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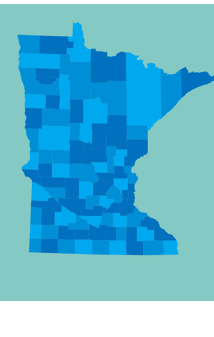
Watershed nutrient loads to accomplish Minnesota's Nutrient Reduction Strategy Goals

Guidance for Watershed Strategies and Planning

MINNESOTA POLLUTION CONTROL AGENCY



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Overview

Purpose

The primary purpose of this guidance document is to provide updated nutrient load reduction estimates needed from each watershed to collectively reduce Minnesota's nutrient contribution to waters outside of the state. The load reductions are needed so that Minnesota can do its part to restore and protect the downstream waters such as the Gulf of Mexico, Lake Winnipeg and the Great Lakes. A secondary purpose is to provide information on how to estimate best management practice (BMP) combinations and levels of adoption that will achieve specific watershed nutrient load reductions. The primary audiences for this information are those working on watershed and regional water quality plans and strategies.

Background and context

Minnesota has agreed with other states to do its part to help reduce nutrient loads downstream of Minnesota, such as the nutrients causing the large hypoxic zone in the Gulf of Mexico and eutrophication problems in Lake Winnipeg. Minnesota is one of twelve states committed to working together on the Gulf of Mexico Hypoxia Task Force. Minnesota has also committed to work with North Dakota and Canada on the International Red River Watershed Board, each doing its part to reduce nutrients that ultimately reach Lake Winnipeg and contribute to the massive algae blooms.

Of course, Minnesota has its own waters needing nutrient reduction. The nutrient reduction work we complete for Minnesota waters has cascading benefits that begin within our local watersheds, and then additionally provide benefits to in-state major rivers and lakes, waters in neighboring states and provinces, and all the way down to the Gulf of Mexico to the south and Lake Winnipeg/Hudson Bay to the north.

To achieve downstream nutrient reduction, Minnesota's 2014 Nutrient Reduction Strategy (NRS) called for each eight-digit Hydrologic Unit Code major watershed (HUC8) to voluntarily do its part to cumulatively achieve goals for the Mississippi River, Red River and Lake Superior. If each watershed reduces a fraction of its reducible or anthropogenic nutrient loads, then downstream nutrient goals can be met and local waters within HUC8s will be markedly improved.

The 2014 NRS provided limited guidance on the magnitude of load reductions needed from each HUC8 watershed to achieve milestone targets for downstream waters. After the 2014 NRS, Minnesota improved monitoring and modeling information became available, enabling the State to develop improved estimates of nutrient load-reduction planning targets for each HUC8 watershed outlet. These updated watershed load reduction targets were more realistic since they were established with an assumption that we cannot expect to achieve load reductions from our "natural" lands, and additionally they were developed with considerably more monitoring and more advanced modeling as compared to the preliminary HUC8 load reduction guidance in the 2014 NRS. While the 2014 NRS focused on the milestone goals for 2025, the updated loads in this guidance focus on the final goals.

In 2022, "interim" load reduction goals were developed. The load reduction goals were called "interim," since they were developed in 2019, mid-way between the original 2014 NRS and the 2025 NRS. During development of the 2024 NRS, the interim load reduction goals were revised to account for (1) updated modeling results for many HUC8s, (2) new load goals for the Red River of the North at Emerson, Manitoba, Canada, and (3) new information about the distribution of loads between Minnesota, North Dakota, and South Dakota in the Red River of the North major basin. The 2025 NRS incorporates these revised load reduction targets.

Using this guidance at the watershed scale

The improved HUC8 outlet load reduction targets provided in tables 3-9 are intended to help watershed planners more accurately understand their part of what it will take for Minnesota to achieve long-term final-goal nutrient load reductions for downstream waters. The load reduction planning goals described below are intended to be one consideration, among many, that will inform long-term land-cover and best management practice (BMP) implementation needs (rural and urban) when Watershed Restoration and Protection Strategies (WRAPS) and associated plans are updated. *These planning goals should be viewed as approximate, recognizing that the modeling and monitoring that supports these goals varies across the state.* Some watersheds have much more updated modeling than other watersheds. Updates and improvements to monitoring and modeling will allow the state to refine the load reduction needs over time.

While the focus of this guidance is on local efforts to address downstream needs, this guidance is not intended to supersede local priorities, strategies and plans. Instead, downstream considerations should be recognized, along with local priorities, when local watersheds re-examine their priorities and needs for long-term BMP adoption. For example, when planning for nitrogen reductions, people living and working in the watershed may establish a top priority of improving drinking water nitrate in source water protection areas. This is an excellent place to initially focus efforts. Many of the same actions to address the local drinking water needs will also reduce nitrogen loads going to downstream waters; however, additional BMP adoption will usually be needed for the downstream water concerns. In many cases, broad adoption of non-structural in-field practices across the watershed (i.e. reduced tillage, precision nutrient applications, cover crops, conservation rotations, etc.), along with wastewater nutrient discharge reductions, will be needed to meet the final nutrient goals.

Assessing Progress

The MPCA will continue to monitor long-term progress toward Minnesota's commitments to the Gulf of Mexico, Lake Winnipeg and other downstream waters such as Lake Pepin. Because the loads vary greatly from year to year due to weather and other factors, progress evaluations will be based on *long-term* monitoring and modeling (i.e. ten-year periods). Additionally, as monitoring results increase, we will be able to re-calibrate models and improve the estimated load reduction needs. The load reduction planning targets should be re-calculated periodically to account for actual progress in changing loads, as well as improvements and updates in our calibrated modeling results.

Basin scale nutrient load reduction needs for downstream waters

Minnesota's NRS, developed and adopted by 11 organizations in 2014 (https://www.pca.state.mn.us/water/nutrient-reduction-strategy) and revised in 2024, emphasizes the importance of improving nutrient pollution for the benefit of Minnesota's waters and those downstream of Minnesota. The state-level strategy called for reducing nutrient levels by 10 to 20% over much of the state between 2014 and 2025, with 45 to 50% reductions by 2040 (Table 1).

Table 1. Goals and milestones outlined in the Minnesota Nutrient Reduction Strategy.

Major basin	Final Goal 2025 to 2040
Mississippi River (Also includes Cedar, Des Moines, and Missouri Rivers)	Achieve **45%** total reduction from 1980-1996 baseline and meet in-state lake and river water quality standards
	Achieve **45%** total reduction from 1980-1996 baseline
Red River (Lake Winnipeg Basin)	Achieve final reductions identified through joint efforts with Manitoba (about 50% from the 1998 to 2001 period)
Lake Superior	Maintain protection goals, no net increase from 1970s
Groundwater/Source Water	Meet the goals of the 1989 Groundwater Protection Act

Since the 2014 NRS, Minnesota has markedly increased river monitoring and associated annual nutrient load calculations. These new data were used to update SPAtially Referenced Regression On Watershed attributes (SPARROW) and Hydrologic Simulation Program – FORTRAN (HSPF) models. The SPARROW model was updated in 2019 (Robertson and Saad, 2019), and HSPF model applications have now been developed and calibrated for most HUC8 watersheds in Minnesota.

To estimate how much load reduction is still needed in our major rivers that leave the state, we added-up all of the recent-decade modeled HUC8 watershed loads delivered to the Minnesota state border and compared those loads to the original major river NRS load goals. The modeled watershed loads represent averages over the most recently modeled 10-year period. A 10-year period was believed to be a long enough time to include a wide-range of hydrologic conditions. Where HSPF models were absent, SPARROW modeling was used to estimate load averages for a similar period of time, as described in a detailed description of the methods (attachment A).

The modeled HUC8 nutrient loads reaching state lines were summed for major drainage basins, including: 1) Mississippi River, 2) Red River of the North (at Emerson), 3) Rainy River (at Lake of the Woods), and 4) Lake Superior, as represented in table 2. By comparing the summed recent loads to the original baseline loads and goals identified in the NRS, we assessed how much additional nutrient reductions are still needed at the state line.

Baseline, recent, current, milestone, and final goal loads are calculated differently for different datasets. The following dataset characteristics determine how loads are calculated:

- **Delivery** – Loads are delivered either to HUC8 outlets or to state boundaries.
- **Source** – Loads are calculated from in-stream monitoring data or from model simulations.
- **Period** – Loads are calculated with different time periods (e.g., 1980-1996, 1998-2001) and different averaging periods (e.g., annual, 5-year rolling).
- **Normalization** – Loads are normalized by flow or are non-flow-normalized.

Generally, it is not appropriate to compare different types of loads. Loads presented in this guidance are from model simulations, averaged over a recent 10-year period, and are non-flow-normalized. As such, loads presented in this guidance should not be compared with monitored loads, flow-normalized loads, or loads calculated for different time periods.

Based on these modeling results (Table 2), most of the long-term nitrogen and phosphorus load reduction for the Mississippi and Red Rivers is still needed (still needing about 47-51% nitrogen reductions from recent loads and about 40-51% phosphorus reductions from recent loads). The Rainy

River basin needs a phosphorus reduction of 5%, while the Lake Superior basin needs nitrogen reductions of less than 1%.

The 2014 NRS did not establish specific goals for HUC8 watersheds in the Rainy River, deferring to the eventual Lake of the Woods TMDL for establishing TP load targets. The TP load goal of 218 MT for the Rainy River basin was computed from the Lake of the Woods TMDL (2018) by summing the allowable Minnesota TP loads to the lake for wastewater, tributaries, lakeshed, and septic systems categories (Schlea at al. 2020). The TP load goal of 218 MT will be included in the 2025 NRS. Allowable TP loads for Canadian sources, shoreline erosion, atmospheric deposition, and internal loading were not included as they were not considered to be part of the Minnesota HUC8 watershed loading to Lake of the Woods. The combined watershed TP load reduction targets would reduce the recent load of 228 MT down to the goal of 218 MT. Numeric TN goals have not been established for the Rainy River major basin.

Table 2. Recent load estimates, final goals and remaining reductions for the Minnesota portion of four major basins, for total phosphorus (TP) and total nitrogen (TN) in units of Metric Tons (MT).

Description	Mississippi River: Upper Mississippi, Minnesota, St. Croix, Lower Mississippi, Cedar, Des Moines, Missouri		Red River of the North		Rainy River		Lake Superior	
	TP	TN	TP	TN	TP	TN	TP	TN
Recent sum of modeled loads at state line (MT)	4,273	94,170	1,084	8,674	228	4,275	245	4,670
Final goal at state line (MT)	2,544	50,089	531	4,210	218*	4,887	248	4,658
% load reduction still needed to meet final goals	40%	47%	51%	51%	5%*	None	None	<1%

*Rainy River load goals were based on a preliminary Lake of the Woods TMDL and will be adjusted to the final TMDL.

What about Lake Pepin? A question sometimes arises whether the level of change needed to meet the phosphorus reduction goals to Lake Pepin is similar to what is needed for our Mississippi River/Gulf of Mexico downstream commitments. An analysis further described in Attachment A, shows that the total phosphorus (TP) reduction needs for the Lake Pepin Watershed Phosphorus Total Maximum Daily Load (TMDL) are currently about the same as what is needed for downstream Mississippi River/Gulf of Mexico TP reduction planning goals. Similar levels of effort in the upstream watersheds will accomplish both the in-state Lake Pepin goal and Minnesota's part in achieving the multi-state TP reductions for the Gulf of Mexico.

A no-net-increase total *nitrogen* goal has been added for the 2025 NRS update, replacing the previous qualitative protection goal for nitrogen. Aggregated HUC8 watershed modeled loads across the Lake Superior basin showed an average TN load of 4,887 MT (average of the most recent 10 years of HSPF modeling for these watersheds). Since we don't currently have estimates for the 1979 baseline load, this recently modeled load could represent a proxy baseline load that should not be exceeded into the future by the combined Minnesota tributaries into Lake Superior.

What about Ground Water nitrate? Groundwater nitrate levels often exceed drinking water standards in wells throughout the state, and nitrate in some surface water community drinking water sources also exceeds drinking water standards. Addressing these local health concerns is often considered by local watershed planners to be a higher priority than addressing waters downstream from Minnesota. Fortunately, the in-field practices that address groundwater nitrate in source water protection areas (i.e. fertilizer and manure efficiency, cover crops and perennials in rotations) will also benefit downstream waters. The intent of these guidelines is to outline the total load reductions needed from all nitrogen pathways (groundwater, surface runoff, tile water, and point source discharges), and part of the groundwater baseflow nitrogen load reduction will come from reducing groundwater nitrate in source water protection areas.

HUC8 watershed nutrient load reduction planning goals for downstream waters

The estimated load reductions from each HUC8 watershed needed to collectively meet our nutrient reduction needs at the state lines were calculated for each watershed outlet. In aggregate, achieving each watershed reduction planning goal would enable Minnesota to meet NRS goals, while at the same time also addressing many nutrient reduction needs within the HUC8 watersheds. These voluntary targets should be considered when watershed managers re-evaluate their needs, goals, priorities and plans. The planning goals included in this document should be considered approximate due to inherent uncertainties and complexities with watershed modeling and monitoring.

The goals at the state border cannot be achieved unless each watershed does its part. The watershed load reduction planning goals were set equitably, such that each HUC8 within a major river basin would reduce a similar fraction of its reducible/anthropogenic nutrient load. While adjustments were made to account for in-stream nutrient losses between each watershed and the state line, the nutrient reduction planning goals were not developed to set disproportionately higher reduction goals for watersheds closer to the state line as compared to those further from the state line.

The HUC8 watershed outlet nutrient reduction planning goals were calculated using the following analyses (each described in detail and shown with maps in **Attachment A**):

- **HSPF load averages** – Average modeled loads over the most recently modeled 10-year period in each watershed[1]. Where HSPF models were absent, SPARROW modeling was used to estimate load averages for a similar period of time.

  Of the 67 HSPF models, the most recently modeled 10-year period for 27 models is in the 2000 to 2014 timeframe. Several such HSPF models are being extended and recalibrated in 2024 (e.g., St. Louis River is being extended to 2021). The most recently modeled 10-year period for the other 40 models is in the 2015 to 2022 timeframe.
- **Reducible load averages** – The HSPF-modeled loads were divided into estimates of non-reducible loads (reflecting natural land uses) and reducible loads (nutrient loads coming from land uses most directly affected by people). The load reduction planning targets were developed as a fraction of the reducible loads only.
- **Watershed outlet loads that reach state lines** – The HUC8 planning goals take into account estimates of in-stream losses between the HUC8 outlet and state lines based on SPARROW modeling results. By accounting for in-stream losses, the sum of the reduction goals at HUC8 outlets equal the nutrient reduction needs at the state line. This was accomplished in an equitable way so that watersheds further from state line are not expected to reduce more nutrients than a similar watershed further upstream.

The watershed loads and load reduction targets were established such that contributions from all the watersheds in the basin would meet the remaining large river NRS nutrient load reductions identified in Table 2. A detailed description of the methods and process used to estimate loads and load reduction targets for each watershed are described in **Attachment A**, which incorporates the work of Schlea et al. (2020) and includes additions and edits by MPCA. **Attachment A** was updated in 2024 with HSPF model results provided by RESPEC and supplemental analyses provided by Tetra Tech.

To find the load reduction target in your watershed of interest, go to the table that aligns with the major river basin where the watershed is located, as follows:

Mississippi River Basin watersheds – nitrogen (Table 3) and phosphorus (Table 4)
Red River Basin watersheds – nitrogen (Table 5) and phosphorus (Table 6)
Lake Superior watersheds – nitrogen (Table 7) and phosphorus (Table 8)
Rainy River watersheds – phosphorus (Table 9)

In Tables 3 to 9, the two green shaded columns are of particular importance to consider for watershed planning. The column, "final goal loads at the HUC8 outlets" reflect the annual river nutrient loads (long-term average) consistent with achieving the final NRS goals. The column, "Load reduction at HUC8 outlet to meet the final goal," represents the load *reduction* amount needed from the recent decade to achieve the final load goal. These load reduction amounts (in Metric Tons per year, on average) to reach the final load goals are also shown in Figures 1 and 3, respectively for TN and TP, and are shown as a percentage of recent annual loads in Figures 2 and 4.

Because the load reduction amounts are based only on the anthropogenic/reducible nutrient sources, watersheds with mostly natural areas show a lower overall percent reduction target (percent of the combined reducible and non-reducible sources) as compared to watersheds with few natural areas. It is important that watersheds with relatively low reducible loads emphasize protection of their existing water resources so that pollution does not increase. More information about how natural and reducible source loads were determined is described in **Attachment A**.

The HUC8 watershed scale was chosen to generally align with Minnesota's Watershed Approach used in developing WRAPS and Comprehensive Watershed Management Plans. In watersheds such as the Mississippi River -Twin Cities, plans are often developed by watershed management organizations for smaller subwatersheds within the HUC8 watershed. In such instances, the percent reduction targets in tables 3 to 9 can be applied to recent 10-year average loads at the subwatershed outlets.

Some load reductions may already have been achieved during recent years that were not included as part of ten-year modeling periods used in this analysis. As previously mentioned, 27 of the 67 HSPF models (40%) cover 10-year periods before 2015, while 40 HSPF models (60%) cover 10-year periods after 2014. Also, in some watersheds the modeling was calibrated with limited monitoring information. Since monitoring information has continued to increase, our ability to improve modeling results is also increasing. For example, the Zumbro River Watershed average annual phosphorus loads were originally estimated through modeling to be 526 MT, based on the 2000-09 period. With river monitoring increases in the Zumbro River watershed and subsequent re-calibrating of the model (2009-18), a more recent estimate of a 10-year modeled average annual load is 372 MT. Since improved monitoring results will become available over time and models will be updated, the loads and planning goals in tables 3-9 should be periodically updated.

Figure 1. Average annual HUC8 watershed TN load reductions (MT) at the watershed outlet to meet the final target loads at state lines.

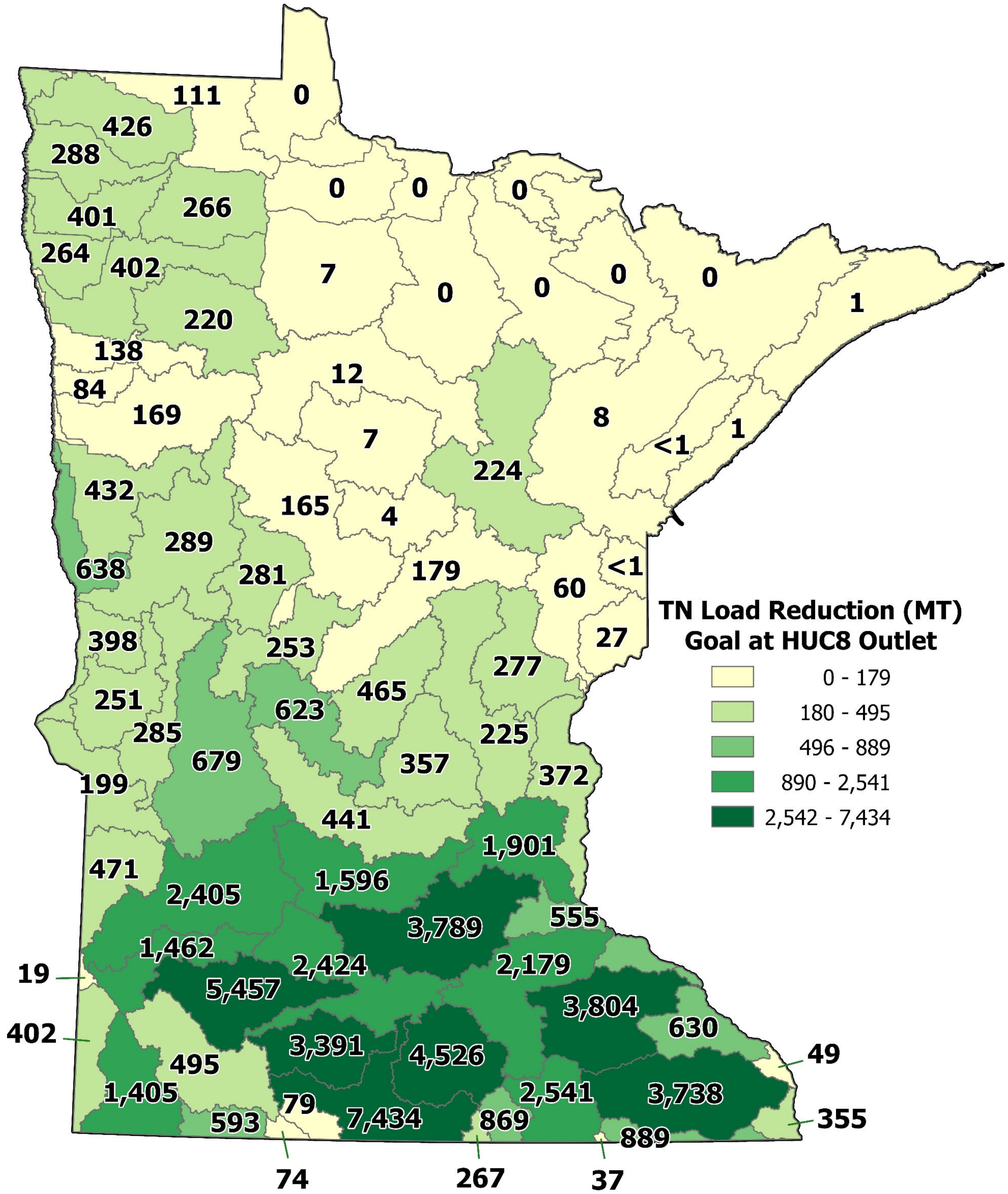

Figure 2. Percent of recent average annual HUC8 watershed TN load to be reduced to meet the final target loads. Note that this is a percent of the total N loads that reach the HUC8 outlet.

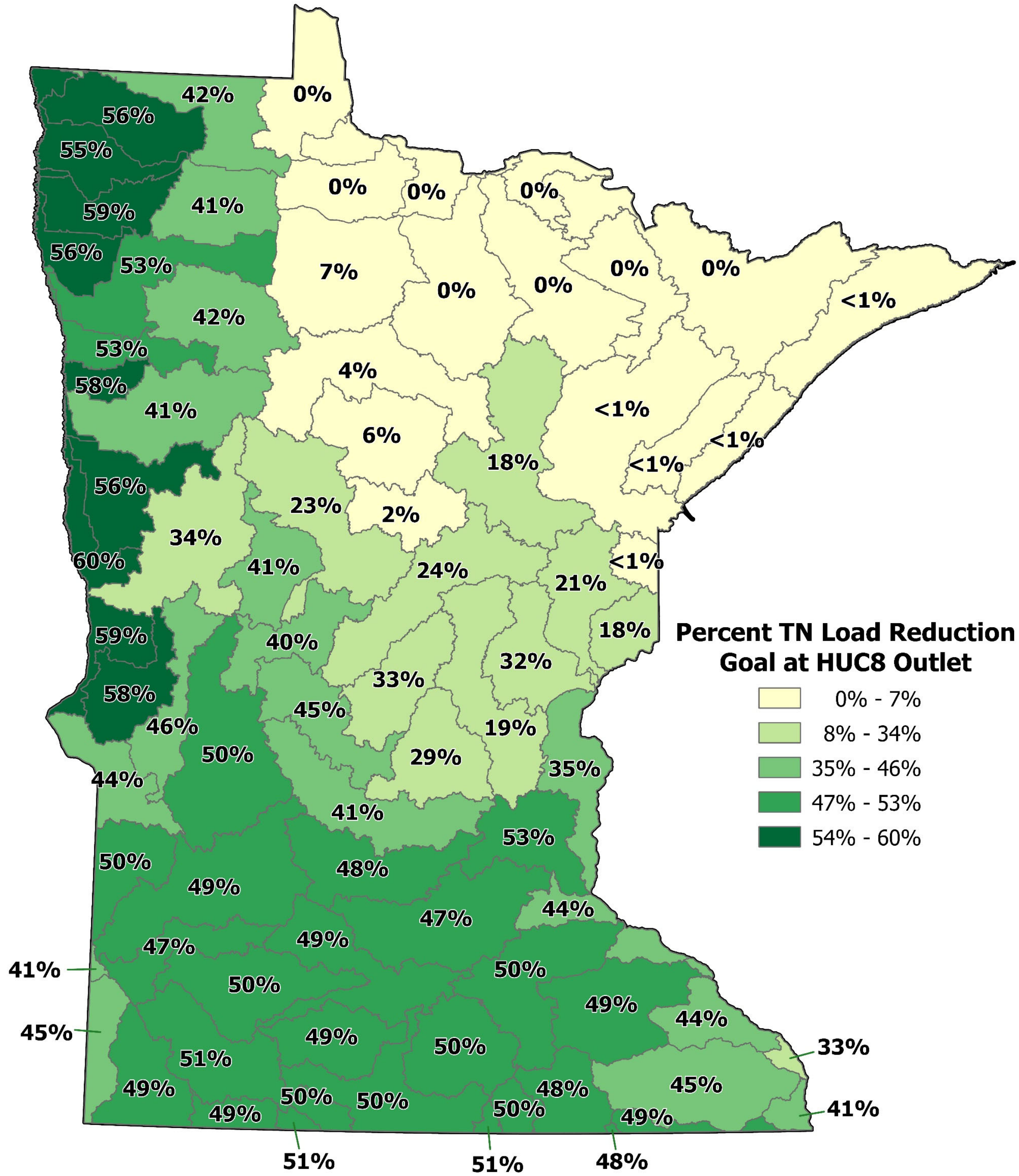

Figure 3. Average annual HUC8 watershed TP load reductions (MT) at the watershed outlet to meet the final target loads at state lines.

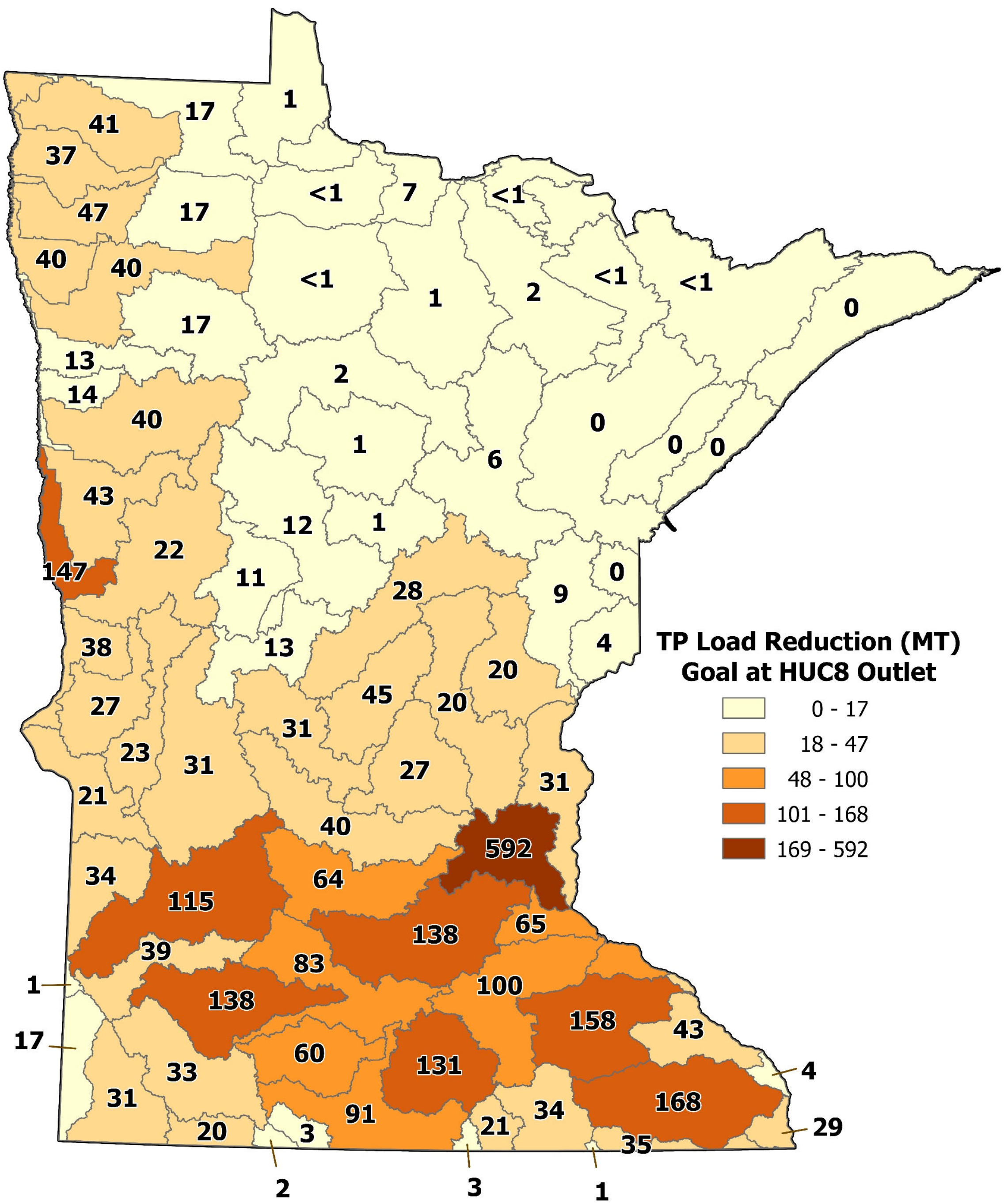

Figure 4. Percent of recent average annual HUC8 watershed TP load to be reduced to meet the final target loads. Note that this is a percent of the total P loads that reach the HUC8 outlet.

Note: In the *Lake Superior* major basin, instead of load reductions, a “hold the line” approach is recommended.

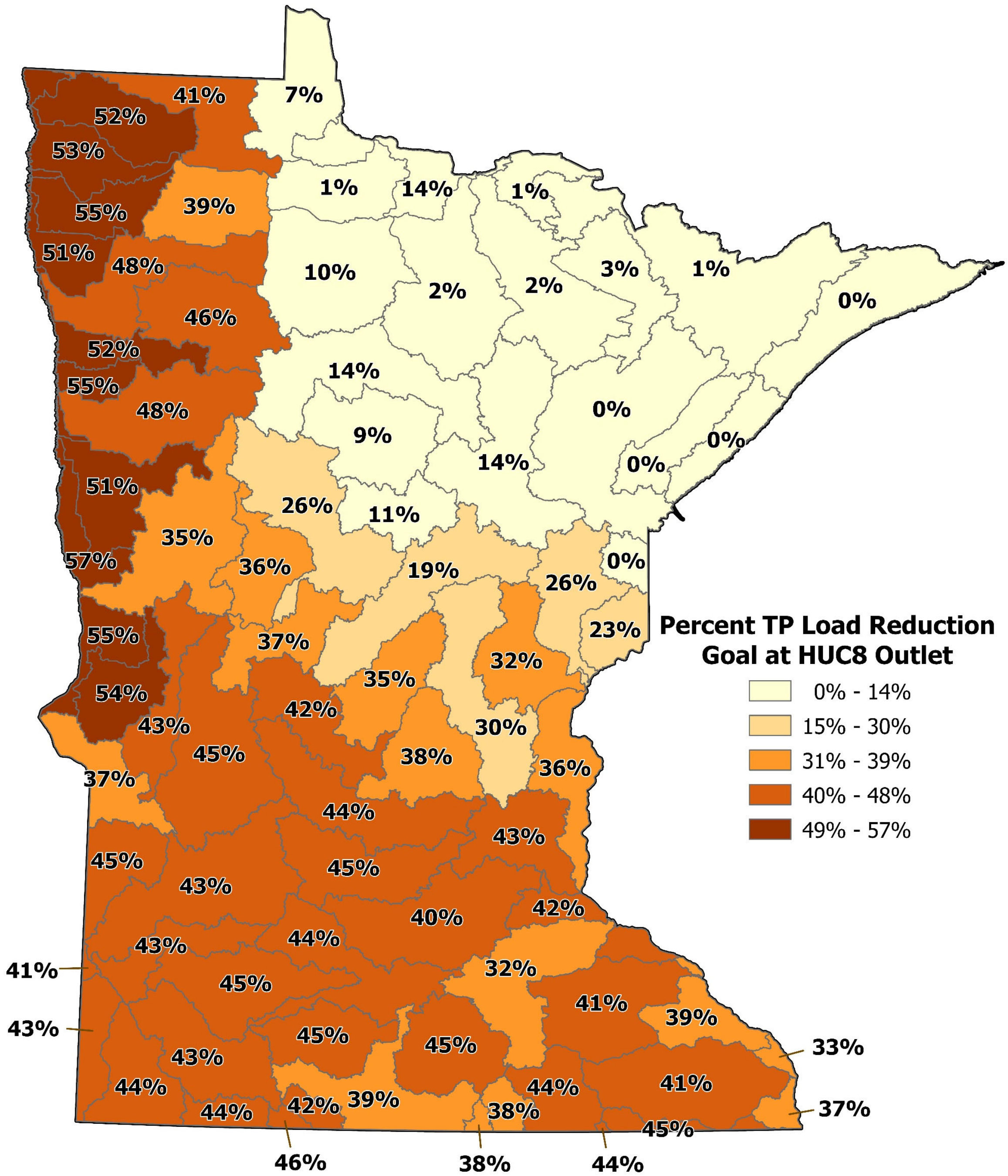

Table 3. Mississippi River Basin HUC8 watershed TN load goal recommendations and load reduction targets to meet the final 2040 NRS goal.

HUC8 Name	HUC8 Number	Recent avg TN load at HUC8 outlet (MT/yr)	Final goal TN load at HUC8 outlet (MT/yr)	TN Load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total HUC8 loads)
Mississippi River - Headwaters	07010101	267	255	12	4%
Leech Lake River	07010102	122	115	7	6%
Mississippi R. - Grand Rapids	07010103	1,265	1,041	224	18%
Mississippi River - Brainerd	07010104	744	564	179	24%
Pine River	07010105	214	210	4	2%
Crow Wing River	07010106	729	564	165	23%
Redeye River	07010107	682	400	281	41%
Long Prairie River	07010108	628	375	253	40%
Mississippi River - Sartell	07010201	1,390	925	465	33%
Sauk River	07010202	1,373	750	623	45%
Mississippi River - St. Cloud	07010203	1,217	860	357	29%
North Fork Crow River	07010204	1,073	632	441	41%
South Fork Crow River	07010205	3,322	1,726	1,596	48%
Mississippi River - Twin Cities	07010206	3,576	1,676	1,901	53%
Rum River	07010207	1,161	937	225	19%
Minnesota River - Headwaters	07020001	449	249	199	44%
Pomme de Terre River	07020002	623	338	285	46%
Lac Qui Parle River	07020003	946	475	471	50%
MN R. - Yellow Medicine River	07020004	4,906	2,500	2,405	49%
Chippewa River	07020005	1,369	691	679	50%
Redwood River	07020006	3,107	1,645	1,462	47%
Minnesota River - Mankato	07020007	4,975	2,551	2,424	49%
Cottonwood River	07020008	10,989	5,532	5,457	50%
Blue Earth River	07020009	14,825	7,391	7,434	50%
Watonwan River	07020010	6,903	3,512	3,391	49%
Le Sueur River	07020011	9,095	4,569	4,526	50%
Lower Minnesota River	07020012	8,086	4,297	3,789	47%
Upper St. Croix River	07030001	153	126	27	18%
Kettle River	07030003	280	220	60	21%
Snake River	07030004	875	597	277	32%
Lower St. Croix River	07030005	1,060	688	372	35%
Mississippi River - Lake Pepin	07040001	1,274	719	555	44%
Cannon River	07040002	4,400	2,221	2,179	50%
Mississippi River - Winona	07040003	1,443	813	630	44%
Zumbro River	07040004	7,764	3,960	3,804	49%

HUC8 Name	HUC8 Number	Recent avg TN load at HUC8 outlet (MT/yr)	Final goal TN load at HUC8 outlet (MT/yr)	TN Load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total HUC8 loads)
Mississippi River - La Crescent	07040006	150	100	49	33%
Root River	07040008	8,254	4,516	3,738	45%
Mississippi River - Reno	07060001	858	503	355	41%
Upper Iowa River	07060002	1,816	927	889	49%
Upper Big Sioux River	010170202	46	27	19	41%
Lower Big Sioux River	010170203	885	483	402	45%
Rock River	010170204	2,844	1,439	1,405	49%
Little Sioux River	010230003	1,202	609	593	49%
Upper Wapsipinicon River	07080102	77	40	37	48%
Cedar River	07080201	5,306	2,765	2,541	48%
Shell Rock River	07080202	1,746	877	869	50%
Winnebago River	07080203	527	261	267	51%
Des Moines R. - Headwaters	07100001	978	484	495	51%
Lower Des Moines River	07100002	146	72	74	51%
East Fork Des Moines River	07100003	157	78	79	50%

Table 4. Mississippi River Basin HUC8 watershed TP load goal recommendations and the associated load reduction targets to meet the final 2040 NRS goals.

HUC8 Name	HUC8 Number	Recent avg TP load at HUC8 outlet (MT/yr)	Final TP load goal at HUC8 outlet (MT/yr)	TP load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Mississippi River - Headwaters	07010101	13	11	2	14%
Leech Lake River	07010102	6	6	1	9%
Mississippi River - Grand Rapids	07010103	45	39	6	14%
Mississippi River - Brainerd	07010104	148	120	28	19%
Pine River	07010105	7	7	1	11%
Crow Wing River	07010106	47	35	12	26%
Redeye River	07010107	31	20	11	36%
Long Prairie River	07010108	36	23	13	37%
Mississippi River - Sartell	07010201	130	85	45	35%
Sauk River	07010202	74	43	31	42%
Mississippi River - St. Cloud	07010203	72	45	27	38%
North Fork Crow River	07010204	91	51	40	44%
South Fork Crow River	07010205	144	80	64	45%

HUC8 Name	HUC8 Number	Recent avg TP load at HUC8 outlet (MT/yr)	Final TP load goal at HUC8 outlet (MT/yr)	TP load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Mississippi River - Twin Cities	07010206	1,365	774	592	43%
Rum River	07010207	67	47	20	30%
Minnesota River - Headwaters	07020001	57	36	21	37%
Pomme de Terre River	07020002	54	31	23	43%
Lac Qui Parle River	07020003	74	41	34	45%
Minn. R. - Yellow Medicine River	07020004	266	151	115	43%
Chippewa River	07020005	68	37	31	45%
Redwood River	07020006	91	52	39	43%
Minnesota River - Mankato	07020007	188	105	83	44%
Cottonwood River	07020008	308	170	138	45%
Blue Earth River	07020009	235	144	91	39%
Watonwan River	07020010	134	74	60	45%
Le Sueur River	07020011	292	160	131	45%
Lower Minnesota River	07020012	342	204	138	40%
Upper St. Croix River	07030001	17	13	4	23%
Kettle River	07030003	32	24	9	26%
Snake River	07030004	62	42	20	32%
Lower St. Croix River	07030005	86	54	31	36%
Mississippi River - Lake Pepin	07040001	155	90	65	42%
Cannon River	07040002	311	210	100	32%
Mississippi River - Winona	07040003	110	67	43	39%
Zumbro River	07040004	383	225	158	41%
Mississippi River - La Crescent	07040006	11	7	4	33%
Root River	07040008	412	244	168	41%
Mississippi River - Reno	07060001	79	50	29	37%
Upper Iowa River	07060002	79	44	35	45%
Upper Big Sioux River	010170202	2	1	1	41%
Lower Big Sioux River	010170203	38	22	17	43%
Rock River	010170204	70	39	31	44%
Little Sioux River	010230003	46	26	20	44%
Upper Wapsipinicon River	07080102	2	1	1	44%
Cedar River	07080201	78	44	34	44%
Shell Rock River	07080202	54	34	21	38%
Winnebago River	07080203	9	5	3	38%
Des Moines River - Headwaters	07100001	77	44	33	43%
Lower Des Moines River	07100002	5	3	2	46%
East Fork Des Moines River	07100003	8	5	3	42%

Table 5. Red River Basin HUC8 Watershed TN load goals and associated load reductions needed to meet the final Red River goals for Minnesota.

HUC8 Name (Red River Basin)	HUC8 Number	Recent TN load at HUC8 outlet (MT/yr)	Final TN load goal at HUC8 outlet (MT/yr)	TN load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Bois de Sioux River	09020101	677	278	398	59%
Mustinka River	09020102	433	182	251	58%
Otter Tail River	09020103	862	573	289	34%
Upper Red River of the North	09020104	1,061	423	638	60%
Buffalo River	09020106	769	337	432	56%
RRN - Marsh River	09020107	147	62	84	58%
Wild Rice River	09020108	411	242	169	41%
RRN - Sandhill River	09020301	263	125	138	53%
Upper/Lower Red Lake	09020302	97	90	7	7%
Red Lake River	09020303	764	362	402	53%
Thief River	09020304	653	387	266	41%
Clearwater River	09020305	520	299	220	42%
RRN - Grand Marais Creek	09020306	473	210	264	56%
Snake River (Red)	09020309	675	274	401	59%
RRN - Tamarac River	09020311	527	239	288	55%
Two Rivers	09020312	765	339	426	56%
Roseau River	09020314	262	151	111	42%

RRN = Red River of the North

Table 6. Red River Basin HUC8 watershed TP load goals and associated load reductions needed to meet Minnesota's part of the final Red River goals.

HUC8 Name (Red River Basin)	HUC8 Number	Recent TP load at HUC8 outlet (MT/yr)	Final TP load goal at HUC8 outlet (MT/yr)	TP load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Bois de Sioux River	09020101	69	31	38	55%
Mustinka River	09020102	50	23	27	54%
Otter Tail River	09020103	64	41	22	35%
Upper Red River of the North	09020104	258	111	147	57%
Buffalo River	09020106	85	41	43	51%
RRN - Marsh River	09020107	25	11	14	55%
Wild Rice River	09020108	84	43	40	48%
RRN - Sandhill River	09020301	24	12	13	52%
Upper/Lower Red Lake	09020302	5	4	0	10%
Red Lake River	09020303	85	44	40	48%
Thief River	09020304	43	26	17	39%
Clearwater River	09020305	36	19	17	46%
RRN - Grand Marais Creek	09020306	78	38	40	51%
Snake River (Red)	09020309	87	39	47	55%
RRN - Tamarac River	09020311	69	32	37	53%
Two Rivers	09020312	79	38	41	52%
Roseau River	09020314	41	24	17	41%

RRN = Red River of the North

Table 7. Lake Superior Basin HUC8 TN recent modeled loads. These loads represent an average recent load to serve as an upper boundary for long-term load averages.

HUC8 Name (Red River Basin)	HUC8 Number	Recent TN load at HUC8 outlet (MT/yr)	Final TN load goal at HUC8 outlet (MT/yr)	TN load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Lake Superior North	04010101	1,482	1,481	1	0.1%
Lake Superior South	04010102	503	501	1	0.3%
St. Louis	04010201	2,218	2,210	8	0.4%
Cloquet River	04010202	362	361	0.2	0.05%
Nemadji River	04010301	140	139	0.3	0.2%

Table 8. Lake Superior Basin HUC8 TP recent modeled loads and load reduction needs to meet NRS goals.

HUC8 Name (Lake Superior Basin)	HUC8 Number	Recent TP load at HUC8 outlet (MT/yr)	Final TP load goal at HUC8 outlet (MT/yr)	TP load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Lake Superior North	04010101	50	50	0	0%
Lake Superior South	04010102	34	34	0	0%
St. Louis	04010201	91	91	0	0%
Cloquet River	04010202	14	14	0	0%
Nemadji River	04010301	59	59	0	0%

Table 9. Rainy River Basin HUC8 TP recent modeled loads and load reduction needs to meet NRS goals that are consisted with the Lake of the Woods TMDL.

HUC8 Name (Red River Basin)	HUC8 Number	Recent TP load at HUC8 outlet (MT/yr)	Final TP load goal at HUC8 outlet (MT/yr)	TP load reduction at HUC8 outlet to meet final goal (MT/yr)	Percent Reduction Target (from recent total loads)
Rainy River - Headwaters	09030001	26	25	0.3	1%
Vermilion River	09030002	14	14	0.4	3%
Rainy River - Rainy Lake	09030003	21	21	0.3	1%
Little Fork River	09030005	76	74	2	2%
Big Fork River	09030006	49	48	1	2%
Rapid River	09030007	20	20	0	1%
Rainy River - Baudette	09030008	51	44	7	14%
Lake of the Woods	09030009	10	9	1	7%

Best management practice scenarios to achieve watershed nutrient load reductions

Understanding the needed nutrient load reduction amounts for downstream waters will help us ultimately estimate the levels of rural and urban best management practice (BMP) adoption needed to achieve those reductions. When natural resource managers periodically reconsider their local watershed goals, priorities, strategies, and plans, the above nutrient reduction planning targets should be considered. For example, consider the following:

- How do watershed nutrient load reductions for downstream needs compare with the sum of local load reduction needs to address priority waters within the watershed?
- How can these load goals for downstream waters be used to set planning goals for HUC8 outlets (milestones and final goals)?
- How do these numbers inform the long-term vision for land-cover changes in the watershed and adoption of other BMPs?

Minnesota's NRS includes basin-wide BMP adoption scenario examples that will meet milestone goals. The strategy also encourages each HUC8 watershed to evaluate the suite of practices and acreages that will achieve the load reduction planning goals for downstream water. In many areas of the state, the acreage of new practices needed for downstream nutrient reduction needs will exceed the sum of those implemented for local nutrient reduction needs. Consider the following suggestions when developing watershed nutrient reduction BMP scenarios:

Set milestones - Break up large daunting goals into milestones or interim targets and focus initially on achieving the first milestone.

Don't get hung up on developing the 'perfect' scenario - Strategy scenarios are meant to provide reasonable expectations of new BMP adoption scales to generally move efforts in the right direction. Scenarios of BMP combinations should identify the key practices and the general magnitude of new BMP adoption needed for each practice, considering both point and nonpoint sources. Strategy scenarios will never be exact or perfect, and multiple combinations of practices can achieve similar nutrient reduction goals at the HUC8 watershed scale. Also, long-term strategies will need to be adapted over time to reflect new research and monitoring, climate trends, land-use trends, social norms, and more.

Consider BMP acceptance in your area - For the short-term, choose practices based partly on the likelihood of practice acceptance in your region. For the long-term, also consider BMPs that are less popular now, but that may become more acceptable after technology, research, and education are advanced.

Do not conflict with regulatory requirements - The NRS and its voluntary goals do not supersede existing regulatory requirements.

Emphasize multiple benefits – When selecting BMP scenarios related to rural sources, first consider in-field BMPs to build soil health, maintain soil cover, optimize fertilizer use, and reduce drinking water nitrate levels. These practices will result in multiple ecosystem benefits. Then, as needed, continue by adding edge-of-field and in-channel practices, especially those that can achieve priority co-benefits to water, air, wildlife, and/or agriculture.

Identify strategies for broad adoption –Often, conservation practices are targeted in small priority areas to efficiently prevent phosphorus and sediment from entering waters. To achieve downstream nutrient reduction goals, local strategies should additionally consider broad adoption of in-field practices (i.e. precision nutrient applications, cover crops and conservation crop rotations).

Use estimates of nutrient load reductions to waters instead of reductions at the field-edge – Nutrient reduction amounts from BMPs at the field edge will often be quite different compared to effects measured at watershed outlets. For example, a BMP may reduce phosphorus at the field edge by 1 lb/acre, but the reduction effects measured at the end of the watershed may only be 0.1 lb/acre, or less. The planning targets in Tables 3-9 are equated to nutrient load reductions needed in the river (at the HUC8 watershed outlet). Therefore, when assessing the effects of BMPs to meet these planning targets, use tools that provide estimates at the watershed outlet.

In summary

While many major watersheds have nutrient-impacted waters locally, often the nutrient reduction needs are greater downstream than the sum of the needs at the local level. Watershed Strategies and subsequent long-term planning work should be developed to not only address the goal of protecting and restoring water resources within the watershed, but to also collectively achieve pollutant load reductions needed for downstream waters (in-state and out-of-state goals for the Mississippi River, Lake Pepin, Gulf of Mexico, Lake Winnipeg, Lake of the Woods, etc.).

Estimates of watershed nutrient load reduction planning targets for meeting downstream water needs were developed for each HUC8 watershed in Minnesota. These voluntary planning goals were set equitably, such that each HUC8 within a major river basin would reduce a similar fraction of its anthropogenic (reducible) nutrient loads. In aggregate, achieving the watershed reductions would enable Minnesota to meet NRS goals, while also addressing many local nutrient goals in lakes and streams within the HUC8 watersheds. These targets should be considered when watersheds re-evaluate their needs, goals, strategies, priorities and plans. In many cases, broad application of in-field BMPs will be needed to achieve the long-term goals for downstream waters.

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Schlea, D., Holmberg H., and Crary, B. 2020. Updating Nutrient Reduction Strategy to Strengthen Linkages with Watersheds and WRAPS. LimnoTech completion report to MPCA May 4, 2020, for contract number 145416.

Watershed nutrient loads

December 2024

Attachment A

Approach and Methods for the interim guidance, “Watershed Nutrient Loads to Accomplish Minnesota’s Nutrient Reduction Strategy Goals”

MINNESOTA POLLUTION CONTROL AGENCY

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This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: wq-s1-86a

Contributors

Attachment A is based largely on the work and writings of Derek Schlea, Hans Holmberg and Ben Crary of LimnoTech conveyed to the MPCA in a memo entitled "Updating Nutrient Reduction Strategy to Strengthen Linkages with Watersheds and WRAPS." Additions and edits were completed by Dave Wall (MPCA), and maps were developed by Ashley Ignatius (MPCA). Attachment A was updated in 2024 based on technical work performed by Tetra Tech.

Attachment A

Approach and Methods for the interim guidance, "Watershed Nutrient Loads to Accomplish Minnesota's Nutrient Reduction Strategy Goals"

Purpose:

This Attachment includes the detailed methods and results associated with the process of determining nutrient load targets and planning goals for the outlet of each HUC8 watershed in Minnesota, as described in "Watershed Nutrient Loads to Accomplish Minnesota's Nutrient Reduction Strategy Goals."

The methods and results for Minnesota's HUC8 nutrient reduction planning targets were described in a memorandum by Derek Schlea, Hans Holmberg and Ben Crary of LimnoTech (Schlea et al. 2020). The memorandum, entitled "Updating Nutrient Reduction Strategy to Strengthen Linkages with Watersheds and WRAPS," was completed in collaboration with the Minnesota Pollution Control Agency (MPCA). This attachment uses the work by Schlea et al. (2020) and was modified by MPCA to 1) extract the methods relevant to the interim guidance document; 2) supplement background information about baseline loads, 3) combine the Cedar, Des Moines and Missouri River Watersheds together with all other watersheds that ultimately drain to the Mississippi River, and 4) update nutrient load information from some watersheds that were recently re-modeled and correspondingly update statewide maps. In 2024, Tetra Tech updated this Attachment to incorporate recent revisions and extensions to Hydrologic Simulation Program – FORTRAN (HSPF) models and to use a new division of loads representing Minnesota and North Dakota contributions to the Red River of the North.

The methods described in this attachment are divided into four separate steps that led to the determination of load reduction planning targets for meeting meet downstream needs.

Step 1 - Compile and compare recent monitoring and modeling load estimates
Step 2 - Estimate natural background or nonreducible nutrient loads
Step 3 - Estimate nutrient attenuation factors
Step 4 - Update nutrient reduction goals

The methods and results for each step are described below.

Step 1 - Compile and compare recent monitoring and modeling load estimates

Estimating load reductions needed to meet NRS goals first requires estimating “current day” TP and TN loads, often referred to as “recent” loads since they typically represent a ten-year average period that ended several years ago. Current day load estimates represent watershed conditions for the most recent years available when this task was conducted. For the purposes of this project, current day load estimates for individual HUC8 watersheds were developed to address the following constraints:

- The Minnesota-only portion of the drainage area (i.e., exclude loading from Canada and other states);
- The local HUC8 loading contribution (i.e., not cumulative for HUC8s with one or more HUC8 watersheds draining into it);
- The total HUC8 loading contribution (i.e., combine all loads for HUC8 watersheds with multiple outlets); and
- The HUC8 loading at the watershed outlet(s) or the point(s) at which rivers last leave the state (i.e., account for internal nutrient attenuation of loads to the receiving stream within a HUC8 watershed).

In 2019, LimnoTech compiled TP and TN load estimates from Minnesota’s Watershed Pollutant Load Monitoring Network (WPLMN), MPCA’s HSPF models, and the USGS SPARROW model. They compared average annual load predictions for HUC8 watersheds where multiple load estimates existed. The purpose of these comparisons was to evaluate each approach for potential use in deriving statewide, current day load estimates for the updated nutrient reduction calculations. This section describes the comparison of the three load estimation approaches and the additional processing of HSPF load estimates to address the constraints listed above.

Basin and Watershed Scale Comparisons

LimnoTech compared TP and TN load estimates from WPLMN, HSPF, and SPARROW to evaluate similarities and differences between the data-based and model-based estimation approaches. The WPLMN characterizes monitoring sites along the mainstems of the Mississippi, Minnesota, Rainy, Red, Cedar, Des Moines, and St. Croix rivers as “basin” scale sites. HSPF models of the mainstem Red and St. Croix rivers were not available, so comparisons were not completed for the basin scale sites on these waterbodies. For the purposes of the basin scale load comparison analysis, the St. Louis River monitoring site at Scanlon was added as a representative location for the Lake Superior basin. The WPLMN characterizes “major watershed” scale monitoring sites as those with a drainage area of approximately 1,350 square miles. The subset of the WPLMN watershed scale sites best corresponding to HUC8 watershed outlets as represented in the HSPF models were compared below.

LimnoTech compared TP and TN load estimates from WPLMN, HSPF, and SPARROW to evaluate similarities and differences between the data-based and model-based estimation approaches. The WPLMN characterizes monitoring sites along the mainstems of the Mississippi, Minnesota, Rainy, Red, Cedar, Des Moines, and St. Croix rivers as “basin” scale sites. HSPF models of the mainstem Red and St. Croix rivers were not available, so comparisons were not completed for the basin scale sites on these waterbodies. For the purposes of the basin scale load comparison analysis, the St. Louis River monitoring site at Scanlon was added as a representative location for the Lake Superior basin. The WPLMN characterizes “major watershed” scale monitoring sites as those with a drainage area of approximately 1,350 square miles. The subset of the WPLMN watershed scale sites best corresponding to HUC8 watershed outlets as represented in the HSPF models were compared below. Results of the basin scale comparisons are shown in Tables 1 and 2. The averaging period is also presented in the tables. These were based on the maximum overlap between the WPLMN information and HSPF model results. The SPARROW model was developed with source inputs and management practices corresponding to a base year of 2012, represents long-term average loads for 1999-2014, and was calibrated with monitoring sites throughout the entire Midwest (Robertson and Saad, 2019). Therefore, output from SPARROW represents a slightly different time period than that from WPLMN and HSPF. For TP, the HSPF load estimates were closer with the WPLMN estimates for most sites as compared to SPARROW, with one notable exception for the Rainy River. The largest relative differences between HSPF and WPLMN were for the Cedar River and Des Moines River sites. Of the basin scale sites evaluated, the SPARROW TP load estimates for the Des Moines River were closer to the WPLMN estimates than the HSPF estimates. Both HSPF and SPARROW TN load estimates were in relatively good agreement with the WPLMN estimates at all basin scale sites evaluated. The largest deviations for the HSPF-based TN estimates relative to the WPLMN values were for the Rainy River (32% lower) and the Des Moines River (18% higher).

Results of the watershed scale comparisons are shown in Figures 1 and 2. Similar to the basin scale results for TP, the HSPF watershed scale load estimates were generally in good agreement for most sites with the WPLMN estimates, while the SPARROW TP load estimates tended to be higher (overall). The watershed scale comparison for TN showed good agreement across all three load estimation approaches, which was the same finding as the basin scale comparison.

Based on these comparisons, LimnoTech and MPCA determined that use of the HSPF results to characterize current day loads was most advantageous for the following reasons:

- HSPF models have been calibrated closely to the same data used in WPLMN. As a result, HSPF and WPLMN estimates of current day TP loads compare more closely than SPARROW and WPLMN;
- HSPF models predict daily values based on inputs such as precipitation, while WPLMN estimates extrapolate between observed data points;
- HSPF models have been developed and calibrated at the HUC8 scale, or finer, for time periods ranging 1996-2016. The SPARROW model was developed from statistical relationships developed over much larger areas and calibrated to the 1999-2014 period, and therefore provides different results from HSPF, particularly at the HUC8 scale; and
- HSPF models have been developed to cover a vast majority of the 81 HUC8s in Minnesota, WPLMN estimates do not cover as many HUC8s.

Table 1: Comparison of WPLMN, HSPF, and SPARROW estimated annual average TP loads for nine basin scale sites in Minnesota

WPLMN Station	Averaging Period (WPLMN and HSPF)	TP (metric tons per year)		
		WPLMN	HSPF	SPARROW
Minnesota River at St. Peter	2007-2012	1,503	1,462	2,484
Minnesota River near Jordan [1]	2007-2012	1,609	1,609	2,752
Minnesota River at Fort Snelling [1]	2007-2012	1,609	1,710	3,000
Mississippi River near Royalton	2007-2011,2014-2015	257	257	495
Mississippi River at Sauk Rapids	2007-2011,2014-2015	320	319	644
Rainy River at Manitou Rapids	2010-2014	383	290	164
St. Louis River at Scanlon	2009-2011,2014	88	80	179
Cedar River near Austin	2008-2011	115	77	233
W. Fork Des Moines River at Jackson	2007-2011,2014	150	286	235

1 – The Minnesota River near Jordan WPLMN and HSPF and Minnesota River at Fort Snelling WPLMN TP loads were all 1,609 MT for this averaging period, when rounded to the nearest whole number.

Table 2: Comparison of WPLMN, HSPF, and SPARROW estimated annual average TN loads for nine basin scale sites in Minnesota

WPLMN Station	Averaging Period (WPLMN and HSPF)	TN (metric tons per year)		
		WPLMN	HSPF	SPARROW
Minnesota River at St. Peter	2007-2012	41,543	41,339	38,477
Minnesota River near Jordan	2007-2012	51,464	45,406	42,855
Minnesota River at Fort Snelling	2007-2012	50,978	47,136	44,943
Mississippi River near Royalton	2007-2015	5,498	5,146	4,835
Mississippi River at Sauk Rapids	2007-2015	6,206	6,133	6,421
Rainy River at Manitou Rapids	2010-2014	8,513	5,778	6,436
St. Louis River at Scanlon	2009-2014	2,279	2,147	1,665
Cedar River near Austin	2008-2012	2,881	2,658	2,704
W. Fork Des Moines River at Jackson	2007-2014	3,698	4,361	3,055

Figure 1: Scatterplot comparison of HSPF and SPARROW vs. WPLMN estimated annual average TP loads for watershed scale sites in Minnesota

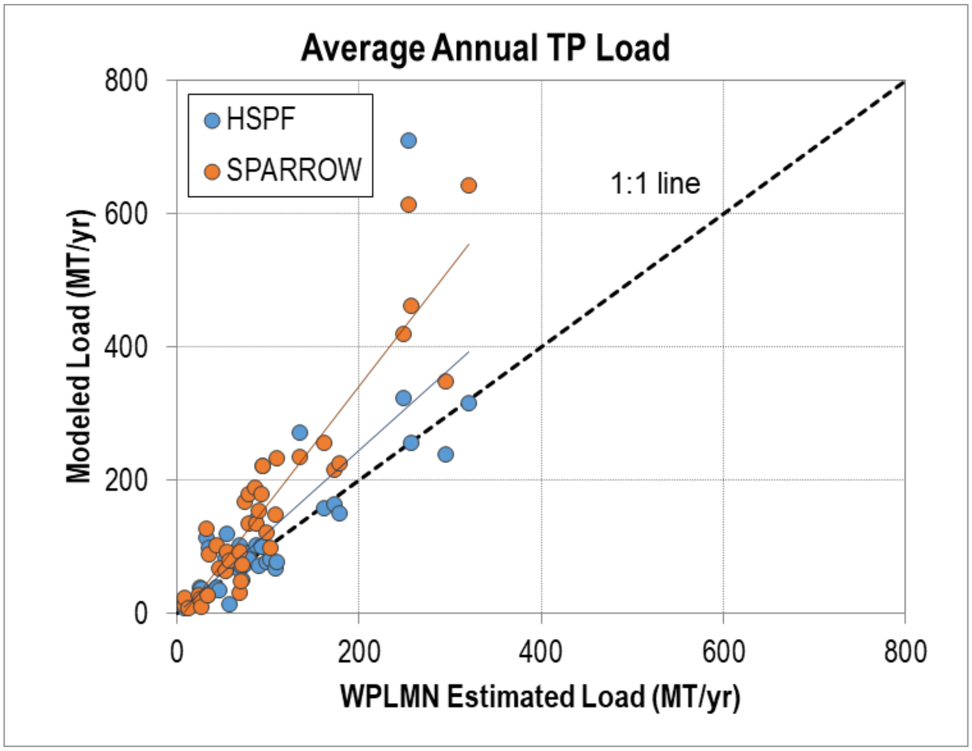
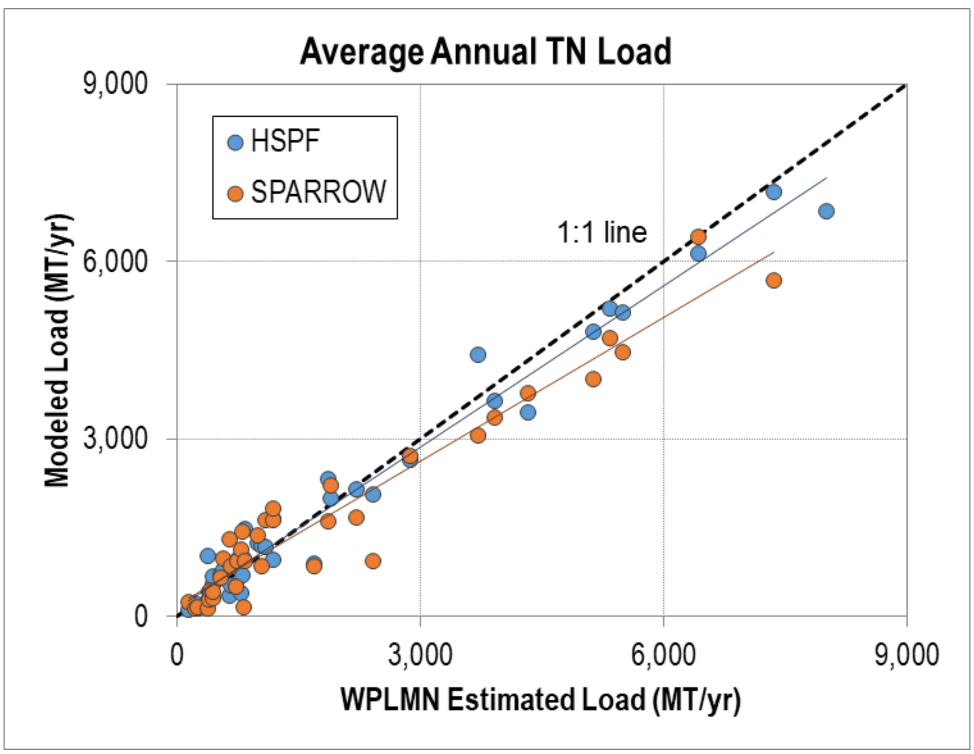


Figure 2: Scatterplot comparison of HSPF and SPARROW vs. WPLMN estimated annual average TN loads for watershed scale sites in Minnesota



HSPF Load Processing

Various processing steps were implemented to convert several of the HSPF annual load estimates provided to LimnoTech by MPCA into the current day load estimates needed for the updated nutrient reduction calculations. First, average annual loads were computed for the most recent 10-year period simulated by each model. A 10-year period was chosen to average the impact of relatively wet or dry years or periods. The last 10 years was chosen rather than the entire simulation period to account for any reductions in point sources and other loading changes that have occurred in recent years.

Meeting the requirements of the constraints previously listed required additional processing of the HSPF load estimates provided to LimnoTech, which included one or more of the complexities listed in Table 3. By addressing the complexities of the HSPF models using the solutions listed in Table 3, we were able to develop current day load estimates for each HUC8 watershed with an existing HSPF model and accommodate the constraints previously listed. Where HSPF models were not available at the time this task was completed in 2019, we filled the gaps by using WPLMN-based TP and TN yield estimates for monitoring locations within the HUC8 watershed or in neighboring watersheds.

Table 3: HSPF load estimate complexities, applied solutions, and applicable watersheds.

Complexity	Solution(s)	Applicable Watershed(s)
Loading includes non-Minnesota drainage areas	Use HSPF-SAM subbasin scale delivered loading and Minnesota-fraction of each subbasin to estimate Minnesota-only loading	Multiple watersheds in the Rainy, Red, St. Croix, Cedar, Des Moines, Iowa, Missouri, and Minnesota river basins
Multiple HUC8 watersheds represented in a single HSPF model	Use HSPF-SAM to estimate loading for outlet reaches not provided	Rainy River (Upper Rainy, Lower Rainy, and Rapid)
Watershed/model has multiple outlet points	Use HSPF-SAM to estimate loading for outlet reaches not provided	Lake Superior North, Lake Superior South, Chippewa, and Tamarac
Watershed/model has one or more HUC8 watersheds upstream	Use HSPF-SAM to estimate proportion of HUC8 outlet loading attributable to upstream boundaries	Crow Wing, North Fork Crow, Blue Earth, Red Lake River, Bois de Sioux, Lower West Fork Des Moines, Mississippi and Minnesota river mainstem HUC8s

Since the initial analysis by LimnoTech, MPCA and its contractors extended the model simulation period and improved model performance through calibration refinements in approximately 20 HSPF watershed models . In 2024, RESPEC computed average annual loads by HUC12 outlet reach by source for the most recent 10-year period simulated in each model and provided the results to Tetra Tech for further analysis. Tetra Tech used a geographic information system (GIS) to determine the relative area within Minnesota for each HUC12 bisected by the state boundary. The fraction of relative area was then applied to the average annual loads of the HUC12 outlet reaches to determine the Minnesota-only loading. Because RESPEC provided simulated loads at HUC12 outlet reaches and because Tetra Tech used GIS to determine Minnesota-only loads, the HSPF-SAM operations presented in Table 3 were not necessary in the 2024 update for this Attachment.

The 10-most recent years in many models do not coincide with the most recent decade (2014-2023). As is discussed in Minnesota’s NRS, best management practices and other nutrient-reducing actions have increased across the state since Minnesota’s 2014 NRS. Unfortunately, the models with older simulation periods will not reflect the most recent, on-the-ground implementation activities that have reduced nutrient loading.

Finally, it is important to note that the HSPF model loads for each HUC8 are different from the long-term monitoring reported for key locations (e.g., Red River of the North at Emerson, Manitoba) that are presented throughout Minnesota's Nutrient Reduction Strategy. While the HSPF models are calibrated to monitoring results, the modeling and monitoring datasets are two different datasets.

Step 2 - Estimate natural background or nonreducible nutrient loads

In Step 1, LimnoTech developed an estimate of natural nutrient loading for each HUC8 watershed. The primary purpose of this analysis was to inform adjustments to nutrient reduction goals by distinguishing reducible and nonreducible load sources, emphasizing reduction goals based on the reducible fraction. Several approaches to quantifying natural nutrient loading were reviewed over the course of this study (Table 4). The paleolimnological studies of Engstrom et al. (2000) and Edlund et al. (2009) were limited in that they only estimated TP, not TN, and they were only representative of a portion of Minnesota. The statistical-based approach of estimating natural background nutrient yields based on major ecoregion (Smith et al., 2003) resulted in background load estimates for several HUC8 watersheds that were substantially higher than the current day load estimated by HSPF and WPLMN. The SPARROW model-based estimates were considered the best alternative methodology but did not explicitly account for natural background sources of TN (Robertson and Saad, 2019). Therefore, LimnoTech chose to use the 10-year average HSPF model predicted TP and TN loading contributions attributable to various source categories for individual HUC8 watersheds using the approach described in the next section.

What could potentially be considered as nonreducible loads of TP and TN may result from the following (MPCA, 2018):

- Surface runoff from the natural landscape;
- Background stream channel erosion;
- Groundwater discharge from the natural landscape; and
- Atmospheric deposition, including windblown particulate matter from the natural landscape.

Internal loads of TP and TN from nutrient cycling in lakes and reservoirs can be from both natural sources and anthropogenic sources and, therefore, portions of the load considered either reducible or nonreducible.

Table 4: Potential approaches investigated for possible use in estimating natural or non-reducible nutrient loading

Approach	Description	Reference(s)
Paleolimnological / mass balance studies	Studies by the St. Croix Watershed Research Station estimating historical nutrient flux into and out of major Minnesota water bodies	Engstrom et al. (2000) Edlund et al. (2009)
Statistical	National data synthesis studies estimating TP and TN yields by ecoregion using land-based characteristics	Smith et al. (2003)
SPARROW model-based estimates	Data-driven, empirical approach for estimating TP and TN loading contributions from 5 or 6 major categories	Robertson and Saad (2019)
HSPF model-based estimates	HUC8 watershed models developed and calibrated with TP and TN load apportionment capabilities to point source and various non-point source categories	MPCA (2014)

Reducible Load Estimates – Approach

Estimating reducible and nonreducible load fractions from the HSPF models involved a number of steps. First, in 2019, the HSPEXP+ software was used to export modeled TP and TN loads for various point source and nonpoint source categories for every model subbasin, averaged for the last 10 years of the model simulation period. The modeled TP and TN loads used for this subtask represent the gross nutrient loading into the receiving waters within a watershed, rather than the loads making it to the watershed outlet. A 10-year period was chosen to average the impact of relatively wet or dry years or periods. The last 10 years was chosen rather than the entire simulation period to account for any reductions in point source loading that have occurred in recent years.

For the 2024 update, RESPEC computed average annual loads by source for the most recent 10-year period simulated in each model and provided the results to Tetra Tech for further analysis. The 68 HSPF models included 136 sources. As MPCA and its contractors updated the HSPF models over the past few years, some new sources were added, while other sources were eliminated.

Second, numerous nonpoint source categories were collapsed into a smaller group of common categories. Although all the Minnesota HSPF models were constructed in a relatively similar fashion with respect to representing landside, atmospheric, and point source loading categories, the development of land segments varied considerably across all models. The collapsing of original categories into common categories facilitated more uniform classification of landside loading into reducible or nonreducible sources across all models.

For the 2024 update, Tetra Tech collapsed the sources from the HSPF models into common categories similar to LimnoTech's previous analysis. These results are presented in Table 8. Tetra Tech explored a few different iterations of common categories, notably more specific agricultural and urban categories. Since the HSPF models were developed differently, MPCA concluded that fewer, broader common categories were more appropriate than more, specific common categories.

Third, after arriving at the common group of loading categories, an average yield for each category was calculated (for land-based sources). Initial attempts at defining reducible fractions for each category were completed by LimnoTech, and revisions were made after consultation with MPCA. Grassland yields were ultimately selected as a baseline for characterizing a nonreducible yield, and the reducible fraction of each category was assigned based on its relative difference from the average grassland yield (Table

5). If a category's average yield was less than the average grassland yield (0.14 lbs TP/acre/year and 2.9 lbs TN/acre/year), no reductions could reasonably be expected, and the reducible fraction was assigned as zero.

An example calculation is shown for the cropland TP reducible fraction:

$$Cropland\ TP\ reducible\ fraction = \frac{Cropland\ TP\ yield - Grassland\ TP\ yield}{Cropland\ TP\ Yield}$$

$$Cropland\ TP\ reducible\ fraction = \frac{0.68\frac{lbs}{acre} - 0.14\frac{lbs}{acre}}{0.68\ \frac{lbs}{acre}} = 80\%$$

MPCA determined that the HSPF source categories of atmospheric deposition, "groundwater" (as defined in the blue text box below), and septic systems would be considered part of the "nonreducible" category (i.e., 0% reducible fraction), while point sources were represented as 80% reducible and bed/bank erosion as 10% reducible.

Groundwater Source Category* versus *Groundwater Flow Pathway

Groundwater can be represented in two ways in the HSPF models. First, groundwater can be represented as a source category, like cultivated crops or grassland. Second, groundwater is one of three flow pathways for all land-based source categories.

Groundwater source category: The *groundwater source category* is included in 24 HSPF models, for flow and load tracking purposes specific to each model. The *groundwater source category* can represent diffuse flow and load that is not part of other source categories (i.e., a residual flow or load that is not accounted for elsewhere). As previously declared, *groundwater source category* is considered nonreducible.

Groundwater flow pathway: The groundwater flow pathway (i.e., baseflow) is one of three flow pathways for land-based source categories, where HSPF simulates flow and load across *surface flow*, *interflow*, and *groundwater flow*. The total flow and total load from all source categories is the summation of the *surface flow*, *interflow*, and *groundwater flow* pathways. The fair share load and reducible load analyses do not alter the *groundwater flow pathways* for all the source categories (i.e., non-reducibility does not apply to the *groundwater flow pathway*).

Nitrate is transported from agricultural fields (i.e., source categories) to surface waters via groundwater (i.e., the *groundwater flow pathway*). This is reducible because nitrates from the agricultural fields are reducible. Again, the groundwater non-reducibility does not apply to the *groundwater flow pathway* but instead only applies to the *groundwater source category* that was included in a subset of HSPF models for model-specific tracking purposes.

MPCA recognizes that although some categories were classified as >75% reducible, it may not be practical to reduce this much of the loading. These assignments were not meant in any way to suggest that these loads can or should be reduced by that quantity. Rather, the purpose of this analysis and the reducible fraction assignments was to inform the eventual updates to the nutrient reduction targets so that watersheds with a dominance of natural landscapes and relatively low nutrient loading do not receive the exact same percentage reduction targets as highly anthropogenic-influenced watersheds with elevated nutrient loading.

The final step involved multiplying each common loading category by its reducible fraction and then summing the individual gross nutrient loads across all subbasins and loading categories for each HUC8 watershed.

Table 5: New collapsed categories, area-weighted average annual yields, and reducible fraction assignments

Collapsed Categories	No. of original categories	Area-weighted Average Annual Yield		Assumed Reducible Fraction	
		TP (lbs/ac)	TN (lbs/ac)	TP	TN
Atmospheric deposition	1	n/a	n/a	0%	0%
Barren	1	0.27	3.7	49%	22%
Bed/Bank	1	n/a	n/a	10%	10%
Bluff/Ravine	1	1.63	3.5	92%	18%
Cropland	28	0.79	17.2	83%	83%
Cropland – Low Conservation/Tillage	11	0.56	13.1	76%	78%
Developed	17	0.33	6.2	59%	54%
Developed EIA	15	0.96	9.7	86%	70%
Feedlot	2	1.66	35.9	92%	92%
Forest	22	0.11	2.0	0%	0%
Grassland	17	0.14	2.9	0%	0%
Groundwater	1	n/a	n/a	0%	0%
Pasture	9	0.33	4.9	59%	42%
Point	1	n/a	n/a	80%	80%
Septic	1	n/a	n/a	0%	0%
Wetland	6	0.09	1.9	0%	0%

The chosen approach was slightly limited in that, at the time this task was completed in 2019, HSPF models were not available for the *Lower St. Croix River* and *Mississippi River-Twin Cities*, *-Lake Pepin*, *-Winona*, and *–La Crescent* HUC8 watersheds. An HSPF model was completed for a portion of the *Mississippi River-Lake Pepin* HUC8 area but excludes the Vermillion River watershed that drains a portion of St. Paul.

To estimate natural background nutrient loading for these HUC8 watersheds, an approach was developed and implemented that involved adjusting SPARROW model estimated natural background nutrient loading based on relationships developed for watersheds with both HSPF and SPARROW model estimates (Figures 3 and 4). As noted above, the SPARROW estimates for TN did not explicitly include natural background sources. For the purposes of developing the relationships shown below, LimnoTech used the SPARROW atmospheric deposition estimates for TN as a surrogate for natural background sources, acknowledging that the source category is elevated due to anthropogenic sources. SPARROW TN atmospheric deposition estimates for SPARROW can be broken down based on the USEPA Community Multiscale Air Quality modeling system it uses (Robertson and Saad, 2019), but this information was not available at the time this task was completed in 2019 by LimnoTech. This could potentially improve the correlations represented below.

Figure 3: Relationship between SPARROW model estimated and HSPF model estimated TP background fractions for Minnesota watersheds.

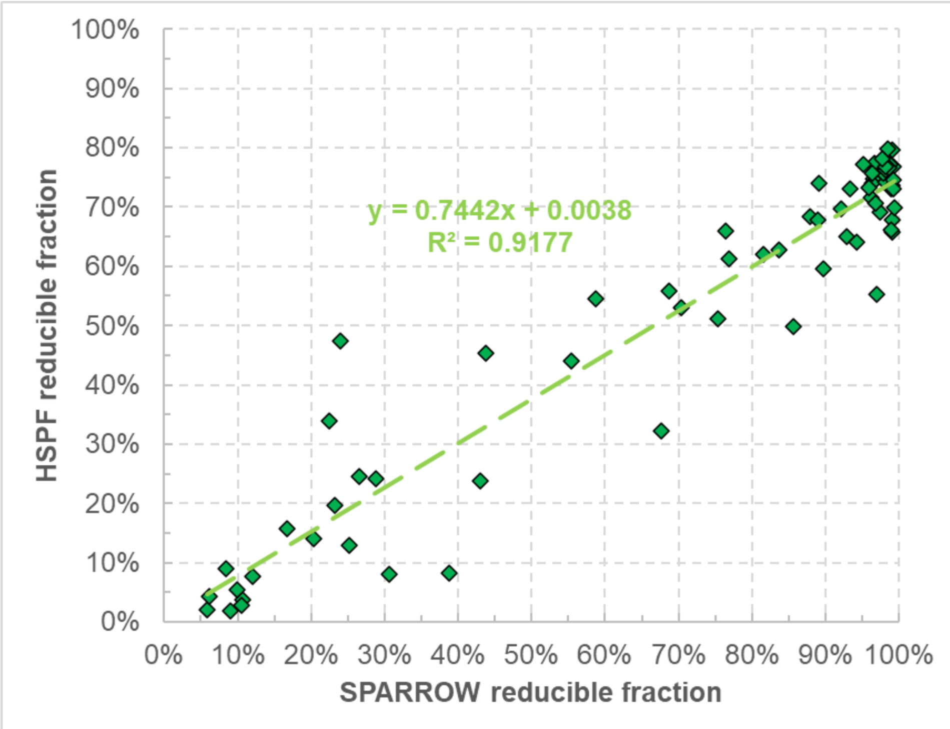
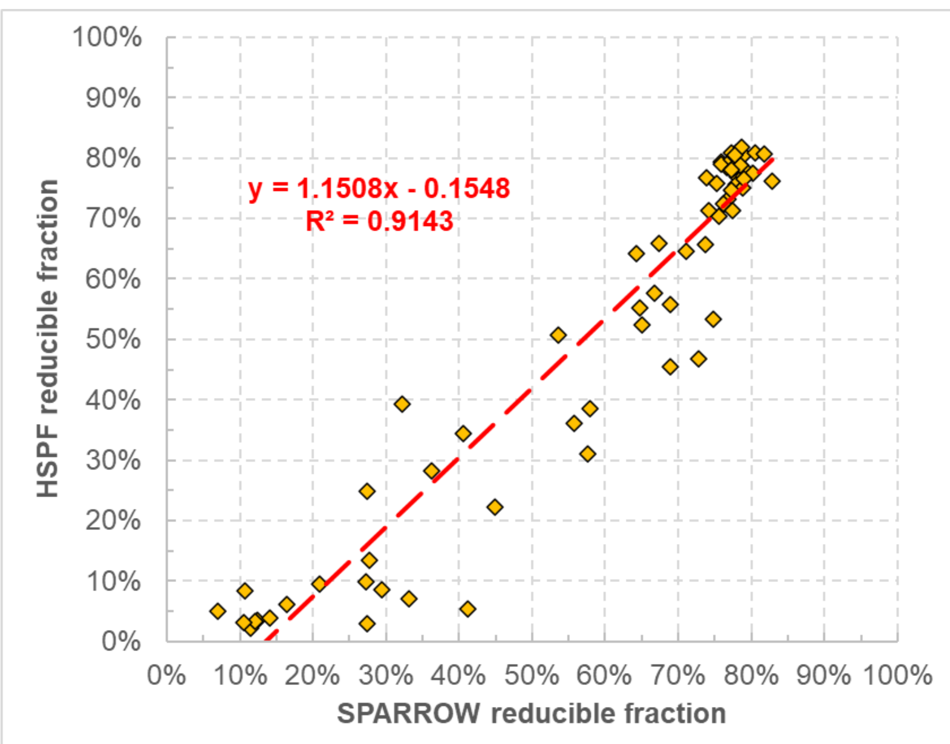


Figure 4: Relationship between SPARROW model estimated and HSPF model estimated TN background fractions for Minnesota watersheds.



Reducible Load Estimates – Results

The resulting TP and TN nonreducible load fractions for all HUC8 watersheds are shown in Figures 5 and 6, respectively. Both TP and TN nonreducible load fractions follow a spatial pattern that correlates strongly with land cover, with the highest values in the northeast quadrant of the state where forested lands and low human populations dominate. Areas with the lowest nonreducible load fractions are those with high human populations and those where agricultural land dominates the landscape.

Figure 5: Nonreducible TP load fractions for all HUC8 watersheds

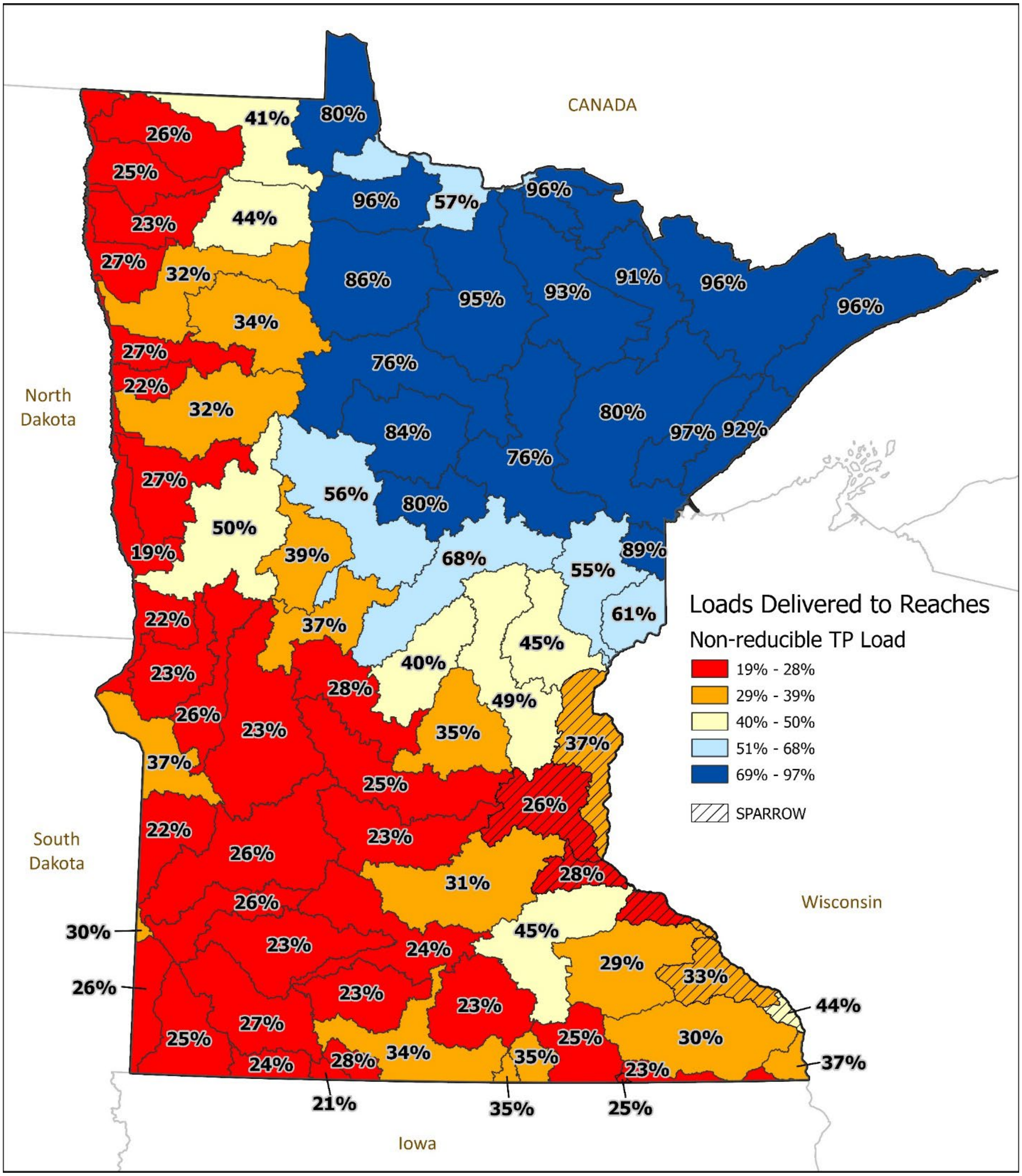
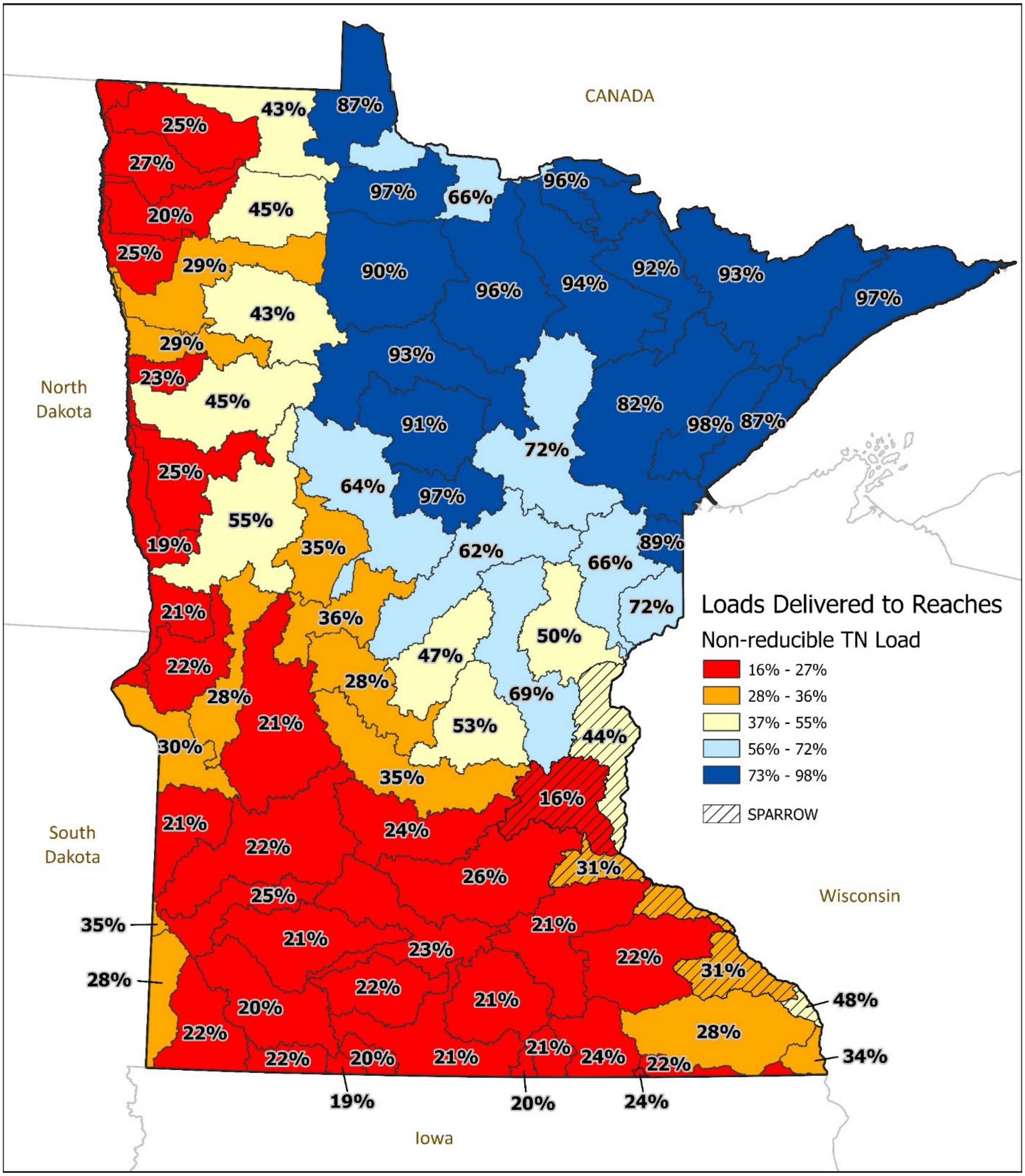


Figure 6: Nonreducible TN load fractions for all HUC8 watersheds



Step 3 - Estimate nutrient attenuation factors

Nutrients can attenuate as waters travel downstream in river networks through a combination of biotic processes such as uptake into aquatic, benthic, and riparian terrestrial biota, and through abiotic processes such as sedimentation. Most of these attenuation reactions can be considered as a form of storage, either into short-term reservoirs (e.g., short-lived plankton and riverbed sediment that gets resuspended with every storm) or long-term reservoirs (e.g., floodplain storage and reservoir sedimentation). Nutrients can either remain in storage, be reintroduced to surface waters via a variety of mechanisms or be permanently removed from the riverine system in the case of nitrogen release to the atmosphere via denitrification. For the purposes of quantifying average annual load delivery from HUC8 watershed outlets to downstream locations, all of these nutrient attenuation processes can be wrapped into an average annual net attenuation of the given nutrient.

Various approaches to quantifying nutrient attenuation were investigated over the course of this study (Table 6). The paleolimnological studies of Engstrom et al. (2000) and Edlund et al. (2009) were limited in that they only estimated TP, not TN, and they were only representative of a portion of Minnesota. The first-order decay based approaches require reach-by-reach estimates of mean annual water velocity, showed a very wide range of coefficients, and typically not applied to systems with large reservoirs or impoundments. The nutrient spiraling approach requires reach-by-reach estimates of mean channel width and also is typically not applied to systems with large reservoirs or impoundments. The SPARROW and HSPF based approaches were therefore determined to be most appropriate for the purposes of this effort.

Table 6: Potential approaches investigated for possible use in estimating nutrient attenuation

Approach	Description	Reference(s)
Paleolimnological / mass balance studies	Local studies estimating historical nutrient flux into and out of major Minnesota water bodies	Engstrom et al. (2000); Edlund et al. (2009)
First-order decay kinetics	Regional and national data synthesis studies estimating first-order nutrient attenuation coefficients over a large range of river reaches	Smith et al. (1997); Alexander et al. (2000); Smith et al. (2003); Moore et al. (2011); Haag et al. (2019, in prep.)
Nutrient spiraling derived uptake velocity	A scale-independent approach used in stream ecology to quantify nutrient uptake rates based on the theory of nutrient spiraling	Newbold et al. (1981); Newbold et al. (1983); Hall et. al. (2013); Gibson et al. (2015)
SPARROW model-based estimates	Data-driven, empirical approach for estimating TP and TN delivery ratios for any NHDPlus segment to a downstream endpoint	Robertson and Saad (2019)
HSPF model-based estimates	HUC8 watershed models developed and calibrated under Minnesota's One Water Program with in-stream nutrient cycling and transport simulation capabilities	MPCA (2014)

For consistency of using the same modeling platform for the current day load estimates and natural background estimates, LimnoTech and MPCA chose to use the long-term average nutrient delivery predicted by various HSPF models that simulate transport from multiple HUC8 watershed outlets through major riverine systems to downstream endpoints. This approach was limited, however, in that HSPF models were not available in 2019 for several major river systems including the Red River of the North, Lower St. Croix River, and Mississippi River from St. Cloud to the Iowa state line.

To estimate nutrient delivery for the river systems without an HSPF model, an approach was developed and implemented that involved adjusting SPARROW model estimated nutrient delivery where an HSPF model was not available based on relationships developed for rivers with both HSPF and SPARROW estimated nutrient delivery (Figures 7 and 8). The SPARROW estimated delivery fractions represent delivery from each catchment to the downstream endpoints of interest or "terminal" endpoints; the Gulf of Mexico, the Great Lakes, or the U.S./Canada border. In order to develop the relationships shown in Figures 8 and 9, computed the SPARROW delivery fractions to intermediate endpoints that overlap with the HSPF riverine models were needed. This was accomplished by dividing the SPARROW terminal delivery for the starting catchment by the SPARROW terminal delivery for the desired intermediate endpoint. Put simply, if the terminal delivery from point A to point C is 80%, and the terminal delivery from point B to point C is 90%, then the delivery from point A to point B is computed as 80%/90%, or 88.9%. Using an actual example, the SPARROW terminal TP delivery for the Watonwan River HUC8 outlet is 90.23% (to the Gulf of Mexico), and the SPARROW terminal TP delivery for the Lower Minnesota River HUC8 outlet is 90.76% (to the Gulf of Mexico), then the SPARROW TP delivery from the Watonwan HUC8 outlet to the Lower Minnesota HUC8 outlet is 99.42% (from 90.23%/90.76%). This and several other "intermediate" delivery fractions for areas of overlap between the HSPF and SPARROW models were then compared with the HSPF delivery to develop the relationships shown in Figures 7 and 8.

Table 7: Potential approaches investigated for possible use in estimating nutrient attenuation

Approach	Description	Reference(s)
Paleolimnological / mass balance studies	Local studies estimating historical nutrient flux into and out of major Minnesota water bodies	Engstrom et al. (2000); Edlund et al. (2009)
First-order decay kinetics	Regional and national data synthesis studies estimating first-order nutrient attenuation coefficients over a large range of river reaches	Smith et al. (1997); Alexander et al. (2000); Smith et al. (2003); Moore et al. (2011); Haag et al. (2019, in prep.)
Nutrient spiraling derived uptake velocity	A scale-independent approach used in stream ecology to quantify nutrient uptake rates based on the theory of nutrient spiraling	Newbold et al. (1981); Newbold et al. (1983); Hall et. al. (2013); Gibson et al. (2015)
SPARROW model-based estimates	Data-driven, empirical approach for estimating TP and TN delivery ratios for any NHDPlus segment to a downstream endpoint	Robertson and Saad (2019)
HSPF model-based estimates	HUC8 watershed models developed and calibrated under Minnesota's One Water Program with in-stream nutrient cycling and transport simulation capabilities	MPCA (2014)

Figure 7: Relationship between SPARROW model estimated and HSPF model estimated TP attenuation factors for major Minnesota rivers.

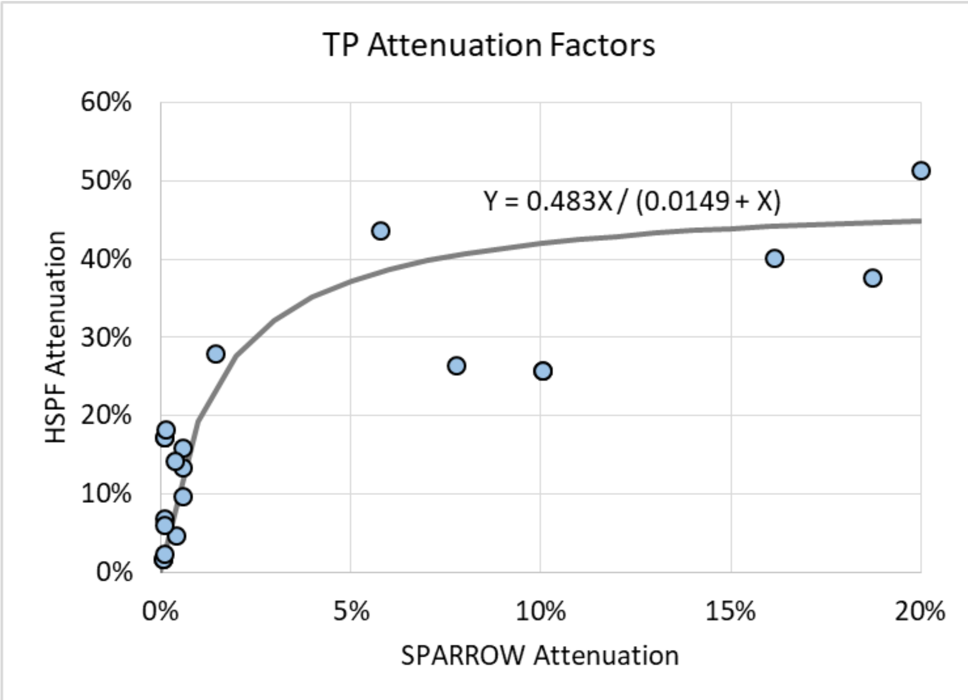
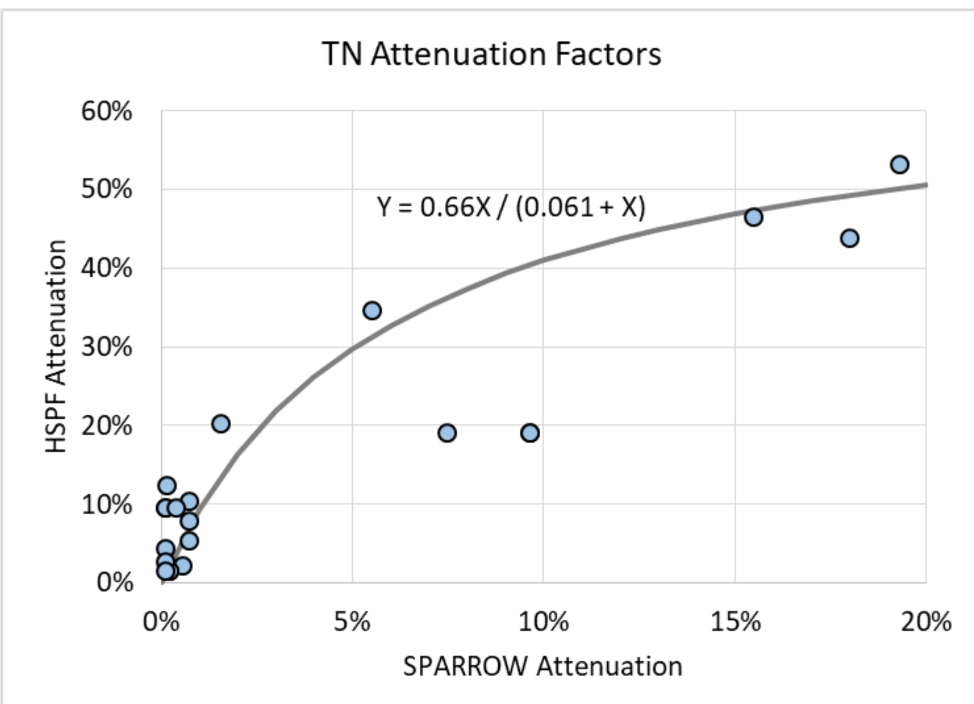


Figure 8: Relationship between SPARROW model estimated and HSPF model estimated TN attenuation factors for major Minnesota rivers.



The resulting TP and TN delivery ratios for all HUC8 watersheds to the most downstream endpoint evaluated are shown in Figures 9 and 10, respectively. The most downstream endpoints evaluated were the Red River at the US/Canada border, the Lake of the Woods inflow, Lake Superior, the Mississippi River at the Iowa border, or the Minnesota state line for the Cedar, Des Moines, and Missouri basin watersheds. HUC8 watersheds with delivery ratios of 1.00 (i.e., all TP and TN load leaving the HUC8 makes it to the downstream endpoint) include those where the HUC8 watershed intersects the downstream endpoint (i.e., the Minnesota state line) or discharges directly to the downstream endpoint. HUC8 watersheds with the lowest delivery ratios include those that have a long travel distance before reaching the downstream endpoint and/or those that discharge upstream of a major reservoir/impoundment.

Figure 9: TP delivery ratios for all HUC8 watershed outlets to the most downstream endpoint evaluated.

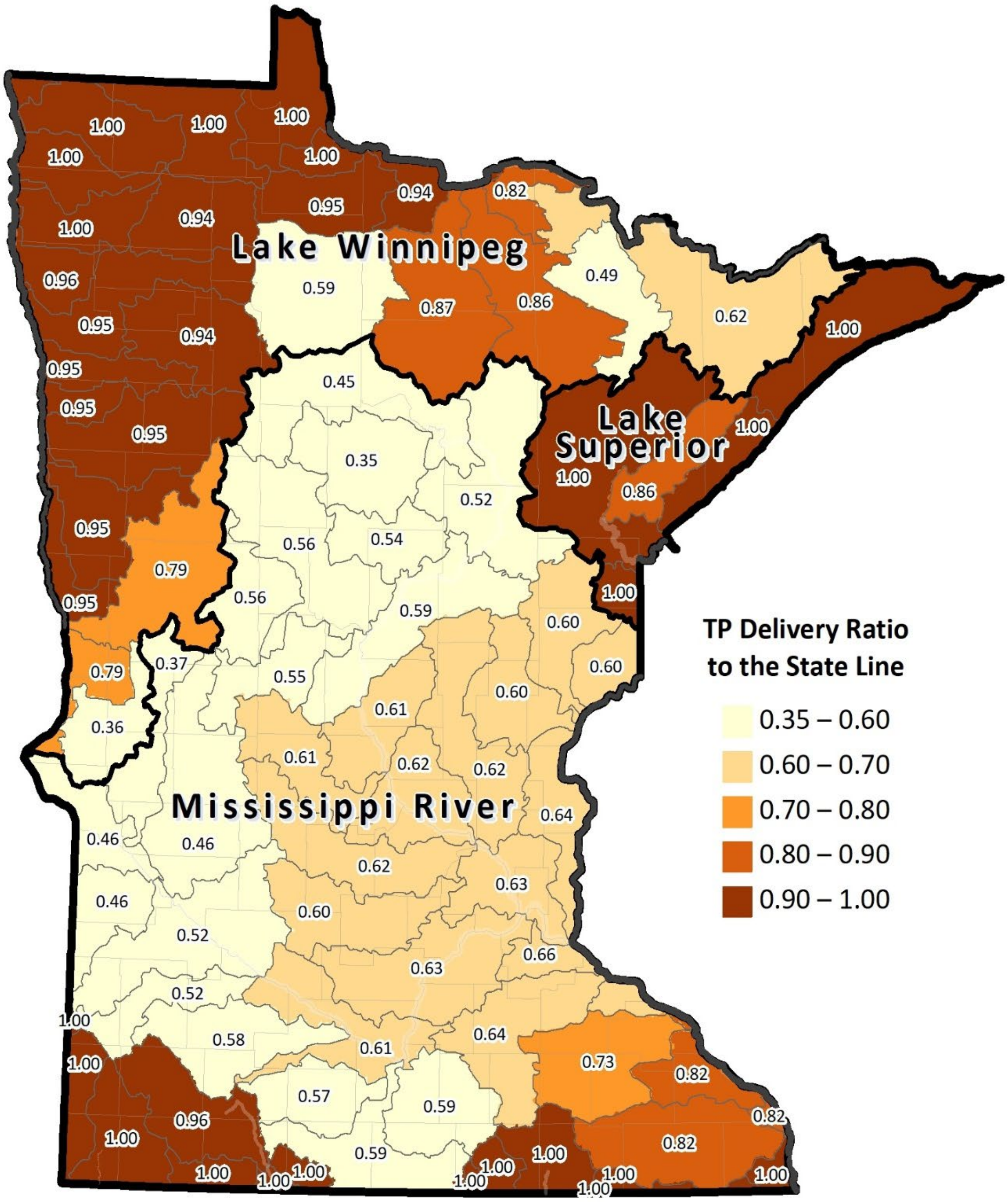
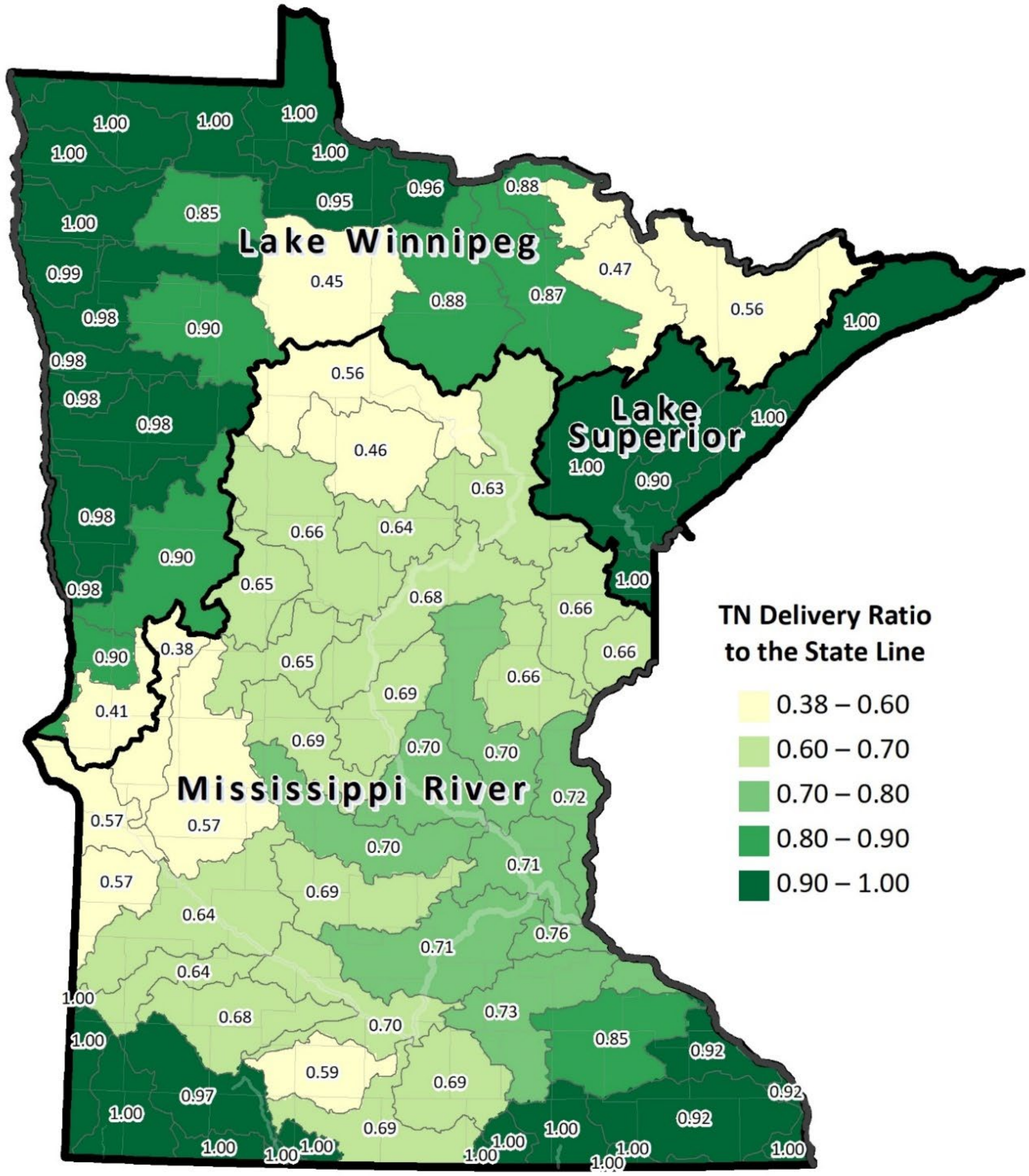


Figure 10: TN delivery ratios for all HUC8 watershed outlets to the most downstream endpoint evaluated.



Step 4 – Update nutrient reduction goals

The ultimate objective of this project was to develop equitable, or fair-share, phosphorus and nitrogen loading planning goals for each HUC8 watershed throughout the State. These planning goals were developed to update preliminary loads provided in the Minnesota NRS. The previous tasks of developing current day load estimates, identifying reducible and nonreducible loads, and estimating downstream attenuation provided the foundation for setting watershed specific goals. For each of these components of the methodology, the assessment was conducted using the best available information at the time this work was completed. The updated nutrient reduction goals described in the sections below represent an assessment of the remaining reductions needed to meet previously established downstream goals and milestones relative to recent loading conditions. Any changes in the estimated recent loading conditions relative to the 2014 NRS will have influenced the assessment of remaining reductions needed. For any given watershed, the updated estimate of recent loading conditions may be influenced by a number of factors, such as better estimates of loading due to monitoring or modeling that was previously not yet available, or relatively higher or lower precipitation over the most recent 10-year period over which annual loads were averaged.

The load reduction strategy in the 2014 NRS established percent load reduction goals equally for each HUC8 watershed within a given major basin, using an earlier version of the SPARROW model than is currently available. A long-term 45% load reduction goal relative to 1980-1996 average conditions was established for both TP and TN for all HUC8s in the Mississippi River basin. An interim 20% TN load reduction milestone was established for all HUC8s in the Mississippi River major. A 10% load reduction was identified in the NRS for TP and a 13% load reduction for TN relative to 2003 conditions for all HUCs in the Lake Winnipeg drainage basin. These goals did not take into consideration the estimated anthropogenic load contribution in each HUC8 watershed, which potentially created unrealistic load reduction targets for certain watersheds. Additionally, the previous goals did not account for in-stream attenuation occurring between the HUC8 outlets and the state line where the targets apply. This simplification may have resulted in cumulative HUC8 load reductions that, when accounting for attenuation between the HUC8 outlet and the state line, were higher or lower than the overall state line target.

The updated NRS planning goals presented here attempt to overcome those shortcomings and improve upon the 2014 NRS preliminary goals by considering the unique nutrient loading conditions and nutrient delivery of each HUC8 watershed. The planning goals were set equitably, such that each HUC8 with a major watershed has the goal of reducing an equal fraction of its reducible load. The equal fraction for all HUC8 watersheds was set to meet the overall load target at the state line, thereby accounting for attenuation that happens downstream of the HUC8 outlets.

Previously established major basin nutrient loading goals

State line targets were established based on waterbody-specific downstream goals, often in cooperation with agencies outside of the State of Minnesota such as the Gulf of Mexico Hypoxia Task Force, International Red River Board (IRRB), and International Joint Commission (IJC). The TP and TN goals and milestones for major drainage basins are listed in Table 8, along with the primary source for the mass-based goal. Nutrient load goals and milestones for the Mississippi River major basin remain the same as defined in the 2014 NRS. Although the 2014 NRS established provisional goals for HUC8 watersheds in the Red River basin based on the 2003 Lake Winnipeg Action Plan, these goals have since been updated based on recent work completed by the IRRB's Water Quality Committee (IRRB, 2019).

Table 8: Previously established TP and TN goals and milestones for five major basins, displayed for Minnesota drainage areas only. Note: For this effort, the MPCA combined all Mississippi River tributary watersheds into one drainage area, which also included the Cedar, Des Moines and Missouri Rivers.

Major Basin	TP Load Goal at State Line (MT)	TN Load Goal at State Line (MT)	Reference
Final Goals / Long-Term Goals			
Mississippi (Upper Mississippi, Minnesota, St. Croix, Cedar, Des Moines, Missouri)	2,544	50,088	Minnesota Nutrient Reduction Strategy (2014)
Lake Superior	248	-	Minnesota Nutrient Reduction Strategy (2014)
Red River	700	4,763	IRRB Water Quality Committee (2019)
Rainy River	218	-	Lake of the Woods TMDL (2018)
Milestones / Interim Goals / Provisional Goals			
Mississippi (Upper Mississippi, Minnesota, St. Croix, Cedar, Des Moines, Missouri)	-	72,856	Minnesota Nutrient Reduction Strategy (2014)
Red River	1,123	7,804	Minnesota Nutrient Reduction Strategy (2014)

Note: The following information in italics was added by the MPCA to supplement baseline load information described in Schlea et al. (2019), providing more background on both the original baseline and remaining load reduction needs at the time of NRS development. This information is also presented graphically in Appendix C to this Attachment.

Mississippi River Baseline loads – *The monitoring for the entire 1980-96 baseline period was not available for monitoring sites near the state line. The original baseline loads outlined in the NRS represented average monitored loads at the Mississippi River in La Crosse, based on 5-year running averages centered on the year 2000. SPARROW modeling was used to estimate the fraction of loads contributed by Iowa and Wisconsin (23%), which was subtracted from the monitored loads so that the loads in the NRS reflect only Minnesota's contributions. Available monitoring and modeled loads from Minnesota's tributaries to the Cedar, Des Moines and Missouri Rivers were added to Minnesota's estimated load contributions at the Mississippi River La Crosse site to represent the estimated Minnesota baseline load from the entire Mississippi River Basin reaching the Minnesota state line.*

> ***Nitrogen** – The original Minnesota contributions to the baseline nitrogen load was estimated at 91,096 MT/yr. To achieve the 45% load reduction goal from this baseline, the loads would need to be reduced to a long-term average load of 50,088 MT/yr (MN contributions to the Mississippi River at state line).*
>
> ***Phosphorus** – The original baseline phosphorus load was estimated to be 4627 MT/yr. To achieve the 45% load reduction goal from this baseline, the loads would need to be reduced to a long-term average load of 2,544 MT/yr.*

Red River baseline loads – *The original Red River baseline loads for Minnesota outlined in the 2014 NRS represented average monitored loads at the Red River in Emerson from 1999-2003, as adjusted to subtract the fraction of load contributed from North Dakota and South Dakota (ND and SD load contributions were estimated from the SPARROW model). The 2014 NRS focused on the previously documented Lake Winnipeg Action Plan reduction goals of 13 and 10% for TN and TP, respectively, while at the same time emphasizing that updated scientific findings were suggesting a final reduction need closer to 50%.*

> ***Nitrogen*** *– The original Red River baseline load for Minnesota was considered to be 8,970 MT. A 50% load reduction from this estimated load would amount to a 4,485 MT load reduction and 4,485 MT final load goal. The International Red River Basin Water Quality Board more recently suggested a similar load goal of 4,763 MT, based on the most recent monitoring and modeling information, assuming an equal split in the loads contributed by Minnesota and North Dakota (IRRB Water Quality Board, 2019).*
>
> *In 2024, Tetra Tech used the updated SPARROW model to estimate the load contributions from Minnesota and North Dakota. This cursory analysis indicated that more nitrogen load was contributed by North Dakota than Minnesota and that an equal split may no longer be appropriate. USGS used the updated SPARROW model to determine that Minnesota's load contribution to the Red River at Emerson was 44.2% of the nitrogen load. Therefore, the watershed load reduction planning goals in this document are based on the most updated load goal of 4,210 MT for the combined Minnesota tributaries.*
>
> ***Phosphorus*** *- The original baseline load was considered to be 1,248 MT. A 50% load reduction would amount to a 624 MT load reduction. The International Red River Basin Water Quality Board more recently suggested a slightly higher load goal of 700 MT, based on the most recent monitoring and modeling information, assuming an equal split in the loads contributed by Minnesota and North Dakota (IRRB Water Quality Board, 2019).*
>
> *In 2024, Tetra Tech used the updated SPARROW model to estimate the TP load contributions from Minnesota and North Dakota. This cursory analysis indicated that more phosphorus load was contributed by North Dakota than Minnesota and that an equal split may no longer be appropriate. USGS used the updated SPARROW model to determine that Minnesota's load contribution to the Red River at Emerson was 37.9% of the phosphorus load. Therefore, the watershed load reduction planning goals in this document are based on the most updated load goal of 531 MT for the combined Minnesota tributaries.*

Lake Superior Basin original baseline loads and load goals

For the Lake Superior major basin, the 2014 NRS defined a TP goal of maintaining 1979 loading conditions and a qualitative TN goal of maintaining protection by continuing to implement nutrient management programs. Since load monitoring for the Lake Superior Basin was not consistently available for the 1979 baseline period, the NRS used the SPARROW model as a way to estimate loads with 2002 land uses, assuming that land uses had not markedly changed between 1979 and 2002 in that part of the state.

> ***Nitrogen*** *– A baseline pollution prevention load goal for TN to maintain pre-2000 conditions was not established in the NRS for the Lake Superior Basin.* However, the NRS revision steering team is recommending that TN loads be prevented from increasing based on our best long-term monitoring data, similar to the TP goal.

***Phosphorus** – An approximate TP baseline of 248 MT/year was proposed in the NRS for maintaining pre-2000 conditions (i.e. back to late 1970s or earliest monitoring available).*

Rainy River Basin

The 2014 NRS did not establish goals for HUC8 watersheds in the Rainy River, deferring to the eventual Lake of the Woods TMDL as the ultimate approach for establishing TP load targets for these watersheds. The TP load goal of 218 MT for the Rainy River basin was computed from the Lake of the Woods TMDL (2018) by summing the allowable USA TP loads to the lake for the wastewater, tributaries, lakeshed, and septic systems categories. Allowable TP loads for Canadian sources, shoreline erosion, atmospheric deposition, and internal loading were not included as they were not considered to be part of the Minnesota HUC8 watershed loading to Lake of the Woods. Numeric TN goals have not been established for the Rainy River major basin.

Goal determination methodology

The following equations and accompanying text describe the nutrient reduction goal calculations. Sample calculations for four HUC8 watersheds are provided in Appendix B.

Load reduction planning targets for each major watershed were calculated by subtracting the loading goal for the major watershed from the total load delivered to the state line. The total delivered load was calculated as the sum of delivered loads from individual HUC8 watersheds:

$$Load\ Reduction\ Target_{mw} =$$

$$\sum(Current\ Load)_i(Delivery\ Ratio)_i - \ State\ Line\ Loading\ Goal_{mw}$$

$Where$:

$'mw'\ refers\ to\ major\ watershed$

$'i' \quad refers\ to\ individual\ HUC8\ watersheds$

This major watershed load reduction target was then expressed as a proportion of the major watershed's total reducible load delivered to the state line. This is the "Fair-Share Proportion" for each HUC8 within the major watershed.

$$Reducible\ Load\ Delivered\ to\ State\ Line_i =$$

$$(Current\ Load)_i \times (Reducible\ Fraction)_i \times (Delivery\ Ratio)_i$$

$$Fair\ Share\ Proportion_{mw} =$$

$$\frac{Load\ Reduction\ Target_{mw}}{\sum Reducible\ Load\ Delivered\ to\ State\ Line_i}$$

The HUC8 Fair-Share Load Reductions were then calculated by multiplying the Fair-Share Proportion by each HUC8 watershed's reducible load.

$$Fair\ Share\ Load\ Reduction_i =$$

$$Reducible\ Load_i \times Fair\ Share\ Proportion_{mw}$$

The Fair-Share Loads for each HUC8 were computed by subtracting the Fair-Share Load Reduction from each HUC8's Current Load.

$$Fair\ Share\ Load_i =$$

$$Current\ Load_i - Fair\ Share\ Load\ Reduction_i$$

The Fair-Share Loads for each HUC8 multiplied by the respective delivery ratio sum up to the State Line Loading Goal for each major watershed.

$$\sum (Fair\ Share\ Load)_i (Delivery\ Ratio)_i = State\ Line\ Loading\ Goal_{mw}$$

Major basin results

As previously described, the most recent 10-years of each HSPF model were compiled for the Minnesota-portion of each HUC8 subbasin, and subbasin-specific delivery factors were applied to estimate the load that is transported to the state lines. These HUC8 loads delivered to state lines were then aggregated to three locations:

- the Mississippi River at the Iowa-Minnesota-Wisconsin state lines, which includes the Cedar, Des Moines, and Missouri rivers at state lines
- the Red River of the North at Emerson,
- the Rainy River at Lake-of-the-Woods.

Table 9 presents the modeled aggregated loads delivered to state lines, final goal loads at the state lines, necessary load reductions to meet final goal loads, and the percent reductions to meet final goal loads. Lake Superior results are described separately, below. Large reductions are needed for the Mississippi and Red rivers for both TP and TN.

While certain loads presented in the NRS are flow-normalized, the loads presented in Table 9 are not flow-normalized. As such, the recent loads and necessary load reductions will vary in the future as river flows (and thus loads) change over time. These recent loads and necessary reductions should not be compared with flow-normalized recent loads and corresponding necessary reductions presented elsewhere in the NRS.

Table 9: Modeled load estimates, final goals loads, and remaining reductions for the Minnesota portion of four major basins.

Description	Mississippi River at the IA-MN-WI state lines		Red River of the North at Emerson, Manitoba		Rainy River at Lake-of-the-Woods	
	TP	TN	TP	TN	TP	TN
Modeled recent loads delivered to state lines (MTA)	4,273	94,170	1,084	8,674	228	4,275
Final goal load at state line (MTA)	2,544	50,089	531	4,210	218	4,887
Necessary load reduction to meet final load goal (MTA)	1,729	44,081	553	4,464	10	*none*
Necessary percent reduction to meet final goal load	40%	47%	51%	51%	4.4%	*none*

Load goals for each HUC8 are provided in Appendix A. The recent HUC8 load estimates, mass load reduction goals, and percent load reduction goals are shown in Figures 11-13 for TP and Figures 14-16 for TN, respectively. HUC8 watersheds with relatively large reducible loads have the highest fair-share percent load reduction planning goals. These HUC8s tend to be the most human-influenced and have higher percentages of urban and agricultural land uses from which loads could be more readily reduced, as previously described.

It is important to note, as previously discussed, that many models most recent 10-years of simulation predated the last decade (2014-2023), and as such, the simulated loads and estimated reduction do not account for on-the-ground load reductions that resulted from implementation of best management practices since Minnesota's 2014 NRS.

Lake Superior results

As stated above, one task of this effort was to determine the average annual nutrient loads to Lake Superior that should be sustained to meet the goals of the NRS. Numeric TN goals were not previously established for the Lake Superior and Rainy River major basins. The TN load planning goals provided in Appendix A for HUC8 watersheds in these major basins represent the average annual loads that should be sustained to maintain loading at current conditions. These loads were computed as the sum of the current day load estimates at each HUC8 outlet times the delivery to the state line end point for that HUC8. These "hold the line" TN load planning goals were estimated as 4,658 MT/year delivered for Lake Superior HUC8 watersheds, and 4,887 MT/year delivered for Rainy River HUC8 watersheds.

Recent, delivered TP load for Lake Superior was estimated as 245 MTA. This updated, HSPF model-based estimate compares extremely well to the 255 MTA estimated for 2006-2010 conditions by the SPARROW model as part of the 2014 NRS. Recent, delivered TP load of 245 MTA is slightly higher than the 248 MT/year proposed in the 2014 NRS for maintaining 1979 conditions, and therefore relatively small load reduction planning goals are needed for the Lake Superior HUC8 watersheds as shown in Table A-1.

Lake Pepin results

An analysis was completed in 2019 by LimnoTech to evaluate whether meeting the TP reduction needs described in the Draft Lake Pepin Watershed Phosphorus TMDL (MPCA and LimnoTech, 2019) would also meet the downstream Mississippi River/Gulf of Mexico needs. The Lake Pepin TMDL TP loading goals evaluated included the following:

- 693 MT/year delivered to Lock & Dam 1 for the Upper Mississippi basin HUC8s, Rum River HUC8, North and South Fork Crow HUC8s, and Twin Cities Metro Area HUC8 above Lock & Dam 1;
- 938 MT/year delivered to the Minnesota River mouth for the Minnesota River basin HUC8s, excluding loading from the South Dakota portion;
- 199 MT/year delivered to the HUC8 outlet for the Twin Cities Metro Area HUC8 below Lock & Dam 1; and
- 159 MT/year delivered to Lake Pepin for the Cannon River HUC8 and Mississippi River/Vermillion HUC8.

The nutrient load methodology described above was then applied to compute the individual HUC8 TP load reductions from the current day estimates needed to cumulatively achieve these Lake Pepin TMDL goals. The computed reductions accounted for the reducible load fractions and the TP delivery to the stated endpoints. The "state line" terms in the methodology were replaced with these Lake Pepin TMDL endpoints.

The summary results of this analysis are provided in Table 10. According to this analysis, the highest TP mass-based load reduction planning goals was for the Cannon River HUC8 and Mississippi River/Vermillion HUC8 at 59%. The overall load reduction planning goals for the Upper Mississippi River and Minnesota River HUC8 watersheds were 27% and 31%, respectively. Current TP loading for the Twin Cities Metro Area HUC8 below Lock & Dam 1 was estimated at 167 MT/year, below the 199 MT/year goal, and therefore a 0% reduction was computed. This finding was largely driven by the Met Council Metro WWTP discharging TP loads below the waste load allocation (WLA) stated in the TMDL. The bottom line finding from this analysis is that the TP reduction needs described in the Draft Lake Pepin

Watershed Phosphorus TMDL will be sufficient to also meet the downstream Mississippi River/Gulf of Mexico TP reduction planning goals established under the NRS. The reduction needs are fairly similar for the Mississippi River and Minnesota River watersheds.

Table 10: Current day, average annual TP load estimates, Lake Pepin TMDL TP load goals, and percent reductions needed to meet Lake Pepin TMDL and NRS goals.

Major Basin	Upper Mississippi, Rum, Crow HUC8s	Minnesota River HUC8s	Twin Cities Metro below L&D1	Cannon and Mississippi/ Vermillion
Recent load at HUC8 outlets (MT)	1049	1543	167	392
Recent load at Lake Pepin TMDL endpoint (MT)	954	1358	167	392
Load goal at Lake Pepin TMDL endpoint (MT)	693	938	199	159
Proportion of current day load needing to be reduced to meet Lake Pepin TMDL goal	27%	31%	0%	59%
Proportion of current day load needing to be reduced to meet NRS goal	26%	32%	-	30%

Figure 11: Recent, average annual HUC8 watershed outlet TP load estimates in Metric Tons (See also Table A-1 in Appendix A)

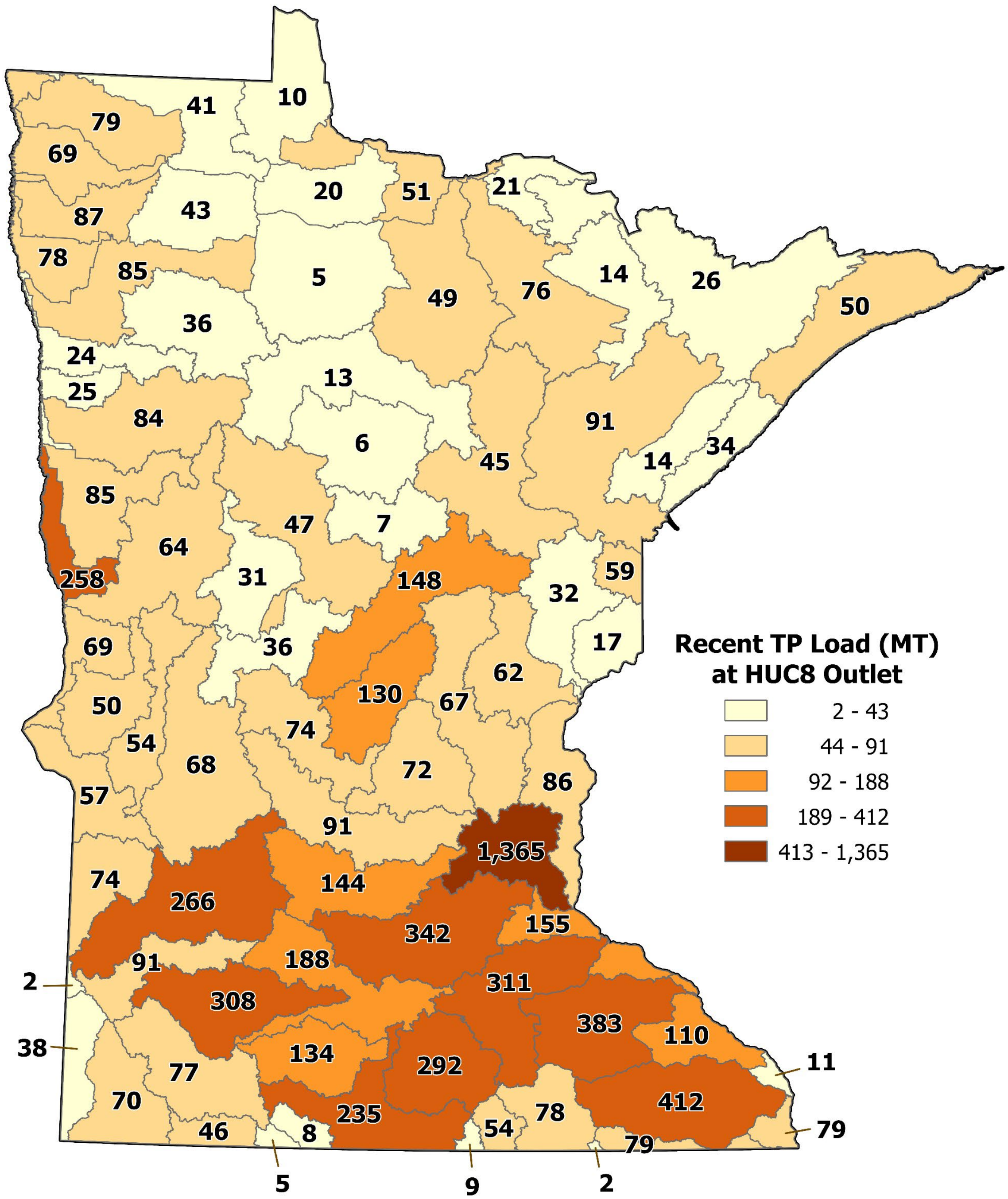


Figure 12: Average annual HUC8 watershed TP load reductions (MT) to meet the final target loads (See also Table A-1 in Appendix A)

Note: In the *Lake Superior* major basin, instead of numeric load reductions, a “hold the line” approach is recommended.

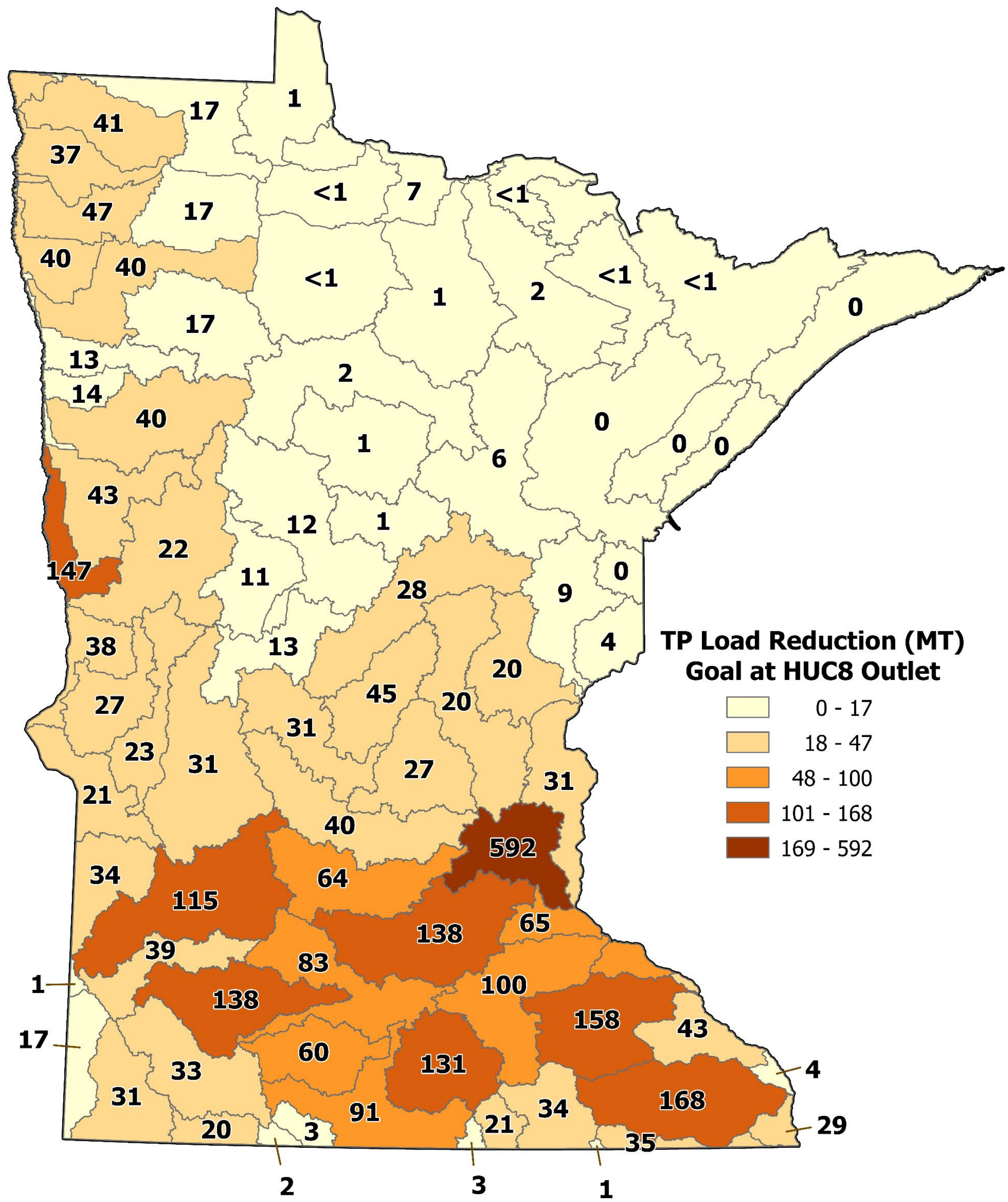


Figure 13: Percent of current day, average annual HUC8 watershed TP load to be reduced to meet the final target loads (See also Table A-1 in Appendix A)

Note: In the *Lake Superior* major basin, instead of relative load reductions, a "hold the line" approach is recommended.

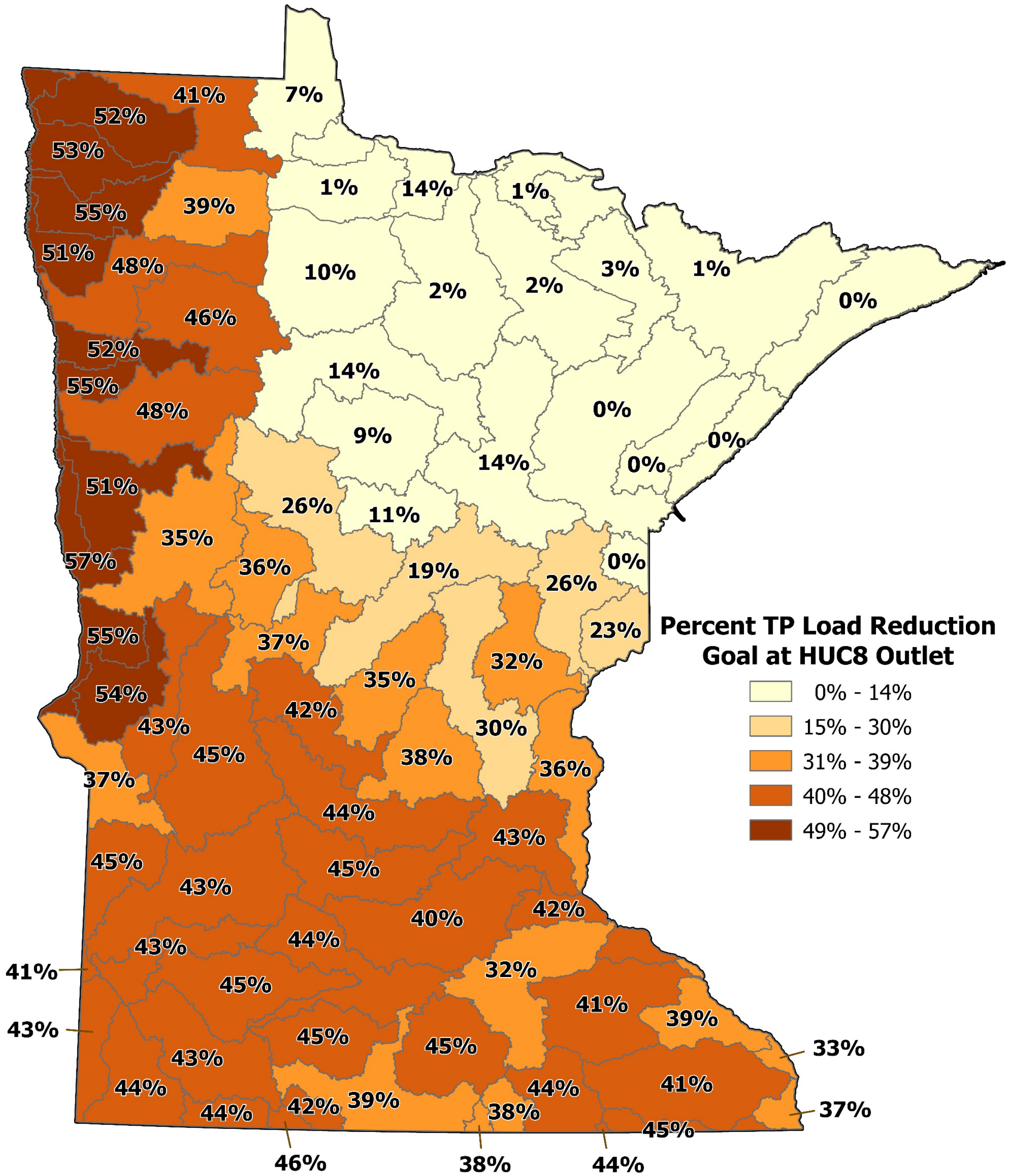


Figure 14. Recent average annual HUC8 watershed TN load estimates (See also Tables A-2 and A-3 in Appendix A)

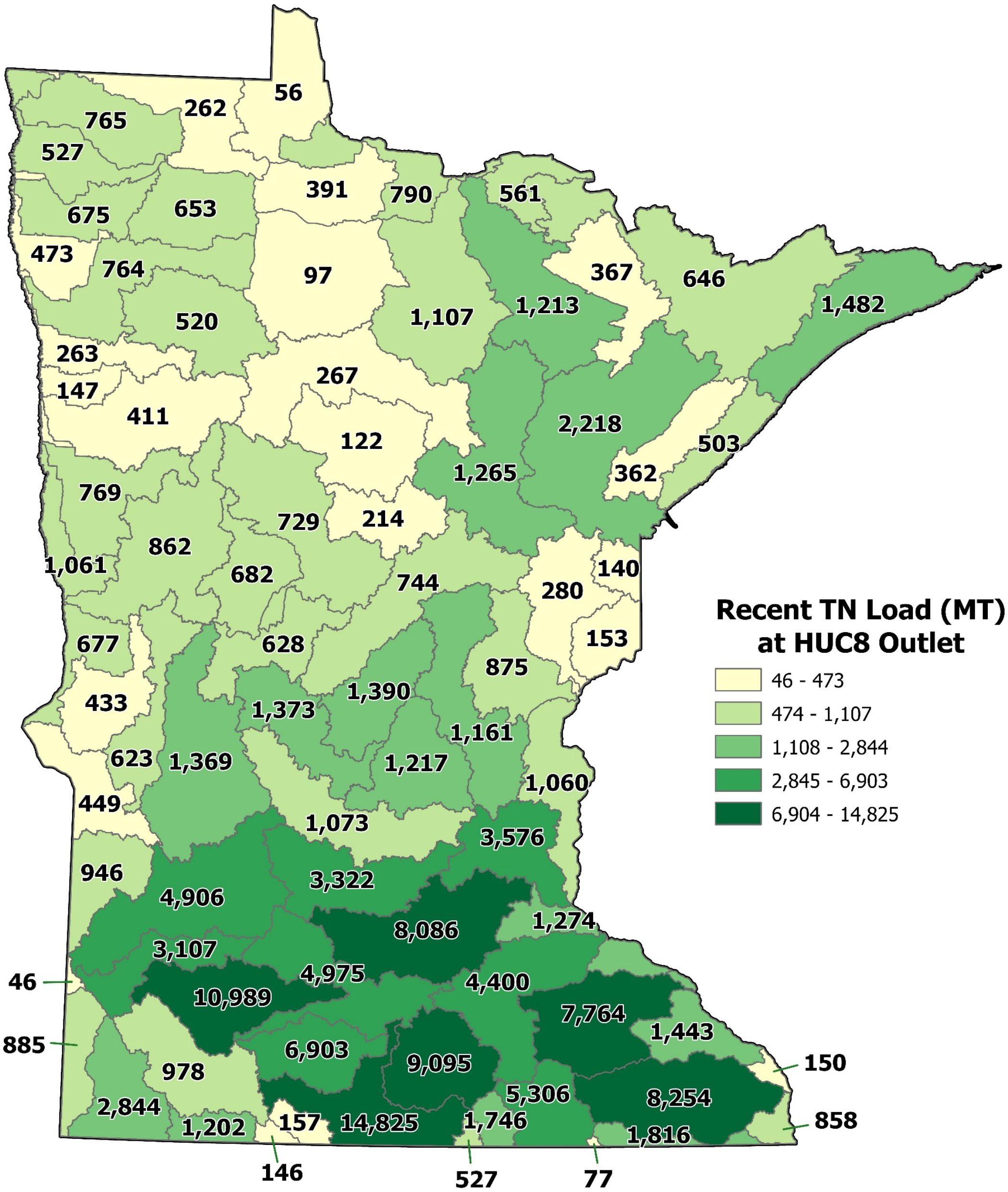


Figure 15. Average annual HUC8 watershed TN load reductions to meet the final target loads (See also Table A-2 in Appendix A)

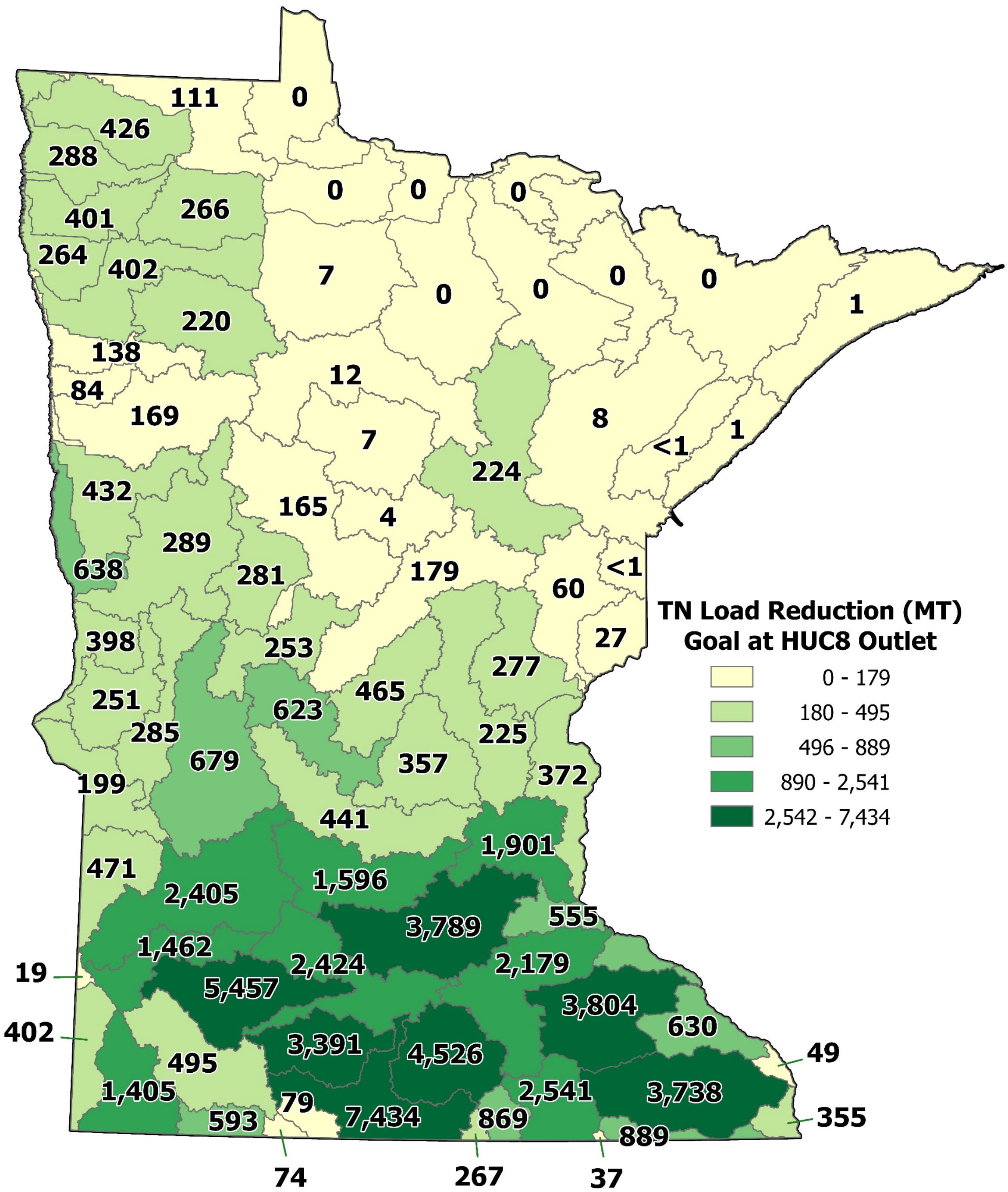
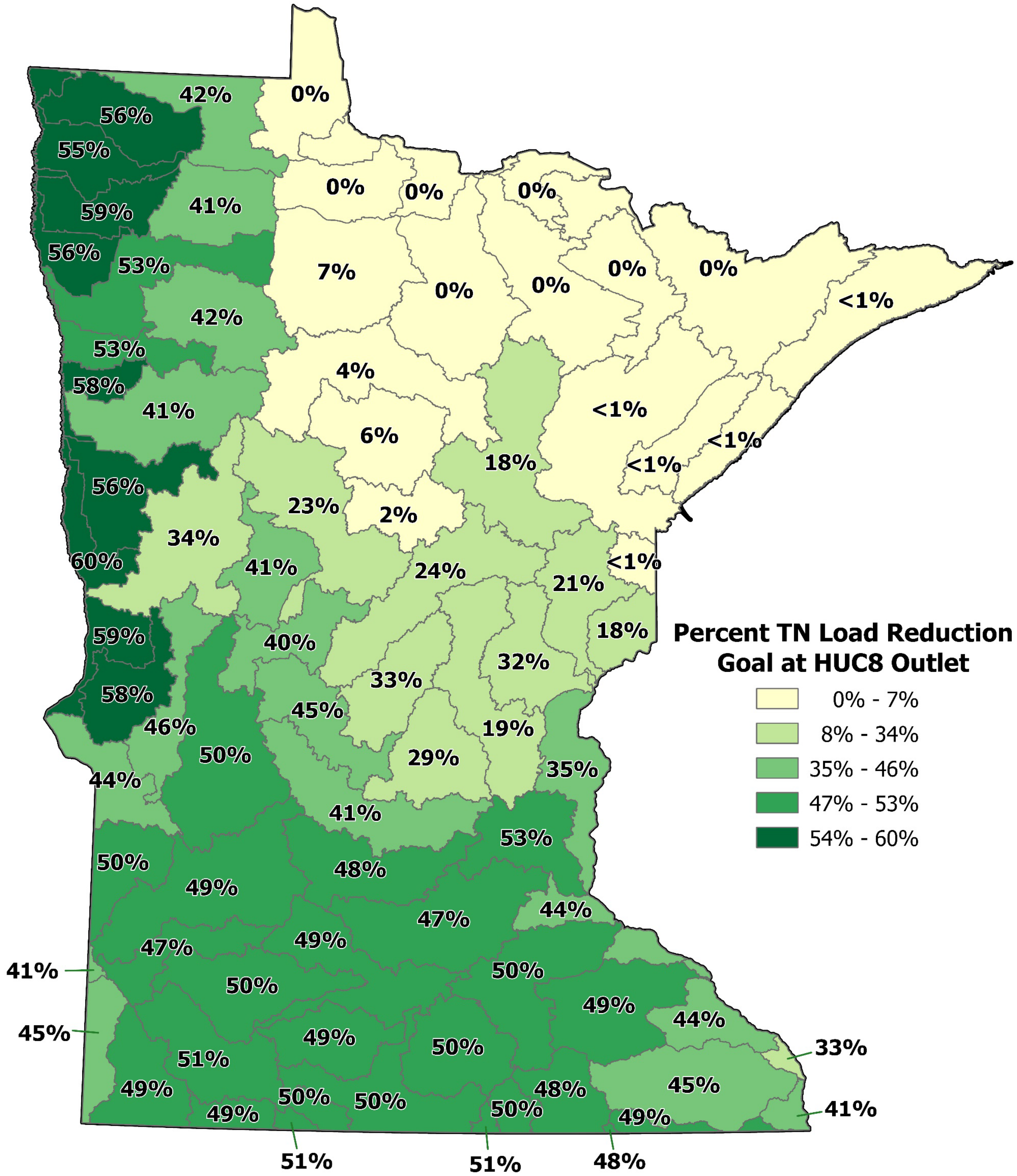


Figure 16: Percent of recent average annual HUC8 watershed TN load to be reduced to meet the final target loads (See also Table A-2 in Appendix A)



In conclusion

The performed work resulted in updated load reduction TP and TN planning goals on a HUC8 basis to achieve NRS goals. These updates to the watershed nutrient reduction needs were based on consideration of the following factors:

- Estimation of revised current day loads using WPLMN and HSPF model results;
- Estimation of load attenuation from the HUC8 outlet to the state line using HSPF and SPARROW model predictions; and
- Proportioning reductions across HUC8s based on estimates of the reducible fraction of the TP and TN loads from each HUC8. Reducible fractions of loads were estimated based on HSPF model predictions of loads across the various source categories specified in the models.

These updated reduction goals provide an improved basis to assess progress and understand the extent of additional efforts needed to achieve NRS planning goals. Continued periodic updates to recent existing loads and comparison to NRS planning goals will be essential for tracking progress, understanding the effectiveness of efforts being implemented, and informing an adaptive management approach. Continued monitoring and integration with the available modeling tools will be important for watershed planning processes.

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Appendix A: Recent and Fair-Share Loads

The following tables present recent and fair-share loads delivered to the state lines.

Table A-1: Current day (recent) load estimates, final fair-share load goals, final load reductions, and final fair-share load goals delivered to the state line for TP for the Minnesota portion of HUC8 watersheds. *

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Percent reduction to meet target	Fair-share load goal, delivered (MTA)
Major drainage basin: Lake Superior							
Lake Superior	Baptism-Brule	04010101	50	50	0	0%	50
Lake Superior	Beaver-Lester	04010102	34	34	0	0%	34
Lake Superior	St. Louis	04010201	91	91	0	0%	91
Lake Superior	Cloquet River	04010202	14	14	0	0%	12
Lake Superior	Nemadji River	04010301	59	59	0	0%	59
Major drainage basin: Mississippi River							
Upper Mississippi	Mississippi River - Headwaters	07010101	13	1	2	14%	5
Upper Mississippi	Leech Lake River	07010102	6	0	1	9%	2
Upper Mississippi	Mississippi River - Grand Rapids	07010103	45	6	6	14%	20
Upper Mississippi	Mississippi River - Brainerd	07010104	148	28	28	19%	71
Upper Mississippi	Pine River	07010105	7	1	1	11%	4
Upper Mississippi	Crow Wing River	07010106	47	12	12	26%	19
Upper Mississippi	Redeye River	07010107	31	11	11	36%	11
Upper Mississippi	Long Prairie River	07010108	36	12	13	37%	13
Upper Mississippi	Mississippi River - Sartell	07010201	130	48	45	35%	52
Upper Mississippi	Sauk River	07010202	74	32	31	42%	26
Upper Mississippi	Mississippi River - St. Cloud	07010203	72	29	27	38%	28
Upper Mississippi	North Fork Crow River	07010204	91	42	40	44%	32
Upper Mississippi	South Fork Crow River	07010205	144	67	64	45%	48
Upper Mississippi	Mississippi River - Twin Cities	07010206	1,365	634	592	43%	484
Upper Mississippi	Rum River	07010207	67	21	20	30%	29
Minnesota	Minnesota River - Headwaters	07020001	57	17	21	37%	17
Minnesota	Pomme de Terre River	07020002	54	15	23	43%	12
Minnesota	Lac Qui Parle River	07020003	74	27	34	45%	19
Minnesota	Minnesota River - Yellow Medicine River	07020004	266	102	115	43%	78

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Percent reduction to meet target	Fair-share load goal, delivered (MTA)
Major drainage basin: Mississippi River (continued)							
Minnesota	Chippewa River	07020005	68	37	31	45%	17
Minnesota	Redwood River	07020006	91	52	39	43%	27
Minnesota	Minnesota River - Mankato	07020007	188	105	83	44%	64
Minnesota	Cottonwood River	07020008	308	170	138	45%	99
Minnesota	Blue Earth River	07020009	235	144	91	39%	85
Minnesota	Watonwan River	07020010	134	74	60	45%	42
Minnesota	Le Sueur River	07020011	292	160	131	45%	94
Minnesota	Lower Minnesota River	07020012	342	204	138	40%	128
St. Croix	Upper St. Croix River	07030001	17	13	4	23%	8
St. Croix	Kettle River	07030003	32	24	9	26%	14
St. Croix	Snake River	07030004	62	42	20	32%	25
St. Croix	Lower St. Croix River	07030005	86	54	31	36%	35
Lower Mississippi	Mississippi River - Lake Pepin	07040001	155	90	65	42%	59
Lower Mississippi	Cannon River	07040002	311	210	100	32%	134
Lower Mississippi	Mississippi River - Winona	07040003	110	67	43	39%	55
Lower Mississippi	Zumbro River	07040004	383	225	158	41%	165
Lower Mississippi	Mississippi River - La Crescent	07040006	11	7	4	33%	6
Lower Mississippi	Root River	07040008	412	244	168	41%	201
Lower Mississippi	Mississippi River - Reno	07060001	79	50	29	37%	50
Lower Mississippi	Upper Iowa River	07060002	79	44	35	45%	44
Missouri	Upper Big Sioux River	10170202	2	1	1	41%	1
Missouri	Lower Big Sioux River	10170203	38	22	17	43%	22
Missouri	Rock River	10170204	70	39	31	44%	39
Missouri	Little Sioux River	10230003	46	26	20	44%	26
Cedar	Upper Wapsipinicon River	07080102	2	1	1	44%	1
Cedar	Cedar River	07080201	78	44	34	44%	44
Cedar	Shell Rock River	07080202	54	34	21	38%	34
Cedar	Winnebago River	07080203	9	5	3	38%	5
Des Moines	Des Moines River - Headwaters	07100001	77	44	33	43%	42

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Percent reduction to meet target	Fair-share load goal, delivered (MTA)
Major drainage basin: Mississippi River (continued)							
Des Moines	Lower Des Moines River	07100002	5	3	2	46%	3
Des Moines	East Fork Des Moines River	07100003	8	5	3	42%	5
Major drainage basin: Lake Winnipeg							
Red	Bois de Sioux River	09020101	69	54	38	55%	24
Red	Mustinka River	09020102	50	38	27	54%	8
Red	Otter Tail River	09020103	64	32	22	35%	32
Red	Upper Red River of the North	09020104	258	208	147	57%	106
Red	Buffalo River	09020106	85	62	43	51%	39
Red	Marsh River	09020107	25	20	14	55%	11
Red	Wild Rice River	09020108	84	57	40	48%	41
Red	Sandhill River	09020301	24	18	13	52%	11
Red	Upper/Lower Red Lake	09020302	5	1	0	10%	3
Red	Red Lake River	09020303	85	57	40	48%	42
Red	Thief River	09020304	43	24	17	39%	24
Red	Clearwater River	09020305	36	24	17	46%	18
Red	Grand Marais Creek	09020306	78	57	40	51%	37
Red	Snake River (Red)	09020309	87	67	47	55%	39
Red	Tamarac River	09020311	69	52	37	53%	32
Red	Two Rivers	09020312	79	58	41	52%	38
Red	Roseau River	09020314	41	24	17	41%	24
Rainy	Rainy Headwaters	09030001	26	25	0	1%	16
Rainy	Vermilion River	09030002	14	14	0	3%	7
Rainy	Rainy Lake	09030003	21	21	0	1%	17
Rainy	Little Fork River	09030005	76	74	2	2%	64
Rainy	Big Fork River	09030006	49	48	1	2%	42
Rainy	Rapid River	09030007	20	20	0	1%	19
Rainy	Rainy River	09030008	51	44	7	14%	44
Rainy	Lake of the Woods	09030009	10	9	1	7%	9

Table A-2: Current load estimates, final fair-share load goals, final load reductions, and final fair-share load goals delivered to the state line for TN for the Minnesota portion of HUC8 watersheds

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Proportion of current load needing reduced	Fair-share load goal, delivered (MTA)
Major drainage basin: Lake Superior							
Lake Superior	Baptism-Brule	04010101	1,482	1,481	1	0.1%	1,481
Lake Superior	Beaver-Lester	04010102	503	501	1	0.3%	501
Lake Superior	St. Louis	04010201	2,218	2,210	8	0.4%	2,210
Lake Superior	Cloquet River	04010202	362	361	0	0%	327
Lake Superior	Nemadji River	04010301	140	139	0	0%	139
Major drainage basin: Mississippi River							
Upper Mississippi	Mississippi River - Headwaters	07010101	267	255	12	4%	142
Upper Mississippi	Leech Lake River	07010102	122	115	7	6%	52
Upper Mississippi	Mississippi River - Grand Rapids	07010103	1,265	1,041	224	18%	653
Upper Mississippi	Mississippi River - Brainerd	07010104	744	564	179	24%	387
Upper Mississippi	Mississippi River - Headwaters	07010101	214	210	4	2%	136
Upper Mississippi	Leech Lake River	07010102	729	564	165	23%	374
Upper Mississippi	Mississippi River - Grand Rapids	07010103	682	400	281	41%	260
Upper Mississippi	Mississippi River - Brainerd	07010104	628	375	253	40%	245
Upper Mississippi	Pine River	07010105	1,390	925	465	33%	638
Upper Mississippi	Crow Wing River	07010106	1,373	750	623	45%	517
Upper Mississippi	Redeye River	07010107	1,217	860	357	29%	603
Upper Mississippi	Long Prairie River	07010108	1,073	632	441	41%	443
Upper Mississippi	Mississippi River - Sartell	07010201	3,322	1,726	1,596	48%	1,187
Upper Mississippi	Sauk River	07010202	267	1,676	1,901	53%	1,183
Upper Mississippi	Mississippi River - St. Cloud	07010203	122	937	225	19%	657
Upper Mississippi	North Fork Crow River	07010204	1,265	249	199	44%	142
Upper Mississippi	South Fork Crow River	07010205	744	338	285	46%	128
Upper Mississippi	Mississippi River - Twin Cities	07010206	3,576	475	471	50%	271
Upper Mississippi	Rum River	07010207	1,161	255	12	4%	142
Minnesota	Minnesota River - Headwaters	07020001	449	115	7	6%	52
Minnesota	Pomme de Terre River	07020002	623	1,041	224	18%	653
Minnesota	Lac Qui Parle River	07020003	946	564	179	24%	387

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Proportion of current load needing reduced	Fair-share load goal, delivered (MTA)
Major drainage basin: Mississippi River (continued)							
Minnesota	Minnesota River - Yellow Medicine River	07020004	4,906	2,500	2,405	49%	1,594
Minnesota	Chippewa River	07020005	1,369	691	679	50%	394
Minnesota	Redwood River	07020006	3,107	1,645	1,462	47%	1,048
Minnesota	Minnesota River - Mankato	07020007	4,975	2,551	2,424	49%	1,773
Minnesota	Cottonwood River	07020008	10,989	5,532	5,457	50%	3,733
Minnesota	Blue Earth River	07020009	14,825	7,391	7,434	50%	5,069
Minnesota	Watonwan River	07020010	6,903	3,512	3,391	49%	2,078
Minnesota	Le Sueur River	07020011	9,095	4,569	4,526	50%	3,133
Minnesota	Lower Minnesota River	07020012	8,086	4,297	3,789	47%	3,033
St. Croix	Upper St. Croix River	07030001	153	126	27	18%	82
St. Croix	Kettle River	07030003	280	220	60	21%	144
St. Croix	Snake River	07030004	875	597	277	32%	391
St. Croix	Lower St. Croix River	07030005	1,060	688	372	35%	498
Lower Mississippi	Mississippi River - Lake Pepin	07040001	1,274	719	555	44%	547
Lower Mississippi	Cannon River	07040002	4,400	2,221	2,179	50%	1,621
Lower Mississippi	Mississippi River - Winona	07040003	1,443	813	630	44%	750
Lower Mississippi	Zumbro River	07040004	7,764	3,960	3,804	49%	3,377
Lower Mississippi	Mississippi River - La Crescent	07040006	150	100	49	33%	93
Lower Mississippi	Root River	07040008	8,254	4,516	3,738	45%	4,164
Lower Mississippi	Mississippi River - Reno	07060001	858	503	355	41%	503
Lower Mississippi	Upper Iowa River	07060002	1,816	927	889	49%	927
Missouri	Upper Big Sioux River	010170202	46	27	19	41%	27
Missouri	Lower Big Sioux River	010170203	885	483	402	45%	483
Missouri	Rock River	010170204	2,844	1,439	1,405	49%	1,439
Missouri	Little Sioux River	010230003	1,202	609	593	49%	609
Cedar	Upper Wapsipinicon River	07080102	77	40	37	48%	40
Cedar	Cedar River	07080201	5,306	2,765	2,541	48%	2,765
Cedar	Shell Rock River	07080202	1,746	877	869	50%	877

Basin	HUC8 Name	HUC8 Number	Recent load at HUC8 outlet (MTA)	Fair-share load goal at HUC8 outlet (MTA)	Load reduction goal at HUC8 outlet (MTA)	Proportion of current load needing reduced	Fair-share load goal, delivered (MTA)
			Major drainage basin: Mississippi River (continued)				
Cedar	Winnebago River	07080203	527	267	261	51%	261
Des Moines	Des Moines River - Headwaters	07100001	978	495	484	51%	470
Des Moines	Lower Des Moines River	07100002	146	74	72	51%	72
Des Moines	East Fork Des Moines River	07100003	157	79	78	50%	78
			Major drainage basin: Lake Winnipeg				
Red	Bois de Sioux River	09020101	677	278	398	59%	251
Red	Mustinka River	09020102	433	182	251	58%	75
Red	Otter Tail River	09020103	862	573	289	34%	516
Red	Upper Red River of the North	09020104	1,061	423	638	60%	415
Red	Buffalo River	09020106	769	337	432	56%	331
Red	Marsh River	09020107	147	62	84	58%	61
Red	Wild Rice River	09020108	411	242	169	41%	237
Red	Sandhill River	09020301	263	125	138	53%	122
Red	Upper/Lower Red Lake	09020302	97	90	7	7%	40
Red	Red Lake River	09020303	764	362	402	53%	356
Red	Thief River	09020304	653	387	266	41%	327
Red	Clearwater River	09020305	520	299	220	42%	268
Red	Grand Marais Creek	09020306	473	210	264	56%	207
Red	Snake River (Red)	09020309	675	274	401	59%	274
Red	Tamarac River	09020311	527	239	288	55%	239
Red	Two Rivers	09020312	765	339	426	56%	339
Red	Roseau River	09020314	262	151	111	42%	151
Rainy	Rainy Headwaters	09030001	646	646	0	0%	363
Rainy	Vermilion River	09030002	367	367	0	0%	172
Rainy	Rainy Lake	09030003	561	561	0	0%	491
Rainy	Little Fork River	09030005	1,213	1,213	0	0%	1,055
Rainy	Big Fork River	09030006	1,107	1,107	0	0%	976
Rainy	Rapid River	09030007	391	391	0	0%	373
Rainy	Rainy River	09030008	790	790	0	0%	790
Rainy	Lake of the Woods	09030009	56	56	0	0%	56

Appendix B: Fair-Share Sample Calculations

The following table and narrative demonstrate the fair-share nutrient reduction calculations for two HUC8 watersheds in the Mississippi River major basin and two HUC8 watersheds in the Red River major basin.

Table B-1: Sample fair-share nutrient reduction calculations for final TP load goals for two watersheds each in the Mississippi River and Red River major basins

Line	Description	Mississippi River - Brainerd (07010104)	Pomme de Terre River (07020002)	Mustinka River (09020102)	Tamarac River (09020311)
	Major Basin	**Mississippi River**		**Red River**	
1	Major basin final TP planning goal (MT/yr)	2,544		531	
2	Major basin current day delivered TP load *Σ Individual current day loads x individual delivery ratios*	4,273		1,084	
3	Load reduction planning goal (MT/yr) *Line 2 minus Line 1*	1,729		553	
4	Reducible TP load delivered to state line (MT/yr) *Σ Individual current day loads x individual delivery ratios x individual reducible fractions*	2,963		784	
5	Proportion of reducible load at HUC8 outlet to be reduced to meet planning goal (MT/yr), i.e., the ***Fair-Share Proportion*** *Line 3 divided by Line 4*	58%		71%	
6	Current day TP load at HUC8 outlet (MT/yr)	148	54	50	69
7	TP delivery ratio to state line endpoint	59.4%	37.4%	36.0%	100%
8	Reducible fraction TP	32%	74%	77%	75%
9	Current day TP load delivered to state line (MT/yr) *Line 6 times Line 7. Used in Line 2 calculation.*	88	20	18	69
10	Reducible TP load at HUC8 outlet (MT/yr) *Line 6 times Line 8*	47	40	38	52
11	Fair-Share TP load reduction goal at HUC8 outlet (MT/yr) *Line 5 times Line 10*	27	23	27	37
12	Fair-Share TP load goal at HUC8 outlet (MT/yr) *Line 6 minus Line 11*	121	31	23	32
13	Proportion of total current day load to be reduced *Line 11 divided by Line 6*	18%	43%	54%	53%
14	Proportion of reducible load to be reduced *Line 11 divided by Line 10. Matches Line 5.*	58%	58%	71%	71%
15	Fair-Share TP load goal at state line (MT/yr) *Line 12 times Line 7. The sum of all of these for HUC8s in a major basin matches Line 1.*	72	12	8	32

Note: All loads were rounded to 1 metric ton and all percentages were rounded to 1 percentage point.

In the Mississippi River basin, the Mississippi-Brainerd HUC8 has a higher current day load estimate and higher delivery ratio, but a lower reducible fraction relative to the Pomme de Terre HUC8. Both HUC8 watersheds have a fair-share load reduction goal set at 40.1% of their respective reducible loads based on the fair-share proportion calculation done at the major basin level. Despite having a higher total current day load, because it has a lower reducible TP load, the Mississippi-Brainerd has a slightly lower fair-share load reduction goal of 14 MT/yr relative to the 15 MT/yr reduction goal for the Pomme de Terre. The fair-share load delivered to the state line from the Mississippi-Brainerd is over two times higher than that of the Pomme de Terre, however, because of the combination of it having a higher delivery ratio, higher current day load, and higher fair-share load at the HUC8 outlet.

In the Red River basin, the Mustinka River HUC8 and Tamarac River HUC8 have very similar current day load estimates and very similar reducible fraction estimates. This results in very similar fair-share load reduction goals for the HUC8s at the outlets and similar proportions of the current day loading needing reduced. The fair-share load delivered is quite different between the two, however, because of the different delivery ratios. The Tamarac River is relatively near the state line end point and therefore essentially all of its load reduction at the HUC8 outlet is also realized as a fair-share load reduction "delivered". The Mustinka River is relatively far from the state line end point (over half of the length of the state) and experiences attenuation in both Lake Traverse and Mud Lake before traveling the entire length of the Red River. This results in a much lower fair-share load reduction "delivered" relative to the Tamarac River HUC8.

Appendix C: Major River Basin nutrient loads to the state line, showing: original baseline loads, and recent-period estimates through modeling

Figures C1-C6 were developed by the MPCA to show the comparison between the total loads (top of stacked bars) and the load upon reaching final goals (top of dark-shading). Most graphs show the loads and load goals for a) estimated original baseline conditions (left bar), and b) sum of recent loads at the state line as modeled primarily with HSPF as described in this document (right bar). The HUC8 watershed nutrient reduction planning goals provided in Appendix A collectively add-up to the load represented by the lighter shading in the ***right-side*** bars. When the HUC8 nutrient reduction goals are achieved, the loads will be equal to the dark-blue shaded loads.

As previously discussed, it is important to differentiate between modeling and monitoring datasets. The loads presented in Appendix C are modeled loads simulated in HSPF models. The "recent" modeled loads represent the average annual load for the most recent 10-years of model simulations. Throughout Minnesota's Nutrient Reduction Strategy, monitored loads are presented; the "recent" monitored loads are the annual averages of the most recent 10-years of monitoring (2021-2022 or 2012-2023). Both the modeled and monitored loads are calculated for loading from only Minnesota (i.e., adjacent states' loads are excluded) delivered to key locations at state borders.

The recent modeled and recent monitored loads are not identical. The recent modeled loads are predicted using available data in each HUC8 that are then extrapolated to state borders. The recent monitored loads are estimated using in-stream flow and in-stream phosphorus or nitrogen sampling. While modeled loads are available for every HUC8 in Minnesota, monitored loads are only located at key locations.

Figure C-1. Baseline and recent modeled TN loads for Minnesota contributions to the Mississippi River Basin drainage area at the state line.

Note: Includes the Cedar, Des Moines, and Missouri rivers' loads.

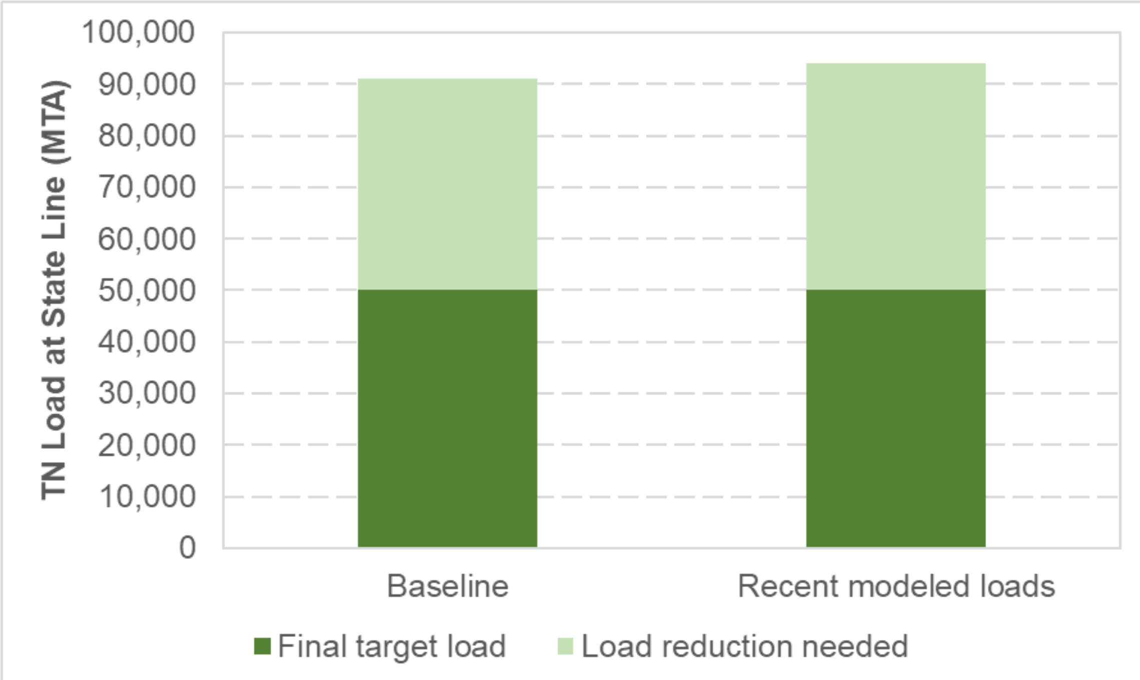

Figure C-2. Baseline and recent modeled TP loads for Minnesota contributions to the Mississippi River Basin drainage areas at the state line.

Note: Includes the Cedar, Des Moines, and Missouri rivers' loads.

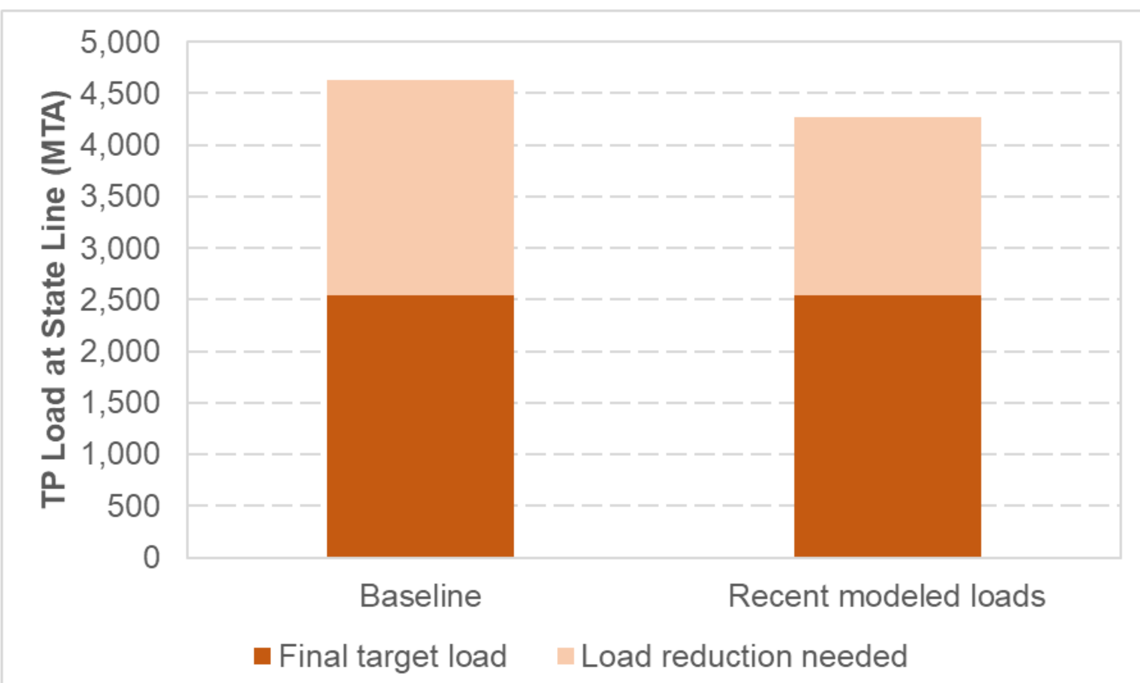

Figure C-3. Baseline and recent modeled TN loads for Minnesota contributions to the Red River of the North Basin drainage area at the state line (at Emerson, Manitoba, Canada).

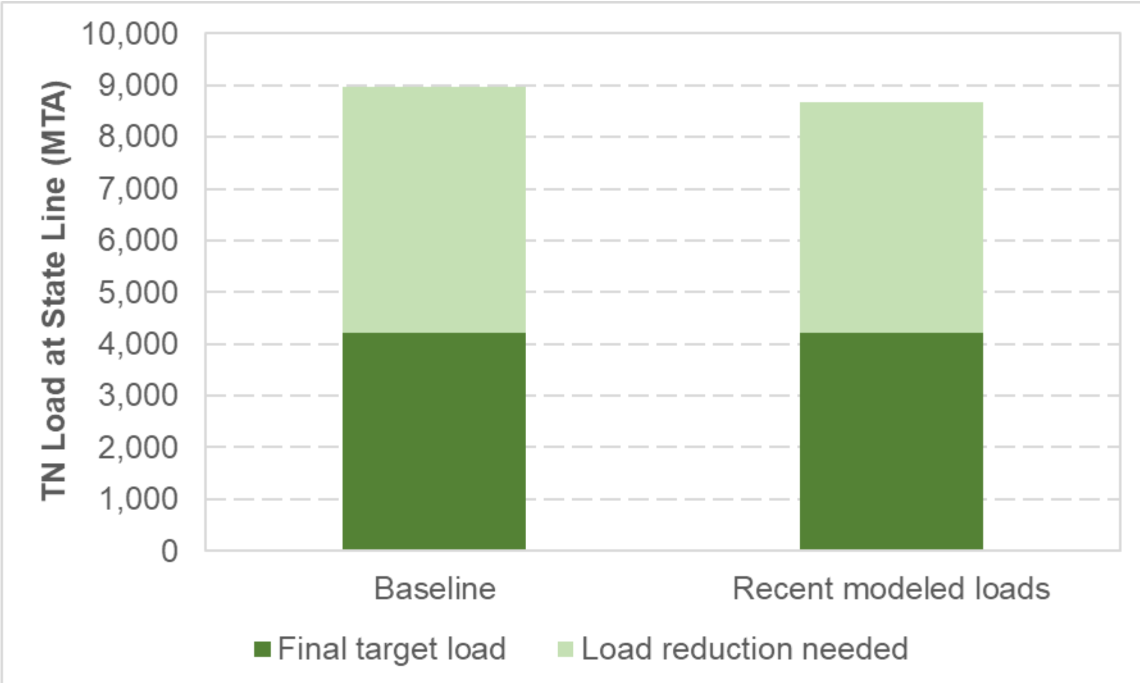

Figure C-4. Baseline and recent modeled TP loads for Minnesota contributions to the Red River of the North Basin drainage area at the state line (Emerson, Manitoba, Canada).

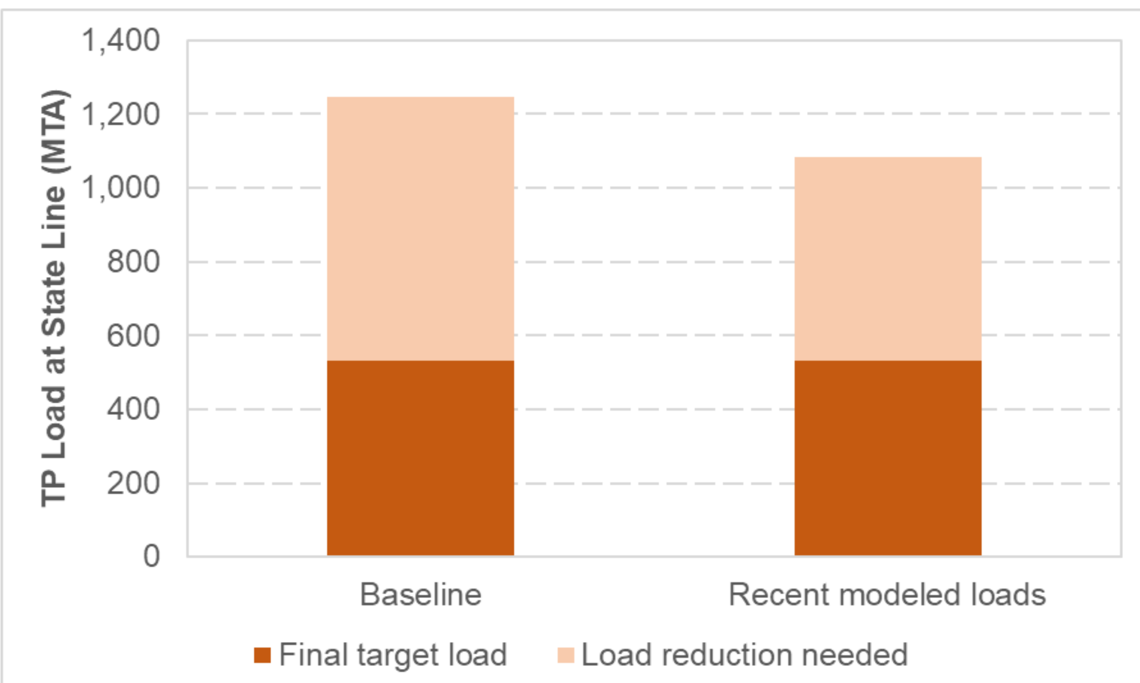

Figure C-5. Recent modeled TN loads for Minnesota contributions into Lake Superior. An original baseline was not defined in the 2014 NRS.

Note: The recent modeled TN load needs to reduce 11 MTA to achieve the final target load.

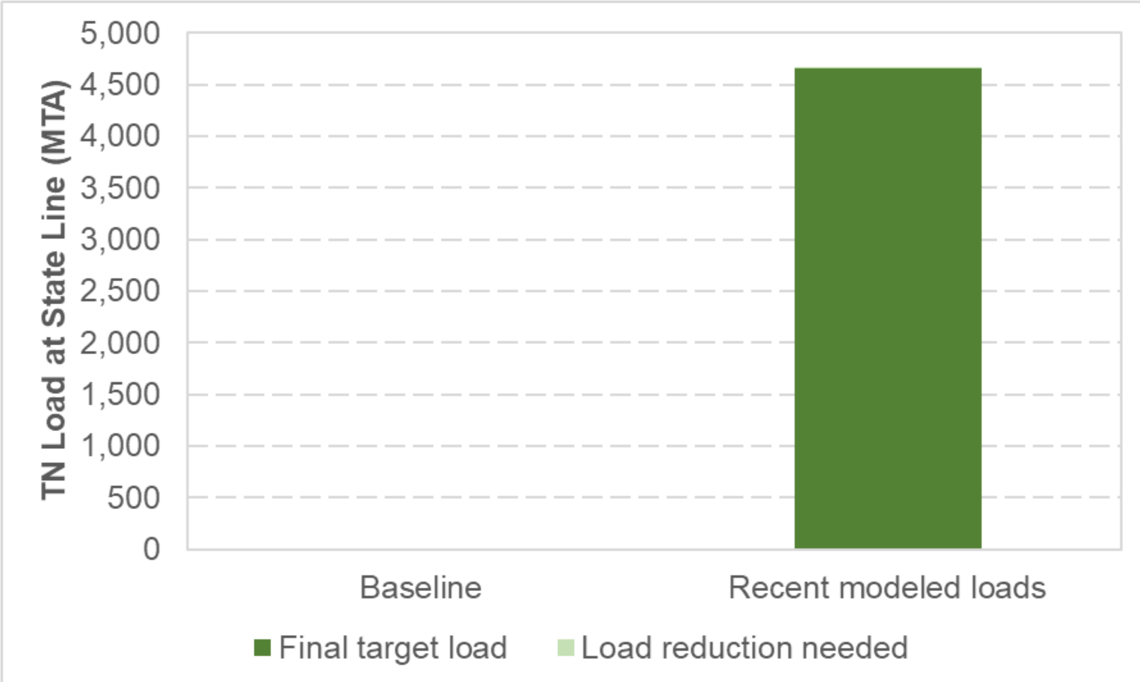

Figure C-6. Original baseline, NRS and recently modeled TP loads for the combined Minnesota watersheds flowing into Lake Superior.

Note: The recent modeled TP load is equivalent to the final target load.