Discussion of DNR Comments on Changes to Water Supply Infrastructure and Environmental Impacts with a Hypothetical Low Water Demand

PREPARED FOR: Wisconsin Department of Natural Resources

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COPIED TO: Waukesha Water Utility

Purpose

The purpose of this memorandum is to provide a summary response to questions asked by the Wisconsin Department of Natural Resources (WDNR) regarding the February 18, 2014 memorandum "*Changes to Water Supply Infrastructure and Environmental Impacts with a Hypothetical Low Water Demand*." The questions provided by the WDNR are shown in *italic* followed by the response or discussion.

Western Unconfined Deep Aquifer Drawdown

1. *In Table 2 for Alternative 5 – the memo indicates at the 2 MGD pumping scenario the drawdown is greater than 150 ft. The modeled drawdown for the 2 MGD scenario is actually reported to be 40 feet in Exhibit 11-34 of volume 2 of the current application. In addition, the modeled drawdown at 10.5 MGD is reported in the application to be slightly more than 150 ft. Thus, [it may not be] a reasonable assumption that the modeled drawdown for an 8.5 MGD withdrawal would be 150 ft or greater. Please correct the memo to address these concerns.*

   Response: The drawdown shown in Exhibit 11-34 of Volume 2 of the Application is the change in drawdown from recent baseline conditions. It does not compare the drawdown to predevelopment conditions, which is the basis for designation as a groundwater management area under Wisconsin Administrative Code Chapter NR 820. The recent baseline condition is approximately 100 feet below predevelopment conditions, as reflected in the Southeastern Wisconsin Regional Planning Commission's (SERWPC's) A Regional Water Supply Plan for Southeastern Wisconsin (SEWRPC, 2010) (See Figures 16, 17, and 18 included as Attachment A for convenience). Consequently, withdrawal of 2 million gallons per day (mgd) results in an additional 40 feet of drawdown or a total drawdown of approximately 150 feet compared to predevelopment conditions. Because the 10.5 mgd analysis reported a drawdown of 150 feet from recent conditions or a total of approximately 250 feet from predevelopment conditions, a hypothetical average day demand (ADD) of 8.5 mgd will easily have a drawdown of 150 feet or greater compared to predevelopment conditions. No change to the memo is necessary.

Infrastructure Cost Estimates

1. *[P]lease provide the cost estimates associated with the infrastructure in Table 1 of the memo. [T]he detailed breakdowns that [were] provided previously, such as in Appendix E.*

   The infrastructure changes for the lower water demand compared to the overall infrastructure needed for an alternative are minor. Consequently, the cost change is also minor and the cost comparison between alternatives does not significantly change. The cost information is included as Attachment B in a similar detailed format to the prior cost estimate.

Western Unconfined Deep Aquifer Modeling

Unconfined Deep Aquifer

1. *In the most recent modeling runs 7 wells were used to simulate 10.5 MGD of pumping. The documentation does not describe how these well locations were chosen, the depth of the wells, why 7 wells were chosen rather the 12 planned in the infrastructure description.*

   Response: The unconfined deep target well field area was identified in *Future Water Supply Plan for Waukesha Water Utility* (CH2M HILL and Ruekert-Mielke, 2002) and is approximately 4 square miles in size. The modeling simulates approximately 0.5 mile spacing between wells to provide some separation between wells and reduce potential cumulative drawdown effects. Based upon these assumptions, there are 7 wells spaced throughout this target area. The wells are to a depth of approximately 1,770 feet below ground surface, with approximately 385 feet of casing.

   There are twelve total wells in this alternative to provide firm capacity at maximum day water demand. Seven of the twelve wells are modeled to produce the average day water demand capacity, the remaining 5 are to achieve the maximum day water demand.

2. *A description of why the particular location for the well field was chosen is needed. This description should address issues such as the well field was not located closer to Waukesha (the Maquoketa shale ends approximately 4 miles to the east of the well field), why the well field is located in wetlands complex (as there are adjacent upland locations), and any other factors that went into selecting this location.*

   Response: The area of the well simulation was identified during development of the *Future Water Supply Plan for Waukesha Water Utility* (CH2M HILL and Ruekert-Mielke, 2002). This area was determined qualitatively considering proximity to other municipal wells, existing development, open land available for well siting, suitable geology, and best professional judgment. Locating the wells 4 miles further east closer to the edge of the Maquoketa shale would place the wells immediately next to or within existing developed communities who have their own wells and next to a number of lakes (see Attachment C). This is not a reasonable expectation. Even if less pipeline was needed, it does not change any of the reasons why this alternative was eliminated.

   The well field site was not selected because wetlands exist in the vicinity. Wetlands are interspersed throughout this area and consequently it is reasonable to expect wetland impacts would occur wherever the wells are sited. As shown in Attachment C, which is the original simulation of 2 wells, the greater drawdown extends both to areas with wetlands and areas without wetlands.

3. *The modeling results continue to show a cone of depression that is not centered in the well field. However there is no discussion of this issue in the documentation and possible explanations for why this is. Unexpected results can indicate a problem with model construction.*

   Response: The model that was used was constructed by the United States Geological Survey (USGS) and was peer reviewed by staff at the Wisconsin Geological and Natural History Survey and University of Wisconsin-Milwaukee. Consequently, no changes were made to the model structure itself. However, significant efforts were made to verify that the model produced reasonable results. The condition of the simulated cone of depression centered near the northernmost well was discussed at length with Daniel Feinstein of the USGS. The mass balance was observed for each layer and each cell, and no significant variations occurred in the results. Review of the geology represented in the model indicated that the northernmost well is situated near some cells in which the sandstone aquifer is not present in some layers. Consequently, it was concluded that the reduced number of saturated cells in the vicinity of this well resulted in a greater drawdown in the saturated cells in this area. This produces a cone of depression skewed from the center of the simulated well field and is reasonable based upon the model representation of the geology.

Shallow Aquifer Modeling

1. *Drs. Cherkauer and Grundl provided comments in November 2013 and follow up comments in February 2014 to the DNR indicating possible problems with the modeling conducted using the Troy Valley Bedrock aquifer model. They indicate that the model designates all of the layers below the upper most layer as confined. This has the potential to create a scenario where the simulation continues to assume water is available to a well, even if the drawdown is below the base of the well or the layer the well is located in. If this is the case, then the results of the model may overestimate the volume of water that can be pumped from this aquifer and overestimate the associated impacts to surface waters. The following information to be provided to the department should clarify if this is indeed a problem with the model.*

    a. *The well depths for each of the simulated wells,*

    b. *the layer the well is pumping from,*

    c. *the top and bottom elevation of that layer*

    d. *the overall thickness of the glacial sediments modeled at the well location*

    e. *The drawdown in the layer the well is pumping from (documentation indicates that the wells are all located in layers 4 and 5) at each well location.*

    Response: The requested information for items a. through e. is included as Attachment D. Note that there were several model runs. The only difference between wells is the amount of drawdown that occurs within each well. Consequently, multiple columns for the various runs are provided. As indicated in Attachment D, all model runs did not have any wells go dry, except for the model run with the highest water demand which did have some model cells go dry. Model cells going dry in the simulation is an indication that additional wells would be required to achieve the necessary water demand. A variation on the alternative that did go dry, but which was modified to contain additional wells did not have any wells go dry. These modeling results are discussed and put into context below.

    All groundwater pumping must achieve a water balance with the environment. Mass balance dictates that all groundwater systems must balance recharge with discharge and changes in storage. The groundwater modeling requires a balance of water between storage, groundwater recharge, and groundwater discharge to surface water. Groundwater modeling provides insights into the relative impact of changes to the water balance from pumping. In shallow aquifers, the storage component is relatively small and changes in storage occur quickly and are not significant over longer periods. Consequently, the major changes in the water balance occur as changes to surface water as induced recharge or reduced discharge.

    For the Shallow Aquifer and Fox River Alluvium alternative, the change to the water balance from induced recharge and reduced discharge to the major surface water sources (Fox River, Pebble Brook, Pebble Creek, Mill Brook, and Mill Creek) is estimated as 6.8 mgd out of a total 10.9 mgd average pumpage. The base flow reduction estimate for the Fox River was estimated at 11 percent (RJN Environmental Services, 2013). The remainder of the pumped water would be associated with surface water impacts that occur to wetlands or other surface waters. Impacts to wetlands have been accounted for in the Environmental Report through the groundwater drawdown impacts.

    For an alternative that was modeled using more wells and still having a 10.9 mgd average day demand, the amount of water from the major surface water sources (Fox River, Pebble Brook, Pebble Creek, Mill Brook, and Mill Creek) is estimated as 5.2 mgd out of a total of 10.9 mgd average day demand. The additional wells created a cone of depression that was shallower but covered a larger area. The remainder of pumped water would be associated with surface water impacts that occur to wetlands or other surface waters over a larger area than the scenario with fewer wells. The base flow reduction estimate for the Fox River was estimated at 7 percent; however, the overall drawdown footprint increased and the impacts to Mill Brook, Mill Creek, and Pebble Brook were estimated at 44 percent and greater, indicating that significant adverse impacts would occur. For this analysis, the model cells did not go dry (RJN Environmental Services, 2013). The drawdown for this alternative is shown in Exhibit 11-19 of the Water Supply Service Area Plan, while the Shallow Aquifer and Fox River Alluvium alternative drawdown is shown in Exhibit 11-18. The small difference in Fox River impacts indicates that the groundwater model still is a reasonably close estimation of Fox River impacts, even though some of the cells went dry. Despite the fact the overall Fox River impacts do not change significantly, the overall drawdown footprint increases due to the use of additional wells, which would increase the number of wetlands within the drawdown footprint.

For further comparison, the shallow aquifer contribution for the Deep and Shallow Aquifer alternative includes 4.4 mgd from the major surface waters out of a total 6.4 mgd shallow aquifer demand. The base flow reduction estimate for the Fox River was estimated at 5 percent for this alternative which did not have any model cells go dry in the groundwater model (RJN Environmental Services, 2013).

The Troy Bedrock Valley groundwater model was originally developed by the SEWRPC. Model calibration considered the confined versus unconfined layers with reasonable results. During SEWRPC model development, decisions were made to improve the stability of the solvers in the face of portions of the upper aquifer layers that are unsaturated in the model area. The model is intended to be used as a regional model in its current form and modified with site specific data or inset models to simulate new well fields in specific locations when they are developed. This requires site data from test drilling and test wells which was not available for the hypothetical well fields simulated for this analysis. As new well fields are developed, test drilling and pumping test data would refine the local model structure and recalibrate the model or possibly develop an inset model to simulate a smaller portion of the model domain in greater detail. Modeling these hypothetical well fields is done using assumed aquifer conditions. Therefore, the results of these simulations are suitable to illustrate general changes in the water balance using average aquifer conditions on a regional basis. Local scale aquifer variability will cause actual results for a well field to vary from these predictions but the overall water balance will not change significantly.

Reducing the number of confined layers is similar to modeling conducted by the United States Geological Survey (USGS, 2012). This modeling sought to evaluate the potential for riverbank inducement wells along the Fox River. This USGS modeling showed that even with 27 wells lining approximately ten miles of the Fox River, the Waukesha water demand needs would still not be met and significant groundwater drawdowns would occur impacting natural resources. The USGS model indicated that for producing 9.1 mgd from the 27 wells, an estimate of 5.9 mgd base flow reduction would occur to the Fox River. Even with all of these wells along miles of the Fox River, the average day demand for the City of Waukesha would not be met. The USGS estimated reduction to the Fox River is greater than all of the groundwater modeling runs the Waukesha Water Utility has done, indicating that the USGS model focused upon simulating a hypothetical condition emphasizing hydrologic connections to the river needed for riverbank inducement. It should be noted that inducing recharge from the Fox River is undesirable because the levels of some constituents, such as chloride, rise to high levels in the river and may negatively impact the water quality of the well field to the point that additional treatment may be required.

The USGS model finding and the City of Waukesha's groundwater modeling have produced the same conclusions: significant groundwater drawdown and surface water flow changes would occur with a groundwater supply source, creating adverse environmental impacts; and the ability of the aquifer to produce sufficient water in the examined wellfield areas is questionable.

2. *Drs. Cherkauer and Grundl also indicate that the model appears to represent the Fox River as discontinuous north of the Vernon Marsh. This may incorrectly represent the inducement from the Fox River and result in over estimation of the impacts to surface waters. The documentation does not indicate that the model was modified to address this problem or if this issue was observed.*

Response: The Fox River is simulated as discontinuous north of Vernon Marsh; however, all of the Fox River simulated near Vernon Marsh within the drawdown footprint is simulated as continuous. The discontinuous portion of the Fox River is at least 6 miles north of Vernon Marsh. Consequently, the model representation of continuous/discontinuous connections to the Fox River does not overestimate surface water impacts.

Modeling Files

1. *It would assist review to receive copies of the unconfined deep aquifer model and the shallow aquifer models and the associated GWV files.*

   Response: These modeling files will be shared with the WDNR.

Conclusion

The water supply infrastructure and environmental impacts of the water supply alternatives are not significantly different for a hypothetical future low water demand (hypothetical ADD of 8.5 mgd or the recommended ADD of 10.1 mgd). Basing the environmental impact review on a hypothetical low 8.5 mgd ADD demand or the 10.1 mgd mid-range projected water demand does not result in a revised water supply recommendation, nor does it change the conclusion of the water supply alternatives evaluation. Under either demand scenario, the Lake Michigan alternative provides the only reasonable water supply alternative because it provides the most net environmental benefits to the waters and water-dependent natural resources of the Great Lakes and Mississippi River basins, is the most reliable, and is the most protective of the environment and public health.

References

CH2M HILL and Ruekert-Mielke. 03/2002. *Future Water Supply Report* prepared for the Waukesha Water Utility.

RJN Environmental Services, LLC. 08/2013. Groundwater Drawdown Analysis.

SEWRPC. 12/2010. *A Regional Water Supply Plan for Southeastern Wisconsin.* Planning Report No. 52. Final Report.

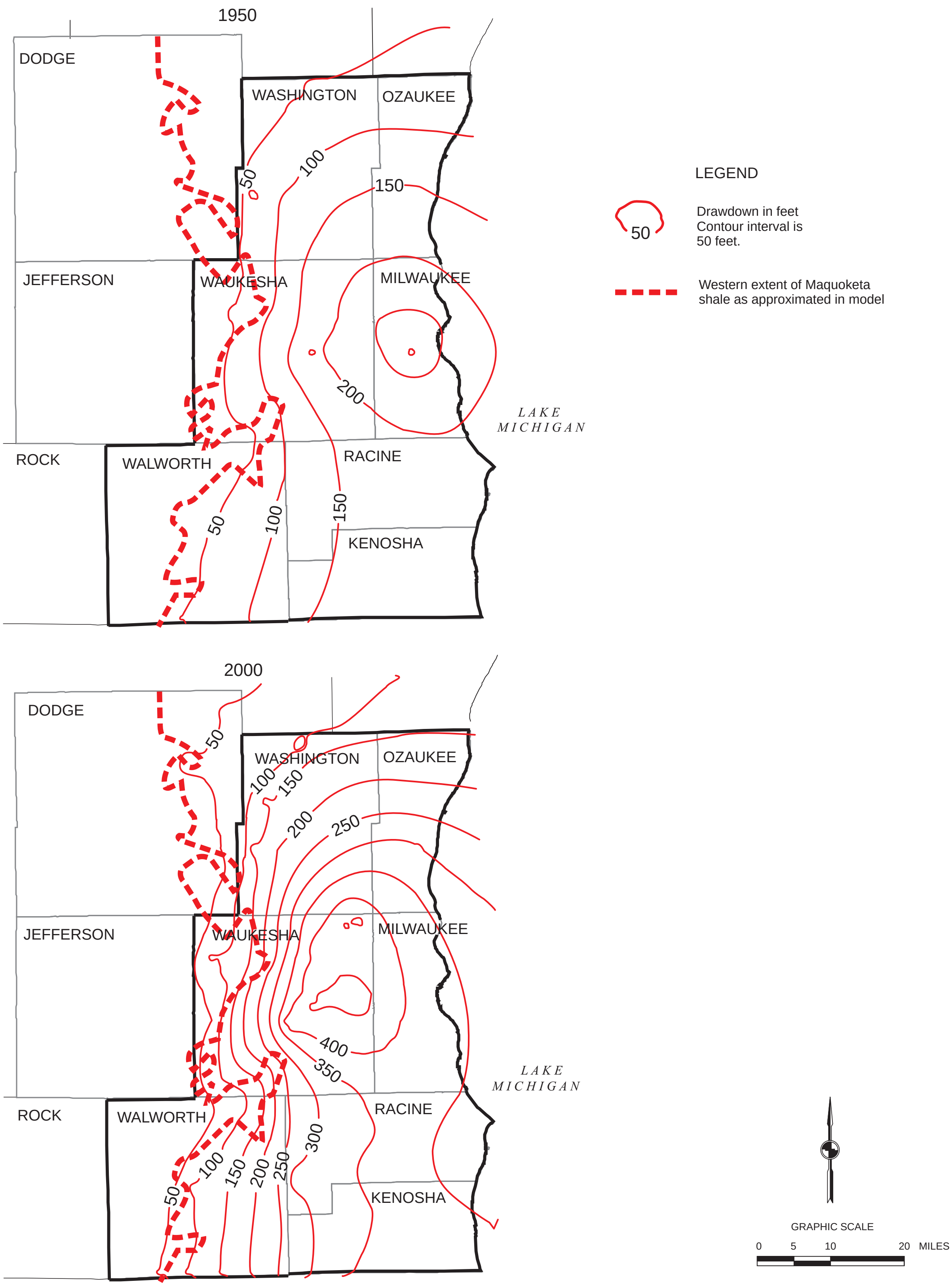
USGS. 2012. Development and application of a groundwater/surface-water flow model using MODFLOW-NWT for the Upper Fox River Basin, southeastern Wisconsin: U.S. Geological Survey Scientific Investigations Report 2012–5108. Authored by Feinstein, D. T., Fienen, M. N., Kennedy, J. L., Buchwald, C. A., and Greenwood, M. M.

Attachment A

SEWRPC Drawdown Maps

Figure 16

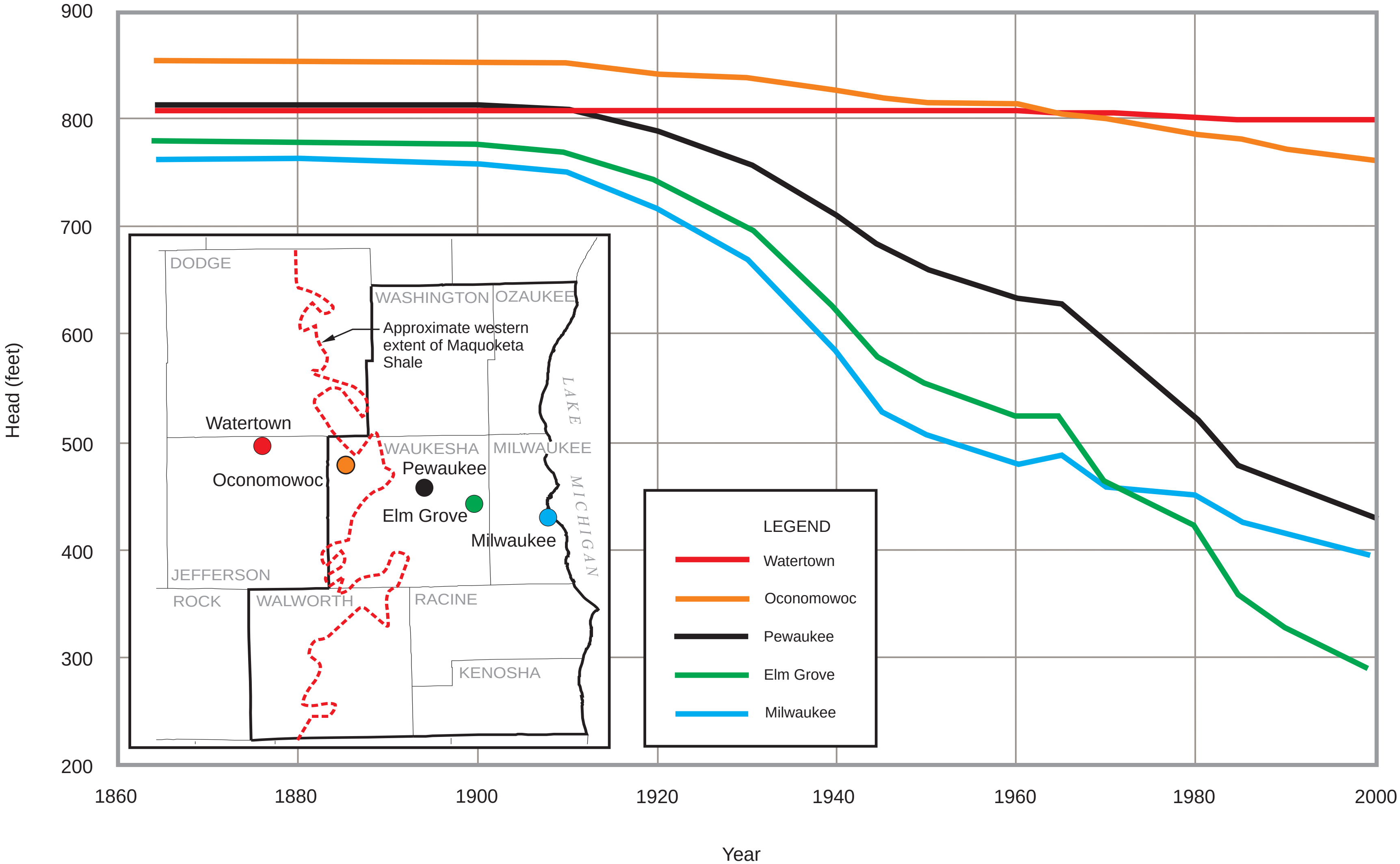
SIMULATED DRAWDOWN IN THE DEEP SANDSTONE AQUIFER FROM PREDEVELOPMENT CONDITIONS: 1950 AND 2000



Source: U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

Figure 17

PIEZOMETRIC SURFACE IN THE DEEP SANDSTONE AQUIFER AT SELECTED LOCATIONS: 1860 TO 2000

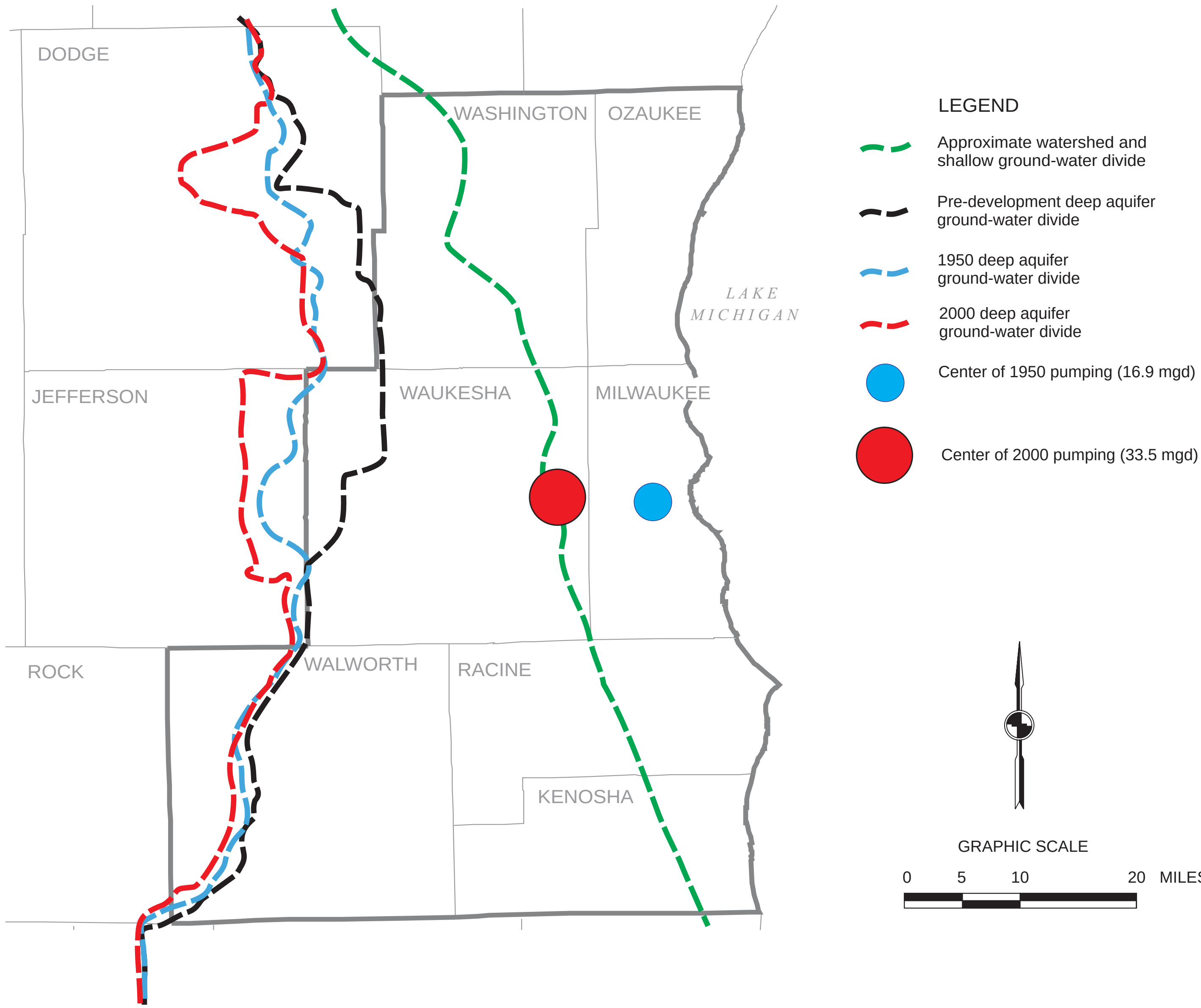


NOTE: Curves represent simulated hydraulic heads (in feet above sea level) near the top of the deep aquifer (St. Peter Formation).

Source: U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

Figure 18

LOCATION OF PUMPING CENTERS AND GROUNDWATER DIVIDES IN THE DEEP SANDSTONE AQUIFER: PREDEVELOPMENT, 1950, AND 2000 CONDITIONS



Source: U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

Attachment B

Cost Estimate

Summary Cost Estimates
Waukesha Supply and Return Alternatives

	2013 Costs			
	Capital Cost(1)	O&M $/yr.(2)	20-Year Present Worth(3)	50-Year Present Worth(3)
Alternative 1—Deep and Shallow Aquifers	$211,000,000	$7,200,000	$294,000,000	$325,000,000
Alternative 1—Deep and Shallow Aquifers—Hypothetical Low Demand	$199,000,000	$6,400,000	$272,000,000	$300,000,000
Alternative 2—Lake Michigan Supply from Oak Creek and Root River Return	$206,000,000	$8,000,000	$298,000,000	$333,000,000
Alternative 2—Lake Michigan Supply from Oak Creek and Root River Return—Hypothetical Low Demand	$201,000,000	$6,700,000	$278,000,000	$307,000,000
Alternative 3—Shallow Aquifers and Fox River Alluvium	$217,000,000	$8,900,000	$320,000,000	$358,000,000
Alternative 3—Shallow Aquifers and Fox River Alluvium—Hypothetical Low Demand	$198,000,000	$7,500,000	$284,000,000	$316,000,000
Alternative 4—Shallow Aquifers and Lake Michigan Supply from Oak Creek and Root River Return	$329,000,000	$8,200,000	$424,000,000	$459,000,000
Alternative 4—Shallow Aquifers and Lake Michigan Supply from Oak Creek and Root River Return—Hypothetical Low Demand	$289,000,000	$7,400,000	$374,000,000	$406,000,000
Alternative 5—Unconfined Deep Aquifers	$234,000,000	$6,400,000	$308,000,000	$335,000,000
Alternative 5—Unconfined Deep Aquifers—Hypothetical Low Demand	$217,000,000	$5,800,000	$284,000,000	$308,000,000
Alternative 6—Multiple Sources	$323,000,000	$7,300,000	$407,000,000	$439,000,000
Alternative 6—Multiple Sources—Hypothetical Low Demand	$266,000,000	$6,500,000	$341,000,000	$368,000,000

Alternative 1 - Deep and Shallow Wells - Hypothetical Low Demand

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Shallow Aquifer Wellfield			*2013 Costs*
Well houses and pumps	8	$ 334,500	$ 2,676,000
Land, acres	8	$ 178,416	$ 1,427,000
Roads, ft	21,000	$ 27.9	$ 585,900
Interconnecting pipe, 8" to 20", ft	21,000	$ 185	$ 3,874,500
Electrical (10% of well houses, pumps, land)	$ 4,103,000.00	10%	$ 410,000
Shallow Aquifer Supply Pipeline to Waukesha			
11 mi of 24" pipe, mixed rural and urban, ft	58,080	$ 357	$ 20,707,000
Shallow Aquifer Treatment Plant and Pump Station			
One groundwater treatment plant @ 14 mgd	14,000,000	$ 1.75	$ 24,500,000
Land	1	$ 2,230,000	$ 2,230,000
Deep Well Treatment Plant			
3 RO plants for Wells 6,8,10 @ 5.35 mgd including land built in 2020	5,350,000	$ 4.57	$ 24,460,000
Distribution System Improvements			
4.3 mi of 16", 24", and 30" pipes	22,500	$ 413	$ 9,289,000
5.1 mi of 16" pipe for blending, ft	26,928	$ 323	$ 8,698,000
Wastewater Forcemain			
5 mi of 6" forcemain, ft	26,400	$ 141	$ 3,715,000
Subtotal			**$ 102,572,400**
3% markup for Bonds & Insurance			$3,078,000
5% markup for Mob/Demob			$5,129,000
8% markup for Contractors Overhead			$8,863,000
4% markup for Contractors profit			$4,432,000
25% Contingency			$31,019,000
Subtotal Markups and Contingency			**$ 52,521,000**
Total Project Construction Costs			**$ 155,093,400**
8% allowance for engineering and design			$12,408,000
12% allowance for permitting, legal and admin.			$18,612,000
8% allowance for engr services during construction			$12,408,000
Subtotal Other Project Costs			**$43,428,000**

TOTAL PROJECT CAPITAL COST **$ 199,000,000**

Alternative 1 - Deep and Shallow Wells - Hypothetical Low Demand

Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	$/yr	Total
Deep Well pumping/maintenance	$/1000 gal	1,642,500	$ 0.350	$ 574,875	
Shallow Well Pumping/Maintenance	$/1000 gal	1,460,000	$ 0.140	$ 204,400	
					$ 779,000
Treatment/Pumping					
Deep Wells 6,7,8 starting in 2020	$/1000 gal	821,250	$ 0.61	$ 500,963	
Shallow Wells	$/1000 gal	1,460,000	$ 1.09	$ 1,589,940	
Residuals	$/1000 gal	152,388	$ 4	$ 609,550	
					$ 2,700,000
Home Softening					
Salt/Equipment/Replacment	$/customer/yr	13,683	$ 209	$ 2,859,747	
					$ 2,860,000
Transmission					
Operation and Maintenance	$/lf/yr	137,280	$ 0.52	$ 71,386	
					$ 71,386
Alternative 1 Total O&M ($/yr.)					**$ 6,400,000**

PRESENT WORTH (6%, 20 yrs)	**$ 73,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 101,000,000**
Total Present Worth (6%, 20 years)	**$ 272,000,000**
Total Present Worth (6%, 50 years)	**$ 300,000,000**

Alternative 2 - Lake Michigan Supply - Hypothetical Low Demand

From Oak Creek. Return to Root River.

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Lake Michigan Supply Pump Station (27th and Puetz Rd)			
14 mgd	1	$ 7,402,500	$ 7,403,000
Lake Michigan Supply Pipeline			
19 miles of 30"	100,320	$ 429	$ 43,084,000
Return Pump Station and Pipeline to Root River (60th and Oakwood)			
14 mgd	1	$ 7,580,120	$ 7,581,000
20.1 miles of 30"	106,128	$ 382	$ 40,578,000
Distribution System Improvements			
5 mi of 24" pipes	24,800	$ 206	$ 5,109,000
Subtotal			**$ 103,755,000**
3% markup for Bonds & Insurance			$3,113,000
5% markup for Mob/Demob			$5,188,000
8% markup for Contractors Overhead			$8,965,000
4% markup for Contractors profit			$4,483,000
25% Contingency			$31,376,000
Subtotal Markups and Contingency			**$ 53,125,000**
Total Project Construction Costs			**$ 156,880,000**
8% allowance for engineering and design			$12,551,000
12% allowance for permitting, legal and admin.			$18,826,000
8% allowance for engr services during construction			$12,551,000
Subtotal Other Project Costs			**$43,928,000**

TOTAL PROJECT CAPITAL COST **$ 201,000,000**

Alternative 2 - Lake Michigan Supply - Hypothetical Low Demand

Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	Ext. Cost	Total
Purchased water	$/1000 gal	3,102,500	$ 1.830	$ 5,677,575	
					$ 5,678,000
Treatment/Pumping					
Lake Michigan Pumping Energy	$/kWh	5,198,145	$ 0.06	$ 311,889	
Lake Michigan Pump Station O&M	%	$ 7,403,000	2%	$ 148,060	
Return Flow Pumping Energy	$/kWh	6,127,469	$ 0.06	$ 367,648	
Return Flow Pump Station O&M	%	$ 7,581,000	2%	$ 151,620	
					$ 979,000
Transmission					
Operation and Maintenance	$/lf/yr	142,560	$ 0.52	$ 74,131	
					$ 74,131
Alternative 1 Total O&M ($/yr.)					**$ 6,700,000**

PRESENT WORTH (6%, 20 yrs)	**$ 77,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 106,000,000**
Total Present Worth (6%, 20 years)	**$ 278,000,000**
Total Present Worth (6%, 50 years)	**$ 307,000,000**

Alternative 3 - Fox Alluvium and Shallow Aquifer - Hypothetical Low Demand

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Shallow Aquifer Wellfield			*2013 Costs*
Well houses and pumps	9	$ 334,500	$ 3,010,500
Land, acres	9	$ 178,416	$ 1,606,000
Roads, ft	26,400	$ 27.9	$ 736,560
Interconnecting pipe, 8" to 20", ft	26,400	$ 185	$ 4,870,800
Electrical (10% of well houses, pumps, land)	$ 4,616,500	10%	$ 462,000
Fox River Alluvium Wellfield			
Well houses and pumps	$ 4	$ 805,000	$ 3,220,000
Land, acres	$ 4	$ 276,000	$ 1,104,000
Roads, ft	4,600	$ 27.9	$ 128,340
Interconnecting pipe, 12" to 16", ft	4,600	$ 172	$ 791,200
Electrical (10% of well houses, pumps, land)	$ 4,324,000	10%	$ 432,000
Treatment Plant and Pump Station			
One lime softening surface water treatment plant @ 14 mgd	14,000,000	$ 4.50	$ 63,000,000
Distribution System Improvements			
7 mi of 16", 20", 24", and 30" pipes	36,800	$ 525	$ 19,320,000
Wastewater Forcemain			
5 mi of 6" forcemain, ft	26,400	$ 141	$ 3,715,000
Subtotal			**$ 102,396,400**
3% markup for Bonds & Insurance			$3,072,000
5% markup for Mob/Demob			$5,120,000
8% markup for Contractors Overhead			$8,848,000
4% markup for Contractors profit			$4,424,000
25% Contingency			$30,966,000
Subtotal Markups and Contingency			**$ 52,430,000**
Total Project Construction Costs			**$ 154,826,400**
8% allowance for engineering and design			$12,387,000
12% allowance for permitting, legal and admin.			$18,580,000
8% allowance for engr services during construction			$12,387,000
Subtotal Other Project Costs			**$43,354,000**

TOTAL PROJECT CAPITAL COST **$ 198,000,000**

Alternative 3 - Fox Alluvium and Shallow Aquifer - Hypothetical Low Demand

Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	$/yr	Total
Wells Pumping/Maintenance	$/1000 gal	3,102,500	$ 0.140	$ 434,350	
					$ 434,000
Treatment/Pumping					
Lime Softening Water Treatment Plant	$/1000 gal	3,102,500	$ 2.17	$ 6,732,425	
Residuals	$/1000 gal	62,050	$ 4	$ 248,200	
					$ 6,981,000
Transmission					
Operation and Maintenance	$/lf/yr	108,281	$ 0.52	$ 56,306	
					$ 56,306
Alternative 1 Total O&M ($/yr.)					**$ 7,500,000**

PRESENT WORTH (6%, 20 yrs)	**$ 86,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 118,000,000**
Total Present Worth (6%, 20 years)	**$ 284,000,000**
Total Present Worth (6%, 50 years)	**$ 316,000,000**

Alternative 4 - Lake Michigan and Shallow wells - Hypothetical Low Demand

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Shallow Aquifer Wellfield			*2013 Costs*
Well houses and pumps	8	$ 334,500	$ 2,676,000
Land, acres	8	$ 178,416	$ 1,427,000
Roads, ft	21,120	$ 27.9	$ 589,248
Interconnecting pipe, 8" to 20", ft	21,120	$ 185	$ 3,896,640
Electrical (10% of well houses, pumps, land)	$ 4,103,000.00	10%	$ 410,000
Shallow Aquifer Supply Pipeline to Waukesha			
11 mi of 24" pipe	58,080	$ 357	$ 20,707,000
Shallow Aquifer Treatment Plant and Pump Station			
One groundwater treatment plant @ 14 mgd	14,000,000	$ 1.75	$ 24,500,000
Land	1	$ 2,230,000	$ 2,230,000
Lake Michigan Supply Pump Station (27th and Puetz Rd)			
7.6 mgd	1	$ 4,971,000	$ 4,971,000
Lake Michigan Supply Pipeline			
19 miles of 24"	100,320	$ 357	$ 35,766,000
Return Pump Station and Pipeline to Root River (60th and Oakwood)			
7.6 mgd	1	$ 5,341,000	$ 5,341,000
20.1 miles of 24"	106,128	$ 318	$ 33,749,000
Distribution System Improvements			
4.3 mi of 16", 24", and 30" pipes	22,500	$ 413	$ 9,289,000
Wastewater Forcemain			
5 mi of 6" forcemain, ft	26,400	$ 141	$ 3,715,000
Subtotal			**$ 149,266,888**
3% markup for Bonds & Insurance			$4,479,000
5% markup for Mob/Demob			$7,464,000
8% markup for Contractors Overhead			$12,897,000
4% markup for Contractors profit			$6,449,000
25% Contingency			$45,139,000
Subtotal Markups and Contingency			**$ 76,428,000**
Total Project Construction Costs			**$ 225,694,888**
8% allowance for engineering and design			$18,056,000
12% allowance for permitting, legal and admin.			$27,084,000
8% allowance for engr services during construction			$18,056,000
Subtotal Other Project Costs			**$63,196,000**

TOTAL PROJECT CAPITAL COST **$ 289,000,000**

Alternative 4 - Lake Michigan and Shallow Wells - Hypothetical Low Demand

Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	Ext. Cost	Total
Purchased water	$/1000 gal	1,642,500	$ 1.830	$ 3,005,775	
Shallow Well Pumping/Maintenance	$/1000 gal	1,460,000	$ 0.140	$ 204,400	
					$ 3,210,000
Treatment/Pumping					
Lake Michigan Pumping Energy	$/kWh	1,536,853	$ 0.06	$ 92,211	
Shallow Wells Pumping Energy	$/1000 gal	1,460,000	$ 1.09	$ 1,589,940	
Residuals	$/1000 gal	142,350	$ 4.00	$ 569,400	
Return Flow Pumping Energy	$/kWh	797,529	$ 0.06	$ 47,852	
Lake Michigan Pump Station O&M	%	$ 4,971,000	2%	$ 99,420	
Return Flow Pump Station O&M	%	$ 5,341,000	2%	$ 106,820	
					$ 2,506,000
Home Softening					
Salt/Equipment/Replacment	$/customer/yr	13,683	$ 116	$ 1,585,602	
					$ 1,586,000
Transmission					
Operation and Maintenance	$/lf/yr	137,280	$ 0.52	$ 71,386	
					$ 71,386
Alternative 1 Total O&M ($/yr.)					**$ 7,400,000**

PRESENT WORTH (6%, 20 yrs)	**$ 85,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 117,000,000**
Total Present Worth (6%, 20 years)	**$ 374,000,000**
Total Present Worth (6%, 50 years)	**$ 406,000,000**

Alternative 5 - Unconfined Deep Aquifer - Hypothetical Low Demand

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Unconfined Deep Aquifer Wellfield			*2013 Costs*
New wells @ 1.5 mgd each	9	$ 557,500	$ 5,017,500
Well houses and pumps	9	$ 334,500	$ 3,010,500
Land	9	$ 334,500	$ 3,010,500
Roads, ft	36,960	$ 27.9	$ 1,030,260
Interconnecting pipe, 12" to 24", ft	36,960	$ 167	$ 6,181,560
Electrical (10% of well houses, pumps, and land)	11,038,500	10%	$ 1,103,850
Unconfined Deep Aquifer Supply Pipeline to Waukesha			
15 miles 36", rural	79,200	$ 390	$ 30,907,800
5 miles 36", urban	26,400	$ 669	$ 17,661,600
Unconfined Deep Aquifer Treatment Plant and Pump Station			
One @ 14 mgd	14,000,000	$ 2.15	$ 30,100,000
Land	1	$ 1,115,000	$ 1,115,000
Distribution System Improvements			
4.3 mi of 16", 24", and 30" pipes	22,500	$ 413	$ 9,289,000
Wastewater Forcemain			
5 mi of 6" forcemain, ft	26,400	$ 141	$ 3,715,000
Subtotal			**$ 112,142,570**
3% markup for Bonds & Insurance			$3,365,000
5% markup for Mob/Demob			$5,608,000
8% markup for Contractors Overhead			$9,690,000
4% markup for Contractors profit			$4,845,000
25% Contingency			$33,913,000
Subtotal Markups and Contingency			**$ 57,421,000**
Total Project Construction Costs			**$ 169,563,570**
8% allowance for engineering and design			$13,566,000
12% allowance for permitting, legal and admin.			$20,348,000
8% allowance for engr services during construction			$13,566,000
Subtotal Other Project Costs			**$47,480,000**

TOTAL PROJECT CAPITAL COST **$ 217,000,000**

Alternative 5 - Unconfined Deep Aquifer - Hypothetical Low Demand

Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	$/yr	Total
Wells Pumping/Maintenance	$/1000 gal	3,102,500	$ 0.350	$ 1,085,875	
					$ 1,086,000
Treatment/Pumping					
Groundwater Water Treatment Plant	$/1000 gal	3,102,500	$ 0.50	$ 1,551,250	
Residuals	$/1000 gal	62,050	$ 4	$ 248,200	
					$ 1,799,000
Home Softening					
Salt/Equipment/Replacment	$/customer/yr	13,683	$ 209	$ 2,859,747	
					$ 2,860,000
Transmission					
Operation and Maintenance	$/lf/yr	137,280	$ 0.52	$ 71,386	
					$ 71,386
Alternative 1 Total O&M ($/yr.)					**$ 5,800,000**

PRESENT WORTH (6%, 20 yrs)	**$ 67,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 91,000,000**
Total Present Worth (6%, 20 years)	**$ 284,000,000**
Total Present Worth (6%, 50 years)	**$ 308,000,000**

Alternative 6 - Multiple Sources - Hypothetical Low Demand

Capital Cost at 14 mgd

	Quantity	Unit Cost	Total
Deep Well Treatment Plant			
3 RO plants for Wells 6,8,10 @ 5.35 mgd including land built in 2020	5,350,000	$ 4.57	$ 24,460,000
Shallow Aquifer Water Treatment Plant			
One @ 3.8 mgd	3,800,000	$ 4.25	$ 16,150,000
5 mi of 6" forcemain, ft	26,400	$ 141	$ 3,715,000
Land	1	$ 2,230,000	$ 2,230,000
Shallow Aquifer Wellfield			
new wells and wellhouses @ 1.5 mgd each	5	$ 780,500	$ 3,902,500
Land	5	$ 278,750	$ 1,393,750
Roads, ft	17,560	$ 27.9	$ 489,485
Interconnecting pipe, 12", ft	20,560	$ 161	$ 3,301,114
Electrical (10% of well houses, pumps, and land)	5,296,250	10%	$ 529,625
Shallow Aquifer Supply Pipeline to Waukesha			
10 miles of 16 " for 4 mgd	52,800	$ 262	$ 13,834,920
Unconfined Deep Aquifer Treatment Plant			$ -
One @ 3.2 mgd	3,200,000	$ 2	$ 7,136,000
Land	1	$ 557,500	$ 557,500
Unconfined Deep Aquifer Wellfield			
3 new wells and wellhouses @ 1.5 mgd each	3	$ 1,338,000	$ 4,014,000
Land	3	$ 334,500	$ 1,003,500
Roads, ft	10,560	$ 28	$ 294,360
Interconnecting pipe, 12", ft	10,560	$ 161	$ 1,695,514
Electrical (10% of well houses, pumps, and land)	5,017,500	10%	$ 501,750
Unconfined Deep Aquifer Supply Pipeline to Waukesha			
12 miles 20", rural	63,360	$ 201	$ 12,716,352
5 miles 20 ", urban	26,400	$ 368	$ 9,713,880
Quarry Water Treatment Plant			$ -
intakes @ 2 mgd each	-	$ 1,672,500	$ -
Intake pump stations	-	$ 557,500	$ -
Land	-	$ 557,500	$ -
One water plant @ 5 mgd	-	$ 4	$ -
4" Sludge pipeline	-	$ 85	$ -
Quarry Supply Pipeline to Waukesha			
7 miles 16", rural	-	$ 158	$ -
Silurian Dolomite Aquifer Treatment Plant			
One @ 2 mgd	2,000,000	$ 2.23	$ 4,460,000
Land	1	$ 557,500	$ 557,500
Silurian Dolomite Aquifer Wellfield			$ -
5 new wells and wellhouses @ .5 mgd each	5	$ 780,500	$ 3,902,500
Land	5	$ 334,500	$ 1,672,500
Roads, ft	10,560	$ 27.9	$ 294,360
Interconnecting pipe, 6", ft	21,120	$ 80.3	$ 1,695,514
Interconnecting pipe, 12", ft	10,560	$ 81.4	$ 859,531
Electrical (10% of well houses, pumps, and land)	5,575,000	10%	$ 557,500
Silurian Dolomite Aquifer Supply Pipeline to Waukesha			
2 mile 12 ", urban	10,560	$ 191	$ 2,013,422
Distribution System Improvements			

4.3 mi of 16", 24", and 30" pipes	22,704	$ 413	$ 9,373,000
2.7 mi of 16" pipe for blending, ft	14,256	$ 323	$ 4,605,000
Subtotal			**$ 137,630,076**
3% markup for Bonds & Insurance			$4,129,000
5% markup for Mob/Demob			$6,882,000
8% markup for Contractors Overhead			$11,892,000
4% markup for Contractors profit			$5,946,000
25% Contingency			$41,620,000
Subtotal Markups and Contingency			**$ 70,469,000**
Total Project Construction Costs			**$ 208,099,076**
8% allowance for engineering and design			$16,648,000
12% allowance for permitting, legal and admin.			$24,972,000
8% allowance for engr services during construction			$16,648,000
Subtotal Other Project Costs			**$58,268,000**

TOTAL PROJECT CAPITAL COST **$ 266,000,000**

Alternative 6 - Multiple Sources - Hypothetical Low Demand

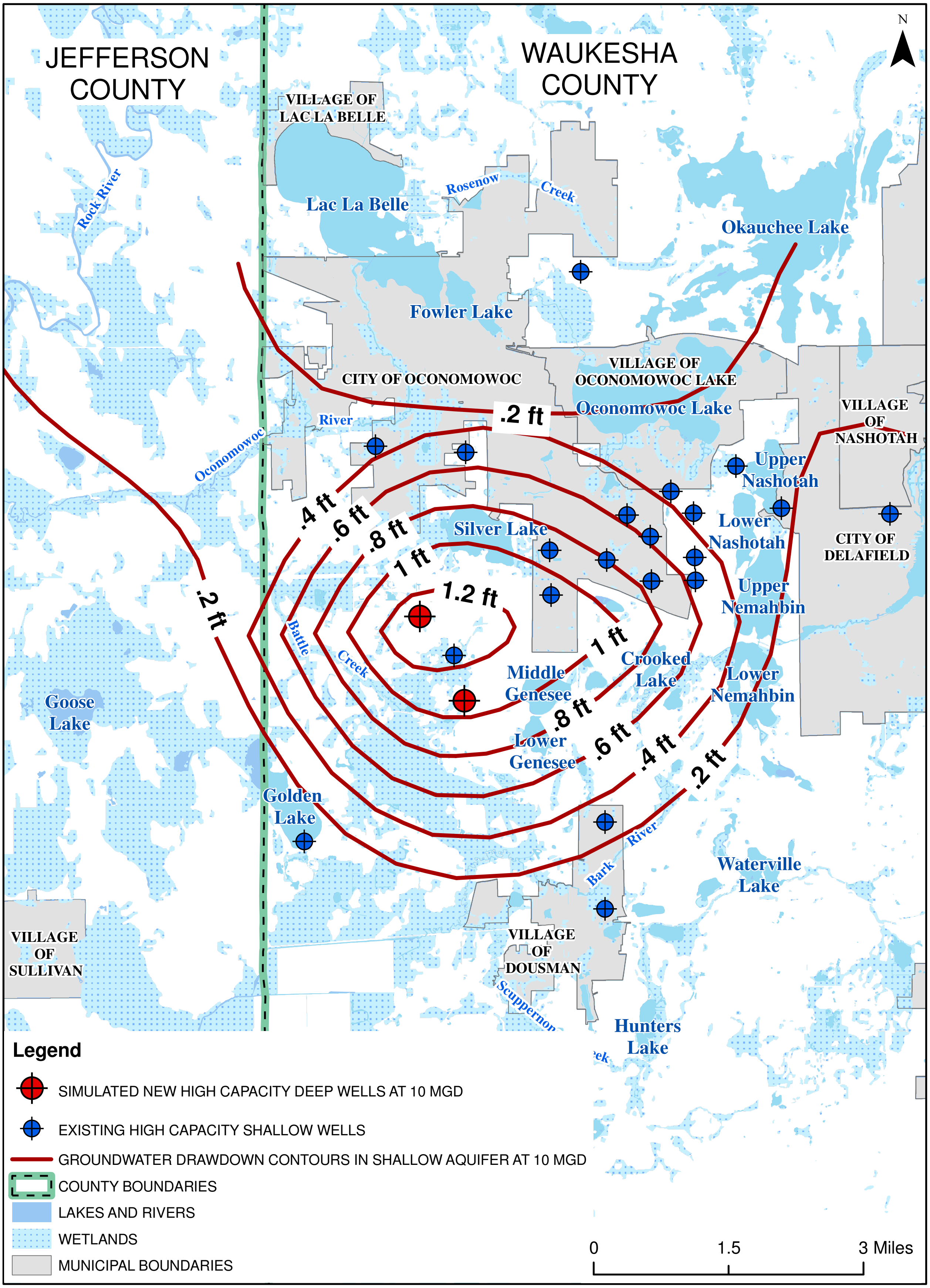
Operating and Maintenance Cost at 8.5 mgd

Source of Supply	Units	Quantity	Unit Cost	$/yr	Total
Deep Well pumping/maintenance	$/1000 gal	1496500	$ 0.35	$ 523,775	
Shallow Well Pumping/Maintenance	$/1000 gal	1168000	$ 0.14	$ 163,520	
Quarry pumping/Maintenance	$/1000 gal	0	$ 0.14	$ -	
Dolomite well pumping/Maintenance	$/1000 gal	438000	$ 0.14	$ 61,320	
					$ 749,000
Treatment/Pumping					
Deep Wells 6,7,8 starting in 2020	$/1000 gal	821,250	$ 0.61	$ 500,963	
Shallow Wells and Quarry	$/1000 gal	1,168,000	$ 1.11	$ 1,296,480	
Unconfined Wells	$/1000 gal	730,000	$ 0.50	$ 365,000	
Residuals	$/1000 gal	92162.5	$ 4	$ 368,650	
Dolomite Wells	$/1000 gal	438,000	$ 0.50	$ 219,000	
					$ 2,750,000
Home Softening					
Salt/Equipment/Replacment	$/customer/yr	13,683	$ 209	$ 2,859,747	
					$ 2,860,000
Transmission					
Operation and Maintenance	$/lf/yr	290,400	$ 0.52	$ 151,008	
					$ 151,008
Alternative 1 Total O&M ($/yr.)					**$ 6,500,000**

PRESENT WORTH (6%, 20 yrs)	**$ 75,000,000**
PRESENT WORTH (6%, 50 yrs)	**$ 102,000,000**
Total Present Worth (6%, 20 years)	**$ 341,000,000**
Total Present Worth (6%, 50 years)	**$ 368,000,000**

Attachment C

Drawdown Contours Shallow Aquifer at 10 mgd with Wetlands



JEFFERSON COUNTY
WAUKESHA COUNTY
N
VILLAGE OF LAC LA BELLE
Lac La Belle
Rosenow
Creek
Okauchee Lake
Rock River
Fowler Lake
CITY OF OCONOMOWOC
VILLAGE OF OCONOMOWOC LAKE
Oconomowoc Lake
River
Oconomowoc
VILLAGE OF NASHOTAH
Upper Nashotah
Lower Nashotah
CITY OF DELAFIELD
Upper Nemahbin
Lower Nemahbin
Silver Lake
.2 ft
.4 ft
.6 ft
.8 ft
1 ft
1.2 ft
Battle
Creek
Middle Genesee
Lower Genesee
Crooked Lake
Goose Lake
Golden Lake
Bark
River
Waterville Lake
VILLAGE OF SULLIVAN
VILLAGE OF DOUSMAN
Scuppernong
Hunters Lake
Legend
SIMULATED NEW HIGH CAPACITY DEEP WELLS AT 10 MGD
EXISTING HIGH CAPACITY SHALLOW WELLS
GROUNDWATER DRAWDOWN CONTOURS IN SHALLOW AQUIFER AT 10 MGD
COUNTY BOUNDARIES
LAKES AND RIVERS
WETLANDS
MUNICIPAL BOUNDARIES
0
1.5
3 Miles

Attachment D

Wakesha Wells Modeling Data

Attachment D

Troy Bedrock Valley Groundwater Modeling Summary

								See Exhibit 11-18		See Exhibit 11-19	
						Deep and Shallow Aquifers Alternative, Total Pumping in Shallow of 6.4 mgd		Shallow Aquifer and Fox River Alluvium Alternative, Total Pumping in Shallow of 10.9 mgd		Shallow Aquifer and Fox River Alluvium Alternative, Total Pumping in Shallow of 10.9 mgd Using more Wells	
						RUN 1-2		RUN 2-1		RUN 2-2	
	Well Depth (ft)	Layer the Well is Pumping From	Elevation of the Layers 4 & 5 (ft)		Overall Thickness of Glacial Sediments - Ground Surface to Bottom of Layer 5 (ft)	Drawdown Below Base of Layer 4 (yes/no)	Drawdown Below Base of Layer 5 (yes/no)	Drawdown Below Base of Layer 4 (yes/no)	Drawdown Below Base of Layer 5 (yes/no)	Drawdown Below Base of Layer 4 (yes/no)	Drawdown Below Base of Layer 5 (yes/no)
			c					e	e	e	e
WELL	**a**	**b**	**Top of Layer 4**	**Bottom of Layer 5**	**d**						
L-1	206	4 & 5	718	604	216	NO	NO	YES	YES	NO	NO
L-2	222	4 & 5	698	578	232	NO	NO			NO	NO
L-3	237	4 & 5	678	553	247	NO	NO	NO	NO	NO	NO
L-4	228	4 & 5	684	562	238	NO	NO			NO	NO
L-5	207	4 & 5	702	583	217	NO	NO	NO	NO	NO	NO
FRA-1	159	4 & 5	739	631	169			YES	YES	NO	NO
FRA-2	170	4 & 5	735	620	180					NO	NO
FRA-3	153	4 & 5	746	637	163			YES	YES	NO	NO
FRA-4	142	4 & 5	753	648	152			YES	YES	NO	NO
T-1	276	4 & 5	691	514	286	NO	NO			NO	NO
T-2	263	4 & 5	704	537	273	NO	NO	NO	NO	NO	NO
T-3	292	4 & 5	682	498	302	NO	NO	NO	NO	NO	NO
T-4	169	4 & 5	742	651	179	NO	NO			NO	NO
T-5	180	4 & 5	731	640	190	NO	NO	NO	NO	NO	NO
T-6	190	4 & 5	731	640	200	NO	NO	NO	NO	NO	NO
T-7	188	4 & 5	714	622	198	NO	NO			NO	NO
T-8	313	4 & 5	749	527	323	NO	NO			NO	NO
T-9	317	4 & 5	738	503	327	NO	NO			NO	NO
T-10	377	4 & 5	768	508	387					NO	NO
T-11	332	4 & 5	713	578	342					NO	NO
T-12	340	4 & 5	714	580	350					NO	NO
T-13	397	4 & 5	581	443	407					NO	NO
T-14	341	4 & 5	634	529	351					NO	NO
T-15	323	4 & 5	696	557	333					NO	NO
T-16	341	4 & 5	588	489	351					NO	NO
T-17	330	4 & 5	641	550	340					NO	NO
T-18	205	4 & 5	696	605	215					NO	NO
T-19	256	4 & 5	695	604	266					NO	NO
T-20	322	4 & 5	639	548	332					NO	NO