SAUK RIVER WATERSHED POLLUTANT SOURCE ASSESSMENT AND EVALUATION OF RESOURCE MANAGEMENT SCENARIOS

Topical Report RSI-2447
Revision 1

prepared for

Sauk River Watershed District
524 4th Street South
Sauk Centre, Minnesota 56378

November 2014

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CONSULTING & SERVICES

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by

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1.0 INTRODUCTION

In 2012, a hydrologic and water-quality model of the Sauk River Watershed was developed with Hydrological Simulation Program–FORTRAN (HSPF) for the Minnesota Pollution Control Agency (MPCA) [Reisinger and Love, 2012]. HSPF is a continuous simulation model that typically produces data on a daily basis by using an hourly time step. The model was calibrated by using water-quality monitoring data and meteorological records of the 15-year timespan from January 1, 1995, to December 31, 2009, and it incorporates both point- and nonpoint-source loads.

The Sauk River HSPF model was used to complete a pollutant source assessment for the Sauk River Watershed District (SRWD) and evaluate potential pollutant load reductions to surface waters under multiple resource management scenarios. The scenarios were selected by the SRWD and other local government units (LGUs), including resource management changes that could have a positive impact on water quality, as well as selecting options that were believed to have a reasonable potential to be adopted by landowners and municipalities. The SRWD and LGUs wanted to analyze changes to both agricultural and urban areas and wanted to view adoption rates that varied from “achievable” to “aggressive.” Lastly, they wanted to review the cumulative result of combining both the urban and agricultural changes on the achievable scale, as well as the aggressive scale.

2.0 POLLUTANT SOURCE ASSESSMENT

2.1 METHODS

The HSPF watershed modeling system is a comprehensive package for simulating watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF is capable of simulating the hydrologic and associated water-quality processes on pervious and impervious land surfaces, in streams, and in well-mixed impoundments. HSPF incorporates the watershed-scale Agricultural Runoff Management (ARM) and nonpoint-source models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment/chemical interactions. The result of this coupled simulation is a continuous record of the runoff flow rate and sediment, nutrient, and other water-quality constituent concentrations at any point in a watershed [Bicknell et al., 2001].

HSPF assesses the effects of land-use change, reservoir operations, point-source or nonpoint-source treatment alternatives, and flow diversions. The model contains hundreds of process algorithms developed from theory, laboratory experiments, and empirical relations from instrumented watersheds. The model simulates processes such as evapotranspiration; interception of precipitation; snow accumulation and melt; surface runoff; interflow; base flow; soil moisture storage; groundwater recharge; nutrient speciation; biochemical oxygen demand; heat transfer; sediment (sand, silt, and clay) detachment and transport; sediment routing by particle size; channel and reservoir routing; algae growth and die-off; bacterial die-off and decay; and build-up, wash-off, routing, and first-order decay of water-quality constituents. Continuous rainfall and other meteorological records are input at an hourly time step into the model algorithms to compute stream flow, pollutant concentrations, and loading time series. Hydrographs and pollutographs can then be created, and frequency and duration analyses can be performed for any output time series.

An HSPF model application for the Sauk River Watershed was developed for the MPCA in 2012 as part of a larger effort to develop model applications for the Crow River Watershed in addition to the Sauk River Watershed. Details about the model construction and calibration provided to the MPCA [Reisinger and Love, 2012]. The model application simulates hydrology and water quality from January 1, 1995, through December 31, 2009, and the results are reported for the years through 1996 through 2009.

Total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) pollutant loads generated from the land surface were summed by source and by model subwatershed. The source categories are based primarily on land use and land cover (Figure 2-1) with some point-source inputs such as septics, feedlots, and National Pollutant Discharge Elimination System-

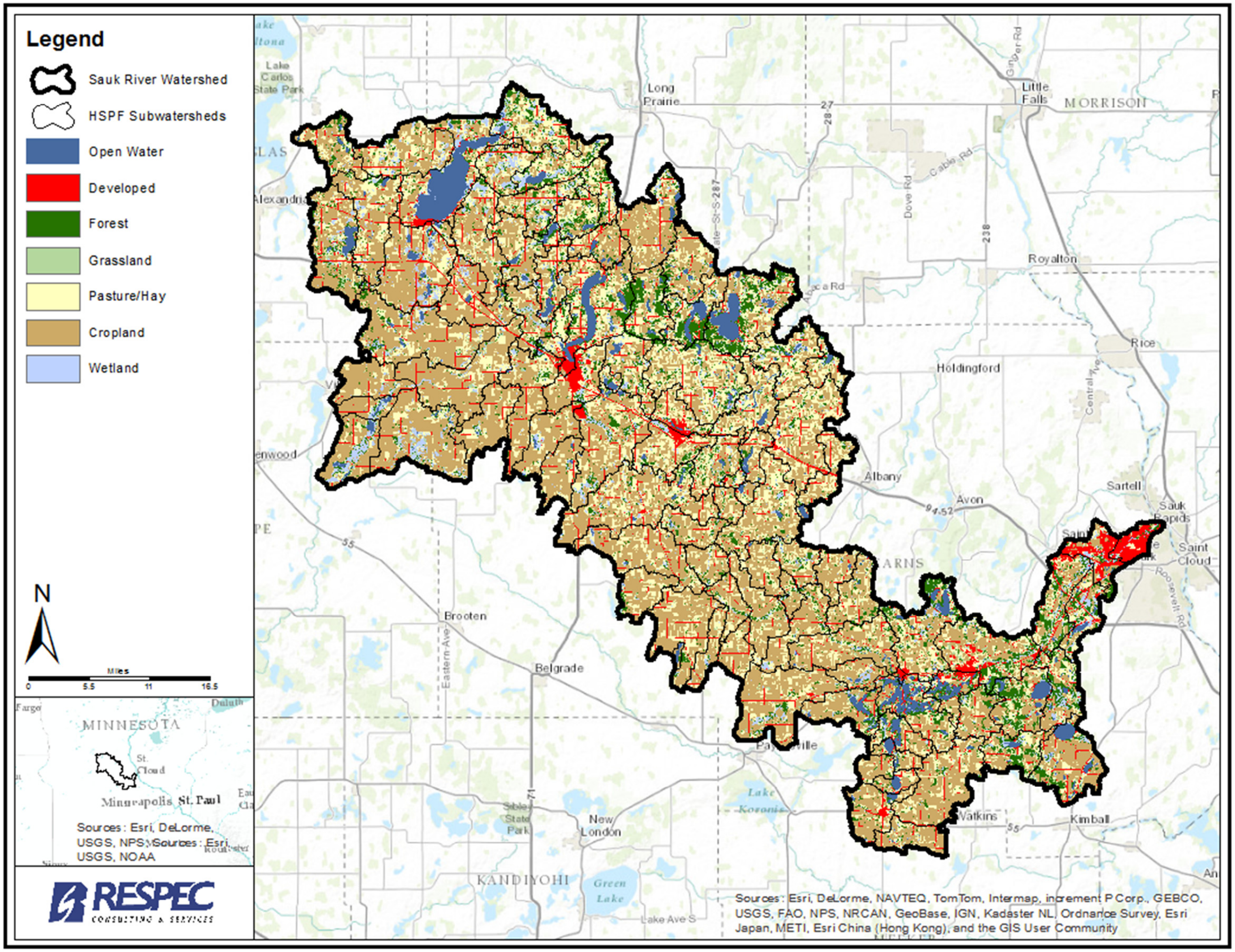

Figure 2-1. Land Classification.

(NPDES-) permitted discharges (Figure 2-2). Municipal Separate Storm Sewer System (MS4) areas were represented separately from nonpermitted developed areas. The pollutant sources represented in the HSPF model application consist of the following classifications that were defined in the initial application [Reisinger and Love, 2012], with some modifications:

- Forest
- Grassland
- Pasture
- Cropland, conventional tillage
- Cropland, conservation tillage
- Feedlot
- Wetland
- Developed
- MS4
- Septics
- NPDES discharges.

2.2 RESULTS

2.2.1 Loads by Subwatershed

Variability of simulated TP, TN, and TSS loads and concentrations in the modeled subwatersheds can be a result of several factors, including land use, precipitation, hydrologic soil group, slope, septic systems, and NPDES-permitted facilities. Spatial patterns of runoff, mean TP, TN, and TSS concentrations are shown in Figures 2-3 through 2-6, respectively. The subwatershed loading rates and contributions for TP, TN, TSS, and runoff volume are provided in Appendix A and have been provided digitally in a geodatabase.

Higher TP concentrations are seen in areas where higher densities of feedlots and developed land-use areas exist. Developed areas cause increased TP loads and concentrations because they have higher densities of impervious areas, major NPDES discharges, and septic systems in close proximity. Higher TP concentrations associated with feedlots are also associated with cropland because of the application of manure from nearby feedlots.

Higher TN concentrations are primarily driven by cultivated cropland on poorly drained soil, as well as major NPDES discharges. Cultivated cropland on poorly drained soil presents a high likelihood of artificial drainage, which can cause increases in nitrogen loads and concentrations. Higher TSS concentrations are driven by high-density impervious areas in the developed land-use category and high till cropland areas.

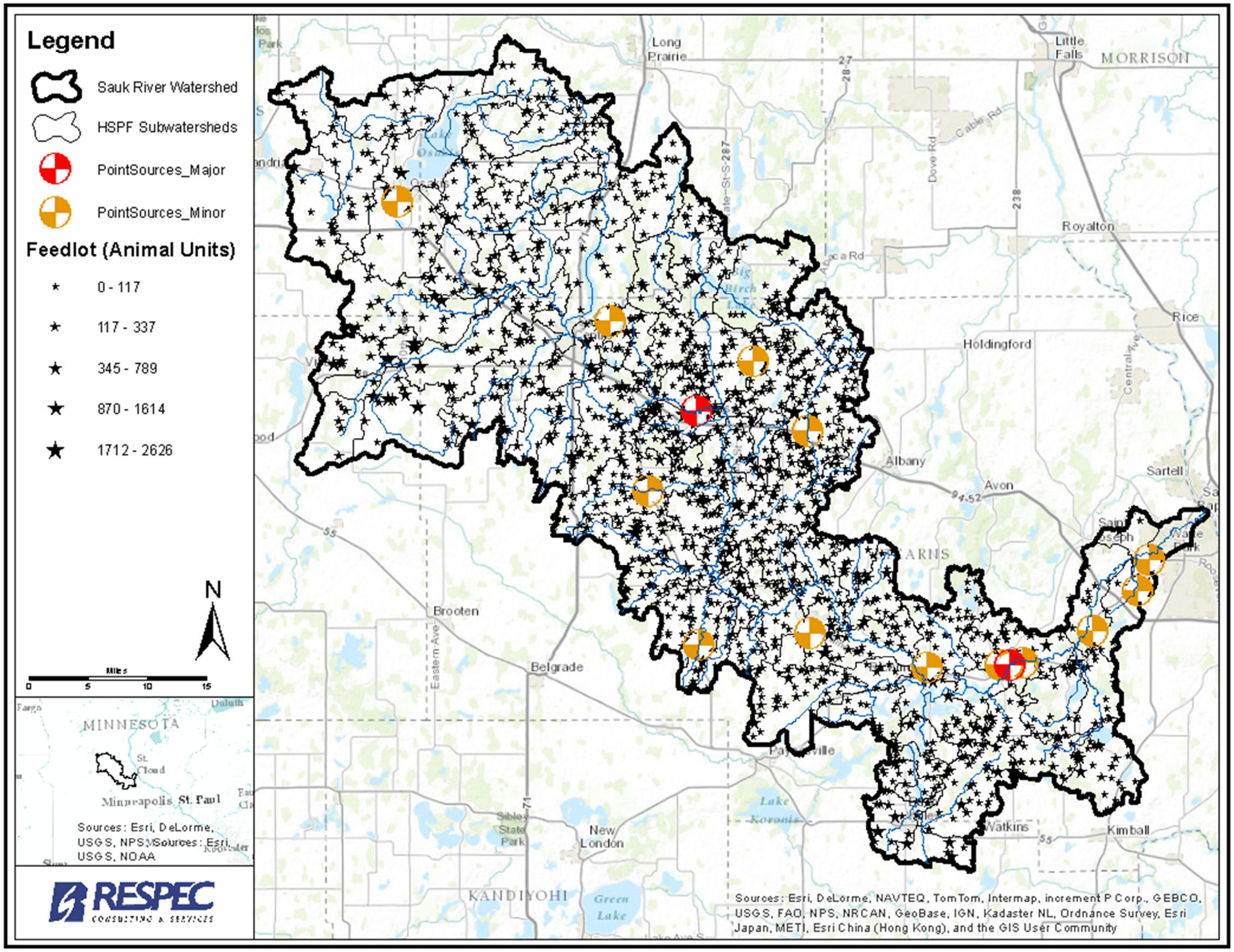

Figure 2-2. Feedlots and Point-Source Locations.

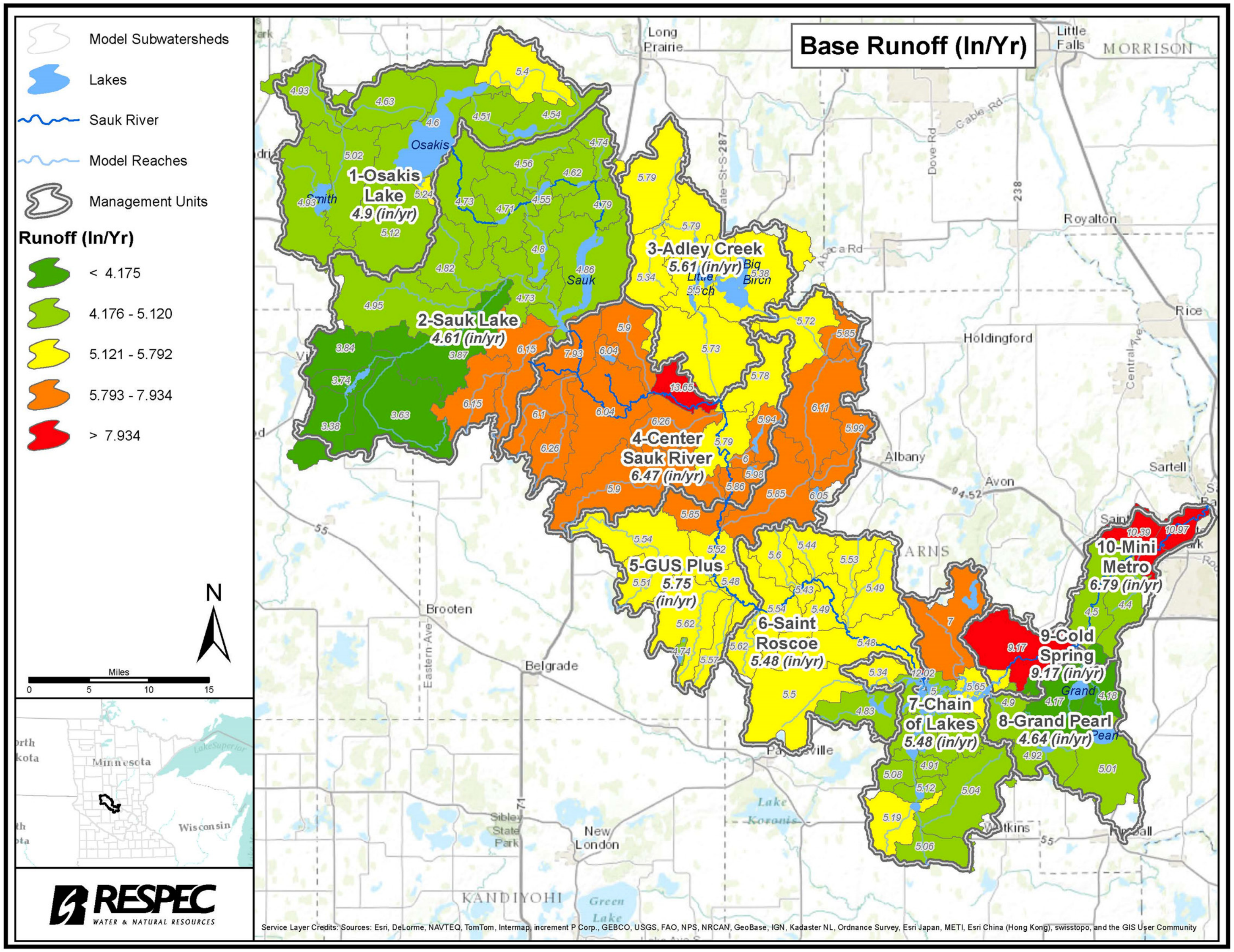

Figure 2-3. Average Runoff by Subwatershed, 1996–2009.

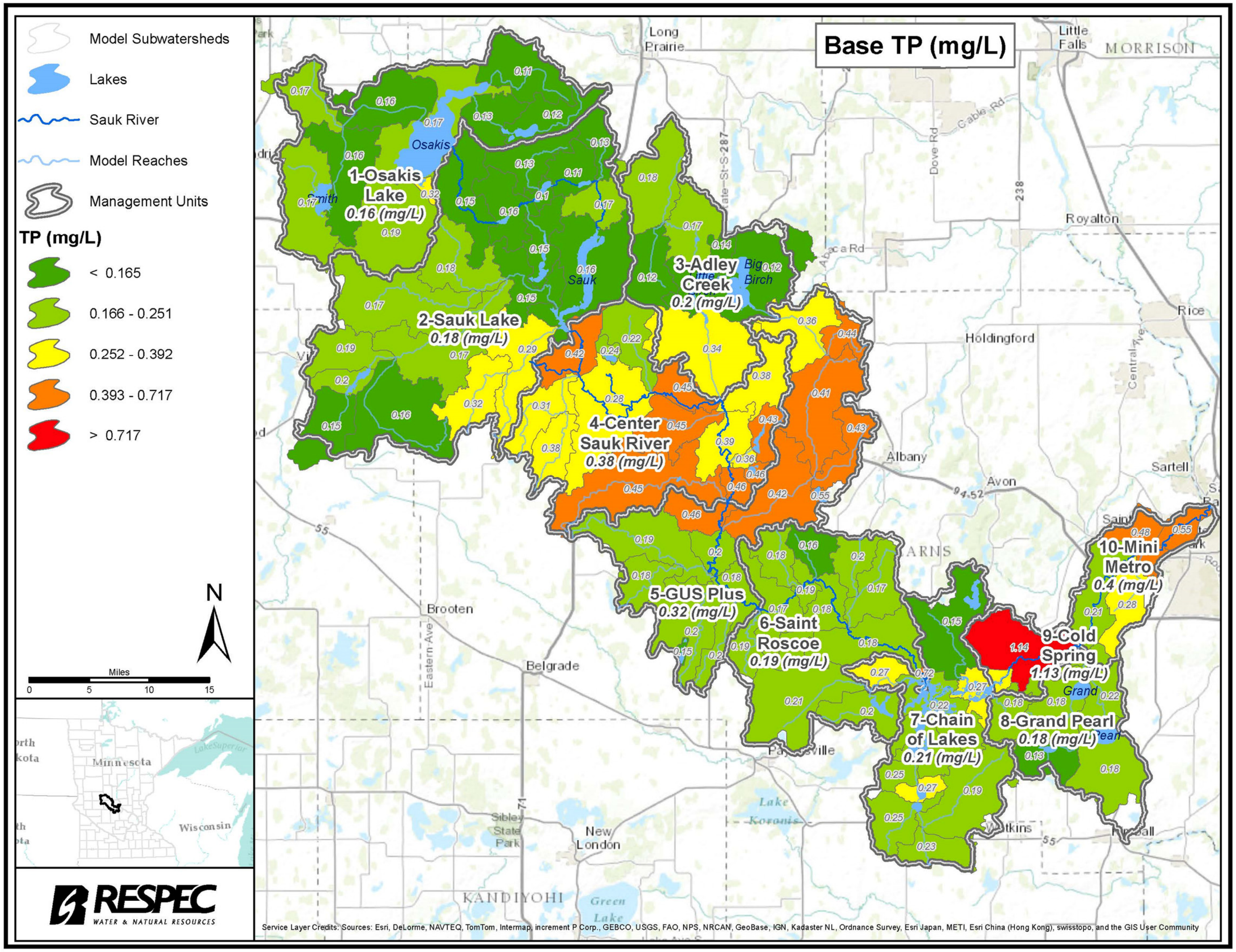

Figure 2-4. Average Simulated Total Phosphorus Concentration by Subwatershed, 1996–2009.

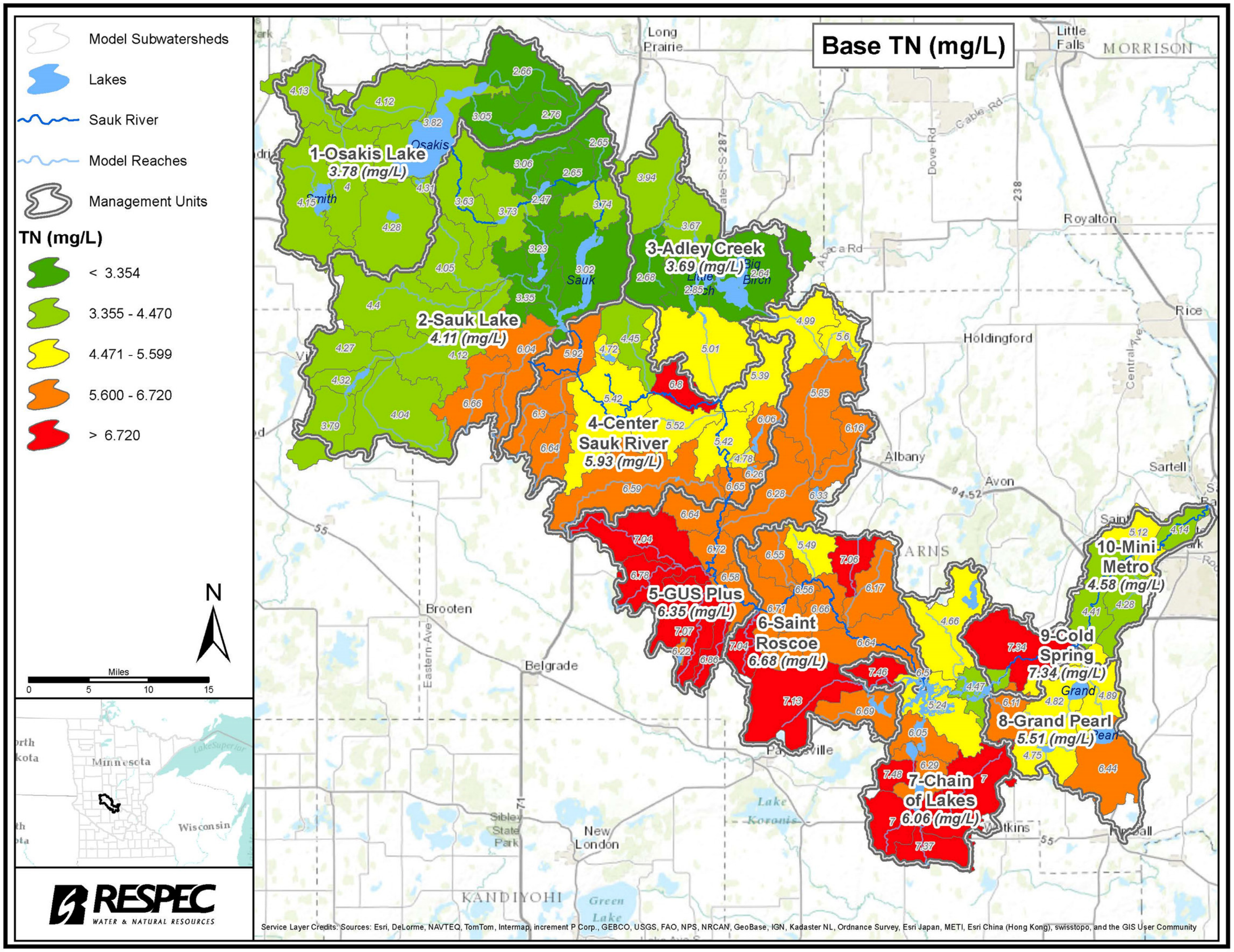

Figure 2-5. Average Simulated Total Nitrogen Concentration by Subwatershed, 1996–2009.

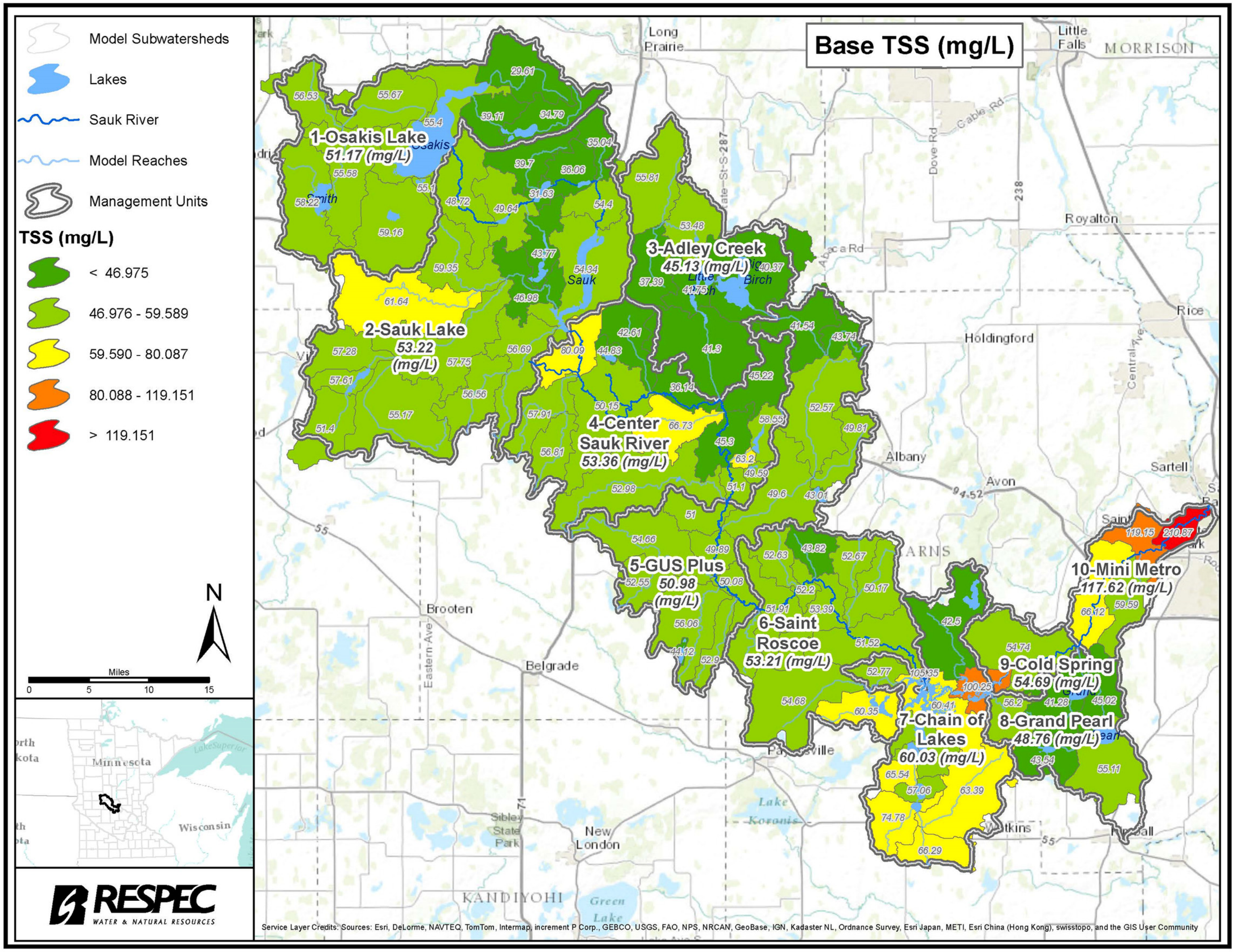

Figure 2-6. Average Simulated Total Suspended Solids Concentration by Subwatershed, 1996–2009.

2.2.2 Loads by Source Category

Table 2-1 contains unit loading rates, annual loads, and percent contributions for TP, TN, TSS, and runoff volume. The largest contributors to nutrient loading per acre are feedlots, followed by MS4 and developed areas. The largest total contributor of annual nutrient loads is cropland, which also represents the largest portion of the total watershed area. Pasture is also a significant contributor of annual nutrient load because it has the second largest portion of the total watershed area. MS4 areas show higher loading rates than nonpermitted developed areas because MS4 areas typically have higher amounts of effective impervious area.

Table 2-1. Average Annual Pollutant Loads and Flow Rates by Land Classification, 1996–2009

Source Category	Area (acres)	Percent Area	Total Phosphorus			Total Nitrogen			Total Suspended Solids			Flow		
			Unit Area Load (lb/ac-yr)	Annual Load (lb/yr)	Percent Watershed Load	Unit Area Load (lb/ac-yr)	Annual Load (lb/yr)	Percent Watershed Load	Unit Area Load (ton/ac-yr)	Annual Load (ton/yr)	Percent Watershed Load	Unit Area Rate (in/yr)	Rate (ac-ft/yr)	Percent Watershed Flow
High Till Cropland	309,021	48.0	0.35	109,586	50.3	9.39	2,900,753	69.2	0.043	13,187	60.0	5.31	136,710	46.6
Low Till Cropland	23,712	3.7	0.23	5,380	2.5	8.62	204,360	4.9	0.027	636	2.9	5.04	9,963	3.4
Pasture	160,393	24.9	0.13	20,956	9.6	2.85	457,432	10.9	0.016	2,594	11.8	5.90	78,839	26.9
Rangeland	17,327	2.7	0.03	530	0.2	1.58	27,322	0.7	0.009	158	0.7	5.63	8,129	2.8
Forest	55,782	8.7	0.01	722	0.3	0.72	40,243	1.0	0.004	244	1.1	3.79	17,609	6.0
Feedlot	1,717	0.3	2.03	3,482	1.6	21.58	37,062	0.9	0.058	100	0.5	6.80	974	0.3
Wetland	35,465	5.5	0.01	301	0.1	0.41	14,483	0.3	0.002	64	0.3	2.63	7,774	2.7
Developed	34,872	5.4	0.68	23,845	11.0	5.91	205,968	4.9	0.094	3,277	14.9	7.08	20,583	7.0
MS4	5,933	0.9	1.37	8,115	3.7	10.05	59,647	1.4	0.278	1,650	7.5	11.12	5,500	1.9
Septics	N/A	N/A	N/A	13,335	6.1	N/A	63,961	1.5	N/A	0	0.0	N/A	1,069	0.4
NPDES	N/A	N/A	N/A	31,417	14.4	N/A	178,068	4.3	N/A	80	0.4	N/A	5,974	2.0

ac = acres

lb/ac-yr = pound per acre per year

lb/yr = pound per year

ton/ac/yr = ton per acre per year

ton/yr = ton per year

in/yr = inches per year

ac-ft/yr = acre foot per year

3.0 EVALUATION OF RESOURCE MANAGEMENT SCENARIOS

Model scenarios were developed to evaluate the hydrologic and water-quality impacts of resource management options in the watershed. Targeted activities in each of the ten management units were identified during the process to develop the draft SRWD's *Comprehensive Watershed Management Plan, 2014–2023* and were considered for the scenarios. The details of the scenarios were determined through input from the SRWD and other LGUs.

3.1 METHODS

Four scenarios and two cumulative scenarios were evaluated with the HSPF model application. The scenarios were based on implementing best management practices (BMPs) in agricultural and urban areas and on implementation levels that were considered to be either achievable or aggressive.

3.1.1 Agriculture, Achievable Management

The agriculture, achievable management scenario simulated the impacts of agricultural BMPs at an achievable level and consisted of the following:

- **Buffers.** An efficiency factor was applied to the runoff from agricultural land that would represent the pollutant reductions equivalent to placing 50-foot buffers on 25 percent of the land immediately adjacent to surface waters. This scenario assumes high-quality buffers with a 68 percent phosphorus removal rate, a 66 percent nitrogen removal rate, and an 85 percent sediment removal rate. These removal efficiencies are based on equations presented in Nieber et al. [2011] and cited in *The Agricultural BMP Handbook for Minnesota* [Miller et al., 2012] and were applied to loads from agricultural lands.
- **Nutrient Management.** Nitrogen and phosphorus fertilizer applications were reduced by approximately 5 percent in this scenario.
- **Erosion Control.** Cropland under conventional tillage was converted to conservation tillage so that the conservation tillage represented 25 percent of cropland, as opposed to the model's baseline condition of 7 percent. This estimate is based on data from the Minnesota Tillage Transect Survey Data Center.
- **Septics.** Approximately 50 percent of all septic systems were considered compliant.

3.1.2 Agriculture, Aggressive Management

The agriculture, aggressive management scenario simulated the impacts of agricultural BMPs at an aggressive level and consisted of the following:

- **Buffers.** An efficiency factor was applied to the runoff from agricultural land that would represent the pollutant reductions equivalent to placing 50-foot buffers on 100 percent of land immediately adjacent to surface waters. The scenario assumes high-quality buffers with a 68 percent phosphorus removal rate, a 66 percent nitrogen removal rate, and an 85 percent sediment removal rate. These removal efficiencies are based on equations presented in Nieber et al. [2011] and cited in the *Agricultural BMP Handbook for Minnesota* [Miller et al., 2012] and were applied to loads from agricultural lands.
- **Nutrient management.** Nitrogen and phosphorus fertilizer application was reduced by approximately 25 percent in this scenario.
- **Erosion control.** Cropland under conventional tillage was converted to conservation tillage so that the conservation tillage represented 50 percent of cropland (The model's baseline conditions include conservation tillage on 7 percent of cropland; this estimate is based on data from the Minnesota Tillage Transect Survey Data Center).
- **Septics.** All of the septic systems were considered compliant.

3.1.3 Urban, Achievable Management

The urban, achievable management scenario simulated the impacts of incorporating additional urban BMPs at a level considered achievable and consisted of the following actions:

- **Stormwater.** Approximately 1.1 inches of runoff from 50 percent of impervious surfaces was captured and retained by increasing the retention storage parameter by 1.1 inches. This volume is based on Minnesota's Minimal Impact Design Standards (MIDS) work group performance goal recommendation for new development.
- **Wastewater.** All wastewater discharges from permitted facilities were considered to meet the Minnesota state standard for wastewater discharges of 0.4 milligram per liter of total phosphorus.

3.1.4 Urban, Aggressive Management

The urban, aggressive management scenario simulated the impacts of urban BMPs at an aggressive level and consisted of the following:

- **Stormwater.** Approximately 1.1 inches of runoff from all impervious surfaces was captured and retained by increasing the retention storage parameter by 1.1 inches. This volume is based on Minnesota's MIDS work group performance goal recommendation for new development.
- **Wastewater.** All wastewater discharges were reduced to exceed the state standard and were set at 0.1 milligram per liter of total phosphorus.

3.1.5 Cumulative, Achievable Management

The cumulative, achievable management combined the management practices implemented for both the agriculture and urban achievable management scenarios.

3.1.6 Cumulative, Aggressive Management

The cumulative, aggressive management scenario combined the management practices implemented for both the agriculture and urban aggressive management scenarios.

3.2 RESULTS

Table 3-1 shows the overall average annual loading rate (lbs/acre/yr) and mean concentrations (mg/L) for all scenarios including the base calibration values. The agriculture management scenarios have proportional impacts to TP, TN, and TSS loads and concentrations, because it is a large portion of the watershed area and is a significant contributing source of these pollutants. The urban management scenarios had the largest impact on TP with small reductions in TSS and little to no reduction in TN. The urban management scenarios significantly reduced the loading rates from developed and MS4 areas but, because they only represent a small portion of the watershed area, their impact on the overall loading rate in the watershed is minimal. The urban management scenarios had a limited impact on TN because the wastewater improvements did not involve nitrogen reductions. Also, increases in retention storage primarily reduce the load through reductions in flow, so concentrations were not impacted as much as loads.

Overall, the agriculture scenarios showed the largest reductions of TP, TN, and TSS loads and concentrations with the aggressive management significantly outperforming the achievable management scenarios. The aggressive urban management scenario only slightly outperformed the urban achievable scenario because the main impact of the urban scenario is the wastewater concentration limitation in which the achievable level of 0.4 mg/L phosphorus is sufficient. The most efficient combination of scenarios is to combine the aggressive agricultural management scenario with the achievable urban management scenario. Maps that show the reductions gained under the urban achievable and agricultural aggressive scenarios are provided in Figures 3-1 through 3-8. Subwatershed loading rates and contributions for TP, TN, TSS, and runoff volume for each of the scenarios are provided in Appendix B and have been provided digitally in a geodatabase.

Table 3-1. Overall Annual Average Watershed Loads and Concentrations for Total Nitrogen, Total Phosphorus, and Total Suspended Solids in the Sauk River Watershed for the Simulated Scenarios

Scenario	TP (mg/L)	TP (lb/ac/yr)	TN (mg/L)	TN (lb/ac/yr)	TSS (mg/L)	TSS (ton/ac/yr)
Base Calibration	0.29	0.34	5.3	6.50	55.1	0.034
Urban Achievable Management	0.24	0.29	5.3	6.45	52.1	0.032
Agriculture Achievable Management	0.23	0.28	4.3	5.31	46.8	0.029
Cumulative Achievable Management	0.19	0.23	4.3	5.26	43.5	0.027
Cumulative % Reduction	34%	32%	19%	19%	21%	21%
Urban Aggressive Management	0.23	0.28	5.3	6.40	48.8	0.030
Agriculture Aggressive Management	0.15	0.18	2.3	2.80	27.3	0.017
Cumulative Aggressive Management	0.10	0.11	2.2	2.65	21.6	0.012
Cumulative % Reduction	66%	68%	58%	59%	61%	65%

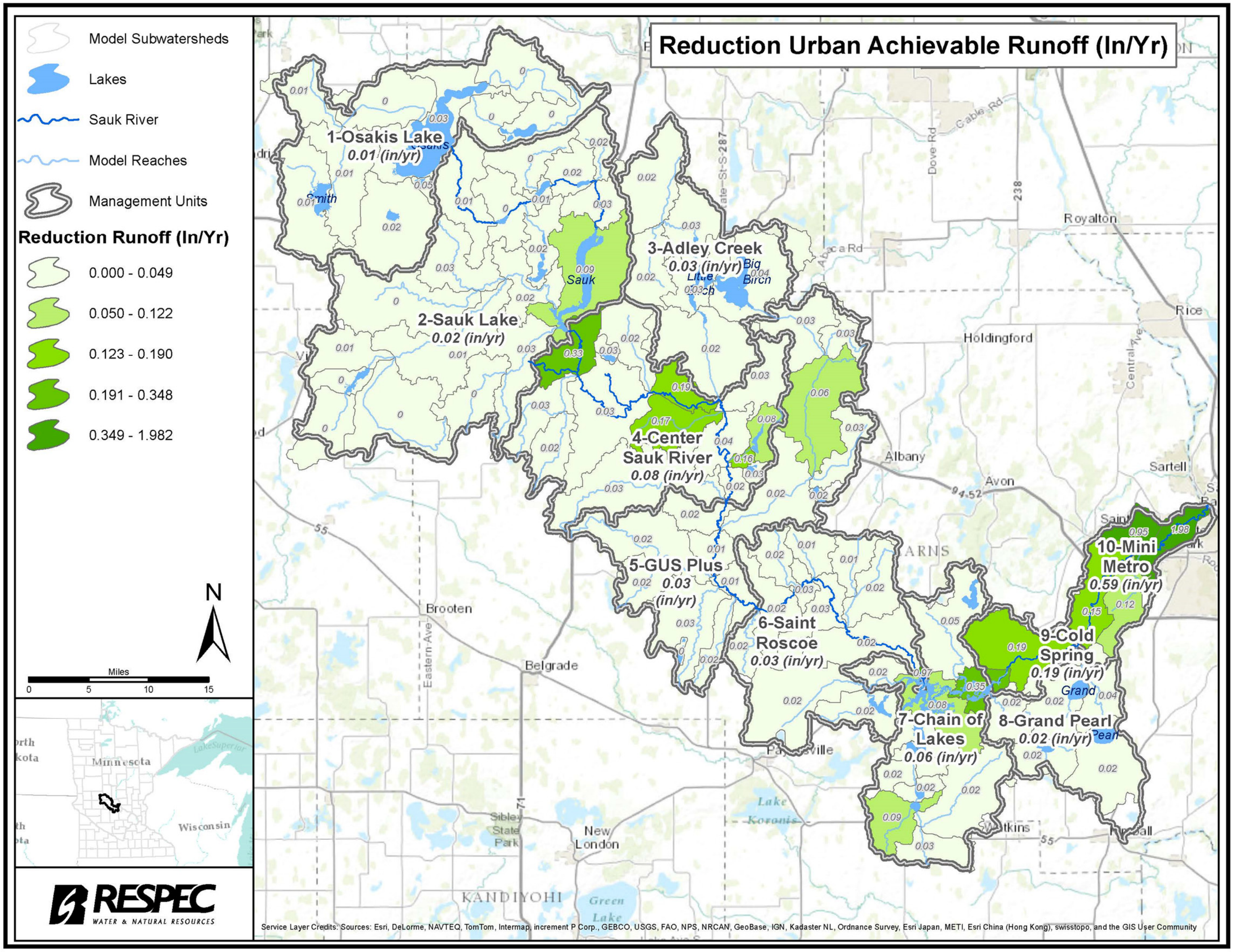

Figure 3-1. Runoff Reductions Under the Urban, Achievable Management Scenario.

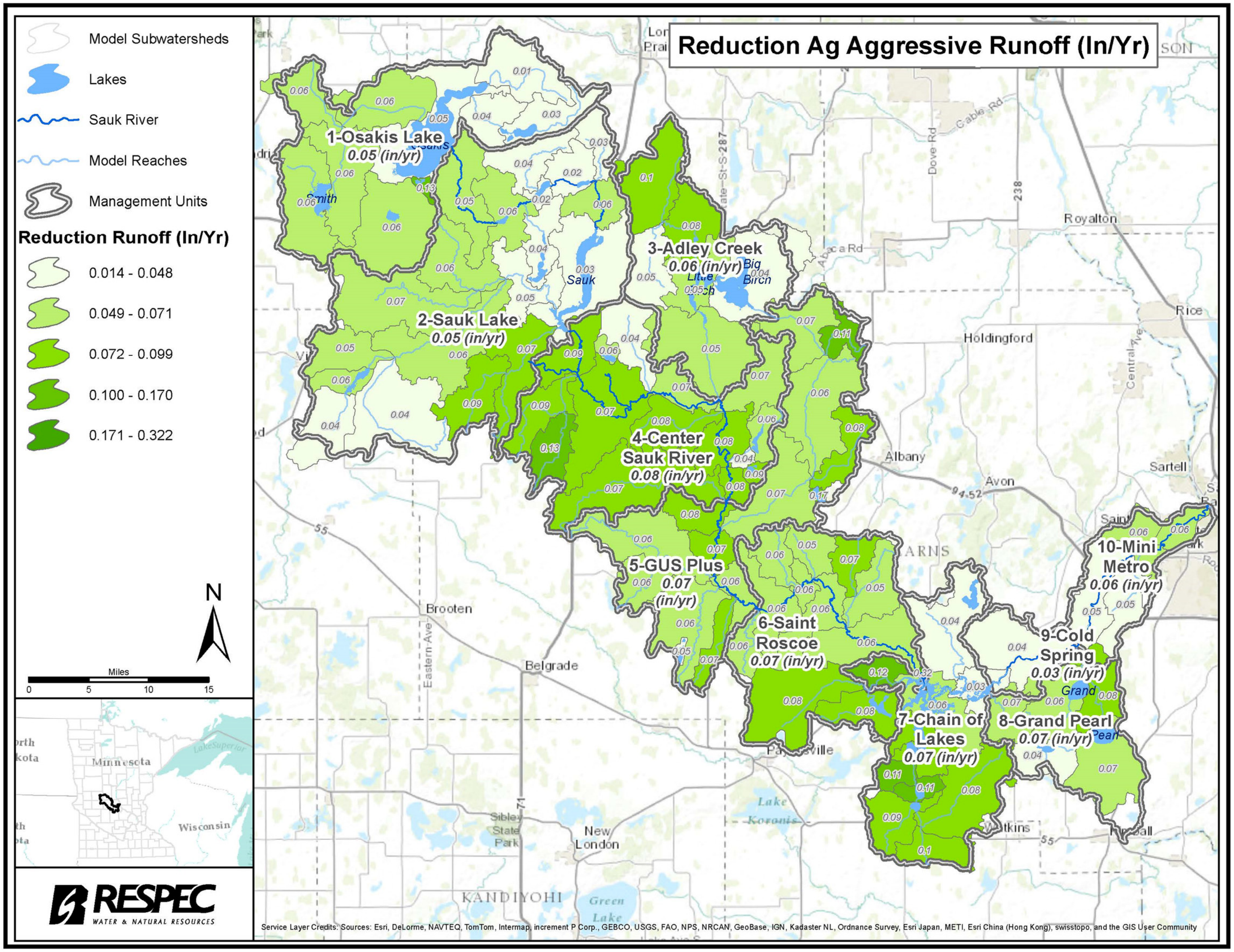

Figure 3-2. Runoff Reductions Under the Agricultural, Aggressive Management Scenario.

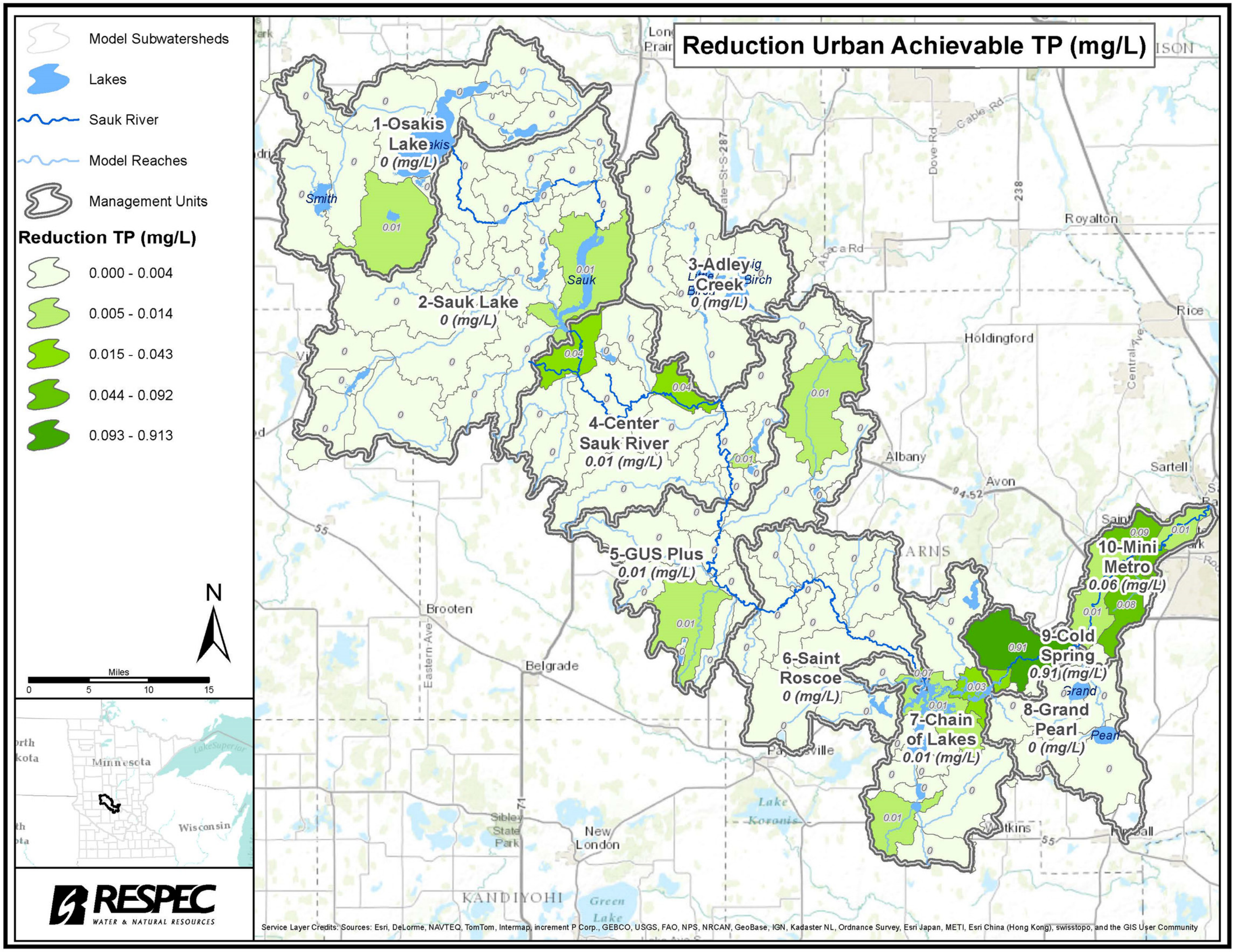

Figure 3-3. Total Phosphorus Reductions Under the Urban, Achievable Management Scenario.

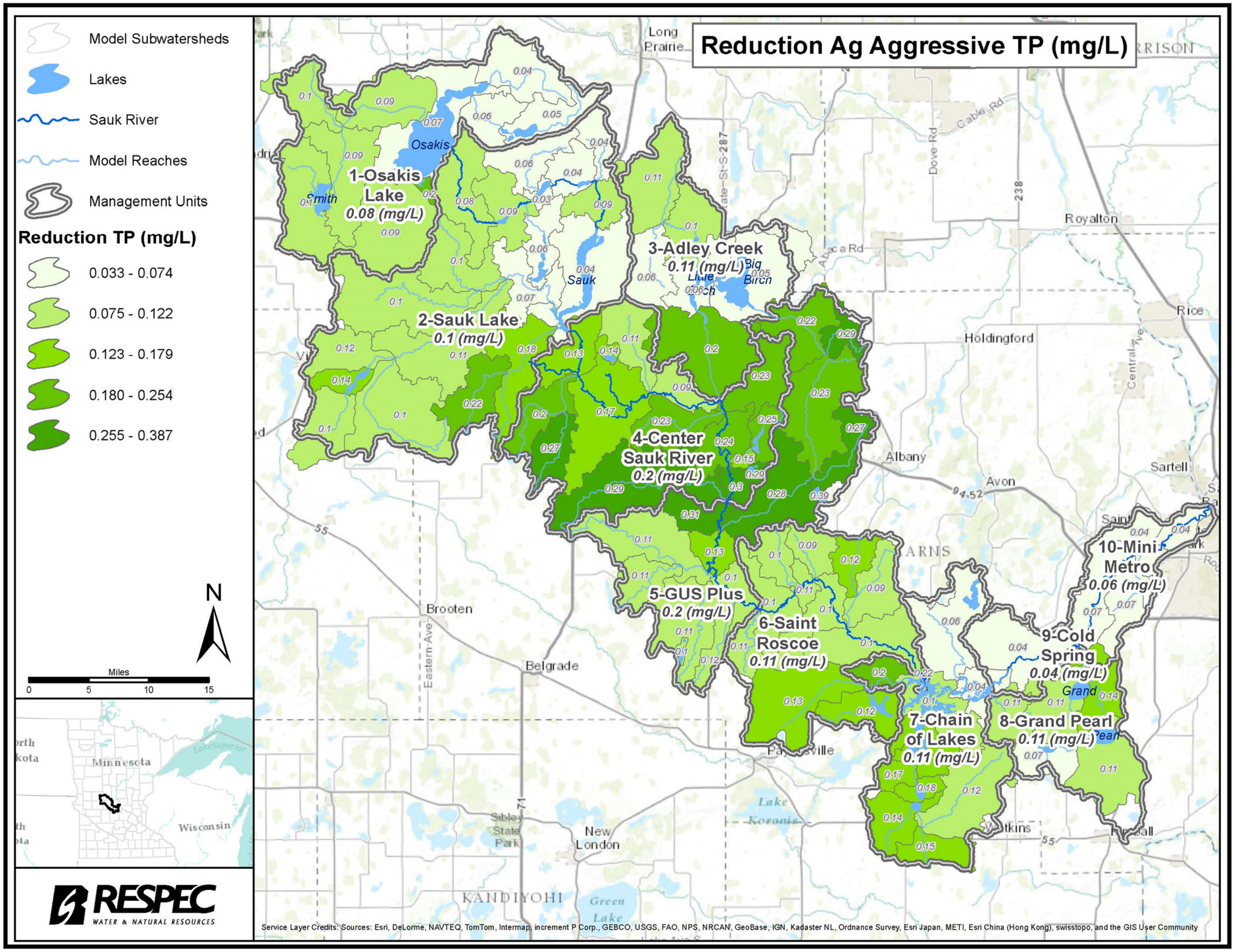

Figure 3-4. Total Phosphorus Reductions Under the Agricultural, Aggressive Management Scenario.

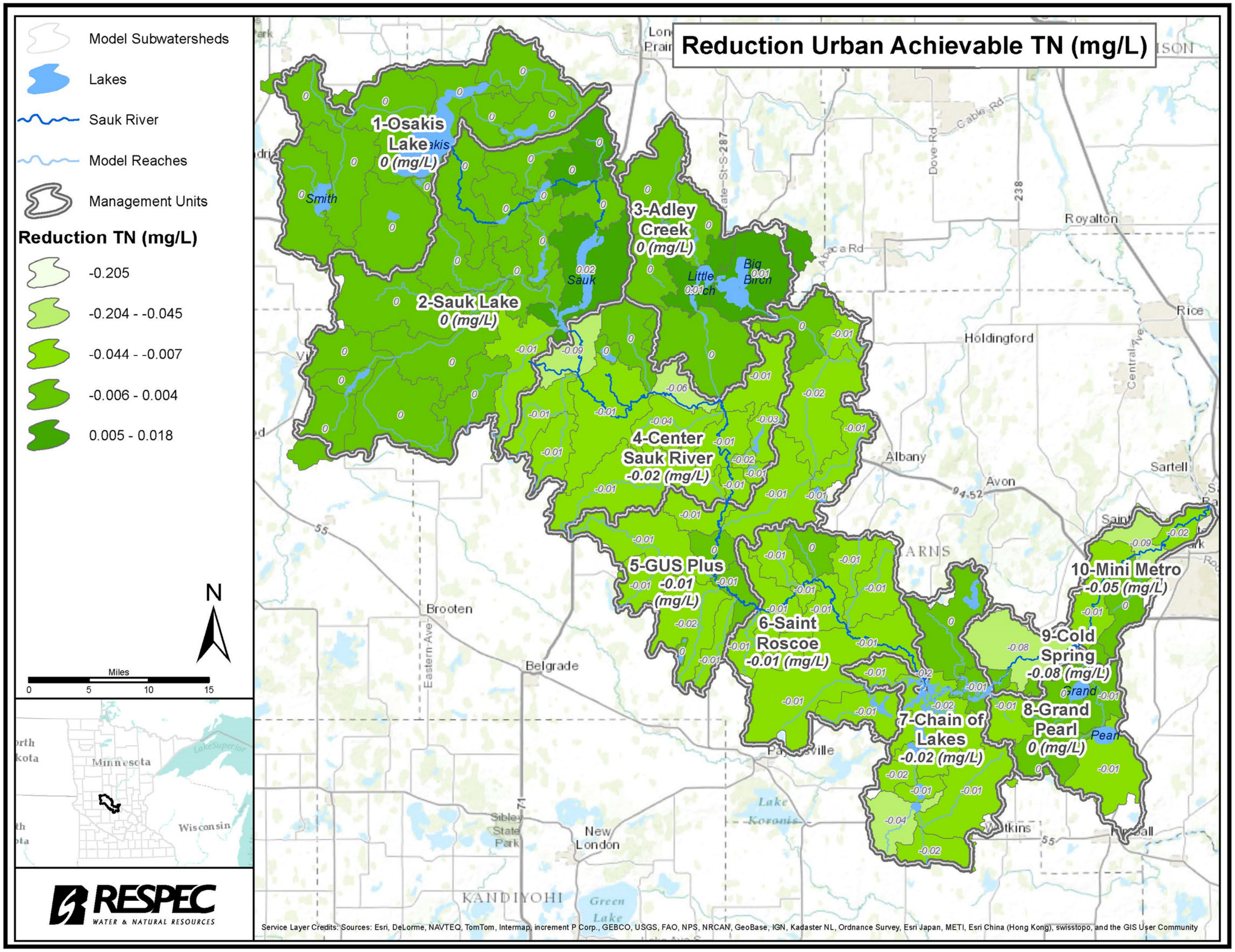

Figure 3-5. Total Nitrogen Reductions Under the Urban, Achievable Management Scenario.

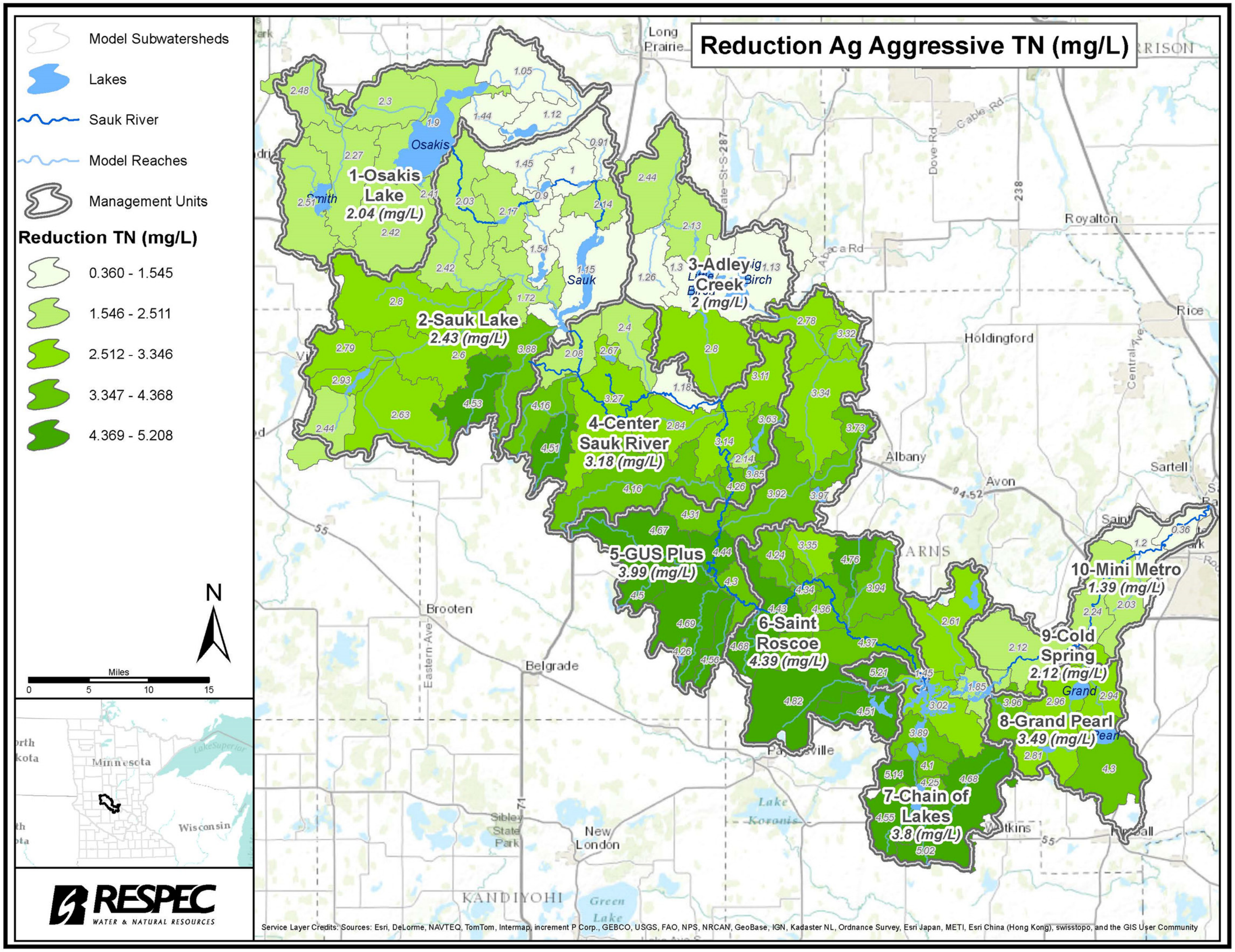

Figure 3-6. Total Nitrogen Reductions Under the Agricultural, Aggressive Management Scenario.

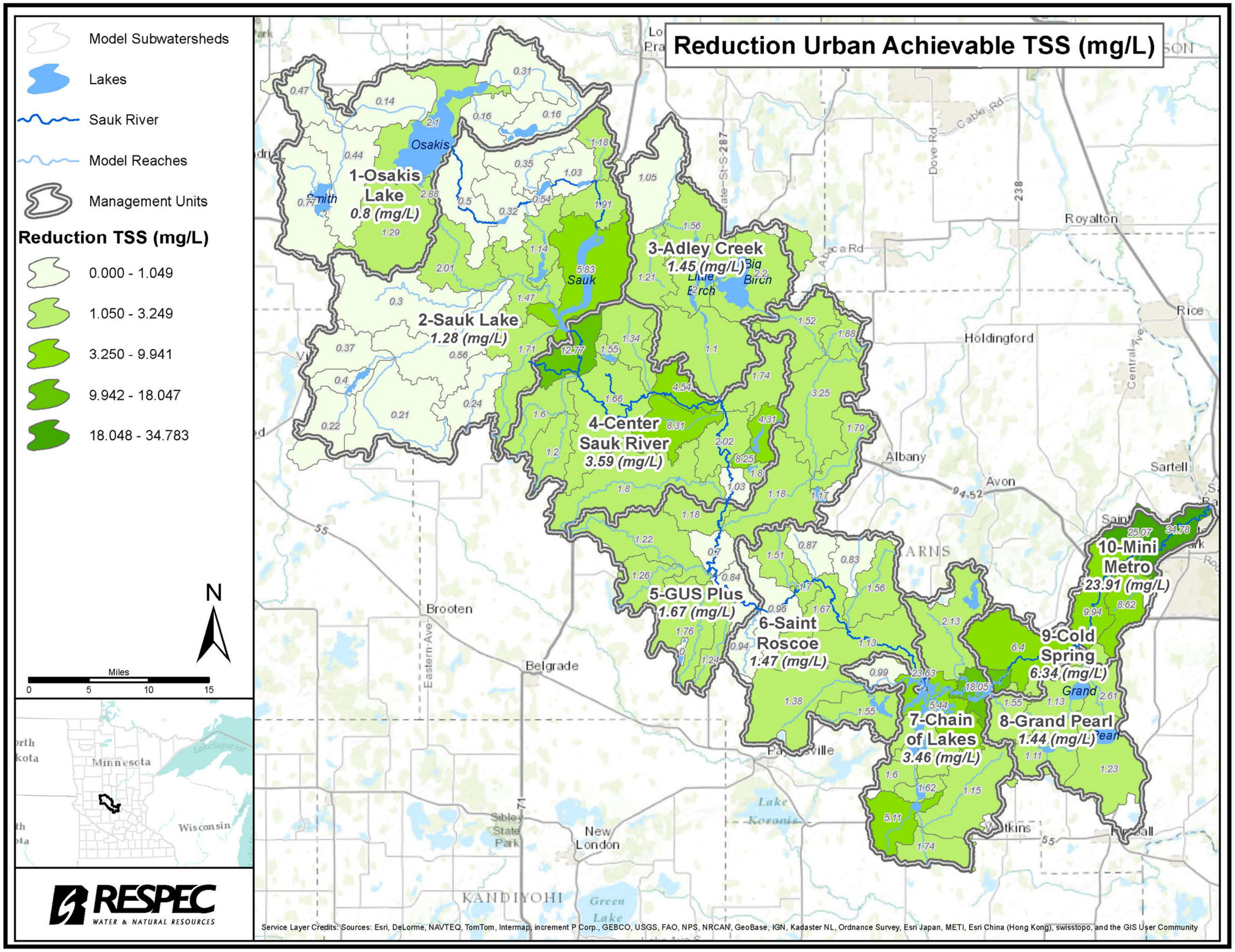

Figure 3-7. Total Suspended Solids Reductions Under the Urban Achievable Scenario.

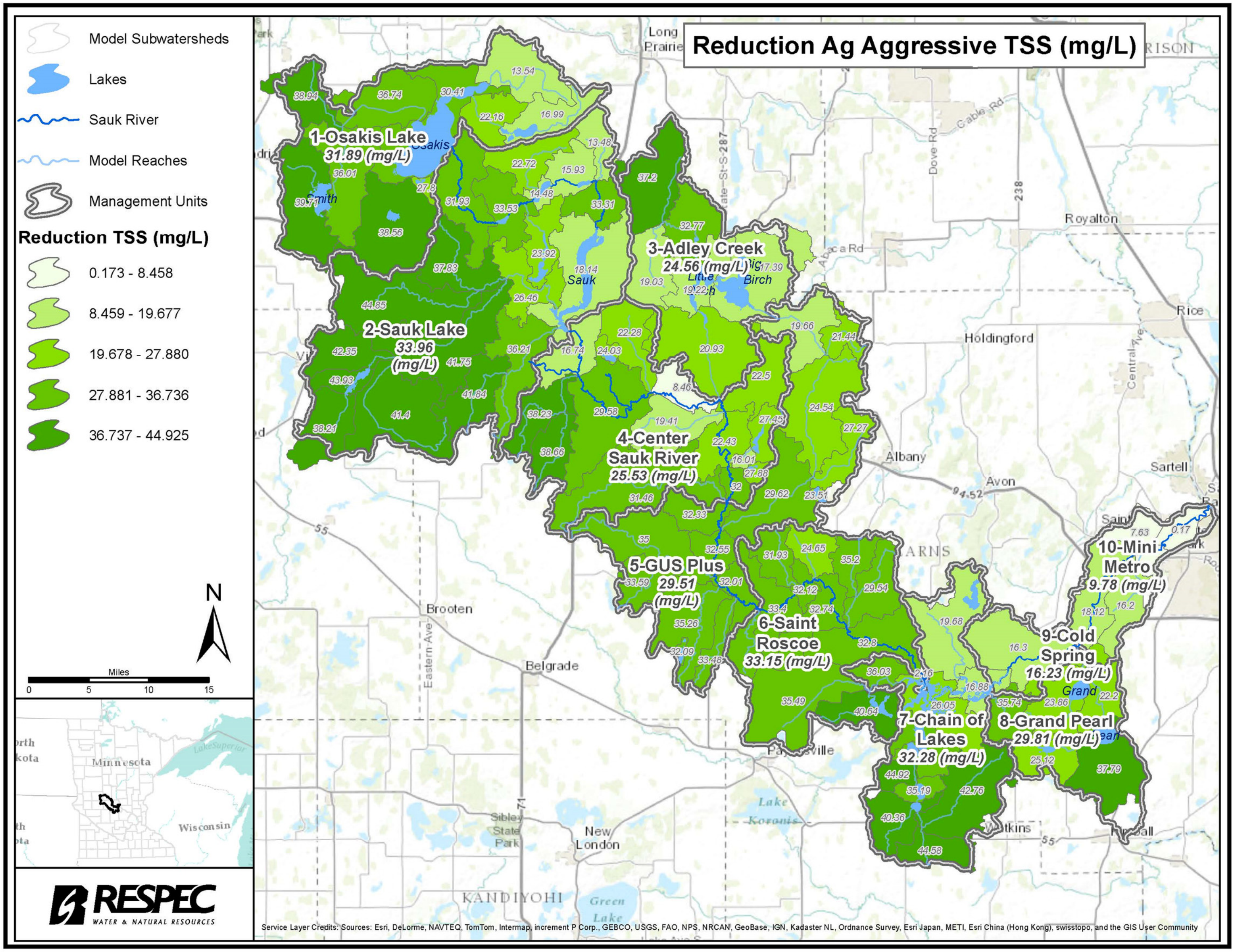

Figure 3-8. Total Suspended Solids Reductions Under the Agricultural, Aggressive Management Scenario.

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APPENDIX A

BASE LOADING CONDITIONS FOR INDIVIDUAL SUBWATERSHED UNITS

Subwatershed loading rates for phosphorus, nitrogen, sediment, and flow for the subwatersheds shown in Figure A-1 are provided in Table A-1.

All data have also been provided electronically in a geodatabase.

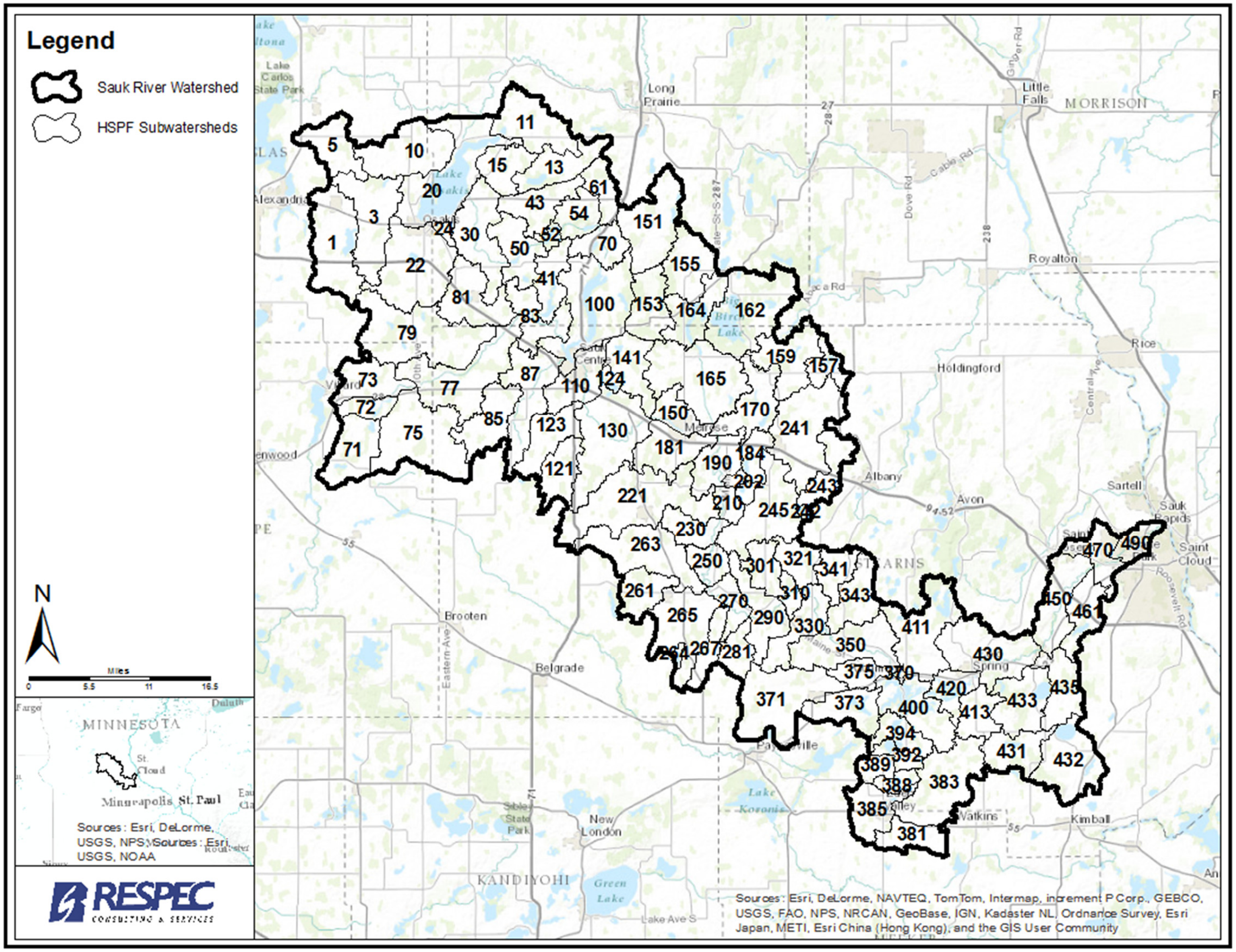

Figure A-1. Subwatershed Key.

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 1 of 4)

Subwatershed[a]	Area (acres)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (ton/ac/yr)	Annual Load (ton/yr)	Unit Area Rate (in/yr)	Rate (ac-ft/yr)
1	11,931	0.19	2,091	4.6	51,311	0.033	360	5.1	4,547
3	10,577	0.18	1,944	4.6	47,996	0.032	333	5.2	4,407
5	6,137	0.19	1,177	4.6	28,311	0.032	194	5.1	2,522
10	9,990	0.17	1,705	4.3	43,131	0.029	292	5.3	3,853
11	8,834	0.14	1,233	3.3	28,758	0.018	160	5.6	3,971
13	6,408	0.12	727	2.8	16,662	0.018	105	5.3	2,218
15	5,022	0.14	683	3.1	15,677	0.020	101	5.2	1,890
20	15,090	0.18	1,507	4.0	33,901	0.029	246	5.3	3,261
22	13,931	0.22	2,986	5.0	68,136	0.034	472	5.1	5,854
24	813	0.37	268	5.1	3,660	0.033	23	5.4	312
30	9,587	0.16	1,552	3.9	37,278	0.026	250	5.5	3,777
41	4,760	0.16	680	3.5	14,994	0.024	101	5.5	1,705
43	6,106	0.13	822	3.2	19,292	0.021	125	5.3	2,319
50	5,847	0.17	1,059	4.0	24,909	0.027	166	5.4	2,455
52	1,130	0.11	89	2.6	2,130	0.016	14	5.3	317
54	4,384	0.12	507	2.8	11,859	0.019	81	5.3	1,645
61	3,924	0.14	532	2.8	11,134	0.019	74	5.5	1,547
70	4,389	0.18	802	4.1	17,832	0.030	129	5.5	1,751
71	7,418	0.11	849	2.9	21,519	0.020	146	3.5	2,088
72	2,722	0.17	392	3.7	8,642	0.024	58	3.9	736
73	6,052	0.16	981	3.7	22,448	0.025	151	4.0	1,933
75	14,910	0.13	1941	3.3	49,539	0.023	338	4.9	4,512
77	13,471	0.15	2051	3.6	48,572	0.025	341	5.0	4,339
79	16,515	0.19	3,109	4.9	81,607	0.035	571	4.9	6,819

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 2 of 4)

Subwatershed[a]	Area (acres)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (ton/ac/yr)	Annual Load (ton/yr)	Unit Area Rate (in/yr)	Rate (ac-ft/yr)
81	8,282	0.20	1,640	4.4	36,659	0.032	269	4.6	3,326
83	6,115	0.16	1,000	3.6	21,995	0.025	154	5.4	2,412
85	7,125	0.44	3,158	9.3	66,141	0.039	281	4.5	3,650
87	9,688	0.41	3,941	8.4	81,583	0.040	383	4.5	4,966
100	15,675	0.18	2,448	3.3	44,647	0.030	402	4.6	5,442
110	6,269	0.75	4,734	10.6	66,732	0.072	452	5.1	4,147
121	5,335	0.54	2,858	9.4	50,281	0.040	215	5.2	2,784
123	6,251	0.43	2,704	8.7	54,358	0.040	250	4.7	3,174
124	1,001	0.33	264	6.5	50,88	0.031	24	4.8	397
130	14,425	0.39	5,624	7.4	106,861	0.034	495	4.6	7,256
141	6,196	0.29	1,810	6.0	36,904	0.029	176	4.7	3,048
150	3,886	1.40	5,449	21.0	81,866	0.056	218	4.5	4,425
151	10,555	0.24	2,528	5.2	54,559	0.037	386	4.6	5,089
153	6,466	0.15	956	3.2	20,928	0.023	146	4.7	2,876
155	7,223	0.22	1,598	4.8	34,521	0.035	252	4.8	3,463
157	3,235	0.58	1,878	7.4	24,000	0.029	94	3.4	1,576
159	7,819	0.46	3,614	6.5	50,588	0.027	210	3.7	3,726
162	13,961	0.15	1,787	3.2	37,910	0.025	290	3.8	5,284
164	6,298	0.18	957	3.6	19,165	0.026	141	3.6	2,473
165	15,065	0.43	6,513	6.5	97,327	0.027	401	3.9	7,148
170	7,389	0.50	3,667	7.1	52,098	0.030	219	5.0	3,555
181	6,871	0.64	4,391	7.8	53,779	0.047	325	4.8	3,582
184	2,932	0.57	1,542	8.2	21,975	0.039	106	4.7	1,332
185	742	0.49	365	6.5	4,827	0.043	32	6.1	371
190	5,586	0.51	2871	7.1	39,700	0.030	166	6.1	2,695
202	984	0.62	532	8.5	7,318	0.034	29	4.9	430
210	2,087	0.61	1,263	8.8	18,407	0.034	71	7.9	1,018

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 3 of 4)

Subwatershed[(a)]	Area (acres)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (ton/ac/yr)	Annual Load (ton/yr)	Unit Area Rate (in/yr)	Rate (ac-ft/yr)
221	17,630	0.60	10,614	8.8	154,955	0.035	623	6.3	8,648
230	4,186	0.60	2,528	8.8	36781	0.034	141	6.1	2,038
241	13,317	0.57	7,625	8.1	107,874	0.036	485	6.0	6,782
242	455	0.75	181	8.7	2,103	0.030	7	6.0	122
243	5,261	0.58	3,049	8.4	44,012	0.034	178	5.9	2,628
245	11,386	0.56	6,415	8.3	94,921	0.033	375	13.7	5,554
250	3,413	0.25	862	8.4	28,695	0.031	106	5.8	1,570
261	5,160	0.23	1,182	8.5	43,659	0.033	169	5.3	2,369
263	11,367	0.24	2,691	8.8	100,343	0.034	390	5.8	5,245
264	445	0.16	46	6.7	1,907	0.024	7	5.9	113
265	10,595	0.25	2,641	9.0	95,332	0.036	378	5.7	4,960
267	3,478	0.25	879	8.7	30,141	0.033	116	5.4	1,616
270	3,508	0.23	794	8.2	28,671	0.031	109	5.5	1,602
281	3,567	0.24	850	9.0	32,003	0.034	122	5.7	1,672
290	6,853	0.22	1,498	8.4	57,748	0.033	223	5.8	3,167
301	4,160	0.23	951	8.3	34,559	0.033	139	6.3	1,941
310	1,813	0.23	415	8.1	14,623	0.032	58	5.9	820
321	4,074	0.20	824	6.8	27,552	0.027	110	6.0	1,846
330	6,346	0.23	1,450	8.3	52,546	0.033	211	5.8	2,903
341	4,045	0.25	1,001	8.8	35,731	0.033	133	6.0	1,862
343	6,315	0.21	1,346	7.7	48,503	0.031	197	5.9	2,889
350	10,401	0.22	2,271	8.2	85,787	0.032	333	5.9	4,751
370	282	1.95	536	17.7	48,59	0.144	39	5.8	,275
371	13,957	0.26	3,581	8.9	124,191	0.034	476	6.1	6,404
373	6,430	0.21	1,283	7.3	43,957	0.033	198	6.1	2,418
375	3,225	0.33	1,054	9.0	29,083	0.032	103	6.0	1,434

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 4 of 4)

Subwatershed[a]	Area (acres)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (lb/ac/yr)	Annual Load (lb/yr)	Unit Area Load (ton/ac/yr)	Annual Load (ton/yr)	Unit Area Rate (in/yr)	Rate (ac-ft/yr)
381	4,734	0.27	1,257	8.4	39,968	0.038	180	5.9	1,995
383	12,519	0.22	2,737	8.0	100,127	0.036	454	5.5	5,259
385	6,033	0.29	1,722	8.2	48,382	0.044	258	5.5	2,541
388	1,943	0.31	514	7.6	12,591	0.033	55	5.5	711
389	2,307	0.29	665	8.6	19,846	0.038	87	4.7	976
392	2,055	0.24	424	7.0	12,166	0.033	56	5.6	711
394	3,995	0.26	894	6.7	23,520	0.031	107	5.6	1,429
400	8,654	0.25	1,679	5.9	40,287	0.034	232	5.5	2,828
411	11,765	0.23	2,609	7.4	82,829	0.034	378	5.6	6,542
413	4,571	0.20	930	6.8	30,987	0.031	143	5.5	1,866
420	4,126	0.35	1,129	5.7	18,509	0.064	207	5.6	1,523
430	11,811	2.36	27,857	15.3	180,141	0.057	671	5.4	9,026
431	5,882	0.15	854	5.3	30,195	0.024	139	5.4	2,337
432	10,438	0.21	2,030	7.3	70,817	0.031	303	5.5	4,046
433	7,859	0.17	1,199	4.6	32,858	0.020	141	5.5	2,504
435	6,548	0.21	1,369	4.6	30,312	0.021	139	5.5	2,280
450	8,176	0.21	1,748	4.5	36,766	0.034	276	5.5	3,064
461	5,569	0.28	1,534	4.3	23,758	0.030	165	12.0	2,040
470	5,204	1.13	5,888	12.1	62,741	0.140	730	5.5	4,509
490	3,154	1.36	4,288	10.3	32,456	0.262	827	4.8	2,883

The numbering system is based on rules for setting up HSPF models and is not sequential.

ac = acres

lb/ac/yr = pound per acre per year

lb/yr = pound per year

ton/ac/yr = ton per acre per year

ton/yr = ton per year

in/yr = inches per year

ac-ft/yr = acre foot per year

APPENDIX B

WATERSHED CONDITIONS BY MANAGEMENT UNITS FOR BASE CONDITIONS AND ALL SCENARIOS

Watershed conditions by management units for runoff, phosphorus, nitrogen, and total suspended solids under the base conditions and all of the scenarios are provided in the following tables.

All data have also been provided electronically in a geodatabase.

Table B-1. Base Conditions

Management Unit		Base Conditions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.9	4.2	0.18	0.03	3.78	0.16	51.17
2	Sauk Lake	4.61	4.3	0.19	0.03	4.11	0.18	53.22
3	Centre Sauk River	5.61	4.69	0.25	0.03	3.69	0.2	45.13
4	Adley Creek	6.47	8.68	0.56	0.04	5.93	0.38	53.36
5	GUS Plus	5.75	8.28	0.41	0.03	6.35	0.32	50.98
6	Saint Roscoe	5.48	8.29	0.24	0.03	6.68	0.19	53.21
7	Chain of Lakes	5.48	7.52	0.26	0.04	6.06	0.21	60.03
8	Grand Pearl	4.64	5.79	0.19	0.03	5.51	0.18	48.76
9	Cold Spring	9.17	15.26	2.36	0.06	7.34	1.13	54.69
10	Mini Metro	6.79	7.05	0.61	0.09	4.58	0.4	117.62

Table B-2. Conditions Under the Urban, Achievable Management Scenario

Management Unit		Urban Achievable						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.89	4.19	0.17	0.03	3.78	0.16	50.37
2	Sauk Lake	4.59	4.28	0.19	0.03	4.11	0.18	51.94
3	Centre Sauk River	5.58	4.67	0.25	0.03	3.69	0.2	43.68
4	Adley Creek	6.39	8.62	0.54	0.04	5.95	0.37	49.77
5	GUS Plus	5.72	8.25	0.41	0.03	6.36	0.31	49.31
6	Saint Roscoe	5.45	8.26	0.23	0.03	6.69	0.19	51.74
7	Chain of Lakes	5.42	7.47	0.25	0.03	6.08	0.2	56.57
8	Grand Pearl	4.62	5.77	0.19	0.02	5.51	0.18	47.32
9	Cold Spring	8.98	15.1	0.45	0.05	7.42	0.22	48.35
10	Mini Metro	6.2	6.5	0.47	0.07	4.63	0.34	93.71

Table B-3. Conditions under the Agricultural, Achievable Management Scenario

Management Unit		Agriculture Achievable						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.88	3.53	0.15	0.02	3.19	0.14	41.8
2	Sauk Lake	4.59	3.55	0.16	0.02	3.41	0.15	43.22
3	Centre Sauk River	5.57	3.92	0.21	0.02	3.1	0.16	37.39
4	Adley Creek	6.42	7.28	0.46	0.03	5	0.32	45.44
5	GUS Plus	5.72	6.76	0.34	0.03	5.22	0.26	42.21
6	Saint Roscoe	5.45	6.73	0.19	0.03	5.45	0.16	43.96
7	Chain of Lakes	5.44	6.13	0.21	0.03	4.97	0.17	50.44
8	Grand Pearl	4.6	4.69	0.15	0.02	4.5	0.14	39.51
9	Cold Spring	9.16	14.02	2.33	0.05	6.75	1.12	50.27
10	Mini Metro	6.75	6.37	0.57	0.09	4.16	0.37	114.78

Table B-4. Conditions under the Cumulative, Achievable Management Scenario

Management Unit		Cumulative Achievable						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.86	3.52	0.15	0.02	3.19	0.13	40.99
2	Sauk Lake	4.57	3.53	0.16	0.02	3.41	0.15	41.89
3	Centre Sauk River	5.55	3.9	0.2	0.02	3.1	0.16	35.9
4	Adley Creek	6.35	7.22	0.44	0.03	5.02	0.31	41.73
5	GUS Plus	5.69	6.73	0.33	0.03	5.22	0.26	40.48
6	Saint Roscoe	5.43	6.71	0.19	0.03	5.46	0.15	42.44
7	Chain of Lakes	5.38	6.07	0.2	0.03	4.98	0.16	46.85
8	Grand Pearl	4.58	4.67	0.15	0.02	4.5	0.14	38.02
9	Cold Spring	8.97	13.87	0.42	0.04	6.82	0.21	43.83
10	Mini Metro	6.16	5.82	0.44	0.06	4.17	0.31	90.47

Table B-5. Conditions under the Urban, Aggressive Management Scenario

Management Unit		Urban Aggressive						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.88	4.18	0.17	0.03	3.78	0.15	49.58
2	Sauk Lake	4.58	4.26	0.18	0.03	4.11	0.18	50.65
3	Centre Sauk River	5.56	4.64	0.25	0.03	3.69	0.2	42.21
4	Adley Creek	6.32	8.55	0.5	0.03	5.97	0.35	46.09
5	GUS Plus	5.69	8.22	0.4	0.03	6.37	0.31	47.64
6	Saint Roscoe	5.43	8.24	0.23	0.03	6.7	0.18	50.26
7	Chain of Lakes	5.36	7.41	0.24	0.03	6.09	0.2	53.05
8	Grand Pearl	4.6	5.75	0.18	0.02	5.52	0.18	45.89
9	Cold Spring	8.79	14.92	0.32	0.04	7.49	0.16	41.74
10	Mini Metro	5.6	5.95	0.36	0.04	4.68	0.28	64.77

Table B-6. Conditions under the Agricultural, Aggressive Management Scenario

Management Unit		Agriculture Aggressive						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.85	1.91	0.09	0.01	1.74	0.08	19.28
2	Sauk Lake	4.56	1.74	0.08	0.01	1.68	0.08	19.26
3	Centre Sauk River	5.55	2.13	0.11	0.01	1.69	0.09	20.57
4	Adley Creek	6.39	3.98	0.26	0.02	2.75	0.18	27.83
5	GUS Plus	5.68	3.04	0.16	0.01	2.36	0.12	21.47
6	Saint Roscoe	5.41	2.81	0.1	0.01	2.29	0.08	20.06
7	Chain of Lakes	5.41	2.76	0.12	0.02	2.26	0.1	27.75
8	Grand Pearl	4.57	2.09	0.07	0.01	2.02	0.07	18.95
9	Cold Spring	9.14	10.81	2.26	0.04	5.22	1.09	38.46
10	Mini Metro	6.73	4.86	0.52	0.08	3.19	0.34	107.84

Table B-7. Conditions under the Cumulative, Aggressive Management Scenario

Management Unit		Cumulative Aggressive						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	4.79	1.83	0.08	0.01	1.69	0.07	17.1
2	Sauk Lake	4.52	1.69	0.08	0.01	1.65	0.07	15.57
3	Centre Sauk River	5.49	2.07	0.1	0.01	1.66	0.08	16.4
4	Adley Creek	5.81	2.97	0.18	0.01	2.26	0.14	17.95
5	GUS Plus	5.6	2.94	0.14	0.01	2.32	0.11	16.56
6	Saint Roscoe	5.33	2.72	0.09	0.01	2.25	0.07	15.75
7	Chain of Lakes	5.27	2.61	0.09	0.01	2.18	0.08	17.69
8	Grand Pearl	4.53	2.04	0.07	0.01	1.99	0.06	14.98
9	Cold Spring	7.07	3.44	0.15	0.02	2.14	0.09	21.11
10	Mini Metro	4.83	2.62	0.19	0.02	2.39	0.17	36.08

APPENDIX C

REDUCTIONS BY MANAGEMENT UNITS FOR ALL SCENARIOS

Reductions from the base conditions to each scenario are shown in the tables that follow.

All data has been shared electronically in a geodatabase as well.

Table C-1. Reductions Under the Urban Achievable Scenario

Management Unit		Urban Achievable - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.01	0.01	0.01	0	0	0	0.8
2	Sauk Lake	0.02	0.02	0	0	0	0	1.28
3	Centre Sauk River	0.03	0.02	0	0	0	0	1.45
4	Adley Creek	0.08	0.06	0.02	0	–0.02	0.01	3.59
5	GUS Plus	0.03	0.03	0	0	–0.01	0.01	1.67
6	Saint Roscoe	0.03	0.03	0.01	0	–0.01	0	1.47
7	Chain of Lakes	0.06	0.05	0.01	0.01	–0.02	0.01	3.46
8	Grand Pearl	0.02	0.02	0	0.01	0	0	1.44
9	Cold Spring	0.19	0.16	1.91	0.01	–0.08	0.91	6.34
10	Mini Metro	0.59	0.55	0.14	0.02	–0.05	0.06	23.91

Table C-2. Reductions Under the Agriculture Achievable Scenario

Management Unit		Agriculture Achievable - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.02	0.67	0.03	0.01	0.59	0.02	9.37
2	Sauk Lake	0.02	0.75	0.03	0.01	0.7	0.03	10
3	Centre Sauk River	0.04	0.77	0.04	0.01	0.59	0.04	7.74
4	Adley Creek	0.05	1.4	0.1	0.01	0.93	0.06	7.92
5	GUS Plus	0.03	1.52	0.07	0	1.13	0.06	8.77
6	Saint Roscoe	0.03	1.56	0.05	0	1.23	0.03	9.25
7	Chain of Lakes	0.04	1.39	0.05	0.01	1.09	0.04	9.59
8	Grand Pearl	0.04	1.1	0.04	0.01	1.01	0.04	9.25
9	Cold Spring	0.01	1.24	0.03	0.01	0.59	0.01	4.42
10	Mini Metro	0.04	0.68	0.04	0	0.42	0.03	2.84

Table C-3. Reductions Under the Cumulative Achievable Scenario

Management Unit		Cumulative Achievable - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.04	0.68	0.03	0.01	0.59	0.03	10.18
2	Sauk Lake	0.04	0.77	0.03	0.01	0.7	0.03	11.33
3	Centre Sauk River	0.06	0.79	0.05	0.01	0.59	0.04	9.23
4	Adley Creek	0.12	1.46	0.12	0.01	0.91	0.07	11.63
5	GUS Plus	0.06	1.55	0.08	0	1.13	0.06	10.5
6	Saint Roscoe	0.05	1.58	0.05	0	1.22	0.04	10.77
7	Chain of Lakes	0.1	1.45	0.06	0.01	1.08	0.05	13.18
8	Grand Pearl	0.06	1.12	0.04	0.01	1.01	0.04	10.74
9	Cold Spring	0.2	1.39	1.94	0.02	0.52	0.92	10.86
10	Mini Metro	0.63	1.23	0.17	0.03	0.41	0.09	27.15

Table C-4. Reductions Under the Urban Aggressive Scenario

Management Unit		Urban Aggressive - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.02	0.02	0.01	0	0	0.01	1.59
2	Sauk Lake	0.03	0.04	0.01	0	0	0	2.57
3	Centre Sauk River	0.05	0.05	0	0	0	0	2.92
4	Adley Creek	0.15	0.13	0.06	0.01	–0.04	0.03	7.27
5	GUS Plus	0.06	0.06	0.01	0	–0.02	0.01	3.34
6	Saint Roscoe	0.05	0.05	0.01	0	–0.02	0.01	2.95
7	Chain of Lakes	0.12	0.11	0.02	0.01	–0.03	0.01	6.98
8	Grand Pearl	0.04	0.04	0.01	0.01	–0.01	0	2.87
9	Cold Spring	0.38	0.34	2.04	0.02	–0.15	0.97	12.95
10	Mini Metro	1.19	1.1	0.25	0.05	–0.1	0.12	52.85

Table C-5. Reductions Under the Agriculture Aggressive Scenario

Management Unit		Agriculture Aggressive - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.05	2.29	0.09	0.02	2.04	0.08	31.89
2	Sauk Lake	0.05	2.56	0.11	0.02	2.43	0.1	33.96
3	Centre Sauk River	0.06	2.56	0.14	0.02	2	0.11	24.56
4	Adley Creek	0.08	4.7	0.3	0.02	3.18	0.2	25.53
5	GUS Plus	0.07	5.24	0.25	0.02	3.99	0.2	29.51
6	Saint Roscoe	0.07	5.48	0.14	0.02	4.39	0.11	33.15
7	Chain of Lakes	0.07	4.76	0.14	0.02	3.8	0.11	32.28
8	Grand Pearl	0.07	3.7	0.12	0.02	3.49	0.11	29.81
9	Cold Spring	0.03	4.45	0.1	0.02	2.12	0.04	16.23
10	Mini Metro	0.06	2.19	0.09	0.01	1.39	0.06	9.78

Table C-6. Reductions Under the Cumulative Aggressive Scenario

Management Unit		Cumulative Aggressive - Reductions						
		Runoff (in/yr)	TN (Ibs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
1	Osakis Lake	0.11	2.37	0.1	0.02	2.09	0.09	34.07
2	Sauk Lake	0.09	2.61	0.11	0.02	2.46	0.11	37.65
3	Centre Sauk River	0.12	2.62	0.15	0.02	2.03	0.12	28.73
4	Adley Creek	0.66	5.71	0.38	0.03	3.67	0.24	35.41
5	GUS Plus	0.15	5.34	0.27	0.02	4.03	0.21	34.42
6	Saint Roscoe	0.15	5.57	0.15	0.02	4.43	0.12	37.46
7	Chain of Lakes	0.21	4.91	0.17	0.03	3.88	0.13	42.34
8	Grand Pearl	0.11	3.75	0.12	0.02	3.52	0.12	33.78
9	Cold Spring	2.1	11.82	2.21	0.04	5.2	1.04	33.58
10	Mini Metro	1.96	4.43	0.42	0.07	2.19	0.23	81.54