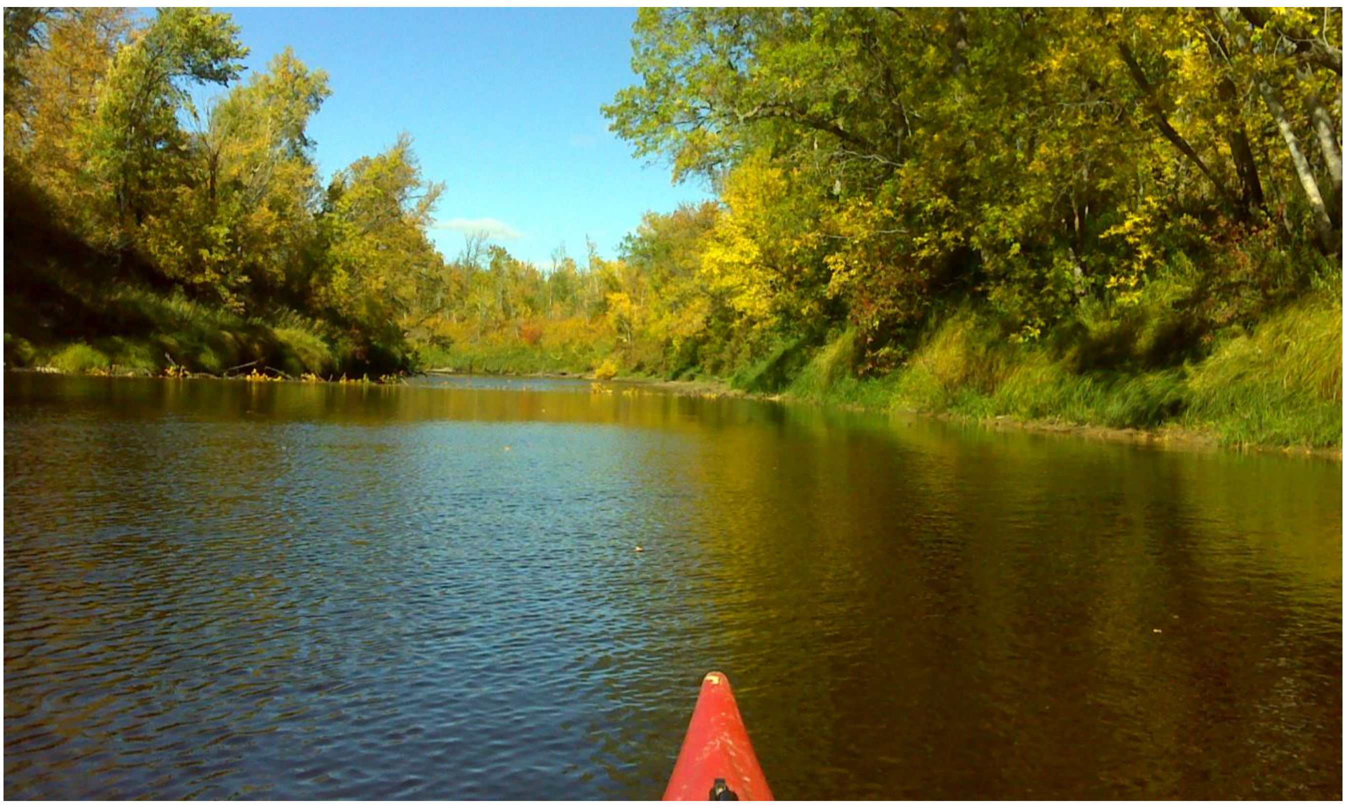
Rapid River Watershed

February 2022

Final Rapid River Watershed Restoration and Protection Strategy Report



MINNESOTA POLLUTION CONTROL AGENCY

Authors

Pat Conrad
Trevor Rundhaug
Meghan Funke, PhD

Contributors/acknowledgements

Mike Hirst
Corryn Trask
Joe Vrtacnik
Cary Hernandez
Mitch Brinks

Editing and graphic design

PIO staff
Graphic design staff
Administrative Staff

Cover photo: Rapid River, Mike Hirst

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Key terms and abbreviations

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Rainy Lake Basin is assigned a HUC-4 of 0903 and the Rapid River Watershed is assigned a HUC-8 of 09030007.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and nonpollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Executive summary

This Watershed Restoration and Protection Strategy (WRAPS) for the Rapid River Watershed (RRW) is a well-researched 10-year roadmap for maintaining healthy waterbodies within the watershed. The WRAPS discusses the characteristics and trends of important resources in the watershed and presents strategies for restoration and protection. These strategies will assist in sustaining a healthy and prosperous environment for the RRW. The WRAPS is intended to be used to guide local water planning, the allocation of funds, and efforts toward conservation practices.

Located in the Laurentian Mixed Forest Ecological Province of northern Minnesota, the RRW covers 573,060 acres. The RRW is characterized by extensive wetlands located on the Glacial Lake Agassiz lake bed. Lake of the Woods County makes up over half of the watershed, with Koochiching and Beltrami Counties accounting for approximately half of the remaining area, at 23% of the total area each.

The RRW is dominated by wetlands and has relatively few streams. In addition to the namesake Rapid River and its North Branch and East Fork tributaries, there are less than 10 named streams within the watershed. There are no lakes in the watershed. Beginning in 2017, the Minnesota Pollution Control Agency (MPCA) initiated intensive watershed monitoring (IWM) efforts of rivers and streams in the watershed. In 2019, the MPCA assessed 12 streams for aquatic life, aquatic recreation, and/or aquatic consumption use support, based on the data collected during IWM. In general, results from the study found that most of the streams in the watershed are in good condition and several of the streams had exceptional biological, chemical, and/or physical characteristics. The lone impairment in the watershed is in the lower reach of the Rapid River (Assessment Unit Identification 09030007-501) from the confluence with the East Fork of the Rapid River to the Rainy River. The Lower Rapid River was assessed as being impaired for aquatic life use due to high levels of total suspended solids (TSS). The main source of TSS in the Lower Rapid River was determined to be from near-stream and stream bank erosion. The watershed's historical ditching practices have significantly altered its watercourses and, subsequently, its flow characteristics. As a result, portions of the Rapid River from upstream of the confluence with the North Branch of the Rapid River to the outlet have become unstable compared to streams in an unaltered watershed.

Several targeting and prioritization processes were conducted to help RRW stakeholders identify, locate, and prioritize WRAPS. The general approach began with a high-level overview of the issues and concerns facing the watershed, and became increasingly more detailed as specific implementation actions were evaluated. Through this process, sediment and altered hydrology were identified as key issues to be addressed in the RRW. Hydrological Simulation Program – FORTRAN (HSPF) modeling was used to evaluate pollutant loading dynamics across the RRW. A variety of geographic datasets were then reviewed by local resource managers and public stakeholders to understand watershed stresses and to prioritize subwatersheds for restoration and protection. Once priority subwatersheds were identified, additional tools were utilized to identify and prioritize specific protection and restoration strategies.

The Agricultural Conservation Planning Framework (ACPF) toolset was used to identify potential grade and ravine stabilization structures that could be built across drainage-ways in the watershed. These potential structures were further prioritized using two indicators of potential feasibility including the distance from the structure to the nearest road and an estimated runoff curve number for the structure's drainage area.

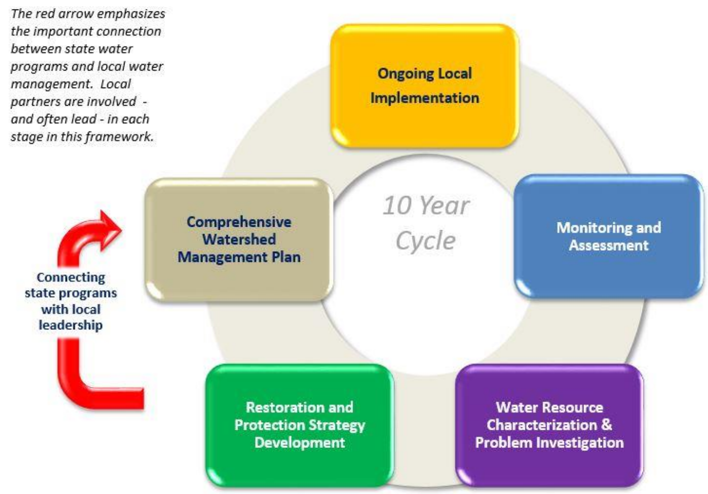
In 2019 and 2020, the Minnesota Department of Natural Resources (DNR) conducted a Bank Erosion Hazard Index (BEHI) geomorphic stream survey of 78.3 miles of streambank in the RRW. The BEHI is a measure of a streambank's vulnerability to erosion and helps determine whether the streambank is eroding at a natural or altered pace. The RRW's BEHI survey was used to identify potential streambank restoration opportunities.

The BEHI survey also identified a total of 108 discreet ravines in the RRW. The ravines were prioritized based on evaluation of each ravine's drainage area. Ravines that have drainage areas with more agriculture, development, or recently harvested timber are more likely to be caused by an increase in runoff. These ravines were prioritized for future stabilization projects.

The collection of current land and water data is an important component to both assess progress and inform management and decision-making. For improved watershed management to work in the RRW, there needs to be reliable data that can be used to generate information. Data from numerous monitoring programs will continue to be collected and analyzed for the RRW. An emphasis should be placed on collecting samples across all flow regimes in the RRW streams to avoid biased sediment concentrations found in high-flow monitoring.

What is the WRAPS report?

Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results into a 10-year cycle that addresses both restoration and protection.



As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds.

This process is called Watershed Restoration and Protection Strategy (WRAPS) development. The WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and total maximum daily load (TMDL) studies are developed for them. The TMDLs are incorporated into the WRAPS reports. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, the WRAPS report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. The WRAPS report also serves as the basis for addressing the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act (CWA) Section 319 implementation funds.

Purpose	•Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning •Summarize watershed approach work done to date including the following reports: •*Rapid River Watershed Monitoring and Assessment* •*Rapid River Watershed Biotic Stressor Identification* •*Rapid River Watershed Total Maximum Daily Load*
Scope	•Impacts to aquatic recreation and impacts to aquatic life in streams
Audience	•Local working groups (local governments, Soil and Water Conservation Districts (SWCDs), watershed management groups, etc.) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The RRW (8-digit Hydrologic Unit Code [HUC] 09030007) is located in the Rainy River Basin. The RRW, which covers 573,060 acres, is located in the Laurentian Mixed Forest Ecological Province of northern Minnesota. Over 79% of the land in the RRW is owned or managed by state entities. The RRW is the third smallest watershed on the Minnesota side of the Rainy River Basin. Like its neighbors, the RRW is characterized by extensive wetlands located on the Glacial Lake Agassiz lake bed. This once-glaciated area is part of the Agassiz Lowlands region. Soils are generally sandy loams, with considerable deposits of glacial till and outwash over a bedrock residuum. Elevations in the RRW range from 1,060 to 1,310 feet above sea level, with the highest values being in the western and northwestern portions of the watershed. Lower elevations are found across the northeastern regions near where the Rapid and Rainy Rivers meet.

As with many areas of northern Minnesota, principal industries include forest product harvesting, forest product manufacturing, farming, and tourism. Much of the land in the RRW is not suited or is poorly suited to agricultural uses. There are 134 farms in the RRW. Most are small farms with less than 1,000 acres.

Wetlands (74.8%) make up most of the RRW, while agricultural lands account for only 3% of the total acres (Figure 1). Development pressure is moderate throughout the RRW, with occasional lands being parceled out for timber production or recreational use. Streams, wetlands, and water resources within the RRW offer ample opportunities for outdoor recreation in a scenic and remote setting, and provide valuable riparian habitat for some of Minnesota's most threatened species. Waterbodies in the RRW that are public waters as defined in Minn. Stat 103G.005, subd. 15, are shown in Figure 1. The watershed contributes to the Rainy River, a widely renowned walleye and lake sturgeon fishery.

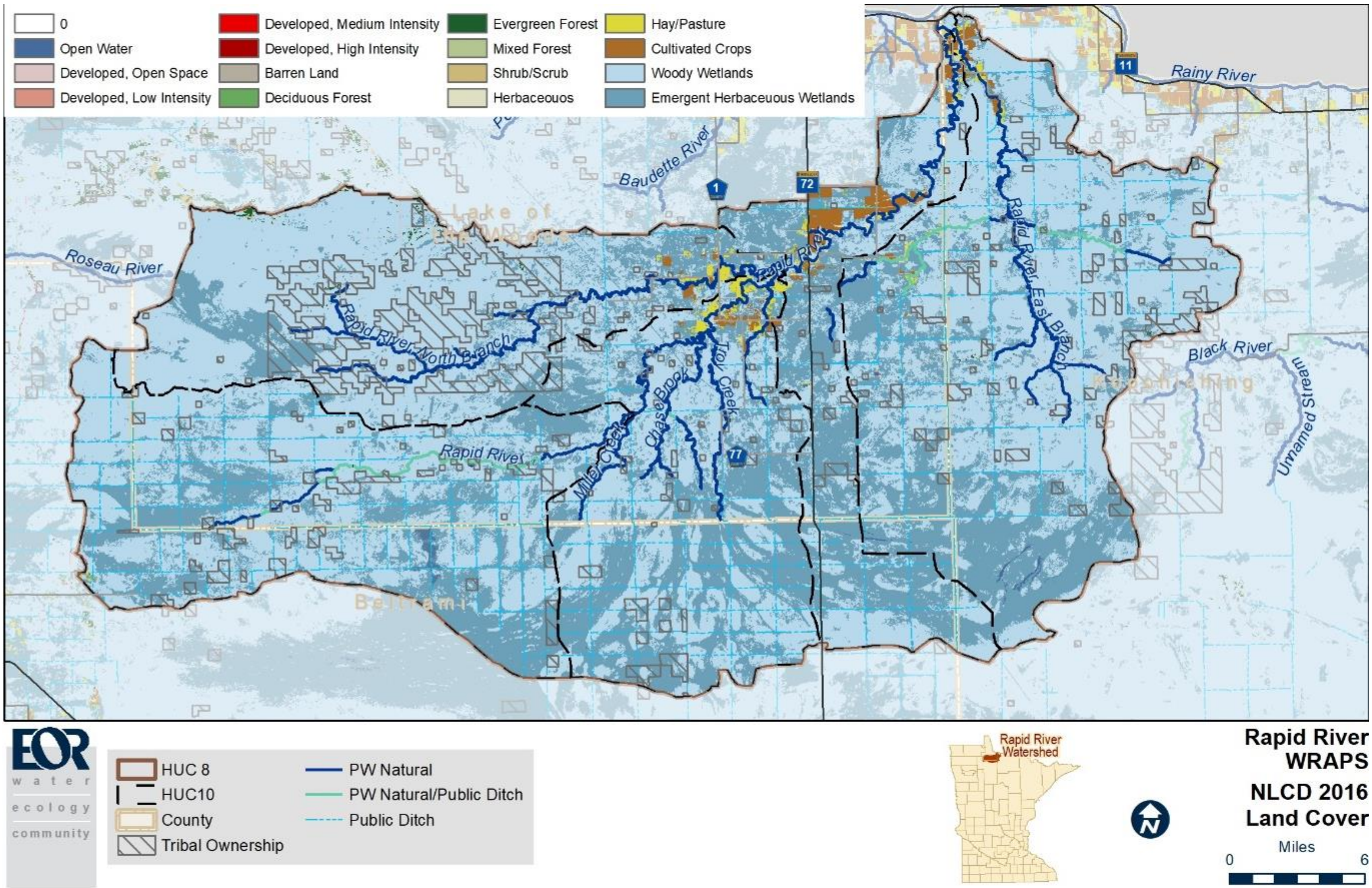


Figure 1. Land Cover in the Rapid River Watershed

Additional Rapid River Watershed resources

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Rapid River Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022947.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Framework Watershed Report Card for the Rapid River Watershed found at:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_78.pdf

Lower Rainy River and Rapid River Watersheds Monitoring and Assessment Report
https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030008b.pdf

Minnesota Nutrient Planning Portal:https://mrbdc.mnsu.edu/mnnutrients/watersheds/rapid-river-watershed

Minnesota Nutrient Reduction Strategy: https://www.pca.state.mn.us/water/nutrient-reduction-strategy

Rapid River Total Maximum Daily Load (TMDL) Study for Total Phosphorus, Total Suspended Solids

Rapid River Geomorphology Summary

International Joint Commission Canada and United States Water and Health in Lake of the Woods and Rainy River:
https://www.ijc.org/sites/default/files/oblak-report.pdf

2. Watershed conditions

In general, water quality conditions within the RRW are good. Low-flow conditions during the Intensive Watershed Monitorting (IWM) effort in 2017 and 2018 limited sampleability within some reaches. However, 11 of 12 (92%) of the stream reaches successfully sampled within the RRW were found to be fully supporting of aquatic life use. The Lower Rapid River, near the Rapid River's mouth, was determined to not support aquatic life use due to elevated levels of TSS (Table 1). The average stream habitat of the 16 streams assessed in the watershed was fair. Channel morphology and substrate ratings were consistently low for the streams, indicating altered hydrology in the watershed.

The RRW bears the legacy of significant ditching campaigns undertaken at the beginning of the 20thcentury to create agricultural land. While these ditches failed to create usable land for farming, they have fundamentally altered the landscape and hydrology within this watershed. A relatively small portion of these ditched systems have been restored to natural conditions. Today, 75% of the RRW's total stream length (including artificially created ditches) is hydrologically altered.

2.1 Condition status

Beginning in 2017, the MPCA initiated IWM efforts of 12 streams within the RRW. In 2019, all 12 streams were assessed for aquatic life and aquatic recreation use support. The MPCA determined that 11 of the streams fully support aquatic life and 1 stream did not support aquatic life use. The MPCA also determined that four streams fully support aquatic recreation and the remaining eight streams did not have sufficient data to assess aquatic recreation. It should be noted that low-flow conditions during the IWM period (2017 through 2018) limited the opportunities to sample some of the stream reaches in the watershed. The results of the IWM monitoring and assessments are further summarized in the following sections. Please refer to the Lower Rainy River and Rapid River Watersheds Monitoring and Assessment Report (Sigl et al. 2020) for full monitoring and assessment details.

Fish tissue samples collected from the Rapid River in 2017 were analyzed for mercury and polychlorinated biphenyls (PCBs). The analyses demonstrated that fish in the Rapid River had low mercury and low PCB levels. Five white suckers collected from the Rapid River were composited into two samples for analysis; both samples were well below the 0.2 parts per million (ppm) mercury standard and PCBs were less than the reporting limit.

For more information on mercury impairments, see the statewide mercury TMDL on the MPCA website at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Note that there are no lakes in the RRW.

Monitoring Design

The main streams within the RRW are the North Branch of the Rapid River, the East Fork Rapid River, and the Rapid River. Tributaries in the RRW include Barton's Brook, Wing River (the only cold-water fishery in the RRW), Troy River, Christy Creek, and Miller Creek. Four water chemistry stations were sampled within the RRW from May through September in 2017, and again June through August of 2018, to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the IWM design, water chemistry stations were placed at the outlet of each aggregated HUC-12 subwatershed that was greater than 40 square miles in area. Additional water chemistry monitoring was conducted by the Lake of the Woods County Soil and Water Conservation District (SWCD) through funding made available by a Surface Water Assessment Grant (SWAG) and as part of the Watershed Pollutant Monitoring Network (WPLMN). The monitoring stations in the RRW are shown in Figure 2.

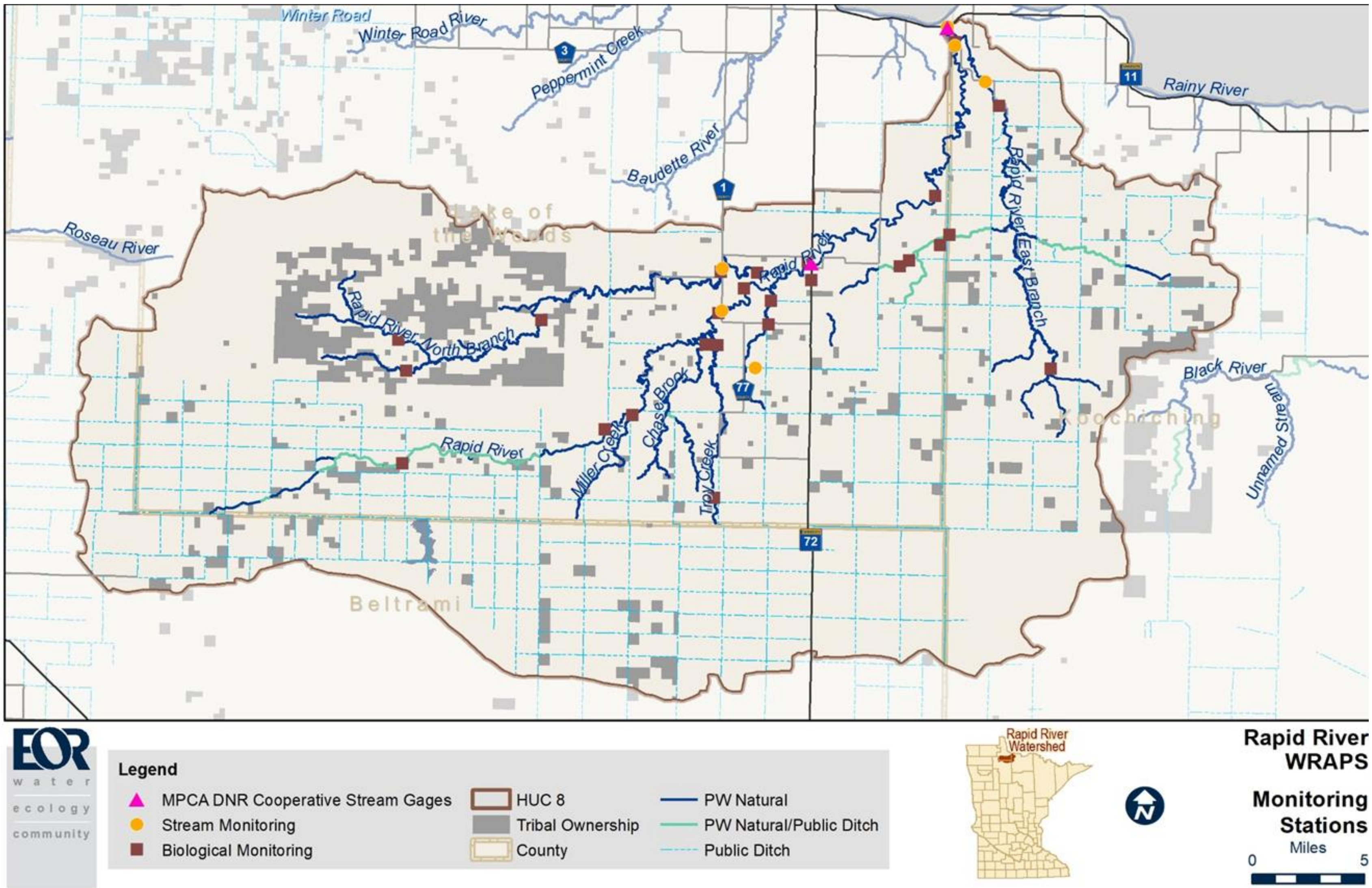


Figure 2. Monitoring stations in the Rapid River Watershed.

Assessments

The assessment status of each river reach in the RRW is shown in Table 1. Figure 3 shows the location of the assessed streams labeled with the last three digits of their AUID. Unassessed streams are included in Appendix B. In many cases (e.g., Christy Creek) fish or aquatic macroinvertebrate communities performed well and meet the state's 'exceptional use' standards (MPCA's highest use class designation). Several of these streams had exceptional biological, chemical, and/or physical characteristics that are worthy of additional protection.

In cases where macroinvertebrate and/or fish communities were impaired, low dissolved oxygen (DO) and altered hydrology/channelization likely played a role. Much of the wetland and peat bog landscape within these watersheds bears the legacy of extensive ditching and dredging campaigns undertaken at the turn of the 20th century. Today, nearly 100 years after the end of these ditching campaigns, 75% of stream lengths in the RRW remain altered. Elevated suspended sediment concentration in the downstream reach of the Rapid River represents a threat to the health of aquatic communities.

Table 1. Assessment status of river reaches in the Rapid River Watershed

Aggregated HUC-12 Subwatershed	AUID (Last 3 digits)	River	Reach description	Aquatic life				Aquatic recreation
				Fish Index of biotic integrity	Macroinvertebrate index of biotic integrity	Dissolved oxygen	Turbidity/TSS	Bacteria
Upper Rapid River	506	Rapid River	Headwaters to Chase Brook	SUP	SUP	IF	IF	SUP
North Branch Rapid River	503	North Branch Rapid River	Headwaters to Rapid River	SUP	SUP	IF	SUP	SUP
	528	Unnamed Creek	Unnamed Creek to North Branch Rapid River	SUP	SUP	NA	NA	NA
Middle Rapid River	504	Rapid River	Troy Creek to North Branch Rapid River	SUP	SUP	IF	SUP	SUP
	508	Troy River	Headwaters to Rapid River	SUP	SUP	NA	NA	NA
	513	Christy Creek	Moose Creek to Unnamed Creek	SUP	NA	NA	NA	NA
	523	Miller Creek	Headwaters to Rapid River	SUP	NA	IF	IF	NA
Lower Rapid River	501	Rapid River	East Fork Rapid River to Rainy River	NA	NA	IF	IMP	NA
	502	Rapid River	North Branch Rapid River to East Fork Rapid River	SUP	SUP	IF	IF	SUP
	529	Unnamed Ditch	Unnamed Ditch to Rapid River	SUP	NA	IF	IF	NA
Barton's Brook	510	Barton's Brook	Headwaters to East Branch Rapid River	SUP	NA	IF	IF	NA
East Fork Rapid River	509	East Fork Rapid River	Barton's Brook to Rapid River	NA	NA	IC	IC	SUP

SUP = (Supporting) found to meet the water quality standard, IMP = does not meet the water quality standard and, therefore, is impaired,
IF = the data collected was insufficient to make a finding, NA = not assessed, IC = Inconclusive, Hydrologic Unit Code (HUC), Assessment Unit Identification (AUID)

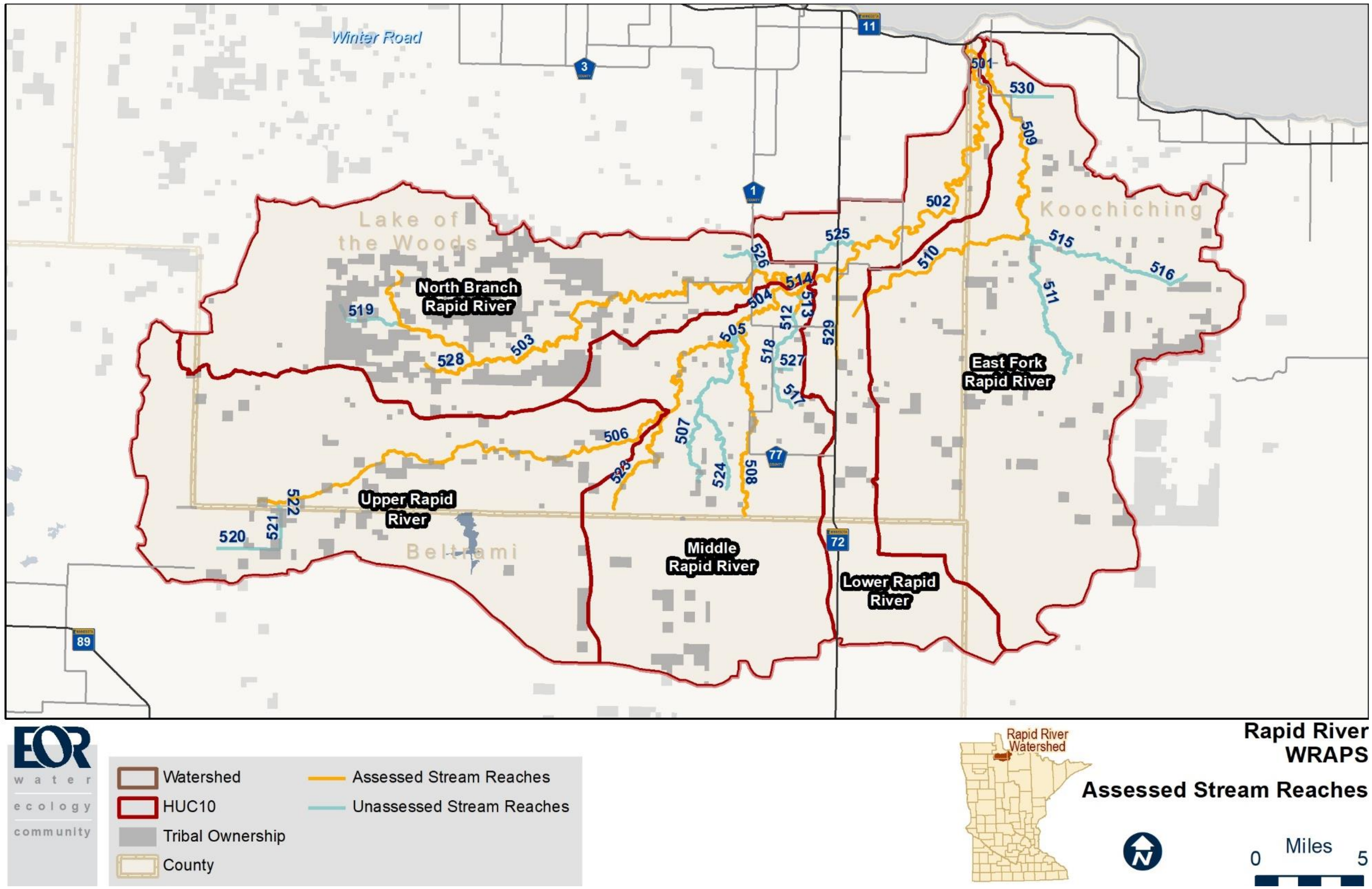


Figure 3. Assessed stream reaches in the Rapid River Watershed.

Problem Investigation Monitoring

To help focus the implementation of restoration strategies on the TSS-related aquatic life use impairment on the lower reach of the Rapid River (AUID 09030007-501 [501]), (Figure 4) the MPCA conducted discrete sampling along the Rapid River and its major tributaries to identify potential contributing sites. Five sites were sampled on 10 different dates between August 2019 and June 2020 (Table 2; Figure 2); most of the samples were collected following storm events. Each sample was analyzed for TSS and Volatile Suspended Solids (VSS).

For the samples collected at Site S000-184 (State Highway 11) on the Rapid River (501), the concentration of VSS ranged from 9% to 23% of the concentration of TSS. This indicates that the largest component of the TSS load of the Rapid River (501) is in the inorganic fraction. According to Table 2, the highest TSS concentrations at Site S000-184 coincided with flow values of 2,000 cfs or greater. At these higher flow levels, the TSS load of the Rapid River (501) appears to be driven by upstream inputs from the main stem of the Rapid River, particularly between Site S009-453 (County State Aid Highway (CSAH) 1 crossing) and Site S009-451 (CSAH 18 crossing). Lastly, the data suggest that the East Fork Rapid River and North Branch Rapid River are not contributing excessive amounts of TSS to the Rapid River (501); nearly all the samples for these tributaries had a TSS concentration well below the standard of 15 milligrams per liter (mg/L). The five water quality monitoring sites and their average TSS concentrations are shown in Figure 5.

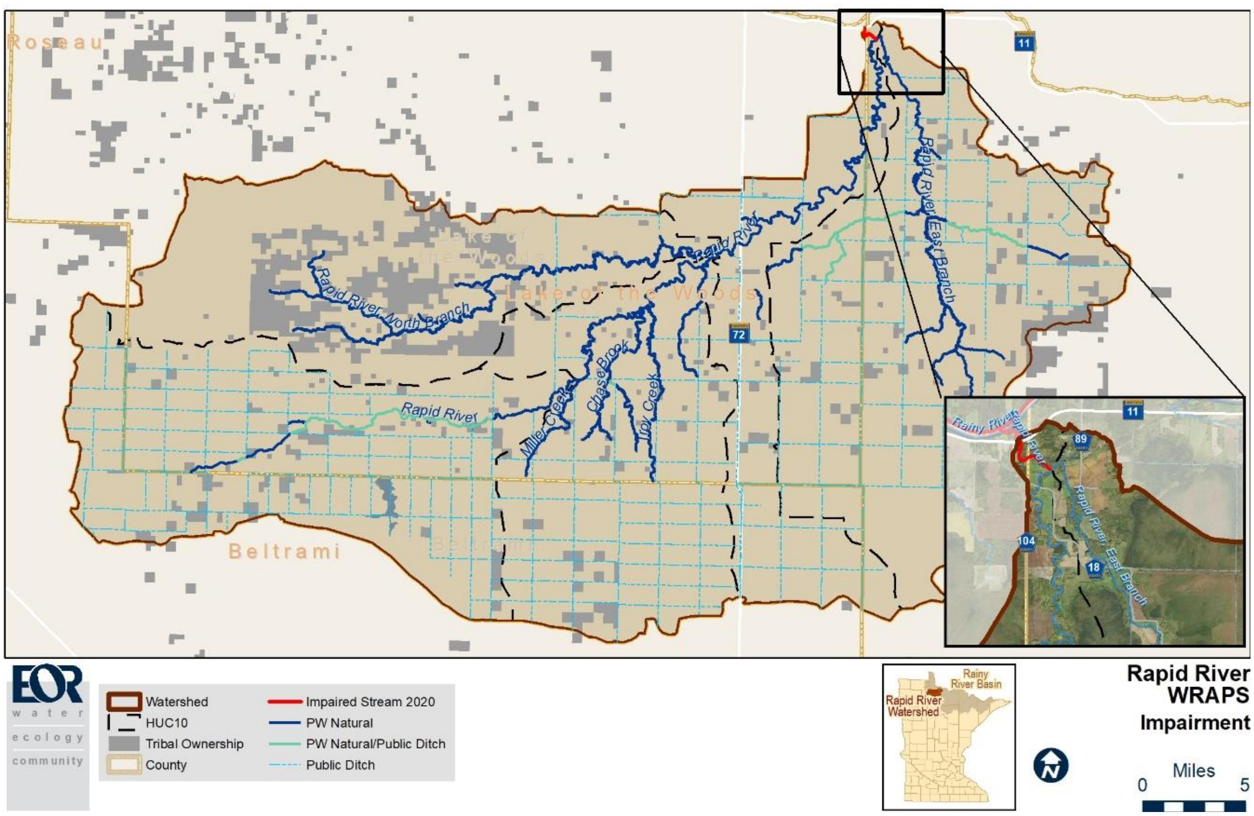


Figure 4. Impaired stream reach in the Rapid River Watershed

Table 2. Summary of available TSS and flow data for discrete sampling sites from 2019-2020 monitoring.

Sample Date	Sampling Sites					
	Rapid River CSAH 1 (S009-453)	N. Branch Rapid River CSAH 1 (S009-452)	Rapid River CSAH 18 (S009-451)	E. Fork Rapid River CSAH 18 (S007-611)	Rapid River State Highway 11 (S000-184)	
	TSS (mg/L)	TSS (mg/L)	TSS (mg/L)	TSS (mg/L)	TSS (mg/L)	Flow (cfs)
8/15/2019	1.2	3.3	3.8	7.3	3.1	40
9/13/2019	4.6	3.1	6.6	11.8	6.6	400
9/16/2019	9.0	3.0	7.6	10.4	7.3	530
10/2/2019	13.8	7.5	23.8	10.6	21.8	2000
10/16/2019	14.7	6.1	36.6	5.7	28.7	4100
5/27/2020	24.4	5.9	3.4	14.7	6.8	400
5/28/2020	18.1	7.6	14.9	10.4	9.0	870
6/3/2020	4.5	3.4	3.8	10.7	4.5	380
6/11/2020	29.5	17.0	53.4	22.4	38.8	2000
6/17/2020	18.0	8.3	17.9	11.2	13.0	760

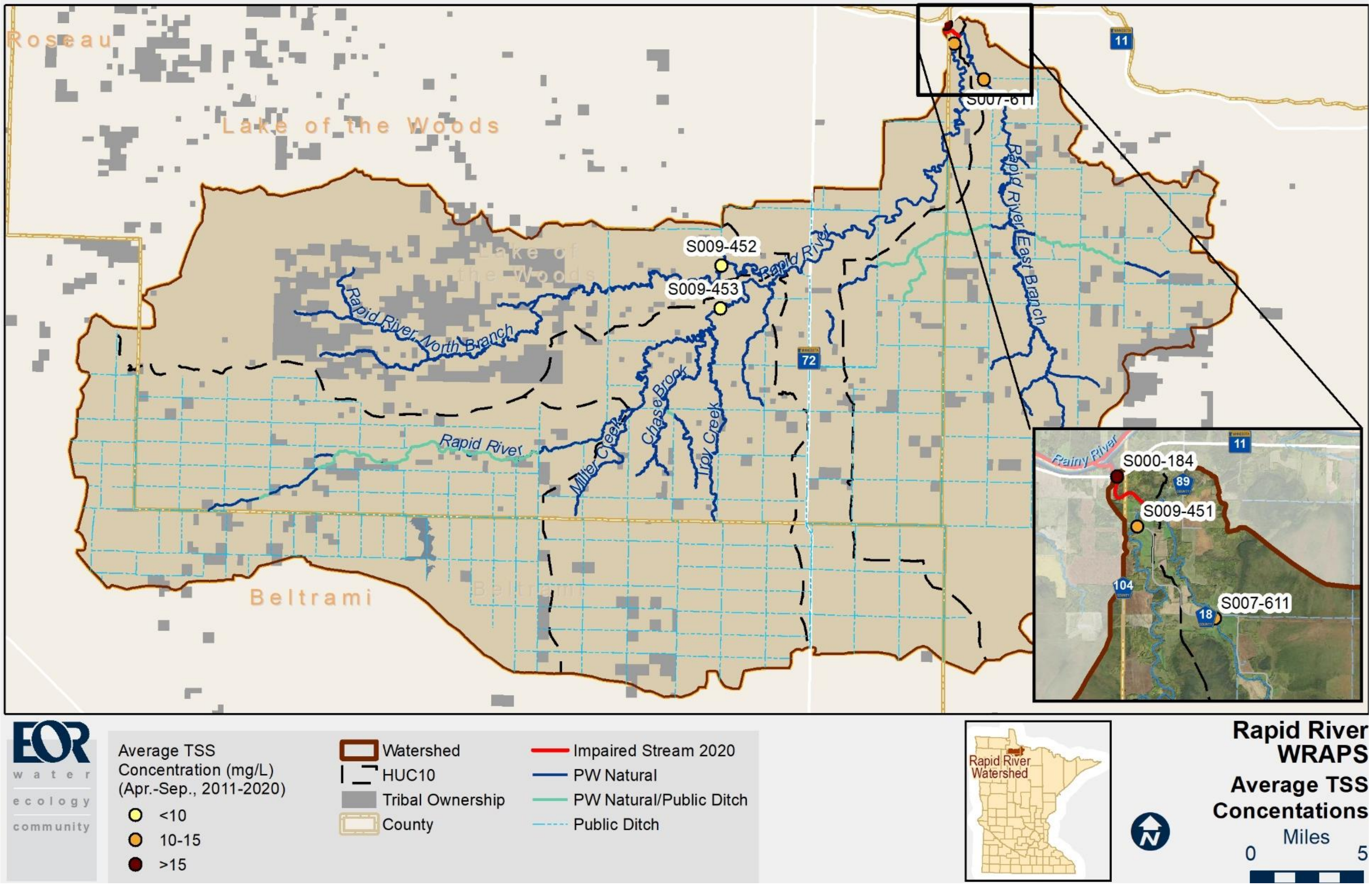


Figure 5. Average April through September total suspended solids in the Rapid River Watershed (2011-2020).

2.2 Water quality trends

Water Clarity

The MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements. The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to Environmental Quality Information System (EQuIS). The trends are calculated using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data, using Secchi disk measurements in lakes and Secchi tube measurements in streams. Three stream sites in the RRW have declining trends in water clarity (Table 3). Two of these sites are in the downstream reaches of the Rapid River (S009-451 and S000-184), one is in the downstream reach of the East Branch Rapid River Subwatershed (S007-611).

Water Quality

Seasonal Kendall statistical tests for water quality trends were conducted using "R", a statistical software program that can be used to identify statistically significant trends in the water quality of streams and lakes in the watershed. This analysis was controlled to include only data collected from June through September for the years 2011 through 2020, and trends were only reported for constituents with at least eight years of data and 90% statistical confidence. The analysis indicated that there were no significant trends in the RRW. Both inorganic nitrogen (nitrate and nitrite) and TSS concentrations were identified as having slight declining trends near the outlet of the Rapid River (501) while the Rapid River, East Branch was identified as having slightly improving trends (Table 4).

Table 3. Water clarity trends in the Rapid River Watershed

Rapid River (09030007)	Streams	Lakes
Number of sites w/improving trend	0	--
Number of sites w/declining trend	3	--
Number of sites w/no trend	0	--

Table 4. Recent water quality trends (2011-2020) in the Rapid River Watershed

Waterbody	AUID	Parameter	Short-term Trend (2011-2020)
Rapid River	09030007-501	Inorganic Nitrogen	Slightly decreasing, not significant
		Total Suspended Solids	Slightly decreasing, not significant
Rapid River, East Branch	09030007-509	Inorganic Nitrogen	Slightly increasing, not significant
		Total Suspended Solids	Slightly increasing, not significant

Assessment Unit Identification (AUID)

In June 2014, the MPCA published its final trend analysis of river monitoring data located statewide based on the historical Milestones Network. The period of record is generally more than 30 years, through 2010, with monitoring at some sites going back to the 1950s. The 2014 final trend analysis reported long-term trends for TSS, total phosphorus (TP), and chloride as decreasing and reported no long-term trends for nitrite/nitrate, ammonia, and biological oxygen demand.

Starting in 2017, the MPCA switched to the Watershed Pollutant Load Monitoring Network (WPLMN). There are two long-term monitoring locations in the RRW, on the Rapid River at Clementson, MN11, and on the East Fork Rapid River at Clementson, CSAH 18. Users can access this data via the WPLMN browser, which shows the location of long-term monitoring sites throughout the state. It includes links to the MPCA's Environmental Data Access portal that contains all monitoring data for the entire period of record, including more recent data through 2019. As shown in Figure 6, Figure 7, and Figure 8, average flow weighted mean TP, total nitrogen (TN), and TSS concentrations from 2007 through 2016, in the RRW were low relative to other areas in the state.

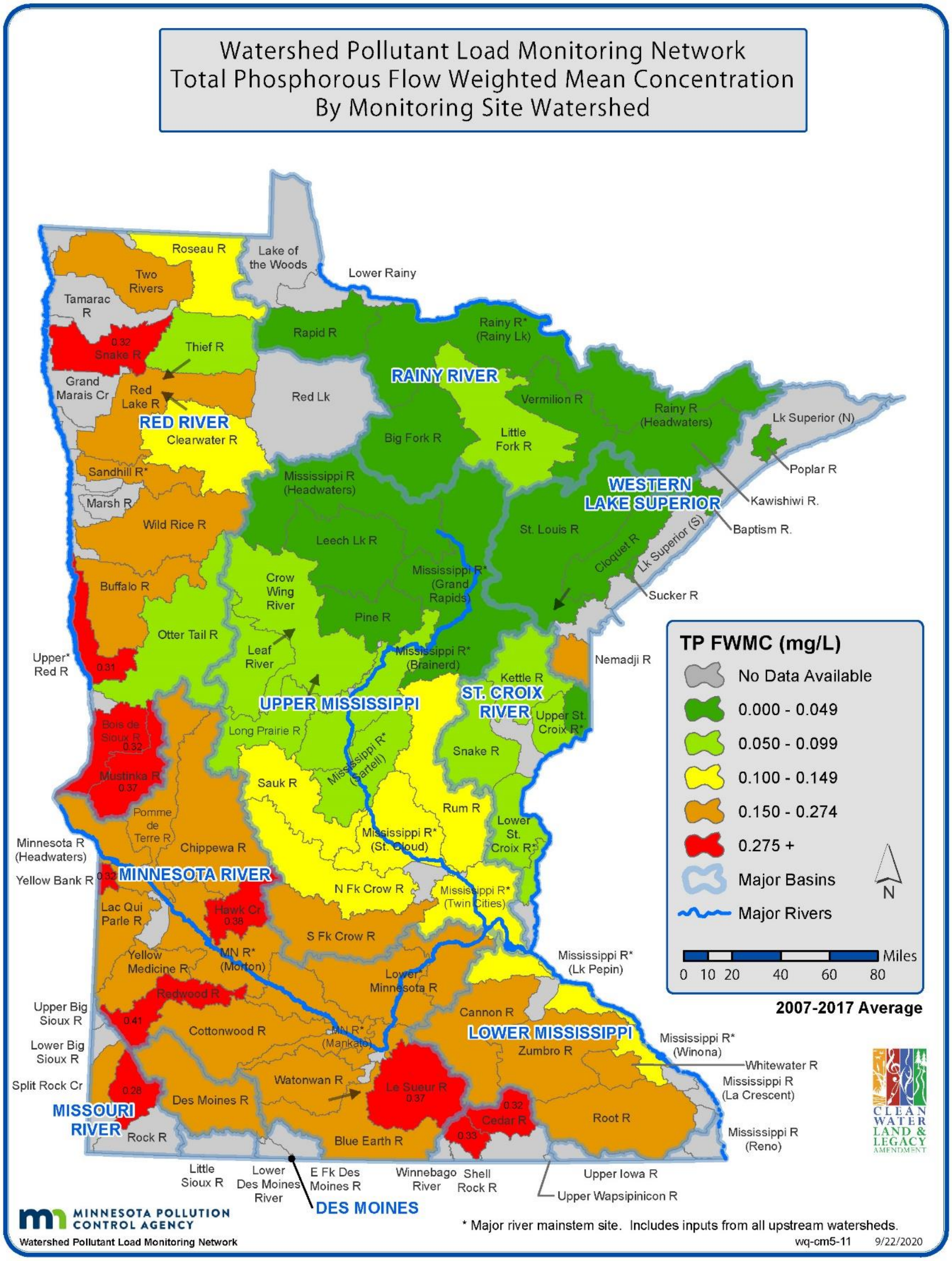


Figure 6. Watershed Pollutant Load Monitoring Network – Average Total Phosphorus Flow Weighted Mean Concentration from 2007-2017

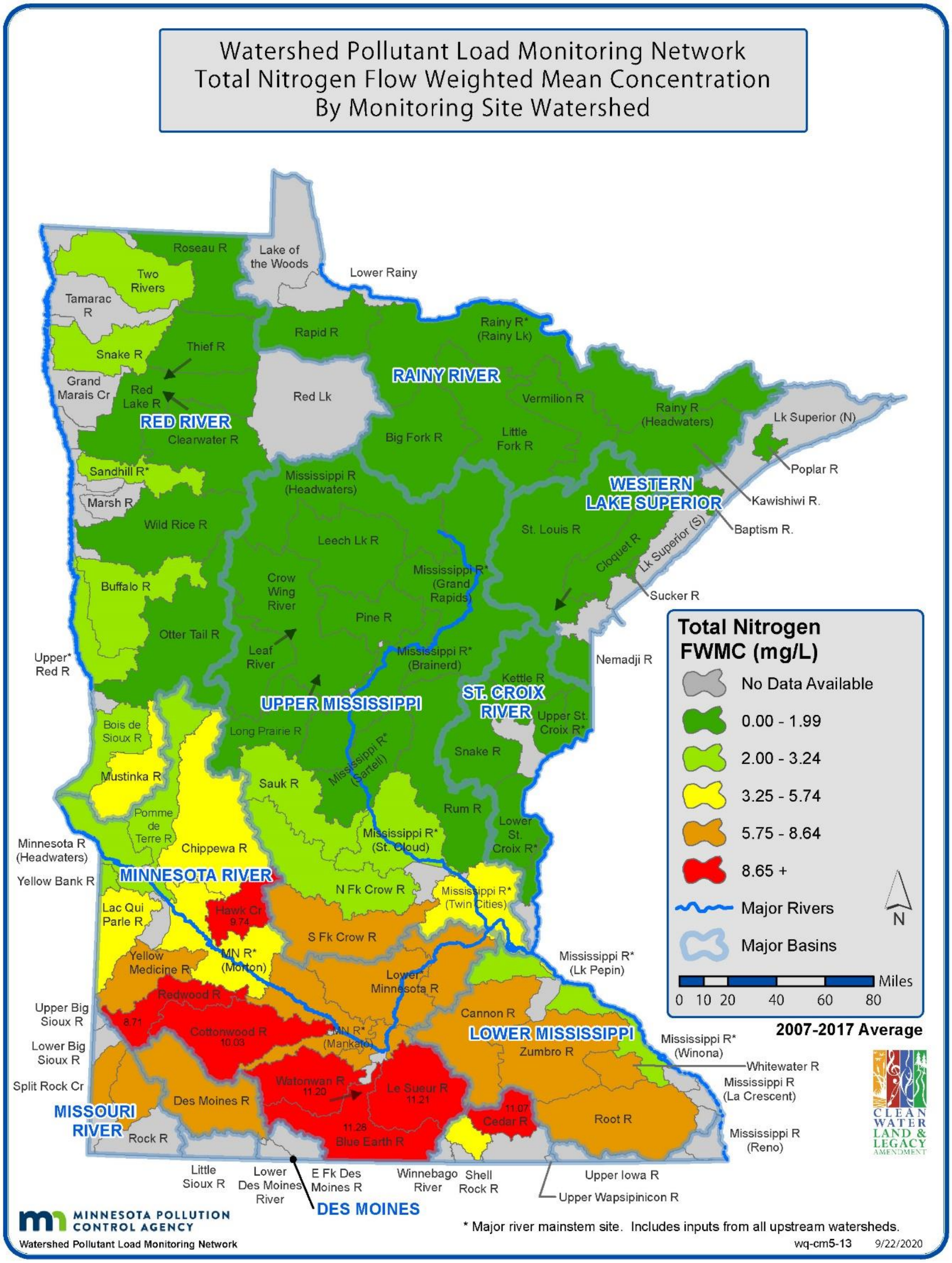


Figure 7. Watershed Pollutant Load Monitoring Network – Average Total Nitrogen Flow Weighted Mean Concentration from 2007-2017

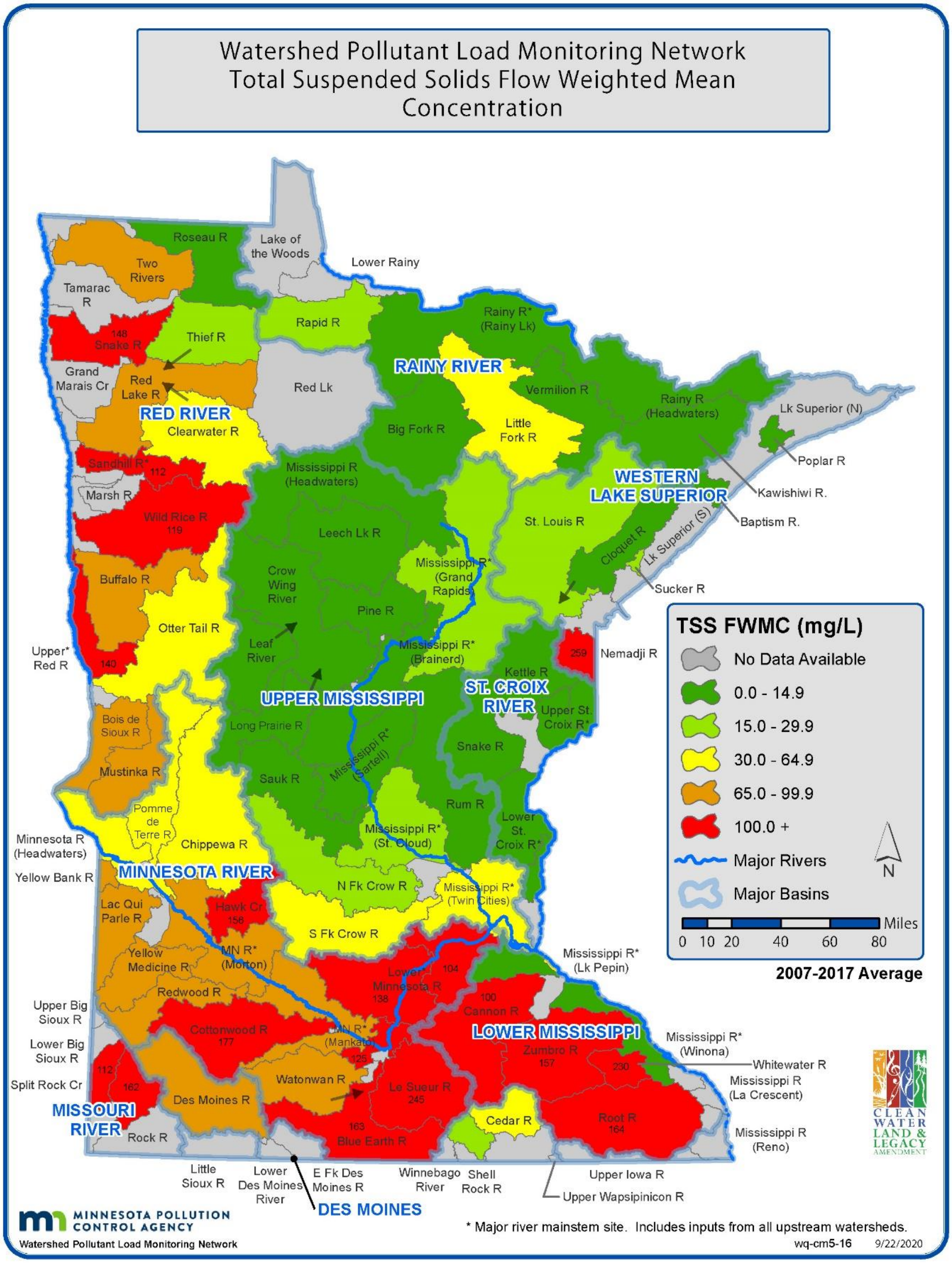


Figure 8. Watershed Pollutant Load Monitoring Network – Average Total Suspended Solids Flow Weighted Mean Concentration from 2007-2017

2.3 Stressors and sources

To develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated.

Stressors

A **stressor** is something that adversely impacts or causes fish and/or macroinvertebrate communities in streams to become unhealthy. A biological stressor identification (SID) study is conducted for streams that are assessed as impaired for aquatic life use due to low fish and/or macroinvertebrate Index of Biological Integrity (IBI) scores.

Pollutant source assessments are completed where a biological SID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings such as TSS.

Overall, the streams in the RRW were found to support healthy aquatic communities. In some cases, like the North Branch Rapid River, the IBI scores for fish and/or aquatic macroinvertebrate communities scored close to their respective IBI impairment thresholds but did not fall below thresholds.

Since there are no RRW river reaches that were assessed as being impaired for aquatic life due to low fish or macroinvertebrate IBI scores a SID effort was not conducted.

Pollutant sources

This section summarizes the sources of pollutants (such as phosphorus, bacteria, or sediment) to streams in the RRW. A detailed breakdown of TSS, TN, and TP loading predicted by the HSPF model at the outlet of the impaired reach (501) is provided in Figure 9. The predicted TSS load represents the input of the pollutant of concern for the impaired reach (501) of the Rapid River. The TP load at HSPF represents the load delivered from the RRW to Rainy River. More information about the HSPF model is provided in Section 3.2 of this document. Nonpoint source pollution represents the dominant pathway for TSS delivery to the impaired stream reach (501) and for TP export from the watershed.

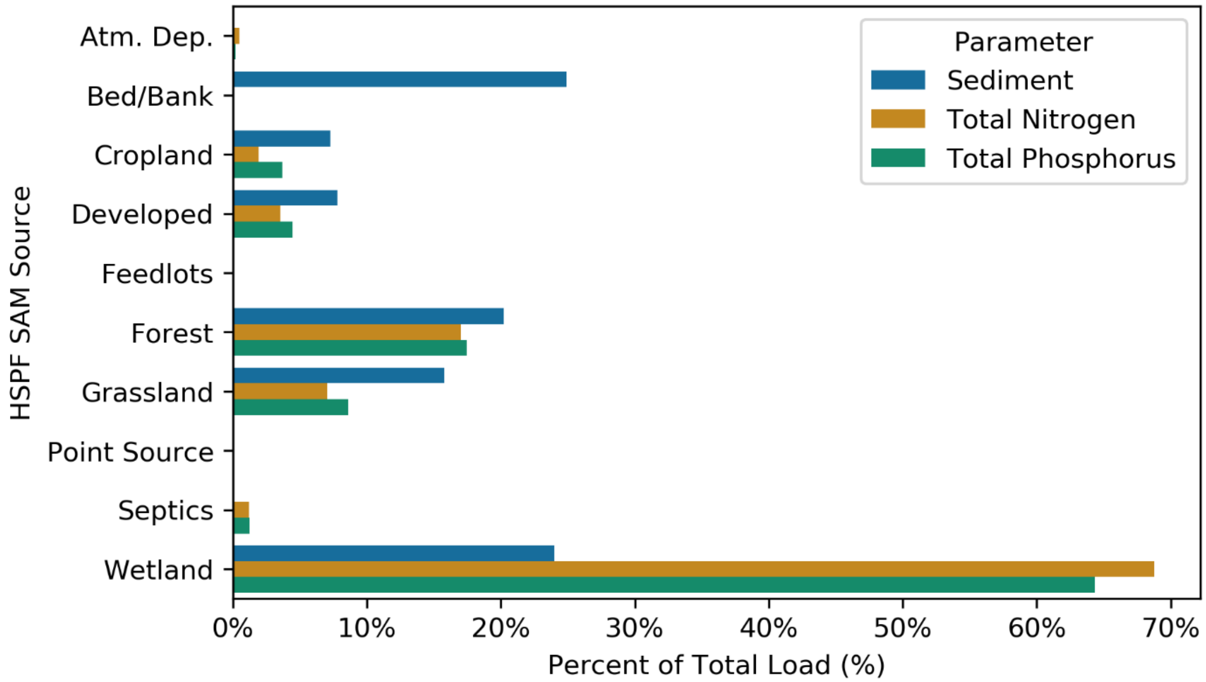


Figure 9. Breakdown of pollutant sources in the Rapid River Watershed from the HSPF SAM model (Reach 370 in the model).

Point Sources

Point sources are defined as facilities that discharge stormwater or wastewater to a lake or stream and have a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Permit (Permit). There are two nonmetallic mining operations that require NPDES/SDS permits located in the RRW. Table 5 shows all permitted point sources in the RRW. There are no active NPDES/SDS permitted feedlots located within the RRW.

Table 5. Point sources in the Rapid River Watershed.

HUC-12 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?
	Name	Permit #	Type	
Troy Creek (090300070203)	Mark Sand & Gravel Acquisition Company	MNG490126	Nonmetallic mining	No
Lower East Fork Rapid River (090300070406)	MNDNR Forestry	MNG490239	Nonmetallic mining	No

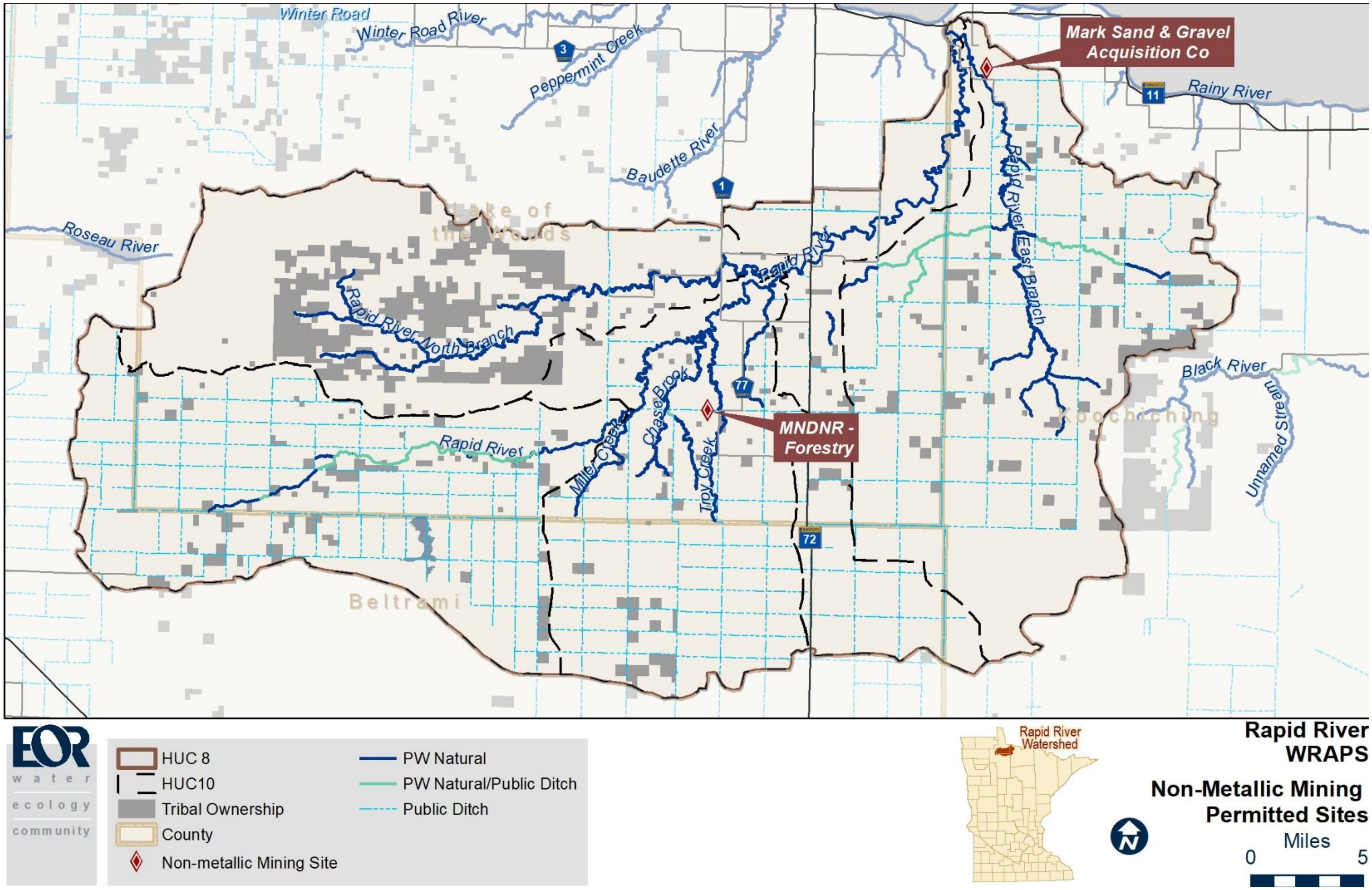


Figure 10. Point sources in the Rapid River Watershed

Nonpoint Sources

Nonpoint pollution, unlike pollution from industrial and municipal sources, comes from many different sources. Nonpoint-source pollution is carried by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-caused pollutants and deposits them into lakes and streams. Significant nonpoint and natural pollutant sources identified in the RRW include:

- **Unstable Streambanks:** Evaluation of the Rapid River from the confluence with North Branch of the Rapid River to the impaired stream reach identified stretches of streams with moderate levels of streambank erosion. The likely causes for the instability are the extensive ditch network in the watershed and land disturbances near the stream bank either from agriculture, roads, or timber harvesting.
- **Watershed runoff:** The HSPF model was used to estimate watershed runoff volumes and TSS loads for all 31 individual subwatersheds in the RRW based on land cover and soil type and was calibrated using meteorological data from 2001 through 2015**.**
- **Timber harvesting**: Forest harvest has been and currently is a major activity within the RRW. Historical large-scale forest removal occurred in the watershed which may have created legacy effects still being experienced by streams today.
- **Geology and soils:** The fine silty clay soils in the RRW were formed in the former glacial Lake Agassiz. Watersheds containing glacial clays are more vulnerable to elevated TSS concentrations because glacial clays are easily suspended and are slow to settle out of the water column.

Altered Hydrology

In addition to traditional point and nonpoint sources of pollutants, human activities to modify drainage patterns within a watershed can play a significant role in determining the health of its water resources. Many subwatersheds in the RRW, particularly in the Upper Rapid River, East Fork Rapid River, and Lower Rapid River Subwatersheds, have extensive alterations to the natural drainage system with over 90% alteration of their watercourses. Almost all these drainage systems were constructed in the early 1900s. Hydrologic alterations within the RRW can result in disruptions to aquatic life, increased peak flows, lower base flows, and increased nutrient and sediment concentrations in the stream. Figure 11 shows an example of one of these impacts, higher bankfull flow. Bankfull flow is a key measure in stream geomorphology and a higher bankfull flow corresponds to more unstable streams. The Rapid River near Baudette is in the higher bankfull flow grouping (Figure 11, red line) in the Rainy River Basin. The watersheds in the higher bankfull flow grouping have similar issues with altered flow and or higher percentages of agricultural land in the Rainy River Basin while the watersheds with lower bankfull flows are more natural. Section 3.1 of the WRAPS provides furthers details on how altered hydrology was used to target implementation areas in the RRW.

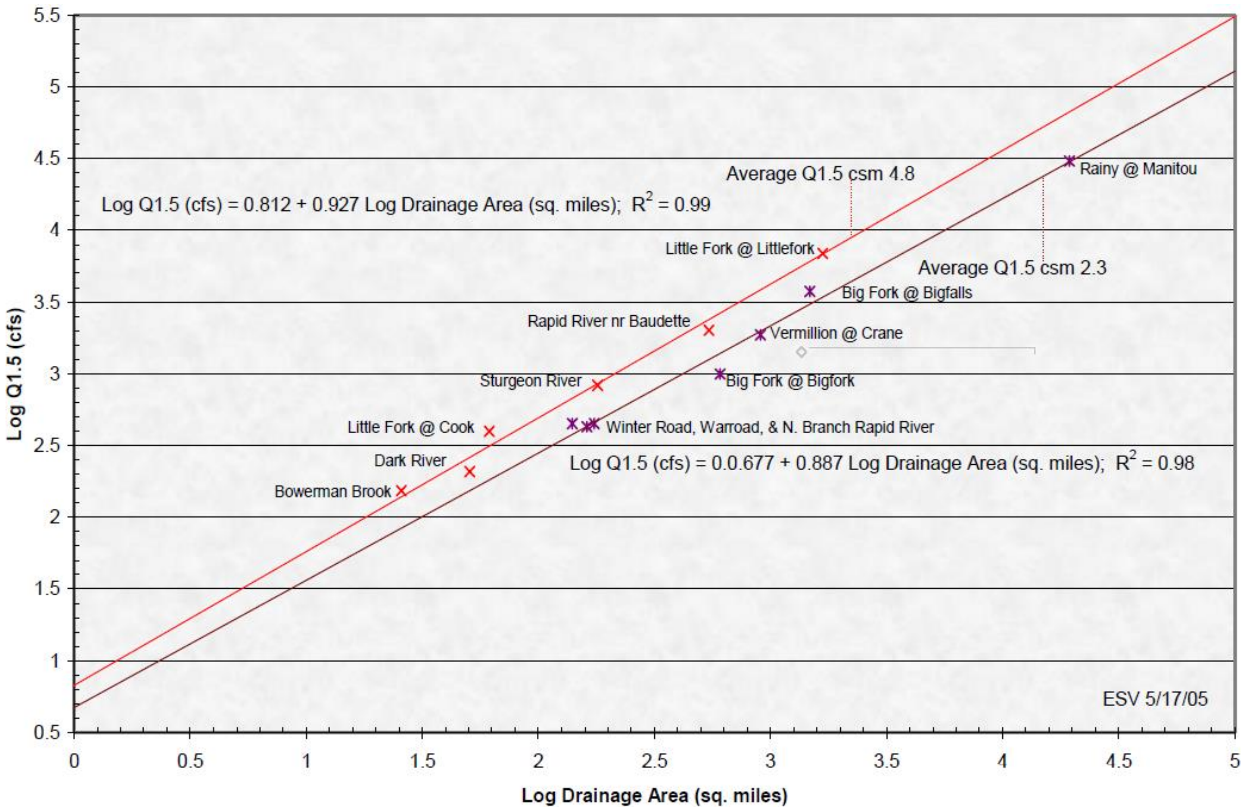


Figure 11. Rainy River Basin Regional Curve. Based on data from US Geologic Survey gaging stations in the Little Fork and Big Fork River physiographic region (Anderson et al. 2006)

2.4 TMDL summary

A TMDL is a calculation of how much pollutant a lake or stream can assimilate while still meeting water quality standards. These studies are required by the CWA for all impaired lakes and streams. There is one impaired stream reach in the RRW with a completed TMDL Study, the lower reach of the Rapid River (501). This reach of the Rapid River is impaired for aquatic life use due to elevated TSS levels (see Table 1). The existing pollutant loading, wasteload allocations (WLA) and load allocations (LA), margin of safety (MOS), and load reductions needed to meet the requirements of the TMDL, for the Rapid River (501), are shown in Table 6.

Table 6. Lower Rapid River (09030007-501) Total Suspended Solids TMDL and Allocations.

Lower Rapid River (09030007-501)		**Flow Regime**				
		Very High (cfs)	High (cfs)	Mid-Range (cfs)	Low (cfs)	Very Low (cfs)
		2090	592	183	27	5.9
Load Component		**Total Suspended Solids (TSS) (lbs per day)**				
Existing Load*		**415,972.2**	**117,726.0**	**36,422.5**	**5,373.9**	**1,174.2**
Wasteload Allocations	*Construction stormwater (MNR1000001)*	*12.0*	*3.4*	*1.0*	*0.2*	*0.03*
	Industrial stormwater (MNR050000)	*58.8*	*16.6*	*5.1*	*0.8*	*0.2*

Lower Rapid River (09030007-501)		Flow Regime				
		Very High (cfs)	High (cfs)	Mid-Range (cfs)	Low (cfs)	Very Low (cfs)
		2090	592	183	27	5.9
Load Component		Total Suspended Solids (TSS) (lbs per day)				
	Nonmetallic Mining (MNG490000)	*11.5*	*3.3*	*1.0*	*0.15*	*0.03*
	Total WLA	**82.3**	**23.3**	**7.1**	**1.15**	**0.26**
Load Allocations	*Nonregulated sources*	*152,102.7*	*43,047.2*	*13,318.2*	*1964.95*	*429.34*
	Total LA	**152,102.7**	**43,047.2**	**13,318.2**	**1964.95**	**429.34**
10% Margin of Safety		**16,909.4**	**4,785.6**	**1,480.6**	**218.4**	**47.7**
Total Loading Capacity		**169,094.4**	**47,856.1**	**14,805.9**	**2,184.5**	**477.3**

*Existing TSS loads were based on 90th percentile TSS concentration from of all samples collected at S000-184 during the months of April-September and the years 2010-2019 multiplied by the median flow for each flow regime at the DNR stream gage Rapid River at Clementson MN11 (78007001).

The reduction goals shown in Table 6 indicate an average annual reduction of 59% is needed to achieve the TSS standard 90th percentile concentration of 15 mg/L from the existing 90th percentile TSS concentration of 37 mg/L, from samples collected between April and September in 2010 through 2019, for the existing load monitoring station S000-184. For the WRAPS, the reduction goal was adjusted to be based on the flow weighted mean concentration (FWMC) instead of the 90th percentile concentration. The FWMC for Rapid River (501) is estimated to be 16 mg/L, using HSPF Scenario Application Manager (SAM) predicted sediment concentrations occurring between April and September in 2010 through 2014. The concentration goal was set at 13.5 mg/L instead of the TSS standard 90th percentile concentration of 15 mg/L. This adjustment in the concentration goal was made to account for uncertainty between the relationship of the TSS standard 90th percentile concentration and the FWMC. Using the FWMC, a 16% reduction is needed to achieve the goal, which equates to an annual load reduction of 4,023 tons/yr.

The uncertainty between the relationships of the TSS standard 90th percentile concentration to the FWMC occurs for several reasons. First, the monitoring station S000-184 is part of the WPLMN. The monitoring strategy for the WPLMN targets sampling high-flow periods more frequently than low-flow periods as that is when concentrations are less stable and when most of the pollutant loads occur. This monitoring strategy may bias the data to have higher percent exceedances of the TSS standard and higher estimated 90th percentile TSS concentrations, compared to the typical monitoring frequencies used to assess streams. For monitoring station S000-184, 79% of the samples collected from April through September during the years 2010 through 2019, were during high or very high flows. Second, the HSPF SAM model estimated that it was not possible to achieve the TMDL's reduction goal of 59% using typical HSPF SAM scenarios. For example, a hypothetical scenario contemplating the complete conversion of the watershed's pasture and agricultural land to wetlands for demonstration purposes, only reduced the predicted 90th percentile concentration by 1% (from 16.0 mg/l to 15.8 mg/L) and the percent exceedances of 15 mg/L TSS dropped from 18.6% to 17.8%. The limitations indicated in the model are further supported by the current land use in the watershed. Approximately 90% of the watershed is owned by public entities which limits the amount of area available for the construction of

BMPs. In addition, there is limited road access to much of the watershed, thus limiting the potential for improvement projects. Lastly, the watershed planning process is meant to be iterative, and a realistic, FWMC-based reduction goal may help local partners acquire funding to implement strategies in the watershed more so than a larger, unattainable reduction goal.

2.5 Protection considerations

Given the overall good quality of the water resources within the RRW, protection strategies will be key to preventing future water quality degradation. Restoration and protection strategies should be developed to both improve the condition of degraded resources and ensure that unimpaired waters remain in good condition.

Lakes

There are no lakes within the RRW.

Protection Streams

As summarized in the Monitoring and Assessment report, the MPCA, DNR and Board of Soil and Water Resources (BWSR) have worked together to prioritize the 10 streams in the RRW that were found to be supportive of designated aquatic life uses (Sigl et al. 2020). The goal of this prioritization exercise was to identify and prioritize streams that are: 1) currently healthy but near the impairment threshold, or 2) currently healthy and are indicating good water quality. For those streams that are currently healthy, further prioritization exercises were performed to identify watersheds that are largely protected versus those that are at risk of degradation.

The stream protection and prioritization exercise identified two main landscape risks to biological condition, including: 1) percent disturbed land, and 2) density of roads. Each risk factor was assessed for each stream’s riparian area, defined as 200 m on each side of the stream and drainage area.

The exercise then identified the amount of land in public ownership or permanent easement at both the riparian scale and watershed scale. Next, each stream was assessed to determine the number of communities (fish, macroinvertebrates, or both) that were near the impairment threshold (Figure 12). Each risk factor was assessed relative to a statewide database for fully supporting streams. The final Protection Priority Rank was calculated as follows:

Protection Priority Rank = [(IBI Threshold Proximity) x (Riparian Risk + Watershed Risk + Current Protection)].

As an example, a stream with biological communities (fish and macroinvertebrates) that were near the IBI impairment threshold, with many roads in the stream’s watershed, and a low percentage of land in protection (e.g., public lands) would be ranked a high risk or Priority A stream. No Priority A streams were identified in the RRW (Table 7; Figure 12). Four Priority B streams were identified in the RRW; these streams represent a secondary priority for protection-based efforts.

Figure 12. Stream protection and prioritization matrix.

Table 7. Stream protection and prioritization results

Aggregated HUC-12	AUID	Stream Name	Reach Length (miles)	TALU	Cold/Warm	Fish or Macroinvertebrate Community Nearly Impaired	Riparian Risk	Watershed Risk	Current Protection Level	Protection Prioritization Class
Lower Rapid River	529	Unnamed ditch	4.75	General	Warm	One	High	Low	High	B
North Branch Rapid River	503	Rapid River, North Branch	44.68	General	Warm	One	Med/Low	Low	High	B
Upper Rapid River	506	Rapid River	35.59	General	Warm	One	Low	Low	High	B
Middle Rapid River	513	Christy Creek	0.80	General	Warm	Neither	Med/High	Med/Low	Medium	B
Middle Rapid River	504	Rapid River	7.97	General	Warm	Neither	Med/High	Low	Med/High	C
Lower Rapid River	502	Rapid River	26.50	General	Warm	Neither	Medium	Low	Med/High	C
Middle Rapid River	508	Troy Creek	13.52	General	Warm	Neither	Med/Low	Low	Med/High	C
Barton's Brook	510	Barton's Brook	11.45	General	Warm	Neither	Med/Low	Low	Med/High	C
Middle Rapid River	523	Miller Creek	8.37	General	Warm	Neither	Low	Low	High	C
North Branch Rapid River	528	Unnamed Creek	3.90	General	Warm	Neither	Low	Low	High	C

Hydrologic Unit Code (HUC); Assessment Unit Identification (AUID); Tiered Aquatic Life Uses (TALU)

3. Strategies for restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS contain strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including water quality goals, strategies, and targets by parameter of concern, and an example of the scales and timeline of adoption to meet water quality protection and restoration goals.

This section of the WRAPS report provides the results of strategy and prioritization development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement best management practices (BMP). Thus, effective ongoing civic engagement is needed for moving forward.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

3.1 Targeting of geographic areas

The following section describes the specific tools that were used during the RRW WRAPS process to help RRW stakeholders identify, locate, and prioritize restoration and protection strategies. The general approach began with a high-level overview of the issues and concerns facing the watershed and became increasingly more detailed as specific implementation actions were evaluated. An HSPF model was used to evaluate pollutant loading dynamics across the RRW. A variety of geographic datasets were then reviewed by local resource managers and public stakeholders to understand watershed stresses and to prioritize subwatersheds. Through this process, sediment and altered hydrology were identified as key issues to address in the RRW. Tools used to target geographic areas to address sediment loading and to restore altered hydrology in the RRW include:

- Agricultural Conservation Planning Framework (ACPF)
- Geomorphic Stream Survey (See Appendix B)
- Ravine Assessment
- Evaluation of Altered Hydrology

The tools' results are summarized in the following section and detailed maps of the potential BMP locations are found in Section 3.3. Recommendations for the level of implementation of these practices needed to meet the goals established in this WRAPS are included, along with estimated costs. While the targeting exercise attempted to evaluate the feasibility of the potential projects, follow-up field reconnaissance is needed to provide further validation.

Critical Area Identification

Hydrologic Simulation Program – FORTRAN (HSPF)

An HSPF model is a large-basin, watershed model that simulates nonpoint source runoff and water quality in urban and rural landscapes. The Lower Rainy River HSPF model, which includes the RRW, incorporates real-world meteorological data and is calibrated to real-world stream flow data. The HSPF model development includes the addition of point source data in the watershed, including both domestic and industrial WWTF.

An HSPF model was used to predict the relative magnitude of TSS, TP, and TN pollution generated in each catchment of the RRW. The HSPF model was also used to evaluate the extent of contributions from point, nonpoint, and atmospheric sources where necessary. Development of the HSPF model helps to better understand existing water quality conditions and predict how water quality might change under different land management practices and/or climatic changes at the subwatershed scale. An HSPF model also provides a means to evaluate the impacts of alternative management strategies to reduce these loads and improve water quality conditions. The TSS, TP, and TN yields predicted from the HSPF model in the RRW are mapped in Figure 13, Figure 14, and Figure 15.

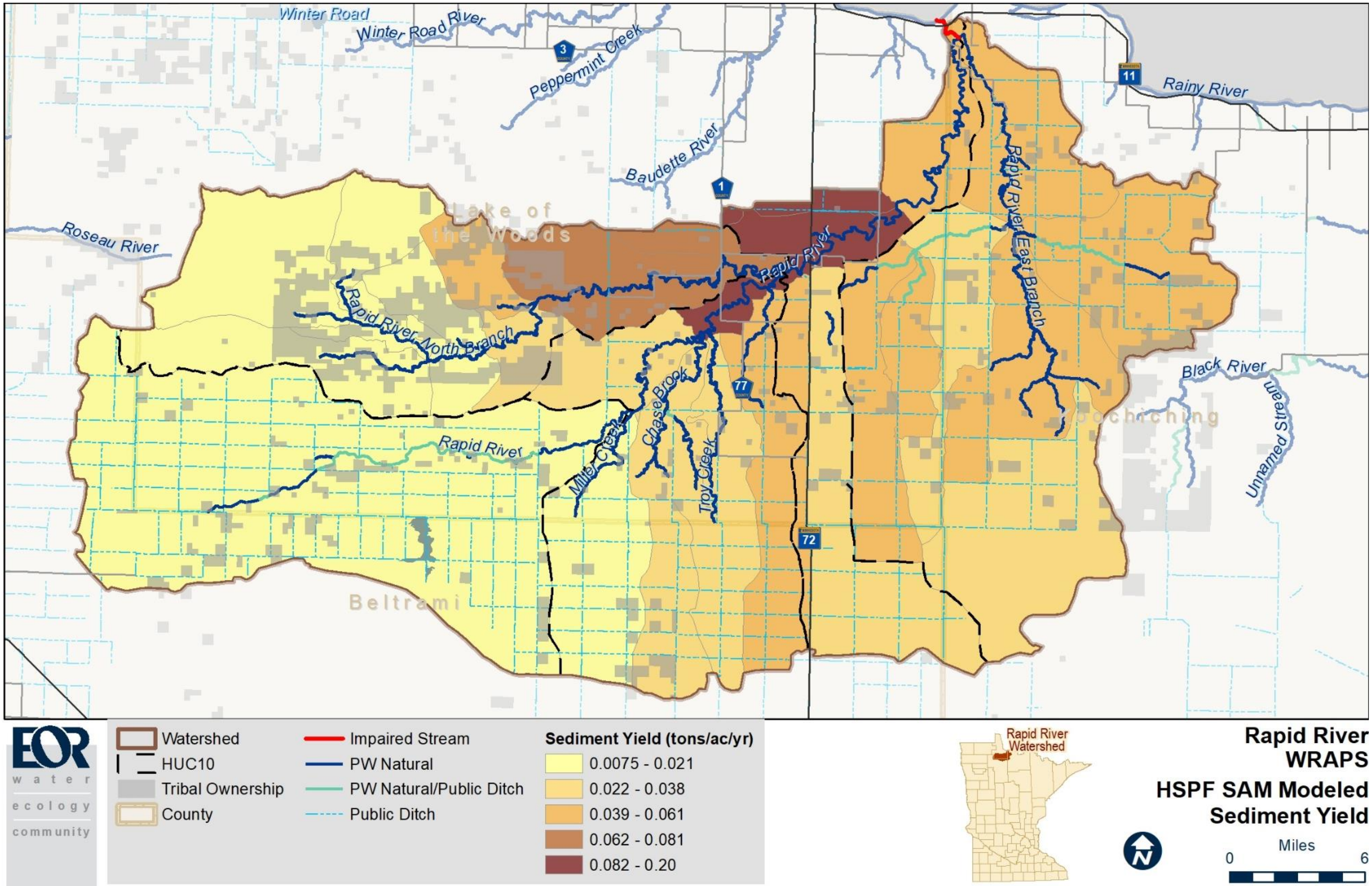


Figure 13. HSPF total suspended solids load (lbs/acre/year)

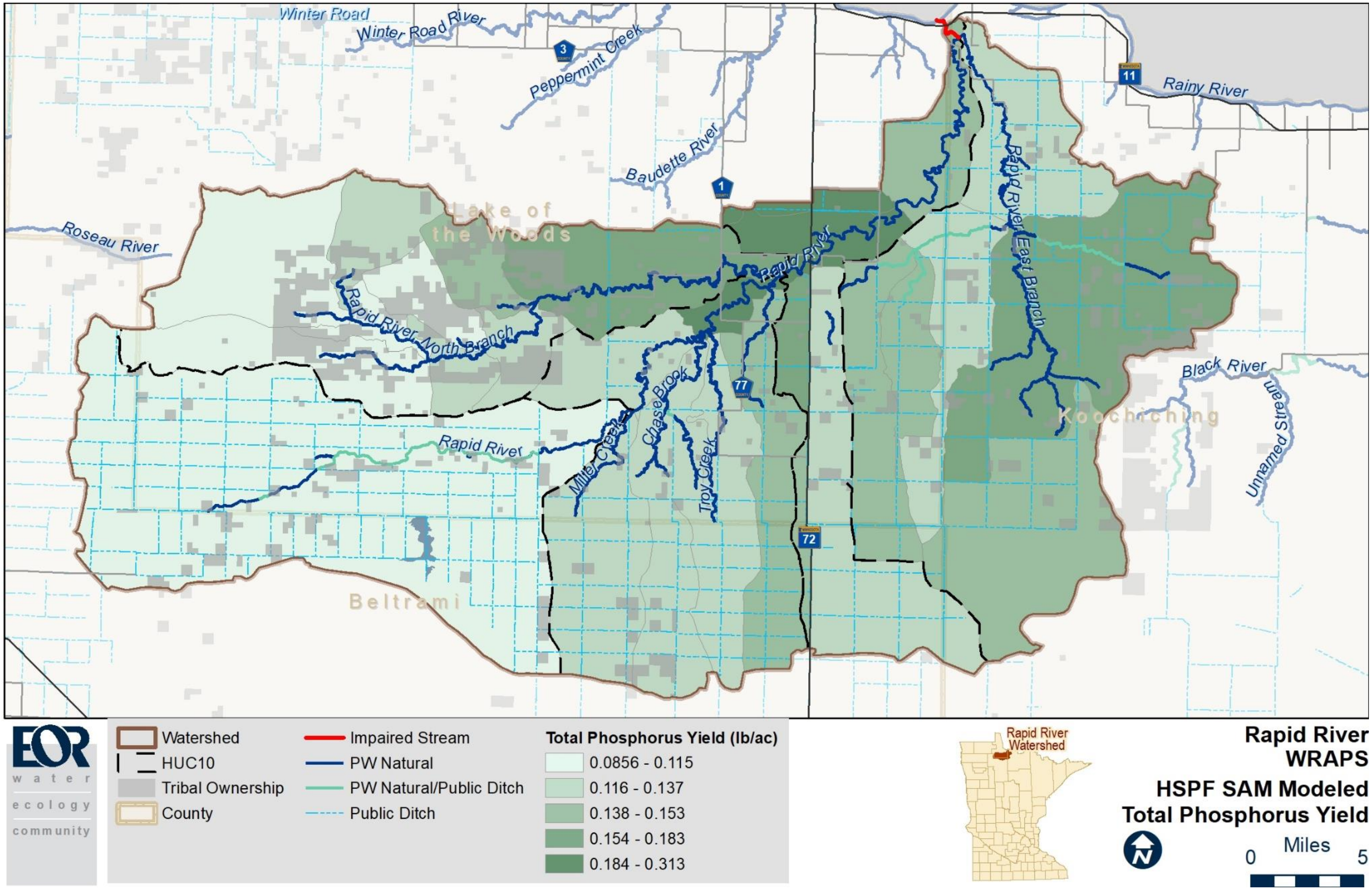


Figure 14. HSPF Total Phosphorus Load (lbs/acre/year)

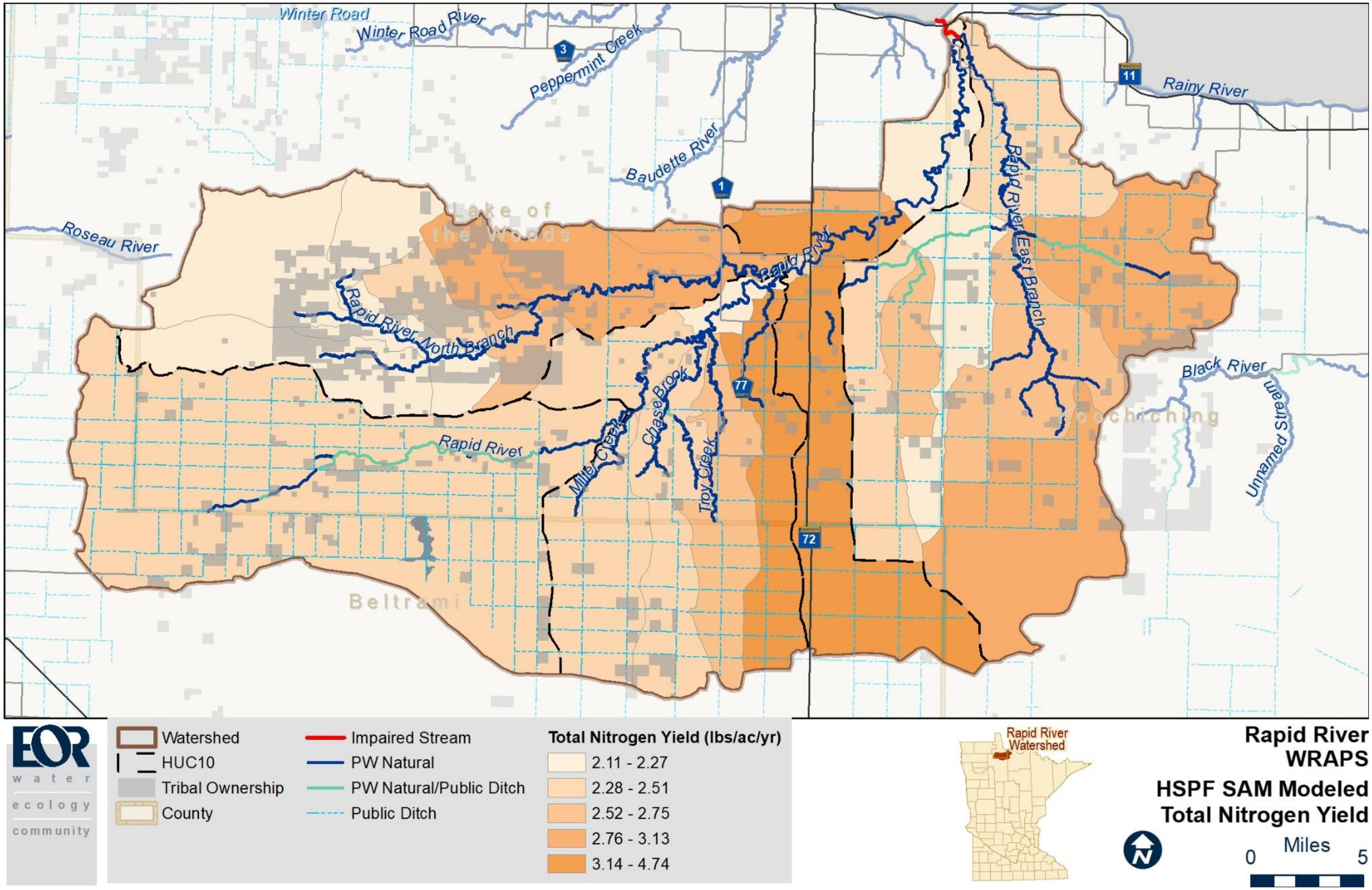


Figure 15. HSPF Total Nitrogen Load (lbs/acre/year)

Aggregated HUC-12 Subwatershed Priority Ranking

During the early stages of the WRAPS planning process in 2020, a small working group of local resource professionals developed a ranking system to prioritize the aggregated HUC-12 subwatersheds within the RRW based on their contribution to the problems facing the watershed and their potential to achieve meaningful improvements. The aggregated HUC-12 subwatersheds are an intersection of HUC-12 subwatersheds, as defined by the United States Geologic Survey (USGS) hydrological system, along with the subwatershed areas defined by the HSPF model. The working group reviewed 56 data sets falling into 9 general categories. Reviewers rated the effectiveness of each data set for prioritizing aggregated HUC-12 subwatersheds. The evaluation was completed specific to the characteristics the watershed. Reviewers rated each data set based on the how useful it would be for prioritizing subwatersheds for focused efforts. The data set categories (altered hydrology, soil erosion, etc.) are presented in order of the priority established by the local working group. Underlined data sets were selected by working group as the most effective tools for prioritizing subwatersheds (Refer to Appendix A for further information on the geographic data sets and process that were used to prioritize subwatersheds). The resulting prioritization of aggregated HUC-12 subwatersheds is shown in Table 8 and Figure 16. The following summarizes the data sets and their ranking:

Altered Hydrology

- <u>Aquatic Disruption</u>
- Connectivity Index
- <u>Altered Watercourses</u>
- Sandy Verry Channel Flow
- Sandy Verry Risk Model

Soil Erosion

- <u>Stream Power Index</u>
- <u>Geo Index - Soil Erosion Susceptibility</u>
- Geo Index - Steep Slopes Near Streams

Water Quality

- <u>HSPF Model - Sediment Yield</u>
- HSPF Model - Stream Bank Erosion
- HSPF Model - Cropland Erosion
- <u>HSPF Model - Phosphorus Yield</u>
- HSPF Model - Total Phosphorus – Cropland
- HSPF Model - Total Phosphorus – Septic load
- HSPF Model - Total Nitrogen
- HSPF Model - Flow Yield
- Monitored in-stream *E. coli* Concentration
- Monitored in-stream Total Phosphorus
- Monitored in-stream Dissolved Oxygen
- Monitored in-stream Total Suspended Solids

Land Use / Land Cover

- Wetlands & Open Water
- Developed Lands
- Agricultural Lands
- Forest and Other Natural Land
- Forest for the Future
- Potential Forest Protection Areas
- Sustainable Forest Incentive Act Lands
- Forest Stewardship Plan Parcels
- Total Protected Lands

- 2008 GAP Public Land
- 2008 GAP Tribal Land
- 2008 GAP Private Land
- 2010 Rural Housing Density.
  Road Distance

Wetlands

- National Wetland Inventory Total
- Surface Outflow Wetlands
- Wetland Water and Erosion Benefit
- Wetland Species Benefit
- Wetland Habitat Stress
- Wetland Phosphorus Stress
- Wetland Nitrogen Stress
- Restorable Wetland Inventory
- Wetland Restoration Viability

Previous Prioritizations

- Local Watershed Prioritization
- DNR Protection Status
- Combined Index - Geomorphology Triage Score

Groundwater

- Groundwater Sensitivity
- Geologic Index - Pollution Sensitivity of Near Surface Materials
- Arsenic Concentration
- Nitrate Concentration

Biodiversity

- DNR Lake Phosphorus Sensitivity
- Wild Rice Lakes
- MBS Biodiversity
- Wild Life Action Network
- Biological Index Terrestrial Habitat Quality

Improvements

- Number of BMPs

Table 8. Priority ratings of aggregated HUC-12 subwatersheds in the RRW

Aggregated HUC-12	HUC-12	Last three digits of Mainstem AUID	HSPF Catchment	Aggregated HUC-12 Subwatershed Rating
Upper Rapid River	Upper Rapid River	506	A250	Medium
Middle Rapid River	Miller Creek	523	A261	Medium
	Chase Brook	507	A281	Medium
	Troy Creek	508	A283	Medium
	Moose Creek	512	A285	High
	Middle Rapid River	505	A270	Medium
		504	A290	High
North Branch Rapid River	Meadow Creek	519	A293	Low
	Upper North Branch Rapid River	503	A291	Low
		503	A295	Medium
	090300070303	528	A297	Low
	Middle North Branch Rapid River	503	A299	Low
		NA	A301	Low
		503	A303	Low
	Lower North Branch Rapid River	NA	A305	Low
		526	A307	High
		503	A309	High
East Fork Rapid River	Upper East Fork Rapid River	NA	A353	Low
	Middle East Fork Rapid River	511	A357	Medium
	Lower East Fork Rapid River	509	A369	Medium
Wing River	Wing River	515	A355	Medium
Barton's Brook	Judicial Ditch No 27	510	A361	Medium
	Barton's Brook	NA	A359	Medium
		510	A363	Medium
Lower Rapid River	Judicial Ditch No 20-Rapid River	NA	A321	Medium
		502	A330	High
		510	A341	Medium
	Rapid River	502	A350	High
		NA	A351	High
		501	A370	High

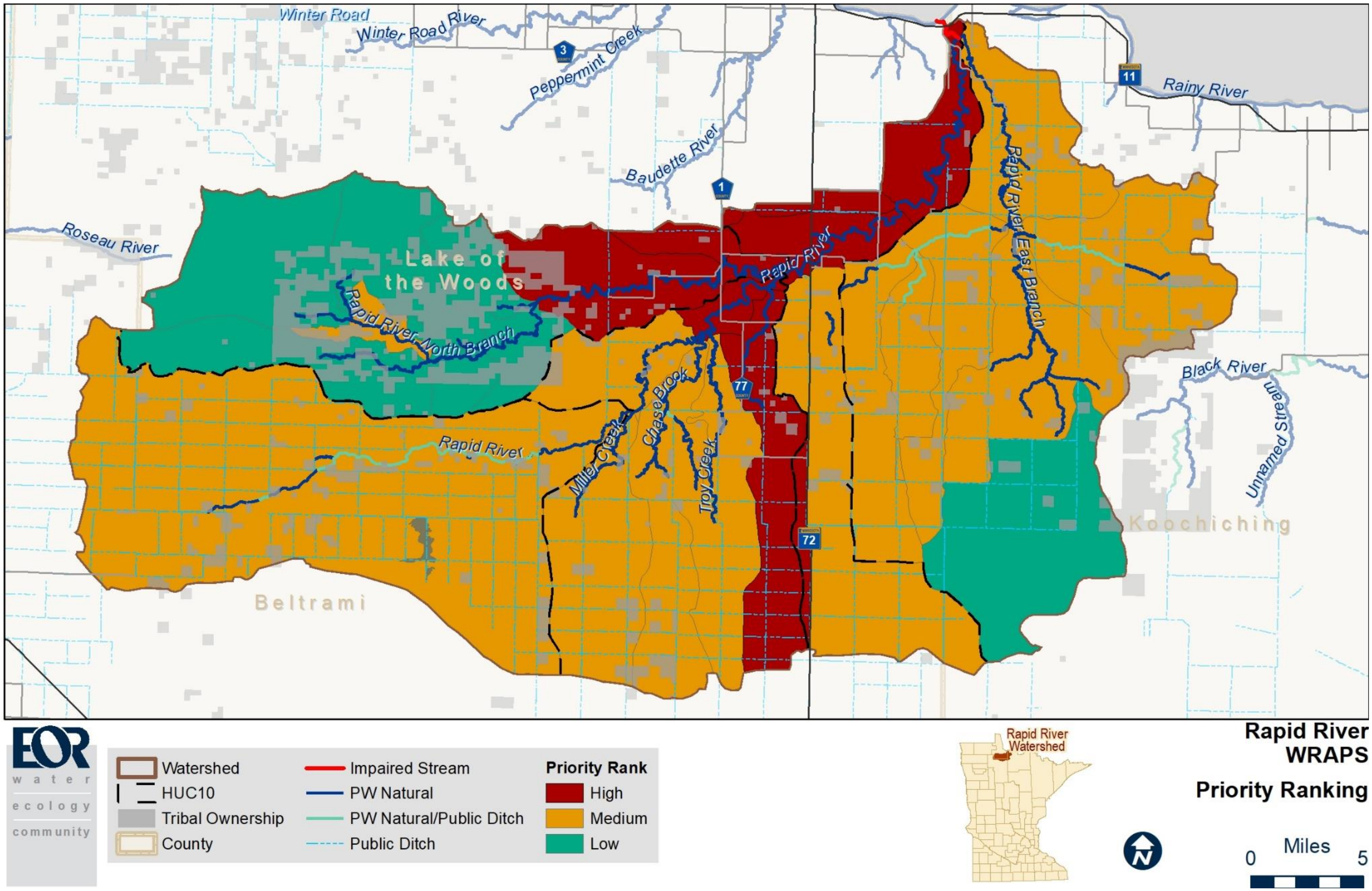


Figure 16. Rapid River Aggregated HUC-12 Subwatershed Implementation Priority Ranking

Riparian Adjacency Quality (RAQ) Parcel Scoring

The Riparian Adjacency Quality (RAQ) process is a method developed in northern Minnesota to help target outreach efforts about forest protection programs to landowners with large tracts of forested land. The overall goal of protection programs is to get over 75% of a watershed into a protected status. The targeting focuses on three criteria. First, riparian ’R’ refers to parcels that are next to lakes or streams as these parcels can have a disproportionate impact on downstream waterbodies. Second, adjacency ’A’” refers to parcels next to other parcels of land that are already protected in some way. Adjacency is important because large continuous tracts of forest are preferred over scattered parcels throughout the watershed. Lastly, quality ’Q’, the most subjective criteria, refers to protecting areas that have unique and important characteristics. Quality is used to include locally important characteristics into the prioritization. For the WRAPS the following layers were included in the prioritization:

- Outstanding Resource Value Waters (MPCA)
- Old Growth Forests (DNR)
- Lakes with Exceptional IBI Scores (DNR)
- Drinking Water Supply Management Areas (Minnesota Department of Health [MDH])
- Medium High or High Wildlife Action Network Score (DNR)
- Priority Shallow/Waterfowl Lakes
- White Cedar Communities
- Audubon Important Bird Areas (IBAs)
- Rare Species (DNR)

The RAQ score is tabulated by adding the scores from each criterion. The scoring values are listed in Table 9. The highest priority parcels for protection have scores greater than eight and the max score is 10. The RAQ prioritization results are summarized by HUC-10 in Table 10. The results show that with the public land, which are assumed to be protected, and the existing percentage of land currently enrolled in a forest protection program, all the HUC-10 watersheds in the RRW exceed the 75% goal developed for forested watersheds in northern Minnesota (Table 11). However, there are still pockets of forest land within the RRW that are not well protected. Further protection strategies prioritization will occur locally to address parcelization and resource needs.

Table 9. RAQ Scoring Criteria

Scoring Criteria:		
Riparian	3	Riparian
	2	Nonriparian: Shoreland (1 parcel back)
	1	2 parcels back
Adjacency	3	2 sides touching public land
	2	1 side touching public land
	1	1 parcel removed from public land or touching parcel with Sustainable Forest Incentive Act (SFIA) land or easement
Quality	4	1 point for each feature that the parcel touches. The max score is 4.
	3	
	2	
	1	

Note: Rare species data included in the RAQ scoring: Copyright 2020, DNR. Rare species data included here were provided by the Division of Ecological and Water Resources Division, DNR, and were current as of May 2020. These data are not based on an exhaustive inventory of the state. The lack of data for any geographic area shall not be construed to mean that no significant features are present.

Table 10. RAQ Parcel Area Prioritization by HUC-10 Watershed in the RRW

Forest Protection Program Prioritization											
		Low Priority		Medium Priority		High Priority		Higher Priority		Highest Priority	
		Enrolled (ac)		Enrolled (ac)		Enrolled (ac)		Enrolled (ac)		Enrolled (ac)	
HUC-10 Name	HUC-10	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Upper Rapid River	903000701	0	0	29	0	343	935	209	290	169	319
Middle Rapid River	903000702	0	0	974	205	3221	1256	4555	1346	981	221
North Branch Rapid River	903000703	0	0	553	642	3092	1987	2523	2570	242	345
East Fork Rapid River	903000704	38	34	1060	882	4624	3727	3434	842	219	81
Lower Rapid River	903000705	43	0	1404	82	7052	910	4250	775	1413	1220

Hydrologic Unit Code (HUC-10)

Table 11. Forest Protection Area and Goals by HUC-10 in the RRW.

HUC-10 Name	HUC-10	Total Area (ac)	Public Land (ac)	Forest Program Area (ac)	Protected Area (ac) (Percentage of Total Area)	Goal	Goal Met
Upper Rapid River	903000701	133,936	131,490	1,543	133,034 (99%)	75%	X
Middle Rapid River	903000702	110,791	97,905	3,028	100,933 (91%)	75%	X
North Branch Rapid River	903000703	118,357	106,328	5,544	111,871 (95%)	75%	X
East Fork Rapid River	903000704	172,661	157,529	5,567	163,096 (94%)	75%	X
Lower Rapid River	903000705	68,101	50,402	2,988	53,389 (78%)	75%	X

Hydrologic Unit Code (HUC-10)

Table 12. Private Land Forest Protection Areas and Goals by HUC-10 in the RRW.

HUC-10 Name	HUC-10	Total Private Land	Private Land Enrolled in Forest Protection (ac) (Percentage of Total Area)	Goal 1 High Higher Highest RAQ Parcels	Goal 2 Higher Highest RAQ Parcels	Goal 3 Highest RAQ Parcels
Upper Rapid River	903000701	2,293	1,543 (67%)	99%	84%	75%
Middle Rapid River	903000702	12,760	3,028 (24%)	92%	67%	31%
North Branch Rapid River	903000703	11954	5,544 (46%)	95%	70%	48%
East Fork Rapid River	903000704	14941	5,532 (37%)	92%	61%	38%
Lower Rapid River	903000705	17149	2,988 (17%)	92%	50%	26%

Hydrologic Unit Code (HUC-10)

Agricultural Conservation Planning Framework GIS Toolset

The ACPF Geographic Information System (GIS) toolset was used to identify potential locations for BMPs in the RRW. The ACPF Toolbox includes tools to process high-resolution Light Detection and Ranging (LiDAR) based digital elevation models (DEM). The processed DEM can then be used to prioritize agricultural fields, prioritize and classify riparian areas, and identify a suite of BMPs to address sediment and nutrient runoff.

The Water and Sediment Control Basins (WASCOB) tool within the ACPF toolset was used to identify potential grade stabilization structures that could be built across drainageways in the watershed. Grade stabilization structures are typically sited within agricultural fields to reduce pollutant loads, slow runoff, and reduce the risk of gully formation. The WASCOBs tool was run for the entire RRW. Since opportunities for agricultural BMPs are limited due to small amounts of row crop agriculture within the watershed, the tool was modified to identify locations for grade stabilization structures in nonagricultural areas as well. The specific targeted areas included gullies downstream of agricultural fields and gullies formed because of an incised stream channel. Modifications to the tool included:

- Expanding the siting analysis to nonagricultural lands; and

- Increasing the allowable drainage area to each grade stabilization structure to 50 to 640 acres instead of the default setting of 2 to 50 acres.

Three iterations of the modified WASCOB tool were applied across the entire RRW to identify potential grade stabilization structures. The first iteration used a standard WASCOB configuration of a 5-foot high embankment to treat 2 to 50 acre drainage areas. In the second and third iterations, the drainage area parameter was increased to between 50 and 640 acres with either a 5-foot embankment (iteration 2) or a 10-foot embankment for iteration 3. Table 13 shows the number of potential grade stabilization structures, by configuration, identified in the RRW. Figure 17 shows the total number of potential grade stabilization practices sited within each HSPF catchment area.

Table 13. Potential Grade Stabilization Structures Identified in the RRW

Embankment Height	Drainage Area	Number of Structures
5	2-50	163
5	50-640	72
10	50-640	40
	Total	**275**

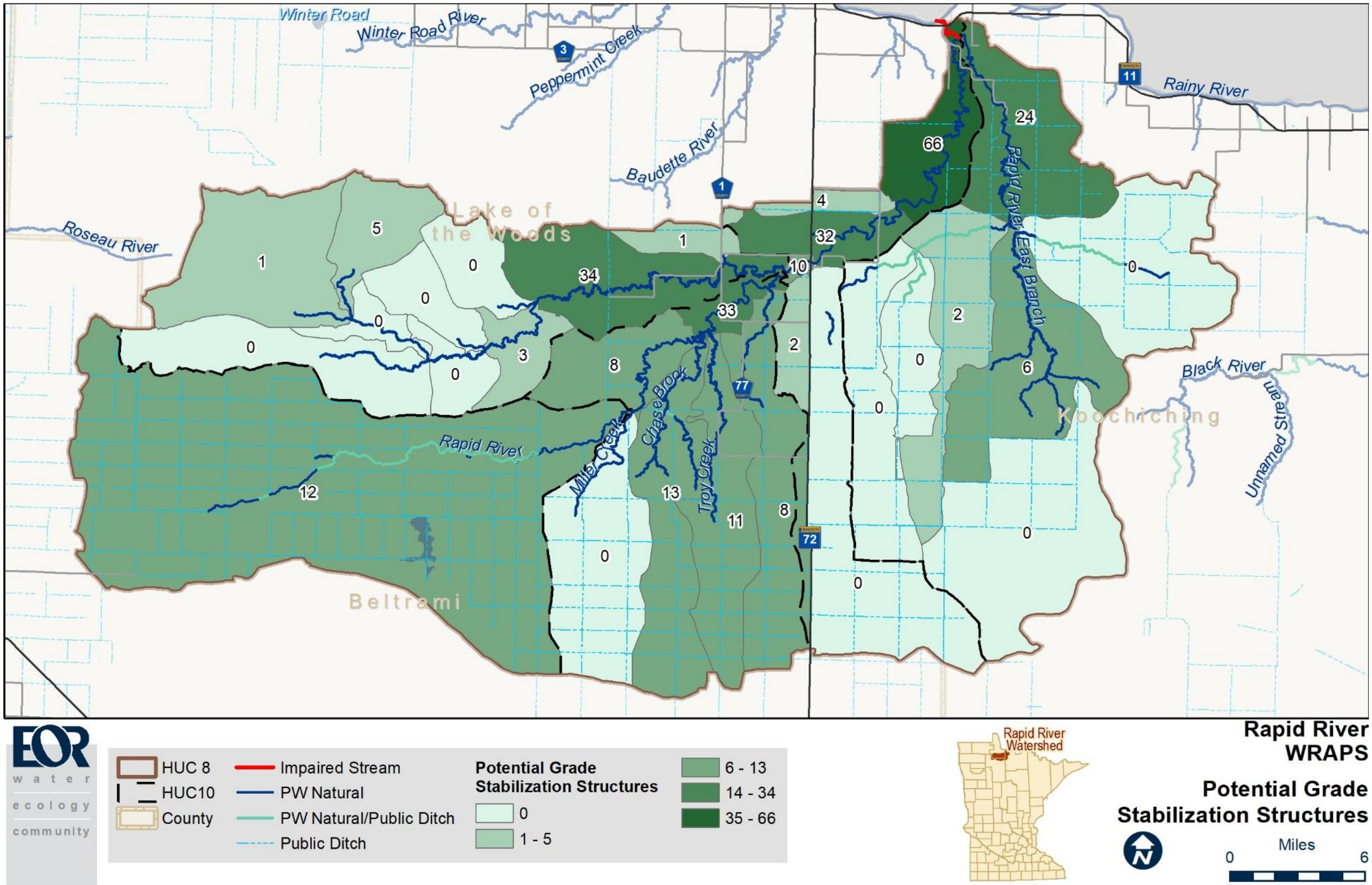


Figure 17. Number of potential grade stabilization structures to be field verified.

Geomorphic Stream Survey

In 2019 and 2020, the DNR conducted BEHI geomorphic stream surveys in the RRW. In total, 78.3 miles of streambanks were assessed (Figure 18) (the term streambank refers to one side of a stream). The BEHI is a measure of a streambank's vulnerability to erosion and helps determine whether the streambank is eroding at a natural or altered pace. The BEHI scores for the RRW are summarized by HUC-10 in Table 14. Most assessed streambanks in the RRW were classified as having low to moderate BEHI. The main branch of the Rapid River (the Upper Rapid River, Middle Rapid River, and the Lower Rapid River) had the highest percentages of high and very high BEHI ratings. The BEHI can be used to identify and prioritize potential streambank restoration projects. For more information on the geomorphic stream surveys see Appendix B.

Table 14. Bank Erosion Hazard Index Rating - Streambank Length (ft)

		Bank Erosion Hazard Index Streambank Length						
HUC-10 Name	HUC-10	Deposition	Very Low	Low	Moderate	High	Very High	Total
Upper Rapid River	903000701	0 (0%)	0 (0%)	1,025 (11%)	8,530 (87%)	203 (2%)	0 (0%)	9,758
Middle Rapid River	903000702	0 (0%)	1,758 (2%)	28,876 (39%)	41,048 (55%)	2,708 (4%)	0 (0%)	74,390
North Branch Rapid River	903000703	135 (1%)	532 (5%)	3,046 (28%)	7,208 (66%)	0 (0%)	0 (0%)	10,922
East Fork Rapid River	903000704	327 (1%)	10,548 (25%)	26,464 (64%)	4,190 (10%)	140 (<1%)	0 (0%)	41,669
Lower Rapid River	903000705	8,442 (3%)	19,642 (7%)	136,047 (49%)	107,977 (39%)	4,338 (2%)	483 (<1%)	276,929
Rapid River Watershed	9030007	8,905 (2%)	32,479 (8%)	195,459 (47%)	168,953 (41%)	7,388 (2%)	483 (<1%)	413,668

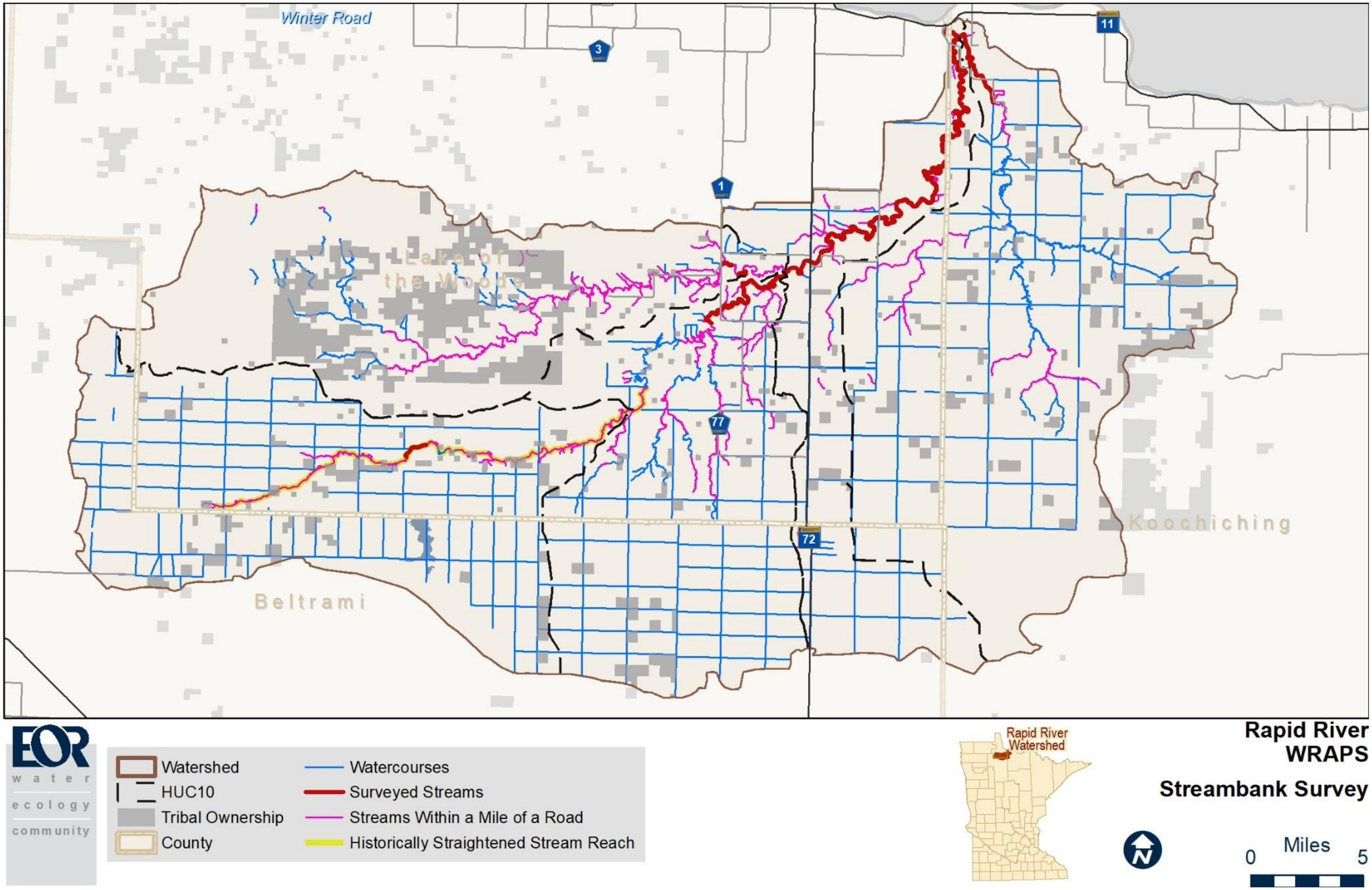


Figure 18. Streambank BEHI survey sites in the Rapid River Watershed.

Ravine Assessment

Ravines are present in the RRW and were noted in several stream reaches during the geomorphic stream survey. Significant examples include the mainstem of the Rapid River from Carp Canoe Access to MN Hwy 72 and near 37th Ave SE to MN Hwy 11. A total of 108 discreet ravines were identified during the survey. To help prioritize which ravines should be targeted first, the drainage areas to each ravine were determined. Table 15 summarizes the number of ravines and their contributing drainage areas and Figure 19 shows the locations of the identified ravines. Ravines that have drainage areas with more agriculture, development, and recently harvested timber are more likely to be caused by an increase in runoff. These ravines should be prioritized for future stabilization projects first. Ravines located directly downstream of a road culvert should also be prioritized because the culvert may be increasing erosion at the site and connectivity for fish passage could be affected as erosion increases downstream of the culverts. Ravines with more natural land cover, such as forests and wetlands, are more likely to be forming because of a down-cutting channel. In these cases, typical ravine stabilization projects can only slow gully erosion. To permanently fix the ravine, the down-cutting channel needs to be addressed. These ravines are a low priority unless they are advancing towards a road or structure.

Table 15. Number of Surveyed Ravines and estimated Drainage Areas

Drainage Area (acres)	<40	40-100	100-200	200-700	>700	Total
Number of Ravines	41	30	15	16	6	108

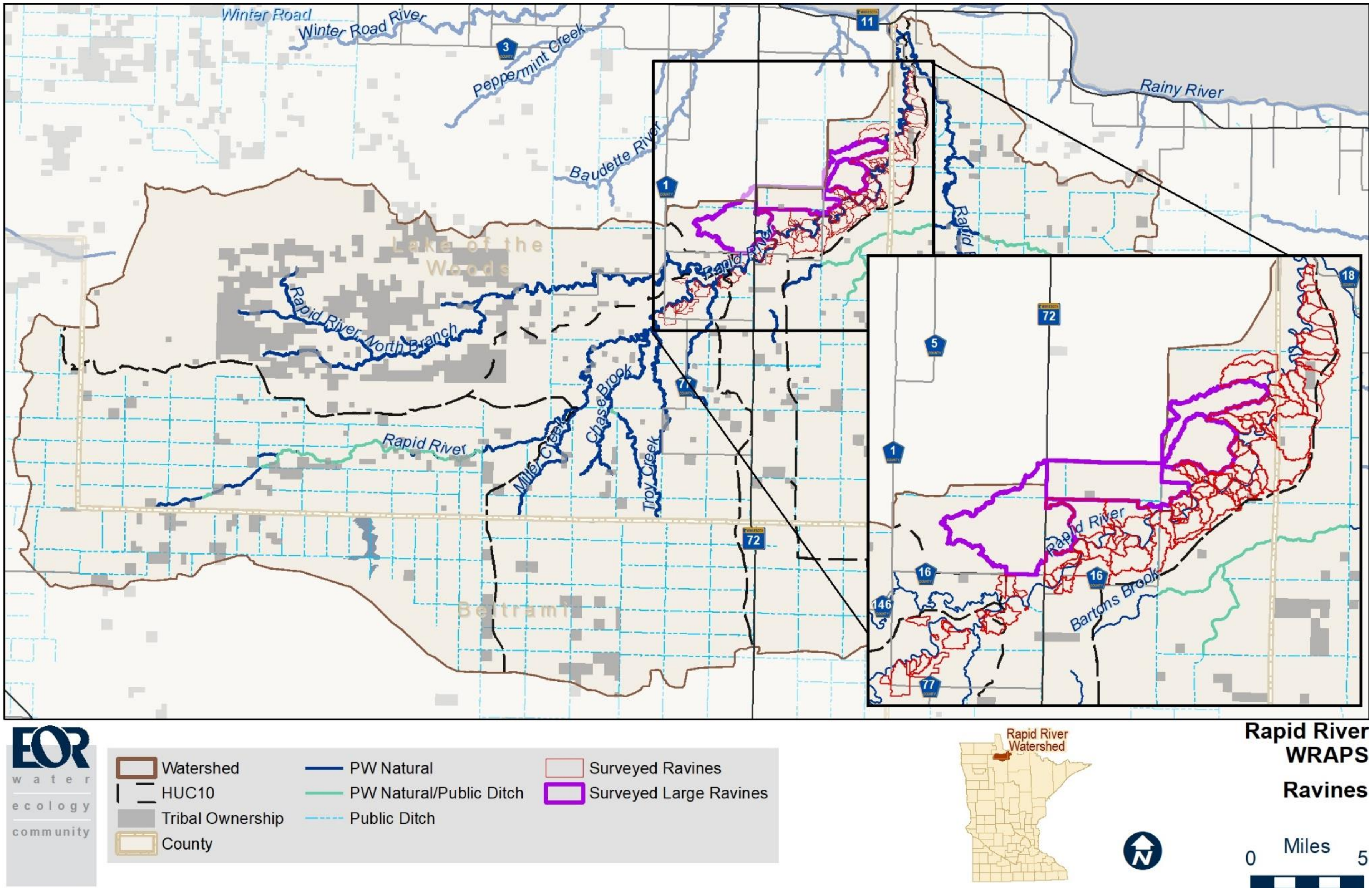


Figure 19. Assessed ravines in the Rapid River Watershed.

Evaluation of Altered Hydrology

As mentioned in Section 2.3, over 90% of the watercourses in the RRW are altered. This includes over 720 miles of ditches constructed in the early 1900s. Today, only about a third of the ditches are within one mile of a road. Ditches located farther than one mile from a road are inaccessible and have most likely not been maintained since they were installed. These ditches have essentially been abandoned. The county could investigate the option of legally abandoning these ditches as a means of preventing future ditch manipulation. Figure 20 shows the most accessible ditches where improvements could be made.

In the RRW, the highest priority potential ditch improvements are the ditches along Highway 72 (shown in Figure 20). The Highway 72 ditches are a priority because they drain a large area (40,631 acres), are easily accessible, and are well maintained, which allows runoff to move rapidly downstream. Specific improvements are dependent on a site visit of the ditch but, could include two-stage ditching, inline or off-channel sediment basins or any structure to make the ditch function more like a natural channel. Grade stabilization may be needed at the outlets of these ditches.

Another potential ditch improvement project would address the two ditches connecting the east branch of the Rapid River with the main branch of the Rapid River. These ditches may be allowing water to short circuit through the main branch of the Rapid River instead of following the natural channel in the east branch of the Rapid River. If this connection is field verified, a ditch plug should be installed at a location to prevent flow through these ditches.

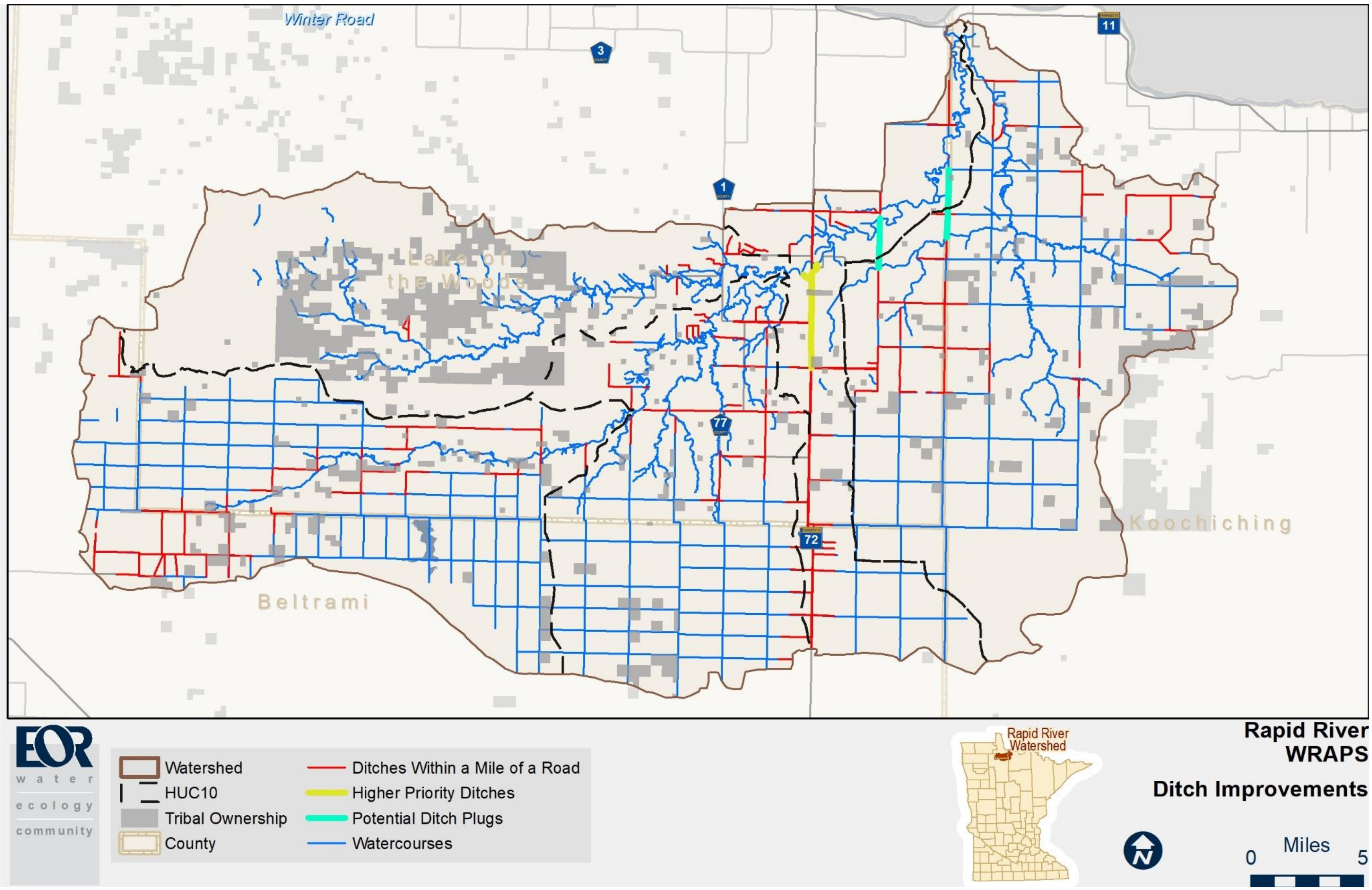


Figure 20. Potential ditch improvements in the Rapid River Watershed

3.2 Public participation

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful public participation. If the strategies in the WRAPS report are promoted with input from local land managers, the likelihood of implementation will increase. In addition, implementation activities will be streamlined due to the collaboration between landowners, local agencies, and funding sources. Strategies identified in the WRAPS will also increase the benefit to the watershed through prioritization and targeting, and success will be measurable.

Accomplishments and future plans

Future Plans and Accomplishments

At the beginning of the RRW WRAPS process, the Lake of the Woods and Koochiching County SWCDs developed a Public Participation Plan with the goal of laying a foundation to build conversations, strong collaborations, and engaged communities focused on the restoration and protection of surface waters within the Rapid River and Lower Rainy River Watersheds. The Public Participation Plan included the objectives of creating a communication network, developing and delivering a project kick-off meeting, conducting project update meetings, and holding a TMDL study and WRAPS report pre-public notice meeting. The dates and locations of the public participation events can be found in Table 16.

The SWCD and other local government units will continue conducting the public outreach efforts that were initiated before and during the WRAPS process. These continued outreach efforts will occur during the One Watershed, One Plan process starting in 2021. They will also continue to utilize existing established groups such as the Rainy/Rapid River Board and Citizens Advisory Committee. Measurable goals, and possible steps to reach these goals, for future public participation efforts in the Lower Rainy and RRW include:

1. Increase the number of watershed residents participating in water quality discussions.
    - Meetings of the Rainy/Rapid River Citizens Advisory Committee will continue, with a goal of increasing participation.
2. Effectively engage citizens in a meaningful way. Continuing to build relationships with and between citizens throughout the watershed will support implementation activities. Successful opportunities will be continued, and new opportunities sought.
    - Participate in community events such as County Fairs.
    - Seek outreach opportunities to existing community and natural resource management groups (sportsmen's clubs, civic groups, local governments, etc).
    - Engage youth through educational opportunities such as:
        - Envirothon
        - Drain Stencil projects
        - Annual Aquatic Invasive Species training, "Starry Trek event,"

3. Increase education and communication of water quality activities within the watershed on a variety of natural resource management topics including forestry, aquatic invasive species, altered hydrology, agricultural BMPs, and more. There may be resource needs identified for technology or other resources to implement these strategies. Through the WRAPS process, the following education efforts have been completed and will continue:
   - Utilize successful communication strategies such as radio, newspapers, social media, and websites;
   - Online meetings and workshops that were recorded and available for later viewing;
   - Online survey developed and distributed;
   - Biannual newsletters distributed to landowners in the watershed;
   - Updates on the Koochiching and Lake of the Woods SWCD Websites; and
4. Coordination of agencies through the core committee established during the WRAPS process to bolster communication between all the partners. Relationships between government staff will be key to moving the watershed protection and restoration strategies forward and these should be fostered into the future. This core committee will make it easier to keep that connection and carry partnerships forward with a cohesive watershed identity.

Table 16. Rapid River Watershed Public Participation Events

Date	Location	Meeting Focus
5/18/2017	Baudette	SWAG Open House
10/24/2017	Birchdale	WRAPS Kick-off
4/25/2019	Baudette	Professional Judgment Group Meeting – review proposed impairments
12/17/2019	WebEx	Impairments Public Meeting
10/20/2020	WebEx	Public informational meeting
10/20/2020 – 11/03/2020	Online	Public Survey
10/27/2020	WebEx	Public Input Meeting
11/9/2021	Baudette	Presenting draft TMDL/WRAPS prior to public notice period

Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from December 13, 2021 to January 12, 2022. There were no comment letters received as a result of the public comment period.

3.3 Restoration and protection strategies

When taken together, restoration and protection strategies can be thought of as pyramid, with each additional practice on succeeding levels working together and providing cumulative benefit in terms of water quality, flood reduction, and improved ecosystem services (Tomer et al. 2013). The base of the pyramid is improving soil health in agricultural and proper management and harvesting of forests. These management practices keep nutrients in the areas where they provide the most benefit. The pollutants that do erode must be captured using in field and edge of field practices such as grade and ravine stabilization structures. These practices are meant to slow down and trap the sediment before they reach the riparian areas. Lastly, riparian management such as restoring ditched wetlands and stream restoration are needed to prevent worsening of the stream reach and to capture sediment and nutrients from entering the streams where it is more difficult to remove them. Underlying all these practices is the need for water quality monitoring. Water quality monitoring provides much needed information to help prioritize practices in restoration hotspots and to help prioritize which areas should be protected. The following section is organized to follow this approach starting with water quality monitoring, followed by improved upland management practices and ending with riparian practices.

Water Quality Monitoring

The MPCA monitoring data indicated that the largest component of the TSS load in the impaired reach of the Rapid River (-501) (Figure 2; Figure 3) was in the inorganic fraction. The data also suggested that at higher-flow levels (above 2,000 cubic feet per second [cfs]) TSS contributions appear to be driven by the mainstem of the Rapid River, particularly between the Lake of the Woods CSAH 1 and the Koochiching CSAH 18 crossings. Finally, the data suggested that the East Fork Rapid River and North Branch Rapid River are not contributing excessive amounts of TSS to the impaired reach of the Rapid River (-501).

At the impaired reach of the Rapid River (-501) water quality is monitored frequently as part of the WPLMN. The monitoring strategy for this station targets high flow periods more frequently than low flow periods as that is when most pollutant loads occur; 79% of samples collected from April through September in 2010 through 2019 were during high or very high flows. For the purposes of assessing against the TSS water quality standard, this monitoring strategy may bias the results to have a higher percentage of samples exceeding the water quality standard. More sampling of low and very low flows at monitoring station S000-184 should be considered to make the sampling more equal across different flow conditions, or more guidance from the MPCA could be provided on the methodology for assessing the TSS exceedances at WPLMN monitoring stations. One option could include using FLUX32 software to interpolate daily TSS concentrations throughout the monitoring period.

To supplement the water quality monitoring, sediment fingerprinting should be considered. Sediment fingerprinting is a process where geochemical tracers in the sediment can be used to separate the more recent overland erosion from the legacy sediments from streambanks and ravines. In the RRW, sediment fingerprinting would determine the proportion of legacy sediment from the ditching that occurred during the early 1900s from the recent erosion.

Forest Protection Programs

Water quality in this watershed is currently in good shape, its quality derived from well-managed forestlands, including forested wetlands. Forestland and forested wetlands rank among the best land cover in providing clean water by absorbing rainfall and snow melt, slowing storm runoff, recharging aquifers, sustaining stream flows, filtering pollutants from the air and runoff before they enter the waterways, and providing critical habitat for fish and wildlife. In addition, forested and wetland-rich watersheds provide abundant recreational opportunities, help support local economies, provide an inexpensive source of drinking water, and improve the quality of our lives.

Minnesotans tend to have strong conservation values. Citizens of Minnesota have long since recognized the value of forests and clean water by creating various legislative conservation programs to help conserve working land forests (see Table 17).

Fortunately, many subwatersheds in the RRW are already forested and are protected by public ownership (federal, state, and county) (Figure 21). Forest protection programs play a major role in ensuring private forest lands stay working forest lands to provide optimal ecosystem services such as wildlife habitat, enhanced water quality, carbon sequestration, and many other benefits, while providing landowners with a monetary incentive to keep the land forested. Figure 21 displays the lands in the RRW that are protected through conservation easements, forest protection programs, or public ownership and Table 17 shows the percentage of private land protected in each HUC-10. Table 18 outlines applicable forest protection programs that will best allow the RRW to continue to maintain its biological integrity and provide healthy waters by promoting forestland stewardship. See the DNR Forest Stewardship webpage for additional information: https://www.dnr.state.mn.us/foreststewardship/index.html.

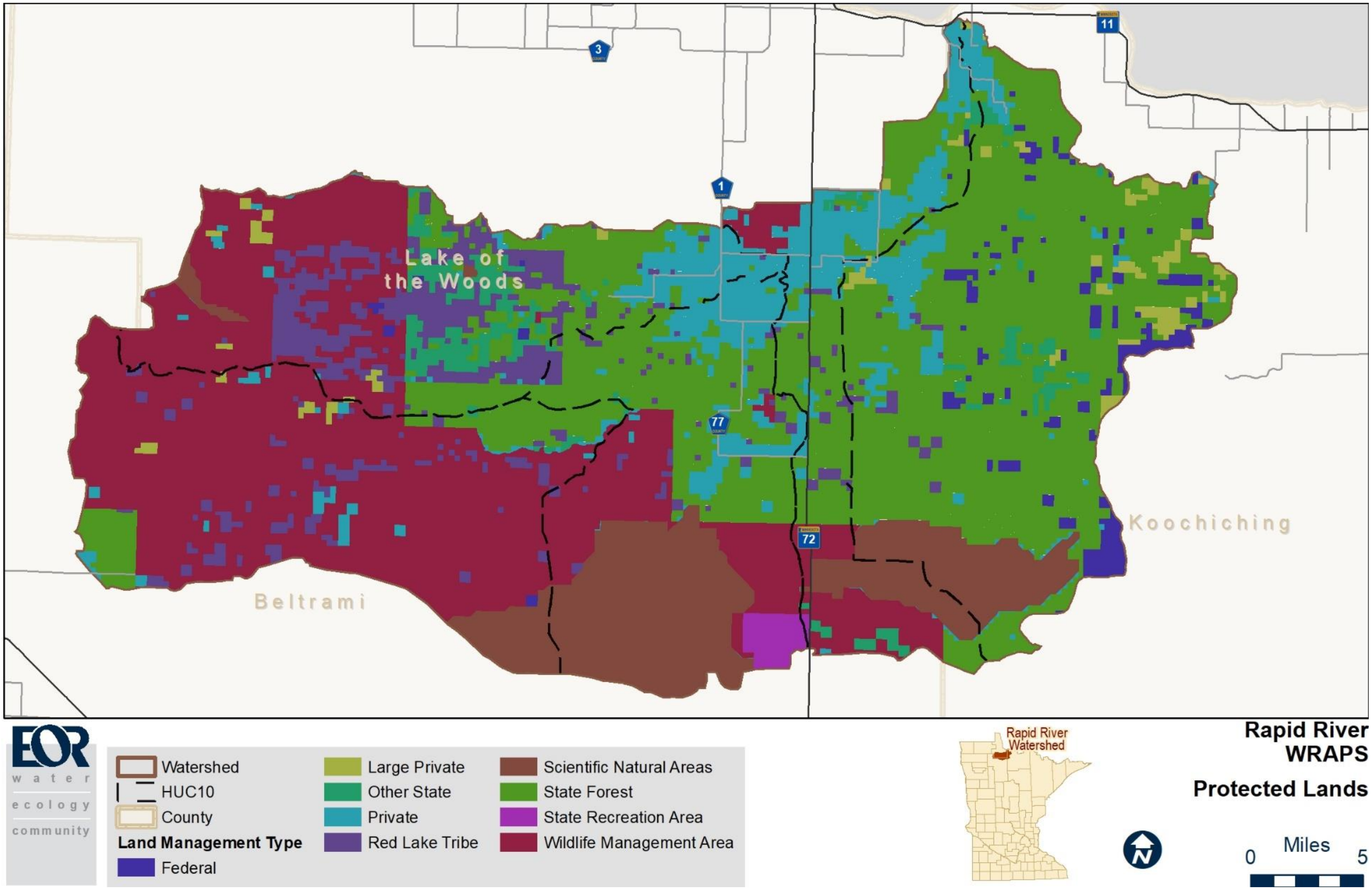


Figure 21. Lands protected by conservation easements, forest protection programs or public ownership in the Rapid River Watershed.

Table 17. Private Land Forest Protection Areas and Goals by HUC-10 in the RRW.

HUC-10 Name	HUC 10	Total Private Land (ac)	Private Land Enrolled in Forest Protection in 2020 (ac) (Percentage of Total Area)
Upper Rapid River	903000701	2,293	1,543 (67%)
Middle Rapid River	903000702	12,760	3,028 (24%)
North Branch Rapid River	903000703	11,954	5,544 (46%)
East Fork Rapid River	903000704	14,941	5,532 (37%)
Lower Rapid River	903000705	17,149	2,988 (17%)

Hydrologic Unit Code (HUC-10)

Table 18. Forest protection programs used within the RRW

Forest Protection Program	Applicability to the RRW
Forest Stewardship Plan	An instrumental plan for family forest landowners who own 20 acres or more of forestland. This voluntary plan offers land management recommendations to landowners based on their goals for their property from a natural resource professional. Plans are updated every 10 years to stay current with landowner needs and woods. A Forest Stewardship Plan registered with the DNR qualifies the landowner for woodland tax and financial incentive programs.
Sustainable Forest Incentive Act (SFIA)	The SFIA is a tax incentive program available for landowners that have a registered Forest Stewardship Plan. This program offers an annual tax incentive payment per acre based off the amount of forest stewardship acres the landowner has. Payments per acre range from the $9 to $16.50, based off the length of covenant the landowner decides to enroll into. The SFIA restricts land use conversion and subdivision of the parcel(s). A minimum of three acres must be excluded from the SFIA program if there is a residential structure present, landowners can exclude more acres if they plan to make future improvements on the land.
Conservation Easements	Most, but not all conservation easements are perpetual. Some landowners want to ensure their land will never be developed or converted to another use by selling or donating a conservation easement. Conservation easements serve a variety of conservation purposes and are generally intended to protect important features of the property. They are voluntary, legally binding agreements by the landowner to give up some of the rights associated with their property such as the right to develop, divide, mine, or farm the land to protect the conservation features such as wildlife habitat, water quality, and forest health, to name a few.
Land Acquisition	Land acquisition is an option to permanently protect the land by selling the land to a conservation organization, agency, or other land trust. Once purchased, land is restored or maintained to perpetually protect important natural resource values.

Timber Harvesting BMPs

Erosion during and after timber harvesting can be a major source of sediment in forested areas. Studies have shown that fine sediment levels increased throughout the watershed after timber harvesting, with unstable banks increasing for several years and windthrow (trees that have been blown down completely and are tilting at the root base) occurring more frequently (Edwards and Williard 2010) . The same study found that higher sediment levels in nearby streams persisted for up to 10 years and only dissipated after a very large storm event flushed the sediment out of the system. Causes of erosion during and after timber harvesting include the use of heavy equipment, which can create ruts and gullies, skid trails where logs are repeatedly dragged to the landing area, and the rapid change in vegetation cover. Several BMPs have been found to be effective at reducing the erosion from timber harvesting. Studies have estimated that the use of BMPs can result in sediment reduction between 53% to 94% compared to timber harvesting without BMPs (Edwards and Williard 2010; Cristan et al. 2019). Common BMPs used to reduce erosion from timber harvesting include:

- filter strips surrounding vulnerable areas such as landings, riparian zones, and wetlands;
- the avoidance of stream and wetland crossings wherever practical, proper design and maintenance of crossings when they are necessary;
- the use of erosion control near waterbodies, the limiting of equipment traffic to reduce compaction and the rutting of soil; and
- locating landings outside of vulnerable areas even in winter operations.

These types of BMPs are monitored in Minnesota by the DNR and the Minnesota Forest Resources Council (MFRC; Wilson and Slesak 2020).

Beaver management

While beavers are a key component of the local ecosystem and provide many environmental values, they can also pose challenges for watershed managers. Water impounded by beaver dams is susceptible to stagnation, increased temperature, wide fluctuations in DO concentrations and algal growth. Removing beaver dams, and the resultant release of impounded waters and can lead to flushes of high-temperature and nutrient-rich water into downstream resources causing stress to aquatic life. In addition, removal of beaver dams typically involves a release of sediment that has built up behind the dam.

Beaver dam management has been identified as a significant issue in the RRW by residents and resource management professionals. According to DNR forestry staff, beaver dams have recently flooded and killed significant timbered acreage along the length of the river. The dams are particularly problematic in the low gradient areas of the watershed where water level management is sensitive.

The most common beaver management option involves removal of the beaver followed by removal of the dam. Dam removal without removing the beaver typically results in immediate rebuilding of the dam. When removing a beaver dam (or naturally occurring log jams), care should be taken to prevent rapid release of accumulated sediments. This can be accomplished through slowly releasing the impounded water behind the beaver dam as it is removed. Either of these options requires mechanical removal of the accumulated sediment. An alternative to dam removal is the use of a water control device that allows water to continue to pass through the dam, and thereby, not cause damaging water level increases. Further information on beaver management for resource managers and residents can be found on the DNR website at https://www.dnr.state.mn.us/livingwith_wildlife/beaver/index.html.

Rice paddy management

Wild rice production in the RRW occurs along the floodplain of the river, primarily near Highway 72 between County Roads 1 and 16. These wild rice growers should be encouraged and provided financial support to continue to improve quality of water discharged from rice paddies. Research from wild rice farms in Clearwater County found that installation of main-line tile systems provides numerous benefits for water quality and farmers (Hanson 2009). When main-line tile drainage is used in wild rice paddies without internal surface drainage, it has all the same benefits as conventional tile drainage (low phosphorus and sediment) while also having low nitrate levels compared to high levels found in conventional agriculture tile drainage. Main-line tile drainage also has many benefits to the wild rice farmer such as more evenness of rice quality and maturity, less ditch maintenance, fewer ruts during harvest, more control over drainage, no topsoil loss, and reduced plugging of tile outlets. Where main-line tile is not feasible, other options (such as sediment traps or settling ponds) should be considered to limit discharge to surface waters and prevent flowing ditch water from leaving paddies.

More information on wild rice paddy management can be found in the Red Lake River Farm to Stream Tile Drainage Water Quality Study Final Report (Hanson 2009). Wild Rice BMPs are proposed for the several areas within the Barton's Brook and Lower Rapid River subwatersheds.

Pasture/manure management

Pasture and manure management strategies tend to focus on manure containment strategies. In the RRW there are currently very few registered feedlots and most animals are located in feedlots with fewer than 50 animals. Therefore, these facilities are not considered to be a major source of pollutants to the watershed, but some improvements can still be made. The primary focus in pasture management in the RRW should be protecting and/or limiting the extent of heavy use areas. Heavy use areas are areas where animals tend to congregate, limiting plant growth and creating mud holes. These areas can include areas surrounding water, feed, shade, and exercise lots. The main strategy for limiting the extent of heavy use areas is rotational grazing where the animals are periodically rotated to different new pastures allowing grass to recover. This strategy may be difficult for the small feedlots in the RRW, which may not have enough land. Protection strategies include building gravel or concrete pads below watering areas and feeding areas. For these types of strategies, it may be necessary to include wastewater filter strips or clean water diversions to clean and divert the runoff from the protected areas. Wastewater filter strips consist of a strip of permanent herbaceous vegetation that receives runoff from a feedlot or basin. Clean runoff diversions are any diversion that moves clean water around the lot to reduce the runoff volume from the feedlot. Diversions may consist of roof gutters, drip trenches, berms, or channels that divert clean runoff. For some facilities constructing a roof above the protected area may be necessary.

Climate protection cost-benefit strategies

Many agricultural BMPs, which reduce the load of nutrients and sediment to receiving waters, also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide (CO_2) emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals.

Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy; while conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage.

The NRCS has developed a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include: conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include: contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. A longer, more detailed assessment of cropland BMP effects on GHG emission can be found at NRCS, *et al*., "COMET-Planner: Carbon and Greenhouse Gas Evaluation for Natural Resources Defense Council, Inc. (NRDC) Conservation Practice Planning http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf.

Nutrient management

While row crop agriculture is not a prevalent land use in the RRW, there are some subwatersheds where small plots of crops are grown. The subwatersheds are more common in the lower portions of the watershed. In subwatersheds where row crops are grown, nutrient management plans could be developed as a strategy to reduce nutrient runoff to streams. Nutrient management plans should follow Natural Resources Conservation Service (NRCS) and Minnesota Department of Agriculture (MDA) Conservation Practice Standards (Lenhart et al. 2017; USDA NRCS 2017). These plans are an effective way to improve water quality and focus on nutrient budgets and supply, proper manure application, application timing and source, minimization of agricultural nonpoint source pollution, and maintaining healthy soils.

Residue and Tillage Management, No-Till

Tillage is a common practice in crop production, where mechanical equipment is used to prepare the soil for planting that year's crop. Tillage has historically been used to help suppress weed growth, aerate the soil, bury crop residue, level the soil, and help incorporate manure and fertilizer into soil. However, it also disrupts the soil structure, making cultivated cropland more vulnerable to surface runoff and increases the likelihood of erosion. An alternative approach to tillage is reduced tillage or no-till. These practices have been shown to reduce erosion from cultivated cropland, increase water infiltration, increase soil water-holding capacity, and maintain long-term soil productivity. Furthermore, no-till has been found to be more economical by cutting costs and labor needed to grow the crop. More information on residue and tillage management can be found at the University of Minnesota Extension:

https://extension.umn.edu/soil-management-and-health/farm-comparison-conservation-tillage-systems#research-and-tillage-methods-1396060

https://extension.umn.edu/soil-management-and-health/economics-tillage

Grade stabilization structures/WASCOBs

The WASCOBs are small earthen ridge-and-channel or embankments built across a small watercourse or area of concentrated flow within a field. They are typically designed to trap agricultural runoff water, sediment, and sediment-borne phosphorus as it flows down the watercourse; this keeps the watercourse from becoming a field gully and reduces the amount of runoff and sediment and phosphorus leaving the field. The WASCOBs are usually straight slivers that are just long enough to bridge an area of concentrated flow and are generally grassed. The runoff water detained in a WASCOB is released slowly, usually via infiltration or a pipe outlet and tile line. These practices also have benefits for water storage/flood risk reduction. Refer to the discussion on the targeting analysis that was done for WASCOBs in Section 3.1.

Ravine Stabilization

Gully erosion is a process where surface runoff cuts through soil, forming a deep channel, or ravine, through the ground. Ravines are formed in two different ways. The more common way is when surface runoff is altered upstream of the ravine, such as when runoff is increased by agriculture or development, or when runoff is concentrated, such as from poorly installed road culverts. Ravines can also be formed from a downcutting channel. In this case, the downcutting channel causes the ravine by forcing all tributaries to the downcutting channel to adjust to a lower elevation. To meet the lowered stream elevation, the slope of the tributaries will increase and become destabilized.

Stabilization of ravines is accomplished through a variety of ways. The simplest way is by re-grading the ravine and planting natural vegetation that can hold soil in place. For ravines with larger drainage areas and steeper slopes, a lining and rock check dams can be installed. Another alternative is constructing an earth embankment or drop structure at the head of the ravine. Both of these types of structures slow the runoff and prevent future erosion. The eventual type of stabilization used requires a field visit and survey. For ravines identified with larger drainage areas greater than 700 acres multiple grade stabilization structures may need to be installed or other techniques may need to be considered.

Restoration of Ditched Wetlands

During the early 1900s, peatlands were seen as having potential to be used as cropland, with the exception that they were far too wet to be farmed. A great deal of work was done to dig trenches through large areas of northern Minnesota's abundant peatlands in hopes of drying them out enough to grow crops. For the most part, this effort failed, and this portion of Minnesota is left with ditch systems in undeveloped lands that are headwaters for many streams and rivers. In some instances, ditching was used to expedite log drives down some of the larger streams. The RRW is one of the major watersheds with particularly high amounts of this type of ditching, especially in the southern portion of the watershed. According to the MPCA, 75% of the watercourses of the RRW have been altered by ditching or straightening (Sigl et al. 2020).

There are two primary scenarios of ditch construction related to draining wetlands in northern Minnesota. One was the trenching of peatlands in areas where no stream channel naturally existed. The second was straightening stream channels downstream of the peatlands to speed the transport of water coming from the upstream trenched areas. Sometimes this straightening occurred by cutting a ditch through the meandering stream channel (Figure 22).

Figure 22. Channel straightening of Wing River, Koochiching County

Other times a straight ditch was constructed a short distance from the original channel and parallel to it within the same stream valley. In still other situations, large parts of channels that had a major bend in the valley were cut off by creating a “short cut” ditch. Trenching of peatlands is the most common ditch construction scenario in the RRW and is particularly prevalent in the southern, headwaters portion of the watershed (Figure 23).

Figure 23. Legacy peatland ditching in the headwaters of the Rapid River Watershed.

Alteration of peatland hydrology by ditching can cause numerous consequences. One possible result of peatland hydrologic alterations is an increase in peak flows in downstream channel reaches. This result was found in a number of studies in fairly analogous situations in European ditched peatlands (Holden et al. 2004). In some cases, ditched peatlands seemed to reduce the peak flows due to greater storage for rain due to a lowered water table. There are numerous variables that can influence how downstream hydrology is affected by ditching, and these factors are still being studied (Holden et al. 2004). Results of altered hydrology include channel instability involving bank erosion and stream bed material alteration, leading to poor biological habitat. In the case of peatland ditching, the export of water quality parameters can be altered in a negative way. Phosphorus export from organic peat soils may increase and create nutrient excesses downstream. Dissolved organic carbon export can be increased (Strack et al. 2008), meaning the ditching is causing a loss of carbon storage, which contributes to climate change.

The remedy for downstream impacts would seem to be a restoration of peatland hydrology where ditching has occurred. Restorations of peatlands are a complex task, and a standard template of peatland restoration does not exist currently (Price et al. 2003). Efforts to restore natural hydrology to stream channels by restoring upstream peatland hydrology should be done in consultation with experienced hydrologists, and it should be realized that attempts at the current time are not fully guaranteed to succeed since peatland hydrology and impacts of ditching are still being researched. Restoration decisions and attempts likely will involve public and local governmental participation, depending on land ownership. Ditch law may also come into play, depending on the jurisdiction of particular ditches.

In the Rainy River Basin, several studies surrounding the issue of ditches and peatland hydrology have been completed. If combined, there may be the opportunity to develop a modeling tool that could begin to address the complex issue of drained peatlands in the RRW and further the science surrounding the impacts of legacy ditches in northern Minnesota. The current modeling tool, HSPF, is limited in its ability to predict the complex surface water-groundwater interactions of ditches in peatlands. The HSPF model's strength is in modeling surface water but lacks a sophisticated groundwater model. However, Reeve et al. created a MODFLOW model for the Glacial Lake Agassiz Peatlands, which includes the Upper and Lower Red Lake Watersheds, the RRW, the Black River Watershed, and portions of the Big Fork River Watershed (2001). The MODFLOW model is a three-dimensional groundwater model that can be combined with an HSPF model and provide a more sophisticated model of the surface water-groundwater interactions in the watershed. The current MODFLOW model; however, is a steady-state model and would need to be improved to simulate runoff from previous years, such as with an HSPF model. To make this improvement, monitoring data are needed so that the model can be adjusted to fit with reality. Monitoring data from the Red Lake Peatland Observatory and from the DNR in the nearby Winter Road Peatland Scientific and Natural Area (SNA) may help in calibrating a combined HSPF-MODFLOW model, which would provide a tool that could assess the impacts of the altered hydrology in the watershed.

Restoration of hydrology in ditched areas is not purely a speculative or hypothetical situation. In recent years, hydrology restoration projects involving ditched wetlands have been completed in Minnesota, mostly in the northwest (e.g., Lawndale Creek near Rothsay, Minnesota) (Aadland 2012), as well as a very large project just reaching completion in northeastern Minnesota, the Sax-Zim Bog restoration (Myers 2015). These completed projects from the region could be used as examples for new projects. Within the Rainy River Basin, the feasibility of restoring a large peatland complex within the Winter Road Lake Peatland SNA, to serve as a wetland mitigation site, was evaluated in 2015 (Walker 2015). The recommendation was to wait to see the results of a similar effort, the Lake Superior Wetland Bank, to determine if the challenges could be overcome and the restoration could generate wetland credits.

In addition to the bog hydrology restoration, there are also numerous areas where stream/habitat restoration (i.e., returning flow back into the original stream channel) of substantial length could be achieved for ecological benefit. This type of project adds habitat in two ways: by providing a more diverse set of habitat features in the channel (these features, such as better depth variability, develop naturally due to sinuosity), and increasing stream channel length (between two points, a meandering channel is longer than a straight channel).

While completely removing a ditch from within a wetland is the ultimate strategy, in most cases this would be very difficult and costly to perform. Alternative options for addressing ditched wetland systems are available that may be far more practical in the RRW. These techniques include effectively disabling a ditch through construction of ditch plugs or small, earthen flow spreading structures. Alternatively, in ditches that are difficult to reach, legal ditch abandonment may be an option. Lake of the Woods and Beltrami Counties have recognized that some legacy ditches in the RRW do not serve a substantial useful purpose as part of the drainage system and are not of substantial public benefit and utility. As a result, the counties petitioned to, and had, portions of Jurisdictional Ditches 30 and 36 abandoned in 2018 (Figure 24). In lieu of effectively disabling the ditches and in areas where the ditch is needed to protect infrastructure or agricultural land, other techniques such as sediment basins or two-stage ditches can help mitigate the impact of the ditches. Sediment basins are essentially a small pool constructed in line with the ditch or connected through a side channel that captures sediment during small rain events. Two-stage ditches are an alternative to a traditional trapezoidal ditch where the bottom stage of the ditch passes the channel-forming flow and a top stage that mimics a floodplain in a natural stage conveys larger flows. Sediment can settle out and become trapped within the top stage.

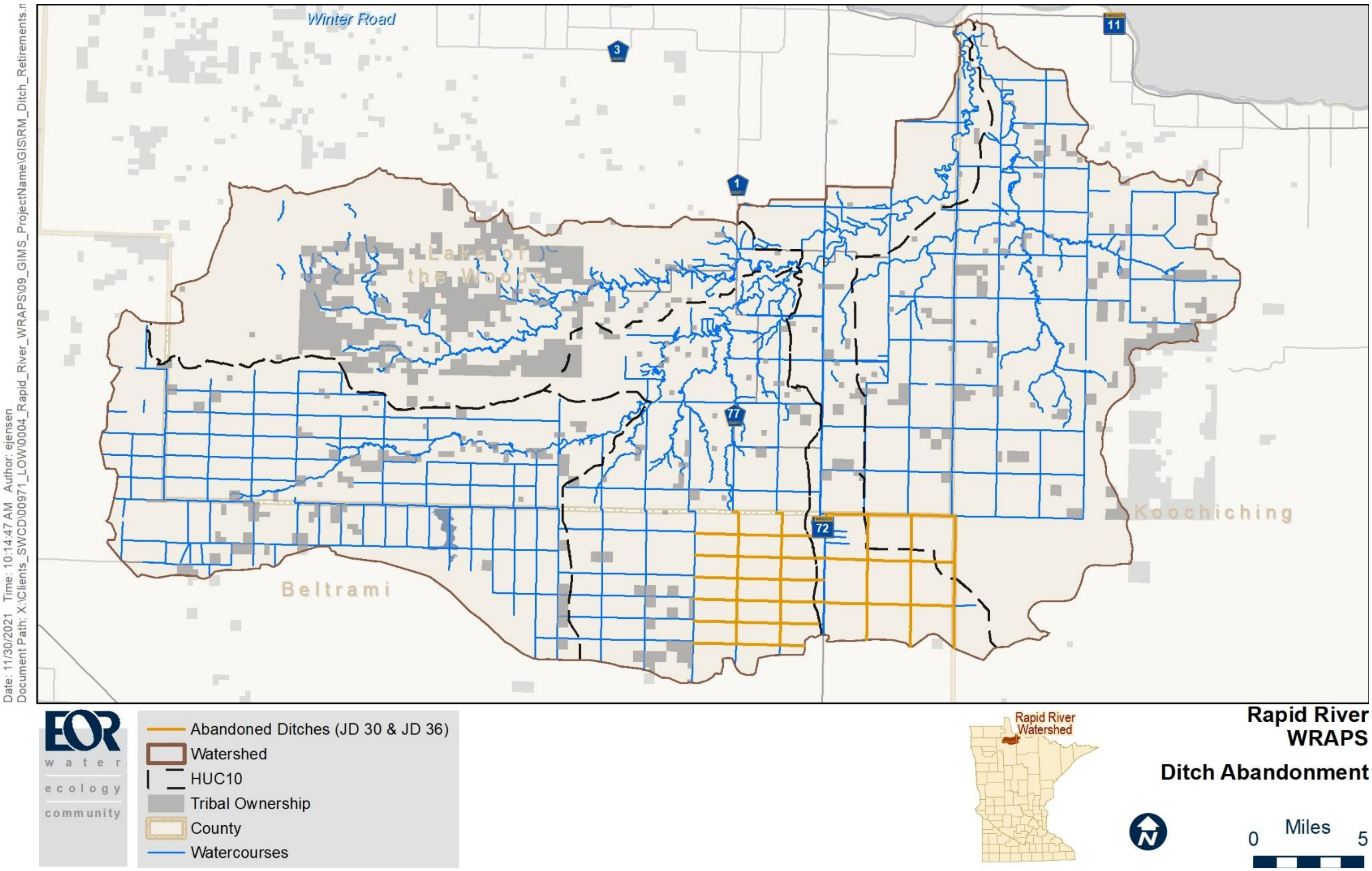


Figure 24. Abandoned ditches in the Rapid River Watershed (JD 30 and JD 36)

Stream Restoration Strategies

The following discussion provides strategies to restore the impaired stream for aquatic life usage. Keep in mind that developing site-specific restoration plans will require further assessment to determine the optimal extent, methods, and locations for restorations. In addition, the length of ditched and incised reaches, local constraints, and project costs may restrict the restoration options available.

Legacy ditching efforts to drain bogs and straighten channels in the headwaters of these streams altered their hydrologic regimes. In response, the downstream channels adjusted to the new hydrologic conditions through channel evolution (Figure 25). Evolving streams often go through predictable changes in form involving periods of accelerated erosion, deposition, and lateral migration. Each stream reacts differently depending on watershed characteristics such as valley shape and slope, substrate, and vegetation composition and density. Many RRW streams have incised, lowering the local water table and causing their floodplain to become inaccessible at bankfull flows. Without floodplain access, higher flows stay concentrated within the channel increasing sheer stress on the bed and banks, leading to accelerated bank erosion. The resulting instability has created excess sediment, a lack of variable bed form, and minimal quality habitat for all life stages of biota. Restoring these streams would stabilize the channel, reconnect them with their floodplain, and immediately provide better habitat.

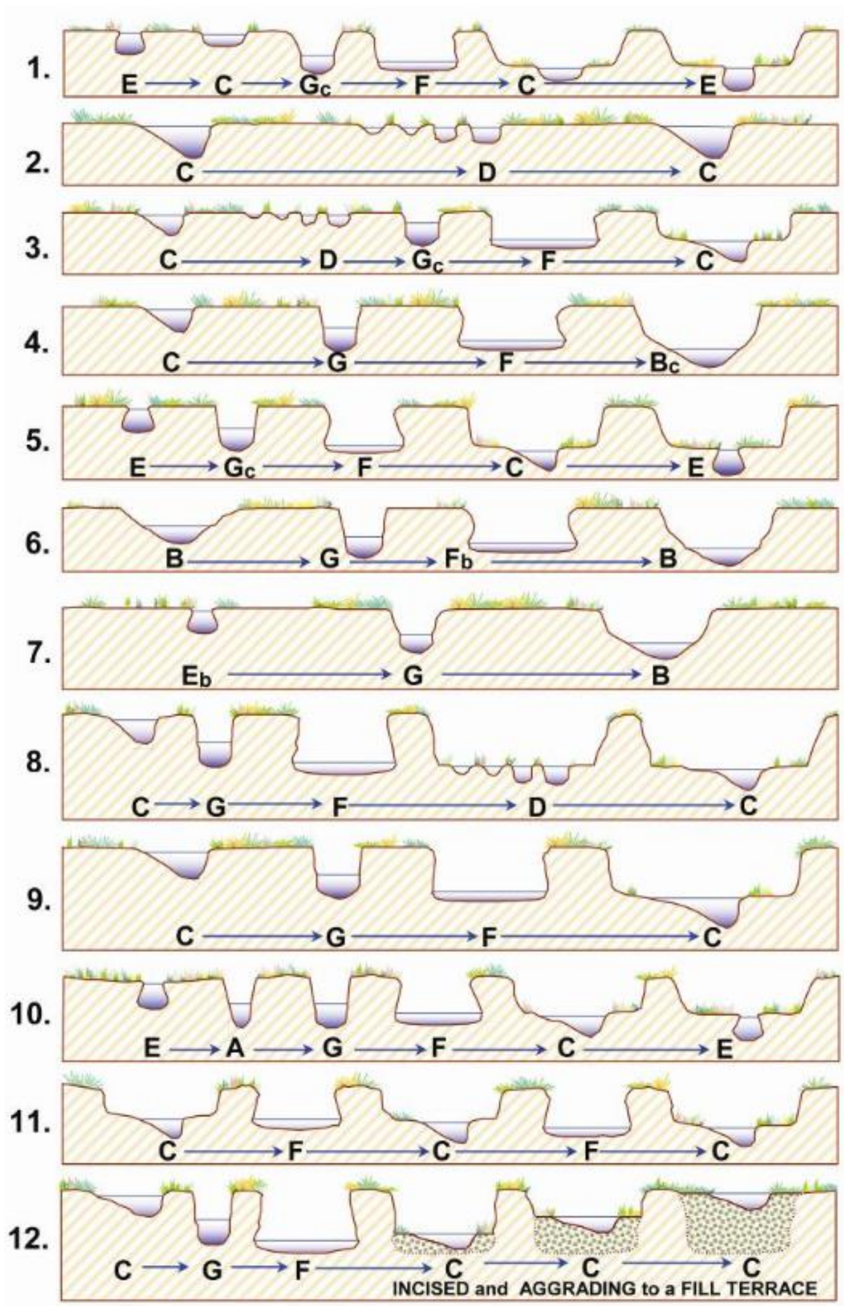


Figure 25. Some of the stream evolution scenarios documented in actual rivers (Rosgen 2011).

The DNR recommends using a holistic approach for stream restoration planning and implementation that addresses the five components of stream health. Rather than fixing isolated symptoms, a holistic approach seeks to alleviate the driver of instability while implementing a stable channel that improves functions within the five components. Since the impacted streams have ditching in their headwaters, addressing the hydrologic impacts there can be a good place to start. Restoration of ditched wetlands opportunities are discussed separately above. However, stream function may not rapidly improve by just restoring headwaters ditches. The degraded channels downstream could still take significant time to recover without additional channel restoration.

Restoration projects that apply natural channel design (NCD), to implement multistage channels to reconnect bankfull flows to their historical floodplain, can provide channel stability and improve ecological function. Site-specific restraints such as land ownership and local risks from a wider floodplain will not always allow for that ideal restoration, but NCD allows for flexibility. The methodology uses a holistic approach that incorporates pattern, profile, and channel dimensions from a stable reference reach of the same stream type under similar morphologic and hydrologic conditions (Rosgen 1998).

There are four priority methods for restoring incised channels, with priority one being the most preferred and priority four being the least (Figure 26) (Rosgen 1997). Priority one reconnects the stream to its historical floodplain by either putting the stream into a relic channel or building a new channel. It cost-effectively creates the best long-term results by raising the water table, reconnecting the floodplain, restoring channel morphology, and increasing habitat diversity. Priority two restoration builds a new channel within the degraded channel but does not raise the water table. It typically involves excavating a wider floodplain, which can have high costs. Priority three restoration converts an incised meandering channel to a step-pool type channel with a narrow floodplain at approximately the current elevation. Priority four involves armoring the channel in place and should only be used when outside restrictions affect the project. It also has the highest risk because it does not address flood sheer stress. The hydrologically altered streams in the RRW are currently incised, two stage channels that lack an inner berm and require higher flows to reach their bankfull and floodplain elevations. Whichever priority method is used for restoration, a multistage channel should be constructed to increase sediment passage, increase water depth at low flows, and to reduce sheer stress at higher flows.

The NCD often incorporates several types of structures needed to hold grade and prevent future incision, create aquatic habitat, or protect susceptible banks. However, careful selection is needed since not all structures are appropriate in every situation. Structures must maintain sediment transport capacity, be compatible with the stream type, and be placed in the correct stream features. If the morphological characteristics of the stream have not been stabilized, structures will often fail or even make conditions worse. Consequently, whether implementing a priority one or two restoration, grade control will be a part of the solution due to the incision and the predominance of small particles in the impaired streams. Cross-vane structures can be installed to hold grade and be constructed with either rock or logs. Since NCD emphasizes the use of native materials, logs make the most sense for streams in the RRW. The benefits of cross vanes include grade control, decreased near bank stress, and enhanced fish habitat. Log J-hook vanes are similar but are positioned at the beginning of stream bends and direct the flow away from the outside bank through the meander. These are useful when protecting newly constructed banks until vegetation can establish or to move flow away from existing eroding banks. Lastly, toe wood can be place on the outside of meanders to protect banks, maintain deep pools, and enhance aquatic habitat. Utilizing local materials can help to make these structures cost effective and keep project budgets lower. Tactics such as hard armoring banks in place only delay negative outcomes or push the problem downstream. Holistic stream restoration is not cheap, but the benefits of incorporating suitable structures with NCD can recreate healthy stable streams.

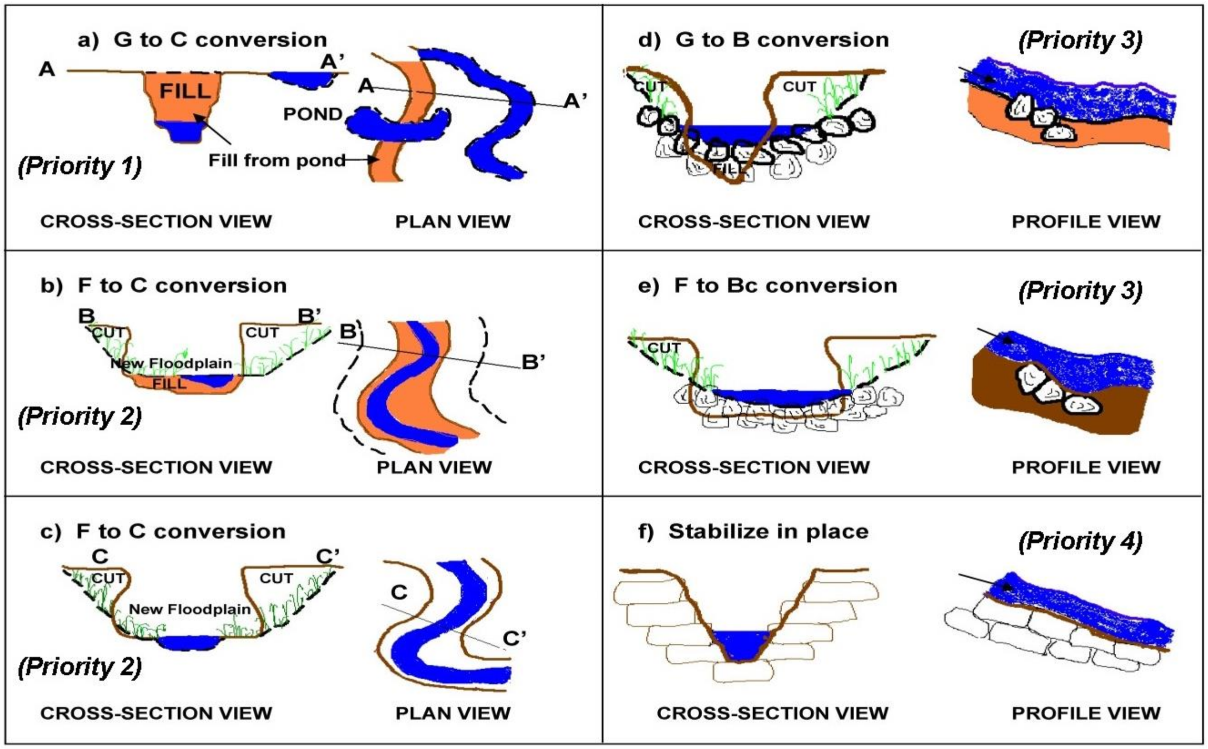


Figure 26. Priority methods for restoring incised rivers (Updated image provided by Wildland Hydrology (Rosgen 1997)).

Best Management Practices Prioritization

To meet the WRAPS reduction goal of 4,023 tons of sediment per year proposed in Section 2.4, potential grade stabilization structures, ravine stabilization structures, two-stage ditches, and surveyed streams identified in Section 3.1 were prioritized.

Grade and ravine stabilization structures were the primary practice identified to be able to meet the reduction goal. Potential structures were classified using two indicators of potential feasibility, including the distance from the structure to the nearest road and an estimated runoff curve number for the structure's drainage area. The runoff curve number is a value estimated from soils and land use that is commonly used to calculate flow from a site. Runoff curve numbers closer to 98, such as cultivated crops and urban areas, have more runoff. Table 19 shows how the grade and ravine stabilization structures were classified. Grade and ravine stabilization structures classified as very high and high are more likely to be feasible.

In addition to the prioritization, sediment load reductions and costs were estimated for each structure. Sediment load reductions were approximated by applying typical sediment reduction efficiencies over the drainage area of each structure. Typical sediment reduction efficiencies are shown in Table 21. The reduction efficiencies were applied to the predicted sediment load contributing to the impaired stream reach from each HSPF-modeled subbasin. Therefore, the estimated load reduction for each structure refers to the load reduction at the impaired stream and not the load reduction at the local HSPF-modeled subbasin. However, this approach applies an average load reduction rate across the entire HSPF-modeled subbasin and does not account for local variations in the drainage area of each structure. For example, the predicted sediment reduction from two structures in the same HSPF-modeled subbasin and with the same sized drainage area, but one with all agricultural land and the other with all forested land, will have the same predicted load reduction based on this method. The prioritization based on Table 19 accounts for this caveat. The costs for each structure were calculated using an equation derived from literature values from the MDA 2017 Agricultural BMP Handbook and shown in Figure 27 where x is the drainage area of the structure. All costs were adjusted to 2020 dollars using data on inflation from the United States Bureau of Labor Statistics.

Table 19. Grade and Ravine Stabilization Structure Feasibility Matrix

Feasibility Prioritization Matrix		Runoff Curve Number		
		<70	70-80	>80
Road Distance (mi)	>1.0	Very Low	Low	Medium
	0.75-1.0	Low	Medium	High
	<0.5	Medium	High	Very High

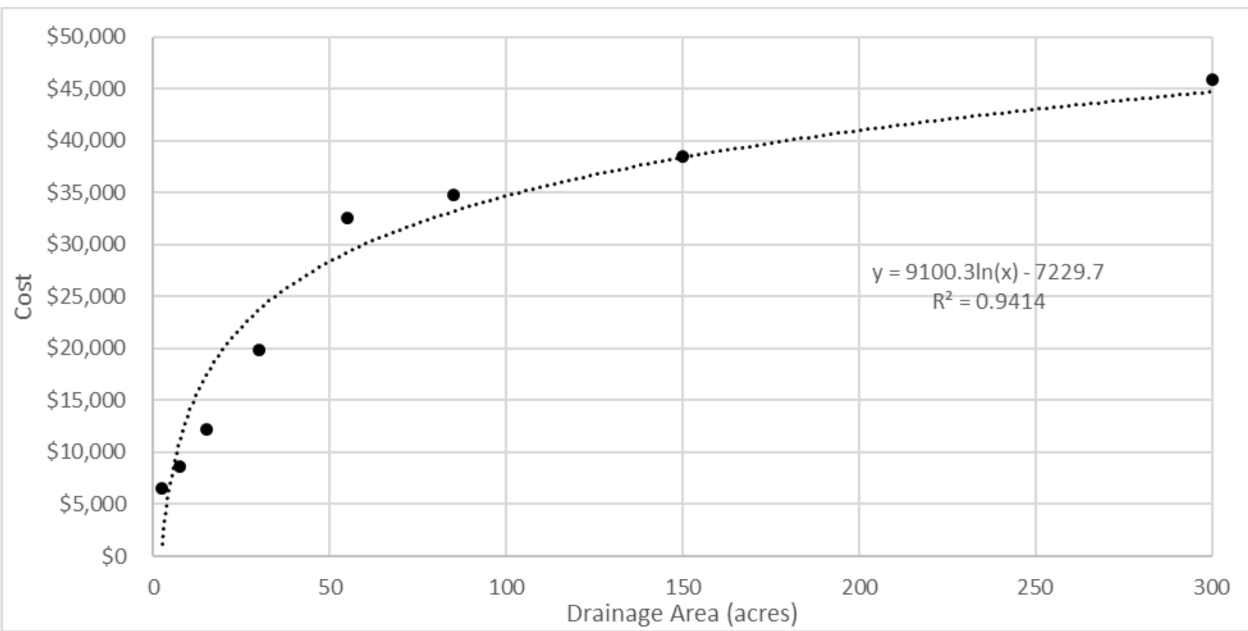


Figure 27. Grade and ravine stabilization structure cost as a function of drainage area based on the MDA 2017 Agricultural BMP Handbook

Ditch improvements and stream restoration were the secondary practices used to meet the reduction goal. Potential stream restoration was prioritized similarly to the grade and ravine stabilization structures using two indicators of feasibility. The first indicator was the distance of the stream to the nearest road. The second indicator was the BEHI estimated from the Rapid River DNR stream study. Table 20 shows the prioritization matrix for stream restoration practices. The sediment load reductions from ditch and stream restoration projects were estimated using the HSPF SAM model too. For stream restoration, the sediment load reductions were estimated from the in-stream sediment load. For the ditch improvements, all overland and stream sources of sediment were included in the reduction. Sediment-load reduction efficiencies and unit costs for each practice were from literature values (Table

21). The stream restoration unit cost was from the 2021 Environmental Quality Incentives Program (EQIP) cost tables. The EQIP unit costs only include the portion of the cost covered by the NRCS, typically around 50%. Stream restoration costs were divided by 50% to approximate the total stream restoration construction cost.

Table 20. Stream Restoration Feasibility Prioritization Matrix

Feasibility Prioritization Matrix		Bank Erosion Hazard Index		
		Very Low & Low	Medium	High & Very High
Road Distance (mi)	>1.0	Very Low	Low	Medium
	0.75-1.0	Low	Medium	High
	<0.5	Medium	High	Very High

Table 21. Literature Values and Sources used to Prioritize Best Management Practices

Best Management Practice (BMP)	Sediment Removal Efficiency	Sediment Removal Efficiency Source	Unit Cost	Cost Source
Grade/Ravine Stabilization Structures	90%	(RESPEC 2017)	See Figure 27	MDA 2017 Agricultural BMP Handbook (Lenhart et al. 2017)
Two-Stage Ditches	15%	(Ohio State University Extension 2021)	$24.10 per linear foot	(Minnesota Board of Water and Soil Resources 2020 Dec 3)
Stream Restoration	90%	MDA 2017 Agricultural BMP Handbook (Lenhart et al. 2017)	$51.72 per linear foot	2021 EQIP Unit Cost for Streambank and Shoreline Protection - Riprap on bank 4 ft to 9 ft high measure from bank top to toe of slope

Table 22 shows the number of stabilization structures and length of stream banks for each prioritization category. The proposed stabilization structures identified through GIS should be reviewed in the field to confirm their feasibility and get landowner interest in the project. For the purposes of this study, the stabilization structures classified as high or very high in the feasibility prioritization matrix are included in the Proposed Strategies and Actions by subwatershed section. With more information from future efforts the estimated number of potential practices available in the watershed may change. By using average sediment reduction values for stabilization structures and for stream restoration, a relationship between the two practices can be developed to identify the full range of possible implementation scenarios as shown in Figure 28. With this relationship the approximate stream restoration length needed can be approximated from the number of potential stabilization structures. For example, if 100 stabilization structures are feasible after being reviewed in the field, then moving up from the x-axis to the diagonal line and then over to the y-axis, the approximate stream restoration length needed to meet the reduction goal is 23.4 miles. In addition, two alternatives that include recurring BMPs are shown. Recurring BMPs are practices that need to be adopted every year to have a benefit such as, nutrient management, no-till, pasture management, and timber harvesting BMPs. The two alternatives were developed using scenarios from HSPF SAM, with one showing the benefit from 50% implementation of the recurring practices and the other showing maximum benefit from full implementation. The practices included in the HSPF SAM scenarios were no-till and timber harvesting BMPs. Table 23 shows the sediment load reduction, the estimated cost, and maximum area available according to the HSPF SAM model.

Table 22. Number of Best Management Practices in each Priority Category

Priority	Grade Stabilization Structures	Ravine Stabilization Structures	Streambanks (miles)
Very High	55	21	1.0
High	93	35	25.5
Medium	65	30	39.5
Low	36	9	10.1
Very Low	26	7	0.6
Deposition	NA	NA	1.7

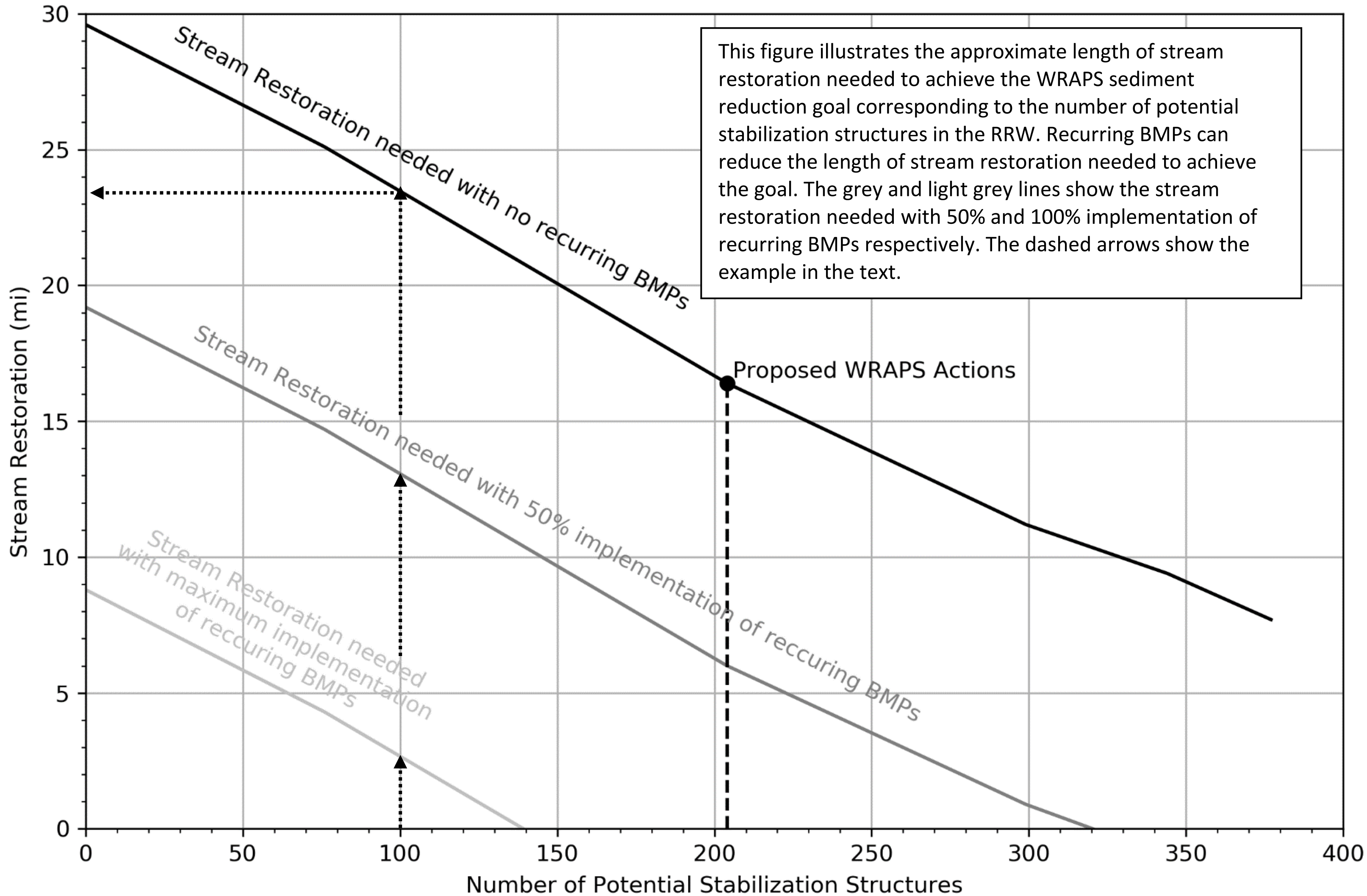


Figure 28. RRW potential stabilization structures and stream restoration options to meet the WRAPS sediment reduction goal.

Table 23. Recurring Best Management Practice Maximum Potential Area, Sediment Load Reduction, and Cost

Practice	Available Area* (acres)	Predicted Total Sediment Load Reduction (tons/yr)	Predicted Average Sediment Load Reduction (tons/ac/yr)	Unit Cost ($/acre/yr)	Total Cost ($/yr)
No-Till	3,277	1,278	0.39	$22[1]	$72,028
Timber Harvesting Erosion Control	10,789	1,559	0.14	$64[2]	$690,496

Sources: 1 (Lenhart et al. 2017) 2:(Soman 2019)
*Area is based on the Lake of the Woods 2010 land use in the HSPF SAM model. No-Till area is the same as the cultivated cropland while the timber harvesting best management practices area is the same as the young forest area. The young forest area is an estimate of the total area of regenerating forest. It is not the area of forest harvested each year in the RRW. The reduction shown is a cumulative impact over more than a decade of timber harvesting BMP implementation. The current implementation of timber harvesting BMPs in the RRW is not known.

Proposed Strategies and Actions by Subwatersheds

The primary strategies used to achieve the sediment load reduction goal in the RRW were grade stabilization structures, ravine stabilization structures, and stream restoration. These strategies were selected because they prevent erosion near the stream and near-stream sediment was determined to be the dominant source of TSS in the RRW. Table 24 and Table 25 show the cost, predicted sediment load reduction, and predicted number of practices needed to achieve the goal through implementation of the grade stabilization structures, ravine stabilization structures, and stream restoration. The predicted potential locations of these practices, based on GIS terrain analysis and stream surveys, are shown in Figure 29 through Figure 33. The number of practices to achieve the TSS reduction goal is meant to be a long-term goal and the strategies needed to achieve that goal may change over time. As a reference, the estimated number of grade stabilization structures built in the LOW County from 2010 through 2020 was 13 structures and the length of stream protection was 0.6 miles.

Additional watershed-wide and HUC-10 level protection strategies were included with the strategies used to meet the TSS reduction goal in Table 25. The proposed implementation for the watershed wide strategies were estimated from the 2010 through 2020 and therefore reflect a similar timeframe into the future. Most of these strategies will also reduce the sediment. Any implementation beyond that shown in Table 25 will reduce the number of stabilization structures and stream restoration needed in the RRW.

Table 24. Predicted Cost and Contributing Sediment Load Reduction to the Impaired stream from BMPs to meet the WRAPS TSS Reduction Goal.

HUC-10 Name	HUC-10	Total Cost ($)	Total Contributing Sediment Load Reduction (Percent Reduction) [tons/yr]
Upper Rapid River	0903000701	$49,000	0.2 (0.02%)
Middle Rapid River	0903000702	$3,260,000	1,526 (33%)
North Branch Rapid River	0903000703	$636,000	119 (3%)
East Fork Rapid River	0903000704	$147,000	31.4 (0.4%)
Lower Rapid River	0903000705	$5,112,000	2,349 (28%)
Rapid River Watershed	09030007	$8,568,000	4,025.6 (16%)

Table 25. Estimated number of BMPs in each HUC-10 Subwatershed to Achieve the WRAPS TSS Reduction Goal

HUC-10 Name	HUC-10	Number of Grade Stabilization Structures	Number of Ravine Stabilization Structures	Length of Stream Restoration (mi)
Upper Rapid River	0903000701	5	0	0
Middle Rapid River	0903000702	48	15	6.3
North Branch Rapid River	0903000703	27	1	0
East Fork Rapid River	0903000704	5	0	0
Lower Rapid River	0903000705	63	40	10.1
Rapid River Watershed	09030007	148	56	16.4

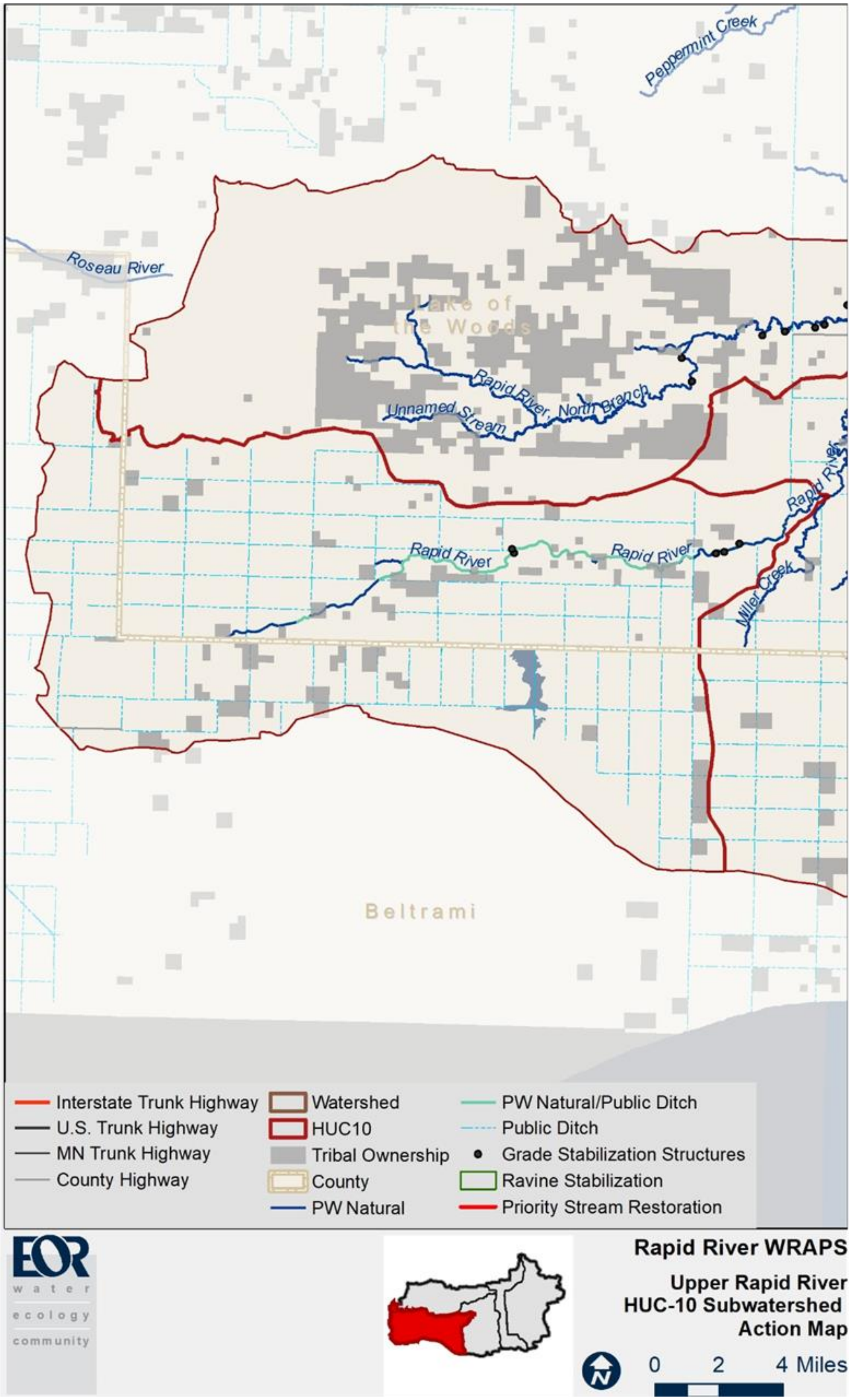


Figure 29. Proposed subwatershed actions for the Upper Rapid River.

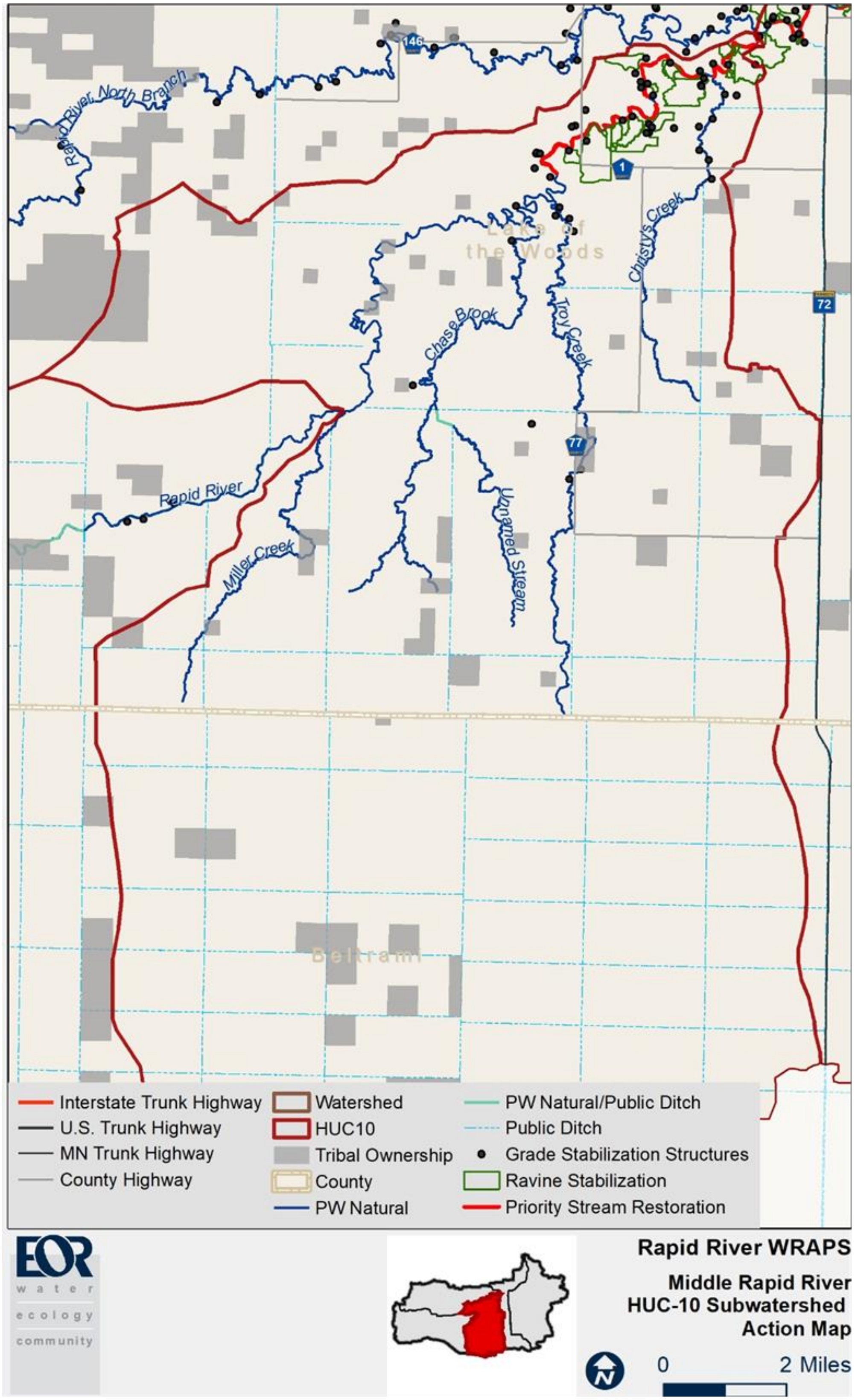


Figure 30. Proposed subwatershed actions for the Middle Rapid River.

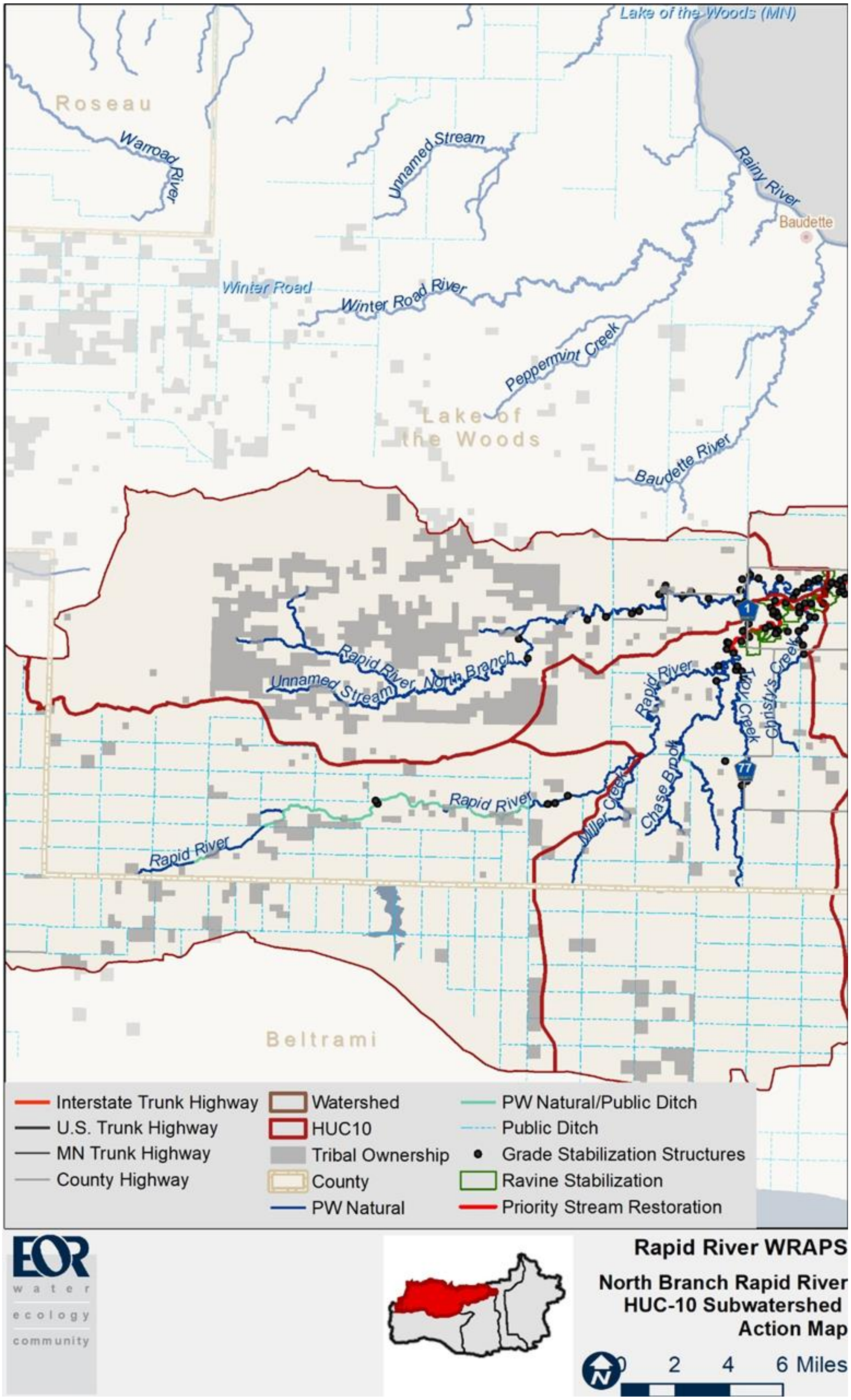


Figure 31. Proposed subwatershed actions for the North Branch of the Rapid River.

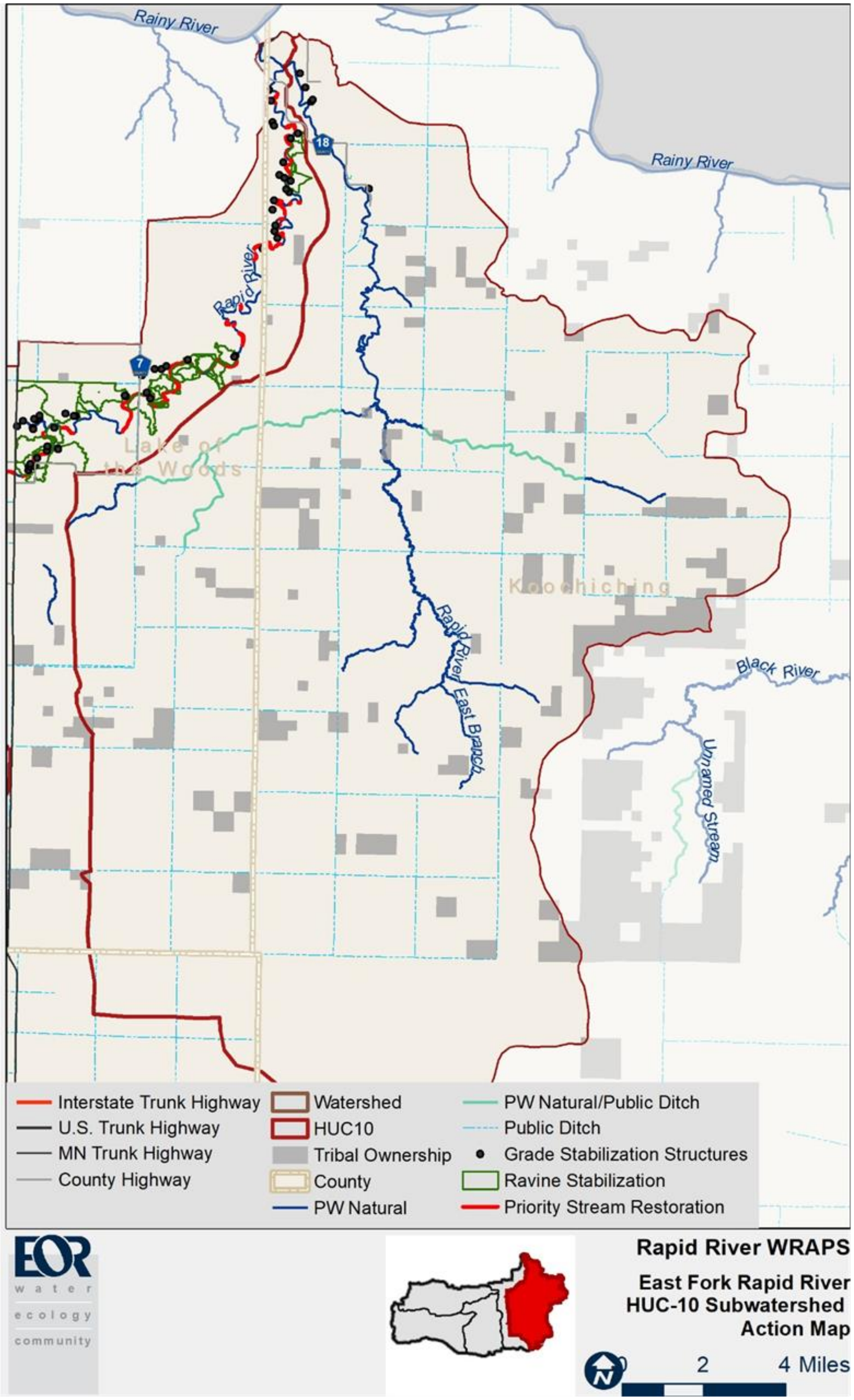


Figure 32. Proposed subwatershed actions for the East Fork Rapid River.

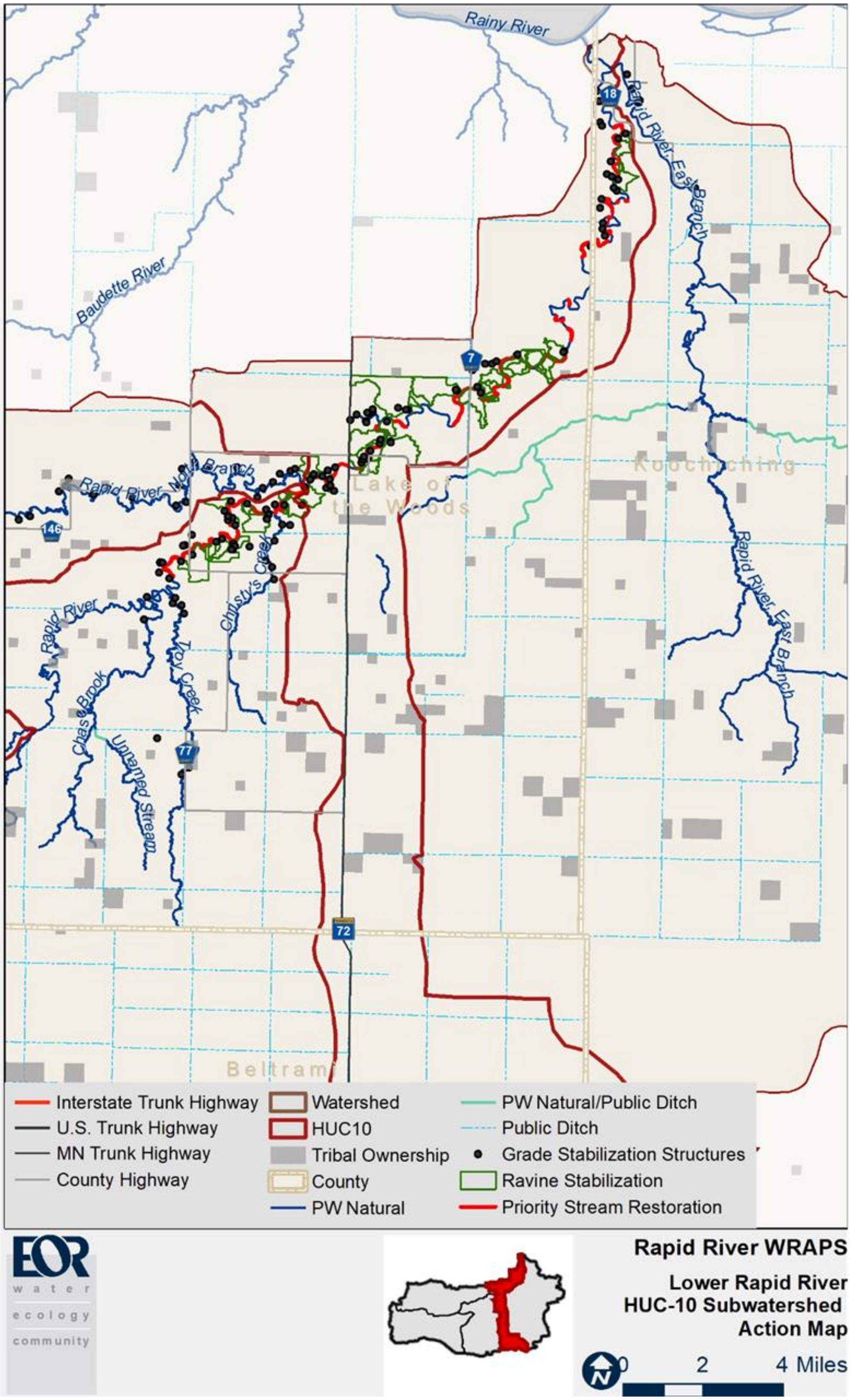


Figure 33. Proposed subwatershed actions for the Lower Rapid River.

Table 26. Strategies and actions proposed for the Rapid River Watershed.

Waterbody and location			Water quality (WQ)			Strategies to achieve final water quality goal			
HUC-10 Subwatershed	Waterbody (AUID)	Location and upstream influence counties	Pollutant/ Stressor	Current WQ conditions (conc. & load as related to impairment)	Final WQ Goal Year: _____ (% and load to reduce)	Strategy type	Best Management Practice (BMP) Scenario		
							BMP	Amount	Unit
All	All	All	**TSS**	-	-	Add cover crops for living cover in fall/spring	Cover Crops	90	ac
						Tillage/Reside management	No-Till	190	ac
						Nutrient Management	Nutrient Management	70	ac
						Pasture Management	Heavy Use Area Protection	1	no
							Conventional pasture to prescribed rotational grazing	110	ac
							Perennial crops for regular Harvest	20	ac
						Pest Management	Integrated Pest Management	60	ac
						Forestry Management	Reforestation on nonforested land and after cutting	110	ac
							Forestry Management and improvement	100	ac
							Forestry Management Plans	20	no
							Forest Erosion Control on harvested lands	See Section 3.3 Timber Harvesting BMPs	

Waterbody and location			Water quality (WQ)			Strategies to achieve final water quality goal			
HUC-10 Subwatershed	Waterbody (AUID)	Location and upstream influence counties	Pollutant/ Stressor	Current WQ conditions (conc. & load as related to impairment)	Final WQ Goal Year: ____ (% and load to reduce)	Strategy type	Best Management Practice (BMP) Scenario		
							BMP	Amount	Unit
							Beaver Management	See Section 3.3 Beaver Management	
						Habitat & stream connectivity management	Early Successional Habitat Development/Management	100	ac
						Stream bans, bluffs and ravines protected/restored	Restoration of Ditched Wetlands	See Section 3.3 Restoration of Ditched Wetlands Opportunities	
Upper Rapid River (903000701)	Unnamed ditch (520) Unnamed ditch (521) Unnamed ditch (522)	Beltrami, Lake of the Woods	**TSS**	-	0.02% 0.2 tons/yr	Stream banks, bluffs and ravines protected/restored	Grade Stabilization	5	no
Middle Rapid River (903000702)	Miller Creek (507) Chase Brook (524) Thompson Creek (524) Troy Creek (508) Moose Creek (512) Christy Creek (513, 514)	Lake of the Woods, Beltrami	**TSS**	-	33% 1,526 tons/yr	Stream banks, bluffs and ravines protected/restored	Grade Stabilization	48	no
							Ravine Stabilization	15	no
							Stream Restoration	6.3	mi

Waterbody and location			Water quality (WQ)			Strategies to achieve final water quality goal			
HUC-10 Subwatershed	Waterbody (AUID)	Location and upstream influence counties	Pollutant/ Stressor	Current WQ conditions (conc. & load as related to impairment)	Final WQ Goal Year: ____ (% and load to reduce)	Strategy type	Best Management Practice (BMP) Scenario		
							BMP	Amount	Unit
	Moose Creek (517, 518) Unnamed ditch (527) Rapid River (505, 506)		**TSS**	-	-	Agricultural tile drainage water treatment	Rice Paddy Management	614	ac
North Branch Rapid River (0903000703)	Meadow Creek (519) Unnamed Creek (528) Kvolnes Creek (526)	Lake of the Woods	**TSS**	-	3% 119 tons/yr	Stream banks, bluffs and ravines protected/restored	Grade Stabilization	27	no
							Ravine Stabilization	1	no
							Log Jam Removal	1	no
East Fork Rapid River (0903000704)	Wing River (515, 516) Rapid River, East Branch (511) Unnamed ditch (530)	Koochiching	**TSS**	-	0.4% 31.4 tons/yr	Stream banks, bluffs and ravines protected/restored	Grade Stabilization	5	no
			TSS	-	-	Stream banks, bluffs and ravines protected/restored	Log Jam Removal	1	no
Lower Rapid River (0903000705)	Rapid River (501)	Lake of the Woods	**TSS**	25,143 tons/yr	16% 4,025.6 tons/yr*	Stream banks, bluffs and ravines protected/restored	Grade Stabilization	63	no
	Rapid River (502, 504)		**TSS**	-	28%		Ravine Stabilization	40	no

Waterbody and location			Water quality (WQ)			Strategies to achieve final water quality goal			
HUC-10 Subwatershed	Waterbody (AUID)	Location and upstream influence counties	Pollutant/ Stressor	Current WQ conditions (conc. & load as related to impairment)	Final WQ Goal Year: _____ (% and load to reduce)	Strategy type	Best Management Practice (BMP) Scenario		
							BMP	Amount	Unit
	Rapid River, North Branch (503) Bartons Brook (510) Unnamed ditch (529) Rapid River, East Branch (509) Monroe Creek (525)	Lake of the Woods, Koochiching, Beltrami			2,349 tons/yr		Stream Restoration	10.1	mi
						Drainage ditch modifications	Two-stage ditches	5	mi
			TSS	-	-	Agricultural tile drainage water treatment	Rice Paddy Management	839	ac
	Restoration								
	Protection								
	Color used to differentiate watersheds								

Hydrologic Unit Code (HUC); Assessment Unit Identification (AUID)

*The load reduction for the Rapid River (501) is the sum of the load reduction from the five HUC-10 watersheds.

4. Monitoring plan

The collection of current land and water data is an important component to both assess progress and inform management and decision-making. For improved watershed management to work in the RRW, there needs to be reliable data that can be used to generate information. The basic needs of a monitoring plan must also include an understanding of variability, scale, confidence, and associated risk levels. For example, the scale of the Rapid River at State Highway 11, and the requirement of reliable stream hydrology data is different than the need for data on land uses, bacteria, and habitat for the Barton's Brook Subwatershed. Monitoring of both land and water components is needed and data are then used to inform and calibrate watershed models, evaluate progress towards defined goals, and desired outcomes. Section 7 of the RRW TMDL Study includes more information on monitoring.

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. The response of the streams will be monitored and subsequently evaluated as management practices are implemented. The SWCDs will annually review the WPLMN data to evaluate the impact of implemented management activities. The management approach to achieving the goals should be reconsidered as new monitoring data are collected and evaluated (Figure 34). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in the RRW TMDL Study. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reach of the Rapid River.

Again, this is a general guideline. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., restoring ditched peatlands, streambank stabilization) and unfavorable climatic factors.

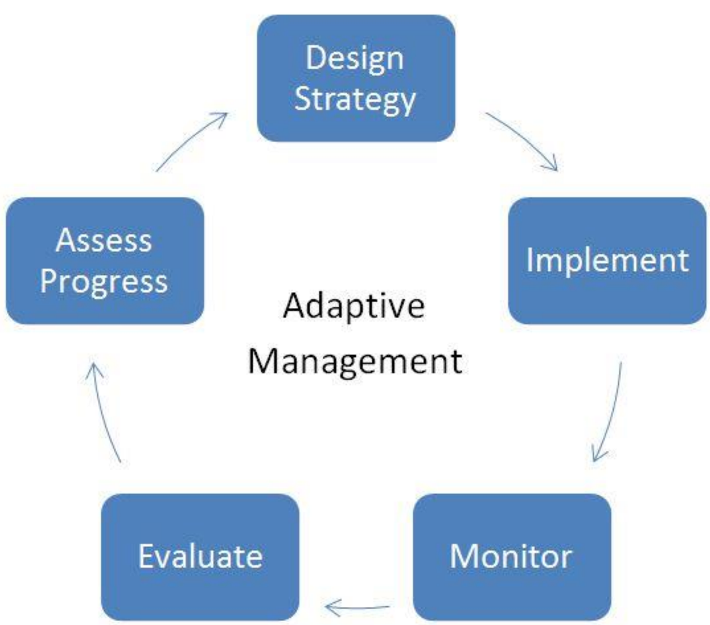


Figure 34. Adaptive Management

Data from numerous monitoring programs will continue to be collected and analyzed for the RRW. Monitoring is conducted by local, state, and federal entities, and also special projects (for example BMP monitoring) as described in the following paragraphs.

Stream Monitoring

As part of the MPCA IWM strategy, 17 stream sites were monitored for biology (fish and macroinvertebrates) and 12 sites were monitored for water chemistry from 2017 through 2018 (Figure 2). A portion of these sites will be sampled in the next 10-year IWM cycle, beginning in 2028. Details about the MPCA IWM strategy can be found in the Lower Rainy River and RRWs Monitoring and Assessment Report: [https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030008b.pdf].

The MPCA and Lake of the Woods SWCD will continue to monitor their long-term sites at the same frequencies. If data collected indicates issues at a particular site, additional monitoring or additional monitoring sites may be added to determine where issues may be arising.

Table 27. RRW 2017-2018 intensive watershed monitoring stream biological stations.

AUID	Biological Station ID	Waterbody Name	Biological Station Location
09030007-502	05RN083	Rapid River	Downstream of CR 18, 1 mi. SE of Clementson
09030007-502	17RN080	Rapid River	Upstream of Hwy 72, 12 mi. S of Baudette
09030007-503	05RN104	Rapid River, North Branch	Upstream of Faunce Rd, 8 mi. S of Faunce
09030007-503	17RN066	Rapid River, North Branch	Upstream of Hwy 1, 12 mi. S of Baudette
09030007-503	17RN067	Rapid River, North Branch	Upstream of Bankton FR, 18.5 miles SW of Baudette
09030007-504	17RN079	Rapid River	Upstream of Hwy 1, 14.5 mi. S of Baudette
09030007-506	17RN070	Rapid River	Upstream of Pitt Grade SW, 21 mi. SW of
09030007-506	17RN081	Rapid River	Upstream of Faunce FR, 30 mi SW of Baudette
09030007-507	17RN075	Chase Brook	Upstream of 67th St SW, 16.5 mi. S of Baudette
09030007-508	17RN076	Troy Creek	Downstream of Hwy 86, 16.5 mi. S of Baudette
09030007-509	05RN013	Rapid River, East Fork	Upstream of UT 9, 4.5 mi. SE of Clementson
09030007-510	17RN060	Barton's Brook	Upstream of Hwy 82, 11 mi. S of Clementson
09030007-510	17RN061	Barton's Brook	Adjacent to Hwy 100, 9.5 mi. S of Clementson
09030007-513	17RN077	Christy Creek (Moose Creek)	Upstream of Hwy 83, 14 mi. S of Baudette
09030007-523	17RN074	Miller Creek	Upstream of Rapid River Rd, 20 mi. S of
09030007-528	17RN069	Unnamed creek	Upstream of Faunce FR, 23 mi SW of Baudette
09030007-529	17RN078	Unnamed ditch	Adjacent to Hwy 72, 12.5 mi. S of Baudette

Assessment Unit Identification (AUID)

Table 28. RRW 2017-2018 intensive watershed monitoring stream chemistry stations.

EQuIS ID	Biological Station ID	AUID	Waterbody Name	Location
S007-611	17RN062	09030007-509	Rapid River, East Branch	Upstream of Co Hwy 18, 3 mi. SE of
S009-451	05RN083	09030007-502	Rapid River	Downstream of Co Hwy 18, 1 mi. SE of
S009-452	17RN066	09030007-503	Rapid River, North Branch	At Co Hwy 1, 12.75 mi S of Baudette
S009-453	17RN079	09030007-504	Rapid River	At Co Hwy 1, 14.5 mi. S of Baudette

Assessment Unit Identification (AUID)

Watershed Pollutant Load Monitoring

The WPLMN, which includes state and federal agencies, Metropolitan Council Environmental Services, state universities, and local partners, collects data on water quality and flow in Minnesota to calculate pollutant loads in rivers and streams. Pollutant loads are the amount of a pollutant that passes a monitoring station over a period of time. Data are collected at 199 sites around the state. There are two WPLMN sites within the RRW.

Table 29. WPLMN stream monitoring sites in the Rapid River Watershed.

Site Type	Stream Name	EQuIS ID
Major Watershed	Rapid River at Clementson, MN11 (78007001)	S000-184
Subwatershed	East Fork Rapid River near Clementson, CSAH18(78006001)	S007-611

WPLMN data assist in watershed modeling, determining pollutant source contributions, developing reports, and measuring water quality restoration efforts.

Each year, approximately 25 to 35 water quality samples are collected at each monitoring site, either year-round or seasonally depending on the site. Water quality samples are collected near gaging stations, at or near the center of the channel. Samples are collected more frequently when water flow is moderate to high, when pollutant levels are typically elevated and most changeable. Pollutant concentrations are generally more stable when water flows are low, and fewer samples are taken in those conditions. This staggered approach generally results in samples collected over the entire range of flows and an accurate estimate of the total pollutant load leaving the watershed. However, it may also skew the percent exceedances and the estimated 90th percentile TSS concentration, which are used to assess TSS conditions in streams. In the future, a protocol should be developed on how to assess TSS conditions in streams with WPLMN stations. The frequent sampling at these sites makes feasible the use of statistical approaches such as FLUX32 to estimate daily TSS concentrations and approximate a more robust TSS exceedance and 90th percentile concentration.

BMP Monitoring

On-site monitoring of implementation practices should also take place in order to better assess BMP effectiveness. All BMPs installed utilizing financial assistance from the state of Minnesota will follow the Operation, Maintenance, and Inspection Procedures adopted by the Minnesota Board of Water and Soil Resources (BWSR). Qualified technical staff prepare an Operation and Maintenance Plan specific to the BMP and site. All practices are to be inspected by the landowner on a regular basis. Technical staff confirm that the project is functioning as designed through completion of site inspections during the effective life of the project. For BMPs installed through other sources, a variety of criteria such as land use, soil type, and other watershed characteristics, as well as monitoring feasibility, will be used to determine which BMPs to monitor. Monitoring of a specific type of implementation practice can be accomplished at one site but can be applied to similar practices under similar criteria and scenarios. Effectiveness of other BMPs can be extrapolated based on monitoring results.

5. References and further information

Aadland L. 2012. Natural Channel Design in a Legal Ditch System: Restoration of Lawndale Creek. http://prrsum.umn.edu/sites/g/files/pua1546/f/restorationsymposium2012.pdf.

Anderson J, Baratono N, Streitz A, Magner J, Verry ES. 2006. Effect of Historical Logging on Geomorphology, Hydrology, and Water Quality in the Little Fork River Watershed. Minnesota Pollution Control Agency (MPCA) Report No.: wq-s1-04. https://www.pca.state.mn.us/sites/default/files/wq-s1-04.pdf.

Cristan R, Aust WM, Bolding MC, Barrett SM. 2019. Estimated Sediment Protection Efficiencies for Increasing Levels of Best Management Practices on Forest Harvests in the Piedmont, USA. Forests. 10(11):997. doi:10.3390/f10110997.

Edwards PJ, Williard KWJ. 2010. Efficiencies of Forestry Best Management Practices for Reducing Sediment and Nutrient Losses in the Eastern United States. Journal of Forestry.:5.

Hanson C. 2009. Red Lake River Watershed Farm to Stream Tile Drainage Water Quality Study. Thief River Falls, MN: Red Lake Watershed District Report No.: 3. http://www.redlakewatershed.org/projects/Red%20Lake%20Watershed%20Farm%20to%20Stream%20Tile%20Drainage%20Study%20Final%20Report%20R3.pdf.

Holden J, Chapman PJ, Labadz JC. 2004. Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration. Progress in Physical Geography: Earth and Environment. 28(1):95–123. doi:10.1191/0309133304pp403ra.

Lenhart C, Peterson H, Wagner M, Gillette T, Hacker B, Gruenes R, Wilcox D, Thompson B, Holter L, Krider L, et al. 2017. Agricultural BMP Handbook for Minnesota 2nd Edition. Saint Paul, MN: MDA.

Minnesota Board of Water and Soil Resources. 2020 Dec 3. Lake of the Woods SWCD ditch fix targets sediment-filled Bostic Bay. Medium. [accessed 2021 Apr 7]. https://mnbwsr.medium.com/lake-of-the-woods-swcd-ditch-fix-targets-sediment-filled-bostic-bay-cb4a0d7cedaa.

Myers J. 2015. From failed cropland to filled wetland, Sax-Zim bog restoration underway. Duluth News Tribune. [accessed 2021 Feb 24]. /news/3840608-failed-cropland-filled-wetland-sax-zim-bog-restoration-underway.

Ohio State University Extension. 2021. Open Channel/Two-Stage Ditch (NRCS 582). AgBMPs. [accessed 2021 Feb 24]. https://agbmps.osu.edu/bmp/open-channeltwo-stage-ditch-nrcs-582.

Price JS, Heathwaite AL, Baird AJ. 2003. Hydrological processes in abandoned and restored peatlands: An overview of management approaches. Wetlands Ecology and Management. 11(1):65–83. doi:10.1023/A:1022046409485.

Reeve AS, Warzocha J, Glaser PH, Siegel DI. 2001. Regional ground-water flow modeling of the Glacial Lake Agassiz Peatlands, Minnesota. Journal of Hydrology. 243(1–2):91–100. doi:10.1016/S0022-1694(00)00402-9.

RESPEC. 2017. Documentation of the Best Management Practice Database Available in the Scenario Application Manager. St. Paul, MN: MPCA.

Rosgen D. 1998. The Reference Reach: A Blueprint for Natural Channel Design. Wetlands Engineering and River Restoration Conference 1998.:1009–1016. doi:10.1061/40382(1998)166.

Rosgen DL. 1997. A geomorphological approach to restoration of incised rivers.in. In: Incision. University of Mississippi.

Rosgen DL. 2011. Natural Channel Design: Fundamental Concepts, Assumptions, and Methods. In: Stream Restoration in Dynamic Fluvial Systems. American Geophysical Union (AGU). p. 69–93. [accessed 2021 Feb 24]. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2010GM000990.

Sigl W, Mielke N, Donatell J, Grayson S, Bourdaghs M, Vaughan S, Monson B, Nerem K. 2020. Lower Rainy River and Rapid River Watersheds Monitoring and Assessment Report. Saint Paul, MN: Minnesota Pollution Control Agency Report No.: wq-ws3-09030008b. https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030008b.pdf.

Soman H. 2019. Productivity, Costs, and Best Management Practices for Major Timber Harvesting Frameworks in Maine. [Orono, ME]: University of Maine.

Strack M, Waddington JM, Bourbonniere RA, Buckton EL, Shaw K, Whittington P, Price JS. 2008. Effect of water table drawdown on peatland dissolved organic carbon export and dynamics. Hydrological Processes. 22(17):3373–3385. doi:https://doi.org/10.1002/hyp.6931.

Tomer MD, Porter SA, James DE, Boomer KMB, Kostel JA, McLellan E. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. Journal of Soil and Water Conservation. 68(5):113A-120A. doi:10.2489/jswc.68.5.113A.

Walker M. 2015. Restoration Strategies for Ditched Peatland Scientific and Natural Areas. Bemidji, MN: Minnesota DNR.

Wilson DC, Slesak R. 2020. Timber Harvesting and Forest Management Guidelines on Public and Private Forest Land in Forested Watersheds in Minnesota. St Paul, MN: MN DNR Division of Forestry and the Minnesota Forest Resources Council. https://www.leg.mn.gov/docs/2020/mandated/200394.pdf.

6. Appendices

https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality

Rapid River Watershed Reports

All Rapid River reports referenced in this watershed report are available at the Rapid River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/rapid-river

Appendix A. Geospatial Prioritization Methodology

A small working group of local resource professionals and the MPCA staff reviewed 56 data sets drawn from various watershed management tools and systems available for WRAPS projects in Minnesota (Table 30), and rated their usefulness in prioritizing subwatersheds in the RRW. The evaluation was completed specific to the characteristics the watershed. Reviewers rated each data set based on the how useful they would be for prioritizing subwatersheds in which to focus efforts.

The available data sets have utility in determining priorities from two perspectives: symptoms or implementation. Some of the data sets are useful in identifying specific areas that are displaying the symptoms of water resource problems, whereas other data sets help target locations where improvements can be most beneficial.

Table 30. Tools available for WRAPS projects in Minnesota

Tools	Description	How can the tool be used?	Notes	Link to information and data
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the BWSR website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions.	Landscape Resiliency - Water Planning Landscape Resiliency - Agricultural Landscapes MPCA download
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity, in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.)	Software
	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) NRCS Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface water and groundwater quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' website.	Restorable Wetlands

Tools	Description	How can the tool be used?	Notes	Link to information and data
National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams, and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for erosion analysis, water storage and flow analysis, siting and design of best management practices (BMPs), wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the Minnesota Geospatial Information Office (MGIO) website.	MGIO
Hydrological Simulation Program – FORTRAN (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of BMPs, and 2) effects of proposed or hypothetical land use changes.	EPA Models USGS

Data Sets Reviewed

The following data sets were reviewed by a small work group made up of local SWCD professionals familiar with the watersheds. The work group was asked to rate the data sets as High, Medium, Low, or not-applicable for their ability to prioritize subwatersheds. The data sets are generally organized by water resource issue. The information contained in each data set was mapped to the subwatershed level for relative comparisons. For example, if the data set was a mapping of lakes, the proportion of lakes within each subwatershed (as a % of the total subwatershed) would be presented. This would allow for comparison of subwatersheds based on their proportion of lakes.

Altered Hydrology

- Aquatic Disruption: Connectivity component index based on a density of aquatic disruptions per mile of stream length within each watershed.
- Connectivity Index: Riparian Connectivity: Connectivity component index based on the amount of development or cropland within riparian zones.
- Altered Watercourses: Based on altered watercourse data layer created by MPCA and Minnesota Geospatial Commons (MNGeo), the quantity of altered watercourses from ditching and straightening estimated as a percentage of total watercourse length.
- Sandy Verry Channel Flow: From Sandy Verry's research on Land fragmentation and impacts to streams - Identifies subbasins with higher amount of land cover change near streams that cause increased bankfull flow and streambank erosion.
- Sandy Verry Risk Model: Sandy Verry research compiled into a decision tree (Jeff Reinhart (DNR Forestry and Minnesota Forest Resources Council (MFRC)), adapted by M. Brinks) - The model assesses stream stability at peak flows in relation to the amount of forest cover in the watershed.

Soil Erosion

- Stream Power Index (SPI): Estimate of the erosive power of flowing water calculated from LiDAR aggregated to a 15 m resolution. Area represents areas with values greater than the 99th percentile.
- SPI - The 99th percentile value used for the Lower Rainy Lake Watershed differed from the value used for the Lower Rainy River and Rapid River because of a difference in landforms and surface geomorphology.
- Geo Index - Soil Erosion Susceptibility: Based on the soil k-factor and 4 slope classes (providing scoring weights: 0% to -1% slope = 1x weight factor, 1% to 2% slope = 2x weight factor, 2% to 3% slope = 3x weight factor, >3% slope = 4x weight factor).
- Geo Index - Steep Slopes Near Streams: Based on the density of steep slopes that are located within a threshold distance of streams, normalized to total stream length.

Water Quality

- Sediment Yield: The HSPF model predicted sediment yield in tons/ac/yr by subwatersheds from 1996 through 2014.
- Stream Bank Erosion: The HSPF model predicted sediment yield from bed and bank erosion in tons/ac/yr by subwatersheds from 1996 through 2014.
- Cropland Erosion: The HSPF model predicted sediment yield from high till cropland in tons/ac/yr by subwatersheds from 1996 through 2014.
- Phosphorus Yield: The HSPF model predicted TP yield in lbs/ac/yr by subwatersheds from 1996 through 2014.
- Total Phosphorus – Cropland: The HSPF model predicted TP yield from high till cropland in lbs/ac/yr by subwatersheds from 1996 through 2014.
- Total Phosphorus – Septics: The HSPF model predicted TP yield from septic systems in lbs/ac/yr by subwatersheds from 199 through -2014.
- Total Nitrogen: The HSPF model predicted TN yields in lbs/ac/yr by subwatersheds from 1996 through 2014.
- Flow Yield: The HSPF model predicted flow yield in ft/yr by subwatersheds from 1996 through 2014.
- *E. coli* Concentration: Estimate of the monthly geometric mean *E. coli* concentrations available in the MPCA Environmental Data Access (EDA) Surface water Database.
- Total Phosphorus: Estimate of the stream summer average phosphorus concentration from the MPCA EDA Surface water Database related to the water quality standard of 50 ug/L for northern streams.
- Dissolved Oxygen: Estimate of the relative percentage of DO measurements in the MPCA EDA Surface water Database below 5 mg/L in the streams.
- Total Suspended Solids: Estimate of the 90th percentile TSS concentration and the number of samples exceeding the water quality standard of 15 mg/L for water samples in the MPCA EDA Surface water Database.

Land Use / Land Cover

- Wetlands and Open Water: The sum of areas classified as open water, woody wetlands, and emergent herbaceous wetlands divided by the area of the subwatershed.
- Developed: The sum of areas classified developed, open space; developed, low-density; developed, medium density; and developed, high density divided by the total area of the subwatershed.
- Agriculture: The sum or areas classified as pasture/hay and cultivated crops divided by the area of the subwatershed.

- Forest and Other Natural Land: The sum of the areas classified as deciduous forest, evergreen forest, mixed forest, shrubland, grassland, and barren land divided by the area of the subwatershed.
- Forest for the Future: Priority Forests for the Minnesota Forests for the Future Program that looked at recreational, economic, and ecological values. Source: DNR (2010).
- Potential Protection: 20+ acre, private parcels that intersect a forested tract of land > 20 acres minus National Wetland Inventory (NWI) wetlands.
- Sustainable Forest Incentive Act: 20+ acre parcel enrolled in the Sustainable Forest Incentive Act (SFIA) program (Minnesota Department of Revenue ([MDOR] and DNR) minus NWI wetlands and divided by the subwatershed area.
- Forest Stewardship Plan: Parcels with a DNR registered woodland/forest stewardship plan on file that is current (written within the last 10 years) minus wetlands and divided by the subbasin area. Source: DNR Forestry.
- Protected Lands: Sum of the Public Lands and waters, easements, SFIA, NWI on private land and other conservation land as a proportion of the subwatershed.
- 2008 GAP (Gap Analysis Project) Public Land: Amount of land owned by a private entity in the 2008 GAP stewardship data layer divided by the subwatershed area.
- 2008 GAP Tribal Land: Amount of land owned by a tribe in the 2008 GAP stewardship data layer divided by the subwatershed area.
- 2008 GAP Private Land: Amount of land owned by a private entity in the 2008 GAP stewardship data layer divided by the subwatershed area.
- 2010 Rural Housing Density: The amount of houses in each subwatershed from the 2010 United States Census outside of city boundaries divided by the subwatershed area.
- Road Distance: The average distance from a federal, state, county or local road in each subwatershed. Projects farther than one to two miles from a roadway may have higher costs. (Does not include minimum maintenance roads).

Wetlands

- NWI Total: The total area of wetlands in the NWI in each subwatershed divided by the subwatershed area.
- Surface Outflow Wetlands: The area of wetlands classified with a dominant flow path of outflow, bi-directional, and throughflow in the hydrogeomorphic classification divided by the subwatershed area.
- Water and Erosion Benefit: Subwatershed average predicted benefit in terms of reductions in terms of water flow and erosion from wetland restoration. Higher values indicate higher benefit from wetland restoration.
- Species Benefit: Subwatershed average predicted benefit in terms of reductions in terms of improving habitat for species from wetland restoration. Higher values indicate higher benefit from wetland restoration.

- Habitat Stress: Subwatershed average predicted wetland habitat stress. Higher values indicate higher wetland stress.
- Phosphorus Stress: Subwatershed average predicted wetland phosphorus stress. Higher values indicate higher wetland stress.
- Nitrogen Stress: Subwatershed average predicted wetland nitrogen stress. Higher values indicate higher wetland stress.
- Restorable Wetland Inventory: Estimate of the area of potential restorable wetlands in each subwatershed divided by the subwatershed area.
- Restoration Viability: Estimate of predicted viability of wetland restoration projects lasting long into the future.

Previous Prioritizations

- Local Watershed Prioritization: Risk Classification as identified in a local County Water Plan (limited extent).
- DNR Protection Status: DNR Lake Protection Framework developed by M. Duval, P. Jacobson, T. Cross.
- Combined Index - Geomorphology Triage Score: This score is used within a targeted decision process for selecting sites for more detailed fluvial geomorphic assessments. This score is calculated by taking the average of eight input index scores: Stream Species Quality, Fish IBI; Con Index - Aquatic Connectivity; Con Index - Riparian Index; Geo Index - Steep Slopes Near Streams; Hyd Index - Impervious Cover; Hyd Metric - Loss of Hydrologic Storage; and WQ Index - Localized Pollution Sources.

Groundwater

- Groundwater Sensitivity: Areas mapped as "High" in the Pollution Sensitivity of Near-Surface Materials layer from DNR/County Geologic Atlas.
- Geologic Index - Pollution Sensitivity of Near Surface Materials: Based on the watershed mean of pollution sensitivity of near-surface materials data, valued on an ordinal basis (DNR County Geologic Atlas, 2016).
- Arsenic Concentration: New well points from MDH. Arsenic only goes back to 2008. The average arsenic concentration in groundwater wells in the subwatershed.
- Nitrate Concentration: New well points from MDH. The average nitrate concentration in groundwater wells in the subwatershed.

Biodiversity

- DNR Lake Phosphorus Sensitivity: Lakes with phosphorus sensitivity “higher" and "highest" classifications only (count and acres)
- Wild Rice Lakes: Prioritized list of DNR's top 350 wild rice lakes across Minnesota.
- Minnesota Biological Survey (MBS) Biodiversity: Sites of native biodiversity that may contain high quality native plant communities, rare plants, rare animals, and/or animal aggregations. Source: DNR Natural Heritage Program/County Biological Survey
- Wild Life Action Network WAN: The WAN was developed as part of the 2015-2025 Minnesota Wildlife Action Plan revision. The WAN is made up of 10 GIS layers representing quality aquatic and terrestrial habitats across the state of Minnesota. The subwatersheds are prioritized based on the area of land classified as High and Medium High as a percentage of the total subwatershed area.
- Biological Index Terrestrial Habitat Quality: Biology component index that ranks the quality of terrestrial habitats within each subwatershed.

Improvements

- Number of BMPs: The number of BMPs according to the BWSR eLink system.

Reviewers were asked to rate each data set on a not applicable (NA), low, medium, high scale. These adjective ratings were converted to a numerical score, aggregated and averaged to determine the priority data sets to be used. The following are the top 10 rated data sets prioritized by the working group for the RRW.

- Forest Stewardship Plan
- 2008 GAP Public Land
- Sediment Yield
- Stream Bank Erosion
- Cropland Erosion
- Phosphorus Yield
- TP - Cropland
- Flow Yield
- Wetland: Water and Erosion Benefit
- Potential Protection

Based on the ratings of general resource issue categories and specific data sets, an overall scoring system was developed to compare and prioritize subwatersheds. In the case of some data sets, there were only slight differences in values from one subwatershed to the next. In other cases, groups of data sets were redundant. A scoring system was developed using the following 10 geographic data sets:

- Altered Hydrology
    - Aquatic Disruption
    - Altered Watercourses
- Soil Erosion
    - SPI
    - Geo Index - Soil Erosion Susceptibility

- Water Quality
    - Sediment Yield
    - Phosphorus Yield
- Wetlands
    - Habitat Stress
    - Phosphorus Stress
    - Nitrogen Stress
    - Restorable Wetland Inventory & Viability

The raw data value for each subwatershed was normalized to 1-100 scale where the lowest subwatershed value was set to 0, while the highest value was set to 100. This normalization interpreted the original data set (i.e., whether a high or low value was indicative of a high priority rating). These values were then summed and averaged for each of the subwatersheds within the RRW. Resultant values were assigned an adjective rating of high, medium, low to reflect the upper 25th percentile, middle 50th percentile and lower 25th percentile respectively as shown in Table 31.

Table 31. Rapid River Watershed Subwatershed Prioritization Rating

HUC-10 Name	HUC-12 Name	HSPF Catchment	Aquatic Disruption	Altered Watercourse	Stream Power Index	Soil Erosion Susceptibility	Habitat Stress	Phosphorus Stress	Nitrogen Stress	Sediment Yield	Phosphorus Yield	Restorable Wetlands & Viability	Total Score	Subwatershed Rating
Upper Rapid River	Upper Rapid River	A250	11.8	95.0	40.5	8.0	30.9	28.6	22.1	0.0	0.0	0.9	23.8	Medium
Middle Rapid River	Miller Creek	A261	0.0	82.8	2.3	4.0	26.5	24.1	17.7	1.4	17.2	0.0	17.6	Medium
	Chase Brook	A281	17.6	58.0	29.3	16.0	31.2	28.6	21.5	2.5	18.5	3.1	22.6	Medium
	Troy Creek	A283	82.4	70.5	18.0	16.0	32.8	30.3	23.9	2.9	20.5	8.5	30.6	Medium
	Moose Creek	A285	100.0	84.0	17.6	16.0	38.7	34.9	31.7	5.6	38.2	28.7	39.6	High
	Middle Rapid River	A270	0.0	43.1	25.0	24.0	33.3	31.5	25.1	4.2	20.6	10.0	21.7	Medium
		A290	5.9	36.5	52.8	96.0	88.3	93.5	97.4	24.9	92.5	76.4	66.4	High
North Branch Rapid River	Meadow Creek	A293	0.0	0.0	7.8	8.0	26.8	24.3	18.2	0.3	9.8	2.8	9.8	Low
	Upper North Branch Rapid River	A291	0.0	0.0	14.9	24.0	36.1	34.8	27.8	1.2	15.3	3.0	15.7	Low
		A295	29.4	23.0	4.7	32.0	38.1	35.8	26.9	2.0	11.4	1.9	20.5	Medium
	090300070303	A297	29.4	0.0	6.4	12.0	25.5	23.4	17.8	0.5	10.3	0.2	12.6	Low
	Middle North Branch Rapid River	A299	0.0	0.0	1.9	12.0	26.1	24.8	19.3	1.6	14.8	0.4	10.1	Low
		A301	0.0	0.0	24.7	8.0	26.2	24.9	19.6	0.4	9.9	0.0	11.4	Low
		A303	35.3	11.4	4.5	16.0	29.0	27.5	21.6	3.5	17.8	0.9	16.8	Low
	Lower North Branch Rapid River	A305	0.0	16.5	21.5	20.0	32.9	31.1	24.4	4.6	24.3	0.0	17.5	Low
		A307	0.0	56.1	1.8	36.0	49.5	50.4	47.9	7.9	42.0	64.1	35.6	High
		A309	52.9	19.2	100.0	60.0	46.7	46.0	40.7	8.1	35.4	28.9	43.8	High
East Fork Rapid River	Upper East Fork Rapid River	A353	0.0	100.0	0.0	0.0	0.3	0.0	0.0	2.1	28.1	0.0	13.1	Low
	Middle East Fork Rapid River	A357	5.9	41.3	65.5	20.0	1.0	1.6	2.8	5.7	34.5	2.2	18.0	Medium
	Lower East Fork Rapid River	A369	17.6	62.0	65.9	24.0	7.4	9.8	12.7	8.0	17.3	8.2	23.3	Medium
	Wing River	A355	0.0	78.2	58.9	24.0	0.0	0.2	0.8	4.0	33.2	0.6	20.0	Medium
	Judicial Ditch No 27	A361	17.6	92.6	16.9	12.0	32.6	31.4	27.1	4.0	26.4	15.6	27.6	Medium
	Barton's Brook	A359	11.8	89.7	10.7	16.0	40.6	40.4	35.8	5.3	28.8	16.7	29.6	Medium
		A363	0.0	94.8	21.6	12.0	13.8	13.8	12.5	2.7	19.7	4.0	19.5	Medium
Lower Rapid River	Judicial Ditch No 20-Rapid River	A321	17.6	100.0	2.9	12.0	50.3	44.2	45.9	3.2	6.0	14.8	29.7	Medium
		A330	11.8	23.1	9.3	100.0	100.0	100.0	100.0	100.0	100.0	59.4	70.4	High
		A341	35.3	96.3	12.2	4.0	29.7	25.7	22.1	2.7	23.0	3.6	25.5	Medium
	Rapid River	A350	11.8	49.0	54.4	64.0	76.7	79.5	83.4	21.6	72.1	61.7	57.4	High
		A351	17.6	84.2	12.7	52.0	83.4	90.0	95.0	16.8	82.6	100.0	63.4	High
		A370	17.6	29.5	61.5	48.0	35.5	37.8	37.1	23.7	24.1	15.1	33.0	High

Appendix B. Unassessed Stream Reaches

Table 32. Unassessed Stream Reaches

HUC-10 Watershed	AUID (Last 3 digits)	River	Reach description
Upper Rapid River (0903000701)	520	Unnamed ditch	Unnamed ditch to Unnamed ditch
	521	Unnamed ditch	Unnamed ditch to Unnamed ditch
	522	Unnamed ditch	Unnamed ditch to Rapid R.
Middle Rapid River (0903000702)	505	Rapid River	Chase Bk. to Troy Cr.
	507	Chase Brook	Headwaters to Rapid R.
	512	Moose Creek	Unnamed ditch to Christy Cr.
	514	Christy Creek	Unnamed Cr. to Rapid R.
	517	Moose Creek	Unnamed ditch to Unnamed ditch
	518	Moose Creek	Unnamed ditch to Unnamed ditch
	524	Thompson Creek	Headwaters to Chase Bk.
	527	Unnamed ditch	Headwaters to Moose Cr.
North Branch Rapid River (0903000703)	519	Meadow Creek	Headwaters to N. Branch Rapid R.
	526	Kvoines Creek	Headwaters to Rapid R.
East Fork Rapid River (0903000704)	511	Rapid River, East Branch	Headwaters to Bartons Bk.
	515	Wing River	Unnamed ditch to E Br. Rapid R.
	516	Wing River	Headwaters to Unnamed ditch
Lower Rapid River (0903000705)	525	Monroe Creek	Headwaters to Rapid R.