External Memorandum

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Subject: Chippewa 10 Percent Scenario Model

The Land Stewardship Project (LSP) and Chippewa River Watershed Project (CRWP) co-coordinate the Chippewa 10% Project (C10). This C10 engages farmers, landowners, scientists and conservationists to advance solutions including more continuous living cover in agriculture that can protect and restore our waters and for fishing hunting, swimming, and recreation, provide good wildlife habitat and be profitable for farmers. CRWP has conducted water quality monitoring in the Chippewa River Watershed. Other partners who worked on modeling include: the Agricultural Research Service's North Central Soil Conservation Research Lab (ARS), University of Minnesota Extension Service and University of Minnesota's West Central Research and Outreach Center. LSP convened and directed modeling efforts of the C10 partners as well as providing the GIS analysis and files to RESPEC for baseline crop rotations in the focal areas and identifying areas to apply "what if" scenarios for modeling changes to water quality. In this document, when LSP is used it means LSP on behalf of the Chippewa 10% Project partners.

The CRWP recently analyzed 15 years of monitoring data and discovered a correlation between land cover and in-stream pollutant concentrations. This correlation suggested water quality goals could be met if perennial cover in the watershed was increased to 34 percent. The current perennial cover is estimated to be 24 percent, which indicates that 10 percent more permanent cover on the landscape is needed. The Agricultural Production Systems sIMulator (APSIM) software was also used to complete the modeling. ARS led modeling on the APSIM allows the user to simulate how a variety of different crops, soils, weather, and management actions interact. It generated ecosystem services output coefficients for crop rotations that were also mapped [Jaradat and Boody, 2011]. LSP selected relevant ecosystem services output

coefficients, generated from APSIM and statistically analyzed by ARS, to use in HSPF modeling.

An HSPF model application existed in the Chippewa River Watershed with a modeling period of 1995–2012. Further information on developing and calibrating the Chippewa model application is available in external memoranda [Kenner, 2014a; 2014b]. Multiple scenarios were run in HSPF to determine results of specified land-use changes that the LSP has been working on with landowners. Before the scenarios were run, the watershed boundaries of the original model were updated to match three LSP-specified focal areas—the East Branch Chippewa, the Middle Main Chippewa, and the Shakopee Creek (Figure 1). Setup included acquiring the model application, Geographic Information System (GIS) files, and model documentation to ensure that the application executed properly. HSPF subwatersheds and reaches are illustrated in Figure 2. In addition, the baseline model predictions were analyzed to quantify the baseline loadings and loading rates for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). TP includes orthophosphate and organic phosphorus, and TN includes nitrate, nitrite, ammonia, and organic nitrogen. The following four scenarios were run, some of which used efficiency factors derived by LSP from ARS APSIM modeling:

- **Scenario A**—Decrease conservation reserve program grasses
- **Scenario B**—Reduce nitrogen application on corn fields
- **Scenario C**—Increase perennial cover
- **Scenario D**—Diversify crop rotations on good farmland.

SCENARIO A—DECREASE CONSERVATION RESERVE PROGRAM GRASSES

The LSP realizes that their goal of improving water quality by increasing perennial cover by 10 percent means that no losses of land currently in perennial cover can occur. Unfortunately, land enrolled in conservation programs, such as the Conservation Reserve Program (CRP), is being threatened by high crop prices. For Scenario A, the impacts of land anticipated to exit the CRP program in focal areas of the Chippewa River Watershed were modeled. Lands to exit CRP were predicted by an economic model used by researchers at the University Of Minnesota Department Of Applied Economics. The economic model uses CRP parcels enrolled in 2007 and predicts their likelihood of exit from 2014-2019 based on 2010 crop prices. The schematic in an HSPF model application tells the model the total area of each land use that contributes to each subwatershed. For Scenario A, the areas that represented CRP exit areas in the East Branch, Middle Main, and Shakopee focal areas were adjusted in the base schematic from their base land use to cropland. Occasionally CRP exit areas slightly overlapped with base land uses that were not grassland or pasture in the National Land Cover Dataset. For this scenario, the overlapping urban areas were not converted to cropland. The Scenario A areas that represented CRP exit areas are illustrated in Figure 3.

Load and concentration changes resulting from Scenario A are provided in Tables 1 and 2, respectively. Scenario A average loads of TN, TP, and TSS in the focal areas increased from the base scenario by 0.8 percent, 0.7 percent, and 0.6 percent, respectively. Scenario A average concentrations of TN, TP, and TSS in the focal areas changed from the base scenario by 0.2 percent, 0.2 percent, and 0.2 percent, respectively.

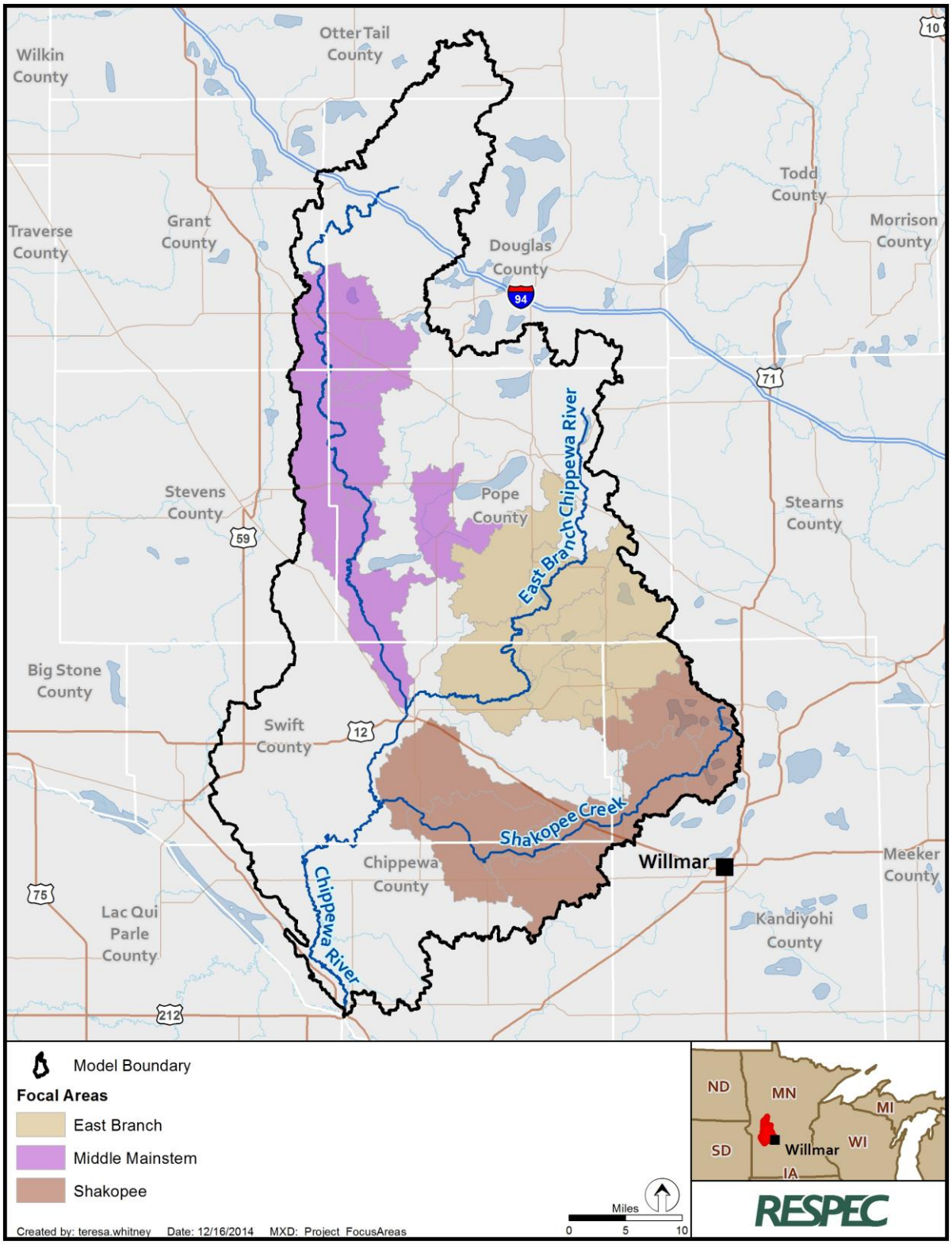

Figure 1. HSPF Model Boundary and Focal Areas.

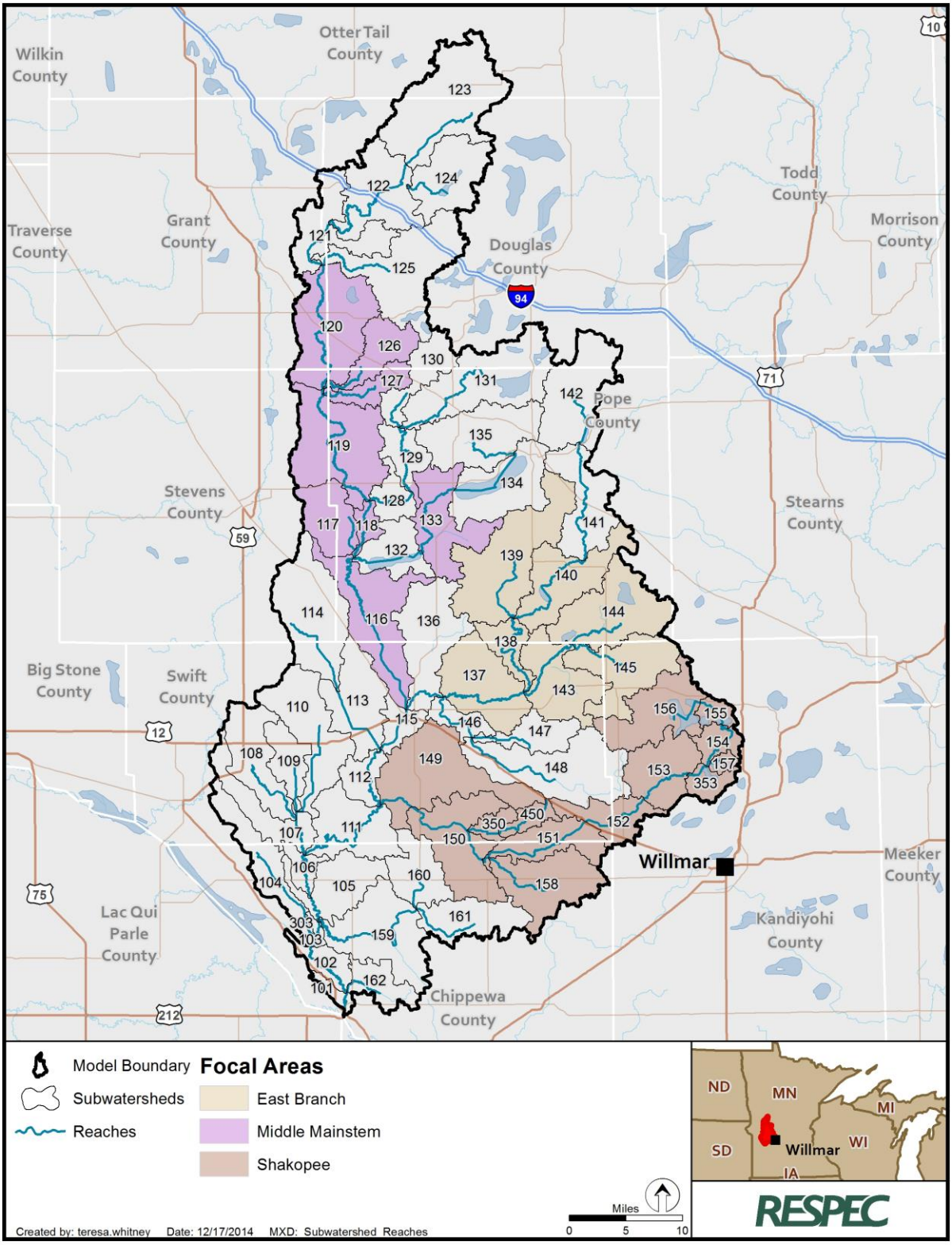

Figure 2. HSPF Subwatersheds and Reaches.

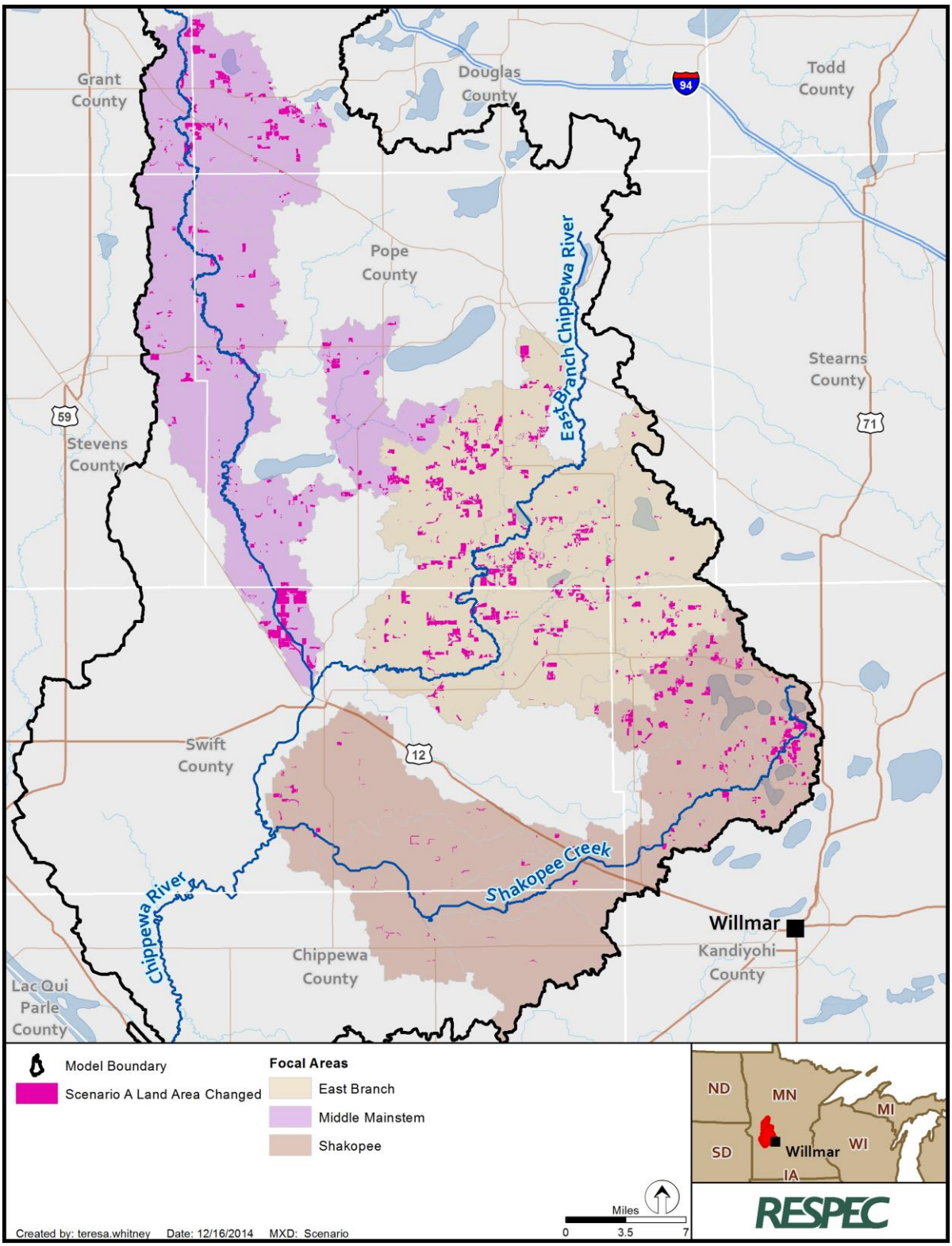

Figure 3. Land Predicted to Exit the Conservation Reserve Program Scenario A.

Table 1. Scenario A: Change in Load from Base Condition

Location	Variable	Base Load (lb/year)	Scenario A Load (lb/year)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	774,947	1.3
	Total Phosphorus	53,207	53,786	1.1
	Total Suspended Solids	31,861,278	32,116,654	0.8
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	896,379	0.5
	Total Phosphorus	117,919	118,660	0.6
	Total Suspended Solids	87,903,141	88,325,623	0.5
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,513,443	0.6
	Total Phosphorus	72,506	72,867	0.5
	Total Suspended Solids	31,695,735	31,886,450	0.6
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,264,816	0.5
	Total Phosphorus	314,598	316,235	0.5
	Total Suspended Solids	182,584,216	183,477,272	0.5

lb/year = pounds per year.

Table 2. Scenario A: Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario A Concentration (mg/L)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.88	0.4
	Total Phosphorus	0.122	0.122	0.3
	Total Suspended Solids	31.85	31.92	0.2
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.59	0.1
	Total Phosphorus	0.141	0.141	0.2
	Total Suspended Solids	30.63	30.64	0.0
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.50	0.2
	Total Phosphorus	0.186	0.186	0.1
	Total Suspended Solids	46.44	46.60	0.4
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.18	0.1
	Total Phosphorus	0.16	0.16	0.1
	Total Suspended Solids	37.78	37.84	0.2

mg/L = milligrams per liter.

SCENARIO B—REDUCE NITROGEN APPLICATION ON CORN FIELDS

In HSPF, loads from different land uses can be adjusted based on efficiencies. The APSIM nitrate (NO3-N) efficiency factor represented NO3-N leaching in the watershed. Therefore, for Scenario B, the APSIM efficiency factor supplied by LSP was used, which represented a 13 percent reduction to NO3-N in subsurface and groundwater outflow in the model application. To acquire an efficiency factor for the nitrates in surface water, RESPEC ran the model application with a 20 percent reduction of the HSPF Monthly Varying Parameters ACCUM and SQOLIM parameters for nitrate to reflect the reduced application. The difference between these results and the base results were used to calculate a percent reduction (16 percent), which was applied to the surface water. Additionally, because LSP determined that 62 percent of the corn/soybean rotation was corn in 2013, the efficiency factors were multiplied by 0.62 to avoid nitrogen application representation on soybeans. The efficiency factors were applied to the East Branch, Middle Main, and Shakopee focal area watersheds.

Load and concentration changes that resulted from Scenario B are provided in Tables 3 and 4, respectively. Scenario B average total nitrogen and nitrate loads in the focal areas decreased from the base scenario by 4 percent and 6 percent, respectively. Scenario B average total nitrogen and nitrate concentrations in the focal areas decreased from the base scenario by 3 percent and 6 percent, respectively.

Table 3. Scenario B Change in Load from Base Condition

Location	Variable	Base Load (lb/year)	Scenario B Load (lb/year)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	733,257	-4.1
	Total Nitrate	448,993	417,546	-7.0
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	884,760	-0.8
	Total Nitrate	244,869	238,034	-2.8
Shakopee (Reach 149)	Total Nitrogen	1,505,064	1,414,942	-6.0
	Total Nitrate	1,108,514	1,018,630	-8.1
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,117,322	-2.9
	Total Nitrate	2,534,959	2,410,556	-4.9

Table 4. Scenario B Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario B Concentration (mg/L)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.81	-3.2
	Total Nitrate	0.97	0.91	-6.1
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.58	-0.8
	Total Nitrate	0.50	0.49	-2.4
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.31	-5.2
	Total Nitrate	2.24	2.06	-8.0
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.13	-2.3
	Total Nitrate	1.15	1.10	-4.4

SCENARIO C—INCREASE PERENNIAL COVER

Various scenarios were run in HSPF to reflect an increase in perennial cover. Scenarios C1 through C5 described in the following sections build on each other cumulatively. For example, Scenario C3 includes the changes made in Scenarios C1 and C2.

Scenario C1—Riparian Filter Strips

In the Chippewa River Watershed, farming to the edge of ditches and streams is common. For Scenario C1, 16-foot riparian buffers were represented along all corn and soybean fields in the Shakopee Basin, and 100-foot riparian buffers were represented along all corn and soybean fields in the East Branch and Middle Main Basins. The LSP determined acres on which buffers should be added in ArcGIS. The totals reflect the filter strips that are not currently in place. These areas were transferred from row crop to grassland. In addition, efficiency factors were incorporated on the loads originating from the cropland buffered by the filter strips to reflect the filtering that would occur before the water reaches local waterbodies in these watersheds. Efficiency factors were calculated for 16-foot and 100-foot riparian buffers based on a study that summarized two other literature reviews showing that TSS, TP, and TN removal can be calculated as a function of buffer width according to Equation 1 (TSS), Equation 2 (TP), and Equation 3 (TN), where y represents removal efficiency (%) and x represents buffer width (feet). Scenario C1 efficiency factors are provided in Table 5 [Miller et al., 2012].

Table 5. Scenario C1 Efficiency Factors [Miller et al., 2012] Before Decreasing by Effective Area Percentage

Constituent	16-Foot Buffer (%)	100-Foot Buffer (%)
Total Suspended Solids	75	90
Total Phosphorus	80	79
Total Nitrogen	43	80

$$y = 8.5Ln(x) + 51.3 \quad (1)$$

$$y = 15.84Ln(x) + 5.9 \quad (2)$$

$$y = 20.24Ln(x) - 13.18 \quad (3)$$

Filter strips are typically assumed to only impact runoff from areas within a distance of the overland flow length, so an overland flow length of 300 feet was assumed. In addition, an effective area was calculated to account for lower delivery ratios further from the filter strips. Using an effective area results in delivery of higher loads from areas closer to filter strips. The

filter strip effective area percentages (9 percent each in the East Branch and the Middle Main and 14 percent in the Shakopee) were estimated by using Equation 4 from the University of Minnesota [2006] where x equals the flow distance between the edge of a field to the nearest surface water and y equals the delivery ratio.

$$y = x^{-0.2069} \quad (4)$$

Load and concentration changes that resulted from Scenario C1 are provided in Tables 6 and 7, respectively. Scenario C1 average load reductions of TN, TP, and TSS in the focal areas were 5 percent, 5 percent, and 4 percent, respectively. Scenario C1 average concentration reductions of TN, TP, and TSS in the focal areas were 4 percent, 4 percent, and 4 percent, respectively.

Table 6. Scenario C1 Change in Load From Base Condition

Location	Variable	Base Load (lb/year)	Scenario C1 Load (lb/year)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	720,858	-5.7
	Total Phosphorus	53,207	50,518	-5.1
	Total Suspended Solids	31,861,278	30,589,002	-4.0
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	863,811	-3.1
	Total Phosphorus	117,919	113,499	-3.7
	Total Suspended Solids	87,903,141	84,767,427	-3.6
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,412,187	-6.2
	Total Phosphorus	72,506	67,838	-6.4
	Total Suspended Solids	31,695,735	30,034,209	-5.2
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,089,513	-3.6
	Total Phosphorus	314,598	303,932	-3.4
	Total Suspended Solids	182,584,216	176,570,652	-3.3

Table 7. Scenario C1 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario C1 Concentration (mg/L)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.78	-4.9
	Total Phosphorus	0.12	0.12	-4.6
	Total Suspended Solids	31.85	30.65	-3.8
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.55	-2.7
	Total Phosphorus	0.14	0.14	-2.8
	Total Suspended Solids	30.63	29.76	-2.8
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.29	-5.8
	Total Phosphorus	0.19	0.18	-5.9
	Total Suspended Solids	46.44	44.29	-4.6
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.12	-2.8
	Total Phosphorus	0.16	0.16	-2.2
	Total Suspended Solids	37.78	36.76	-2.7

Scenario C2—Marginal Row Crop to Management-Intensive Rotational Grazing Pasture

In Scenario C2, corn and soybean fields in the focal area watersheds with areas greater than 40 acres with Land Cover Classification (LCC) = 3 and a slope > 6 percent or with LCC = 4–8 were converted to grassland, which was used as a surrogate for Management Intensive Rotational Grazing (MIRG) pasture. The GIS layer representing areas to be converted was supplied by LSP. After the scenario was run, reductions were compared to efficiencies from APSIM supplied by LSP. The comparison showed that using grassland as a surrogate for MIRG pasture had efficiencies within 3 percent of the APSIM efficiencies for TSS and within 4 percent of the APSIM efficiencies for nitrates.

Load and concentration changes that resulted from Scenario C2 are provided in Tables 8 and 9, respectively. Tables 8 and 9 also show the percent change from Scenario C1 to C2. Scenario C2 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 6 percent, 6 percent, and 5 percent, respectively. Scenario C2 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 5 percent, 5 percent, and 5 percent, respectively.

Table 8. Cumulative Scenarios C1 and C2 Change in Load from Base Condition

Location	Variable	Base Load (lb/year)	Scenario C2 Load (lb/year)	Percent Change	Percent Change From Scenario C1
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	703,604	-8.0	-2.4
	Total Phosphorus	53,207	49,459	-7.0	-2.1
	Total Suspended Solids	31,861,278	29,972,614	-5.9	-2.0
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	861,422	-3.4	-0.3
	Total Phosphorus	117,919	112,794	-4.3	-0.6
	Total Suspended Solids	87,903,141	84,340,026	-4.1	-0.5
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,406,551	-6.5	-0.4
	Total Phosphorus	72,506	67,613	-6.7	-0.3
	Total Suspended Solids	31,695,735	29,959,890	-5.5	-0.2
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,064,232	-4.2	-0.6
	Total Phosphorus	314,598	301,934	-4.0	-0.7
	Total Suspended Solids	182,584,216	175,424,509	-3.9	-0.6

Table 9. Cumulative Scenarios C1 and C2 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario C2 Concentration (mg/L)	Percent Change	Percent Change From Scenario C1
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.78	-5.1	-0.2
	Total Phosphorus	0.12	0.12	-4.9	-0.4
	Total Suspended Solids	31.85	29.97	-5.9	-2.2
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.55	-2.7	-0.1
	Total Phosphorus	0.14	0.14	-3.1	-0.3
	Total Suspended Solids	30.63	29.65	-3.2	-0.4
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.28	-6.0	-0.2
	Total Phosphorus	0.19	0.17	-6.1	-0.1
	Total Suspended Solids	46.44	44.21	-4.8	-0.2
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.12	-2.9	-0.1
	Total Phosphorus	0.16	0.16	-2.4	-0.2
	Total Suspended Solids	37.78	36.56	-3.2	-0.5

Scenario C3—Prairie Strips

The LSP has been following a research project being performed by Iowa State called Science-Based Trials of Rowcrops Integrated with Prairie Strips (STRIPS). This research project is studying the overall farmland health of adding small areas of prairie into row-cropped fields along the contours and especially at the foot of a field. Scenario C3 evaluated implementing this practice on some of the smaller fields where crop productivity is determined to be marginal.

For Scenario C3, corn and soybean land with LCC = 3, a slope greater than 6 percent, and field size less than 40 acres were transitioned to prairie strips (grassland) in HSPF. Scenario C3 efficiency factors, provided in Table 10, were calculated by using Neiber's filter strip equations from Miller et al. [2012], which assumes that runoff would run through 50-foot-wide strips in Shakopee and 100-foot-wide strips in the East Branch and the Middle Main. Also, efficiency factors from two Iowa State University studies on the loads originating from the cropland buffered by these prairie strips were reviewed [Zhou et al., 2014; Helmers et al., 2012]. Load reductions from the Iowa State University papers were 96 percent for TSS, 90 percent for TP, and 84 percent for TN. For consistency with the filter strip scenario (C1) and to ensure the reduction estimates were conservative, efficiency factors calculated by using Neiber's filter strip equations were used. Similar to Scenario C1, prairie strip effective area percentages (44 percent in the East Branch and the Middle Main and 35 percent in the Shakopee) were also estimated by using Equation 4 from the University of Minnesota [2006].

Table 10. Scenario C3 Efficiency Factors Before Decreasing by Effective Area Percentage

Constituent	50-Foot Buffer (%)	100 Foot Buffer (%)
Total Suspended Solids	85	90
Total Phosphorus	68	79
Total Nitrogen	66	80

Load and concentration changes resulting from Scenario C3 are provided in Tables 11 and 12, respectively. Tables 11 and 12 also show the percent change from Scenario C2 to C3. Scenario C3 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 26 percent, 24 percent, and 20 percent, respectively. Scenario C3 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 22 percent, 20 percent, and 18 percent, respectively.

Table 11. Cumulative Scenario C1, C2, and C3 Change in Load from Base Condition

Location	Variable	Base Load (lb/ year)	Scenario C3 Load (lb/ year)	Percent Change	Percent Change From Scenario C2
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	520,365	-32.0	-26.0
	Total Phosphorus	53,207	38,765	-27.1	-21.6
	Total Suspended Solids	31,861,278	24,775,010	-22.2	-17.3
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	746,758	-16.2	-13.3
	Total Phosphorus	117,919	95,741	-18.8	-15.1
	Total Suspended Solids	87,903,141	72,023,670	-18.1	-14.6
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,074,232	-28.6	-23.6
	Total Phosphorus	72,506	52,743	-27.3	-22.0
	Total Suspended Solids	31,695,735	25,502,164	-19.5	-14.9
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	3,479,667	-18.0	-14.4
	Total Phosphorus	314,598	263,325	-16.3	-12.8
	Total Suspended Solids	182,584,216	153,631,849	-15.9	-12.4

Table 12. Cumulative Scenario C1, C2, and C3 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario C3 Concentration (mg/L)	Percent Change	Percent Change From Scenario C2
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.41	-25.0	-20.9
	Total Phosphorus	0.12	0.09	-22.7	-18.7
	Total Suspended Solids	31.85	24.84	-22.0	-17.1
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.38	-13.1	-10.6
	Total Phosphorus	0.14	0.12	-13.7	-10.9
	Total Suspended Solids	30.63	26.14	-14.7	-11.9
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	2.56	-26.6	-21.9
	Total Phosphorus	0.19	0.14	-24.2	-19.3
	Total Suspended Solids	46.44	38.25	-17.6	-13.5
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	1.88	-13.6	-11.0
	Total Phosphorus	0.16	0.15	-10.0	-7.9
	Total Suspended Solids	37.78	32.89	-13.0	-10.1

Scenario C4—Diversified Crop Rotations

Scenario C4 represents a diversification the of the corn soybean rotation to include 3 years of hay for land with LCC = 4–8 and field size less than 40 acres. Table 13 shows APSIM model efficiency factors that represented this rotation of 1 year of corn, 1 year of soybeans, and 3 years of hay were used as efficiency factors for the lands converted.

Table 13. Scenario C4 Efficiency Factors

Constituent	APSIM Efficiency
Total Suspended Solids	0.71
Total Phosphorus	0.54[(a)]
Nitrates	0.42

(a) From Literature, [Yoo et al., 1988]

Load and concentration changes resulting from Scenario C4 are provided in Tables 14 and 15, respectively. Tables 14 and 15 also show the percent change from Scenario C3 to C4. Scenario C4 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 26 percent, 25 percent, and 20 percent, respectively. Scenario C4 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 22 percent, 20 percent, and 18 percent, respectively.

Table 14. Cumulative Scenario C1, C2, C3, and C4 Change in Load from Base Condition

Location	Variable	Base Load (lb/ year)	Scenario C4 Load (lb/ year)	Percent Change	Percent Change From Scenario C3
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	517,831	-32.3	-0.5
	Total Phosphorus	53,207	38,517	-27.6	-0.6
	Total Suspended Solids	31,861,278	24,646,705	-22.6	-0.5
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	745,966	-16.3	-0.1
	Total Phosphorus	117,919	95,338	-19.1	-0.4
	Total Suspended Solids	87,903,141	71,685,595	-18.4	-0.5
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,072,078	-28.8	-0.2
	Total Phosphorus	72,506	52,609	-27.4	-0.3
	Total Suspended Solids	31,695,735	25,458,904	-19.7	-0.2
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	3,474,460	-18.1	-0.1
	Total Phosphorus	314,598	262,614	-16.5	-0.3
	Total Suspended Solids	182,584,216	153,126,883	-16.1	-0.3

Table 15. Cumulative Scenario C1, C2, C3, and C4 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario C4 Concentration (mg/L)	Percent Change	Percent Change From Scenario C3
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.40	-25.2	-0.3
	Total Phosphorus	0.12	0.09	-23.1	-0.5
	Total Suspended Solids	31.85	24.73	-22.4	-0.4
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.38	-13.2	-0.1
	Total Phosphorus	0.14	0.12	-13.9	-0.3
	Total Suspended Solids	30.63	26.04	-15.0	-0.4
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	2.56	-26.7	-0.2
	Total Phosphorus	0.19	0.14	-24.3	-0.2
	Total Suspended Solids	46.44	38.19	-17.8	-0.1
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	1.88	-13.7	-0.1
	Total Phosphorus	0.16	0.15	-10.2	-0.1
	Total Suspended Solids	37.78	32.81	-13.2	-0.2

Scenario C5—Management Intensive Rotational Grazing

Scenario C5 represented converting all land anticipated to exit the CRP program in the focal areas of the Chippewa River Watershed to grasslands, which were a surrogate for MIRG. Occasionally CRP exit areas slightly overlapped with base land uses that were not grassland or pasture in the National Land Cover Dataset. For this scenario, the overlapping forest and wetland areas were not converted to grassland. After the scenario was run, reductions were compared to efficiencies from APSIM supplied by LSP. The comparison showed that using grassland as a surrogate for MIRG pasture had efficiencies within 13 percent of the APSIM efficiencies for TSS and within 1 percent of the APSIM efficiencies for nitrates. The TSS APSIM efficiency factor was assumed to be zero, because it was calculated from a soil loss of 0.01 ton per acre per year on CRP to a soil loss of 0.06 tons per acre per year on MIRG.

Load and concentration changes resulting from Scenario C5 are provided in Tables 16 and 17, respectively. Tables 16 and 17 also show the percent change from Scenario C4 to C5. Scenario C5 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 26 percent, 25 percent, and 21 percent, respectively. Scenario C5 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 21 percent, 20 percent, and 19 percent, respectively. Figure 4 illustrates the land that was converted as described in Scenarios C1 through C5. Lands illustrated in Figure 4 make up approximately 12 percent of the total area in focal areas.

Table 16. Cumulative Scenario C1, C2, C3, C4, and C5 Change in Load from Base Condition

Location	Variable	Base Load (lb/ year)	Scenario C5 Load (lb/ year)	Percent Change	Percent Change From Scenario C4
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	515,148	-32.6	-0.5
	Total Phosphorus	53,207	38,349	-27.9	-0.4
	Total Suspended Solids	31,861,278	24,409,029	-23.4	-1.0
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	747,283	-16.2	0.2
	Total Phosphorus	117,919	94,847	-19.6	-0.5
	Total Suspended Solids	87,903,141	71,446,886	-18.7	-0.3
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,063,521	-29.3	-0.8
	Total Phosphorus	72,506	52,264	-27.9	-0.7
	Total Suspended Solids	31,695,735	25,272,029	-20.3	-0.7
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	3,462,960	-18.4	-0.3
	Total Phosphorus	314,598	261,453	-16.9	-0.4
	Total Suspended Solids	182,584,216	152,430,776	-16.5	-0.5

Table 17. Cumulative Scenario C1, C2, C3, C4, and C5 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario C5 Concentration (mg/L)	Percent Change	Percent Change From Scenario C4
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.43	-23.7%	1.9
	Total Phosphorus	0.12	0.10	-21.8%	1.7
	Total Suspended Solids	31.85	24.23	-23.9%	-2.0
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.39	-12.7%	0.5
	Total Phosphorus	0.14	0.12	-13.9%	0.0
	Total Suspended Solids	30.63	25.89	-15.5%	-0.6
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	2.55	-27.0%	-0.3
	Total Phosphorus	0.19	0.14	-24.5%	-0.1
	Total Suspended Solids	46.44	37.93	-18.3%	-0.7
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	1.89	-13.5%	0.3
	Total Phosphorus	0.16	0.15	-10.1%	0.1
	Total Suspended Solids	37.78	32.61	-13.7%	-0.6

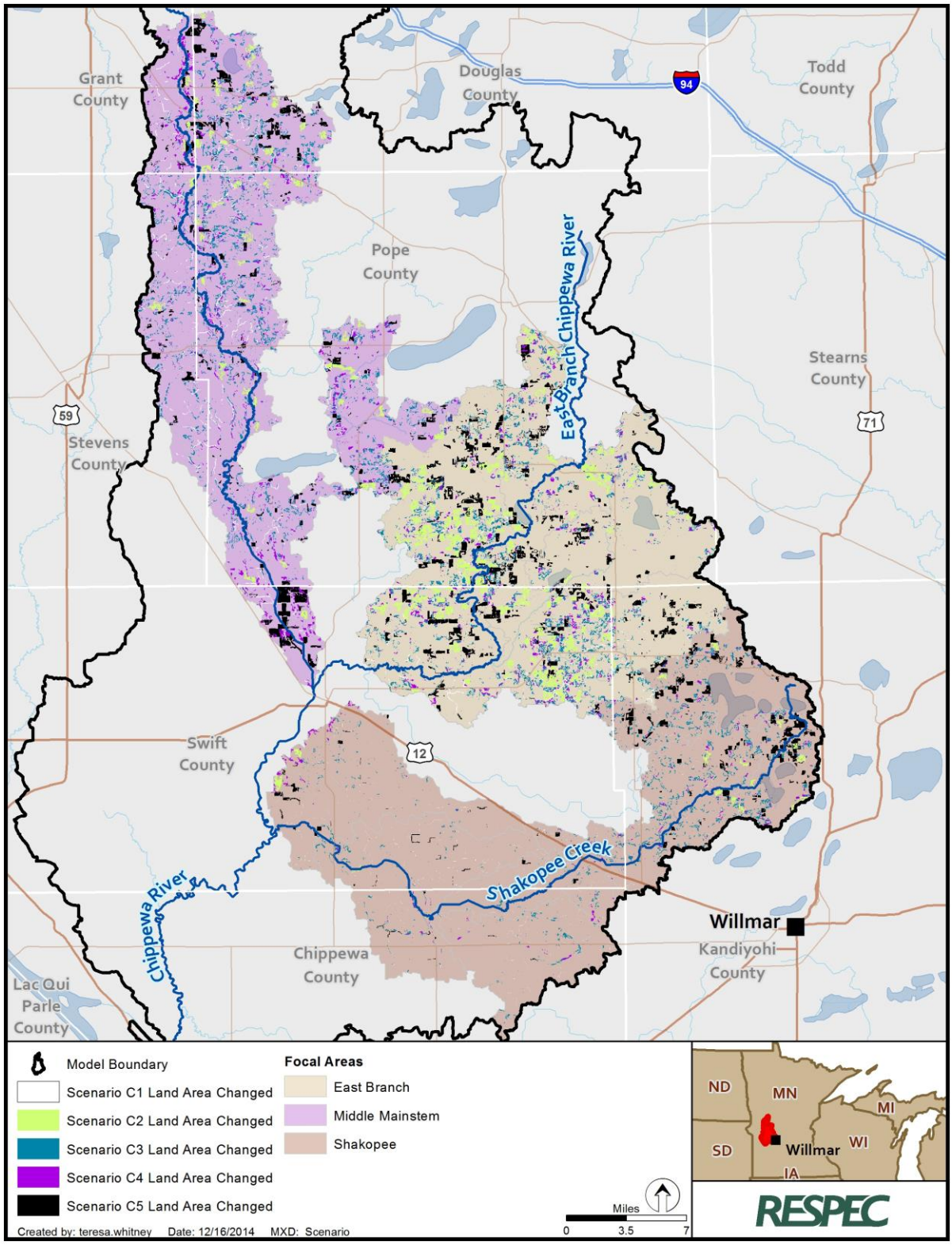

Figure 4. Areas Meeting Criteria for Scenarios C1 Through C5.

SCENARIO D—DIVERSIFY CROP ROTATIONS ON GOOD FARMLAND

The purpose of Scenario D was to analyze the impact of diversifying the crop rotation on 10 percent of the land in the targeted watersheds with LCC = 1, 2 and for land with LCC = 3 with a slope less than 6 percent. Typical crop rotations include corn and soybeans, and Scenario D adds in 1 year of wheat and 1 year of alfalfa after each corn/soybean (CS) rotation. Two versions of Scenario D were run. Scenario D1 used efficiency factors from APSIM where available and Scenario D2 used efficiency factors from literature. Table 18 shows the efficiency factors used for Scenario D1. Table 19 shows the literature efficiency factors used for Scenario D2. Areas that met the Scenario D criteria are illustrated in Figure 5.

Table 18. Scenario D1 Efficiency Factors

Constituent	APSIM Efficiency
Total Suspended Solids	0.34
Total Phosphorus	0.54[(a)]
Nitrates	0.13

(a) From literature [Yoo et al., 1988].

Table 19. Scenario D2 Efficiency Factors

Constituent	Literature Efficiency	Source
Total Suspended Solids	0.70	Merriman [2009]
Total Phosphorus	0.54	Yoo et al. [1988]
Nitrates	0.61	Kaspar et al. [2007]

Load and concentration changes that resulted from Scenario D1 are provided in Tables 20 and 21, respectively. Scenario D1 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 2 percent, 2 percent, and 4 percent, respectively. Scenario D1 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 2 percent, 1 percent, and 4 percent, respectively. Load and concentration changes that resulted from Scenario D2 are provided in Tables 22 and 23, respectively. Scenario D2 average load reductions of TN, TP, and TSS in the focal areas from the base scenario were 4 percent, 9 percent, and 4 percent, respectively. Scenario D2 average concentration reductions of TN, TP, and TSS in the focal areas from the base scenario were 4 percent, 8 percent, and 4 percent, respectively.

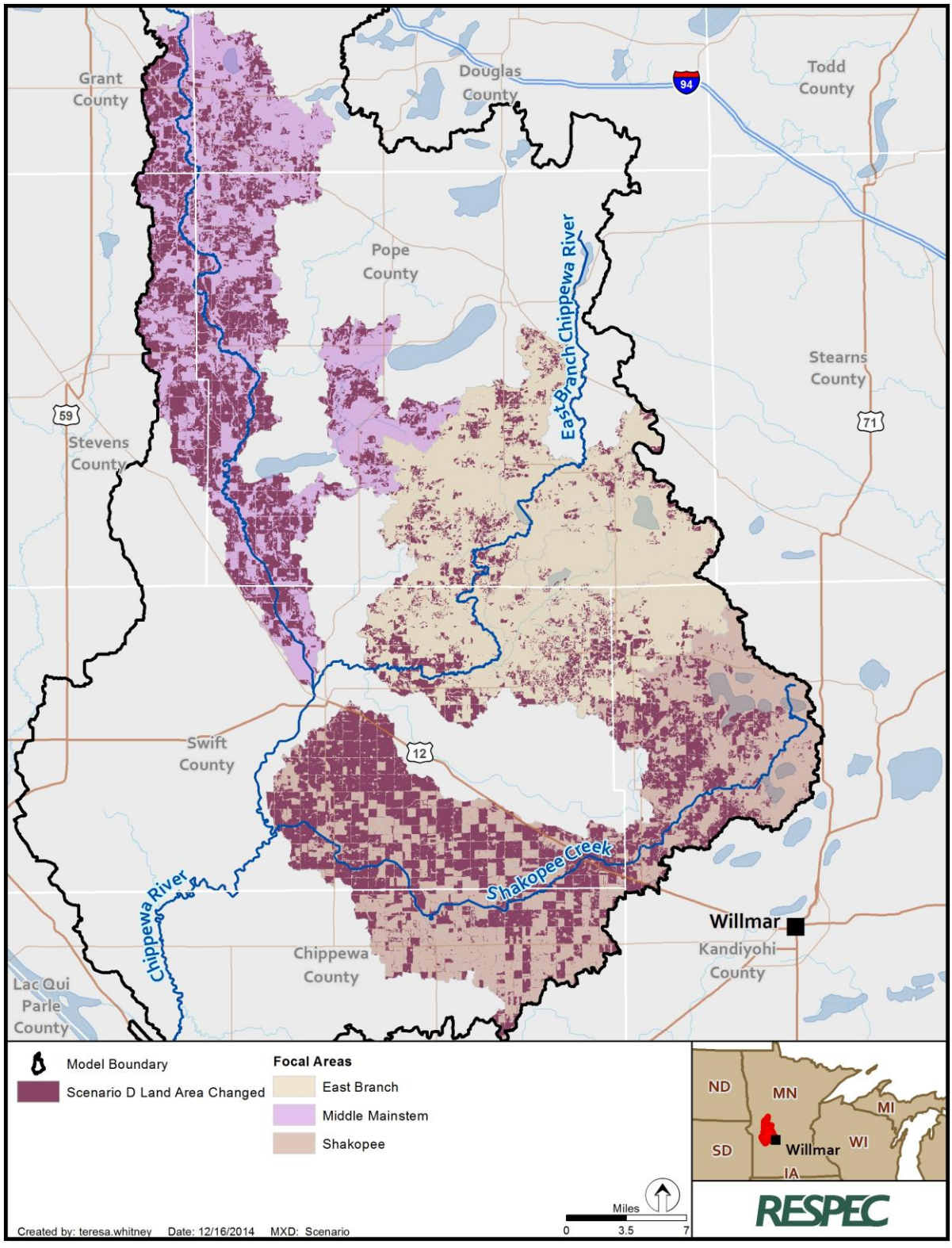

Figure 5. Areas Meeting Criteria for Scenario D.

Table 20. Scenario D1 Change in Load from Base Condition

Location	Variable	Base Load (lb/ year)	Scenario D1 Load (lb/ year)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	756,500	-1.1
	Total Phosphorus	53,207	51,021	-4.1
	Total Suspended Solids	31,861,278	31,220,231	-2.0
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	887,720	-0.4
	Total Phosphorus	117,919	114,929	-2.5
	Total Suspended Solids	87,903,141	86,407,291	-1.7
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,483,018	-1.5
	Total Phosphorus	72,506	68,253	-5.9
	Total Suspended Solids	31,695,735	31,015,894	-2.1
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,209,977	-0.8
	Total Phosphorus	314,598	306,125	-2.7
	Total Suspended Solids	182,584,216	179,796,057	-1.5

Table 21. Scenario D1 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario D1 Concentration (mg/L)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.85	-1.0
	Total Phosphorus	0.12	0.12	-4.0
	Total Suspended Solids	31.85	31.29	-1.8
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.58	-0.4
	Total Phosphorus	0.14	0.14	-2.2
	Total Suspended Solids	30.63	30.24	-1.3
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.44	-1.4
	Total Phosphorus	0.19	0.18	-5.5
	Total Suspended Solids	46.44	45.59	-1.8
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.17	-0.6
	Total Phosphorus	0.16	0.16	-1.9
	Total Suspended Solids	37.78	37.33	-1.2

Table 22. Scenario D2 Change in Load from Base Condition

Location	Variable	Base Load (lb/ year)	Scenario D2 Load (lb/ year)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	764,720	727,438	-4.9
	Total Phosphorus	53,207	48,546	-8.8
	Total Suspended Solids	31,861,278	30,492,372	-4.3
Middle Main (HSPF Reach 116)	Total Nitrogen	891,630	875,604	-1.8
	Total Phosphorus	117,919	110,909	-5.9
	Total Suspended Solids	87,903,141	84,786,960	-3.5
Shakopee (HSPF Reach 149)	Total Nitrogen	1,505,064	1,403,525	-6.7
	Total Phosphorus	72,506	63,885	-11.9
	Total Suspended Solids	31,695,735	30,243,626	-4.6
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	4,242,047	4,095,409	-3.5
	Total Phosphorus	314,598	296,223	-5.8
	Total Suspended Solids	182,584,216	176,714,451	-3.2

Table 23. Scenario D2 Change in Concentration from Base Condition

Location	Variable	Base Concentration (mg/L)	Scenario D2 Concentration (mg/L)	Percent Change
East Branch (HSPF Reach 137)	Total Nitrogen	1.87	1.79	-4.2
	Total Phosphorus	0.12	0.11	-7.9
	Total Suspended Solids	31.85	30.49	-4.3
Middle Main (HSPF Reach 116)	Total Nitrogen	1.59	1.56	-1.7
	Total Phosphorus	0.14	0.13	-4.4
	Total Suspended Solids	30.63	29.71	-3.0
Shakopee (HSPF Reach 149)	Total Nitrogen	3.49	3.27	-6.3
	Total Phosphorus	0.19	0.17	-10.8
	Total Suspended Solids	46.44	44.45	-4.3
Chippewa Outlet (HSPF Reach 106)	Total Nitrogen	2.18	2.12	-2.8
	Total Phosphorus	0.16	0.16	-3.8
	Total Suspended Solids	37.78	36.73	-2.8

SUMMARY

In summary, the cumulative Scenario C was most effective in removing TN, TP, and TSS loads. Scenario A, which represented changing land that is likely to exit the CRP program given 2010 crop prices, resulted in a slight increase in loads. The maximum Scenario A percent load increase was 1.3 percent in total nitrogen. Scenario B was less effective than Scenario C in removing total nitrogen and total nitrate loads, with maximum total nitrogen load reductions of approximately 6 percent and maximum nitrate load reductions of approximately 5.2 percent in Shakopee Creek. The combination of Scenarios C1 through C5 resulted in the highest load reductions in all focal areas, with TN load reductions as high as 33 percent, TP load reductions as high as 28 percent, and TSS reductions as high as 23 percent. All of the highest Scenario C reductions occurred in the East Branch focal area. Of Scenarios C1 through C5, Scenario C3 resulted in the highest load and concentration reductions, with average load and concentration reductions from Scenario C2 to C3 over 20 percent. Scenario C5 resulted in minimal reductions, and sometimes slight increases, because of the similarities between CRP and MIRG. Scenarios D1 and D2 were less effective than Scenario C in removing TN, TP, and TSS with load reductions ranging from 0.4 to 6 percent for Scenario D1 and 2 to 12 percent for Scenario D2. Bar charts of TN, TP, and TSS load changes that resulted from all scenarios in each focal area are illustrated in Figures 6 through 8. Table 24 provides an average of the percent reductions (TN, TP, and TSS) in each focus area divided by the percent of the actual implementation area in each focus area. These percent changes per areas implemented upon are positive for Scenario A and negative for all of the other scenarios. The highest reduction per area occurs from Scenario C4 in the Shakopee focal area. In terms of the Chippewa River Watershed taking steps to meet water quality goals, Scenario C3 (Prairie Strips) would be an excellent starting point. A combination of Scenarios B, C, and D would make significant strides toward reducing nitrogen, phosphorus, and sediment loading to the Chippewa River.

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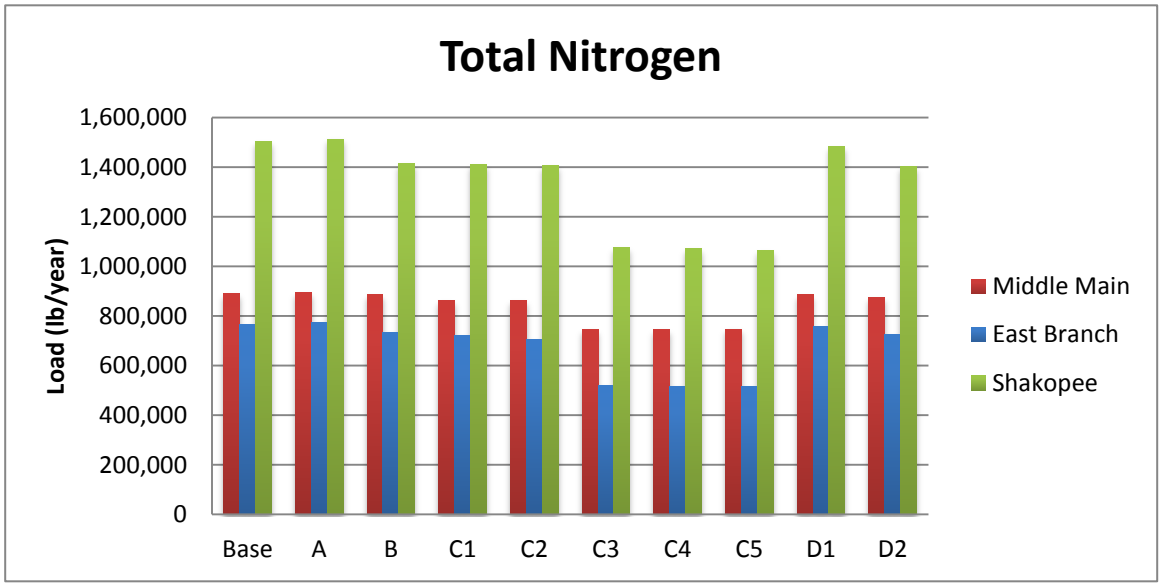

Figure 6. Total Average Annual Nitrogen Loads (1996–2012) for Each Scenario.

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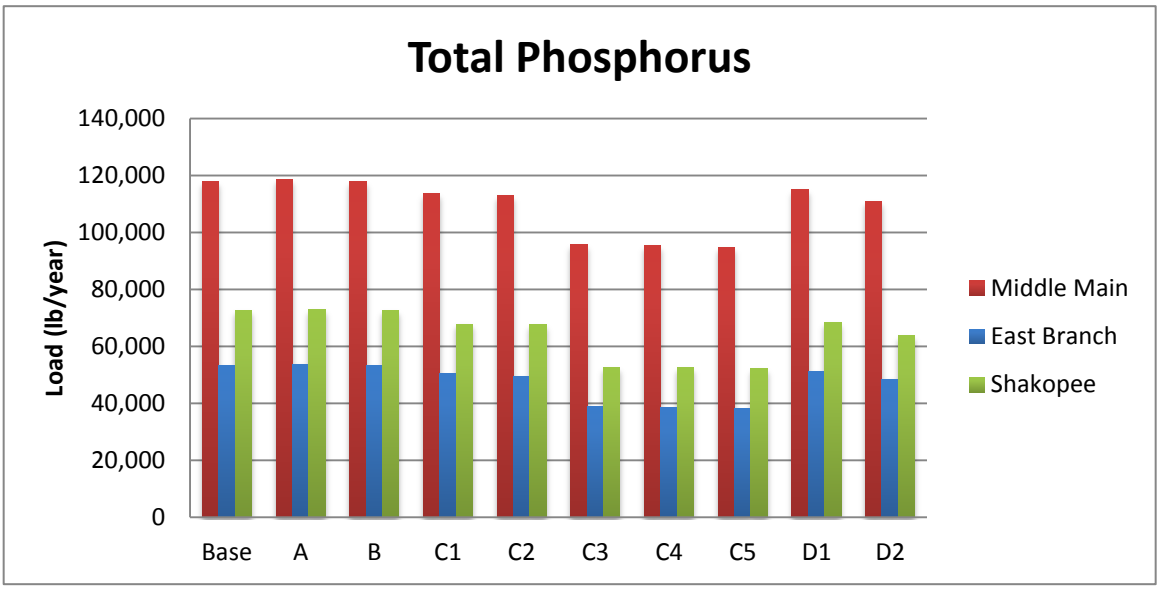

Figure 6. Total Average Annual Phosphorus Loads (1996–2012) for Each Scenario.

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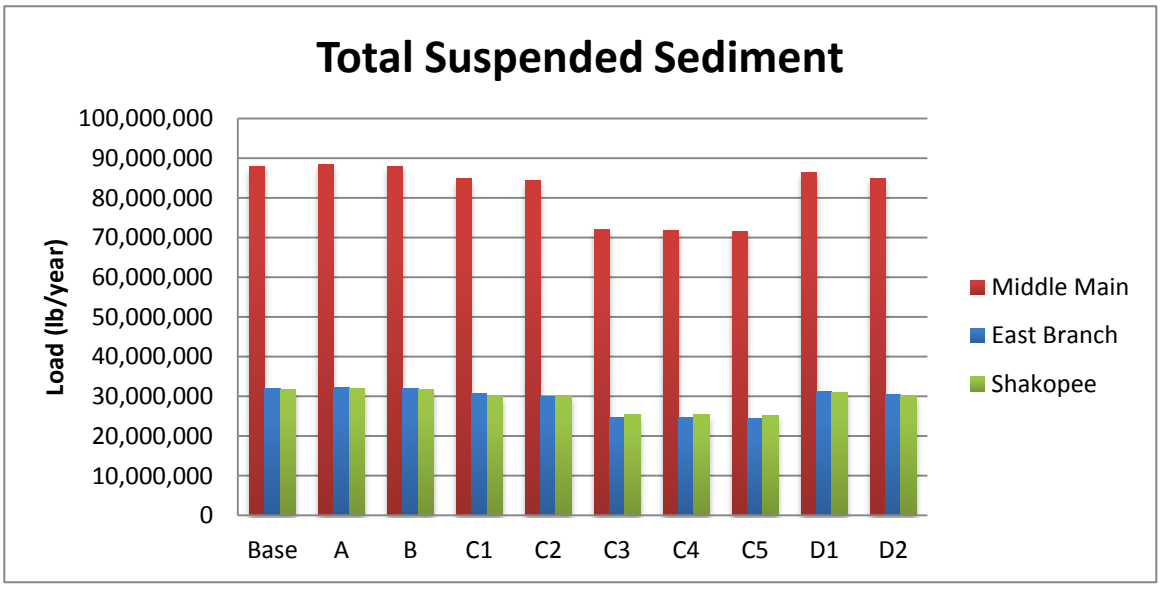

Figure 7. Total Average Annual Suspended Solids Loads (1996–2012) for Each Scenario.

Table 24. Water Quality Factors Representing Average Percent Load Reductions per Percent Area Implementation

Scenario	Focal Area	Water Quality Factor
A	East Branch	0.2
	Middle Main	0.1
	Shakopee	0.2
	Chippewa Outlet	0.3
C1	East Branch	-8.6
	Middle Main	-2.6
	Shakopee	-20.5
	Chippewa Outlet	-10.9
C2	East Branch	-1.4
	Middle Main	-2.3
	Shakopee	-12.7
	Chippewa Outlet	-4.0
C3	East Branch	-6.1
	Middle Main	-3.5
	Shakopee	-10.6
	Chippewa Outlet	-9.9
C4	East Branch	-14.8
	Middle Main	-7.5
	Shakopee	-40.2
	Chippewa Outlet	-24.5
C5	East Branch	-4.9
	Middle Main	-3.9
	Shakopee	-11.4
	Chippewa Outlet	-9.6
D1	East Branch	-1.6
	Middle Main	-0.4
	Shakopee	-0.7
	Chippewa Outlet	-1.2
D2	East Branch	-3.9
	Middle Main	-1.0
	Shakopee	-1.8
	Chippewa Outlet	-3.0

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