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TETRA TECH

Memorandum

To:	**Heidi Rauenhorst (Hawk Creek Watershed Project) and Mike Weckwerth (MPCA)**	**Date:**	**March 11, 2015**
From:	**Andrea Plevan**	**Subject:**	**Watershed Management Scenarios for Hawk Creek Watershed Restoration and Protection Strategy**
cc:	**Pete von Loewe, Jon Butcher**		

This memorandum transmits the results of the watershed management scenarios that were developed to support the Hawk Creek Watershed Restoration and Protection Strategy (WRAPS). The Hawk Creek watershed is located in west central Minnesota and includes the drainage from Hawk Creek and its tributaries in addition to streams that flow directly into the Minnesota River. This area is collectively referred to as the Hawk Creek watershed and covers approximately 1,030 square miles. High concentrations of sediment, phosphorus, and nitrates are found in the water bodies, the sources of which include agriculture runoff, livestock manure, stormwater runoff, wastewater treatment plants, failing septic systems, and industrial and processing plants. Much of the watershed is ditched and channelized or tiled, and high stream flows lead to stream bank erosion. The primary land use in the watershed is agriculture.

The WRAPS is the culmination of a 4-year process led by the Minnesota Pollution Control Agency (MPCA) and the Hawk Creek Watershed Project to monitor the water quality in the watershed, assess the water bodies for impairment, develop total maximum daily loads (TMDLs) for the impaired water bodies, and prescribe strategies to restore and protect the water bodies. A model application was developed with the program Hydrological Simulation Program–FORTRAN (HSPF) that simulates flow and water quality in the Hawk Creek watershed on approximately a Hydrologic Unit Code 12 (HUC12) basis. For the current project, management scenarios using the HSPF model application were developed to inform management strategies that will be recommended through the WRAPS process.

The management scenarios to be modeled were determined through discussions with the Hawk Creek Watershed Project, MPCA, and the Hawk Creek local work group. The work group held a meeting on December 30, 2014 during which Tetra Tech staff explained the model inputs, outputs, level of resolution, and examples of management scenarios that can be developed using the model. The work group selected three scenarios, which are discussed in this memo.

1 Model Scenario Approach

Hawk Creek, Yellow Medicine River, and several adjacent tributaries to the Minnesota River constitute the 8-digit USGS Hydrologic Unit 07020004. MPCA is supporting development of detailed HSPF watershed models for all 8-digit HUCs throughout the state for management planning. Tetra Tech (2011) developed the detailed (HUC12-scale) HSPF model of the HUC8 containing Hawk Creek and Yellow Medicine River with meteorology set up to run through 2010. More recently, RESPEC (2014a, 2014b) completed an update of the existing models for the Minnesota River drainage. The original setup of the Hawk-Yellow Medicine model was largely retained, except that four reaches were modified to better represent defined impaired stream segments (RESPEC 2014a; see Figure 1). In addition, the model simulation period was extended through 2012 and the representation of point sources was improved. RESPEC (2014b) also undertook some adjustment to the model calibration based on additional monitoring data through 2012.

The model scenario simulations were undertaken with the latest version of the model, as updated by RESPEC and provided by MPCA. It should be noted that this version of the model is still under review by MPCA and it is possible that some aspects of the model calibration may be modified. Nonetheless, the current version of the model provides the best currently available tool for investigating the WRAPS scenarios.

The model represents upland land use in the basin through 24 different Hydrologic Response Units (HRUs). Each HRU combines an overlay of land use, hydrologic soil group (an index of infiltration capacity), and slope category. There are 12 agricultural land use categories representing conventional tillage, conservation tillage (defined as maintaining 30 percent residue cover), and manure application areas on different combinations of hydrologic soil group and soils. The landscape is dominated by tilled agriculture, primarily in corn/soy bean rotation (Figure 2). Agriculture on soils with dual hydrologic soil group classifications (e.g., B/D) is assumed to have tile drains installed, represented in HSPF through the interflow (shallow groundwater) component.

The model includes a full representation of major and minor point source discharges. The major point sources within HUC 0702004 on the north side of the Minnesota River (including Hawk Creek and other tributaries east to Beaver Creek) are Willmar WWTP, Clara City WWTP, Maynard WWTP, Olivia WWTP, Renville WWTP, and Southern Minnesota Beet Sugar Coop.

The Hawk Creek portion of the model achieved acceptable calibration for flow at six seasonal flow gages (three on Hawk Creek, two on Beaver Creek, and one on Chetomba Creek). The water quality model is fully calibrated and validated for sediment, inorganic nitrogen, total nitrogen, inorganic phosphorus, and total phosphorus. The model also simulates dissolved oxygen, biochemical oxygen demand, algal growth, and bacteria based on parameters derived from an earlier model; however, the current model has not been rigorously calibrated for these parameters.

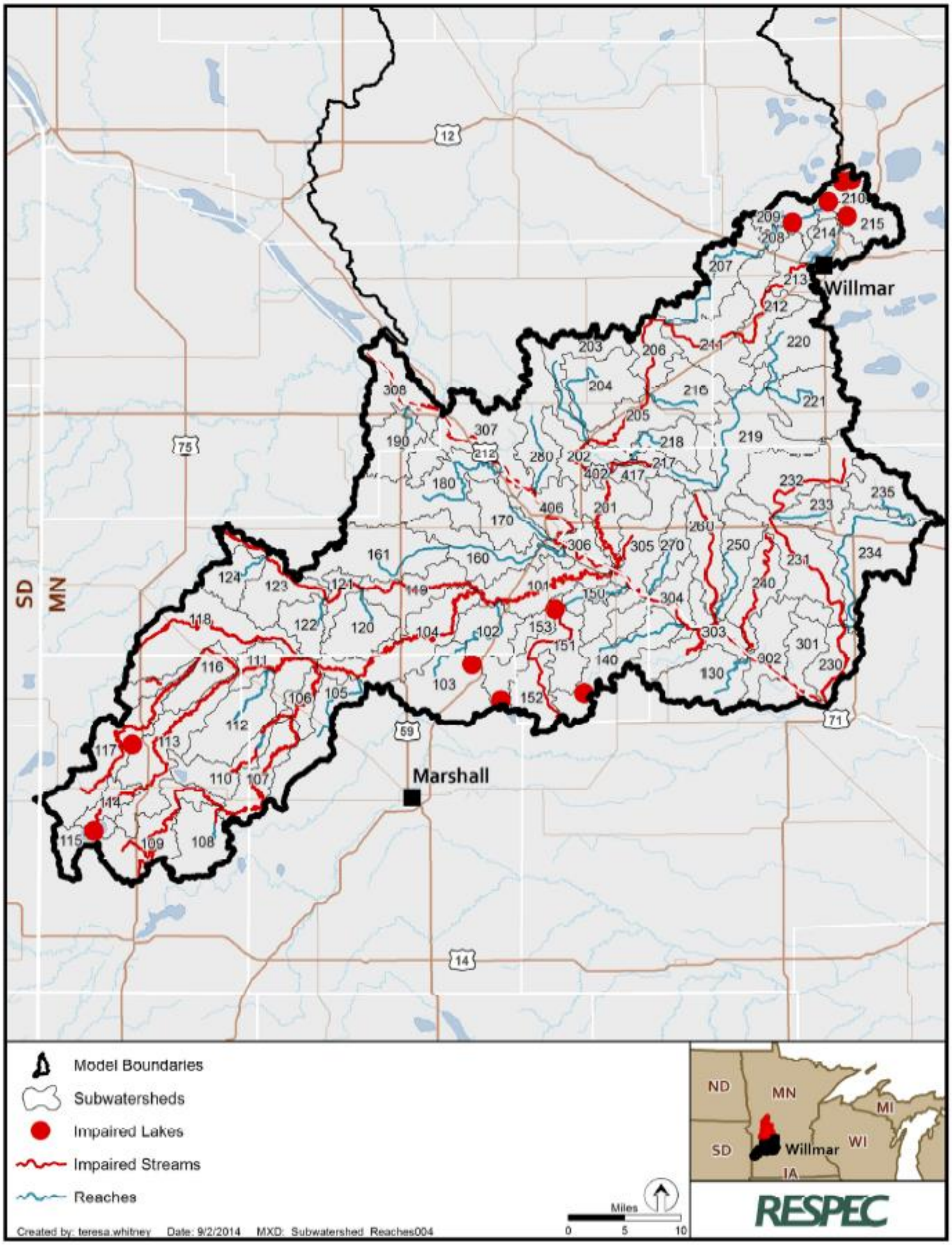

Figure 1. Hawk-Yellow Medicine Model Reach and Subwatershed Identifiers (RESPEC 2014a)

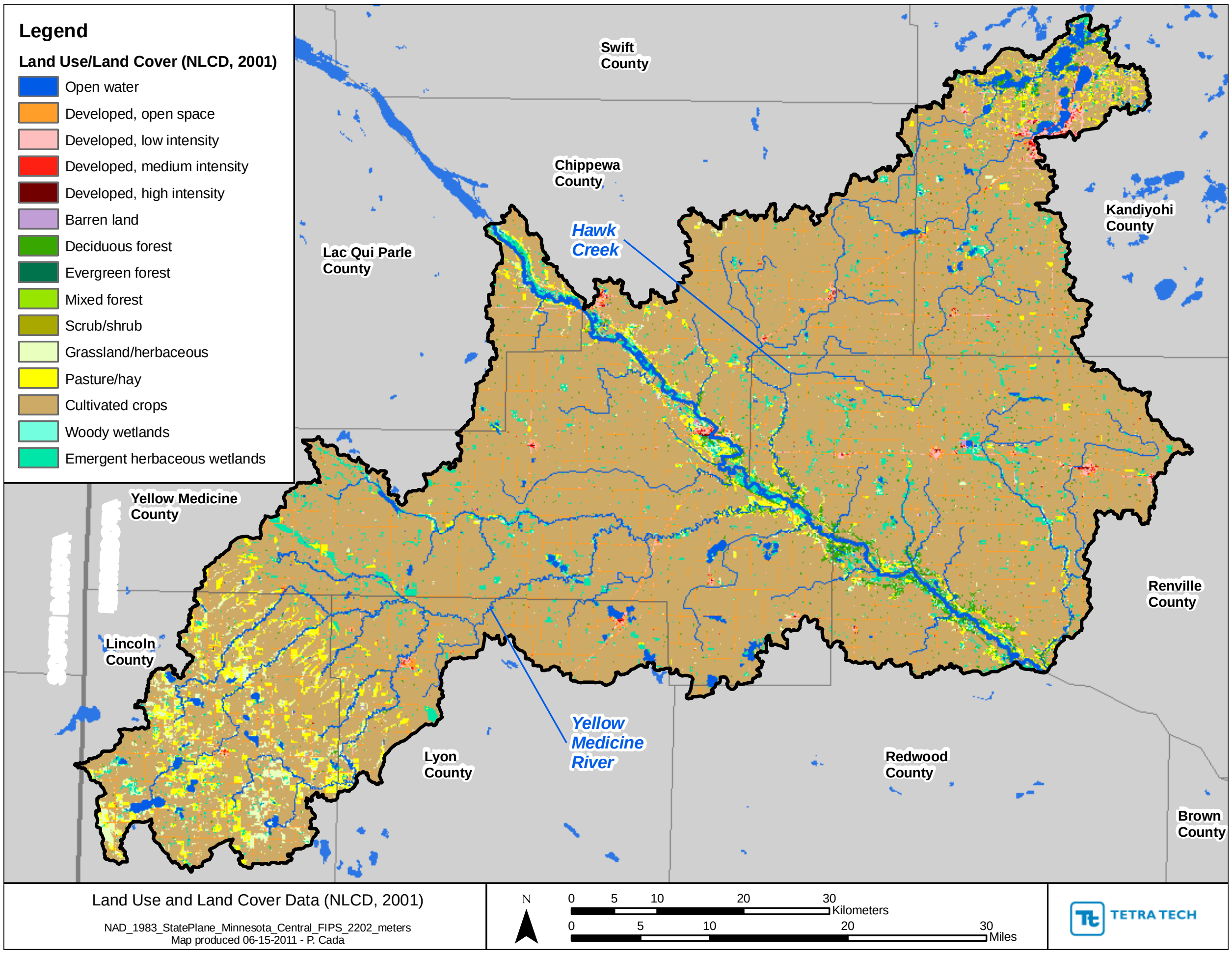

Figure 2. Land use/land cover in the Yellow Medicine/Hawk Creek basin

The following three scenarios were simulated in HSPF:

1) **Water and sediment control basins**. The model was modified to include explicit simulation of unit-area sedimentation basins that capture and hold 50 percent of the first two inches of runoff from agricultural lands. "Runoff" included surface runoff and shallow groundwater flow; tile drainage is captured in shallow groundwater flow. The captured flow is drained over a 48-hour period. Sediment and nutrient attenuation rates for flow entering the sedimentation basins were based on literature values. Specifically, the sedimentation basins were assumed to remove 80% of solids, 25 percent of inorganic phosphorus, and 30 percent of organic matter (including organic nitrogen and organic phosphorus) in the captured fraction of the first two inches of runoff based on typical performance of generic sedimentation basins (Novotny and Olem 1994). No reduction in inorganic nitrogen occurs, and no reduction is assigned to flows in excess of 2 inches that bypass the detention basin.

2) **Conversion of top EBI lands to permanent vegetation.** Using BWSR's Environmental Benefits Index (EBI), the locations that fall in the top 5 percent of the scores observed in the Hawk Creek watershed and are currently in agricultural and barren land uses were identified and converted to grassland. This resulted in the conversion of 105 acres of barren land and 11,706 acres of cropland to grassland, representing 1.7 percent of the watershed area. Other EBI lands are not currently in agricultural or barren land uses.

3) **Stream bank stabilization**. Scour of stream beds and banks occurs in HSPF when stream power and shear stress rises above a critical threshold. The model is, however, a one-dimensional simulation of stream reaches at a fairly coarse scale; further, the RESPEC implementation of the model has not been calibrated to represent the channel morphology of individual stream segments and reaches identified in the field as degrading are not necessarily the same segments as those that would be identified as unstable in the field. As a result, the benefits associated with stream bank stabilization can be assessed only approximately. This was accomplished by reducing the erodibility parameter that controls scour rate relative to shear stress for silt and clay (M) in those reaches where the greatest amount of channel/bank erosion is simulated by the model. These rates were reduced by 20 percent in the 24 (out of 79) stream reaches for which the largest scour was predicted in the baseline model. As the eroding sediment has associated with it concentrations of ammonia and orthophosphate, reduction in scour will also have a small impact on nutrient loads. However, given the approximate nature of the simulation the results are best evaluated in relative terms.

2 Scenario Results

Scenario results can be generated for each segment in the watershed model. This memorandum focuses on the integrated results present at the mouth of Hawk Creek (reach 201) as well as the mouth of the next largest stream Beaver Creek (reach 230). Scenario results are presented for the baseline conditions and for the three scenarios for 1996 through 2012 (Table 1, Table 2, and Figure 3). The first year of simulation was removed to avoid model spin-up issues. The relative changes shown in Table 2 for phosphorus (and, to a lesser, extent nitrogen) are strongly affected by the presence of large point source loads in Hawk Creek proper, averaging about 26 tons/yr total phosphorus, 66 tons/yr total nitrogen, and 56 tons/yr total suspended solids over the simulation period. In the upland erosion control scenario, suspended solids concentrations decreased by 13 percent, with lower reductions in nutrients. The presence of these point source loads diminishes the apparent effectiveness of the nonpoint source controls for phosphorus. Results for the nonpoint source loads only are shown in Figure 4, which shows that Scenario 1 reduces almost 15 percent of the nonpoint source load (this calculation is not exact because a fraction of the point source load is lost to deposition before reaching the mouth).

Table 1. Scenario results, concentrations and mass at Hawk Creek mouth, 1996–2012

Parameter	Baseline	Scenario 1: Water and Sediment Control Basins	Scenario 2: Conversion of Top EBI Lands to Permanent Vegetation	Scenario 3: Stream Bank Stabilization
TSS median concentration (mg/L)	19.2	18.7	18.9	18.5
TSS mean concentration (mg/L)	65.5	64.8	65.4	65.1
TSS load (tons/yr)	7,871	6,862	7,799	7,762
Nitrate + nitrite median concentration (mg/L)	2.94	2.94	2.92	2.94
Nitrate + nitrite mean concentration (mg/L)	4.46	4.47	4.45	4.46
Total N median concentration (mg/L)	3.56	3.56	3.54	3.56
Total N mean concentration (mg/L)	6.84	6.84	6.83	6.84
Total N load (tons/yr)	836	831	828	837
Total P median concentration (mg/L)	0.36	0.34	0.36	0.36
Total P mean concentration (mg/L)	1.36	1.35	1.36	1.36
Total P load (tons/yr)	49.0	46.0	48.6	48.9

Table 2. Scenario results, percent changes relative to baseline

Parameter	Scenario 1: Water and Sediment Control Basins	Scenario 2: Conversion of Top EBI Lands to Permanent Vegetation	Scenario 3: Stream Bank Stabilization
TSS median concentration	-2.9%	-1.7%	-3.7%
TSS mean concentration	-1.1%	-0.1%	-0.6%
TSS load	-12.8%	-0.9%	-1.4%
Nitrate + nitrite median concentration	0.2%	-0.7%	0.0%
Nitrate + nitrite mean concentration	0.2%	-0.1%	0.0%
Total N median concentration	0.1%	-0.4%	0.0%
Total N mean concentration	0.0%	-0.1%	0.0%
Total N load	-0.7%	-1.0%	0.0%
Total P median concentration	-3.9%	0.5%	0.0%
Total P mean concentration	-0.2%	0.3%	0.0%
Total P load	-6.1%	-0.7%	0.0%

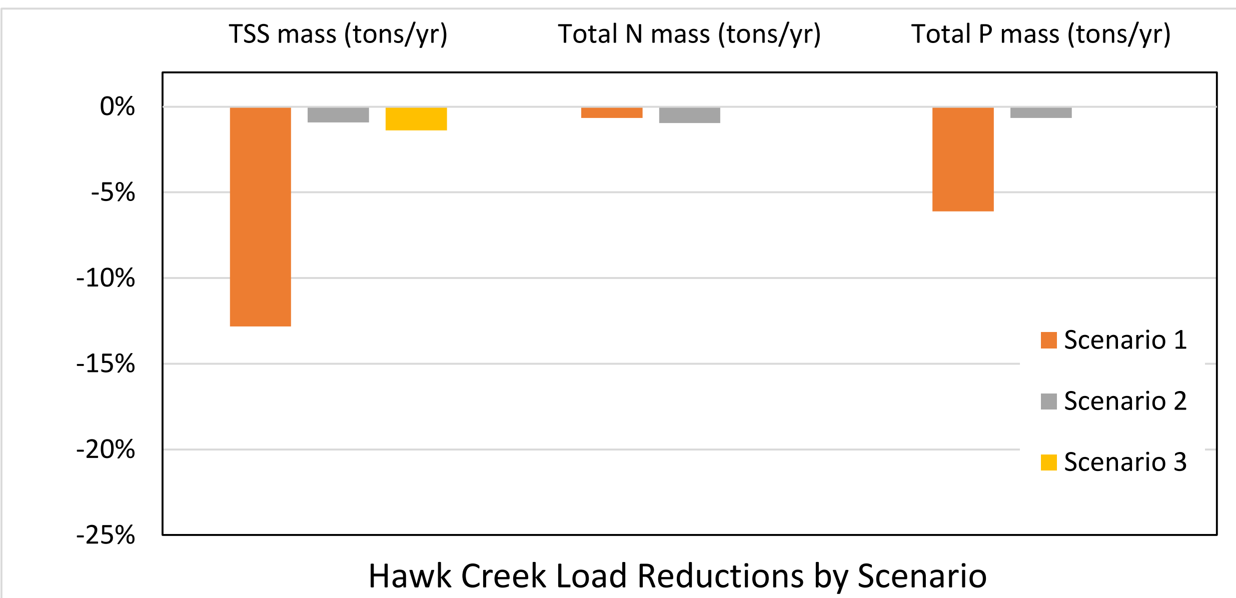

Figure 3. Changes in pollutant loading at mouth of Hawk Creek by scenario

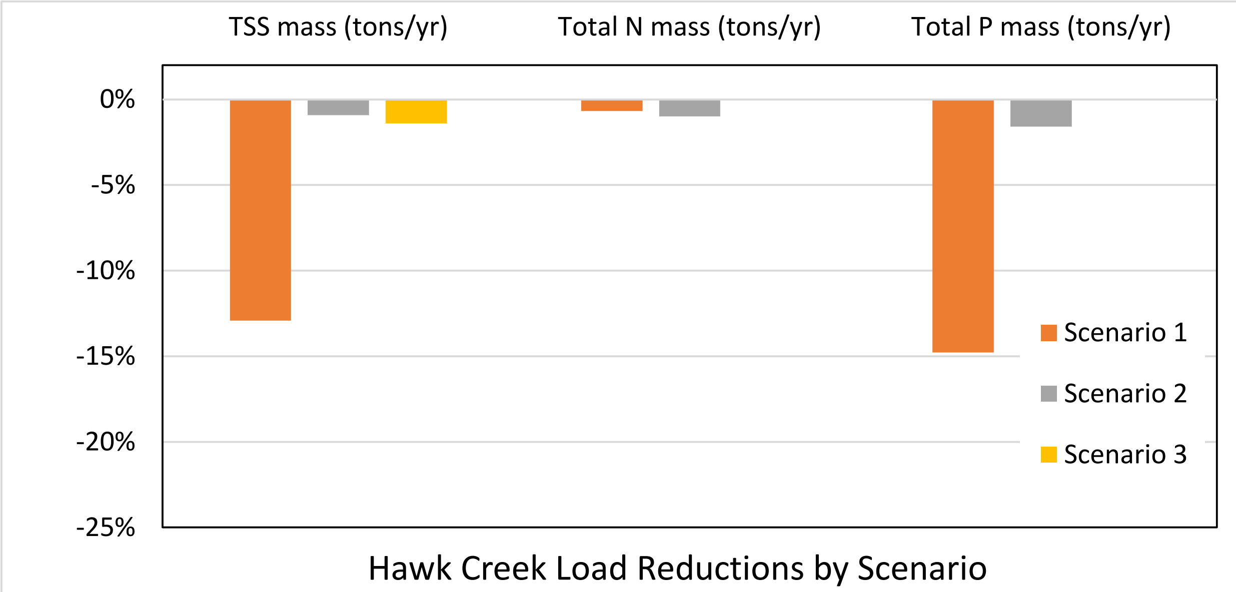

Figure 4. Changes in pollutant loading at mouth of Hawk Creek (nonpoint loads only)

Results at the mouth of Beaver Creek are shown in Table 3. Scenario 3 is not shown for Beaver Creek because none of the reaches selected for reduced scour representation were in the Beaver Creek drainage. As in Hawk Creek, the phosphorus statistics are strongly affected by point source discharges, which contribute over 3 tons/year.

Table 3. Scenario results, concentrations and mass at Beaver Creek mouth, 1996–2012

Parameter	Baseline	Scenario 1: Water and Sediment Control Basins	Scenario 2: Conversion of Top EBI Lands to Permanent Vegetation
TSS median concentration (mg/L)	14.3	14.0	14.3
TSS mean concentration (mg/L)	84.7	84.2	83.7
TSS load (tons/yr)	2,911	2,590	2,893
Nitrate + nitrite median concentration (mg/L)	2.84	2.85	2.80
Nitrate + nitrite mean concentration (mg/L)	3.24	3.25	3.19
Total N median concentration (mg/L)	3.76	3.76	3.71
Total N mean concentration (mg/L)	5.28	5.27	5.18
Total N load (tons/yr)	310	308	304
Total P median concentration (mg/L)	0.17	0.17	0.17
Total P mean concentration (mg/L)	0.62	0.62	0.61
Total P load (tons/yr)	12.8	11.8	12.5

For Scenario 1, the water and sediment control basins that are simulated in this scenario primarily remove sediment through settling of particulates; the phosphorus that is adsorbed to the sediment is also removed, but the dissolved fractions of nutrients are not substantially changed. For phosphorus, 25 percent of the inorganic P load and 30 percent of the organic matter load is removed from the first two inches of runoff for the 50 percent of lands where treatment is applied. The basins also reduce peak flow velocities in the receiving streams and spread out the surface runoff peak, resulting in more deposition of phosphorus, for a net reduction in nonpoint source total phosphorus loads of nearly 15 percent at the mouth of Hawk Creek and nearly 10 percent at the mouth of Beaver Creek.

In contrast, Scenario 2, which simulates the conversion of the lands with the top 5 percent environmental benefits index to permanent vegetation achieves a reduction in sediment and nutrient loads of only about 1 percent. The net effect is small because this scenario converted less than 2 percent of the basin area to grassland.

As set up, the stream bank stabilization scenario (Scenario 3) results in little net change in sediment load. Examination of model results shows that the rate of scouring is indeed reduced by approximately 20 percent in those reaches that were modified; however, the basin-scale sediment loads decreased by only 1.4 percent, with no significant change in nutrient loads. The primary reason for this result is that, while the current baseline model simulates the reaches upstream of the Hawk Creek mouth contributing over 1,300 tons of sediment per year, the majority of this scoured sediment subsequently settles out, such that the simulated net of scour and deposition is near zero. There is concern, however, that the current calibration (RESPEC 2014b) for this watershed may under-estimate channel bank erosion processes, so this scenario may need to be revisited.

3 References

Novotny, V. and H. Olem. 1994. *Water Quality; Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold, New York.

RESPEC. 2014a. Model Resegmentation and Extension for Minnesota River Watershed Model Application. Memorandum to Dr. Charles Regan, MPCA, 30 Sept. 2014.

RESPEC. 2014b. Hydrology and Water Quality Calibration and Validation of Minnesota River Watershed Model Applications. Memorandum to Dr. Charles Regan, MPCA, 30 Sept. 2014.

Tetra Tech. 2011. Hawk Creek/Yellow Medicine River Detailed Model. Prepared for Hawk Creek Watershed Project by Tetra Tech, Inc., Research Triangle Park, NC.