Lower Minnesota River Model (LMRM)
Technical Meeting #9, July 8, 2008
Notes by Cathy Larson, Metropolitan Council

- Twenty people representing six organizations attended the meeting. The groups represented were the Met Council, Carver County, MPCA, U of M, USACE, and Xcel Energy. The meeting revolved around the CE-QUAL-W2 model of the lower Minnesota River. We received an update on the calibration, discussed methods for assessing performance, and started designing loading scenarios. Below are notes that are posted with other documents at www.metrocouncil.org/environment/Water/LMRM. Copies of the presentations are available upon request.

Project Update (Cathy Larson, Met Council)

- Sponsors. The six-year LMRM project has been funded by the Met Council, LMRWD, MAC, MPCA, USACE, and USGS. Special thanks go to the USACE, St. Paul District, for providing support through the Planning Assistance to States (PAS) program since 2005. We also thank the MPCA and EQB for supporting our requests for federal cost-share funding through this program.
- Status. We completed the three-year monitoring program in 2006 and started developing the CE-QUAL-W2 model in 2005. The USA-ERDC has made considerable progress on the full-year calibration of the hydrodynamic and water-quality models of water years 2004-06 (plus July-Sept 2003). However, we have identified areas in the calibration of the summer low-flow periods in 2003 and 2006 where additional work is indicated, such as model-estimated DO concentrations running higher than measured values. Calibration of the hydrodynamic models for water years 2001-03 has started, but calibration of the water-quality models has not. The Met Council finished compiling data for water year 1988 last month. We have more work to do on the modeling project, including final presentations and report, but we have nearly exhausted PAS funding.
- Funding. The LMRM project was awarded an additional $65,000 in federal cost-share funding for fiscal year 2008 to be equally matched by the Met Council. Originally, we proposed a field study of the effects of barge traffic on water quality; however, the funds are now needed to complete the modeling work. The USA-ERDC prepared a scope for the remaining tasks, and the Met Council and USACE are working on an amendment to the PAS agreement. In addition to dropping the navigation study, we also dropped the optional tasks discussed at last November's meeting: variable algal stoichiometry and sediment transport.
- Schedule. Pending approval of the amendment, the USA-ERDC plans to complete the calibration this summer for presentation in October and to complete the modeling report later this fall. When the model is adequately tested, the Met Council will use it to test different loading scenarios to understand how the river might respond to changes in BOD, nutrient, and suspended-solids loads. Finally, the Met Council plans to complete an overall summary report for the LMRM project by next spring.
- Conferences. The Met Council, USA-ERDC, HydrO_2, MPCA, and USGS submitted an abstract on the LMRM monitoring program to the National Water-Quality Monitoring Conference, and it was accepted. Cathy Larson made the presentation in May. The conference emphasized the need to collaborate and to connect monitoring and modeling, and the LMRM project provided a very good example. The Met Council proposed a concurrent session on the LMRM project at the Minnesota Water Resources Conference on October 27-28 in St. Paul. The planning committee accepted the proposal, and the LMRM session is scheduled for Tuesday, October 28, 1:00-2:30. Cathy Larson, Bill James, and Dave Smith will present various aspects of the LMRM project.
- Next Meeting. Taking advantage of folks in town for the conference, we scheduled the next LMRM meeting for the following day: Wednesday, October 29 (location and times TBD). Dave Smith will present the final calibration of the CE-QUAL-W2 model, and Cathy Larson will present initial results

from the model projections. We would also like to involve the partners and stakeholders in a discussion of the key findings of the LMRM project.

Model Calibration Report (Dave Smith, USA-ERDC)

- A copy of the presentation is available upon request. The final slides show the calibration as of last November for comparison. Animations of the preliminary model results for water years 2004-06 and spreadsheets containing plots of the model inputs may also be downloaded (very large files). Note: "water year 2004" includes the three preceding low-flow months of July-Sept 2003 (15 months total).
- To build the CE-QUAL-W2 models, Council staff compiled data on meteorology, bathymetry, flow, stage, temperature, and water quality for the river, point sources, and tributaries. ERDC applied all the data, filling gaps where necessary through linear interpolation. Interpolation is necessary when variables are sampled at different frequencies, and the highest frequency was generally applied. No original data were changed or deleted with the exception of changing dates to match the beginning and end of the water year.
- The model is divided into two branches due to different hydrodynamics: Jordan to Savage and Savage to the mouth. The results are passed "as is" from one branch to the other. The model has two dimensions with 102 longitudinal segments and vertical layers that are 0.4 to 0.6 m deep. The grid has approximately 1100 active cells.
- The time step is typically 10 to 30 seconds. It is longer at lower stages, shorter at higher. For example, the drought year of WY1988 will run slower than the flood year of WY2001. Total run time is approximately four hours per year.
- The calibration strategy was to start with default settings and adjust one parameter at a time. In addition to plotting the model results against measured values, ERDC applies a number of goodness-of-fit statistics, including r^2, ME, AME, and RMSE, to assess model performance.
- ERDC applied the set of higher SOD rates measured by $HydrO_2$ in 2006, interpolating the rates between the six stations. The model varies the rates by temperature. Cathy recommended that ERDC adjust the rates according to the dominant sediment type using the sediment-bed map. Dave said the model was not sensitive to SOD rates on an annual basis, but he will check the summer periods.
- Since our meeting last November, ERDC has adjusted the model to better fit Dr. Megard's research on light attenuation, and they have applied ultimate BOD ratios and rates using the BODu analyses. ERDC also plans to compare model results to Bill James' findings, including sediment nutrient fluxes.
- Dave presented results for the hydrodynamic models of WY2004-06, with the last 100 days (July-Sept) shown separately, and early results for WY2001-03. The calibration targets were absolute mean errors of 0.1 m for stage and 0.5 ºC for temperature. The temperature target is met in most cases, and the stage and flow predictions are excellent. The stage predictions improve as you move downstream. The error increases as the analysis window decreases (that is, the error is greater for the 100-day periods due in part to fewer observations). CE-QUAL-W2 is 2D with lateral averaging, which appears to be valid at mile 3.5 near Fort Snelling but not at mile 8.5 near the Black Dog Generating Plant.
- Dave presented preliminary calibration results for the water-quality models of July 2003 to September 2006. The models perform well upstream of the navigation channel, Jordan through Savage, but do a poorer job of matching data near Black Dog and Fort Snelling. Dave presented plots and statistics to compare model-calculated results with field-measured data for 11 systems, including solids, nutrients, BOD/DO, and three algal groups. Detailed results were presented for the key calibration site, Fort Snelling, and longitudinal plots were provided as a summary of performance at the upstream sites.
- The Black Dog power plant, cooling lake, and watershed present a challenge to model calibration. Only the intake and two outfalls are defined in the model; the lake and watershed are not. At times, the plant withdraws a large portion of the river flow. The water is used for cooling within the facility and then discharged to Black Dog Lake, where the heated water is cooled before it is discharged to the river at two outfalls: one downstream of I35W and one upstream of Cedar Avenue. In addition to

cooling, the lake may affect water quality in other ways, including settling, resuspension by wind or fish, algal growth, and sediment nutrient fluxes. Only flow and temperature are routinely monitored at the outfalls, and flow at the intake. The Council monitored the outfalls only during low river flows in the summers of 2005 (5 samples) and 2006 (10 samples). For the extended periods when no water-quality data were available, ERDC applied a "reflected boundary condition" where model results upstream of the plant near I35W are used to define water quality at the outfalls. This assumes that the water quality at the outfalls is similar to the river upstream of the plant. Dave presented an aerial photo and Cathy presented results from the 2005-06 samples that suggest water quality at the outfalls may differ from the river at times. Dissolved oxygen, our key variable, may especially be affected by a number of factors at Black Dog including algal dynamics in the shallow lake, hydrodynamics at the outfalls, and thermal dynamics. Currently, DO at the outfalls is estimated at 100% saturation plus 3 mg/L, which improved overall model performance but weakened it during critical summer low-flow periods and at other times. Dave summarized the modeling issues at Black Dog as 1) highly variable flow with small time steps, 2) water-quality data not temporally matched with operation, 3) changes in retention time, 4) lake serving as a sink, and 5) drives results for the critical lower reach. Next steps include updating the reflected inputs and considering methods to estimate DO in the two discharges.

Model Performance Expectations (Cathy Larson, Met Council)

- We are nearing the end of the project, so ERDC is soliciting feedback on the model's performance in order to complete the calibration and begin documenting the project. The Council and MPCA met twice in June to review assessment methods applied in their various modeling projects and initiate discussion of LMRM performance.
- As in other modeling projects, ERDC is applying a variety of tools to assess model performance, including graphical comparisons and statistical tests.
- No specific performance goals were recommended at the meeting. Most appear to favor a weight-of-evidence approach. We identified key variables, locations, and time periods for calibration:
  - Variables (in order): oxygen, ammonia, nutrients, and sediment
  - Location: Fort Snelling but include results for the upstream sites
  - Time Period: summer during low river flows
- As evidenced by diel fluctuation at the Fort Snelling station during summer 2003 and 2006, oxygen dynamics do not appear to intensify until river flows fall below ~2500 cfs in the summer.
- Three specific areas of the calibration were marked for further evaluation:
  - The model overestimates DO during summer low-flow periods (e.g., summer 2003).
  - The model underestimates ammonia during summer 2003 and nitrate during summer 2004.
  - Of secondary concern, the model underestimates diatoms (the dominant algal group) and overestimates soluble reactive P at times (e.g., fall 2003 through winter 2004).
- Cathy recommended putting the greatest effort into summer 2006, when river flows were low and we collected the most extensive data set including the seven-week low flow survey, Black Dog monitoring, ERDC nutrient research, and HydrO_2 oxygen-dynamics assessments.
- ERDC provides periodic updates on model calibration to the Council via teleconference. We will start inviting other model reviewers to these briefing. If you would like to receive notice of the briefings, please inform Cathy at cathy.larson@metc.state.mn.us.

Model Performance (Dr. Robert Megard, University of Minnesota)

- Dr. Megard prepared five graphs in response to our plea for feedback on model performance.
- He strongly recommends using log-log plots for comparisons because water-quality data are highly variable and often skewed. It is better to evaluate apparent discrepancies and reveal patterns by normalizing the data and model results with log-log plots and adding confidence intervals.

- Any model output should be congruent with log plots of measured data. This is a good test of model performance. For example, plots relating different measurements of suspended solids and light attenuation compiled by Dr. Megard from observed data should be reproducible from model results.
- Using log-log plots of the model results may also reveal that what appeared to be a problem in a normal plot may not be.
- Dr. Megard has developed formulas relating turbidity and light attenuation to suspended solids that apply to the Minnesota, Mississippi, and St. Croix Rivers. We are trying to mimic the light formulation in the LMR model and will consider his turbidity relationship when evaluating this standard in the loading scenarios.

Loading Scenarios (Cathy Larson, Met Council)

- Our project goal was to build an assessment and management tool for water quality in the lower Minnesota River. The model will be tested and ready for application this fall. The model should be valid for several years, and we will have multiple opportunities to apply it. At this time, we would like to design some initial loading scenarios to better understand the river's response. These projections would be completed this fall and winter and summarized in the project report next spring.
- The CE-QUAL-W2 model produces a wealth of information for interpretation: more than 20 state variables that are simulated (11 currently used) and more than 60 derived variables that are calculated from the state variables.
- Water-quality standards for turbidity and dissolved oxygen provide two established metrics for measuring the response to loading changes. Nutrient standards for rivers have not yet been established. DO is best tested under summer low-flow conditions, and turbidity is best tested after storm events.
- For flow and other conditions, we are limited to the seven years we chose to model. Compared to mean annual flows for WY1935-2007, 1988 ranks in the lower 10th percentile, 2001-03 rank near the median, 2005-06 are in the upper quartile, and 2001 is in the upper 10th. Summer flows present a somewhat different picture with 1988 remaining the lowest by a wide margin, but 2003 and 2006 had the next lowest summer flows with extended periods under the median for historic daily flows.
- WY2001-06 provided only a handful of DO concentrations under 6 mg/L at Fort Snelling; however, this site benefits from aeration at the Seneca WWTP under low flow conditions. We collected evidence of low oxygen levels in summer 2003 and 2006. By contrast, looking at grab samples at Fort Snelling, DO was under 6 mg/L for much of summer 1988 with several values under 4 mg/L. This was before upgrades at the two WWTPs.
- With turbidity, the six recent years offer many instances of exceeding the standard of 25 NTU. The standard was exceeded a few times in spring 1988 but not in the summer at Fort Snelling. We will examine the data to see if algae and other organic matter are important components of turbidity.
- The model does not output turbidity, so we must develop a relationship to suspended solids. Examples were provided from stream monitoring, LimnoTech, and Dr. Megard.
- For the initial scenarios, the Council recommends the following:
  - Test NPDES-permitted loads on the seven modeled years. Are water-quality standards met? If not, decrease upstream loads to the TMDL targets: TP, 0.131 mg/L; BOD, 3.7 mg/L.
  - Test model sensitivity to reduced nonpoint-source loads, such as suspended solids, phosphorus, BOD, and algae. Plot the response in turbidity, DO, and algae.
- One person suggested removing the point-source loads. Another suggested increasing loads and running some scenarios on global climate change. Another suggested adjusting point and nonpoint-source loads in the tributaries, but each stream is represented as a single loading source to the CE-QUAL-W2 model, so this type of scenario must be deferred to the watershed models.
- This was our initial discussion of scenarios. We will resume the discussion at our next meeting.