Simulating Impacts of Increased Stomatal Closure under Future CO_2 Concentrations in the Menomonee River Watershed Climate Response Model

Prepared for

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1 Introduction

Future changes in climate may affect watershed health in a variety of ways, including complex interactions among forcing variables. Some impacts are intuitively obvious: If precipitation increases, runoff is likely to increase; while, if air temperature increase, evapotranspiration is likely to increase. If both precipitation and air temperature change the net effect on watersheds is a balance between competing processes and less easy to deduce from first principles. Indirect effects on plant growth of changes in nutrient availability or CO_2 concentrations can also exert a strong influence on the water balance. Watershed simulation models are used to evaluate the net results of such changes; however, the results that are obtained can be strongly constrained by the structure of the models. For example, watershed models that do not explicitly model plant growth may omit significant impacts on the water balance.

This paper examines the potential influence of increased CO_2 concentrations, which may reduce evapotranspiration by plants, on future climate watershed response modeling conducted in southeastern Wisconsin. The work includes development of methods to incorporate CO_2 impacts on evapotranspiration into a physically based modeling framework that does not explicitly model plant growth.

1.1 Menomonee River Climate Response Modeling

The National Oceanic and Atmospheric Administration (NOAA) is sponsoring a study entitled "Evaluating Climate Change Risks and Impacts on Urban Coastal Water Resources in the Great Lakes." This project is a collaborative effort involving the University of Wisconsin-Milwaukee Great Lakes WATER Institute, the University of Wisconsin-Milwaukee Department of Civil Engineering and Mechanics, the University of Wisconsin-Madison Center for Climate Research, and the Southeastern Wisconsin Regional Planning Commission (SEWRPC). The overall objective of this project is to create a decision support tool for understanding climate impacts on water resources within the greater Milwaukee watersheds. The results of this project will be disseminated through the Wisconsin Initiative on Climate Change Impacts Milwaukee Working Group to both water resources managers for planning purposes, and the public to increase awareness of the potential consequences of climate change.

The overall analysis includes simulation of both the Greater Milwaukee watersheds draining to Lake Michigan and the receiving waters in Lake Michigan. Tetra Tech undertook the analysis of climate impacts on watershed processes using a calibrated HSPF (Bicknell et al., 2005) watershed simulation model that had previously been developed and subjected to extensive calibration in support of the *Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (SEWRPC, 2007). This well-established and EPA-supported model provides a detailed simulation of various components of the water balance, as well as water quality. Multiple models were developed for all the greater Milwaukee watersheds, including a model of the Menomonee River, which represents a gradient from rural to densely urban land and was selected for further analysis here. The Menomonee River simulation was conducted with a 15-min time step and calibrated to a baseline period from 1988 through 1997.

Potential climate impacts are estimated based on expected conditions at mid-century (from 2046 through 2065). The envelope of potential impacts is estimated by comparing "best case" and "worst case" climate change conditions for rainfall, air temperature, and potential evapotranspiration to current conditions, where current conditions are represented by the 1988 through 1997 meteorological time series. To provide a consistent basis for comparison, the future weather series were based on perturbations of the 1987 – 1997 time series (allowing a year for model spin-up). Specifically, the UW-Madison Center for Climate Research created downscaled versions of 1987 – 1997 precipitation and temperature representing the 10^{th} percentile and 90^{th} percentile of predicted climate statistics for mid-century under the A1B emissions scenario (which projects emissions for a future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technology). The underlying ensemble is derived from the suite of archived output from 14 general circulation models (GCMs) contained in the World Climate Research Programme's (WCRP's) CMIP3 multi-model dataset, statistically downscaled to the local scale using the CRU CL 2.0 20th century climate dataset. Results were provided at a 15-minute time step. Potential evapotranspiration (PET) was computed using the Penman Pan Evaporation formula along with some localized monthly adjustments.

The climate models are generally in agreement that spring rainfall will increase in the Milwaukee area. The "best case" (10^{th} percentile) and "worst case" (90^{th} percentile) scenarios for mid-century were defined relative to the spring rainfall thresholds associated with SSO and CSO events over the past ten years (McLellan et al., 2011). Specifically, the choice of a particular distribution for rescaling the historical precipitation and temperature records was based on interpolating the two models closest to the upper 90^{th} percentile and the two closest to the lower 10^{th} percentile for increases in the number of spring precipitation events larger than 1 inch in 24 hours. The 10^{th} percentile ("best case") simulations are based on a 50/50 blend of ipsl_cm4 and csiro_mk3_0; the 90^{th} percentile ("worst case") simulations are based on a 50/50 blend of the miub_echo_g and microc3_2_hires simulations. The future time series were created from observed data using a remapping approach in which the gridded climate output is related to the probability density function of temperature and precipitation at a point meteorological station and the time-mean cumulative distribution function for the present and future conditions is used to map percentiles between present and future. This approach allows the future time series to incorporate any changes in the probability distribution that are predicted by the GCM, such as a higher frequency of intense rainfall events.

For the watershed model application, the two scenarios represent an increase of from 5.6 to 8.7 degrees Fahrenheit in annual average temperature relative to the 1988-1997 baseline (Table 1). While the two scenarios were selected to describe the potential range of frequency of large spring rainfall events, the resulting differences in annual average precipitation are small. On the other hand, PET is estimated to increase by 25 to 38 percent, with predictions for a more arid future in which average annual PET exceeds precipitation.

Table 1. Comparison of 2050 Climate Scenarios to 1988 – 1997 Baseline

	Baseline (1988 – 1997)	10^{th} Percentile ("Best Case")	90^{th} Percentile ("Worst Case")
Precipitation (in/yr)	32.5	33.2	33.4
Average Temperature (°F)	47.7	53.3	56.4
Potential Evapotranspiration (in/yr)	30.4	37.5	42.1

In application of the HSPF model, significant decreases in annual flow are predicted for both the "best" and "worst" case climate scenarios for 2050. This occurs because PET is predicted to increase at a much faster rate than precipitation. In many, but not all cases, annual pollutant load is also predicted to decrease due to lower total volumes of storm runoff. This is offset by the observation that both the "best" and "worst" case scenarios predict an increase in the frequency of large spring rainfall events – resulting in less total storm runoff but more high runoff events. The predicted effects on total suspended solids (TSS) loads reflect the complex interplay between upland loading rates and channel scour/resuspension events.

Effects on pollutant concentration reflect the combined impact of changes in flow and load. If both flow and load decrease, average concentration can go up or down depending on which component changes more. For TSS, there is a tendency in the more urban parts of the Menomonee River for average concentrations to increase while the median concentration decreases. This reflects a situation in which concentrations are generally predicted to decrease in the future, but the averages are higher due to a small number of large, scouring events.

1.2 CO_2, STOMATAL CLOSURE, AND THE WATER BALANCE

The HSPF model does not include a plant growth module, and thus does not automatically adjust the simulation for the effects of increased CO_2 on plant growth. IPCC estimates of future atmospheric CO_2 concentrations under the assumptions of the A1B emissions scenario (the basis of climate and land use change scenarios in this study) call for an increase from 369 ppmv CO_2 in 2000 to about 532 ppmv (using the ISAM model reference run) or 522 ppmv (using the Bern-CC model reference run) in 2050 (Appendix II in IPCC, 2001). Plants require CO_2 from the atmosphere for photosynthesis. An important effect of CO_2 fertilization is increased stomatal closure, as plants do not need to transpire as much water to obtain the CO_2 they need for growth. This effect can potentially counterbalance projected increases in temperature and potential evapotranspiration (PET). It may also reduce water stress on plants, resulting in greater biomass and litter production, which in turn will influence pollutant loads.

In the past it has been argued that these effects, long documented at the leaf and organism level, might not translate to true ecosystem effects. However, recent research, particularly the FACE experiments summary (Leakey et al., 2009) seems to confirm that significant ET reductions do occur at the ecosystem level under CO_2 fertilization. Although there are differences in responses among plant species, with lesser effects with C_4 photosynthesis, the magnitude of the response to CO_2 levels projected by the mid-21st century appears to be on the order of a 10 percent reduction in ET response (e.g., Bernacchi et al., 2007). Further, a recent study by Cao et al. (2010) suggests that up to 25 percent of the temperature increase projected for North America could result directly from decreased plant ET under increased CO_2 concentrations.

To assess the sensitivity of streamflow and water quality endpoints to the effects of increased atmospheric CO_2 concentrations, we performed sets of SWAT model (Neitsch et al., 2005) simulations with and without CO_2 fertilization for five large watersheds (Apalachicola-Chattahoochee-Flint, Salt-San Pedro-Verde, Minnesota River, Susquehanna, and Willamette) as part of a study for the EPA ORD Global Change Research Program (Johnson et al., 2012). SWAT simulates plant growth and models the effect of CO_2 fertilization on stomatal conductance using the equation developed by Easterling et al. (1992), in which increased CO_2 leads to decreased leaf conductance, which in turn results in an increase in the canopy resistance term in the PET calculation. The model also simulates the change in radiation use efficiency of plants as a function of CO_2 concentration using the method developed by Stockle et al. (1992). Simulations for the five watersheds suggest increases in mean annual flow from 3 to 38 percent due to increased CO_2, with a median of 11 percent, in the same range as the results summarized by Leakey et al. (2009). Simulations also suggest CO_2 fertilization results in increased pollutant loads. Loads of TSS show increases from 3 to 57 percent, with a median of 15 percent. TP loads increase from zero to 29 percent, with a median of 6 percent. TN loads increase from zero to 34 percent, with a median of 6 percent. The large increases in TSS load indicate that the effects of higher runoff under CO_2 fertilization (largely due to greater soil moisture prior to rainfall events) may outweigh benefits associated with greater ground cover.

2 Methods

2.1 HSPF Native Implementation of Evapotranspiration

HSPF does not include a plant growth model that can automatically respond to changes in CO_2 concentrations; however, the discussion in the previous section indicates that incorporating such responses is important. To plan how best to implement this adjustment it is useful to first discuss how HSPF handles evapotranspiration.

In HSPF, time series of PET are an externally specified input to the model. PET is used to evaluate evaporative losses from impervious surfaces, from free water surfaces, and from pervious land units. The first two cases are straightforward. For pervious land units, both surface evaporation and plant transpiration are important. The model first allocates potential evaporation in the following order (Bicknell et al., 2005):

1. Active groundwater discharge to streams (to the extent allowed by the parameter BASETP),
2. Interception storage in the canopy,
3. Storage in the upper soil/litter zone, and
4. Active groundwater storage in land units where the water table is at or above the surface (e.g., wetlands).

Remaining PET is then applied to moisture storage in the lower soil zone (defined as the root zone of the soil profile), representing transpiration by rooted plants. The ET from the lower soil zone is modified by the parameter LZETP, which can vary throughout the year. If LZETP is equal to one, representing near complete areal coverage of deep rooted vegetation with unlimited leaf area, then the potential ET for the lower soil zone is equal to the demand that remains. However, this is usually not the case. Further, the actual ET can be limited by tension as water storage declines. HSPF represents this through use of an empirical probability density function in which the maximum lower zone ET (when PET is not limiting) per simulation interval is calculated as

$$\frac{0.125}{1-LZETP}\cdot\frac{LZS}{LZSN}\cdot\frac{DELT60}{24},$$

where *LZS* is the current lower zone storage (depth), *LZSN* is the lower zone nominal storage parameter (depth), and *DELT60* is the number of hours in a simulation interval. *LZETP* is restricted to the range of 0 – 1 and typically assigned within the range 0.1 – 0.9 (USEPA, 2000).

In practice, LZETP can be considered to behave like an ET crop coefficient (USEPA, 2000) that reflects density of vegetation, depth of the root zone, and seasonally changing leaf area development.

In the specific case of the Milwaukee 2020 models, PET is calculated by the Penman Pan method (Penman, 1948) modified by a pan coefficient that converts Class A pan evaporation to free water surface evaporation. The portion of PET that is applied to plant transpiration is then modified by a crop coefficient.

2.2 HSPF Modifications: Theoretical Basis

Under a future climate, increased CO_2 concentration will not, directly of itself, alter evaporation from water surface stores. Therefore, the PET time series itself should not be altered to account for stomatal closure effects. Instead, only the portion of ET calculated for the lower soil zone should be modified to reflect decreased transpiration. That is, the modification should be made through changes to the LZETP parameters in HSPF.

As seen above, the relationship between lower zone ET capacity and LZETP is non-linear. However, an adjustment to reflect a fractional change in actual ET (as a result of increased CO_2) can readily be calculated. Suppose τ is the ratio between actual ET calculated after accounting for increased CO_2 (AET_1) and that calculated without accounting for increased CO_2 (AET_0). If the long term effect of varying LZETP on the remaining water storage at a point in time, LZS, is ignored, then

$$\tau = \frac{AET_1}{AET_0} = \frac{1/(1 - LZETP_1)}{1/(1 - LZETP_0)} = \frac{1 - LZETP_0}{1 - LZETP_1}.$$

From this we can solve to determine that $LZETP_1$ – the modified value of the parameter to achieve the ratio τ – should be set (enforcing an appropriate minimum value) to

$$Max\left\{ LZETP_1 = 1 - \frac{1 - LZETP_0}{\tau}, 0.1 \right\}.$$

For example, if the model originally had $LZETP_0 = 0.7$ and we wish to apply an adjustment $\tau = 0.85$, the resulting value of the parameter is $LZETP_1 = 0.65$, which is slightly greater than the simple product 0.7 x 0.85 = 0.595.

2.3 Calculating the Adjustment Ratio

The Penman Pan equation is an energy balance approach to evaporation (mm/d) from a Class A evaporation pan, which takes the form

$$E_P = \frac{Q\Delta + E_a \gamma}{\Delta + \gamma},$$

where Q is the net radiation exchange (further expanded in practical applications as a function of air temperature and solar radiation), Δ is the slope of the saturation vapor pressure curve (which varies as a function of air temperature), E_a (mm/d) is a function of vapor pressure deficit and wind travel, and γ is the psychrometric constant (kPa/°K; which varies as a function of elevation).

A full energy balance analysis of ET from plants takes a similar form, based on Monteith's (1965) insights into the use of the resistance concept to descript stomatal control over respiration and known as the "full form" Penman-Monteith equation:

$$\lambda E_t = \frac{\Delta(R_n - G) + \rho_{air} \cdot c_p \cdot \left(e_z^0 - e_z\right)/r_a}{\Delta + \gamma \cdot \left(1 + r_c/r_a\right)}$$

in which λ is the latent heat of vaporization (MJ/kg), E_t is the maximum (non-water limited) evapotranspiration rate (mm/d), ρ_{air} is the density of air (kg/m^3), c_p is the specific heat of the air (MJ/kg-°C), e_z^0 is the saturation vapor pressure at elevation z (kPa), e_z is the actual vapor pressure at elevation z, r_a is the aerodynamic resistance (s/m), r_c is the plant canopy (stomatal) resistance (s/m), and γ is again the psychrometric constant (as kPa/°C). The second term in the numerator is further expanded under a range of assumptions concerning soil water supply and atmospheric stability into the form recommended by ASCE (Allen et al., 2005) and implemented by the SWAT model (Neitsch et al., 2005). The simplified form of the Penman-Monteith equation known as FAO 56 (Allen et al., 1998) makes a number of explicit assumptions to replace the resistance terms with a function of wind speed to yield an expression for evapotranspiration from a reference crop with assumed fixed height and stomatal resistance.

The important point from the perspective of evaluating the effect of increased CO_2 concentrations on PET is that actual ET (AET) varies as a function of $1/[\Delta + \gamma(1+r_c/r_a)]$ in the full Penman-Monteith equation.

As noted above, Easterling et al. (1992) developed an equation to express the canopy resistance as a function of CO_2 effects on stomatal closure as

$$r_{c1} = r_l \cdot \frac{1}{0.5\,LAI \cdot \left(1.4 - 0.4 \cdot \frac{CO_2}{330}\right)}$$

where r_l is the minimum effective stomatal resistance of a single leaf (s/m) and *LAI* is the leaf area index. This is the form implemented in SWAT (Neitsch et al., 2005). One caveat is that Easterling et al. developed this equation relative to a mean CO_2 concentration for the early 1990s of 330 ppmv, and adjustments may need to be made for a different starting baseline as CO_2 levels have increased.

As seen in the previous equation, canopy resistance has a seasonal component that depends on *LAI*; however, the correction to *LZETP* factors (which themselves incorporate the seasonal changes in *LAI*) depend only the ratio of future to current CO_2. The corrections should, however, be calculated on a month-by-month basis.

Interpretation is enhanced by referring to the simplifications of the FAO 56 reference crop version of the Penman-Monteith equation. In this form, r_c/r_a is replaced by 0.34 u_2, where u_2 is the wind speed at 2 m height (m/s). The reference crop equation was developed under the assumption of a hypothetical short crop of 0.12 m height with albedo of 0.23 and surface resistance of 70 s/m based on a stomatal resistance of an individual leaf of r_l = 100 s/m and a leaf area index (LAI) of 24 times the crop height and $r_c = r_l/(0.5$ LAI). Further, r_a is approximated as $208/u_2$, where u_2 is the wind speed at 2 m above ground. It is thus clear that the CO_2 effect on AET should be calculated by replacing the current condition r_{c0} with Easterling's modified estimate, r_{c1}, in the Penman-Monteith equation. As r_c appears only in the denominator of the Penman-Monteith equation, the ratio can be represented as:

$$\tau = \frac{AET_1}{AET_0} = \frac{(\Delta + \gamma\, r_a) + \gamma\, r_{c0}}{(\Delta + \gamma\, r_a) + \gamma\, r_{c1}}.$$

In this equation,

$$r_{c1} = \frac{r_{c0}}{\left(1.4 - 0.4 \frac{CO_2}{330}\right)}$$

The remaining terms are estimated, following FAO 56, as:

$$r_{co} = \frac{r_l}{0.5\,LAI} = 70,$$

$$r_a = 208/u_2,$$

$$\Delta = \frac{4098\left[0.6108 \exp\left(\frac{17.27\,T}{T + 273.3}\right)\right]}{(T + 273.3)^2}, \text{ and}$$

$$\gamma = 0.673645\left(\frac{293 - 0.0065\,z}{293}\right)^{5.26},$$

where T is air temperature (°C) and z is elevation (m).

It will be noted that Δ is a function of temperature and will thus change under future climates. However, it would be incorrect to include changes in Δ in the estimation of revised LZETP parameters. This is because the effects of changing temperature on PET via Δ are already incorporated in the Penman Pan PET time series, and varying it here would double-count the effect. Instead, τ should be calculated with Δ set to a single appropriate value for the month in both the numerator and denominator of the equation for τ. Because the intent is to isolate the effect of CO_2 increase from the effect of temperature increase, the monthly calculations of τ are based on current monthly average temperatures. Calculation of τ at higher future temperatures would result in a slightly smaller downward adjustment in LZETP.

3 Implementation for the Menomonee River

The methods described in Section 2 were applied to develop monthly adjustment factors for LZETP in the Menomonee River model under an increase of 197 ppmv in CO_2. Assuming an elevation of 203 m, γ = 0.065784 kPA/°C, while the increase in CO_2 yields $r_{c1} = 91.9586$.

Δ and r_a are estimated from existing monthly climate normals for air temperature and wind at elevation z = 6.096 m (20 ft) reported for Milwaukee, assuming a logarithmic profile where $u_2 = u_z \cdot 4.87/[\ln(67.8\ z - 5.42)]$. Estimates were interpolated to the first of each month consistent with the way that HSPF assigns the monthly parameters.

Table 2. Monthly Parameters for LZETP Adjustment

Month	u_2 (m/s)	T (°C)	Δ	r_a	τ
January	4.49	-0.81	0.042	46.31	0.869
February	4.49	-0.97	0.042	46.31	0.869
March	4.55	3.08	0.054	45.76	0.875
April	4.62	9.03	0.078	45.04	0.885
May	4.38	15.53	0.113	47.46	0.901
June	3.97	21.75	0.159	52.45	0.919
July	3.64	25.94	0.198	57.14	0.932
August	3.46	26.72	0.206	60.14	0.936
September	3.59	24.17	0.181	58.01	0.929
October	3.95	18.92	0.136	52.69	0.914
November	4.29	11.64	0.091	48.46	0.894
December	4.45	4.11	0.058	46.69	0.878

LZETP values at the start of each month were constrained to be at least 0.01. The values contained in the original calibrated model and those adjusted for the effects of increased CO_2 are shown in Table 3.

Table 3. LZETP Values at the Start of Each Month in Original Model and Adjusted for Increased CO_2

	Original LZETP					Revised LZETP				
Cover	Urban Grass	Forest	Crop	Pasture	Wetland	Urban Grass	Forest	Crop	Pasture	Wetland
Jan	0.010	0.100	0.010	0.010	0.050	0.010	0.010	0.010	0.010	0.010
Feb	0.010	0.100	0.010	0.010	0.050	0.010	0.010	0.010	0.010	0.010
Mar	0.100	0.200	0.010	0.100	0.050	0.010	0.085	0.010	0.010	0.010
Apr	0.100	0.250	0.050	0.100	0.300	0.010	0.152	0.010	0.010	0.209
May	0.250	0.500	0.150	0.250	0.500	0.167	0.445	0.056	0.167	0.445
Jun	0.650	0.750	0.750	0.550	0.900	0.619	0.728	0.728	0.510	0.891
Jul	0.750	0.750	0.850	0.650	0.900	0.732	0.732	0.839	0.624	0.893
Aug	0.750	0.750	0.850	0.650	0.900	0.733	0.733	0.840	0.626	0.893
Sep	0.600	0.500	0.550	0.500	0.800	0.569	0.462	0.516	0.462	0.785
Oct	0.250	0.250	0.100	0.100	0.500	0.179	0.179	0.015	0.015	0.453
Nov	0.100	0.150	0.050	0.050	0.150	0.010	0.049	0.010	0.010	0.049
Dec	0.100	0.050	0.010	0.010	0.030	0.010	0.010	0.010	0.010	0.010

The revised LZETP values were incorporated into the Menomonee River model, and the full model was re-run for both the 10^{th} percentile ("best case") and 90^{th} percentile ("worst case") 2050 climate scenarios developed on the 1988-1997 ten-year baseline run.

4 Results

4.1 HYDROLOGY

The model contains representations of different cover types on soils in SCS hydrologic soil groups ranging from low permeability (hydrologic soil group D) to moderately high permeability (hydrologic soil group B). As expected, modifications to the LZETP parameters to address CO_2 enrichment result in reduced lower zone ET and increased total runoff from upland pervious land segments. Results for the 90^{th} percentile scenario (Table 4) show a reduction in lower zone ET of from 6 to 8.5 percent on an annual basis compared to the simulation without correction for stomatal closure, while total runoff increases by from 3.6 to 6.6 percent. Results for the 10^{th} percentile scenario (Table 5) show slightly larger decreases in lower zone ET (6.7 to 8.9 percent) but slightly smaller increases in total runoff from the pervious land segments (3.5 to 5.7 percent).

Table 4. Changes in Lower Zone ET and Pervious Land Water Yield in Response to CO_2-modulated Stomatal Closure Representation for the 90th Percentile 2050 Climate Scenario

Pervious Land Segment	Lower Zone ET	Water Yield
Urban Grass - B soils	-8.19%	6.56%
Urban Grass - C soils	-8.11%	5.62%
Urban Grass - D soils	-7.90%	5.25%
Forest	-7.84%	6.09%
Crop - B soils	-6.21%	4.27%
Crop - C soils	-6.12%	3.76%
Crop - D soils	-6.04%	3.57%
Pasture - B soils	-8.63%	5.11%
Pasture - C soils	-8.46%	4.42%
Pasture - D soils	-8.30%	4.12%

Table 5. Changes in Lower Zone ET and Pervious Land Water Yield in Response to CO_2-modulated Stomatal Closure Representation for the 10th Percentile 2050 Climate Scenario

Pervious Land Segment	Lower Zone ET	Water Yield
Urban Grass - B soils	-8.12%	5.69%
Urban Grass - C soils	-8.07%	4.91%
Urban Grass - D soils	-7.87%	4.65%
Forest	-7.72%	4.90%
Crop - B soils	-6.88%	3.99%
Crop - C soils	-6.81%	3.64%
Crop - D soils	-6.70%	3.48%
Pasture - B soils	-8.89%	4.67%
Pasture - C soils	-8.73%	4.11%
Pasture - D soils	-8.58%	3.95%

A greater reduction in lower zone ET is generally predicted for more permeable soils. Smaller reductions in ET are predicted for crops than for other land covers because ET from crops is more strongly focused on the summer months when moisture availability is more likely to be limiting actual ET under the hotter conditions of the future climate scenarios. The increases in water yield from pervious surfaces are also noticeably less than the decreases in lower zone ET under both scenarios. This occurs because there is also ET from other pathways – primarily from interception storage in the canopy and storage in the upper soil/litter zone – that are not primarily controlled by plant transpiration and are thus unaffected by the LZETP modification.

Total runoff from the entire Menomonee River watershed also includes runoff generated by impervious surfaces, which is not affected by increased CO_2. As a result, the percentage increases in total flow in the river are smaller than the increases in flow from pervious land segments. Over the entire 10-year simulation, flow at the mouth of the Menomonee increases by 2.53 percent under the 10^{th} percentile scenario, and by 2.76% under the hotter and slightly wetter, 90^{th} percentile scenario.

Figure 1 shows the percentage difference in flows relative to the simulation without modifying LZETP for each individual hour in the simulation. This suggests that the percentage changes are greatest in the fall and winter, with lesser changes in the summer months – as is confirmed by tabulation by month (Table 6). Lower zone ET has the greatest impact on baseflow, which predominates in the fall and early winter month low-flow period (Figure 2.

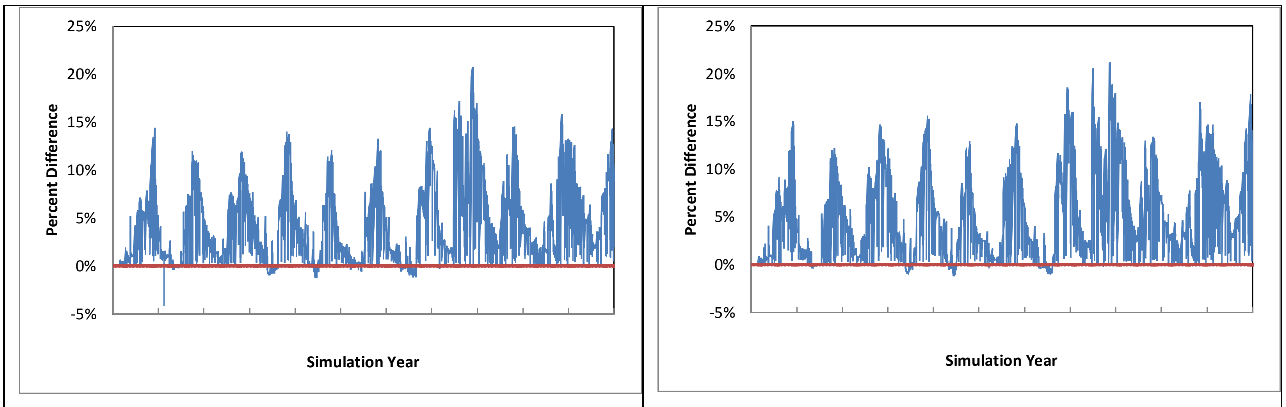

Figure 1. Percent Difference in Hourly Flows at the Mouth of the Menomonee River for the 10^{th} Percentile Scenario (Left) and 90^{th} Percentile Scenario (Right) after Modifying LZETP to Account for Increased Stomatal Closure

Table 6. Average Change in Hourly Flow at the Mouth of the Menomonee River by Month

Month	10th Percentile Scenario	90th Percentile Scenario
January	4.57%	5.55%
February	3.56%	4.68%
March	2.53%	3.46%
April	1.70%	2.34%
May	1.13%	1.52%
June	1.18%	1.68%
July	2.85%	3.61%
August	4.18%	4.70%
September	5.16%	5.65%
October	7.76%	8.01%
November	8.53%	9.21%
December	7.41%	8.76%

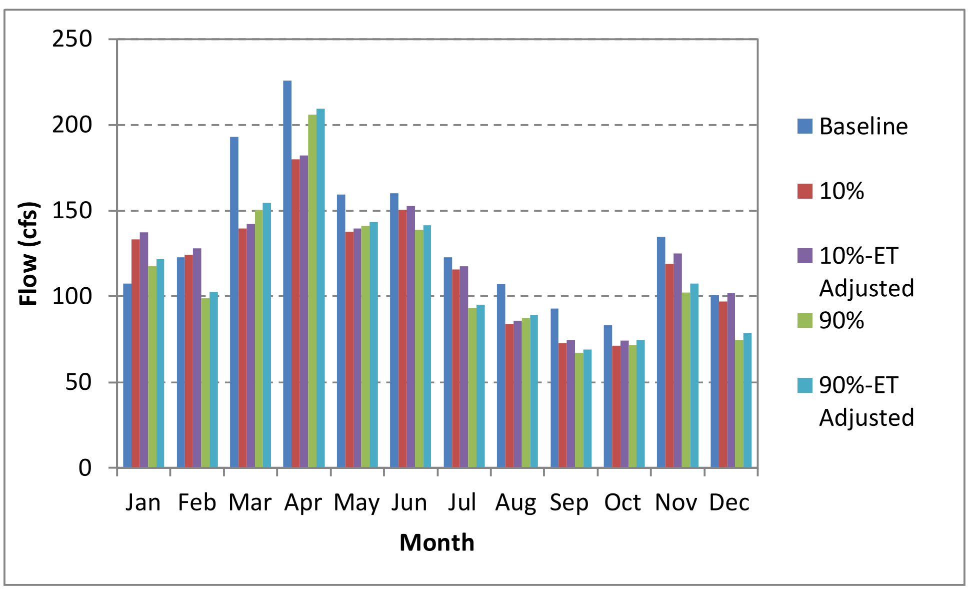

Figure 2. Average Flow by Month in the Menomonee River for Baseline Conditions and Climate Scenarios with and without Lower Zone ET Adjustments

4.2 WATER QUALITY RESULTS

As seen in the preceding section, accounting for the effects of CO_2 enrichment on stomatal closure in the Menomonee River model results in a small increase in total flow volume for future climate scenarios; however, the total flow remains less than under current baseline conditions.

The changes in flow lead to similar changes in pollutant loading. Simulations for both baseline weather and the 10th and 90th percentile climate scenarios were conducted with predicted 2020 population and land use, coupled with the recommended regional water quality management plan (SEWRPC, 2007), which contains a variety of management practices. Pollutant loads increase with the CO_2 adjustment, but only by a small amount (Table 7). The percentage load increase for TSS is notably smaller than the percentage load increase for flow, as TSS is derived primarily from surface runoff from pervious surfaces (coupled with channel scour), and the increase in flow is primarily focused in baseflow.

Table 7. Average Annual Flow Volume and Pollutant Load

Parameter	Recommended Plan with Baseline Weather Inputs	Recommended Plan under 10th Percentile Scenario	Recommended Plan under 10th Percentile Scenario with CO_2 Adjustment	Recommended Plan under 90th Percentile Scenario	Recommended Plan under 90th Percentile Scenario with CO_2 Adjustment
Flow (AF/yr)	97,117	85,877	88,079	81,391	83,662
Fecal Coliform Bacteria (#/yr)	7.21E+15	6.59E+15	6.60E+15	6.12E+15	6.14E+15
Total Phosphorus (MT/yr)	15.65	14.36	14.67	14.23	14.57
Total Nitrogen (MT/yr)	124.8	110.4	113.1	107.5	110.4
Total Suspended Solids (MT/yr)	5,251	5,338	5,365	5,544	5,574
Copper (kg/yr)	825	768	776	733	742

While pollutant loads increase slightly, pollutant concentrations tend to decrease (and dissolved oxygen concentrations increase) in the models with the lower zone ET adjustment for increased CO_2 (Table 8). This again reflects the role of decreased lower zone ET in increasing baseflow, and thus diluting the average pollutant concentration.

Appendix A presents revised water quality summary statistics at each of the Menomonee River assessment points. The main table reports statistics relative to variance standards, where appropriate, consistent with prior exhibits. This is followed by a separate table that gives statistics relative to fish and aquatic life and full recreational use standards for the four variance reaches.

Table 8. Average Annual Flow Rate and Downstream Pollutant Concentration

Parameter	Recommended Plan based on GMIA Weather Inputs	Recommended Plan under 10th Percentile Scenario	Recommended Plan under 10th Percentile Scenario with CO_2 Adjustment	Recommended Plan under 90th Percentile Scenario	Recommended Plan under 90th Percentile Scenario with CO_2 Adjustment
Flow (cfs)	134.0	118.5	121.6	112.3	115.5
Fecal Coliform Bacteria (#/100 ml)	3,835	3,437	3,351	3,209	3,125
Total Phosphorus (mg/L)	0.136	0.149	0.143	0.160	0.155
Total Nitrogen (mg/L)	1.150	1.191	1.173	1.243	1.218
Total Suspended Solids (mg/L)	13.09	13.55	13.49	13.54	13.48
Copper (mg/L)	0.0045	0.0044	0.0044	0.0043	0.0043
Dissolved Oxygen (mg/L)	11.13	10.79	10.80	10.59	10.60

5 Discussion

A method was developed and successfully implemented to incorporate effects of increased CO_2 concentrations and resulting stomatal closure and reduced plant transpiration within the HSPF model, consistent with theory. The approach appears to work well, although actual changes in transpiration from specific land cover types could well differ from the simplified predictions in the equation of Easterling et al. (1992).

The predicted changes in flow and pollutant loading after accounting for the CO_2 effect are small, and substantially less than those predicted for other watersheds (not including the Menomonee, but including the Minnesota River at a similar latitude) using the SWAT watershed model (Johnson et al., 2012). There appear to be three major reasons why the magnitude of the effect is smaller in the HSPF model than in the SWAT model:

1. A substantial portion of the Menomonee River watershed is occupied by impervious surfaces, from which evaporative losses are not dependent on CO_2 concentrations. This clearly reduces the effect relative to large agricultural watersheds, such as the Minnesota River. However, analysis of lower zone evapotranspiration rates and water yield from pervious lands alone still shows a relatively small effect.
2. The SWAT model, in default mode, uses a Curve Number approach to hydrologic simulation (SCS, 1972) with a fixed assumption that 20 percent of precipitation is lost to initial abstractions (interception and surface storage). In contrast, the HSPF model simulates a greater percentage of the annual precipitation volume going to interception, which is subject to evaporation without any reduction due to stomatal closure. Indeed, previous work with the SWAT model in the

Menomonee watershed showed that the Curve Number method over-estimated the fraction of total water yield that resulted from direct surface runoff compared to the HSPF model and SWAT's Green-Ampt infiltration option. Garen and Moore (2005) critiqued the use of the Curve Number approach in continuous watershed models and showed that the Curve Number is appropriately used for estimating total runoff volume for large storms at a relatively large spatial scale, but provides no information on the sources and pathways of runoff, and does not perform properly for smaller storm events. It is therefore likely that the SWAT model approach over-estimates the fraction of evapotranspiration that is mediated by plant root uptake, and thus subject to reduction due to increased stomatal closure.

3. There appears to be a conceptual flaw in the way in which SWAT implements the Penman-Monteith approach to evapotranspiration. Specifically, SWAT calculates potential evapotranspiration from plants using the FAO 56 approach (Allen et al., 1998), but then estimates the total evapotranspiration from all sources (including interception and surface evaporation) as limited by the Penman-Monteith estimate of PET. This is incorrect when applied to environments with increased CO_2 concentrations because all ET components are reduced, including those, such as evaporation from interception, that are not affected by increased stomatal closure.

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Appendix A. Water Quality Summary Statistics

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WATER QUALITY SUMMARY STATISTICS FOR THE MENOMONEE RIVER WATERSHED BEFORE AND AFTER ADJUSTING FOR CO_2 IMPACTS ON STOMATAL CLOSURE (With Variance Standards)

Assessment Point	Water Quality Indicator	Statistic	Condition: Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-1 North Branch Menomonee River	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	602	654	628	686	654
		Percent compliance with single sample standard (<400 cells per 100 ml)	81	83	83	84	84
		Geometric mean (cells per 100 ml)	67	55	54	49	48
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	326	353	355	361	361
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	506	568	551	569	548
		Percent compliance with single sample standard (<400 cells per 100 ml)	89	88	88	88	89
		Geometric mean (cells per 100 ml)	42	41	41	38	38
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	153	153	153	153	153
	Dissolved Oxygen	Mean (mg/l)	9.93	9.49	9.54	9.14	9.22
		Median (mg/l)	10.14	9.67	9.71	9.19	9.32
		Percent compliance with dissolved oxygen standard (>5 mg/l)	93	90	91	88	89
	Total Phosphorus	Mean (mg/l)	0.0578	0.0575	0.0570	0.0583	0.0577
		Median (mg/l)	0.0437	0.0431	0.0430	0.0429	0.0427
		Percent compliance with 0.1 mg/l standard	92	93	93	93	93
		Percent compliance with 0.075 mg/l standard	89	90	90	91	91
	Total Nitrogen	Mean (mg/l)	1.59	1.63	1.63	1.67	1.66
		Median (mg/l)	1.42	1.46	1.45	1.51	1.49
	Total Suspended Solids	Mean (mg/l)	7.19	7.34	7.30	7.48	7.42
		Median (mg/l)	5.86	5.80	5.78	5.79	5.76
	Copper	Mean (mg/l)	0.0020	0.0021	0.0021	0.0022	0.0021
		Median (mg/l)	0.0012	0.0012	0.0012	0.0012	0.0012

Assessment Point	Water Quality Indicator	Statistic	Condition: Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-2 Upper Menomonee River	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	763	794	767	810	781
		Percent compliance with single sample standard (<400 cells per 100 ml)	73	76	76	78	78
		Geometric mean (cells per 100 ml)	115	103	101	92	91
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	258	283	287	293	295
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	414	432	424	411	403
		Percent compliance with single sample standard (<400 cells per 100 ml)	86	86	86	87	87
		Geometric mean (cells per 100 ml)	56	53	53	46	46
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	149	149	149	149	149
	Dissolved Oxygen	Mean (mg/l)	9.60	9.21	9.25	8.93	8.98
		Median (mg/l)	9.67	8.96	9.07	8.56	8.67
		Percent compliance with dissolved oxygen standard (>5 mg/l)	100	99	99	99	99
	Total Phosphorus	Mean (mg/l)	0.1172	0.1342	0.1299	0.1512	0.1458
		Median (mg/l)	0.0934	0.1073	0.1035	0.1217	0.1167
		Percent compliance with 0.1 mg/l standard	56	47	49	41	43
		Percent compliance with 0.075 mg/l standard	42	36	37	31	33
	Total Nitrogen	Mean (mg/l)	1.18	1.21	1.20	1.25	1.24
		Median (mg/l)	1.10	1.13	1.12	1.16	1.15
	Total Suspended Solids	Mean (mg/l)	7.61	7.93	7.87	8.09	8.02
		Median (mg/l)	5.46	5.31	5.31	5.26	5.29
	Copper	Mean (mg/l)	0.0024	0.0025	0.0024	0.0025	0.0024
		Median (mg/l)	0.0011	0.0011	0.0011	0.0011	0.0011

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-3 West Branch Menomonee River	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1074	1008	977	959	927
		Percent compliance with single sample standard (<400 cells per 100 ml)	76	80	80	82	82
		Geometric mean (cells per 100 ml)	130	103	102	89	88
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	263	307	309	325	326
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	513	557	543	543	527
		Percent compliance with single sample standard (<400 cells per 100 ml)	88	88	88	88	88
		Geometric mean (cells per 100 ml)	72	70	69	64	64
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	149	151	151	151	151
	Dissolved Oxygen	Mean (mg/l)	9.74	9.24	9.30	8.87	8.94
		Median (mg/l)	9.91	9.28	9.37	8.83	8.93
		Percent compliance with dissolved oxygen standard (>5 mg/l)	94	92	93	90	90
	Total Phosphorus	Mean (mg/l)	0.0507	0.0668	0.0659	0.0657	0.0647
		Median (mg/l)	0.0377	0.0435	0.0431	0.0422	0.0421
		Percent compliance with 0.1 mg/l standard	92	89	89	90	90
		Percent compliance with 0.075 mg/l standard	88	87	87	88	89
	Total Nitrogen	Mean (mg/l)	0.78	1.31	1.29	1.33	1.31
		Median (mg/l)	0.70	1.17	1.16	1.19	1.17
	Total Suspended Solids	Mean (mg/l)	10.30	10.51	10.44	10.62	10.54
		Median (mg/l)	7.30	7.10	7.07	7.06	7.07
	Copper	Mean (mg/l)	0.0034	0.0033	0.0032	0.0032	0.0031
		Median (mg/l)	0.0012	0.0012	0.0012	0.0012	0.0012

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-4 Willow Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1098	1068	1029	1041	999
		Percent compliance with single sample standard (<400 cells per 100 ml)	76	79	79	81	81
		Geometric mean (cells per 100 ml)	161	141	137	133	128
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	239	267	272	271	279
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	496	538	524	516	500
		Percent compliance with single sample standard (<400 cells per 100 ml)	87	86	87	86	87
		Geometric mean (cells per 100 ml)	94	100	98	97	95
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	141	141	142	137	139
	Dissolved Oxygen	Mean (mg/l)	8.86	8.66	8.66	8.50	8.51
		Median (mg/l)	8.93	8.80	8.82	8.52	8.53
		Percent compliance with dissolved oxygen standard (>5 mg/l)	96	94	94	92	92
	Total Phosphorus	Mean (mg/l)	0.0539	0.0521	0.0514	0.0512	0.0504
		Median (mg/l)	0.0312	0.0291	0.0289	0.0281	0.0280
		Percent compliance with 0.1 mg/l standard	89	90	90	91	91
		Percent compliance with 0.075 mg/l standard	86	88	88	89	89
	Total Nitrogen	Mean (mg/l)	1.03	1.04	1.03	1.05	1.04
		Median (mg/l)	0.94	0.91	0.90	0.92	0.91
	Total Suspended Solids	Mean (mg/l)	9.06	9.34	9.29	9.51	9.44
		Median (mg/l)	6.81	6.80	6.78	6.88	6.86
	Copper	Mean (mg/l)	0.0028	0.0028	0.0028	0.0028	0.0027
		Median (mg/l)	0.0012	0.0012	0.0012	0.0012	0.0012

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-5 Menomonee River at Washington-Waukesha County Line	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1307	1295	1256	1270	1229
		Percent compliance with single sample standard (<400 cells per 100 ml)	66	69	70	72	72
		Geometric mean (cells per 100 ml)	206	184	180	159	156
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	187	186	188	203	206
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	578	583	575	535	527
		Percent compliance with single sample standard (<400 cells per 100 ml)	82	83	83	84	84
		Geometric mean (cells per 100 ml)	82	76	75	63	63
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	131	137	137	139	139
	Dissolved Oxygen	Mean (mg/l)	10.33	10.07	10.05	9.90	9.88
		Median (mg/l)	10.43	10.17	10.14	9.84	9.84
		Percent compliance with dissolved oxygen standard (>5 mg/l)	99	98	98	98	98
	Total Phosphorus	Mean (mg/l)	0.0882	0.0962	0.0935	0.1048	0.1012
		Median (mg/l)	0.0559	0.0602	0.0587	0.0645	0.0622
		Percent compliance with 0.1 mg/l standard	76	72	74	69	70
		Percent compliance with 0.075 mg/l standard	67	64	65	60	62
	Total Nitrogen	Mean (mg/l)	0.98	1.00	1.00	1.02	1.01
		Median (mg/l)	0.90	0.90	0.89	0.90	0.89
	Total Suspended Solids	Mean (mg/l)	10.47	11.09	10.98	11.39	11.25
		Median (mg/l)	5.98	5.85	5.85	5.87	5.85
	Copper	Mean (mg/l)	0.0041	0.0042	0.0041	0.0043	0.0042
		Median (mg/l)	0.0018	0.0017	0.0017	0.0017	0.0017

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-6 Nor-X-Way Channel	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1915	1794	1752	1688	1646
		Percent compliance with single sample standard (<400 cells per 100 ml)	70	74	74	77	77
		Geometric mean (cells per 100 ml)	149	111	111	90	90
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	236	265	267	292	293
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	807	839	830	790	780
		Percent compliance with single sample standard (<400 cells per 100 ml)	83	83	83	84	84
		Geometric mean (cells per 100 ml)	62	56	56	47	48
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	142	146	146	147	147
	Dissolved Oxygen	Mean (mg/l)	10.33	9.80	9.85	9.51	9.58
		Median (mg/l)	10.37	9.64	9.73	9.35	9.44
		Percent compliance with dissolved oxygen standard (>5 mg/l)	100	100	100	100	100
	Total Phosphorus	Mean (mg/l)	0.1452	0.1667	0.1606	0.1879	0.1795
		Median (mg/l)	0.1084	0.1254	0.1198	0.1404	0.1331
		Percent compliance with 0.1 mg/l standard	49	43	45	38	40
		Percent compliance with 0.075 mg/l standard	33	29	31	26	27
	Total Nitrogen	Mean (mg/l)	0.86	0.86	0.86	0.86	0.86
		Median (mg/l)	0.77	0.75	0.75	0.74	0.73
	Total Suspended Solids	Mean (mg/l)	11.71	12.08	12.01	12.19	12.11
		Median (mg/l)	3.26	3.10	3.10	2.95	2.97
	Copper	Mean (mg/l)	0.0034	0.0032	0.0032	0.0031	0.0031
		Median (mg/l)	0.0008	0.0008	0.0008	0.0008	0.0008

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-7 Lilly Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1077	1020	993	967	938
		Percent compliance with single sample standard (<400 cells per 100 ml)	70	74	74	77	77
		Geometric mean (cells per 100 ml)	202	170	167	154	151
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	196	220	224	247	251
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	490	521	513	495	485
		Percent compliance with single sample standard (<400 cells per 100 ml)	84	84	84	85	85
		Geometric mean (cells per 100 ml)	131	132	130	126	124
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	111	114	115	120	121
	Dissolved Oxygen	Mean (mg/l)	9.54	9.13	9.16	8.82	8.86
		Median (mg/l)	9.69	9.19	9.23	8.84	8.89
		Percent compliance with dissolved oxygen standard (>5 mg/l)	95	93	93	91	91
	Total Phosphorus	Mean (mg/l)	0.0751	0.0736	0.0727	0.0726	0.0715
		Median (mg/l)	0.0436	0.0427	0.0424	0.0423	0.0420
		Percent compliance with 0.1 mg/l standard	82	84	84	85	85
		Percent compliance with 0.075 mg/l standard	78	80	80	82	82
	Total Nitrogen	Mean (mg/l)	0.94	0.94	0.94	0.94	0.93
		Median (mg/l)	0.87	0.85	0.84	0.83	0.83
	Total Suspended Solids	Mean (mg/l)	13.76	14.34	14.23	14.38	14.24
		Median (mg/l)	5.32	5.22	5.22	5.20	5.20
	Copper	Mean (mg/l)	0.0035	0.0034	0.0034	0.0034	0.0033
		Median (mg/l)	0.0009	0.0009	0.0009	0.0009	0.0009

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-8 Butler Ditch	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1257	1109	1079	1039	1008
		Percent compliance with single sample standard (<400 cells per 100 ml)	67	74	74	77	77
		Geometric mean (cells per 100 ml)	247	182	179	160	157
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	170	205	208	235	238
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	613	615	607	596	587
		Percent compliance with single sample standard (<400 cells per 100 ml)	83	84	84	85	85
		Geometric mean (cells per 100 ml)	142	137	136	129	128
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	104	109	110	115	115
	Dissolved Oxygen	Mean (mg/l)	9.97	9.34	9.42	8.94	9.05
		Median (mg/l)	9.89	9.09	9.21	8.68	8.85
		Percent compliance with dissolved oxygen standard (>5 mg/l)	94	91	92	89	90
	Total Phosphorus	Mean (mg/l)	0.0805	0.0745	0.0736	0.0721	0.0712
		Median (mg/l)	0.0459	0.0430	0.0429	0.0425	0.0422
		Percent compliance with 0.1 mg/l standard	80	84	84	86	86
		Percent compliance with 0.075 mg/l standard	75	80	80	82	82
	Total Nitrogen	Mean (mg/l)	1.01	0.99	0.99	0.99	0.98
		Median (mg/l)	0.97	0.92	0.91	0.89	0.88
	Total Suspended Solids	Mean (mg/l)	12.54	13.23	13.07	13.43	13.25
		Median (mg/l)	5.64	5.61	5.61	5.59	5.59
	Copper	Mean (mg/l)	0.0035	0.0032	0.0031	0.0031	0.0030
		Median (mg/l)	0.0011	0.0010	0.0010	0.0010	0.0010

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-9 Menomonee River Downstream of Butler Ditch	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	1626	1567	1523	1509	1463
		Percent compliance with single sample standard (<400 cells per 100 ml)	64	68	68	70	71
		Geometric mean (cells per 100 ml)	275	240	234	216	209
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	160	156	160	172	175
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	679	682	673	625	616
		Percent compliance with single sample standard (<400 cells per 100 ml)	80	81	81	82	83
		Geometric mean (cells per 100 ml)	112	110	109	98	97
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	119	121	123	128	129
	Dissolved Oxygen	Mean (mg/l)	10.75	10.47	10.45	10.36	10.35
		Median (mg/l)	10.82	10.49	10.49	10.29	10.29
		Percent compliance with dissolved oxygen standard (>5 mg/l)	99	99	99	99	99
	Total Phosphorus	Mean (mg/l)	0.0861	0.0926	0.0900	0.0998	0.0962
		Median (mg/l)	0.0494	0.0522	0.0506	0.0570	0.0543
		Percent compliance with 0.1 mg/l standard	75	73	74	70	72
		Percent compliance with 0.075 mg/l standard	68	66	67	63	65
	Total Nitrogen	Mean (mg/l)	0.85	0.86	0.85	0.85	0.85
		Median (mg/l)	0.79	0.76	0.76	0.74	0.74
	Total Suspended Solids	Mean (mg/l)	13.31	13.91	13.83	14.03	13.93
		Median (mg/l)	5.24	5.04	5.05	4.90	4.92
	Copper	Mean (mg/l)	0.0043	0.0044	0.0043	0.0044	0.0043
		Median (mg/l)	0.0016	0.0015	0.0015	0.0015	0.0015

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-10 Little Menomonee Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	3599	3737	3600	3803	3651
		Percent compliance with single sample standard (<400 cells per 100 ml)	59	64	64	66	66
		Geometric mean (cells per 100 ml)	265	210	203	181	174
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	156	162	167	189	194
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	2643	2702	2649	2548	2493
		Percent compliance with single sample standard (<400 cells per 100 ml)	75	75	76	77	78
		Geometric mean (cells per 100 ml)	98	95	93	80	78
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	106	107	109	119	120
	Dissolved Oxygen	Mean (mg/l)	8.99	9.01	8.97	8.99	8.95
		Median (mg/l)	8.95	9.06	9.04	8.93	8.90
		Percent compliance with dissolved oxygen standard (>5 mg/l)	98	98	98	97	97
	Total Phosphorus	Mean (mg/l)	0.0716	0.0704	0.0698	0.0715	0.0707
		Median (mg/l)	0.0515	0.0500	0.0498	0.0500	0.0497
		Percent compliance with 0.1 mg/l standard	85	85	86	85	86
		Percent compliance with 0.075 mg/l standard	78	79	80	80	80
	Total Nitrogen	Mean (mg/l)	1.35	1.35	1.35	1.36	1.36
		Median (mg/l)	1.22	1.23	1.22	1.23	1.22
	Total Suspended Solids	Mean (mg/l)	19.92	19.55	19.46	19.87	19.70
		Median (mg/l)	10.05	8.85	8.94	8.24	8.30
	Copper	Mean (mg/l)	0.0024	0.0025	0.0024	0.0026	0.0025
		Median (mg/l)	0.0012	0.0012	0.0012	0.0012	0.0012

Assessment Point	Water Quality Indicator	Statistic	Condition: Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-11 Little Menomonee River	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	5453	5251	5097	5100	4933
		Percent compliance with single sample standard (<400 cells per 100 ml)	54	59	59	61	62
		Geometric mean (cells per 100 ml)	533	408	402	335	328
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	90	98	98	117	118
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	2438	2512	2470	2353	2304
		Percent compliance with single sample standard (<400 cells per 100 ml)	72	72	73	75	75
		Geometric mean (cells per 100 ml)	168	154	153	123	122
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	68	72	73	85	86
	Dissolved Oxygen	Mean (mg/l)	10.49	9.99	10.03	9.65	9.70
		Median (mg/l)	10.72	10.03	10.04	9.65	9.69
		Percent compliance with dissolved oxygen standard (>5 mg/l)	98	97	97	96	96
	Total Phosphorus	Mean (mg/l)	0.0949	0.1036	0.1001	0.1157	0.1108
		Median (mg/l)	0.0623	0.0677	0.0656	0.0760	0.0720
		Percent compliance with 0.1 mg/l standard	73	70	72	66	68
		Percent compliance with 0.075 mg/l standard	62	59	61	54	56
	Total Nitrogen	Mean (mg/l)	0.93	0.97	0.95	1.02	1.00
		Median (mg/l)	0.87	0.88	0.87	0.92	0.90
	Total Suspended Solids	Mean (mg/l)	10.67	11.00	10.94	11.15	11.08
		Median (mg/l)	3.48	3.34	3.33	3.35	3.32
	Copper	Mean (mg/l)	0.0038	0.0037	0.0037	0.0037	0.0036
		Median (mg/l)	0.0014	0.0012	0.0012	0.0011	0.0011

Assessment Point	Water Quality Indicator	Statistic	Condition: Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-12 Menomonee River Downstream of Little Menomonee River	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	2710	2536	2459	2465	2382
		Percent compliance with single sample standard (<400 cells per 100 ml)	57	62	62	65	65
		Geometric mean (cells per 100 ml)	447	371	360	329	318
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	94	94	96	115	118
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	999	1037	1019	961	941
		Percent compliance with single sample standard (<400 cells per 100 ml)	75	76	76	78	78
		Geometric mean (cells per 100 ml)	166	159	157	137	135
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	74	76	77	92	94
	Dissolved Oxygen	Mean (mg/l)	10.67	10.33	10.32	10.18	10.18
		Median (mg/l)	10.80	10.39	10.40	10.16	10.17
		Percent compliance with dissolved oxygen standard (>5 mg/l)	99	99	99	98	98
	Total Phosphorus	Mean (mg/l)	0.0867	0.0942	0.0913	0.1030	0.0990
		Median (mg/l)	0.0505	0.0534	0.0516	0.0593	0.0564
		Percent compliance with 0.1 mg/l standard	74	72	74	69	71
		Percent compliance with 0.075 mg/l standard	67	65	66	62	63
	Total Nitrogen	Mean (mg/l)	0.83	0.84	0.83	0.85	0.84
		Median (mg/l)	0.77	0.76	0.76	0.78	0.77
	Total Suspended Solids	Mean (mg/l)	11.21	11.66	11.59	11.85	11.78
		Median (mg/l)	4.36	4.12	4.12	4.01	4.03
	Copper	Mean (mg/l)	0.0043	0.0044	0.0043	0.0043	0.0042
		Median (mg/l)	0.0016	0.0015	0.0015	0.0014	0.0014

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-13 Underwood Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	4904	4254	4130	3958	3835
		Percent compliance with single sample standard (<400 cells per 100 ml)	61	70	70	73	73
		Geometric mean (cells per 100 ml)	477	317	314	265	261
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	105	133	134	147	149
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	2045	1903	1885	1780	1762
		Percent compliance with single sample standard (<400 cells per 100 ml)	80	82	82	83	83
		Geometric mean (cells per 100 ml)	205	185	184	170	168
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	63	75	76	83	84
	Dissolved Oxygen	Mean (mg/l)	10.25	9.47	9.57	8.99	9.08
		Median (mg/l)	10.19	9.08	9.26	8.62	8.72
		Percent compliance with dissolved oxygen standard (>5 mg/l)	96	93	94	91	92
	Total Phosphorus	Mean (mg/l)	0.0834	0.0773	0.0765	0.0750	0.0743
		Median (mg/l)	0.0566	0.0512	0.0509	0.0503	0.0501
		Percent compliance with 0.1 mg/l standard	79	82	82	84	84
		Percent compliance with 0.075 mg/l standard	70	75	75	78	78
	Total Nitrogen	Mean (mg/l)	1.02	1.00	1.00	1.00	0.99
		Median (mg/l)	0.99	0.94	0.94	0.91	0.90
	Total Suspended Solids	Mean (mg/l)	13.14	13.69	13.59	13.74	13.62
		Median (mg/l)	5.60	5.56	5.55	5.52	5.52
	Copper	Mean (mg/l)	0.0038	0.0035	0.0034	0.0034	0.0033
		Median (mg/l)	0.0010	0.0010	0.0010	0.0010	0.0010

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-14 Underwood Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	4375	3555	3448	3180	3076
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	72	79	79	82	82
		Geometric mean (cells per 100 ml)	421	273	270	228	224
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	268	314	317	332	333
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	1209	1111	1097	1034	1021
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	89	90	90	91	91
		Geometric mean (cells per 100 ml)	174	158	158	147	146
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	153	153	153	153	153
	Dissolved Oxygen	Mean (mg/l)	11.11	10.61	10.66	10.18	10.29
		Median (mg/l)	11.23	10.61	10.71	9.96	10.14
		Percent compliance with dissolved oxygen standard (>2 mg/l)	100	100	100	100	100
	Total Phosphorus	Mean (mg/l)	0.084	0.0782	0.0767	0.0769	0.0752
		Median (mg/l)	0.0567	0.0535	0.0530	0.0528	0.0521
		Percent compliance with 0.1 mg/l standard	79	83	83	84	85
		Percent compliance with 0.075 mg/l standard	70	75	76	76	77
	Total Nitrogen	Mean (mg/l)	1.00	0.98	0.97	0.97	0.96
		Median (mg/l)	0.98	0.92	0.91	0.87	0.87
	Total Suspended Solids	Mean (mg/l)	13.00	13.39	13.30	13.38	13.27
		Median (mg/l)	5.82	5.71	5.71	5.67	5.67
	Copper	Mean (mg/l)	0.0038	0.0034	0.0033	0.0032	0.0031
		Median (mg/l)	0.0010	0.0010	0.0010	0.0010	0.0010

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-15 Menomonee Mainstem	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	3404	3098	3007	2938	2845
		Percent compliance with single sample standard (<400 cells per 100 ml)	54	61	62	65	65
		Geometric mean (cells per 100 ml)	557	436	424	381	370
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	76	82	84	99	103
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	1250	1233	1215	1140	1120
		Percent compliance with single sample standard (<400 cells per 100 ml)	75	76	76	78	79
		Geometric mean (cells per 100 ml)	201	189	186	166	163
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	58	65	66	79	82
	Dissolved Oxygen	Mean (mg/l)	10.80	10.49	10.48	10.32	10.32
		Median (mg/l)	10.88	10.49	10.48	10.26	10.25
		Percent compliance with dissolved oxygen standard (>5 mg/l)	99	99	99	99	99
	Total Phosphorus	Mean (mg/l)	0.0907	0.0944	0.0921	0.0995	0.0964
		Median (mg/l)	0.0561	0.0573	0.0555	0.0613	0.0587
		Percent compliance with 0.1 mg/l standard	73	72	73	70	71
		Percent compliance with 0.075 mg/l standard	65	64	65	62	64
	Total Nitrogen	Mean (mg/l)	0.90	0.89	0.89	0.89	0.89
		Median (mg/l)	0.84	0.80	0.80	0.80	0.80
	Total Suspended Solids	Mean (mg/l)	12.07	12.57	12.50	12.66	12.57
		Median (mg/l)	4.57	4.30	4.30	4.13	4.15
	Copper	Mean (mg/l)	0.0046	0.0045	0.0044	0.0045	0.0044
		Median (mg/l)	0.0017	0.0015	0.0014	0.0013	0.0013

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-16 Honey Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	5033	4107	4008	3627	3537
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	73	79	80	82	83
		Geometric mean (cells per 100 ml)	403	244	243	195	194
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	270	322	322	339	340
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	1743	1636	1620	1524	1509
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	89	89	89	90	90
		Geometric mean (cells per 100 ml)	170	149	149	132	133
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	153	153	153	153	153
	Dissolved Oxygen	Mean (mg/l)	11.09	10.62	10.64	10.38	10.39
		Median (mg/l)	10.92	10.28	10.34	10.03	10.05
		Percent compliance with dissolved oxygen standard (>2 mg/l)	98	96	96	94	95
	Total Phosphorus	Mean (mg/l)	0.1103	0.1083	0.1056	0.1109	0.1075
		Median (mg/l)	0.0818	0.0814	0.0793	0.0875	0.0844
		Percent compliance with 0.1 mg/l standard	65	65	66	61	63
		Percent compliance with 0.075 mg/l standard	50	48	50	45	47
	Total Nitrogen	Mean (mg/l)	1.19	1.16	1.15	1.16	1.14
		Median (mg/l)	1.14	1.09	1.08	1.09	1.07
	Total Suspended Solids	Mean (mg/l)	11.72	11.90	11.83	11.85	11.78
		Median (mg/l)	5.81	5.47	5.50	5.19	5.21
	Copper	Mean (mg/l)	0.0039	0.0035	0.0034	0.0033	0.0032
		Median (mg/l)	0.0015	0.0014	0.0014	0.0015	0.0015

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-17 Menomonee River Downstream of Honey Creek	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	3744	3382	3287	3186	3090
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	70	75	76	78	79
		Geometric mean (cells per 100 ml)	570	434	423	375	365
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	241	284	288	302	306
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	1457	1422	1404	1317	1298
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	88	89	89	90	90
		Geometric mean (cells per 100 ml)	203	188	186	165	162
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	152	152	152	152	152
	Dissolved Oxygen	Mean (mg/l)	10.88	10.56	10.56	10.40	10.39
		Median (mg/l)	10.94	10.57	10.56	10.32	10.31
		Percent compliance with dissolved oxygen standard (>2 mg/l)	100	100	100	100	100
	Total Phosphorus	Mean (mg/l)	0.0992	0.1038	0.1012	0.1101	0.1065
		Median (mg/l)	0.0656	0.0691	0.0667	0.0742	0.0707
		Percent compliance with 0.1 mg/l standard	69	69	69	66	68
		Percent compliance with 0.075 mg/l standard	60	58	60	54	56
	Total Nitrogen	Mean (mg/l)	0.92	0.92	0.91	0.92	0.91
		Median (mg/l)	0.86	0.83	0.83	0.83	0.82
	Total Suspended Solids	Mean (mg/l)	12.57	13.09	13.00	13.16	13.08
		Median (mg/l)	4.78	4.53	4.54	4.42	4.44
	Copper	Mean (mg/l)	0.0046	0.0045	0.0044	0.0045	0.0044
		Median (mg/l)	0.0017	0.0014	0.0014	0.0013	0.0013

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-18 Menomonee River near Upstream Limit of Estuary	Fecal Coliform Bacteria (annual)	Mean (cells per 100 ml)	3810	3436	3345	3226	3136
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	70	75	76	78	79
		Geometric mean (cells per 100 ml)	556	417	407	355	346
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	242	285	289	305	308
	Fecal Coliform Bacteria (May-September: 153 days total)	Mean (cells per 100 ml)	1525	1471	1456	1363	1346
		Percent compliance with single sample standard (<2,000 cells per 100 ml)	88	89	89	90	90
		Geometric mean (cells per 100 ml)	194	177	175	153	151
		Days of compliance with geometric mean standard (<1,000 cells per 100 ml)	152	152	152	152	152
	Dissolved Oxygen	Mean (mg/l)	10.86	10.55	10.55	10.38	10.38
		Median (mg/l)	10.89	10.53	10.54	10.29	10.30
		Percent compliance with dissolved oxygen standard (>2 mg/l)	100	100	100	100	100
	Total Phosphorus	Mean (mg/l)	0.1200	0.1292	0.1255	0.1396	0.1347
		Median (mg/l)	0.0898	0.0982	0.0944	0.1073	0.1018
		Percent compliance with 0.1 mg/l standard	59	54	56	49	52
		Percent compliance with 0.075 mg/l standard	41	37	39	33	35
	Total Nitrogen	Mean (mg/l)	1.04	1.07	1.06	1.10	1.08
		Median (mg/l)	0.99	1.01	1.00	1.05	1.04
	Total Suspended Solids	Mean (mg/l)	12.70	13.18	13.11	13.20	13.13
		Median (mg/l)	4.70	4.39	4.41	4.19	4.21
	Copper	Mean (mg/l)	0.0045	0.0044	0.0044	0.0043	0.0043
		Median (mg/l)	0.0017	0.0014	0.0014	0.0013	0.0013

WATER QUALITY SUMMARY STATISTICS FOR THE MENOMONEE RIVER WATERSHED BEFORE AND AFTER ADJUSTING FOR CO_2 IMPACTS ON STOMATAL CLOSURE (Additional Analyses for Water Quality Compliance/Concentration Statistics Relative to Fish and Aquatic Life and Full Recreational Use Standards in Variance Reaches)

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-14 Underwood Creek	Fecal Coliform Bacteria (annual)	Percent compliance with single sample standard (<400 cells per 100 ml)	63	71	71	74	74
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	128	156	157	173	176
	Fecal Coliform Bacteria (May-September: 153 days total)	Percent compliance with single sample standard (<400 cells per 100 ml)	81	83	83	84	84
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	77	90	90	97	98
	Dissolved Oxygen	Percent compliance with dissolved oxygen standard (>5 mg/l)	98	97	97	95	96
MN-16 Honey Creek	Fecal Coliform Bacteria (annual)	Percent compliance with single sample standard (<400 cells per 100 ml)	65	73	73	77	77
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	138	168	168	198	198
	Fecal Coliform Bacteria (May-September: 153 days total)	Percent compliance with single sample standard (<400 cells per 100 ml)	83	84	84	86	85
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	81	94	94	105	104
	Dissolved Oxygen	Percent compliance with dissolved oxygen standard (>5 mg/l)	91	87	88	85	85
MN-17 Menomonee River Downstream of Honey Creek	Fecal Coliform Bacteria (annual)	Percent compliance with single sample standard (<400 cells per 100 ml)	55	62	62	65	65
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	75	83	86	100	103
	Fecal Coliform Bacteria (May-September: 153 days total)	Percent compliance with single sample standard (<400 cells per 100 ml)	76	77	77	79	79
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	56	64	66	79	81
	Dissolved Oxygen	Percent compliance with dissolved oxygen standard (>5 mg/l)	100	99	99	99	99

Assessment Point	Water Quality Indicator	Statistic	Condition				
			Recommended Plan Based on GMIA Weather Inputs	10th Percentile, no ET adjustment	10th Percentile, adjusted ET	90th Percentile, no ET adjustment	90th Percentile, adjusted ET
MN-18 Menomonee River near Upstream Limit of Estuary	Fecal Coliform Bacteria (annual)	Percent compliance with single sample standard (<400 cells per 100 ml)	55	62	63	66	66
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	80	90	92	109	111
	Fecal Coliform Bacteria (May-September: 153 days total)	Percent compliance with single sample standard (<400 cells per 100 ml)	76	77	77	79	79
		Days of compliance with geometric mean standard (<200 cells per 100 ml)	60	69	70	85	86
	Dissolved Oxygen	Percent compliance with dissolved oxygen standard (>5 mg/l)	100	100	99	99	99