Appendix H

Water Quality Model of Proposed Discharge to Underwood Creek

Draft Water Quality Model of Proposed Discharge to Underwood Creek

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Executive Summary

The City of Waukesha Wastewater Treatment Plant is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. To simulate water quality changes to Underwood Creek and the downstream Menomonee River, a watershed water quality model previously developed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) was obtained and updated to include a new point source for Waukesha return flow.

The updated model simulated the SEWRPC existing condition and preferred alternative (recommended plan) scenarios with Waukesha return flow set either equal to average historical operating conditions (the expected discharge condition) based upon October 2002 through August 2009 data or equal to a worst case scenario using higher flow rates and worse water quality discharge conditions (maximum potential discharge condition). The analysis used 11 years of continuous simulation, the same as the SEWRPC models.

The water quality modeling found that average water quality improved or continued to meet water quality standards or background reference concentrations for 3 out of 4 water quality parameters (fecal coliform, dissolved oxygen, and total suspended solids).

For the fourth water quality parameter (phosphorus), concentrations increased and were more frequently higher than the planning level goal used in the SEWRPC modeling (0.1 mg/L). However, the modeling results indicate that with return flow, nuisance algae growth will decrease in Underwood Creek and the Menomonee River. The WDNR is developing new phosphorus standards that could further reduce the phosphorus discharge concentration in the return flow.

Introduction

The City of Waukesha Wastewater Treatment Plant is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) developed a set of watershed simulation models to evaluate management of water quality from both point and non-point sources in the Greater Milwaukee area. The models for the Menomonee River system were utilized to evaluate the potential water quality changes of the return flow within Underwood Creek and the Menomonee River downstream of its confluence with Underwood Creek. This technical memorandum (TM) describes the process used to adapt the SEWRPC models for evaluation of the return flow as well as the results of the evaluations.

Background

The City of Waukesha Wastewater Treatment Plant currently discharges treated effluent to the Fox River in the Mississippi River watershed. With a proposed future Lake Michigan water source, return flow back to the Great Lakes basin (Lake Michigan) will be required. The Waukesha Wastewater Treatment Plant has been investigating the potential for returning flow to Underwood Creek, a tributary to the Menomonee River and Lake Michigan. The analysis documented in this memorandum describes water quality changes associated with return flow to Underwood Creek.

SEWRPC undertook a large-scale effort detailed in *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds* (RWQMPU) (SEWRPC, 2007) to evaluate water quality under current conditions and potential future scenarios in the Greater Milwaukee area. These evaluations were based in part on water quality modeling using the U.S. EPA's Hydrologic Simulation Program - FORTRAN (HSPF) (Bicknell et al., 2000). This model simulates watershed hydrology, pollutant loading in runoff from the watershed, and the fate and transport of pollutants in streams and rivers. The SEWRPC model included pollutant contributions from non-point sources in the watershed, point sources, and sanitary sewer overflows (SSO). Scenarios evaluated in the model included existing conditions (Existing) and a variety of management practices which could improve water quality in the study area. A final set of management practices were selected and considered as the "Preferred Alternative" (PA).

CH2M HILL requested the HSPF models from SEWRPC to evaluate water quality changes in Underwood Creek with a proposed return flow. SEWRPC provided the HSPF models for all model segments in the Menomonee River Basin for the Existing scenario and the PA scenario.

Scenarios Modeled

Four new scenarios were modeled using continuous simulation over an 11-year period consistent with the SEWRPC RWQMPU to assess the changes under existing and future conditions with Waukesha return flow. The discharge was characterized either by actual historical effluent quality for the expected discharge condition scenario or by a worse case scenario that combined permit limits and high observed concentrations into a maximum potential discharge condition scenario. Table 1 lists the modeled scenarios.

TABLE 1
Description of Scenarios Modeled

Scenario	Description
1	Existing Conditions (no discharge to Underwood Creek)
2A	Existing Conditions with Return Flow to Underwood Creek – Expected Discharge Condition
2B	Existing Conditions with Return Flow to Underwood Creek – Maximum Potential Discharge Condition
3	RWQMPU Recommended Plan Conditions (no discharge to Underwood Creek)
3A	RWQMPU Recommended Plan Conditions with Return Flow to Underwood Creek - Expected Discharge Condition
3B	RWQMPU Recommended Plan Conditions with Return Flow to Underwood Creek – Maximum Potential Discharge Condition

Determination of Discharge Characteristics

The expected discharge concentration scenarios are characterized using monthly water quality data measured at the plant under current operating conditions. These values were calculated using data from October 1, 2002 to August 31, 2009. The processing and tabulation of these data are provided as Attachment 1 of this document. A summary of the typical values are provided as Table 2.

The maximum potential discharge condition set of runs uses discharge characteristics as specified in the plant's Wisconsin Pollutant Discharge Elimination System (WPDES) permit. If a water quality parameter was not included in the WPDES permit, representative values based upon current operation were used. In the case of phosphorus, the plant currently operates at a much lower level than the 1 mg/l permit limit and future phosphorus regulations are pending that could lower the limit. As a result, the value for the highest monthly average (October) under current actual operating conditions was used (0.24 mg/l). The estimates for TKN were specified as organic N in the model. This is conservative since TKN also includes ammonia and ammonia is specified separately. To be conservative, a future return flow rate higher than the 12.0 mgd requested beyond 2035 average day water supply demand was used (12.9 mgd = 20 cfs) as a conservative estimation of potential average day return flow. The typical values calculated based on current operation were used if there is no permit limit. In the case of fecal coliform outside of the disinfection season, to be conservative, a high value available for normal operating conditions without disinfection was used (915 cfu/100mL). Preliminary information from additional sampling indicates 915 cfu/100mL is very conservative because all additional samples reported to date have been much less than 915 cfu/100mL. The discharge characteristics for the maximum potential discharge condition runs are provided in Table 3.

Modification of the SEWRPC Models

The models for the Existing and PA scenarios were modified to include the proposed discharge to Underwood Creek. This discharge is a new input to the model. Point source inputs to the HSPF model can be specified through the use of timeseries text files. The HSPF file structure for both scenarios were modified to read in two additional files, one which specified flow, thermal load (in British Thermal Units (BTUs)), and fecal coliform and one which specified the sediment, nutrient, dissolved oxygen, and metals related water quality parameters for the point source discharge. The values in the two files are input on a 15-minute time-step and were based on monthly values specified in Tables 2 and 3.

The HSPF models were also modified to specify the location of the new discharge. Based on information from the Waukesha Wastewater Treatment Plant, this was set to model segment 901 of the Menomonee watershed (See Figure 1). Since HSPF is a lumped model, a discharge to any point in segment 901 is modeled as entering at the upstream end of segment 901. For this reason, an exact location is not required.

The baseline and return flow scenarios were run using the WinHSPF interface. The original models were run using HSPF version 12 but this is a DOS based program and WinHSPF is the version of the model currently supported by the US EPA. Differences in the coding of the model results in a slight but insignificant difference from the original model runs. The baseline and scenario models were all run using WinHSPF to provide a representative comparison of results run under the same computing platform.

TABLE 2
Expected Discharge Condition (Monthly Average Values - based on 10/02 through 8/09 data)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	Org N (mg/L)	Ammonia (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO_4 (mg/L)	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Cu (µg/L)	Zn (µg/L)
January	9.4	14.5	1.7	0.98	0.10	18.6	0.11	0.07	10.3	12.0	0.9	915	6.6	42.0
February	9.3	14.4	1.7	0.98	0.06	19.1	0.10	0.06	10.5	11.5	0.9	915	12.4	48.6
March	11.3	17.4	1.7	0.98	0.14	16.1	0.12	0.08	10.4	12.3	1.1	915	6.1	49.6
April	12.3	19.1	1.7	0.98	0.09	12.9	0.10	0.06	9.7	14.1	1.4	915	8.6	22.0
May	11.5	17.7	2.0	0.98	0.20	13.9	0.12	0.08	9.0	16.4	1.2	2	7.1	45.7
June	12.1	18.7	2.6	0.98	0.14	12.7	0.21	0.14	8.2	18.8	1.8	49	6.1	30.5
July	9.2	14.3	1.8	0.98	0.05	16.8	0.16	0.11	8.0	20.6	1.0	2	6.1	29.3
August	9.0	14.0	1.8	0.98	0.07	14.8	0.19	0.13	7.9	21.3	1.1	2	6.3	37.2
September	8.8	13.7	2.1	0.98	0.10	16.2	0.21	0.14	8.0	20.8	1.0	2	8.7	39.0
October	8.8	13.6	1.6	0.98	0.04	17.3	0.24	0.16	8.7	18.6	1.1	915	5.7	36.6
November	8.6	13.3	1.6	0.98	0.07	18.1	0.21	0.14	9.5	16.0	1.1	915	6.7	33.8
December	9.2	14.2	1.6	0.98	0.07	20.7	0.15	0.10	10.3	13.3	1.1	915	9.3	47.4

TABLE 3
Maximum Potential Discharge Condition (Monthly Values)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	Org N (mg/L)	Ammonia (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO_4 (mg/L)	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Cu (µg/L)	Zn (µg/L)
January	12.9	20.0	10.0	0.98	5.0	18.6	0.24	0.16	7.0	12.0	10.0	915	6.6	42.0
February	12.9	20.0	10.0	0.98	5.2	19.1	0.24	0.16	7.0	11.5	10.0	915	12.4	48.6
March	12.9	20.0	10.0	0.98	6.0	16.1	0.24	0.16	7.0	12.3	10.0	915	6.1	49.6
April	12.9	20.0	10.0	0.98	5.6	12.9	0.24	0.16	7.0	14.1	10.0	915	8.6	22.0
May	12.9	20.0	10.0	0.98	4.9	13.9	0.24	0.16	7.0	16.4	10.0	400	7.1	45.7
June	12.9	20.0	10.0	0.98	3.1	12.7	0.24	0.16	7.0	18.8	10.0	400	6.1	30.5
July	12.9	20.0	8.5	0.98	2.0	16.8	0.24	0.16	7.0	20.6	10.0	400	6.1	29.3
August	12.9	20.0	8.5	0.98	2.1	14.8	0.24	0.16	7.0	21.3	10.0	400	6.3	37.2
September	12.9	20.0	8.2	0.98	2.9	16.2	0.24	0.16	6.7	20.8	10.0	400	8.7	39.0
October	12.9	20.0	10.0	0.98	4.5	17.3	0.24	0.16	7.0	18.6	10.0	915	5.7	36.6
November	12.9	20.0	10.0	0.98	5.4	18.1	0.24	0.16	7.0	16.0	10.0	915	6.7	33.8
December	12.9	20.0	10.0	0.98	5.1	20.7	0.24	0.16	7.0	13.3	10.0	915	9.3	47.4

Evaluation of Results

The SEWRPC model includes output at numerous locations for the purpose of comparison. Results were compared at the established assessment points and at each model segment below the confluence with Underwood Creek. The five evaluation locations are MN-14 (the outlet of Underwood Creek), MN-15(Reach 883 at the confluence of Underwood Creek and the Menomonee River), MN-17 (Reach 908 on the Menomonee River below the confluence with Underwood Creek), MN-18 (Reach 919), and Reach 922 (the most downstream segment in the HSPF model). These locations are shown on Figure 1.

The results of each scenario run were summarized for comparison with the existing conditions and are summarized in Table 4 through Table 8. No results comparison to the SEWRPC findings for the baseline existing and PA runs are available for Reach 922 since this was not one of the assessment points described in the original SEWRPC study (SEWRPC, 2007).

For fecal coliform, results are evaluated by comparing mean values as well as geometric mean (geomean) values. The overall geomean values were calculated using the entire 11-year dataset. For the evaluation of compliance with the geomean standard, a rolling 30-day geomean was calculated and compared to the standard.

Expected Discharge Condition Results

Fecal Coliform

The expected discharge condition shows dramatic improvement in Underwood Creek and good improvement in the Menomonee River for mean recreational season (May-September) fecal coliform concentration at all locations for all models.

The expected discharge condition improves compliance with the fecal coliform single sample standard during the recreational season (May-September) for all models at all assessment points.

It was observed that the compliance calculations were providing artificial results because the 30-day rolling average used in the geometric mean calculation requires data from outside of the recreational season. Data from outside the recreational season included the high discharge value (915 cfu/100mL) assumed for the October through April season. Preliminary information from additional sampling indicates 915 cfu/100mL is very conservative because all additional samples reported to date have been much less than 915 cfu/100mL. Consequently, the period of June through September was used to compare alternatives and calculate compliance during the summer recreational season. The findings indicate fecal coliform compliance improves or stays the same at all locations for all models.

Dissolved Oxygen

Under the expected discharge condition, dissolved oxygen concentration is lower but not significantly and compliance with the DO standard does not change for both the existing and recommended plan alternative SEWRPC models.

Total Phosphorus

The WDNR is currently developing phosphorus standards. When the standards are finalized, it is expected that many wastewater treatment plants in Wisconsin will have to reduce their phosphorus discharge. The Waukesha Wastewater Treatment Plant will have to meet the WDNR phosphorus discharge limits whether discharging to the Fox River or Underwood Creek. While the WDNR final requirements are unknown, the new requirement may be more stringent than that represented in the expected discharge condition scenarios.

Under the expected discharge condition, the phosphorus concentration increases in Underwood Creek, but the percentage of time the recommended phosphorus planning level goal is met only decreases by 1 to 2 percent indicating very little change in meeting the phosphorus planning level goal in Underwood Creek. In the Menomonee River, the phosphorus concentration increases, with the percentage of time the recommended phosphorus planning level goal is met either staying the same (2 assessment points) or reduced (2 assessment points).

Total Suspended Solids

Under the expected discharge condition, average total suspended solids concentration improves at all locations for both the existing and recommended plan alternative SEWRPC models.

Maximum Potential Discharge Condition Results

Fecal Coliform

The maximum potential discharge condition shows good improvement in Underwood Creek and good improvement in the Menomonee River for mean recreational season (May-September) fecal coliform concentration at all locations for all models.

The maximum potential discharge condition improves compliance or stays the same with the fecal coliform single sample standard during the recreational season (May–September) for all models at all assessment points.

For the maximum potential discharge condition, the fecal coliform concentration was conservatively set to always be equal to the permit limit (400 cfu/100 ml). Making the assumption that the discharge concentration will be this high every day is an overly conservative assumption when comparing compliance with the geometric mean standard, which is intended to be a long-term 30 day average comparison. For example, the fecal coliform geometric mean standard is only 200 cfu/mL which makes the conservative discharge concentration twice as high as the standard. The single sample standard is consequently a more appropriate point for compliance comparison under the worst case scenario represented by the maximum potential discharge condition. As noted in the above paragraph, single sample standard compliance always improves or stays the same during the recreational season for all models at all assessment points.

Dissolved Oxygen

Under the maximum potential discharge condition, dissolved oxygen concentration is lower but not significantly and compliance with the dissolved oxygen standard does not change for both the existing and recommended plan SEWRPC models.

Total Phosphorus

The WDNR is currently developing phosphorus standards. When the standards are finalized, it is expected that many wastewater treatment plants in Wisconsin will have to reduce their phosphorus discharge. The Waukesha Wastewater Treatment Plant will have to meet the WDNR phosphorus discharge limits whether discharging to the Fox River or Underwood Creek. While the WDNR final requirements are unknown, the new requirement could easily be more stringent than that represented in the maximum potential discharge condition scenarios.

Under the maximum potential discharge condition, the phosphorus concentration increases at all assessment points. Mean annual phosphorus concentration before return flow ranges from 0.057 to 0.132 mg/L and from 0.092 to 0.178 mg/L with return flow at the maximum potential discharge condition scenarios.

With increases in phosphorus concentration, there is a potential to cause increased algae growth, which is measured by chlorophyll *a* concentration. The SEWRPC model calibration noted that, "some of the highest chlorophyll concentrations coincide with low dissolved nutrient concentrations. This suggests a situation where nutrients are typically present in concentrations that are less limiting than other factors" (SEWRPC, 2007 Appendix D). As a result, higher phosphorus concentrations would not necessarily be expected to cause increased algae growth. To check this theory, the model predicted chlorophyll *a* concentrations were examined at assessment point MN-14 in Underwood Creek and assessment point MN-18 in the Menomonee River. A comparison between the baseline and maximum potential discharge scenario indicates that average chlorophyll *a* concentration would go down from 8.8ug/L to 2.1ug/L at assessment point MN-14 and from 5.5 ug/L to 4.5 ug/L at assessment point MN-18. These results indicate that algae growth would decrease at these locations in Underwood Creek and the Menomonee River even though slightly higher phosphorus concentrations would be present.

Total Suspended Solids

Under the maximum potential discharge condition, total suspended solids concentration either increases slightly or decreases slightly depending upon the assessment point in both the existing conditions and preferred alternative SEWRPC models. In all cases the median concentration stayed at least 45 percent better than the reference concentration (an estimated background concentration) of 17.2 mg/L used in the SEWRPC modeling, even when there was a slight increase in concentration.

Independent Review

The model was reviewed by an independent third party to verify model set-up and data interpretation accuracy. The company, Tetra Tech, the original developers of the model conducted the independent review. Results of their review are included as Attachment 2.

Conclusions

Fecal Coliform

Mean fecal coliform concentration shows dramatic to good improvement at all locations for all models. Compliance with standards showed improvement or stayed the same in all cases.

Dissolved Oxygen

Dissolved oxygen concentration is lower but not significantly and compliance with the dissolved oxygen standard does not change under all modeling scenarios.

Total Phosphorus

While the phosphorus concentration increases at all assessment points, the potential of the higher concentration to cause a negative impact is low. The SEWRPC model calibration noted that, "some of the highest chlorophyll concentrations coincide with low dissolved nutrient concentrations. This suggests a situation where nutrients are typically present in concentrations that are less limiting than other factors" (SEWRPC, 2007 Appendix D). Modeling results indicate that algae growth would decrease in Underwood Creek and the Menomonee River even though slightly higher phosphorus concentrations would be present with return flow. WDNR phosphorous standards under development could also reduce future phosphorus discharge limits.

Total Suspended Solids

The total suspended solids average concentration improves at all locations under the expected discharge condition while under the maximum potential discharge condition, total suspended solids concentration either increases slightly or decreases slightly depending upon the assessment point. In all cases the median concentration stayed significantly better than the reference concentration used in the SEWRPC modeling.

References

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Jobes, T.H., and Donigian, A.S., Jr. 2001. Hydrological Simulation Program -- FORTRAN, User's Manual for version 12. U.S. Environmental Protection Agency. Mountain View, CA.

SEWRPC. 2007. Planning Report Number 50, A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds. Milwaukee, WI.

FIGURE 1.
Menomonee River Watershed HSPF Model Segments, Potential Discharge Location, and Assessment Points

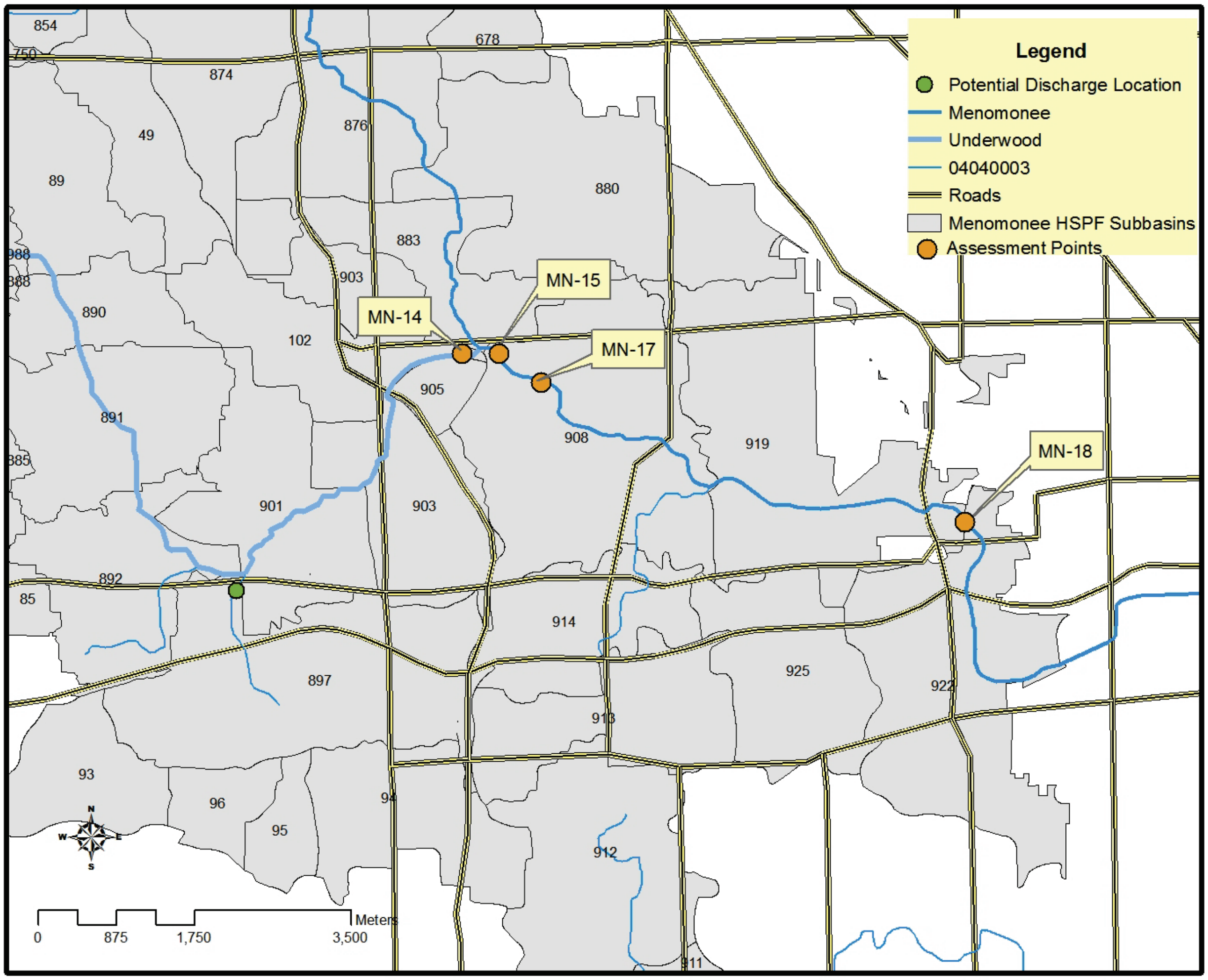

TABLE 4
Reach 905 – Assessment Point MN-14 Underwood Creek

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios 2A	Existing Scenarios 2B
Fecal Coliform Bacteria (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	3,032	1,950	2,064
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	80	82	82
	Geometric mean (cells per 100 ml), June-September 122 days	413	150	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	117	121	Note 1
Dissolved Oxygen	Mean (mg/l)	11.0	10.6	10.5
	Median (mg/l)	11.1	10.4	10.3
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.066	0.086	0.147
	Median (mg/l)	0.043	0.080	0.144
	Percent of time meeting planning goal (0.1 mg/l)	80	79	2
Total Suspended Solids	Mean (mg/l)	16.9	11.2	16.6
	Median (mg/l)	7.9	3.3	9.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 5

Reach 883 – Assessment Point MN-15 Menomonee Mainstem

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios 2A	2B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total unless noted)	Mean (cells per 100 ml)	3,098	2,566	2,568
	Percent compliance with single sample standard (<400 cells per 100ml)	60	64	61
	Geometric mean (cells per 100 ml), June-September 122 days	474	326	Note 1
	Days of compliance with geometric mean standard (<200 cells per 100 ml), (June-September) per year	6	22	Note 1
Dissolved Oxygen	Mean (mg/l)	11.0	10.7	10.4
	Median (mg/l)	11.1	10.7	10.4
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.9	99.9	99.9
Total Phosphorus	Mean (mg/l)	0.063	0.073	0.101
	Median (mg/l)	0.042	0.061	0.094
	Percent of time meeting planning goal (0.1 mg/l)	82	82	56
Total Suspended Solids	Mean (mg/l)	15.6	13.8	16.4
	Median (mg/l)	5.7	4.6	7.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 6
Reach 908 – Assessment Point MN-17 Menomonee River Downstream of Honey Creek

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios 2A	Existing Scenarios 2B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,604	3,110	3,129
	Percent compliance with single variance sample standard (<2,000 cells per 100ml)	74	76	76
	Geometric mean (cells per 100 ml), June-September 122 days	499	360	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	111	118	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.7	10.5
	Median (mg/l)	11.1	10.7	10.5
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.110	0.129	0.169
	Median (mg/l)	0.072	0.109	0.156
	Percent of time meeting planning goal (0.1 mg/l)	63	44	16
Total Suspended Solids	Mean (mg/l)	16.3	14.6	16.9
	Median (mg/l)	6.1	5.0	7.7

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 7
Reach 919 – Assessment Point MN-18 Menomonee River near Upstream Limit of Estuary

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios 2A	2B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,550	3,112	3,119
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	74	76	76
	Geometric mean (cells per 100 ml), June-September 122 days	471	349	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	112	118	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.4
	Median (mg/l)	11.0	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.132	0.142	0.178
	Median (mg/l)	0.101	0.123	0.166
	Percent of time meeting planning goal (0.1 mg/l)	50	35	12
Total Suspended Solids	Mean (mg/l)	16.0	14.4	15.0
	Median (mg/l)	5.7	4.6	5.8

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 8
Reach 922 – Assessment Point Menomonee River at Upstream Limit of Estuary

Water Quality Indicator	Statistic	Existing Baseline	Existing Scenarios 2A	2B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	3,409	3,023	3,026
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	75	77	77
	Geometric mean (cells per 100 ml), June-September 122 days	411	321	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September) per year	116	119	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.7	10.6
	Median (mg/l)	10.9	10.7	10.6
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.068	0.074	0.094
	Median (mg/l)	0.048	0.061	0.085
	Percent of time meeting planning goal (0.1 mg/l)	81	81	68
Total Suspended Solids	Mean (mg/l)	15.8	14.5	14.7
	Median (mg/l)	5.4	4.6	5.1

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 9
Reach 905 – Assessment Point MN-14 Underwood Creek

		Future	Future Scenarios	
Water Quality Indicator	**Statistic**	**Baseline**	**3A**	**3B**
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,351	871	1,046
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	83	86	86
	Geometric mean (cells per 100 ml), June-September 122 days	213	86	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	122	122	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.4	10.1
	Median (mg/l)	11.2	10.3	10.1
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.057	0.081	0.140
	Median (mg/l)	0.039	0.078	0.139
	Percent of time meeting planning goal (0.1 mg/l)	85	83	3
Total Suspended Solids	Mean (mg/l)	12.8	8.9	14.5
	Median (mg/l)	5.9	2.9	9.4

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 10
Reach 883 – Assessment Point MN-15 Menomonee Mainstem

Water Quality Indicator	Statistic	Future Baseline	Future Scenarios 3A	Future Scenarios 3B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,527	1,260	1,326
	Percent compliance with single sample standard (<400 cells per 100ml)	65	67	65
	Geometric mean (cells per 100 ml), June-September 122 days	260	184	Note 1
	Days of compliance with geometric mean standard (<200 cells per 100 ml) (June-September), per year	35	62	Note 1
Dissolved Oxygen	Mean (mg/l)	10.8	10.5	10.2
	Median (mg/l)	10.9	10.6	10.2
	Percent compliance with dissolved oxygen standard (>5 mg/l)	99.9	99.9	99.9
Total Phosphorus	Mean (mg/l)	0.059	0.070	0.097
	Median (mg/l)	0.042	0.061	0.092
	Percent of time meeting planning goal (0.1 mg/l)	85	85	59
Total Suspended Solids	Mean (mg/l)	12.4	11.1	13.7
	Median (mg/l)	4.6	3.8	7.0

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 11
Reach 908 – Assessment Point MN-17 Menomonee River Downstream of Honey Creek

Water Quality Indicator	Statistic	Future Baseline	Future Scenarios 3A	Future Scenarios 3B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,812	1,557	1,607
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	80	80
	Geometric mean (cells per 100 ml), June-September 122 days	272	201	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.3
	Median (mg/l)	11.0	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.104	0.123	0.162
	Median (mg/l)	0.073	0.107	0.153
	Percent of time meeting planning goal (0.1 mg/l)	64	45	17
Total Suspended Solids	Mean (mg/l)	13.2	11.8	14.2
	Median (mg/l)	4.9	4.1	7.0

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 12
Reach 919 – Assessment Point MN-18 Menomonee River near Upstream Limit of Estuary

Water Quality Indicator	Statistic	Future Baseline	Future Scenarios 3A	Future Scenarios 3B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,847	1,618	1,653
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	80	81
	Geometric mean (cells per 100 ml), June-September 122 days	263	199	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	10.9	10.6	10.4
	Median (mg/l)	10.9	10.6	10.4
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.126	0.136	0.171
	Median (mg/l)	0.101	0.121	0.162
	Percent of time meeting planning goal (0.1 mg/l)	49	36	13
Total Suspended Solids	Mean (mg/l)	13.1	11.8	12.5
	Median (mg/l)	4.8	4.0	5.4

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

TABLE 13
Reach 922 – Assessment Point Menomonee River at Upstream Limit of Estuary

Water Quality Indicator	Statistic	Future Baseline	Future Scenarios 3A	Future Scenarios 3B
Fecal Coliform Bacteria during Recreational Season (May-September: 153 days total) unless noted	Mean (cells per 100 ml)	1,831	1,628	1,657
	Percent compliance with single sample variance standard (<2,000 cells per 100ml)	79	81	81
	Geometric mean (cells per 100 ml), June-September 122 days	254	197	Note 1
	Days of compliance with geometric mean variance standard (<1,000 cells per 100 ml) (June-September), per year	121	122	Note 1
Dissolved Oxygen	Mean (mg/l)	11.1	10.9	10.8
	Median (mg/l)	11.1	10.9	10.8
	Percent compliance with dissolved oxygen variance standard (>2 mg/l)	100.0	100.0	100.0
Total Phosphorus	Mean (mg/l)	0.065	0.072	0.092
	Median (mg/l)	0.048	0.062	0.085
	Percent of time meeting planning goal (0.1 mg/l)	83	83	69
Total Suspended Solids	Mean (mg/l)	13.4	12.2	12.4
	Median (mg/l)	4.9	4.1	4.6

Note 1: Not applicable for this scenario because the maximum potential discharge condition represents a worst case discharge condition more appropriately compared to the single sample standard.

Attachment 1
Summary of Waukesha WWTP Effluent Data Analysis

Summary of Waukesha WWTP Effluent Data Analysis

PREPARED FOR: Project Team

PREPARED BY: CH2M HILL

DATE: November 16, 2009

This memorandum documents the methods and procedures used to compile data provided by the Waukesha Wastewater Treatment Plant (WWTP). The data is anticipated to be used to predict in-stream water quality parameter changes with a future WWTP return flow to a Lake Michigan tributary river. The WWTP effluent is routinely monitored for the following characteristics:

- Flow (million gallons per day, MGD)
- Total Suspended Solids (TSS, mg/L)
- Temperature (ºC)
- Dissolved Oxygen (DO, mg/L)
- Biochemical Oxygen Demand (BOD, mg/L)
- Total Phosphorus (TP, mg/L)
- Ammonia (NH_3-N, mg/L)
- Fecal Coliforms (# per 100 mL)
- Copper (Cu, µg/L)
- Zinc (Zn, µg/L)

WWTP effluent data was provided by Randy Thater (WWTP) for the period between October 1, 2002 to August 31, 2009. October 1, 2002 represents the first day of operation of the UV Disinfection system when prior to this date, the effluent was disinfected with chlorine. Effluent data was not provided prior to this time because the use of a chlorine disinfectant would not provide representative effluent data for current and future conditions. The data was provided in two distinct data sets that represent two different computer systems at the WWTP (October 1, 2002 to April 30, 2004 and May 1, 2004 to August 31, 2009). The effluent data was consolidated into one Excel spreadsheet to allow it to be summarized into monthly averages.

Because the data was collected over a long period of time, some assumptions were required to allow the data to be analyzed and compared over the entire period. These assumptions and the rationale for each are summarized below.

- The copper and zinc average monthly effluent concentrations between October 1, 2002 and April 30, 2004 were greater than the more recent effluent data (copper was about 10 times greater and zinc was about 3 times greater). It is not known why the values were greater. Because the most recent effluent data (May 2004 through August 2009) represents effluent concentrations that are most indicative of a potential return flow, only these average monthly effluent concentrations are used.

- The geometric mean monthly fecal coliform values consistent with permit reporting requirements were calculated for May through September months because this is the time when disinfection is required by the WWTP's effluent permit. May 2003 fecal coliform data was excluded from the analysis because this was the first month of operation for the UV system and incomplete data were available for the entire month. Fecal coliform effluent permit requirements for two other municipal wastewater dischargers whose effluent discharges to a Lake Michigan tributary (Cedarburg, WI discharges to Cedar Creek and Grafton, WI discharges to the Milwaukee River) confirmed the same disinfection season permit requirements as Waukesha's permit. Because the permit requirements for fecal coliform were the same between the three discharges, the WWTP's effluent data was used to analyze the potential return flow on a seasonal disinfection basis.
- When effluent concentrations were below the detection limits, the actual concentration is a value less than the detection limit. Because the actual concentration cannot be determined, the days where the concentration was reported less than the detection limit were replaced with a value equal to the detection limit (e.g., if the effluent zinc concentration was reported as < 10 μg/L, the value was assumed to be 10 μg/L). This approach provides a conservatively high value for purposes of calculating water quality parameter concentrations. For parameters that were limited by detection limits, any zero-value or blank entries were excluded from the analysis.

The water quality modeling requires additional effluent parameters than what is routinely collected by the WWTP, specifically orthophosphate (OP), nitrate (NO_3-N), and total Kjeldahl nitrogen (TKN). To support the modeling, the WWTP staff collected three composite effluent samples on 9/21/09, 9/22/09 and 9/23/09 (Table 1) and analyzed them for these parameters. The samples were used to calculate ratios or averages (Table 2) which were used to estimate average monthly effluent values for OP, NO_3-N, and TKN, similar to the other effluent parameters summarized above. A summary of the methods used to estimate the parameters is below.

TABLE 1
Waukesha Wastewater Treatment Plant Effluent Composite Sample Data

Effluent Constituents	9/21/2009	9/22/2009	9/23/2009	Average
Flow (MGD)	8	8.1	8.4	8.2
TSS (mg/L)	<1.0	<1.0	<1.0	<1.0
Temperature (Deg C)	19.8	19.7	20.4	20
Phosphorus (mg/L)	0.31	0.26	0.26	0.28
NH3-N (mg/L)	<0.04	<0.04	<0.04	<0.04
BOD (mg/L)	<2.0	<2.0	<2.0	<2.0
D.O. (mg/L)	8.7	8.4	8.6	8.6
Fecal Coliform (No/100mL)	1	1	0	1
Nitrate-Nitrite (mg/L)	12	12	13	12.3
Orthophosphate (mg/L)	0.22	0.18	0.16	0.19
TKN (mg/L)	0.57	0.26	0.98	0.6

Orthophosphate: The OP concentration represents dissolved reactive phosphorus that is not removed in settling or filtration. The TP concentration includes the dissolved reactive

TABLE 2
Average Waukesha Wastewater Treatment Plant Effluent Ratios (9/21/09 – 9/23/09)

Effluent OP/TP	0.67
Effluent NO_3-N/Aeration Basin Influent NH3-N	1.17

phosphorus and also includes colloidal and particulate phosphorus. Most of the particulate phosphorus is removed in filtration, however a portion of the smaller particulates and colloidal phosphorus can pass through filtration as part of the WWTP effluent. To estimate the monthly average effluent OP (similar to the other effluent parameters discussed above), the calculated monthly average TP from the WWTP effluent data was proportioned by the fraction of OP measured in the three samples. The effluent ratio of OP to TP should be generally similar unless upstream chemical dosing changes (affecting precipitation of soluble phosphorus) or filter performance deteriorates. For the three composite samples, the OP/TP ratio ranged between 0.62 and 0.71, with an average ratio of 0.67. Using the average OP/TP ratio of 0.67, the average monthly effluent TP concentration was multiplied by 0.67 to obtain the monthly average effluent OP concentration.

Nitrate: To estimate the average monthly WWTP effluent NO_3-N concentration, the aeration basin influent ammonia (NH_3-N) concentration was used. The concentration of NH_3-N in the aeration basin influent is an appropriate surrogate for effluent NO_3-N data because the ratio of effluent NO_3-N to influent NH_3-N is relatively constant on average. This is because:

- NO_3-N is formed as influent NH_3-N and influent organic nitrogen that is solubilized to NH_3-N are oxidized to NO_3-N in secondary treatment.
- The ratio of NH_3-N to TKN, which includes ammonia and organic nitrogen, is relatively constant on average.
- NH_3-N is almost fully converted to NO_3-N in the aeration basin and because there is no anoxic zone where dissolved NO_3-N is converted to nitrogen gas, NO_3-N formed in secondary treatment is not removed.

Because aeration basin influent NH_3-N was not available for the three NO_3-N sample dates, the NH_3-N average of the day before and the day after the three NO_3-N samples was used to calculate this ratio. After speaking with Randy Thater of the WWTP, it was expected that the aeration basin influent NH_3-N was fairly constant during the week of sampling because there was no biosolids dewatering occurring, which has been observed to change the influent NH_3-N. Using this composite sample data, the ratio of WWTP effluent NO_3-N to aeration basin influent NH_3-N was calculated to be 1.17. This ratio was then used in conjunction with the historic monthly average aeration basin influent NH_3-N data to estimate the monthly average effluent NO_3-N (i.e., by multiplying the average monthly aeration basin influent NH_3-N by 1.17).

Total Kjeldahl Nitrogen: Effluent TKN was assumed to be 0.98 mg/L, which was the highest TKN observed in the three composite effluent samples. Effluent TKN varies based on the amount of solids and ammonia in the effluent. When effluent TSS is less than 1 mg/L and effluent ammonia is less than 0.04 mg/L, as observed in the three composite samples, TKN would likely be less than 1 mg/L, which was observed.

The calculated average monthly WWTP effluent concentrations for the above water quality parameters are summarized in Table 3.

TABLE 3
Waukesha Wastewater Treatment Plant Average Monthly Effluent Values (October 2002- August 2009)

Month	Flow (mgd)	Flow (cfs)	BOD5 (mg/L)	TKN (as N) (mg/L)	Ammonia (as N) (mg/L)	Nitrate-Nitrite (as N) (mg/L)	TP (mg/L)	Ortho P (as P) PO4 (mg/L)[3]	DO (mg/L)	Temp (deg C)	TSS (mg/L)	Fecal Coliform (cfu/100mL)[1]	Cu (µg/L)[2]	Zn (µg/L)[2]
January	9.4	14.5	1.7	0.98	0.10	18.6	0.11	0.07	10.3	12.0	0.9	ND	6.6	42.0
February	9.3	14.4	1.7	0.98	0.06	19.1	0.10	0.06	10.5	11.5	0.9	ND	12.4	48.6
March	11.3	17.4	1.7	0.98	0.14	16.1	0.12	0.08	10.4	12.3	1.1	ND	6.1	49.6
April	12.3	19.1	1.7	0.98	0.09	12.9	0.10	0.06	9.7	14.1	1.4	ND	8.6	22.0
May	11.5	17.7	2.0	0.98	0.20	13.9	0.12	0.08	9.0	16.4	1.2	2	7.1	45.7
June	12.1	18.7	2.6	0.98	0.14	12.7	0.21	0.14	8.2	18.8	1.8	49	6.1	30.5
July	9.2	14.3	1.8	0.98	0.05	16.8	0.16	0.11	8.0	20.6	1.0	2	6.1	29.3
August	9.0	14.0	1.8	0.98	0.07	14.8	0.19	0.13	7.9	21.3	1.1	2	6.3	37.2
September	8.8	13.7	2.1	0.98	0.10	16.2	0.21	0.14	8.0	20.8	1.0	2	8.7	39.0
October	8.8	13.6	1.6	0.98	0.04	17.3	0.24	0.16	8.7	18.6	1.1	ND	5.7	36.6
November	8.6	13.3	1.6	0.98	0.07	18.1	0.21	0.14	9.5	16.0	1.1	ND	6.7	33.8
December	9.2	14.2	1.6	0.98	0.07	20.7	0.15	0.10	10.3	13.3	1.1	ND	9.3	47.4

[1]Geometric means were used for fecal coliform data. The numbers shown in the table represent the average geometric mean for each month (i.e. the geometric mean was determined for the seven Januaries in the dataset. These seven geometric means were then averaged.
[2]Data for Copper (Cu) and Zinc (Zn) from 2002-2004 was not used as described above.
[3]Based on Effluent OP/TP (Orhophosphate/Total Phosphorus) ratio of 0.67, determined from three samples collected 9/21, 9/22, and 9/23
ND – No Disinfection. The WPDES permit only has a disinfection requirement and associated limit on fecal coliforms from May-September. As a result, UV disinfection is only operated from May-September.

Attachment 2
Independent Model Review Findings

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MEMORANDUM

To: Daniel S. Duchniak, PE (WWU)
Klaus Albertin (CH2M HILL)

Date: December 3, 2009

From: Jonathan Butcher, Ph.D., P.H.

Project: Waukesha Water Diversion

Subject: Underwood Creek Model Review

The City of Waukesha Water Utility (WWU) is proposing to route return flow from their Wastewater Treatment Plant to Underwood Creek. To analyze the potential impacts of the proposed discharge, CH2M HILL modified an existing water quality model of the Menomonee River system, including Underwood Creek. This model is an HSPF model developed for the Southeastern Wisconsin Regional Planning Commission (SEWRPC) by Tetra Tech to support the regional water quality management plan update. Results of this analysis are presented in a technical memorandum dated November 24, 2009 from CH2M HILL to the City of Waukesha.

The City of Waukesha contracted with Tetra Tech to provide an independent review of the modified water quality model. Dr. Jonathan Butcher, the reviewer, was the lead developer of the Menomonee River model for SEWRPC, and is intimately familiar with the modeling system. Klaus Albertin of CH2M HILL provided the draft report and the accompanying modeling files to Tetra Tech for review.

Detailed review of the modeling files and supporting information revealed only one significant flaw (in the specification of the point source input files). CH2M HILL was apprised of this issue and has re-run the model to correct the error. Therefore, the revised model is appropriate and ready for the evaluation of the proposed discharge, although some corrections may be needed in the way that results are reported. I do suggest, however, that Waukesha may wish to re-evaluate the representation of "typical conditions" discharge characteristics. Some additional comparisons of conditions with and without the discharge may also be useful.

Specific aspects of the review are documented below.

Applicability of the Modeling System

The modeling system developed for SEWRPC uses U.S. EPA's Hydrologic Simulation Program-FORTRAN (HSPF). The model is implemented at a 15-minute time step and is set up to run over the evaluation period of 1/1/1987 – 12/31/1997. Weather data are available and set up to cover the period of 1983-2002; however, SEWRPC specifically selected 1987-1997 as a representative base period for the evaluation of future water quality management plans. Use of this same time period is appropriate for evaluating the general impact of the proposed discharge on water quality time series. The dynamic model analysis should likely be supplemented with a separate, steady-state critical condition analysis for end-of-pipe permit limit calculations.

The SEWRPC Menomonee River model provides a complete representation of flow, sediment, nutrients, bacteria, algae, BOD/DO, and water temperature and has been calibrated and validated for each of these components. The model was also set up to simulate concentrations of copper and zinc. However, as directed by SEWRPC, simulation of the metals is in a simplified form and not rigorously calibrated. Caution should thus be used in analysis of model results for copper.

Modeling Files

SEWRPC provided the basic modeling files to CH2M HILL, representing the Existing and Preferred Alternative (PA) production run scenarios, where the PA scenario represents 2020 land use with proposed management strategies. These final scenarios were selected from a much larger set of scenarios conducted by Tetra Tech. Internally, the final Existing scenario is known as the ESM run, representing existing land use and management combined with CSO/SSO simulation using Streamline Mouse, while the SEWRPC PA scenario is Tetra Tech's PA2 run.

HSPF execution is controlled by User Control Input (UCI) files. A separate file is provided for each major subwatershed in the Menomonee. I compared the UCI files provided by CH2M HILL to those in the Tetra Tech archive and determined that the files used for Scenarios 1 and 2 (representing existing conditions) are identical those developed for the ESM run, while the files used for Scenario 3 (future conditions) are identical to those developed for the PA2 run, with two exceptions: (1) the addition of the new discharge to Underwood Creek, and (2) additions to write water temperature output for the evaluation points in the Underwood Creek and Menomonee-Downstream submodels.

The model also depends on the weather data and text "mutsin" files that provide information on point source discharges, CSOs, and SSOs. The weather data files used by CH2M HILL are identical to those in the Tetra Tech archive. The mutsin files for a run are stored in two directories – a global directory for point source discharges that do not change with scenario, and a scenario-specific directory for discharges that vary by scenario. SEWRPC neglected to provide the global mutsin files to CH2M HILL, so Tetra Tech provided these directly. I confirmed that the appropriate scenario-specific mutsin files were used by CH2M HILL and that these are identical to the ones in the Tetra Tech archive.

Scenario Modification

Modifications of the existing models to address the proposed discharge are simple and straightforward. The only change required in the UCI files was the addition of new point source mutsin files representing the proposed Waukesha discharge and their linkage to reach 901 in the Underwood Creek submodel. As noted above, no other changes were made to the existing UCI files except for the provision of additional write statements for water temperature. I confirmed that these modifications to the UCI files were implemented correctly.

Completion of the scenarios also required construction of mutsin files to represent the Waukesha discharge. CH2M HILL did this via two separate mutsin files, one representing flow, thermal load, and bacterial load, and the other representing loads of other pollutants. (The CH2M HILL memorandum implies that the first file contains only "monthly flow and temperature"; however, fecal coliform bacteria loads are also transmitted via this file.)

The mutsin input must be supplied to the model at the simulation time step of 15 minutes and in the appropriate units. As originally developed by CH2M HILL, the mutsin files specified values at the start (end of the first hour of the first day) of each month, but were implemented with a missing value flag of 3 in the UCI file – indicating that missing values are to be filled with the next available value. The effect of this is that the model read a value for the first hour of a month, then treated the next interval as missing and substituted the next available value, which is entered for the first of the next month. This resulted in a shift in the values. That is, all but the first hour of the January simulation uses February flows and loads. As the number entered for January was intended to represent an average for the month of January, the model was not correctly interpreting the input. I notified CH2M HILL of this problem, which can be remedied by changing the date representation to the last hour of the last day of the month instead of the first hour of the first day. The CH2M HILL modeler indicated that the models will be rerun and the memorandum revised to incorporate this correction.

As noted above, the mutsin file must provide loads in the correct units and at the modeled 15-minute time interval. The model is implemented in English units, so the mutsin file must be set up as follows:

- Flow: AF/15-min
- Nutrient and metals load: lb/15-min
- Bacterial load: cfu/15-min
- Thermal load: BTUs (relative to freezing)/15-min
- Solids: tons/15-min

Point source monitoring data are typically in MGD for flow, mg/L for standard pollutants, temperature for thermal load, and cfu/100 ml for bacteria. Converting these to mutsin units can be tricky. I confirmed that all unit conversions were performed properly. There are several minor criticisms, which do not impact model performance. First, the text incorrectly says the first mutsin "specified monthly flow and temperature", whereas it is actually specifying 15-minute flow and thermal load. Second, the header in the first mutsin incorrectly says that FC is being given in cfu/100 ml, whereas the units are cfu/15-min. Finally, the spreadsheet calculation of bacterial load uses a factor of 28.33 to convert from cubic feet to liters. The correct factor should be 28.317; however, any discrepancies that might have resulted appear to be eliminated by round off to two significant digits (scientific notation) in the mutsin file.

Confirmation of Model Runs

I implemented the model files provided by CH2M HILL and confirmed that they do indeed run as intended.

Model output for segments upstream of Underwood Creek, as well as for Scenario 1 in Underwood Creek and downstream, should be identical to those obtained previously by Tetra Tech. I compared a variety of output files and determined that results were very close, but not identical, for output of daily average pollutant concentrations, with a maximum difference of about 2 percent in fecal coliform concentrations. Investigations of the causes of this discrepancy revealed that it is not due to any differences in model input. Rather, the differences arose because CH2M HILL ran the models with WinHSPFLt, whereas the SEWRPC models were implemented with an older DOS version of HSPF running in batch mode. The two versions of the model differ slightly in their calculation of daily averages – particularly for constituents that vary widely in concentration over the course of a day – due to the accumulation of round off error in the underlying FORTRAN code.

The CH2M HILL modeler confirmed that they had also rerun the baseline (Scenario 1) model with WinHSPFLt. Therefore, the comparison presented in the memorandum is done on a consistent basis and the difference in round off error between the two models is not a problem for the purposes of the analysis.

Analysis of Scenario Results

Scenario results are presented in a series of tables, for four assessment points in Underwood Creek and the downstream Menomonee River, which assess various water quality statistics with and without the proposed discharge. I have some minor issues with the reporting of statistics; however, the most important thing is that they are reported in a consistent way, allowing comparison across scenarios.

The actual results will be revised to correct the representation of the new point source, as noted above. It is, however, also important to review the way in which the results are calculated and presented. CH2M HILL did not provide the spreadsheets used to calculate the tables; however, I made an independent investigation of the results based on the output files created by the current version of the model. In general, the reported means, geometric means, and medians appear to correctly represent the output of the model. Most of the percent compliance (or days per year) results also appear to correctly represent the model. It is, however, worth noting that these statistics are based on daily average output, not on the raw model output at 15-minute intervals. This has an impact on the percent compliance and geometric mean outputs, but is not a problem given use of a consistent comparison to baseline conditions. I do note that the "days of compliance" results should be stated to be on a "per year" basis.

In at least two cases there appears to be some discrepancy in the reported model results for fecal coliform bacteria. The first is for the "Days of compliance with geometric mean standard (<1000 cells per 100 ml)." I assume this is simply a count of the average number of days per year when the daily average concentration is less than 1000 as comparison to running 30-day geometric means yields a much lower count. For Station MN-14, the reported number of days in Table 4 is Existing Baseline: 268; Scenario 2A: 203; and Scenario 2B: 174. Tetra Tech's previous analysis of the existing conditions run yielded a count of 235 days; my reanalysis of the output for scenarios 2A and 2B yielded 230 days in both cases. CH2M HILL should thus recheck the calculations for this statistic, and correct it if necessary; or, if it is correct, explain how it was calculated.

The second discrepancy is with the recreation-season calculation of percent compliance with the single sample standard of 1000 cells per 100 ml. In Table 4, CH2M HILL reports 34 percent compliance at Station MN-14, and similar low percentages of compliance are reported for other stations. My calculations show that the rate should be about 86% for the existing baseline and about 82% for Scenarios 2A and 2B. That the reported numbers are wrong is obvious from the fact that 34 percent of the 153 days in May through September yields 52 days per year in compliance with the 2000 per 100 ml, whereas the number of days in compliance with the 1000 per 100 ml standard is reported as around 130 per year. It appears that the discrepancy is due to calculating the percentage by dividing the number of recreation-season days in compliance by 365, rather than by the number of days contained within the recreation season (153).

It is worth noting that the simulations with the new discharge present show at least a small degradation in the frequency during which the fecal coliform standards are met. As is discussed below, this seems to be due to the assumption that the non-recreation season fecal coliform concentration in the effluent is always equal to 915 per 100 ml, just less than the geometric mean standard.

The memorandum states that "Copper values are higher in the discharge scenarios", but does not provide numeric results in the revised version (the initial version of the memorandum that was provided to Tetra Tech did give numeric copper results). As noted above, Tetra Tech does not consider the model to be calibrated for copper; therefore, it is probably best to omit the copper comparison entirely.

On the other hand, a comparison of ammonia-N concentrations with and without the discharge would likely be of interest. Impacts on conditions downstream in the harbor are also likely to be of considerable interest. I suggest that model results may also need to be analyzed to evaluate changes in mass loading of nutrients and bacteria to the harbor with and without the new discharge.

Representation of the Discharge

The proposed discharge is represented in two ways, first as typical monthly average values based on data from October 2002 to August 2009, and second at permit limits. I believe this is adequate for the purposes of the study. It is worth noting that plant discharge is likely to be positively correlated with precipitation, and a more refined representation would use daily flows that are matched to the model simulation period. This was apparently not possible as the production run period of the model (1987-1997) is different from the effluent monitoring period. The effect of a positive correlation between effluent discharge and precipitation (and thus with instream flow) would be that more of the discharge would occur when instream dilution capacity is greater. The existing analysis, with constant monthly values, is therefore likely conservative in that it will tend to overestimate loading from the Waukesha discharge during low flow conditions when impact will be greatest.

CH2M HILL's memorandum discusses the determination of discharge characteristics only briefly, and does not include the promised Attachment 1 ("Summary of Waukesha WWTP Effluent Data Analysis").

Two anomalies stand out in the representation of the actual conditions discharge (Table 2). The first is that the fecal coliform concentration during the non-recreation season is always assigned a value of 915 cfu/100 ml. This is the permit limit value. I assume that this value was assigned because fecal coliform has not been monitored during the non-recreation season? However, I doubt that the concentration is always exactly at the permit limit. A more reasonable representation of existing conditions might provide more favorable statistics. If this is not possible, justification for use of the 915 concentration should be provided in the text.

Table 4 also assigns for existing conditions a TKN concentration that is always equal to 0.98. This appears to be the value used for organic N in the permit limit table. Again, justification needs to be provided – although N concentrations are not used in the comparison of existing conditions and conditions with the discharge at this time.

Summary

The model application appears to be correct and defensible, with the exception of the time series representation of the discharge, which is being corrected by CH2M HILL. In addition, the methods by which the summary reporting statistics are calculated should be further reviewed. Once these changes and checks are made, the results should be ready for submission to the appropriate regulatory authorities.

Attachment 3
Review Response

Response to Comments on the Underwood Creek and Menomonee River HSPF Model Analysis

PREPARED FOR: City of Waukesha

PREPARED BY: CH2M HILL

DATE: January 13, 2010

The City of Waukesha Water Utility (WWU) is proposing to route return flow to Underwood Creek in order to meet the requirements of the Great Lakes Compact. To analyze the potential water quality changes of the proposed discharge, CH2M HILL modified an existing water quality model of the Menomonee River system, including Underwood Creek. This model is an HSPF model developed for the Southeastern Wisconsin Regional Planning Commission (SEWRPC) by Tetra Tech to support the Regional Water Quality Management Plan Update (RWQMPU). Results of this analysis are presented in a technical memorandum from CH2M HILL to the City of Waukesha.

The City of Waukesha contracted with Tetra Tech to provide an independent review of the modified water quality model. This document summarizes the comments that TetraTech provided as well as a response to comments by CH2M HILL.

Comment 1:

As originally developed by CH2M HILL, the mutsin files specified values at the start (end of the first hour of the first day) of each month, but were implemented with a missing value flag of 3 in the UCI file – indicating that missing values are to be filled with the next available value. The effect of this is that the model read a value for the first hour of a month, then treated the next interval as missing and substituted the next available value, which is entered for the first of the next month. This resulted in a shift in the values.

Response 1:

Values in the mutsin files were shifted so that missing values would be filled with the representative values. The models were rerun and results were updated to reflect the revision of the mutsin files. The changes to the results were slight for all parameters except fecal coliform. This correction improved compliance with the recreational season standard since the fecal coliform values varied significantly between the summer recreational season and winter months..

Comment 2:

The text incorrectly says the first mutsin “specified monthly flow and temperature”, whereas it is actually specifying 15-minute flow and thermal load. Second, the header in the first mutsin incorrectly says that FC is being given in cfu/100 ml, whereas the units are cfu/15-min.

Response 2:

This comment was addressed in the final technical memorandum (TM).

Comment 3:

The spreadsheet calculation of bacterial load uses a factor of 28.33 to convert from cubic feet to liters. The correct factor should be 28.317; however, any discrepancies that might have resulted appear to be eliminated by round off to two significant digits (scientific notation) in the mutsin file.

Response 3:

As noted in the comment, the effect of this difference in conversion factors is very minor and would at most conservatively overestimate coliform loading by less than 0.5 percent.

Comment 4:

Model output … for a variety of output files and determined that results were very close, but not identical, for output of daily average pollutant concentrations, with a maximum difference of about 2 percent in fecal coliform concentrations. Investigations of the causes of this discrepancy revealed that it is not due to any differences in model input. Rather, the differences arose because CH2M HILL ran the models with WinHSPFLt, whereas the SEWRPC models were implemented with an older DOS version of HSPF running in batch mode. The two versions of the model differ slightly in their calculation of daily averages – particularly for constituents that vary widely in concentration over the course of a day – due to the accumulation of round off error in the underlying FORTRAN code.

Response 4:

All scenarios including the baseline models (existing and preferred alternative) were run with WinHSPFLt. Therefore, the comparison presented in the memorandum is done on a consistent basis and the difference in round off error between the two models is not a problem for the purposes of the analysis. As noted in the comment, the existing and preferred alternatives results may differ from those previously reported due to the minor differences in model computer platform calculation procedures.

Comment 5:

It is, however, also important to review the way in which the results are calculated and presented. CH2M HILL did not provide the spreadsheets used to calculate the tables; however, I made an independent investigation of the results based on the output files created by the current version of the model. In general, the reported means, geometric means, and medians appear to correctly represent the output of the model. Most of the percent compliance (or days per year) results also appear to correctly represent the model. It is, however, worth noting that these statistics are based on daily average output, not on the raw model output at 15-minute intervals. This has an impact on the percent compliance and geometric mean outputs, but is not a problem given use of a consistent comparison to baseline conditions. I do note that the "days of compliance" results should be stated to be on a "per year" basis.

In at least two cases there appears to be some discrepancy in the reported model results for fecal coliform bacteria. The first is for the "Days of compliance with geometric mean standard (<1000 cells per 100 ml)." I assume this is simply a count of the average number of days per year when the daily average concentration is less than 1000 as comparison to running 30-day geometric means yields a much lower count. For Station MN-14, the reported number of days in Table 4 is Existing Baseline: 268; Scenario 2A: 203; and Scenario 2B: 174. Tetra Tech's previous analysis of the existing conditions run yielded a count of 235 days; my reanalysis of the output for scenarios 2A and 2B yielded 230 days in both cases. CH2M HILL should thus recheck the calculations for this statistic, and correct it if necessary; or, if it is correct, explain how it was calculated.

The second discrepancy is with the recreation-season calculation of percent compliance with the single sample standard of 1000 cells per 100 ml. In Table 4, CH2M HILL reports 34 percent compliance at Station MN-14, and similar low percentages of compliance are reported for other stations. My calculations show that the rate should be about 86% for the existing baseline and about 82% for Scenarios 2A and 2B. That the reported numbers are wrong is obvious from the fact that 34 percent of the 153 days in May through September yields 52 days per year in compliance with the 2000 per 100 ml, whereas the number of days in compliance with the 1000 per 100 ml standard is reported as around 130 per year. It appears that the discrepancy is due to calculating the percentage by dividing the number of recreation-season days in compliance by 365, rather than by the number of days contained within the recreation season (153).

Response 5:

Tables in the final TM were revised to state compliance is on a per year basis. The TM was also revised to state that the calculation of the geomean standard compliance used a 30-day rolling geomean calculation. This results in a much lower number as noted in the comment. The calculations and tables were revised to calculate the percent compliance during the summer using the total number of recreation season days (153 days).

Comment 6:

It is worth noting that the simulations with the new discharge present show at least a small degradation in the frequency during which the fecal coliform standards are met. As is discussed below, this seems to be due to the assumption that the non-recreation season fecal coliform concentration in the effluent is always equal to 915 per 100 ml, just less than the geometric mean standard.

Response 6:

It is agreed that the specification of fecal coliform as 915 cfu/100 mL for the non-recreation contact period has a significant impact on the statistics for fecal coliform. Monitoring is not typically performed during the non-recreation season so a high level was used to be conservative. More representative numbers could improve the compliance statistics.

Comment 7:

The memorandum states that "Copper values are higher in the discharge scenarios", but does not provide numeric results in the revised version (the initial version of the memorandum that was provided to Tetra Tech did give numeric copper results). As noted above, Tetra Tech does not consider the model to be calibrated for copper; therefore, it is probably best to omit the copper comparison entirely.

Response 7:

Discussion of copper was removed from the TM.

Comment 8:

…. a comparison of ammonia-N concentrations with and without the discharge would likely be of interest. Impacts on conditions downstream in the harbor are also likely to be of considerable interest. I suggest that model results may also need to be analyzed to evaluate changes in mass loading of nutrients and bacteria to the harbor with and without the new discharge.

Response 8:

Data for comparison between scenarios was provided for those water quality parameters which the Waukesha Wastewater Treatment Plant currently has in its permit.

Comment 9:

Two anomalies stand out in the representation of the actual conditions discharge (Table 2). The first is that the fecal coliform concentration during the non-recreation season is always assigned a value of 915 cfu/100 ml. This is the permit limit value. I assume that this value was assigned because fecal coliform has not been monitored during the non-recreation season? However, I doubt that the concentration is always exactly at the permit limit. A more reasonable representation of existing conditions might provide more favorable statistics. If this is not possible, justification for use of the 915 concentration should be provided in the text.

Table 4 also assigns for existing conditions a TKN concentration that is always equal to 0.98. This appears to be the value used for organic N in the permit limit table. Again, justification needs to be provided – although N concentrations are not used in the comparison of existing conditions and conditions with the discharge at this time.

Response 9:

The final TM was revised to address this comment. The TM will emphasize that the discharge was characterized either by actual historical effluent quality for the expected discharge condition scenario or by permit limits and high observed concentrations for the maximum potential discharge condition scenario.