Memorandum. January 30.

Wright, Sarah, J. Kinzelman. 2012. *Baseline Assessment of Water Quality in Support of the Root River Watershed Restoration Plan.* August 2. City of Racine, WI.

Appendix A
Facility Plan Amendment—City of Waukesha 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

October 2013

CH2MHILL
135 S. 84th Street, Suite 325
Milwaukee, WI 53214

Contents

1 Background Information and Existing Conditions 1
1.1 Need for Proposed Project 1
1.2 Planning Areas 1
1.3 Wastewater Treatment Plant Effluent 4
1.4 Infiltration and Inflow 5
2 Alternatives Identification 7
2.1 Alternative 1: Underwood Creek 7
2.2 Alternative 2: Root River 8
2.3 Alternative 3: Direct to Lake Michigan near Milwaukee and Oak Creek 9
2.4 Alternative 4: Direct to Lake Michigan near Racine 10
2.5 Alternative 5: Return Untreated Wastewater to MMSD 11
2.6 Alternative 6: Return Treated Wastewater to MMSD 11
3 Effluent Limits 12
4 Alternatives Analysis 12
4.1 Economic Analysis 12
4.2 Nonmonetary Analysis 13
5 Environmental Assessment 14
6 Recommended Plan 15
6.1 Return Flow Reaeration and Pipe Outfall 16
6.2 Return Flow Chlorides 20
6.3 Return Flow Temperature 21

Attachments

A-1 WPDES Permit (Effective Date: August 1, 2013)
A-2 Evaluation of Alternatives for Return Flow to the Milwaukee Metropolitan Sewerage District
A-3 Wisconsin Department of Natural Resources: Limits for Waukesha Return Water
A-4 Compliance Plan to Meet Proposed Chloride Limits for Return Flow with a City of Waukesha Lake Michigan Water Supply
A-5 Preliminary Thermal Analysis of a City of Waukesha Lake Michigan Return Flow to the Root River Current WPDES Permit

Tables

1 Summary of Water-only and Wastewater-only Volume and Flow in the City of Waukesha Water and Sewer Service Areas 4
2 General Summary of City of Waukesha WWTP WPDES Effluent Permit Limits (August 1, 2013 Permit) 5
3 Waukesha WWTP Average Monthly Effluent Concentrations (October 2002–August 2009) 5
4 Cost Comparison for Return Flow Alternatives (2013 dollars unless noted) 13

Figures

1 Sanitary Sewer Service Planning Area (SEWRPC, 2007) 2
2 Projected Ultimate Water Service Area for the City of Waukesha 3
3 City of Waukesha WWTP Effluent Average Daily Flow 6
4 Alternative 1: Underwood Creek Return Flow Alignment 8
5 Alternative 2: Root River Return Flow Alignment 9
6 Alternative 3: Direct to Lake Michigan Return Flow Alignment 10

7 Return Flow Pipeline Alignment Direct to Lake Michigan near Racine 10
8 Plan View Aerial of the Return Flow Pump Station 15
9 Conceptual Plan for the Return Flow Pump Station and Associated Improvements 16
10 Flow Path Through Disinfection and Aeration to Return Flow Pump Station 17
11 Flow Chart of the Return Flow Operation 18
12 Pipe Outfall with Flared End Section along Underwood Creek in Wauwatosa 19
13 Rock Outfall from the Madison Metropolitan Sewerage District Wastewater Treatment Plant Discharge to Badger Mill Creek. 19
14 Outfall and Cascade Aerator from a Wastewater Treatment Plant in Fort Campbell, TN 20

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 Application for Lake Michigan Diversion with Return Flow (Application). The Great Lakes Water Resources Compact (Compact) and Wisconsin Statutes require the City of Waukesha to return the water that it withdraws from Lake Michigan, less an allowance for consumption.

The City'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 City of Waukesha's Wastewater Treatment Facility Plan (May 2011).

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 parts 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. Figure 1 shows the sanitary sewer service area.

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] The City of Waukesha Water Supply Service Area Plan (Volume 2 of the Application) contains a detailed discussion of the water supply service area. Figure 2 shows the projected ultimate water supply service area.

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 differences between the two areas currently:

- 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 sanitary sewer service area but not in the water supply service area. The area is served by the City of Pewaukee's municipal water supply system but the sanitary sewer flow is treated by the City of Waukesha.

---

[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.)

[2] SEWRPC, December 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 2.

[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.

FIGURE 1
Sanitary Sewer Service Planning Area (SEWRPC, 2007)

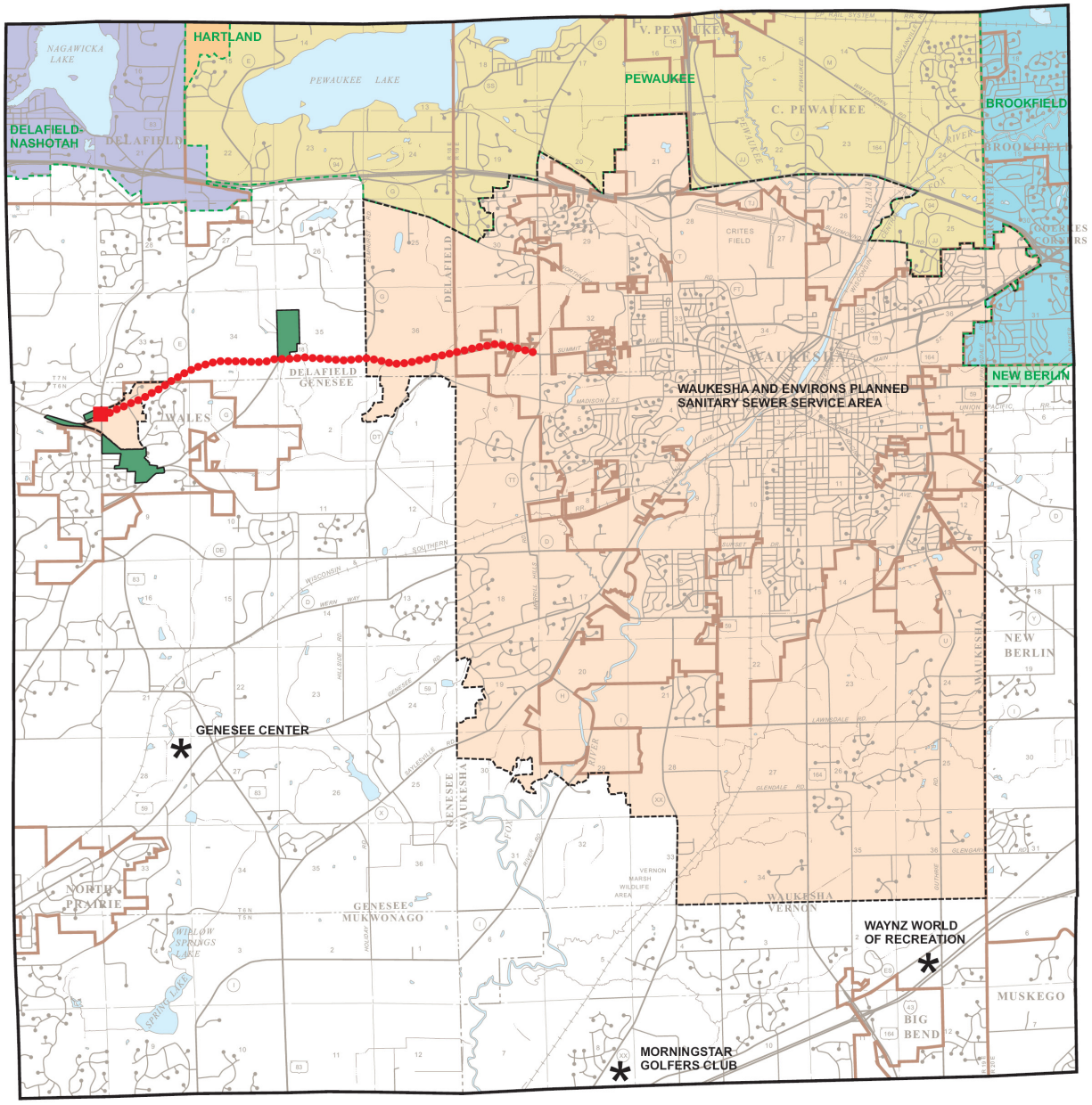
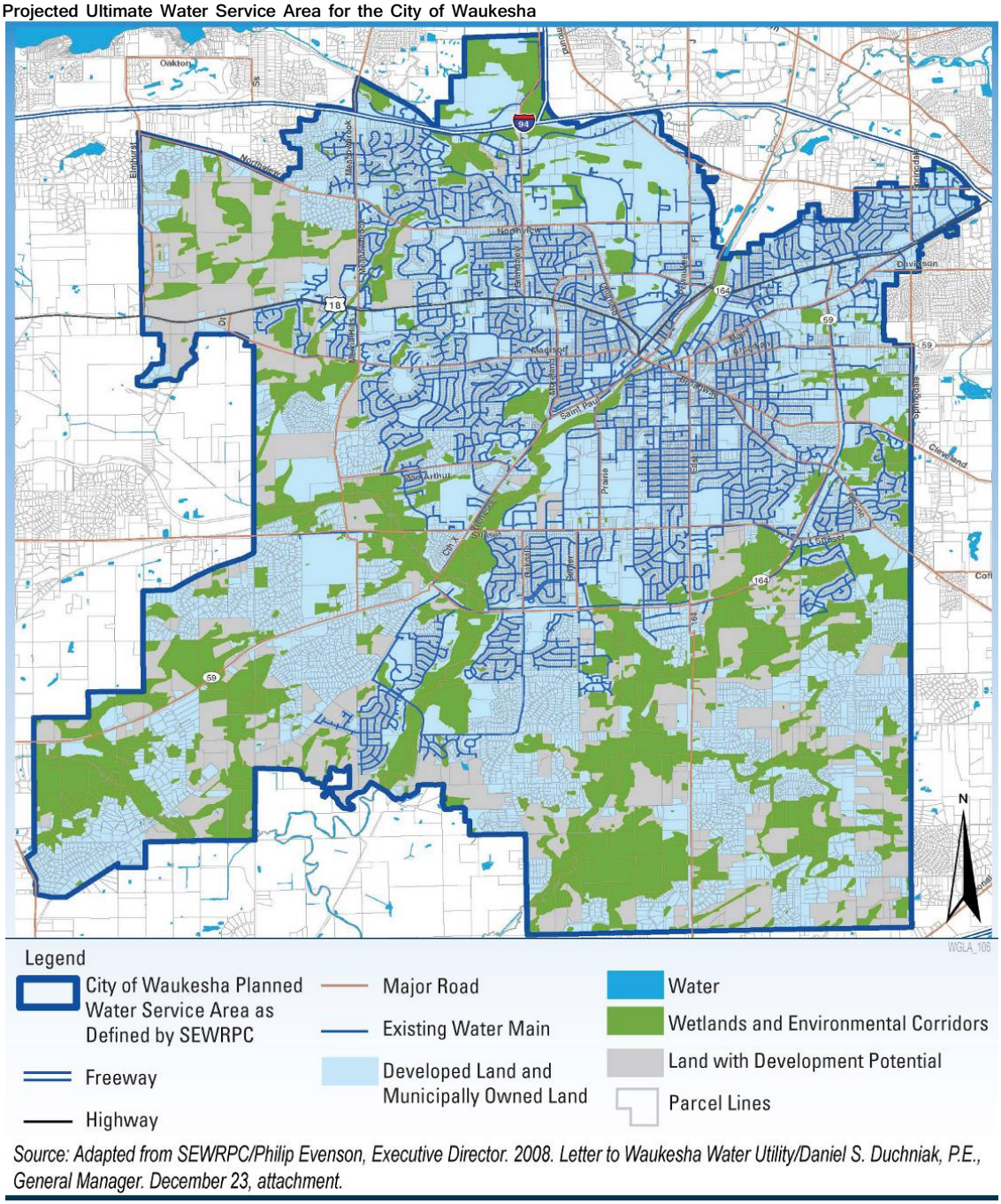


FIGURE 2
Projected Ultimate Water Service Area for the City of Waukesha



Source: Adapted from SEWRPC/Philip Evenson, Executive Director. 2008. Letter to Waukesha Water Utility/Daniel S. Duchniak, P.E., General Manager. December 23, attachment.

- 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 (i.e. this area is planned to be a water-only 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 Wisconsin Department of Natural Resources due to groundwater bacterial contamination.[4] Sanitary sewer service for these water-only users is anticipated to be provided by onsite

[4] SEWRPC, December 2008. Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin, p. 3.

wastewater treatment systems (e.g. septic tank and drain field). This area includes about 530 parcels[5] and includes an estimated population between 1,770 to 1,850.[6]

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.[7]

1.2.3.1 Quantification of Planning Area Differences in WWTP Flow Rates

To demonstrate the current small differences in the service areas, records for City of Waukesha wastewater-only customers (customers that receive only wastewater treatment services from the City) and water-only customers (customers that receive only water service from the City) were used for years 2007 to 2010 to calculate the net volume of wastewater conveyed to the WWTP from the Mississippi Basin. The water-only and wastewater-only data was used because the remaining customers are served by the City for both water and wastewater, and therefore do not contribute to this calculation. Daily wastewater-only flow rates are not available because meters are read quarterly, or some wastewater-only customers (62) have fixed usage billing. Consequently, daily average wastewater-only volumes are calculated by averaging the yearly volumes for each day.

The annual volume of wastewater received at the WWTP from locations that do not receive water service ranges between 53.4 million gallons (Mgal) in 2007 to 69.0 Mgal in 2008 (Table 1). This equates to an average daily flow between 0.15 and 0.19 million gallons per day (mgd), which is between 1.4 and 1.6 percent of the total average daily WWTP flow. When compared to the water-only annual volumes between 39.8 and 49.5 Mgal (0.11 and 0.14 mgd, respectively), slightly more volume (between 0.01 and 0.06 mgd) from the Mississippi Basin reaches the WWTP than water would be distributed to water-only customers if a Lake Michigan supply was provided over these years.

TABLE 1
Summary of Water-only and Wastewater-only Volume and Flow in the City of Waukesha Water and Sewer Service Areas

	2007	2008	2009	2010
Water-only Service Total Annual Volume (Mgal)	49.4	46.9	49.5	39.8
Wastewater-only Service Total Annual Volume (Mgal)	53.4	69.0	57.7	59.8
Net Annual Volume to WWTP from Mississippi Basin (Mgal)	**4.0**	**22.1**	**8.2**	**20.0**
Water-only Service Average Daily Flow (mgd)	0.14	0.13	0.14	0.11
Wastewater-only Service Average Daily Flow (mgd)	0.15	0.19	0.16	0.16
Net Average Daily Flow to WWTP from Mississippi Basin (mgd)	**0.01**	**0.06**	**0.02**	**0.05**
WWTP Average Daily Flow (mgd)	10.7	11.7	10.7	10.6
Fraction of WWTP Flow that is from the Wastewater-only Customers (%)	1.4%	1.6%	1.5%	1.6%

1.3 Wastewater Treatment Plant Effluent

The Wisconsin Pollutant Discharge Elimination System (WPDES) permit for the City's WWTP was issued by the Wisconsin Department of Natural Resources (WDNR) effective August 1, 2013. It is included in Attachment A-1 and is generally summarized in Table 2. 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).

---

[5] City of Waukesha parcel data. March 22, 2010.

[6] SEWRPC. January 25, 2012. *Estimated Buildout Population within the Planned Waukesha Water Supply Service Area by Community*. Analysis by William Stauber (WJS).

[7] SEWRPC, December 2008. *Water Supply Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* p. 3.

TABLE 2
General Summary of City of Waukesha WWTP WPDES Effluent Permit Limits (August 1, 2013 Permit)

Parameter	Permit Limit
BOD5, total	≤8.2 to 10 mg/L weekly (varies by season)
TSS, total	≤10 mg/L weekly
NH3-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)	≤0.7 mg/L monthly interim (≤0.075 mg/L future limit)
Fecal coliform	≤400#/100 mL monthly geometric mean (May–September)
Chlorides	690 mg/L weekly with a target value of 440 mg/L. 431 mg/L water quality based effluent limit.
Temperature	Determined to be unnecessary

The average monthly WWTP effluent concentrations is summarized in Table 3 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. These are discussed in more detail in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

TABLE 3
Waukesha WWTP Average Monthly Effluent Concentrations (October 2002–August 2009)

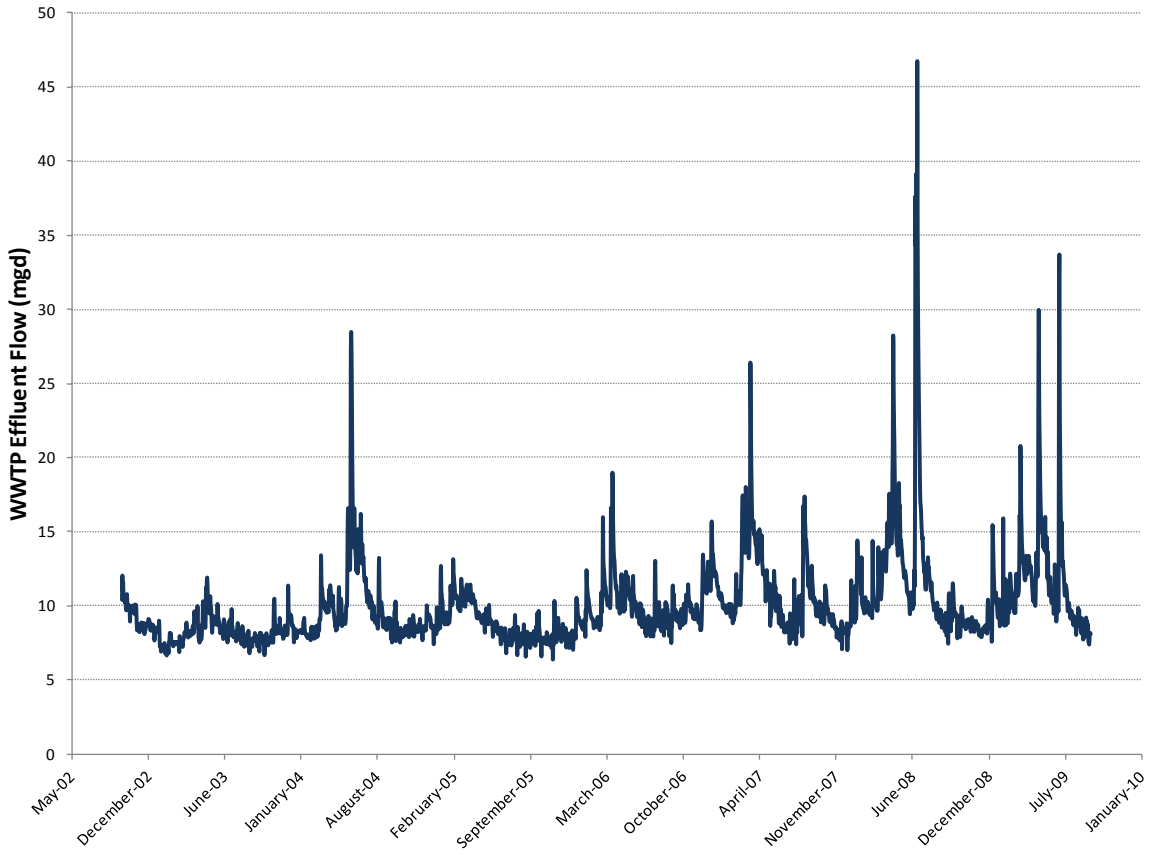
Month	Flow (mgd)	BOD_5 (mg/L)	Ammonia (as N) (mg/L)	TP (mg/L)	Dissolved Oxygen (mg/L)	Temp (°C)	TSS (mg/L)	Fecal Coliform (cfu/100 mL)[a]	Copper (µg/L)[b]	Zinc (µg/L)[b]
Jan.	9.4	1.7	0.10	0.11	10.3	12.0	0.9	ND	6.6	42.0
Feb.	9.3	1.7	0.06	0.10	10.5	11.5	0.9	ND	12.4	48.6
March	11.3	1.7	0.14	0.12	10.4	12.3	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.

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.

FIGURE 3
City of Waukesha WWTP Effluent Average Daily 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 through its Master Plans[8,9] and Construction, Management, Operations, and Maintenance (CMOM) Plan[10] 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). The City is performing annual self-audits[11] and quarterly progress reports. Extensive inspection and maintenance measures are continuing to reduce I/I in the collection system. Examples of these measures include.[12,13]

- 475,000 linear feet (LF) of sewer televising with an additional 500,000 LF scheduled to be completed by 2013. At the end of 2013, 76 percent of the entire gravity sewer system will be inspected.
- 37,280 LF of sanitary sewer pipe lining between 2011 and 2013.
- 12,726 LF of sanitary sewer pipe replacement between 2011 and 2012.
- 6,926 manhole inspections between 2011 and 2013. At the end of 2013, 79 percent of the City's manholes will have been inspected.

8 Donohue & Associates. 2011. Final Report, Phase I Sanitary Sewer Master Plan; City of Waukesha.
9 Donohue & Associates. 2011. Phase II Final Report Sanitary Sewer System Master Plan; City of Waukesha.
10 Superior Engineer, LLC and Donohue & Associates. 2011. Final CMOM Plan, City of Waukesha.
11 Ibid. Page 54.
12 City of Waukesha. CMOM Quarterly Collection System Progress Report. March 31, 2012.
13 City of Waukesha. CMOM Quarterly Collection System Progress Report. June 30, 2012.

- Manhole rehabilitation measures including 462 cover replacements, 58 chimney linings, 200 chimney replacements, five chimney/cone replacements, 158 complete manhole linings, 31 total manhole replacements, grouting three manholes, and 202 invert rehabilitations by the end of 2012. In 2013, approximately 200 additional manholes are expected to be rehabilitated.[14]
- Inspection and maintenance work on force mains will include the replacement of 6350 LF of ferrous pipe in 2012, with an additional 3100 LF planned for 2013.[15]

The City has been implementing key elements of a CMOM program before they were required by the EPA, including sewer cleaning, pump station inspection and maintenance programs.[16]

2 Alternatives Identification

Six 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:

- 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 near Milwaukee and Oak Creek—Return treated wastewater effluent directly to Lake Michigan.
- Alternative 4: Return Flow Direct to Lake Michigan near Racine — Return treated wastewater effluent directly to Lake Michigan.
- Alternative 5: Return untreated wastewater to the Milwaukee Metropolitan Sewerage District for treatment and return to Lake Michigan.
- Alternative 6: 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 alternatives are discussed below.

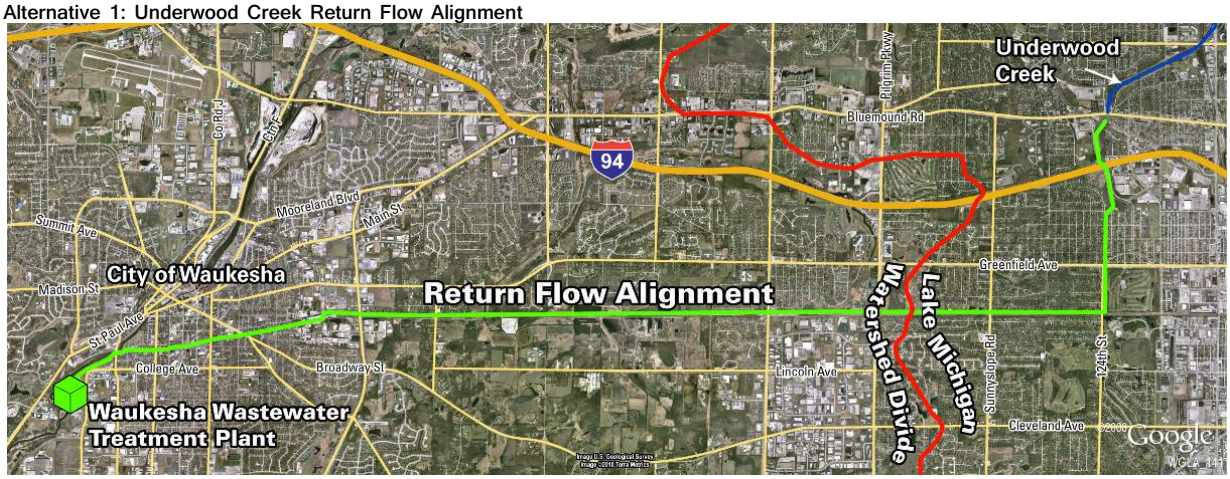
2.1 Alternative 1: Underwood Creek

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 30-inch pipe.

[14] CMOM Annual Self-Audit. 2012. Page 1.
[15] CMOM Annual Self-Audit. 2012. Page 1.
[16] Superior Engineer, LLC and Donohue & Associates. 2011. Final CMOM Plan, City of Waukesha. Page 1.

FIGURE 4
Alternative 1: Underwood Creek Return Flow Alignment



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 16.7 mgd. Wastewater flow exceeding 16.7 mgd is anticipated to flow through the existing Fox River outfall.

The effect of the return flow on water quality, habitat and fisheries, and geomorphic stability in Underwood Creek were analyzed in the City of Waukesha Return Flow Plan (Volume 4 of the Application). These analyses were completed for a return flow management plan that had a maximum return flow rate of about 12.5 mgd (slightly less than 16.7 mgd maximum return flow). The maximum flow rate is experienced infrequently and effects to water quality, habitat and fisheries are not anticipated to impact the analysis results because comparisons were generally completed with average return flows that are observed more frequently.

Water quality modeling was completed using permit limits developed by the WDNR.[17] Since this time, revised return flow permit limits were developed by WDNR (see Section 3) that included lower phosphorus limits. The modeling predicts that return flow will have some impact on water quality in the creek, but it will improve the water quality of Underwood Creek for some parameters. However, with the lower limits now proposed by the WDNR, water quality is expected to remain the same or improve because return flow water quality will be higher quality than the ambient river water quality for some parameters, such as phosphorus. This is consistent with water quality modeling completed for return flow to the Root River that was completed with the revised effluent limits (see Section 2.2).

The return flow will have a beneficial effect on habitat and fisheries, it will not negatively affect the geomorphic stability of the creek, and the City will continue to meet current and future WDNR effluent limits for an Underwood Creek discharge. This is further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

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 urbanized, the middle reaches are primarily agriculture and lower density development, and the lower parts of the watershed near Lake Michigan are heavily urbanized. Return flow is proposed to enter the Root River near the middle of reach, downstream of the confluence with the Root River Canal.

The conceptual pipeline alignment for return flow to the Root River is the same as the water supply pipeline, for a City of Oak Creek supply, for most of its distance. The total length of the return flow pipeline is about 20 miles

[17] Wisconsin Department of Natural Resources. 2008. WPDES Effluent Limitations [for Return Flow from a Lake Michigan water supply]. October 16. Letter from Duane Schuettpelz/WDNR to Dan Duchniak/Waukesha Water Utility.

(Figure 5). Leaving the WWTP, the first 3.5 miles of pipeline follows urban streets to the southeast side of the City. From there, it continues southeast and additional 8 miles following major roadway alignments through rural land use. The final 8.5 miles pipeline continues southeast through the City of Franklin where the land use varies between medium and low density residential, agricultural and commercial land use. The entire alignment follows previously disturbed areas such as roads and the City's WWTP site. The return flow rate and pipe size are the same as the Underwood Creek alternative.

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. Water quality modeling on the Root River was completed for a maximum return flow rate of 18.5 mgd, slightly more than the maximum return flow rate of 16.7 mgd, and it included the revised permit limits that included strict phosphorus limits (see Section 3). The water quality modeling found that average water quality improved or continued to meet water quality standards or background reference concentrations for all water quality parameters (fecal coliform, dissolved oxygen, total phosphorus and total suspended solids). Modeling results also indicate that with return flow, nuisance algae growth will also decrease in the Root River.

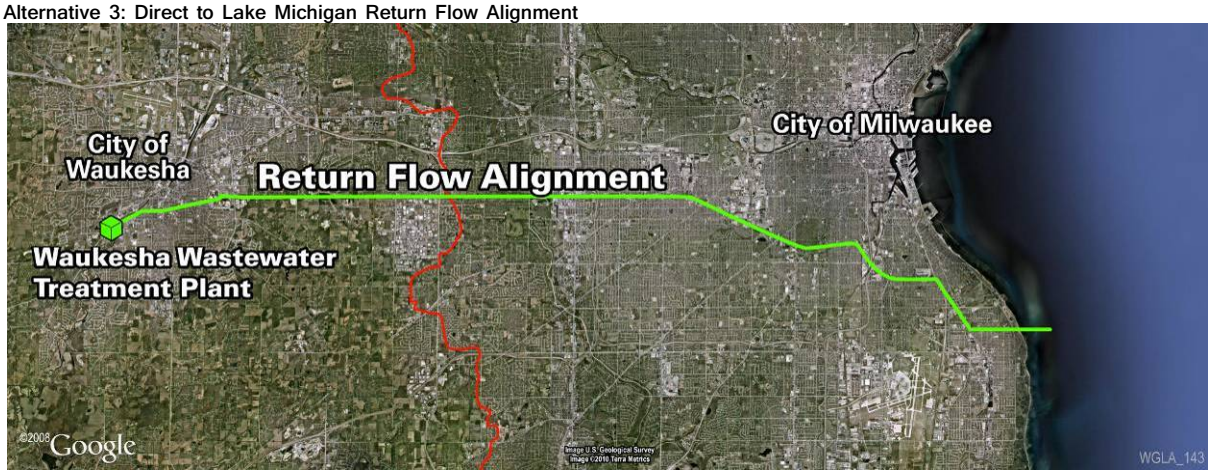
The return flow is expected to improve the habitat and fisheries and not have negative impacts on the geomorphic stability. This is further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

2.3 Alternative 3: Direct to Lake Michigan near Milwaukee and Oak Creek

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 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. The return flow rate and pipe size are the same as the Underwood Creek alternative.

The return flow will not negatively affect the habitat, 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 reaches Lake Michigan. This is further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

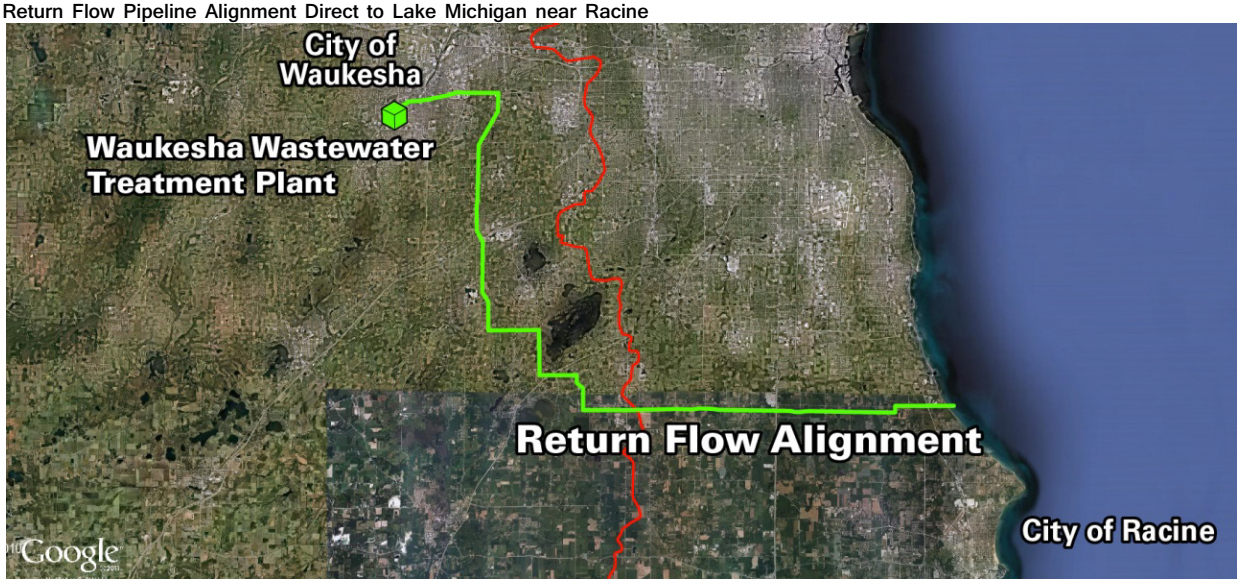
FIGURE 6
Alternative 3: Direct to Lake Michigan Return Flow Alignment



2.4 Alternative 4: Direct to Lake Michigan near Racine

A screening-level alignment for return flow directly to Lake Michigan near Racine was developed to evaluate the environmental effects and costs (Figure 7). The conceptual pipeline alignment is the same as that for Underwood Creek for about the first 4.4 miles, after which the Lake Michigan near Racine alignment proceeds south following the same alignment as the Racine water supply alignment. The Racine water supply and Lake Michigan return alignments share a corridor for about 28 miles. The eastern 4 miles of the shared corridor is where the water supply and return flow alignments diverge, where the proposed water supply continues south to connect with the Racine distribution system and the return flow alignment continues east towards Lake Michigan. The return flow alignment for these 4 miles was chosen because it allowed the discharge location to be near the City of Racine (within about 6.5 miles of the water treatment plant) and the alignment was able to follow an existing utility corridor and previously disturbed open space at the Lake Michigan shoreline. Sharing a corridor between the water supply and return flow alignments will minimize cost, construction, and environmental impacts for this alternative. The corridor follows previously disturbed lands that include agriculture, utility corridors, roads and recreational paths. The same as the Lake Michigan near Milwaukee and Oak Creek return flow alternative, this alignment extends into Lake Michigan about 0.5 mile to provide an offshore outfall. The return flow rate and pipe size are the same as the Underwood Creek alternative.

FIGURE 7
Return Flow Pipeline Alignment Direct to Lake Michigan near Racine



The return flow will not negatively affect the habitat, 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 reaches Lake Michigan. This is further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

2.5 Alternative 5: Return Untreated Wastewater to MMSD

This alternative includes constructing about 10 miles of 30-inch force main from the City's WWTP to the MMSD collection system. The City'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 and Root River alternatives.

The City 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 16.7 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 also likely required because the MMSD system is capacity limited during wet weather. As a result, 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.[18] Consequently, this alternative was not evaluated further, but additional alternatives that include returning *all* flow from the City's WWTP were evaluated.

2.5.1 Alternatives to Return All Untreated Wastewater to MMSD

The City evaluated three sub-alternatives for returning untreated wastewater to MMSD. The sub-alternatives include decommissioning the City's WWTP and returning *all* WWTP flow to MMSD:

- Sub-Alternative 1: Wet Weather Equalization and Pipeline to MMSD South Shore
- Sub-Alternative 2: Wet Weather Equalization and Pipeline to MMSD Interceptor near Greenfield Park Pump Station
- Sub-Alternative 3: Pipeline to MMSD South Shore and Biological High Rate Treatment Facility at South Shore

Cost estimates were completed for the sub-alternatives (Attachment A-2). Each was significantly more expensive than any other return flow alternative. Consequently, these sub-alternatives were not evaluated in further detail in this Facility Plan Amendment.

2.6 Alternative 6: Return Treated Wastewater to MMSD

This alternative includes the continued use the City's WWTP for all discharges to the Fox River and return flow to MMSD. After the wastewater is treated at the City's 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. A force main would convey the return flow from the WWTP to the MMSD collection system.

This alternative would be less challenging to implement than Alternative 5 that included intermittent operation of the Waukesha WWTP. 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.[19]

Providing double-treatment of the return flow (first at the City's 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.

---

[18] SEWRPC. 2008. Planning Report No. 52: A Regional Water Supply Plan for Southeastern Wisconsin. Chapter 9, Page 37.
[19] Ibid.

3 Effluent Limits

The WDNR has provided effluent limits[20] for a return flow using existing conditions for Underwood Creek and the Root River. The proposed limits are summarized below and included in Attachment A-3, and are very similar to those in the permit for the Fox River discharge (Table 2):

- Maximum weekly effluent BOD concentrations between 5.7 to 10 mg/L
- Maximum weekly effluent TSS concentrations of 10 mg/L
- Minimum daily effluent dissolved oxygen concentration of 7 mg/L
- Maximum 6-month average effluent TP concentration of 0.075 mg/L
- Maximum monthly NH_3-N ammonia nitrogen concentration of 1.3 to 4.3 mg/L
- Maximum monthly mercury concentration of 1.3 ng/L
- Maximum weekly chloride concentration of 395 mg/L
- Maximum monthly geometric mean May through September fecal coliform concentration of 400 counts per 100 mL
- Maximum weekly effluent temperature between 49^0 F to 81^0 F.
- 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 4 (details of the cost estimates are included in The City of Waukesha Return Flow Plan in Volume 4 of the Application). Cost estimates were developed for return flow to Underwood Creek, Root River, and the two alternatives for direct to Lake Michigan. The cost estimates include a pump station at the City of Waukesha WWTP, a pipeline, and an outfall. Cost estimates were also developed for the three MMSD sub-alternatives that included returning all of the City's wastewater flow. 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.

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 8.6 more miles of force main and a more powerful pump station. The direct Lake Michigan near Milwaukee and Oak Creek return flow is the next most expensive of the four 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. The direct to lake Michigan near Racine return flow is the most expensive alternative that maintains the City's WWTP for return flow because it has the longest pipeline and similar infrastructure as the other direct to Lake Michigan alternative. The three MMSD sub-alternatives were the most expensive because they included decommissioning the City's WWTP and building the most infrastructure for conveyance, storage, and treatment. The MMSD alternatives are significantly more costly than any other alternative so they were not evaluated in further detail.

[20] Wisconsin Department of Natural Resources (WDNR). 2011. Limits for Waukesha Return Flow. December 13, 2011 correspondence from Jackie Fratrick/WDNR to Kristy Rogers/WDNR and Diane Figiel/WDNR. Correspondence provided to City of Waukesha on February 5, 2013. Chloride limit of 395 mg/L instead of 400 mg/L to be consistent with water quality standard and August 1, 2013 permit documentation.

TABLE 4
Cost Comparison for Return Flow Alternatives (2013 dollars unless noted)

Return Flow Alternative	Capital Cost[a]	Annual Operations and Maintenance	20-Year Present Worth	50-Year Present Worth
1: Underwood Creek	$58,059,000	$288,000	$61,059,000	$63,059,000
2: Root River	$96,038,000	$618,000	$103,038,000	$106,038,000
3: Direct to Lake Michigan near Milwaukee and Oak Creek	$117,247,000	$423,000	$122,247,000	$124,247,000
4: Direct to Lake Michigan near Racine	$166,708,000	$947,000	$177,570,000	$181,634,000
5: MMSD Sub-Alternative 1: Wet Weather Equalization and Force Main to South Shore [(b)]	$980,400,000	$1,444,000	$997,400,000	-
5: MMSD Sub-Alternative 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station [(b)]	$869,400,000	$1,300,000	$884,400,000	-
5: MMSD Sub-Alternative 3: Force Main and Biological HRT at South Shore [(b)]	$262,400,000	$1,063,000	$274,400,000	-

[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.
[b] 2009 Dollars

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 of the project is to improve fish passage. As described in The City of Waukesha Return Flow Plan (Volume 4 of the Application) and The City of Waukesha Environmental Report for Water Supply Alternatives (Volume 5 of the Application), the return flow could support the rehabilitation efforts and provide additional environmental improvements to Underwood Creek and Lake Michigan.

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. 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. Flow augmentation for the Root River has been documented since 1966 as a means to improve the river fisheries and water quality. These are further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

In 1994, the WDNR constructed the Root River Steelhead Facility to collect fish eggs as part of the State's support of fisheries stocking and fish monitoring in Lake Michigan and its tributaries. However, the operation of the facility and public angling opportunities are greatly diminished with the current low flows observed in the Root River. At another WDNR Lake Michigan egg harvesting facility, augmenting flow in Strawberry Creek from the Sturgeon Bay

ship canal has allowed the WDNR to improve its harvesting operations.[21] The WDNR had considered augmenting the flow in the Root River with Lake Michigan water, but construction and energy costs were prohibitive. Providing flow augmentation to the Root River with Waukesha return flow would eliminate the low flow conditions that have been documented in WDNR and SEWRPC reports dating back to 1966. Return flow to Root River would improve the operation of the Root River Steelhead Facility and improve angling opportunities in the Root River and in Lake Michigan. Because the return flow rate is small compared to the higher flows in the river, return flow would not adversely impact the geomorphic stability of the river. These are further discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application).

Although this alternative is longer in distance than Underwood Creek, this alternative has less impacts to wetlands and streams during construction because the pipeline corridor follows a previously disturbed corridor for its entire route. These construction impacts are temporary. These are further discussed in The City of Waukesha Environmental Report for Water Supply Alternatives (Volume 5 of the Application).

4.2.3 Alternative 3: Direct to Lake Michigan near Milwaukee and Oak Creek

This alternative has greater construction impacts than return flow to Underwood Creek or the Root River because it requires more 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 just returning the water to Lake Michigan, because the return flow would be conveyed in a pipe, instead of through surface water body.

The proposed alignment 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 The City of Waukesha Return Flow Plan (Volume 4 of the Application) and The City of Waukesha Environmental Report for Water Supply Alternatives (Volume 5 of the Application).

4.2.4 Alternative 4: Direct to Lake Michigan near Racine

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 just returning the water to Lake Michigan, because the return flow would be conveyed in a pipe, instead of through surface water body.

The impacts of this alternative are discussed in more detail in The City of Waukesha Return Flow Plan (Volume 4 of the Application) and The City of Waukesha Environmental Report for Water Supply Alternatives (Volume 5 of the Application).

4.2.5 Alternative 5: 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.

4.2.6 Alternative 6: 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

The City of Waukesha Environmental Report for Water Supply Alternatives (Volume 5 of the Application) has been completed that evaluates the environmental effects of the return flow alternatives. In summary, a return flow

[21] WDNR technical memorandum from Brad Eggold (WDNR Southern Lake Michigan Fisheries Supervisor). August 6, 2012. Water Return to Root River from Waukesha.

pipeline to Root River has low environmental impacts and the return flow provides an environmental improvement to the habitat and fisheries within the Root River.

6 Recommended Plan

Return flow to Underwood Creek is least cost, it has the least amount of infrastructure, it can provide an improvement to the habitat and fisheries in Underwood Creek, and it requires the smallest pump station at the City's WWTP, which will have the least energy demand. However, a total maximum daily load (TMDL) is being completed for Underwood Creek and the Menomonee River, and it will not be complete until after the Application is submitted to the WDNR. The WDNR has determined that an Underwood Creek return flow could not be approved until after the TMDL is complete and the City's return flow had an allocation. Consequently, return flow to Underwood Creek is not considered implementable at this time and is therefore not the preferred discharge location.

Root River is similar to Underwood Creek for its benefits to the fisheries and water quality, and for its insignificant impact on river stability and geomorphology. However, return flow has greater environmental benefits because SEWRPC and WDNR have reported impairments due to low flows that negatively affect fisheries and water quality. Flow augmentation has also been considered by the WDNR to support the Steelhead Facility because production at that facility is sometimes limited by insufficient flow rates in the river. The Root River return flow alternative also has the least cost, least infrastructure and construction impacts, and least energy demands for return flow pumping than the other alternatives that are considered to be implementable at this time.

To provide return flow for a Lake Michigan water supply, the modifications required at the WWTP would include the construction of a return flow pump station with related appurtenances such as inlet gates, an effluent discharge weir, and the extension of the effluent channel. Figures 8, 9, and 10 show conceptual modifications to the WWTP to provide return flow and allow discharge to the Fox River. The City's WWTP site is about elevation 794 feet. The highest elevation along the length of the return flow alignment is about 1,000 feet, and the discharge to Root River is about 672 feet. The pump station would be designed to overcome the static head of about 206 feet, plus the friction losses in the pipeline.

Discharge to the Fox River would only occur when WWTP flow exceeds 16.7 mgd, as discussed in The City of Waukesha Return Flow Plan (Volume 4 of the Application). The return flow pump station would be for pumping fully treated, disinfected, and aerated effluent. The pumps would have variable frequency drives to allow the return flow rate to be adjusted to meet return flow requirements (i.e. the pump speed would dictate the return flow rate).

FIGURE 8
Plan View Aerial of the Return Flow Pump Station

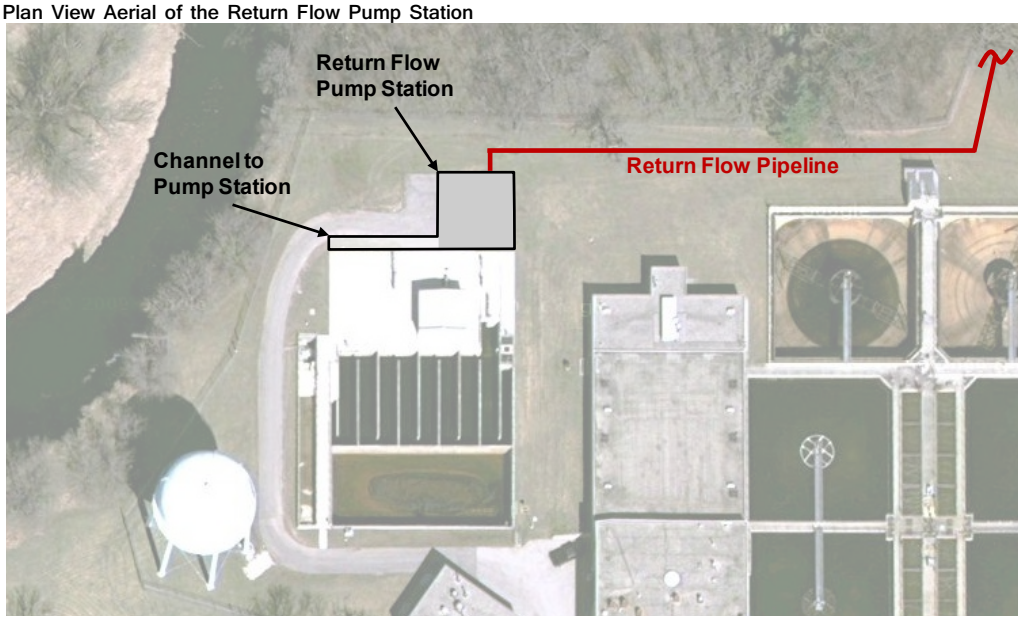
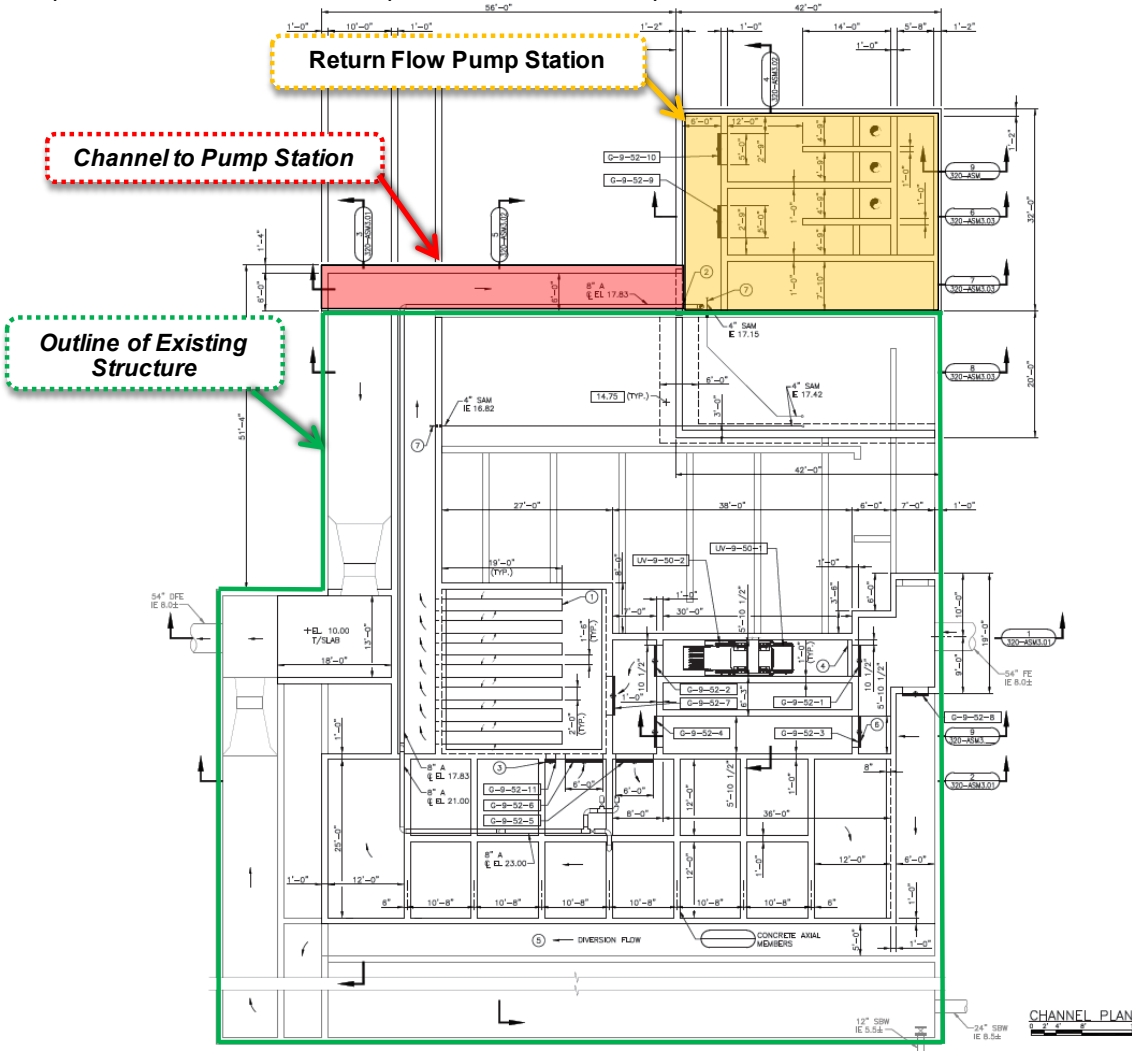


FIGURE 9
Conceptual Plan for the Return Flow Pump Station and Associated Improvements



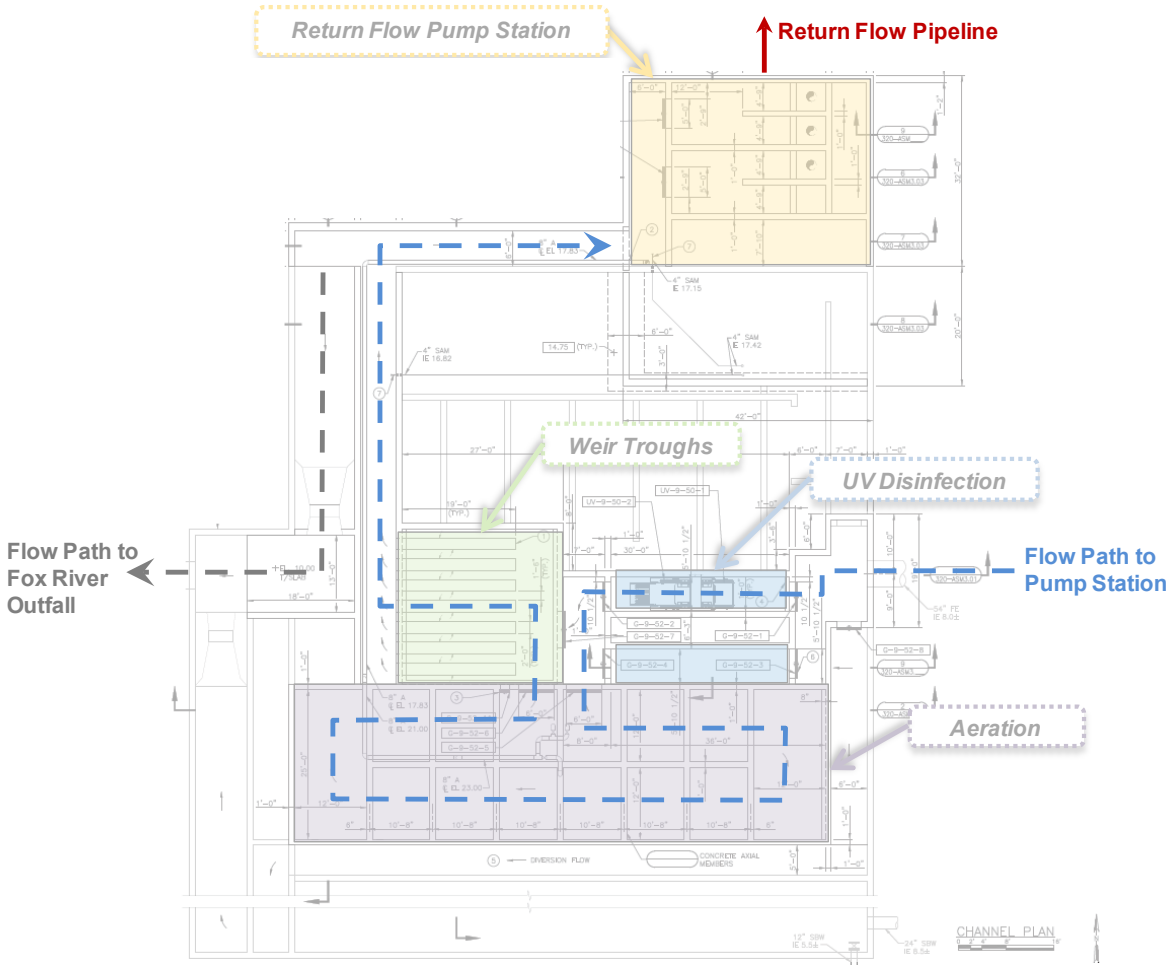
Background image provided by Strand Associates.

The capacity of each wetwell, including the pumps for each, would be sized to provide the anticipated return flow. This would allow the City to complete maintenance of the wetwells while not limiting their ability to provide return flow. All return flow would originate from the return flow pump station after the water receives full treatment. Flows in excess of the return flow rate would not reach the pump station and would instead flow to the existing Fox River outfall (Figure 10). The channel to the Fox River outfall is planned to be about 7 feet higher than the channel to the return flow pump station. When WWTP flow is 16.7 mgd or less, the pump station would pump all the flow. When WWTP flow exceeds 16.7 mgd, the excess flow would crest the channel to the Fox River outfall. The pump station would have instrumentation and controls to allow for the automated operation of the pump station to adjust flow rates based on flow at the WWTP. A flow chart summarizing the return flow and pump station automated operation is shown in Figure 11.

6.1 Return Flow Reaeration and Pipe Outfall

The City's WWTP currently provides aeration to meet dissolved oxygen (dissolved oxygen) permit limits with a diffused air system immediately downstream of the ultraviolet light disinfection system. As part of the WWTP facility planning (May 2011), the existing aeration system will be upgraded. The return flow will be pumped from downstream of the aeration system (Figure 11). This is anticipated to allow the aeration system at the WWTP site to provide sufficient dissolved oxygen to maintain permit compliance for the return flow discharge to Underwood Creek.

FIGURE 10
Flow Path Through Disinfection and Aeration to Return Flow Pump Station



Background image provided by Strand Associates.

An analysis was completed using daily WWTP performance data between 2002 and 2009 to determine if a diffused air system at the WWTP could meet a minimum dissolved oxygen limit of 7 mg/L [22] at the proposed return flow outfall location at Root River. This is the same dataset used for the return flow water quality modeling in Root River and that is included in The City of Waukesha Return Flow Plan (Volume 4 of the Application). A force main algorithm was used to evaluate different scenarios of dissolved oxygen depletion through the proposed 20 mile, 30-inch diameter return flow force main.[23] The algorithm models dissolved oxygen depletion as a first-order reaction between dissolved oxygen and the 5-day biochemical oxygen demand (BOD_5). The algorithm requires the force main length and initial values for flow, temperature, BOD_5 concentration, and dissolved oxygen concentration.

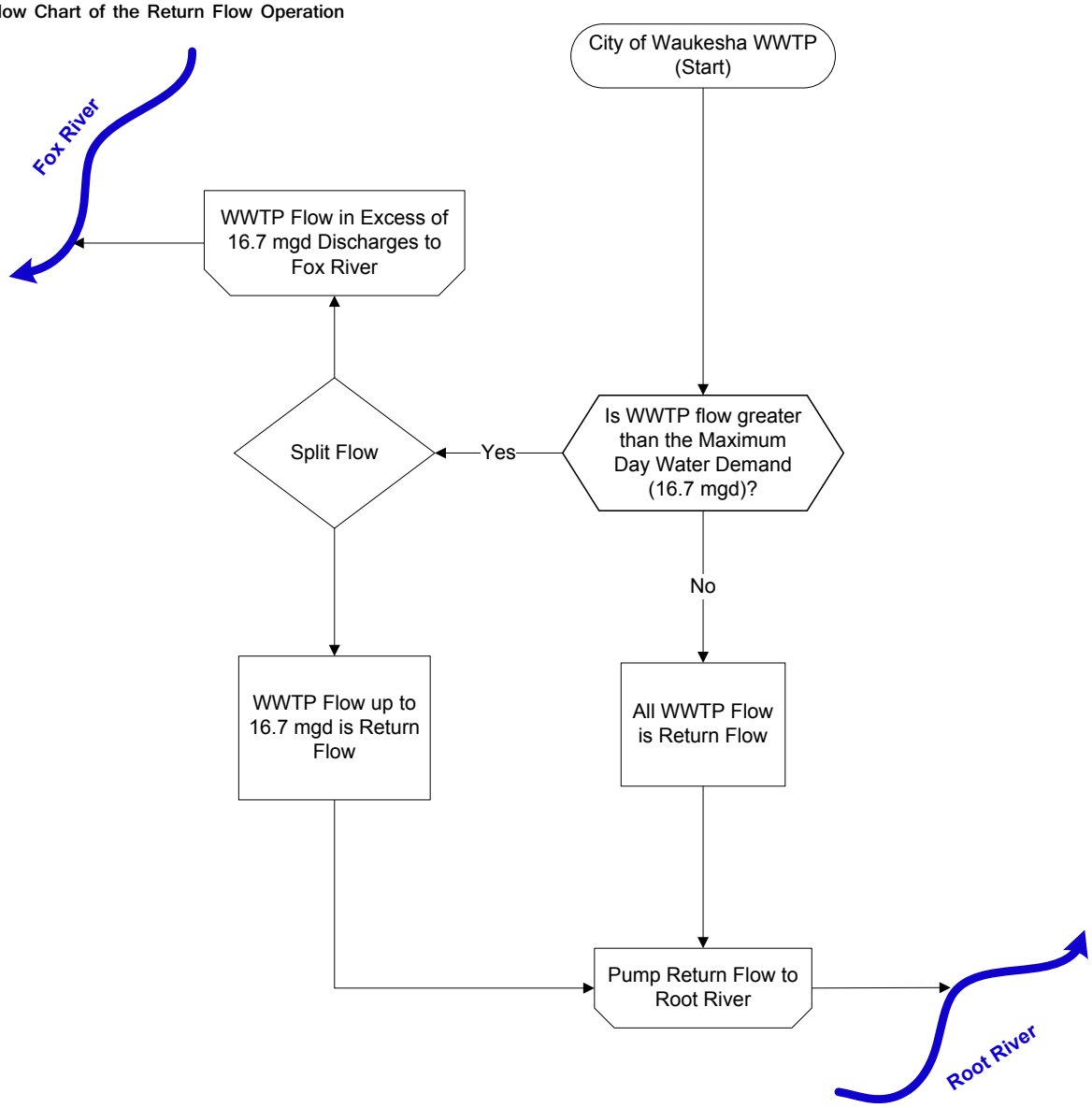
The following values were used in the algorithm from the 2002-2009 data set:

- **Minimum Flow.** Using the minimum flow of 6.34 million gallons per day (mgd) will provide the lowest flow velocity and longest travel time in the return flow force main for BOD_5 to react with and deplete the dissolved oxygen prior to discharge.

[22] Wisconsin Department of Natural Resources (WDNR). 2011. Limits for Waukesha Return Flow. December 13, 2011 correspondence from Jackie Fratrick/WDNR to Kristy Rogers/WDNR and Diane Figiel/WDNR. Correspondence provided to City of Waukesha on February 5, 2013

[23] *Wastewater Engineering: Treatment, Disposal and Reuse,* 3rd Edition, Metcalf and Eddy, Inc., George Tchobanoglous and Franklin Burton, 1991. Page 74.

FIGURE 11
Flow Chart of the Return Flow Operation



- **Maximum Temperature.** Using the maximum temperature of 24.2ºC will provide for the highest microbial activity and consequently high dissolved oxygen depletion.
- **95th Percentile BOD_5.** The 95th percentile effluent BOD5 was reported as <2 mg/L and was assumed to be 2 mg/L for modeling purposes. Using a high BOD_5 value allows for greater dissolved oxygen depletion.

Using the minimum flow and maximum temperature provides a boundary condition, and coupled with a BOD_5 greater than the 95^{th} percentile, these values represent an unlikely condition that will result in a high depletion of dissolved oxygen in the return flow force main. Consequently, the model results provide a conservative estimate of the dissolved oxygen needed at the WWTP to meet effluent limits at the Root River outfall.

Model runs indicated an initial dissolved oxygen concentration of 7.48 mg/L at the WWTP would provide a dissolved oxygen concentration of 7 mg/L at a Root River outfall. This means that under these conservative assumptions, 0.48 mg/L dissolved oxygen would be depleted between the WWTP and discharge to Root River. A review of historical data shows that a dissolved oxygen concentration of 7.48 is achievable with the existing aeration system for the above modeled scenario and it is achievable in nearly all conditions. However, with a new aeration system planned as part of the WWTP facility planning, providing 7.48 mg/L is within the design guidelines for a new aeration system and supplemental aeration system at the Root River outfall is consequently not anticipated at this time.

The outfall to Root River will be designed to blend in with the topography along Root River so that the outfall structure will not raise the flood elevations. Two example outfall designs are shown in Figures 12 and 13. Figure 12 is a pipe outfall along Underwood Creek downstream of the proposed return flow outfall location, and is of similar size as that anticipated for return flow to Root River. Figure 13 is an outfall for the Madison Metropolitan Sewerage District (Madison MSD) to Badger Mill Creek, where the outfall structure has been designed to blend in with the surrounding landscape.

FIGURE 12
Pipe Outfall with Flared End Section along Underwood Creek in Wauwatosa



FIGURE 13
Rock Outfall from the Madison Metropolitan Sewerage District Wastewater Treatment Plant Discharge to Badger Mill Creek.



Final design of the outfall may include hydraulic modeling if needed, such as using HEC-RAS to ensure that the design causes no rise in the regulatory flood elevation. Detailed design and hydraulic modeling of the outfall structure will be complete prior to WDNR Chapter 30 permitting.

If during detailed design and permitting supplemental aeration is determined to be needed to meet dissolved oxygen limits for a Root River outfall, additional dissolved oxygen may be provided by an outfall similar to Madison MSD's (Figure 13) or by a cascade aerator as shown in Figure 14. The cost of a potential future aeration structure is included within the contingency of the return flow cost estimate.

FIGURE 14
Outfall and Cascade Aerator from a Wastewater Treatment Plant in Fort Campbell, TN



6.2 Return Flow Chlorides

Chloride concentrations from the City's WWTP were reviewed from March 2006 through May 2013 (Attachment A-4). The average weekly chloride concentration was 479 mg/L with a maximum weekly concentration of 690 mg/l and minimum weekly concentration of 310 mg/L. The average weekly chloride concentration for the months impacted by winter use of road salts (Dec, Jan, Feb, Mar and Apr) was 497 mg/L with a maximum of 690 mg/L. The average for non-winter months was 465 mg/L with a maximum of 595 mg/L. The 90th percentile weekly chloride concentration was 590 mg/L.

The WWTP's permit includes chloride limits for a Fox River discharge less than their previous permit. The permit limit is 690 mg/L weekly average and it requires the City implement a chloride compliance plan to achieve a target value of 440 mg/l and water quality based effluent limit (WQBEL) of 431 mg/L. The permit also included chloride limits of 395 mg/L for a Lake Michigan return flow through Underwood Creek and Root River. This concentration is also the water quality criterion. The WQBEL proposed for Underwood Creek and Root River are lower than their current target value (440 mg/L and WQBEL (431 mg/L) for discharge to the Fox River, but they are not significantly different. Consequently, achieving the return flow limits are likely to be achieved by meeting the Fox River limits.

The permit identified several chloride reduction measures that the City will have to implement for their Fox River discharge. These requirements are expected to move the City closer to or in compliance with the Fox River WQBEL over the duration of the permit. The reduction measures are summarized in Attachment A-4.

The chloride reduction measures included in the permit and additional measures identified as part of the Application were evaluated to estimate the effluent chloride concentrations for return flow (Attachment A-4).

Several scenarios were evaluated that show reducing return flow chlorides concentrations to below the requirements is achievable. Much of the chloride reduction is achieved by residential and commercial/industrial water softener removal because a Lake Michigan water supply will not require softening, but many of the chloride reduction measures will be needed. Using the 90th percentile historic weekly chloride concentration, less than a 60 percent reduction in residential and commercial/industrial water softening is estimated to be required to achieve an effluent limit of 395 mg/L. Complying with the return flow chloride limits will be achievable because it is anticipated that softening will be reduced by more than 60 percent and reduction of chlorides above the 90th percentile will be accomplished by chloride reduction measures that target winter events, such as deicing operations and salt water runoff from storage facilities.

6.3 Return Flow Temperature

A preliminary thermal analysis of the City's return flow discharge to the Root River was completed (Attachment A-5). The purpose of the analysis was to identify one or more methods to comply with the WDNR thermal regulations in NR 102 and NR 106. The City's return flow is not "hot" and does not pose acute thermal threat to aquatic life. Rather, like many wastewater treatment plants in Wisconsin, the return flow temperature is warmer than the ambient Root River temperature in late fall and winter months, with the highest measured temperatures ranging from 51 to 70 degrees Fahrenheit (October through January). The WDNR thermal sub-lethal standards during these months can be triggered by typical municipal wastewater effluent.

The analysis compares the physical riverine characteristics of the current WWTP Fox River discharge to that of the Root River. Preliminary indications are that mixing of the discharge within the Fox River will meet the thermal requirements, and presumably, if similar conditions exist on the Root River, mixing will also satisfactorily meet the thermal discharge requirements to the Root River.

The analysis concludes that several options exist to meet the thermal requirements. These include:

- Thermal mixing analysis of the Root River
- Using site specific ambient temperatures to establish thermal limits
- Management techniques to lower the return flow temperature before discharge
- Combinations of the above techniques

The analysis demonstrates that multiple options exist for the Root River return flow to achieve WDNR thermal rule compliance. Consequently, return flow as it relates to thermal discharge, can reasonably protect the chemical, physical, and biological integrity of the Root River. With a successful Application, more detailed data gathering and analysis for thermal and other water quality requirements will occur to apply for a Root River discharge permit.

6.4 Return Flow Mercury

The City implemented a Mercury Pollutant Minimization Program for the WWTP that began in 2007. Since then the mercury concentration in the WWTP effluent has dropped to levels that will meet the return flow limit of 1.3 ng/L. The City will continue their mercury minimization program and therefore return flow will meet its requirements for the mercury water quality limits.

Attachment A-1

WPDES Permit (Effective Date: August 1, 2013)

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 Lloyd L Eagan
Lloyd L Eagan
Southern District Water Leader

July 26, 2013
Date Permit Signed/Issued

PERMIT TERM: EFFECTIVE DATE – August 01, 2013
EXPIRATION DATE – June 30, 2018

TABLE OF CONTENTS

1 INFLUENT REQUIREMENTS **1**

1.1 SAMPLING POINT(S) 1
1.2 MONITORING REQUIREMENTS 1
1.2.1 Sampling Point 702 - INFLUENT *1*

2 IN-PLANT REQUIREMENTS **2**

2.1 SAMPLING POINT(S) 2
2.2 MONITORING REQUIREMENTS AND LIMITATIONS 2
2.2.1 Sampling Point 101 - Mercury Effluent Blank *2*
2.2.2 Sampling Point 102 - In-Plant Diversion *2*

3 SURFACE WATER REQUIREMENTS **4**

3.1 SAMPLING POINT(S) 4
3.2 MONITORING REQUIREMENTS AND EFFLUENT LIMITATIONS 4
3.2.1 Sampling Point (Outfall) 001 - EFFLUENT *4*

4 LAND APPLICATION REQUIREMENTS **10**

4.1 SAMPLING POINT(S) 10
4.2 MONITORING REQUIREMENTS AND LIMITATIONS 10
4.2.1 Sampling Point (Outfall) 002 - Anaerobic Belt Pressed Sludge *10*

5 SCHEDULES **15**

5.1 CHLORIDE TARGET VALUE 15
5.2 WATER QUALITY BASED EFFLUENT LIMITS (WQBELS) FOR TOTAL PHOSPHORUS 15
5.3 ULTRAVIOLET DISINFECTION SYSTEM UPGRADE 17
5.4 CMOM AUDIT AND COLLECTION SYSTEM PROGRESS REPORTS 17

6 STANDARD REQUIREMENTS **18**

6.1 REPORTING AND MONITORING REQUIREMENTS 18
6.1.1 Monitoring Results *18*
6.1.2 Sampling and Testing Procedures *18*
6.1.3 Pretreatment Sampling Requirements *18*
6.1.4 Recording of Results *18*
6.1.5 Reporting of Monitoring Results *19*
6.1.6 Compliance Maintenance Annual Reports *19*
6.1.7 Records Retention *19*
6.1.8 Other Information *20*
6.2 SYSTEM OPERATING REQUIREMENTS 20
6.2.1 Noncompliance Notification *20*
6.2.2 Flow Meters *20*
6.2.3 Raw Grit and Screenings *20*
6.2.4 Sludge Management *20*
6.2.5 Prohibited Wastes *21*
6.2.6 Unscheduled Bypassing *21*
6.2.7 Scheduled Bypassing *21*
6.2.8 Proper Operation and Maintenance *22*
6.3 SURFACE WATER REQUIREMENTS 22
6.3.1 Permittee-Determined Limit of Quantitation Incorporated into this Permit *22*
6.3.2 Appropriate Formulas for Effluent Calculations *22*
6.3.3 Effluent Temperature Requirements *22*
6.3.4 Visible Foam or Floating Solids *23*
6.3.5 Percent Removal *23*
6.3.6 Chloride Notification *23*

6.3.7 Fecal Coliforms *23*
6.3.8 Seasonal Disinfection *23*
6.3.9 Whole Effluent Toxicity (WET) Monitoring Requirements *23*
6.3.10 Whole Effluent Toxicity (WET) Identification and Reduction *23*
6.3.11 Whole Effluent Toxicity (WET) and Chloride Source Reduction Measures *24*
6.4 PRETREATMENT PROGRAM REQUIREMENTS 24
6.4.1 Inventories *25*
6.4.2 Regulation of Industrial Users *25*
6.4.3 Annual Pretreatment Program Report *26*
6.4.4 Pretreatment Program Modifications *26*
6.4.5 Program Resources *27*
6.5 LAND APPLICATION REQUIREMENTS 27
6.5.1 Sludge Management Program Standards And Requirements Based Upon Federally Promulgated Regulations *27*
6.5.2 General Sludge Management Information *27*
6.5.3 Sludge Samples *27*
6.5.4 Land Application Characteristic Report *27*
6.5.5 Calculation of Water Extractable Phosphorus *27*
6.5.6 Monitoring and Calculating PCB Concentrations in Sludge *28*
6.5.7 Annual Land Application Report *28*
6.5.8 Other Methods of Disposal or Distribution Report *28*
6.5.9 Approval to Land Apply *29*
6.5.10 Soil Analysis Requirements *29*
6.5.11 Land Application Site Evaluation *29*
6.5.12 Class B Sludge: Anaerobic Digestion *29*
6.5.13 Vector Control: Volatile Solids Reduction *29*

7 SUMMARY OF REPORTS DUE ERROR! BOOKMARK NOT DEFINED.

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 after screening and grit removal prior to addition of recycled flows (i.e. filter backwash, sludge press water, sludge thickener supernatant and clarifier drains).

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 Total Metals Analyses

Measurements of total metals and total recoverable metals shall be considered as equivalent.

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 current 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 This is the flow diverted around the UV system (Q-bypassed)

2.2.2.1 In-Plant Diversion Requirements

This permit includes a compliance schedule in section 5.3 to upgrade the UV disinfection system. If, prior to the completion of the upgrade, a diversion occurs around the UV disinfection system (due to wet weather conditions) 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 such diversion, 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
  $Q_{bypassed}$ = flow rate of flow diverted around UV system
  $[FC]_{eff}$ = 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).

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 chamber after the UV disinfection system but before the Parshall flume. Grab samples are collected from the effluent drop box, after Parshall flume .

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 3.2.1.1
BOD_5, Total	Weekly Avg	8.5 mg/L	Daily	24-Hr Flow Prop Comp	July and Aug limit
BOD_5, Total	Weekly Avg	8.2 mg/L	Daily	24-Hr Flow Prop Comp	Sept limit
BOD_5, Total	Weekly Avg	10 mg/L	Daily	24-Hr Flow Prop Comp	Oct-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 Jan, Feb, Mar, Apr, Nov and Dec.
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	11 mg/L	Daily	24-Hr Flow Prop Comp	Jan limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	12 mg/L	Daily	24-Hr Flow Prop Comp	Feb, Nov and Dec limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	13 mg/L	Daily	24-Hr Flow Prop Comp	Mar limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	10 mg/L	Daily	24-Hr Flow Prop Comp	Apr and Oct 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	Jun 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	Aug limit
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	5.8 mg/L	Daily	24-Hr Flow Prop Comp	Sept limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.0 mg/L	Daily	24-Hr Flow Prop Comp	Jan limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.2 mg/L	Daily	24-Hr Flow Prop Comp	Feb limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	6.0 mg/L	Daily	24-Hr Flow Prop Comp	Mar limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.6 mg/L	Daily	24-Hr Flow Prop Comp	Apr 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	Aug limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	2.9 mg/L	Daily	24-Hr Flow Prop Comp	Sept limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	4.5 mg/L	Daily	24-Hr Flow Prop Comp	Oct limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.4 mg/L	Daily	24-Hr Flow Prop Comp	Nov limit
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	5.1 mg/L	Daily	24-Hr Flow Prop Comp	Dec limit
Dissolved Oxygen	Daily Min	6.7 mg/L	Daily	Grab	Sept limit
Dissolved Oxygen	Daily Min	7.0 mg/L	Daily	Grab	Oct-Aug limit
Chloride	Weekly Avg	690 mg/L	Monthly	24-Hr Comp	See 3.2.1.9, 3.2.1.10 and 5.1
Phosphorus, Total	Monthly Avg	0.7 mg/L	Daily	24-Hr Flow Prop Comp	This is an interim limit. Final limits are 0.075 mg/L, 8.76 lb/day and 0.225 mg/L. See 3.2.1.6, 3.2.1.7 and 5.2
Fecal Coliform	Geometric Mean	400 #/100 ml	3/Week	Grab	May-Sept limit
Cadmium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Chromium, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3
Copper, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3
Lead, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3
Mercury, Total Recoverable		ng/L	Monthly	Grab	See 3.2.1.4
Nickel, Total Recoverable		µg/L	Quarterly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3
Zinc, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	See 3.2.1.2 and 3.2.1.3
Acute WET		TU_a	See Listed Qtr(s)	24-Hr Flow Prop Comp	
Chronic WET		rTU_c	See Listed Qtr(s)	24-Hr Flow Prop Comp	
Temperature Maximum		deg F	Continuous	Continuous	Monitor from Oct-April. Also see 3.2.1.5

3.2.1.1 Average Annual Design Flow

The current average annual design flow of Waukesha's wastewater treatment facility is 14 MGD. Waukesha submitted a 20-year Wastewater Treatment Plant Facilities Planning report to the Department. This report, with 5-year staged implementations of projects (as needed) and a year 2030 average annual design flow of 11.65 MGD, was approved by the Department in March 2013. Calculations of the Water Quality-Based Effluent Limits (WQBEL) for this permit are based on the current 14 MGD average annual design flow.

3.2.1.2 Total Metals Analyses

Measurements of total metals and total recoverable metals shall be considered as equivalent.

3.2.1.3 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.

3.2.1.4 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.

3.2.1.5 Effluent Temperature Monitoring

For monitoring temperature continuously, collect measurements in accordance with s. NR 218.04(13). This means that discrete measurements shall be recorded at intervals of not more than 15 minutes during the 24-hour period. Report the maximum temperature measured during the day on the DMR.

3.2.1.6 Phosphorus Water Quality Based Effluent Limitations

The final calculated effluent limits for phosphorus are 0.075 mg/L and 8.76 lbs/day, both expressed as six month averages (averaging periods - May through October and November through April) and 0.225 mg/L, monthly average, unless:

(A) As part of the application for the next reissuance, or prior to filing the application, the permittee submits either: 1.) a watershed adaptive management plan and a completed Watershed Adaptive Management Request Form 3200-139; or 2.) an application for water quality trading; or 3.) an application for a variance; or 4.) new information or additional data that supports a recalculation of the numeric limitation; and
(B) The Department modifies, revokes and reissues, or reissues the permit to incorporate a revised limitation before the expiration of the compliance schedule*.

If Adaptive Management or Water Quality Trading is approved as part of the permit application for the next reissuance or as part of an application for a modification or revocation and reissuance, the plan and specification submittal, construction, and final effective dates for compliance with the total phosphorus WQBEL may change in the reissued or modified permit. In addition, the numeric value of the water quality based effluent limit may change based on new information (e.g. a TMDL) or additional data If a variance is approved for the next reissuance, interim limits and conditions will be imposed in the reissued permit in accordance with s. 283.15, Stats., and applicable regulations. A permittee may apply for a variance to the phosphorus WQBEL at the next reissuance even if the permittee did not apply for a phosphorus variance as part of this permit reissuance.

Interim Limitation: The interim effluent limit for phosphorus of 0.7 mg/L becomes effective on permit reissuance.

*Note: The Department will prioritize reissuances and revocations, modifications, and reissuances of permits to allow permittees the opportunity to implement adaptive management or nutrient trading in a timely and effective manner.

*Note: If a water quality based effluent limit has taken effect in a permit, any increase in the limit is subject to s. NR 102.05(1) and ch. NR 207 Wis. Adm. Code.

3.2.1.7 Alternative Approaches to Phosphorus WQBEL Compliance

Rather than upgrading its wastewater treatment facility to comply with WQBELs for total phosphorus, the permittee may use Water Quality Trading or the Watershed Adaptive Management Option, to achieve compliance under ch. NR 217, Wis. Adm. Code, provided that the permit is modified, revoked and reissued, or reissued to incorporate any such alternative approach. A permittee may also implement a upgrade to its wastewater treatment facility in combination with Water Quality Trading or the Watershed Adaptive Management Option to achieve compliance, provided that the permit is modified, revoked and reissued, or reissued to incorporate any such alternative approach. If the Final Compliance Alternatives Plan concludes that a variance will be pursued, the Plan shall provide information regarding the basis for the variance.

Submittal of Permit Application for Next Reissuance and Adaptive Management or Pollutant Trading Plan or Variance Application: The permittee shall submit the permit application for the next reissuance at least 6 months prior to expiration of this permit. If the permittee intends to pursue adaptive management to achieve compliance with the phosphorus water quality based effluent limitation, the permittee shall submit with the application for the next reissuance: a completed Watershed Adaptive Management Request Form 3200-139, the completed Adaptive Management Plan and final plans for any system upgrades necessary to meet interim limits pursuant to s. NR 217.18. If the permittee intends to pursue pollutant trading to achieve compliance, the permittee shall submit an application for water quality trading with the application for the next reissuance. If system upgrades will be used in combination with pollutant trading to achieve compliance with the final water quality-based limit, the reissued permit will specify a schedule for the necessary upgrades. If the permittee intends to seek a variance, the permittee shall submit an application for a variance with the application for the next reissuance.

3.2.1.8 Whole Effluent Toxicity (WET) Testing

Primary Control Water: the SE Fox River, upstream and outside the mixing zone of the discharge (outfall) 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, 2013; July-Sept, 2014; Apr-June, 2015; Jan-Mar, 2016; July-Sept, 2017
- **Chronic:** Oct-Dec, 2013; July-Sept, 2014; Apr-June, 2015; Jan-Mar, 2016; July-Sept, 2017

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 Water Quality, 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 90 day reporting period shall begin the day after the test which showed a positive result. The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

3.2.1.9 Chloride Sampling and Calculation of Weekly Averages

A sampling frequency of 4/month requires that samples be collected on four consecutive days each month. Any four consecutive days of sampling shall be exclusive to one week of a month; where Week 1 is days 1-7, Week 2 is days 8-14, Week 3 is days 15-21, and Week 4 is days 22-28. The weekly average discharge shall be calculated and reported for any week that samples are collected.

3.2.1.10 Chloride Variance – Implement Source Reduction Measures

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:

- Amend the sewer use ordinance and plumbing code language by March 31, 2014, to require:
  - High efficiency demand initiated regeneration (DIR) type softeners for both newly installed and replacement softeners for residences, commercial and industrial businesses.
  - Significant industrial, commercial, and other large water users (e.g. hospitals) to evaluate their water treatment systems with regard to softened water requirements, and where feasible upgrade current water softeners with brine reclaim system. Include discussions on these efforts and follow-up actions in the first chloride Progress Report.

  Please Note: NR 106.92, Wisconsin Admin Code authorizes a publicly owned treatment works to regulate chloride discharges from its wastewater contributors.
- Investigate new or increased chloride sources from industrial, commercial, hauled wastes and large water users. Characterize and quantify chloride from identified sources. Require identified sources to evaluate their processes with regard to reducing chloride. . Include discussions on these efforts and follow-up actions in

submitted chloride reports.

- Provide information on accomplishment in terms of reduction of clear water entry into the plant (through the collection system) as a result of the on-going collection system I/I reduction project implementations (sanitary/storm sewer line, manhole and chimney rehabilitation, replacement/elimination and repair). Include discussions (along with graphs) in the first annual chloride report and subsequent chloride reports.
- Track concentration and mass of chloride from the discharge of brine from all sources (as indicated in Waukesha's final chloride report dated March 31, 2012) to the WWTP. Characterize and quantify the chloride added to the plant from each source. Coordinate permit required chloride monitoring with periods when brine is hauled to the WWTP. Discuss in the annual chloride reports, measures being taken to eliminate (e.g. by banning brine discharge) or reduce chloride from these sources.
- Continue education of homeowners on impact of chloride from residential softeners and on options available for increasing softener efficiency.
- Request voluntary support from licensed softener installers or self-installers on providing unsoftened water for outside faucets or other water faucets where softened water is not essential.

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.
005	Liquid sludge. The Waukesha plant typically generates and disposes of belt pressed cake sludge (sample pt 002). This liquid sludge type (sample pt 005) is infrequently generated usually from the cleaning of digesters. The permittee shall notify the Department prior to land applying liquid sludge.

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	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Nitrogen, Ammonium (NH_4-N) Total		Percent	1/ 2 Months	Grab Comp	
Phosphorus, Total		Percent	1/ 2 Months	Grab Comp	
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.	**BiMonthly**
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.	**BiMonthly**

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 2014. 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
Amount 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

5.1 Chloride Target Value

As a condition of the variance to the water quality based effluent limitation 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
Annual 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 3.2.1.10 of this permit. Note that the interim limitation of 690 mg/L, weekly average, remains enforceable until new enforceable limits are established in the next permit issuance. The first annual chloride progress report is to be submitted by the Date Due.	06/30/2014
Annual Chloride Progress Report #2: Submit a chloride progress report.	06/30/2015
Annual Chloride Progress Report #3: Submit a chloride progress report.	06/30/2016
Final Chloride Report: Submit a final report documenting the success in meeting the chloride target value of 440 mg/L, 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.	12/31/2017

5.2 Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus

The permittee shall comply with the WQBELs for Phosphorus as specified. No later than 30 days following each compliance date, the permittee shall notify the Department in writing of its compliance or noncompliance. If a submittal is required, a timely submittal fulfills the notification requirement.

Required Action	Date Due
Operational Evaluation Report: The permittee shall prepare and submit to the Department for approval an operational evaluation report. The report shall include an evaluation of collected effluent data, possible source reduction measures, operational improvements or other minor facility modifications that will optimize reductions in phosphorus discharges from the treatment plant during the period prior to complying with final phosphorus WQBELs and, where possible, enable compliance with final phosphorus WQBELs by 06/30/2016. The report shall provide a plan and schedule for implementation of the measures, improvements, and modifications as soon as possible, but not later than 06/30/2016 and state whether the measures, improvements, and modifications will enable compliance with final phosphorus WQBELs. Regardless of whether they are expected to result in compliance, the permittee shall implement the measures, improvements, and modifications in accordance with the plan and schedule specified in the operational evaluation report. If the operational evaluation report concludes that the facility can achieve final phosphorus WQBELs using the existing treatment system with only source reduction measures, operational improvements, and minor facility modifications, the permittee shall comply with the final phosphorus WQBEL by 06/30/2016 and is not required to comply with the milestones identified below('Preliminary Compliance Alternatives Plan', 'Final Compliance Alternatives Plan', 'Final Plans and Specifications' 'Treatment Plant Upgrade to Meet WQBELs', 'Complete Construction, 'Achieve Compliance').	06/30/2014

Study of Feasible Alternatives: If the Operational Evaluation Report concludes that the permittee cannot achieve final phosphorus WQBELs with source reduction measures, operational improvements and other minor facility modifications, the permittee shall initiate a study of feasible alternatives for meeting final phosphorus WQBELs and comply with the remaining required actions of this schedule of compliance. If the Department disagrees with the conclusion of the report, and determines that the permittee can achieve final phosphorus WQBELs using the existing treatment system with only source reduction measures, operational improvements, and minor facility modifications, the Department may reopen and modify the permit to include an implementation schedule for achieving the final phosphorus WQBELs sooner than 06/30/2020.	06/30/2014
Compliance Alternatives, Source Reduction, Improvements and Modifications Status: The permittee shall submit a 'Compliance Alternatives, Source Reduction, Operational Improvements and Minor Facility Modification' status report to the Department. The report shall provide an update on the permittee's: (1) progress implementing source reduction measures, operational improvements, and minor facility modifications to optimize reductions in phosphorus discharges and, to the extent that such measures, improvements, and modifications will not enable compliance with the WQBELs, (2) status evaluating feasible alternatives for meeting phosphorus WQBELs.	06/30/2015
Preliminary Compliance Alternatives Plan: The permittee shall submit a preliminary compliance alternatives plan to the Department. If the plan concludes upgrading of the permittee's wastewater treatment facility is necessary to achieve final phosphorus WQBELs, the submittal shall include a preliminary engineering design report. If the plan concludes Adaptive Management will be used, the submittal shall include a completed Watershed Adaptive Management Request Form 3200-139 without the Adaptive Management Plan. If water quality trading will be undertaken, the plan must state that trading will be pursued.	06/30/2016
Final Compliance Alternatives Plan: The permittee shall submit a final compliance alternatives plan to the Department. If the plan concludes upgrading of the permittee's wastewater treatment is necessary to meet final phosphorus WQBELs, the submittal shall include a final engineering design report addressing the treatment plant upgrades, and a facility plan if required pursuant to ch. NR 110, Wis. Adm. Code. If the plan concludes Adaptive Management will be implemented, the submittal shall include a completed Watershed Adaptive Management Request Form 3200-139 and an engineering report addressing any treatment system upgrades necessary to meet interim limits pursuant to s. NR 217.18, Wis. Adm. Code. If the plan concludes water quality trading will be used, the submittal shall identify potential trading partners. Note: See 'Alternative Approaches to Phosphorus WQBEL Compliance' in the Surface Water section of this permit.	06/30/2017
Progress Report on Plans & Specifications: Submit progress report regarding the progress of preparing final plans and specifications. Note: See 'Alternative Approaches to Phosphorus WQBEL Compliance' in the Surface Water section of this permit.	06/30/2018
Final Plans and Specifications: Unless the permit has been modified, revoked and reissued, or reissued to include Adaptive Management or Water Quality Trading measures or to include a revised schedule based on factors in s. NR 217.17, Wis. Adm. Code, the permittee shall submit final construction plans to the Department for approval pursuant to s. 281.41, Stats., specifying treatment plant upgrades that must be constructed to achieve compliance with final phosphorus WQBELs, and	06/30/2019

a schedule for completing construction of the upgrades by the complete construction date specified below. (Note: Permit modification, revocation and reissuance, and reissuance are subject to s. 283.53(2), Stats.) Note: See 'Alternative Approaches to Phosphorus WQBEL Compliance' in the Surface Water section of this permit.	
Treatment Plant Upgrade to Meet WQBELs: The permittee shall initiate construction of the upgrades. The permittee shall obtain approval of the final construction plans and schedule from the Department pursuant to s. 281.41. Stats. Upon approval of the final construction plans and schedule by the Department pursuant to s. 281.41, Stats., the permittee shall construct the treatment plant upgrades in accordance with the approved plans and specifications. Note: See 'Alternative Approaches to Phosphorus WQBEL Compliance' in the Surface Water section of this permit.	09/30/2019
Complete Construction and Achieve Compliance: The permittee shall complete construction of wastewater treatment system upgrade and achieve compliance with the final phosphorus WQBELs. Note: See 'Alternative Approaches to Phosphorus WQBEL Compliance' in the Surface Water section of this permit.	06/30/2020

5.3 Ultraviolet Disinfection System Upgrade

The permittee shall upgrade the UV disinfection system as follows:

Required Action	Date Due
Updated Engineering Design Report for UV Disinfection System: Submit for Department's review an updated engineering design report addressing the UV disinfection system upgrade	06/30/2014
Plans and Specifications: Submit plans and specifications for the UV Disinfection System upgrade	03/31/2015
Initiate Construction : Initiate Construction for the UV Disinfection System upgrade	09/30/2015
Complete Construction: Complete construction for the UV Disinfection System upgrade	03/31/2017

5.4 CMOM Audit and Collection System Progress Reports

The following reports shall be submitted to the Department as indicated below:

Required Action	Date Due
CMOM Annual Self-Audit: : Submit a CMOM self-audit by June 30, annually. The CMOM annual self-audit shall evaluate all goals, O&M tasks and projects identified in the CMOM Plan; with the goals, tasks, projects and budgets developed and reprioritized as needed for the next year. Capital improvement projects for the next year should be identified as part of the audit. The CMOM annual self-audit can be submitted at the same time of the Compliance Maintenance Annual Report (CMAR).	
Collection System Semi-annual Progress Report: Submit semi-annual progress reports by June 30 and December 31 of each year. The December 31st progress report shall include a schedule of collection system O&M priorities and CIP projects for the upcoming year.	

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. A copy of the Wastewater Discharge Monitoring Report Form or an electronic file of the report shall be retained by the permittee.

Monitoring results shall be reported on an electronic discharge monitoring report (eDMR). The eDMR shall be certified electronically by a principal executive officer, a ranking elected official or other duly authorized representative. The 'eReport Certify' page certifies that the electronic report form is true, accurate and complete.

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.

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 purposes of calculating NR 101 fees, the 2 mg/l lower reporting limits for BOD_5 and Total Suspended Solids shall be considered to be limits of quantitation

- 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 all of the following occur:

- 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.
- The permittee notifies the department of the unscheduled bypass or overflow. The permittee shall notify the department within 24 hours of initiation of the bypass or overflow occurrence by telephone, voicemail, fax or e-mail. Within 5 days of conclusion of the bypass or overflow occurrence, the permittee shall submit to the department in writing, all of the following information:
  - 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 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.
- Alternatives to bypassing.
- Measures to mitigate environmental harm caused by the bypass.
- Estimated volume of 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 concentration limits and mass limits and total load limits:

Weekly/Monthly/Six-Month/Annual Average Concentration = the sum of all daily results for that week/month/six-month/year, divided by the number of results during that time period. [Note: When a six-month average effluent limit is specified for Total Phosphorus the applicable periods are May through October and November through April.]

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.

Six-Month 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 six-month period. [Note: When a six-month average effluent limit is specified for Total Phosphorus the applicable periods are May through October and November through April.]

Annual 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 entire year.

Total Monthly Discharge: = monthly average concentration (mg/L) x total flow for the month (MG/month) x 8.34.

Total Annual Discharge: = sum of total monthly discharges for the calendar year.

6.3.3 Effluent Temperature Requirements

Weekly Average Temperature – The permittee shall use the following formula for calculating effluent results to determine compliance with the weekly average temperature limit (as applicable): Weekly Average Temperature = the sum of all daily maximum results for that week divided by the number of daily maximum results during that time period.

Cold Shock Standard – Water temperatures of the discharge shall be controlled in a manner as to protect fish and aquatic life uses from the deleterious effects of cold shock. 'Cold Shock' means exposure of aquatic organisms to a

rapid decrease in temperature and a sustained exposure to low temperature that induces abnormal behavior or physiological performance and may lead to death.

Rate of Temperature Change Standard – Temperature of a water of the state or discharge to a water of the state may not be artificially raised or lowered at such a rate that it causes detrimental health or reproductive effects to fish or aquatic life of the water of the state.

6.3.4 Visible Foam or Floating Solids

There shall be no discharge of floating solids or visible foam in other than trace amounts.

6.3.5 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.

6.3.6 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.

6.3.7 Fecal Coliforms

The limit for fecal coliforms shall be expressed as a monthly geometric mean.

6.3.8 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.

6.3.9 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.

6.3.10 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.

6.3.11 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 Report Form 3400-49 and Lab Report. The Characteristic Report Form 3400-49 shall be submitted electronically by January 31 following each year of analysis. Following submittal of the electronic Characteristic Report Form 3400-49, this form shall be certified electronically via the 'eReport Certify' page by a principal executive officer, ranking elected official or duly authorized representative. The 'eReport Certify' page certifies that the electronic report form is true, accurate and complete. The Lab Report must be sent directly to the facility's DNR sludge representative or basin engineer unless approval for not submitting the lab reports has been given.

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 Calculation of Water Extractable Phosphorus

When sludge analysis for Water Extractable Phosphorus is required by this permit, the permittee shall use the following formula to calculate and report Water Extractable Phosphorus:
Water Extractable Phosphorus (% of Total P) =

[Water Extractable Phosphorus (mg/kg, dry wt) ÷ Total Phosphorus (mg/kg, dry wt)] x 100

6.5.6 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

6.5.7 Annual Land Application Report

The Annual Land Application Report Form 3400-55 shall be submitted electronically by January 31 each year whether or not non-exceptional quality sludge is land applied. Non-exceptional quality sludge is defined in s. NR 204.07(4), Wis. Adm. Code. Following submittal of the electronic Annual Land Application Report Form 3400-55, this form shall be certified electronically via the 'eReport Certify' page by a principal executive officer, ranking elected official or duly authorized representative. The 'eReport Certify' page certifies that the electronic report form is true, accurate and complete.

6.5.8 Other Methods of Disposal or Distribution Report

The permittee shall submit electronically the Other Methods of Disposal or Distribution Report Form 3400-52 by January 31 each year whether or not sludge is hauled, landfilled, incinerated, or exceptional quality sludge is

distributed or land applied. Following submittal of the electronic Report Form 3400-52, this form shall be certified electronically via the 'eReport Certify' page by a principal executive officer, ranking elected official or duly authorized representative. The 'eReport Certify' page certifies that the electronic report form is true, accurate and complete.

6.5.9 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.

6.5.10 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.

6.5.11 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.

6.5.12 Class B Sludge: Anaerobic Digestion

Treat the sludge in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 15 days at 35° C to 55° C and 60 days at 20° C. Straight-line interpolation to calculate mean cell residence time is allowable when the temperature falls between 35° C and 20° C.

6.5.13 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
Chloride Target Value -Annual Chloride Progress Report	June 30, 2014	15
Chloride Target Value -Annual Chloride Progress Report #2	June 30, 2015	15
Chloride Target Value -Annual Chloride Progress Report #3	June 30, 2016	15
Chloride Target Value -Final Chloride Report	December 31, 2017	15
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Operational Evaluation Report	June 30, 2014	15
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Study of Feasible Alternatives	June 30, 2014	16
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Compliance Alternatives, Source Reduction, Improvements and Modifications Status	June 30, 2015	16
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Preliminary Compliance Alternatives Plan	June 30, 2016	16
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Final Compliance Alternatives Plan	June 30, 2017	16
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Progress Report on Plans & Specifications	June 30, 2018	16
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Final Plans and Specifications	June 30, 2019	17
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Treatment Plant Upgrade to Meet WQBELs	September 30, 2019	17
Water Quality Based Effluent Limits (WQBELs) for Total Phosphorus - Complete Construction and Achieve Compliance	June 30, 2020	17
Ultraviolet Disinfection System Upgrade -Updated Engineering Design Report for UV Disinfection System	June 30, 2014	17
Ultraviolet Disinfection System Upgrade -Plans and Specifications	March 31, 2015	17
Ultraviolet Disinfection System Upgrade -Initiate Construction	September 30, 2015	17
Ultraviolet Disinfection System Upgrade -Complete Construction	March 31, 2017	17
CMOM Audit and Collection System Progress Reports -CMOM Annual Self-Audit	See Permit	17
CMOM Audit and Collection System Progress Reports -Collection System Semi-annual Progress Report	See Permit	17
Compliance Maintenance Annual Reports (CMAR)	by June 30, each year	19
Industrial User Compliance Evaluation and Violation Reports	Semiannual	26

Pretreatment Program Report	Annually	26
General Sludge Management Form 3400-48	prior to any significant sludge management changes	27
Characteristic Report Form 3400-49 and Lab Report	by January 31 following each year of analysis	27
The Annual Land Application Report Form 3400-55	by January 31 each year whether or not non-exceptional quality sludge is land applied	28
electronically the Other Methods of Disposal or Distribution Report Form 3400-52	by January 31 each year whether or not sludge is hauled, landfilled, incinerated, or exceptional quality sludge is distributed or land applied	28
Wastewater Discharge Monitoring Report	no later than the date indicated on the form	18

Report forms shall be submitted to the address printed on the report form. Any facility plans or plans and specifications for municipal, industrial, industrial pretreatment and non-industrial wastewater systems shall be submitted to the Bureau of Water Quality, P.O. Box 7921, Madison, WI 53707-7921. All other submittals required by this permit shall be submitted to:
Southeast Region, 2300 N Dr ML King Drive, Milwaukee, WI 53212.

Attachment A-2

Evaluation of Alternatives for Return Flow to the Milwaukee Metropolitan Sewerage District

Evaluation of Alternatives for Return Flow to the Milwaukee Metropolitan Sewerage District

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: May 17, 2012

Introduction

The purpose of this technical memorandum is to present a supplemental evaluation of alternatives to return untreated municipal wastewater, or raw sewage, from the City of Waukesha to the Milwaukee Metropolitan Sewerage District (MMSD) for treatment. Conveying raw sewage from the City of Waukesha (City) to MMSD is one way of meeting the intent of the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact) and Wisconsin Compact Implementation Statute §281.346 for returning flow to the Great Lakes basin that has been diverted for the City's water supply. This alternative was previously considered during the City's Future Water Supply Study, evaluated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and retired from further consideration because it was significantly more costly than other return flow alternatives. At the recent request of the Wisconsin Department of Natural Resources (WDNR), the City has conducted additional economic analysis of demolishing their wastewater treatment plant (WWTP) for raw sewage return to MMSD.

Background

A City of Waukesha return flow to MMSD was evaluated by the Southeastern Wisconsin Planning Commission (SEWRPC) as part of the Regional Water Supply Plan for Southeastern Wisconsin[1]. This analysis for Waukesha return flow was based in-part on an earlier evaluation completed by SEWRPC during the Regional Water Quality Management Plan Update[2] that evaluated in detail the City of South Milwaukee abandoning its WWTP and connecting to MMSD. The Regional Water Quality Management Plan Update was a coordinated effort with MMSD's sewerage facilities planning program and followed an approach cooperatively developed by WDNR, MMSD, and SEWRPC[3]. Four alternatives for South Milwaukee involving different types of high rate treatment and equalization storage for wet weather flows were considered. These alternatives were chosen because the MMSD system was determined to have sufficient treatment capacity for South Milwaukee flows during dry weather, but did not have sufficient treatment capacity during wet weather periods. Given that the location of the South Milwaukee plant is near the MMSD South Shore plant, no significant conveyance costs were involved in SEWRPC's South Milwaukee evaluation. The connection of the City of South Milwaukee to MMSD was estimated to have a capital cost ranging between $19.9 and $39.3 Million[4]. An MMSD connection for South Milwaukee was not recommended by SEWRPC due to cost and implementation considerations.

As with the South Milwaukee analysis, SEWRPC determined that a City of Waukesha connection to MMSD would require development of additional wet weather WWTP capacity, wet weather storage, or both – but at significantly greater costs than those predicted for South Milwaukee for treatment of wet weather flows. SEWRPC's analysis of a City return flow to MMSD concluded "…that the costs involved would be well in excess of

[1] Southeastern Wisconsin Regional Planning Commission (SEWRPC). 2010. *A Regional Water Supply Plan for Southeastern Wisconsin*. Planning Report No. 52. Chapter 9, Page 631

[2] Southeastern Wisconsin Regional Planning Commission (SEWRPC). 2007. Regional Water Quality Management Plan Update. Planning Report 50.

[3] Southeastern Wisconsin Regional Planning Commission (SEWRPC).Regional Water Quality Management Plan website. http://www.sewrpc.org/SEWRPC/Environment/RegionalWaterQualityManagement.htm.

[4] Southeastern Wisconsin Regional Planning Commission (SEWRPC). 2007. Regional Water Quality Management Plan Update. Planning Report 50. Page 544.

the cost of the return flow alternatives previously described [discharge to Underwood Creek or Root River or direct to Lake Michigan][5]" and was eliminated from further consideration by SEWRPC. This conclusion is consistent with the Future Water Supply Study[6] conclusion that eliminated City return flow to MMSD during screening because it was not cost effective.

Waukesha Wastewater Flow Rates

The City of Waukesha completed a wastewater treatment plant facility plan in 2011[7] that developed design flow rates for year 2030. These flow rates are summarized in Table 1.

TABLE 1
Design Flow Rates for the Waukesha Wastewater Treatment Plant

Flow	2030 Design Criteria (mgd)
Average Daily Flow	14.0
Maximum Monthly Flow	18.5
Maximum Daily Flow	33.5
Maximum Hourly Flow	53.6

Source: City of Waukesha Wastewater Treatment Plant Facility Plan, 2011.

Alternatives for Return Flow to MMSD

Three City return flow to MMSD alternatives were developed to support a screening-level cost analysis. The MMSD treatment facilities have sufficient capacity for return flow during dry weather, but are capacity limited during wet weather events. Therefore, alternatives to providing wet weather equalization storage or additional treatment capacity at MMSD's South Shore Water Reclamation Facility (South Shore) were identified. Previous MMSD and SEWRPC studies have identified South Shore as a facility to expand wet weather treatment capacity.

The three alternatives include:

- Alternative 1: Wet Weather Equalization and Pipeline to MMSD South Shore
- Alternative 2: Wet Weather Equalization and Pipeline to MMSD Interceptor near Greenfield Park Pump Station
- Alternative 3: Pipeline to MMSD South Shore and Biological High Rate Treatment Facility at South Shore

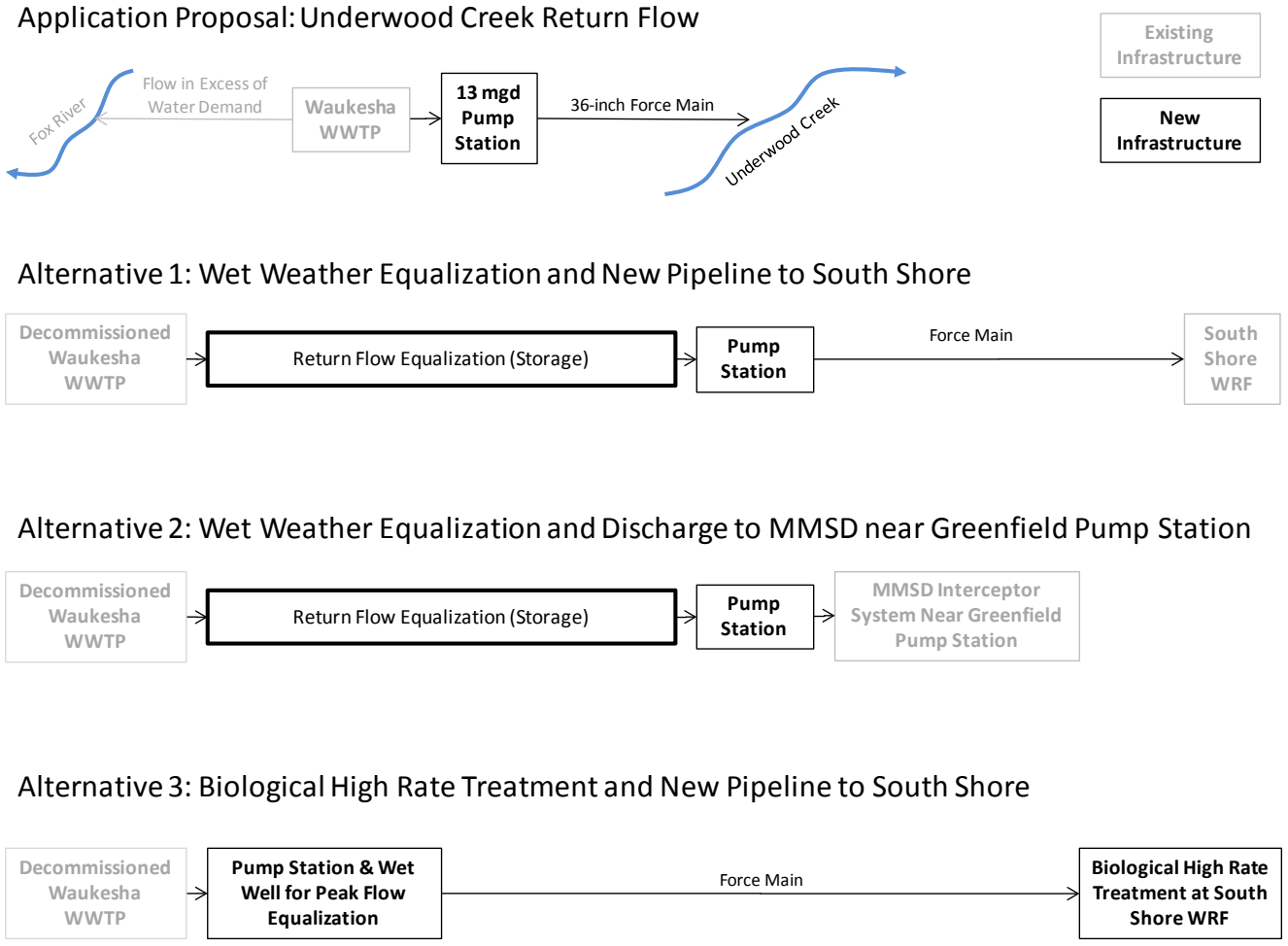
The alternatives, including the proposed return flow plan included in the City's May 2010 Application for Lake Michigan Water Supply (Application) for return flow to Underwood Creek, is shown in Figure 1. The three alternatives included in this analysis are intended to bracket assumptions of utilizing existing MMSD infrastructure or providing new infrastructure for conveyance and treatment for the return flow. It is acknowledged that significant facility planning and hydraulic computer modeling would be required to determine the exact nature of alternatives for return flow to MMSD. However, this analysis is valid for screening alternatives.

[5] Southeastern Wisconsin Regional Planning Commission (SEWRPC). 2010. *A Regional Water Supply Plan for Southeastern Wisconsin*. Planning Report No. 52. Chapter 9, Page 631

[6] CH2M HILL. 2002. Future Water Supply Study for the City of Waukesha, WI.

[7] Strand Associates, Inc. 2011. City of Waukesha Wastewater Treatment Plant Facilities Plan.

FIGURE 1
Return Flow Proposed in May 2010 Application and Three Alternatives for Return Flow to MMSD
(grey text is existing infrastructure; black text is new infrastructure)

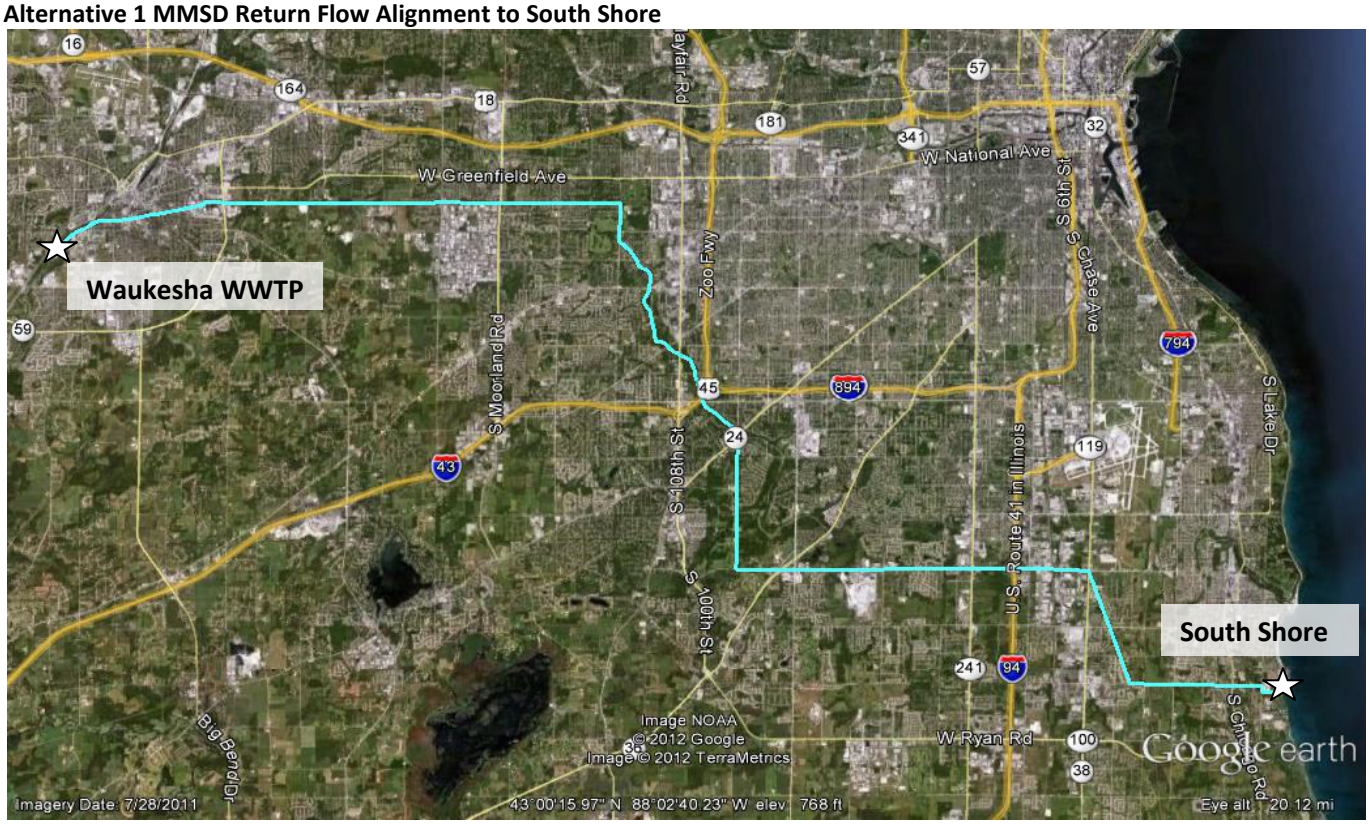


In each of the alternatives for an MMSD return flow, the Waukesha wastewater treatment plant (WWTP) would be decommissioned and a new raw sewage pump station and pipeline would be constructed to convey flow to MMSD.

Alternative 1

Alternative 1 assumes that new infrastructure is needed for wet weather equalization and for conveying dry and wet weather flow to South Shore. During wet weather, return flow would be stored in an underground tunnel until sufficient treatment capacity is available at South Shore. A conceptual alignment of the storage tunnel and force main between the Waukesha wastewater treatment plant (WWTP) and South Shore is shown in Figure 2.

FIGURE 2
Alternative 1 MMSD Return Flow Alignment to South Shore



Alternative 1: Wet Weather Equalization

South Shore has a maximum daily flow capacity of 250 million gallons per day (mgd) with a 300 mgd peak hourly flow capacity. It was assumed for this analysis that when average daily flows at South Shore exceeded 225 mgd, return flow would be stored in a tunnel until the South Shore flow rate drops below 225 mgd. The 225 mgd flow rate equates to 90 percent of the rated maximum daily flow rate at South Shore[8]. Using these capacities and reviewing recent average daily flow rates at South Shore for 2006 through 2010, it was estimated that 9 days of equalization would be required (Table 2) to allow for return flow discharge to South Shore. The criteria of 9 days of equalization was selected because that storage volume would be needed during rain events like those that occurred between June 7-15, 2008 when South Shore was operating at or above 225 mgd. Additional equalization could be needed, especially if a longer period of record is analyzed or if a lower flow threshold (lower than 225 mgd flow at South Shore) is required by MMSD or the Wisconsin Department of Natural Resources (WDNR).

TABLE 2
Estimated Duration of Wet Weather Equalization For Waukesha Return Flow to MMSD

Consecutive Days the Average Daily Flow at South Shore was Equaled or Exceeded	**Number of Events between 2006 and 2010 When South Shore Average Daily Flow Rate ≥ 225 mgd (90% of Maximum Day Capacity)**
2	23
3	10
4	3
5	2

[8] South Shore Operations and Maintenance Manual.

TABLE 2
Estimated Duration of Wet Weather Equalization For Waukesha Return Flow to MMSD

Consecutive Days the Average Daily Flow at South Shore was Equaled or Exceeded	**Number of Events between 2006 and 2010 When South Shore Average Daily Flow Rate ≥ 225 mgd (90% of Maximum Day Capacity)**
6	1
7	1
8	1
9	1
10	0

During the June 7-15, 2008 period, the Waukesha WWTP average daily flow rate was 34 mgd. Using this flow rate, and assuming 9 days of equalization (Table 2), 302 million gallons (MG) of equalization would be needed. For this analysis, the equalization volume is provided by an 11 mile long tunnel 30 feet in diameter. A storage tunnel, rather than lagoons or basins, is assumed because of the required capacity, similarity to other MMSD infrastructure, and to be protective of public health.

Alternative 1: Pump Station and Force Main

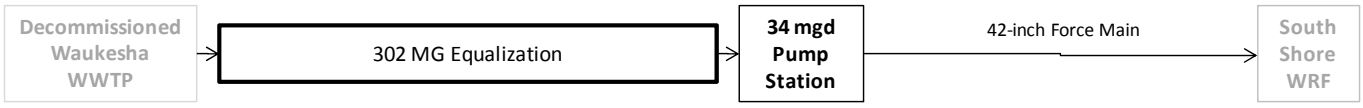
A 34 mgd pump station is anticipated at the downstream end of the equalization tunnel to dewater the tunnel and convey return flow through an estimated 17-mile, 42-inch force main to South Shore (28 total miles less the 11 mile storage tunnel). This pump station capacity is consistent with the peak daily design flow rate from the Waukesha WWTP[9]. The force main and pump station size was selected to provide reasonable operating pressures and velocities under average and maximum daily flow conditions. The maximum hourly flows will be equalized in the storage tunnel. Based on the force main hydraulics, a single pump station is anticipated to be sufficient for conveying the return flow to South Shore.

Alternative 1: Utilizing Existing Infrastructure

Alternative 1 includes the most amount of new infrastructure. This alternative anticipates using the existing South Shore treatment plant for return flow but includes new infrastructure to store and convey flow from the Waukesha WWTP to South Shore.

A schematic layout of Alternative 1 is included in Figure 3.

FIGURE 3
Alternative 1 Details of MMSD Return Flow Alignment to South Shore



Alternative 2

Alternative 2 includes conveying return flow to an existing MMSD interceptor located near MMSD's Greenfield Park Pump Station located at 124th Street and Greenfield Avenue. This location for return flow discharge was identified by MMSD[10] as the point in MMSD's system nearest to the proposed return flow alignment corridor. The 30 mgd Greenfield Pump Station only operates during wet weather periods[11] and discharges to a 30-inch gravity

[9] Strand Associates, Inc. 2011. City of Waukesha Wastewater Treatment Plant Facilities Plan.

[10] Letter to Dan Duchniak (Waukesha Water Utility) from Kevin Shafer (MMSD). January 20, 2010.

[11] Pump Station capacity and sewer capacity obtained from the MMSD 2009 Comprehensive System Model.

sewer. The 30-inch sewer segment receiving the flow has a pipe-full flow capacity of about 35 mgd[12], which is sufficient for 34 mgd from the City. This alternative assumes return flow from the storage tunnel discharges into the same 30-inch sewer during dry weather periods when the sewer is not receiving flow from the Greenfield Pump Station. During wet weather, return flow would be stored in an underground tunnel until the return flow could be conveyed and treated once wet weather flows subside.

The conceptual alignment of the storage tunnel and force main between the Waukesha WWTP and 30-inch interceptor near the Greenfield Pump Station is shown in Figure 4.

FIGURE 4
Alternative 2 MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station



Alternative 2: Wet Weather Equalization

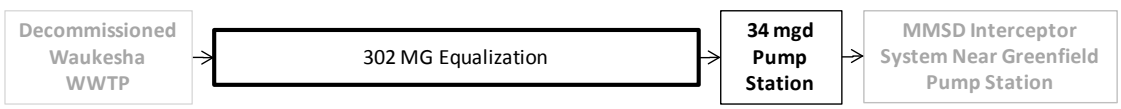
Alternative 2 includes an equalization tunnel that would extend from the Waukesha WWTP to the MMSD interceptor system near Greenfield Pump Station. Like Alternative 1, this alternative includes 302 MG of underground tunnel storage for wet weather flow equalization.

Alternative 2: Pump Station and Force Main

One new 34 mgd pump station located at the downstream end of the equalization tunnel is anticipated to dewater the tunnel and convey flow to the 30-inch interceptor. The MMSD interceptor near the Greenfield Pump Station is about 11 miles from the Waukesha WWTP, which is the estimated length of the tunnel. Increasing the capacity or changing the operation of the Greenfield Pump Station is not anticipated because the return flow would be discharging to the existing MMSD collection system during dry weather flow periods.

A schematic layout of Alternative 2 is included in Figure 5.

FIGURE 5
Alternative 2 Details of MMSD Return Flow Alignment to Interceptor Near Greenfield Pump Station



[12] Detailed hydraulic modeling would be required to determine pipe capacities further downstream in the MMSD collection system to determine if sufficient capacity exists for the return flow throughout the downstream system and with existing flow rates within the MMSD system.

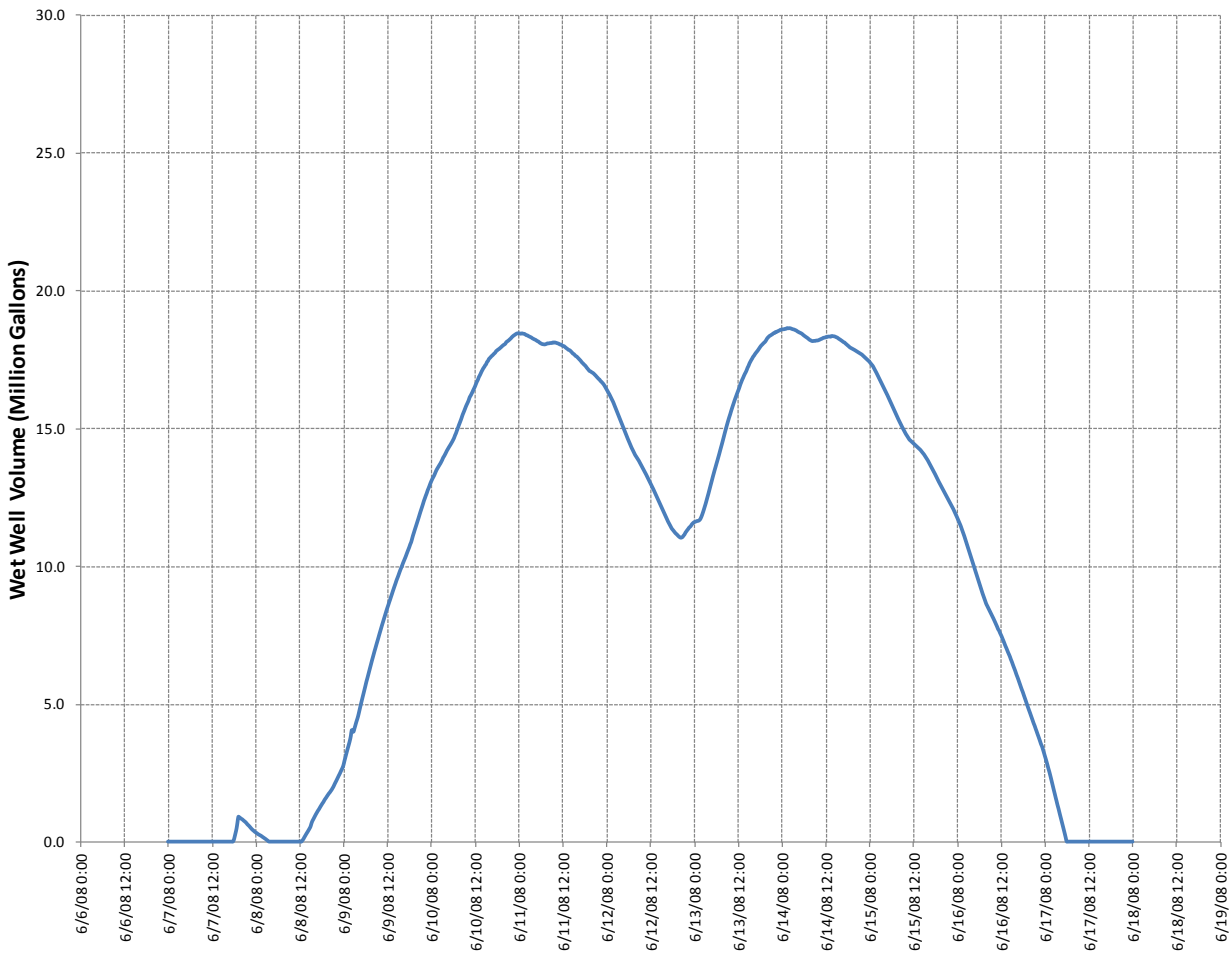
Alternative 3

Alternative 3 includes additional wet weather treatment capacity at South Shore in lieu of wet weather equalization storage. This alternative has similar equipment and operational assumptions as with SEWRPC's evaluation of the City's return to MMSD in the Regional Water Supply Plan. This alternative is also consistent with MMSD's plans for expanding wet weather treatment capacity within its existing service area. Alternative 3 includes a pump station, a large wet well located near the Waukesha WWTP site, and new force main to South Shore. A new biological high rate treatment facility would be constructed at South Shore with capacity equivalent to Waukesha's wet weather return flow rate. During dry weather, return flow would be treated through existing South Shore facilities. During wet weather, the high rate treatment facility would provide treatment for a flow rate equivalent to return flow. The conceptual alignment for Alternative 3 force main is the same as Alternative 1 (Figure 2).

Alternative 3: Pump Station, Wet Well, and Force Main

Based on preliminary hydraulic analysis, Alternative 3 includes one 34 mgd pump station that is anticipated to be located near the site of the demolished Waukesha WWTP. The pump station is anticipated to include an equalization wet well to buffer the 54 mgd peak hourly flows that were estimated in the Waukesha WWTP Facility Plan. Based on the same June 2008 rain events used to estimate equalization storage volume in Alternatives 1 and 2, a 20 million gallon wet well is anticipated (Figure 6). The pump station capacity and force main size were selected to provide reasonable operating pressures and velocities during average and maximum daily flow conditions while minimizing the wet well volume. Increasing the pump and pipe sizes would decrease wet well volume; however, minimum recommended velocities in the force main during average daily flows could not be maintained. The maximum hourly flows will be equalized in the wet well.

FIGURE 6
Simulated Wet Well Filling and Dewatering with 34 mgd Pump Station during June 7-15, 2008 Rain Events.



Included in Attachment A is tabulated data graphed in Figure 6. It includes Waukesha WWTP influent flows during this event and calculates the filling and dewatering of the wet well using a 34 mgd pump station. Similar to the evaluation of storage tunnel equalization, additional wet well volume could be needed if a longer period of record is analyzed and more back-to-back rain events are considered.

Alternative 3: Increased Wet Weather Treatment Capacity at South Shore

While MMSD is currently conducting studies to determine optimum wet weather treatment capacity at South Shore, Alternative 3 assumes 34 mgd of biological high rate treatment and disinfection capacity is provided (HRT is also generally referred to as physical-chemical treatment, ballasted flocculation, or chemically enhanced clarification). This flow rate is equivalent to Waukesha's maximum daily flow rate. Flows in excess of the maximum daily flow rate would be temporarily stored in the equalization wet well.

A schematic layout of Alternative 3 is included in Figure 7.

FIGURE 7
Alternative 3 Details of Pipeline and Biological High Rate Treatment at South Shore



Cost Estimates

Conceptual-level cost estimates for the MMSD return flow alternatives, and the return flow alternative to Underwood Creek that was included in the Application, are summarized in Table 3. The three MMSD alternatives include a capital cost "credit" of about $72.6 Million[13] for Waukesha WWTP Facility Plan improvements that would not be required if the Waukesha WWTP is demolished. The $72.6M credit is not specific to return flow, instead it represents improvements identified in the Waukesha WWTP Facility Plan that would be required if the Waukesha WWTP were to remain, including treating phosphorus for discharge to meet the water quality standard of the Fox River (which is also the same as Underwood Creek). This cost is not applied to the proposed return flow to Underwood Creek because the Facility Plan improvements would be required regardless of the WWTP's discharge location (Fox River or Underwood Creek). Instead it is credited to the three MMSD return flow alternatives so that a comparison can be made with the total wastewater treatment and return flow conveyance costs of the proposed return flow to Underwood Creek. Backup documentation for the cost estimates is in Attachment B. The same contingency, markups, and interest rate factors used in all other cost estimating (Appendix M of the Application) are also used in these cost estimates. The cost estimates are based on the analysis summarized above and do not include safety factors for sizing equalization storage, treatment or conveyance facilities (e.g., tunnel volumes and pump station and pipe sizes). If such factors were included, the facility sizes and associated costs would be greater.

Wastewater treatment operations and maintenance (O&M) costs for Waukesha and MMSD are similar. Based on the 2012 MMSD Cost Recovery Manual, the average annual household wastewater service fee is $111.87. This fee is generally associated with wastewater treatment O&M and not capital costs. Similarly for the City of Waukesha, a 2012 Sanitary Sewer User Rate Study yields an average annual household service fee of about $108.41 for WWTP O&M. Because the service fees are essentially the same, there is negligible net impact on wastewater treatment O&M costs regardless of whether MMSD or the City provides the service. However, conveyance system O&M, the new return flow pipelines for the MMSD return flow alternatives and for the Underwood Creek proposal include O&M costs that are in addition to service fees reported in Waukesha's Sanitary Sewer User Rate Study. Therefore, the economic evaluation of each alternative only includes the O&M costs for the equalization tunnels, pipelines, pump stations, and bio-HRT for the return flow infrastructure.

[13] Strand Associates, Inc. 2011. City of Waukesha Wastewater Treatment Plant Facilities Plan.

The capital costs for the three MMSD return flow alternatives include costs for demolition and site restoration of the Waukesha WWTP. These costs assume that no contaminated soil, lead paint, asbestos or other unique site factors exist. The site restoration cost includes rough grading and seeding.

TABLE 3
Screening Level Cost Estimates for Return Flow Alternatives to MMSD

Return Flow Alternative	Capital Cost	Annual O & M [(2)]	20-Year Present Worth	20-Year Present Worth Cost of MMSD Alternatives above the Proposed Underwood Creek Return Flow
Application Proposal: Return Flow to Underwood Creek	$ 56,174,000	$ 204,000	$ 58,174,000	-
Alternative 1: Wet Weather Equalization and Force Main to South Shore [(1)]	$ 980,400,000	$ 1,444,000	$ 997,400,000	$ 939,226,000
Alternative 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station [(1)]	$ 869,400,000	$ 1,300,000	$ 884,400,000	$ 826,226,000
Alternative 3: Force Main and Biological HRT at South Shore [(1)]	$ 262,400,000	$ 1,063,000	$ 274,400,000	$ 216,226,000

Notes
(1) Alternatives 1, 2 and 3 include a $72.6M capital cost "credit" for Waukesha Facility Plan improvements that would not be required if the Waukesha WWTP were to be decommissioned. The $72.6M credit is not specific to return flow, instead it represents improvements identified in the 2030 Facility Plan that would be required if the Waukesha WWTP were to remain, including meeting phosphorus water quality standards. This cost is not applied to the proposed return flow to Underwood Creek because the Facility Plan improvements would be required regardless of the WWTP's discharge location, but it is credited to the MMSD return flow alternatives so that the alternatives can be compared on a true cost basis.
(2) Does not include WWTP O&M costs because they are essentially the same between Waukesha and MMSD, and are therefore negligible when comparing cost differences between the three MMSD alternatives and the proposed return flow to Underwood Creek.

Summary

Three alternatives for return flow to MMSD were evaluated to compare the estimated costs with the proposed return flow to Underwood Creek. The three alternatives included in this screening level analysis are intended to bracket the assumptions and costs associated with return flow to MMSD. The MMSD collection and treatment system has adequate dry weather capacity for return flow, but does not have sufficient wet weather capacity. Therefore, the three MMSD alternatives include wet weather storage or treatment facilities that are sized for the return flow. It is acknowledged that significant facility planning, hydraulic modeling, and engineering would be required to determine the exact nature of the MMSD return flow alternatives and how the return flow could be integrated into the complex operation of MMSD's system. However, this analysis is valid for screening the three alternatives.

The least costly alternative for return flow to MMSD is estimated to be more than $216 million more expensive (more than four and a half times more expensive) than the proposed return flow through Underwood Creek. The most costly alternative for return flow to MMSD is estimated to be more than $939 million more expensive than the proposed return flow through Underwood Creek. This economic evaluation corroborates the work conducted by SEWRPC in the Regional Water Supply Plan and the findings that return flow to MMSD is significantly more expensive than other alternatives considered because of the additional infrastructure and treatment facilities required. While additional analyses could further refine these alternatives and cost estimates, the conclusions reached in this alternative screening analysis will not change. Return flow to MMSD is not cost effective compared to other alternatives and is eliminated from further consideration for Waukesha's Application for Lake Michigan Water Supply.

Attachment A
Tabular Data for Wet Well Sizing of Alternative 3

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/7/08 0:00	9.99	0.0	9.99
6/7/08 0:15	10.40	0.0	10.40
6/7/08 0:30	10.00	0.0	10.00
6/7/08 0:45	9.77	0.0	9.77
6/7/08 1:00	10.59	0.0	10.59
6/7/08 1:15	9.72	0.0	9.72
6/7/08 1:30	9.22	0.0	9.22
6/7/08 1:45	9.18	0.0	9.18
6/7/08 2:00	9.16	0.0	9.16
6/7/08 2:15	9.19	0.0	9.19
6/7/08 2:30	10.20	0.0	10.20
6/7/08 2:45	8.37	0.0	8.37
6/7/08 3:00	7.98	0.0	7.98
6/7/08 3:15	9.57	0.0	9.57
6/7/08 3:30	8.40	0.0	8.40
6/7/08 3:45	9.00	0.0	9.00
6/7/08 4:00	8.57	0.0	8.57
6/7/08 4:15	8.79	0.0	8.79
6/7/08 4:30	8.36	0.0	8.36
6/7/08 4:45	8.57	0.0	8.57
6/7/08 5:00	8.79	0.0	8.79
6/7/08 5:15	8.36	0.0	8.36
6/7/08 5:30	7.98	0.0	7.98
6/7/08 5:45	8.39	0.0	8.39
6/7/08 6:00	7.99	0.0	7.99
6/7/08 6:15	7.97	0.0	7.97
6/7/08 6:30	9.38	0.0	9.38
6/7/08 6:45	9.16	0.0	9.16
6/7/08 7:00	8.76	0.0	8.76
6/7/08 7:15	8.36	0.0	8.36
6/7/08 7:30	9.16	0.0	9.16
6/7/08 7:45	9.22	0.0	9.22
6/7/08 8:00	9.59	0.0	9.59
6/7/08 8:15	10.79	0.0	10.79
6/7/08 8:30	11.44	0.0	11.44
6/7/08 8:45	12.05	0.0	12.05
6/7/08 9:00	12.27	0.0	12.27
6/7/08 9:15	13.48	0.0	13.48
6/7/08 9:30	12.00	0.0	12.00
6/7/08 9:45	12.43	0.0	12.43

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/7/08 10:00	13.08	0.0	13.08
6/7/08 10:15	16.83	0.0	16.83
6/7/08 10:30	12.64	0.0	12.64
6/7/08 10:45	12.84	0.0	12.84
6/7/08 11:00	12.86	0.0	12.86
6/7/08 11:15	12.86	0.0	12.86
6/7/08 11:30	13.90	0.0	13.90
6/7/08 11:45	13.05	0.0	13.05
6/7/08 12:00	13.05	0.0	13.05
6/7/08 12:15	13.28	0.0	13.28
6/7/08 12:30	12.62	0.0	12.62
6/7/08 12:45	13.00	0.0	13.00
6/7/08 13:00	12.68	0.0	12.68
6/7/08 13:15	12.43	0.0	12.43
6/7/08 13:30	12.45	0.0	12.45
6/7/08 13:45	13.30	0.0	13.30
6/7/08 14:00	12.01	0.0	12.01
6/7/08 14:15	13.90	0.0	13.90
6/7/08 14:30	13.28	0.0	13.28
6/7/08 14:45	11.80	0.0	11.80
6/7/08 15:00	11.63	0.0	11.63
6/7/08 15:15	12.02	0.0	12.02
6/7/08 15:30	11.59	0.0	11.59
6/7/08 15:45	11.20	0.0	11.20
6/7/08 16:00	11.01	0.0	11.01
6/7/08 16:15	11.42	0.0	11.42
6/7/08 16:30	11.44	0.0	11.44
6/7/08 16:45	12.42	0.0	12.42
6/7/08 17:00	10.82	0.0	10.82
6/7/08 17:15	12.85	0.0	12.85
6/7/08 17:30	12.85	0.0	12.85
6/7/08 17:45	27.68	0.0	27.68
6/7/08 18:00	39.48	0.1	34.00
6/7/08 18:15	46.07	0.2	34.00
6/7/08 18:30	47.36	0.3	34.00
6/7/08 18:45	48.36	0.5	34.00
6/7/08 19:00	54.53	0.7	34.00
6/7/08 19:15	54.53	0.9	34.00
6/7/08 19:30	32.69	0.9	34.00
6/7/08 19:45	31.58	0.9	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/7/08 20:00	31.36	0.8	34.00
6/7/08 20:15	32.23	0.8	34.00
6/7/08 20:30	31.35	0.8	34.00
6/7/08 20:45	31.09	0.8	34.00
6/7/08 21:00	31.56	0.7	34.00
6/7/08 21:15	31.10	0.7	34.00
6/7/08 21:30	30.49	0.7	34.00
6/7/08 21:45	30.01	0.6	34.00
6/7/08 22:00	31.10	0.6	34.00
6/7/08 22:15	30.72	0.6	34.00
6/7/08 22:30	30.27	0.5	34.00
6/7/08 22:45	30.27	0.5	34.00
6/7/08 23:00	30.50	0.4	34.00
6/7/08 23:15	31.10	0.4	34.00
6/7/08 23:30	31.35	0.4	34.00
6/7/08 23:45	31.10	0.4	34.00
6/8/08 0:00	31.80	0.3	34.00
6/8/08 0:15	31.80	0.3	34.00
6/8/08 0:30	31.61	0.3	34.00
6/8/08 0:45	31.80	0.3	34.00
6/8/08 1:00	32.25	0.2	34.00
6/8/08 1:15	32.21	0.2	34.00
6/8/08 1:30	32.21	0.2	34.00
6/8/08 1:45	31.56	0.2	34.00
6/8/08 2:00	31.78	0.2	34.00
6/8/08 2:15	31.80	0.1	34.00
6/8/08 2:30	31.79	0.1	34.00
6/8/08 2:45	31.78	0.1	34.00
6/8/08 3:00	31.32	0.1	34.00
6/8/08 3:15	31.79	0.0	34.00
6/8/08 3:30	31.08	0.0	34.00
6/8/08 3:45	31.35	0.0	31.35
6/8/08 4:00	31.80	0.0	31.80
6/8/08 4:15	31.60	0.0	31.60
6/8/08 4:30	31.09	0.0	31.09
6/8/08 4:45	31.40	0.0	31.40
6/8/08 5:00	31.10	0.0	31.10
6/8/08 5:15	31.36	0.0	31.36
6/8/08 5:30	30.72	0.0	30.72
6/8/08 5:45	31.09	0.0	31.09

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/8/08 6:00	31.11	0.0	31.11
6/8/08 6:15	31.58	0.0	31.58
6/8/08 6:30	31.10	0.0	31.10
6/8/08 6:45	31.10	0.0	31.10
6/8/08 7:00	31.10	0.0	31.10
6/8/08 7:15	31.12	0.0	31.12
6/8/08 7:30	31.10	0.0	31.10
6/8/08 7:45	31.10	0.0	31.10
6/8/08 8:00	31.11	0.0	31.11
6/8/08 8:15	31.10	0.0	31.10
6/8/08 8:30	30.73	0.0	30.73
6/8/08 8:45	31.35	0.0	31.35
6/8/08 9:00	31.11	0.0	31.11
6/8/08 9:15	31.13	0.0	31.13
6/8/08 9:30	31.10	0.0	31.10
6/8/08 9:45	31.10	0.0	31.10
6/8/08 10:00	30.72	0.0	30.72
6/8/08 10:15	31.10	0.0	31.10
6/8/08 10:30	31.11	0.0	31.11
6/8/08 10:45	31.08	0.0	31.08
6/8/08 11:00	31.58	0.0	31.58
6/8/08 11:15	31.13	0.0	31.13
6/8/08 11:30	31.58	0.0	31.58
6/8/08 11:45	32.22	0.0	32.22
6/8/08 12:00	34.41	0.0	34.00
6/8/08 12:15	32.21	0.0	32.21
6/8/08 12:30	31.58	0.0	31.58
6/8/08 12:45	38.42	0.0	34.00
6/8/08 13:00	37.73	0.1	34.00
6/8/08 13:15	39.93	0.1	34.00
6/8/08 13:30	39.52	0.2	34.00
6/8/08 13:45	39.50	0.3	34.00
6/8/08 14:00	39.27	0.3	34.00
6/8/08 14:15	39.08	0.4	34.00
6/8/08 14:30	39.53	0.4	34.00
6/8/08 14:45	39.52	0.5	34.00
6/8/08 15:00	40.59	0.6	34.00
6/8/08 15:15	44.69	0.7	34.00
6/8/08 15:30	42.17	0.7	34.00
6/8/08 15:45	39.96	0.8	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/8/08 16:00	40.24	0.9	34.00
6/8/08 16:15	40.23	0.9	34.00
6/8/08 16:30	39.93	1.0	34.00
6/8/08 16:45	39.52	1.1	34.00
6/8/08 17:00	39.52	1.1	34.00
6/8/08 17:15	38.67	1.2	34.00
6/8/08 17:30	39.52	1.2	34.00
6/8/08 17:45	39.52	1.3	34.00
6/8/08 18:00	39.08	1.3	34.00
6/8/08 18:15	39.27	1.4	34.00
6/8/08 18:30	38.41	1.4	34.00
6/8/08 18:45	39.93	1.5	34.00
6/8/08 19:00	39.05	1.6	34.00
6/8/08 19:15	38.40	1.6	34.00
6/8/08 19:30	39.07	1.6	34.00
6/8/08 19:45	38.64	1.7	34.00
6/8/08 20:00	38.67	1.7	34.00
6/8/08 20:15	37.73	1.8	34.00
6/8/08 20:30	38.67	1.8	34.00
6/8/08 20:45	38.42	1.9	34.00
6/8/08 21:00	39.52	1.9	34.00
6/8/08 21:15	39.53	2.0	34.00
6/8/08 21:30	40.86	2.1	34.00
6/8/08 21:45	40.61	2.1	34.00
6/8/08 22:00	40.19	2.2	34.00
6/8/08 22:15	40.59	2.3	34.00
6/8/08 22:30	40.61	2.3	34.00
6/8/08 22:45	40.63	2.4	34.00
6/8/08 23:00	40.20	2.5	34.00
6/8/08 23:15	41.11	2.5	34.00
6/8/08 23:30	40.63	2.6	34.00
6/8/08 23:45	40.86	2.7	34.00
6/9/08 0:00	43.15	2.8	34.00
6/9/08 0:15	47.62	2.9	34.00
6/9/08 0:30	46.28	3.0	34.00
6/9/08 0:45	46.29	3.2	34.00
6/9/08 1:00	46.07	3.3	34.00
6/9/08 1:15	45.39	3.4	34.00
6/9/08 1:30	45.64	3.5	34.00
6/9/08 1:45	46.29	3.7	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/9/08 2:00	48.99	3.8	34.00
6/9/08 2:15	54.50	4.0	34.00
6/9/08 2:30	28.72	4.0	34.00
6/9/08 2:45	34.41	4.0	34.00
6/9/08 3:00	44.94	4.1	34.00
6/9/08 3:15	44.94	4.2	34.00
6/9/08 3:30	45.36	4.3	34.00
6/9/08 3:45	44.01	4.4	34.00
6/9/08 4:00	44.94	4.6	34.00
6/9/08 4:15	47.39	4.7	34.00
6/9/08 4:30	47.89	4.8	34.00
6/9/08 4:45	47.63	5.0	34.00
6/9/08 5:00	46.98	5.1	34.00
6/9/08 5:15	46.96	5.3	34.00
6/9/08 5:30	46.76	5.4	34.00
6/9/08 5:45	46.98	5.5	34.00
6/9/08 6:00	46.99	5.7	34.00
6/9/08 6:15	47.41	5.8	34.00
6/9/08 6:30	45.64	5.9	34.00
6/9/08 6:45	46.07	6.0	34.00
6/9/08 7:00	46.31	6.2	34.00
6/9/08 7:15	46.31	6.3	34.00
6/9/08 7:30	46.07	6.4	34.00
6/9/08 7:45	46.31	6.6	34.00
6/9/08 8:00	45.62	6.7	34.00
6/9/08 8:15	45.64	6.8	34.00
6/9/08 8:30	45.64	6.9	34.00
6/9/08 8:45	44.94	7.0	34.00
6/9/08 9:00	45.39	7.1	34.00
6/9/08 9:15	44.94	7.3	34.00
6/9/08 9:30	44.94	7.4	34.00
6/9/08 9:45	45.42	7.5	34.00
6/9/08 10:00	44.94	7.6	34.00
6/9/08 10:15	44.93	7.7	34.00
6/9/08 10:30	44.94	7.8	34.00
6/9/08 10:45	44.45	7.9	34.00
6/9/08 11:00	44.43	8.1	34.00
6/9/08 11:15	44.45	8.2	34.00
6/9/08 11:30	44.45	8.3	34.00
6/9/08 11:45	44.43	8.4	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/9/08 12:00	43.98	8.5	34.00
6/9/08 12:15	43.38	8.6	34.00
6/9/08 12:30	44.01	8.7	34.00
6/9/08 12:45	43.10	8.8	34.00
6/9/08 13:00	44.00	8.9	34.00
6/9/08 13:15	43.38	9.0	34.00
6/9/08 13:30	44.01	9.1	34.00
6/9/08 13:45	43.38	9.2	34.00
6/9/08 14:00	43.39	9.3	34.00
6/9/08 14:15	43.11	9.4	34.00
6/9/08 14:30	43.77	9.5	34.00
6/9/08 14:45	42.20	9.6	34.00
6/9/08 15:00	42.42	9.7	34.00
6/9/08 15:15	43.12	9.7	34.00
6/9/08 15:30	42.71	9.8	34.00
6/9/08 15:45	42.23	9.9	34.00
6/9/08 16:00	41.79	10.0	34.00
6/9/08 16:15	42.68	10.1	34.00
6/9/08 16:30	41.79	10.2	34.00
6/9/08 16:45	41.75	10.3	34.00
6/9/08 17:00	41.79	10.3	34.00
6/9/08 17:15	42.69	10.4	34.00
6/9/08 17:30	42.42	10.5	34.00
6/9/08 17:45	42.20	10.6	34.00
6/9/08 18:00	42.20	10.7	34.00
6/9/08 18:15	43.38	10.8	34.00
6/9/08 18:30	41.55	10.9	34.00
6/9/08 18:45	45.26	11.0	34.00
6/9/08 19:00	45.64	11.1	34.00
6/9/08 19:15	44.01	11.2	34.00
6/9/08 19:30	44.43	11.3	34.00
6/9/08 19:45	43.78	11.4	34.00
6/9/08 20:00	43.98	11.5	34.00
6/9/08 20:15	44.04	11.6	34.00
6/9/08 20:30	44.01	11.7	34.00
6/9/08 20:45	44.43	11.8	34.00
6/9/08 21:00	44.45	11.9	34.00
6/9/08 21:15	43.76	12.0	34.00
6/9/08 21:30	43.76	12.2	34.00
6/9/08 21:45	44.01	12.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/9/08 22:00	44.46	12.4	34.00
6/9/08 22:15	42.71	12.5	34.00
6/9/08 22:30	43.11	12.6	34.00
6/9/08 22:45	42.19	12.6	34.00
6/9/08 23:00	43.75	12.7	34.00
6/9/08 23:15	41.78	12.8	34.00
6/9/08 23:30	42.19	12.9	34.00
6/9/08 23:45	42.68	13.0	34.00
6/10/08 0:00	41.55	13.1	34.00
6/10/08 0:15	41.11	13.1	34.00
6/10/08 0:30	40.20	13.2	34.00
6/10/08 0:45	39.93	13.3	34.00
6/10/08 1:00	41.12	13.3	34.00
6/10/08 1:15	41.78	13.4	34.00
6/10/08 1:30	40.61	13.5	34.00
6/10/08 1:45	39.60	13.6	34.00
6/10/08 2:00	39.25	13.6	34.00
6/10/08 2:15	39.51	13.7	34.00
6/10/08 2:30	39.06	13.7	34.00
6/10/08 2:45	40.19	13.8	34.00
6/10/08 3:00	40.22	13.8	34.00
6/10/08 3:15	41.55	13.9	34.00
6/10/08 3:30	39.08	14.0	34.00
6/10/08 3:45	39.93	14.0	34.00
6/10/08 4:00	40.20	14.1	34.00
6/10/08 4:15	40.63	14.2	34.00
6/10/08 4:30	39.53	14.2	34.00
6/10/08 4:45	39.53	14.3	34.00
6/10/08 5:00	39.27	14.3	34.00
6/10/08 5:15	39.08	14.4	34.00
6/10/08 5:30	39.56	14.5	34.00
6/10/08 5:45	39.56	14.5	34.00
6/10/08 6:00	40.21	14.6	34.00
6/10/08 6:15	40.61	14.6	34.00
6/10/08 6:30	42.68	14.7	34.00
6/10/08 6:45	41.12	14.8	34.00
6/10/08 7:00	43.12	14.9	34.00
6/10/08 7:15	42.17	15.0	34.00
6/10/08 7:30	43.38	15.1	34.00
6/10/08 7:45	42.20	15.2	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/10/08 8:00	42.42	15.3	34.00
6/10/08 8:15	42.72	15.4	34.00
6/10/08 8:30	43.77	15.5	34.00
6/10/08 8:45	42.20	15.5	34.00
6/10/08 9:00	41.79	15.6	34.00
6/10/08 9:15	42.20	15.7	34.00
6/10/08 9:30	42.19	15.8	34.00
6/10/08 9:45	41.12	15.9	34.00
6/10/08 10:00	40.87	15.9	34.00
6/10/08 10:15	41.79	16.0	34.00
6/10/08 10:30	43.38	16.1	34.00
6/10/08 10:45	39.53	16.2	34.00
6/10/08 11:00	40.22	16.2	34.00
6/10/08 11:15	40.60	16.3	34.00
6/10/08 11:30	41.12	16.4	34.00
6/10/08 11:45	40.60	16.5	34.00
6/10/08 12:00	41.16	16.5	34.00
6/10/08 12:15	42.20	16.6	34.00
6/10/08 12:30	41.56	16.7	34.00
6/10/08 12:45	40.23	16.8	34.00
6/10/08 13:00	42.68	16.8	34.00
6/10/08 13:15	39.95	16.9	34.00
6/10/08 13:30	40.60	17.0	34.00
6/10/08 13:45	41.12	17.1	34.00
6/10/08 14:00	39.96	17.1	34.00
6/10/08 14:15	39.96	17.2	34.00
6/10/08 14:30	38.44	17.2	34.00
6/10/08 14:45	39.55	17.3	34.00
6/10/08 15:00	37.99	17.3	34.00
6/10/08 15:15	41.56	17.4	34.00
6/10/08 15:30	37.48	17.4	34.00
6/10/08 15:45	40.64	17.5	34.00
6/10/08 16:00	37.47	17.5	34.00
6/10/08 16:15	37.47	17.6	34.00
6/10/08 16:30	37.49	17.6	34.00
6/10/08 16:45	36.65	17.6	34.00
6/10/08 17:00	37.48	17.7	34.00
6/10/08 17:15	37.12	17.7	34.00
6/10/08 17:30	37.08	17.7	34.00
6/10/08 17:45	39.08	17.8	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/10/08 18:00	36.19	17.8	34.00
6/10/08 18:15	37.11	17.9	34.00
6/10/08 18:30	35.74	17.9	34.00
6/10/08 18:45	36.86	17.9	34.00
6/10/08 19:00	36.63	17.9	34.00
6/10/08 19:15	37.12	18.0	34.00
6/10/08 19:30	36.86	18.0	34.00
6/10/08 19:45	36.60	18.0	34.00
6/10/08 20:00	36.00	18.0	34.00
6/10/08 20:15	36.62	18.1	34.00
6/10/08 20:30	39.07	18.1	34.00
6/10/08 20:45	36.63	18.1	34.00
6/10/08 21:00	36.19	18.2	34.00
6/10/08 21:15	36.60	18.2	34.00
6/10/08 21:30	37.08	18.2	34.00
6/10/08 21:45	36.86	18.3	34.00
6/10/08 22:00	37.74	18.3	34.00
6/10/08 22:15	37.11	18.3	34.00
6/10/08 22:30	36.66	18.4	34.00
6/10/08 22:45	36.19	18.4	34.00
6/10/08 23:00	36.22	18.4	34.00
6/10/08 23:15	36.18	18.4	34.00
6/10/08 23:30	35.33	18.4	34.00
6/10/08 23:45	34.43	18.4	34.00
6/11/08 0:00	33.97	18.4	34.00
6/11/08 0:15	33.12	18.4	34.00
6/11/08 0:30	33.32	18.4	34.00
6/11/08 0:45	35.33	18.4	34.00
6/11/08 1:00	33.35	18.4	34.00
6/11/08 1:15	33.10	18.4	34.00
6/11/08 1:30	33.55	18.4	34.00
6/11/08 1:45	31.81	18.4	34.00
6/11/08 2:00	31.81	18.4	34.00
6/11/08 2:15	33.56	18.4	34.00
6/11/08 2:30	31.81	18.3	34.00
6/11/08 2:45	32.47	18.3	34.00
6/11/08 3:00	32.24	18.3	34.00
6/11/08 3:15	32.70	18.3	34.00
6/11/08 3:30	31.81	18.3	34.00
6/11/08 3:45	31.81	18.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/11/08 4:00	32.44	18.2	34.00
6/11/08 4:15	32.23	18.2	34.00
6/11/08 4:30	32.72	18.2	34.00
6/11/08 4:45	31.81	18.2	34.00
6/11/08 5:00	31.81	18.2	34.00
6/11/08 5:15	32.72	18.1	34.00
6/11/08 5:30	31.35	18.1	34.00
6/11/08 5:45	31.59	18.1	34.00
6/11/08 6:00	32.23	18.1	34.00
6/11/08 6:15	32.23	18.1	34.00
6/11/08 6:30	33.12	18.0	34.00
6/11/08 6:45	33.56	18.0	34.00
6/11/08 7:00	33.56	18.0	34.00
6/11/08 7:15	34.84	18.0	34.00
6/11/08 7:30	35.06	18.1	34.00
6/11/08 7:45	35.75	18.1	34.00
6/11/08 8:00	33.96	18.1	34.00
6/11/08 8:15	34.43	18.1	34.00
6/11/08 8:30	34.84	18.1	34.00
6/11/08 8:45	33.99	18.1	34.00
6/11/08 9:00	34.40	18.1	34.00
6/11/08 9:15	35.74	18.1	34.00
6/11/08 9:30	33.13	18.1	34.00
6/11/08 9:45	34.85	18.1	34.00
6/11/08 10:00	33.13	18.1	34.00
6/11/08 10:15	33.12	18.1	34.00
6/11/08 10:30	32.70	18.1	34.00
6/11/08 10:45	33.12	18.1	34.00
6/11/08 11:00	32.22	18.1	34.00
6/11/08 11:15	32.23	18.0	34.00
6/11/08 11:30	33.98	18.0	34.00
6/11/08 11:45	31.36	18.0	34.00
6/11/08 12:00	31.86	18.0	34.00
6/11/08 12:15	33.55	18.0	34.00
6/11/08 12:30	31.62	18.0	34.00
6/11/08 12:45	31.09	17.9	34.00
6/11/08 13:00	31.60	17.9	34.00
6/11/08 13:15	31.59	17.9	34.00
6/11/08 13:30	31.12	17.8	34.00
6/11/08 13:45	33.08	17.8	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/11/08 14:00	31.82	17.8	34.00
6/11/08 14:15	30.74	17.8	34.00
6/11/08 14:30	30.73	17.7	34.00
6/11/08 14:45	30.28	17.7	34.00
6/11/08 15:00	32.44	17.7	34.00
6/11/08 15:15	30.46	17.6	34.00
6/11/08 15:30	30.76	17.6	34.00
6/11/08 15:45	32.44	17.6	34.00
6/11/08 16:00	30.73	17.6	34.00
6/11/08 16:15	30.73	17.5	34.00
6/11/08 16:30	30.47	17.5	34.00
6/11/08 16:45	30.73	17.5	34.00
6/11/08 17:00	30.02	17.4	34.00
6/11/08 17:15	29.99	17.4	34.00
6/11/08 17:30	31.10	17.3	34.00
6/11/08 17:45	30.45	17.3	34.00
6/11/08 18:00	31.12	17.3	34.00
6/11/08 18:15	30.47	17.2	34.00
6/11/08 18:30	29.58	17.2	34.00
6/11/08 18:45	30.03	17.2	34.00
6/11/08 19:00	30.28	17.1	34.00
6/11/08 19:15	30.03	17.1	34.00
6/11/08 19:30	32.70	17.1	34.00
6/11/08 19:45	31.80	17.0	34.00
6/11/08 20:00	31.82	17.0	34.00
6/11/08 20:15	32.17	17.0	34.00
6/11/08 20:30	31.11	17.0	34.00
6/11/08 20:45	30.73	16.9	34.00
6/11/08 21:00	30.73	16.9	34.00
6/11/08 21:15	30.27	16.9	34.00
6/11/08 21:30	30.72	16.8	34.00
6/11/08 21:45	30.28	16.8	34.00
6/11/08 22:00	31.59	16.8	34.00
6/11/08 22:15	29.58	16.7	34.00
6/11/08 22:30	31.08	16.7	34.00
6/11/08 22:45	30.47	16.6	34.00
6/11/08 23:00	30.46	16.6	34.00
6/11/08 23:15	29.58	16.6	34.00
6/11/08 23:30	28.72	16.5	34.00
6/11/08 23:45	28.30	16.5	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/12/08 0:00	28.30	16.4	34.00
6/12/08 0:15	28.30	16.3	34.00
6/12/08 0:30	28.30	16.3	34.00
6/12/08 0:45	28.30	16.2	34.00
6/12/08 1:00	27.50	16.1	34.00
6/12/08 1:15	27.50	16.1	34.00
6/12/08 1:30	27.50	16.0	34.00
6/12/08 1:45	27.50	15.9	34.00
6/12/08 2:00	26.00	15.9	34.00
6/12/08 2:15	26.00	15.8	34.00
6/12/08 2:30	26.00	15.7	34.00
6/12/08 2:45	26.00	15.6	34.00
6/12/08 3:00	26.00	15.5	34.00
6/12/08 3:15	26.00	15.4	34.00
6/12/08 3:30	26.00	15.4	34.00
6/12/08 3:45	26.00	15.3	34.00
6/12/08 4:00	26.00	15.2	34.00
6/12/08 4:15	26.00	15.1	34.00
6/12/08 4:30	26.00	15.0	34.00
6/12/08 4:45	26.00	14.9	34.00
6/12/08 5:00	26.00	14.9	34.00
6/12/08 5:15	26.00	14.8	34.00
6/12/08 5:30	26.00	14.7	34.00
6/12/08 5:45	26.00	14.6	34.00
6/12/08 6:00	26.50	14.5	34.00
6/12/08 6:15	26.50	14.5	34.00
6/12/08 6:30	26.50	14.4	34.00
6/12/08 6:45	26.50	14.3	34.00
6/12/08 7:00	27.50	14.2	34.00
6/12/08 7:15	27.50	14.2	34.00
6/12/08 7:30	27.50	14.1	34.00
6/12/08 7:45	27.50	14.0	34.00
6/12/08 8:00	29.00	14.0	34.00
6/12/08 8:15	29.00	13.9	34.00
6/12/08 8:30	29.00	13.9	34.00
6/12/08 8:45	29.00	13.8	34.00
6/12/08 9:00	28.00	13.8	34.00
6/12/08 9:15	28.00	13.7	34.00
6/12/08 9:30	28.00	13.6	34.00
6/12/08 9:45	28.00	13.6	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/12/08 10:00	28.00	13.5	34.00
6/12/08 10:15	28.00	13.4	34.00
6/12/08 10:30	28.00	13.4	34.00
6/12/08 10:45	28.00	13.3	34.00
6/12/08 11:00	27.50	13.3	34.00
6/12/08 11:15	27.50	13.2	34.00
6/12/08 11:30	27.50	13.1	34.00
6/12/08 11:45	27.50	13.0	34.00
6/12/08 12:00	27.50	13.0	34.00
6/12/08 12:15	27.50	12.9	34.00
6/12/08 12:30	27.50	12.8	34.00
6/12/08 12:45	27.50	12.8	34.00
6/12/08 13:00	27.00	12.7	34.00
6/12/08 13:15	27.00	12.6	34.00
6/12/08 13:30	27.00	12.6	34.00
6/12/08 13:45	27.00	12.5	34.00
6/12/08 14:00	27.00	12.4	34.00
6/12/08 14:15	27.00	12.3	34.00
6/12/08 14:30	27.00	12.3	34.00
6/12/08 14:45	27.00	12.2	34.00
6/12/08 15:00	27.00	12.1	34.00
6/12/08 15:15	27.00	12.0	34.00
6/12/08 15:30	27.00	12.0	34.00
6/12/08 15:45	27.00	11.9	34.00
6/12/08 16:00	27.00	11.8	34.00
6/12/08 16:15	27.00	11.8	34.00
6/12/08 16:30	27.00	11.7	34.00
6/12/08 16:45	27.00	11.6	34.00
6/12/08 17:00	28.00	11.5	34.00
6/12/08 17:15	28.00	11.5	34.00
6/12/08 17:30	28.00	11.4	34.00
6/12/08 17:45	28.00	11.4	34.00
6/12/08 18:00	30.00	11.3	34.00
6/12/08 18:15	30.00	11.3	34.00
6/12/08 18:30	30.00	11.2	34.00
6/12/08 18:45	30.00	11.2	34.00
6/12/08 19:00	31.00	11.2	34.00
6/12/08 19:15	31.00	11.1	34.00
6/12/08 19:30	30.44	11.1	34.00
6/12/08 19:45	31.11	11.1	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/12/08 20:00	31.60	11.0	34.00
6/12/08 20:15	32.71	11.0	34.00
6/12/08 20:30	34.84	11.0	34.00
6/12/08 20:45	36.21	11.1	34.00
6/12/08 21:00	38.44	11.1	34.00
6/12/08 21:15	37.74	11.1	34.00
6/12/08 21:30	40.20	11.2	34.00
6/12/08 21:45	38.46	11.3	34.00
6/12/08 22:00	38.44	11.3	34.00
6/12/08 22:15	37.99	11.3	34.00
6/12/08 22:30	38.66	11.4	34.00
6/12/08 22:45	36.86	11.4	34.00
6/12/08 23:00	37.48	11.5	34.00
6/12/08 23:15	39.09	11.5	34.00
6/12/08 23:30	37.47	11.5	34.00
6/12/08 23:45	37.03	11.6	34.00
6/13/08 0:00	35.71	11.6	34.00
6/13/08 0:15	35.33	11.6	34.00
6/13/08 0:30	35.06	11.6	34.00
6/13/08 0:45	35.33	11.6	34.00
6/13/08 1:00	34.42	11.6	34.00
6/13/08 1:15	35.75	11.7	34.00
6/13/08 1:30	37.12	11.7	34.00
6/13/08 1:45	39.94	11.8	34.00
6/13/08 2:00	41.79	11.8	34.00
6/13/08 2:15	43.11	11.9	34.00
6/13/08 2:30	43.78	12.0	34.00
6/13/08 2:45	44.49	12.1	34.00
6/13/08 3:00	44.47	12.2	34.00
6/13/08 3:15	45.39	12.4	34.00
6/13/08 3:30	45.64	12.5	34.00
6/13/08 3:45	45.39	12.6	34.00
6/13/08 4:00	46.10	12.7	34.00
6/13/08 4:15	46.32	12.9	34.00
6/13/08 4:30	46.10	13.0	34.00
6/13/08 4:45	46.09	13.1	34.00
6/13/08 5:00	46.32	13.2	34.00
6/13/08 5:15	45.62	13.4	34.00
6/13/08 5:30	45.64	13.5	34.00
6/13/08 5:45	44.95	13.6	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/13/08 6:00	45.39	13.7	34.00
6/13/08 6:15	44.95	13.8	34.00
6/13/08 6:30	45.39	13.9	34.00
6/13/08 6:45	45.39	14.1	34.00
6/13/08 7:00	46.10	14.2	34.00
6/13/08 7:15	45.64	14.3	34.00
6/13/08 7:30	45.62	14.4	34.00
6/13/08 7:45	46.09	14.6	34.00
6/13/08 8:00	46.32	14.7	34.00
6/13/08 8:15	46.29	14.8	34.00
6/13/08 8:30	46.10	14.9	34.00
6/13/08 8:45	45.64	15.1	34.00
6/13/08 9:00	45.40	15.2	34.00
6/13/08 9:15	44.95	15.3	34.00
6/13/08 9:30	44.47	15.4	34.00
6/13/08 9:45	43.78	15.5	34.00
6/13/08 10:00	44.93	15.6	34.00
6/13/08 10:15	44.01	15.7	34.00
6/13/08 10:30	43.78	15.8	34.00
6/13/08 10:45	43.38	15.9	34.00
6/13/08 11:00	43.78	16.0	34.00
6/13/08 11:15	42.68	16.1	34.00
6/13/08 11:30	42.70	16.2	34.00
6/13/08 11:45	42.69	16.3	34.00
6/13/08 12:00	42.26	16.4	34.00
6/13/08 12:15	42.69	16.5	34.00
6/13/08 12:30	43.78	16.6	34.00
6/13/08 12:45	42.20	16.7	34.00
6/13/08 13:00	42.20	16.7	34.00
6/13/08 13:15	40.87	16.8	34.00
6/13/08 13:30	41.55	16.9	34.00
6/13/08 13:45	40.87	17.0	34.00
6/13/08 14:00	39.97	17.0	34.00
6/13/08 14:15	41.13	17.1	34.00
6/13/08 14:30	42.42	17.2	34.00
6/13/08 14:45	40.22	17.3	34.00
6/13/08 15:00	42.20	17.3	34.00
6/13/08 15:15	40.22	17.4	34.00
6/13/08 15:30	39.93	17.5	34.00
6/13/08 15:45	39.27	17.5	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/13/08 16:00	39.93	17.6	34.00
6/13/08 16:15	37.99	17.6	34.00
6/13/08 16:30	39.09	17.7	34.00
6/13/08 16:45	38.42	17.7	34.00
6/13/08 17:00	37.99	17.8	34.00
6/13/08 17:15	37.99	17.8	34.00
6/13/08 17:30	38.70	17.9	34.00
6/13/08 17:45	38.68	17.9	34.00
6/13/08 18:00	38.68	18.0	34.00
6/13/08 18:15	37.99	18.0	34.00
6/13/08 18:30	37.12	18.0	34.00
6/13/08 18:45	37.47	18.1	34.00
6/13/08 19:00	37.11	18.1	34.00
6/13/08 19:15	36.86	18.1	34.00
6/13/08 19:30	38.42	18.2	34.00
6/13/08 19:45	39.53	18.2	34.00
6/13/08 20:00	38.42	18.3	34.00
6/13/08 20:15	37.10	18.3	34.00
6/13/08 20:30	37.11	18.3	34.00
6/13/08 20:45	35.74	18.4	34.00
6/13/08 21:00	36.16	18.4	34.00
6/13/08 21:15	35.74	18.4	34.00
6/13/08 21:30	37.12	18.4	34.00
6/13/08 21:45	35.04	18.4	34.00
6/13/08 22:00	36.17	18.5	34.00
6/13/08 22:15	35.33	18.5	34.00
6/13/08 22:30	35.74	18.5	34.00
6/13/08 22:45	35.30	18.5	34.00
6/13/08 23:00	35.72	18.5	34.00
6/13/08 23:15	35.33	18.5	34.00
6/13/08 23:30	36.20	18.6	34.00
6/13/08 23:45	34.43	18.6	34.00
6/14/08 0:00	34.85	18.6	34.00
6/14/08 0:15	34.40	18.6	34.00
6/14/08 0:30	34.19	18.6	34.00
6/14/08 0:45	35.33	18.6	34.00
6/14/08 1:00	33.98	18.6	34.00
6/14/08 1:15	36.59	18.6	34.00
6/14/08 1:30	33.35	18.6	34.00
6/14/08 1:45	34.18	18.6	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/14/08 2:00	34.19	18.6	34.00
6/14/08 2:15	33.37	18.6	34.00
6/14/08 2:30	32.73	18.6	34.00
6/14/08 2:45	32.69	18.6	34.00
6/14/08 3:00	33.12	18.6	34.00
6/14/08 3:15	33.14	18.6	34.00
6/14/08 3:30	32.44	18.6	34.00
6/14/08 3:45	32.70	18.5	34.00
6/14/08 4:00	31.80	18.5	34.00
6/14/08 4:15	31.81	18.5	34.00
6/14/08 4:30	32.39	18.5	34.00
6/14/08 4:45	32.20	18.5	34.00
6/14/08 5:00	32.69	18.5	34.00
6/14/08 5:15	32.23	18.4	34.00
6/14/08 5:30	31.60	18.4	34.00
6/14/08 5:45	31.10	18.4	34.00
6/14/08 6:00	31.59	18.4	34.00
6/14/08 6:15	31.58	18.3	34.00
6/14/08 6:30	31.80	18.3	34.00
6/14/08 6:45	31.86	18.3	34.00
6/14/08 7:00	31.58	18.3	34.00
6/14/08 7:15	31.16	18.2	34.00
6/14/08 7:30	31.60	18.2	34.00
6/14/08 7:45	32.44	18.2	34.00
6/14/08 8:00	32.24	18.2	34.00
6/14/08 8:15	33.15	18.2	34.00
6/14/08 8:30	34.44	18.2	34.00
6/14/08 8:45	34.38	18.2	34.00
6/14/08 9:00	33.99	18.2	34.00
6/14/08 9:15	35.06	18.2	34.00
6/14/08 9:30	34.16	18.2	34.00
6/14/08 9:45	34.43	18.2	34.00
6/14/08 10:00	35.34	18.2	34.00
6/14/08 10:15	35.34	18.2	34.00
6/14/08 10:30	35.78	18.2	34.00
6/14/08 10:45	35.06	18.2	34.00
6/14/08 11:00	35.76	18.3	34.00
6/14/08 11:15	35.76	18.3	34.00
6/14/08 11:30	34.44	18.3	34.00
6/14/08 11:45	35.06	18.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/14/08 12:00	35.37	18.3	34.00
6/14/08 12:15	33.99	18.3	34.00
6/14/08 12:30	35.33	18.3	34.00
6/14/08 12:45	34.19	18.3	34.00
6/14/08 13:00	33.99	18.3	34.00
6/14/08 13:15	33.36	18.3	34.00
6/14/08 13:30	36.63	18.3	34.00
6/14/08 13:45	33.40	18.3	34.00
6/14/08 14:00	33.56	18.3	34.00
6/14/08 14:15	33.56	18.3	34.00
6/14/08 14:30	32.71	18.3	34.00
6/14/08 14:45	32.44	18.3	34.00
6/14/08 15:00	32.70	18.3	34.00
6/14/08 15:15	31.71	18.3	34.00
6/14/08 15:30	31.57	18.2	34.00
6/14/08 15:45	32.23	18.2	34.00
6/14/08 16:00	31.60	18.2	34.00
6/14/08 16:15	31.81	18.2	34.00
6/14/08 16:30	31.62	18.1	34.00
6/14/08 16:45	31.58	18.1	34.00
6/14/08 17:00	32.69	18.1	34.00
6/14/08 17:15	30.73	18.1	34.00
6/14/08 17:30	31.38	18.0	34.00
6/14/08 17:45	31.12	18.0	34.00
6/14/08 18:00	31.35	18.0	34.00
6/14/08 18:15	31.12	18.0	34.00
6/14/08 18:30	31.12	17.9	34.00
6/14/08 18:45	32.23	17.9	34.00
6/14/08 19:00	32.23	17.9	34.00
6/14/08 19:15	32.23	17.9	34.00
6/14/08 19:30	32.23	17.9	34.00
6/14/08 19:45	32.23	17.8	34.00
6/14/08 20:00	32.00	17.8	34.00
6/14/08 20:15	32.00	17.8	34.00
6/14/08 20:30	32.00	17.8	34.00
6/14/08 20:45	32.00	17.8	34.00
6/14/08 21:00	32.00	17.7	34.00
6/14/08 21:15	32.00	17.7	34.00
6/14/08 21:30	32.00	17.7	34.00
6/14/08 21:45	32.00	17.7	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/14/08 22:00	31.00	17.6	34.00
6/14/08 22:15	31.00	17.6	34.00
6/14/08 22:30	31.00	17.6	34.00
6/14/08 22:45	31.00	17.5	34.00
6/14/08 23:00	31.00	17.5	34.00
6/14/08 23:15	31.00	17.5	34.00
6/14/08 23:30	31.00	17.4	34.00
6/14/08 23:45	31.00	17.4	34.00
6/15/08 0:00	30.00	17.4	34.00
6/15/08 0:15	30.00	17.3	34.00
6/15/08 0:30	30.00	17.3	34.00
6/15/08 0:45	30.00	17.3	34.00
6/15/08 1:00	28.00	17.2	34.00
6/15/08 1:15	28.00	17.1	34.00
6/15/08 1:30	28.00	17.1	34.00
6/15/08 1:45	28.00	17.0	34.00
6/15/08 2:00	27.50	16.9	34.00
6/15/08 2:15	27.50	16.9	34.00
6/15/08 2:30	27.50	16.8	34.00
6/15/08 2:45	27.50	16.7	34.00
6/15/08 3:00	27.50	16.7	34.00
6/15/08 3:15	27.50	16.6	34.00
6/15/08 3:30	27.50	16.5	34.00
6/15/08 3:45	27.50	16.5	34.00
6/15/08 4:00	27.50	16.4	34.00
6/15/08 4:15	27.50	16.3	34.00
6/15/08 4:30	27.50	16.3	34.00
6/15/08 4:45	27.50	16.2	34.00
6/15/08 5:00	27.00	16.1	34.00
6/15/08 5:15	27.00	16.0	34.00
6/15/08 5:30	27.00	16.0	34.00
6/15/08 5:45	27.00	15.9	34.00
6/15/08 6:00	27.00	15.8	34.00
6/15/08 6:15	27.00	15.8	34.00
6/15/08 6:30	27.00	15.7	34.00
6/15/08 6:45	27.00	15.6	34.00
6/15/08 7:00	27.00	15.5	34.00
6/15/08 7:15	27.00	15.5	34.00
6/15/08 7:30	27.00	15.4	34.00
6/15/08 7:45	27.00	15.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/15/08 8:00	27.50	15.2	34.00
6/15/08 8:15	27.50	15.2	34.00
6/15/08 8:30	27.50	15.1	34.00
6/15/08 8:45	27.50	15.0	34.00
6/15/08 9:00	28.00	15.0	34.00
6/15/08 9:15	28.00	14.9	34.00
6/15/08 9:30	28.00	14.9	34.00
6/15/08 9:45	28.00	14.8	34.00
6/15/08 10:00	29.00	14.7	34.00
6/15/08 10:15	29.00	14.7	34.00
6/15/08 10:30	29.00	14.6	34.00
6/15/08 10:45	29.00	14.6	34.00
6/15/08 11:00	31.00	14.6	34.00
6/15/08 11:15	31.00	14.5	34.00
6/15/08 11:30	31.00	14.5	34.00
6/15/08 11:45	31.00	14.5	34.00
6/15/08 12:00	31.00	14.4	34.00
6/15/08 12:15	31.00	14.4	34.00
6/15/08 12:30	31.00	14.4	34.00
6/15/08 12:45	31.00	14.3	34.00
6/15/08 13:00	31.00	14.3	34.00
6/15/08 13:15	31.00	14.3	34.00
6/15/08 13:30	31.00	14.2	34.00
6/15/08 13:45	31.00	14.2	34.00
6/15/08 14:00	30.00	14.2	34.00
6/15/08 14:15	30.00	14.1	34.00
6/15/08 14:30	30.00	14.1	34.00
6/15/08 14:45	30.00	14.0	34.00
6/15/08 15:00	29.00	14.0	34.00
6/15/08 15:15	29.00	13.9	34.00
6/15/08 15:30	29.00	13.9	34.00
6/15/08 15:45	29.00	13.8	34.00
6/15/08 16:00	28.00	13.8	34.00
6/15/08 16:15	28.00	13.7	34.00
6/15/08 16:30	28.00	13.6	34.00
6/15/08 16:45	28.00	13.6	34.00
6/15/08 17:00	28.00	13.5	34.00
6/15/08 17:15	28.00	13.5	34.00
6/15/08 17:30	28.00	13.4	34.00
6/15/08 17:45	28.00	13.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/15/08 18:00	27.50	13.3	34.00
6/15/08 18:15	27.50	13.2	34.00
6/15/08 18:30	27.50	13.1	34.00
6/15/08 18:45	27.50	13.1	34.00
6/15/08 19:00	28.00	13.0	34.00
6/15/08 19:15	28.00	12.9	34.00
6/15/08 19:30	28.00	12.9	34.00
6/15/08 19:45	28.00	12.8	34.00
6/15/08 20:00	28.00	12.8	34.00
6/15/08 20:15	28.00	12.7	34.00
6/15/08 20:30	28.00	12.6	34.00
6/15/08 20:45	28.00	12.6	34.00
6/15/08 21:00	28.00	12.5	34.00
6/15/08 21:15	28.00	12.4	34.00
6/15/08 21:30	28.00	12.4	34.00
6/15/08 21:45	28.00	12.3	34.00
6/15/08 22:00	28.00	12.3	34.00
6/15/08 22:15	28.00	12.2	34.00
6/15/08 22:30	28.00	12.1	34.00
6/15/08 22:45	28.00	12.1	34.00
6/15/08 23:00	27.00	12.0	34.00
6/15/08 23:15	27.00	11.9	34.00
6/15/08 23:30	27.00	11.8	34.00
6/15/08 23:45	27.00	11.8	34.00
6/16/08 0:00	26.50	11.7	34.00
6/16/08 0:15	26.50	11.6	34.00
6/16/08 0:30	26.50	11.5	34.00
6/16/08 0:45	26.50	11.5	34.00
6/16/08 1:00	25.00	11.4	34.00
6/16/08 1:15	25.00	11.3	34.00
6/16/08 1:30	25.00	11.2	34.00
6/16/08 1:45	25.00	11.1	34.00
6/16/08 2:00	24.00	11.0	34.00
6/16/08 2:15	24.00	10.9	34.00
6/16/08 2:30	24.00	10.8	34.00
6/16/08 2:45	24.00	10.7	34.00
6/16/08 3:00	24.00	10.6	34.00
6/16/08 3:15	24.00	10.5	34.00
6/16/08 3:30	24.00	10.4	34.00
6/16/08 3:45	24.00	10.3	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/16/08 4:00	24.00	10.1	34.00
6/16/08 4:15	24.00	10.0	34.00
6/16/08 4:30	24.00	9.9	34.00
6/16/08 4:45	24.00	9.8	34.00
6/16/08 5:00	24.00	9.7	34.00
6/16/08 5:15	24.00	9.6	34.00
6/16/08 5:30	24.00	9.5	34.00
6/16/08 5:45	24.00	9.4	34.00
6/16/08 6:00	24.00	9.3	34.00
6/16/08 6:15	24.00	9.2	34.00
6/16/08 6:30	24.00	9.1	34.00
6/16/08 6:45	24.00	9.0	34.00
6/16/08 7:00	25.00	8.9	34.00
6/16/08 7:15	25.00	8.8	34.00
6/16/08 7:30	25.00	8.7	34.00
6/16/08 7:45	25.00	8.6	34.00
6/16/08 8:00	27.50	8.6	34.00
6/16/08 8:15	27.50	8.5	34.00
6/16/08 8:30	27.50	8.4	34.00
6/16/08 8:45	27.50	8.4	34.00
6/16/08 9:00	27.50	8.3	34.00
6/16/08 9:15	27.50	8.2	34.00
6/16/08 9:30	27.50	8.2	34.00
6/16/08 9:45	27.50	8.1	34.00
6/16/08 10:00	27.00	8.0	34.00
6/16/08 10:15	27.00	7.9	34.00
6/16/08 10:30	26.81	7.9	34.00
6/16/08 10:45	26.86	7.8	34.00
6/16/08 11:00	26.04	7.7	34.00
6/16/08 11:15	29.17	7.7	34.00
6/16/08 11:30	26.40	7.6	34.00
6/16/08 11:45	27.30	7.5	34.00
6/16/08 12:00	26.82	7.4	34.00
6/16/08 12:15	25.98	7.3	34.00
6/16/08 12:30	26.37	7.3	34.00
6/16/08 12:45	25.71	7.2	34.00
6/16/08 13:00	25.75	7.1	34.00
6/16/08 13:15	26.82	7.0	34.00
6/16/08 13:30	26.00	6.9	34.00
6/16/08 13:45	26.16	6.9	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/16/08 14:00	26.82	6.8	34.00
6/16/08 14:15	26.36	6.7	34.00
6/16/08 14:30	24.86	6.6	34.00
6/16/08 14:45	26.20	6.5	34.00
6/16/08 15:00	25.05	6.4	34.00
6/16/08 15:15	25.33	6.3	34.00
6/16/08 15:30	25.74	6.3	34.00
6/16/08 15:45	25.31	6.2	34.00
6/16/08 16:00	24.45	6.1	34.00
6/16/08 16:15	25.74	6.0	34.00
6/16/08 16:30	25.33	5.9	34.00
6/16/08 16:45	24.71	5.8	34.00
6/16/08 17:00	24.87	5.7	34.00
6/16/08 17:15	24.68	5.6	34.00
6/16/08 17:30	25.09	5.5	34.00
6/16/08 17:45	25.96	5.4	34.00
6/16/08 18:00	24.45	5.3	34.00
6/16/08 18:15	24.86	5.2	34.00
6/16/08 18:30	24.86	5.1	34.00
6/16/08 18:45	24.45	5.0	34.00
6/16/08 19:00	24.67	4.9	34.00
6/16/08 19:15	24.86	4.8	34.00
6/16/08 19:30	25.09	4.8	34.00
6/16/08 19:45	25.35	4.7	34.00
6/16/08 20:00	24.86	4.6	34.00
6/16/08 20:15	25.05	4.5	34.00
6/16/08 20:30	24.86	4.4	34.00
6/16/08 20:45	24.86	4.3	34.00
6/16/08 21:00	26.19	4.2	34.00
6/16/08 21:15	24.45	4.1	34.00
6/16/08 21:30	25.33	4.0	34.00
6/16/08 21:45	24.68	3.9	34.00
6/16/08 22:00	25.31	3.8	34.00
6/16/08 22:15	24.86	3.7	34.00
6/16/08 22:30	24.68	3.6	34.00
6/16/08 22:45	24.45	3.5	34.00
6/16/08 23:00	26.82	3.5	34.00
6/16/08 23:15	23.79	3.4	34.00
6/16/08 23:30	23.37	3.2	34.00
6/16/08 23:45	22.92	3.1	34.00

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/17/08 0:00	23.36	3.0	34.00
6/17/08 0:15	22.96	2.9	34.00
6/17/08 0:30	22.45	2.8	34.00
6/17/08 0:45	21.88	2.7	34.00
6/17/08 1:00	22.92	2.5	34.00
6/17/08 1:15	21.67	2.4	34.00
6/17/08 1:30	21.21	2.3	34.00
6/17/08 1:45	20.83	2.1	34.00
6/17/08 2:00	20.81	2.0	34.00
6/17/08 2:15	20.81	1.9	34.00
6/17/08 2:30	21.26	1.7	34.00
6/17/08 2:45	20.80	1.6	34.00
6/17/08 3:00	21.45	1.5	34.00
6/17/08 3:15	20.82	1.3	34.00
6/17/08 3:30	22.52	1.2	34.00
6/17/08 3:45	20.85	1.1	34.00
6/17/08 4:00	21.23	0.9	34.00
6/17/08 4:15	21.67	0.8	34.00
6/17/08 4:30	21.28	0.7	34.00
6/17/08 4:45	21.48	0.5	34.00
6/17/08 5:00	21.26	0.4	34.00
6/17/08 5:15	21.23	0.3	34.00
6/17/08 5:30	20.62	0.1	34.00
6/17/08 5:45	20.81	0.0	34.00
6/17/08 6:00	21.51	0.0	21.51
6/17/08 6:15	21.67	0.0	21.67
6/17/08 6:30	22.52	0.0	22.52
6/17/08 6:45	22.52	0.0	22.52
6/17/08 7:00	22.93	0.0	22.93
6/17/08 7:15	23.56	0.0	23.56
6/17/08 7:30	24.45	0.0	24.45
6/17/08 7:45	24.83	0.0	24.83
6/17/08 8:00	25.07	0.0	25.07
6/17/08 8:15	26.85	0.0	26.85
6/17/08 8:30	24.86	0.0	24.86
6/17/08 8:45	24.45	0.0	24.45
6/17/08 9:00	24.42	0.0	24.42
6/17/08 9:15	24.46	0.0	24.46
6/17/08 9:30	24.86	0.0	24.86
6/17/08 9:45	24.21	0.0	24.21

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/17/08 10:00	24.19	0.0	24.19
6/17/08 10:15	24.71	0.0	24.71
6/17/08 10:30	26.37	0.0	26.37
6/17/08 10:45	24.67	0.0	24.67
6/17/08 11:00	25.07	0.0	25.07
6/17/08 11:15	24.70	0.0	24.70
6/17/08 11:30	23.36	0.0	23.36
6/17/08 11:45	24.70	0.0	24.70
6/17/08 12:00	24.68	0.0	24.68
6/17/08 12:15	24.42	0.0	24.42
6/17/08 12:30	23.56	0.0	23.56
6/17/08 12:45	23.80	0.0	23.80
6/17/08 13:00	24.20	0.0	24.20
6/17/08 13:15	22.52	0.0	22.52
6/17/08 13:30	23.31	0.0	23.31
6/17/08 13:45	22.36	0.0	22.36
6/17/08 14:00	23.34	0.0	23.34
6/17/08 14:15	23.33	0.0	23.33
6/17/08 14:30	22.09	0.0	22.09
6/17/08 14:45	22.32	0.0	22.32
6/17/08 15:00	22.92	0.0	22.92
6/17/08 15:15	22.92	0.0	22.92
6/17/08 15:30	22.92	0.0	22.92
6/17/08 15:45	22.33	0.0	22.33
6/17/08 16:00	22.93	0.0	22.93
6/17/08 16:15	21.67	0.0	21.67
6/17/08 16:30	23.34	0.0	23.34
6/17/08 16:45	22.06	0.0	22.06
6/17/08 17:00	21.87	0.0	21.87
6/17/08 17:15	22.07	0.0	22.07
6/17/08 17:30	22.33	0.0	22.33
6/17/08 17:45	22.33	0.0	22.33
6/17/08 18:00	22.92	0.0	22.92
6/17/08 18:15	22.11	0.0	22.11
6/17/08 18:30	22.07	0.0	22.07
6/17/08 18:45	24.46	0.0	24.46
6/17/08 19:00	22.93	0.0	22.93
6/17/08 19:15	22.08	0.0	22.08
6/17/08 19:30	22.06	0.0	22.06
6/17/08 19:45	23.33	0.0	23.33

TABLE A-1

Tabular Output of Pump Station and Wet Well Operation for Return Flow to MMSD Alternative 3.

Date/Time	Waukesha WWTP Influent Flow Rate (Million Gallons per Day)	Wet Well Volume (Million Gallons)	Pump Station Flow Rate (Million Gallons per Day)
6/17/08 20:00	23.33	0.0	23.33
6/17/08 20:15	22.29	0.0	22.29
6/17/08 20:30	23.33	0.0	23.33
6/17/08 20:45	22.51	0.0	22.51
6/17/08 21:00	22.92	0.0	22.92
6/17/08 21:15	22.51	0.0	22.51
6/17/08 21:30	23.33	0.0	23.33
6/17/08 21:45	22.32	0.0	22.32
6/17/08 22:00	23.37	0.0	23.37
6/17/08 22:15	22.33	0.0	22.33
6/17/08 22:30	22.36	0.0	22.36
6/17/08 22:45	22.04	0.0	22.04
6/17/08 23:00	22.07	0.0	22.07
6/17/08 23:15	22.07	0.0	22.07
6/17/08 23:30	21.23	0.0	21.23
6/17/08 23:45	21.19	0.0	21.19

Attachment B
Cost Estimate Details for MMSD Return Flow Alternatives

Cost Estimate Summary for MMSD Return Flow Alternatives

Return Flow Alternative	Capital Cost	Annual O&M [2]	20-Year Present Worth	20-Year Present Worth Cost in Addition to Proposed Underwood Creek Return Flow
Application Proposal: Return Flow to Underwood Creek	$ 56,174,000	$ 204,000	$ 58,174,000	-
Alternative 1: Wet Weather Equalization and Force Main to South Shore [1]	$ 980,400,000	$ 1,444,000	$ 997,400,000	$ 939,226,000
Alternative 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station [1]	$ 869,400,000	$ 1,300,000	$ 884,400,000	$ 826,226,000
Alternative 3: Force Main and Biological HRT at South Shore [1]	$ 262,400,000	$ 1,063,000	$ 274,400,000	$ 216,226,000

Notes

1. Alternatives 1, 2 and 3 include a $72.6M cost "credit" for Waukesha Facility Plan improvements that would not be required if the Waukesha WWTP were to be decommissioned. The $72.6M credit is not specific to return flow, instead it represents improvements identified in the 2030 Facility Plan that would be required if the Waukesha WWTP were to remain. This cost is not applied to the proposed return flow to Underwood Creek because the Facility Plan improvements would be required regardless of the WWTP's discharge location, but it is credited to the MMSD return flow alternatives so that the alternatives can be compared on a true cost basis.

2. Does not include WWTP O&M costs because they are essentially the same between Waukesha and MMSD, and are therefore negligible when comparing cost differences between the three MMSD alternatives and the proposed return flow to Underwood Creek.

Conceptual Cost Comparison of Return Flow Alternatives to the Milwaukee Metropolitan Sewerage District

Calculation of Unit Prices for Pump Station and Pipelines Based on the Proposed Underwood Creek Return Flow Included in the Application.				
Alternative and Details		**Capital Cost**	**Unit**	**Comment**
Pump Station Unit Price				
Pump Station Cost for Proposed Underwood Creek Return Flow	$	3,508,000		Pump Station for fully treated wastewater (not raw wastewater)
Unit Price of Pump Station	$	278,413	$/mgd	12.6 mgd pump station for proposed return flow (10.9 mgd * 1.15=12.6)
Pipeline Unit Price				
Pipeline, Valves and Appertenances Cost for Proposed Underwood Creek Return Flow	$	25,515,000		
Length of Underwood Creek Pipeline		11.4	miles	
Unit cost Pipeline	$	2,238,158	$ per mile	36-inch diameter pipe

Alt 1: Wet Weather Equalization and Force Main to South Shore				
Description: The Waukesha WWTP would be decommissioned and a new pipeline would be constructed to return untreated wastewater to Milwaukee MSD's South Shore Water Reclamation Facility. A storage tunnel would be constructed to temporarily equalize wet weather flows to MMSD. The volume stored in the tunnel would be treated at South Shore once wet weather flows subside, and Waukesha's return flow would be treated with "dry weather" flow from MMSD's existing collection system. A new pipeline for Waukesha's return flow would convey untreated wastewater from Waukesha's existing WWTP location to South Shore.				
Alternative and Details		**Capital Cost**	**Unit**	**Comment**
Waukesha WWTP Max Day 2030 Flows		33,500,000	gpd	from 2011 WWTP Facility Plan
Days of EQ needed for MMSD Return to South Shore		9	days	Estimated from consecutive days when South Shore is operating at 75% or more of its Peak Capacity. Based on South Shore average daily flow data from 2006-2010.
Volume of EQ		302,000,000	gallons	
Storage Tunnel Cost	$	462,400,000		See "Tunnel Cost"
Pipeline Length to South Shore WWTF		17	miles	28 total miles minus 11 miles of tunnel
Cost of Return flow Pipeline to South Shore WWTF	$	57,700,000		Escalated proposed Underwood Creek pipeline cost from 36" pipe to 42" pipe to accommodate 34 mgd flow rate. Escalated by 30% because alignment to South Shore is mostly medium to highly urban (from CPES constructability factors).
Pump Station Cost	$	10,400,000		Escalated pump station cost to 34 mgd (peak day flow from 2011 FP). Assumed one pump station to dewater the storage tunnel. Escalated by 10% because unit price was for treated wastewater whereas this price is for raw wastewater.
Waukesha WWTP Demolition and Site Restoration	$	13,700,000		See "WWTP Demolition"
Estimated Construction Cost	**$**	**544,200,000**		
3% markup for Bonds & Insurance	$	16,326,000		
5% markup for Mob/Demob	$	27,210,000		
8% markup for Contractors Overhead	$	47,018,880		
4% markup for Contractors profit	$	23,509,440		
25% Contingency	$	164,566,080		
Subtotal Markups and Contingency	**$**	**278,630,400**		
Total Project Construction Costs	**$**	**822,830,400**		
8% allowance for engineering and design	$	65,826,432		
12% allowance for permitting, legal and administration	$	98,739,648		
8% allowance for engr services during construction	$	65,826,432		
Subtotal Other Project Costs	**$**	**230,392,512**		
GRAND TOTAL PROJECT CAPITAL COST	**$**	**1,053,000,000**		
Annual O&M ($/year)	**$**	**1,444,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.
20-year Present Worth	**$**	**1,070,000,000**		
2030 Facility Plan Improvements at Waukesha WWTP	$	(72,600,000)		Facility Plan page 10-5: $60.8M + $5.0M UV Disinfection + $6.8M Reactive Filtration
Total Capital Costs for Waukesha Return to MMSD with "credit" for Facility Plan Improvements	$	980,400,000		Subtracting Facility Plan improvements because those would not be required if the Waukesha WWTP is decommissioned. Note that the Facility Plan projects are not required for return flow, they are required only if the Waukesha WWTP were to be maintained. Therefore, this would be a "credit" to an MMSD return alternative.
20-year Present Worth with Waukesha WWTP Facility Plan Improvements	**$**	**997,400,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.

Alt 2: Wet Weather Equalization with Return Flow to MMSD Interceptor Near Greenfield Pump Station

Description: The Waukesha WWTP would be decommissioned and a new pipeline would be constructed to return untreated wastewater to Milwaukee MSD's existing collection system. Return flow discharge would occur at MMSD's existing collection system near the Greenfield Pump Station (sanitary sewer pump station located near 124th St. and Greenfield Ave). A storage tunnel would be constructed to temporarily equalize wet weather flows to MMSD. The volume stored in the tunnel would be discharged through a new pump station to the existing MMSD collection system for conveyance and treatment within MMSD's existing system, where Waukesha's return flow would be treated with "dry weather" in MMSD's existing system.

Alternative and Details		Capital Cost	Unit	Comment
Volume of EQ		302,000,000	gallons	
Storage Tunnel Cost	$	462,400,000		See "Tunnel Cost"
Length of Pipeline to MMSD Interceptor		0.1	miles	Pipeline length nearly all tunnel volume
Cost of Return flow Pipeline From Tunnel to Greenfield Pump Station	$	339,000		Short pipeline length from tunnel pump station to MMSD interceptor near Greenfield Pump Station. Escalated proposed Underwood Creek pipeline cost from 36" pipe to 42" pipe to accommodate 34 mgd flow rate. Escalated by 30% because alignment to South Shore is mostly medium to highly urban (from CPES constructability factors).
Pump Station to Dewater Tunnel Cost	$	10,400,000		Escalated pump station cost to 34 mgd (peak day flow from 2011 FP). Assumed one pump station to dewater the storage tunnel. Escalated by 10% because unit price was for treated wastewater whereas this price is for raw wastewater.
Waukesha WWTP Demolition and Site Restoration	$	13,700,000		See "WWTP Demolition"
Estimated Construction Cost	**$**	**486,839,000**		
3% markup for Bonds & Insurance	$	14,605,170		
5% markup for Mob/Demob	$	24,341,950		
8% markup for Contractors Overhead	$	42,062,890		
4% markup for Contractors profit	$	21,031,445		
25% Contingency	$	147,220,114		
Subtotal Markups and Contingency	**$**	**249,261,568**		
Total Project Construction Costs	**$**	**736,100,568**		
8% allowance for engineering and design	$	58,888,045		
12% allowance for permitting, legal and administration	$	88,332,068		
8% allowance for engr services during construction	$	58,888,045		
Subtotal Other Project Costs	**$**	**206,108,159**		
GRAND TOTAL PROJECT CAPITAL COST	**$**	**942,000,000**		
Annual O&M ($/year)	**$**	**1,300,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.
20-year Present Worth	**$**	**957,000,000**		
2030 Facility Plan Improvements at Waukesha WWTP	$	(72,600,000)		Facility Plan page 10-5: $60.8M + $5.0M UV Disinfection + $6.8M Reactive Filtration
Total Capital Costs for Waukesha Return to MMSD with "credit" for Facility Plan Improvements	$	869,400,000		Subtracting Facility Plan improvements because those would not be required if the Waukesha WWTP is decommissioned. Note that the Facility Plan projects are not required for return flow, they are required only if the Waukesha WWTP were to be maintained. Therefore, this would be a "credit" to an MMSD return alternative.
20-year Present Worth with Waukesha WWTP Facility Plan Improvements	**$**	**884,400,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.

Alt 3: Force Main and Biological HRT at South Shore

Description: The Waukesha WWTP would be decommissioned and a new pipeline would be constructed to return untreated wastewater to Milwaukee MSD's South Shore Water Reclamation Facility. A biological high-rate treatment facility (biological physical-chemical treatment) would be constructed at South Shore to treat the peak day flow rate from the return flow for wet-weather flows. Dry weather flows would be treated in conventional processes at the existing South Shore facility. A new pipeline for Waukesha's return flow would convey untreated wastewater from Waukesha's existing WWTP location to South Shore.

Alternative and Details		Capital Cost	Unit	Comment
Volume of Wet Well		20,000,000	gallons	
Wet Well Tunnel Cost	$	33,200,000		See "Tunnel Cost"
Pipeline Length to South Shore WWTF		27	miles	28 total miles minus 1 mile of tunnel
Cost of Return flow Pipeline to South Shore WWTF	$	91,700,000		Escalated proposed Underwood Creek pipeline cost from 36" pipe to 42" pipe to accommodate 34 mgd flow rate. Escalated by 30% because alignment to South Shore is mostly medium to highly urban(from CPES constructability factors).
Pump Station Cost	$	10,400,000		Escalated pump station cost to 34 mgd (peak hour flow from 2011 FP). Assumed one pump station to convey flow to HRT facility at South Shore. Escalated by 10% because unit price was for treated wastewater whereas this price is for raw wastewater.
Biological High Rate Treatment for Wet Weather Flow at South Shore	$	23,647,000		Developed in previous works for 50 mgd for MMSD South Shore WWTF. See "Biological HRT Cost". Cost was prorated for 34 mgd peak day flow estimated in Waukesha 2011 FP.
Waukesha WWTP Demolition and Site Restoration	$	13,700,000		See "WWTP Demolition"
Total Cost for MMSD Return to South Shore with HRT	**$**	**173,000,000**		
3% markup for Bonds & Insurance	$	5,190,000		
5% markup for Mob/Demob	$	8,650,000		
8% markup for Contractors Overhead	$	14,947,200		
4% markup for Contractors profit	$	7,473,600		
25% Contingency	$	52,315,200		
Subtotal Markups and Contingency	**$**	**88,576,000**		
Total Project Construction Costs	**$**	**261,576,000**		
8% allowance for engineering and design	$	20,926,080		
12% allowance for permitting, legal and administration	$	31,389,120		
8% allowance for engr services during construction	$	20,926,080		
Subtotal Other Project Costs	**$**	**73,241,280**		
GRAND TOTAL PROJECT CAPITAL COST	**$**	**335,000,000**		
Annual O&M ($/year)	**$**	**1,063,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.
20-year Present Worth	**$**	**347,000,000**		
2030 Facility Plan Improvements at Waukesha WWTP	$	(72,600,000)		Facility Plan page 10-5: $60.8M + $5.0M UV Disinfection + $6.8M Reactive Filtration
Total Capital Costs for Waukesha Return to MMSD with "credit" for Facility Plan Improvements	$	262,400,000		Subtracting Facility Plan improvements because those would not be required if the Waukesha WWTP is decommissioned. Note that the Facility Plan projects are not required for return flow, they are required only if the Waukesha WWTP were to be maintained. Therefore, this would be a "credit" to an MMSD return alternative.
20-year Present Worth with Waukesha WWTP Facility Plan Improvements	**$**	**274,400,000**		Does not include MMSD service fee ($111.87/year avg household for O&M) or the "credit" of the Waukesha wastewater treatment service fee ($108.41/year avg household for WWTP O&M) once the WWTP would be abandoned because they are essentially the same and therefore offset each other. In other words, because the above service fees represent annual O&M costs (not capital costs) and they are essentially the same, the annual O&M costs of the Waukesha WWTP is anticipated to be similar to the O&M at MMSD.

Tunnel Cost

Date: May 04, 2012
Question: What is the cost to install a tunnel that can accommodate 302,000,000 gallons of fluid?

Assume: The tunnel is in rock and is lined. The diameter of the tunnel is reasonable in size and can be completed using a mainbeam gripper type TBM that is readily available. There are geologic constraints that may impact the price such as uncontrolled inflow of groundwater.

	302,000,000	gallons
	40,371,528	volume required (cf)
	41,054,333	volume achieved (cf)
	15	required radius of tunnel (ft)
	58080	required length of tunnel (ft)
	11	miles of tunnel
$	5,000	*Lower Bound Cost per Foot (2-Pass In Rock)
$	14,000	*Upper Bound Cost Per Foot (2-Pass In Rock)
$	290,400,000	*Lower Bound Cost (2-Pass In Rock)
$	813,120,000	*Upper Bound Cost (2-Pass In Rock)

*Includes shafts, 4.2% mobilization, 8% overhead, 4% profit, and other typical tunnel project costs.

$	243,400,000	Lower Bound Construction Cost (less 4.2% Mob/demob, 8% overhead, and 4% profit)
$	681,400,000	Upper Bound Construction Cost (less 4.2% Mob/demob, 8% overhead, and 4% profit)
$	**462,400,000**	**Median Tunnel Construction Cost**

Date: May 04, 2012
Question: What is the cost to install a tunnel that can accommodate 302,000,000 gallons of fluid?

Assume: The tunnel is in rock and is lined. The diameter of the tunnel is reasonable in size and can be completed using a mainbeam gripper type TBM that is readily available. There are geologic constraints that may impact the price such as uncontrolled inflow of groundwater.

	20,000,000	gallons
	2,673,611	volume required (cf)
	2,866,339	volume achieved (cf)
	12	required radius of tunnel (ft)
	6336	required length of tunnel (ft)
	1.2	miles of tunnel
$	4,500	*Lower Bound Cost per Foot (2-Pass In Rock)
$	8,000	*Upper Bound Cost Per Foot (2-Pass In Rock)
$	28,512,000	*Lower Bound Cost (2-Pass In Rock)
$	50,688,000	*Upper Bound Cost (2-Pass In Rock)

*Includes shafts, 4.2% mobilization, 8% overhead, 4% profit, and other typical tunnel project costs.

$	23,900,000	Lower Bound Construction Cost (less 4.2% Mob/demob, 8% overhead, and 4% profit)
$	42,500,000	Upper Bound Construction Cost (less 4.2% Mob/demob, 8% overhead, and 4% profit)
$	**33,200,000**	**Median Tunnel Construction Cost**

Biological HRT Cost

EXHIBIT X
Bio CEPT/CEC Cost Estimate

Flow (MLD)	**190**	**190 (50 mgd)**	**380**	**380**	**760**	**760**
CEPT/CEC	**CEPT**	**CEC**	**CEPT**	**CEC**	**CEPT**	**CEC**
Disinfection	**UV**	**UV**	**UV**	**UV**	**UV**	**UV**
Screening/Grit Removal[1]	$8,181,000	$8,181,000	$10,370,000	$10,370,000	$15,077,000	$15,077,000
Biological Contact Basins[1]	$1,527,000	$1,527,000	$2,792,000	$2,792,000	$3,949,000	$3,949,000
Blower Building[1]	$1,178,000	$1,178,000	$1,200,000	$1,200,000	$1,255,000	$1,255,000
Primary Clarifiers[1]	$4,232,000	---	$6,927,000	---	$13,788,000	---
Primary Sludge Pump Station[1]	$625,000	---	$625,000	---	$929,000	---
Actiflo[1]	---	$7,948,000	---	$13,281,000	---	$24,839,000
UV Disinfection[1]	$4,327,000	$4,327,000	$8,550,000	$8,550,000	$16,821,000	$16,821,000
Chemical Feed[1]	$3,614,000	$3,614,000	$4,279,000	$4,279,000	$5,972,000	$5,972,000
Yard Piping[1]	$3,206,000	$3,206,000	$4,408,000	$4,408,000	$7,236,000	$7,236,000
Subtotal – Construction Cost[2]	$31,189,000	$34,775,000	$45,412,000	$52,058,000	$75,426,000	$87,168,000
Total – Capital Cost[3]	$40,545,000	$45,208,000	$59,035,000	$67,675,000	$98,054,000	$113,319,000

[1] Note: Individual facility costs do not include general demolition, overall sitework, plant computer system, yard electrical, and yard piping costs. These costs are included in Subtotal- Construction Cost.
[2] Includes general demolition, overall sitework, plant computer system, yard electrical, and yard piping costs.
[3] Adds 30% for permitting, engineering, services during construction, commissioning and startup, and legal/administration.

Conceptual Level Cost Estimate for Demolition and Site Restoration of the Waukesha WWTP

Description	QTY	UNIT	CREW	Labor Cost/Unit	Total Labor	Material Cost/Unit	Total Material	Equipment Cost/Unit	Total Equipment	Total Unit Cost	Total Direct Cost
Site Preparation											
Disconnect Electrical Service to Site/Facilities	20	DAY	R21	$2,528.00	$50,560			$63.00	$1,260	$2,591.00	$51,820
Disconnect Water/Gas Service to Site/Facilities	20	DAY	Q3	$2,510.00	$50,200					$2,510.00	$50,200
Building and Facility Demolition											
WWTP Facility Equipment Removal and Salvage	60	DAY	Q22A	$2,200.00	$132,000			$675.00	$40,500	$2,875.00	$172,500
Building and Facility Demolition	7,500,000	CF	B8	$0.12	$900,000	$0.15	$1,125,000	$0.27	$2,025,000	$0.54	$4,050,000
Building and Facility Demolition Footings and Foundations, 18" Thick, Rod Reinforced	500,000	SF	B9	$9.46	$4,730,000			$1.40	$700,000	$10.86	$5,430,000
Yard and Site Piping Demolition Allowance	40	DAY	B12F	$1,445.00	$57,800			$715.00	$28,600	$2,160.00	$86,400
Demolish Asphalt Paving, 6" Thick	43,156	SY	B38	$5.80	$250,302			$3.10	$133,782	$8.90	$384,084
Load Demolished Material	142,000	CY	B10U	$0.48	$68,160			$0.66	$93,720	$1.14	$161,880
Haul and Dispose of Demolished Material, 20 CY Truck, 50 Mile Round Trip	7,500	Load	B34D	$80.35	$602,625	$200.00	$1,500,000	$136.15	$1,021,125	$416.50	$3,123,750
Site Restoration											
Rough Grade Site	55	ACR	B10B	$484.00	$26,620			$1,160.00	$63,800	$1,644.00	$90,420
Hydro or Air Seeding, with Mulch and Fertilizer, 8#/MSF	2,396	MSF	B81	$11.70	$28,033	$19.60	$46,962	$7.75	$18,569	$39.05	$93,564
Subtotal Direct Cost, Not Including Markups or Contingency					**$6,900,000**		**$2,700,000**		**$4,100,000**		**$13,700,000**

Cost Source: RS Means Cost Data, 31st Manual Edition, 2012.

Alternative 1: Wet Weather Equalization and New Pipeline to South Shore

Hydraulics and Energy Costs

Pipeline Segment	Miles	Diameter
A	17.0	42

Tunnel Invert Elev at End of Tunne	673	Invert is 100 ft below ground (60 ft bury depth [2 times the 30ft tunnel diameter]
Peak Elevation Along Alignment	809	
Ground Elevation at South Shore	654	
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	Pipeline Velocity	Pipeline Frict Loss	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	14	9716	2.25	30.18	0.54	30.72	136	167	167	72	511	424	3711167	$223,000	3450
MDD	34	23596	5.47	177.99	3.18	181.17	136	317	317	137	2362	1957	17146508	$1,029,000	15938

O&M Costs

Return Flow Pump Station	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
Energy	mgd	14 mgd			$ 223,000		
O&M		2% of Capital cost of pump station	$ 0.0200	$ 10,400,000	$ 208,000		
Total Return Flow Pump Station						$ 431,000	

Return Flow Pipeline	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/lf/yr	89,760 (17 miles)	$ 0.52	$ 47,000	$ 47,000		Historical Waukesha Unit Costs
Total Return Flow Pipeline						$ 47,000	

Equalization	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/Mgal/yr	302	$ 3,200.00	$ 966,400	$ 966,400		Unit Cost from MMSD 2012 Cost Recovery for Inline Storage System $1.679M for 521 Mgal Storage.
Total Equalization						$ 966,400	

Alternative Total O&M ($/yr.)	**$ 1,444,000**
PRESENT WORTH (6%, 20 yrs)	**$ 16,600,000**

Alternative 2: Wet Weather Equalization and Discharge to MMSD Interceptor near Greenfield Pump Station

Hydraulics and Energy Costs

Pipeline		
Segment	Miles	Diameter
A	0.1	42

Tunnel Invert Elev at End of Tunnel	677	Invert is 100 ft below ground (60 ft bury depth [2 times the 30ft tunnel diameter]
Discharge Elev at MMSD Interceptor	770	Discharge is 15 ft below ground elevation.
Ground Elev at MMSD Interceptor	785	
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	Pipeline Velocity	Pipeline Frict Loss	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	14	9716	2.25	0.18	0.54	0.72	93	94	94	41	287	238	2086145	$125,000	1939
MDD	34	23596	5.47	1.05	3.18	4.23	93	97	97	42	724	600	5256092	$315,000	4886

O&M Costs

Return Flow Pump Station	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
Energy	mgd	14 mgd			$ 125,000		
O&M		2% of Capital cost of pump station	$ 0.0200	$ 10,400,000	$ 208,000		
Total Return Flow Pump Station						$ 333,000	

Return Flow Pipeline	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/lf/yr	528 (0.1 miles)	$ 0.52	$ 270	$ 270		Historical Waukesha Unit Costs
Total Return Flow Pipeline						$ 270	

Equalization	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/Mgal/yr	302	$ 3,200.00	$ 966,400	$ 966,400		Unit Cost from MMSD 2012 Cost Recovery for Inline Storage System. $1.679M for 521 Mgal Storage.
Total Equalization						$ 966,400	

Alternative Total O&M ($/yr.)	**$ 1,300,000**
PRESENT WORTH (6%, 20 yrs)	**$ 14,900,000**

Alternative 3: Pump Station and Pipeline to Biological High Rate Treatment Facility at South Shore

Hydraulics and Energy Costs

Pipeline		
Segment	Miles	Diameter
A	27.0	42

Wet Well/Tunnel Invert Elev at End	732	Invert is 80 ft below ground (50 ft bury depth [2 times the 24 ft tunnel diameter])
Peak Elevation Along Alignment	866	
Ground Elev at South Shore	654	
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	Pipeline Velocity	Pipeline Frict Loss	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	14	9716	2.25	47.93	0.54	48.47	134	182	182	79	560	464	4061816	$244,000	3775
MDD	34	23596	5.47	282.70	3.18	285.88	134	420	420	182	3127	2591	22698635	$1,362,000	21098

O&M Costs

Return Flow Pump Station	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
Energy	mgd	14 mgd			$ 244,000		
O&M		2% of Capital cost of pump station	$ 0.0200	$ 10,400,000	$ 208,000		
Total Return Flow Pump Station						$ 452,000	

Return Flow Pipeline	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/lf/yr	142,560 (0.1 miles)	$ 0.52	$ 74,130	$ 74,130		Historical Waukesha Unit Costs
Total Return Flow Pipeline						$ 74,130	

Wet Well Equalization	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M	$/Mgal/yr	20	$ 3,200.00	$ 64,000	$ 64,000		Unit Cost from MMSD 2012 Cost Recovery for Inline Storage System. $1.679M for 521 Mgal Storage.
Total Wet Well Equalization						$ 64,000	

Biological High Rate Treatment	**Units**	**Quantity**	**Unit Cost**	**Ext. Cost**	**$/yr**		
O&M		2% of Capital cost of HRT facility	$ 0.0200	$ 23,647,000	$ 473,000		
Total Bio-HRT						$ 473,000	

Alternative Total O&M ($/yr.)	**$ 1,063,000**
PRESENT WORTH (6%, 20 yrs)	**$ 12,200,000**

Attachment A-3

Wisconsin Department of Natural Resources: Limits for Waukesha Return Water

Received on February 5, 2013

CORRESPONDENCE/MEMORANDUM

State of Wisconsin

DATE: December 13th, 2011 FILE REF:

TO: Kristy Rogers
Diane Figiel

FROM: Jackie Fratrick

SUBJECT: Limits for Waukesha Return Water

This document addresses water quality-based effluent limits for wastewater that would need to be returned to a receiving water in the Lake Michigan Basin as a condition of diversion of Lake Michigan water for Waukesha's public water supply. The limits to be addressed are: BOD_5, Total Suspended Solids (TSS), Ammonia-Nitrogen (NH3-N), Dissolved Oxygen (D.O.), Total Phosphorus, Fecal Coliform, Chloride, Total Mercury, and temperature.

Discharge Flow: The assessment of return flows have evolved somewhat since initial discussions on the objectives of diversion and water return. However, a July 23rd, 2009 memo from SEH (Technical Memo No. 108425) estimated an average daily flow of 11 to 13 million gallons per day (MGD). For the purposes of these recommendations, 13 MGD will be used.

Underwood Creek:

Stream Flow for Determination of Limits: Considerable daily flow data exists for Underwood Creek from a USGS gauging station. However, flow frequencies derived from these data do not correspond exactly to the flow statistics needed for determination of limits. Most limit determinations require use of a fraction or all of a seven day average, ten year low flow (7Q10) or seven day average, two year low flow (7Q2). In reference to evaluation of hydraulic conditions on Underwood Creek under various return flows, consultants for Waukesha used 3 cubic feet per second (cfs) as Underwood Creek's base flow.

For initial estimates of limitations in 2008, I determined flow frequencies for Underwood Creek, based on daily flow data from 1974 through 2008. The 3 cfs 'base flow' corresponds to the lower 10th percentile for this time period. This flow would seem consistent with a 7Q2. **For 7Q10, a flow of 1.6 cfs,** which corresponds to the lower 1 percentile of flow, is used. It should be noted that, for a proposed effluent discharge that is far greater than the receiving water (as if the case for the return flow to Underwood Creek), a slight difference in the statistical flow does not translate to a significant change in the resulting limits.

BOD_5: To determine the allowable BOD that can be discharged without lowering the dissolved oxygen in the receiving water to below 5.0 mg/l, the 26-pound method is used. Using the 26-pound method, BOD limits are based on a 1 mg/l drop in dissolved oxygen for every 13 lb of BOD discharged per cubic feet of stream flow during critical conditions. Underwood Creek has a typical background dissolved oxygen concentration of no less than 7.0 mg/l. The formula for calculating the allowable BOD is as follows:

$$BOD\ (mg/l) = 2.4\ (DO_{mix}\text{-}DO_{criterion})(a)(0.967)^{T\text{-}24}$$

where $a = [(7Q10)(0.646) + Q_{Effluent,\ in\ MGD}] / Q_{Effluent,\ in\ MGD}$

Printed on Recycled Paper

For ‘summer’ limits (May through October) a stream temperature of 21 degrees C is used; and for ‘winter’ limits (November through April), a stream temperature of 3 degrees C is used. A minimum effluent level for dissolved oxygen of 7.0 mg/l is used for this determination.

The resulting calculated BOD_5 limits are:

May-October – 5.7 mg/l, weekly average;
November-April – 10.5 mg/l, weekly average

Note: the current BOD_5 limits for Waukesha for November through April are 10 mg/l, so the November-April limits for Underwood Creek shall be no greater than 10 mg/l, weekly average.

Dissolved Oxygen: The proposed daily minimum effluent dissolved oxygen level shall be set equal to that used for determining limitations for BOD_5 ; i.e. **7 mg/l, daily minimum**.

Total Suspended Solids: There are no water quality criteria for total suspended solids. In the absence of a wasteload allocation (such as with a TMDL), the total suspended solids are generally set equal to the limits for BOD_5, except that the limits shall not be set lower than 10 mg/l. The current TSS limit for the Waukesha wastewater plant is 10 mg/l, weekly average, and this limit is proposed for the Underwood Creek discharge as well. **However, see ‘Note on Underwood Creek Discharge’ at the end of this section.**

Ammonia-Nitrogen: The determination of acute criteria for ammonia is established in ch. NR 105, Table 2C. The acute criterion (and the limit, which is twice the criterion) is only dependent on the maximum pH of the effluent discharge. Therefore, a daily maximum ammonia-nitrogen limit would be the same as for the current Waukesha facility, which is 24 mg/l, applicable in the months of November through April.

The determination of chronic criteria for ammonia are specified in ch. NR 105, Table 4B, and the procedures for the determination of chronic (weekly and monthly) ammonia limits are specified in ch. NR 106.32(3). Chronic criteria are dependent on the classification, temperature and pH of the receiving water, as well as the presence or absence of spawning species.

The proposed weekly and monthly limits for discharge to Underwood Creek are:

Months	Weekly Average Limits	Monthly Average Limits
May-Sept	3.2 mg/l	1.3 mg/l
October	9.2 mg/l	3.7 mg/l
November-March	10.5 mg/l	4.2 mg/l
April	6.5 mg/l	2.6 mg/l

These limits are slightly lower than those in Waukesha’s current permit.

Fecal Coliform: NR 210 specifies an effluent standard of 400 counts per 100 ml as a monthly geometric mean. Since Underwood Creek is not classified as a public water supply, this requirement would apply for the months of May through September. **However, see 'Note on Underwood Creek Discharge' at the end of this section.**

Total Phosphorus: Revisions to administrative rules regulating phosphorus took effect on December 1, 2010. These rule revisions include additions to NR 102 (NR 102.05), which establish phosphorus standards for surface waters. NR 102.06(3)(a) specifically names reaches of rivers for which a phosphorus criterion of 0.1 mg/l applies. For other stream segments that are not specified in NR 102.06(3)(a), NR 102.06(3)(b) specifies a phosphorus criterion of 0.075 mg/l. The phosphorus criterion of 0.075 mg/l applies for Underwood Creek.

Ambient data for Underwood Creek indicate that the median phosphorus concentration exceeds the 0.075 mg/l standard (USGS Report 2007-5084). A mass balance calculation would result in a limit that is less than the criterion. NR 217.13(7) specifies that if the resulting limit is less than the criterion, then the criterion would apply as the limit. Therefore, the proposed limit would be 0.075 mg/l as a six month average (May-October and November-April averaging periods) and 0.225 as a monthly average. **However, see 'Note on Underwood Creek Discharge' at the end of this section.**

Mercury: An overview of ambient river data indicates that mercury levels typically exceed the wildlife based criterion in NR 105 (1.3 ng/l as a monthly average. Therefore, in accordance with NR 106.06(6), the limit for mercury shall be set equal to the wildlife criterion of 1.3 ng/l, and shall be expressed as a monthly average.

Chloride: In accordance with the procedures in NR 106, the calculated limits for chloride are 1500 mg/l, daily maximum, and 400 mg/l, weekly average. The daily maximum will not be considered as a proposed limit, since such a concentration is not seen in municipal discharges, and since permit requirements for daily maximum chloride have not been needed for Waukesha's current permit. Therefore the proposed chloride limit is 400 mg/l, expressed as a weekly average.

Note on Underwood Creek Discharge: Work is underway on development of a Total Maximum Daily Load (TMDL) for the Milwaukee River Basin, of which the Underwood Creek Watershed is a part. The intent of the Milwaukee River TMDL is to determine wasteload and load allocations for phosphorus, total supended solids, and fecal coliform for existing point and nonpoint sources. Unless Waukesha is considered a discharger in reference to the TMDL development, or unless the TMDL provides reserve capacity for the appropriate stream reaches to accommodate a new discharge, there would be no allowable levels for phosphorus, total suspended solids, and fecal coliform.

Thermal (Temperature) limits are addressed in a separate addendum.

Root River:

Stream Flow for Determination of Limits: Historical data has determined a 7Q10 of 1.8 cfs, and a 7Q2 of 3.8 for the Root River.

BOD_5: The allowable BOD that can be discharged in the Root River is determined in the same way as for Underwood Creek. The resulting calculated BOD_5 limits are:

May-October – 5.8 mg/l, weekly average;
November-April – 10.6 mg/l, weekly average

Note: the current BOD_5 limits for Waukesha for November through April are 10 mg/l, so the November-April limits for the Root River shall be no greater than 10 mg/l, weekly average.

Dissolved Oxygen: The proposed daily minimum effluent dissolved oxygen level shall be set equal to that used for determining limitations for BOD_5 ; i.e. **7 mg/l, daily minimum**.

Total Suspended Solids: The current TSS limit for the Waukesha wastewater plant is 10 mg/l, weekly average, and this limit is proposed for the Root River discharge as well.

Ammonia-Nitrogen: As with Underwood Creek, a daily maximum ammonia-nitrogen limit would be the same as for the current Waukesha facility, which is 24 mg/l, applicable in the months of November through April. The proposed weekly and monthly limits for discharge to the Root River are:

Months	Weekly Average Limits	Monthly Average Limits
May-Sept	3.2 mg/l	1.4 mg/l
October	9.3 mg/l	3.8 mg/l
November-March	10.5 mg/l	4.3 mg/l
April	6.5 mg/l	2.6 mg/l

Fecal Coliform: NR 210 specifies an effluent standard of 400 counts per 100 ml as a monthly geometric mean. Since the Root River is not classified as a public water supply, this requirement would apply for the months of May through September.

Total Phosphorus: The phosphorus criterion of 0.075 mg/l applies for the Root River. There is insufficient ambient phosphorus data from for the Root River to determine a seasonal median of the phosphorus concentration in the stream, but available data suggest that the ambient concentration is close to, if not exceeding, the 0.075 mg/l standard. In addition, the Root River is listed on the 303(d) list of impaired waters due to impacts from phosphorus. Therefore, the proposed limit would be 0.075 mg/l as six month average (May-October and November-April averaging periods), and 0.225 as a monthly average.

Mercury: An overview of ambient river data indicates that mercury levels typically exceed the wildlife based criterion in NR 105 (1.3 ng/l as a monthly average. Therefore, in accordance with NR 106.06(6), the limit for mercury shall be set equal to the wildlife criterion of 1.3 ng/l, and shall be expressed as a monthly average.

Chloride: In accordance with the procedures in NR 106, the calculated limits for chloride are 1500 mg/l, daily maximum, and 400 mg/l, weekly average. The daily maximum will not be considered as a proposed limit, since such a concentration is not seen in municipal discharges, and since permit requirements for

daily maximum chloride have not been needed for Waukesha's current permit. Therefore the proposed chloride limit is 400 mg/l, expressed as a weekly average.

Thermal (Temperature) limits are addressed in a separate addendum.

Lake Michigan:

Lake Michigan is classified as cold water, public water supply.

Lake dilution for determination of limits: For determination of limits for BOD, ammonia, and chloride; a lake:discharge ratio of 10:1 is used in the absence of a site specific model. This ratio does not apply for phosphorus.

BOD_5 and TSS: a lake to effluent ratio of 10 to 1 results in BOD_5 and total suspended solids limits of greater than 45 mg/l as a weekly average. NR 210 specifies that a municipal wastewater system shall meet as a minimum, limits of 30 mg/l (monthly average) and 45 mg/l (weekly average) for BOD_5 and total suspended solids. These levels are well in excess of Waukesha's current limits, however, so the current limits shall apply.

Dissolved Oxygen: The levels from Waukesha's current permit are recommended.

Ammonia-Nitrogen: The acute criterion for cold water is more restrictive than that for warm water streams, and is independent of lake dilution. Based on historical upp 99th percentile of effluent pH (7.8 s.u.) the daily maximum limit would be 16.2 mg/l and would apply year round.

Calculated weekly and monthly ammonia limits are well in excess of Waukesha's current limits, so the current limits would apply.

Fecal Coliform: NR 210 specifies an effluent standard of 400 counts per 100 ml as a monthly geometric mean. Since Lake Michigan is classified as a public water supply, this requirement would apply year-round.

Mercury: Federal rules require an elimination of use of a mixing zone for discharges of bioaccumulating chemicals of concern (BCCs) to the Great Lakes as of November 15th, 2010. Mercury is a BCC. In the absence of a mixing zone, the limit for mercury would be set equal to the most restrictive criterion, which is 1.3 ng/l, expressed as a monthly average.

Chloride: Because of the 10:1 dilution, the most restrictive chloride limit is 1514 mg/l,, expressed as a daily maximum.

Thermal (Temperature) limits are addressed in a separate addendum.

Received on February 5, 2013

Addendum – Thermal (Temperature) Determinations for Waukesha Return Flows

Chapter NR 102, Subchapter II of the Wisconsin Administrative Code establishes water quality standards for temperature, in order to protect fish and other aquatic life from lethal and sub-lethal effects. Chapter NR 106, Subchapter V, specifies procedures for calculating water quality based effluent limitations for temperature. These rule changes became effective on October 1st, 2010.

In accordance with NR 106.53(2)(b), the highest daily maximum flow rate for a calendar month is used to determine the acute (daily maximum) effluent limitation. In accordance with NR 106.53(2)(c), the highest 7-day rolling average flow rate for a calendar month is used to determine the sub-lethal (weekly average) effluent limitation.

In the tables below, the two columns to the far right provide weekly average and daily maximum temperature limitations for the corresponding months listed in the column to the far left. A notation of 'NA' for weekly average temperatures indicates that a weekly average temperature is not needed for the corresponding month, since the daily maximum limit is more restrictive. Regardless of the calculated value, no daily maximum temperature limit may exceed 120 degrees F in order to protect public welfare, unless the permittee can demonstrate that the discharge does not pose a potential for human scalding.

Discharge to Underwood Creek:

Month	Water Quality Criteria			Receiving Water Flow Rate (Qs)	Effluent Flow Rate (Qe)		**Calculated Effluent Limit**	
	Ta (default)	Sub-Lethal WQC	Acute WQC		Highest 7-day Rolling Average Flow Rate (Qesl)	Highest Daily Max Flow Rate (Qea)	**Weekly Average Effluent Limitation**	**Daily Maximum Effluent Limitation**
	(°F)	(°F)	(°F)	(cfs)	(mgd)	(mgd)	(°F)	(°F)
JAN	33	49	76	1.60	13.000	13.000	49	77
FEB	34	50	76	1.60	13.000	13.000	50	77
MAR	38	52	77	1.60	13.000	13.000	52	78
APR	48	55	79	1.60	13.000	13.000	55	80
MAY	58	65	82	1.60	13.000	13.000	65	82
JUN	66	76	84	1.60	13.000	13.000	76	84
JUL	69	81	85	1.60	13.000	13.000	81	85
AUG	67	81	84	1.60	13.000	13.000	81	84
SEP	60	73	82	1.60	13.000	13.000	73	82
OCT	50	61	80	1.60	13.000	13.000	61	81
NOV	40	49	77	1.60	13.000	13.000	49	78
DEC	35	49	76	1.60	13.000	13.000	49	77

Discharge to Root River:

Month	Water Quality Criteria			Receiving Water Flow Rate (Qs)	Effluent Flow Rate (Qe)		**Calculated Effluent Limit**	
	Ta (default)	Sub-Lethal WQC	Acute WQC		Highest 7-day Rolling Average Flow Rate (Qesl)	Highest Daily Max Flow Rate (Qea)	**Weekly Average Effluent Limitation**	**Daily Maximum Effluent Limitation**
	(°F)	(°F)	(°F)	(cfs)	(mgd)	(mgd)	(°F)	(°F)
JAN	33	49	76	1.80	13.000	13.000	49	77
FEB	34	50	76	1.80	13.000	13.000	50	77
MAR	38	52	77	1.80	13.000	13.000	52	78
APR	48	55	79	1.80	13.000	13.000	55	80
MAY	58	65	82	1.80	13.000	13.000	65	83
JUN	66	76	84	1.80	13.000	13.000	76	84
JUL	69	81	85	1.80	13.000	13.000	81	85
AUG	67	81	84	1.80	13.000	13.000	81	84
SEP	60	73	82	1.80	13.000	13.000	73	82
OCT	50	61	80	1.80	13.000	13.000	61	81
NOV	40	49	77	1.80	13.000	13.000	49	78
DEC	35	49	76	1.80	13.000	13.000	49	77

Key for two tables above–

Ta (default) = Default ambient monthly temperature of the receiving water.. These ambient temperatures are specific to each calendar month (from NR 102, Table 2, small warm water stream (‘Warm – Small’ on the table))

Sub-lethal WQC =sub-lethal (weekly) water quality criteria for the receiving water.. These criteria are specific to each calendar month (from NR 102, Table 2, small warm water stream (‘Warm – Small’ on the table))

Acute WQC = acute (daily maximum) water quality criterion for the receiving water.. These criteria are specific to each calendar month (from NR 102, Table 2, small warm water stream ('Warm – Small' on the table))

Qesl = In the absence of actual flow data, 13 MGD was used as highest seven day rolling average flow rate.

Qea = In the absence of actual flow data, 13 MGD was used as the highest daily flow rate.

Weekly Average Effluent Limitation = provides the limitation for the 7-day average of daily maximum temperature. If 'NA' is indicated, a weekly limitation is greater than the calculated daily maximum effluent limitation, and a weekly average limit is not needed.

Daily Maximum Temperature Limitation: Limitation applicable to daily maximum temperature. This limit applies to the maximum temperature determined by continuous monitoring, or the maximum of several discrete temperatures taken by discrete monitoring, over a 24 hour period.

Discharge to Lake Michigan:

Month	Water Quality Criteria			Representative Highest Effluent Flow Rate (Qe)					**Calculated Effluent Limit**	
	Ta (default)	Sub-Lethal WQC	Acute WQC	7-day Rolling Average (Qesl)	Daily Maximum Flow Rate (Qea)	B	e^{-a} (for SL-WQBEL)	e^{-a} (for A-WQBEL)	**Weekly Average Effluent Limitation**	**Daily Maximum Effluent Limitation**
	(°F)	(°F)	(°F)	(mgd)	(mgd)				(°F)	(°F)
JAN	35	43	69	13.00	13.00	0.405	0.036	0.036	NA	120
FEB	34	46	69	13.00	13.000	0.405	0.036	0.036	NA	120
MAR	37	52	70	13.00	13.000	0.405	0.036	0.036	NA	120
APR	43	59	70	13.00	13.000	0.405	0.036	0.036	NA	120
MAY	48	65	72	13.00	13.000	0.405	0.036	0.036	NA	120
JUN	54	70	73	13.00	13.000	0.405	0.036	0.036	NA	120
JUL	59	71	74	13.00	13.000	0.405	0.036	0.036	NA	120
AUG	63	70	76	13.00	13.000	0.555	0.019	0.019	NA	120
SEP	60	64	74	13.00	13.000	0.555	0.019	0.019	NA	120
OCT	53	57	73	13.00	13.000	0.405	0.036	0.036	NA	120
NOV	45	49	71	13.00	13.000	0.405	0.036	0.036	NA	120
DEC	38	44	70	13.00	13.000	0.405	0.036	0.036	NA	120

Key to table above –

Ta (default) = Ambient monthly temperature of Lake Michigan waters south of the Milwaukee River mouth, these ambient temperatures are specific to each calendar month (from NR 102, Table 5)

Sub-lethal WQC = sub-lethal (weekly) water quality criterion for Lake Michigan waters south of the Milwaukee River mouth, these criteria are specific to each calendar month (from NR 102, Table 5)

Acute WQC = acute (daily maximum) water quality criterion for Lake Michigan waters south of the Milwaukee River mouth, these criteria are specific to each calendar month (from NR 102, Table 5)

Qesl = In the absence of actual flow data, 13 MGD was used as highest seven day rolling average flow rate.

Qea = In the absence of actual flow data, 13 MGD was used as the highest daily flow rate.

B = a coefficient which is a function of the monthly ambient temperature, as defined in NR 106.55(7)(b)

e^{-a} = a factor as defined in NR 106.55(7)(b). e^{-a} for the sub-lethal temperature limit (SL-WQBEL) is different from the e^{-a} for the acute temperature limit (A-WQBEL) because the e^{-a} (SL-WQBEL) uses the 7-day rolling average flow rate as a factor, where the e^{-a} (A-WQBEL) uses the highest daily maximum flow rate for the calendar month.

Weekly Average Effluent Limitation = provides the limitation for the 7-day average of daily maximum temperature. If 'NA' is indicated, a weekly limitation is greater than the calculated daily maximum effluent limitation, and a weekly average limit is not needed.

Daily Maximum Temperature Limitation: Limitation applicable to daily maximum temperature. This limit applies to the maximum of temperature determined by continuous monitoring, or the maximum of several discrete temperatures taken by discrete monitoring, over a 24 hour period.

Attachment A-4

Compliance Plan to Meet Proposed Chloride Limits for Return Flow with a City of Waukesha Lake Michigan Water Supply

Compliance Plan to Meet Proposed Chloride Limits for Return Flow with a City of Waukesha Lake Michigan Water Supply

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: June 19, 2013

The purpose of this memorandum is to summarize chloride limits for the City of Waukesha's wastewater treatment plant and to evaluate the potential elements and effectiveness of a chloride compliance plan for achieving chloride limits for a return flow to Lake Michigan that would be required for a Lake Michigan water supply.

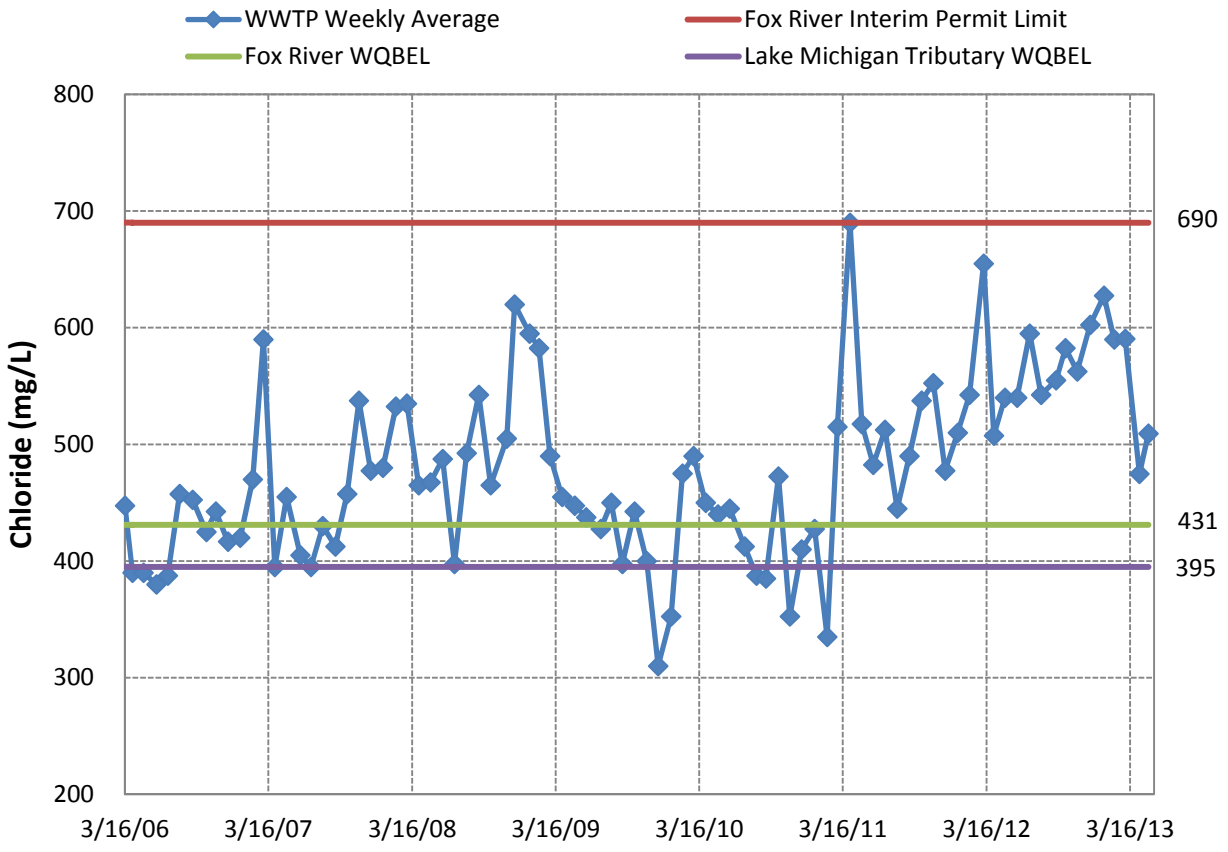
Introduction

The City of Waukesha (City) is preparing an Application for Lake Michigan Diversion with Return Flow (Application) to replace their drinking water source from deep and shallow groundwater to a Lake Michigan supply. A Lake Michigan water supply will include return flow of treated water from the City's wastewater treatment plant (WWTP). The Wisconsin Department of Natural Resources (WDNR) has calculated water quality-based effluent limitations (WQBEL) for the City's current WWTP discharge to the Fox River that also includes chloride limits for a future return flow to Lake Michigan. The return flow limits are much lower than current chloride limits for the WWTP discharge to the Fox River.

A wastewater effluent chloride concentration generally consists of chlorides from the background concentration of the source water and additional sources from within the wastewater collection system and its users. Significant chloride sources can include water softening for residential, commercial and industrial uses, industrial and commercial process waters, sanitary waste, runoff from salt storage facilities, and infiltration and inflow from roadway deicing operations. Very little chloride is removed in conventional wastewater treatment processes. Therefore, control of chlorides in wastewater effluent is typically accomplished by source controls.

Chloride concentrations from the City's WWTP were reviewed from March 2006 through May 2013. The average weekly chloride concentration was 479 mg/L with a maximum weekly concentration of 690 mg/l and minimum weekly concentration of 310 mg/L. The average weekly chloride concentration for the months impacted by winter use of road salts (Dec, Jan, Feb, Mar and Apr) was 497 mg/L with a maximum of 690 mg/L. The average for non-winter months was 465 mg/L with a maximum of 595 mg/L. The weekly average chloride concentrations over this period are shown on Exhibit 1.

EXHIBIT 1
WWTP Chloride Concentrations and Limits for Fox River and Lake Michigan Tributary



Permit Conditions

The City's WWTP received a permit from the WDNR (August 1, 2013) that included chloride limits less than their previous permit. It also included limits for a return flow through two Lake Michigan tributaries – Underwood Creek and Root River. The permit limit for chlorides for discharge to the Fox River is 690 mg/L weekly average. The weekly average is based on 24-hour composite samples for 4 consecutive days within defined weeks of the month. The City consistently meets this limit where only one week in March 2011 had an average equal to 690 mg/L. This is an interim limit that is established while the City implements a chloride compliance plan to achieve a target value of 440 mg/L and WQBEL of 431 mg/L for discharge to the Fox River. The interim limit is necessary in part because of water softening and the associated chloride discharge. Various source reduction measures are included in the permit as a means to achieve compliance. As conditions of the permit the City must:

- Maintain effluent quality at or below the interim effluent limit of 690 mg/L
- Implement the chloride source reduction measures specified in the permit
- Perform the actions listed in the compliance schedule

The source reduction measures specified in the permit include:

- Amend the sewer use ordinance and plumbing code language by March 31, 2014, to require:
  - High efficiency demand initiated regeneration (DIR) type softeners for both newly installed and replacement softeners for residences, commercial and industrial businesses (required by current state law).
  - Significant industrial, commercial, and other large water users (e.g. hospitals) to evaluate their water treatment systems with regard to softened water requirements, and where feasible upgrade current

water softeners with brine reclaim system. Include discussions on these efforts and follow-up actions in the first Annual Chloride Progress Report (due June 30, 2014).

- Investigate new or increased chloride sources from industrial, commercial, hauled wastes and large water users. Characterize and quantify chloride from identified sources. Require identified sources to evaluate their processes with regard to reducing chloride. Include discussions on these efforts and follow-up actions in Annual Chloride Progress Reports.
- Provide information on accomplishment in terms of reduction of clear water entry into the plant (through the collection system) as a result of the on-going collection system I/I reduction project implementations (sanitary/storm sewer line, manhole and chimney rehabilitation, replacement/elimination and repair). Include discussions (along with graphs) in the first Annual Chloride Progress Report and subsequent reports.
- Track concentration and mass of chloride from the discharge of brine from all sources (as indicated in Waukesha's final chloride report dated March 31, 2012) to the WWTP. Characterize and quantify the chloride added to the plant from each source. Coordinate permit required chloride monitoring with periods when brine is hauled to the WWTP. Discuss in the annual chloride reports, measures being taken to eliminate (e.g. by banning brine discharge) or reduce chloride from these sources.
- Continue education of homeowners on impact of chloride from residential softeners and on options available for increasing softener efficiency.
- Request voluntary support from licensed softener installers or self-installers on providing unsoftened water for outside faucets or other water faucets where softened water is not essential.

Actions listed within the compliance schedule of the permit include:

- Submit an Annual Chloride Progress Report in 2014, 2015, and 2016 that shall indicate which chloride source reduction measures have been implemented.
- Submit a Final Chloride Report in 2017 documenting the success in meeting the chloride target value of 440 mg/L, as well as the anticipated future reduction in chloride sources and chloride effluent concentrations.

These source reduction measures and reporting requirements are expected to move the City closer to or in compliance with the WQBEL over the duration of the permit. While these requirements are specific for the City's existing WWTP discharge to the Fox River, each are equally supportive for achieving chloride limits for a return flow to Lake Michigan. All of the actions required to achieve the target value are required before 2018. Consequently, these actions will also support return flow that is anticipated to begin in June 2018.

Alternative Permit Conditions for Lake Michigan Water Supply and Return Flow to Root River or Underwood Creek

As part of the permit, effluent limitations were calculated for continued discharge to the Fox River as well as limitations for certain constituents for return flow to Lake Michigan. The WDNR calculated that a return flow to Lake Michigan through either Underwood Creek or the Root River would have a chloride limit 395 mg/L, which is also the water quality criterion. The Root River return flow location proposed in the Application has been relocated to be further downstream than that proposed in previous documentation for which other limits have been calculated[1] (e.g. May 2010 Application). A specific location for the discharge to Underwood Creek or the Root River was not identified in the WDNR calculation. Consequently, the effluent limits have been calculated for the previous location, which has a significantly smaller watershed area than the proposed Root River return flow location. Because the proposed limit is the water quality criteria, it will not likely be lower for the new Root River location, but it could be higher because the watershed area at that location is much great (it is the same as the existing Fox River watershed area). The limits proposed for Underwood Creek and Root River are a WQBEL and

[1] Wisconsin Department of Natural Resources (WDNR). 2011. Limits for Waukesha Return Flow. December 13, 2011 correspondence from Jackie Fratrick/WDNR to Kristy Rogers/WDNR and Diane Figiel/WDNR. Correspondence provided to City of Waukesha on February 5, 2013. Chloride limit of 395 mg/L instead of 400 mg/L to be consistent with water quality standard and permit documentation.

are lower than their current target value of 440 mg/l and WQBEL of 431 mg/l for discharge to the Fox River, but they are not significantly different. Consequently, achieving the return flow limits are likely to be achieved by meeting the Fox River limits.

Chloride Source Reduction Measures and Compliance for Return Flow

A considerable reduction in the chloride concentration will be required of the existing WWTP discharge to achieve the target chloride effluent concentration of 440 mg/L for discharge to the Fox River or a WQBEL of 395 mg/L for return flow to Root River or Underwood Creek. The reduction to meet limits for the Fox River and return flow to Lake Michigan may be achieved in part by a reduction in the source water concentration of chlorides and to a greater extent by a reduction in water softening by residential, commercial, and industrial users. Additional source reduction measures will also contribute to chloride reductions.

Chloride Reduction Due to Lake Michigan Water Supply

The current City groundwater supply has an average annual chloride concentration of about 31 mg/L. This is a blended concentration from deep and shallow wells. This concentration varies slightly seasonally and from well to well. The chloride concentration of treated water from Lake Michigan has an average concentration of 12 mg/l[2]. The difference in source water concentration is 19 mg/l. Given this reduction in the source water concentration and the conservative nature of chloride through the WWTP process, an equivalent reduction WWTP effluent concentration is anticipated. The estimated daily load reduction of chloride due to alternative source water from Lake Michigan is shown on Exhibit 2.

Chloride Reduction Due to Reduced Water Softening

Water with a hardness of less than 100 mg/L $CaCO_3$ (calcium carbonate) is generally considered suitable for domestic use. Water having more than 180 mg/L $CaCO_3$ is considered very hard and softening is required for most purposes[3]. The hardness of the City's groundwater source water varies from well to well but is generally between 260 to 530 mg/l (total hardness as $CaCO_3$)[4]. The hardness of a Lake Michigan water supply less than 135 mg/L which is considered suitable for domestic uses without softening. A switch from very hard to soft source water is expected to significantly reduce, and potentially eliminate, the use of chlorides (salt) for softening. This will directly reduce the chloride concentration in wastewater and will similarly reduce the concentration of chloride in WWTP effluent and return flow.

The extent of the reduction of chlorides in the return flow due to a reduction in the hardness of source water and associated softening has been estimated. A range of reduction scenarios for residential customers from 50 percent to 100 percent removal of water softeners has been evaluated. Similar reductions for commercial and industrial customers have also been evaluated. Commercial and industrial users represent about 47 percent of the total water use in 2012 and about 55 percent of the projected water use for the ultimate build-out demand forecasts[5]. The reduction of chlorides will depend in part on the actual extent of softening in the various user sectors and success of implementation measures applied. Aggressive implementation measures such as an incentive program for water softener removal will tend to result in more rapid chloride reductions. Ultimately the reduction will trend toward 100 percent as softeners are phased out of the wastewater collection system. The estimated daily load reduction of chloride due to removal of residential and commercial/industrial water softeners is shown on Exhibit 2.

---

2 Milwaukee Water Works. 2011 Raw Water Annual Water Quality Report.

3 P.A. Kammerer, Jr., Groundwater Quality Atlas of Wisconsin, U.S. Geological Survey and University of Wisconsin-Extension, Wisconsin Geological and Natural History Survey, Information Circular 39-1981.

4 City of Waukesha IOC samples from 1993 to 2012 for wells 10, 11, 12, and 13.

5 AECOM. 2013. Draft Technical Memorandum Water Demand Projections. Table 11, Page 10. June 6, 2013.

EXHIBIT 2

Waukesha WWTP Historic Chloride Loads and Estimated Load Reductions From Source Reduction Measures

	Weekly Average	Weekly Maximum	Winter Average (b)	Non-winter Average (b)	90th Percentile Weekly Average
Weekly Chloride Concentration (mg/L) (a)	479	690	497	465	590
WWTP Average Daily Flow (mgd) (a)	10.9	10.9	10.9	10.9	10.9
Chloride Load (lb/day)	43,521	62,693	45,157	42,249	53,607
Source Water Supply Reduction (lb/day) (c)	1,739	1,739	1,739	1,739	1,739
Chloride Reduction from Residential Softening (lb/day) (d)					
100% reduction of softening	12,216	12,216	12,216	12,216	12,216
90%	10,994	10,994	10,994	10,994	10,994
80%	9,773	9,773	9,773	9,773	9,773
70%	8,551	8,551	8,551	8,551	8,551
60%	7,330	7,330	7,330	7,330	7,330
50%	6,108	6,108	6,108	6,108	6,108
Chloride Reduction from Commercial/Industrial Softening (lb/day) (e)					
100% reduction of softening	8,790	8,790	8,790	8,790	8,790
90%	7,911	7,911	7,911	7,911	7,911
80%	7,032	7,032	7,032	7,032	7,032
70%	6,153	6,153	6,153	6,153	6,153
60%	5,274	5,274	5,274	5,274	5,274
50%	4,395	4,395	4,395	4,395	4,395
Reduction from other Source Measure Controls					
7.5%	3,264	4,702	3,387	3,169	4,021
Resulting Chloride Load (lb/day)					
100% reduction of softening	17,511	35,245	19,024	16,335	26,840
90%	19,612	37,345	21,125	18,435	28,941
80%	21,713	39,446	23,226	20,536	31,042
70%	23,813	41,547	25,326	22,637	33,142
60%	25,914	43,647	27,427	24,737	35,243
50%	28,015	45,748	29,527	26,838	37,344
Resulting Chloride Concentration (mg/L) (f)					
100% reduction of softening	193	388	209	180	295
90%	216	**411**	233	203	319
80%	239	**434**	256	226	342
70%	262	**457**	279	249	365
60%	285	**480**	302	272	388
50%	308	**504**	325	295	**411**

Notes:

(a) Weekly chloride values over period from March 2006 to May 2013. Average daily WWTP flow.

(b) Months that are influenced by winter road salt runoff are considered Dec, Jan, Feb, Mar, and Apr

(c) The difference in average chloride between Waukesha ground water vs. treated Lake Michigan water is 19 mg/l

(d) Assumes 80 percent of residential customers have water softeners

(e) Assumes 60 percent of commercial and industrial water is softened

(f) Bold values exceed the target chloride of 395 mg/l for discharge to Root River or Underwood Creek

Chloride Reduction Due to Permit Source Reduction Measures

The permit requires chloride reduction measures for discharge to the Fox River. Similar measures are anticipated for discharge to the Root River or Underwood Creek. These measures as a whole are expected to provide considerable chloride reduction over the duration of the permit. Of particular significance in these source reduction measures is the collection system infiltration and inflow (I/I) reduction implementation. The City has an aggressive I/I reduction program and continues to investigate I/I throughout the collection system to prioritize projects that provide the most efficient I/I reduction. This program is designed to reduce stormwater intrusion into the sanitary sewer system including intrusion of stormwater containing road salt. The program is summarized in the Return Flow Plan (Appendix C of the Application). A part of the I/I reduction program is the capacity management operation and maintenance (CMOM) program that includes sewer cleaning, pump station inspection and maintenance programs.[6] 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. Many of these I/I reduction measures, in particular the measures that address deficiencies in the street ROW, will have an impact on reduction of road salt in the sanitary sewer system. Road salt intrusion is a likely cause of the high winter levels of chlorides in the WWTP discharge. Nearly all of the elevated chloride levels occur during winter months.

Monitoring and controlling the discharge of brine waste to the sanitary sewer system in particular brine waste from City and County road salt storage facilities also has the potential to reduce chlorides in wastewater effluent. Considerable progress on this chloride source including source identification and monitoring is already in place[7].

While it is difficult to estimate the effectiveness of individual source reduction practices it is expected that the combined effectiveness of all practices could be 5 to 15 percent of current chloride levels. With phase-out of water softeners due to a switch to Lake Michigan water, the estimated effectiveness of these source reduction measures will tend to be reduced because the water softener related measures will be diminished with phase out of softeners. A reduction of 7.5 percent was assumed for the calculations in Exhibit 2.

Other Chloride Reduction Measures

In addition to the chloride reduction measures discussed above, others that will be considered as part of a chloride compliance plan include:

- Evaluate revisions to City of Waukesha Municipal Code Chapter 29 Sewer Use and Wastewater Treatment to include prohibiting brackish (high salts) wastewater discharges to the public sewer.
- Initiate a sampling program to determine character and quantity of industrial and commercial brackish water discharges.
- Require identified sources to evaluate their processes to reduce chloride.
- Investigate high-volume water softening customers (e.g., industry, hospitals) to identify potential strategies to optimize softening to minimize chloride discharge
- Codify appropriate and cost-effective discharge restrictions, enforcement actions, and monitoring procedures
- Initiate water softening public education campaign prior to construction completion of new Lake Michigan supply. The goal of the campaign is to remove customers' water softeners, or if there are special water softening requirements, adjustment them to Lake Michigan water hardness. This measure will not only reduce the amount of chloride discharged, but result in water savings from reduced/eliminated softener regeneration cycles. Water savings from reduced or eliminated customer softening will contribute to the City's water conservation goals.

6 Superior Engineer, LLC and Donohue & Associates. 2011. Final CMOM Plan, City of Waukesha. Page 1.

7 City of Waukesha, Wastewater Treatment Facility, Final Chloride Report, March 31, 2012

- Offer incentives like free softener disposal, low-income assistance for softener removal, and custom assistance for commercial and industrial customers.

These reduction measures are reflected in *other source reduction measures* calculated in Exhibit 2.

Summary

These source reduction measures and reporting requirements are expected to move the City closer to or in compliance with the Fox River WQBEL over the duration of the permit. While these requirements are specific for the City's existing WWTP discharge to the Fox River, each are equally supportive for achieving chloride limits for a return flow to Lake Michigan. All of the actions required to achieve the target value are required before 2018 so these actions will also support the return flow that is anticipated to begin in June 2018.

Switching to a Lake Michigan water supply requires chloride reduction measures to meet the anticipated chloride limit for discharge to the Root River or Underwood Creek. Obtaining a Lake Michigan water supply and reducing/removing softeners associated with residential, commercial and industrial users is expected to have the largest influence on wastewater effluent levels. Other source reduction measures, in particular I/I reduction measures and limitations on brine waste discharge that impact winter chloride levels, are expected to allow return flow to Lake Michigan through the Root River or Underwood Creek to meet the WQBEL of 395 mg/L. Exhibit 2 shows anticipated reductions due to these reduction measures from base conditions of the average of average weekly chloride concentrations since they were first measured in 2006 (479 mg/L), average winter (497 mg/L) and non-winter (465 mg/L) periods, maximum average weekly value (690 mg/l), and the 90th percentile average weekly value (590 mg/L) over the period of record. The maximum average weekly value is the most critical base condition requiring 100 percent removal of residential as well as commercial/industrial softeners. The weekly maximum value is most likely associated with event-driven winter deicing operations and is significantly greater than other weekly averages. The 90th percentile is likely a more appropriate planning number because the values above this likely result from single winter events that have significant precipitation/melt and road salting operations. Using the 90th percentile concentration, less than 60 percent removal of residential and commercial/industrial softeners are required. Complying with the return flow chloride limits will be achievable because it is anticipated that softening will be reduced by more than 60 percent, and reduction of chlorides above the 90th percentile will be accomplished by source reduction measures that target winter events.

Attachment A-5

Preliminary Thermal Analysis of a City of Waukesha Lake Michigan Return Flow to the Root River

Preliminary Thermal Analysis of a City of Waukesha Lake Michigan Return Flow to the Root River

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: June 24, 2013

Summary

This memorandum is a preliminary thermal analysis of a City of Waukesha return flow discharge to the Root River. The purpose of this analysis is to identify one or more methods to comply with the Wisconsin Department of Natural Resources (WDNR) thermal regulations in NR 102 and NR 106. The Waukesha return flow is not "hot" and does not pose any acute thermal threat to aquatic life. Rather, like many wastewater treatment plants in Wisconsin, the return flow temperature is warmer than the ambient Root River temperature in late fall and winter months, with the highest measured temperatures ranging from 51 to 70 degrees Fahrenheit (October through January, see Exhibit 1). The WDNR thermal sub-lethal standards during these months can be triggered by typical municipal wastewater effluent.

The analysis compares the physical riverine characteristics of the current City of Waukesha Fox River discharge to that of the Root River. Preliminary indications are that mixing of the discharge within the Fox River will meet the thermal requirements, and presumably, if similar conditions exist on the Root River, mixing will also satisfactorily meet the thermal discharge requirements to the Root River.

The analysis concludes that several options exist to meet the thermal requirements. These include:

- Thermal mixing analysis of the Root River
- Using site specific ambient temperatures to establish thermal limits
- Management techniques to lower the return flow temperature before discharge
- Combinations of the above techniques

This analysis demonstrates that multiple options exist for the Root River return flow to achieve WDNR thermal rule compliance. Consequently, return flow as it relates to thermal discharge, can reasonably protect the chemical, physical, and biological integrity of the Root River. With a successful Lake Michigan application, more detailed data gathering and analysis for thermal and other water quality requirements will occur to apply for a Root River discharge permit.

Introduction

As part of the City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application), return flow to the Root River is being evaluated. The City's wastewater treatment plant (WWTP) currently discharges to the Fox River, which is in the Mississippi River watershed. The proposed project will include a new return flow pump station, pipeline, and outfall for return flow to the Root River, a tributary to Lake Michigan. The potential discharge location is near river mile 25.5, downstream of the confluence of the Root River Canal with the Root River. The purpose of this memorandum is to summarize a preliminary analysis of thermal limits and compliance alternatives.

Methods applicable to the Root River return flow which could be used to reasonably achievable compliance with the thermal discharge requirements include:

- Comparison of the watershed hydrology, geomorphology, and river flow rates of the Root River with those from the Fox River where the existing WWTP discharge does not require thermal limits
- Mixing zone and dissipative cooling study
- Consideration of site specific ambient temperatures on the Root River
- The following management techniques
    - Heat Exchange in Return Flow Pipeline
    - Treatment Wetlands
    - Surface Aerators
    - Cooling Towers
    - Chillers
    - Multiple Discharge Locations
    - Subsurface Flow
- Combinations of the above techniques

This memorandum summarizes background information applicable to a Root River discharge and each of the methods which could be used to meet the thermal discharge requirements.

Background

The Wisconsin Department of Natural Resources has adopted new thermal rules (NR 102 and 106) for the protection and propagation of aquatic life that applies to WPDES permit holders discharging to surface waters. In preparation for this new rule, the City has been collecting effluent temperature data since December 2010. The WDNR had provided the City with weekly average effluent limitations for the Fox River on January 17, 2012. More recently in the permit for the WWTP (August 1, 2013), effluent temperature limits were not proposed based on results of a mixing zone study and only effluent monitoring is required. In contrast to the Fox River, the WDNR has proposed effluent thermal limits for a Root River discharge. On February 5, 2013 the WDNR provided the City with draft effluent thermal limits (WDNR, 2011) for a Root River return flow that were based in-part on a return flow rate used during an Underwood Creek evaluation (SEH, 2009). A summary of the potential thermal limits for a Root River return flow is shown in Exhibit 1.

EXHIBIT 1
Water Quality-Based Effluent Temperature Limitation

			Root River		
Month	**Sub-Lethal Water Quality Criteria (F)**	**WWTP Highest Monthly Effluent Temperature; [Weekly Average] [1] (F)**	**Receiving Water Flow Rate (cfs)**	**Highest 7-day Rolling Average Effluent Flow Rate (mgd)**	**Weekly Average Effluent Limitation (F)**
Jan	49	51	1.8	13.0	49
Feb	50	52	1.8	13.0	50
Mar	52	52	1.8	13.0	52
Apr	55	55	1.8	13.0	55
May	65	61	1.8	13.0	65

EXHIBIT 1

Water Quality-Based Effluent Temperature Limitation

			Root River		
Month	Sub-Lethal Water Quality Criteria (F)	WWTP Highest Monthly Effluent Temperature; [Weekly Average] [1] (F)	Receiving Water Flow Rate (cfs)	Highest 7-day Rolling Average Effluent Flow Rate (mgd)	Weekly Average Effluent Limitation (F)
Jun	76	65	1.8	13.0	76
Jul	81	72	1.8	13.0	81
Aug	81	73	1.8	13.0	81
Sep	73	70	1.8	13.0	73
Oct	61	68	1.8	13.0	61
Nov	49	60	1.8	13.0	49
Dec	49	57	1.8	13.0	49

1. WDNR analysis of WWTP effluent from January 17, 2012.

Some of the information used in the analysis is not representative of the return flow management plan. For example, a constant return flow rate of 13 mgd was used for each month and did not consider a maximum return flow rate of 16.7 mgd or seasonal flow variations at the WWTP, such as October through December when WWTP flow rates are less. Seasonal variations were also not accounted for in the receiving water flow rate where they are typically greater than the constant 1.8 cfs used in the analysis. The location of the return flow discharge was also in a much smaller portion of the watershed - approximately 15 square miles compared to the 126.2 square miles of the proposed return flow discharge location (see below of additional watershed size documentation). While these changes would result in higher effluent limits, they are expected to only have a minor affect (raising the effluent limit less than 3 degrees). This is supported by effluent limits calculated by the WDNR for the Fox River discharge in Exhibit 2 which had greater receiving water flow rates and lower WWTP flow rates. (These effluent limits were calculated prior to the mixing zone study being completed, when WDNR evaluated reasonable potential for thermal effluent limits. As summarized in the permit, the mixing zone study has demonstrated that thermal limits are not needed for the Fox River.)

EXHIBIT 2

Calculated Effluent Limits for a Fox River Discharge - Prior to Mixing Zone Study

Receiving Water Flow Rate (cfs)	Highest 7-day Rolling Average Effluent Flow Rate (mgd)	Weekly Average Effluent Limitation (F)
10.00	13.043	51
13.00	11.374	53
23.00	17.302	55
58.00	22.276	58
28.00	15.952	67
21.00	37.566	77
12.00	26.029	82
12.00	15.527	83
9.90	11.443	75

EXHIBIT 2

Calculated Effluent Limits for a Fox River Discharge - Prior to Mixing Zone Study

Receiving Water Flow Rate (cfs)	Highest 7-day Rolling Average Effluent Flow Rate (mgd)	Weekly Average Effluent Limitation (F)
11.0	10.434	63
15.00	9.800	51
12.00	12.094	51

These effluent limits were calculated prior to the mixing zone study being completed, when WDNR was evaluating reasonable potential for thermal effluent limits. As summarized in the permit documentation, the mixing zone study has demonstrated that numeric thermal limits are not needed for the Fox River.

The WDNR also provided daily maximum effluent limitations for the Root River but based on the WWTP's effluent temperature data, the daily maximum effluent limits will be met.

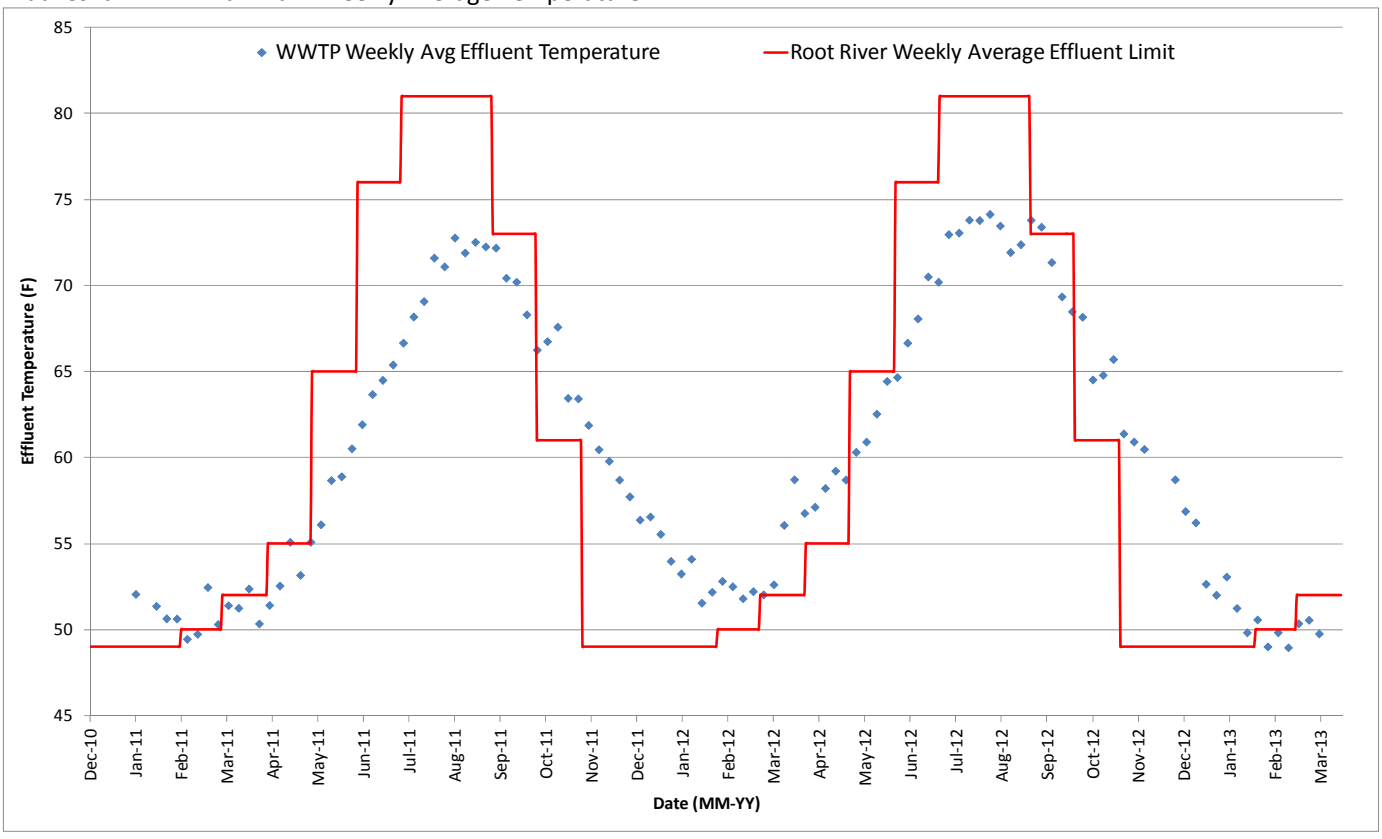
Evaluation

Initial Compliance assessment

Root River effluent limits and effluent temperature data from the WWTP was evaluated for the period of record, from December 2010 to March 2013 (Exhibit 3). The WWTP effluent generally meets the temperature limits except for fall and winter months October through March. This is common among many municipal wastewater treatment plants and of the City's Fox River discharge, however as noted above a mixing zone study was completed and demonstrated that the WWTP effluent temperature does not impact the Fox River.

EXHIBIT 3

Waukesha WWTP Maximum Weekly Average Temperature



Based upon these data, an evaluation of probable alternatives to demonstrate compliance with the thermal rules was conducted. These include comparing to mixing zone results in the Fox River and other methods to demonstrate thermal rule compliance. These alternatives are described below.

Watershed Size and Receiving Water Flow Rate Adjustments

Thermal limits are influenced by the receiving water flow rates, which are affected by factors such as the watershed's size, climate, slope, and land use. These factors are essentially the same for the Fox River at the WWTP and the Root River at the return flow location. The Root and Fox River watershed's are adjacent to each other and have similar development patterns, and therefore their climate and land use are essentially the same. The WWTP existing outfall is within 0.6 miles of the USGS stream gage 05543830 where the Fox River watershed area is 126 square miles. This is essentially the same as the 126.2 square mile watershed area for the Root River return flow, based on the HSPF model from the Southeastern Wisconsin Planning Commission's (SEWRPC) Regional Water Quality Management Plan Update (Exhibits 4 and 5). In addition, the watershed slope is also essentially the same size as calculated by the Flood Insurance Studies for the Fox River and Root River locations – 0.08 percent slope for the Fox River upstream of the WWTP Fox River outfall and 0.09 percent slope for the Root River upstream of the return flow location. The Fox River upstream of the WWTP has greater point source discharges (e.g. Brookfield and Sussex WWTP) than does the Root River and Root River Canal, but the Root River low flows used for determining effluent thermal limits are expected to be more similar to the Fox River flows and greater than the 1.8 cfs used in the draft effluent limit calculations (Exhibit 1).

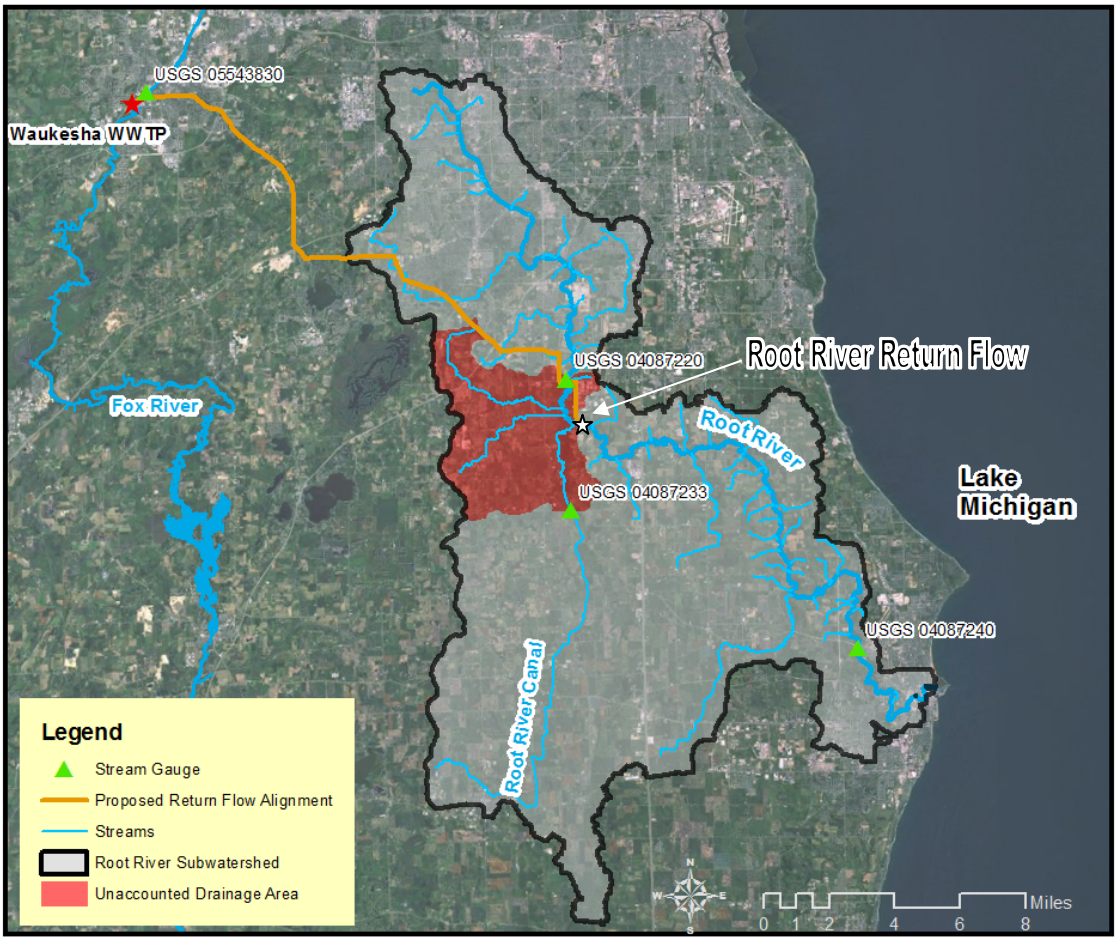
EXHIBIT 4
Drainage Area at River Gage Locations

Location	Drainage Area (sq miles)
USGS 04087220—Root River near Franklin	49.2
USGS 04087233—Root River Canal near Franklin	57.0
Unaccounted Subbasins (from SEWRPC HSPF model)	20.0
Root River at the Potential Discharge	126.2
USGS 05543830—Fox River at Waukesha	126.0

Source: USGS, 2013

EXHIBIT 5

Waukesha WWTP, Root River Watershed, and Root River Return Flow Location Map



The daily average and 7-day rolling average flow rates over a 49 year period of record at each stream gauge were acquired from USGS. Review of USGS flow gage information shows that that flow rates are similar between the Fox River at the WWTP outfall and the Root River return flow location (Exhibits 6 and 7). The flow rate at the Root River return flow location was estimated as the sum of the flow rate at the USGS gage at Franklin (gage # 04087220) and the gage on the Root River Canal near Franklin (gage # 04087233), and prorated for the unaccounted drainage area (Exhibit 4 and 5). Because the flow rates are similar, and for some periods the Root River is significantly greater than the Fox River, the effluent thermal limits for the Root River discharge are expected to be greater than currently calculated by WDNR, and closer to the limits calculated for the Fox River (Exhibit 2). Consequently, the temperature difference between the calculated limit and the return flow is expected to be less (Exhibit 1), especially for months when thermal standards are more stringent (October-March).

EXHIBIT 6

Average Daily Flow Rates of Fox River near the WWTP and Root River at the Return Flow Location

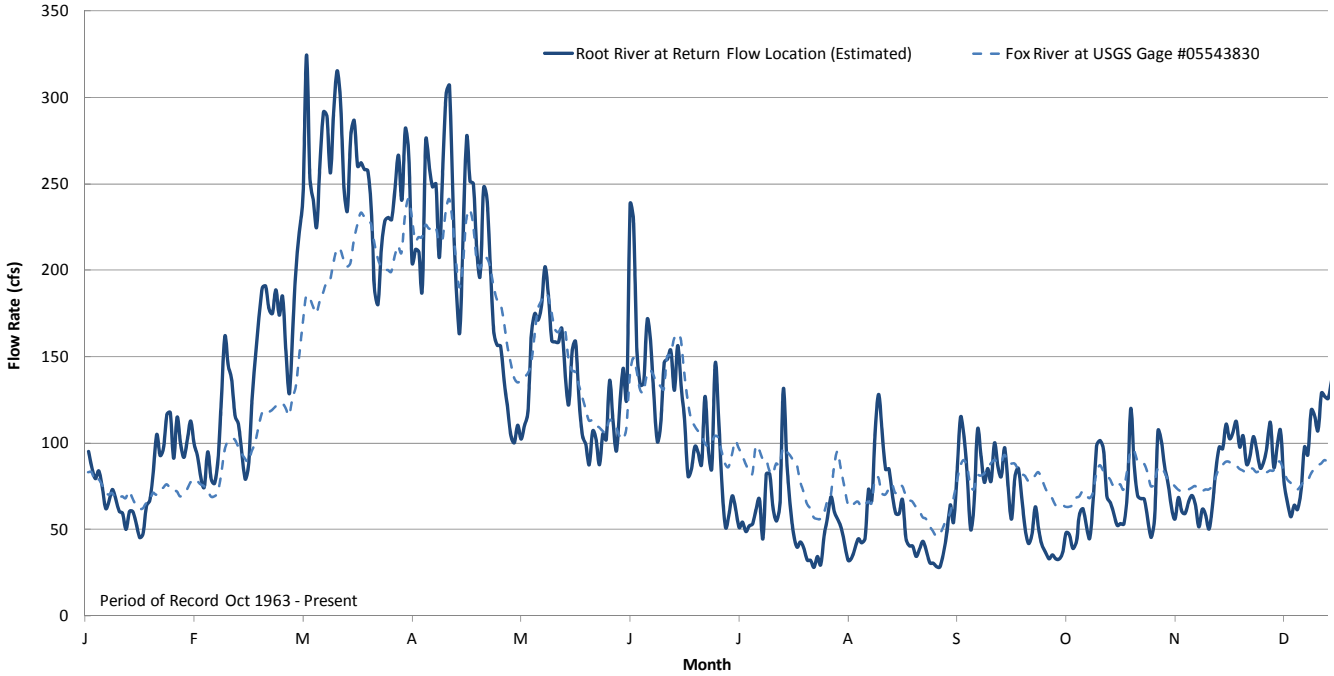
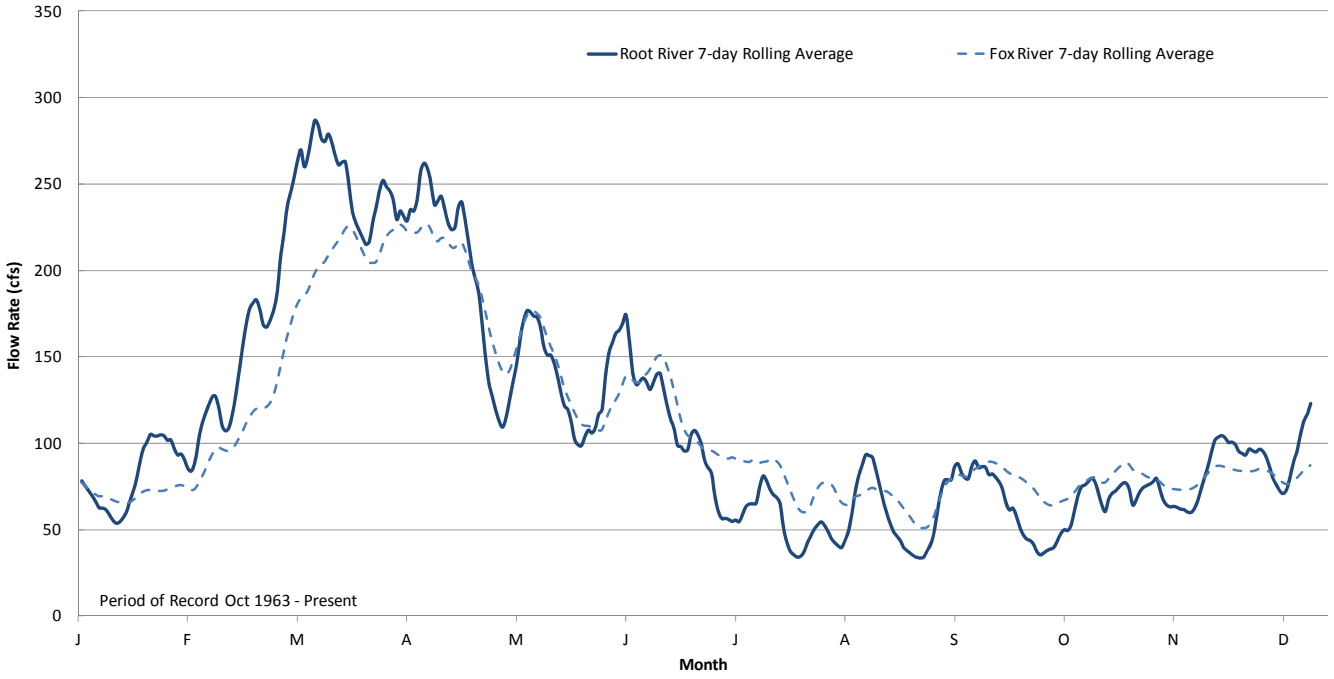


EXHIBIT 7

7-day Rolling Average Daily Flow Rates of Fox River near the WWTP and Root River at the Return Flow Location



Methods to Comply with Thermal Requirements

Mixing Zone Study

The Fox River Mixing Zone Study was completed in September 2012 in support of the WWTP's permit renewal application and to demonstrate the rivers ability to dissipate heat from the effluent. The mixing zone analysis concluded that the existing discharge location meets the provisions specified in NR 102.05 (Strand Associates, 2012) and the discharge is progressively diluted from the source of the receiving system. As noted above, the WDNR has reviewed this study as part of the permit issuance and concluded that sufficient dissipative cooling occurs, a thermal barrier is not present, and that thermal limits are not needed for the Fox River.

While it is not possible to complete a mixing zone study the same as what was done on the Fox River, there are several similarities to the Root River and Fox River at the discharge locations where correlations could be made on expected findings. In fact, initial observations show promise that the Root River location is more conducive to thermal dissipation and preventing a thermal barrier than the Fox River location.

- The Fox River has four meanders that start 250 feet downstream of the WWTP outfall (Exhibit 8). These meanders would encourage shifting of the thermal plume across the channel at each meander creating a possible thermal barrier, but this shifting was not observed during the mixing zone study. In contrast, the Root River return flow location is along the outside bend of one long gradual bend that is about 1,500 feet before its first meander (Exhibit 9). Return flow discharge along this long meander would encourage the return flow to remain along the river's edge (the same as that observed in the Fox River for a similar river setting) and not create a thermal barrier. The Fox River meanders would be more likely to create a thermal barrier with effluent exceeding 50 percent of the width, however this was not observed during the mixing study. Because the Root River is less likely to have these conditions, similar (or better) conditions are expected at the Root River location than the Fox River discharge to maintain a zone of free passage within the mixing zone.
- The outfall location at the Fox and Root River is on the outside bend of the river where flow patterns are more turbulent than inside bends or straight sections, and consequently mixing is more prevalent. This is evidenced by scour that commonly occurs along the outside of river bends, in contrast to inner bends where scour is less or possibly non-existent. The Root River has very little scour along the outside bend because it is protected with dense vegetation, but because of these flow patterns, there is a greater potential for thermal dissipation and mixing when compared to an inside bend or straight portion of river. Consequently, the Root and Fox Rivers have similar geomorphic features near these outfall locations and could be expected to have similar thermal dissipation qualities. The Root River could have better mixing qualities because the meander bend is much longer than at the Fox River location.
- The Fox and Root Rivers are similarly sized – the Fox River is about 70 feet wide at the outfall and downstream, and the Root River is about 65 feet. Because they also have similar flow rates and slopes as discussed above, their hydraulic characteristics are similar and could be expected to have similar thermal dissipation and mixing.
- The Root River has significantly more shading with mature trees along the river banks than does the Fox River. This could cool the effluent more quickly than that in the Fox River.
- The Fox River outfall is oriented at a sharp angle to the river to encourage the effluent to hug the shoreline. A similar design detail could be incorporated into the Root River outfall, however an outfall with greater turbulence could be considered to enhance mixing while encouraging the return flow to "hug the shoreline" to maintain a zone of free passage.

EXHIBIT 8
WWTP Outfall to Fox River

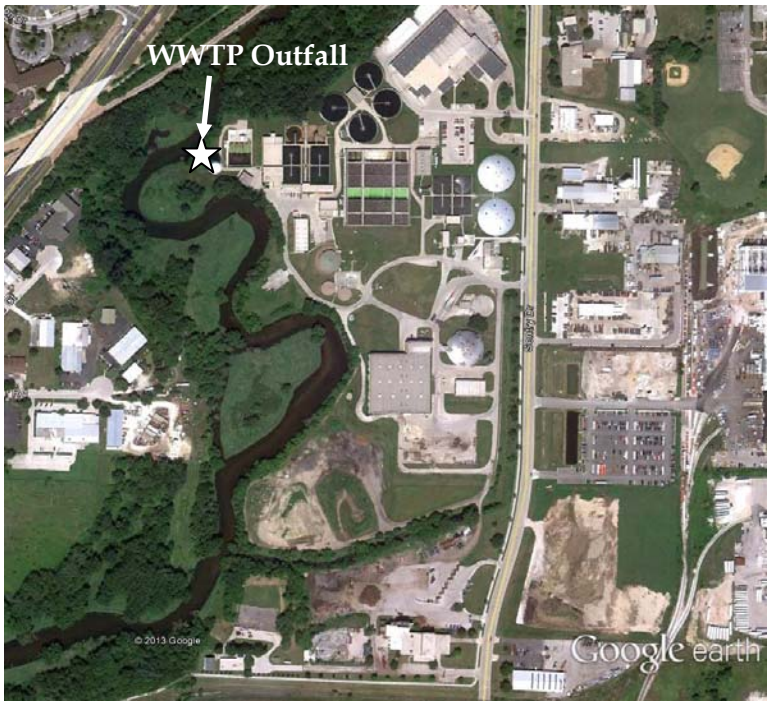
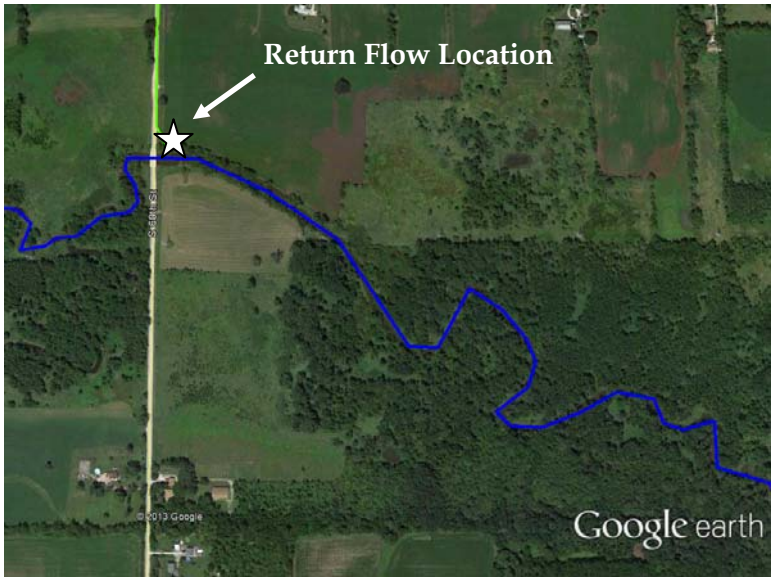


EXHIBIT 9
Root River Return Flow Location



Because of the significant similarities between the Fox and Root River at the outfall locations, the Fox River mixing zone study, and similarities of environmental and geomorphic conditions, thermal characteristics are expected to be similar or possible better for the Root River location.

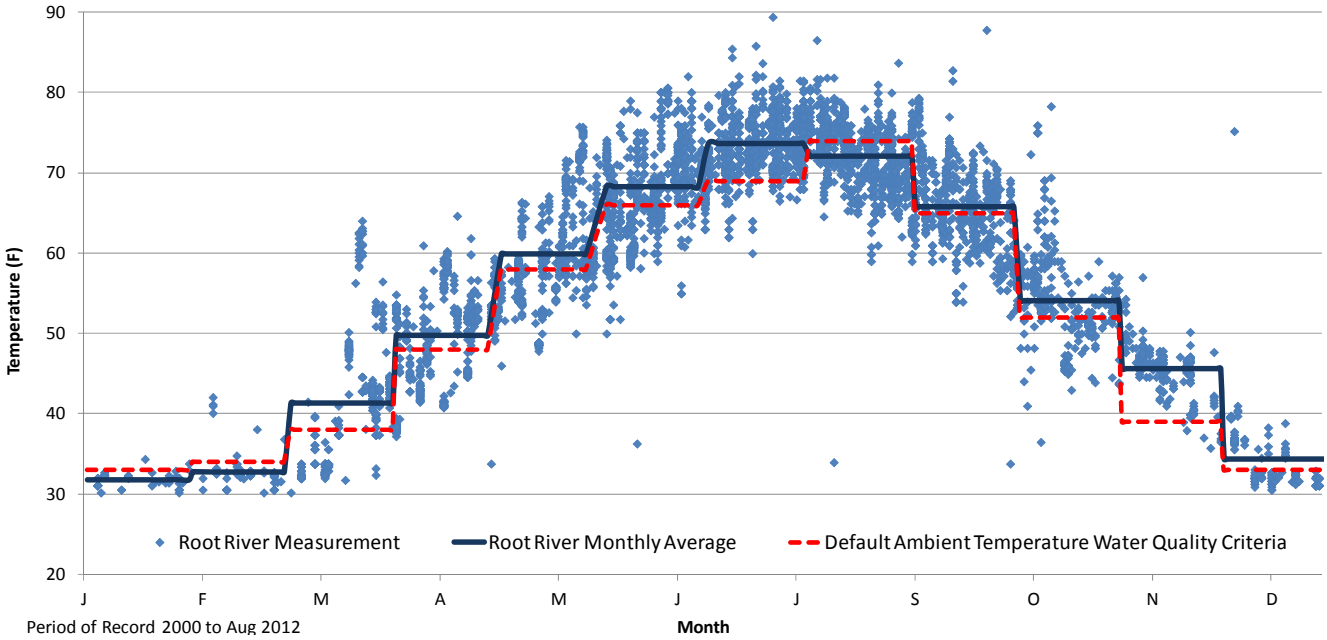
In-Stream Temperature Analysis

As part of the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) Root River Restoration Plan, Root River temperature measurements were compiled from multiple sources from early 1964 through August

2012.[1] The data was provided to the City and included more than 5,700 temperature measurements between 2000 and August 2012 in the Lower Root River subwatershed that extends from Lake Michigan to the river's confluence with the Root River Canal (Exhibit 10).

EXHIBIT 10

Lower Root River Temperature Measurements

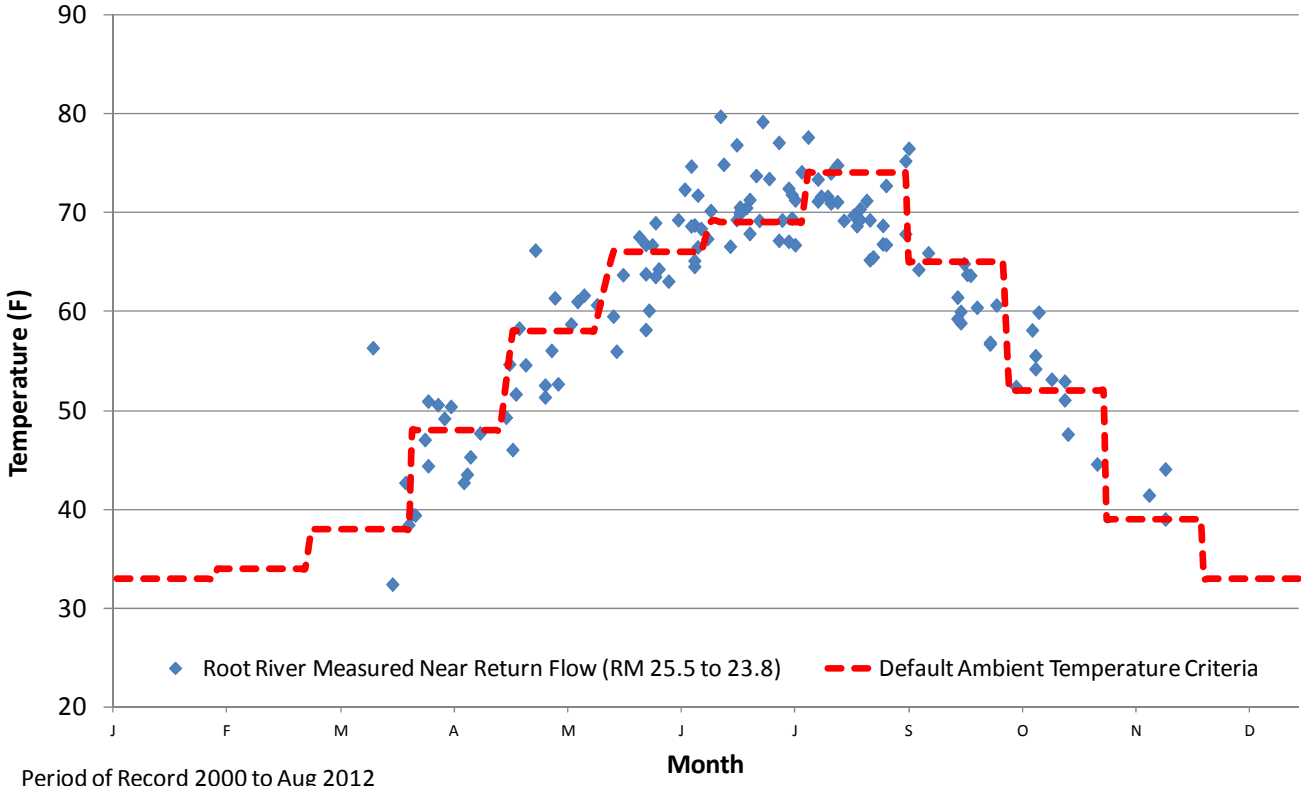


The monthly average temperature based on the sampling data since 2000 is very different for some months than the default (not site specific) ambient temperature for a small warm stream provided in NR 102.25. The sampling data is most often greater than the default values and in some months, such as November, the sampling data shows that the river is about six degrees warmer than the default ambient temperatures. Because the default ambient temperature values are lower than the site specific values, and the default values are used to determine effluent temperature limitations in the absence of site-specific ambient temperature data, if the site specific data were to be used, it would result in a higher effluent temperature limits for months like November. This similar trend is observed at measurement locations nearest the return flow location that is between river miles 25.5 and 23.8 (Exhibit 11). Consequently if the City is successful is receiving Lake Michigan water, the City may choose to gather additional site specific temperature data to evaluate site specific temperature requirements. This initial data evaluation indicates a higher temperature limit is likely using site specific data.

[1] Root River temperature data from the following sources: the Milwaukee Metropolitan Sewerage District, the City of Racine Health Department, US Geologic Survey, Wisconsin Department of Natural Resources, the University of Wisconsin-Extension's Water Action Volunteers Program, and SEWRPC.

EXHIBIT 11

Lower Root River Temperature Measurements Near Return Flow Location (River Mile 25.5 to 23.8)



Period of Record 2000 to Aug 2012

HSPF Model

As part of the Root River water quality modeling (CH2M HILL 2013) the temperature data within the HSPF model supplied by SEWRPC and used in the Regional Water Quality Management Plan Update was reviewed. The model simulated existing conditions temperature at an assessment point near the potential discharge location using 11 years (1987-1997) of continuous simulation. The temperature data within the model was not consistent with the measured data more recently supplied by SEWRPC, therefore it was not considered further in this evaluation.

Data Evaluation Conclusions

As discussed above, the calculated effluent temperature limits are expected to be greater than currently calculated due to updates in receiving water and return flow rates, and using site specific temperature data instead of default values. In addition, the mixing zone study completed for the Fox River and its support of removing temperature limits for the Fox River discharge is promising for the Root River because the rivers are similar in size, environmental factors, and geomorphology, and the Root River return flow has some features that are more beneficial for mitigating the return flow temperature. Based upon these observations, achieving a reasonable expectation of thermal standards compliance is shown by the mixing zone findings on the Fox River and the similar characteristics of flow on the Root River.

Other Thermal Discharge Management Alternatives

Should additional measures need to be taken to reduce temperature effects on the Root River, there are several alternatives that could be evaluated during detailed design and site-specific permitting. These are discussed below.

Heat Exchange in Return Flow Pipeline

Preliminary heat loss calculations were performed for the return flow pipeline using Applied Flow Technology (AFT) Fathom software. The software requires that the user provide the air film convective heat transfer coefficient (1993 ASHRAE Handbook-Fundamentals, American Society of Heating, Refrigeration and Air-

Conditioning Engineers, Inc.). A 20-mile 30-inch ductile iron pipe conveying 16.7 mgd was assumed for the return flow. The months of November and October were evaluated because they have the highest difference between historical discharge temperature and temperature limits. These months also have the least temperature differential between the return flow temperature and ambient air. For these months, the preliminary calculations have a temperature drop of approximately one to two degrees F. While there is a temperature drop, it would have to be combined with mixing or other measures to meet the proposed effluent limits.

Treatment Wetlands

The return flow location is a large flat area adjacent to the Root River that is currently farmed. The city has an agreement with the land owner for purchase of the land. The land could be converted to a treatment wetland to reduce temperature before discharge. Wetlands are a proven sustainable solution to temperature compliance (among other benefits such as nutrient uptake and habitat creation). For example, three cities in Oregon are using treatment wetlands as part of their compliance for temperature (Cities of Salem, Woodburn, and Roseburg).

Wetlands directly reduce effluent temperature through evaporative and radiant cooling. The degree of temperature reduction is determined by several factors, including topographic and riparian shading, vegetative coverage and density, climatic conditions and the effluent flow and temperature. Preliminary calculations to estimate the wetland surface area and hydraulic retention time needed to meet effluent limitations currently calculated by WDNR (a change of 11 degrees F in November) resulted in a wetland system of approximately 150 acres. This exceeds the practical space available for return flow but it demonstrates that a wetland system could serve as part of the thermal compliance and that with higher limit calculations based upon site specific conditions, a wetland system would be sufficient. If needed, detailed heat source modeling could be conducted during detailed design and site specific permitting.

Surface Aerators

Similar to the treatment wetland area, surface aerators could be used. Surface aerators are often used at industrial treatment plants where effluent temperatures can be significantly greater than the discharge from a municipal WWTP. Surface aerators would require an impoundment several feet deep, which is possible at the return flow location, and would have high energy demands.

Cooling Towers

Cooling towers remove latent heat through evaporative cooling using a fan that blows air across the cooling fluid. Cooling towers are significantly influence by ambient air temperatures and for months when the ambient air temperature is similar to the temperature limit (e.g. October and parts of November), cooling towers have less effectiveness. Cooling towers have moderate energy demands and could be located at the WWTP or at the return flow location.

Chillers

Chillers use a refrigeration cycle to remove heat from circulating fluid. They are effective at reducing temperatures to 35 to 45 degrees F but they have very high energy demands for compressor operation and have high capital costs.

Multiple Discharge Locations

In lieu of having a single discharge point, which is common for nearly all dischargers, multiple pipe outfalls could be located along the Root River to gradually disperse the return flow in the river. A lower effluent flow rate enables the receiving river's flow rate to more quickly dissipate heat and minimizes the potential for a thermal barrier. The return flow location includes over 900 feet of river shoreline that could be used for multiple (e.g. two or three) outfall locations. Using multiple discharge locations has the potential to fully mitigate the thermal impact from return flow because the Root River has a much greater length before its first bend, and because the Root and Fox Rivers have similar geomorphic features at the outfall locations.

Subsurface Flow

A subsurface flow system consisting of granular media could be used to cool the return flow effluent prior to discharge to the Root River. A system could be similar to that used in the City of Milwaukee's Menomonee Valley

and Canal Street stormwater management units. As part of that system, stormwater in each of the stormwater treatment units (i.e. bioretention facilities) infiltrates into a gravel bed consisting of recycled concreted several feet thick and three-to-four feet below the ground surface. The infiltrated water flows through the gravel/recycled concrete to feed a treatment wetland and ultimately the Menomonee River. This system was designed as part of the Canal Street redevelopment to provide a cool water discharge to one of the stormwater management units (swamp forest that required a cool water discharge) and to the Menomonee River. A similar system could be developed for the Root River return flow.

Combinations of Management Techniques

Combinations of the various techniques described above, including mixing zone analysis, site specific temperature data considerations, and any number of management techniques to reduce the return flow temperature can be used to satisfactorily achieve the WDNR thermal requirements.

Conclusion

There are significant similarities between the Fox River at the WWTP and the Root River return flow location that allow a reasonable comparison between the thermal limits between both locations. Based on analyses completed for the WWTP discharge to the Fox River, thermal limits are not needed. Similarly, limits also may not be needed for a Root River discharge or they could be several degrees less stringent than currently proposed by the WDNR.

The watershed size, land use, slope, river width/depth, and other environmental factors such as climate are very similar, and for some parameters like watershed size, slope, and climate, the locations are essentially the same. When reviewing USGS flow gage information for the Fox and Root Rivers, the historic flow rates are very similar yet the flow rates in the thermal calculations performed by WDNR for the Fox and Root Rivers are very different. The flow rates are not expected to be the same, but the Root River flow rates used for the thermal calculation are expected to be similar to the Fox River and are expected to provide slightly higher limits. Similarly, the return flow rates used in the WDNR Root River limit calculation will be less in fall/winter months (October through February) and will result in slightly higher limits because the current return flow management plan has a maximum daily return flow rate of 16.7 mgd.

The Fox River mixing zone study has supported the WDNR's decision that the WWTP's discharge complies with thermal requirements. There are significant similarities between the Root River discharge location and the Fox River, and there are several geomorphic features at the Root River that are *more* supportive of thermal dissipation and preventing a thermal barrier. A more detailed analysis of the Root River could be completed during detailed design and permitting, but the Fox River mixing zone study can be correlated to the Root River location and is supportive of return flow having minimal or no thermal impacts. Consequently, the same as the Fox River, the Root River may comply with thermal standards without having numeric limits.

While relying upon mixing appears reasonable for complying with thermal standards, several alternatives exist for addressing thermal impacts of a return flow if it is needed. Treatment wetlands, dissipation through the pipeline, and having multiple discharge locations all contribute towards reducing thermal impacts. More expensive and energy intensive options exist if they are needed to meet limits. However, based on the Fox River mixing zone study and this preliminary analysis for the Root River, thermal limits may not be needed or could be less strict than those calculated. Consequently complying with thermal requirements will be achieved and any additional costs are expected to be marginal and included within the contingency of the cost estimates for return flow.

This analysis demonstrates that multiple options exist for the Root River return flow to achieve WDNR thermal rule compliance. Consequently, return flow as it relates to thermal discharge, can reasonably protect the chemical, physical, and biological integrity of the Root River. With a successful Lake Michigan application, more detailed data gathering and analysis for thermal and other water quality requirements will occur to apply for a Root River discharge permit.

References

CH2M HILL. 2013. Water Quality Model of Potential Return Flow Discharge to Root River. May 8, 2013.

Strand Associates, Inc. 2012. Waukesha Wastewater Treatment Plant (WTP) Permit No. WI-0029971-07-0 Mixing Zone Study Results. October 17, 2012.

SEH. 2009. Underwood Creek Effluent Return Evaluation. July 23, 2009. SEH Report No. 108425.

Wisconsin Department of Natural Resources (WDNR), Bureau of Watershed Management. 2010. Guidance for Implementation of Wisconsin's Thermal Water Quality Standards. Guidance Number: 3400-2010-03, Edition Number 1.

Wisconsin Department of Natural Resources (WDNR). 2011. Correspondence/Memorandum: Limits for Waukesha Return Flow. From Jackie Fratrick to Kristy Rogers and Diane Figiel. December 13, 2011.

Appendix B

City of Brookfield Co-applicant Letter for an Underwood Creek Return Flow Outfall Structure

DIRECTOR OF PUBLIC WORKS
Thomas M. Grisa, P.E.
2000 North Calhoun Road
Brookfield, Wisconsin 53005-5095
(262) 782-9650 Fax (262) 782-1323

March 16, 2011

RECEIVED
MAR 17 2011
Waukesha
Water Utility

Mr. Dan Duchniak, P.E.
General Manager
Waukesha Water Utility
115 Delafield Street
Waukesha WI 53188

Dear Mr. Duchniak:

Thank you for taking the time to meet with City of Brookfield officials regarding your January 17, 2011 request for the City's support of a proposed pipeline and outfall structure on City-owned land adjacent to Underwood Creek. The purpose of the pipeline and structure is to allow Waukesha's treated wastewater to be discharged, with possible aeration, to the creek. This is needed to provide return flow to Lake Michigan if your application for Great Lakes water is approved.

You have requested that we participate in the review of your design of the structure after approval of your application for Great Lakes water and that construction, operations and maintenance of the pipeline and outfall structure would be at Waukesha's expense. The City has reviewed your proposal and has no objection to this concept. The Board of Public Works, at their meeting on March 8th has authorized me to inform you that the City, as owner of the lands where the pipeline and outfall structure are proposed to be located, would be willing to be a co-applicant for a Chapter 30 permit for installation of same.

Sincerely,

CITY OF BROOKFIELD

Thomas M. Grisa, P.E.
Director of Public Works

Cc: Bill Kolstad, Director of Parks, Recreation and Forestry

Appendix C

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

Supplement to Underwood Creek Effluent Return Evaluation

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: December 30, 2011

In a December 2010 letter to the City of Waukesha from the Wisconsin Department of Natural Resources (WDNR)[1], two clarifying questions were asked about the enclosed memorandum by SEH, Inc.. Below is the WDNR question followed by the response. The enclosed memorandum is that referenced in the below question, and was Appendix G in the May 2010 City of Waukesha Application for Lake Michigan Diversion with Return Flow.

The purpose of this memorandum is to supplement the enclosed analysis by SEH, Inc..

WDNR Question

On page 7 of Appendix G to the application, the indicator fish species is identified as Northern pike. Why was the Northern pike chosen as the indicator species for Underwood Creek? Also, what is the source for stating the average maximum swimming speed for Northern pike?

Response

Northern pike were chosen as a surrogate species for how other warm water fish would respond to return flow in Underwood Creek in order to be consistent with the rehabilitation goals of the recent Underwood Creek Rehabilitation and Flood Management Project.[2] As part of the basis of design for that project, rehabilitation goals were developed through discussions with project stakeholders including the Milwaukee Metropolitan Sewerage District, Milwaukee County, the City of Wauwatosa, and the Wisconsin Department of Natural Resources. Six priorities were identified during stakeholder meetings, including fisheries and stream biota. An excerpt from the design report for the Underwood Creek rehabilitation identifies northern pike as the surrogate species:

> For rehabilitation purposes, northern pike (*Esox lucius*) are considered a surrogate species for other warm water fish in the Underwood Creek system. Their life history and habitat requirements (passage, spawning, rearing, juvenile and adult habitat) are considered those that should be achieved where possible in order to provide conditions for all warm water fish species that might be expected to inhabit Underwood Creek. Furthermore, these conditions will meet the habitat requirements of forage fish and of warm water fish that might periodically move in from the Menomonee River.

The average maximum velocity range of 1.5 to 1.7 feet per second reported in Appendix G of the May 2010 Application was obtained by the Underwood Creek rehabilitation design team from the following references[3]:

- U.S. Department of Agriculture – Forest Service. *Fish-Xing*. Stream Systems Technology Center. Software program. Version 3; 2006.
- Bell, M.C. 1990. *Fisheries Handbook of Engineering Requirements and Biological Criteria, 3rd edition.* Fish Passage Development and Evaluation Program, Corps of Engineers, North Pacific Division, Portland, OR.
- Behlke, C.E., D.L. Kane, R.F. McLean and M.D. Travis. 1991. *Fundamentals of Culvert Design for Passage of Weak-swimming Fish.* Alaska Department of Transportation. FHWA-AK-RD-90-10. 159 p.

[1] Letter from Bruce Baker, Wisconsin Department of Natural Resources, to City of Waukesha Common Council President Paul Ybarra. December 2, 2010.

[2] Milwaukee Metropolitan Sewerage District. 2006. Underwood Creek Rehabilitation and Flood Management Project - Preliminary Engineering Design Project. August 2006. Contract No. P12424011T.01. Tetra Tech. Pages 2-8 and 2-10.

[3] Email correspondence from Dale Miller, Mainstream Restoration. January 27, 2011.

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

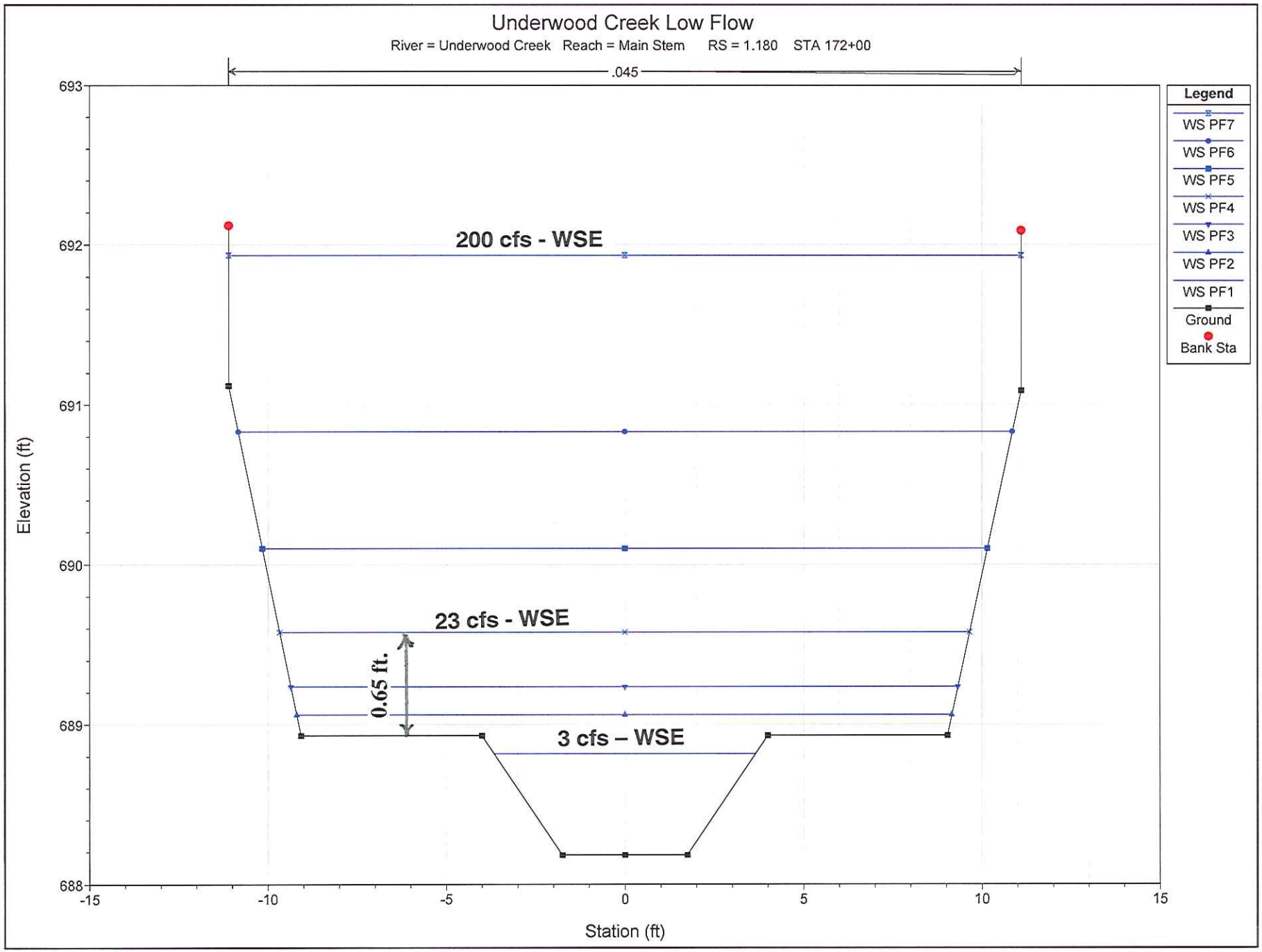


Exhibit A-1
Phase 1 Project - Main and Low Flow Channels

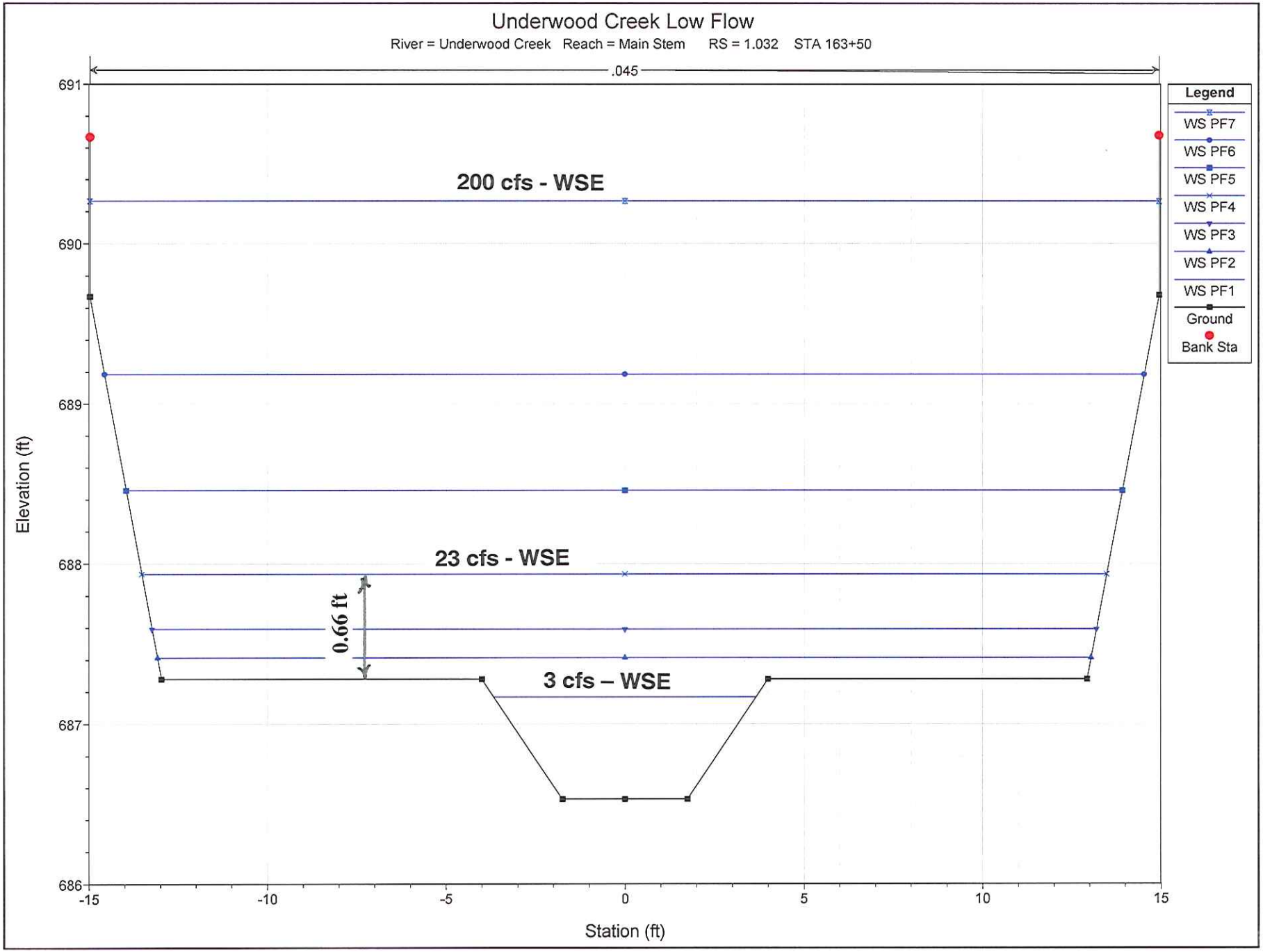


Exhibit A-2
Phase 1 Project - Main and Low Flow Channels

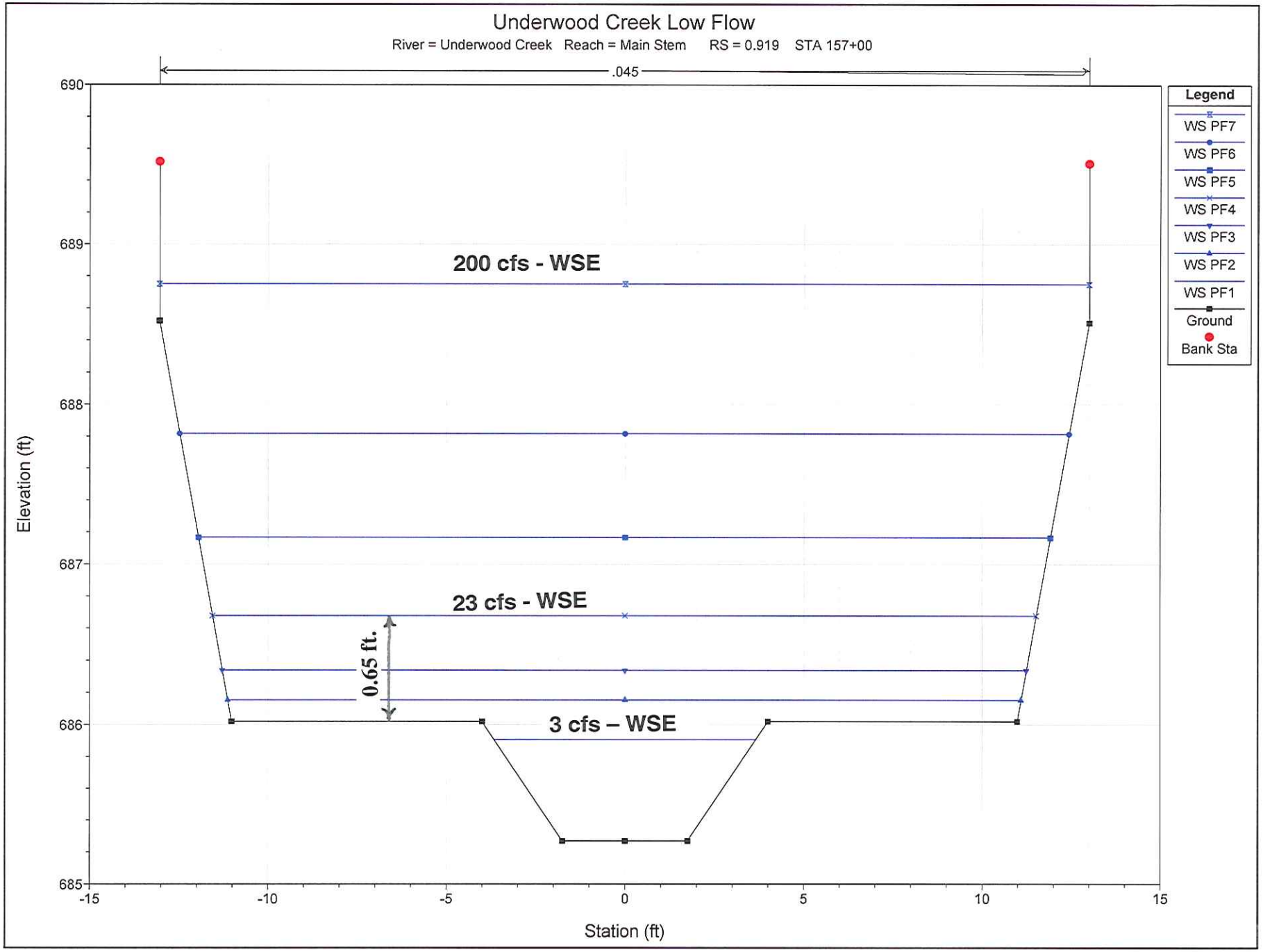


Exhibit A-3
Phase 1 Project - Main and Low Flow Channels

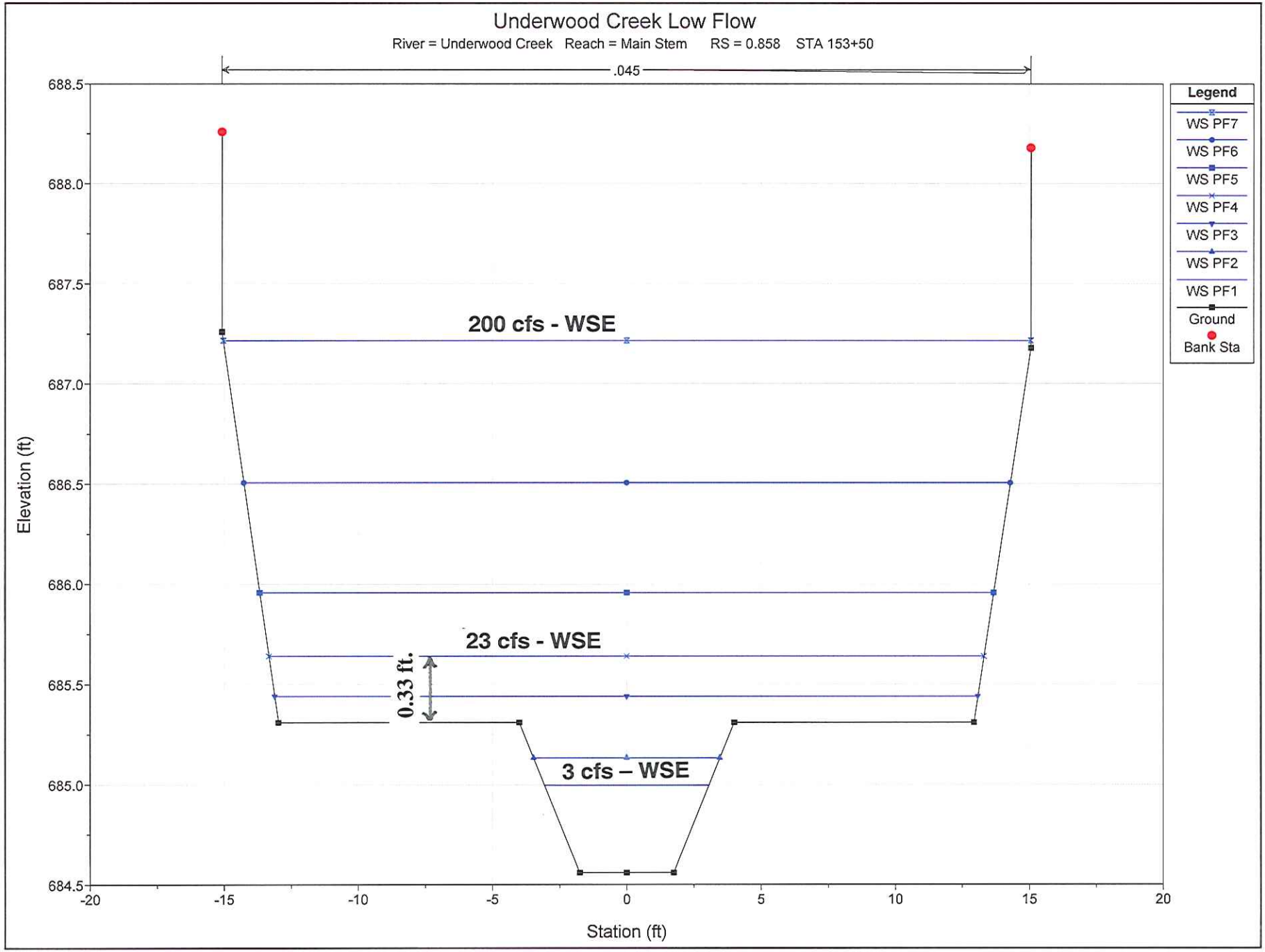


Exhibit A-4
Phase 1 Project - Main and Low Flow Channels

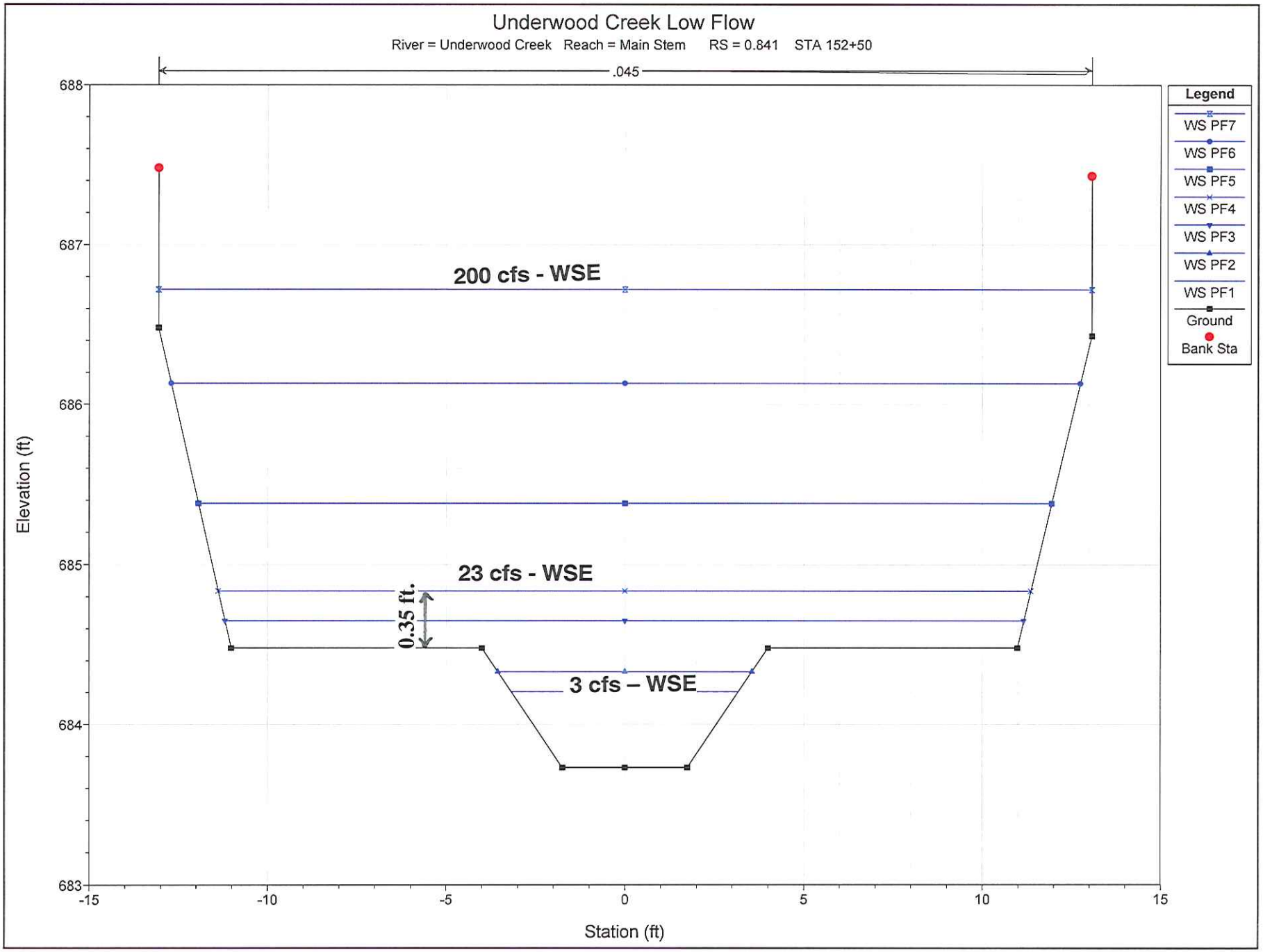


Exhibit A-5
Phase 1 Project - Main and Low Flow Channels

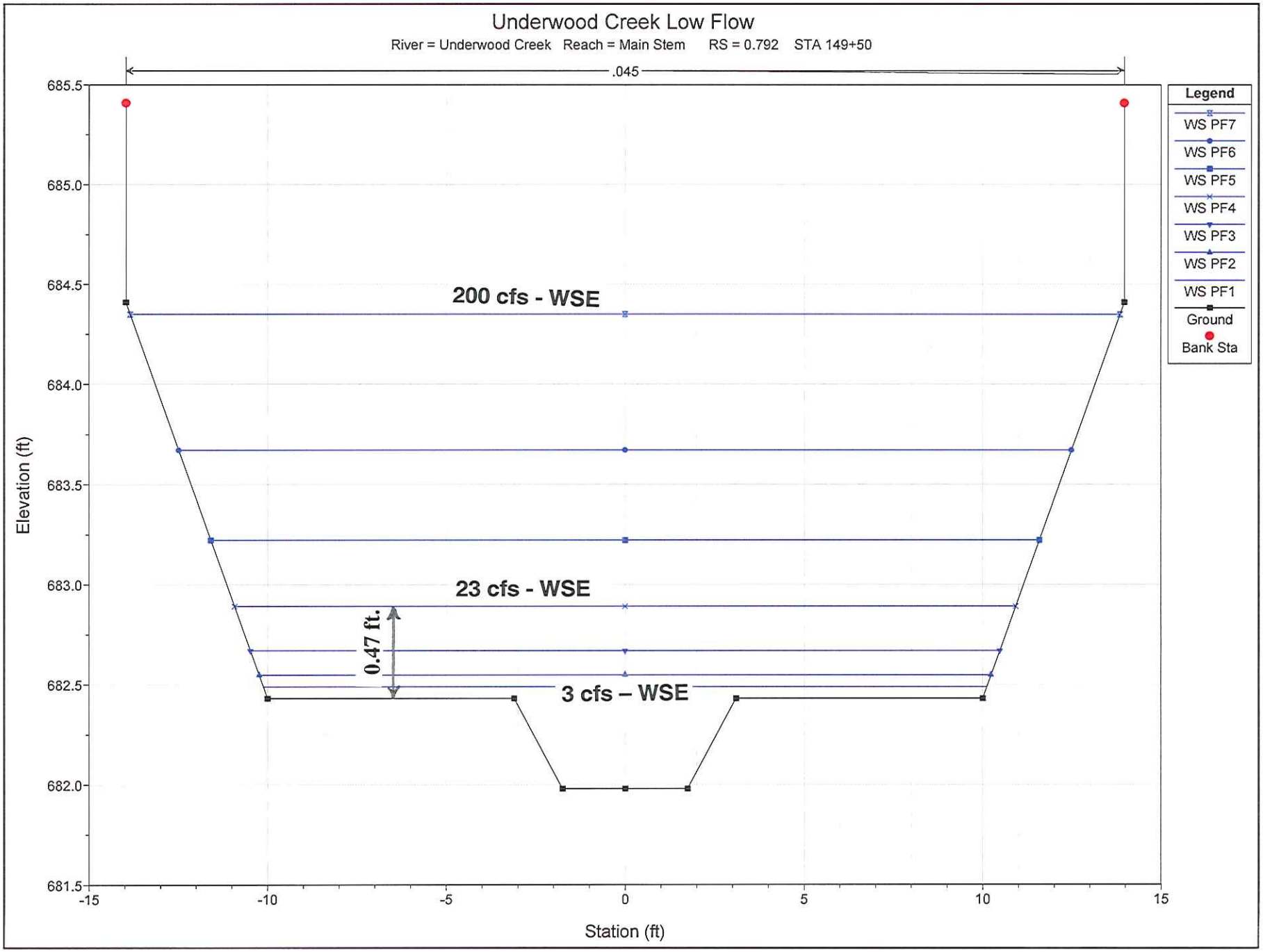


Exhibit B-1
Phase 2 Project - Main and Low Flow Channels

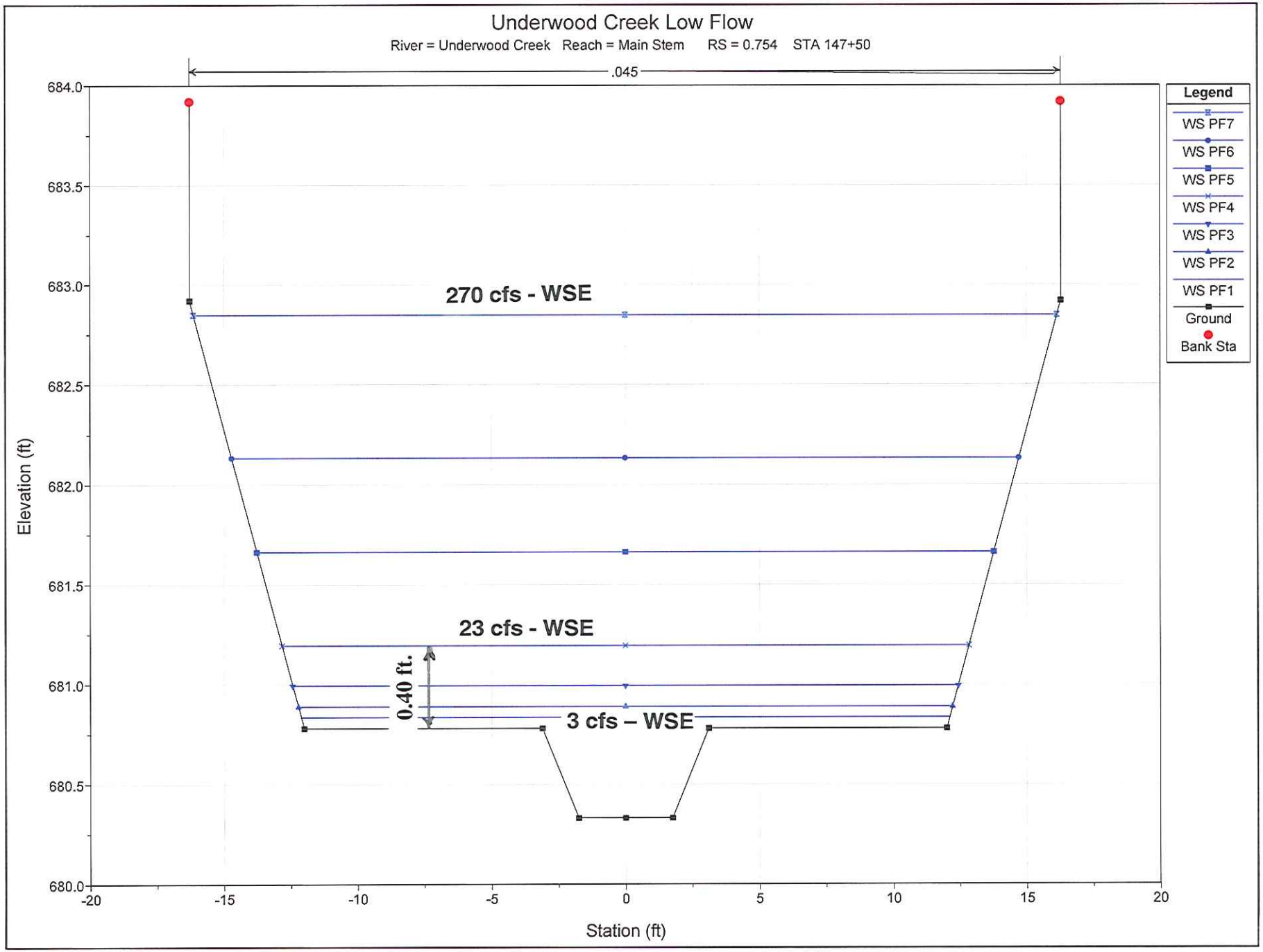


Exhibit B-2
Phase 2 Project - Main and Low Flow Channels

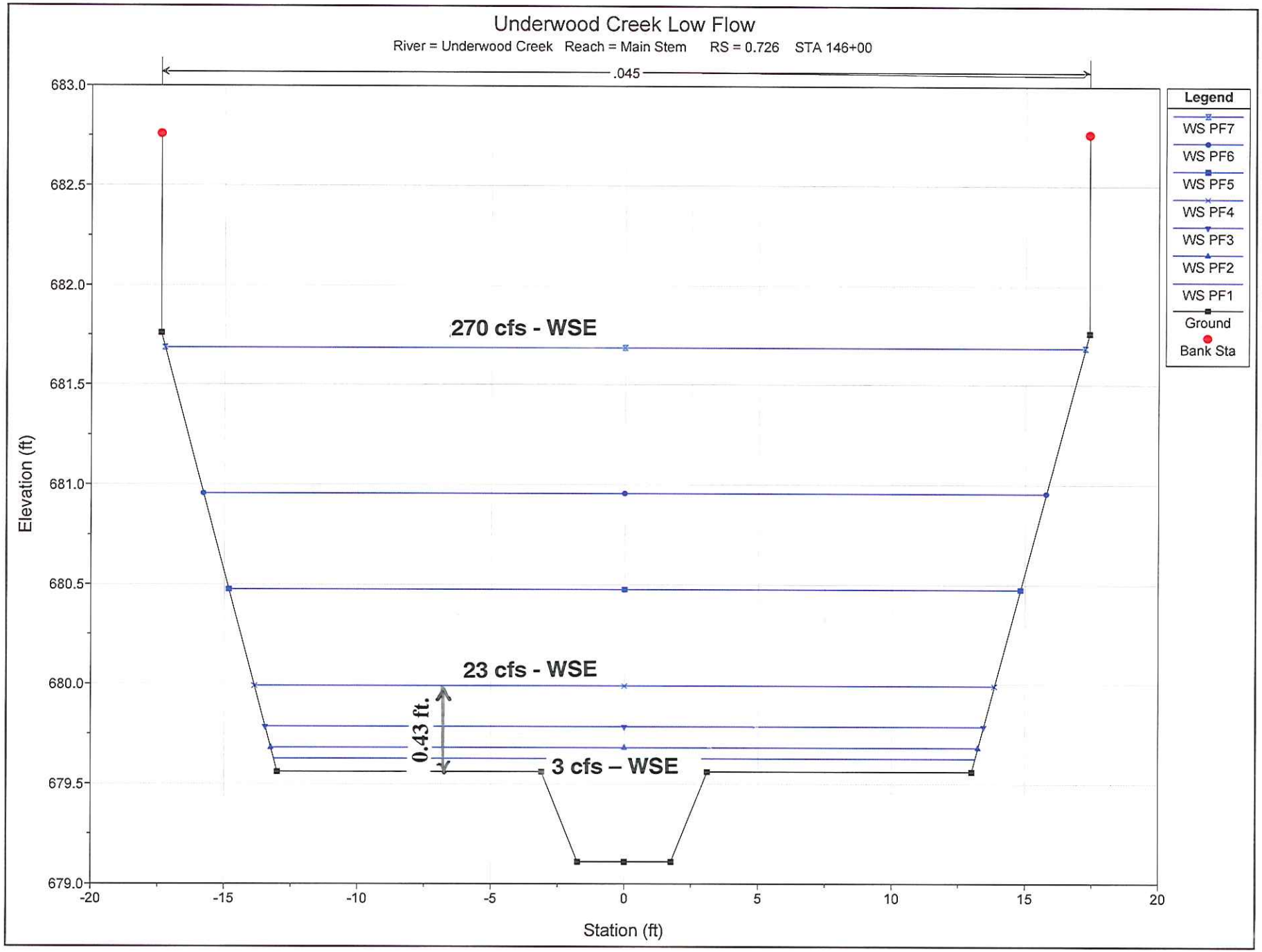


Exhibit B-3
Phase 2 Project - Main and Low Flow Channels

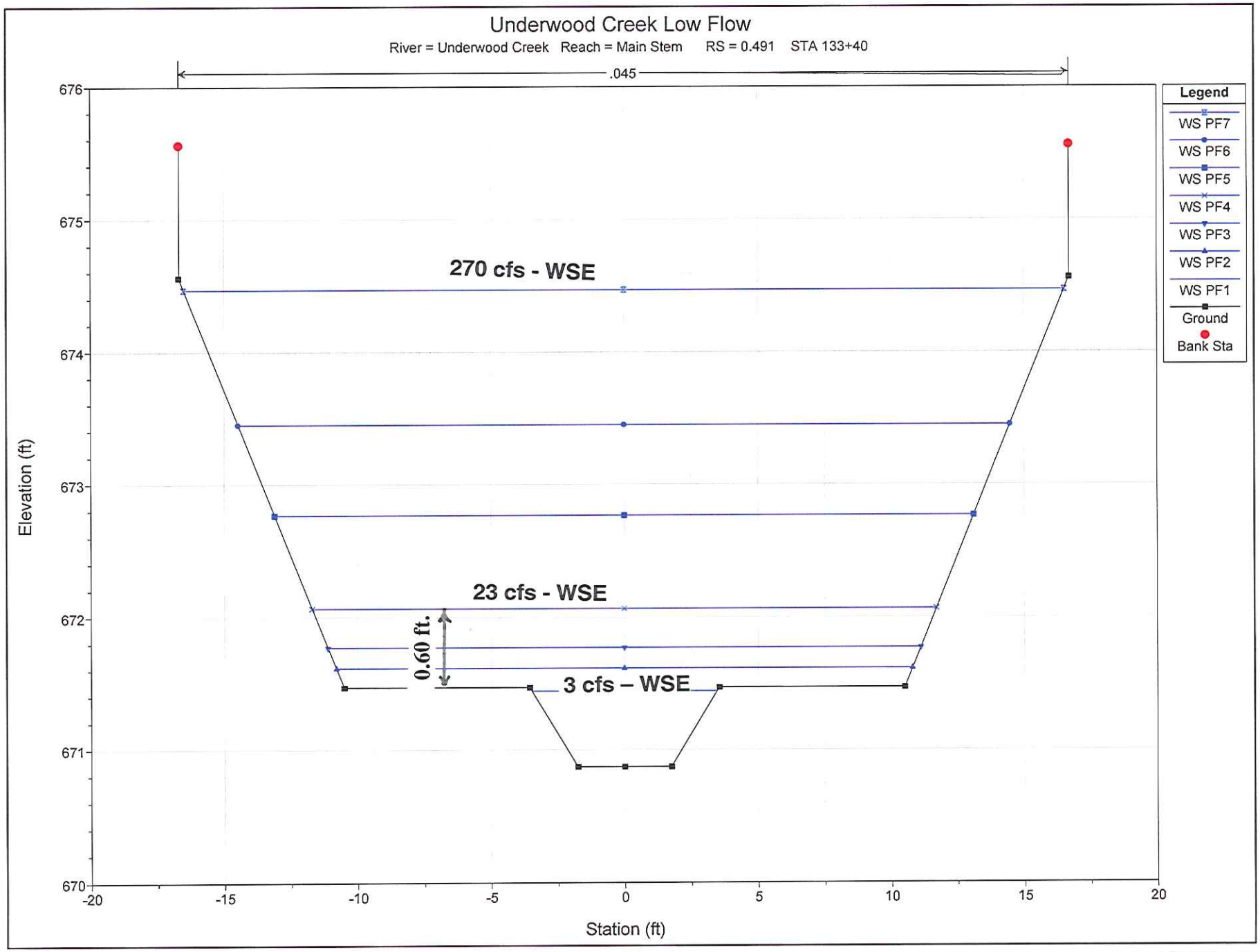


Exhibit B-4
Phase 2 Project - Main and Low Flow Channels

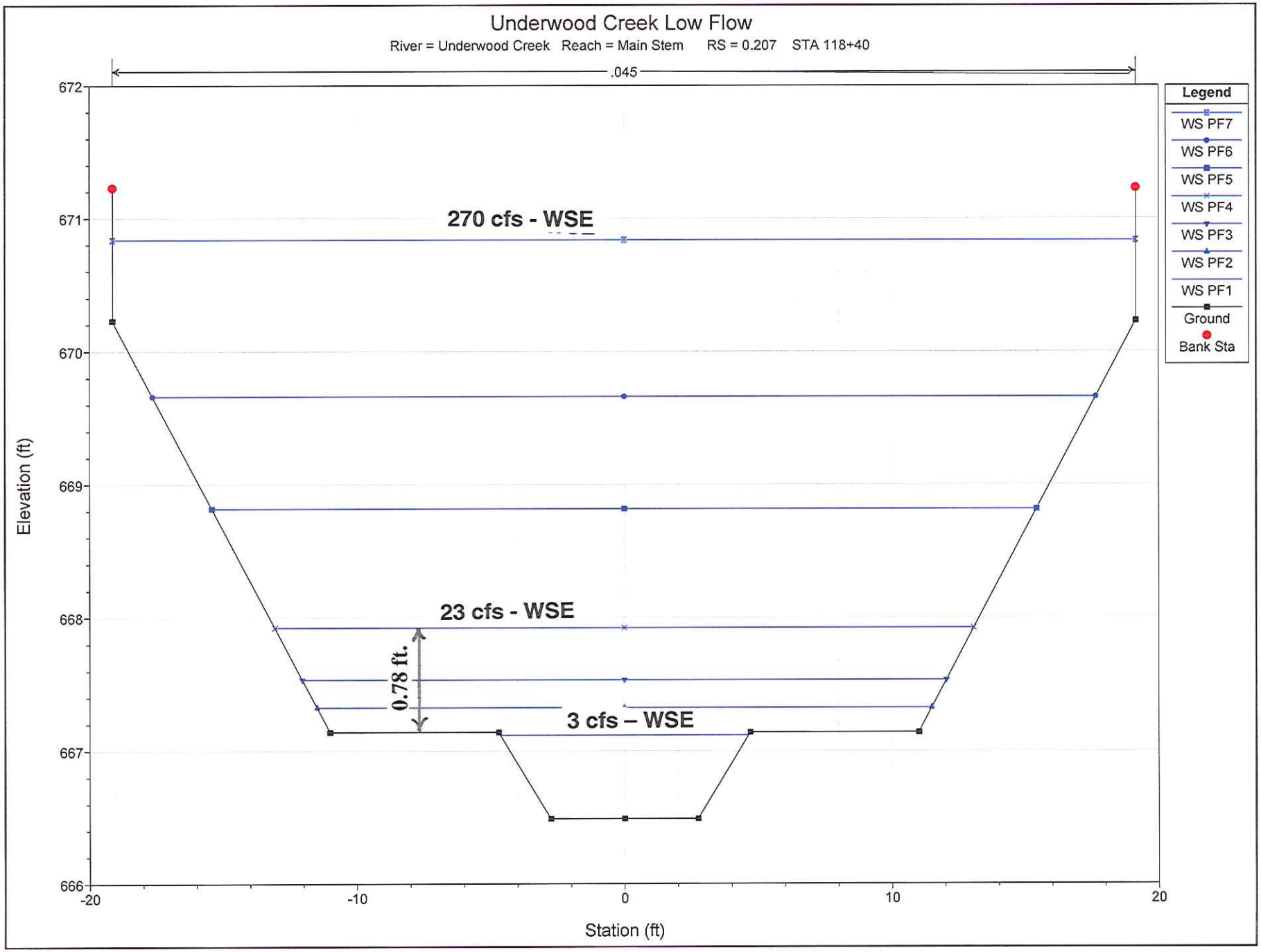


Exhibit B-5
Phase 2 Project - Main and Low Flow Channels

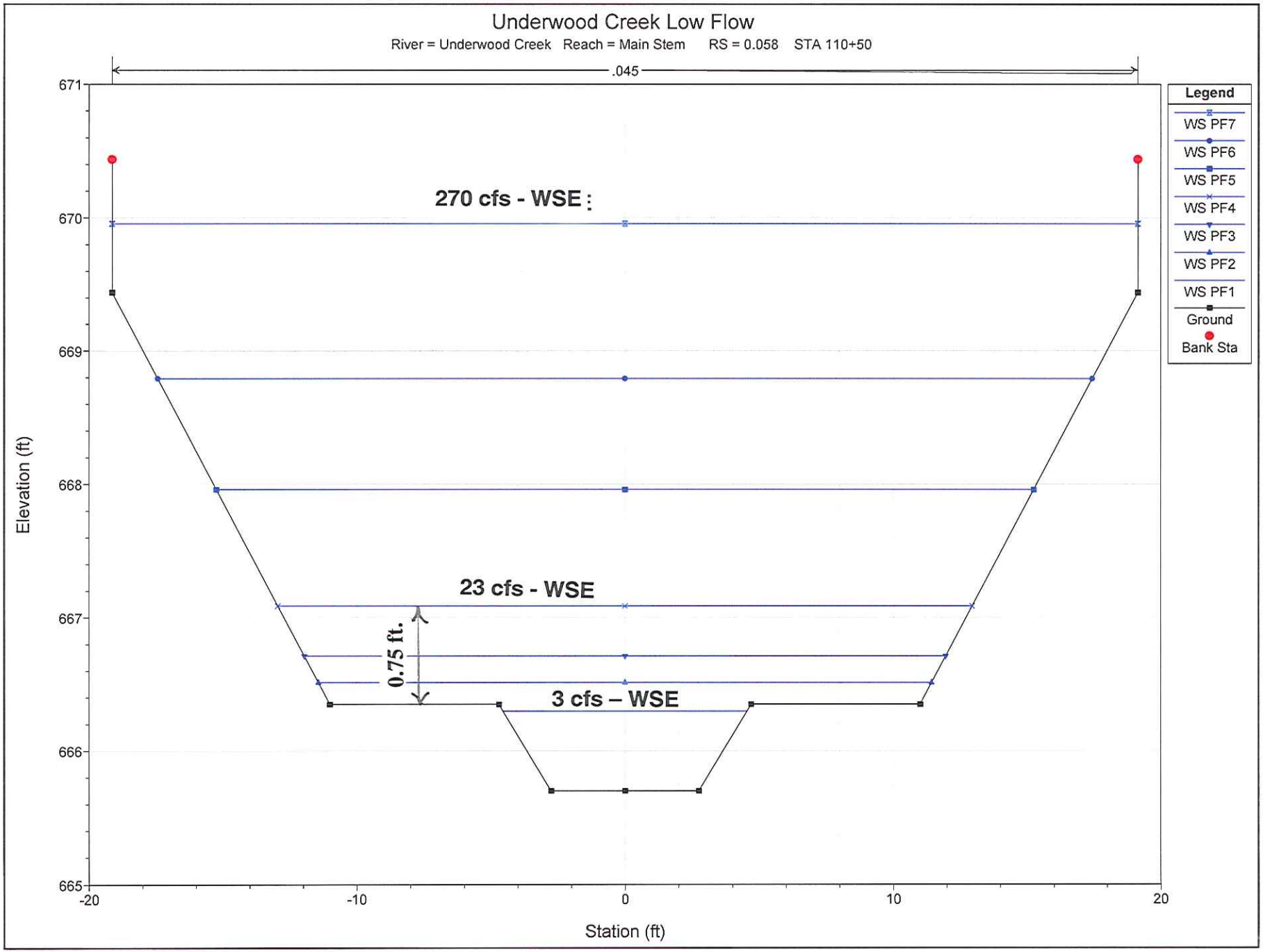


Exhibit B-6
Phase 2 Project - Main and Low Flow Channels

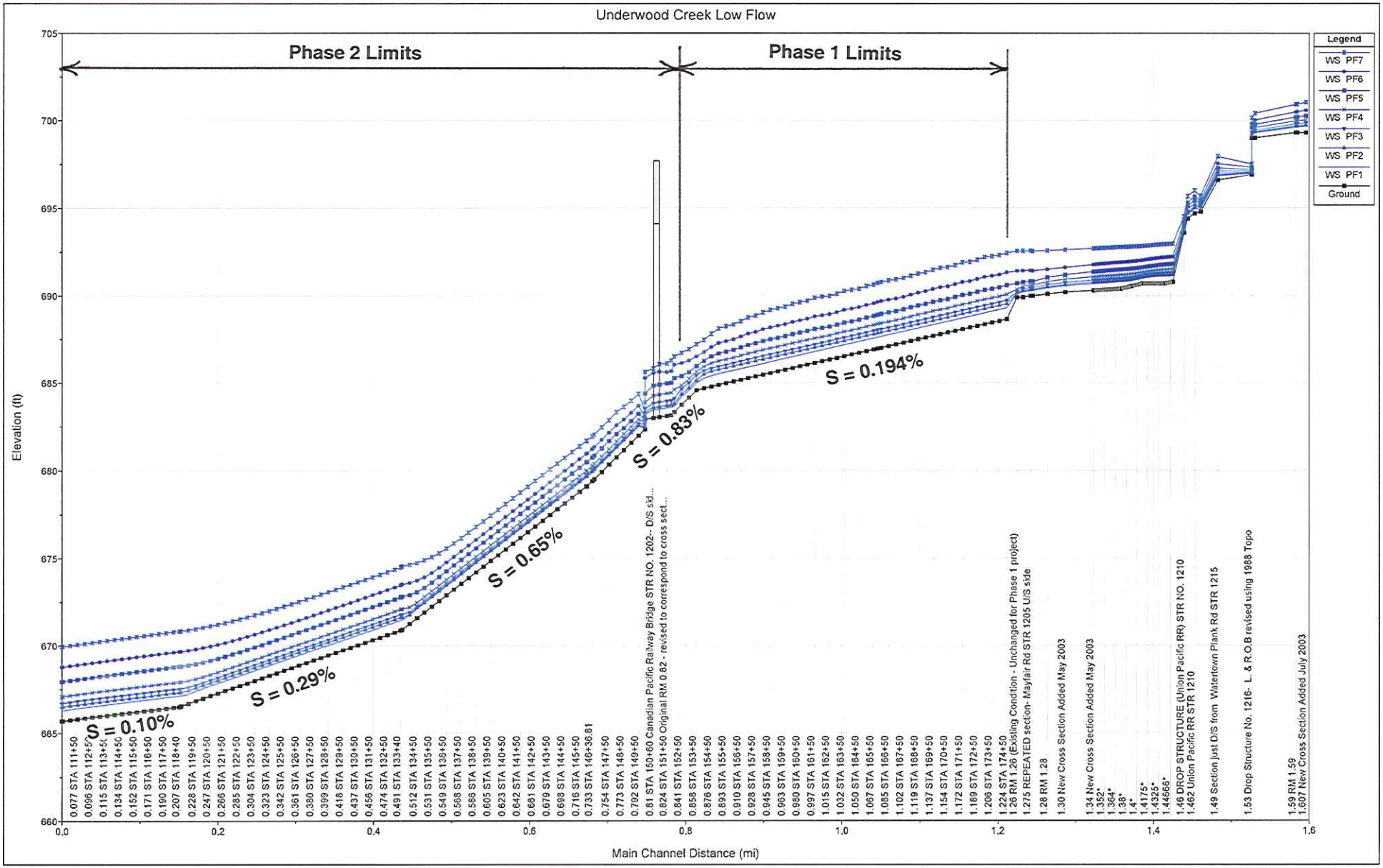
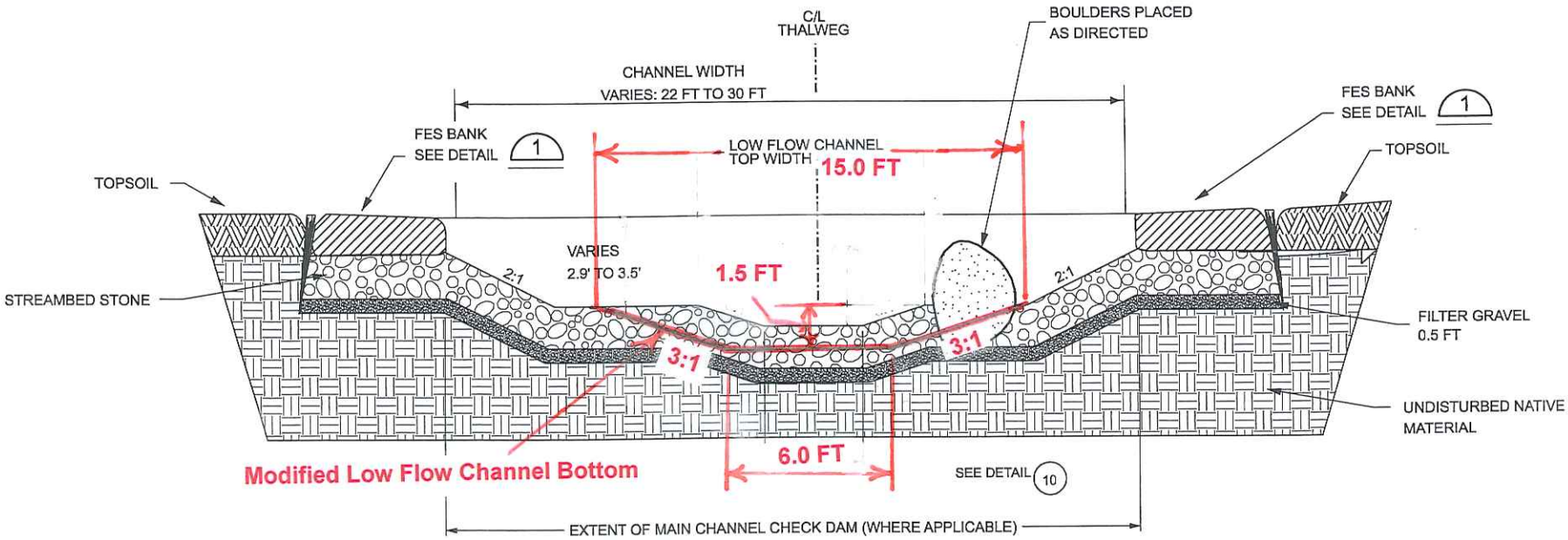


Exhibit C

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

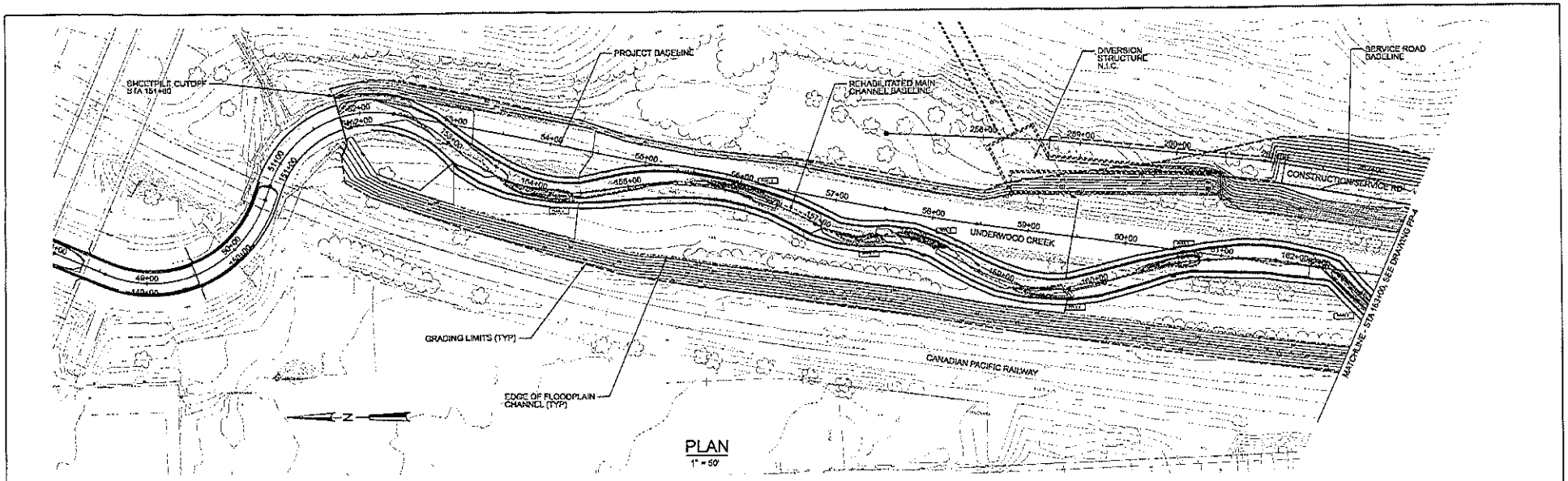
For information regarding this project call: David C. Fowler, Senior Project Manager: (414) 277-6368

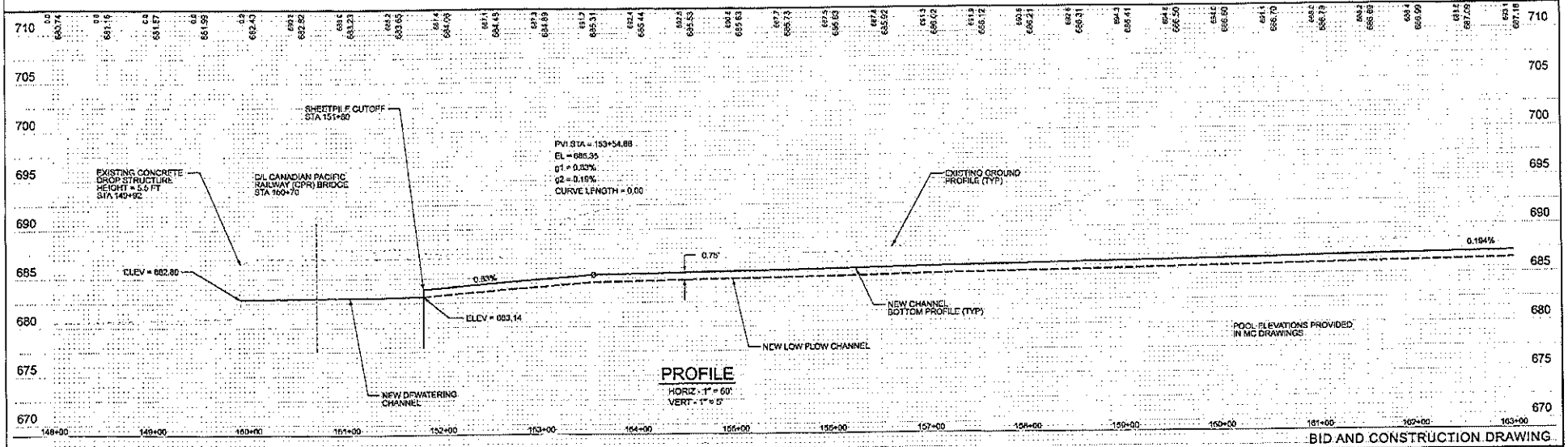
MMSD
Preserving The Environment · Improving Water Quality

Bid - April 2008

BID AND CONSTRUCTION DRAWING SET

MMSD FILE NO. 151-572.DGN





BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0" ——— 1"
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY.

DSGN T. SEAR
DR M. WEBER
CHK T. SEAR
APVD T. SEAR

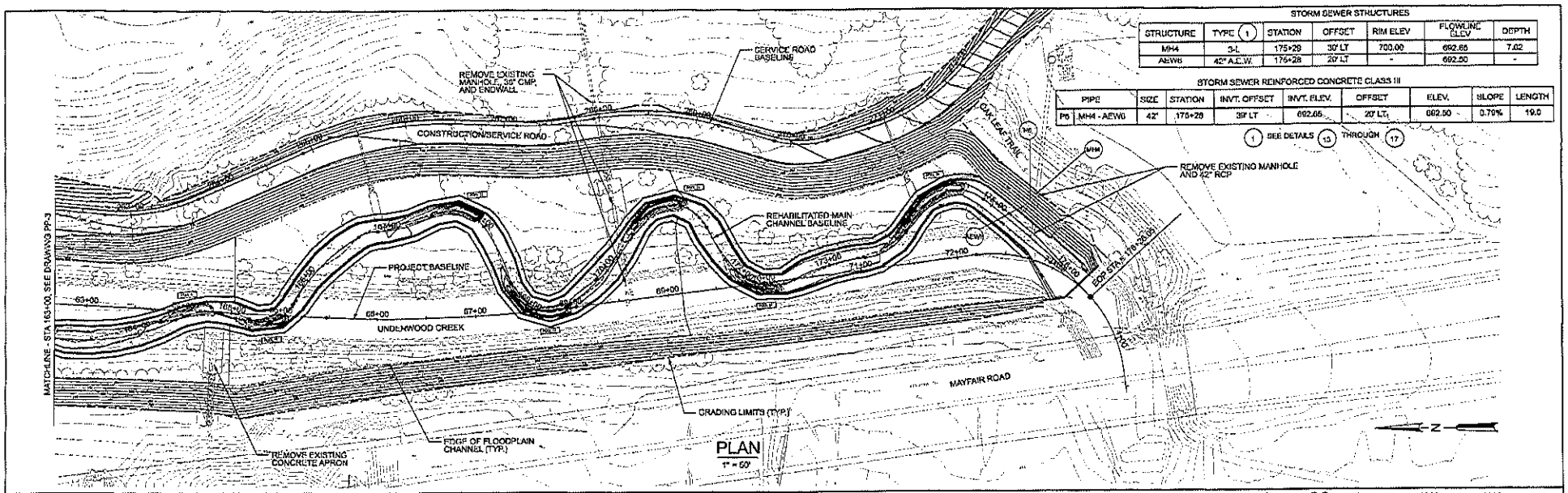
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

Preserving The Environment - Improving Water Quality

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



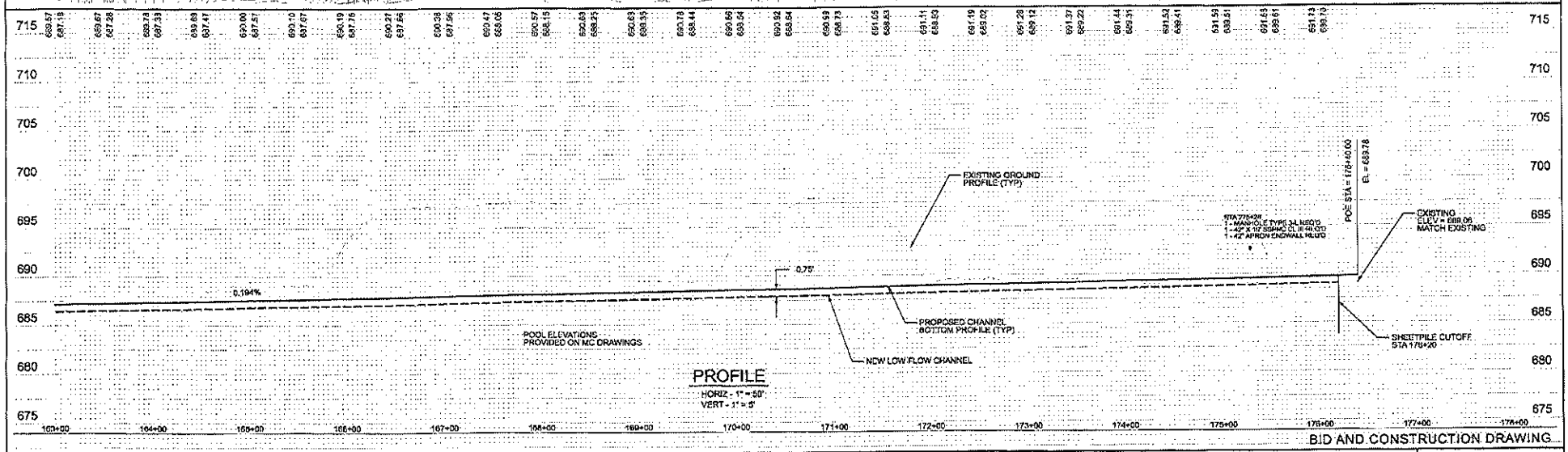
STORM SEWER STRUCTURES

STRUCTURE	TYPE (1)	STATION	OFFSET	RIM ELEV	FLOWLINE ELEV	DEPTH
MH4	3-L	175+28	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
P5	MH4 - AEW6	42"	175+28	39' LT	692.65	20' LT	692.50	0.79%	19.0

(1) SEE DETAILS (13) THROUGH (17)



BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IN ANY PART/PART OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

DSGN	T. SEAR
DR	M. WEBER
CHK	T.SEAR
APVD	T. SEAR

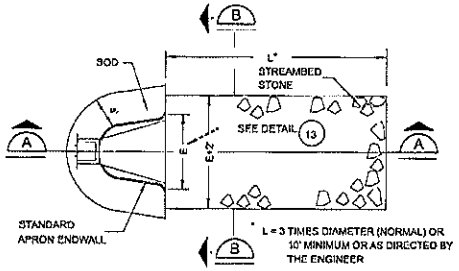
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

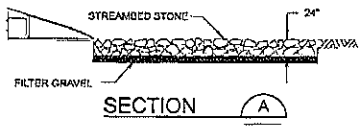
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

Preserving The Environment - Improving Water Quality

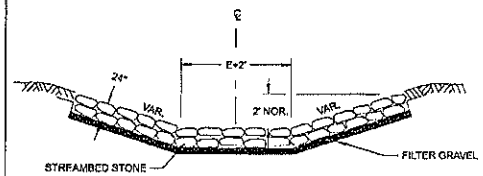
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
REHABILITATED MAIN CHANNEL
PLAN AND PROFILE

DRAWING NO.:	PP-4
SHEET:	15
DATE:	APRIL, 2009
CONTRACT:	W21005C01
MMSD FILE:	151-589.DGN





SECTION A

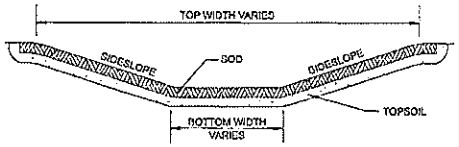


SECTION B

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'

BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

DSGN T. SEAR
DR M. WEBER
CHK T.SEAR
APVD T. SEAR

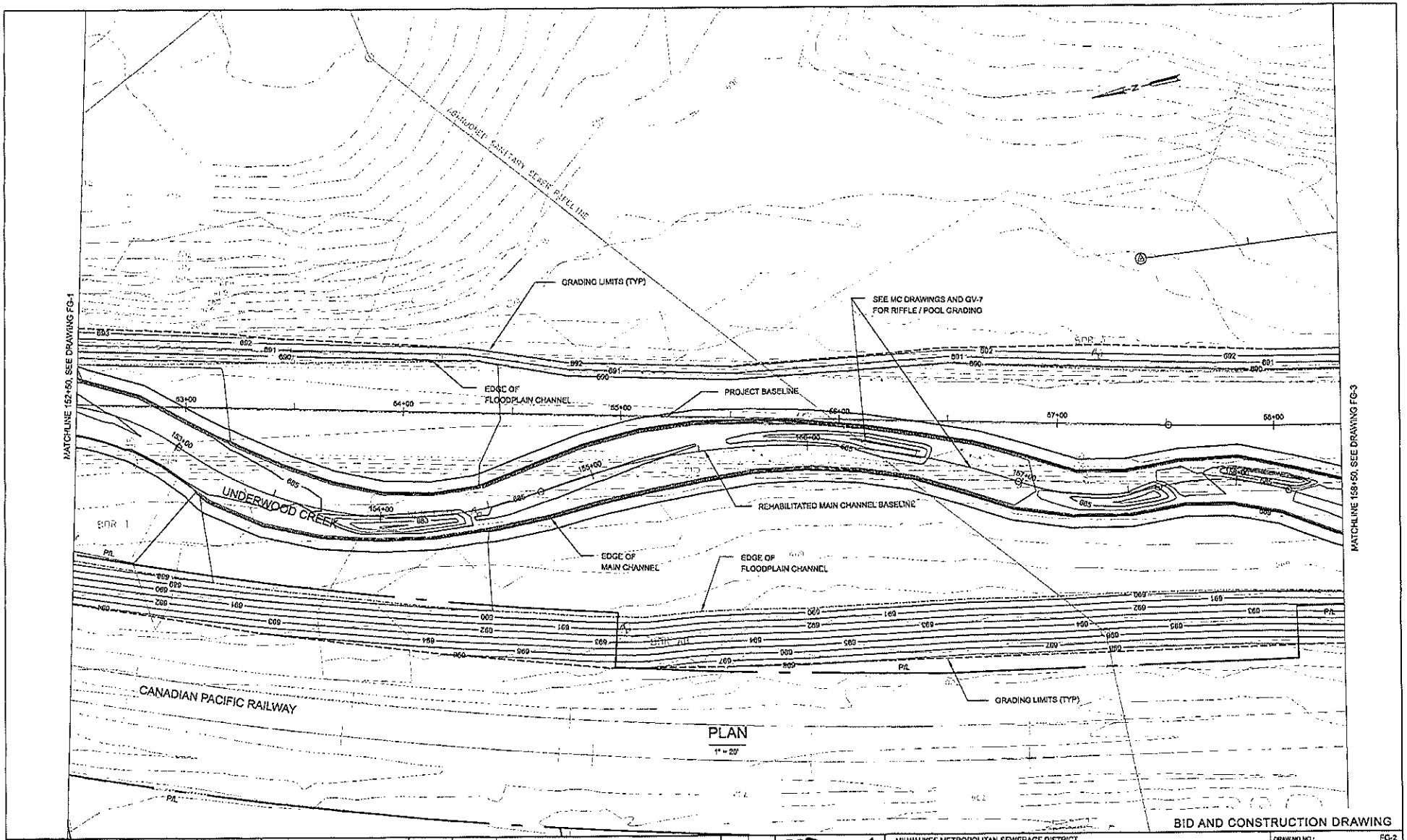
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

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
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



BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY

DSGN T. SEAR
DR M. WEBER
CHK T.SEAR
APVD T. SEAR

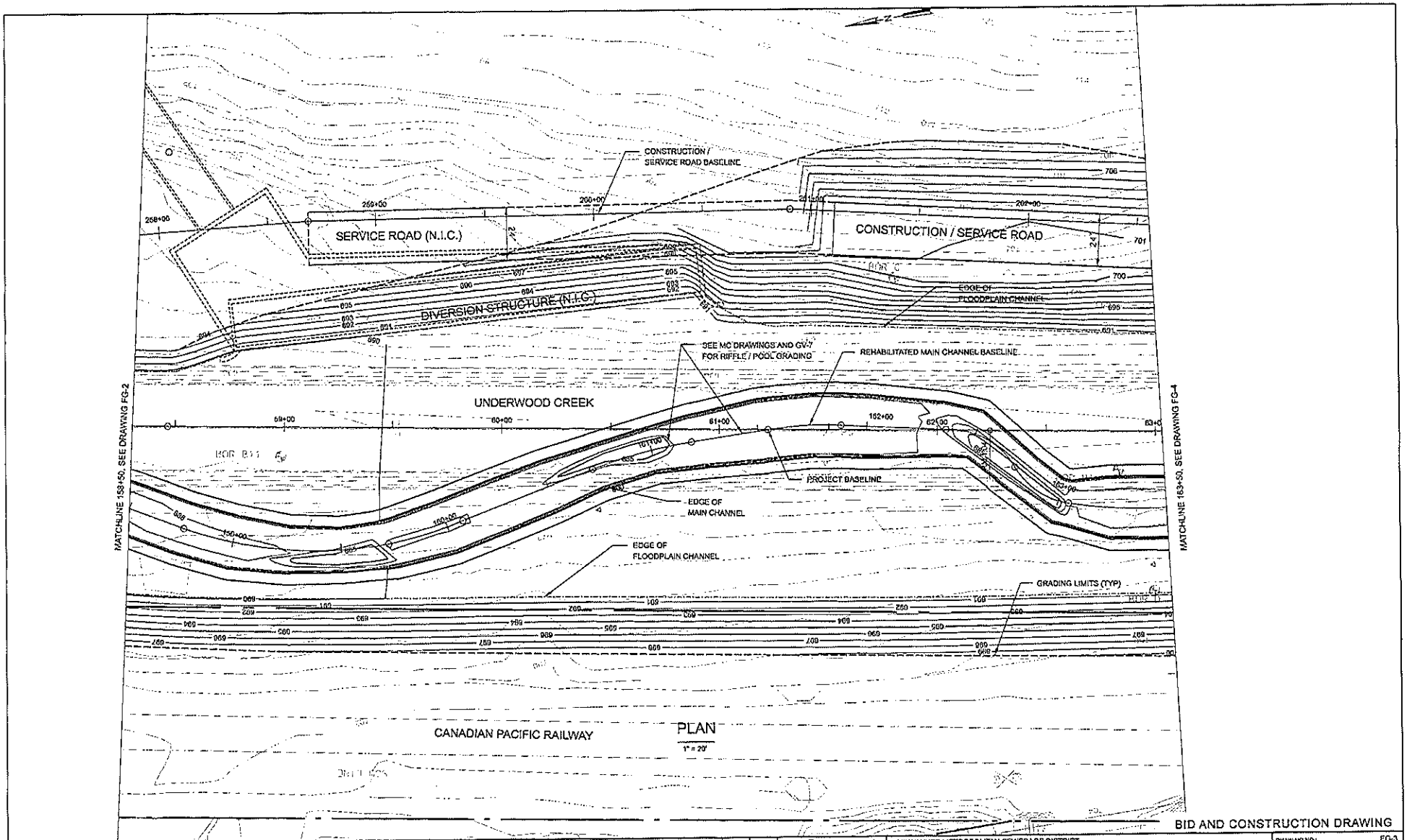
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

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
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

DRAWING NO.:	FG-2
SHEET:	23
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-504.DGN



BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY.

DSGN	T. SEAR
DR	M. WEBER
CHK	T. SEAR
APVD	T. SEAR

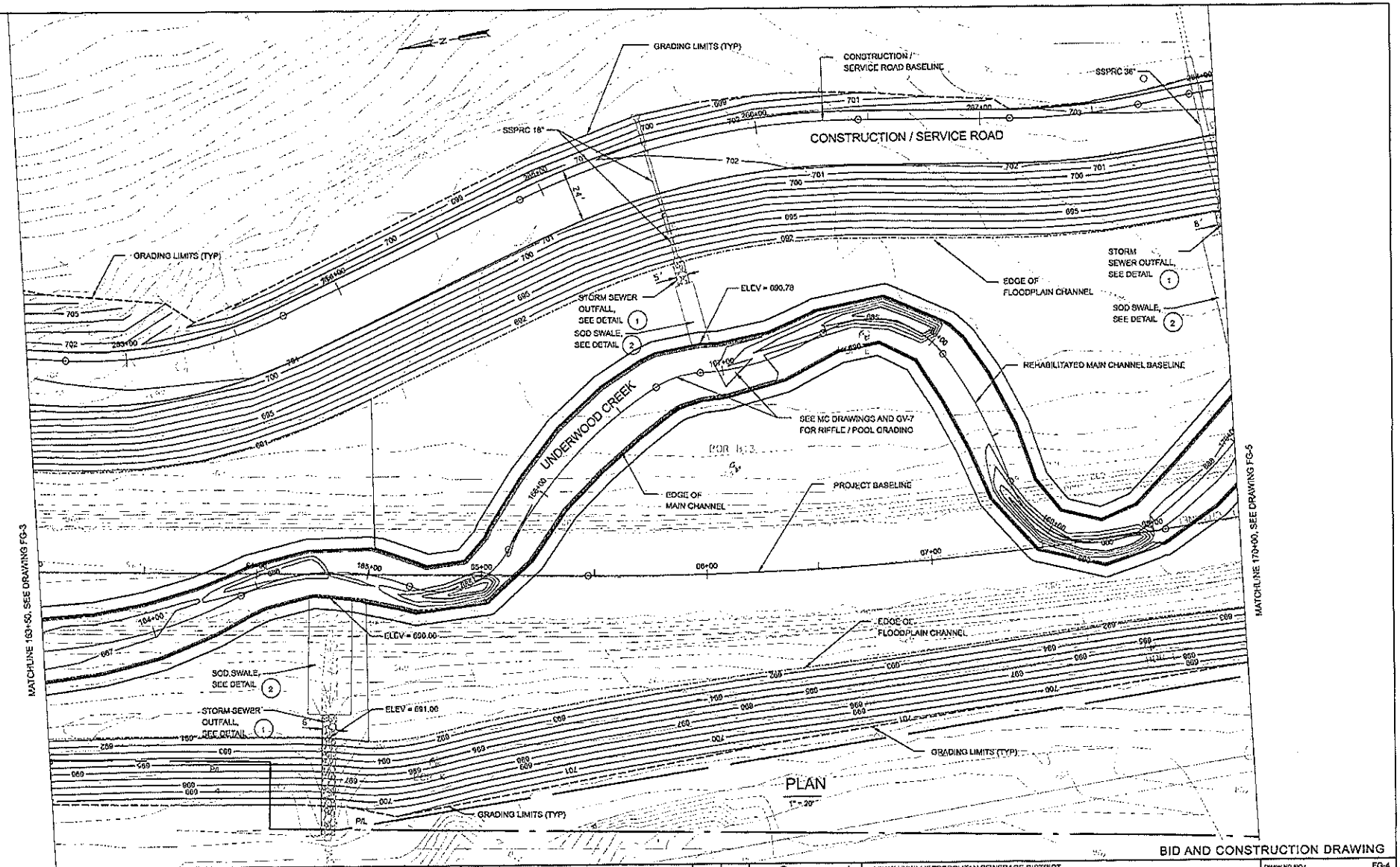
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

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
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

DRAWING NO.:	FG-3
SHEET:	24
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	161-595.DGN



BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0" 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN T. SEAR
DR M. WEBER
CHK T.SEAR
APVD T. SEAR

This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

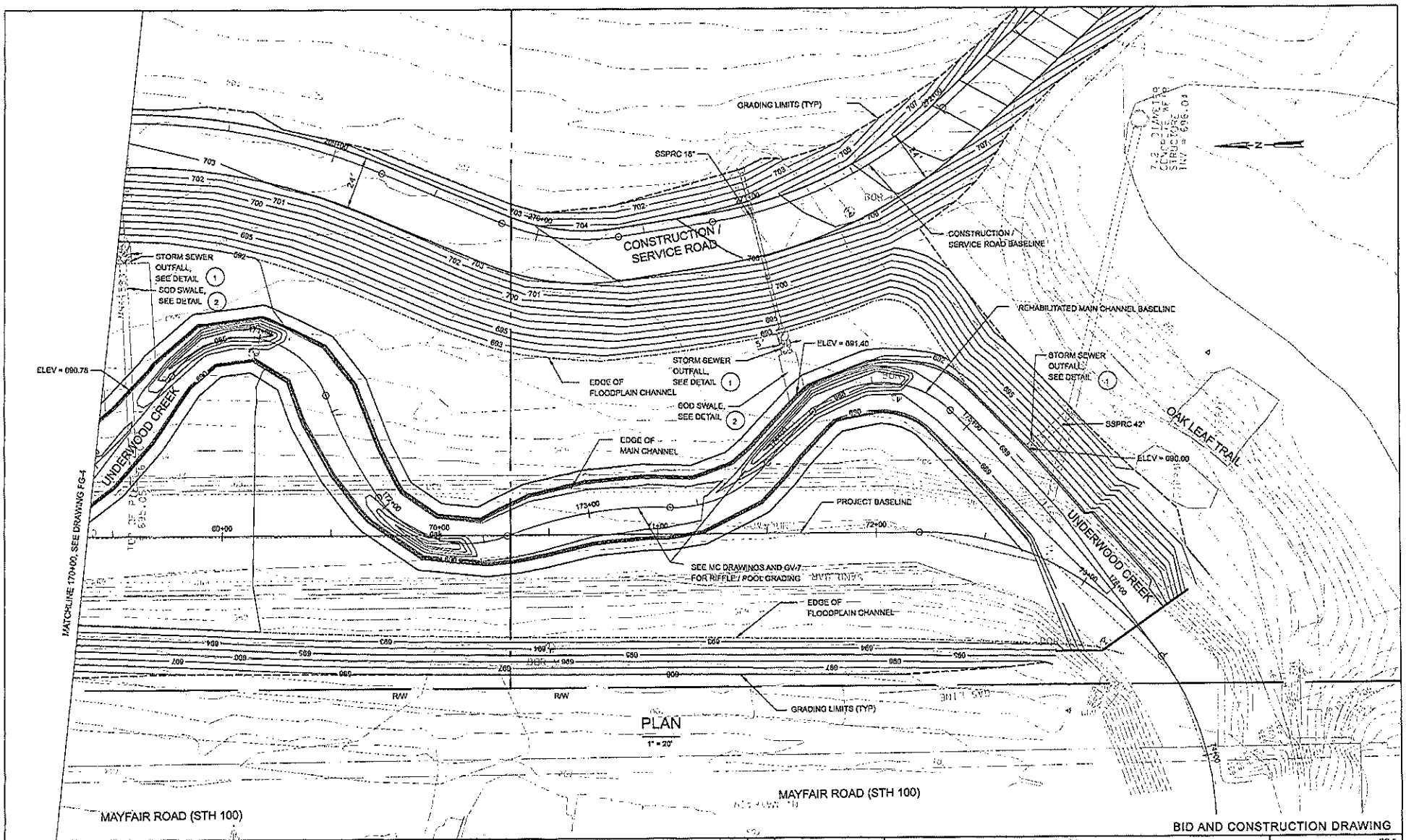
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

Preserving The Environment · Improving Water Quality

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

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



THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN AS AN INSTRUMENT OF PROFESSIONAL SERVICE IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN	T. SCAR
DR	M. WEBER
CHK	T.SCAR
APVD	T. SCAR

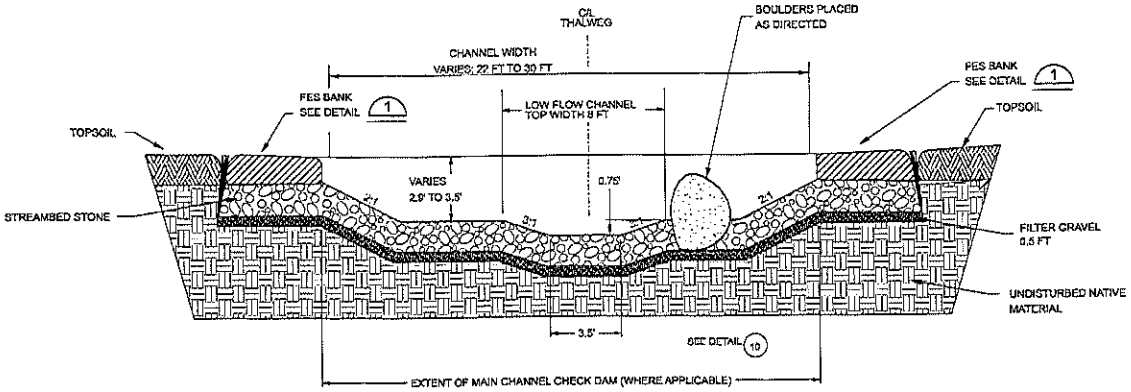
This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

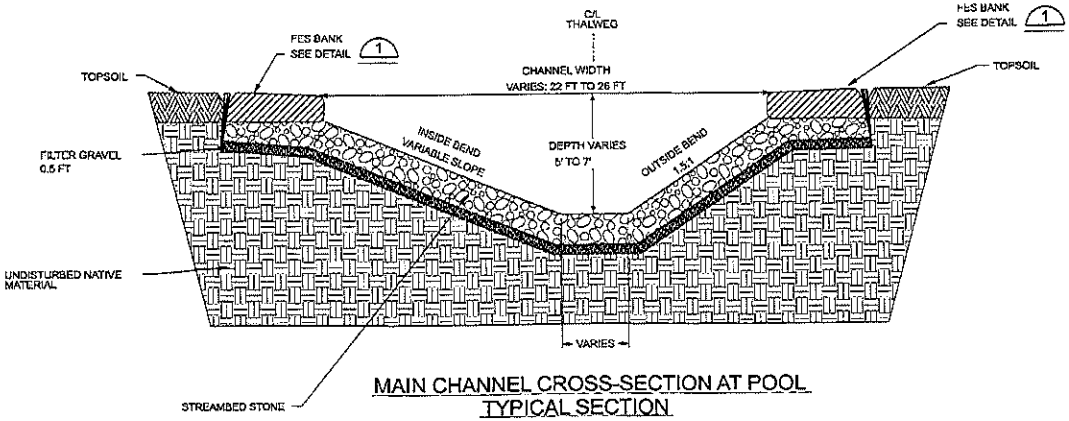
Preserving The Environment - Improving Water Quality

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
FLOODPLAIN GRADING
PLAN

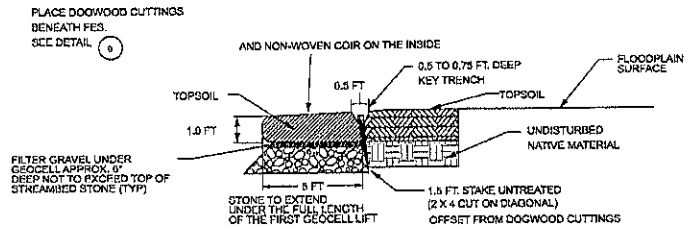
DRAWING NO.:	FG-5
SHEET:	28
DATE:	APRIL, 2008
CONTRACT:	W21005C01
MMSD FILE:	151-597.DGN



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+60		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+76	157+80	1
158+25	159+05	10
159+65	160+45	10
161+10	162+35	15
163+05	164+10	13
164+80	164+85	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+60	176+50	29
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'

BID AND CONSTRUCTION DRAWING

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY

DSGN T. SCAR
DR M. WEBER
CHK T.SCAR
APVD T. SCAR

This Design Prepared For MMSD By:
SEH
SHORT ELLIOTT HENDRICKSON INC.

REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

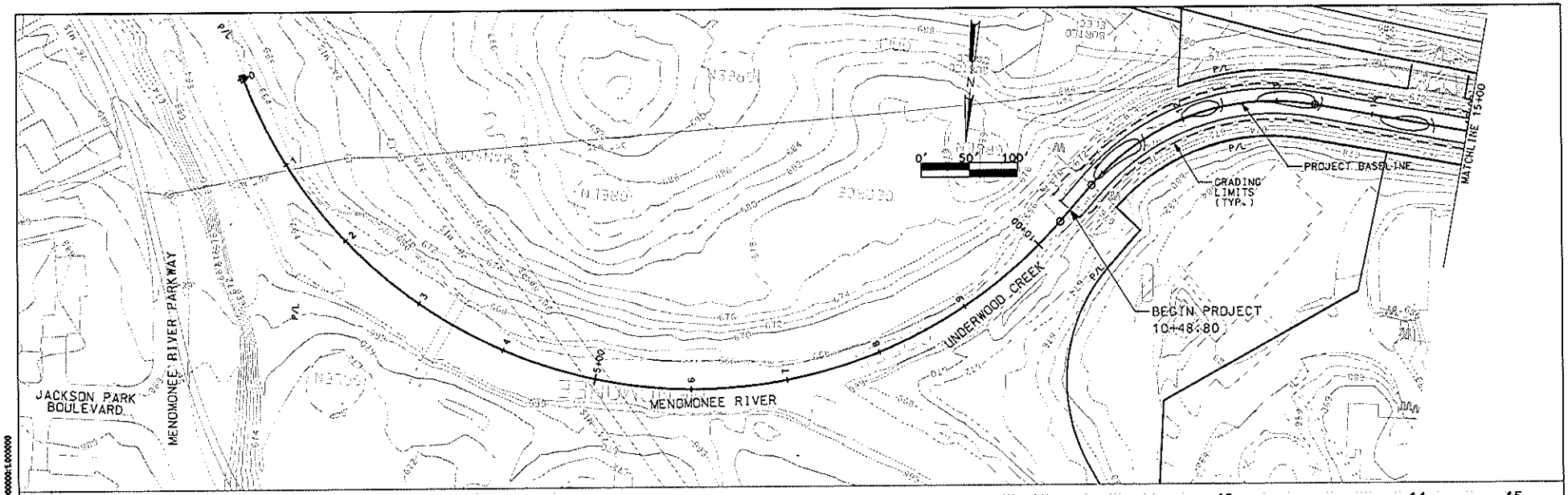
MMSD Preserving The Environment - Improving Water Quality

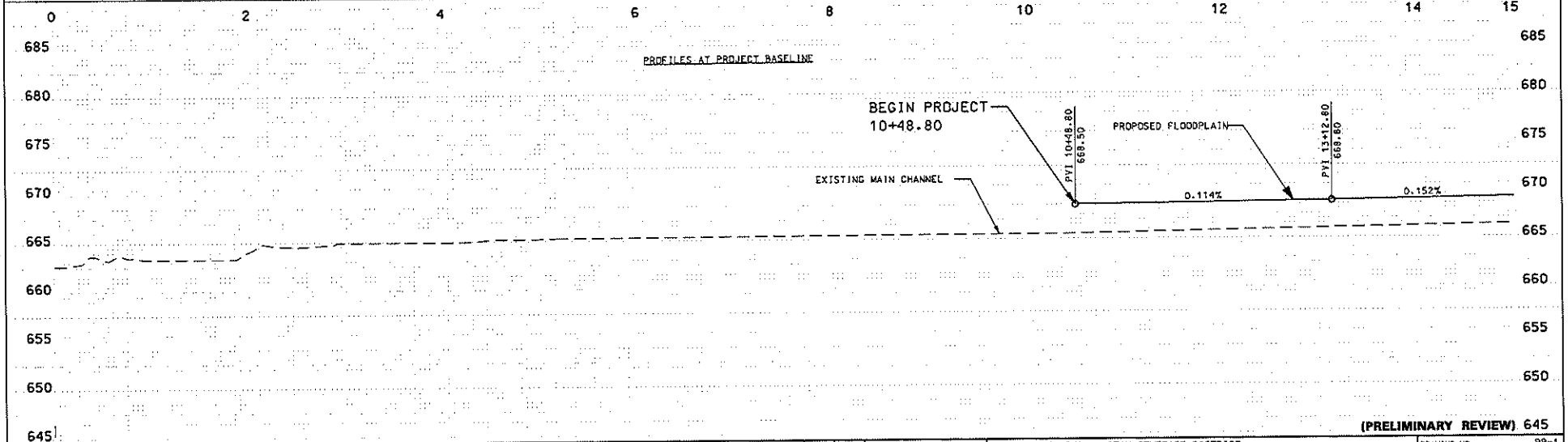
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
WATERCOURSE IMPROVEMENTS - PHASE 1
GEOMORPHIC AND VEGETATION
TYPICAL CHANNEL SECTIONS

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





(PRELIMINARY REVIEW)

PLOTTED BY: mstevenson
TIME: 28-JAN-2006 15:18
FILE NAME: I:\W0007\07\temp-item\U-Crk 12-28-05\etpp01.dgn
PEN TABLE: E:\config\plot\mmsd4.pen
SCALE: 100.000000:1.000000

REUSE OF DOCUMENTS
THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0" _____ 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN | DR | CHK | APVD

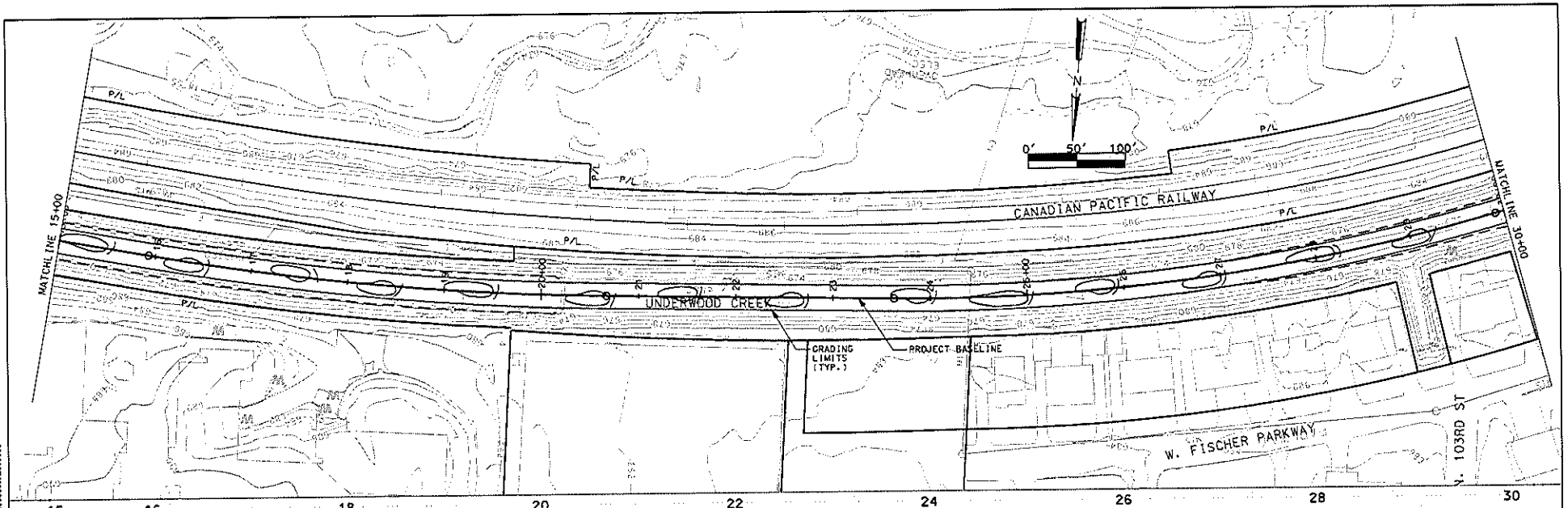
This Design Prepared For MMSD By:
TETRA TECH
In Association With
HNTB

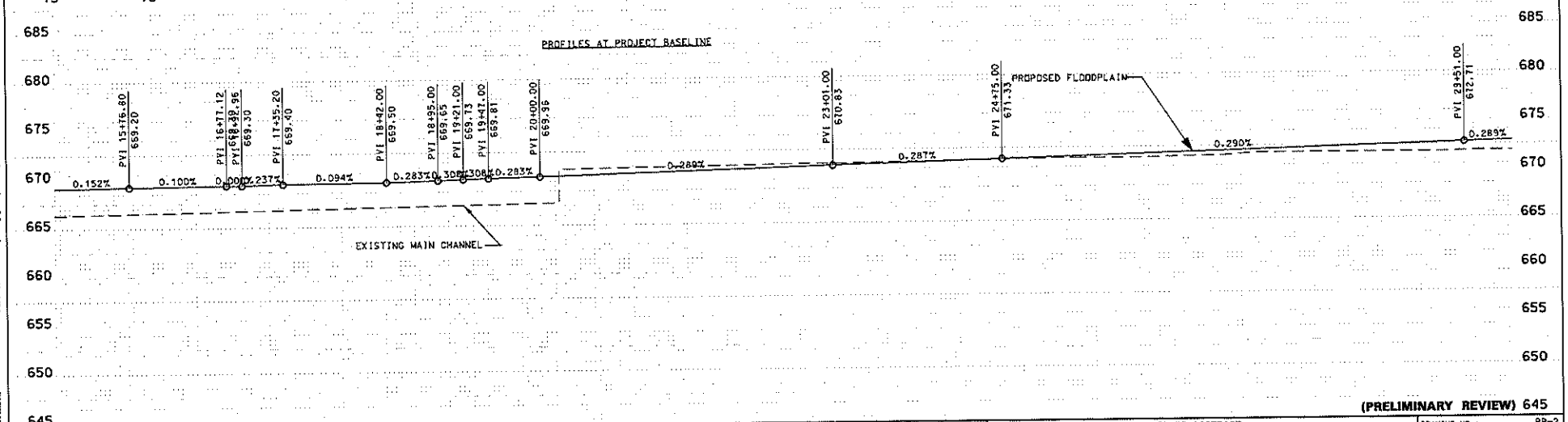
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

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





(PRELIMINARY REVIEW)

USE OF DOCUMENTS
THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0" 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN
DR
CHK
APVD

This Design Prepared For MMSD By:
TETRA TECH
In Association With
HNTB

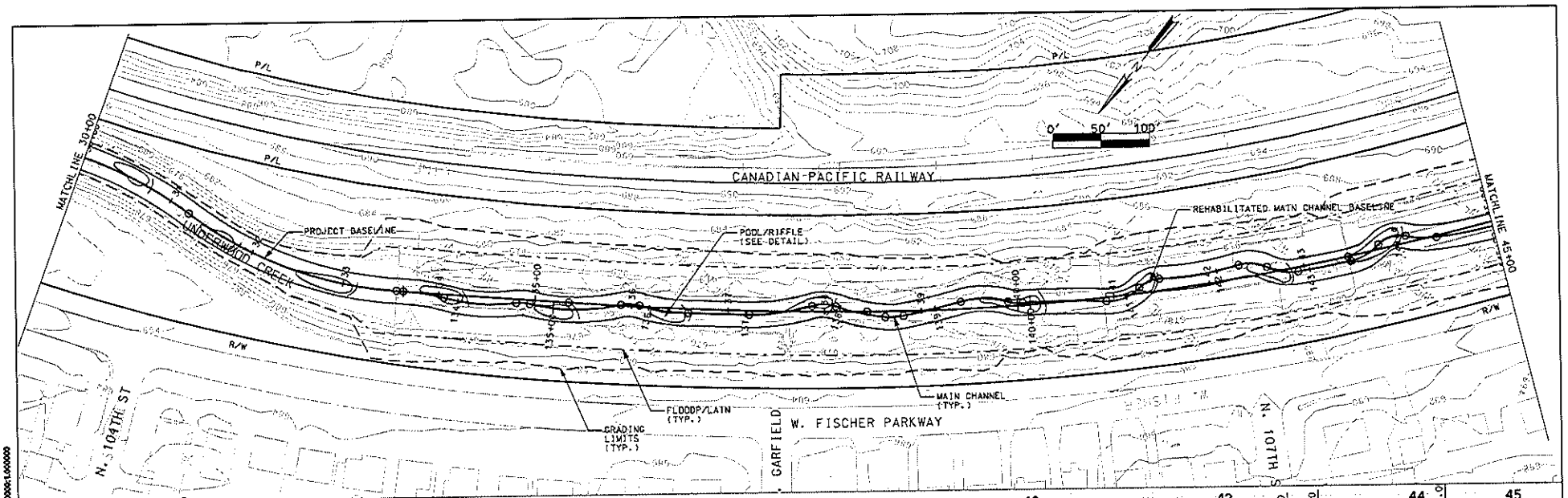
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

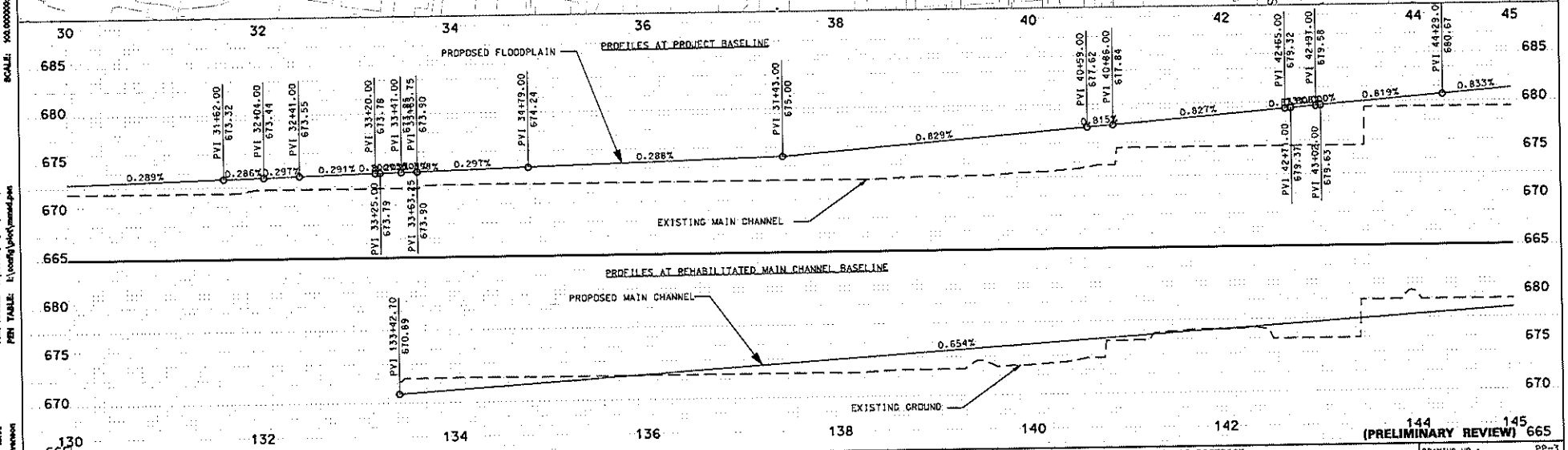
MMSD
Preserving The Environment · Improving Water Quality

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-2
SHEET:	13
DATE:	JANUARY, 2006
CONTRACT:	W21005D01
MMSD FILE:	XXX-XXX.DGN

FILE NAME: I:\35487\cf\comp-ken\U-Crk 12-29-06\wtpp02.dgn
PEN TABLE: E:\config\pkr\pmmd.pen
SCALE: 1"=XXX.XXXXXX=1.0000000
TIME: 29-JAN-2006 13:56
PLOTTED BY: wstevenson





(PRELIMINARY REVIEW)

REUSE OF DOCUMENTS

THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES

BAR IS ONE INCH ON ORIGINAL DRAWING.
0" ——— 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN
DR
CHK
APVD

This Design Prepared For MMSD By:
TETRA TECH
In Association With:
HNTB

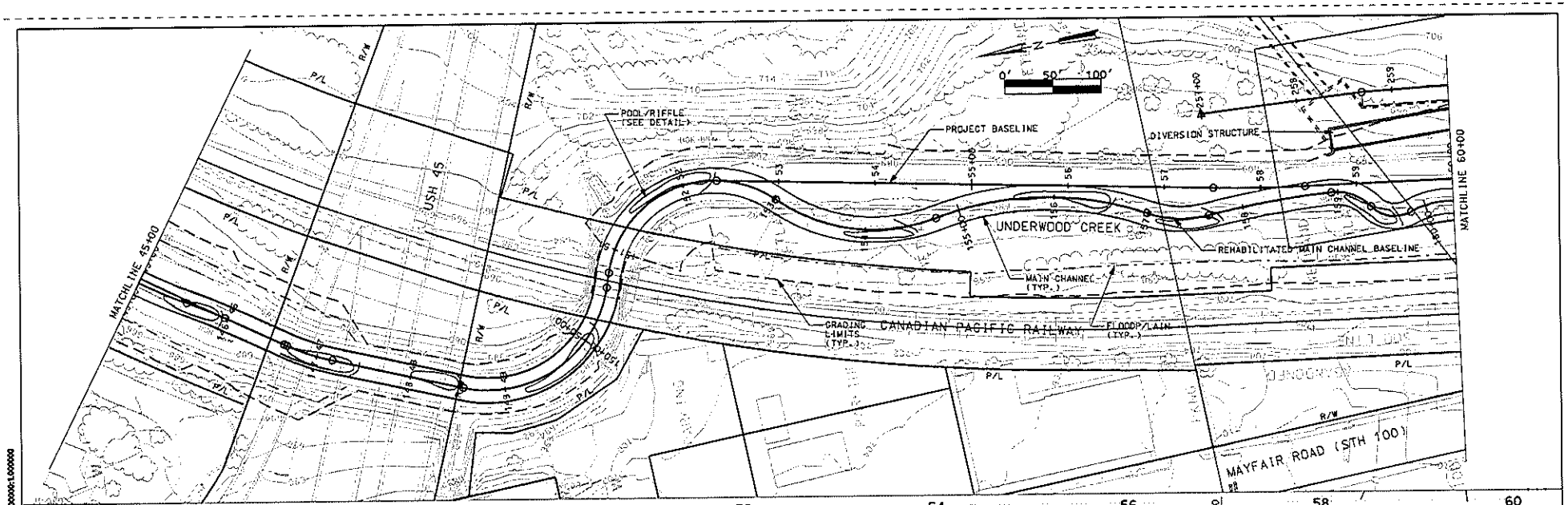
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

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-3
SHEET:	14
DATE:	JANUARY, 2006
CONTRACT:	W21005D01
MMSD FILE:	XXX-XXX.DGN

TIME: 20-JAN-2006 13:54
PLOTTED BY: wstevenson
FILE NAME: I:\W4MT\c\temp-tsm\U-Crk 13-28-08\wl4pp03.dgn
PEN TABLE: L:\config\plot\tsmmd.pen
SCALE: XX.XXXXXX:1.000000



(PRELIMINARY REVIEW)

REUSE OF DOCUMENTS
THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0" 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN
DR
CHK
APVD

This Design Prepared For MMSD By:
TETRA TECH
In Association With the
HNTB

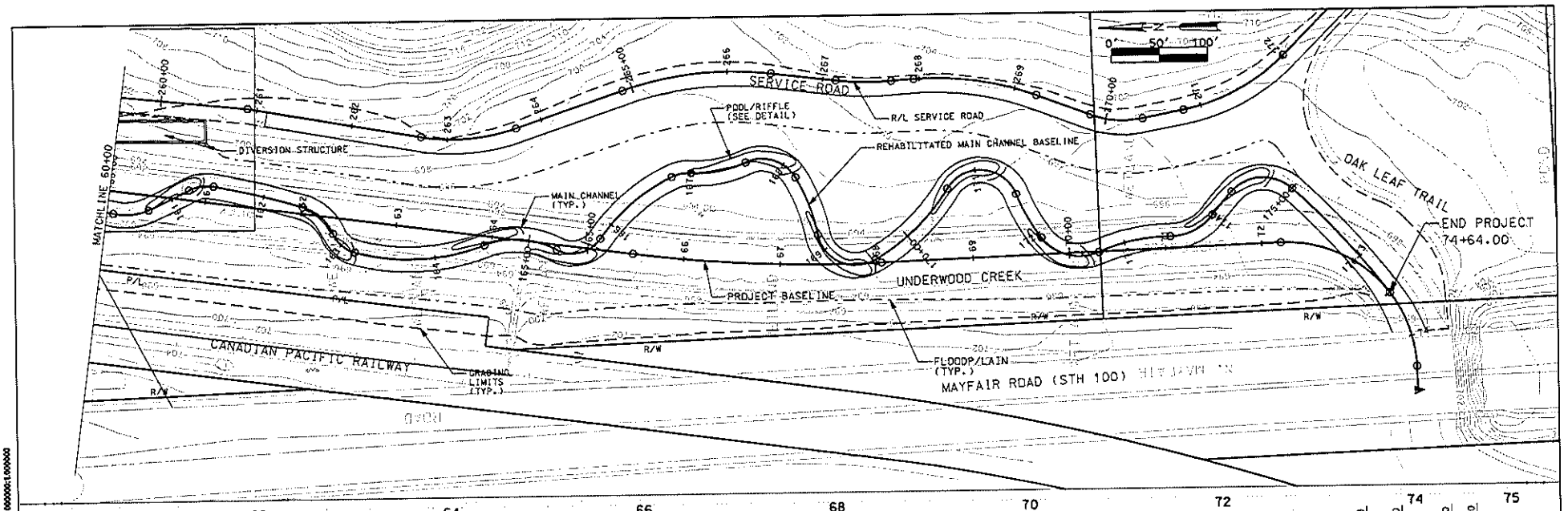
REV. NO.	DATE	REVISION DESCRIPTION	BY	APVD

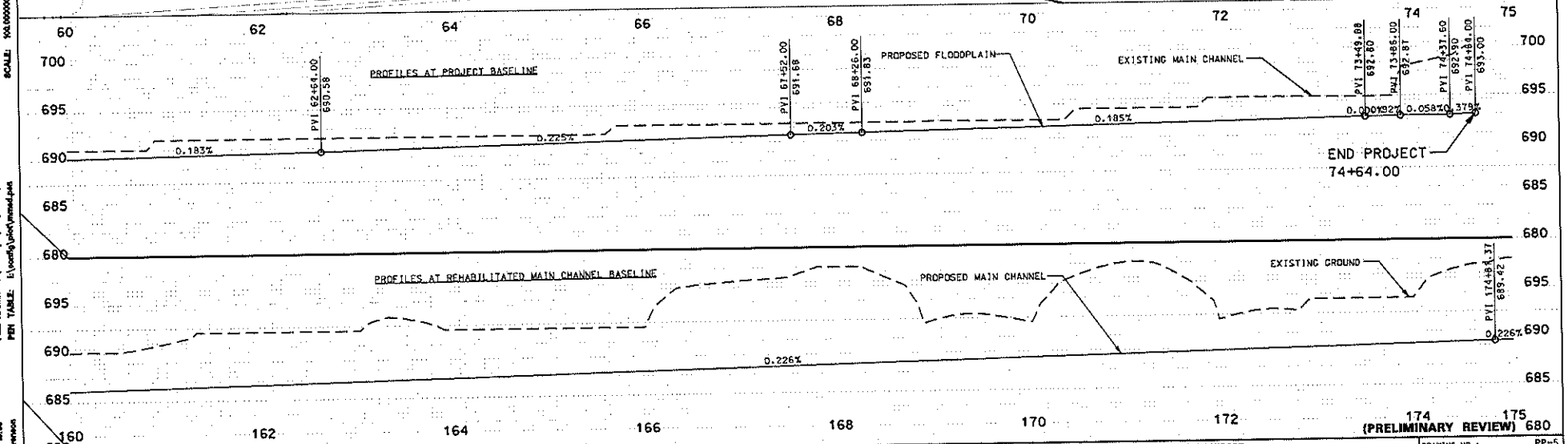
MMSD
Preserving The Environment - Improving Water Quality

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WATERCOURSE
UNDERWOOD CREEK REHABILITATION AND FLOOD MANAGEMENT
PLAN
PLAN AND PROFILE UNDERWOOD CREEK

DRAWING NO.:	PP-4
SHEET:	15
DATE:	JANUARY, 2006
CONTRACT:	W21005001
MMSD FILE:	XXX-XXX.DGN

FILE NAME: I:\MMSD\W\temp-kmm\U-Crk 15-26-04\wrlpp04.dgn
PEN TABLE: I:\config\dot\pnmsd.pen
PLOTTED BY: edmwood
TIME: 20-JAN-2006 13:56
SCALE: XX.XXXXXX:1.000000





(PRELIMINARY REVIEW)

REUSE OF DOCUMENTS
THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN IS AN INSTRUMENT OF PROFESSIONAL SERVICE AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT.

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DSGN | DR | CHK | APVD

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-5
SHEET:	16
DATE:	JANUARY, 2006
CONTRACT:	W21005D01
MMSD FILE:	XXX-XXX.DGN

PLOTTED BY: eatevenson
TIME: 24-JAN-2006 13:58
PEN TABLE: E:\config\pltcfg\mmsd.pen
FILE NAME: I:\W4687\01\temp-tsm\U-C4 12-29-05\ut-pp05.dgn
SCALE: 100.000000:1.000000

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 D

Return Flow Effects on Habitat and Fisheries in Underwood Creek, Menomonee River, and Fox River

Return Flow Effects on Habitat and Fisheries in Underwood Creek, Menomonee River, and Fox River

TO: Waukesha Water Utility

FROM: CH2M HILL

DATE: February 20, 2012

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 and fisheries in Underwood Creek, the Menomonee River, and the Fox 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, allowing aquatic habitat to always be available instead of having intermittent periods when habitat features provide no function because of lack of water.
- 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,

- An increase in wetted perimeter would provide additional substrate for the production of macroinvertebrates, thus improving the quantity of the food base for fish.
- 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.

This study also evaluated the fisheries impacts on the Fox River for a return flow to Underwood Creek. The fish community in the Fox River is fairly diverse with several species indicative of cool water habitats. The cool-water species were surveyed near the mouth of Genesee Creek, a known cold water fishery. In addition, designated State of Wisconsin threatened or species of special concern were present. The flow models suggest a maximum loss of water depth of less than two inches in the Fox River. That flow reduction would have an insignificant impact on the Fox River fisheries.

Introduction

In support of the City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application), 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

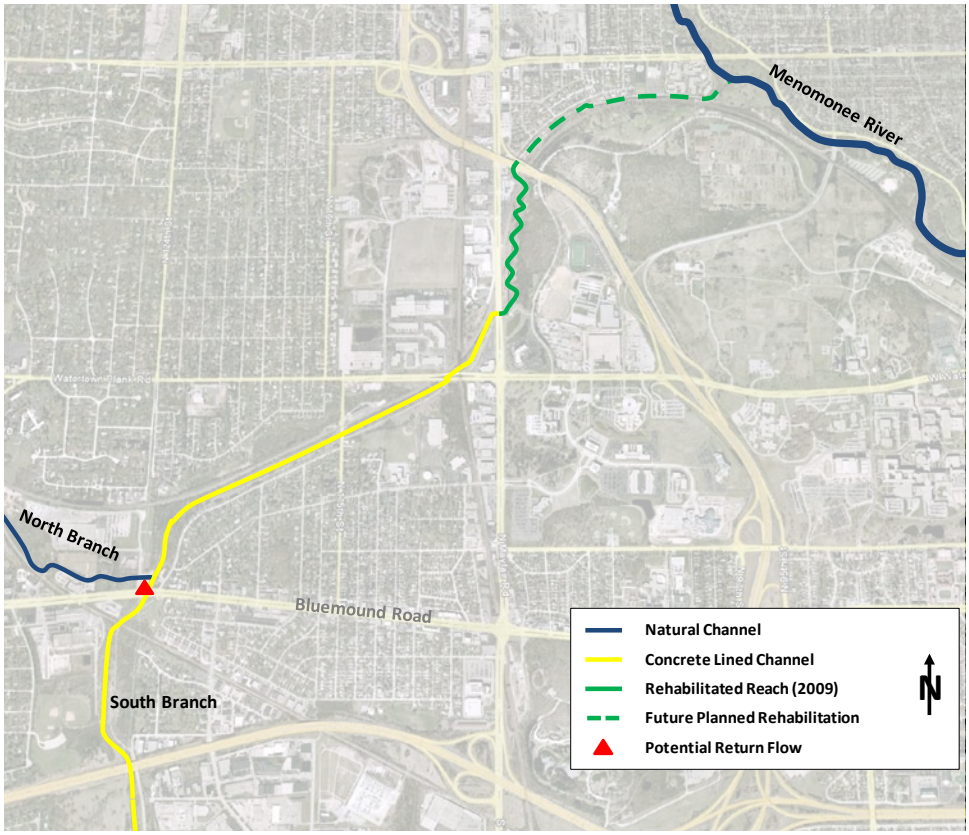


FIGURE 2
Concrete Lining in Underwood Creek



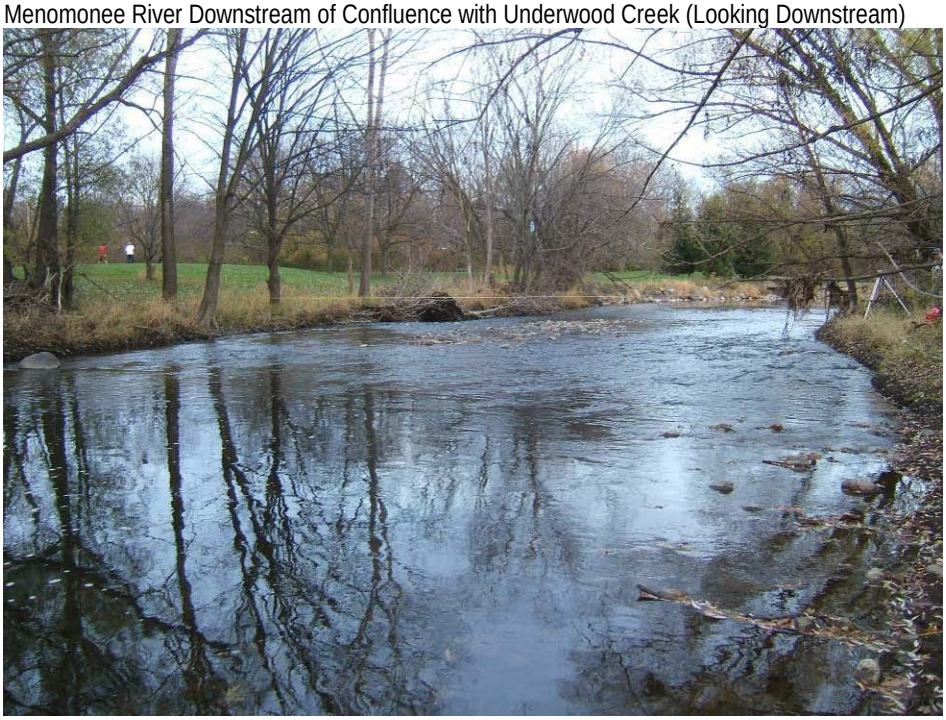
FIGURE 3
Rehabilitated Reach of Underwood Creek (during Construction)



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.

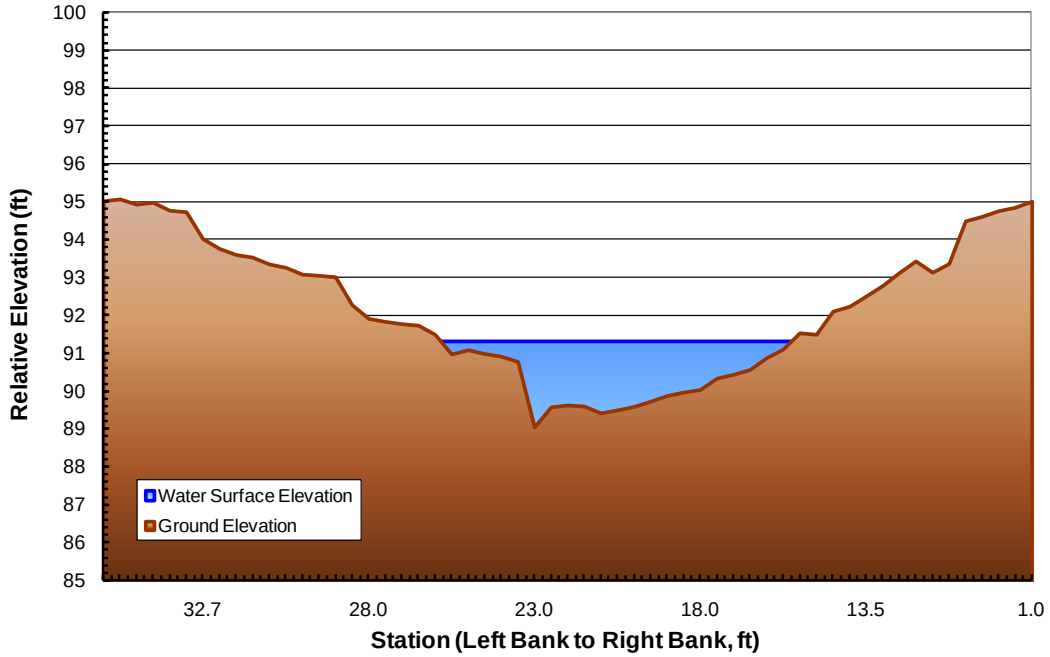
[5] Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Milwaukee Metropolitan Sewerage District, 2001. Computer Model. Modified for newer HEC-RAS model v3.1.3.

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.)

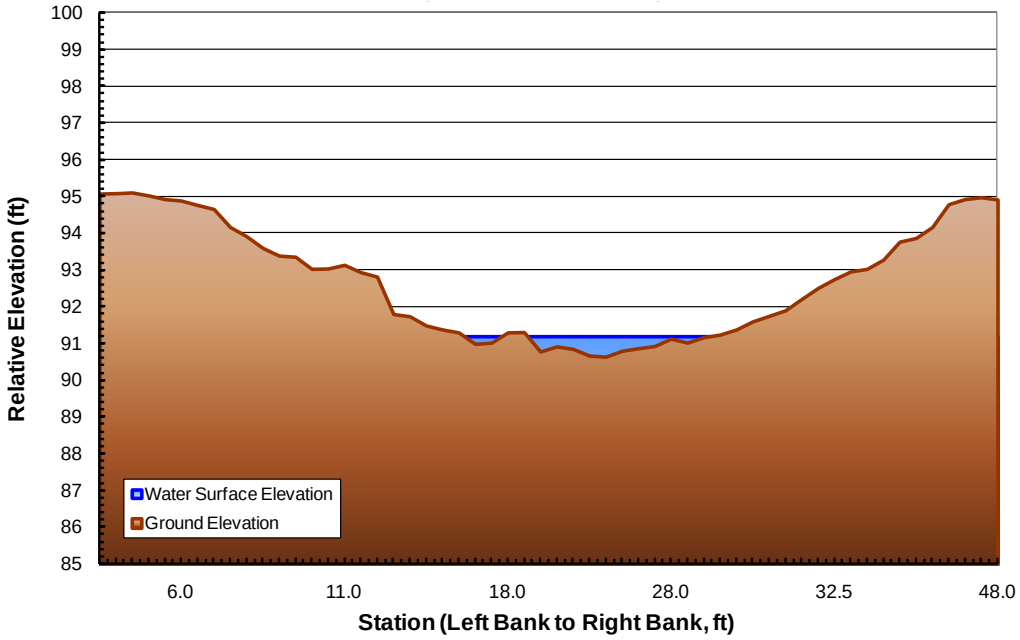
FIGURE 6
Baseflow at a Pool in the Underwood Creek Rehabilitated Reach



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[7], 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.

[7] 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

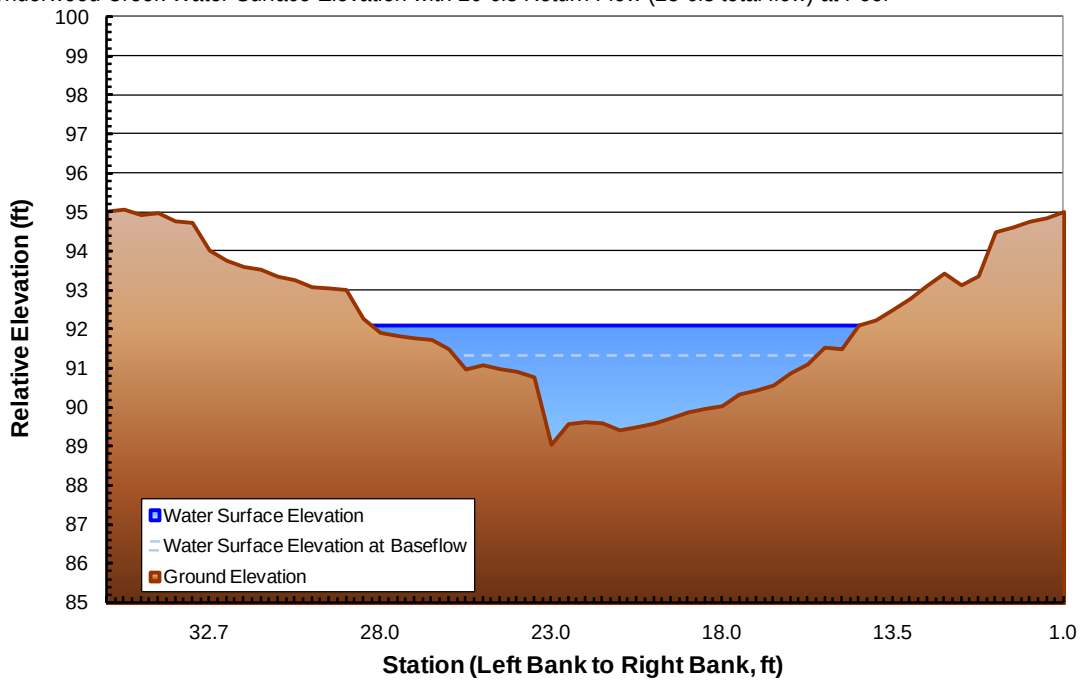


FIGURE 9
Underwood Creek Water Surface Elevation with 20-cfs Return Flow (23-cfs Total Flow) at Riffle-run

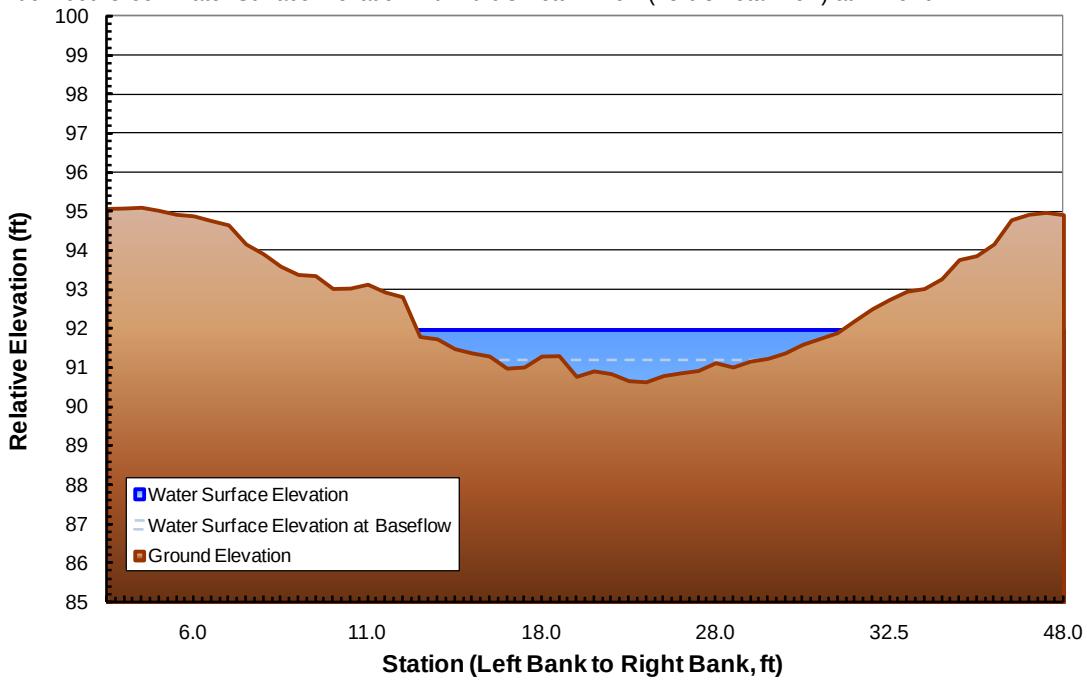


TABLE 1
Underwood Creek Summary Output for Surveyed Cross Sections During Baseflow with Varying Return Flow

		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)[8] 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.

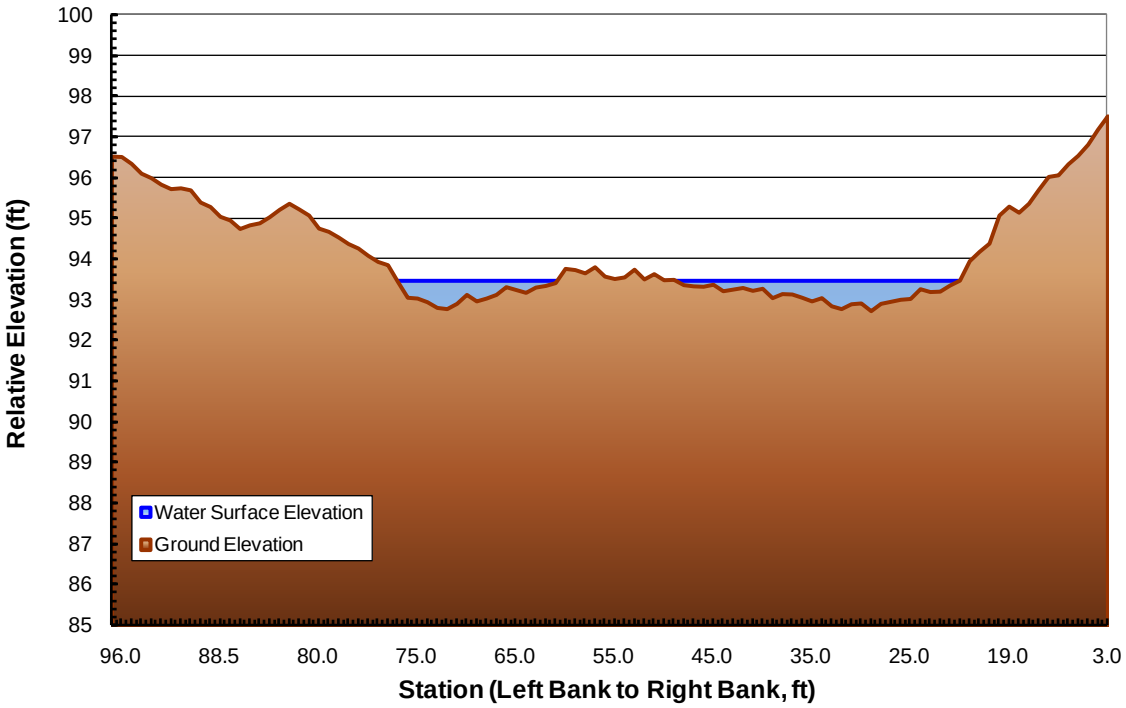
Dominant fish and macroinvertebrates, and associated preferred habitats were identified for these areas (Attachment A). Based on that analysis and the results above, the habitats for the dominant species would most benefit from a return flow during periods of low flow, such as baseflow conditions, and 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.

[8] 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.

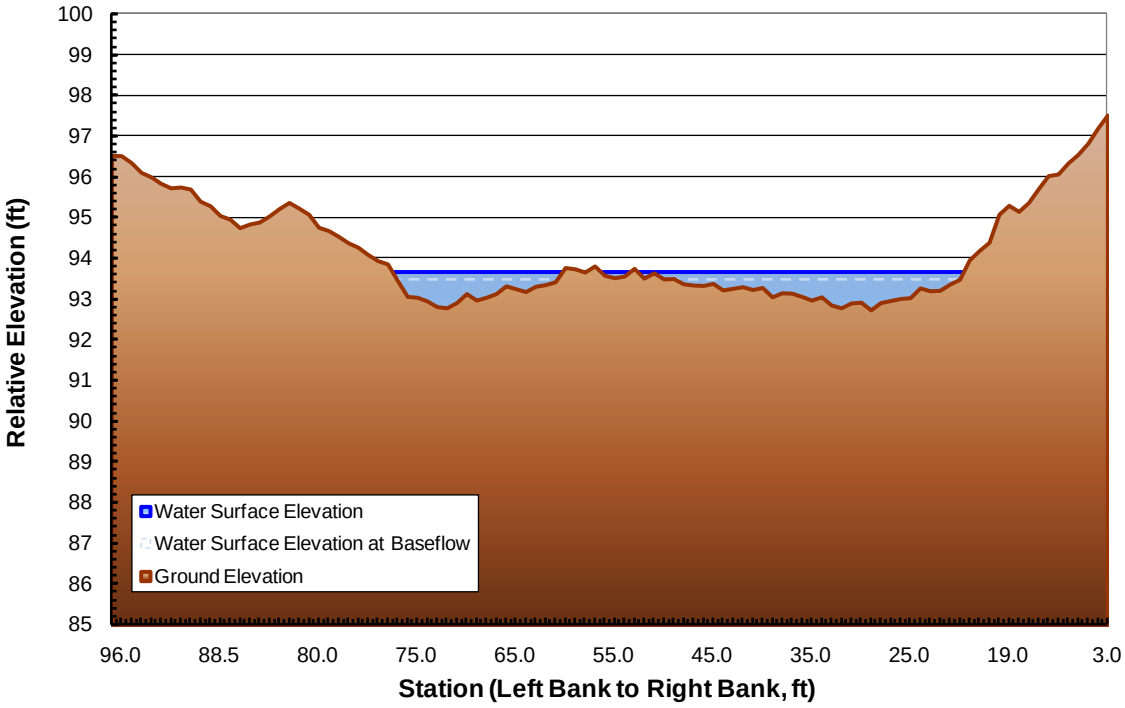
FIGURE 10
Baseflow at Surveyed Riffle Cross Section in the Menomonee River



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)[9] 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 Underwood Creek and Menomonee River (Attachment A). Based on that analysis and the results above, the Underwood Creek and Menomonee River 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.

Return Flow Effect on the Fox River

Dominant fish species and associated flow regimes and preferred habitats were identified for the Fox River near the City of Waukesha's wastewater treatment plant. Changes to the flow regime in the Fox River are summarized in the Return Flow Plan (see Volume 4 of the Application). Changes to the fisheries are included in Attachment B of this document. Based on these analyses, there will be insignificant changes to the Fox River fisheries as a result of return flow.

[9] 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 and Menomonee River Return Flow

Desktop Fisheries Analysis Assessment for Underwood Creek and Menomonee River Return Flow

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: February 20, 2012

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. Exhibit 1 lists the 14 most abundant species collected, along with their preferred habitat characteristics and potential changes to habitat with return flow. Underwood Creek sampling found 12 species. The consolidated information in Exhibit 1 is from information collected from several sources (see Attachment A-1). These species are common in other subwatersheds in the Menomonee River Basin.

EXHIBIT 1
Habitat Characteristic for Dominant Fish Species in Underwood Creek and Menomonee River Near Underwood Creek

Dominant Fish Species	Preferred Current Velocity Range[a]	Stream Gradient[a]	General Habitat Characteristics[a]	Dominant Substrate Preference[a]	Potential Changes to Habitat with Return Flow
Pearl dace	Not documented in reviewed literature	Not documented in reviewed literature	Pools	Sand/gravel	Improved pool depth, especially during low-flow periods. Additional substrate habitat could become available.
Creek chub	Less than 0.98 ft/sec	3 to 23 meters per kilometer (m/km)	Pools	Sand/gravel	Improved pool depth, especially during low-flow periods. Preferred velocity is out of range, but larger pools should offer more refuge. Additional substrate habitat could become available.
White sucker	1.31 ft/sec	Wide range	Wide range	Gravel/sand	Improved preferred current velocity. Additional substrate habitat could become available.
Long nose dace	More than 1.48 ft/sec	1.9 to 18.7 m/km	Riffles	Gravel/rubble	Improved preferred current velocity. Additional substrate habitat could become available.
Blunt nose minnow	Not documented in reviewed literature	Not documented in reviewed literature	Wide range	Gravel/sand	Additional substrate habitat could become available.

EXHIBIT 1
Habitat Characteristic for Dominant Fish Species in Underwood Creek and Menomonee River Near Underwood Creek

Dominant Fish Species	Preferred Current Velocity Range[a]	Stream Gradient[a]	General Habitat Characteristics[a]	Dominant Substrate Preference[a]	Potential Changes to Habitat with Return Flow
Black nose dace	0.49 to 1.48 ft/sec	11.4 to 23.3 m/km	Rocky runs and pools	Gravel/sand	Improved pool depth, especially during low-flow periods. Improvement in preferred current velocity. Additional substrate habitat could become available.
Central stoneroller	Not documented in reviewed literature	Not documented in reviewed literature	Rocky riffles, runs, pools	Gravel/sand/ rubble	Improved pool depth, especially during low-flow periods. Additional substrate habitat could become available.
Common shiner	Not documented in reviewed literature	Not documented in reviewed literature	Rocky pools near riffles	Hard bottom/ gravel/sand/ rubble	Improved pool depth, especially during low-flow periods. Additional substrate habitat could become available.
Fathead minnow	Not documented in reviewed literature	Not documented in reviewed literature	Muddy pools	Sand/rubble/ gravel	Improved pool depth, especially during low-flow periods. Additional substrate habitat could become available.
Largemouth Bass	More than 0.33 ft/sec	Not documented in reviewed literature	Not documented in reviewed literature	Vegetated areas, sand/ gravel/mud	Improved preferred current velocity. Additional substrate habitat could become available.
Green sunfish	Less than 0.33 ft/sec	0.2 to 5.7 m/km	50 percent pool areas	Vegetated cover	Improved pool depth, especially during low-flow periods. Preferred velocity is out of range, but larger pools should offer more refuge. No change in vegetated cover habitat expected.
Johnny darter	Not documented in reviewed literature	Not documented in reviewed literature	Pools	Sand/mud	Improvement pool depth, especially during low-flow periods. Additional substrate habitat could become available.
Bluegill	Less than 0.33 ft/sec	≤ 0.5 m/km	60 percent pool areas	Submerged vegetation/ logs/brush	Improved pool depth, especially during low-flow periods. Preferred velocity is out of range; however, larger pools should offer more refuge. No change in vegetated cover habitat expected.
Central mud minnow	Not documented in reviewed literature	Not documented in reviewed literature	Quiet areas	Soft mud bottom/dense vegetation	Additional substrate habitat could become available.

[a]Main sources of information were Froese and Pauly (2009), Becker (1983), Stuber et al. (1982a and 1982b), McMahon (1982), McMahon and Terrell (1982), Twomey et al. (1984), Trial et al. (1983), Clark (1943), Copes (1978), Hardin and Bovee (1978), Mraz et al. (1961), Page and Burr (1991), Inskip (1982), Hamilton and Nelson (1984).

A search of the Wisconsin Natural Heritage Working List (Wisconsin Department of Natural Resources, 2009) and the WDNR Animals, Plants, and Natural Communities Database identified several threatened, endangered, or species of special concern in

Underwood Creek area (Exhibit 2). Because of the physical habitat limitation within Underwood Creek noted above, it is unlikely any of these species would be present.

EXHIBIT 2
Summary of Return Flow Effects on Habitat Characteristic for Fish Species Identified in WDNR Online Data Base as Threatened, Endangered, and Species of Special Concern in the Vicinity of Underwood Creek, but not Documented as Present in Recent Fish Surveys

Fish Species[a]	Preferred Current Velocity Range	Stream Gradient	General Habitat Characteristics	Dominant Substrate Preference	Potential Changes to Habitat with Return Flow
Striped shiner (endangered)	Not documented in reviewed literature.	Not documented in reviewed literature.	Clear to slightly turbid waters of runs and shallow pools, with dense aquatic vegetation.	Cobble, boulders, silt, sand, mud or bedrock	Preferred habitat for this species is unlikely to exist in this reach of Underwood Creek; therefore no change expected.
Redfin shiner (threatened)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers turbid waters of pools in low-gradient streams.	Boulders, cobble, sand, silt or detritus	Preferred habitat for this species is unlikely to exist in this reach of Underwood Creek; therefore no change expected.
Redside dace (special concern)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers cool water pools and quiet riffles of small streams (usually adjacent to meadows or pastures).	Cobble, sand, clay silt or bedrock	Preferred habitat for this species is unlikely to exist in this reach of Underwood Creek; therefore no change expected.
Lake chubsucker (special concern)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers moderately clear lakes, oxbow lakes, sloughs of weedy lakes and their associated marshy streams.	Organic debris over bottoms of cobble, sand, boulders, mud or silt.	Preferred habitat for this species does not exist in this reach of Underwood Creek; therefore no change expected.
Least darter (special concern	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers clear, warm, quiet waters of overflow ponds, pools, lakes and streams.	Gravel, silt, sand, boulders, mud or clay with dense vegetation or filamentous algal beds	Preferred habitat for this species is unlikely to exist in this reach of Underwood Creek; therefore no change expected.

[a]WDNR. Online Natural Heritage Inventory Database: http://dnr.wi.gov/org/land/er/nhi/CountyElements/.

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

EXHIBIT 4
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 Exhibit 3 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.

EXHIBIT 3
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. Exhibit 4 presents consolidated 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.

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 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 two 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 two feet deep with a cobble bottom. Embeddedness was 25 percent or more.

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: USGS 2007 data; Hilsenhoff 1987 and 1998 HBI methodology

Summary

The fish community in Underwood Creek was limited to 12 of the 20 species found at three 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.

References

Becker, G. C. 1983. *Fishes of Wisconsin*. University of Wisconsin Press, Madison.

Clark, C. F. 1943. "Creek Chub Minnow Propagation." *Ohio Conservation Bulletin.* 7(6): 12–13.

Copes, F. A. 1978. "Ecology of the Creek Chub." University of Wisconsin–Stevens Point, *Museum of Natural History Report on Fauna and Flora of Wisconsin*. No. 12.

Froese, R., and D. Pauly, ed. 2009. FishBase. www.fishbase.org. Accessed September, 2009.

Hamilton, K., and P. C. Nelson. 1984. *Habitat Suitability Index Models and Instream Flow Suitability Curves: White Bass.* U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.89.

Hardin, T., and K. Bovee. 1978. Largemouth bass. Instream Flow Group, U.S. Fish Wildlife Service, Western Energy and Land Use Team, Ft. Collins, Colorado. Unpublished data.

Hilsenhoff, W. L. 1987. "An Improved Biotic Index of Organic Stream Pollution." *Great Lakes Entomologist.* v. 20, no. 1, pp. 31–40.

Hilsenhoff, W. L. 1998. A Modification of the Biotic Index of Organic Stream Pollution to Remedy Problems and Permit Its Use Throughout the Year." *Great Lakes Entomologist.* v. 31, no. 1, pp. 1–12.

Inskip, P. D. 1982. Habitat Suitability Index Models: Northern Pike. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.17.

Lyons, John. 1992. *Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin.* St. Paul, Minn., U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, 48 p.

McMahon, T. E. 1982. Habitat Suitability Index Models: Creek Chub. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.4.

McMahon, T. E., and J. W. Terrell. 1982. Habitat Suitability Index Models: Channel Catfish. U.S. Department of the Interior–Fish and Wildlife Service. FWS/OBS-82/10.2.

Mraz, D., S. Kmiotek, and L. Frankenberger. 1961. *The Largemouth Bass, Its Life History, Ecology, and Management.* Wisconsin Conserv. Dept. Publ. 232.

Page, L. M., and B. M. Burr. 1991. *A Field Guide to Freshwater Fishes of North America North of Mexico*. Houghton Mifflin Company, Boston.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982a. Habitat Suitability Index Models: Bluegill. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.8.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982b. Habitat Suitability Index Models: Largemouth Bass. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.16.

Thomas, J. C., M. A. Lutz, et al. 2007. *Water-Quality Characteristics for Selected Sites within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, February 2004–September 2005.* U.S. Geological Survey Scientific Investigations Report 2007–5084, 187 p.

Trial, J. G., C. S. Wade, J. G. Stanley, and P. C. Nelson. 1983. Habitat Suitability Index Models: Common Shiner. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.40.

Twomey, K. A., K. L. Williamson, and P.C. Nelson. 1984. Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker. U.S. Department of the Interior–Fish and Wildlife Service. FWS/OBS-82/10.64.

Wisconsin Department of Natural Resources. 2009. Wisconsin Natural Heritage Working List. Wisconsin Natural Heritage Program—Bureau of Endangered Resources.

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).

References

Adams, C., and T. L. Hankinson. 1928. The ecology and economics of Oneida lake fish. *Roosevelt Wildl. Ann.* 1(3, 4): 235-548.

Barber, W.E. and W. L. Minckley. 1971. Summer foods of the cyprinid fish *Semotilus atromaculatus*. *Trans. Am. Fish. Soc.* 100(2): 283–89.

Bartnik, V. G. 1972. Comparison of the breeding habitats of two subspecies of longnose dace, *Rhinichthys cataractae*. *Can. J. Zool.* 50: 83–86.

Bartnik, V.G. 1970 Reproductive isolation between two sympatric dace, *Rhinichthys atratulus* and *Rhinichthys cataractae*, in Manitoba. *J. Fish. Res. Bd. Can.* 27:2125–41.

Becker, G. C. 1983. *Fishes of Wisconsin.* University of Wisconsin Press, Madison. 1052p.

Billard, R. 1997. *Les poissons d'eau douce des rivières de France.* Identification, inventaire et répartition des 83 espèces. Lausanne, Delachaux & Niestlé, 192p.

Breder, C.M., and D. E. Rosen 1966 Modes of reproduction in fishes. T.F.H. Publications, Neptune City, New Jersey. 941 p.

Burton, G W., and E. P. Odum. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. *Ecology* 26: 182–94.

Calabrese, A. 1969. Effects of acid and alkalies on survival of bluegills and largemouth bass. *U.S. Dept. Int. Bur. Sport Fish. Wildl. Tech.* Pap. 42:2–10.

Clark, C.F. 1943. Creek chub minnow propogation. *Ohio Conserv. Bull.* 7(6): 12–13.

Coker, G.A., C.B. Portt and C.K. Minns. 2001. *Morphological and ecological characteristics of Canadian freshwater fishes.* Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2554. 89p.

Copes, F.A. 1978. Ecology of the creek chub. Univ. Wisc., Stevens Point, Mus. Nat. Hist. Rept. On Fauna and Flora of Wis. No. 12. 21p.

Cross, F. 1954. Fishes of Cedar Creek and the South Fork of the Cottonwood River, Chase County, Kansas. Trans. Kans. Acad. Sci. 57: 303–14.

Cross. F. 1967. Handbook of fishes of Kansas. Univ. Kansas. Mus. Nat. Hist Misc. Publ. 45. 357 p.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24: 631-641.

Gee, J. H., and T. G. Northcote. 1963. Comparative ecology of two sympatric species of dace *Rhinichthys* in the Fraser River system, British Columbia. J. Fish. Res. Board Can. 20: 105-118.

Dudley, R. G. 1969. Survival of largemouth bass embryos at low dissolved oxygen concentrations. M.S. Thesis, Cornell Univ., Ithaca, New York, 61 pp.

Edwards, E. A., H. Li, and C. B. Schreck. 1983. Habitat suitability index models: Longnose dace. U. S. Dept. Int., Fish Wildl. Derv. FWS/OBS-82/10.33. 13 pp.

Froese, R. and D. Pauly. Editors. 2009. FishBase. World Wide Web electronic publication. www. Fishbase. Org. version (09/2009).

Funk, J.L. 1975a. The fishery of Black River, Missouri, 1947-1957. Missouri Dept. Conserv. Aquatic Ser. 12. 22p.

Funk, J. L. 1975b. The fishery of Gasconade River, Missouri, 1947-1957. Missouri Dept. Conserv. Aquatic Ser. 13 26p.

Gibbons, J. R. H., and J. H. Gee. 1972. Ecological separation between longnose and blacknose dace (genus *Rhinichthys*) in the Mink River, Manitoba. J. Fish. Res. Board Can. 29: 1245-1252.

Hardin, T., and K. Bovee. 1978. Largemouth bass. Instream Flow Group, U.S. Fish Wildl. Serv., Western Energy and Land Use Team, Ft. Collins, Colorado. Unpublished data.

Harlan, J. R., and E. B. Speaker. 1951. Iowa fish and fishing, 2nd ed. Iowa Conserv. Comm. 238p.

Harlan, J.R., and E.B. Speaker. 1956. Iowa Fish and Fishing. 3rd Ed. State of Iowa. 377 p.

Harvey, H. 1980. Widespread and diverse changes in the biota of North American lakes and rivers coincident with acidification. Pages 93-98 in Drablos and Tollan, eds. Proceedings of the International Conference on ecological impact of acis precipation - effects on forest and fish project, Aas, Norway. 383p.

Hassan-Williams, C. and T.H. Bonner. Photographs by C. Thomas 2007 Texas freshwater fishes. Texas State University- San Marcos: Biology Department/ Aquatic Station.

Held, J.W. and J.J. Peterka 1974 Age, growth and food habits of the fathead minnow, *Pimephales promelas*, in North Dakota saline lakes. Trans. Am. Fish. Soc. 103:743-756.

Hubbs, C. L., and K. F. Lagler. 1958. Fishes of the Great Lakes region. Univ. Michigan Press, Ann Arbor. 213 pp.

Heman, M. L., R. S. Campbell, and L. C. Redmond. 1969. Manipulation of fish populations through reservoir drawdown. Trans. Am. Fish. Soc. 98:293-304.

Hocutt, C.H. and J.R. Stauffer. 1975. Influence of gradient on the distribution of fishes in Conowingo Creek, Maryland and Pennsylvania. Chesapeake Sci. 16(1): 143-147.

Hynes, H.B.N. 1970. The ecology of running waters. Univ. Toronto Press, Canada. 555p.

Jenkins, R. M., and J. C. Finnell. 1957. The fishery resources of the Verdigris River in Oklahoma. Oklahoma Fish. Res. Lab. Rep. 59. 46p.

Jenkins, R. M., E. M. Leonard, and G. E. Hall. 1952. An investigation of the fisheries resources of the Illinois River and pre-impoundment study of Tenkiller Reservoir, Oklahoma. Oaklahoma Fish. Res. Lab. Rep. 26. 136p.

Kallemeyn, L. W., and J. F. Novotny. 1977. Fish and fish food organisms in various habitats of the Missouri River in South Dakota, Nebraska, and Iowa. USDI Fish Wildl. Serv., FWS/OBS-77/25.

Klinger, S. A., J. J. Magnuson and G. W. Gallepp 1982 Survival mechanisms of the central mudminnow (*Umbra limi*), fathead minnow (*Pimephales promelas*) and brook stickleback (*Culaea inconstans*) for low oxygen in winter. *Environ. Biol. Fish.* 7:113–20.

Kuehn, J. H. 1949. A study od a population of longnose dace (*Rhinichthys cataractae*). Proc. of the Minn. Acad Sci. 17: 81–87.

Kuehn, R. A. 1962. A classification of streams, illustrated by fish distributions in eastern Kentucky creek. *Ecology* 43 (4): 608–14.

Lee, D. S., C. R Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer. 1980. Atlas of North American Freahwater Fishes. North Carolina Biol. Surv. Publ. 1980-12. 854p.

McMahon, T. E. 1982. Habitat suitability index models: Creek chub. U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.4. 23 pp.

Miller, R. J. 1975. Comparative behavior of centrarchid basses. Pages 85-94 in H. Clepper, ed. Black bass biology and management. Sport Fish. Inst., Washington, D. C.

Moore, W. G. 1942. Field studies on the oxygen requirements of certain fresh-water fishes. Ecology 23: 319-329.

Moshenko, R. W. and J. H. Gee. 1973. Diet, time and place of spawning , and environments occupied by creek chub (*Semotilus atromaculatus*) in Mink River, Manitoba. *J. Fish Resh. Board Can.* 30(3): 357–62.

Mraz, D., and E. L. Copper. 1957. Reproduction of carp, largemouth bass, bluegills, and black crappies in small rearing ponds. *J. Wildl. Manage.* 21: 127–33.

Mraz, D., S. Kmiotek, and L. Frankenberger. 1961. The largemouth bass, its life history, ecology, and management. Wisconsin Conserv. Dept. Publ. 232. 15 p.

Moyle, P. B., and R. D. Nichols. 1973. Ecology of some native and introduced fishes of the Sierra Nevada foothills in central California. *Copeia* 1973: 478–90.

Newell, A. E. 1960. Biological sirvey of the lakes and ponds in Coos, Grafton, and Carrolll Counties. New Hampshire Fish Game Surv. Rep. 8a. 297 pp.

Page, L. 1983 Handbook of darters. T.F.H. Publications, Inc. USA. 271 p.

Page, L.M. and B.M. Burr 1991 A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Company, Boston. 432 p.

Petit, G. D. 1973. Effects of dissolved oxygen on survival and behavior of selected fishes of western Lake Erie. Ohio Biol. Surv. Bull. 4 (4): 1-76.

Reed, R. J. 1959. Age, growth, and food of the longnose dace, *Rhinichthys cataractae*, in northern Pennsylvania. *Copeia* 1959: 160–62.

Reed, R. J., and J. C. Moulton. 1973. Age and growth of blacknose dace *Rhinichthys atratulus,* and longnose dace *Rhinichthys cataractae*, in Massachusetts. Am. Midl. Nat. 90: 206–10.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and W.B. Scott 1991 Common and scientific names of fishes from the United States and Canada. *Am. Fish. Soc. Spec. Pub.* (20):183 p.

Robinson, D.W. 1961. Utilization of spawning box by bass. *Prog. Fish-Cult.* 23:119.

Saiki, M. K., and J. C. Tash. 1979. Use of cover and dispersal by crayfish to reduce predation by largemouth bass. Pages 44-48 In D.L. Johnson and R.A. Stein, eds. Response of fish to habitat structure in standing water. N. Central Div. Am. Fish. Soc. Spec. Publ. 6.

Scarola, J. F. 1973. *Freshwater fishes of New Hampshire.* N. H. Fish Game Dept., Concord. 13p.

Scott, W.B. and E.J. Crossman 1973 Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184:1-966.

Stroud, R.H. 1967. Water quality criteria to protect aquatic life: a summary. Am. Fish. Soc. Spec. Publ. 4: 33-37.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982a. Habitat suitability index models: Bluegill. U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.8. 26pp.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982b. Habitat suitability index models: Largemouth bass. U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.16. 32pp.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982c. Habitat suitability index models: Green sunfish. U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.15. 28pp.

Swingle, H. S., and E. V. Smith. 1943. Factors affecting the reproduction of bluegill bream and largemouth black bass in ponds. Alabama Polytech. Inst. Agric. Exp. Stn. Circ. 87. 8 pp.

Trama, F. 1954. The pH tolerance of the common bluegill (*Lepomis macrochirus Rafinesque*). *Notulae Nat.* 256: 1–13.

Trautman, M.B. 1957. The Fishes of Ohio. Ohio State University Press, Columbus. 683p.

Traver, J. R. 1929. The habitats of the blacknose dace, *Rhinichthys atratulus* (Mitchell). *J. Elisha Mitchell Sci. Soc.* 45 (1): 101–29.

Trial, J. G., C. S. Wade, J. G. Stanley, and P. C. Nelson. 1983. Habitat suitability index models: Common shiner. U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.40. 22pp.

Twomey, K. A., K. L. Williamson, and P.C. Nelson. 1984. *Habitat suitability index models and instream flow suitability curves: White sucker.* U. S. D. I. Fish and Wildlife Service. FWS/OBS-82/ 10.64. 56pp.

Ultsch, G. R. 1978. Oxygen consumption as a function of pH in three species of freshwater fishes. *Copeia* 1978: 272–79.

Welcomme, R. L. 1988 *The fishes of Tennessee*. The University of Tennessee Press, Knoxville, Tennessee, USA.

Welcomme, R. L. 1988 International introductions of inland aquatic species. FAO Fish. Tech. Pap. 294. 318 p.

Attachment B

Fox River Fisheries Analysis

Fox River Fisheries Analysis

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: February 20, 2012

This memorandum presents a review of Wisconsin Department of Natural Resources (WDNR) fisheries data collected from the Fox River downstream of the City of Waukesha wastewater treatment plant (WWTP) discharge. The objective of this memorandum is to evaluate the impacts to fish species in the Fox River if the City's WWTP were to reduce, or at times eliminate, its discharge to the Fox River. A change in flow in the Fox River from its current flow regime would occur when return flow is provided for a Lake Michigan water supply.[1] This memorandum summarizes first the hydraulic changes in the Fox River with return flow to Lake Michigan, then the Fox River fisheries impacts with return flow. For a Lake Michigan water supply, the current WWTP discharge to the Fox River will be redirected according to the Return Flow Management Plan to instead be returned to the Great Lakes basin. For a non-Lake Michigan water supply, the current WWTP discharge to the Fox River will continue.

Fox River Hydrology

A stage-discharge rating table was obtained from the USGS[2] for the Fox River gage in downtown Waukesha (USGS gage 05543830). The data were plotted and fit with two polynomial best-fit trendlines. One trendline was for flows less than 43 cubic feet per second, the other for flows greater than 43 cfs. The following two trendlines were needed because the data had different patterns above and below 43 cfs where a single trendline would not provide as accurate interpolation results.

Fox River Flow ≤ 43 cfs:

$$\text{Gage Height (ft)} = -0.000229x^2 + 0.021359x + 2.30124$$

$$x = \text{Fox River flow, cfs}$$

Fox River Flow > 43 cfs:

$$\text{Gage Height (ft)} = 3.3110\text{E-}17x^5 - 3.9901\text{E-}13x^4 + 1.6212\text{E-}09x^3 - 3.1431\text{E-}06x^2 + 5.3123\text{E-}03x + 2.6133$$

$$x = \text{Fox River flow, cfs}$$

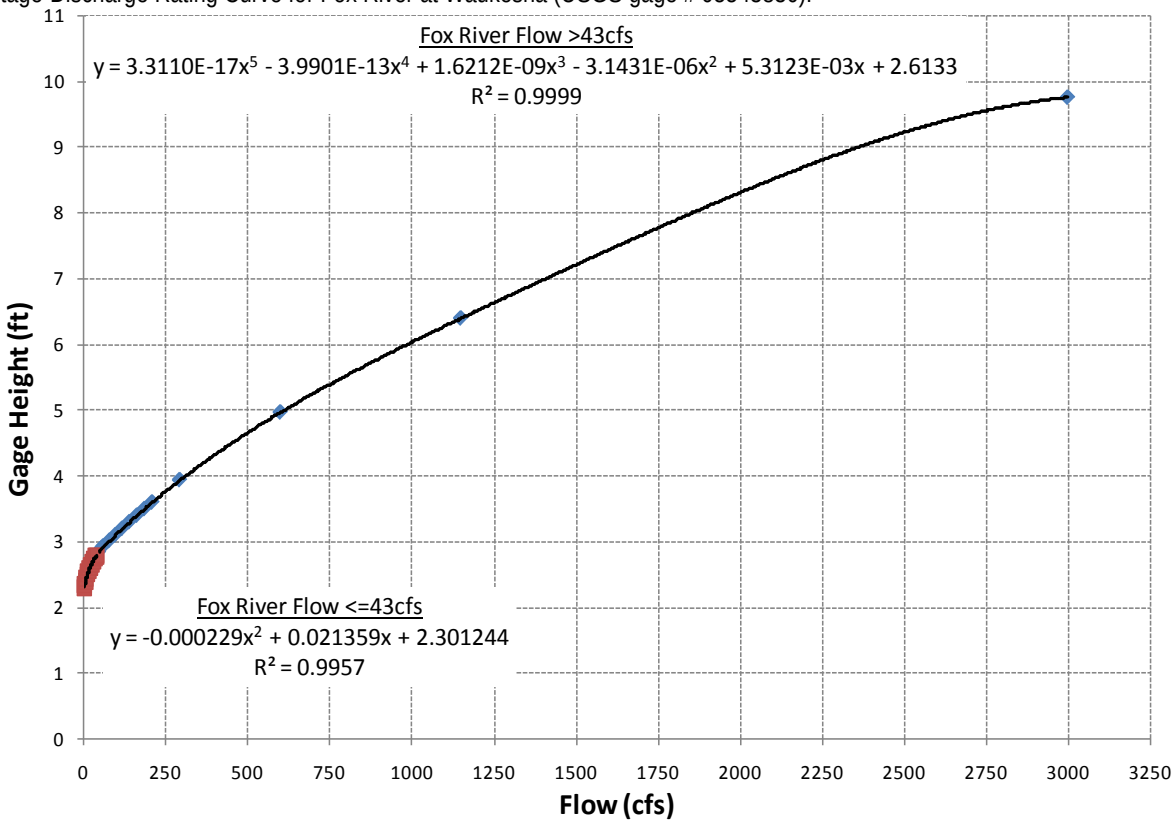
The rating table data points and best-fit trendlines are shown in Exhibit 1. The r-squared correlation coefficients of the best-fit trendlines were 0.9957 and 0.9999, which suggest a

[1] Return flow does not affect tributaries to the Fox River, such as Pebble Creek, Pebble Brook, and Mill Brook. For information on flow impacts to the Fox River and the tributaries for water supply alternatives that do not include Lake Michigan (and consequently do not have return flow), refer to the Environmental Report for Water Supply Alternatives (see Volume 5 of The City of Waukesha Application for Lake Michigan Diversion with Return Flow).

[2] Provided by the USGS by email. January 13, 2011.

strong relationship between the gage data and best-fit lines. Therefore the two trendlines were used to estimate gage heights for different Fox River flow rates.

EXHIBIT 1
Stage-Discharge Rating Curve for Fox River at Waukesha (USGS gage # 05543830).



USGS flow gage information was obtained for years 2005 and 2008 to determine the effect that the return flow management plan has on water depths and flow rates in the Fox River. The year 2005 was selected because it was a relatively dry year in recent past. The year 2008 was selected because it was a relatively wet year in recent past. Using these two years provides a range of water depth and flow changes that could be similar in range for future years. The stage-discharge best-fit trendline equations were applied to the average daily Fox River flows[3] for each day of the years 2005 and 2008, to estimate the water level with and without the Waukesha WWTP discharge.

The gage heights were subtracted from each other to estimate the water level change in the Fox River during years 2005 and 2008 as a result of the return flow management plan. The maximum difference in Fox River depth as a result of the return flow management plan is 1.74 inches during the "dry" year 2005 and 1.20 inches in the "wet" year 2008 (Exhibit 2). The flow difference in the Fox River with and without return flow to Underwood Creek is shown in graphical and tabular format in the Return Flow Plan (see Volume 4 of The City of Waukesha Application for Lake Michigan Diversion with Return Flow).

[3] The average daily Fox River flow rates for 2005 and 2008 were developed for a scenario with and without a Lake Michigan water supply. The flow rates are summarized in the Return Flow Plan, Volume 4 of The City of Waukesha Application for Lake Michigan Diversion with Return Flow.

EXHIBIT 2
Difference in Fox River Depth and Flow Rate with and without a Lake Michigan Water Supply

	2005 (dry year)		2008 (wet year)	
	Depth (in.)	Flow (cfs)	Depth (in.)	Flow (cfs)
Maximum difference	1.74	13.8	1.20	12.3
Minimum difference	0.54	9.8	0.00	0.0
Average difference	0.94	12.7	0.63	11.9

The results of the Fox River hydrology analysis indicates that the change in surface water height in the Fox River at the USGS gage would be less than two inches with the largest change in flow depth equal to 1.74 inches during these years. The flow change estimated in the Fox River was as high as 13.8 cubic feet per second (cfs) in 2005 and 12.3 cfs in 2008. This flow depth change is considered to be negligible.

Fox River Fisheries

Fisheries information for the Fox River downstream of the WWTP was obtained from the WDNR (WDNR 2011). The data were collected along roughly 2 miles of the Fox River between County Highway I and the confluence of Genesee Creek, about 6 miles downstream of the Waukesha WWTP discharge (Exhibit 3). Exhibit 4 shows the approximate sampling locations relative to the WWTP. Fishery surveys were conducted in 1999, 2000, 2003, 2004, and 2006 (Exhibit 5).

EXHIBIT 3
Location of WDNR Fox River Survey Site Numbers and Year of Survey

WDNR Site Number	Survey Number	Year	Location
62121	2664	1999	At confluence with Genesee Creek.
62129	2663	1999	0.6 river mile east of Site #62121.
62245	2608	1999	Upstream of County Hwy I.
62605	2609	2000	
	52059	2003	
	92051	2004	
	92253	2006	

Note: The WDNR lists Genesee Creek as an exceptional resource water and cold water fishery (WDNR, 2002).

The surveys identified 36 species of fish (Exhibit 5). The most abundant species collected were golden redhorse, common carp, bluegill, channel catfish, largemouth bass, white bass, northern pike, rock bass, common shiner, sand shiner, bluntnose minnow, emerald shiner, longnose gar, white sucker, and creek chub. Most are considered warm water species, although they may also be found in cool water habitats. The greater redhorse, a designated threatened species, also was collected in this stream reach. Several coldwater species (brook and brown trout) were noted at the confluence of Genesee Creek (a cold water fishery) and Fox River but were only present in small numbers.

EXHIBIT 4
Approximate Fish Sampling Locations Relative to the WWTP

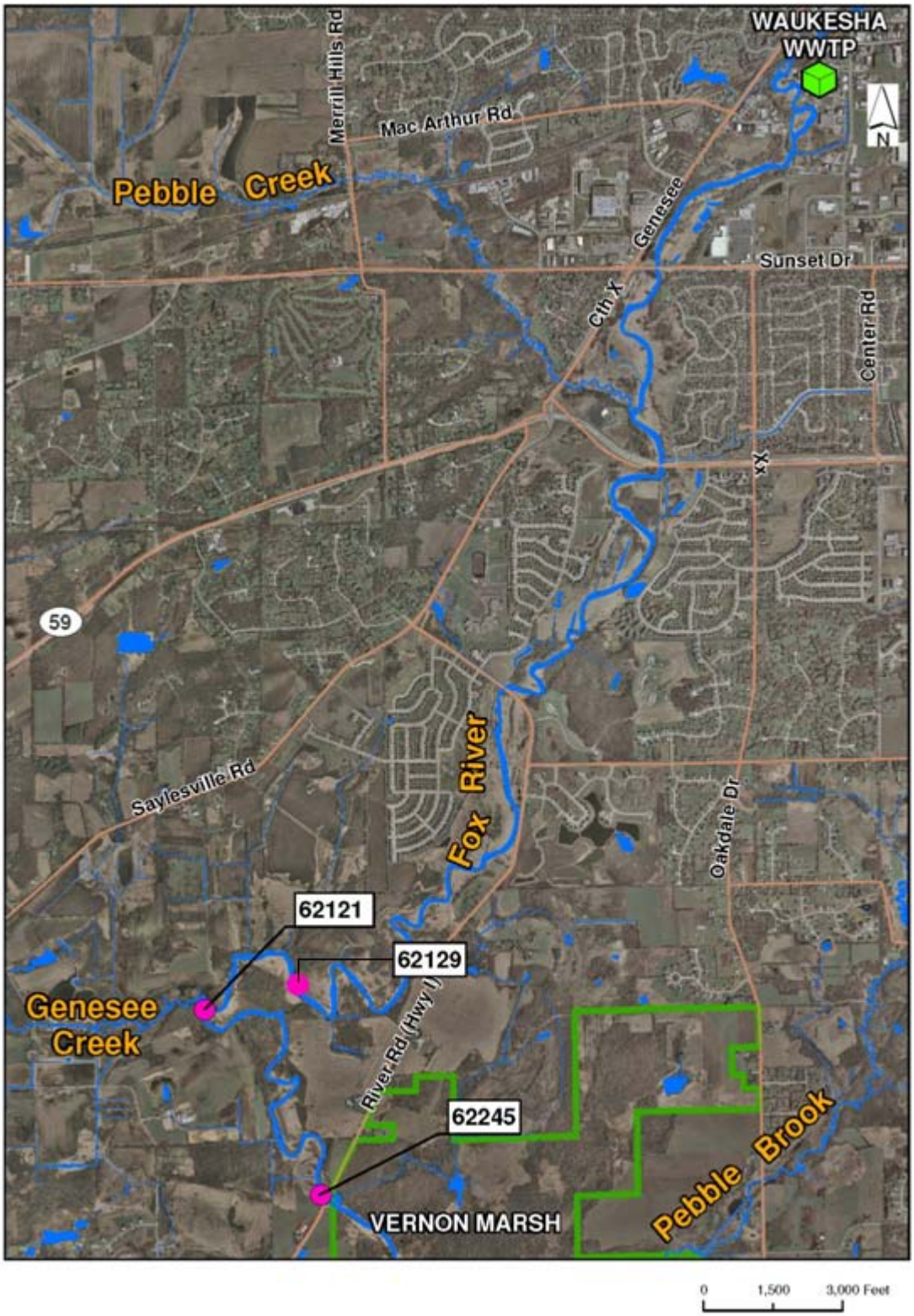


EXHIBIT 5
Fisheries Data from WDNR Surveys in the Fox River Downstream of the Waukesha WWTP

	WDNR Site Numbers			
Species	**62121**	**62129**	**62245**	**62605**
Bigmouth shiner				X
Black bullhead			X	
Black crappie			X	
Blackstripe topminnow				X
Bluegill			X	X
Bluntnose minnow				X
Bowfin				X
Brook silverside				X
Brook trout	X	X		
Brown trout	X	X		
Central mudminnow	X	X		X
Central stoneroller				X
Channel catfish			X	X
Common carp			X	X
Creek chub	X	X		X
Emerald shiner				X
Golden redhorse			X	X
Grass pickerel	X			X
Greater redhorse			X	X
Green sunfish				X
Johnny darter				X
Largemouth bass	X			X
Longnose gar				X
Mottled sculpin	X	X		
Northern pike			X	X
Pumpkinseed			X	X
Quilback				X
Rock bass			X	X
Sand shiner				X
Spotfin shiner				X
Walleye				X
White bass				X
White sucker	X	X		X
Yellow bass				X
Yellow perch				X

In addition to the WDNR surveys, a fish survey was conducted at the confluence of the Fox River and Pebble Creek (Waukesha County Department of Parks and Southeastern Wisconsin Regional Planning Commission 2008), 1.65 miles downstream of the Waukesha WWTP. Many species were the same as those collected in the WDNR surveys, but several others not found farther downstream in the Fox River were collected. These included brook stickleback, spottail shiner, banded killifish, golden shiner, longear sunfish, orange-spotted sunfish, starhead topminnow, and tadpole madtom. The additional species are all warm water species except for the brook stickleback which is a cool water species. The longear sunfish is a designated threatened species in Wisconsin. The starhead topminnow and banded killifish are special species of concern.

Potential Impacts

The flow difference in the Fox River with and without return flow to Underwood Creek is shown in graphical and tabular format in Return Flow Plan (see Volume 4 of the Application).

As noted, stopping Waukesha WWTP discharge to the Fox River as part of the return flow requirement for a Lake Michigan water supply was predicted to reduce the water depth in the Fox River by less than two inches. This small reduction in depth is not expected to have a significant impact on the fishery. The individual fish habitat requirements for dominant species (Exhibit 6) and threatened and endangered species (Exhibits 7 and 8) generally would still be met. Exhibit 7 includes cold water as well as threatened and endangered species found during surveys used for this analysis while Exhibit 8 includes threatened and endangered species not found during the surveys, but included in the NHI list of species potentially in the vicinity. No significant impacts to these species are expected.

Summary

The fish community in the Fox River is fairly diverse with several species indicative of cool water habitats. The cool-water species were surveyed near the mouth of Genesee Creek, a known cold water fishery. In addition, designated State of Wisconsin threatened or species of special concern were present. The flow models suggest a maximum loss of water depth of less than two inches in the Fox River. That flow reduction would have an insignificant impact on the Fox River fisheries.

EXHIBIT 6
Summary of Return Flow Effects on Habitat Characteristics for Dominant Fish Species in Fox River

Dominant Fish Species	Preferred Current Velocity Range[a]	Stream Gradient[a]	General Habitat Characteristics[a]	Dominant Substrate Preference[a]	Potential Changes to Habitat with Return Flow
Channel catfish	Wide range	Not documented in reviewed literature	Wide range	Mud / sand / clay / gravel	With the wide range of preferred velocities, habitat characteristics, and substrate preference, no significant changes are expected.
Creek chub	< 0.98 ft/sec	3–23 m/km	Pools	Sand / gravel	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
White sucker	1.31 ft/sec	Wide Range	Wide Range	Gravel / sand	With the wide range of preferred habitat characteristics and substrate preference, no significant changes are expected.
Golden redhorse	Not documented in reviewed literature	Not documented in reviewed literature	Pools in river bends	Sand / gravel	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Bluntnose minnow	Not documented in reviewed literature	Not documented in reviewed literature	Wide Range	Gravel / sand	With the wide range of preferred habitat characteristics and substrate preference, no significant changes are expected.
Common carp	Not documented in reviewed literature	Not documented in reviewed literature	Wide range	Sand / gravel / clay	With the wide range of preferred habitat characteristics and substrate preference, no significant changes are expected.
White bass	Moderate currents	Not documented in reviewed literature	Generally occurs in waters 6m in depth or less	Sand / mud / rubble / gravel	With the wide range of preferred habitat characteristics and variety of substrate preference, no significant changes are expected.
Common shiner	Not documented in reviewed literature	Not documented in reviewed literature	Rocky Pools near Riffles	Hard bottom / gravel / sand / rubble	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Northern pike	Not documented in reviewed literature	Not documented in reviewed literature	Shallow vegetated areas	Vegetated areas	Shallow areas will become shallower on average, but less than 2 inches water depth change would occur. With critical spawning times for northern pike during early spring when flows are high, water depth change would be even less. Consequently, no significant changes are expected.

EXHIBIT 6
Summary of Return Flow Effects on Habitat Characteristics for Dominant Fish Species in Fox River

Dominant Fish Species	Preferred Current Velocity Range[a]	Stream Gradient[a]	General Habitat Characteristics[a]	Dominant Substrate Preference[a]	Potential Changes to Habitat with Return Flow
Largemouth bass	> 0.33 ft/sec	Not documented in reviewed literature	Not documented in reviewed literature	Vegetated areas, sand / gravel / mud	With the wide range of preferred substrate preference, no significant changes are expected.
Rock bass	Not documented in reviewed literature	Not documented in reviewed literature	Preference for clear cool to warm water	Sand / gravel	No significant changes expected to general habitat characteristics or preferred substrate.
Emerald shiner	Not documented in reviewed literature	Not documented in reviewed literature	Wide Range	Sand / gravel	With the wide range of preferred habitat characteristics and substrate preference, no significant changes are expected.
Bluegill	< 0.33 ft/sec	≤ 0.5 m/km	60% pool areas	Submerged vegetation/ logs / brush	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Longnose gar	Not documented in reviewed literature	Not documented in reviewed literature	Backwaters, quiet currents	Gravel / sand	No significant changes expected to general habitat characteristics or preferred substrate.

[a]Main sources of information were Froese and Pauly (2009), Becker (1983), Stuber et al. (1982a, 1982b), McMahon (1982), McMahon and Terrell (1982), Twomey et al. (1984), Trial et al. (1983), Clark (1943), Copes (1978), Hardin and Bovee (1978), Mraz et al. (1961), Page and Burr (1991), Inskip (1982), Hamilton and Nelson (1984).

EXHIBIT 7
Return Flow Effects on Preferred Habitat for Threatened, Endangered, Special Concern, and Cold Water Species Recorded Since 1999 within the Fox River

Fish Species	Preferred Current Velocity Range[a]	Stream Gradient[a]	General Habitat Characteristics[a]	Dominant Substrate Preference[a]	Potential Changes to Habitat with Return Flow
Greater redhorse (threatened)	Not documented in reviewed literature	Not documented in reviewed literature	Pools and runs of medium to large rivers	Sandy to rocky pools	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Longear sunfish (threatened)	Not documented in reviewed literature	Not documented in reviewed literature	Slow moving rivers and streams	Shallow dense vegetation	Shallow areas will become shallower on average, but less than 2 inches water depth change would occur. Consequently, no significant changes are expected.
Banded killifish (special concern)	Not documented in reviewed literature	Not documented in reviewed literature	Shallow sluggish streams	Sand/mud/near vegetation.	Shallow areas will become shallower on average, but less than 2 inches water depth change would occur. No significant changes are expected to the preferred substrate. Consequently, no significant changes are expected.
Starhead topminnow (special concern)	Not documented in reviewed literature	Not documented in reviewed literature	Quit pools and backwaters	Vegetated areas	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Brook trout (cold water species)	Not documented in reviewed literature	Not documented in reviewed literature	Clear, cool, well oxygenated streams	Sand/ gravel/rubble	Lower flow in the Fox River could extend cool water influence from Genesee Creek. No significant changes are expected to the preferred substrate. Consequently, no significant changes expected.
Brown trout (cold water species)	Not documented in reviewed literature	Not documented in reviewed literature	Cold, well oxygenated waters	Submerged rocks, undercut banks, overhanging vegetation	Lower flow in the Fox River could extend cool water influence from Genesee Creek. No significant changes are expected to the preferred substrate. Consequently, no significant changes expected.

[a]Main sources of information were Froese and Pauly (2009), Becker (1983), Stuber et al. (1982a, 1982b), McMahon (1982), McMahon and Terrell (1982), Twomey et al. (1984), Trial et al. (1983), Clark (1943), Copes (1978), Hardin and Bovee (1978), Mraz et al. (1961), Page and Burr (1991), Inskip (1982), Hamilton and Nelson (1984).

EXHIBIT 8
Return Flow Effects on Habitat Characteristic for Fish Species Identified in the WDNR Online NHI Database as Threatened, Endangered, and Species of Special Concern in the Vicinity of the Fox River, but not Documented as Present in Recent Fish Surveys

Fish Species[a]	Preferred Current Velocity Range	Stream Gradient	General Habitat Characteristics	Dominant Substrate Preference	Potential Changes to Habitat with Return Flow
Striped shiner (endangered)	Not documented in reviewed literature.	Not documented in reviewed literature.	Clear to slightly turbid waters of runs and shallow pools, with dense aquatic vegetation.	Cobble, boulders, silt, sand, mud or bedrock	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Slender madtom (endangered)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers clear, moderate to swift currents of streams and wide rivers.	Gravel and boulders interspersed with fine sand	Some reduction in current velocity could occur during low periods. However, no significant changes are expected. No significant changes expected to preferred substrate.
River redhorse (threatened)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers moderate to swift currents in large rivers systems, including impoundments and pools.	River bottoms of clean gravel.	The preferred habitat for this species likely does not exist in the Fox River because it is not a large river.
Pugnose shiner (threatened)	Not documented in reviewed literature	Not documented in reviewed literature	Prefers weedy shoals of glacial lakes and low-gradient streams	Mud, sand, cobble, silt, and clay	Some weedy areas may be exposed under low flow conditions, however no significant changes are expected. No significant changes expected to preferred substrate.
Lake chubsucker (special concern)	Not documented in reviewed literature.	Not documented in reviewed literature.	Prefers moderately clear lakes, oxbow lakes, sloughs of weedy lakes and their associated marshy streams.	Organic debris over bottoms of cobble, sand, boulders, mud or silt.	The preferred habitat for this species likely does not exist in the Fox River because it is not a lake.
Least darter (special concern)	Not documented in reviewed literature	Not documented in reviewed literature	Prefers clear, warm, quiet waters of overflow ponds, pools, lakes and streams.	Gravel, silt, sand, boulders, mud or clay with dense vegetation or filamentous algal beds	Slightly less pool depth, but because pools are by definition deeper areas no significant changes expected. No significant changes expected to preferred substrate.
Weed shiner (special concern)	Not documented in reviewed literature	Not documented in reviewed literature	Prefers sloughs, lakes, and still to sluggish sections of medium streams to large rivers	Sand, mud, clay, silt, detritus, gravel or boulders	Some slough areas may have less water in them under low flow conditions. No significant changes expected. No significant changes expected to preferred substrate.

[a]WDNR. Online Natural Heritage Inventory Database: http://dnr.wi.gov/org/land/er/nhi/CountyElements/

References

Becker, G. C. 1983. *Fishes of Wisconsin.* University of Wisconsin Press, Madison. 1,052 pp.

Clark, C. F. 1943. "Creek Chub Minnow Propagation." *Ohio Conservation Bulletin* 7(6): 12–13.

Copes, F. A. 1978. *Ecology of the Creek Chub.* University of Wisconsin–Stevens Point, Mus. Nat. Hist. Rept. On Fauna and Flora of Wis. No. 12. 21p.

Froese, R., and D. Pauly, eds. 2009. FishBase. World Wide Web electronic publication. www.fishbase.org. version (09/2009).

Hamilton, K., and P. C. Nelson. 1984. Habitat Suitability Index Models and Instream Flow Suitability Curves: White Bass. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.89. 35pp.

Hardin, T., and K. Bovee. 1978. Largemouth Bass. Instream Flow Group, U.S. Fish and Wildlife Service, Western Energy and Land Use Team, Ft. Collins, Colorado. Unpublished data.

Inskip, P. D. 1982. Habitat Suitability Index Models: Northern Pike. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.17. 40pp.

McMahon, T. E. 1982. Habitat Suitability Index Models: Creek Chub. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.4. 23 pp.

McMahon, T. E., and J. W. Terrell. 1982. Habitat Suitability Index Models: Channel Catfish. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.2. 29 pp.

Mraz, D., S. Kmiotek, and L. Frankenberger. 1961. *The Largemouth Bass, Its Life History, Ecology, and Management.* Wisconsin Conserv. Dept. Publ. 232. 15 p.

Page, L. M., and B. M. Burr. 1991. *A Field Guide to Freshwater Fishes of North America North of Mexico.* Houghton Mifflin Company, Boston. 432 p.

Pebble Creek *Watershed Protection Plan Waukesha County, Wisconsin (Part One).* 2008. Waukesha County Department of Parks and Southeastern Wisconsin Regional Planning Commission.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982a. Habitat Suitability Index Models: Bluegill. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.8. 26pp.

Stuber, R. J., G. Gebhart, and O. E. Maughan. 1982b. Habitat Suitability Index Models: Largemouth Bass. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.16. 32pp.

Trial, J. G., C. S. Wade, J. G. Stanley, and P. C. Nelson. 1983. Habitat Suitability Index Models: Common Shiner. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.40. 22pp.

Twomey, K. A., K. L. Williamson, and P.C. Nelson. 1984. Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/ 10.64. 56pp.

Wisconsin Department of Natural Resources. 2002. *The State of the Southeast Fox River Basin.* A report by the WDNR in cooperation within the Southeast Fox River Basin Land and Water Partners Team, PUBL WT-701-2002. February.

Wisconsin Department of Natural Resources. 2011. Personal communications with Sue Beyler, Regional Fisheries Biologist.

Appendix E

Root River, Underwood Creek, and Fox River Flow Rates with Return Flow in Years 2005 and 2008

Root River, Underwood Creek, and Fox River Flow Rates with Return Flow in Years 2005 and 2008

TO: Waukesha Water Utility

FROM: CH2M HILL

DATE: June 20, 2013

The purpose of this memorandum is to summarize how the proposed return flow management plan would have operated in years 2005 and 2008, based on the actual daily flows during those years. This analysis was completed as requested by the Wisconsin Department of Natural Resources (WDNR) [1] for an Underwood Creek return flow in support of The City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application). It has since been updated for return flow to Root River.

This memorandum demonstrates the effects of the return flow management plan on the Root River, Underwood Creek and the Fox River. Historical daily flow data from USGS and daily effluent flow from the City's Wastewater Treatment Plant (WWTP) were used to simulate each watercourse's flow rate with the return flow for year 2005 and 2008. The year 2005 was selected because it is a relatively dry year in recent past and 2008 was a relatively wet year in recent past.

The return flow management plan is different for the Root River return flow alternative and Underwood Creek return flow alternative. The analysis of return flow effects on Underwood Creek were completed in December 2011, while the analysis of return flow effects on Root River was completed in June 2013. Due to differences in return flow management between the alternatives, the Fox River flow rate was simulated with and without a return flow to Root River or Underwood Creek. The return flow management plan proposed for the Root River is that proposed in the Application. The management plan previously evaluated for Underwood Creek return flow is similar and therefore the previous analysis is retained for evaluation within this memorandum. Each is discussed in detail below.

Root River Return Flow

The return flow to Root River would include returning all flow from the City's WWTP up to a maximum daily flow of 16.7 mgd. This is consistent with maximum daily water demand of 16.7 mgd that is proposed in the Application. Flow from the WWTP in excess of the maximum return flow rate would continue to flow the Fox River through the City's existing outfall. Following this return flow management plan, hydrographs for the Root River and the Fox River were developed (Exhibits 1 through 4).

Fox River flow data at the WWTP outfall was estimated as the sum of the average daily flow rate at USGS Fox River Gage in Waukesha (#05543830) and the average daily WWTP discharge rates. The USGS gage is only about 0.5 miles upstream of the WWTP and there are no significant tributaries between the gage and WWTP. Therefore, the river flow at the gage is assumed to be similar to the river flow immediately upstream of the WWTP outfall.

Root River flow data at the return flow location was estimated as the sum of the flow rate at the USGS gage at Franklin (gage # 04087220) and the gage on the Root River Canal near Franklin (gage # 04087233), and prorated for the unaccounted 20.0 square mile[2] drainage area between these USGS gages and the return flow location.

Exhibit 1 is a graphical summary of the average daily flows in the Root River at the potential discharge location in year 2005 with one line showing actual historic flow and one line showing historic flow with return flow following

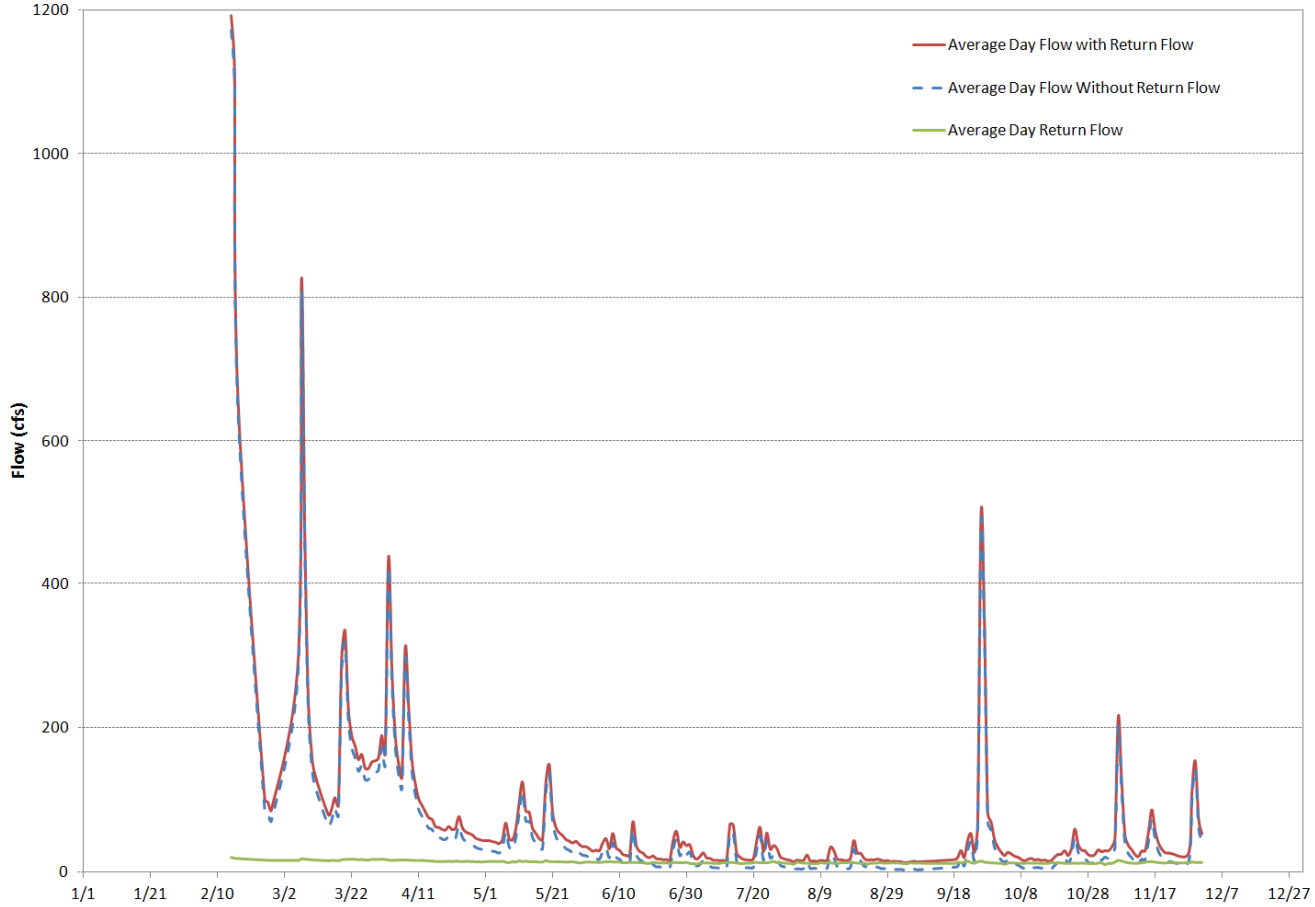
[1] Letter from Bruce Baker, Wisconsin Department of Natural Resources, to City of Waukesha Common Council President Paul Ybarra. December 2, 2010.

[2] Area obtained from the Southeastern Wisconsin Regional Planning Commission HSPF model used in the Regional Water Quality Management Plan Update.

the return flow management plan (a tabular summary is provided in Exhibit A-1 included Attachment A). Exhibit 2 displays the average daily flows in the Fox River during 2005 with and without a Root River return flow (a tabular summary is provided in Exhibit A-2 included in Attachment A). During 2005, the average daily return flow rate is 8.7 mgd (13.4 cfs) and the maximum daily average return flow rate is 13.1 mgd (20.3 cfs). Using the average daily flow rates from the WWTP and in the Root River for dry year 2005, all WWTP flow was return flow.

EXHIBIT 1

Year 2005 Average Daily Flow in the Root River with Simulated Return Flow[1]



[a] USGS flow data for the Root River was unavailable for January 2005 and portions of February and December 2005.

EXHIBIT 2

Year 2005 Average Daily Flow in the Fox River with Simulated Lake Michigan Water Supply and Return Flow to the Root River

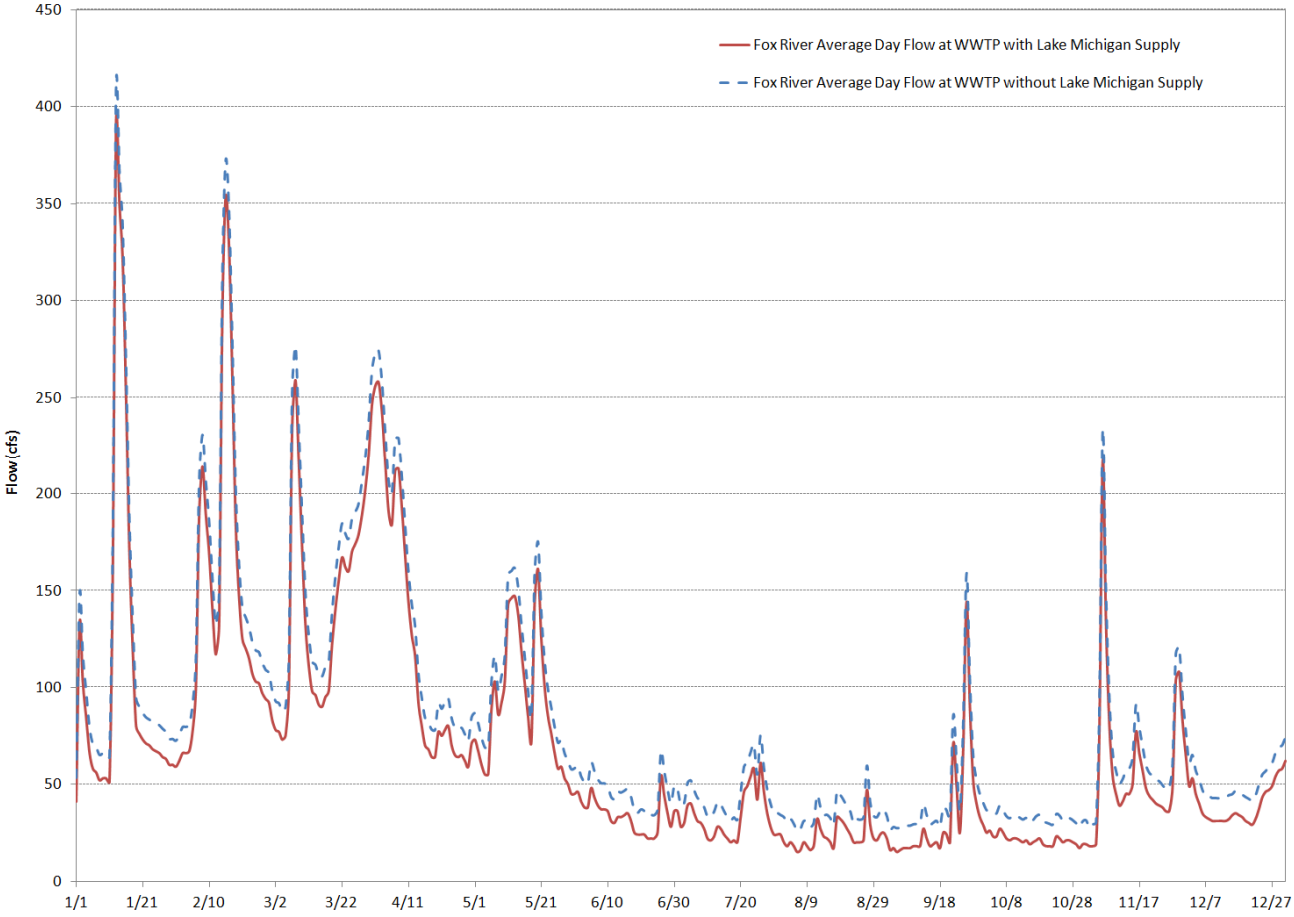


Exhibit 3 shows the historical average daily flows in the Root River and the simulated daily average flows with return flow during year 2008 (a tabular summary is provided in Exhibit A-3 included Attachment A). Exhibit 4 displays the historical average daily flows in the Fox River and the simulated daily flows with a Root River return flow during year 2008 (a tabular summary is provided in Exhibit A-4 included Attachment A). In 2008, the average return flow rate is 11.7 mgd (18.0 cfs) and the maximum return flow rate is 46.7 mgd (72.3 cfs). When WWTP flow exceeded the maximum return flow of 16.7 mgd, the excess WWTP flow was conveyed to the existing outfall to the Fox River.

EXHIBIT 3

Year 2008 Average Daily Flow in the Root River with Simulated Return Flow

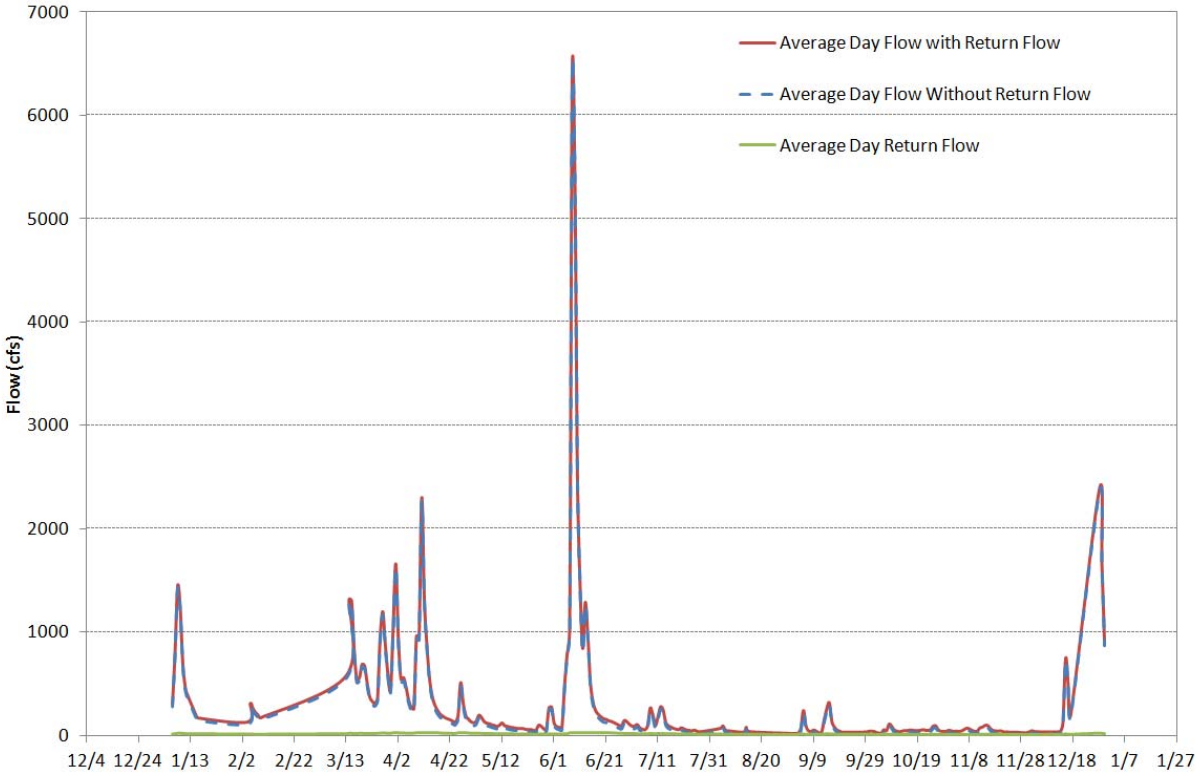
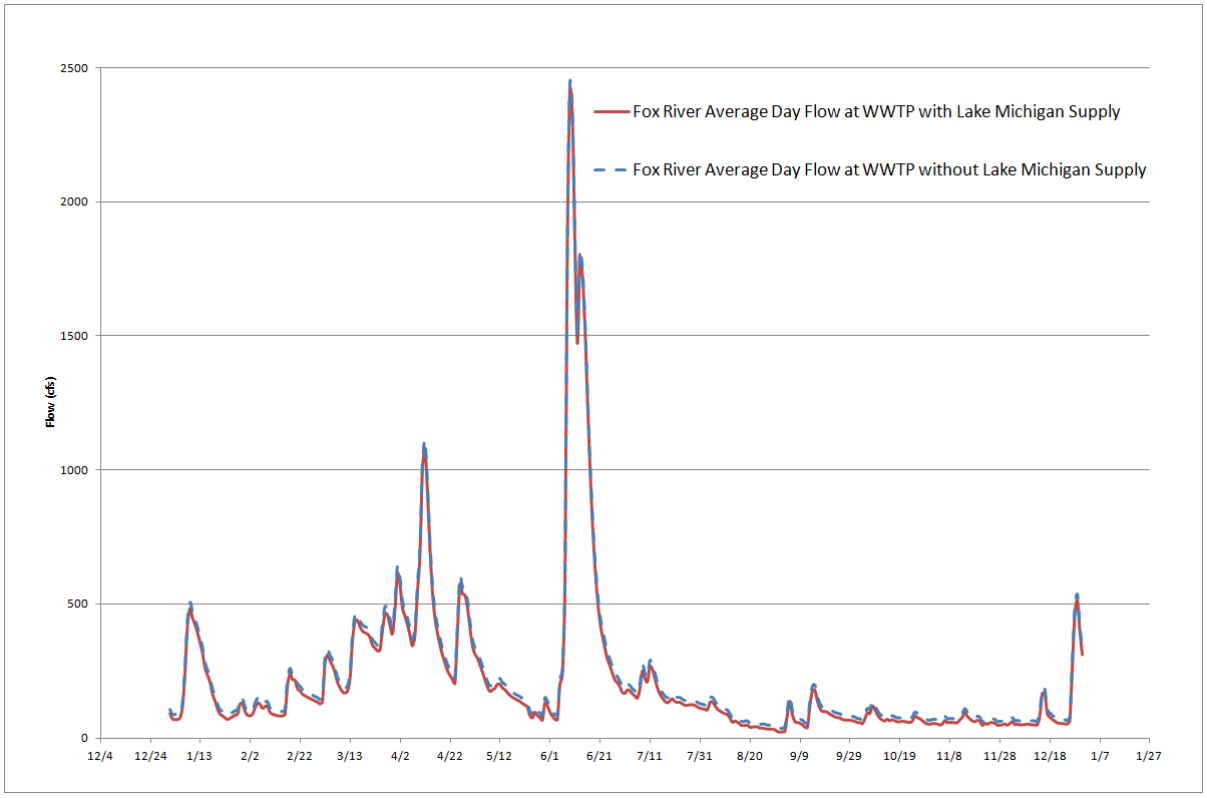


EXHIBIT 4

Year 2008 Average Daily Flow in the Fox River with Simulated Lake Michigan Water Supply and Return Flow to the Root River



Summary of Root River Return Flow

The simulated return flow to the Root River and the associated reduction of flow to the Fox River is different in dry year 2005 and wet year 2008. Flow in the Root River was noticeably increased in 2005 during low flow periods June through October. Root River flow without return flow was often less than 5 cfs which is much less than other times of that year or during low flow times in 2008. The return flow eliminated these very low flow periods with a relatively uniform return flow rate. In 2008, base flow in the Root River was also increased but was less noticeable. In both 2005 and 2008, return flow was not significant when river flows were above base flow because the return flow is a small percentage of river flow.

Average daily flow in the Fox River was reduced by an amount equal to the return flow rate. The reduction was more noticeable in dry year 2005 compared to wet year 2008, however the maximum reduction was about 30 percent. During wet year 2008, the difference in hydrograph of the Fox River with and without return flow was small. In both 2005 and 2008, the absence of WWTP flow was not significant when river flows were above base flow because the return flow is a small percentage of river flow.

Underwood Creek Return Flow

The return flow plan to Underwood Creek included returning flow from the City's WWTP when the creek flow was not experiencing high flows (e.g. creek flow less than 1,000 cfs). Continuous return flow was simulated in 2005 because the creek never exceeded 1,000 cfs in 2005. The return flow plan also included a maximum daily flow of 115 percent of the average daily water demand. Following this operational plan, base flow in Underwood Creek would increase but the high-flow event flow rates would not change because return flow would be temporarily paused during those times. When return flow is paused, all flow from the WWTP is conveyed through the existing outfall to the Fox River. There were no days in year 2005 when Underwood Creek flow exceeded 1,000 cfs so the flow was not paused.

In the context of a hydrograph for Underwood Creek, the low creek flows would be increased but the high creek flows would not change as a result of the return flow. This operational scenario is different than that evaluated for Root River because the Underwood Creek return flow plan was evaluated prior to completing the Root River evaluation. However, these results are still anticipated to be representative because the average hourly return flow to Root River (8.7 mgd) is also very similar to that for Underwood Creek (8.6 mgd) in dry year 2005 when return flow is most influential of base flow rates.

The average daily water withdrawal in 2005 and 2008 were 12.0 cfs (7.8 mgd) and 10.7 cfs (6.9 mgd), respectively, which results in a daily average maximum return flow to Underwood Creek of 13.8 cfs in 2005 and 12.3 cfs in 2008. Using the USGS flow information for Underwood Creek (gage #04087088) and Fox River (gage #05543830), Exhibits 5 through 9 demonstrate how the return flow would have changed the daily flows in each watercourse during 2005 and 2008. Exhibit 5 is a graphical summary of the average daily flows in Underwood Creek in year 2005 with one line showing actual historic flow and one line showing historic flow with return flow following the return flow management plan (a tabular summary is provided in Exhibit B-1 included Attachment B). Note that the maximum return flow is 13.8 cfs and is relatively uniform throughout the year.

EXHIBIT 5

Year 2005 Average Daily Flow in Underwood Creek with Simulated Return Flow

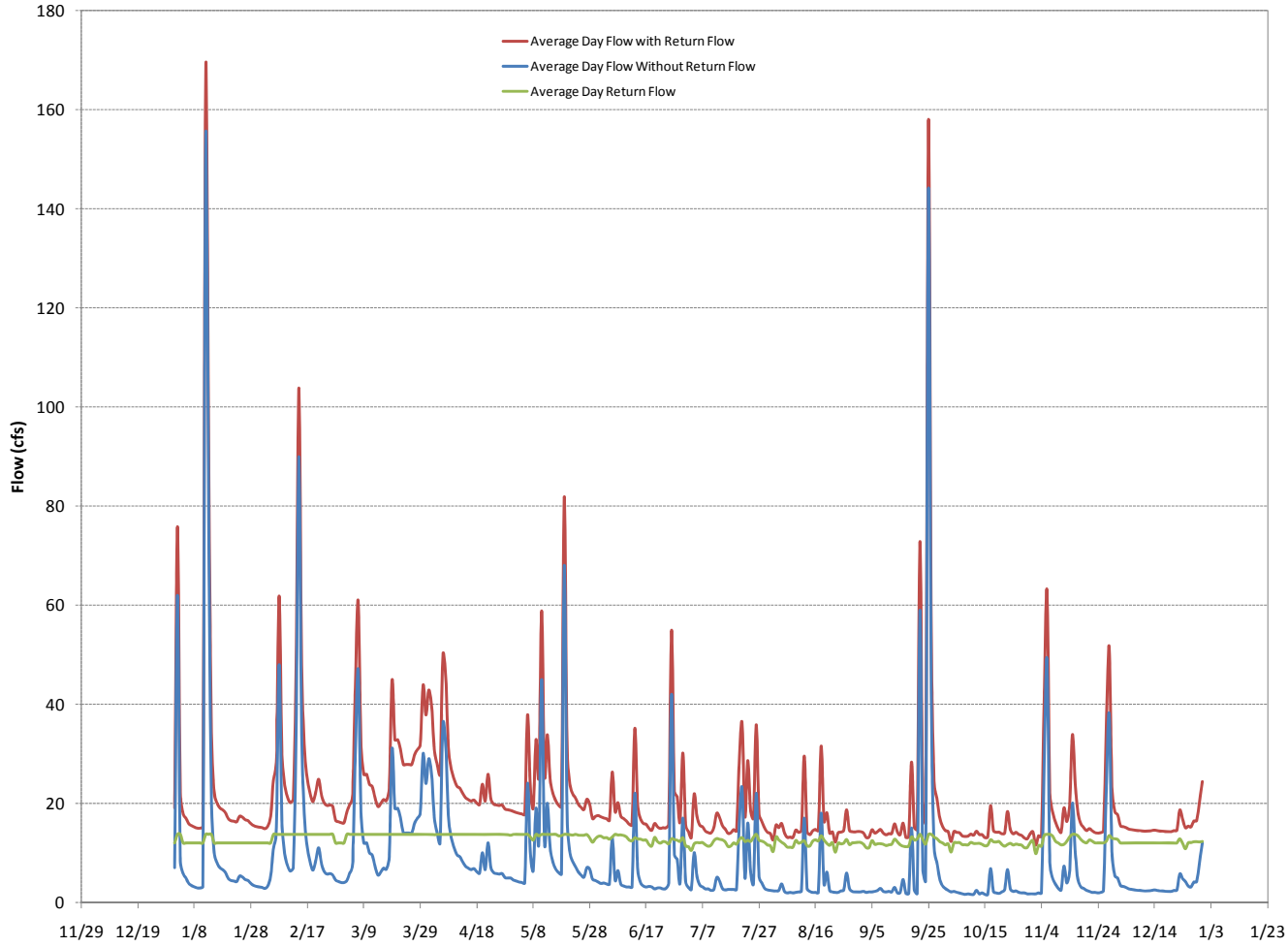
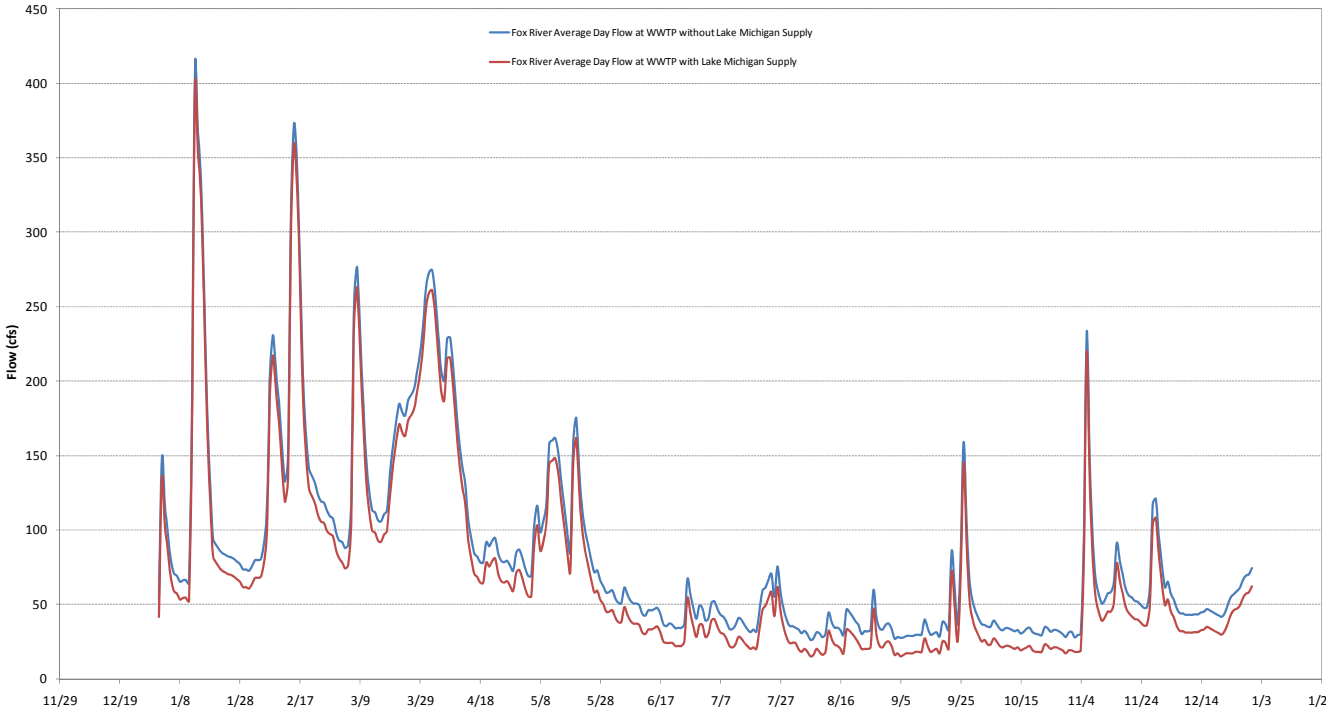


Exhibit 6 is a graphical summary of the average daily flows in the Fox River in year 2005 (a tabular summary is provided in Exhibit B-2 included in Attachment B). Note that the average daily flow for the Fox River represents river flow at the City of Waukesha WWTP outfall. This data was developed the same as for the Root River return evaluation – by adding the actual historic average daily USGS flow for year 2005 to the WWTP average daily discharge to the Fox River, where one line shows historic flow and one line shows historic flow with return flow following the return flow management plan. For the simulation that includes a Lake Michigan water supply, the USGS average daily flow data was added to the WWTP flow that was not returned to Underwood Creek.

EXHIBIT 6
Year 2005 Average Daily Flow in the Fox River with Simulated Lake Michigan Water Supply



Exhibits 7 and 8 are graphical summaries of the average daily flows in Underwood Creek in year 2008 with one line showing historic flow and one line showing historic flow with return flow following the return flow management plan (a tabular summary is provided in Exhibit B-3 included in Attachment B). The maximum return flow is 12.3 cfs and is relatively uniform throughout the year. The return flow was temporarily paused for about one day in June 2008 because Underwood Creek flow exceeded 1,000 cfs for about one day. The return flow meets the Compact requirement of returning the withdrawn water less consumptive use because the maximum return flow on other days (days other than the one day in June) is slightly greater (a maximum of 15 percent) than the average water withdrawal. Consequently, this management plan *makes up* the return flow that was temporarily paused during the June flood event in Underwood Creek (this is further discussed in the Application).

Exhibit 9 is a graphical summary of the average daily flows in the Fox River in year 2008 with one line showing historic flow and one line showing historic flow with return flow following the return flow management plan (a tabular summary is provided in Exhibit B-4 included in Attachment B). The same as year 2005, the average daily flow for the Fox River represents river flow at the City of Waukesha WWTP outfall. This data was developed by adding the average daily USGS flow for year 2008 to the WWTP average daily discharge to the Fox River. For the simulation that includes a Lake Michigan water supply, the USGS average daily flow data was added to the WWTP flow that was not returned to Underwood Creek (e.g. flow that exceeded 115 percent of the average daily water withdrawal). Note that during the June 2008 event that exceeded 1,000 cfs in Underwood Creek, the Fox River flow at the WWTP is the same with and without the Lake Michigan water supply because the return flow to Underwood Creek was temporarily paused and all WWTP flow was conveyed to the existing Fox River outfall.

EXHIBIT 7

Year 2008 Average Daily Flow in Underwood Creek with Simulated Return Flow

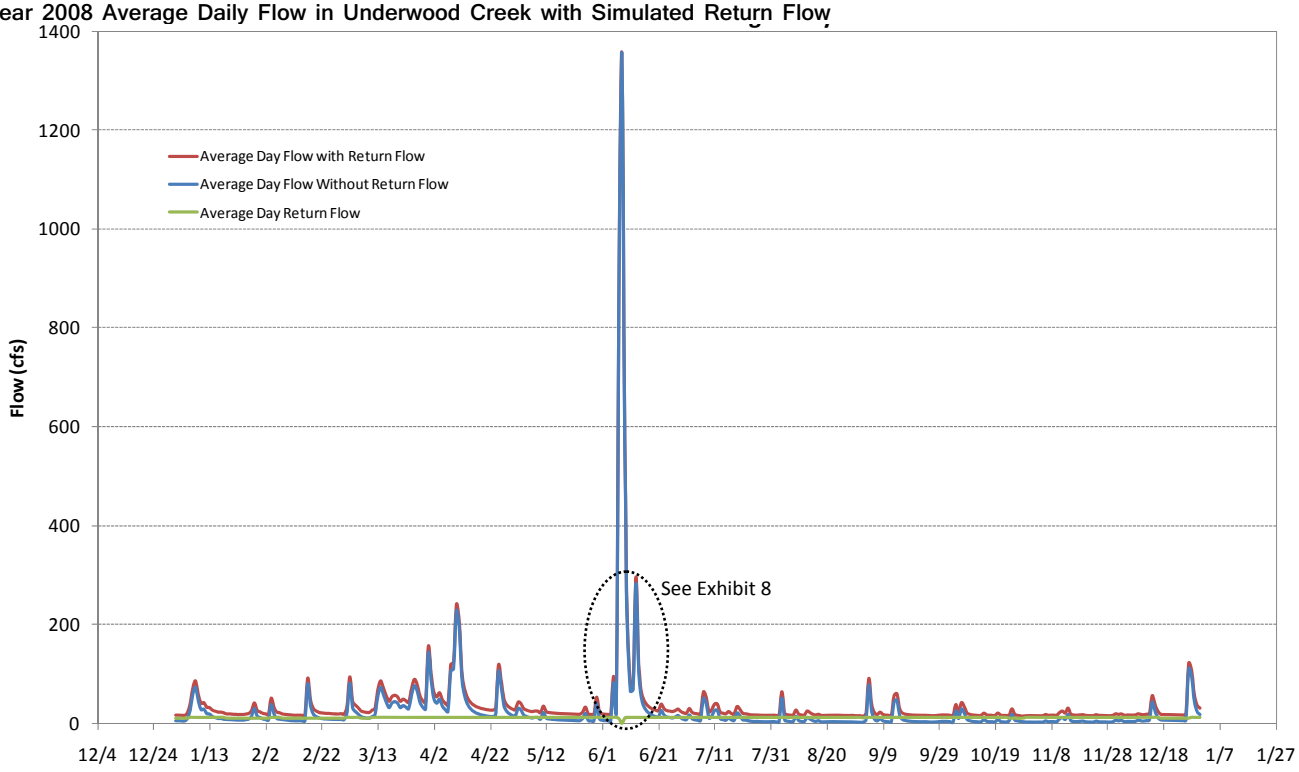


EXHIBIT 8

June 2008 Average Daily Flow in Underwood Creek with Simulated Return Flow

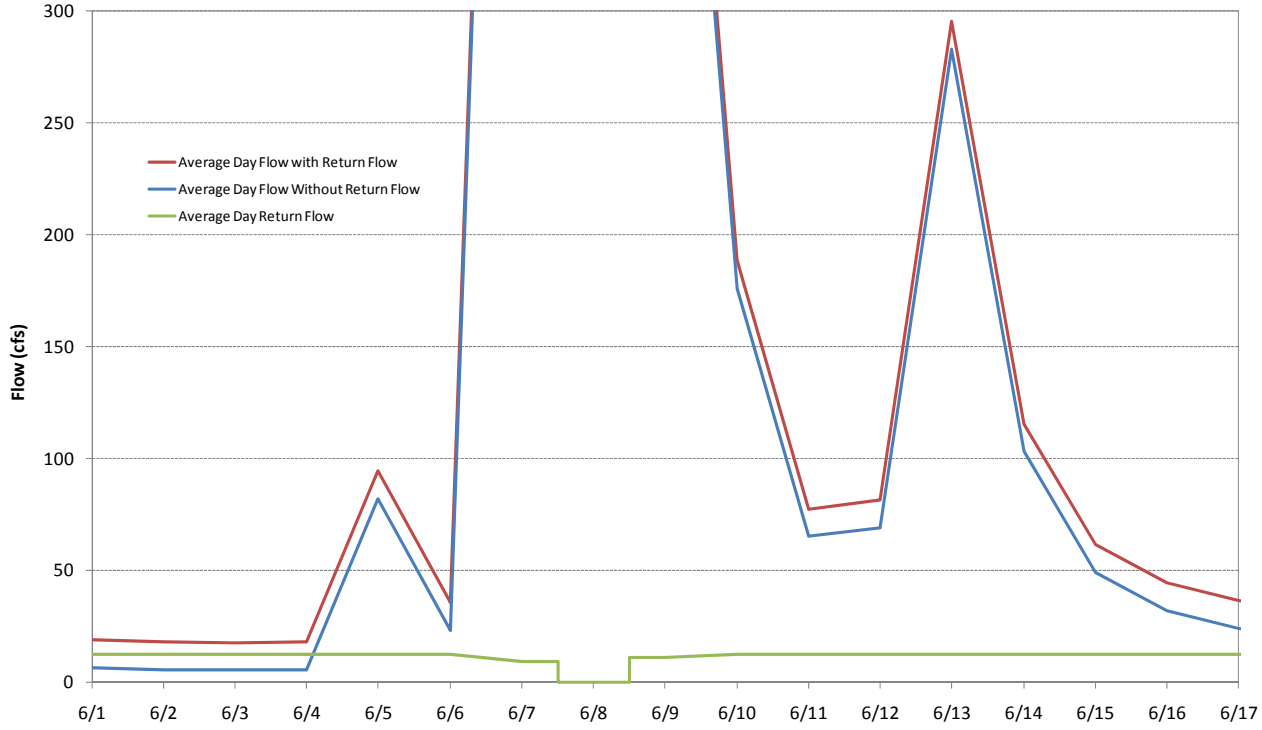
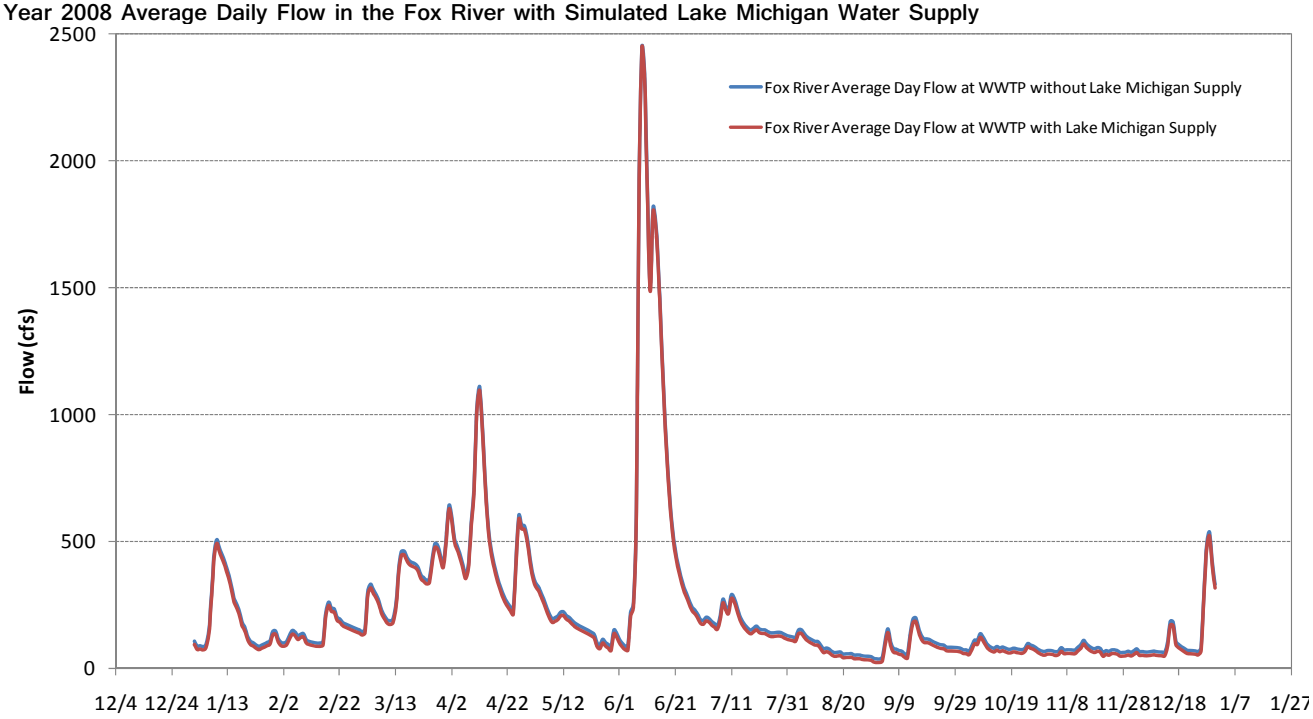


EXHIBIT 9

Year 2008 Average Daily Flow in the Fox River with Simulated Lake Michigan Water Supply



Summary of Underwood Creek Return Flow

The simulated return flow to Underwood Creek and the associated reduction of flow to the Fox River is different in dry year 2005 and wet year 2008. Flow in Underwood Creek was noticeably increased in 2005 during low flow periods observed throughout the year. Underwood Creek flow without return flow was often less than 5 cfs during 2005 and 2008. The return flow eliminated these very low flow periods with a relatively uniform return flow rate. In both 2005 and 2008, return flow was not significant when creek flows were above base flow because the return flow is a small percentage of river flow.

Average daily flow in the Fox River was reduced by an amount equal to the return flow rate. The reduction was more noticeable in dry year 2005 compared to wet year 2008, however the maximum reduction was about 30 percent. During wet year 2008, the difference in hydrograph of the Fox River with and without return flow was small. In both 2005 and 2008, the absence of river flow from the WWTP was not significant when river flows were above base flow because the return flow is a small percentage of river flow.

Attachment A
Tabular Summary of Root River Return Flow Simulations

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
2/14/2005	1172.6	20.3	1192.9
2/15/2005	1097.8	18.9	1116.7
2/16/2005	644.1	18.5	662.6
2/24/2005	85.2	16.3	101.4
2/25/2005	80.9	16.2	97.1
2/26/2005	70.1	15.9	86
3/6/2005	278.9	15.9	294.7
3/7/2005	807.5	18.3	825.8
3/8/2005	452.4	17.7	470.1
3/9/2005	227	17.3	244.2
3/10/2005	150.4	16.7	167.2
3/11/2005	119.5	16.3	135.8
3/15/2005	64.2	15.4	79.7
3/16/2005	71.5	15.8	87.3
3/17/2005	87.7	15.6	103.4
3/18/2005	76.9	15.3	92.2
3/19/2005	279.4	16.8	296.2
3/20/2005	318.2	17.2	335.4
3/21/2005	209.5	17.5	227
3/22/2005	172	17.6	189.7
3/23/2005	158.1	17.5	175.6
3/24/2005	139.4	16.9	156.3
3/25/2005	146.2	17.1	163.3
3/26/2005	127.6	16.7	144.3
3/27/2005	127.7	16	143.7
3/28/2005	135.2	17.5	152.7
3/29/2005	137.4	17	154.4
3/30/2005	140.9	17.4	158.3
3/31/2005	172.1	17.7	189.7
4/1/2005	147.7	17.1	164.8
4/2/2005	420.6	16.5	437
4/3/2005	266.9	15.7	282.6
4/4/2005	174	16.3	190.3

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
4/5/2005	134.8	16.1	150.9
4/6/2005	115.3	16.5	131.8
4/7/2005	295.7	16.6	312.3
4/8/2005	214.6	16.2	230.7
4/9/2005	138.6	16.1	154.7
4/10/2005	107.2	15.7	122.8
4/11/2005	86	15.7	101.7
4/12/2005	76.5	16	92.5
4/13/2005	67.9	15.5	83.4
4/14/2005	60.1	15.2	75.3
4/15/2005	58.1	14.8	72.9
4/16/2005	48.7	14.4	63
4/17/2005	47.8	14.1	62
4/18/2005	44.9	14.3	59.2
4/19/2005	44.1	14.1	58.2
4/20/2005	48.5	14.7	63.2
4/21/2005	44.7	14.1	58.8
4/22/2005	45.9	14.8	60.7
4/23/2005	62.6	14.4	77.1
4/24/2005	47.8	14.2	62
4/25/2005	41.6	14.3	55.9
4/26/2005	39.3	14.4	53.6
4/27/2005	37.4	14.2	51.6
4/28/2005	33.2	13.9	47.1
4/29/2005	31.5	13.7	45.2
4/30/2005	30.2	13.6	43.8
5/1/2005	29.7	13.8	43.5
5/2/2005	29.1	14.5	43.6
5/3/2005	28.1	14.2	42.3
5/4/2005	27.2	14.1	41.3
5/5/2005	25.3	14	39.3
5/6/2005	30.1	14.6	44.7
5/7/2005	54.9	13.3	68.1

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
5/8/2005	34.3	12.6	46.9
5/9/2005	30.6	13.9	44.5
5/10/2005	46	13.5	59.5
5/11/2005	80.4	15.2	95.5
5/12/2005	110.8	14.2	125
5/13/2005	70.2	14.7	84.8
5/14/2005	69.2	14	83.2
5/15/2005	47	13.9	60.9
5/16/2005	39.9	13.8	53.7
5/17/2005	32.9	13.5	46.4
5/18/2005	31.1	13.5	44.6
5/19/2005	108.5	15.5	124
5/20/2005	134.9	14.3	149.1
5/21/2005	69.4	13.7	83.1
5/22/2005	48.5	13.6	62.2
5/23/2005	40.5	14	54.5
5/24/2005	37	13.6	50.6
5/25/2005	31.5	13.6	45.1
5/26/2005	29.2	13.6	42.8
5/27/2005	26.4	13.8	40.2
5/28/2005	29.5	13.1	42.6
5/29/2005	26	12.2	38.1
5/30/2005	22.2	12.9	35.1
5/31/2005	21.8	13.4	35.2
6/1/2005	19	13.4	32.4
6/2/2005	15.8	13.1	28.9
6/3/2005	17.3	13.1	30.4
6/4/2005	16.7	12.8	29.5
6/5/2005	27.3	13.3	40.5
6/6/2005	32.4	13.8	46.2
6/7/2005	18.7	13.7	32.4
6/8/2005	39.9	13.7	53.6
6/9/2005	19.8	13.6	33.3

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
6/10/2005	16.9	13.3	30.2
6/11/2005	11.6	12.6	24.2
6/12/2005	10.7	12.5	23.2
6/13/2005	9.4	13.1	22.4
6/14/2005	57.1	12.9	69.9
6/15/2005	23.8	12.8	36.6
6/16/2005	16.1	12.6	28.7
6/17/2005	13.7	12.6	26.3
6/18/2005	9.7	11.7	21.4
6/19/2005	8.6	11.4	20
6/20/2005	9.1	13.2	22.2
6/21/2005	6.1	12.3	18.5
6/22/2005	6.1	12	18.1
6/23/2005	4.7	12.3	17
6/24/2005	5.1	12.2	17.3
6/25/2005	4.4	11.9	16.3
6/26/2005	30.5	12.9	43.4
6/27/2005	43.8	12.7	56.5
6/28/2005	21.8	12.6	34.4
6/29/2005	29.3	12.3	41.7
6/30/2005	23.5	13.1	36.6
7/1/2005	26.4	11.4	37.8
7/2/2005	11.5	11.2	22.7
7/3/2005	7.3	10.5	17.8
7/4/2005	9.4	11.8	21.2
7/5/2005	14.5	12.1	26.6
7/6/2005	7.6	12	19.7
7/7/2005	6.8	12.1	18.9
7/8/2005	4.8	11.6	16.5
7/9/2005	4.9	11.3	16.2
7/10/2005	4.1	11.6	15.7
7/11/2005	3.7	12.5	16.2
7/12/2005	3.9	12.9	16.8

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
7/13/2005	53.5	12.8	66.3
7/14/2005	52.1	12.7	64.8
7/15/2005	13.8	12.2	26.1
7/16/2005	9.2	11.3	20.5
7/17/2005	6.2	11.4	17.6
7/18/2005	4.9	12	16.9
7/19/2005	4.6	11.8	16.4
7/20/2005	5.6	12.7	18.4
7/21/2005	30.3	13.1	43.5
7/22/2005	49.6	12.3	61.9
7/23/2005	15.8	12.6	28.3
7/24/2005	41.7	12.3	54.1
7/25/2005	18.5	13.2	31.7
7/26/2005	22.3	14.5	36.8
7/27/2005	20.1	12.6	32.7
7/28/2005	8.9	12.4	21.2
7/29/2005	6.4	12.1	18.5
7/30/2005	5.4	11.6	17
7/31/2005	4.7	11.4	16.1
8/1/2005	3.9	10.3	14.1
8/2/2005	3.1	13.2	16.4
8/3/2005	3.2	12.6	15.8
8/4/2005	3.9	12.2	16.1
8/5/2005	11.8	11.8	23.5
8/6/2005	3.9	11.2	15
8/7/2005	4.3	11.1	15.4
8/8/2005	3.4	11.2	14.6
8/9/2005	3.4	12.5	15.9
8/10/2005	3.7	12	15.7
8/11/2005	4.2	12.2	16.4
8/12/2005	21.8	12.5	34.3
8/13/2005	18.5	11.5	30
8/14/2005	6.7	11.4	18.1

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
8/15/2005	4.8	12.4	17.2
8/16/2005	3.5	12.7	16.1
8/17/2005	3.5	12.5	16
8/18/2005	5.4	13.5	18.9
8/19/2005	31	12.6	43.6
8/20/2005	14.5	11.9	26.5
8/21/2005	14.6	11.5	26.1
8/22/2005	7.3	12.1	19.4
8/23/2005	6.1	10.1	16.2
8/24/2005	5.1	12	17.1
8/25/2005	4.7	11.8	16.5
8/26/2005	5.9	12	17.9
8/27/2005	3.9	12.7	16.7
8/28/2005	3.5	11.7	15.2
8/29/2005	3.9	12	15.9
8/30/2005	2.4	12.1	14.5
8/31/2005	2.7	12.2	14.9
9/1/2005	2.4	12.1	14.5
9/2/2005	2.6	11.7	14.4
9/3/2005	1.8	11	12.8
9/4/2005	2.2	11.1	13.3
9/5/2005	1.7	12.5	14.2
9/6/2005	3.2	11.7	14.9
9/7/2005	2.1	11.9	14
9/18/2005	5.7	11.4	17.1
9/19/2005	6.6	13.3	19.9
9/20/2005	17.2	12.6	29.8
9/21/2005	7.4	12.9	20.2
9/22/2005	29	14.6	43.6
9/23/2005	40.5	12.7	53.2
9/24/2005	15.2	11.8	26.9
9/25/2005	54	13.7	67.7
9/26/2005	482.1	14.9	497

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
9/27/2005	336.7	13.2	349.9
9/28/2005	68.9	12.9	81.8
9/29/2005	57.4	12.3	69.7
9/30/2005	33.7	12	45.7
10/1/2005	23	11.6	34.6
10/2/2005	15.7	11.8	27.5
10/3/2005	12.6	10.1	22.7
10/4/2005	15.2	12	27.3
10/5/2005	13	12.1	25.1
10/6/2005	9.7	12.1	21.8
10/7/2005	8.9	11.7	20.5
10/8/2005	5.7	11.7	17.4
10/9/2005	3.9	11.6	15.5
10/10/2005	5.4	12.1	17.6
10/11/2005	6.9	11.9	18.9
10/12/2005	4.7	11.9	16.6
10/13/2005	5.5	11.9	17.4
10/14/2005	4.2	11.7	16
10/15/2005	5.2	11.4	16.6
10/16/2005	3.4	11.6	15
10/17/2005	3.2	12.7	15.9
10/18/2005	8.5	12.3	20.8
10/19/2005	12.1	12.2	24.3
10/20/2005	12.4	12.3	24.7
10/21/2005	17.8	11.7	29.5
10/22/2005	11.5	11.4	22.9
10/23/2005	20.3	11.7	32
10/24/2005	47.6	11.9	59.6
10/25/2005	26.9	11.6	38.5
10/26/2005	18.7	11.8	30.5
10/27/2005	17.8	11.7	29.5
10/28/2005	12.6	11.6	24.2
10/29/2005	11.3	11	22.4

EXHIBIT A-1

Summary Table of Year 2005 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
10/30/2005	13	11.1	24.1
10/31/2005	18.7	12.1	30.8
11/1/2005	15.6	12.5	28.1
11/2/2005	19.8	9.8	29.6
11/3/2005	17.8	11.5	29.3
11/4/2005	23.1	11.4	34.5
11/5/2005	32.7	13.6	46.3
11/6/2005	200.4	15.9	216.4
11/7/2005	111.6	14.9	126.6
11/8/2005	37.3	13.4	50.7
11/9/2005	24.7	12.4	37
11/10/2005	18.9	12	31
11/11/2005	12.5	11.6	24.1
11/12/2005	9.5	11.7	21.3
11/13/2005	16.9	12.4	29.3
11/14/2005	16.1	13.3	29.4
11/15/2005	40.9	13.9	54.7
11/16/2005	72.1	14.2	86.3
11/17/2005	44.2	13.5	57.6
11/18/2005	27.5	12.7	40.2
11/19/2005	19.2	12.2	31.5
11/20/2005	14.8	12	26.8
11/21/2005	13.7	12.6	26.4
11/22/2005	13	12.4	25.4
11/27/2005	13.4	12.4	25.8
11/28/2005	97.9	13.5	111.5
11/29/2005	141	13	154
11/30/2005	60.7	12.9	73.6
12/1/2005	40	12.7	52.7

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
1/1/2005	53.5	41
1/2/2005	148.3	133
1/3/2005	116.2	102
1/4/2005	97.6	84
1/5/2005	79.1	66
1/6/2005	70.9	58
1/7/2005	69.2	56
1/8/2005	65.2	52
1/9/2005	66.2	53
1/10/2005	66.3	53
1/11/2005	64.1	51
1/12/2005	178.8	161
1/13/2005	411.6	392
1/14/2005	367.1	350
1/15/2005	336.6	320
1/16/2005	266.1	250
1/17/2005	186	170
1/18/2005	134.8	120
1/19/2005	94.5	80
1/20/2005	90.2	76
1/21/2005	86.9	73
1/22/2005	84.6	71
1/23/2005	83.5	70
1/24/2005	82.2	68
1/25/2005	81.7	67
1/26/2005	80.6	66
1/27/2005	78.8	64
1/28/2005	77	63
1/29/2005	73.6	60
1/30/2005	73.5	60
1/31/2005	72.6	59
2/1/2005	75.6	62

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
2/2/2005	79.6	66
2/3/2005	79.7	66
2/4/2005	80.7	67
2/5/2005	91.1	77
2/6/2005	113.9	99
2/7/2005	206.5	189
2/8/2005	230.9	214
2/9/2005	206.3	189
2/10/2005	185.6	169
2/11/2005	155.9	140
2/12/2005	132.5	117
2/13/2005	148.4	132
2/14/2005	315.3	295
2/15/2005	372.9	354
2/16/2005	345.5	327
2/17/2005	277.8	260
2/18/2005	202.4	185
2/19/2005	163.6	147
2/20/2005	141.4	125
2/21/2005	136.2	120
2/22/2005	131.3	115
2/23/2005	123.5	107
2/24/2005	119.3	103
2/25/2005	118.2	102
2/26/2005	112.9	97
2/27/2005	109.1	94
2/28/2005	107.5	92
3/1/2005	98.3	83
3/2/2005	93	78
3/3/2005	91.9	77
3/4/2005	87.9	73
3/5/2005	89.9	75

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
3/6/2005	114.9	99
3/7/2005	253.3	235
3/8/2005	276.7	259
3/9/2005	233.3	216
3/10/2005	188.7	172
3/11/2005	148.3	132
3/12/2005	126.7	111
3/13/2005	113.5	98
3/14/2005	111.8	96
3/15/2005	106.4	91
3/16/2005	105.8	90
3/17/2005	110.6	95
3/18/2005	113.3	98
3/19/2005	138.8	122
3/20/2005	157.2	140
3/21/2005	172.5	155
3/22/2005	184.6	167
3/23/2005	179.5	162
3/24/2005	176.9	160
3/25/2005	187.1	170
3/26/2005	190.7	174
3/27/2005	195	179
3/28/2005	206.5	189
3/29/2005	219	202
3/30/2005	237.4	220
3/31/2005	263.7	246
4/1/2005	273.1	256
4/2/2005	274.5	258
4/3/2005	258.7	243
4/4/2005	232.3	216
4/5/2005	207.1	191
4/6/2005	200.5	184

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
4/7/2005	228.6	212
4/8/2005	229.2	213
4/9/2005	209.1	193
4/10/2005	183.7	168
4/11/2005	159.7	144
4/12/2005	143	127
4/13/2005	131.5	116
4/14/2005	107.2	92
4/15/2005	94.8	80
4/16/2005	84.4	70
4/17/2005	82.1	68
4/18/2005	78.3	64
4/19/2005	78.1	64
4/20/2005	91.7	77
4/21/2005	89.1	75
4/22/2005	92.8	78
4/23/2005	94.4	80
4/24/2005	84.2	70
4/25/2005	79.3	65
4/26/2005	78.4	64
4/27/2005	79.2	65
4/28/2005	75.9	62
4/29/2005	72.7	59
4/30/2005	84.6	71
5/1/2005	86.8	73
5/2/2005	81.5	67
5/3/2005	74.2	60
5/4/2005	69.1	55
5/5/2005	69	55
5/6/2005	103.6	89
5/7/2005	116.3	103
5/8/2005	98.6	86

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
5/9/2005	105.9	92
5/10/2005	116.5	103
5/11/2005	158.2	143
5/12/2005	160.2	146
5/13/2005	161.7	147
5/14/2005	152	138
5/15/2005	132.9	119
5/16/2005	115.8	102
5/17/2005	98.5	85
5/18/2005	85.5	72
5/19/2005	159.5	144
5/20/2005	175.3	161
5/21/2005	138.7	125
5/22/2005	113.6	100
5/23/2005	99	85
5/24/2005	89.6	76
5/25/2005	79.6	66
5/26/2005	71.6	58
5/27/2005	72.8	59
5/28/2005	66.1	53
5/29/2005	62.2	50
5/30/2005	57.9	45
5/31/2005	58.4	45
6/1/2005	59.4	46
6/2/2005	54.1	41
6/3/2005	51.1	38
6/4/2005	50.8	38
6/5/2005	61.3	48
6/6/2005	56.8	43
6/7/2005	52.7	39
6/8/2005	50.7	37
6/9/2005	50.6	37

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
6/10/2005	49.3	36
6/11/2005	43.6	31
6/12/2005	42.5	30
6/13/2005	46.1	33
6/14/2005	45.9	33
6/15/2005	46.8	34
6/16/2005	47.6	35
6/17/2005	43.6	31
6/18/2005	36.7	25
6/19/2005	35.4	24
6/20/2005	37.2	24
6/21/2005	36.3	24
6/22/2005	34	22
6/23/2005	34.3	22
6/24/2005	34.2	22
6/25/2005	36.9	25
6/26/2005	66.9	54
6/27/2005	56.7	44
6/28/2005	47.6	35
6/29/2005	40.3	28
6/30/2005	49.1	36
7/1/2005	47.4	36
7/2/2005	39.2	28
7/3/2005	40.5	30
7/4/2005	50.8	39
7/5/2005	52.1	40
7/6/2005	47	35
7/7/2005	43.1	31
7/8/2005	41.6	30
7/9/2005	38.3	27
7/10/2005	33.6	22
7/11/2005	33.5	21

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
7/12/2005	35.9	23
7/13/2005	40.8	28
7/14/2005	39.7	27
7/15/2005	36.2	24
7/16/2005	33.3	22
7/17/2005	31.4	20
7/18/2005	33	21
7/19/2005	31.8	20
7/20/2005	45.7	33
7/21/2005	59.1	46
7/22/2005	61.3	49
7/23/2005	66.6	54
7/24/2005	70.3	58
7/25/2005	55.2	42
7/26/2005	75.5	61
7/27/2005	58.6	46
7/28/2005	47.4	35
7/29/2005	40.1	28
7/30/2005	35.6	24
7/31/2005	35.4	24
8/1/2005	34.3	24
8/2/2005	33.2	20
8/3/2005	30.6	18
8/4/2005	32.2	20
8/5/2005	29.8	18
8/6/2005	26.2	15
8/7/2005	27.1	16
8/8/2005	31.2	20
8/9/2005	30.5	18
8/10/2005	28	16
8/11/2005	30.2	18
8/12/2005	44.5	32

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
8/13/2005	38.5	27
8/14/2005	34.4	23
8/15/2005	34.4	22
8/16/2005	32.7	20
8/17/2005	29.5	17
8/18/2005	46.5	33
8/19/2005	44.6	32
8/20/2005	41.9	30
8/21/2005	38.5	27
8/22/2005	36.1	24
8/23/2005	30.1	20
8/24/2005	32	20
8/25/2005	31.8	20
8/26/2005	33	21
8/27/2005	59.7	47
8/28/2005	40.7	29
8/29/2005	34	22
8/30/2005	33.1	21
8/31/2005	36.2	24
9/1/2005	37.1	25
9/2/2005	33.7	22
9/3/2005	27	16
9/4/2005	28.1	17
9/5/2005	27.5	15
9/6/2005	27.7	16
9/7/2005	28.9	17
9/8/2005	28.9	17
9/9/2005	28.7	17
9/10/2005	29.5	18
9/11/2005	29.6	18
9/12/2005	29.8	18
9/13/2005	39.8	27

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
9/14/2005	34.3	22
9/15/2005	29.6	18
9/16/2005	30.3	19
9/17/2005	31.2	20
9/18/2005	28.4	17
9/19/2005	38.3	25
9/20/2005	36.6	24
9/21/2005	32.9	20
9/22/2005	85.6	71
9/23/2005	61.7	49
9/24/2005	36.8	25
9/25/2005	81.7	68
9/26/2005	158.9	144
9/27/2005	104.2	91
9/28/2005	64.9	52
9/29/2005	52.3	40
9/30/2005	45	33
10/1/2005	40.6	29
10/2/2005	36.8	25
10/3/2005	36.1	26
10/4/2005	35	23
10/5/2005	35.1	23
10/6/2005	39.1	27
10/7/2005	36.7	25
10/8/2005	33.7	22
10/9/2005	32.6	21
10/10/2005	34.1	22
10/11/2005	33.9	22
10/12/2005	32.9	21
10/13/2005	31.9	20
10/14/2005	32.7	21
10/15/2005	30.4	19

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
10/16/2005	31.6	20
10/17/2005	33.7	21
10/18/2005	34.3	22
10/19/2005	31.2	19
10/20/2005	30.3	18
10/21/2005	29.7	18
10/22/2005	29.4	18
10/23/2005	34.7	23
10/24/2005	33.9	22
10/25/2005	31.6	20
10/26/2005	32.8	21
10/27/2005	32.7	21
10/28/2005	31.6	20
10/29/2005	30	19
10/30/2005	28.1	17
10/31/2005	31.1	19
11/1/2005	31.5	19
11/2/2005	27.8	18
11/3/2005	29.5	18
11/4/2005	30.4	19
11/5/2005	90.6	77
11/6/2005	232.9	217
11/7/2005	146.9	132
11/8/2005	94.4	81
11/9/2005	66.4	54
11/10/2005	57	45
11/11/2005	50.6	39
11/12/2005	52.7	41
11/13/2005	57.4	45
11/14/2005	58.3	45
11/15/2005	63.9	50
11/16/2005	91.2	77

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
11/17/2005	79.5	66
11/18/2005	69.7	57
11/19/2005	60.2	48
11/20/2005	56	44
11/21/2005	54.6	42
11/22/2005	52.4	40
11/23/2005	51.7	39
11/24/2005	49.7	38
11/25/2005	47.7	36
11/26/2005	48	36
11/27/2005	60.4	48
11/28/2005	117.5	104
11/29/2005	121	108
11/30/2005	95.9	83
12/1/2005	77.7	65
12/2/2005	61.6	49
12/3/2005	65.2	53
12/4/2005	57.2	45
12/5/2005	53.1	40
12/6/2005	47.2	35
12/7/2005	44.1	33
12/8/2005	43.9	32
12/9/2005	43	31
12/10/2005	43	31
12/11/2005	42.9	31
12/12/2005	43.4	31
12/13/2005	43.2	31
12/14/2005	44.5	32
12/15/2005	45	34
12/16/2005	46.8	35
12/17/2005	45.9	34
12/18/2005	44.8	33

EXHIBIT A-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
12/19/2005	43.5	31
12/20/2005	42.5	30
12/21/2005	41.7	29
12/22/2005	44.3	32
12/23/2005	49.9	37
12/24/2005	55	43
12/25/2005	56.8	46
12/26/2005	59	47
12/27/2005	61.1	49
12/28/2005	66.3	54
12/29/2005	69.3	57
12/30/2005	70.2	58
12/31/2005	74.3	62

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
1/6/2008	281.7	15.7	297.4
1/7/2008	777.3	19.3	796.6
1/8/2008	1422.8	22.3	1445.1
1/9/2008	1208.3	21.6	1229.9
1/10/2008	667.5	20.4	688
1/11/2008	434.7	19.9	454.6
1/12/2008	357.1	18.9	376.1
1/13/2008	295.9	18.8	314.7
1/14/2008	238.9	19.2	258.1
1/15/2008	179	18.4	197.4
1/16/2008	148.2	18.2	166.4
2/4/2008	112.4	15.9	128.3
2/5/2008	289.7	15.6	305.3
2/6/2008	243.8	15.5	259.3
2/7/2008	204.7	14.7	219.4
2/8/2008	179.9	15	195
2/9/2008	154.8	14.8	169.6
3/13/2008	558.5	18.9	577.4
3/14/2008	1292.4	21.1	1313.5
3/15/2008	1280.3	21	1301.3
3/16/2008	795.6	20.6	816.2
3/17/2008	516.6	20.8	537.4
3/18/2008	533.8	21.3	555.1
3/19/2008	664.2	21	685.2
3/20/2008	651.5	20.7	672.1
3/21/2008	482.5	20.1	502.6
3/22/2008	350.4	19.5	369.9
3/23/2008	307	19	326
3/24/2008	287.3	20	307.3
3/25/2008	338.3	21.4	359.7
3/26/2008	929.7	23.1	952.8
3/27/2008	1172.3	24.1	1196.5

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
3/28/2008	842.8	23.1	865.8
3/29/2008	566.2	22	588.2
3/30/2008	418.1	21.5	439.6
3/31/2008	993.2	25.8	1019.1
4/1/2008	1632	25.8	1657.8
4/2/2008	904.8	25.1	929.8
4/3/2008	517.9	24.2	542
4/4/2008	533.7	23.8	557.5
4/5/2008	439.1	22.4	461.5
4/6/2008	314.2	21.9	336.2
4/7/2008	246	21.9	267.9
4/8/2008	231.4	23.6	255
4/9/2008	936.7	25.8	962.5
4/10/2008	928	25.8	953.8
4/11/2008	2270.7	25.8	2296.5
4/12/2008	1308.4	25.8	1334.2
4/13/2008	842.6	25.8	868.4
4/14/2008	521.6	25.8	547.5
4/15/2008	356.9	25.8	382.7
4/16/2008	269.4	25.8	295.2
4/17/2008	217.5	25.8	243.3
4/18/2008	181.7	24.3	206
4/19/2008	164.3	22.8	187.1
4/20/2008	147.7	21.9	169.6
4/21/2008	135.9	21.7	157.7
4/22/2008	128.3	21.5	149.8
4/23/2008	114.2	20.7	134.8
4/24/2008	107.1	20.7	127.8
4/25/2008	161.8	25.8	187.6
4/26/2008	481.8	25.8	507.6
4/27/2008	281.9	25.5	307.5
4/28/2008	162.5	25.8	188.3
4/29/2008	131.2	24.4	155.6

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
4/30/2008	108	21.8	129.8
5/1/2008	98.7	22.3	121
5/2/2008	112.7	21.9	134.6
5/3/2008	172.2	21.4	193.6
5/4/2008	151.7	21.1	172.8
5/5/2008	113.4	20.2	133.7
5/6/2008	97.1	19.8	116.9
5/7/2008	92.1	19.6	111.7
5/8/2008	81.8	19	100.9
5/9/2008	75.5	18.6	94.1
5/10/2008	66.4	18.3	84.7
5/11/2008	78.5	19	97.5
5/12/2008	99.2	19.1	118.3
5/13/2008	71.6	18.8	90.4
5/14/2008	67.6	18.6	86.2
5/15/2008	59.7	18.1	77.8
5/16/2008	56.7	17.6	74.3
5/17/2008	52.5	17	69.5
5/18/2008	48.7	16.8	65.5
5/19/2008	48.1	16.8	64.9
5/20/2008	47.9	16.9	64.8
5/21/2008	40.7	16.5	57.2
5/22/2008	38.9	16.3	55.2
5/23/2008	39.6	15.8	55.5
5/24/2008	33	15	48
5/25/2008	32.2	14.5	46.7
5/26/2008	79.8	15.8	95.6
5/27/2008	71.8	15.8	87.6
5/28/2008	46.6	15.5	62.1
5/29/2008	39	15.6	54.6
5/30/2008	246	16.9	262.9
5/31/2008	255.9	15.6	271.5
6/1/2008	101.1	15.1	116.2

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
6/2/2008	68.9	15.4	84.3
6/3/2008	60.8	15.7	76.6
6/4/2008	55.9	15.5	71.4
6/5/2008	457	19.2	476.2
6/6/2008	764.5	17.4	782
6/7/2008	999.5	25.2	1024.7
6/8/2008	6407.6	25.8	6433.4
6/9/2008	5352.6	25.8	5378.4
6/10/2008	2481.3	25.8	2507.1
6/11/2008	1429.1	25.8	1455
6/12/2008	814	25.8	839.9
6/13/2008	1259.8	25.8	1285.6
6/14/2008	924.6	25.8	950.5
6/15/2008	473.1	25.8	498.9
6/16/2008	292.7	25.8	318.5
6/17/2008	212.2	25.8	238
6/18/2008	176.3	25.8	202.2
6/19/2008	152.1	25.8	178
6/20/2008	134.1	25.8	160
6/21/2008	128.1	25.8	153.9
6/22/2008	114.2	25.8	140.1
6/23/2008	107.8	25.1	132.9
6/24/2008	98.6	23.8	122.4
6/25/2008	86.9	23.1	110
6/26/2008	72.9	22.4	95.3
6/27/2008	69	22.6	91.7
6/28/2008	121	20.7	141.7
6/29/2008	110.7	20	130.7
6/30/2008	85.8	19.7	105.6
7/1/2008	69.2	18.9	88.1
7/2/2008	68.9	19.9	88.8
7/3/2008	85.1	18.4	103.4
7/4/2008	54.3	17.3	71.5

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
7/5/2008	41.9	17.1	59
7/6/2008	36	17.1	53.1
7/7/2008	69.3	18.8	88.1
7/8/2008	241.7	19.7	261.4
7/9/2008	179.4	19	198.3
7/10/2008	77.7	18.1	95.8
7/11/2008	158.8	20.5	179.3
7/12/2008	255.3	19.3	274.7
7/13/2008	222.8	19.5	242.3
7/14/2008	104.3	18.8	123.2
7/15/2008	72.8	18.4	91.2
7/16/2008	60.3	18	78.3
7/17/2008	49	17.9	66.8
7/18/2008	40.7	17.3	58
7/19/2008	38	17	55
7/20/2008	54	17.9	71.9
7/21/2008	44.9	17	61.9
7/22/2008	33.5	16.6	50.1
7/23/2008	31.2	16.1	47.3
7/24/2008	25.7	15.8	41.5
7/25/2008	33.9	15.7	49.5
7/26/2008	24.2	15.3	39.5
7/27/2008	18	14.9	33
8/4/2008	50.4	15.8	66.2
8/5/2008	75.7	15	90.6
8/6/2008	32.2	14.9	47.1
8/7/2008	28.6	14.5	43
8/13/2008	15.9	15	31
8/14/2008	62.5	14.7	77.2
8/15/2008	21.8	14.3	36.1
9/2/2008	4.4	11.5	15.9
9/3/2008	4.4	15.7	20.1
9/4/2008	46.7	16.7	63.5

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
9/5/2008	222.9	16	238.9
9/6/2008	75.1	14.2	89.3
9/7/2008	27.9	14.1	42
9/8/2008	21.2	15.1	36.4
9/9/2008	37.3	12.8	50
9/10/2008	22.9	15.8	38.7
9/11/2008	10.1	14.4	24.4
9/12/2008	14.8	13.8	28.6
9/13/2008	130.1	16.7	146.9
9/14/2008	236.7	17.8	254.5
9/15/2008	296.1	17.2	313.4
9/16/2008	114.1	16.2	130.3
9/17/2008	61.8	15.4	77.2
9/18/2008	34.5	15	49.5
9/19/2008	24.7	14.7	39.4
9/20/2008	14.6	14.3	29
9/29/2008	17.1	13.8	30.8
9/30/2008	23.7	13.8	37.5
10/1/2008	23.9	14.4	38.3
10/2/2008	24.6	13.5	38.1
10/3/2008	16.5	12.2	28.7
10/4/2008	8.2	12.6	20.8
10/5/2008	6.3	13.9	20.2
10/6/2008	38.7	14.4	53.1
10/7/2008	26.8	15.3	42.2
10/8/2008	92.6	14.7	107.3
10/9/2008	72.3	14.7	87
10/10/2008	36.4	14.1	50.5
10/11/2008	26.6	13.4	40
10/12/2008	20.4	13.3	33.7
10/13/2008	26.1	13.5	39.6
10/14/2008	31.9	13.6	45.5
10/15/2008	31.1	13.8	44.9

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
10/16/2008	37	13.5	50.6
10/17/2008	34.6	13.4	48
10/18/2008	32.2	13	45.2
10/19/2008	31.5	13.2	44.7
10/20/2008	33.1	13.9	47
10/21/2008	39.8	13.4	53.2
10/22/2008	35.6	13.3	49
10/23/2008	33.1	13.2	46.3
10/24/2008	41.3	13.7	55
10/25/2008	73.2	14	87.2
10/26/2008	76.8	13.7	90.5
10/27/2008	37.3	13.7	51
10/28/2008	25.1	13.5	38.6
10/29/2008	22.9	13.3	36.2
10/30/2008	24.4	13.3	37.8
10/31/2008	35.6	12.7	48.4
11/1/2008	29	13.7	42.7
11/2/2008	23.5	14	37.5
11/3/2008	24.1	14.3	38.4
11/4/2008	24	13.6	37.6
11/5/2008	28.3	13.8	42
11/6/2008	42.7	13.9	56.7
11/7/2008	55.7	12.9	68.6
11/8/2008	47.5	12.7	60.2
11/9/2008	33.3	12.7	46
11/10/2008	25.3	12.7	38
11/11/2008	27	13	40.1
11/12/2008	58.2	13.3	71.6
11/13/2008	65	13.7	78.7
11/14/2008	81.7	13.8	95.5
11/15/2008	80.7	13.2	93.9
11/16/2008	51.2	13.5	64.7
11/17/2008	32.5	13.4	45.9

EXHIBIT A-3

Summary Table of Year 2008 Flow in the Root River with Simulated Return Flow

Date	River Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	River Average Day Flow with Return Flow (cfs)
11/18/2008	28.7	13.5	42.2
11/19/2008	25.7	13.4	39.1
11/20/2008	29.5	13.4	42.9
11/21/2008	21	12.6	33.6
11/22/2008	18.7	12.3	31
11/23/2008	17.4	12.7	30
11/24/2008	16.2	12.8	29
11/25/2008	18.3	12.4	30.7
11/26/2008	16.9	12.9	29.7
11/27/2008	15.5	12.3	27.8
11/28/2008	12.2	12.1	24.4
11/29/2008	11.5	12.3	23.7
11/30/2008	10.9	12.8	23.7
12/1/2008	19	12.8	31.9
12/2/2008	30.5	12.9	43.4
12/3/2008	23.2	13.2	36.3
12/5/2008	19.5	12.7	32.2
12/6/2008	18.2	12.7	30.9
12/7/2008	18.1	12.9	31
12/8/2008	17.4	13.4	30.7
12/9/2008	19.7	13.4	33.1
12/13/2008	26.6	12.5	39.2
12/14/2008	112.6	15.1	127.6
12/15/2008	725.8	16.1	741.9
12/16/2008	470.9	15.1	486
12/17/2008	190.6	14.2	204.9
12/28/2008	2355.2	22.8	2378
12/29/2008	1617.9	21	1639
12/30/2008	872.2	19.1	891.3

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
1/1/2008	105.7	92
1/2/2008	85.8	72
1/3/2008	87.5	70
1/4/2008	84.1	70
1/5/2008	90	76
1/6/2008	131.7	116
1/7/2008	267.3	248
1/8/2008	446.3	424
1/9/2008	505.6	484
1/10/2008	469.4	449
1/11/2008	443.9	424
1/12/2008	412.9	394
1/13/2008	375.8	357
1/14/2008	337.2	318
1/15/2008	281.4	263
1/16/2008	253.2	235
1/17/2008	226.8	209
1/18/2008	181.6	165
1/19/2008	160.5	140
1/20/2008	125.8	110
1/21/2008	105.6	90
1/22/2008	99.4	84
1/23/2008	91.2	76
1/24/2008	85.1	70
1/25/2008	89.9	75
1/26/2008	94.6	80
1/27/2008	100.8	86
1/28/2008	106.6	91
1/29/2008	143.3	127
1/30/2008	145.6	130
1/31/2008	115.3	100
2/1/2008	100.9	86
2/2/2008	98.8	84

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
2/3/2008	104.7	90
2/4/2008	128.9	113
2/5/2008	147.6	132
2/6/2008	141.5	126
2/7/2008	126.7	112
2/8/2008	133	118
2/9/2008	134.8	120
2/10/2008	111.5	97
2/11/2008	105.2	90
2/12/2008	102.1	87
2/13/2008	99.2	84
2/14/2008	98	83
2/15/2008	98.5	84
2/16/2008	104.1	90
2/17/2008	219.2	197
2/18/2008	259.2	241
2/19/2008	236.1	219
2/20/2008	232.4	216
2/21/2008	201.2	185
2/22/2008	192.9	177
2/23/2008	179.7	164
2/24/2008	173.5	158
2/25/2008	168.6	153
2/26/2008	163.4	148
2/27/2008	159.2	144
2/28/2008	153.9	139
2/29/2008	150.1	135
3/1/2008	142.9	128
3/2/2008	153	137
3/3/2008	302.5	281
3/4/2008	330.3	311
3/5/2008	308.3	290
3/6/2008	289.8	272

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
3/7/2008	262.3	245
3/8/2008	226	209
3/9/2008	205.5	189
3/10/2008	189.1	173
3/11/2008	185.8	169
3/12/2008	193.2	176
3/13/2008	241.9	223
3/14/2008	383.1	362
3/15/2008	458	437
3/16/2008	460.6	440
3/17/2008	436.8	416
3/18/2008	421.3	400
3/19/2008	415	394
3/20/2008	409.7	389
3/21/2008	396.1	376
3/22/2008	366.5	347
3/23/2008	356	337
3/24/2008	346	326
3/25/2008	350.4	329
3/26/2008	425.1	402
3/27/2008	489.1	465
3/28/2008	483.1	460
3/29/2008	443	421
3/30/2008	411.5	390
3/31/2008	508	482.1
4/1/2008	639.1	613.3
4/2/2008	597.1	572
4/3/2008	510.2	486
4/4/2008	479.8	456
4/5/2008	447.4	425
4/6/2008	406.9	385
4/7/2008	366.9	345
4/8/2008	408.6	385

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
4/9/2008	572.3	546.4
4/10/2008	712.7	686.9
4/11/2008	1025.7	999.8
4/12/2008	1109	1083.2
4/13/2008	949.1	923.2
4/14/2008	737.5	711.6
4/15/2008	571.1	545.2
4/16/2008	475	449.2
4/17/2008	417.9	392.1
4/18/2008	372.3	348
4/19/2008	332.8	310
4/20/2008	302.9	281
4/21/2008	274.7	253
4/22/2008	256.5	235
4/23/2008	239.7	219
4/24/2008	225.7	205
4/25/2008	421.3	395.5
4/26/2008	600.3	574.4
4/27/2008	563.5	538
4/28/2008	559.9	534.1
4/29/2008	514.4	490
4/30/2008	434.8	413
5/1/2008	369.3	347
5/2/2008	335.9	314
5/3/2008	320.4	299
5/4/2008	295.1	274
5/5/2008	267.2	247
5/6/2008	238.8	219
5/7/2008	210.6	191
5/8/2008	194	175
5/9/2008	198.6	180
5/10/2008	205.3	187
5/11/2008	220	201

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
5/12/2008	221.1	202
5/13/2008	206.8	188
5/14/2008	199.6	181
5/15/2008	188.1	170
5/16/2008	177.6	160
5/17/2008	170	153
5/18/2008	163.8	147
5/19/2008	158.8	142
5/20/2008	153.9	137
5/21/2008	146.5	130
5/22/2008	140.3	124
5/23/2008	131.8	116
5/24/2008	99	84
5/25/2008	90.5	76
5/26/2008	112.8	97
5/27/2008	100.8	85
5/28/2008	92.5	77
5/29/2008	83.6	68
5/30/2008	148.9	132
5/31/2008	136.6	121
6/1/2008	113.1	98
6/2/2008	97.4	82
6/3/2008	86.7	71
6/4/2008	84.5	69
6/5/2008	220.2	201
6/6/2008	254.4	237
6/7/2008	579.2	554
6/8/2008	1868.2	1842.4
6/9/2008	2443	2417.2
6/10/2008	2340.5	2314.7
6/11/2008	1879	1853.1
6/12/2008	1499.4	1473.5
6/13/2008	1812.3	1786.5

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
6/14/2008	1754.4	1728.6
6/15/2008	1566	1540.2
6/16/2008	1301.4	1275.6
6/17/2008	1047.7	1021.8
6/18/2008	834.5	808.6
6/19/2008	669.7	643.9
6/20/2008	548.4	522.5
6/21/2008	459.3	433.4
6/22/2008	406.9	381.1
6/23/2008	361.1	336
6/24/2008	319.8	296
6/25/2008	293.1	270
6/26/2008	264.4	242
6/27/2008	239.6	217
6/28/2008	227.7	207
6/29/2008	211	191
6/30/2008	190.7	171
7/1/2008	186.9	168
7/2/2008	199.9	180
7/3/2008	195.4	177
7/4/2008	183.3	166
7/5/2008	175.1	158
7/6/2008	167.1	150
7/7/2008	202.8	184
7/8/2008	270.7	251
7/9/2008	243	224
7/10/2008	229.1	211
7/11/2008	287.5	267
7/12/2008	276.3	257
7/13/2008	242.5	223
7/14/2008	206.8	188
7/15/2008	183.4	165
7/16/2008	168	150

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
7/17/2008	155.9	138
7/18/2008	149.3	132
7/19/2008	157	140
7/20/2008	164.9	147
7/21/2008	154	137
7/22/2008	150.6	134
7/23/2008	150.1	134
7/24/2008	143.8	128
7/25/2008	138.7	123
7/26/2008	138.3	123
7/27/2008	139.9	125
7/28/2008	140.5	125
7/29/2008	138.6	123
7/30/2008	132.4	117
7/31/2008	127.5	112
8/1/2008	124.8	110
8/2/2008	122.2	108
8/3/2008	120	106
8/4/2008	148.8	133
8/5/2008	151	136
8/6/2008	136.9	122
8/7/2008	123.5	109
8/8/2008	116.2	102
8/9/2008	109.7	96
8/10/2008	104.6	91
8/11/2008	103.8	89
8/12/2008	89.7	75
8/13/2008	75	60
8/14/2008	78.7	64
8/15/2008	74.3	60
8/16/2008	65.1	52
8/17/2008	60.3	47
8/18/2008	61.8	48

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
8/19/2008	63.1	49
8/20/2008	54.8	41
8/21/2008	55.9	42
8/22/2008	55.9	42
8/23/2008	56.4	43
8/24/2008	50.8	38
8/25/2008	51.2	38
8/26/2008	50.7	36
8/27/2008	47.7	34
8/28/2008	46.5	34
8/29/2008	46.3	34
8/30/2008	44.5	32
8/31/2008	37.8	25
9/1/2008	35.8	23
9/2/2008	35.5	24
9/3/2008	41.7	26
9/4/2008	104.7	88
9/5/2008	154	138
9/6/2008	102.2	88
9/7/2008	77.1	63
9/8/2008	74.1	59
9/9/2008	68.8	56
9/10/2008	65.8	50
9/11/2008	56.4	42
9/12/2008	53.8	40
9/13/2008	135.7	119
9/14/2008	192.8	175
9/15/2008	197.2	180
9/16/2008	156.2	140
9/17/2008	127.4	112
9/18/2008	115	100
9/19/2008	114.7	100
9/20/2008	111.3	97

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
9/21/2008	104.3	90
9/22/2008	99.7	85
9/23/2008	94.4	80
9/24/2008	91.4	77
9/25/2008	90	76
9/26/2008	82	70
9/27/2008	81.5	68
9/28/2008	81.4	68
9/29/2008	80.8	67
9/30/2008	79.8	66
10/1/2008	77.4	63
10/2/2008	71.5	58
10/3/2008	71.2	59
10/4/2008	66.6	54
10/5/2008	85.9	72
10/6/2008	109.4	95
10/7/2008	107.3	92
10/8/2008	134.7	120
10/9/2008	122.7	108
10/10/2008	102.1	88
10/11/2008	88.4	75
10/12/2008	81.3	68
10/13/2008	77.5	64
10/14/2008	84.6	71
10/15/2008	78.8	65
10/16/2008	82.5	69
10/17/2008	78.4	65
10/18/2008	74	61
10/19/2008	74.2	61
10/20/2008	77.9	64
10/21/2008	75.4	62
10/22/2008	73.3	60
10/23/2008	72.2	59

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
10/24/2008	77.7	64
10/25/2008	96	82
10/26/2008	90.7	77
10/27/2008	86.7	73
10/28/2008	79.5	66
10/29/2008	71.3	58
10/30/2008	67.3	54
10/31/2008	64.7	52
11/1/2008	68.7	55
11/2/2008	69	55
11/3/2008	67.3	53
11/4/2008	63.6	50
11/5/2008	66.8	53
11/6/2008	79.9	66
11/7/2008	70.9	58
11/8/2008	71.7	59
11/9/2008	71.7	59
11/10/2008	70.7	58
11/11/2008	71	58
11/12/2008	82.3	69
11/13/2008	91.7	78
11/14/2008	108.8	95
11/15/2008	95.2	82
11/16/2008	85.5	72
11/17/2008	78.4	65
11/18/2008	75.5	62
11/19/2008	80.4	67
11/20/2008	76.4	63
11/21/2008	60.6	48
11/22/2008	68.3	56
11/23/2008	64.7	52
11/24/2008	70.8	58
11/25/2008	71.4	59

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
11/26/2008	68.9	56
11/27/2008	61.3	49
11/28/2008	61.1	49
11/29/2008	62.3	50
11/30/2008	65.8	53
12/1/2008	61.8	49
12/2/2008	67.9	55
12/3/2008	75.2	62
12/4/2008	63.9	51
12/5/2008	64.7	52
12/6/2008	62.7	50
12/7/2008	62.9	50
12/8/2008	64.4	51
12/9/2008	66.4	53
12/10/2008	64.4	51
12/11/2008	63	50
12/12/2008	62.7	50
12/13/2008	62.5	50
12/14/2008	98.1	83
12/15/2008	183.1	167
12/16/2008	181.1	166
12/17/2008	105.2	91
12/18/2008	92.8	79
12/19/2008	83.9	70
12/20/2008	77.3	64
12/21/2008	70	57
12/22/2008	69.1	56
12/23/2008	68.1	55
12/24/2008	67	54
12/25/2008	64.7	53
12/26/2008	79.9	67
12/27/2008	288.9	265
12/28/2008	485.8	463

EXHIBIT A-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Root River

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
12/29/2008	536	515
12/30/2008	418.1	399
12/31/2008	329.9	312

Attachment B
Tabular Summary of Underwood Creek Return Flow Simulations

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
1/1/05	7.0	12.0	19.0
1/2/05	62.0	13.8	75.8
1/3/05	8.4	13.8	22.2
1/4/05	5.8	12.0	17.8
1/5/05	4.9	12.0	16.9
1/6/05	3.8	12.0	15.8
1/7/05	3.4	12.0	15.4
1/8/05	3.1	12.0	15.1
1/9/05	2.9	12.0	14.9
1/10/05	2.9	12.0	14.9
1/11/05	3.2	12.0	15.2
1/12/05	154.0	13.8	167.8
1/13/05	82.0	13.8	95.8
1/14/05	21.0	13.8	34.8
1/15/05	10.0	12.0	22.0
1/16/05	8.0	12.0	20.0
1/17/05	7.0	12.0	19.0
1/18/05	6.6	12.0	18.6
1/19/05	6.0	12.0	18.0
1/20/05	4.8	12.0	16.8
1/21/05	4.4	12.0	16.4
1/22/05	4.3	12.0	16.3
1/23/05	4.2	12.0	16.2
1/24/05	5.3	12.0	17.3
1/25/05	5.1	12.0	17.1
1/26/05	4.6	12.0	16.6
1/27/05	4.4	12.0	16.4
1/28/05	3.8	12.0	15.8
1/29/05	3.4	12.0	15.4
1/30/05	3.2	12.0	15.2
1/31/05	3.1	12.0	15.1
2/1/05	3.0	12.0	15.0
2/2/05	2.8	12.0	14.8

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
2/3/05	3.3	12.0	15.3
2/4/05	5.2	12.0	17.2
2/5/05	11.0	13.8	24.8
2/6/05	14.0	13.8	27.8
2/7/05	48.0	13.8	61.8
2/8/05	16.0	13.8	29.8
2/9/05	9.8	13.8	23.6
2/10/05	7.3	13.8	21.1
2/11/05	6.3	13.8	20.1
2/12/05	7.0	13.8	20.8
2/13/05	33.0	13.8	46.8
2/14/05	90.0	13.8	103.8
2/15/05	33.0	13.8	46.8
2/16/05	17.0	13.8	30.8
2/17/05	11.0	13.8	24.8
2/18/05	8.0	13.8	21.8
2/19/05	6.5	13.8	20.3
2/20/05	8.5	13.8	22.3
2/21/05	11.0	13.8	24.8
2/22/05	7.8	13.8	21.6
2/23/05	6.2	13.8	20.0
2/24/05	5.7	13.8	19.5
2/25/05	5.8	13.8	19.6
2/26/05	5.5	13.8	19.3
2/27/05	4.5	12.0	16.5
2/28/05	4.2	12.0	16.2
3/1/05	4.0	12.0	16.0
3/2/05	4.0	12.0	16.0
3/3/05	4.4	13.8	18.2
3/4/05	5.9	13.8	19.7
3/5/05	7.3	13.8	21.1
3/6/05	30.0	13.8	43.8
3/7/05	47.0	13.8	60.8

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
3/8/05	18.0	13.8	31.8
3/9/05	12.0	13.8	25.8
3/10/05	12.0	13.8	25.8
3/11/05	10.0	13.8	23.8
3/12/05	9.5	13.8	23.3
3/13/05	7.2	13.8	21.0
3/14/05	5.5	13.8	19.3
3/15/05	6.1	13.8	19.9
3/16/05	6.9	13.8	20.7
3/17/05	6.7	13.8	20.5
3/18/05	9.0	13.8	22.8
3/19/05	31.0	13.8	44.8
3/20/05	19.0	13.8	32.8
3/21/05	19.0	13.8	32.8
3/22/05	17.0	13.8	30.8
3/23/05	14.0	13.8	27.8
3/24/05	14.0	13.8	27.8
3/25/05	14.0	13.8	27.8
3/26/05	14.0	13.8	27.8
3/27/05	16.0	13.8	29.8
3/28/05	17.0	13.8	30.8
3/29/05	18.0	13.8	31.8
3/30/05	30.0	13.8	43.8
3/31/05	24.0	13.8	37.8
4/1/05	29.0	13.8	42.8
4/2/05	26.0	13.8	39.8
4/3/05	17.0	13.7	30.7
4/4/05	14.0	13.8	27.8
4/5/05	12.0	13.8	25.8
4/6/05	36.0	13.8	49.8
4/7/05	32.0	13.8	45.8
4/8/05	17.0	13.8	30.8
4/9/05	13.0	13.8	26.8

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
4/10/05	11.0	13.8	24.8
4/11/05	9.6	13.8	23.4
4/12/05	9.2	13.8	23.0
4/13/05	8.2	13.8	22.0
4/14/05	7.3	13.8	21.1
4/15/05	6.9	13.8	20.7
4/16/05	6.6	13.8	20.4
4/17/05	6.8	13.8	20.6
4/18/05	6.2	13.8	20.0
4/19/05	5.9	13.8	19.7
4/20/05	10.0	13.8	23.8
4/21/05	6.6	13.8	20.4
4/22/05	12.0	13.8	25.8
4/23/05	7.0	13.8	20.8
4/24/05	6.0	13.8	19.8
4/25/05	5.8	13.8	19.6
4/26/05	5.7	13.8	19.5
4/27/05	5.8	13.8	19.6
4/28/05	5.0	13.8	18.8
4/29/05	4.9	13.7	18.6
4/30/05	4.9	13.6	18.5
5/1/05	4.5	13.8	18.3
5/2/05	4.3	13.8	18.1
5/3/05	4.1	13.8	17.9
5/4/05	4.0	13.8	17.8
5/5/05	3.9	13.8	17.7
5/6/05	24.0	13.8	37.8
5/7/05	9.7	13.3	23.0
5/8/05	6.4	12.6	19.0
5/9/05	19.0	13.8	32.8
5/10/05	12.0	13.5	25.5
5/11/05	45.0	13.8	58.8
5/12/05	12.0	13.8	25.8

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
5/13/05	20.0	13.8	33.8
5/14/05	11.0	13.8	24.8
5/15/05	8.1	13.8	21.9
5/16/05	6.7	13.8	20.5
5/17/05	6.0	13.5	19.5
5/18/05	5.7	13.5	19.2
5/19/05	68.0	13.8	81.8
5/20/05	17.0	13.8	30.8
5/21/05	10.0	13.7	23.7
5/22/05	8.2	13.6	21.8
5/23/05	7.2	13.8	21.0
5/24/05	6.1	13.6	19.7
5/25/05	5.5	13.6	19.1
5/26/05	5.1	13.6	18.7
5/27/05	7.0	13.8	20.8
5/28/05	6.7	13.1	19.8
5/29/05	4.7	12.2	16.9
5/30/05	4.4	12.9	17.3
5/31/05	4.1	13.4	17.5
6/1/05	3.8	13.4	17.2
6/2/05	3.9	13.1	17.0
6/3/05	3.7	13.1	16.8
6/4/05	3.7	12.8	16.5
6/5/05	13.0	13.3	26.3
6/6/05	4.5	13.8	18.3
6/7/05	6.4	13.7	20.1
6/8/05	3.7	13.7	17.4
6/9/05	3.3	13.6	16.9
6/10/05	3.1	13.3	16.4
6/11/05	3.1	12.6	15.7
6/12/05	3.1	12.5	15.6
6/13/05	22.0	13.1	35.1
6/14/05	6.7	12.9	19.6

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
6/15/05	4.0	12.8	16.8
6/16/05	3.3	12.6	15.9
6/17/05	3.1	12.6	15.7
6/18/05	3.2	11.7	14.9
6/19/05	3.1	11.4	14.5
6/20/05	2.7	13.2	15.9
6/21/05	2.9	12.3	15.2
6/22/05	2.9	12.0	14.9
6/23/05	2.7	12.3	15.0
6/24/05	2.8	12.2	15.0
6/25/05	3.9	11.9	15.8
6/26/05	42.0	12.9	54.9
6/27/05	9.7	12.7	22.4
6/28/05	8.7	12.6	21.3
6/29/05	3.9	12.3	16.2
6/30/05	17.0	13.1	30.1
7/1/05	4.1	11.4	15.5
7/2/05	3.0	11.2	14.2
7/3/05	2.6	10.5	13.1
7/4/05	10.0	11.8	21.8
7/5/05	5.2	12.1	17.3
7/6/05	3.5	12.0	15.5
7/7/05	3.1	12.1	15.2
7/8/05	2.7	11.6	14.3
7/9/05	2.7	11.3	14.0
7/10/05	2.4	11.6	14.0
7/11/05	2.6	12.5	15.1
7/12/05	5.0	12.9	17.9
7/13/05	4.3	12.8	17.1
7/14/05	2.8	12.7	15.5
7/15/05	2.5	12.2	14.7
7/16/05	2.6	11.3	13.9
7/17/05	2.6	11.4	14.0

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
7/18/05	2.6	12.0	14.6
7/19/05	2.6	11.8	14.4
7/20/05	16.0	12.7	28.7
7/21/05	23.0	13.1	36.1
7/22/05	4.9	12.3	17.2
7/23/05	16.0	12.6	28.6
7/24/05	6.1	12.3	18.4
7/25/05	3.8	13.2	17.0
7/26/05	22.0	13.8	35.8
7/27/05	5.2	12.6	17.8
7/28/05	3.9	12.4	16.3
7/29/05	2.8	12.1	14.9
7/30/05	2.5	11.6	14.1
7/31/05	2.4	11.4	13.8
8/1/05	2.3	10.3	12.6
8/2/05	2.3	13.2	15.5
8/3/05	2.4	12.6	15.0
8/4/05	3.7	12.2	15.9
8/5/05	2.2	11.8	14.0
8/6/05	1.9	11.2	13.1
8/7/05	2.0	11.1	13.1
8/8/05	1.9	11.2	13.1
8/9/05	2.0	12.5	14.5
8/10/05	2.1	12.0	14.1
8/11/05	2.3	12.2	14.5
8/12/05	17.0	12.5	29.5
8/13/05	2.8	11.5	14.3
8/14/05	2.2	11.4	13.6
8/15/05	2.0	12.4	14.4
8/16/05	2.0	12.7	14.7
8/17/05	2.0	12.5	14.5
8/18/05	18.0	13.5	31.5
8/19/05	3.7	12.6	16.3

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
8/20/05	6.1	11.9	18.0
8/21/05	2.4	11.5	13.9
8/22/05	2.1	12.1	14.2
8/23/05	2.0	10.1	12.1
8/24/05	2.0	12.0	14.0
8/25/05	2.3	11.8	14.1
8/26/05	2.5	12.0	14.5
8/27/05	5.9	12.7	18.6
8/28/05	2.8	11.7	14.5
8/29/05	2.2	12.0	14.2
8/30/05	2.1	12.1	14.2
8/31/05	2.1	12.2	14.3
9/1/05	2.1	12.1	14.2
9/2/05	2.2	11.7	13.9
9/3/05	2.0	11.0	13.0
9/4/05	2.1	11.1	13.2
9/5/05	2.1	12.5	14.6
9/6/05	2.2	11.7	13.9
9/7/05	2.4	11.9	14.3
9/8/05	2.8	11.9	14.7
9/9/05	2.2	11.7	13.9
9/10/05	2.1	11.5	13.6
9/11/05	2.2	11.6	13.8
9/12/05	2.1	11.8	13.9
9/13/05	3.0	12.8	15.8
9/14/05	1.9	12.3	14.2
9/15/05	2.0	11.6	13.6
9/16/05	4.6	11.3	15.9
9/17/05	1.8	11.2	13.0
9/18/05	1.8	11.4	13.2
9/19/05	15.0	13.3	28.3
9/20/05	2.4	12.6	15.0
9/21/05	1.8	12.9	14.7

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
9/22/05	59.0	13.8	72.8
9/23/05	6.5	12.7	19.2
9/24/05	4.4	11.8	16.2
9/25/05	144.0	13.7	157.7
9/26/05	40.0	13.8	53.8
9/27/05	11.0	13.2	24.2
9/28/05	8.0	12.9	20.9
9/29/05	4.7	12.3	17.0
9/30/05	3.3	12.0	15.3
10/1/05	2.8	11.6	14.4
10/2/05	2.4	11.8	14.2
10/3/05	2.1	10.1	12.2
10/4/05	2.2	12.0	14.2
10/5/05	2.0	12.1	14.1
10/6/05	1.9	12.1	14.0
10/7/05	1.7	11.7	13.4
10/8/05	1.6	11.7	13.3
10/9/05	1.7	11.6	13.3
10/10/05	1.6	12.1	13.7
10/11/05	1.6	11.9	13.5
10/12/05	2.4	11.9	14.3
10/13/05	1.7	11.9	13.6
10/14/05	1.9	11.7	13.6
10/15/05	1.6	11.4	13.0
10/16/05	1.6	11.6	13.2
10/17/05	6.8	12.7	19.5
10/18/05	2.2	12.3	14.5
10/19/05	1.9	12.2	14.1
10/20/05	1.8	12.3	14.1
10/21/05	2.1	11.7	13.8
10/22/05	2.6	11.4	14.0
10/23/05	6.6	11.7	18.3
10/24/05	2.7	11.9	14.6

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
10/25/05	2.2	11.6	13.8
10/26/05	2.3	11.8	14.1
10/27/05	2.0	11.7	13.7
10/28/05	1.9	11.6	13.5
10/29/05	1.9	11.0	12.9
10/30/05	1.7	11.1	12.8
10/31/05	1.7	12.1	13.8
11/1/05	1.7	12.5	14.2
11/2/05	1.7	9.8	11.5
11/3/05	1.9	11.5	13.4
11/4/05	1.9	11.4	13.3
11/5/05	28.0	13.6	41.6
11/6/05	49.0	13.8	62.8
11/7/05	7.9	13.8	21.7
11/8/05	4.8	13.4	18.2
11/9/05	3.7	12.4	16.1
11/10/05	2.8	12.0	14.8
11/11/05	2.5	11.6	14.1
11/12/05	7.3	11.7	19.0
11/13/05	3.9	12.4	16.3
11/14/05	6.1	13.3	19.4
11/15/05	20.0	13.8	33.8
11/16/05	10.0	13.8	23.8
11/17/05	4.4	13.5	17.9
11/18/05	3.1	12.7	15.8
11/19/05	2.8	12.2	15.0
11/20/05	2.4	12.0	14.4
11/21/05	2.2	12.6	14.8
11/22/05	2.0	12.4	14.4
11/23/05	2.0	12.0	14.0
11/24/05	1.9	12.0	13.9
11/25/05	2.0	12.0	14.0
11/26/05	2.4	12.0	14.4

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
11/27/05	23.0	12.4	35.4
11/28/05	38.0	13.5	51.5
11/29/05	9.9	13.0	22.9
11/30/05	5.4	12.9	18.3
12/1/05	4.9	12.7	17.6
12/2/05	3.4	12.0	15.4
12/3/05	3.2	12.0	15.2
12/4/05	3.0	12.0	15.0
12/5/05	2.7	12.0	14.7
12/6/05	2.6	12.0	14.6
12/7/05	2.5	12.0	14.5
12/8/05	2.4	12.0	14.4
12/9/05	2.4	12.0	14.4
12/10/05	2.3	12.0	14.3
12/11/05	2.3	12.0	14.3
12/12/05	2.3	12.0	14.3
12/13/05	2.4	12.0	14.4
12/14/05	2.5	12.0	14.5
12/15/05	2.4	12.0	14.4
12/16/05	2.3	12.0	14.3
12/17/05	2.3	12.0	14.3
12/18/05	2.2	12.0	14.2
12/19/05	2.2	12.0	14.2
12/20/05	2.2	12.0	14.2
12/21/05	2.4	12.0	14.4
12/22/05	2.5	12.0	14.5
12/23/05	5.7	12.9	18.6
12/24/05	4.8	12.0	16.8
12/25/05	4.2	10.8	15.0
12/26/05	3.3	12.0	15.3
12/27/05	3.1	12.1	15.2
12/28/05	4.1	12.3	16.4
12/29/05	4.2	12.3	16.5

EXHIBIT B-1

Summary Table of Year 2005 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
12/30/05	8.0	12.2	20.2
12/31/05	12.0	12.3	24.3

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
1/1/05	53.5	41.5
1/2/05	148.3	134.5
1/3/05	116.2	102.4
1/4/05	97.6	85.6
1/5/05	79.1	67.1
1/6/05	70.9	58.9
1/7/05	69.2	57.2
1/8/05	65.2	53.2
1/9/05	66.2	54.1
1/10/05	66.3	54.3
1/11/05	64.1	52.1
1/12/05	178.8	165.0
1/13/05	411.6	397.8
1/14/05	367.1	353.3
1/15/05	336.6	324.6
1/16/05	266.1	254.1
1/17/05	186.0	173.9
1/18/05	134.8	122.8
1/19/05	94.5	82.5
1/20/05	90.2	78.1
1/21/05	86.9	74.9
1/22/05	84.6	72.6
1/23/05	83.5	71.5
1/24/05	82.2	70.2
1/25/05	81.7	69.6
1/26/05	80.6	68.5
1/27/05	78.8	66.7
1/28/05	77.0	65.0
1/29/05	73.6	61.5
1/30/05	73.5	61.5
1/31/05	72.6	60.6
2/1/05	75.6	63.5
2/2/05	79.6	67.6

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
2/3/05	79.7	67.7
2/4/05	80.7	68.7
2/5/05	91.1	77.3
2/6/05	113.9	100.1
2/7/05	206.5	192.7
2/8/05	230.9	217.1
2/9/05	206.3	192.5
2/10/05	185.6	171.8
2/11/05	155.9	142.1
2/12/05	132.5	118.7
2/13/05	148.4	134.6
2/14/05	315.3	301.5
2/15/05	372.9	359.1
2/16/05	345.5	331.7
2/17/05	277.8	264.0
2/18/05	202.4	188.6
2/19/05	163.6	149.8
2/20/05	141.4	127.6
2/21/05	136.2	122.4
2/22/05	131.3	117.5
2/23/05	123.5	109.7
2/24/05	119.3	105.5
2/25/05	118.2	104.4
2/26/05	112.9	99.1
2/27/05	109.1	97.1
2/28/05	107.5	95.4
3/1/05	98.3	86.3
3/2/05	93.0	80.9
3/3/05	91.9	78.1
3/4/05	87.9	74.1
3/5/05	89.9	76.1
3/6/05	114.9	101.1
3/7/05	253.3	239.5

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
3/8/05	276.7	262.9
3/9/05	233.3	219.5
3/10/05	188.7	174.9
3/11/05	148.3	134.5
3/12/05	126.7	112.9
3/13/05	113.5	99.7
3/14/05	111.8	98.0
3/15/05	106.4	92.6
3/16/05	105.8	92.0
3/17/05	110.6	96.8
3/18/05	113.3	99.5
3/19/05	138.8	125.0
3/20/05	157.2	143.4
3/21/05	172.5	158.7
3/22/05	184.6	170.8
3/23/05	179.5	165.7
3/24/05	176.9	163.1
3/25/05	187.1	173.3
3/26/05	190.7	176.9
3/27/05	195.0	181.2
3/28/05	206.5	192.7
3/29/05	219.0	205.2
3/30/05	237.4	223.6
3/31/05	263.7	249.9
4/1/05	273.1	259.3
4/2/05	274.5	260.7
4/3/05	258.7	244.9
4/4/05	232.3	218.5
4/5/05	207.1	193.3
4/6/05	200.5	186.7
4/7/05	228.6	214.8
4/8/05	229.2	215.4
4/9/05	209.1	195.3

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
4/10/05	183.7	169.9
4/11/05	159.7	145.9
4/12/05	143.0	129.2
4/13/05	131.5	117.7
4/14/05	107.2	93.4
4/15/05	94.8	81.0
4/16/05	84.4	70.6
4/17/05	82.1	68.3
4/18/05	78.3	64.5
4/19/05	78.1	64.3
4/20/05	91.7	77.9
4/21/05	89.1	75.3
4/22/05	92.8	79.0
4/23/05	94.4	80.6
4/24/05	84.2	70.4
4/25/05	79.3	65.5
4/26/05	78.4	64.6
4/27/05	79.2	65.4
4/28/05	75.9	62.1
4/29/05	72.7	59.0
4/30/05	84.6	71.0
5/1/05	86.8	73.0
5/2/05	81.5	67.7
5/3/05	74.2	60.4
5/4/05	69.1	55.3
5/5/05	69.0	55.2
5/6/05	103.6	89.8
5/7/05	116.3	103.0
5/8/05	98.6	86.0
5/9/05	105.9	92.1
5/10/05	116.5	103.0
5/11/05	158.2	144.4
5/12/05	160.2	146.4

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
5/13/05	161.7	147.9
5/14/05	152.0	138.2
5/15/05	132.9	119.1
5/16/05	115.8	102.0
5/17/05	98.5	85.0
5/18/05	85.5	72.0
5/19/05	159.5	145.7
5/20/05	175.3	161.5
5/21/05	138.7	125.0
5/22/05	113.6	100.0
5/23/05	99.0	85.2
5/24/05	89.6	76.0
5/25/05	79.6	66.0
5/26/05	71.6	58.0
5/27/05	72.8	59.0
5/28/05	66.1	53.0
5/29/05	62.2	50.0
5/30/05	57.9	45.0
5/31/05	58.4	45.0
6/1/05	59.4	46.0
6/2/05	54.1	41.0
6/3/05	51.1	38.0
6/4/05	50.8	38.0
6/5/05	61.3	48.0
6/6/05	56.8	43.0
6/7/05	52.7	39.0
6/8/05	50.7	37.0
6/9/05	50.6	37.0
6/10/05	49.3	36.0
6/11/05	43.6	31.0
6/12/05	42.5	30.0
6/13/05	46.1	33.0
6/14/05	45.9	33.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
6/15/05	46.8	34.0
6/16/05	47.6	35.0
6/17/05	43.6	31.0
6/18/05	36.7	25.0
6/19/05	35.4	24.0
6/20/05	37.2	24.0
6/21/05	36.3	24.0
6/22/05	34.0	22.0
6/23/05	34.3	22.0
6/24/05	34.2	22.0
6/25/05	36.9	25.0
6/26/05	66.9	54.0
6/27/05	56.7	44.0
6/28/05	47.6	35.0
6/29/05	40.3	28.0
6/30/05	49.1	36.0
7/1/05	47.4	36.0
7/2/05	39.2	28.0
7/3/05	40.5	30.0
7/4/05	50.8	39.0
7/5/05	52.1	40.0
7/6/05	47.0	35.0
7/7/05	43.1	31.0
7/8/05	41.6	30.0
7/9/05	38.3	27.0
7/10/05	33.6	22.0
7/11/05	33.5	21.0
7/12/05	35.9	23.0
7/13/05	40.8	28.0
7/14/05	39.7	27.0
7/15/05	36.2	24.0
7/16/05	33.3	22.0
7/17/05	31.4	20.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
7/18/05	33.0	21.0
7/19/05	31.8	20.0
7/20/05	45.7	33.0
7/21/05	59.1	46.0
7/22/05	61.3	49.0
7/23/05	66.6	54.0
7/24/05	70.3	58.0
7/25/05	55.2	42.0
7/26/05	75.5	61.7
7/27/05	58.6	46.0
7/28/05	47.4	35.0
7/29/05	40.1	28.0
7/30/05	35.6	24.0
7/31/05	35.4	24.0
8/1/05	34.3	24.0
8/2/05	33.2	20.0
8/3/05	30.6	18.0
8/4/05	32.2	20.0
8/5/05	29.8	18.0
8/6/05	26.2	15.0
8/7/05	27.1	16.0
8/8/05	31.2	20.0
8/9/05	30.5	18.0
8/10/05	28.0	16.0
8/11/05	30.2	18.0
8/12/05	44.5	32.0
8/13/05	38.5	27.0
8/14/05	34.4	23.0
8/15/05	34.4	22.0
8/16/05	32.7	20.0
8/17/05	29.5	17.0
8/18/05	46.5	33.0
8/19/05	44.6	32.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
8/20/05	41.9	30.0
8/21/05	38.5	27.0
8/22/05	36.1	24.0
8/23/05	30.1	20.0
8/24/05	32.0	20.0
8/25/05	31.8	20.0
8/26/05	33.0	21.0
8/27/05	59.7	47.0
8/28/05	40.7	29.0
8/29/05	34.0	22.0
8/30/05	33.1	21.0
8/31/05	36.2	24.0
9/1/05	37.1	25.0
9/2/05	33.7	22.0
9/3/05	27.0	16.0
9/4/05	28.1	17.0
9/5/05	27.5	15.0
9/6/05	27.7	16.0
9/7/05	28.9	17.0
9/8/05	28.9	17.0
9/9/05	28.7	17.0
9/10/05	29.5	18.0
9/11/05	29.6	18.0
9/12/05	29.8	18.0
9/13/05	39.8	27.0
9/14/05	34.3	22.0
9/15/05	29.6	18.0
9/16/05	30.3	19.0
9/17/05	31.2	20.0
9/18/05	28.4	17.0
9/19/05	38.3	25.0
9/20/05	36.6	24.0
9/21/05	32.9	20.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
9/22/05	85.6	71.8
9/23/05	61.7	49.0
9/24/05	36.8	25.0
9/25/05	81.7	68.0
9/26/05	158.9	145.1
9/27/05	104.2	91.0
9/28/05	64.9	52.0
9/29/05	52.3	40.0
9/30/05	45.0	33.0
10/1/05	40.6	29.0
10/2/05	36.8	25.0
10/3/05	36.1	26.0
10/4/05	35.0	23.0
10/5/05	35.1	23.0
10/6/05	39.1	27.0
10/7/05	36.7	25.0
10/8/05	33.7	22.0
10/9/05	32.6	21.0
10/10/05	34.1	22.0
10/11/05	33.9	22.0
10/12/05	32.9	21.0
10/13/05	31.9	20.0
10/14/05	32.7	21.0
10/15/05	30.4	19.0
10/16/05	31.6	20.0
10/17/05	33.7	21.0
10/18/05	34.3	22.0
10/19/05	31.2	19.0
10/20/05	30.3	18.0
10/21/05	29.7	18.0
10/22/05	29.4	18.0
10/23/05	34.7	23.0
10/24/05	33.9	22.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
10/25/05	31.6	20.0
10/26/05	32.8	21.0
10/27/05	32.7	21.0
10/28/05	31.6	20.0
10/29/05	30.0	19.0
10/30/05	28.1	17.0
10/31/05	31.1	19.0
11/1/05	31.5	19.0
11/2/05	27.8	18.0
11/3/05	29.5	18.0
11/4/05	30.4	19.0
11/5/05	90.6	77.0
11/6/05	232.9	219.1
11/7/05	146.9	133.1
11/8/05	94.4	81.0
11/9/05	66.4	54.0
11/10/05	57.0	45.0
11/11/05	50.6	39.0
11/12/05	52.7	41.0
11/13/05	57.4	45.0
11/14/05	58.3	45.0
11/15/05	63.9	50.1
11/16/05	91.2	77.4
11/17/05	79.5	66.0
11/18/05	69.7	57.0
11/19/05	60.2	48.0
11/20/05	56.0	44.0
11/21/05	54.6	42.0
11/22/05	52.4	40.0
11/23/05	51.7	39.7
11/24/05	49.7	37.6
11/25/05	47.7	35.7
11/26/05	48.0	36.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
11/27/05	60.4	48.0
11/28/05	117.5	104.0
11/29/05	121.0	108.0
11/30/05	95.9	83.0
12/1/05	77.7	65.0
12/2/05	61.6	49.5
12/3/05	65.2	53.2
12/4/05	57.2	45.1
12/5/05	53.1	41.1
12/6/05	47.2	35.2
12/7/05	44.1	32.0
12/8/05	43.9	31.9
12/9/05	43.0	30.9
12/10/05	43.0	31.0
12/11/05	42.9	30.8
12/12/05	43.4	31.3
12/13/05	43.2	31.2
12/14/05	44.5	32.5
12/15/05	45.0	33.0
12/16/05	46.8	34.8
12/17/05	45.9	33.9
12/18/05	44.8	32.7
12/19/05	43.5	31.5
12/20/05	42.5	30.5
12/21/05	41.7	29.6
12/22/05	44.3	32.3
12/23/05	49.9	37.0
12/24/05	55.0	43.0
12/25/05	56.8	46.0
12/26/05	59.0	47.0
12/27/05	61.1	49.0
12/28/05	66.3	54.0
12/29/05	69.3	57.0

EXHIBIT B-2

Summary Table of Year 2005 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
12/30/05	70.2	58.0
12/31/05	74.3	62.0

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
1/1/08	5.4	10.7	16.1
1/2/08	5.3	10.7	16.0
1/3/08	5.2	10.7	15.9
1/4/08	4.9	10.7	15.6
1/5/08	9.0	10.7	19.7
1/6/08	24.0	12.3	36.3
1/7/08	57.0	12.3	69.3
1/8/08	73.0	12.3	85.3
1/9/08	46.0	12.3	58.3
1/10/08	28.0	12.3	40.3
1/11/08	29.0	12.3	41.3
1/12/08	20.0	12.3	32.3
1/13/08	19.0	12.3	31.3
1/14/08	14.0	12.3	26.3
1/15/08	12.0	12.3	24.3
1/16/08	10.0	12.3	22.3
1/17/08	10.0	12.3	22.3
1/18/08	8.6	12.3	20.9
1/19/08	8.0	10.7	18.7
1/20/08	7.8	10.7	18.5
1/21/08	7.3	10.7	18.0
1/22/08	7.1	10.7	17.8
1/23/08	6.7	10.7	17.4
1/24/08	6.6	10.7	17.3
1/25/08	6.7	10.7	17.4
1/26/08	7.7	10.7	18.4
1/27/08	8.9	10.7	19.6
1/28/08	15.0	10.7	25.7
1/29/08	30.0	10.7	40.7
1/30/08	15.0	10.7	25.7
1/31/08	12.0	10.7	22.7
2/1/08	9.0	10.7	19.7
2/2/08	8.0	10.7	18.7

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
2/3/08	7.0	10.7	17.7
2/4/08	38.0	12.3	50.3
2/5/08	19.0	12.3	31.3
2/6/08	10.0	12.3	22.3
2/7/08	8.6	12.3	20.9
2/8/08	7.7	10.7	18.4
2/9/08	7.3	10.7	18.0
2/10/08	6.0	10.7	16.7
2/11/08	5.6	10.7	16.3
2/12/08	5.4	10.7	16.1
2/13/08	5.3	10.7	16.0
2/14/08	5.3	10.7	16.0
2/15/08	5.2	10.7	15.9
2/16/08	5.2	10.7	15.9
2/17/08	80.0	10.7	90.7
2/18/08	36.0	10.7	46.7
2/19/08	19.0	10.7	29.7
2/20/08	14.0	10.7	24.7
2/21/08	11.0	10.7	21.7
2/22/08	9.8	10.7	20.5
2/23/08	9.2	10.7	19.9
2/24/08	8.9	10.7	19.6
2/25/08	8.7	10.7	19.4
2/26/08	8.0	10.7	18.7
2/27/08	7.8	10.7	18.5
2/28/08	7.7	10.7	18.4
2/29/08	8.3	10.7	19.0
3/1/08	7.8	10.7	18.5
3/2/08	21.0	12.3	33.3
3/3/08	81.0	12.3	93.3
3/4/08	32.0	12.3	44.3
3/5/08	24.0	12.3	36.3
3/6/08	19.0	12.3	31.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
3/7/08	14.0	10.7	24.7
3/8/08	12.0	10.7	22.7
3/9/08	11.0	10.7	21.7
3/10/08	11.0	10.7	21.7
3/11/08	14.0	12.3	26.3
3/12/08	18.0	12.3	30.3
3/13/08	55.0	12.3	67.3
3/14/08	73.0	12.3	85.3
3/15/08	58.0	12.3	70.3
3/16/08	43.0	12.3	55.3
3/17/08	32.0	12.3	44.3
3/18/08	41.0	12.3	53.3
3/19/08	44.0	12.3	56.3
3/20/08	41.0	12.3	53.3
3/21/08	32.0	12.3	44.3
3/22/08	36.0	12.3	48.3
3/23/08	33.0	12.3	45.3
3/24/08	30.0	12.3	42.3
3/25/08	57.0	12.3	69.3
3/26/08	76.0	12.3	88.3
3/27/08	66.0	12.3	78.3
3/28/08	43.0	12.3	55.3
3/29/08	33.0	12.3	45.3
3/30/08	29.0	12.3	41.3
3/31/08	143.0	12.3	155.3
4/1/08	87.0	12.3	99.3
4/2/08	49.0	12.3	61.3
4/3/08	41.0	12.3	53.3
4/4/08	49.0	12.3	61.3
4/5/08	35.0	12.3	47.3
4/6/08	28.0	12.3	40.3
4/7/08	24.0	12.3	36.3
4/8/08	106.0	12.3	118.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
4/9/08	111.0	12.3	123.3
4/10/08	227.0	12.3	239.3
4/11/08	195.0	12.3	207.3
4/12/08	88.0	12.3	100.3
4/13/08	55.0	12.3	67.3
4/14/08	38.0	12.3	50.3
4/15/08	30.0	12.3	42.3
4/16/08	25.0	12.3	37.3
4/17/08	21.0	12.3	33.3
4/18/08	19.0	12.3	31.3
4/19/08	17.0	12.3	29.3
4/20/08	16.0	12.3	28.3
4/21/08	15.0	12.3	27.3
4/22/08	14.0	12.3	26.3
4/23/08	14.0	12.3	26.3
4/24/08	18.0	12.3	30.3
4/25/08	105.0	12.3	117.3
4/26/08	72.0	12.3	84.3
4/27/08	35.0	12.3	47.3
4/28/08	24.0	12.3	36.3
4/29/08	19.0	12.3	31.3
4/30/08	16.0	12.3	28.3
5/1/08	15.0	12.3	27.3
5/2/08	30.0	12.3	42.3
5/3/08	27.0	12.3	39.3
5/4/08	17.0	12.3	29.3
5/5/08	14.0	12.3	26.3
5/6/08	12.0	12.3	24.3
5/7/08	11.0	12.3	23.3
5/8/08	12.0	12.3	24.3
5/9/08	12.0	12.3	24.3
5/10/08	8.7	12.3	21.0
5/11/08	22.0	12.3	34.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
5/12/08	11.0	12.3	23.3
5/13/08	9.0	12.3	21.3
5/14/08	8.5	12.3	20.8
5/15/08	7.7	12.3	20.0
5/16/08	7.4	12.3	19.7
5/17/08	7.0	12.3	19.3
5/18/08	6.6	12.3	18.9
5/19/08	6.4	12.3	18.7
5/20/08	6.3	12.3	18.6
5/21/08	6.1	12.3	18.4
5/22/08	5.9	12.3	18.2
5/23/08	5.6	12.3	17.9
5/24/08	5.6	12.3	17.9
5/25/08	10.0	12.3	22.3
5/26/08	20.0	12.3	32.3
5/27/08	6.0	12.3	18.3
5/28/08	5.3	12.3	17.6
5/29/08	5.1	12.3	17.4
5/30/08	40.0	12.3	52.3
5/31/08	9.4	12.3	21.7
6/1/08	6.4	12.3	18.7
6/2/08	5.6	12.3	17.9
6/3/08	5.3	12.3	17.6
6/4/08	5.4	12.3	17.7
6/5/08	82.0	12.3	94.3
6/6/08	23.0	12.3	35.3
6/7/08	918.0	9.2	927.2
6/8/08	1350.0	0.0	1350.0
6/9/08	573.0	10.8	583.8
6/10/08	176.0	12.3	188.3
6/11/08	65.0	12.3	77.3
6/12/08	69.0	12.3	81.3
6/13/08	283.0	12.3	295.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
6/14/08	103.0	12.3	115.3
6/15/08	49.0	12.3	61.3
6/16/08	32.0	12.3	44.3
6/17/08	24.0	12.3	36.3
6/18/08	19.0	12.3	31.3
6/19/08	16.0	12.3	28.3
6/20/08	14.0	12.3	26.3
6/21/08	13.0	12.3	25.3
6/22/08	26.0	12.3	38.3
6/23/08	17.0	12.3	29.3
6/24/08	13.0	12.3	25.3
6/25/08	12.0	12.3	24.3
6/26/08	11.0	12.3	23.3
6/27/08	13.0	12.3	25.3
6/28/08	16.0	12.3	28.3
6/29/08	11.0	12.3	23.3
6/30/08	8.4	12.3	20.7
7/1/08	7.7	12.3	20.0
7/2/08	17.0	12.3	29.3
7/3/08	9.5	12.3	21.8
7/4/08	7.2	12.3	19.5
7/5/08	6.5	12.3	18.8
7/6/08	6.0	12.3	18.3
7/7/08	50.0	12.3	62.3
7/8/08	41.0	12.3	53.3
7/9/08	11.0	12.3	23.3
7/10/08	15.0	12.3	27.3
7/11/08	26.0	12.3	38.3
7/12/08	26.0	12.3	38.3
7/13/08	10.0	12.3	22.3
7/14/08	7.8	12.3	20.1
7/15/08	6.4	12.3	18.7
7/16/08	11.0	12.3	23.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
7/17/08	7.2	12.3	19.5
7/18/08	6.2	12.3	18.5
7/19/08	21.0	12.3	33.3
7/20/08	16.0	12.3	28.3
7/21/08	7.6	12.3	19.9
7/22/08	6.7	12.3	19.0
7/23/08	5.4	12.3	17.7
7/24/08	4.4	12.3	16.7
7/25/08	4.2	12.3	16.5
7/26/08	4.0	12.3	16.3
7/27/08	3.7	12.3	16.0
7/28/08	3.5	12.3	15.8
7/29/08	3.5	12.3	15.8
7/30/08	3.4	12.3	15.7
7/31/08	3.3	12.3	15.6
8/1/08	3.7	12.3	16.0
8/2/08	3.2	12.3	15.5
8/3/08	3.1	12.3	15.4
8/4/08	51.0	12.3	63.3
8/5/08	7.1	12.3	19.4
8/6/08	4.6	12.3	16.9
8/7/08	3.8	12.3	16.1
8/8/08	3.6	12.3	15.9
8/9/08	14.0	12.3	26.3
8/10/08	5.8	12.3	18.1
8/11/08	4.1	12.3	16.4
8/12/08	3.8	12.3	16.1
8/13/08	12.0	12.3	24.3
8/14/08	8.9	12.3	21.2
8/15/08	5.6	12.3	17.9
8/16/08	4.1	12.3	16.4
8/17/08	5.5	12.3	17.8
8/18/08	3.4	12.3	15.7

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
8/19/08	3.3	12.3	15.6
8/20/08	3.4	12.3	15.7
8/21/08	3.5	12.3	15.8
8/22/08	3.4	12.3	15.7
8/23/08	3.8	12.3	16.1
8/24/08	3.4	12.3	15.7
8/25/08	3.3	12.3	15.6
8/26/08	3.1	12.3	15.4
8/27/08	3.1	12.3	15.4
8/28/08	3.0	12.3	15.3
8/29/08	3.3	12.3	15.6
8/30/08	2.8	12.3	15.1
8/31/08	2.6	12.3	14.9
9/1/08	2.6	12.3	14.9
9/2/08	2.5	11.5	14.0
9/3/08	7.8	12.3	20.1
9/4/08	78.0	12.3	90.3
9/5/08	25.0	12.3	37.3
9/6/08	8.8	12.3	21.1
9/7/08	5.2	12.3	17.5
9/8/08	9.8	12.3	22.1
9/9/08	5.3	12.3	17.6
9/10/08	3.9	12.3	16.2
9/11/08	3.5	12.3	15.8
9/12/08	3.3	12.3	15.6
9/13/08	43.0	12.3	55.3
9/14/08	47.0	12.3	59.3
9/15/08	16.0	12.3	28.3
9/16/08	8.0	12.3	20.3
9/17/08	5.9	12.3	18.2
9/18/08	4.8	12.3	17.1
9/19/08	4.3	12.3	16.6
9/20/08	3.9	12.3	16.2

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
9/21/08	3.6	12.3	15.9
9/22/08	3.5	12.3	15.8
9/23/08	3.3	12.3	15.6
9/24/08	3.6	12.3	15.9
9/25/08	3.2	12.3	15.5
9/26/08	3.1	12.0	15.1
9/27/08	2.9	12.3	15.2
9/28/08	2.9	12.3	15.2
9/29/08	3.8	12.3	16.1
9/30/08	4.2	12.3	16.5
10/1/08	4.1	12.3	16.4
10/2/08	4.0	12.3	16.3
10/3/08	3.5	12.2	15.7
10/4/08	2.6	12.3	14.9
10/5/08	25.0	12.3	37.3
10/6/08	10.0	12.3	22.3
10/7/08	29.0	12.3	41.3
10/8/08	21.0	12.3	33.3
10/9/08	8.3	12.3	20.6
10/10/08	5.5	12.3	17.8
10/11/08	4.0	12.3	16.3
10/12/08	3.5	12.3	15.8
10/13/08	3.2	12.3	15.5
10/14/08	3.1	12.3	15.4
10/15/08	7.8	12.3	20.1
10/16/08	4.3	12.3	16.6
10/17/08	3.6	12.3	15.9
10/18/08	3.3	12.3	15.6
10/19/08	3.0	12.3	15.3
10/20/08	7.9	12.3	20.2
10/21/08	3.8	12.3	16.1
10/22/08	3.2	12.3	15.5
10/23/08	3.0	12.3	15.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
10/24/08	5.4	10.7	16.1
10/25/08	18.0	10.7	28.7
10/26/08	7.0	10.7	17.7
10/27/08	5.0	10.7	15.7
10/28/08	4.1	10.7	14.8
10/29/08	3.4	10.7	14.1
10/30/08	2.9	12.3	15.2
10/31/08	2.8	12.3	15.1
11/1/08	2.6	12.3	14.9
11/2/08	2.7	12.3	15.0
11/3/08	2.8	12.3	15.1
11/4/08	2.8	12.3	15.1
11/5/08	2.6	12.3	14.9
11/6/08	5.0	12.3	17.3
11/7/08	3.4	12.3	15.7
11/8/08	3.8	12.3	16.1
11/9/08	3.6	12.3	15.9
11/10/08	3.5	12.3	15.8
11/11/08	9.3	12.3	21.6
11/12/08	12.0	12.3	24.3
11/13/08	8.1	12.3	20.4
11/14/08	18.0	12.3	30.3
11/15/08	5.7	12.3	18.0
11/16/08	4.2	12.3	16.5
11/17/08	3.7	12.3	16.0
11/18/08	4.0	12.3	16.3
11/19/08	4.8	12.3	17.1
11/20/08	3.9	12.3	16.2
11/21/08	2.7	12.3	15.0
11/22/08	2.9	12.3	15.2
11/23/08	2.7	12.3	15.0
11/24/08	4.6	12.3	16.9
11/25/08	3.4	12.3	15.7

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
11/26/08	3.2	12.3	15.5
11/27/08	3.0	12.3	15.3
11/28/08	2.8	12.1	14.9
11/29/08	2.7	12.3	15.0
11/30/08	3.5	12.3	15.8
12/1/08	6.5	12.3	18.8
12/2/08	5.2	12.3	17.5
12/3/08	6.2	12.3	18.5
12/4/08	3.7	12.3	16.0
12/5/08	3.9	12.3	16.2
12/6/08	4.2	12.3	16.5
12/7/08	3.9	12.3	16.2
12/8/08	4.2	12.3	16.5
12/9/08	6.5	12.3	18.8
12/10/08	5.2	12.3	17.5
12/11/08	4.8	12.3	17.1
12/12/08	5.7	12.3	18.0
12/13/08	7.2	12.3	19.5
12/14/08	43.0	12.3	55.3
12/15/08	25.0	12.3	37.3
12/16/08	12.0	12.3	24.3
12/17/08	7.3	10.7	18.0
12/18/08	6.7	10.7	17.4
12/19/08	6.6	10.7	17.3
12/20/08	6.4	10.7	17.1
12/21/08	6.2	10.7	16.9
12/22/08	6.0	10.7	16.7
12/23/08	5.9	10.7	16.6
12/24/08	5.8	10.7	16.5
12/25/08	5.8	10.7	16.5
12/26/08	6.4	10.7	17.1
12/27/08	110.0	10.7	120.7
12/28/08	96.0	12.3	108.3

EXHIBIT B-3

Summary Table of Year 2008 Flow in Underwood Creek with Simulated Return Flow

Date	Creek Average Day Flow without Return Flow (cfs)	Average Day Return Flow (cfs)	Creek Average Day Flow with Return Flow (cfs)
12/29/08	45.0	12.3	57.3
12/30/08	24.0	12.3	36.3
12/31/08	18.0	12.3	30.3

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
1/1/08	105.7	95.0
1/2/08	85.8	75.1
1/3/08	87.5	76.8
1/4/08	84.1	73.4
1/5/08	90.0	79.3
1/6/08	131.7	119.4
1/7/08	267.3	255.0
1/8/08	446.3	434.0
1/9/08	505.6	493.3
1/10/08	469.4	457.1
1/11/08	443.9	431.6
1/12/08	412.9	400.6
1/13/08	375.8	363.5
1/14/08	337.2	324.9
1/15/08	281.4	269.1
1/16/08	253.2	240.9
1/17/08	226.8	214.5
1/18/08	181.6	169.3
1/19/08	160.5	149.8
1/20/08	125.8	115.1
1/21/08	105.6	94.9
1/22/08	99.4	88.7
1/23/08	91.2	80.5
1/24/08	85.1	74.4
1/25/08	89.9	79.2
1/26/08	94.6	83.9
1/27/08	100.8	90.1
1/28/08	106.6	95.9
1/29/08	143.3	132.6
1/30/08	145.6	134.9
1/31/08	115.3	104.6
2/1/08	100.9	90.2
2/2/08	98.8	88.1

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
2/3/08	104.7	94.0
2/4/08	128.9	116.6
2/5/08	147.6	135.3
2/6/08	141.5	129.2
2/7/08	126.7	114.4
2/8/08	133.0	122.4
2/9/08	134.8	124.1
2/10/08	111.5	100.8
2/11/08	105.2	94.5
2/12/08	102.1	91.4
2/13/08	99.2	88.5
2/14/08	98.0	87.3
2/15/08	98.5	87.8
2/16/08	104.1	93.4
2/17/08	219.2	208.5
2/18/08	259.2	248.5
2/19/08	236.1	225.4
2/20/08	232.4	221.7
2/21/08	201.2	190.5
2/22/08	192.9	182.2
2/23/08	179.7	169.0
2/24/08	173.5	162.8
2/25/08	168.6	157.9
2/26/08	163.4	152.7
2/27/08	159.2	148.5
2/28/08	153.9	143.3
2/29/08	150.1	139.4
3/1/08	142.9	132.2
3/2/08	153.0	140.7
3/3/08	302.5	290.2
3/4/08	330.3	318.0
3/5/08	308.3	296.0
3/6/08	289.8	277.5

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
3/7/08	262.3	251.6
3/8/08	226.0	215.3
3/9/08	205.5	194.8
3/10/08	189.1	178.4
3/11/08	185.8	173.5
3/12/08	193.2	180.9
3/13/08	241.9	229.6
3/14/08	383.1	370.8
3/15/08	458.0	445.7
3/16/08	460.6	448.3
3/17/08	436.8	424.5
3/18/08	421.3	409.0
3/19/08	415.0	402.7
3/20/08	409.7	397.4
3/21/08	396.1	383.8
3/22/08	366.5	354.2
3/23/08	356.0	343.7
3/24/08	346.0	333.7
3/25/08	350.4	338.1
3/26/08	425.1	412.8
3/27/08	489.1	476.8
3/28/08	483.1	470.8
3/29/08	443.0	430.7
3/30/08	411.5	399.2
3/31/08	508.0	495.7
4/1/08	639.1	626.8
4/2/08	597.1	584.8
4/3/08	510.2	497.9
4/4/08	479.8	467.5
4/5/08	447.4	435.1
4/6/08	406.9	394.6
4/7/08	366.9	354.6
4/8/08	408.6	396.3

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
4/9/08	572.3	560.0
4/10/08	712.7	700.4
4/11/08	1025.7	1013.4
4/12/08	1109.0	1096.7
4/13/08	949.1	936.8
4/14/08	737.5	725.2
4/15/08	571.1	558.8
4/16/08	475.0	462.7
4/17/08	417.9	405.6
4/18/08	372.3	360.0
4/19/08	332.8	320.5
4/20/08	302.9	290.6
4/21/08	274.7	262.4
4/22/08	256.5	244.2
4/23/08	239.7	227.4
4/24/08	225.7	213.4
4/25/08	421.3	409.0
4/26/08	600.3	588.0
4/27/08	563.5	551.2
4/28/08	559.9	547.6
4/29/08	514.4	502.1
4/30/08	434.8	422.5
5/1/08	369.3	357.0
5/2/08	335.9	323.6
5/3/08	320.4	308.1
5/4/08	295.1	282.8
5/5/08	267.2	254.9
5/6/08	238.8	226.5
5/7/08	210.6	198.3
5/8/08	194.0	181.7
5/9/08	198.6	186.3
5/10/08	205.3	193.0
5/11/08	220.0	207.7

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
5/12/08	221.1	208.8
5/13/08	206.8	194.5
5/14/08	199.6	187.3
5/15/08	188.1	175.8
5/16/08	177.6	165.3
5/17/08	170.0	157.7
5/18/08	163.8	151.5
5/19/08	158.8	146.5
5/20/08	153.9	141.6
5/21/08	146.5	134.2
5/22/08	140.3	128.0
5/23/08	131.8	119.5
5/24/08	99.0	86.7
5/25/08	90.5	78.2
5/26/08	112.8	100.5
5/27/08	100.8	88.5
5/28/08	92.5	80.2
5/29/08	83.6	71.3
5/30/08	148.9	136.6
5/31/08	136.6	124.3
6/1/08	113.1	100.8
6/2/08	97.4	85.1
6/3/08	86.7	74.4
6/4/08	84.5	72.2
6/5/08	220.2	207.9
6/6/08	254.4	242.1
6/7/08	579.2	566.9
6/8/08	1868.2	1868.2
6/9/08	2443.0	2443.0
6/10/08	2340.5	2328.2
6/11/08	1879.0	1866.7
6/12/08	1499.4	1487.1
6/13/08	1812.3	1800.0

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
6/14/08	1754.4	1742.1
6/15/08	1566.0	1553.7
6/16/08	1301.4	1289.1
6/17/08	1047.7	1035.4
6/18/08	834.5	822.2
6/19/08	669.7	657.4
6/20/08	548.4	536.1
6/21/08	459.3	447.0
6/22/08	406.9	394.6
6/23/08	361.1	348.8
6/24/08	319.8	307.5
6/25/08	293.1	280.8
6/26/08	264.4	252.1
6/27/08	239.6	227.3
6/28/08	227.7	215.4
6/29/08	211.0	198.7
6/30/08	190.7	178.4
7/1/08	186.9	174.6
7/2/08	199.9	187.6
7/3/08	195.4	183.1
7/4/08	183.3	171.0
7/5/08	175.1	162.8
7/6/08	167.1	154.8
7/7/08	202.8	190.5
7/8/08	270.7	258.4
7/9/08	243.0	230.7
7/10/08	229.1	216.8
7/11/08	287.5	275.2
7/12/08	276.3	264.0
7/13/08	242.5	230.2
7/14/08	206.8	194.5
7/15/08	183.4	171.1
7/16/08	168.0	155.7

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
7/17/08	155.9	143.6
7/18/08	149.3	137.0
7/19/08	157.0	144.7
7/20/08	164.9	152.6
7/21/08	154.0	141.7
7/22/08	150.6	138.3
7/23/08	150.1	137.8
7/24/08	143.8	131.5
7/25/08	138.7	126.4
7/26/08	138.3	126.0
7/27/08	139.9	127.6
7/28/08	140.5	128.2
7/29/08	138.6	126.3
7/30/08	132.4	120.1
7/31/08	127.5	115.2
8/1/08	124.8	112.5
8/2/08	122.2	109.9
8/3/08	120.0	107.7
8/4/08	148.8	136.5
8/5/08	151.0	138.7
8/6/08	136.9	124.6
8/7/08	123.5	111.2
8/8/08	116.2	103.9
8/9/08	109.7	97.4
8/10/08	104.6	92.3
8/11/08	103.8	91.5
8/12/08	89.7	77.4
8/13/08	75.0	62.7
8/14/08	78.7	66.4
8/15/08	74.3	62.0
8/16/08	65.1	52.8
8/17/08	60.3	48.0
8/18/08	61.8	49.5

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
8/19/08	63.1	50.8
8/20/08	54.8	42.5
8/21/08	55.9	43.6
8/22/08	55.9	43.6
8/23/08	56.4	44.1
8/24/08	50.8	38.5
8/25/08	51.2	38.9
8/26/08	50.7	38.4
8/27/08	47.7	35.4
8/28/08	46.5	34.2
8/29/08	46.3	34.0
8/30/08	44.5	32.2
8/31/08	37.8	25.5
9/1/08	35.8	23.5
9/2/08	35.5	24.0
9/3/08	41.7	29.4
9/4/08	104.7	92.4
9/5/08	154.0	141.7
9/6/08	102.2	89.9
9/7/08	77.1	64.8
9/8/08	74.1	61.8
9/9/08	68.8	56.5
9/10/08	65.8	53.5
9/11/08	56.4	44.1
9/12/08	53.8	41.5
9/13/08	135.7	123.4
9/14/08	192.8	180.5
9/15/08	197.2	184.9
9/16/08	156.2	143.9
9/17/08	127.4	115.1
9/18/08	115.0	102.7
9/19/08	114.7	102.4
9/20/08	111.3	99.0

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
9/21/08	104.3	92.0
9/22/08	99.7	87.4
9/23/08	94.4	82.1
9/24/08	91.4	79.1
9/25/08	90.0	77.7
9/26/08	82.0	70.0
9/27/08	81.5	69.2
9/28/08	81.4	69.1
9/29/08	80.8	68.5
9/30/08	79.8	67.5
10/1/08	77.4	65.1
10/2/08	71.5	59.2
10/3/08	71.2	59.0
10/4/08	66.6	54.3
10/5/08	85.9	73.6
10/6/08	109.4	97.1
10/7/08	107.3	95.0
10/8/08	134.7	122.4
10/9/08	122.7	110.4
10/10/08	102.1	89.8
10/11/08	88.4	76.1
10/12/08	81.3	69.0
10/13/08	77.5	65.2
10/14/08	84.6	72.3
10/15/08	78.8	66.5
10/16/08	82.5	70.2
10/17/08	78.4	66.1
10/18/08	74.0	61.7
10/19/08	74.2	61.9
10/20/08	77.9	65.6
10/21/08	75.4	63.1
10/22/08	73.3	61.0
10/23/08	72.2	59.9

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
10/24/08	77.7	67.0
10/25/08	96.0	85.4
10/26/08	90.7	80.0
10/27/08	86.7	76.0
10/28/08	79.5	68.8
10/29/08	71.3	60.6
10/30/08	67.3	55.0
10/31/08	64.7	52.4
11/1/08	68.7	56.4
11/2/08	69.0	56.7
11/3/08	67.3	55.0
11/4/08	63.6	51.3
11/5/08	66.8	54.5
11/6/08	79.9	67.6
11/7/08	70.9	58.6
11/8/08	71.7	59.4
11/9/08	71.7	59.4
11/10/08	70.7	58.4
11/11/08	71.0	58.7
11/12/08	82.3	70.0
11/13/08	91.7	79.4
11/14/08	108.8	96.5
11/15/08	95.2	82.9
11/16/08	85.5	73.2
11/17/08	78.4	66.1
11/18/08	75.5	63.2
11/19/08	80.4	68.1
11/20/08	76.4	64.1
11/21/08	60.6	48.3
11/22/08	68.3	56.0
11/23/08	64.7	52.4
11/24/08	70.8	58.5
11/25/08	71.4	59.1

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
11/26/08	68.9	56.6
11/27/08	61.3	49.0
11/28/08	61.1	49.0
11/29/08	62.3	50.0
11/30/08	65.8	53.5
12/1/08	61.8	49.5
12/2/08	67.9	55.6
12/3/08	75.2	62.9
12/4/08	63.9	51.6
12/5/08	64.7	52.4
12/6/08	62.7	50.4
12/7/08	62.9	50.6
12/8/08	64.4	52.1
12/9/08	66.4	54.1
12/10/08	64.4	52.1
12/11/08	63.0	50.7
12/12/08	62.7	50.4
12/13/08	62.5	50.2
12/14/08	98.1	85.8
12/15/08	183.1	170.8
12/16/08	181.1	168.8
12/17/08	105.2	94.6
12/18/08	92.8	82.2
12/19/08	83.9	73.2
12/20/08	77.3	66.6
12/21/08	70.0	59.3
12/22/08	69.1	58.4
12/23/08	68.1	57.4
12/24/08	67.0	56.3
12/25/08	64.7	54.0
12/26/08	79.9	69.2
12/27/08	288.9	278.2
12/28/08	485.8	473.5

EXHIBIT B-4

Summary Table of Year 2008 Flow in Fox River with Simulated Lake Michigan Water Supply and Return Flow to Underwood Creek

Date	River Average Daily Flow at WWTP without Lake Michigan Supply (cfs)	River Average Daily Flow at WWTP with Lake Michigan Supply (cfs)
12/29/08	536.0	523.7
12/30/08	418.1	405.8
12/31/08	329.9	317.6

Appendix F

Diurnal Return Flow Effects on Root River and Underwood Creek Flow Rates

Diurnal Return Flow Effects on Root River and Underwood Creek Flow Rates

PREPARED FOR: City of Waukesha
PREPARED BY: CH2M HILL
DATE: June 24, 2013

This memorandum summarizes the diurnal effects of return flow on Root River and Underwood Creek flow rates. This analysis was originally completed as requested by the Wisconsin Department of Natural Resources (WDNR)[1] for Underwood Creek, in support of The City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application). It has since been updated for return flow to Root River.

Introduction

It is common for wastewater treatment plants (WWTPs) to experience flow fluctuations throughout the day as influent flows change depending upon the size and layout of the sewer system, and the timing of commercial, industrial, and residential customers' water use. For example, it is common for WWTP flows during daylight hours to be greater than flows during nighttime hours when water use is lower.

To demonstrate how diurnal fluctuation in wastewater flow would affect return flow, hourly flow data from the City of Waukesha WWTP was analyzed for year 2005. Year 2005 was chosen because it was a relatively dry year in recent past when return flow would have a greater influence on flow rates in the receiving water. Using the dry year 2005 is also consistent with other analyses completed for the City's Application.

Hourly WWTP flow data and USGS 15-minute flow data from year 2005 were used to simulate flow rates in the Root River and Underwood Creek with and without return flow. To visualize the effect of diurnal fluctuation in wastewater flow, exhibits with historical and simulated hourly flow rates in the receiving water are included for a time period in June 2005. These time periods were chosen because they included moderate peak flows and low flow periods in-between the peaks. The diurnal flow variation is minor, but is more apparent during these moderate and low flow periods because the return flow is a greater percentage of the stream flow. Stream flow rates greater than those in June were observed during year 2005, but return flow is a smaller fraction of the stream flows during these times causing the diurnal flow variation to be much less apparent. This memorandum also provides analyses for the entire 2005 year of hourly flow data for the Root River and Underwood Creek return flow alternatives.

The return flow management plan proposed for the Root River is that proposed in the Application. The management plan previously evaluated for Underwood Creek return flow is similar and therefore the previous analysis is retained for evaluation within this memorandum. Each is discussed in detail below.

Root River

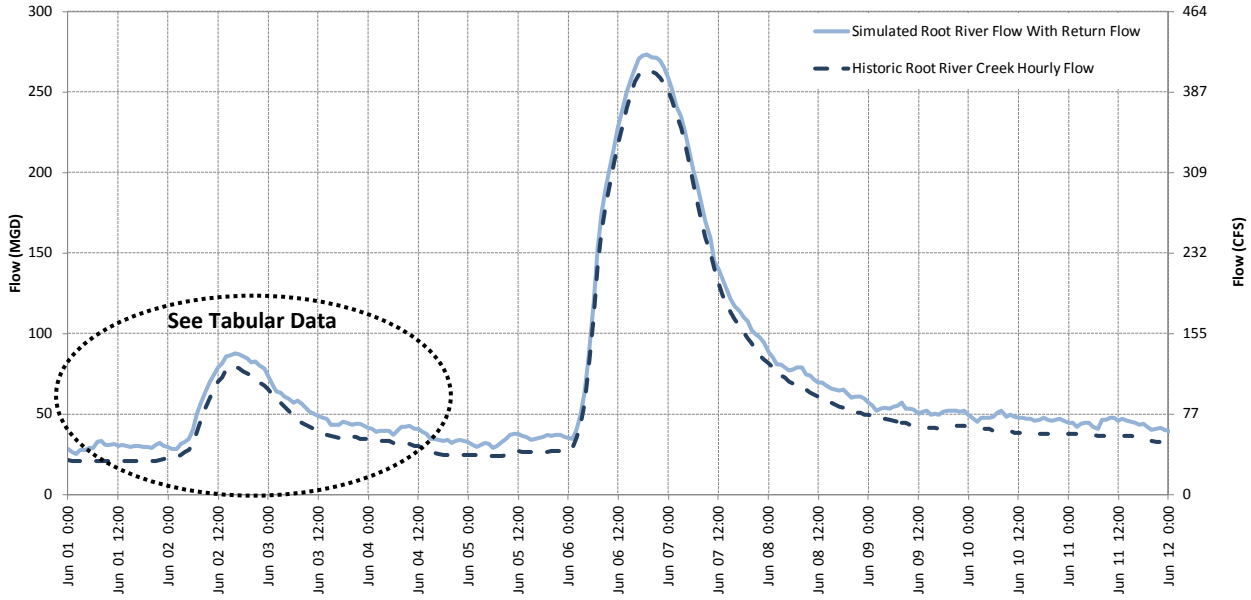
The return flow management plan to Root River simulates returning all flow from the City's WWTP up to a maximum daily flow of 16.7 mgd. This is consistent with maximum daily water demand of 16.7 mgd that is proposed in the Application. The return flow discharge location for the Root River is anticipated to be near 60th Street and Oakwood Avenue near Franklin, WI. Root River flow data at this location for 2005 was estimated as the sum of the flow rate at the USGS gage at Franklin (gage # 04087220) and the gage on the Root River Canal near Franklin (gage # 04087233), and prorated for the unaccounted 20.0 square mile[2] drainage area between these USGS gages and the return flow location. An 11-day period in June 2005 is shown in Exhibit 1 to graphically demonstrate the return flow effects on

[1] Letter from Bruce Baker, Wisconsin Department of Natural Resources, to City of Waukesha Common Council President Paul Ybarra. December 2, 2010.

[2] Area obtained from the Southeastern Wisconsin Regional Planning Commission HSPF model used in the Regional Water Quality Management Plan Update.

low flows in the Root River. Tabular data for 4-days within this time period is shown in Exhibit 2 (see facing page). These time periods were chosen because the span includes low flow and moderately higher flows.

EXHIBIT 1
June 2005 Hourly Flow Root River with Simulated Return Flow



Using hourly flow data for the entire year 2005, the diurnal change (i.e. difference between the daily minimum and maximum flow rates) of the simulated return flow was calculated for each day. The diurnal change in the return flow rate ranged from a minimum of 7.1 cfs (4.6 mgd) to a maximum of 18.9 cfs (12.2 mgd) with an average daily diurnal change of 11.0 cfs (7.1 mgd). Root River flow (without return flow) had a maximum daily diurnal change of 4,765 cfs (3,082 mgd) and an average change of 165 cfs (107 mgd). The maximum diurnal flow change from return flow was only 0.01 percent of the maximum change and 11 percent of the average change in Root River flow. Therefore the return flow diurnal change is insignificant to the current fluctuation observed in the Root River.

The hourly flow data for year 2005 was further evaluated to simulate daytime and nighttime flow rates. Exhibit 3 summarizes statistics of the average daytime (8am-7pm) and nighttime (8pm-7am) return flow rates to the Root River. The daytime and nighttime return flow statistics are very similar and demonstrate that there is little flow variation from the WWTP. This demonstrates the relatively uniform return flow.

EXHIBIT 3
Simulated Daytime and Nighttime Return Flow Rates to the Root River During 2005 Using Hourly Flow Data

	Simulated Return Flow Rates, mgd (cfs)			
	Minimum	**Maximum**	**Average**	**Median**
Average Daytime Flow (8 am–7 pm)	6.3	14.0	9.8	9.4
	(9.7)	(21.7)	(15.2)	(14.5)
Average Nighttime Flow (8 pm–7 am)	5.1	13.3	7.6	7.3
	(7.9)	(20.6)	(11.8)	(11.3)

EXHIBIT 2

Tabular Data of June 2005 Hourly Flow in the Root River with Simulated Return Flow

Date	Root River Flow (mgd)	Root River Flow (cfs)	Simulated Return Flow (mgd)	Simulated Return Flow (cfs)	Root River Flow with Return (mgd)	Root River Flow with Return (cfs)	Date	Root River Flow (mgd)	Root River Flow (cfs)	Simulated Return Flow (mgd)	Simulated Return Flow (cfs)	Root River Flow with Return (mgd)	Root River Flow with Return (cfs)	Date	Root River Flow (mgd)	Root River Flow (cfs)	Simulated Return Flow (mgd)	Simulated Return Flow (cfs)	Root River Flow with Return (mgd)	Root River Flow with Return (cfs)
6/1/05 0:00	21.0	32.4	7.3	11.4	28.3	43.8	6/2/05 7:00	38.5	59.6	11.2	17.4	49.7	76.9	6/3/05 14:00	37.0	57.2	9.7	15.0	46.7	72.2
6/1/05 1:00	20.8	32.1	5.8	9.0	26.6	41.1	6/2/05 8:00	46.4	71.8	10.6	16.4	57.0	88.2	6/3/05 15:00	36.0	55.7	7.5	11.5	43.5	67.2
6/1/05 2:00	20.8	32.1	4.5	7.0	25.3	39.1	6/2/05 9:00	54.1	83.8	10.2	15.8	64.4	99.6	6/3/05 16:00	35.4	54.8	7.9	12.3	43.4	67.1
6/1/05 3:00	20.8	32.2	6.6	10.2	27.4	42.3	6/2/05 10:00	60.3	93.3	9.5	14.7	69.8	108.0	6/3/05 17:00	34.8	53.9	8.1	12.5	42.9	66.4
6/1/05 4:00	20.8	32.2	6.8	10.5	27.5	42.6	6/2/05 11:00	65.4	101.1	9.3	14.4	74.6	115.5	6/3/05 18:00	34.6	53.6	10.6	16.3	45.2	69.9
6/1/05 5:00	20.8	32.2	8.0	12.3	28.8	44.5	6/2/05 12:00	69.8	108.0	9.0	13.9	78.8	121.9	6/3/05 19:00	35.2	54.5	9.5	14.6	44.7	69.1
6/1/05 6:00	20.8	32.2	7.8	12.0	28.6	44.2	6/2/05 13:00	72.7	112.5	8.8	13.6	81.5	126.1	6/3/05 20:00	35.4	54.8	7.5	11.6	42.9	66.4
6/1/05 7:00	20.8	32.2	11.9	18.4	32.7	50.5	6/2/05 14:00	77.4	119.7	8.5	13.1	85.8	132.8	6/3/05 21:00	35.4	54.8	8.6	13.3	44.0	68.1
6/1/05 8:00	20.8	32.2	12.5	19.3	33.2	51.4	6/2/05 15:00	78.7	121.8	7.5	11.6	86.2	133.4	6/3/05 22:00	34.7	53.6	9.2	14.2	43.8	67.8
6/1/05 9:00	20.8	32.2	9.7	15.0	30.5	47.2	6/2/05 16:00	79.1	122.4	8.1	12.6	87.3	135.0	6/3/05 23:00	34.7	53.6	7.9	12.2	42.5	65.8
6/1/05 10:00	20.8	32.2	9.8	15.1	30.6	47.3	6/2/05 17:00	78.0	120.6	8.8	13.7	86.8	134.3	6/4/05 0:00	34.7	53.6	6.6	10.2	41.3	63.8
6/1/05 11:00	20.8	32.2	10.6	16.4	31.4	48.6	6/2/05 18:00	76.4	118.3	9.2	14.2	85.6	132.5	6/4/05 1:00	34.7	53.6	5.8	9.0	40.5	62.6
6/1/05 12:00	20.8	32.2	9.1	14.0	29.8	46.2	6/2/05 19:00	75.1	116.2	9.5	14.8	84.6	130.9	6/4/05 2:00	33.7	52.1	4.9	7.6	38.6	59.8
6/1/05 13:00	20.8	32.2	10.1	15.6	30.9	47.8	6/2/05 20:00	73.6	113.8	8.5	13.1	82.0	126.9	6/4/05 3:00	33.3	51.5	6.1	9.4	39.4	60.9
6/1/05 14:00	20.8	32.2	9.3	14.4	30.1	46.5	6/2/05 21:00	71.8	111.1	10.8	16.7	82.6	127.8	6/4/05 4:00	33.1	51.2	6.3	9.7	39.4	60.9
6/1/05 15:00	20.8	32.2	8.8	13.6	29.6	45.8	6/2/05 22:00	69.7	107.8	10.4	16.1	80.1	123.9	6/4/05 5:00	32.9	50.9	6.3	9.7	39.2	60.7
6/1/05 16:00	20.8	32.2	9.0	13.9	29.8	46.1	6/2/05 23:00	67.4	104.2	10.5	16.2	77.9	120.5	6/4/05 6:00	31.8	49.2	4.9	7.6	36.7	56.8
6/1/05 17:00	20.8	32.2	9.3	14.3	30.0	46.5	6/3/05 0:00	65.2	100.9	7.7	12.0	73.0	112.9	6/4/05 7:00	31.6	48.9	7.6	11.8	39.2	60.6
6/1/05 18:00	20.8	32.2	8.9	13.8	29.7	45.9	6/3/05 1:00	62.1	96.1	5.8	9.0	67.9	105.1	6/4/05 8:00	31.6	48.9	10.4	16.0	41.9	64.9
6/1/05 19:00	20.8	32.2	8.7	13.5	29.5	45.6	6/3/05 2:00	59.2	91.6	4.7	7.3	64.0	99.0	6/4/05 9:00	31.6	48.9	10.5	16.3	42.1	65.1
6/1/05 20:00	20.6	31.9	8.3	12.9	28.9	44.7	6/3/05 3:00	56.7	87.7	6.6	10.1	63.3	97.9	6/4/05 10:00	31.0	48.0	11.4	17.7	42.4	65.6
6/1/05 21:00	20.8	32.2	10.0	15.4	30.8	47.6	6/3/05 4:00	54.2	83.8	6.2	9.6	60.4	93.4	6/4/05 11:00	30.0	46.5	10.3	15.9	40.3	62.4
6/1/05 22:00	21.5	33.3	10.3	15.9	31.8	49.3	6/3/05 5:00	51.9	80.3	7.8	12.1	59.7	92.4	6/4/05 12:00	30.0	46.5	10.3	15.9	40.3	62.4
6/1/05 23:00	21.7	33.6	8.2	12.6	29.9	46.3	6/3/05 6:00	48.8	75.5	7.9	12.2	56.7	87.7	6/4/05 13:00	28.9	44.7	10.0	15.5	38.9	60.2
6/2/05 0:00	22.3	34.5	7.0	10.8	29.3	45.3	6/3/05 7:00	47.0	72.8	10.9	16.8	57.9	89.6	6/4/05 14:00	27.7	42.9	9.8	15.2	37.5	58.1
6/2/05 1:00	22.3	34.5	5.6	8.7	27.9	43.2	6/3/05 8:00	44.7	69.2	11.8	18.3	56.5	87.4	6/4/05 15:00	26.9	41.7	7.5	11.6	34.4	53.3
6/2/05 2:00	22.9	35.4	5.0	7.7	27.8	43.1	6/3/05 9:00	43.2	66.8	10.3	16.0	53.5	82.8	6/4/05 16:00	25.8	39.9	8.3	12.9	34.1	52.8
6/2/05 3:00	24.6	38.1	6.3	9.8	31.0	47.9	6/3/05 10:00	41.8	64.7	9.7	15.1	51.6	79.8	6/4/05 17:00	25.2	39.0	8.7	13.5	33.9	52.5
6/2/05 4:00	26.2	40.5	6.6	10.3	32.8	50.8	6/3/05 11:00	40.5	62.6	9.4	14.5	49.8	77.1	6/4/05 18:00	24.6	38.1	8.5	13.1	33.1	51.2
6/2/05 5:00	27.7	42.9	6.8	10.5	34.5	53.4	6/3/05 12:00	39.3	60.8	9.3	14.4	48.6	75.2	6/4/05 19:00	24.6	38.1	9.3	14.3	33.9	52.4
6/2/05 6:00	31.6	48.8	8.4	13.0	40.0	61.8	6/3/05 13:00	38.3	59.3	9.4	14.6	47.7	73.8	6/4/05 20:00	24.6	38.1	7.2	11.2	31.8	49.3

Exhibit 4 summarizes daily flow statistics for existing historic hourly low flow conditions in the Root River and for conditions with return flow. Because the return flow management plan includes continuous return flow to the Root River, return flow will provide additional flow to the river under all conditions. This is most beneficial to the river and its fisheries during low flow periods. The 2005 minimum hourly low flow in the river increased from 3.9 cfs (2.5 mgd) to 10.5 cfs (6.8 mgd) with return flow. The one percentile flow (low flow) increased from 4.3 cfs (2.8 mgd) to 11.0 cfs (7.7 mgd), which is very similar to the five percentile flow. This demonstrates that while the increase is significant for the one percentile flow (36 percent increase), it is a frequent flow rate that is experienced currently within the Root River.

EXHIBIT 4
Minimum Daily Flow Statistics for the Root River with Historic Hourly Flow Data and Simulated Return Flow

	Minimum Daily Flows Based on Hourly Flows, mgd (cfs)						
			Flow Percentile				
	Min.	Avg.	1%	5%	50%	95%	99%
Historic 2005 Root River Flow	2.5	138.3	2.8	7.4	37.3	623.4	1249.5
	(3.9)	(214)	(4.3)	(11.4)	(57.7)	(964.4)	(1933)
2005 Root River Flow with Simulated Return Flow	6.8	145.5	7.7	13.3	44.7	634.9	1256.4
	(10.5)	(225.1)	(11.9)	(20.6)	(69.2)	(982.2)	(1943.7)

The diurnal variations in the return flow to the Root River are very small and are significantly lower than the existing daily flow fluctuations within the Root River. The diurnal fluctuations of return flow in the river are significantly less than that experienced during a runoff event, where a runoff event can be several orders of magnitude greater than the diurnal fluctuation of return flow. For example, during the moderately high flow event on June 6, 2008, the creek flow increased from 54.3 cfs to 253.7 cfs in 6 hours (Exhibit 1). In comparison, the return flow maximum diurnal fluctuation is 18.9 cfs. Even when accounting for the return flow rates' diurnal variations, return flow will provide a benefit to water dependent resources in the river by creating additional habitat during all low flow conditions. This improvement to the water dependent resources in the river is consistent with the calculated reduction in the Root River flashiness index as discussed in the Return Flow Plan (see Volume 4 of the Application).

Underwood Creek

The return flow plan to Underwood Creek included returning flow from the City's WWTP when the creek flow was not experiencing high flows (e.g. creek flow less than 1,000 cfs). Continuous return flow was simulated because the creek never exceeded 1,000 cfs in 2005. The return flow plan also included a maximum daily flow from the City's WWTP of 9.0 mgd, which represents 115 percent of the average daily water demand in 2005. This operational scenario is different than that evaluated for Root River because the Underwood Creek return flow plan was evaluated prior to completing the Root River evaluation. However, these results are still anticipated to be comparable to the return flow plan evaluated for Root River because the flow rates in excess of the Underwood Creek maximum return flow rate of 9.0 mgd are not variations in diurnal periods, but instead represent wet weather flows. The average hourly return flow to Root River (8.7 mgd) is also very similar to that for Underwood Creek (8.6 mgd).

Exhibits 5 and 6 show the graphical and tabular hourly flow data in Underwood Creek (USGS gage #4087088) for a 5-day period in June 2005. Also shown is the simulated creek flow with return flow using actual hourly wastewater flows from the WWTP and following the return flow management plan. This 5-day period was chosen because it included moderate peak flows in the creek and includes periods with low creek flows in-between the peaks. The diurnal flow is more readily apparent during these moderate and low flow periods because the return flow is a greater percentage of the creek flow. Higher creek flow rates were observed during year 2005 but return flow is a small fraction of the creek flows during these times causing the diurnal flow variation to be much less apparent.

For example, during the moderately high flows on June 26, 2005 01:00, the return flow was about 2.7 percent of the creek flow with return flow. This difference is barely noticeable in Exhibit 1 and therefore including peak creek flow rates greater than this were not conducive for graphical display because they would not be visible. However, the entire year of data was used for the statistical analyses summarized below.

EXHIBIT 5

June 2005 Hourly Flow in Underwood Creek with Simulated Return Flow

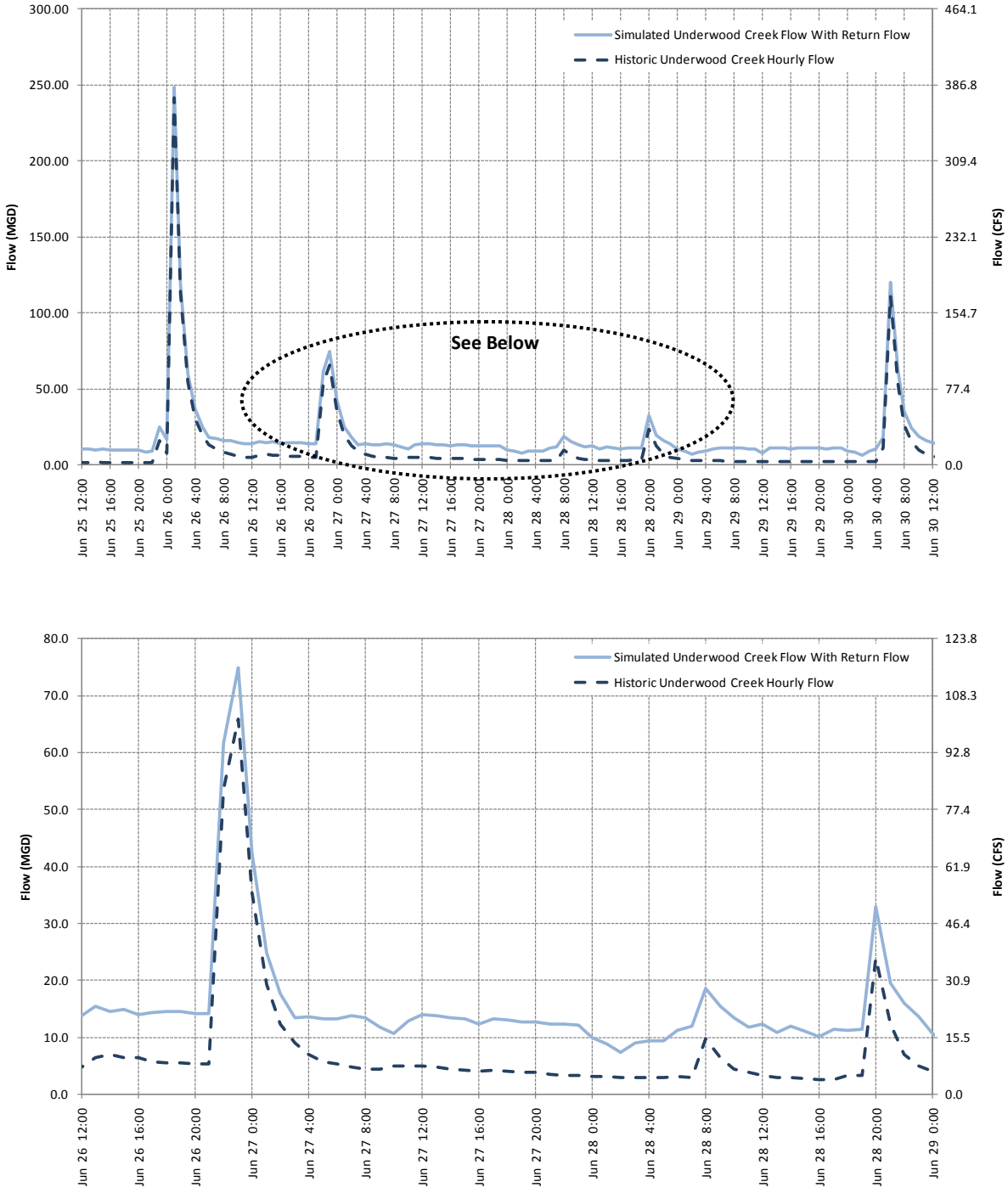


EXHIBIT 6

Tabular Data of June 2005 Hourly Flow in Underwood Creek with Simulated Return Flow

Date	Underwood Creek Flow (mgd)	(cfs)	Simulated Return Flow (mgd)	(cfs)	Underwood Creek Flow with Return (mgd)	(cfs)	Date	Underwood Creek Flow (mgd)	(cfs)	Simulated Return Flow (mgd)	(cfs)	Underwood Creek Flow with Return (mgd)	(cfs)	Date	Underwood Creek Flow (mgd)	(cfs)	Simulated Return Flow (mgd)	(cfs)	Underwood Creek Flow with Return (mgd)	(cfs)
6/25/2005 12:00	1.7	2.6	9.0	13.9	10.7	16.6	6/27/2005 4:00	7.1	11.0	6.5	10.1	13.6	21.1	6/28/2005 20:00	23.9	37.0	9.0	13.9	32.9	50.9
6/25/2005 13:00	1.7	2.6	9.0	13.9	10.7	16.6	6/27/2005 5:00	5.8	9.0	7.4	11.5	13.3	20.5	6/28/2005 21:00	12.3	19.0	7.2	11.1	19.5	30.1
6/25/2005 14:00	1.9	2.9	7.7	12.0	9.6	14.9	6/27/2005 6:00	5.3	8.2	8.1	12.5	13.4	20.7	6/28/2005 22:00	7.1	11.0	9.0	13.9	16.1	24.9
6/25/2005 15:00	1.7	2.6	9.0	13.9	10.7	16.6	6/27/2005 7:00	4.8	7.4	9.0	13.9	13.8	21.3	6/28/2005 23:00	5.0	7.7	8.7	13.4	13.7	21.2
6/25/2005 16:00	1.7	2.6	7.9	12.2	9.6	14.9	6/27/2005 8:00	4.5	7.0	9.0	13.9	13.5	20.9	6/29/2005 0:00	4.1	6.3	6.6	10.2	10.7	16.5
6/25/2005 17:00	1.7	2.6	8.2	12.7	9.9	15.4	6/27/2005 9:00	4.5	7.0	7.3	11.3	11.8	18.3	6/29/2005 1:00	3.4	5.3	5.7	8.7	9.1	14.0
6/25/2005 18:00	1.7	2.6	7.9	12.2	9.6	14.9	6/27/2005 10:00	5.0	7.7	5.6	8.6	10.6	16.4	6/29/2005 2:00	3.0	4.6	4.1	6.4	7.1	11.0
6/25/2005 19:00	1.7	2.6	8.4	13.0	10.1	15.7	6/27/2005 11:00	5.0	7.7	7.9	12.3	13.0	20.1	6/29/2005 3:00	2.8	4.3	5.7	8.8	8.5	13.1
6/25/2005 20:00	1.7	2.6	8.1	12.5	9.9	15.3	6/27/2005 12:00	5.0	7.7	9.0	13.9	14.0	21.7	6/29/2005 4:00	2.8	4.3	6.1	9.4	8.9	13.8
6/25/2005 21:00	1.7	2.6	6.4	9.9	8.2	12.6	6/27/2005 13:00	4.8	7.4	9.0	13.9	13.8	21.3	6/29/2005 5:00	2.7	4.2	7.5	11.6	10.2	15.7
6/25/2005 22:00	1.7	2.6	7.2	11.2	9.0	13.9	6/27/2005 14:00	4.5	7.0	9.0	13.9	13.5	20.9	6/29/2005 6:00	2.7	4.2	8.4	13.0	11.1	17.1
6/25/2005 23:00	16.2	25.1	9.0	13.9	25.1	38.9	6/27/2005 15:00	4.3	6.7	9.0	13.9	13.2	20.5	6/29/2005 7:00	2.5	3.9	9.0	13.9	11.4	17.7
6/26/2005 0:00	7.8	12.1	9.0	13.9	16.7	25.9	6/27/2005 16:00	4.1	6.3	8.4	12.9	12.4	19.2	6/29/2005 8:00	2.5	3.9	9.0	13.9	11.4	17.7
6/26/2005 1:00	241.8	374.1	6.7	10.4	248.5	384.4	6/27/2005 17:00	4.3	6.7	9.0	13.9	13.2	20.5	6/29/2005 9:00	2.5	3.9	9.0	13.9	11.4	17.7
6/26/2005 2:00	113.1	175.0	5.8	9.0	119.0	184.0	6/27/2005 18:00	4.1	6.3	9.0	13.9	13.0	20.2	6/29/2005 10:00	2.3	3.6	8.5	13.1	10.8	16.7
6/26/2005 3:00	54.9	84.9	5.5	8.4	60.4	93.4	6/27/2005 19:00	3.8	5.9	9.0	13.9	12.8	19.8	6/29/2005 11:00	2.3	3.6	8.1	12.5	10.4	16.1
6/26/2005 4:00	30.4	47.0	6.3	9.7	36.6	56.7	6/27/2005 20:00	3.8	5.9	9.0	13.9	12.8	19.8	6/29/2005 12:00	2.3	3.6	5.2	8.1	7.6	11.7
6/26/2005 5:00	19.4	30.0	5.8	9.0	25.2	39.0	6/27/2005 21:00	3.6	5.6	8.7	13.4	12.3	19.0	6/29/2005 13:00	2.3	3.6	8.7	13.4	11.0	17.0
6/26/2005 6:00	13.6	21.0	4.4	6.7	17.9	27.7	6/27/2005 22:00	3.4	5.3	9.0	13.9	12.4	19.2	6/29/2005 14:00	2.5	3.9	9.0	13.9	11.4	17.7
6/26/2005 7:00	10.3	15.9	6.8	10.5	17.1	26.5	6/27/2005 23:00	3.4	5.3	8.8	13.6	12.2	18.9	6/29/2005 15:00	2.5	3.9	9.0	13.9	11.4	17.7
6/26/2005 8:00	8.4	13.0	7.9	12.2	16.3	25.2	6/28/2005 0:00	3.2	5.0	6.8	10.5	10.0	15.4	6/29/2005 16:00	2.5	3.9	8.3	12.8	10.7	16.6
6/26/2005 9:00	7.1	11.0	8.6	13.3	15.7	24.3	6/28/2005 1:00	3.2	5.0	5.7	8.8	8.9	13.7	6/29/2005 17:00	2.3	3.6	9.0	13.9	11.3	17.5
6/26/2005 10:00	5.8	9.0	9.0	13.9	14.8	22.9	6/28/2005 2:00	3.0	4.6	4.4	6.8	7.4	11.4	6/29/2005 18:00	2.3	3.6	9.0	13.9	11.3	17.5
6/26/2005 11:00	5.3	8.2	9.0	13.9	14.3	22.1	6/28/2005 3:00	3.0	4.6	6.2	9.5	9.1	14.1	6/29/2005 19:00	2.3	3.6	9.0	13.9	11.3	17.5
6/26/2005 12:00	4.8	7.4	9.0	13.9	13.8	21.3	6/28/2005 4:00	3.0	4.6	6.4	9.9	9.4	14.5	6/29/2005 20:00	2.1	3.2	9.0	13.9	11.1	17.2
6/26/2005 13:00	6.5	10.1	9.0	13.9	15.4	23.9	6/28/2005 5:00	3.0	4.6	6.4	9.9	9.4	14.5	6/29/2005 21:00	2.1	3.2	8.2	12.7	10.3	15.9
6/26/2005 14:00	7.1	11.0	7.4	11.4	14.5	22.4	6/28/2005 6:00	3.2	5.0	8.2	12.6	11.3	17.5	6/29/2005 22:00	2.1	3.2	9.0	13.9	11.1	17.2
6/26/2005 15:00	6.5	10.1	8.5	13.2	15.0	23.2	6/28/2005 7:00	3.0	4.6	9.0	13.9	11.9	18.5	6/29/2005 23:00	2.1	3.2	8.8	13.7	11.0	17.0
6/26/2005 16:00	6.5	10.1	7.6	11.7	14.1	21.8	6/28/2005 8:00	9.7	15.0	9.0	13.9	18.7	28.9	6/30/2005 0:00	2.1	3.2	7.1	11.0	9.2	14.3
6/26/2005 17:00	5.8	9.0	8.6	13.3	14.4	22.3	6/28/2005 9:00	6.5	10.1	9.0	13.9	15.4	23.9	6/30/2005 1:00	2.0	3.1	6.2	9.6	8.2	12.7
6/26/2005 18:00	5.6	8.7	9.0	13.9	14.5	22.5	6/28/2005 10:00	4.5	7.0	9.0	13.9	13.5	20.9	6/30/2005 2:00	2.0	3.1	4.2	6.5	6.2	9.6
6/26/2005 19:00	5.6	8.7	9.0	13.9	14.5	22.5	6/28/2005 11:00	3.8	5.9	7.9	12.3	11.7	18.1	6/30/2005 3:00	2.0	3.1	6.9	10.6	8.9	13.7
6/26/2005 20:00	5.3	8.2	9.0	13.9	14.3	22.1	6/28/2005 12:00	3.4	5.3	9.0	13.9	12.4	19.2	6/30/2005 4:00	2.0	3.1	8.6	13.3	10.6	16.4
6/26/2005 21:00	5.3	8.2	8.9	13.8	14.2	22.0	6/28/2005 13:00	3.0	4.6	7.8	12.1	10.8	16.7	6/30/2005 5:00	11.0	17.0	7.3	11.2	18.3	28.2
6/26/2005 22:00	53.7	83.1	8.0	12.4	61.7	95.4	6/28/2005 14:00	3.0	4.6	9.0	13.9	11.9	18.5	6/30/2005 6:00	111.2	172.0	9.0	13.9	120.2	185.9
6/26/2005 23:00	65.9	101.9	9.0	13.9	74.9	115.9	6/28/2005 15:00	2.8	4.3	8.2	12.6	11.0	17.0	6/30/2005 7:00	53.7	83.1	9.0	13.9	62.6	96.9
6/27/2005 0:00	35.6	55.1	7.0	10.8	42.5	65.7	6/28/2005 16:00	2.7	4.2	7.5	11.6	10.2	15.7	6/30/2005 8:00	26.5	41.0	9.0	13.9	35.5	54.9
6/27/2005 1:00	19.4	30.0	5.5	8.4	24.9	38.4	6/28/2005 17:00	2.7	4.2	8.7	13.5	11.4	17.6	6/30/2005 9:00	15.5	24.0	9.0	13.9	24.5	37.9
6/27/2005 2:00	12.3	19.0	5.5	8.5	17.8	27.5	6/28/2005 18:00	3.4	5.3	7.9	12.2	11.3	17.5	6/30/2005 10:00	9.7	15.0	9.0	13.9	18.7	28.9
6/27/2005 3:00	9.0	13.9	4.5	6.9	13.5	20.9	6/28/2005 19:00	3.4	5.3	8.0	12.3	11.4	17.6	6/30/2005 11:00	7.1	11.0	9.0	13.9	16.1	24.9
														6/30/2005 12:00	5.8	9.0	9.0	13.9	14.8	22.9

During 2005, the diurnal change of the simulated return flow in Underwood Creek ranged from a minimum of 0.0 cfs (i.e. return flow was constant for the entire day) to a maximum of 10.5 cfs (6.8 mgd). The average diurnal change of return flow was 6.3 cfs (4.1 mgd). Underwood Creek flow (without return flow) had a maximum daily change of 977 cfs (632 mgd) and an average change of 26.9 cfs (17.4 mgd). The maximum daily flow change from return flow was only one percent of the maximum change in Underwood Creek flow, and therefore the return flow diurnal change is insignificant to the current changes experienced in Underwood Creek.

Statistics of the average daytime (8am-7pm) and nighttime (8pm-7am) simulated return flow rates to Underwood Creek are summarized in Exhibit 7. As shown, the daytime and nighttime return flow statistics are very similar.

EXHIBIT 7
Simulated Daytime and Nighttime Return Flow Rates to Underwood Creek During 2005 Using Hourly Flow Data

	Simulated Return Flow Rates, mgd (cfs)			
	Minimum	**Maximum**	**Average**	**Median**
Average Daytime Flow (8 am–7 pm)	6.3 (9.7)	8.9 (13.8)	8.6 (13.3)	8.7 (13.5)
Average Nighttime Flow (8 pm–7 am)	5.1 (7.9)	8.9 (13.8)	7.2 (11.1)	7.1 (11.0)

As seen in Exhibit 5 and further discussed in the Return Flow Plan (see Volume 4 of the Application) Underwood Creek has extended periods of very low flows. However, as seen in Exhibits 5 and 7, the diurnal flow variation is small and there will always be continuous return flow to Underwood Creek consistent with the return flow management plan. This allows the return flow to always provide an improvement to the habitat and flow dependent resources (e.g. fish and macroinvertebrates) in Underwood Creek compared to the current conditions of the creek, even when accounting for diurnal variations in flow rates.

Exhibit 8 summarizes general daily flow statistics for existing historic hourly low flow conditions in Underwood Creek and for conditions with return flow. As seen in Exhibit 8 return flow will provide more flow in Underwood Creek under all low flow conditions, and as summarized in the Return Flow Plan, this will benefit the water dependent natural resources within Underwood Creek. The Return Flow Plan included flow area and wetted perimeter calculations for 14.6 cfs of flow within Underwood Creek. This is very similar to the average low flow value of 13.6 cfs (Exhibit 8) with return flow. The 2005 minimum hourly low flow in the creek increased from 0.84 mgd (1.3 cfs) to 3.6 mgd (5.5 cfs) with return flow, which demonstrates additional habitat is always provided because of the enhanced base flow.

EXHIBIT 8
Minimum Daily Flow Statistics For Underwood Creek with Historic Hourly Flow Data and Simulated Return Flow

	Minimum Daily Flows Based on Hourly Flows, mgd (cfs)						
			Flow Percentile				
	Min.	**Avg.**	**1%**	**5%**	**50%**	**95%**	**99%**
Historic 2005 Underwood Creek Flow	0.84 (1.3)	3.3 (5.1)	0.9 (1.4)	1.0 (1.5)	2.1 (3.2)	9.7 (15.0)	16.2 (25.1)
2005 Underwood Creek Flow with Simulated Return Flow	3.6 (5.5)	8.8 (13.6)	4.0 (6.2)	4.8 (7.4)	7.3 (11.3)	18.4 (28.5)	25.1 (38.8)

The diurnal variations in the return flow are small (Exhibit 7) and are within the range of existing flow fluctuations within Underwood Creek. The diurnal fluctuations of return flow in the creek are significantly less than that experienced during a runoff event, where a runoff event can be several orders of magnitude greater than the diurnal fluctuation of return flow. For example, during the moderately high flow event on June 26, 2008, the creek flow increased from 2.6 cfs to 374.1 cfs in 3 hours (Exhibit 6). In comparison, the return flow maximum diurnal

fluctuation is 10.5 cfs. Consequently, the return flow will provide a benefit to water dependent resources in the creek by creating additional habitat during all low flow conditions. This improvement to the water dependent resources in the creek is consistent with the calculated reduction in the Underwood Creek flashiness index as discussed in the Return Flow Plan.

Appendix G

Return Flow Effects on Root River, Underwood Creek, and Fox River Flashiness Index

Return Flow Effects on Root River, Underwood Creek, and Fox River Flashiness Index

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: June 20, 2013

This memorandum summarizes the effects of return flow on the Root River, Underwood Creek and Fox River flashiness index. This analysis was completed as requested by the Wisconsin Department of Natural Resources (WDNR)[1], in support of The City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application). It has since been updated for return flow to Root River.

Background

Baker et al.[2] defined flashiness as "the frequency and rapidity of short term changes in stream flow." A general frame of reference for the flashiness index is that a larger index number represents a flashier river that has relatively high storm runoff peak flows and low base flows. For example, a river with a flashiness index of 0.49 is more "flashy" than if that *same* river had an index of 0.39. The index can be calculated for any river, but the Fox River flashiness cannot be directly compared to the Root River or the Underwood Creek flashiness because of differences in watershed sizes, land use, available floodplain, and other hydrologic and hydraulic variables that influence the frequency and rapidity of stream flow change. The index was calculated for the rivers and creek to compare how each could be affected by return flow for a Lake Michigan water supply. The flashiness index was calculated for years 2005 and 2008 for the Root River and Fox River (at the WWTP) under the Root River return flow management plan, and for Underwood Creek and the Fox River (at the WWTP) under the Underwood Creek return flow management plan. The return flow management plan proposed for the Root River is that proposed in the Application. The management plan previously evaluated for Underwood Creek return flow is similar and therefore the previous analysis is retained for evaluation within this memorandum.

The year 2005 was selected because it is a relatively dry year in recent past, and 2008 was a relatively wet year in recent past. The flashiness index is based on mean daily flows and is usually applied over a one year time period, however the index was also calculated for 3-month intervals for 2005 and 2008 to show the changes in the index between different times of the year as requested by the WDNR.

Root River Return Flow

The return flow management plan to Root River would include returning all flow from the City's WWTP up to a maximum daily flow of 16.7 mgd. This is consistent with maximum daily water demand of 16.7 mgd that is proposed in the Application. Flow from the WWTP in excess of the maximum return flow rate would continue to flow the Fox River through the City's existing outfall. Following this return flow management plan, the flashiness index for the Root River and the Fox River were calculated (Tables 1 and 2).

[1] Letter from Bruce Baker, Wisconsin Department of Natural Resources, to City of Waukesha Common Council President Paul Ybarra. December 2, 2010.

[2] David B. Baker, R, Peter Richards, Timothy T. Loftus, and Jack W. Kramer, A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams, Journal of the American Water Resources Association, April 2004.

TABLE 1
Changes in the Flashiness Index for the Root River Before and After Return Flow

Year/Date	Historic/Actual (without return flow)	With Return Flow
2005		
January–March	0.40	0.38
April–June	0.35	0.28
July–September	0.76	0.50
October–December	0.59	0.41
Year 2005	0.45	0.37
2008		
January–March	0.40	0.39
April–June	0.51	0.49
July–September	0.55	0.45
October–December	0.74	0.66
Year 2008	0.51	0.48

TABLE 2
Changes in the Flashiness Index for the Fox River (at the WWTP) Before and After Return Flow to the Root River

Year/Date	Historic/Actual (without return flow to Root River)	With Return Flow to Root River Creek
2005		
January-March	0.16	0.18
April-June	0.10	0.11
July-September	0.19	0.25
October-December	0.17	0.21
Year 2005	0.15	0.17
2008		
January-March	0.120[a]	0.127[a]
April-June	0.182[a]	0.189[a]
July-September	0.100[a]	0.110[a]
October-December	0.188[a]	0.212[a]
Year 2008	0.157[a]	0.167[a]

[a]Three decimal places are reported to show the difference in index values.

The Root River flashiness index is lower with return flow when compared to historic conditions. This is because the return flow adds base flow but has an insignificant impact to peak storm runoff events. The flashiness index reduction is anticipated to have a beneficial impact to aquatic resources in the river due to the improvement in base flow (see Volume 4, City of Waukesha Return Flow Plan in the Application).

Conversely, the Fox River flashiness index is slightly higher with return flow than historic conditions. This is because base flows in the Fox River would be reduced with return flow to the Root River. The flashiness index increase is anticipated to have a negligible impact on aquatic resources because the change in base flow has a change in water depth of about 2-inches or less (see Volume 4 of the Application).

Underwood Creek Return Flow

The return flow plan to Underwood Creek included returning flow from the City's WWTP when the creek flow was not experiencing high flows (e.g. creek flow less than 1,000 cfs). Continuous return flow was simulated in 2005 because the creek never exceeded 1,000 cfs in 2005. The return flow plan also included a maximum daily flow of 115 percent of the average daily water demand. Following this operational plan, base flow in Underwood Creek would increase but the high-flow event flow rates would not change because return flow would be temporarily paused during those times. In the context of a hydrograph for Underwood Creek, the low creek flows would be increased but the high creek flows would not change as a result of the return flow.

Following this return flow management plan, the flashiness index for Underwood Creek and the Fox River were calculated (Tables 3 and 4). This operational scenario is different than that evaluated for Root River because the Underwood Creek return flow plan was evaluated prior to completing the Root River evaluation. However, these results are still anticipated to be representative because the flashiness index is most influenced by changes in base flow, and average hourly return flow to Root River (8.7 mgd) is also very similar to that for Underwood Creek (8.6 mgd) in dry year 2005 when return flow is most influential of base flow rates. This is further demonstrated by comparing Tables 2 and 4 for the Fox River for the two return flow management plan scenarios – the flashiness index are nearly identical.

TABLE 3
Changes in the Flashiness Index for Underwood Creek Before and After Return Flow

Year/Date	Historic/Actual (without return flow)	With Return Flow
2005		
January–March	0.65	0.33
April–June	0.59	0.26
July–September	1.00	0.39
October–December	0.57	0.18
Year 2005	0.69	0.29
2008		
January–March	0.44	0.28
April–June	0.70	0.57
July–September	0.65	0.27
October–December	0.55	0.24
Year 2008	0.62	0.41

TABLE 4
Changes in the Flashiness Index for the Fox River (at the WWTP) Before and After Return Flow to Underwood Creek

Year/Date	Historic/Actual (without return flow to Underwood Creek)	With Return Flow to Underwood Creek
2005		
January-March	0.16	0.18
April-June	0.10	0.11
July-September	0.19	0.25
October-December	0.17	0.21
Year 2005	0.15	0.17
2008		
January-March	0.120[a]	0.126[a]
April-June	0.182[a]	0.187[a]
July-September	0.100[a]	0.111[a]
October-December	0.188[a]	0.213[a]
Year 2008	0.157[a]	0.166[a]

[a]Three decimal places are reported to show the difference in index values.

The flashiness index is lower for Underwood Creek when a Lake Michigan supply with return flow is compared to the creek flow without return flow. This is because the return flow adds base flow but does not contribute to peak storm runoff events, and because the return flow will be relatively uniform.

The flashiness index slightly increases for the Fox River because WWTP flow that historically discharged to the Fox River is instead discharged to Underwood Creek through return flow.

The reduction in flashiness index for Underwood Creek is anticipated to have a beneficial impact on the aquatic resources in the creek due to the improvement in base flow, which has anticipated benefits to the aquatic resources as summarized in the Return Flow Plan (see Volume 4 of the Application). The change in the flashiness index for the Fox River will likely have a negligible effect on aquatic resources because the change is very small and the proposed return flow management plan will not negatively affect the rate at which peak flow in the river occurs compared to existing conditions. The Return Flow Plan contains more detailed information on the impacts of the return flow management plan on the aquatic resources of the Fox River.

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 20, 2012

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. The HSPF model used in the RWQMPU simulates phytoplankton and periphyton separately, but it reports chlorophyll *a* as the total for the two together for each segment (i.e. the model does not output changes in phytoplankton and periphyton, instead it reports chlorophyll *a*). 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

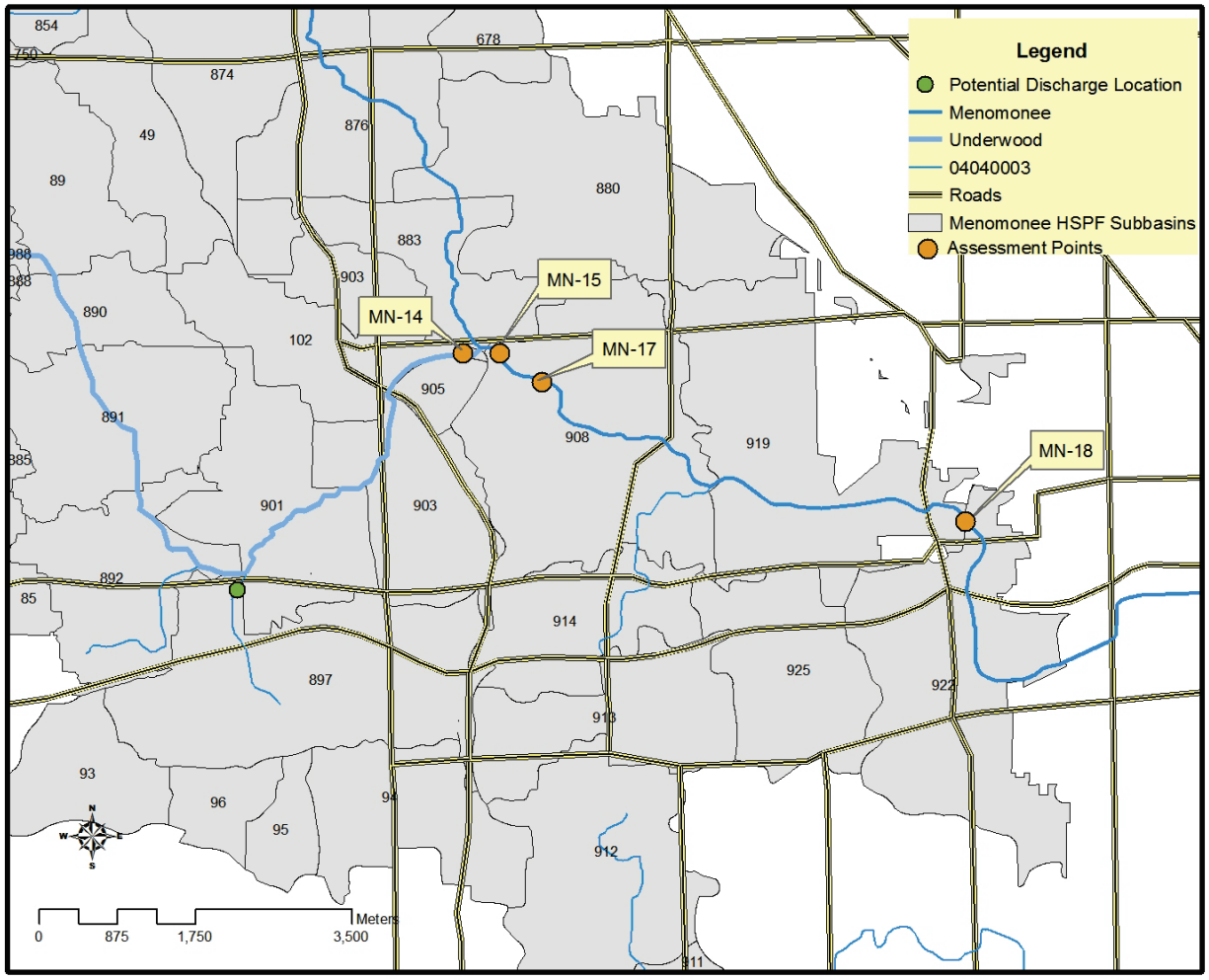


TABLE 4
Reach 905 – Assessment Point MN-14 Underwood Creek

		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

TETRA TECH, INC.
Cape Fear Building, Suite 105
3200 Chapel Hill-Nelson Hwy.
P.O. Box 14409
Research Triangle Park, NC 27709
Telephone: (919) 485-8278
Telefax: (919) 485-8280

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 I
Return Flow Plan Cost Estimates

Return Flow Cost Estimates

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: July 2, 2013

As part of the City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application), screening-level cost estimates for the following return flow alignments were developed.

- Return flow to Underwood Creek
- Return flow to Root River
- Return flow direct to Lake Michigan near Milwaukee and Oak Creek
- Return flow direct to Lake Michigan near Racine

Summaries of these cost estimates are included herein. Documentation of the cost estimates methodologies, contingency factors, and price indexes are included in Section 10 of The City of Waukesha Water Supply Service Area Plan (Volume 2 of the Application). Also included are cost estimate summaries for the water supply alternatives.

Cost estimates for return flow to the Milwaukee Metropolitan Sewerage District are included in Attachment A of The City of Waukesha Return Flow Plan (see Volume 4 of the Application).

Underwood Creek Return Flow

(Costs include corridor sharing with a Milwaukee Water Supply)

Capital Cost

	Quantity	Unit Cost	Total
Pipelines			
11.4 miles of 30-inch pipe	60,192	$ 358	$ 21,550,000
10% allowance for pipeline valves & appurtenances			$ 2,155,000
Pipeline Construction Cost			$ 23,705,000
WWTP Effluent Pump Station			
One 16.7 mgd pump station, generator and power supply	1	$ 6,293,000	$ 6,293,000
Subtotal Return Flow Construction Cost			**$ 29,998,000**
3% markup for Bonds & Insurance			$900,000
5% markup for Mob/Demob			$1,500,000
8% markup for Contractors Overhead			$2,592,000
4% markup for Contractors profit			$1,296,000
25% Contingency			$9,072,000
Subtotal Markups and Contingency			**$15,360,000**
Total Project Construction Costs			**$45,358,000**
8% allowance for pipeline engineering and design			$3,629,000
12% allowance for permitting, legal and administration			$5,443,000
8% allowance for pipeline engr services during construction			$3,629,000
Subtotal Other Project Costs			**$12,701,000**

GRAND TOTAL PROJECT COST **$58,059,000**

Operating and Maintenance Cost

	Units	Quantity	Unit Cost	Ext. Cost	Total
Energy	mgd	11.7			$ 162,362
O&M		2% of Capital cost of pump station	0.02	$ 6,293,000	$ 125,860

Alternative Total O&M ($/yr.) **$ 288,000**

TOTAL PROJECT PRESENT WORTH (6%, 20 yrs) **$ 61,059,000**

TOTAL PROJECT PRESENT WORTH (6%, 50 yrs) **$ 63,059,000**

Root River Return Flow

(Costs include corridor sharing with an Oak Creek Water Supply)

Capital Cost

	Quantity	Unit Cost	Total
Pipelines			
20.1 miles of 30-inch pipe	106,128.0	$ 348	$36,889,000
10% allowance for pipeline valves & appurtenances			$3,689,000
Pipeline Construction Cost			$40,578,000
WWTP Effluent Pump Station			
One 16.7 mgd pump station, generator and power supply	1	$ 9,042,000	$9,042,000
Subtotal Return Flow Construction Cost			**$49,620,000**
3% markup for Bonds & Insurance			$1,489,000
5% markup for Mob/Demob			$2,481,000
8% markup for Contractors Overhead			$4,288,000
4% markup for Contractors profit			$2,144,000
25% Contingency			$15,006,000
Subtotal Markups and Contingency			**$25,408,000**
Total Project Construction Costs			**$75,028,000**
8% allowance for pipeline engineering and design			$6,003,000
12% allowance for permitting, legal and administration			$9,004,000
8% allowance for pipeline engr services during construction			$6,003,000
Subtotal Other Project Costs			**$21,010,000**

GRAND TOTAL PROJECT COST **$96,038,000**

Operating and Maintenance Cost

	Units	Quantity	Unit Cost	Ext. Cost	Total
Energy	mgd	11.7			$ 436,852
O&M		2% of Capital cost of pump station	0.02	$ 9,042,000	$ 180,840

Alternative Total O&M ($/yr.) **$ 618,000**

TOTAL PROJECT PRESENT WORTH (6%, 20 yrs) **$ 103,038,000**

TOTAL PROJECT PRESENT WORTH (6%, 50 yrs) **$ 106,038,000**

Direct to Lake Michigan Return Flow Near Milwaukee and Oak Creek

(Costs do not include corridor sharing)

Capital Cost

	Quantity	Unit Cost	Total
Pipelines			
22 miles of 30-inch pipe	116,160	$ 417	$ 48,438,000
10% allowance for pipeline valves & appurtenances			$ 4,844,000
Pipeline Construction Cost			$ 53,282,000
WWTP Effluent Pump Station			
One 16.7 mgd pump station, generator and power supply	1	$ 7,297,000	$ 7,297,000
Conveyance System Construction Cost			**$ 60,579,000**
3% markup for Bonds & Insurance			$1,818,000
5% markup for Mob/Demob			$3,029,000
8% markup for Contractors Overhead			$5,235,000
4% markup for Contractors profit			$2,618,000
25% Contingency			$18,320,000
Subtotal Markups and Contingency			**$31,020,000**
Total Project Construction Costs			**$91,599,000**
8% allowance for pipeline engineering and design			$7,328,000
12% allowance for permitting, legal and administration			$10,992,000
8% allowance for pipeline engr services during construction			$7,328,000
Subtotal Other Project Costs			**$25,648,000**

GRAND TOTAL PROJECT COST **$117,247,000**

Operating and Maintenance Cost

	Units	Quantity	Unit Cost	Ext. Cost	Total
Energy	mgd	11.7			$ 276,976
O&M		2% of Capital cost of pump station	0.02	$ 7,297,000	$ 145,940

Alternative Total O&M ($/yr.) **$ 423,000**

TOTAL PROJECT PRESENT WORTH (6%, 20 yrs) **$ 122,247,000**

TOTAL PROJECT PRESENT WORTH (6%, 50 yrs) **$ 124,247,000**

Direct to Lake Michigan Return Flow Near Racine

(Costs include corridor sharing with a Racine Water Supply)

Capital Cost

	Quantity	Unit Cost	Total
Pipelines			
37 of miles of 30-inch pipe	195,360	$ 331	$ 64,651,000
10% allowance for pipeline valves & appurtenances			$ 6,466,000
Pipeline Construction Cost			$ 71,117,000
Two WWTP Effluent Pump Stations			
Two 16.7 mgd pump stations, generators and power supplies	2	$ 7,508,500	$ 15,017,000
Subtotal Return Flow Construction Cost			**$ 86,134,000**
3% markup for Bonds & Insurance			$2,585,000
5% markup for Mob/Demob			$4,307,000
8% markup for Contractors Overhead			$7,443,000
4% markup for Contractors profit			$3,722,000
25% Contingency			$26,048,000
Subtotal Markups and Contingency			**$44,105,000**
Total Project Construction Costs			**$130,239,000**
8% allowance for pipeline engineering and design			$10,420,000
12% allowance for permitting, legal and administration			$15,629,000
8% allowance for pipeline engr services during construction			$10,420,000
Subtotal Other Project Costs			**$36,469,000**

GRAND TOTAL PROJECT COST **$166,708,000**

Operating and Maintenance Cost

	Units	Quantity	Unit Cost	Ext. Cost	Total
Energy	mgd	11.7			$ 646,636
O&M		2% of Capital cost of pump station	0.02	$ 15,017,000	$ 300,340

Alternative Total O&M ($/yr.) **$ 947,000**

TOTAL PROJECT PRESENT WORTH (6%, 20 yrs) **$ 177,570,000**

TOTAL PROJECT PRESENT WORTH (6%, 50 yrs) **$ 181,634,000**

Appendix J

Option to Purchase for Root River Return Flow

WB-24 OPTION TO PURCHASE

~~LICENSEE DRAFTING THIS OPTION ON~~ _____, ~~DATE~~ ~~(AGENT OF BUYER)~~
~~(AGENT OF SELLER/LISTING BROKER) (AGENT OF BUYER AND SELLER) STRIKE THOSE NOT APPLICABLE~~

The Seller (Optionor), Laona Grudzielanek and Judith Gyuro, hereby grants to the Buyer (Optionee), City of Waukesha, a Wisconsin Municipal Corporation an option to purchase (Option) the Property known as [Street Address] 5207 West Oakwood Rd., 58.9 acres, see attached map and legal description in the City of Franklin, County of Milwaukee, Wisconsin, on the following terms:

DEADLINE FOR GRANT OF OPTION This Option is void unless a copy of the Option, or separate but identical copies, is/are signed by all Sellers and delivered to Buyer on or before February 15, 2013 at 4:30 p.m. (Time is of the Essence).

OPTION TERMS

■ INITIAL OPTION TERM: A nonrefundable option fee of $ 57,947.90 will be paid by Buyer to Seller within 10 days of the later of: (i) the granting of this Option, or (ii) the deadline for execution of a lease if line 141 of this Option is checked. This Option may only be exercised if Buyer delivers written notice to Seller no later than midnight February 15, 2017 unless extended below.

■ EXTENDED OPTION TERM: The Deadline to exercise this Option shall be extended until midnight N/A, upon payment of $_____ to Seller on or before _____, as an option extension fee which shall not be refundable.

■ EXERCISE: To exercise this Option, Buyer must sign and deliver (i) the notice at lines 355-361, or (ii) any other written notice which states that Buyer exercises this Option. If the Option is exercised, $ 57,947.90 of the option fee and $ N/A of the option extension fee, if any, shall be a credit against the purchase price at closing.

CAUTION: **If the option fees are to be paid into listing broker's trust account or to a third party, specify in additional provisions at lines 256-268 or 326-330 or in a separate agreement attached per line 325.**

TERMS OF PURCHASE If this Option is exercised per the terms of this Option, the following shall be the terms of purchase:

■ PURCHASE PRICE: Five hundred seventy nine thousand, four hundred seventy nine & 00/100 Dollars ($ 579,479.00) will be paid in cash or equivalent at closing unless otherwise provided below.

■ INCLUDED IN PURCHASE PRICE: Seller is including in the purchase price the Property, all Fixtures on the Property on the date of this Option not excluded at lines 28-29, and the following additional items: none

■ NOT INCLUDED IN PURCHASE PRICE: sellers personal property if any

CAUTION: Identify trade fixtures owned by tenant, if applicable, and Fixtures that are on the Property (see lines 75-82) to be excluded by Seller or which are rented and will continue to be owned by the lessor.

NOTE: The terms of this Option, not the listing contract or marketing materials, determine what items are included/excluded.

OPTIONAL PROVISIONS TERMS OF THIS OPTION THAT ARE PRECEDED BY AN OPEN BOX (☐) ARE PART OF THIS OPTION ONLY IF THE BOX IS MARKED SUCH AS WITH AN "X." THEY ARE NOT PART OF THIS OPTION IF MARKED "N/A" OR ARE LEFT BLANK.

DELIVERY OF DOCUMENTS AND WRITTEN NOTICES Unless otherwise stated in this Option, delivery of documents and written notices to a party shall be effective only when accomplished by one of the methods specified at lines 37-54.

(1) Personal Delivery: giving the document or written notice personally to the Party, or the Party's recipient for delivery if named at line 38 or 39.
Seller's recipient for delivery (optional): Laona Grudzielanek
Buyer's recipient for delivery (optional): Dan Duchniak, Waukesha Water Utility

[XX] (2) Fax: fax transmission of the document or written notice to the following telephone number:
Seller: (_____) _____ Buyer: (262) 521-5265

[XX] (3) Commercial Delivery: depositing the document or written notice fees prepaid or charged to an account with a commercial delivery service, addressed either to the Party, or to the Party's recipient for delivery if named at line 38 or 39, for delivery to the Party's delivery address at line 47 or 48.

[XX] (4) U.S. Mail: depositing the document or written notice postage prepaid in the U.S. Mail, addressed either to the Party, or to the Party's recipient for delivery if named at line 38 or 39, for delivery to the Party's delivery address at line 47 or 48.

Delivery address for Seller: 4604 West Thorncrest Drive., Franklin, WI 53132
Delivery address for Buyer: 115 Delafield St., PO Box 1648, Waukesha, WI 53187

[ ] (5) E-Mail: electronically transmitting the document or written notice to the Party's e-mail address, if given below at line 53 or 54. If this is a consumer transaction where the property being purchased or the sale proceeds are used primarily for personal, family or household purposes, each consumer providing an e-mail address below has first consented electronically to the use of electronic documents, e-mail delivery and electronic signatures in the transaction, as required by federal law.

E-Mail address for Seller (optional): _____
E-Mail address for Buyer (optional): _____

TIME IS OF THE ESSENCE "Time is of the Essence" as to: (1) payment of option fees; (2) payment of extension fees; (3) Seller's grant of this Option; (4) Buyer's exercise of this Option; (5) occupancy; (6) date of closing; STRIKE AS APPLICABLE and all other dates and Deadlines in this Option except: no exceptions. If "Time is of the Essence" applies to a date or Deadline, failure to perform by the exact date or Deadline is a breach of contract. If "Time is of the Essence" does not apply to a date or Deadline, then performance within a reasonable time of the date or Deadline is allowed before a breach occurs.

PERSONAL DELIVERY/ACTUAL RECEIPT Personal delivery to, or Actual Receipt by, any named Buyer or Seller constitutes personal delivery to, or Actual Receipt by, all Buyers or Sellers.

DEFINITIONS

■ ACTUAL RECEIPT: "Actual Receipt" means that a Party, not the Party's recipient for delivery, if any, has the document or written notice physically in the Party's possession, regardless of the method of delivery.

■ DEADLINES: "Deadlines" expressed as a number of "days" from an event, such as acceptance, are calculated by excluding the day the event occurred and by counting subsequent calendar days. The deadline expires at midnight on the last day. Deadlines expressed as a specific number of "business days" exclude Saturdays, Sundays, any legal public holiday under Wisconsin or Federal law, and any other day designated by the President such that the postal service does not receive registered mail or make regular deliveries on that day. Deadlines expressed as a specific number of "hours" from the occurrence of an event, such as receipt of a notice, are calculated from the exact time of the event, and by counting 24 hours per calendar day. Deadlines expressed as a specific day of the calendar year or as the day of a specific event, such as closing, expire at midnight of that day.

■ DEFECT: "Defect" means a condition that would have a significant adverse effect on the value of the Property; that would significantly impair the health or safety of future occupants of the Property; or that if not repaired, removed or replaced would significantly shorten or adversely affect the expected normal life of the premises or adversely affect the use of the Property.

■ FIXTURE: A "Fixture" is an item of property which is physically attached to or so closely associated with land or improvements so as to be treated as part of the real estate, including, without limitation, physically attached items not easily removable without damage to the premises, items specifically adapted to the premises and items customarily treated as fixtures, including, but not limited to, all: garden bulbs; plants; shrubs and trees; screen and storm doors and windows; electric lighting fixtures; window shades; curtain and traverse rods; blinds and shutters; central heating and cooling units and attached equipment; water heaters and treatment systems; sump pumps; attached or fitted floor coverings; awnings; attached antennas; garage door openers and remote controls; installed security systems; central vacuum systems and accessories; in-ground sprinkler systems and component parts; built-in appliances; ceiling fans; fences; storage buildings on permanent foundations and docks/piers on permanent foundations. A "Fixture" does not include trade fixtures owned by tenants of the Property.

CAUTION: Exclude any Fixtures to be retained by Seller or which are not owned by Seller, such as rented fixtures (e.g., water softener or other water conditioning systems, home entertainment and satellite dish components, L.P. tanks, etc.) on lines 28-29.

■ PROPERTY: Unless otherwise stated, "Property" means the real estate described at lines 5-7.

PROPERTY DIMENSIONS AND SURVEYS Buyer acknowledges that any land, building or room dimensions, or total acreage or building square footage figures, provided to Buyer by Seller or by a broker, may be approximate because of rounding, formulas used or other reasons, unless verified by survey or other means.

CAUTION: Buyer should verify total square footage formula, total square footage/acreage figures, and land, building or room dimensions, if material.

BUYER'S WALK-THROUGHS Within 3 days of the earlier of: (i) the Deadline for Buyer's exercise of this Option; or (ii) the Buyer's exercise of this Option; and again within 3 days prior to closing, at a reasonable time pre-approved by Seller or Seller's agent, Buyer shall have the right to walk through the Property to determine that there has been no significant change in the condition of the Property, except for ordinary wear and tear and changes approved by Buyer, and that any Defects Seller has agreed to cure have been repaired in the manner agreed to by the Parties.

PROPERTY DAMAGE BETWEEN EXERCISE OF OPTION AND CLOSING Seller shall maintain the Property until the earlier of closing or occupancy of Buyer in materially the same condition as of the date Buyer exercises this Option, except for ordinary wear and tear. If, prior to closing, the Property is damaged in an amount of not more than five percent (5%) of the purchase price, Seller shall be obligated to repair the Property and restore it to the same condition that it was on the day this Option was exercised. No later than closing, Seller shall provide Buyer with lien waivers for all lienable repairs and restoration. If the damage shall exceed such sum, Seller shall promptly notify Buyer in writing of the damage and this Option may be canceled at the option of Buyer. Should Buyer elect to carry out this Option despite such damage, Buyer shall be entitled to the insurance proceeds, if any, relating to the damage to the Property, plus a credit towards the purchase price equal to the amount of Seller's deductible on such policy, if any. However, if this sale is financed by a land contract or a mortgage to Seller, any insurance proceeds shall be held in trust for the sole purpose of restoring the Property.

DISTRIBUTION OF INFORMATION Buyer and Seller authorize the agents of Buyer and Seller to: (i) distribute copies of the Option to Buyer's lender, appraisers, title insurance companies and any other settlement service providers for the transaction as defined by the Real Estate Settlement Procedures Act (RESPA); (ii) report sales and financing concession data to multiple listing service sold databases; and (iii) provide active listing, pending sale, closed sale and financing concession information and data, and related information regarding seller contributions, incentives or assistance, and third party gifts, to appraisers researching comparable sales, market conditions and listings, upon inquiry.

NOTICE ABOUT SEX OFFENDER REGISTRY You may obtain information about the sex offender registry and persons registered with the registry by contacting the Wisconsin Department of Corrections on the Internet at http://www.widocoffenders.org or by telephone at (608) 240-5830.

CLOSING This transaction is to be closed (within forty-five (45) days after the exercise of this Option) ~~(no later than xxxxxxxxxxxxxxxxxxxxxxxxxxxx)~~ STRIKE AND COMPLETE AS APPLICABLE at the place selected by Seller, unless otherwise agreed by the Parties in writing.

CLOSING PRORATIONS The following items, if applicable, shall be prorated at closing, based upon date of closing values: ~~real estate taxes~~, rents, prepaid insurance (if assumed), private and municipal charges, property owners association assessments, fuel and _____.

CAUTION: Provide basis for utility charges, fuel or other prorations if date of closing value will not be used.

Any income, taxes or expenses shall accrue to Seller, and be prorated at closing, through the day prior to closing.

~~Real estate taxes shall be prorated at closing based on [CHECK BOX FOR APPLICABLE PRORATION FORMULA]:~~

☐ The net general real estate taxes for the preceding year, or the current year if available (Net general real estate taxes are defined as general property taxes after state tax credits and lottery credits are deducted) (NOTE: THIS CHOICE APPLIES IF NO BOX IS CHECKED)

☐ Current assessment times current mill rate (current means as of the date of closing)

☐ Sale price, multiplied by the municipality area-wide percent of fair market value used by the assessor in the prior year, or current year if known, multiplied by current mill rate (current means as of the date of closing)

☒ XX See addendum to Option to Purchase

CAUTION: Buyer is informed that the actual real estate taxes for the year of closing and subsequent years may be substantially different than the amount used for proration especially in transactions involving new construction, extensive rehabilitation, remodeling or area-wide re-assessment. Buyer is encouraged to contact the local assessor regarding possible tax changes.

☐ Buyer and Seller agree to re-prorate the real estate taxes, through the day prior to closing based upon the taxes on the actual tax bill for the year of closing, with Buyer and Seller each owing his or her pro-rata share. Buyer shall, within 5 days of receipt, forward a copy of the bill to the forwarding address Seller agrees to provide at closing. The Parties shall re-prorate within 30 days of Buyer's receipt of the actual tax bill. Buyer and Seller agree this is a post-closing obligation and is the responsibility of the Parties to complete, not the responsibility of the real estate brokers in this transaction.

LEASED PROPERTY If Property is currently leased and lease(s) extend beyond closing, Seller shall assign Seller's rights under the lease(s) and transfer all security deposits and prepaid rents thereunder to Buyer at closing. The terms of the (written) ~~(oral)~~ STRIKE ONE lease(s), if any, are _____. Insert additional terms, if any, at lines 256-268 or 326-330 or attach as an addendum per line 325.

LEASE-OPTION PROVISIONS [CHECK BOX ON LINE 140 OR 141, IF APPLICABLE]:

☐ Concurrent with the granting of the Option, Seller and Buyer have entered into a written lease for the Property.

☐ This Option is contingent upon Seller and Buyer, within _____ days from the granting of this Option, entering into a written lease for the Property with minimum terms which shall include: term from _____ to _____ and an initial rent of $ _____ per month or this Option shall be null and void.

[CHECK ANY OF THE FOLLOWING THAT APPLY, IF LINE 140 OR 141 WAS CHECKED ABOVE]:

☐ In the event that this Option is timely exercised, $_____ of each monthly rent payment of $_____ shall be applied to the purchase price while the balance shall be deemed solely rent that is retained by Seller.

NOTE: Lenders may not recognize a credit for rent paid under a lease.

☐ Buyer may not exercise this Option unless Buyer is current with all rent.

☐ Any material breach of the lease by Buyer shall also constitute a default under this Option.

PROPERTY CONDITION REPRESENTATIONS Seller represents to Buyer that, as of the date Seller grants this Option, Seller has no notice or knowledge of any Defects (lines 72-74) other than those identified in Seller's disclosure report dated N/A and, if applicable, Real Estate Condition Report dated N/A, and, if applicable, Vacant Land Disclosure Report dated N/A, which was/were received by Buyer prior to Buyer signing this Option and which is/are made a part of this Option by reference COMPLETE DATES OR STRIKE AS APPLICABLE and _____

_____

_____ INSERT CONDITIONS NOT ALREADY INCLUDED IN THE DISCLOSURE OR CONDITION REPORT(S)

CAUTION: If the Property includes 1-4 dwelling units, a Real Estate Condition Report containing the disclosures provided in Wis. Stat. § 709.03 may be required. If the Property does not include any buildings, a Vacant Land Disclosure Report containing the disclosures provided in Wis. Stat. § 709.033 may be required. Excluded from these requirements are sales of property with 1-4 dwelling units that has never been inhabited, sales exempt from the real estate transfer fee, and sales by certain court-appointed fiduciaries (for example, personal representatives who have never occupied the Property). The buyer may have certain rescission rights per Wis. Stat. § 709.05 if Seller does not furnish such report(s) within 10 days after Seller grants this Option or if a report disclosing Defects is furnished before expiration of those 10 days, but after the Option is submitted to Seller. Buyer should review the report form or consult with an attorney for additional information regarding rescission rights.

Seller agrees to notify Buyer in writing of any Defect which Seller becomes aware of after Seller's granting of, but prior to Buyer's exercise of this Option, which is materially inconsistent with the above representations. For purposes of this provision (lines 150-156), Defect does not include structural, mechanical or other conditions of which the Buyer has actual knowledge or written notice or which Buyer discovers prior to the exercise of this Option.

ZONING Seller represents that the property is zoned R-2; Estate Single Family District, IW; Floodway District, FC: Floodplain Conservancy District.

OCCUPANCY Occupancy of the entire Property shall be given to Buyer at time of closing unless otherwise provided in this Option at lines 256-268 or 326-330 or in an addendum attached per line 325. At time of Buyer's occupancy, Property shall be in broom swept condition and free of all debris and personal property except for personal property belonging to current tenants, or that sold to Buyer or left with Buyer's consent. Occupancy shall be given subject to tenant's rights, if any.

CAUTION: Consider an agreement which addresses responsibility for clearing the Property of personal property and debris, if applicable.

RENTAL WEATHERIZATION Unless otherwise agreed, Buyer shall be responsible for compliance with Rental Weatherization Standards (Wis. Admin. Code Ch. SPS 367), if applicable.

DEFAULT Seller and Buyer each have the legal duty to use good faith and due diligence in completing the terms and conditions of this Option. A material failure to perform any obligation under this Option is a default which may subject the defaulting party to liability for damages or other legal remedies.

If Buyer defaults, Seller may:

(1) sue for specific performance if Buyer has exercised this Option; or

(2) terminate the Option and may sue for actual damages.

If Seller defaults, Buyer may:

(1) sue for specific performance; or

(2) terminate the Option and may sue for actual damages.

In addition, the Parties may seek any other remedies available in law or equity.

The Parties understand that the availability of any judicial remedy will depend upon the circumstances of the situation and the discretion of the courts. If either Party defaults, the Parties may renegotiate the Option or seek nonjudicial dispute resolution instead of the remedies outlined above. By agreeing to binding arbitration, the Parties may lose the right to litigate in a court of law those disputes covered by the arbitration agreement.

NOTE: IF ACCEPTED, THIS OPTION CAN CREATE A LEGALLY ENFORCEABLE CONTRACT. BOTH PARTIES SHOULD READ THIS DOCUMENT CAREFULLY. BROKERS MAY PROVIDE A GENERAL EXPLANATION OF THE PROVISIONS OF THE OPTION BUT ARE PROHIBITED BY LAW FROM GIVING ADVICE OR OPINIONS CONCERNING YOUR LEGAL RIGHTS UNDER THIS OPTION OR HOW TITLE SHOULD BE TAKEN AT CLOSING. AN ATTORNEY SHOULD BE CONSULTED IF LEGAL ADVICE IS NEEDED.

ENTIRE CONTRACT This Option, including any amendments to it, contains the entire agreement of the Buyer and Seller regarding the transaction. All prior negotiations and discussions have been merged into this Option. This agreement binds and inures to the benefit of the Parties to this Option and their successors in interest.

BUYER DUE DILIGENCE Prior to the granting or exercising of this Option, Buyer may wish to perform certain authorized inspections, investigations and testing of the Property. Buyer shall provide for any specific inspections, investigations or tests Buyer intends to perform as part of Buyer's due diligence items on lines 256-268, 314-321, or 326-330 or attach as an addendum per line 325. In addition, Buyer may need to obtain and review documents relevant to financing approval, appraisals, or perform general due diligence activities for the transaction, including but not limited to: business records, condominium documents, maps or other information, municipal and zoning ordinances, recorded building and use restrictions, covenants and easements of record, as they may prohibit or restrict certain uses and improvements for the Property. Buyer may also need to obtain or verify certain permits, zoning variances, other governmental or private approvals, environmental audits and subsoil tests, required road improvements, utility hook-up and installation costs, or other development related costs and fees, in order to fully determine the feasibility of any proposed or planned development of the Property. Seller agrees to cooperate with Buyer as necessary to complete any due diligence items or any authorized investigations, testing and inspections as provided for in this Option, without cost to Seller, unless otherwise agreed by the Parties in writing.

RECORDING OF OPTION Buyer (may) ~~(may not)~~ STRIKE ONE record this Option at Buyer's expense.
Buyer (may) ~~(may not)~~ STRIKE ONE ("may" if neither is stricken) record a separate instrument evidencing this Option at Buyer's expense. If this Option or a separate instrument evidencing this Option is to be recorded, insert legal description at lines 256-268 or 326-330 or attach as an addendum per line 325. If recording, the parties agree to provide authenticated or acknowledged signatures as may be required.
CAUTION: Failure to record may give persons with subsequent interests in the Property priority over this Option.

TITLE EVIDENCE

■ CONVEYANCE OF TITLE: **Upon payment of the purchase price, Seller shall convey the Property by warranty deed (or condominium deed if Property is a condominium unit, trustee's deed if Seller is a trust, personal representative's deed if Seller is an estate or other conveyance as provided herein),** free and clear of all liens and encumbrances, except: municipal and zoning ordinances and agreements entered under them, recorded easements for the distribution of utility and municipal services, recorded building and use restrictions and covenants, present uses of the Property in violation of the foregoing disclosed in Seller's Real Estate Condition Report and in this Option, general taxes levied in the year of closing and no other exceptions

Buyer which constitutes merchantable title for purposes of this transaction. ~~Seller~~ Buyer's shall complete and execute the documents necessary to record the conveyance at ~~Seller's~~ Buyer's cost and pay the Wisconsin Real Estate Transfer Fee. The Parties agree that Seller shall not rezone the Property or create any additional liens or encumbrances on title after Seller grants this Option without Buyer's written consent except for liens and encumbrances that will be removed at closing.
WARNING: Municipal and zoning ordinances, recorded building and use restrictions, covenants and easements may prohibit certain improvements or uses and therefore should be reviewed, particularly if Buyer contemplates making improvements to Property or a use other than the current use.

■ TITLE EVIDENCE: Seller shall give evidence of title in the form of an owner's policy of title insurance in the amount of the purchase price on a current ALTA form issued by an insurer licensed to write title insurance in Wisconsin. ~~Seller~~ Buyer shall pay all costs of providing title evidence to Buyer. Buyer shall pay all costs of providing title evidence required by Buyer's lender.

■ GAP ENDORSEMENT: Seller shall provide a "gap" endorsement or equivalent gap coverage at ~~(Seller's)~~(Buyer's) STRIKE ONE ("Seller's" if neither stricken) cost to provide coverage for any liens or encumbrances first filed or recorded after the effective date of the title insurance commitment and before the deed is recorded, subject to the title insurance policy exclusions and exceptions, provided the title company will issue the endorsement. If a gap endorsement or equivalent gap coverage is not available, Buyer may give written notice that title is not acceptable for closing (see lines 242-248).

■ PROVISION OF MERCHANTABLE TITLE: For purposes of closing, title evidence shall be acceptable if the required title insurance commitment is delivered to Buyer's attorney or Buyer not more than 15 days after Seller grants this Option ("15" if left blank), showing title to the Property as of a date no more than 15 days before delivery of such title evidence to be merchantable per lines 215-223, subject only to liens which will be paid out of the proceeds of closing and standard title insurance requirements and exceptions, as appropriate.
CAUTION: Buyer should consider obtaining an update of the title commitment prior to exercising this Option.

■ TITLE NOT ACCEPTABLE FOR CLOSING: If title is not acceptable for closing, Buyer shall notify Seller in writing of objections to title within 15 days ("15" if left blank) after delivery of the title commitment to Buyer or Buyer's attorney. In such event, Seller shall have a reasonable time, but not exceeding 5 days ("5" if left blank), from Buyer's delivery of the notice stating title objections, to deliver notice to Buyer stating Seller's election to remove the objections by the time set for closing. In the event that Seller is unable to remove said objections, Buyer may deliver to Seller written notice waiving the objections, and the time for closing shall be extended accordingly. If Buyer does not waive the objections, Buyer shall deliver written notice of termination and this Option shall be null and void. Providing title evidence acceptable for closing does not extinguish Seller's obligations to give merchantable title to Buyer.

■ SPECIAL ASSESSMENTS/OTHER EXPENSES: Special assessments, if any, levied or for work actually commenced prior to the date this Option is exercised shall be paid by Seller no later than closing. All other special assessments shall be paid by Buyer.
CAUTION: Consider a special agreement if area assessments, property owners association assessments, special charges for current services under Wis. Stat. § 66.0627 or other expenses are contemplated. "Other expenses" are one-time charges or ongoing use fees for public improvements (other than those resulting in special assessments) relating to curb, gutter, street, sidewalk, municipal water, sanitary and storm water and storm sewer (including all sewer mains and hook-up/connection and interceptor charges), parks, street lighting and street trees, and impact fees for other public facilities, as defined in Wis. Stat. § 66.0617(1)(f).

ADDITIONAL PROVISIONS

See Attached Addendum

CONDOMINIUM UNITS

CAUTION: If this Option involves a condominium unit, Buyer should obtain and review the condominium disclosure documents before entering into this Option. See lines (198-208)

If the Property is a residential condominium unit, Seller must comply with the following:

■ CONDOMINIUM DISCLOSURE MATERIALS: Seller agrees to provide Buyer, at Seller's cost, within 10 days of Buyer exercising this Option, but no later than 15 days prior to closing, current and accurate copies of the condominium disclosure materials required by Wis. Stat. § 703.33. The condominium disclosure materials include a copy of the following and any amendments to any of these [except as may be limited for small condominiums with no more than 12 units per Wis. Stat. § 703.365(1)(b) and (8)]: (a) proposed or existing declaration, bylaws and any rules or regulations, and an index of the contents; (b) proposed or existing articles of incorporation of the association, if it is or is to be incorporated; (c) proposed or existing management contract, employment contract or other contract affecting the use, maintenance or access of all or part of the condominium; (d) projected annual operating budget for the condominium including reasonable details concerning the estimated monthly payments by the purchaser for assessments and other monthly charges; (e) leases to which unit owners or the association will be a party; (f) general description of any contemplated expansion of condominium including each stage of expansion and the maximum number of units that can be added to the condominium; (g) unit floor plan showing location of common elements and other facilities available to unit owners; (h) the executive summary.

■ BUYER RESCISSION RIGHTS: As provided in Wis. Stat. § 703.33(4)(a), Buyer may, within 5 business days of receipt of all the required disclosure documents, rescind this Option by written notice delivered to Seller. If the disclosure materials are delivered to Buyer and Buyer does not receive all of the disclosure documents, Buyer may, within 5 business days of Buyer's receipt of the disclosure materials, either rescind the Option or request any missing documents. Seller has 5 business days following receipt of Buyer's request for missing documents to deliver the requested documents. Buyer may rescind the sale within 5 business days of the earlier of Buyer's receipt of requested missing documents or the deadline for Seller's delivery of the documents [Wis. Stat. § 703.33(4)(b)]. **The Parties agree that the 5 business days begin upon the earlier of: (1) Buyer's Actual Receipt of the disclosure materials or requested missing documents or (2) upon the deadline for Seller's delivery of the documents.**

NOTE: BUYER SHOULD READ ALL DOCUMENTS CAREFULLY. BROKERS MAY PROVIDE A GENERAL EXPLANATION OF THE PROVISIONS OF THE DOCUMENTS BUT ARE PROHIBITED BY LAW FROM GIVING LEGAL ADVICE OR OPINIONS.

■ ADDITIONAL CONDOMINIUM ISSUES: In addition to the disclosure materials required by Wis. Stat. § 703.33, Buyer may wish to consider reviewing other condominium materials as may be available, such as copies of: the condominium association's financial statements for the last two years, the minutes of the last 3 Unit owners' meetings, the minutes of condominium board meetings during the 12 months prior to acceptance, information about contemplated or pending condominium special assessments, the association's certificate of insurance, a statement from the association indicating the balance of reserve accounts controlled by the association, a statement from the association of the amount of any unpaid assessments on the unit (per Wis. Stat. § 703.165), any common element inspection reports (e.g. roof, swimming pool, elevator and parking garage inspections, etc.), any pending litigation involving the association and the declaration, bylaws, budget and/or most recent financial statement of any master association or additional association the unit may be part of. Not all of these materials may exist or be available from the condominium association.

■ OPTION FEES NOT A DEPOSIT: The Parties agree that if this Option is for a residential condominium unit, the option fee and any option extension fee are not deposits subject to return under Wis. Stat. § 703.33(4)(c).

INSPECTIONS AND TESTING Buyer may only conduct inspections or tests if specific authorizations are included in this Option. An "inspection" is defined as an observation of the Property which does not include an appraisal or testing of the Property, other than testing for leaking carbon monoxide, or testing for leaking LP gas or natural gas used as a fuel source, which are hereby authorized. A "test" is defined as the taking of samples of materials such as soils, water, air or building materials from the Property and the laboratory or other analysis of these materials. Seller agrees to allow Buyer's inspectors, testers, appraisers and qualified third parties reasonable access to the Property upon advance notice, if necessary to perform the activities authorized in this Option. Buyer and licensees may be present at all inspections and testing. Except as otherwise provided, Seller's authorization for inspections does not authorize Buyer to conduct testing of the Property. Buyer agrees to promptly restore the Property to its original condition after Buyer's inspections and testing are completed unless otherwise agreed to with Seller. Buyer agrees to promptly provide copies of all inspection and testing reports to Seller. Seller acknowledges that certain inspections or tests may detect environmental pollution which may be required to be reported to the Wisconsin Department of Natural Resources.

AUTHORIZATION FOR APPRAISAL, INSPECTIONS AND TESTS Buyer is authorized to have the Property appraised by a Wisconsin licensed or certified appraiser and to conduct the following inspections and tests (see lines 304-313) prior to Buyer's exercise of this Option. Any inspection(s) and test(s) shall be performed by a qualified independent inspector or expert, or an independent qualified third party. Inspections and testing shall be conducted pursuant to government or industry protocols and standards, as applicable.

List inspections (e.g., home, roof, foundation, septic) here: _____

_____

List tests (e.g., radon, lead-based paint, well water) here: _____

_____

Describe additional inspections and tests, if any, at lines 256-263 or 326-330 or attach as an addendum per line 325.

NOTE: Any testing authorizations should specify the areas of the Property to be tested, the purpose of the test, (e.g., to determine if environmental contamination is present), any limitations on Buyer's testing and any other material terms.

[XX] **ADDENDA:** The attached Addendum is/are made part of this Option.

ADDITIONAL PROVISIONS _____

_____

_____

_____

_____

IF GRANTED, THIS OPTION CAN CREATE A LEGALLY ENFORCEABLE CONTRACT. BOTH PARTIES SHOULD READ THIS OPTION AND ALL ATTACHMENTS CAREFULLY. BROKERS MAY PROVIDE A GENERAL EXPLANATION OF THE PROVISIONS OF THE OPTION BUT ARE PROHIBITED BY LAW FROM GIVING ADVICE OR OPINIONS CONCERNING YOUR LEGAL RIGHTS UNDER THIS OPTION OR HOW TITLE SHOULD BE TAKEN AT CLOSING IF THE OPTION IS EXERCISED. AN ATTORNEY SHOULD BE CONSULTED IF LEGAL ADVICE IS NEEDED.

This Option was drafted by [Licensee and Firm] _____

_____ on _____.

Buyer Entity Name (if any): City of Waukesha, a Wisconsin Municipal Corporation

(x) _____ 2-5-13

Buyer's/Authorized Signature ▲ Print Name/Title Here ► Mayor Jeff Scrima Date ▲

(x) _____

Buyer's/Authorized Signature ▲ Print Name/Title Here ► Date ▲

SELLER GRANTS THIS OPTION. THE WARRANTIES, REPRESENTATIONS AND COVENANTS MADE IN THIS OPTION SURVIVE CLOSING AND THE CONVEYANCE OF THE PROPERTY. SELLER AGREES TO CONVEY THE PROPERTY ON THE TERMS AND CONDITIONS AS SET FORTH HEREIN AND ACKNOWLEDGES RECEIPT OF A COPY OF THIS OPTION.

Seller Entity Name (if any): _____

(x) Laona Grudzielanek Laona Grudzielanek 2-12-13

Seller's/Authorized Signature ▲ Print Name/Title Here ► Date ▲

(x) Judith E. Gyuro Judith E. Gyuro 2-12-13

Seller's/Authorized Signature ▲ Print Name/Title Here ► Date ▲

This Option was presented to Seller by [Licensee and Firm] _____

_____ on _____ at _____ a.m./p.m.

This Option is rejected _____ _____ This Option is countered _____ _____

Seller Initials ▲ Date ▲ Seller Initials ▲ Date ▲

NOTE: Parties wishing to counter this Option should draft a new Option (WB-24) or draft a Counter-Offer (WB-44) to reference this Option.

NOTICE OF EXERCISE OF OPTION By signing below and delivering this notice (see lines 35-54) to Seller, Buyer hereby exercises this Option to Purchase.

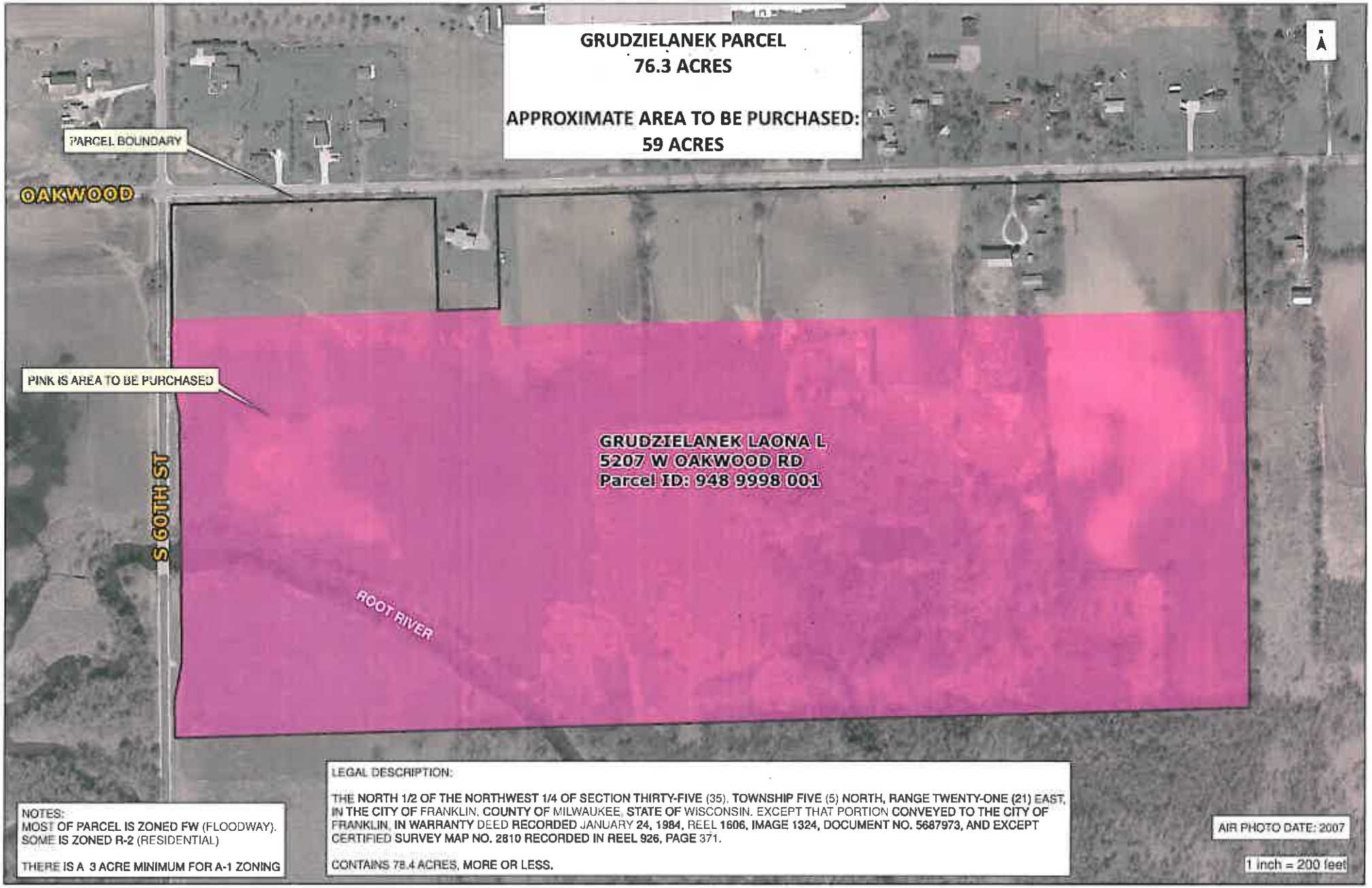
Buyer Entity Name (if any): _____

(x) _____

Buyer's/Authorized Signature ▲ Print Name/Title Here ► Date ▲

(x) _____

Buyer's/Authorized Signature ▲ Print Name/Title Here ► Date ▲


GRUDZIELANEK PARCEL
76.3 ACRES
APPROXIMATE AREA TO BE PURCHASED:
59 ACRES
PARCEL BOUNDARY
OAKWOOD
PINK IS AREA TO BE PURCHASED
S 60TH ST
GRUDZIELANEK LAONA L
5207 W OAKWOOD RD
Parcel ID: 948 9998 001
ROOT RIVER
NOTES:
MOST OF PARCEL IS ZONED FW (FLOODWAY).
SOME IS ZONED R-2 (RESIDENTIAL)
THERE IS A 3 ACRE MINIMUM FOR A-1 ZONING
LEGAL DESCRIPTION:
THE NORTH 1/2 OF THE NORTHWEST 1/4 OF SECTION THIRTY-FIVE (35), TOWNSHIP FIVE (5) NORTH, RANGE TWENTY-ONE (21) EAST, IN THE CITY OF FRANKLIN, COUNTY OF MILWAUKEE, STATE OF WISCONSIN. EXCEPT THAT PORTION CONVEYED TO THE CITY OF FRANKLIN, IN WARRANTY DEED RECORDED JANUARY 24, 1984, REEL 1606, IMAGE 1324, DOCUMENT NO. 5687973, AND EXCEPT CERTIFIED SURVEY MAP NO. 2810 RECORDED IN REEL 926, PAGE 371.
CONTAINS 78.4 ACRES, MORE OR LESS.
AIR PHOTO DATE: 2007
1 inch = 200 feet

Addendum to Option to Purchase 58.9 acres located at 5207 West Oakwood Road in the City of Franklin, Milwaukee County.

1. The parties to this Option to Purchase intend that the foregoing be incorporated as additional terms to the provisions of Form WB-24 Option to Purchase.
2. Seller acknowledges that the ultimate intended use of the property is for return flow of treated wastewater to the Root River as related to the pending application of Buyer to obtain Great Lakes Water for use by the City of Waukesha. Sellers shall cooperate and execute any document or permit required by Buyer and/or the Wisconsin Department of Natural Resources as required to advance Buyer's application for Great Lakes Water.
3. Initially, the intended use of the property is park land.
4. Any proposed park located at the site shall be named the "John Giese Park". Said park shall not be open to the public until after such time as the current occupants of the property located at 5733 West Oakwood Road, Franklin, WI, vacate the premises. The property is currently occupied by Laona and Max Gurdzielanek.
5. Buyer may also utilize the property for the potential storage of the wastewater on the property. Buyer may construct and maintain a pond on site for the storage of wastewater subsequent to the exercise of this option. During the construction of said pond, any spoil material shall remain onsite and be utilized to modify the property along Oakwood Road if feasible.
6. Buyers agrees that the property will not be used for a purpose other than park land or return of water to the Root River, nor will Buyer sell said property to a third party until after such time as the current occupants of the property located at 5733 West Oakwood Road, Franklin, WI, vacate the premises. The property is currently occupied by Laona and Max Grudlielanek.
7. Buyer agrees that no sludge disposal shall occur on the premises.
8. Buyer and Seller agree that until such time as the Option is exercised, the property will continue to be farmed by the current owner or their representative. If there are any written leases related to the farming of the property, Seller shall provide a copy of lease(s) to Buyer within 10 days of the acceptance of the Option.
9. At the time of the closing of the sale transaction, Buyer shall be responsible for payment of normal and usual costs of sale, including real estate taxes, real estate transfer taxes and title commitment. Buyer shall not be responsible for Seller's attorney fees, if any.
10. The payment of the option fee of $57,947.90 is non-refundable; the option fee shall, however, be applied to the purchase price of $579,479.00 at the time of closing. Exercise of the Option to Purchase is at the sole discretion of the Buyer.
11. Buyer shall, during the term of the Option, pay all real property taxes levied against the property; said taxes shall be prorated accordingly in the first year of the Option.
12. In further consideration for the sum paid for this option, seller shall not sell, convey or otherwise encumber the property subject to this agreement during the period of the option.
13. This Option may not be assigned and shall be binding upon heirs and successors of the respective parties.

14. The term of the Option to Purchase agreement may be extended by mutual agreement of the parties.

Jeff Scrima, Mayor
City Of Waukesha

Laona Grudzielanek

Judith Gyuro

Appendix K

Return Flow Effects on Hydraulic Conditions within the Root River from a City of Waukesha Lake Michigan Water Supply

Return Flow Effects on Hydraulic Conditions within the Root River from a City of Waukesha Lake Michigan Water Supply

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: July 2, 2013

As part of The City of Waukesha Application for Lake Michigan Diversion with Return Flow (Application), an analysis was performed to evaluate the effects that return flow would have on the hydraulic conditions at two locations in the Root River. The first location is nearest the return flow outfall downstream of the 60th Street bridge. This location is within Milwaukee County and about one mile upstream of the boundary with Racine County. The second location is located about 150 feet downstream of the Root River Steelhead Egg Harvesting Facility in the City of Racine. This is about 3.8 miles from Lake Michigan.

Hydraulic Modeling

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is developing hydrologic and hydraulic models for the Root River as part of the Root River Restoration Plan[1]. The only existing hydraulic model of the Root River was provided by SEWRPC. The model provided included several separate HEC-2 models that were originally developed for the Racine County Federal flood insurance study and later updated in 1988 by SEWRPC as part of the flood control planning for the Milwaukee Metropolitan Sewerage District (MMSD). The models collectively covered the Root River from Lake Michigan to just upstream of the return flow location (downstream of the confluence with the Root River Canal). Each of the models was separate files and no single model exists of the entire Root River. The models have not been updated in 25 years and because new models are in development, the two individual models that included the return flow location and Steelhead Egg Harvesting Facility were utilized to evaluate the hydraulic changes from return flow at the two locations noted above.

HEC-2 models LR22.hc2 and LR13.RJP were imported into HEC-RAS version 4.1.0. Bridge adjustments were made to allow for the model to run within HEC-RAS software. The critical water surface elevation was used as the downstream boundary condition for each model.

Table 1 summarizes the flows that were simulated in the Root River at the discharge location and Table 2 summarizes the flows that were simulated in the Root River downstream of the Steelhead Egg Harvesting Facility. The low flow base flows were estimated by reviewing USGS stream gage information for sites nearest these locations. USGS gage 04087220 Root River near Franklin was used for the return flow discharge location and USGS gage 04087240 Root River at Racine was used for the location near the Steelhead Egg Harvesting Facility. There is a significant drainage area difference between the Franklin gage and the return flow discharge location (49.2 square miles versus 126.2 square miles), but the Franklin gage data was used as a conservative estimate of low flow impacts from return flow. Root River flow rates at the discharge location for the 2-year through 100-year profiles were obtain from MMSD[2]. This location is nearest the discharge location, slightly downstream of the Franklin gage but upstream of the confluence with the Root River Canal. The watershed area at this location is 59.2 square miles which is still significantly less than the watershed area at the discharge location (126.2 square miles). These flow rates were used as a conservative estimate of flow impacts from a return flow. The Root River flow rates at the Steelhead Egg Harvesting Facility for the 2-year through 100-year profiles were obtained using USGS Racine gage data and the USGS PeakFQ software.

[1] http://www.sewrpc.org/SEWRPC/Environment/Root-River-Watershed-Restoration-Plan.htm

[2] Milwaukee Metropolitan Sewerage District (MMSD). Root River Sediment Transport Planning Study. Hydrology Technical Memorandum. September 5, 2007. Table 3, page 9.

TABLE 1
Flows from Root River Model at Discharge Location

Profile	Base Flow (cfs)	Return Flow Rate (cfs)	Flow with Return Flow (cfs)
Low Flow	3	18.0	21
2-year	1030	25.8	1055.8
5-year	1720	25.8	1745.8
10-year	2300	25.8	2325.8
25-year	3180	25.8	3205.8
50-year	3940	25.8	3965.8
100-year	4820	25.8	4845.8

TABLE 2
Flows from Root River Model at Steelhead Location

Profile	Base Flow (cfs)	Return Flow Rate (cfs)	Flow with Return Flow (cfs)
Low Flow	5.6	18.0	23.6
2-year	1927	25.8	1952.8
5-year	2843	25.8	2868.8
10-year	3510	25.8	3535.8
25-year	4421	25.8	4446.8
50-year	5148	25.8	5173.8
100-year	5916	25.8	5941.8

The return flow of 25.8 cfs (16.7 mgd) is the maximum return flow from the City's wastewater treatment plant (WWTP), which is equal to the maximum daily water demand in the Application. This flow rate is used for the 2-year through 100-year profiles to estimate the maximum potential change in hydraulic conditions as a result from return flow. The return flow of 18.0 cfs (11.7 mgd) is the 2030 average annual WWTP flow rate[3]. This flow is used for the low flow profile because this return flow rate is more likely during low flow in the Root River than the peak return flow rate (i.e. return flow rates above 18 cfs are associated with wet weather events and not low flow conditions).

Model Results

Changes in water depth and velocity are summarized in Table 3 for the location near the discharge and Table 4 near the Steelhead Egg Harvesting Facility. Graphical summaries for the two locations for each flow scenario is included in Attachment A for the discharge location and Attachment B for the Steelhead Egg Harvesting Facility.

[3] Strand Associates. City of Waukesha Wastewater Treatment Plant Facilities Plan. May 2011. Table 4.03-4, Section 4, page 4-6. Table amended on October 5, 2012.

TABLE 3
Summary of HEC-RAS Model Simulation Results for Return Flow at the Discharge Location

Root River Flow Scenario	River Flow Rate (cfs)	Return Flow Rate (cfs)	River Flow Rate with Return Flow (cfs)	Percent Increase in River Flow Rate (%)	Increase in water depth (ft)	Percent Increase water depth (%)	River Average Velocity (fps)	River Average Velocity with Return Flow (fps)
Low Flow	3	18.0	21.0	600%	0.66	58%	0.11	0.41
2-year	1030	25.8	1055.8	2.50%	0.07	0.81%	1.54	1.53
5-year	1720	25.8	1745.8	1.50%	0.05	0.49%	1.47	1.47
10-year	2300	25.8	2325.8	1.12%	0.05	0.45%	1.48	1.48
25-year	3180	25.8	3205.8	0.81%	0.03	0.24%	1.56	1.57
50-year	3940	25.8	3965.8	0.65%	0.02	0.15%	1.66	1.66
100-year	4820	25.8	4845.8	0.54%	0.02	0.14%	1.75	1.76

TABLE 4
Summary of HEC-RAS Model Simulation Results for Return Flow at the Steelhead Egg Harvesting Facility

Root River Flow Scenario	River Flow Rate (cfs)	Return Flow Rate (cfs)	River Flow Rate with Return Flow (cfs)	Percent Increase in River Flow Rate (%)	Increase in water depth (ft)	Percent Increase water depth (%)	River Average Velocity (fps)	River Average Velocity with Return Flow (fps)
Low Flow	5.6	18	23.6	321%	0.51	75%	0.63	0.87
2-year	1927	25.8	1952.8	1.34%	0.05	0.68%	3.44	3.45
5-year	2843	25.8	2868.8	0.91%	0.03	0.34%	3.9	3.91
10-year	3510	25.8	3535.8	0.74%	0.03	0.31%	4.14	4.15
25-year	4421	25.8	4446.8	0.58%	0.02	0.19%	4.5	4.52
50-year	5148	25.8	5173.8	0.50%	0.02	0.18%	4.82	4.83
100-year	5916	25.8	5941.8	0.44%	0.02	0.17%	5.04	5.05

Summary

The HEC-RAS models were used to simulate return flow impacts on hydraulic conditions at two locations along the Root River. One location was at the return flow discharge location and the second was at the Steelhead Egg Harvesting Facility near the downstream extents of the watershed. These two locations were chosen to provide an evaluation at the upstream and downstream extents of the watershed that would be influenced by return flow. The Wisconsin Department of Natural Resources (WDNR) operates the Steelhead Egg Harvesting Facility. This facility is upstream of Lake Michigan backwater influence so it is influence by low flows that limit the ability of Lake Michigan fish from reaching the facility. The WDNR has reported that production at the facility is limited because of low flows and flow augmentation through return flow could improve operations[4]. Flow augmentation with Lake Michigan water had been evaluated previously but was cost prohibitive.

[4] Wisconsin Department of Natural Resources (WDNR). Water Return to Root River from Waukesha. Memorandum from Brad Eggold to Eric Ebersberger. August 16, 2012.

The flow rates used for the Root River were developed by the MMSD and USGS. They are for locations upstream of the two evaluation points so the flow rates are less than what could be expected. Consequently they are conservative estimates (i.e. over estimates) of changes to the hydraulic conditions resulting from return flow. As shown in the tables above, return flow has a greater impact on water depth and average velocity at low river flow. At low flow conditions, return flow would increase the water depth and the average velocity at these two locations between 0.51 to 0.66 feet and 0.30 and 0.24 feet per second, respectively. The increase in water depth in well within the low flow river bank and the increases in velocity are insignificant. Consequently, return flow is not expected to have a negative impact on the river during low flows but instead it is expected to provide a benefit to the water dependent resources with additional flow, water depth, wetted area within the river and greater available habitat. This is also consistent with Root River Sediment Transport Planning Study that concluded that the stability and geomorphology of the Root River is relatively insensitive to changes in flow. During higher river flow rates, such as the 10-year through 100-year flow events, return flow has an insignificant impact on water depths and velocity.

Attachment A
Summary Graphs for Return Flow Discharge Location

FIGURE A-1

Cross Section of Root River at Return Flow Discharge Location: Low Flow

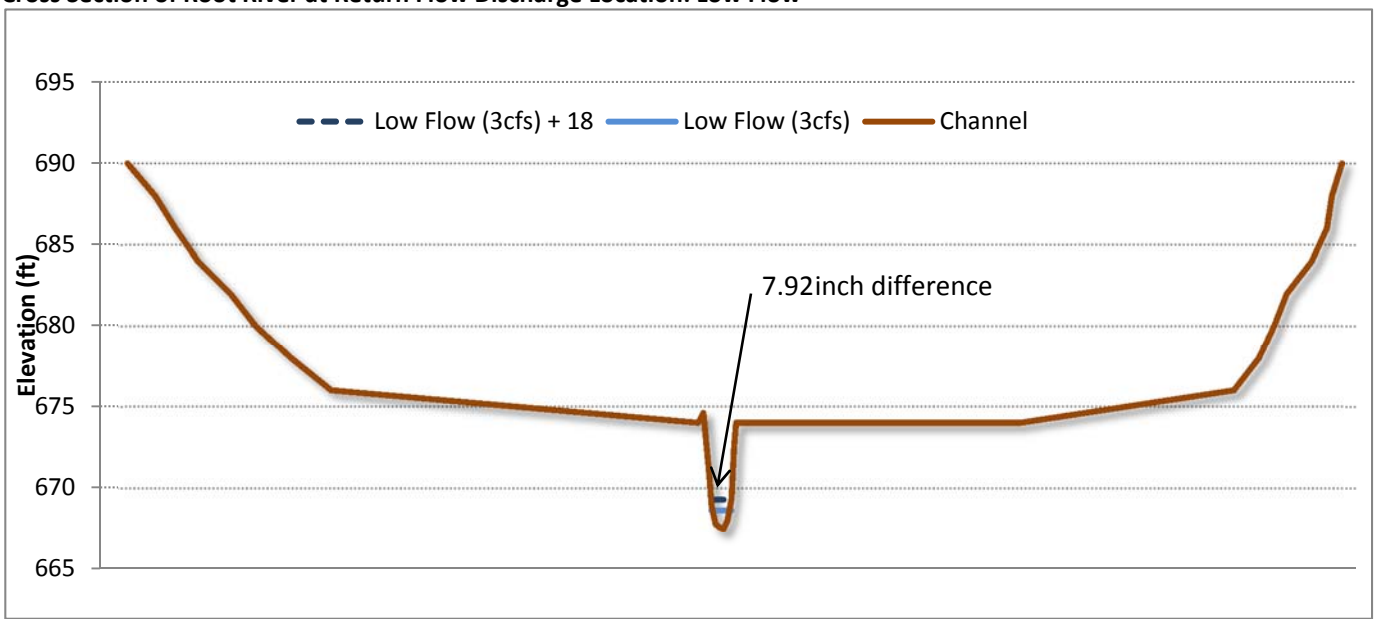


FIGURE A-2

Cross Section of Root River at Return Flow Discharge Location: 2-year

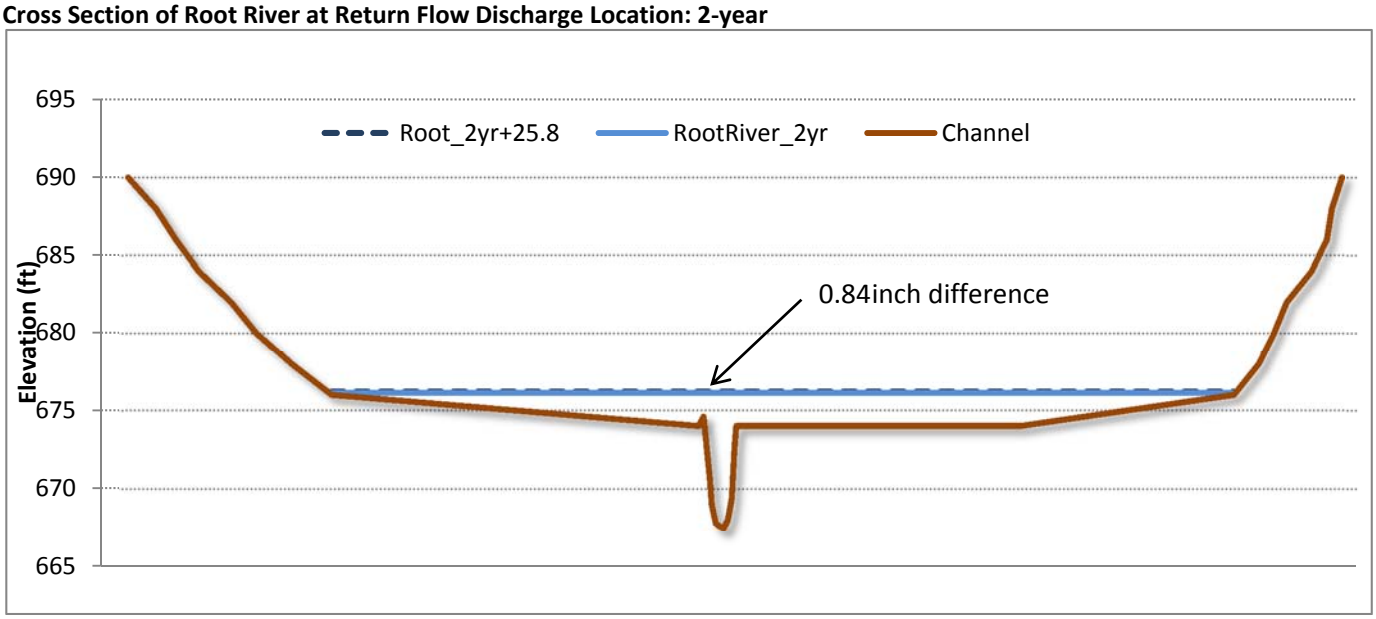


FIGURE A-3

Cross Section of Root River at Return Flow Discharge Location: 5-year

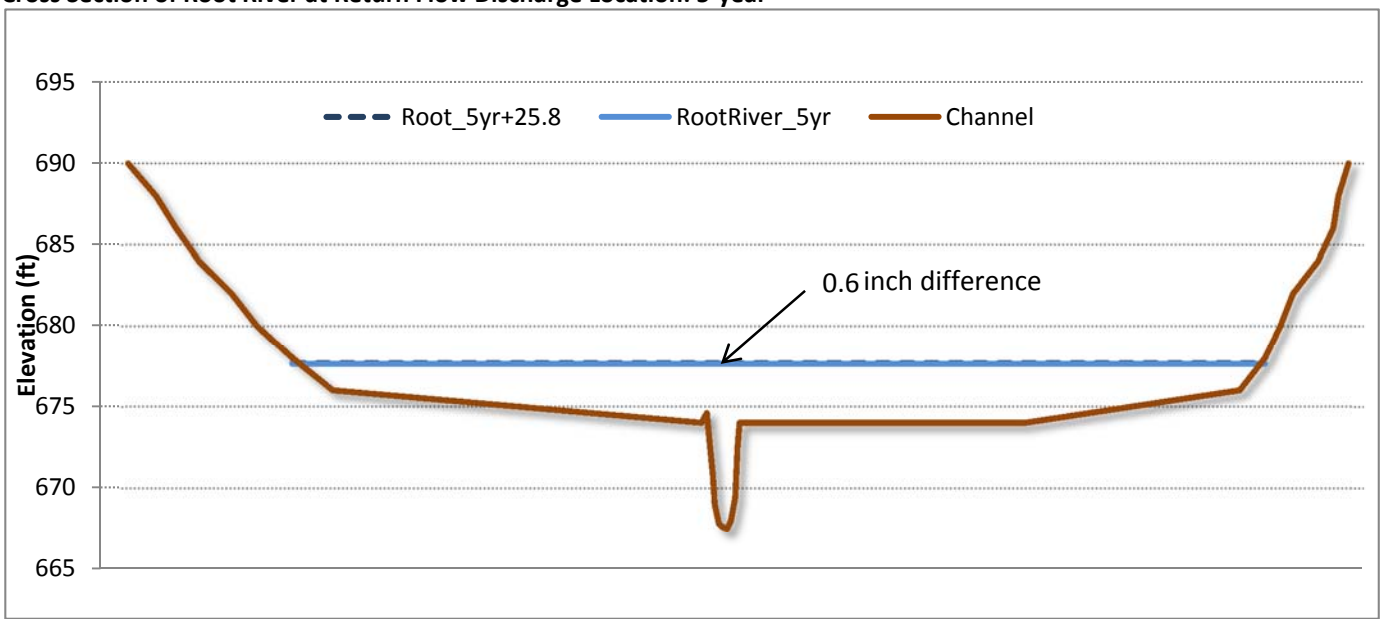


FIGURE A-4

Cross Section of Root River at Return Flow Discharge Location: 10-year

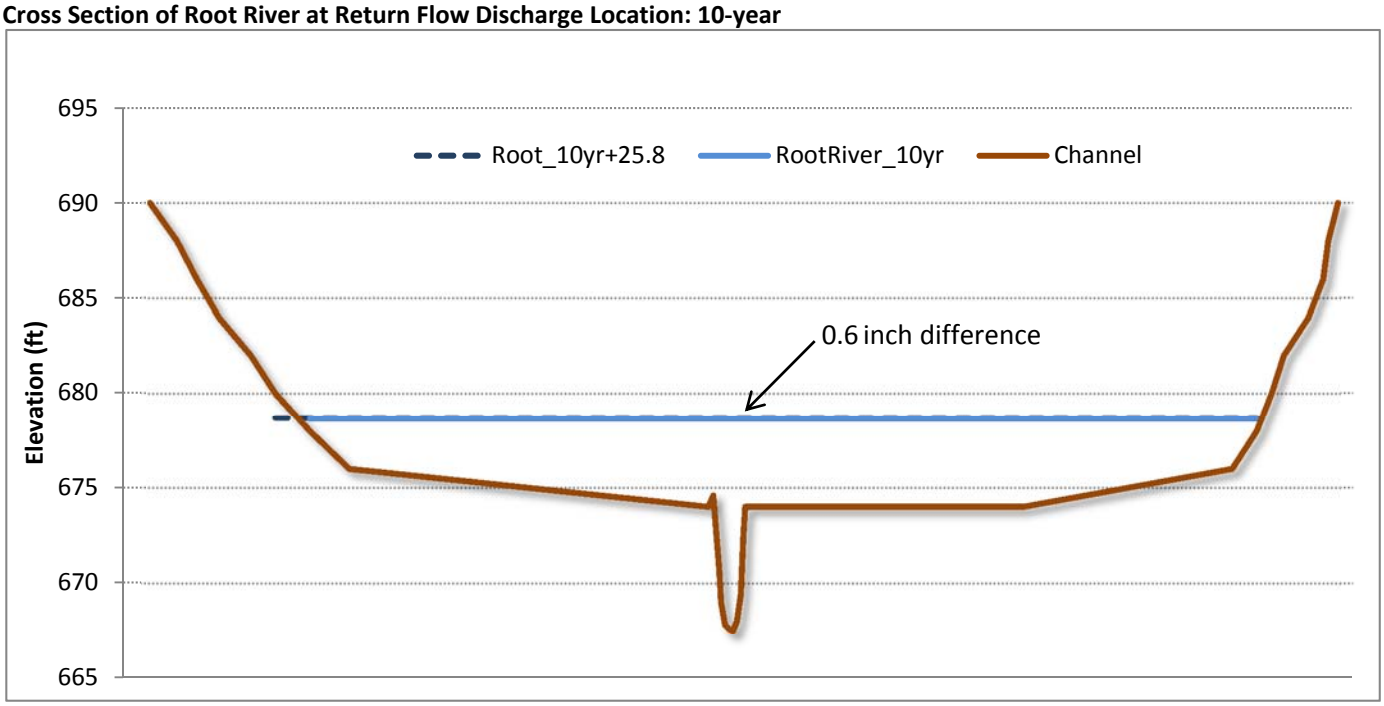


FIGURE A-5

Cross Section of Root River at Return Flow Discharge Location: 25-year

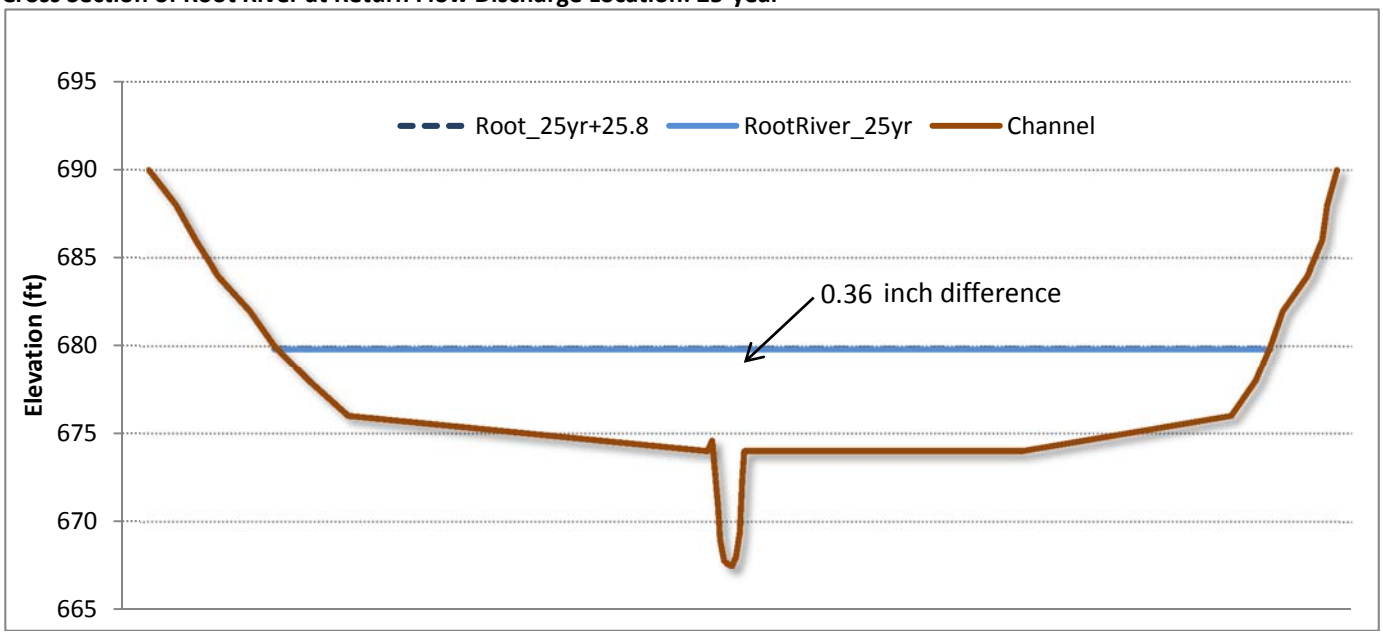


FIGURE A-6

Cross Section of Root River at Return Flow Discharge Location: 50-year

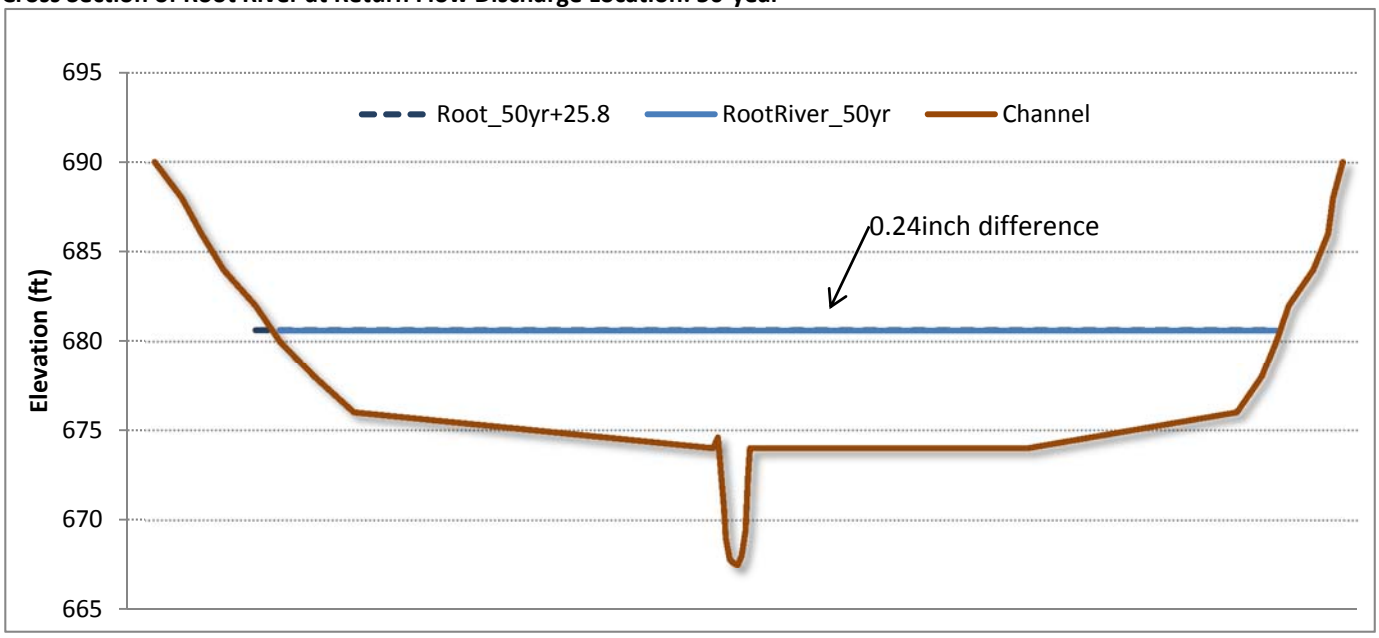
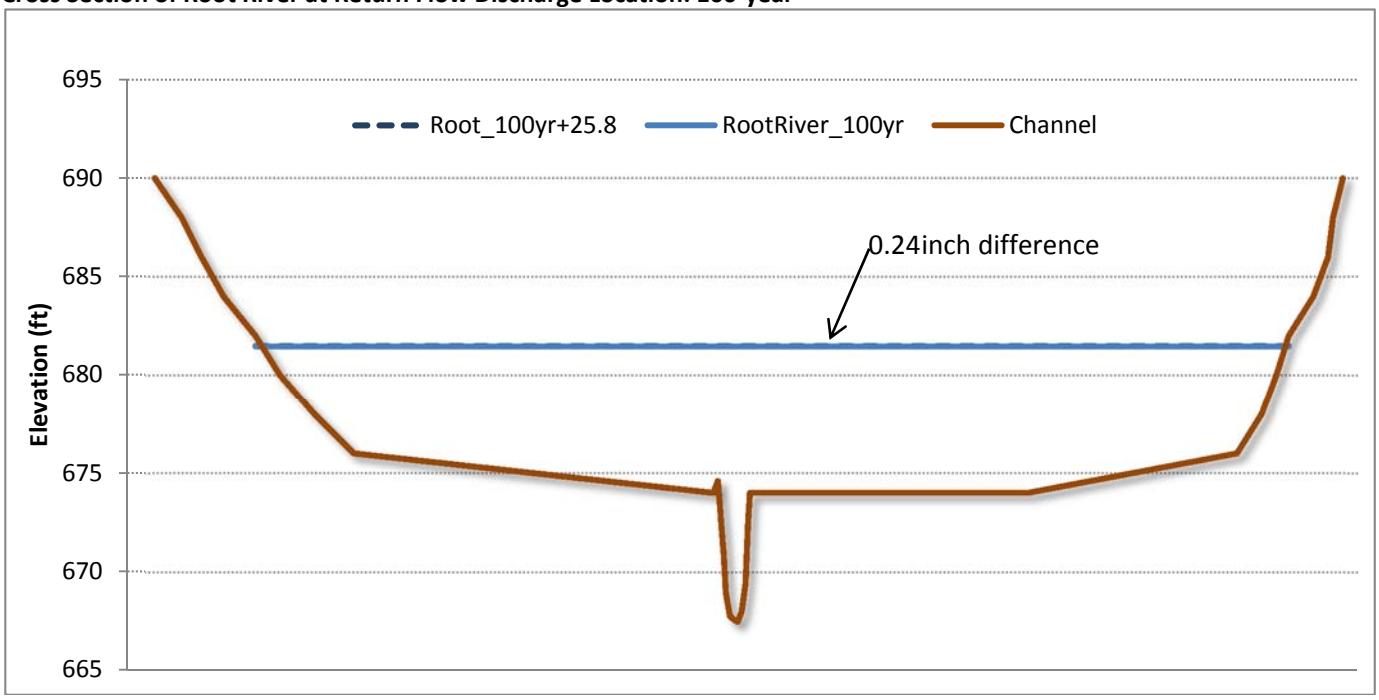


FIGURE A-7

Cross Section of Root River at Return Flow Discharge Location: 100-year



Attachment B
Summary Graphs for Steelhead Egg Harvesting Facility

FIGURE B-1

Cross Section of Root River at Steelhead Egg Harvesting Facility: Low Flow

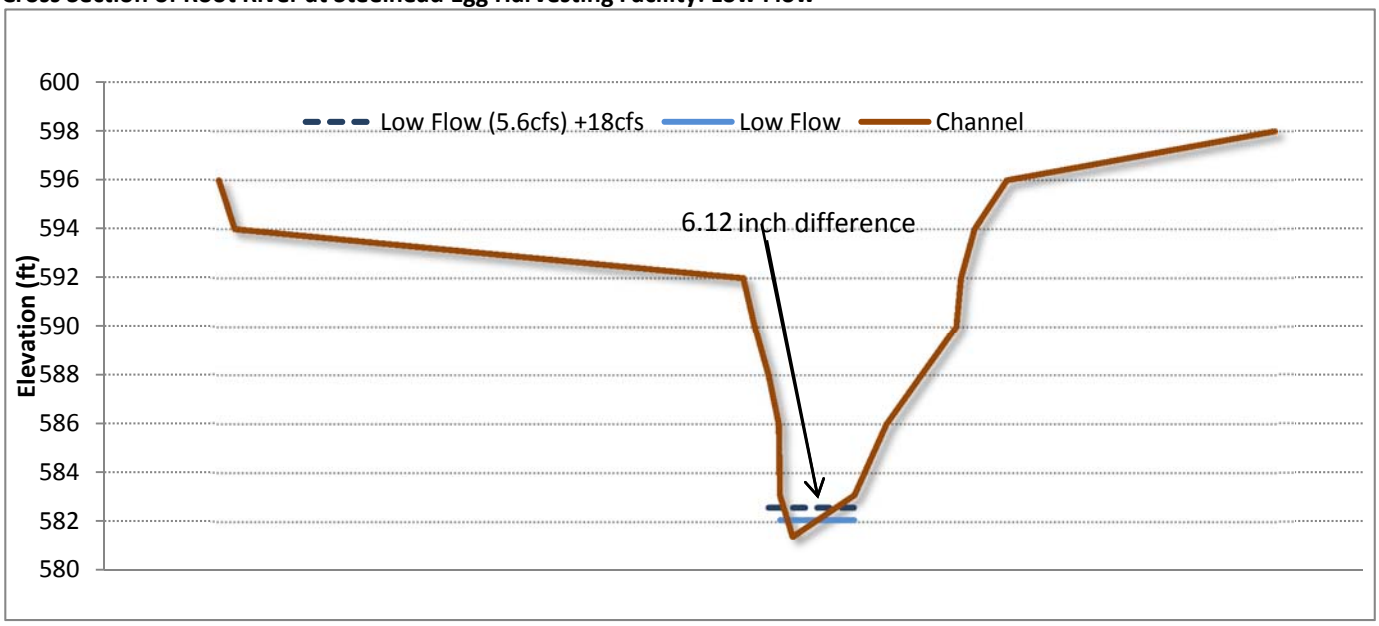


FIGURE B-2

Cross Section of Root River at Steelhead Egg Harvesting Facility: 2-year

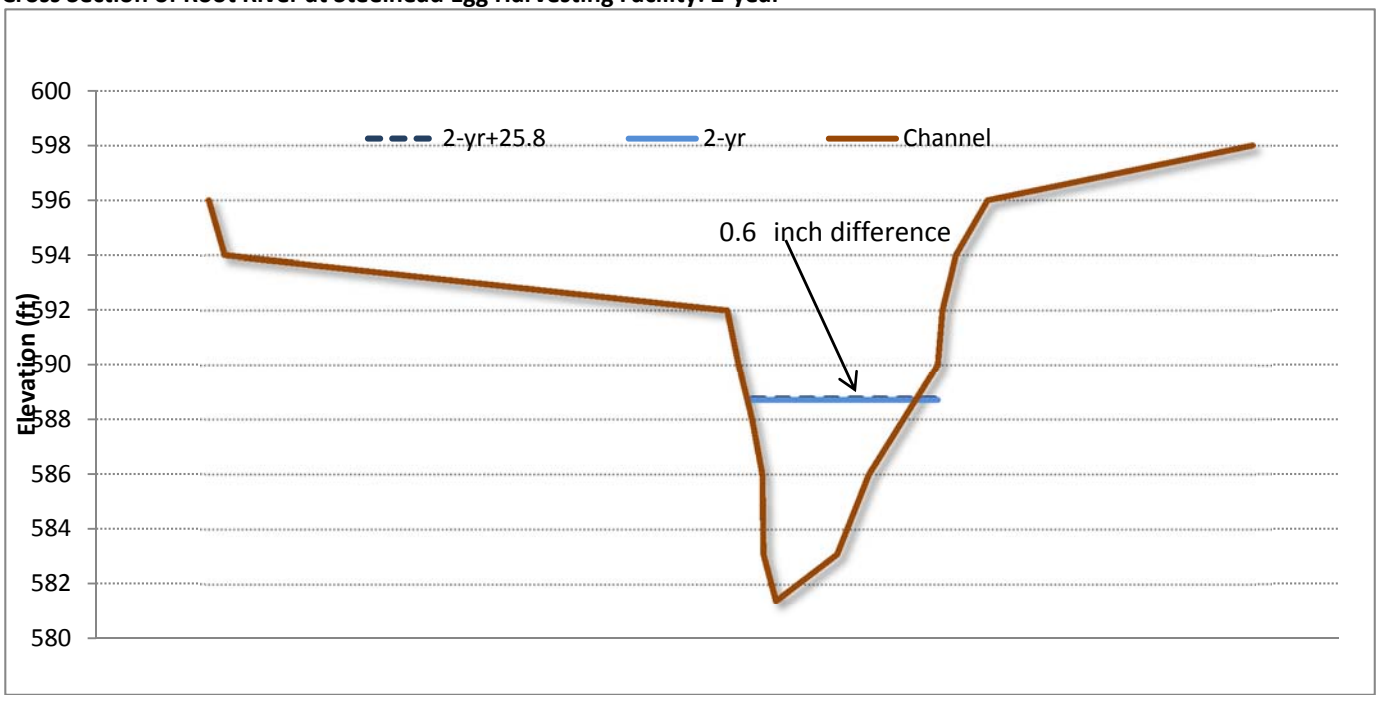


FIGURE B-3

Cross Section of Root River at Steelhead Egg Harvesting Facility: 5-year

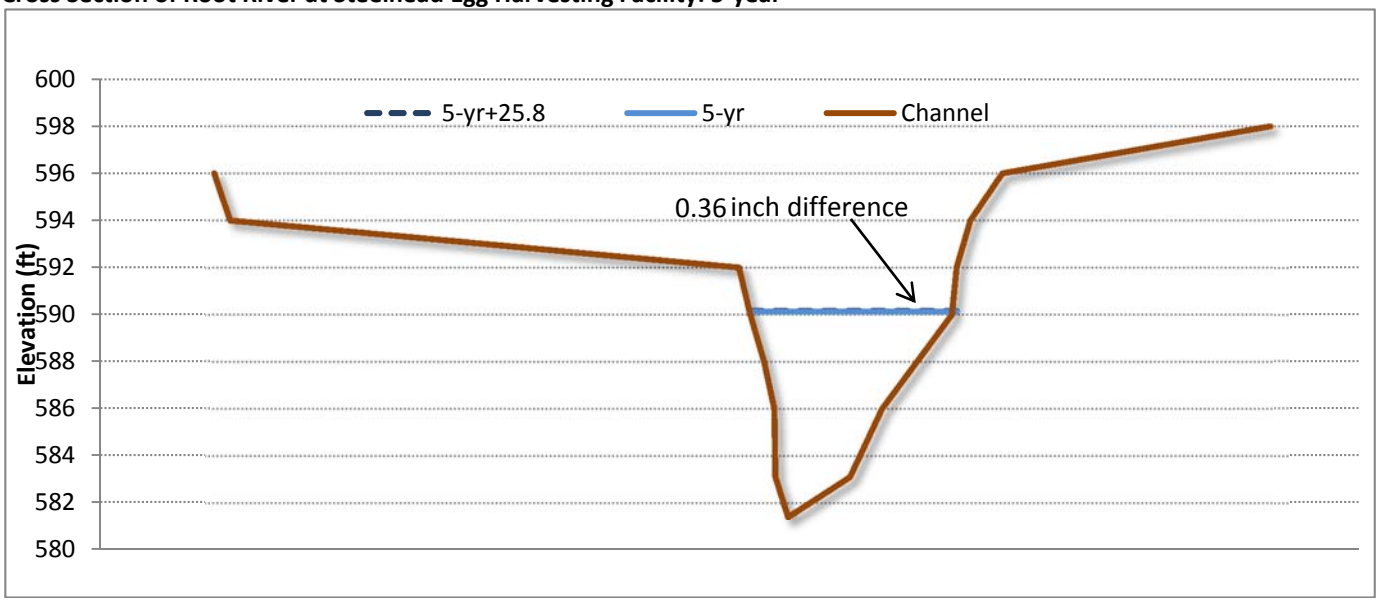


FIGURE B-4

Cross Section of Root River at Steelhead Egg Harvesting Facility: 10-year

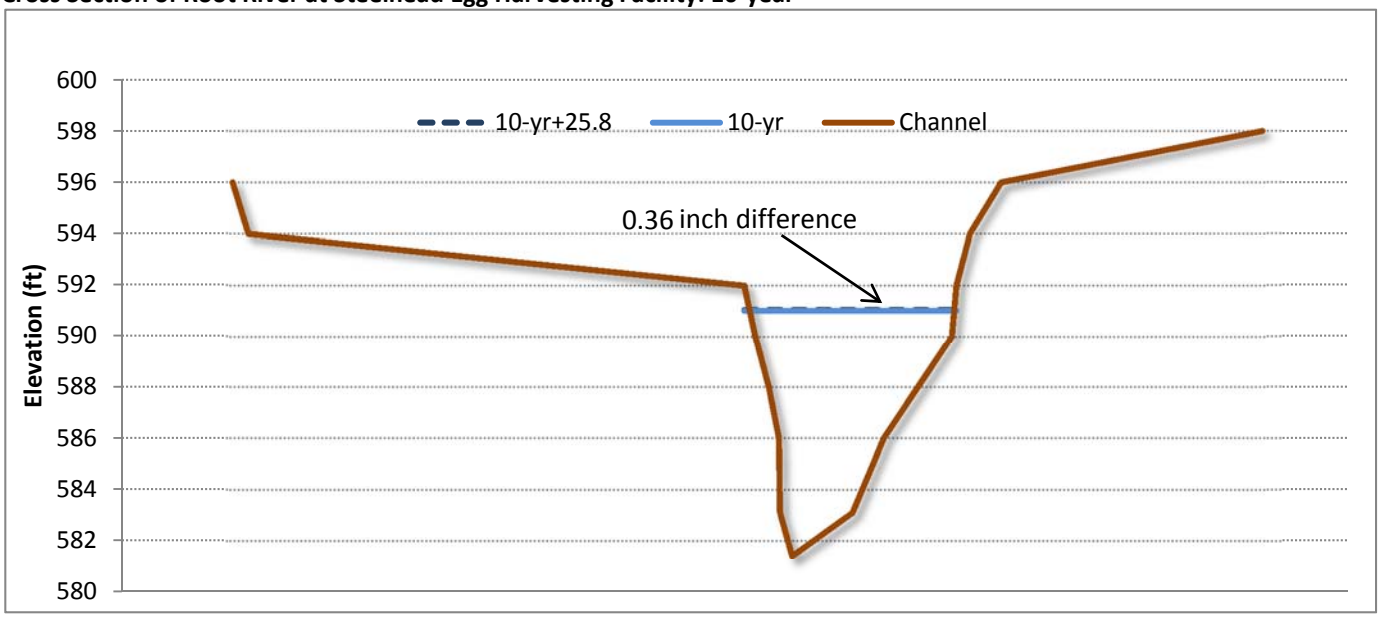


FIGURE B-5

Cross Section of Root River at Steelhead Egg Harvesting Facility: 25-year

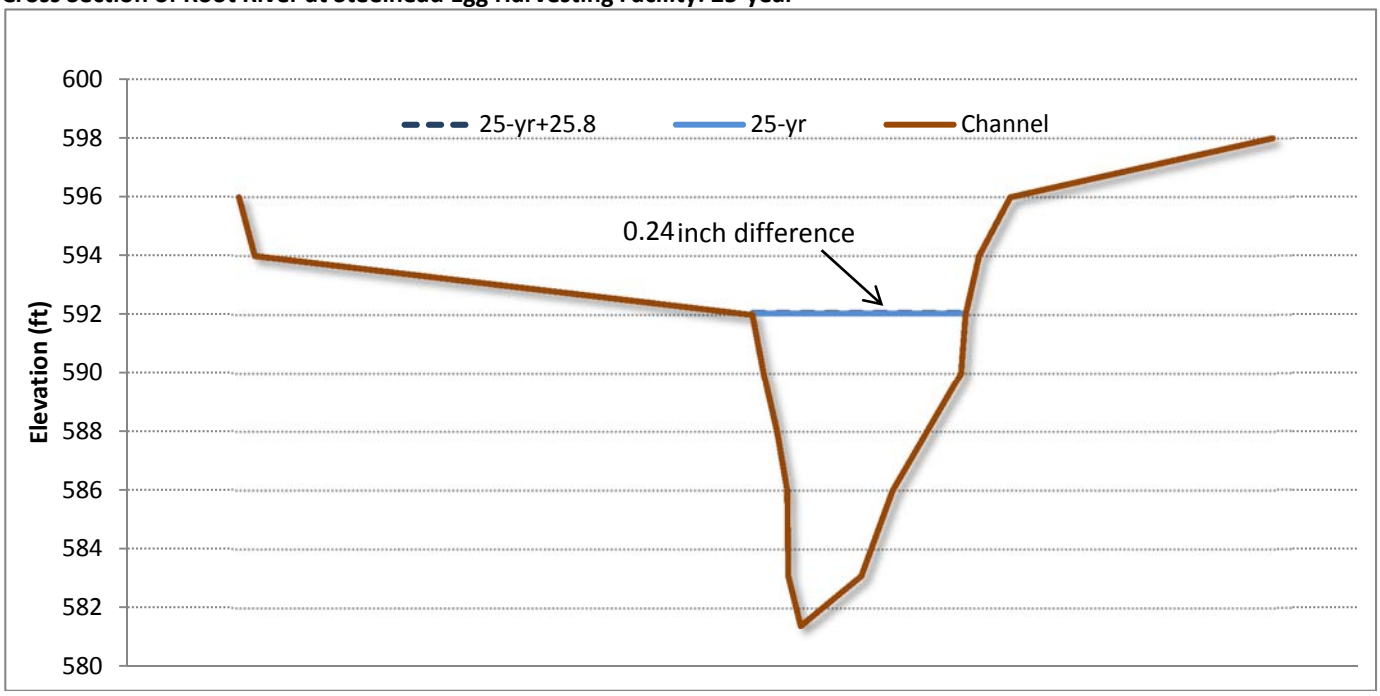


FIGURE B-6

Cross Section of Root River at Steelhead Egg Harvesting Facility: 50-year

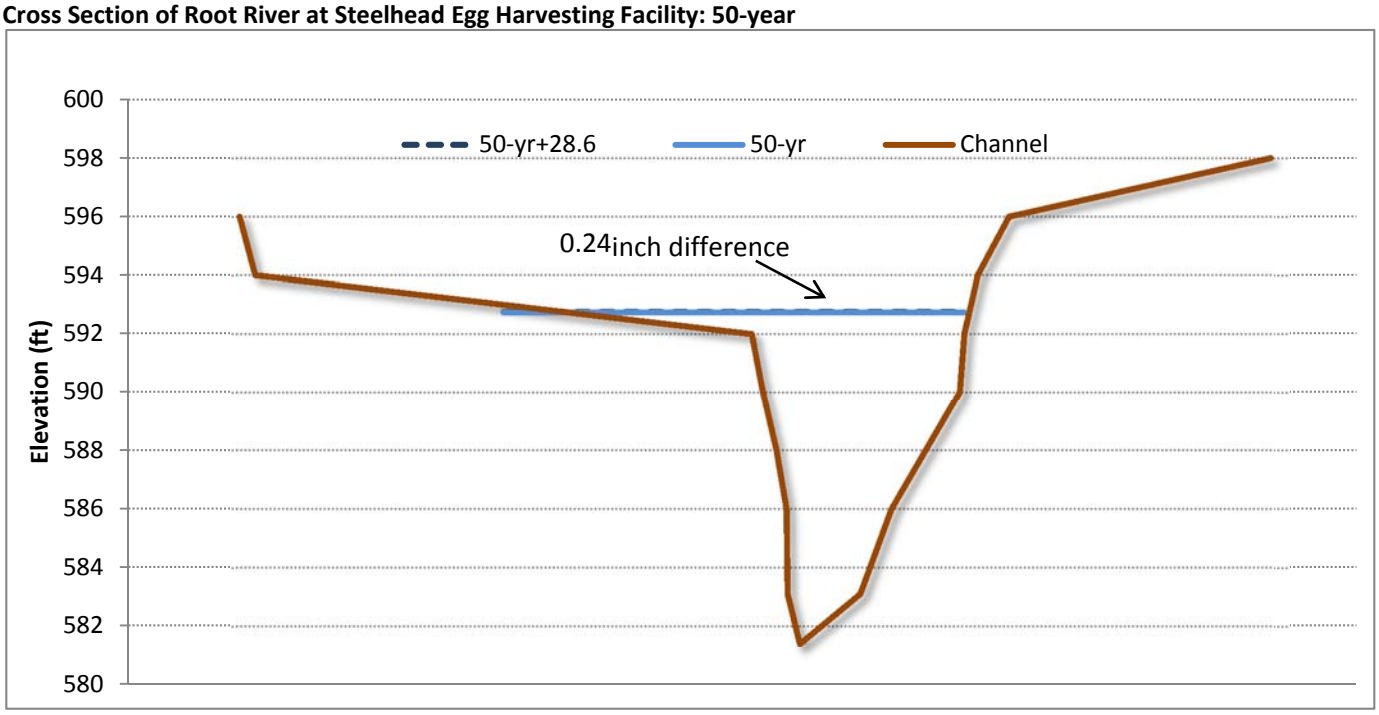
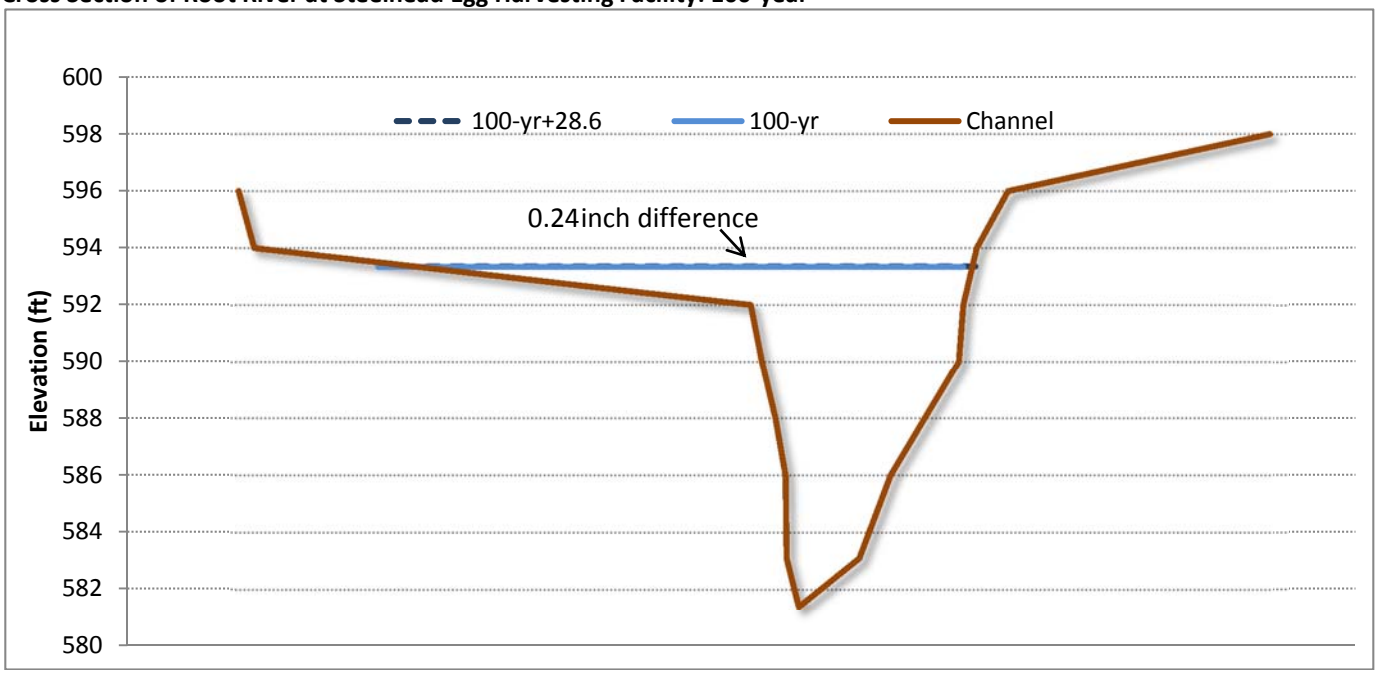


FIGURE B-7

Cross Section of Root River at Steelhead Egg Harvesting Facility: 100-year



Appendix L

Wisconsin Department of Natural Resources: Water Return to Root River from Waukesha

CORRESPONDENCE/MEMORANDUM

State of Wisconsin

DATE: August 16, 2012 FILE REF: 3600

TO: Eric Ebersberger

FROM: Brad Eggold

SUBJECT: Water return to Root River from Waukesha

The Root River does provide a significant fishing opportunity for thousands of anglers in the densely populated area of southeast Wisconsin. In the spring there are spawning runs of steelhead (Chambers Creek and Ganaraska strain rainbow trout) from Lake Michigan and in the fall there are spawning runs of coho salmon, Chinook salmon, steelhead (Skamania strain rainbow trout) and brown trout. Because of these strong spawning runs observed in the Root River, the department, in 1994, constructed a facility to collect eggs for our hatcheries named the Root River Steelhead Facility. Eggs are collected from these spawning fish so that we can rear the correct number for stocking in subsequent years. These young fish are subsequently stocked back into Wisconsin's Lake Michigan Harbors and tributaries. In addition, this facility was constructed to enable us to regularly monitor the salmon and trout entering the Root River and collected in the facility. In peak years, we have experienced runs of over 10,000 salmonids providing angling opportunities which at times exceeded 100,000 angling hours. In addition, movements of these fish in the lake provide many thousands of angling hours for both sport and charter boats fishing off-shore near Racine.

Because the upper reaches of the Root River lie in heavily urbanized areas, the upstream hydrology has been significantly altered by development and stormwater sewer construction. This has had an impact on the total stream flow to the extent that in dry years, particularly during the fall, the average stream flows in Racine can drop below 10 cubic feet per second. These low flows have a very negative impact on the fishery. Understandably, this also results in a significant decrease in the department's ability to collect adequate supplies of eggs for our hatcheries. Further, the angling opportunities are greatly diminished downstream of the Horlick Dam. In short, no water means few fish, inadequate or hard to obtain egg collection and a decreased number of anglers. As a result we believe that increasing the total stream flow by about 15 cfs (the average return flow from Waukesha) would be beneficial to our fisheries program goals for the Root River and for Lake Michigan. Not only would increased flows have a positive impact on the number of fish entering the river and thus into our facility, it is also likely that the angling experiences would be expanded because with more water, there could be more places to fish below the Horlick Dam. Further, with higher flows, fish may enter the river earlier and stay in the river for longer periods thereby extending the angling "season" for these anadromous fish.

At our Strawberry Creek Weir facility in Door County, we have constructed a water pipeline to take water from the Sturgeon Bay ship canal and pump it to the water right above that weir. This has increased the water flow into Strawberry Creek and has allowed us to collect sufficient Chinook salmon eggs for our production needs. We have considered this method to augment flow in the Root River, however the department would incur significant construction and ongoing energy costs to pump water from the Lake to augment the total stream flow in the river. The future discharge of the highly treated wastewater from Waukesha could provide a flow augmentation solution without any new investments needed at our facility.

Printed on Recycled Paper

Appendix M
Water Quality Model of Potential Return Flow Discharge to Root River

Water Quality Model of Potential Return Flow Discharge to Root River

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: May 8, 2013

Executive Summary

The City of Waukesha Application for Lake Michigan Diversion with Return Flow is evaluating an option for the City's Wastewater Treatment Plant to route return flow to the Root River to meet the requirements of the Great Lakes Compact. To simulate water quality changes to the Root 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 was used to simulate the SEWRPC existing condition and preferred alternative (recommended plan) scenarios and to include a discharge from the Waukesha Wastewater Treatment Plant. The return flow characteristics were set to either represent average historical operating conditions (the expected discharge condition) based upon October 2002 through August 2009 data or to represent a conservative scenario based on higher flow rates and permit limit conditions (maximum potential discharge condition). The analysis used the same continuous simulation periods as SEWRPC's Regional Water Quality Management Plan Update.

The water quality modeling found that average water quality improved or continued to meet water quality standards or background reference concentrations for all water quality parameters (fecal coliform, dissolved oxygen, total phosphorus and total suspended solids). Modeling results also indicate that with return flow, nuisance algae growth will also decrease in the Root River.

Introduction

The City of Waukesha is considering an option to route return flow to the Root River 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 Root River system were utilized to evaluate the potential water quality changes of the return flow within the Root River downstream of the return flow location. This technical memorandum (TM) describes the process used to adapt the SEWRPC models for evaluation of the return flow and summarizes the results of the evaluations.

Background

The City of Waukesha Wastewater Treatment Plant (WWTP) currently discharges treated effluent to the Fox River in the Mississippi River watershed. With a proposed future Lake

required. The City has been investigating several alternatives for returning flow. One proposed project is a return flow to the Root River, a tributary to Lake Michigan. The analysis documented in this memorandum describes water quality changes associated with a return flow to the Root River.

The following analysis follows a similar methodology as the TM *Water Quality Model of Proposed Potential Return Flow Discharge to Underwood Creek* (CH2M HILL, 2012) which evaluated a similar alternative for discharge to Underwood Creek. The water quality analysis for Root River includes two additional scenarios (Scenario 2C and Scenario 3C) than were evaluated for Underwood Creek. These include a maximum return flow rate of 18.5 mgd which represents the maximum return flow rate for the current return flow management plan.

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 the Root River with a proposed return flow. SEWRPC provided the HSPF models for all model segments in the Root River Basin for the Existing and PA scenarios.

Scenarios Modeled

Two baseline and six new scenarios were modeled using continuous simulation over an 11-year period consistent with the SEWRPC effort to assess the changes under existing and future conditions with Waukesha return flow. The discharge was characterized either by historical effluent quality to represent expected discharge condition scenario or by conservative characteristics that combined permit limits and high observed concentrations into a maximum potential discharge condition scenario. Table 1 summarizes the modeled scenarios.

Table 1
Description of Scenarios Modeled

Scenario	Description
1	Existing Conditions (no discharge to Root River)
2A	Existing Conditions with Return Flow to Root River – Expected Discharge Condition
2B	Existing Conditions with 14.0 mgd Return Flow to Root River – Maximum Potential Discharge Condition
2C	Existing Conditions with 18.5 mgd Return Flow to Root River – Maximum Potential Discharge Condition
3	RWQMPU Recommended Plan Conditions (no discharge to Root River)
3A	RWQMPU Recommended Plan Conditions with Return Flow to Root River - Expected Discharge Condition
3B	RWQMPU Recommended Plan Conditions with 14.0 mgd Return Flow to Root River – Maximum Potential Discharge Condition
3C	RWQMPU Recommended Plan Conditions with 18.5 mgd Return Flow to Root River – Maximum Potential Discharge Condition

Determination of Discharge Characteristics

In a December 2011 Wisconsin Department of Natural Resources (WDNR) correspondence, revised effluent limits were calculated for a Root River return flow. These limits were used in combination with past WWTP performance data as input for the return flow in the water quality modeling. The same as the modeling previously completed for Underwood Creek, the existing WWTP provides water quality that meets all of the modeled parameters, however revised phosphorus limits are lower than the current performance. Therefore, the expected discharge concentration scenarios are characterized using monthly water quality data measured at the WWTP under current operating conditions (see Attachment 1 in CH2M HILL, 2012) for all parameters except phosphorus. Modeled phosphorus concentrations were set to the WDNR permit limit and water quality standard of 0.075 mg/L. A summary of the typical values are provided in Table 2.

The HSPF model obtained from SEWRPC includes an internal computation where BOD decay is converted to organic nitrogen (3 percent of BOD) and labile phosphorus (0.7 percent of BOD). These components are indirect additions of nutrients to the system. The user must also specify the remaining nutrient components as direct additions, such as from return flow. The combination of the indirect and direct components of organic nitrogen and phosphorus used in the modeling are represented by the return flow values in Table 2. Based on the BOD concentrations in the return flow (between 1.6 to 2.6 mg/L), the organic nitrogen fraction associated with the BOD decay was between 0.05 to 0.08 mg/L (0.03 × BOD) and the labile phosphorus concentration was between 0.011 to 0.018 mg/L (0.007 × BOD). This organic nitrogen fraction is between 5 to 8 percent of the organic nitrogen in the return flow (0.05 to 0.08 mg/L compared to 0.98 mg/L). The labile phosphorus fraction is more significant and has a noticeable impact on total phosphorus because the fraction from BOD decay ranges between 15 to 24 percent of the total phosphorus in the return flow (0.011 to 0.018 mg/L labile phosphorus compared to 0.075 mg/L total phosphorus). Because the return flow phosphorus permit limit is the water quality standard for <u>total</u> phosphorus, it includes phosphorus in the return flow derived from BOD decay *and* direct input of organic

phosphorus and orthophosphorus in the return flow. Consequently the values in Table 2 are total phosphorus (TP) consistent with the permit limit and water quality standard. There is no permit limit for organic nitrogen, but the organic nitrogen in Table 2 is that from the return flow *and* BOD decay within the return flow.

The contribution of BOD derived organic nitrogen and phosphorus was not adjusted during the Underwood Creek modeling —it was not noticeable because the phosphorus limits used for the return flow were greater than the in-stream concentrations and were much greater than the water quality standard. Due to the new ultra low phosphorus limits now proposed by the WDNR, this addition of phosphorus from BOD decay within the return flow is noticeable and improperly adds phosphorus beyond the total phosphorus limit of 0.075 mg/L. If left unaccounted for, the model would double-count the labile fraction of phosphorus and result in increasing the in-stream phosphorus concentrations. This result is not consistent with requirements in NR217 and is mathematically incorrect since it would specify return flow phosphorus concentrations above the permit limit. Because HSPF internally adds phosphorus and nitrogen to the return flow, the values for organic nitrogen and labile phosphorus input to the model were adjusted. The total phosphorus values used in the model where those in Tables 2 and 3 less the labile phosphorus fraction, to account for the labile phosphorus added by the model through BOD decay and to maintain a return flow total phosphorus limit of 0.075 mg/L. The organic nitrogen values used in the model where similarly adjusted. This adjustment preserves the SEWRPC HSPF model and all of its calibration, accurately reflects the total phosphorus limits calculated by the WDNR and NR217, and properly accounts for the phosphorus and organic nitrogen in the Root River from the return flow.

The maximum potential discharge condition set of runs uses a combination of discharge characteristics as specified in the plant's Wisconsin Pollutant Discharge Elimination System (WPDES) permit and historical measurements. As with the Underwood Creek analysis, if a water quality parameter was not included in the WPDES permit, representative values based upon current operation were used. For TSS and BOD, the model inputs were not set at their maximum permit limits and were instead values based on their current operation (Table 2). This is because the low phosphorus limits could not be achieved by discharging at their permitted TSS or BOD maximums. The total phosphorus and organic nitrogen values in Table 3 represents the combination of the phosphorus derived from BOD and phosphorus specified as a direct input of organic phosphorus and orthophosphorus. For the remainder of the permitted input values for the maximum potential discharge conditions, the input parameters were the same as that for Underwood Creek. The discharge characteristics for the maximum potential discharge condition runs are provided in Table 3.

The City's WWTP's permit rated capacity of 14.0 mgd was used as the future return flow rate for Scenarios 2B and 3B. This is a conservative flow rate because the future average annual flow rate is estimated to be 11.7 mgd (Strand Associates, 2011). In Scenarios 2C and 3C, a maximum return flow rate of 18.5 mgd was used as the return flow rate, which represents the peak day water supply demand, and the peak return flow rate. These flow rates are greater than those modeled previously and are considered to be a conservative estimate of water quality impacts because they are modeled as monthly flows, whereas the peak flow rates will not be realized for each month nor for the entire month duration.

Modification of the SEWRPC Models

The models for the Existing and PA scenarios were modified to include the proposed discharge to the Root River. This discharge is a new input to the model. Point source inputs to the HSPF model can be specified through the use of time-series 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 an hourly 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. The location was set to model segment 898 of the Root River watershed (See Figure 1). Since HSPF is a lumped model, a discharge to any point in segment 898 is modeled as entering at the upstream end of segment 898. For this reason, an exact location is not required.

The baseline and return flow scenarios were run using the WinHSPFLt interface. The original models were run using HSPF version 12 but this is a DOS based program and WinHSPFLt 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 WinHSPFLt to provide a representative comparison of results run under the same computing platform.

TABLE 2
Expected Discharge Condition

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	0.075	0.025	10.3	12.0	0.9	915	6.6	42.0
February	9.3	14.4	1.7	0.98	0.06	19.1	0.075	0.025	10.5	11.5	0.9	915	12.4	48.6
March	11.3	17.4	1.7	0.98	0.14	16.1	0.075	0.025	10.4	12.3	1.1	915	6.1	49.6
April	12.3	19.1	1.7	0.98	0.09	12.9	0.075	0.025	9.7	14.1	1.4	915	8.6	22.0
May	11.5	17.7	2.0	0.98	0.20	13.9	0.075	0.025	9.0	16.4	1.2	2	7.1	45.7
June	12.1	18.7	2.6	0.98	0.14	12.7	0.075	0.025	8.2	18.8	1.8	49	6.1	30.5
July	9.2	14.3	1.8	0.98	0.05	16.8	0.075	0.025	8.0	20.6	1.0	2	6.1	29.3
August	9.0	14.0	1.8	0.98	0.07	14.8	0.075	0.025	7.9	21.3	1.1	2	6.3	37.2
September	8.8	13.7	2.1	0.98	0.10	16.2	0.075	0.025	8.0	20.8	1.0	2	8.7	39.0
October	8.8	13.6	1.6	0.98	0.04	17.3	0.075	0.025	8.7	18.6	1.1	915	5.7	36.6
November	8.6	13.3	1.6	0.98	0.07	18.1	0.075	0.025	9.5	16.0	1.1	915	6.7	33.8
December	9.2	14.2	1.6	0.98	0.07	20.7	0.075	0.025	10.3	13.3	1.1	915	9.3	47.4

TABLE 3
Maximum Potential Discharge Condition

Month	Flow (mgd)[a]	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	14.0 or 18.5	21.7	1.7	0.98	4.3	18.6	0.075	0.025	7.0	12.0	0.9	915	6.6	42.0
February	14.0 or 18.5	21.7	1.7	0.98	4.3	19.1	0.075	0.025	7.0	11.5	0.9	915	12.4	48.6
March	14.0 or 18.5	21.7	1.7	0.98	4.3	16.1	0.075	0.025	7.0	12.3	1.1	915	6.1	49.6
April	14.0 or 18.5	21.7	1.7	0.98	2.6	12.9	0.075	0.025	7.0	14.1	1.4	915	8.6	22.0
May	14.0 or 18.5	21.7	2.0	0.98	1.4	13.9	0.075	0.025	7.0	16.4	1.2	400	7.1	45.7
June	14.0 or 18.5	21.7	2.6	0.98	1.4	12.7	0.075	0.025	7.0	18.8	1.8	400	6.1	30.5
July	14.0 or 18.5	21.7	1.8	0.98	1.4	16.8	0.075	0.025	7.0	20.6	1	400	6.1	29.3
August	14.0 or 18.5	21.7	1.8	0.98	1.4	14.8	0.075	0.025	7.0	21.3	1.1	400	6.3	37.2
September	14.0 or 18.5	21.7	2.1	0.98	1.4	16.2	0.075	0.025	7.0	20.8	1	400	8.7	39.0
October	14.0 or 18.5	21.7	1.6	0.98	3.8	17.3	0.075	0.025	7.0	18.6	1.1	915	5.7	36.6
November	14.0 or 18.5	21.7	1.6	0.98	4.3	18.1	0.075	0.025	7.0	16.0	1.1	915	6.7	33.8
December	14.0 or 18.5	21.7	1.6	0.98	4.3	20.7	0.075	0.025	7.0	13.3	1.1	915	9.3	47.4

[a] Scenarios 2B and 3B use a 14 mgd flow rate. Scenarios 2C and 3C use an 18.5 mgd flow rate.

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 potential discharge location. The four evaluation locations are RR-17 (Reach 899 on Root River upstream of Milwaukee-Racine County Line and downstream of Root River Canal), RR-18 (Reach 120 on Root River upstream of Hoods Creek), RR-21 (Reach 132 on the Root River at the City of Racine), and RR-22 (Reach 140 on the mouth of Root River at Lake Michigan). 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 7 and with the SEWRPC future conditions in Table 8 through Table 11. As in the RWQMPU, the 11 year data set was simulated within the model but the last 10 years of data (1988-1997) were used for data analysis and reporting.

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 for the primary contact season of May through September and compared to the standard. A set of 122 geomean values, using the previous 30-days of data, were calculated for each primary contact season.

Expected Discharge Condition Results

Fecal Coliform

The expected discharge condition shows dramatic improvement in the Root River downstream of the potential discharge location for mean recreational season (May-September) fecal coliform concentration 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. Geomean concentrations are high under existing conditions and the geomean standard is rarely met. Geomean concentrations decrease under the discharge scenarios but not sufficiently to increase compliance significantly. The findings indicate fecal coliform compliance improves at all locations for all models.

Dissolved Oxygen

Under the expected discharge condition, average dissolved oxygen concentrations are either the same as the existing and recommended plan concentrations or very slightly lower. In all scenarios the average DO is above the DO standard and compliance with the DO standard does not change for both the existing and recommended plan alternative SEWRPC models.

Total Phosphorus

In the existing and recommended plan models for the expected discharge conditions, the average phosphorus concentration decreased or remained the same at all model locations. Median concentrations decrease or stay the same in all reaches, except in the recommended plan model in the reach immediately below the return flow location, which increases slightly (0.001 mg/L) because the discharge contributions raise concentrations slightly

during dry conditions. The percentage of time the stream is in compliance with the standard increases at all locations downstream of the potential discharge location. The discharge has the effect of dampening instream changes in phosphorus in the reach below the return flow. Concentrations during low flow conditions are slightly higher whereas concentrations rise more slowly and to a lesser extent during storm events. Average and median concentrations decrease at the remaining stations.

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.

Chlorophyll a

Under the expected discharge condition, average chlorophyll *a* concentrations decrease at all locations for both the existing and recommended plan alternative SEWRPC models, indicating a decrease in algal populations.

Maximum Potential Discharge Condition Results

The maximum potential discharge scenarios included modeling for 14 mgd and 18.5 mgd return flow. The results for these scenarios show a consistent pattern. For this reason, the conclusions below describe both scenarios unless otherwise specified.

Fecal Coliform

The maximum potential discharge condition shows good improvement in the Root River for mean recreational season (May-September) fecal coliform concentration at all locations for all models.

The maximum potential discharge condition improves compliance 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 conservative scenario represented by the maximum potential discharge condition. As noted in the above paragraph, single sample standard compliance always improves during the recreational season for all models at all assessment points.

Dissolved Oxygen

Under the maximum potential discharge condition, dissolved oxygen concentrations are very slightly lower than the baseline conditions but compliance with the dissolved oxygen standard does not change for either the existing and recommended plan SEWRPC models.

Total Phosphorus

Under the maximum potential discharge condition, total phosphorus concentrations decrease from the baseline conditions and compliance with the water quality standard is increased for the existing and recommended plan models. Median concentrations in the reach below the return flow increase slightly as the discharge contributions raise concentrations slightly during dry conditions. The percentage of time the stream is in compliance with the standard increases at all locations downstream of the potential discharge location. As in the expected discharge scenario, discharge has the effect of dampening instream changes in phosphorus in the reach below the return flow. Concentrations during low flow conditions are slightly higher whereas as concentration rise more slowly and to a lesser extent during storm events. This impact is even greater for the maximum potential discharge scenarios since the volume of the discharge is greater and therefore comprises a greater percentage of the instream flow volume. Average and median concentrations both decrease at the RR-18, RR-21, and RR-22 stations.

Chlorophyll a

Under the maximum potential discharge condition, average chlorophyll *a* concentrations decrease at all locations for both the existing and recommended plan alternative SEWRPC models, indicating a decrease in algal populations.

Total Suspended Solids

Under the maximum potential discharge condition, average total suspended solids concentration improves at all locations for both the existing and recommended plan alternative SEWRPC models.

Independent Review

The model and its output were 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 1 and have been incorporated in this TM. No significant issues were identified during the review and the model results provided in Tables 4 through 11 were revised to summarize the last 10 years of data (1988-1997) instead of the full simulation period, as suggested by the reviewer.

Conclusions

Fecal Coliform

Mean fecal coliform concentration shows dramatic to good improvement at all locations for all models. Compliance with standards showed improvement in all cases.

Dissolved Oxygen

Dissolved oxygen concentration is very slightly lower but not significantly and compliance with the dissolved oxygen standard does not change under all modeling scenarios.

Total Phosphorus

Total phosphorus concentrations improved or remained the same at all locations for all models. Compliance with standards showed improvement at all locations.

Total Suspended Solids

The total suspended solids average concentration improves at all locations under the expected discharge and the maximum potential discharge conditions.

Chlorophyll *a*

Under the maximum potential discharge condition, average chlorophyll *a* concentrations decrease at all locations for both the existing and recommended plan alternative SEWRPC models, indicating a decrease in algal populations.

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.

CH2M HILL. 2012. Water Quality Model of Proposed Potential Return Flow Discharge to Underwood Creek TM. Milwaukee, WI. (Updated in response to a WDNR question [regarding chlorophyll a] from original version included in the May 2010 Application).

SEWRPC. 2007. Planning Report Number 50, A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds. Milwaukee, WI.

Strand Associates. 2011. City of Waukesha Wastewater Treatment Plant Facility Plan. Table 4.03-4.

Wisconsin Department of Natural Resources (WDNR). 2011. Limits for Waukesha Return Flow. December 13, 2011 correspondence from Jackie Fratrick/WDNR to Kristy Rogers/WDNR and Diane Figiel/WDNR. Correspondence provided to City of Waukesha on February 5, 2013.

FIGURE 1.
Root River Watershed HSPF Model Segments, Potential Discharge Location, and Assessment Points

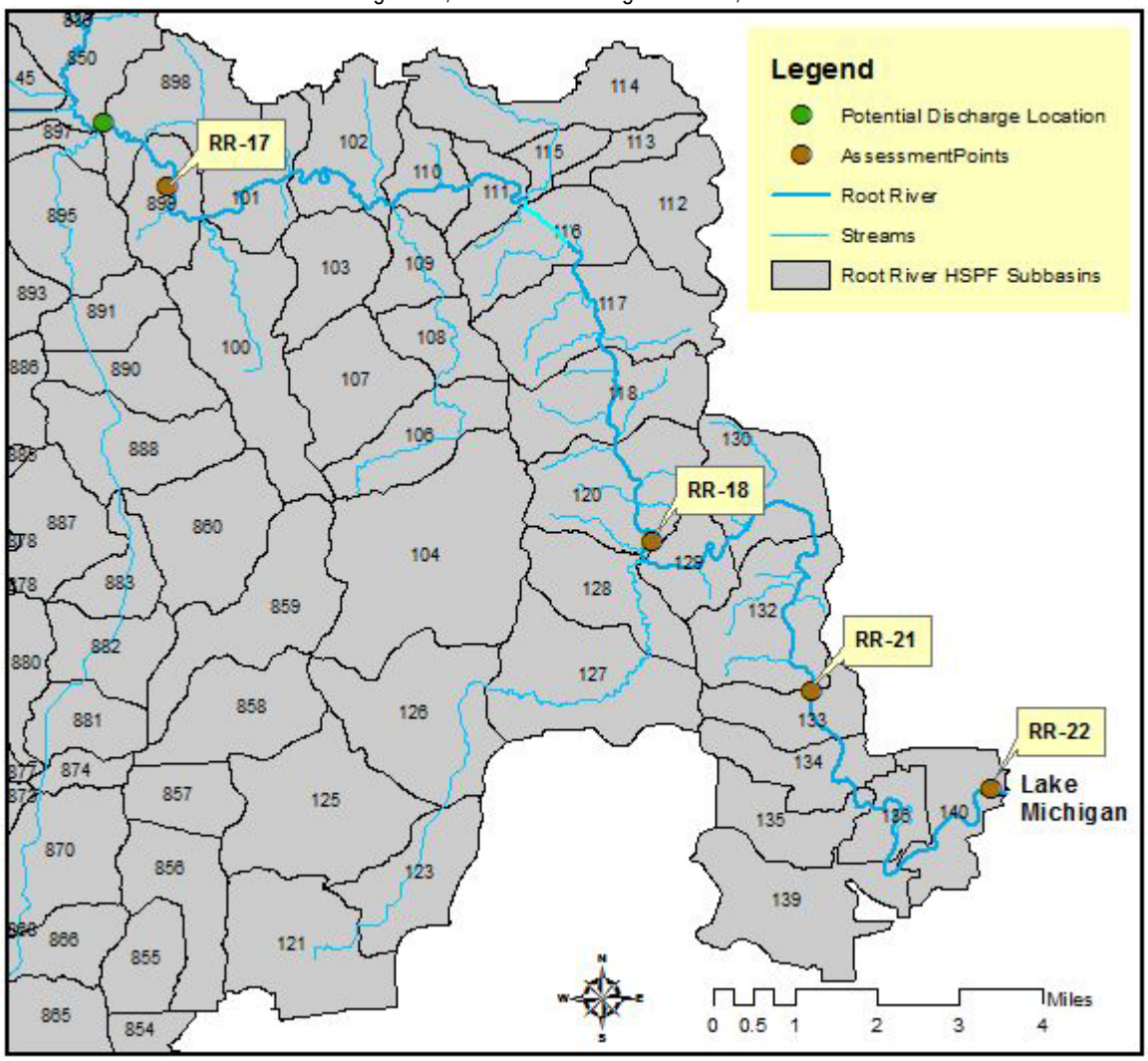


TABLE 4
Reach 899– Assessment Point RR-17 Root River at Upstream Crossing of Milwaukee-Racine County Line and Downstream of Root River Canal

		Existing	Existing Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**	**2C**
Fecal Coliform Bacteria (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	2,994	2,120	2,092	1,953
	Percent compliance with single sample standard (<400 cells per 100ml)	48.1	56.3	51.4	52.4
	Days of compliance with geometric mean standard (<200cells per 100 ml) (June-September), per year	3	14	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.5	11.3	11.1	11.1
	Median (mg/l)	11.7	11.3	11.1	11.0
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.7	99.6	99.6	99.6
Total Phosphorus	Mean (mg/l)	0.104	0.098	0.097	0.091
	Median (mg/l)	0.071	0.071	0.071	0.065
	Percent compliance with phosphorus standard (0.075 mg/l)	53.3	56.4	57.5	57.7
Total Suspended Solids	Mean (mg/l)	20.6	18.5	18.0	17.4
	Median (mg/l)	4.6	3.6	3.3	3.0
Chlorophyll *a*	Mean (µg/l)	5.92	3.52	3.18	2.96
	Median (µg/l)	2.82	2.03	1.80	1.65

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 120 – Assessment Point RR-18 Root River Upstream of Hoods Creek

		Existing	Existing Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**	**2C**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	2,687	1,928	1,854	1,726
	Percent compliance with single sample standard (<400 cells per 100ml)	53.1	58.6	57.2	58.1
	Days of compliance with geometric mean standard (<200 cells per 100 ml), (June-September) per year	8	28	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.4	11.3	11.2	11.2
	Median (mg/l)	11.6	11.4	11.3	11.3
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.5	99.5	99.5	99.5
Total Phosphorus	Mean (mg/l)	0.102	0.096	0.096	0.095
	Median (mg/l)	0.068	0.064	0.063	0.063
	Percent compliance with phosphorus standard (0.075 mg/l)	55.2	61.6	62.5	62.9
Total Suspended Solids	Mean (mg/l)	30.9	28.7	28.1	27.4
	Median (mg/l)	5.2	4.4	4.2	3.9
Chlorophyll *a*	Mean (µg/l)	8.36	5.43	4.95	4.62
	Median (µg/l)	2.90	2.32	2.11	2.00

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 132 – Assessment Point RR-21 Root River at the City of Racine, USGS Sampling Location (4087240)

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios		
			2A	2B	2C
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,041	2,097	1,989	1,834
	Percent compliance with single sample standard (<400 cells per 100ml)	55.8	58.4	57.7	58.0
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September) per year	11	32	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.0	11.0	10.8	10.8
	Median (mg/l)	11.3	11.2	11.1	11.0
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.1	99.1	99.1	99.1
Total Phosphorus	Mean (mg/l)	0.109	0.100	0.099	0.098
	Median (mg/l)	0.075	0.066	0.065	0.065
	Percent compliance with phosphorus standard (0.075 mg/l)	49.8	58.3	59.5	60.5
Total Suspended Solids	Mean (mg/l)	35.8	33.1	32.3	32.3
	Median (mg/l)	7.0	5.7	5.4	5.4
Chlorophyll *a*	Mean (µg/l)	10.69	7.36	6.79	6.40
	Median (µg/l)	3.33	2.54	2.40	2.32

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 140 – Assessment Point RR-22 Mouth of Root River at Lake Michigan

		Existing	Existing Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**2A**	**2B**	**2C**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,327	2,463	2,327	2,159
	Percent compliance with single sample standard (<400 cells per 100ml)	55.6	57.9	57.7	58.1
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September) per year	20	37	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	11.0	10.9	10.9
	Median (mg/l)	11.3	11.3	11.1	11.1
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.1	99.1	99.1	99.1
Total Phosphorus	Mean (mg/l)	0.116	0.105	0.104	0.102
	Median (mg/l)	0.079	0.069	0.067	0.067
	Percent compliance with phosphorus standard (0.075 mg/l)	47.1	55.3	56.5	56.9
Total Suspended Solids	Mean (mg/l)	38.5	36	35.2	7.4
	Median (mg/l)	9.3	8.3	8.1	2.5
Chlorophyll *a*	Mean (µg/l)	11.78	8.35	7.76	7.76
	Median (µg/l)	3.39	2.71	2.55	2.55

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 899– Assessment Point RR-17 Root River at Upstream Crossing of Milwaukee-Racine County Line and Downstream of Root River Canal

		Future	Future Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**	**3C**
Fecal Coliform Bacteria (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	1,594	1,159	1,212	1,149
	Percent compliance with single sample standard (<400 cells per 100ml)	56.3	60.5	57.8	58.2
	Days of compliance with geometric mean standard (<200cells per 100 ml) (June-September), per year	11	35	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.5	11.3	11.2	11.1
	Median (mg/l)	11.7	11.3	11.1	11.1
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.7	99.8	99.8	99.8
Total Phosphorus	Mean (mg/l)	0.088	0.088	0.088	0.088
	Median (mg/l)	0.068	0.069	0.069	0.069
	Percent compliance with phosphorus standard (0.075 mg/l)	60.5	61.7	61.7	61.6
Total Suspended Solids	Mean (mg/l)	13.8	12.3	11.9	11.6
	Median (mg/l)	3.6	2.7	2.5	2.3
Chlorophyll *a*	Mean (µg/l)	5.77	3.43	3.10	2.89
	Median (µg/l)	2.76	2.00	1.77	1.62

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 120 – Assessment Point RR-18 Root River Upstream of Hoods Creek

		Future	Future Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**	**3C**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	1,589	1,160	1,150	1,082
	Percent compliance with single sample standard (<400 cells per 100ml)	58.8	62.5	61.8	62.3
	Days of compliance with geometric mean standard (<200 cells per 100 ml), (June-September) per year	26	52	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.4	11.3	11.3	11.2
	Median (mg/l)	11.6	11.5	11.4	11.3
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.8	99.8	99.8	99.8
Total Phosphorus	Mean (mg/l)	0.089	0.085	0.085	0.085
	Median (mg/l)	0.064	0.062	0.062	0.062
	Percent compliance with phosphorus standard (0.075 mg/l)	58.3	63.6	64.5	64.9
Total Suspended Solids	Mean (mg/l)	19.9	18.4	18.0	17.6
	Median (mg/l)	4.1	3.4	3.3	3.1
Chlorophyll *a*	Mean (µg/l)	8.18	5.3	4.84	4.52
	Median (µg/l)	2.85	2.29	2.10	1.97

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 132 – Assessment Point RR-21 Root River at the City of Racine, USGS Sampling Location (4087240)

		Future	Future Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**	**3C**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,489	1,057	1,046	979
	Percent compliance with single sample standard (<400 cells per 100ml)	61.6	64.4	63.7	64.0
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September) per year	39	59	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	11.0	10.9	10.8
	Median (mg/l)	11.4	11.3	11.1	11.1
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.4	99.4	99.4	99.4
Total Phosphorus	Mean (mg/l)	0.094	0.087	0.087	0.086
	Median (mg/l)	0.070	0.063	0.063	0.062
	Percent compliance with phosphorus standard (0.075 mg/l)	53.9	61.6	62.6	63.4
Total Suspended Solids	Mean (mg/l)	22.7	21.0	20.4	19.9
	Median (mg/l)	5.2	4.3	4.1	3.9
Chlorophyll *a*	Mean (µg/l)	10.13	7.10	6.58	6.23
	Median (µg/l)	3.26	2.59	2.40	2.30

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 140 – Assessment Point RR-22 Mouth of Root River at Lake Michigan

		Future	Future Scenarios		
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**	**3C**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,508	1,142	1,113	1,045
	Percent compliance with single sample standard (<400 cells per 100ml)	61.0	63.5	63.1	63.6
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September) per year	48	66	Note 1	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	11.1	11.0	10.9
	Median (mg/l)	11.4	11.3	11.2	11.1
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.5	99.5	99.5	99.5
Total Phosphorus	Mean (mg/l)	0.099	0.091	0.090	0.090
	Median (mg/l)	0.073	0.065	0.065	0.064
	Percent compliance with phosphorus standard (0.075 mg/l)	51.5	58.7	59.5	60.2
Total Suspended Solids	Mean (mg/l)	25.2	23.6	23.1	22.7
	Median (mg/l)	7.4	6.7	6.5	6.4
Chlorophyll *a*	Mean (µg/l)	11.23	8.05	7.52	7.16
	Median (µg/l)	3.38	2.75	2.59	2.49

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

Independent Model Review Finding

TETRA TECH, INC.
Cape Fear Building, Suite 105
3200 Chapel Hill-Nelson Hwy.
P.O. Box 14409
Research Triangle Park, NC 27709
Telephone: (919) 485-8278
Telefax: (919) 485-8280

MEMORANDUM

To: Daniel S. Duchniak, P.E. (WWU)
Klaus Albertin (CH2M HILL)

Date: April 10, 2013

From: Jonathan Butcher, Ph.D., P.H.

Project: Waukesha Review

Subject: Draft Review of Modeling of Waukesha Return Flow to Root River

---

The City of Waukesha Water Utility (WWU) is applying for Lake Michigan Water Supply. In conjunction with this application, WWU is evaluating an option for the City's Wastewater Treatment Plant to route return flow to the Root River to meet the requirements of the Great Lakes Compact. To analyze the potential impacts of the proposed discharge, CH2M HILL modified an existing flow and water quality model of the Root River. 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 draft technical memorandum dated April 9, 2013 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 HSPF modeling system for SEWRPC. 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 no major flaws and only a few minor points in need of correction. CH2M HILL has fixed the technical issues 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.

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 Root River model is implemented at a 1-hour time step and is set up to run over the evaluation period of 1/1/1987 – 12/31/1997 (models for other Milwaukee tributaries operate at a 15-minute time step). 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 SEWRPC Root 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

Modeling Files

SEWRPC provided the basic modeling files to CH2M HILL, representing the Existing and Preferred Alternative (PA) production run scenarios. 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 ES run, representing existing land use and land management. (For the RWQMPU simulations in general, the existing condition is represented by the "ESM" run, which includes District CSO/SSO simulations using Streamline Mouse, as opposed to the earlier Mini Mouse modeling system. However, there are no District CSO/SSOs in the Root River watershed, so the ES and ESM runs are the same). The SEWRPC PA scenario corresponds to Tetra Tech's PA2 run.

HSPF execution is controlled by User Control Input (UCI) files. A separate file is provided for each major subarea in the Root River watershed. I compared the UCI files provided by CH2M HILL to those in the Tetra Tech archive and determined that the files used for existing conditions are identical those developed for the ES run, while the files used for future conditions are identical to those developed for the PA2 run, with two exceptions: (1) the addition of the new discharge to Root River, and (2) changes to model output to correct TN summations and enable the use of WinHSPFLt, as discussed below.

Two minor issues were identified in the model UCI files. In March 2012 Tetra Tech made corrections to the existing models to fix the internal calculation of total nitrogen, for which there was an incorrect conversion factor applied to certain model output. CH2M HILL had made these corrections at the direction of SEWRPC; however, they had not been informed of an additional correction in which nitrite nitrogen was added in to the sum of total nitrogen in certain instances where it was missing. In addition, there is an issue regarding the NVSI parameter (vertical sediment input to the land surface). The RWQMPU simulations were undertaken with an older, DOS-based version of HSPF (for automation efficiency). The DOS version was used to run all the models, with the exception of the Lower Root, for which the then recently released WinHSPFLt was required due to the number of operations represented. During model calibration, the NVSI parameter was set to nonzero values. A bug in the DOS version of HSPF resulted in these NVSI values being ignored. The model calibration is thus actually based on NVSI = 0, except in the Lower Root model, which was run with WinHSPFLt during the calibration. When the models are re-run with WinHSPFLt the non-zero NVSI values are no longer ignored – resulting in slight changes in the sediment simulation and in the behavior of sediment-associated pollutants, such as fecal coliform bacteria and phosphorus. Thus, to ensure consistency with the RWQMPU calibration, when the calibrated models (other than Lower Root) are re-run using WinHSPFLt, NVSI should be set to zero.

After discussion of these issues, CH2M HILL fixed and re-ran the model.

The model also depends on the weather data and text "*mutsin*" files that provide information on point source discharges and SSOs. Both the weather data files and the *mutsin* files used by CH2M HILL are identical to those 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 898 in the Lower Root sub-model, which was performed correctly. No other changes were made to the baseline UCI files.

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, as in the prior Underwood Creek evaluation. The mutsin input must be supplied to the model so that it is compatible with the simulation time step of one hour and is in the appropriate units. The current *mutsin* files are set up on an hourly basis (with constant values by month), avoiding issues with the interpretation of the missing value flag that were present in the first iterations of the Underwood Creek model.

As noted above, the *mutsin* file must provide loads in the correct units and compatible with the one hour simulation time interval. The model is implemented in English units, so the *mutsin* file must be set up as follows:

- Flow: AF/hr
- Nutrient and metals load: lb/hr
- Bacterial load: cfu/hr
- Thermal load: BTUs (relative to freezing)/hr
- Solids: tons/hr

Point source monitoring data are typically in MGD for flow, mg/L for standard pollutants, µg/L for metals, temperature (F) for thermal load, and cfu/100 ml for bacteria. I confirmed that all unit conversions were performed properly. One minor note is that the conversion of flow in MGD to AF/hr uses a factor of 325,900 gal/AF, whereas I calculate 325,851.4. Rounding up is conservative, however, so it does not present a problem for the analysis.

Confirmation of Model Runs

I implemented the model files provided by CH2M HILL and confirmed that they do indeed run as intended and provide output that matches the tables in the written report.

Model output and accompanying statistics for existing conditions should be identical to the results obtained previously by Tetra Tech. It was therefore surprising to note that the statistics reported for the ES and PA runs (without the new discharge) differ noticeably from those given in the RWQMPU and Tetra Tech's analyses. The CH2M HILL modeler confirmed that they had rerun the baseline models with WinHSPFLt and with the NVSI corrections. The remaining differences were explained as follows: "The baseline and return flow scenarios were run using the WinHSPFLt interface. The original models were run using HSPF version 12 but this is a DOS based program and WinHSPFLt 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." I examined this issue and believe that the DOS and WinHSPFLt models produce essentially the same output once the NVSI correction is made. Instead, it turns out that the differences between the baseline and the RWQMPU is due to the fact that CH2M HILL calculated statistics over the full 11-year period of the model run (1987-1997). The RWQMPU statistics are calculated on the 10-year period of 1988-1997, with the first year omitted to allow for model spin-up. The comparison presented in the CH2M HILL draft memo is valid in the sense that scenarios with and without the new discharge are calculated on the same time basis, but the comparison could be affected by model spin-up. For this reason, and to ensure consistency with the RWQMPU, the statistics should be recalculated using 1988-1997 in the final version of the memo.

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 the Root River, with presentation of 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 final results should be revised to correct the averaging period, as noted above. CH2M HILL did not provide the spreadsheets or code used to calculate the statistics tables; however, I made an independent investigation of the results based on the output files created by re-running the model and analyzing for the 1987-1997 time period. In general, the reported results appear to accurately represent the output of the model.

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 was also seen in the Underwood Creek analysis, this is 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.

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. The approach is identical to that used for the Underwood Creek analysis, except that an additional discharge scenario is added and the new phosphorus limits are added.

I agree with CH2M HILL's representation of phosphorus in the discharge. The HSPF model represents labile organic phosphorus and organic nitrogen as proportional to CBOD (with refractory organic phosphorus and organic nitrogen specified separately). Thus, the specification of the CBOD load also implies a certain level of organic phosphorus and organic nitrogen. At ultra-low phosphorus limits this could lead to an unintentional assignment of more phosphorus than is allowed by the permit if the fraction of labile organic phosphorus modeled as part of CBOD is not accounted for.

This issue is not very well documented in the HSPF manual, so some further details are given here. The documentation does state the following:

> In subroutine NUTRX the total BOD decay for the time interval is used to compute the corresponding amounts of inorganic nitrogen and orthophosphorus produced by the decay are determined as:
>
> ```
> DECNIT = BODOX*CVON                                              (24)
> DECPO4 = BODOX*CVOP                                              (25)
>
> where:
>      BODOX = total BOD decay (mg O/l per interval)
>      CVON  = stoichiometric conversion factor from mg oxygen to mg nitrogen
>      CVOP  = stoichiometric conversion factor from mg oxygen to mg
>      phosphorus
> ```

This is confusing because CVOP is not an input factor. Instead, it is computed from the following block:

```
  CONV-VAL1
    RCHRES       CVBO     CVBPC     CVBPN    BPCNTC ***
    # -  #      mg/mg  mols/mol  mols/mol           ***
    1  999       1.68      106.       16.       49.
  END CONV-VAL1
```

Specifically, the calculation is done in subroutine HRCHNUT.FOR:

```
      CALL RTABLE
      I              (I2,I1,I4,UUNITS,
      M               RVAL)
C
       CVBO  = RVAL(1)
       CVBPC = RVAL(2)
       CVBPN = RVAL(3)
       BPCNTC= RVAL(4)
C
C      calculate derived values
       CVBP= (31.*BPCNTC)/(1200.*CVBPC)
       CVBN= 14.0*CVBPN*CVBP/31.0
```

```
CVOC= BPCNTC/(100.0*CVBO)
CVON= CVBN/CVBO
CVOP= CVBP/CVBO
```

Putting this together, CVOP = 31 x BPCNTC/(1200 x CVBPC x CVBO) = 0.007108. The HSPF model NETWORK block is designed to separate a "total" P input into orthophosphate as P and refractory organic P, while CBOD (and associated labile organic P is input separately). CH2M HILL correctly discounts the "total" P input by 0.007 times CBOD so that the sum of orthophosphate as P, refractory organic P, and labile organic P achieves the desired concentration of 0.075 mg/L.

There is one slight discrepancy in the representation of phosphorus in the discharge in that the UCI NETWORK block is set up to represent PO_4-P as a fixed 40 percent of the input time series that represents the sum of orthophosphate P and refractory organic P. The sum of these components varies over time because the CBOD concentration (and its contribution to total phosphorus) varies over time. As a result, the model sees an influent PO_4-P concentration that varies slightly from 0.0228 to 0.0256 mg/L, with an average of 0.0248 mg/L, rather than remaining at the constant value of 0.025 mg/L as specified in Table 2 of the report. These small variations should not, however, significantly affect results.

As with the Underwood Creek study, I believe the approach taken to the representation of the discharge is adequate for the purposes of the analysis. 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.

Summary

The model application, as revised, appears to be correct and defensible. The presentation of results should, however, be revised to match the RWQMPU analysis period of 1988-1997.