6. UMR-LP MODEL APPLICATION

The calibrated UMR-Lake Pepin model was applied to simulate a series of solids and nutrient load reduction scenarios to inform the establishment of a turbidity and eutrophication TMDL for the system. The general approach for undertaking the scenario runs is outlined below, followed by a discussion of water quality metrics/targets and model scenario design. The final section of this chapter presents the results of the load reduction scenarios run to date.

6.1 GENERAL APPROACH

The UMR-LP model load reduction scenarios included simulation of 22 years corresponding to 1985-2006 hydrology so that the model response could be evaluated across a wide range of system hydraulic conditions. Model simulations were initialized using the water column and sediment conditions predicted at the end of 2006 by the final model calibration simulation. For the purpose of evaluating critical conditions for the turbidity and eutrophication TMDL, years 2006, 1998, and 2002 were selected to represent the 10^{th}, 50^{th}, and 90^{th} percentile flow years, respectively, based on the past 30 years of record (1978-2007) for the USGS flow gage at Prescott. The rationale for establishing flow percentiles based on the recent 30-year period of record has been documented elsewhere by MPCA (Wasley and Heiskary, 2009).

The UMR-LP model application considered load reductions for the following tributary sources:

- Upper Mississippi River at Lock and Dam No. 1
- Minnesota River
- St. Croix River
- Cannon River
- Vermillion River
- Rush River
- Urban/suburban loadings for the Metro area
- Minor tributary loadings to Lake Pepin (MN/WI)

Load reductions applied to the individual tributaries were applied to historical total daily loading rates at the tributary mouths. Point sources located within the individual tributary basins (e.g., Blue Lake and Seneca WWTPs in the Minnesota basin) were not treated separately.

In addition to the tributary sources listed above, the UMR-LP model application considered loadings from seven wastewater treatment plants (WWTPs) that discharge directly to Pools 2, 3, or 4:

- Pool 2: Metro Plant, Empire, Eagles Point
- Pool 3: Hastings, Prescott
- Pool 4: Red Wing, Lake City

The "baseline" total phosphorus (TP) loadings for the direct WWTPs were calculated as the product of permitted effluent (i.e., average wet weather) daily flow rates and TP concentrations (Table 6-1). "Reduced" TP loads for direct WWTP sources were represented by reducing the TP concentration from 1.0 mg/l to 0.3 mg/l while maintaining permitted flow rates (representing a 70% load reduction). While the permitted WWTP loads represent a maximum loading rate, the "reduced" loads are more representative of typical present-day TP loads for the WWTPs that directly discharge to the UMR-LP system.

Table 6-1. Direct WWTP Loadings for UMR-LP Model Application

Point Source	Location	Permitted Flow[1] (MGD)	Reduced TP Loads[2] (MT/yr)	Permitted TP Loads[3] (MT/yr)
Metro Plant	Pool 2	314.0	130.2	433.8
Empire	Pool 2	28.6	11.9	39.5
Eagles Point	Pool 2	11.9	4.9	16.4
Hastings	Pool 3	2.9	1.2	10.4
Prescott	Pool 3	0.5	0.2	0.7
Red Wing	Pool 4	4.5	1.9	6.2
Lake City	Pool 4	1.5	0.6	2.1
Totals:		*364*	*151*	*509*

[1]Based on average wet weather daily flows.
[2]Based on effluent TP concentrations of 0.3 mg/l for all facilities.
[3]Based on permitted effluent TP concentrations of 1.0 mg/l for all facilities except Hastings, which is based on a TP concentration of 2.6 mg/l in lieu of a permitted concentration.

Implementation of load reduction scenarios in the UMR-LP model required that reduction factors be applied to the individual state variables described in Table 2-1. Reduced TP loadings were represented in the model by reducing loads for the following state variables:

- Algal and zooplankton carbon biomass (PHYT1/PHYT2/PHYT3 and ZOO1/ZOO2/ZOO3);
- Algal and zooplankton nitrogen biomass (included in the NH4T variable);
- Algal and zooplankton phosphorus biomass (included in PO4T);
- Total inorganic P – dissolved and particulate components (included in PO4T);
- Refractory and labile particulate organic P (RPOP, LPOP); and
- Refractory and labile dissolved organic P (RDOP, LDOP).

Reduced total suspended solids (TSS) loadings were represented by reducing loads for the following additional variables:

- Non-volatile suspended solids (SS1, SS2);
- Refractory and labile particulate organic carbon (RPOC, LPOC); and
- Refractory and labile particulate organic nitrogen (RPON, LPON).

6.1.1 Metrics and Targets

A central task of the Lake Pepin TMDL is the development of site-specific criteria for chlorophyll *a*, transparency and phosphorus concentrations that provides adequate

protection of aquatic recreation over a defined range of flows. MPCA has recently developed a revised set of metrics and associated targets to address turbidity issues in Pools 2 and 3 and eutrophication issues in Lake Pepin. The set of metrics and targets employed for the model application are summarized in Table 6-2. This table represents the status of metrics and targets as of early summer 2009; however, it should be noted that this information does not necessarily reflect the final TMDL metrics or targets. The most recent proposed targets for SAV growth from Pool 2 to Upper Lake Pepin include a site-specific criterion of 32 mg/L TSS as a long-term median of summer averages. The most recent proposed nutrient targets, or site-specific criteria, for Lake Pepin include summer average chlorophyll *a* of 32 µg/L, total phosphorus of 100 µg/L, and Secchi depth of 0.8 m (MPCA, 2008b).

Table 6-2. UMR-LP Water Quality Metrics and Targets

Variable	Metric	UMR-LP Location-Specific Water Quality Targets[1]							
		LD1	Spring Lake	LD2	LD3	Lake Pepin	Upper LP	Lower LP	LP Outlet
Turbidity (based on MCES meter)	Monthly Average (Oct.-Apr.)	*	*	≤ 25 NTU		*	*	*	*
Total Suspended Solids (TSS)	Average (June-Sep.)	*	*	≤ 32 mg/l (long-term median)		*	*	*	*
	Average (June-Sep.)	*	*	≤ 44 mg/l (long-term 90th percentile)		*	*	*	*
Secchi Depth	Average (June-Sep.)	*	*	*	*	≥ 0.8 m	*	*	*
Total Phosphorus	Average (June-Sep.)	*	*	*	*	≤ 100 µg/l	*	*	*
Dissolved Phosphorus	Average (June-Sep.)	*	*	*	*	*	*	*	*
Chlorophyll-a	# of days > 50 µg/l	*	*	*	*	(minimize)	*	*	*
	Average (June-Sep.)	*	*	*	*	≤ 32 µg/l	*	*	*
Blue-Green Chlorophyll-a	Average (June-Sep.)	*	*	*	*	(minimize)	*	*	*
Blue-Green % Biomass	Average (June-Sep.)	*	*	*	*	(minimize)	*	*	*

[1]Locations with site-specific targets are highlighted in yellow and indicate the target value. An asterisk (*) indicates that model results are reported for the location-variable combination, but are not compared against a target.

The TSS and turbidity metrics presented in Table 6-2 (seasonal average and 90th percentile) are intended to address the turbidity TMDL, while the metrics for Secchi depth, total phosphorus, and chlorophyll *a* address the eutrophication TMDL for Lake Pepin. Therefore, the turbidity targets are only relevant upstream of Pool 4, with Spring Lake, LD2, and LD3 serving as the key locations in this reach. The Secchi depth and chlorophyll *a* targets for Lake Pepin include specific targets for the upper lake and lower lake, in addition to whole lake targets. A uniform target concentration of 100 µg P/l is applied for total phosphorus in Lake Pepin. The turbidity and eutrophication targets apply when the summer (June-September) average USGS-reported flow at Prescott (gage #05344500) is in the 10,100-31,400 cfs range. The lower and upper limits of this flow range correspond to the 10th and 90th percentile flows, respectively.

To facilitate evaluation of the metrics in Table 6-2, the RCA component of the UMR-LP model was configured to output daily average values for all model cells for the following variables:

- Non-volatile suspended solids;
- Volatile suspended solids;
- Total suspended solids;
- Light extinction coefficient;
- Total phosphorus;
- Dissolved inorganic phosphorus;
- Total chlorophyll *a*; and
- Biomass for the blue-green, diatom, and summer assemblage phytoplankton groups.

Additional variables were output for diagnostic purposes and for linking RCA to the SAV model, including dissolved oxygen, zooplankton biomass, nitrite/nitrate, dissolved ammonia, and water volume, velocity, depth, and temperature.

Turbidity is not included in the above list of output variables because turbidity is not a computed state variable in the UMR-LP model. The RCA model derives turbidity from non-volatile suspended solids (NVSS) per Equation 2-35 and volatile suspended solids (VSS) as the sum of algal solids (*ALGS*, see Eqn. 2-37) and non-living organic solids (*NLOS*, see Eqn. 2-38). Paired turbidity, TSS, and VSS data were used to develop multiple linear regressions between turbidity and VSS/NSS for the LTRMP and MCES turbidity datasets. Because these monitoring programs use different meters, it was necessary to develop a unique regression for each dataset. Turbidities associated with the LTRMP and MCES datasets are computed by Equations 6-1 and 6-2, respectively:

$$Turb_{LTRMP} = 0.64 * NVSS + 0.90 * VSS \quad (6\text{-}1)$$

$$Turb_{MCES} = 0.28 * NVSS + 0.62 * VSS \quad (6\text{-}2)$$

where $Turb_{xxx}$ is the estimated turbidity (NTU), and *NVSS* and *VSS* are expressed in units of mg/l. Two sets of turbidity metrics are calculated to represent potential outcomes based on both the LTRMP dataset and the MCES dataset.

6.1.2 Scenario Development

Application of the UMR-LP model to support the turbidity and eutrophication TMDLs could potentially include hundreds of simulations in order to evaluate the various combinations of total suspended solids (TSS) and total phosphorus (TP) loading reductions for each tributary and direct wastewater treatment source. In order to simplify the model application, the initial set of load reduction scenarios applied the same relative percent reductions for suspended solids and phosphorus, including algal and zooplankton biomass.

The load reduction scenarios were designed in consultation with MPCA using the best information available in spring 2008 (Table 6-3). Separate studies for the St. Croix River and the Cannon River suggested that TSS/TP reductions of 20% and 50%, respectively, were reasonable for these watersheds. Therefore, all load reductions scenarios assumed these reductions. For simplicity, other minor tributaries were assumed to have a 20% reduction in TSS and TP loads. These tributaries included the Vermillion, Rush, and other minor tributaries. With the reductions for the St. Croix River and other smaller tributaries set at fixed percentages, it was possible to run a series of percent reduction combinations for the Minnesota River and the Upper Mississippi River (UMR) at L&D 1. For the Minnesota River, reductions of 20%, 50%, and 80% were considered. For the UMR at L&D 1, which has significantly lower concentrations of TSS and TP relative to the Minnesota, 50% was deemed to be the greatest reduction possible. Therefore, only 20% and 50% reductions were considered for the UMR at L&D 1. All tributary load reductions were made relative to historical daily loading rates.

As discussed previously, permitted TP loads were defined as the “baseline” loads for direct WWTP sources, and “reduced” loads were defined as a 70% reduction relative to permitted TP loads. The impact of the direct WWTP loads relative to the tributary loads was evaluated by conducting two sets of scenario simulations based on the permitted loads (#2-8) and reduced loads (#9-15). In addition to these two sets of scenarios, scenario 16 was developed as a “natural background” case where the Minnesota River and UMR at L&D 1 loads were reduced by 90% and direct WWTP loads were completely removed.

The scenarios described above reduce tributary and (in the case of scenarios 9-15) direct WWTP loads, but resuspension rates in Pool 2 are maintained at baseline values. Based on current knowledge of the system, resuspension of cohesive sediments in Spring Lake and lower Pool 2 is an important contributor to the total solids load at L&D 2 in the system during low-flow summer periods. Therefore, it is also important to consider the potential reductions in resuspension that might occur as a result of reducing tributary TSS loads. Scenarios 17, 18, and 19 were developed to address this need. Scenarios 17 and 18 are based on the same tributary and direct

WWTP loads as scenarios 11 and 15, respectively. For these two scenarios, all resuspension terms, including "background" resuspension, were reduced by 50% and 80% to be consistent with Minnesota River reductions. This approach was considered reasonable because the Minnesota River delivers a large majority (~75%) of the total solids load to Pool 2. Scenario 19 represents the "natural background" load reductions in the same manner as scenario 16, but also includes a 90% reduction for Pool 2 resuspension.

Table 6-3. Load Reduction Scenarios for the UMR-LP Model Application

Scenario No.	Load Reduction Scenario	UMR / MR Load Reductions	Upper Miss. River				Minnesota River					St. Croix		Cannon		Other Tribs		WWTPs			
			Hist	20%	50%	90%	Hist	20%	50%	80%	90%	Hist	20%	Hist	50%	Hist	20%	Hist	Permit	Red.	Rem.
1	Historical Tributary & WWTP Loads	(none)	x				x					x		x		x		x			
2	Tributary Load Reductions with Permitted WWTP Loads	(none)	x				x					x		x		x			x		
3		20% / 20%		x				x					x		x		x		x		
4		20% / 50%		x					x				x		x		x		x		
5		20% / 80%		x						x			x		x		x		x		
6		50% / 20%			x			x					x		x		x		x		
7		50% / 50%			x				x				x		x		x		x		
8		50% / 80%			x					x			x		x		x		x		
9	Tributary Load Reductions with Reduced WWTP Loads	(none)	x				x					x		x		x				x	
10		20% / 20%		x				x					x		x		x			x	
11		20% / 50%		x					x				x		x		x			x	
12		20% / 80%		x						x			x		x		x			x	
13		50% / 20%			x			x					x		x		x			x	
14		50% / 50%			x				x				x		x		x			x	
15		50% / 80%			x					x			x		x		x			x	
16	"Natural Background" Case	90% / 90%				x					x		x		x		x				x
17	Tributary Load Reductions with Reduced Pool 2 Resuspension	20% / 50%		x					x				x		x		x			x	
18		50% / 80%			x					x			x		x		x			x	
19		90% / 90%				x					x		x		x		x				x

6.2 UMR-LP MANAGEMENT ANALYSIS TOOL

The results of the UMR-LP model application were used as the basis for developing an UMR-LP "Management Analysis Tool" (MAT). The MAT was developed for the purpose of facilitating visualization and communication of model results for MPCA and stakeholders. The MAT is programmed as a customized Microsoft Excel spreadsheet, and therefore is accessible to anyone with Microsoft Office installed on their computer. A set of supporting databases stores information for the water quality metrics and targets and daily output for the model output variables. The MAT provides users with the ability to compare model results across scenarios, metrics, locations, and years in a variety of ways. Specific visualization options include:

- Box-and-whisker plots of metric results and comparison to targets for the 22-year period (Figure 6-1);
- Comparison of scenario metric results across individual years (Figure 6-2);
- Scatter charts designed to compare one metric/location/year combination against a second combination for all 19 scenarios;
- Tabular summaries of metric results and formatting to indicate when and where water quality targets are exceeded;

- Calculation and comparison of general metric statistics (mean, minimum, 50th percentile, etc.) across individual years;
- Pie chart summaries of solids and nutrient loading rates;
- Comparison of daily results for model output variables used to derive metric results; and
- Mass balance diagrams indicating the magnitude of major transport pathways for key compartments within the UMR-LP system (e.g., Lake Pepin).

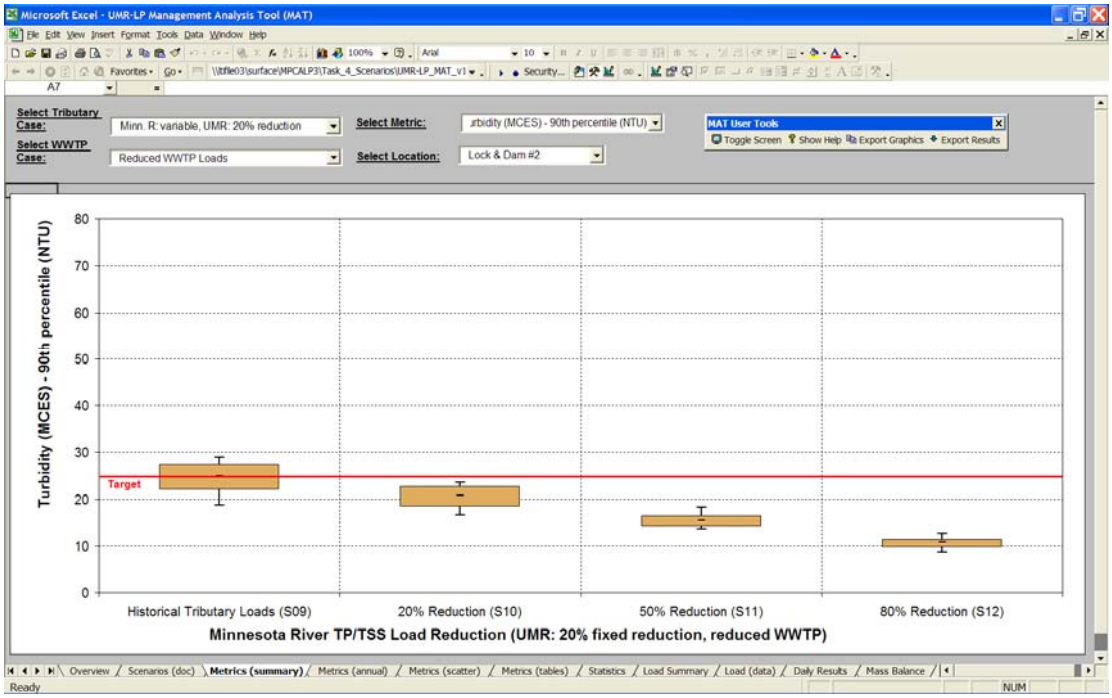

Figure 6-1. MAT Box-and-Whisker Comparison of Metric Results

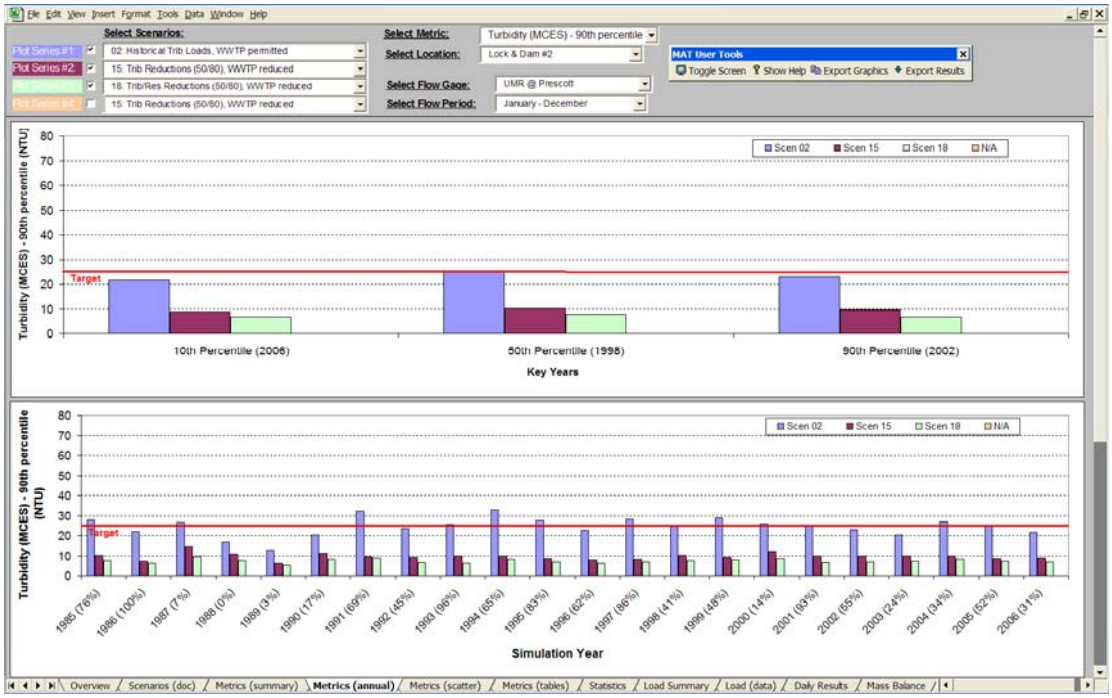

Figure 6-2. MAT Annual Comparison of Metric Results

6.3 SCENARIO RESULTS AND DISCUSSION

The model results presented in this section are intended to be illustrative of the information available from model application when reductions are made in loadings from various sources. These results are based on the preliminary set of TMDL metrics and targets available in early 2008, and are not intended to represent final wasteload and load allocations for the TMDLs. Also, it is not possible to present in this report results for each scenario as it relates to each metric, each specific location within the model domain, and under each of the 22 years of various hydrologic conditions that have been simulated. For those readers wishing to review model application results in greater detail, the Management Analysis Tool is available from MPCA for distribution and use.

The essential questions to be answered by applying the model to simulate baseline conditions and load reduction scenarios are:

- "To what extent do baseline conditions result in impairments?"; and
- "How much do loads need to be reduced to attain compliance with targets for water quality metrics?"

This section will discuss these questions and related model results in the context of the turbidity impairment and the nutrient enrichment impairment, as well as the concern over the rate of sediment deposition in Lake Pepin.