Missouri River Basin HSPF Model

wq-iw7-44p

Minnesota Pollution Control Agency

Hydrologic models were used to support decision-making for potential sediment and nutrient reduction strategies in the Missouri River basin as well as other impairments. The three major watersheds of the Missouri basin – the Big Sioux, Little Sioux, and Rock watersheds – were modeled distinctly but under the same project. An HSPF (Hydrological Simulation Program – FORTRAN) model was developed for the entire basin.

HSPF Development

HSPF models allow for advanced hydrologic simulation of a basin through multiple sources of spatial and temporal observed data. The model was developed and continues to be supported by the EPA and has been consistently used in peer-reviewed watershed studies. More on HSPF can be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=21398. This model was created by RESPEC, an environmental and engineering consulting firm in 2014. The simulation period for the model was between 1995 and 2009. For any questions regarding this model, please contact Ben Roush (Benjamin.Roush@state.mn.us) or Chuck Regan (Chuck.Regan@state.mn.us) at the Minnesota Pollution Control Agency (MPCA).

Model Segmentation and Point Source Data

The watershed was separated into subwatersheds based on hydrography data (from GIS analysis) and could also be adjusted based on specific stream concerns (such as impairments). Sixteen lakes in the model were chosen to be explicitly modeled because of management interest and based on lake area and data availability. Bathymetry data for these lakes were provided by both the Minnesota and Iowa DNR. When possible, bathymetry data for streams were also acquired from Pipestone and Noble Counties, the Eastern Dakota Water Development District, the Minnesota DNR, and the US Geological Survey.

Pervious and impervious land segments within each subwatershed divide the subwatersheds into distinct sections based on land use, soil properties, tillage, and proximity to meteorological stations (used by the model for calibration). This data was compiled from multiple federal, state, and local organizations. For example, National Land Cover Database data from 2001 and 2006 was utilized to help determine land use. In the Little Sioux and Rock River, land segments were categorized as developed, grassland, forest, pasture, cropland, and wetland. Land segments in the Big Sioux River were categorized as developed, pasture, cropland and wetland. In the Big Sioux, forest and grassland were categorized with pasture because of grazing on both land segment types. For all models, crop land segments were further dived into high and low tillage areas.

Fifty-six point source facilities in the watersheds were utilized in the model simulation, primarily in the simulation of nutrients, which included three major point source facilities, and 53 minor point sources. Monthly discharge data were provided by the MPCA, Iowa DNR, and South Dakota Department of Environment and Natural Resources.

Calibration - Hydrology

Stream-flow data from three gages in Pipestone Creek, four gages in the Rock River, one gage in the Little Sioux River, one gage in the Ocheyedan River, and one gage on a tributary near

Pipestone, MN were used for hydrologic calibration. While the time periods when these gages were active varied, but all data were collected between 1995 and 2009. Hydrologic calibration involves examination of annual water balance, season flow differences, low-flow/high-flow distribution, storm flow/hydrograph shape, snow accumulation and melting, and lake levels (with corresponding hydraulic effects). Land cover flow parameters are adjusted to ensure flow is adequately calibrated. Note that these models also cover watershed area in Iowa and South Dakota, along with Minnesota.

All Missouri basin models had "fair to good" hydrologic calibration results based on a variety of statistics such as correlation coefficient, coefficient of determination, mean error, and other metrics. Visual examination of the data also reviled sufficient model calibration. (Examples of calibration diagrams can be found in the *Calibration and Validation* document for the Missouri models, accessible from Ben Roush at the MPCA.) Without effective hydrologic calibration, accurate simulation of water quality would not be possible.

Calibration – Water Quality

Multiple water quality constituents were calibrated within these models. These included sediment (TSS), temperature, dissolved oxygen, biochemical oxygen demand, algae, and nutrients. Water quality was observed at multiple sites throughout the watershed and was collected from the MPCA, Iowa DNR, Environmental Protection Agency, and US Geological Survey.

<u>Sediment</u>

Sediment calibration involved both observed sediment data but was also utilized with historical records an expected in-stream sediment behavior. Model parameters were adjusted for both in-stream and field sediment loading rates. The model included simulations of both field sediment erosion and in-stream sediment processes. The Revised Universal Soil Loss Equation was used as a comparison for simulated field sediment erosion. In-stream sediment processes like deposition, scour, and transport were calibrated on a reach-by-reach basis.

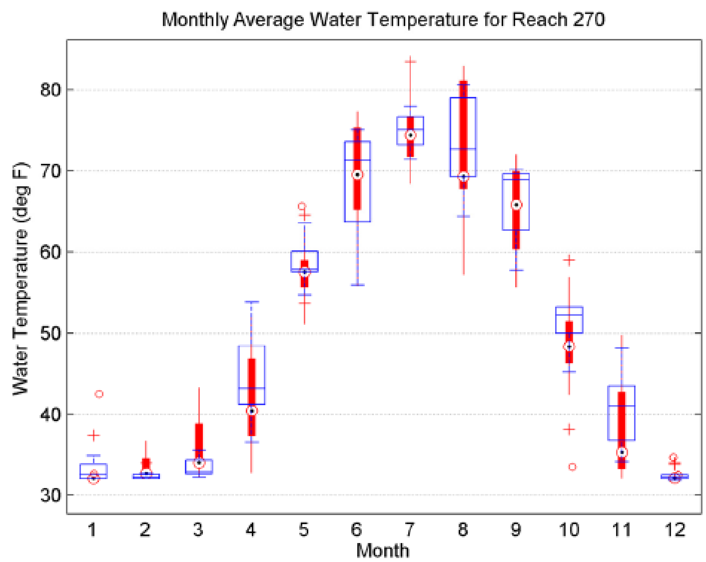
<u>Other Water Quality Constituents</u>

Temperature, dissolved oxygen, biochemical oxygen demand, algae, and nutrients were also simulated in the model. Simulated nutrients included organic and inorganic nitrogen, ammonia, organic and inorganic phosphorus. Nutrient sources in the model included point sources (e.g. wastewater facilities), septic systems, non-point source runoff from land segments, and atmospheric deposition. Individual sewage treatment systems (ISTS) nutrient loading was calculated using the average number of people per household that would be using such systems. Biological oxygen demand sources also included point sources and non-point runoff.

<u>Water Quality Calibration Results</u>

The goal of water quality calibration is to accurately simulate variability over time as well as seasonal and flow-regiment trends. All water quality constituents had reasonable calibration results. Visual comparison (often representing statistical analysis) was made between observed and simulated results. A catalog of these figures is available in the *Calibration and Validation* document for the Missouri models and is accessible from Ben Roush at the MPCA. Figure 1 shows an example of these figures for water temperature in the Little Sioux watershed.

Figure 1: *Water temperature calibration: blue data is observed, red data is simulated with HSPF. Note this represents one subwatershed in the Little Sioux Watershed.*



Water Temperature Monthly Averages–Little Sioux (Reach 270).

Model Results and Data Availability

Please contact Ben Roush or Chuck Regan at the MPCA for any questions or requests for data from these models. The annual average loading to the stream and land segment loading rates of total nitrogen, total phosphorus, and sediment in the Big Sioux, Little Sioux, and Rock watersheds follow:

Table 1: Total loading to streams in the three watersheds of the Missouri Basin.

Constituent	**Big Sioux**	**Little Sioux**	**Rock**
TN (lbs/yr)	4,033,796	13,990,313	12,467,865
TP (lbs/yr)	168,971	558,280	338,010
Sediment (tons/yr)	30,226	37,379	73,493

Table 2: Loading rates for each land segment type. Note that in the Big Sioux, Forest and Wetland are included in the Pasture category.

	Big Sioux (lbs/ac/yr for TN/TP, tons/ac/yr for sediment)			**Little Sioux** (lbs/ac/yr for TN/TP, tons/ac/yr for sediment)			**Rock River** (lbs/ac/yr for TN/TP, tons/ac/yr for sediment)		
Land Segment	**TN**	**TP**	**Sediment**	**TN**	**TP**	**Sediment**	**TN**	**TP**	**Sediment**
Developed	15.78	0.33	0.27	8.89	0.81	0.17	8.07	0.49	0.24
Forest	-	-	-	0.46	0.02	<0.01	0.38	0.01	<0.01
Wetland	-	-	-	0.27	0.01	<0.01	0.25	0.01	<0.01
Pasture	2.16	0.05	0.01	2.33	0.10	0.02	2.01	0.06	0.02
Crop (Low Till)	7.28	0.33	0.04	16.02	0.60	0.02	13.22	0.33	0.06
Crop (High Till)	6.60	0.31	0.03	16.79	0.62	0.03	13.87	0.34	0.06