Lower Minnesota River Model
Technical Meeting #5, November 16, 2005
Notes by Cathy Larson, Metropolitan Council

Nineteen people, representing eight organizations, attended the meeting. The groups represented were the Met Council, LMR Watershed District, MPCA, MDNR, USACE, USGS, and Xcel Energy. The meeting featured speakers from the USACE providing information on the modeling project, nutrient research, and navigation effects. We also discussed the BOD test. Following are notes from the five presentations.

Project Update (Cathy Larson, Met Council)

- An electronic or printed copy of the presentation is available upon request.
- Schedule. The schedule is unchanged: start in 2003 and end in 2008. We are midway through the project. We've completed two years of monitoring and are entering our third and final year of fieldwork. We started building the model in April 2005 and plan to have a fully tested model by the end of 2007 with reports to follow in 2008. Next year is a year of transition from data collection to data assessment. You should expect less planning and more results at subsequent meetings.
- Monitoring. River, stream, and effluent monitoring in support of the model will continue through September 2006. Three of four special USGS monitoring projects were completed in 2003-2004, with the stream-flow gaging station at Ft. Snelling continuing through March 2007. Field and lab work for nutrient and sediment research by the USA-ERDC started this year and will continue through the next. We were unable to complete any low flow monitoring during the past two summers due to high flows, which pins all our remaining hopes on summer 2006.
- Modeling. We experienced a couple delays in the modeling project but are confident we can make up this time in the years to come. Setbacks: The Council-USACE agreement was signed three months later than expected, and the original project manager, Tom Cole, is retiring and passing the baton to Carlos Ruiz, a colleague at the USA-ERDC. Nonetheless, we've made some headway this year. The model grid is nearly designed with completion expected in December. Cathy has compiled most of the flow, elevation, meteorological, and temperature inputs for the model of WY2004 and will next tackle the water-quality inputs. We'll probably build the CY1988-1991 model before the WY2005 model. The schedule for the modeling project will be updated in December.
- Low Flow Target. Due to higher-than-average flows during the past two summers, we've made some adjustments. First, we've extended the model of WY2004 to include the three preceding months to incorporate low flow conditions from July-September 2003. Second, we collected five composite samples from the two Black Dog outfalls and grab samples from an upstream site this past summer when flows decreased below 3000 cfs. Third, we increased the flow target for the oxygen-dynamics assessment from <1500 cfs to <2000 cfs. The decision was based on the following:
  - Reaeration. We should be able to extrapolate rates measured at higher flows to low flow conditions by selecting the right reaeration equation for the river.
  - SOD. Sediment characteristics change more slowly than water quality, so SOD rates measured at one point in time should represent rates over a broader range of flows. Stable, late-summer conditions are more important to capture than a specific flow or velocity. However, comparing velocity to flow at the Fort Snelling gage, we expect velocities <0.5 fps and fine particles to settle at flows <2000 cfs.
  - Production and respiration. These rates vary greatly, so the best option is to collect a second set of data at lower flows. An optional second survey was included in the HydrO_2 contract. Looking at past data on diurnal DO fluctuations and chlorophyll-a concentrations, we expect algal activity to be high at flows <2000 cfs.
- Phytoplankton. Results from the phytoplankton analyses are starting to arrive. Water year 2004 displayed two peaks in biomass: ~50,000 mg/m3 in mid-December and ~70,000 mg/m3 in mid-April. Diatoms dominate the community most of the year, but blue-green algae can out-compete the diatoms in late summer (e.g., 7/18/03). One sample in fall 2004 and two samples in summer 2005 collected at mile 3.5 contained small numbers of an invasive toxic blue-green algae, *Cylindrospermopsis raciborskii.* The species was first reported in Minnesota and the LMR watershed in the late 1960s.
- Web Site. A Web site was launched for the project: www.metrocouncil.org/environment/Water/LMRM

CE-QUAL-W2 Modeling Update (Dr. Carlos Ruiz, USA-ERDC)

- An electronic or printed copy of the presentation is available upon request.
- This was a good review of the capabilities and limitations of the CE-QUAL-W2 model. I'll list my take-home notes here. Request the complete presentation if you want to learn more about the model.
- Tom Cole will be available in December to help Carlos assume the reins on the project. Before Tom retires, Carlos hopes to finish calibrating the thermal and hydrodynamics of one year (WY2004), and I hope to compile most of the water-quality inputs. The water-quality systems for WY2004 should be calibrated by mid-2006, so Carlos can report on them when he next visits St. Paul in Fall 2006.
- A new version of W2 is expected in 2006 or 2007, and it may benefit the LMRM project. Sediment processes in the current version are semi-predictive (that is, mostly empirical); they'll become more mechanistic in the new version. Processes to be included are sediment-bed diagenesis, fluxes across the sediment-water interface, and scouring/deposition.
- The bathymetry will be done in 2-3 weeks. This is a critical step, as the bathymetry establishes timing in the model (e.g., residence time, which affects algal growth, BOD decay, and on). In the preliminary grid, there are as many as six vertical layers.
- The next critical system is temperature; as it is the main driver behind DO concentrations and biochemical processes in water. Users are urged to model temperature for as many years as time and budget will allow. Here's where our choice of seven years (1988-91 and 2004-2006) should pay off.
- Next, he'll calibrate the model for DO concentrations. If you get the model-estimated values for temperature and DO to match closely with measured data, "you're almost there."
- In general, you can expect a tighter calibration for temperatures than DO, and tighter DO than other water-quality systems. For DO and the other water-quality systems, you hope to pick up the basic trends and patterns of the data. By calibrating and verifying the model against seven years of data, we should deliver a well-tested model for managing the lower Minnesota River.

Navigation System and Water Quality (Dan Wilcox, USACE-St. Paul)

- An electronic or printed copy of the presentation is available upon request.
- The nine-foot navigation channel extends from the mouth to mile 14.7 at Savage. It was constructed between 1966 and 1968. The LMRWD is the local cost-share partner. River traffic and the associated jobs are estimated to generate $1 billion/yr in the Minnesota economy.
- Ten port facilities (e.g., Cargill, Bunge and Harvest States) are located between miles 14.7 and 11.1. Between 1999 and 2003, the number of loaded barges ranged from ~2000 to ~3200 per year going downstream (grain) and averaged around 500 going upstream (fertilizer, oil, etc.). On an average day, two tows go upstream and two go downstream. The length of the navigation season is controlled by ice-out and ice-in in Lake Pepin. During the past six years, the season ranged from 250 to 280 days at Lock & Dam 2. Records of barge traffic are available for 1988-1991 if needed for the model.
- The lower Minnesota River is closely tied to Pool 2 and its regulation. For example, note the similarities between water elevations at Savage and tail-water elevations at Lock & Dam 1. Lock & Dam 2 raises the level of the lower Minnesota River by ~12 feet at low flow.
- Seven historic dredge cuts are located in the channel. Dredging most frequently occurs between miles 11.8 and 14.7. Dredging is all mechanical now, not hydraulic. The Corps does dredging on an as-needed basis.
- Terry Schwalbe, LMRWD, commented that private dredging by the grain companies is substantial, and the volume may be within the range of work done by the Corps. The LMRWD has information on both Corps and private dredging.
- In addition to resuspending sediments, navigation traffic can mobilize nutrients from the sediment bed and transfer oxygen demand from the sediment bed to the water column. When Dan worked at Black Dog, he measured downward spikes in DO concentrations as barges passed during summer low flow periods. The effects of navigation traffic on the lower Minnesota River are more pronounced due to its small channel. Hong Wang, MCES watershed modeler, noted that navigation could also increase DO.
- The Corps recently completed an ecological study of the Upper Mississippi River that included much work on navigation effects. Four models were built to predict hydraulic disturbances produced by navigation traffic, notably changes to TSS concentrations. The models weren't linked to water-quality models. If we want to do a

similar exercise on the LMR, the necessary navigation data are available. Dan recommends that we model navigation effects, especially at low flows.

- There is some, but not a lot, of recreational traffic on the LMR. Wave wake patterns from recreational boats are very different from barges. For example, a typical boat yields 12 wake wave peaks, while a barge yields ~100 low-amplitude wake wave peaks.
- Summary of possible effects of navigation on water quality in the lower Minnesota River:
  - Impoundment: Reduced hydraulic exchange
  - River regulation: Water level fluctuations
  - Dredging: Sediment resuspension, nutrient mobilization
  - Commercial navigation traffic: Sediment resuspension, bank erosion, nutrient mobilization, DO depletion
  - Recreational boating traffic: Sediment resuspension, bank erosion
  - Accidental spills of fuel and products

Nutrient and Sediment Research Update (Bill James, USA-ERDC)

- An electronic or printed copy of the presentation is available upon request. Bill presented preliminary results from data collected this year for three of four research tasks. Another round of samples will be collected next year. Note: SRP = soluble reactive phosphorus, also known as PO4 or orthophosphate.
- Bioavailable Nutrients. The Eau Galle lab analyzed particulate forms of phosphorus in LMR water samples. Some forms are more readily available to algae; for example, iron-bound P is biologically available while calcium-bound P is not. At various times/flows in 2005, water samples were collected near Jordan and Ft. Snelling. While the lab is still processing refractory organic P, it appears that biologically available forms represent at least half of the particulate P. If the final results agree, this will be an important finding as many people assume that particulate P is "bound up" and not available for algal uptake. It also appears that, as flows increase, so do TSS and iron-bound P concentrations.
- Equilibrium Studies. The same samples were used to study equilibrium processes between P in water (aqueous) and P attached to suspended solids (particulate). One test attempts to find the SRP concentration at which phosphorus stops adsorbing to particles and starts to desorb. This is called the equilibrium phosphorus concentration (EPC). On five dates in 2005, the EPC ranged from 0.079 to 0.178 mg/L, with desorption occurring at lower concentrations and adsorption occurring at higher concentrations. This test also yields a linear sorption coefficient. The coefficient in the LMR samples was lower (0.2-0.3 L/g) than other systems Eau Galle has tested. Higher coefficients usually translate to higher buffering, so the LMR is not buffering as much as expected. Bill also noted that they derived less information from samples collected during summer low flow because factors other than sorption (e.g., algal cells lysing) were probably at work. We should target other seasons for sampling in 2006. In another test, they measured how quickly phosphorus desorbed from particles under low SRP concentrations. Desorption occurred very quickly—within 24 hours. Information from the equilibrium and kinetics studies will become very valuable to modeling when we start to describe how and when phosphorus adsorbs to/desorbs from suspended solids and becomes un/available to algae.
- Sediment Fluxes. This past fall, 24 sediment samples were collected from the lower 26 miles of the Minnesota River to analyze sediment characteristics, and 12 samples were collected to measure nutrient release rates in the lab. Sampling was stratified by river reach (miles 0-12 and 12-26) and sample type (60% sand-silt, 30% silt, and 10% sand) according to the sediment-bed map developed by the USGS and MCES. P release rates under both oxic and anoxic conditions were similar to rates measured from Lake Pepin samples (oxic, 0.8-4.6 mg/m2/day; anoxic 1-28 mg/m2/day). Iron- and calcium-bound P fractions were found in higher concentrations in the sediment than loosely- and aluminum-bound P. All P forms appeared to increase in concentration with the moisture content. Anoxic P release rates appear to be most closely related to iron-bound P concentrations in sediment.
- Budgetary Analysis. The WY2004 budget for nutrients and sediment is still in process. Cathy sent FLUX-ready data for five river sites, five discharges, and 13 tributaries. Bill showed time-series plots of TSS, chlorophyll-a, and SRP concentration for the LMR at Jordan and Ft. Snelling. When algal/chl-a levels were high in spring and late summer, SRP concentrations were very low. At other times (late May to early August and late September), it appeared that the sorption kinetics between phosphorus and suspended particles controlled SRP concentrations. Bill noted the surprisingly high SRP concentrations during the winter (Jan-Mar 2005). Jim Klang commented that they could be due to phytoplankton sloughing and cell lysing in upstream waters.

BOD Test and High Quality Effluent (Cathy Larson and Grant Haffely, MCES)

- An electronic or printed copy of the presentation is available upon request.
- Annual average effluent CBOD5 concentrations at the Blue Lake and Seneca WWTPs have decreased from 8-18 mg/L in the 1980s to 3-4 mg/L since they were upgraded in the early 1990s. The 1985 wasteload allocation study was based on data from the 1970s and 1980 when effluent BOD concentrations were double-digit. Current effluent concentrations approximate river concentrations during low flow conditions. Modeling BOD from high-quality effluents may be a challenge because it may be difficult to discern the effect of effluent BOD on river water quality.
- Further, there are differences in how the lab has reported BOD for river and effluent samples that make the numbers difficult to compare:
  - The detection limit is generally 1.0 mg/L for river samples and 3 mg/L for effluent samples.
  - While we collect 5-8 times more effluent samples than river samples, a higher percentage of the effluent values are flagged as below the detection limit. For example, in 2003, 13% of the river CBOD5 values were flagged compared to 35% for Blue Lake and 65% for Seneca.
  - River BOD concentrations are reported to the nearest tenth, while effluent concentrations are reported to the nearest whole number.
- Grant Haffely, MCES Lab Services, provided the lab perspective. The reported values for river and effluent BOD are different because Standard Methods requires the seeding of chlorinated effluent samples. Seeding with bacteria from another source—primary effluent in this case—replaces the bacteria lost to chlorination. The measurement error of the seed is added to the measurement error of the effluent sample, which increased the reported error. Further, seeding is currently achieved by adding seeded dilution water to the BOD bottle, so the BOD result must be corrected for dilution.
- So, greater error in the effluent BOD test leads to larger standard deviations (SD) and higher reporting limits. On top of this, Standard Methods established a lower detection limit of 2 mg/L due to a minimum DO depletion of 2 mg/L. Accounting for dilution, the detection limit becomes 3 mg/L.
- The Lab examined actual data for Blue Lake and Seneca: 479 sets of replicates. The mean and SD were 3.35 and 0.77 mg/L, respectively, compared to 1.47 and 0.02 mg/L for 16 sets of river replicates. The detection limit is generally interpreted to be three times the SD, or 2.31 mg/L for the WWTPs.
- Next steps: The Lab will explore adding seed and nutrients directly to BOD bottles and eliminate the multiplication of error by dilution. They will also explore the feasibility of calculating a separate effluent value for modeling purposes (e.g., use a DL of < 2.3 mg/L and recover values between 2.3 and 3.0 mg/L, which should give better definition to many of the previously reported <3 values). They will explore eliminating seeding in the winter when chlorination is stopped; however, we sometimes measure residual chlorine even in the winter. Someone suggested running tests on samples collected before chlorination and comparing them to the post-chlorination tests; however, in the model, we want to represent the BOD in the chlorinated effluent as it reaches the river. Also, the additional error in the seeded measurement makes them difficult to compare.
- Note: We are also running 70-day BOD tests on effluent samples to derive ultimate-to-5-day ratios for the model; however, these tests are done without nutrients, seeding, or dilution. We need to know ultimate BOD for the model; that is, how much oxygen demand is actually expressed in the river. For practical purposes, we measure 5-day BOD for permit compliance. Can we relate U/5 ratios from unseeded BOD tests for the model to 5-day values from seeded BOD tests for permit compliance??
- Finally, Grant described another problem that may affect all CBOD5 results: river, stream and effluent. In 1994, the Lab discovered that the product used to inhibit nitrification in the ultimate CBOD test was being degraded and serving as an additional source of BOD (report available upon request). They adopted a new method to avoid this problem. In the 2000s, the same problem was identified in 5-day CBOD tests. The Lab suspects that a degrader enters the lab, colonizes on probes, and spreads to other samples. They are testing a technique using sanitized probes. Until this problem is resolved, BOD5 results (i.e., total BOD, nitrogenous plus carbonaceous) are more reliable than CBOD5 results (i.e., carbonaceous only).