Watershed

June 2019

Two Rivers
Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Minnesota Pollution Control Agency (MPCA). North Branch Two Rivers at County Road 58 (September 30, 2015).

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Contents

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, total suspended solids (TSS), 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 Red River of the North Basin is assigned a HUC-4 of 0902 and the Two Rivers Watershed is assigned a HUC-8 of 09020312.

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.

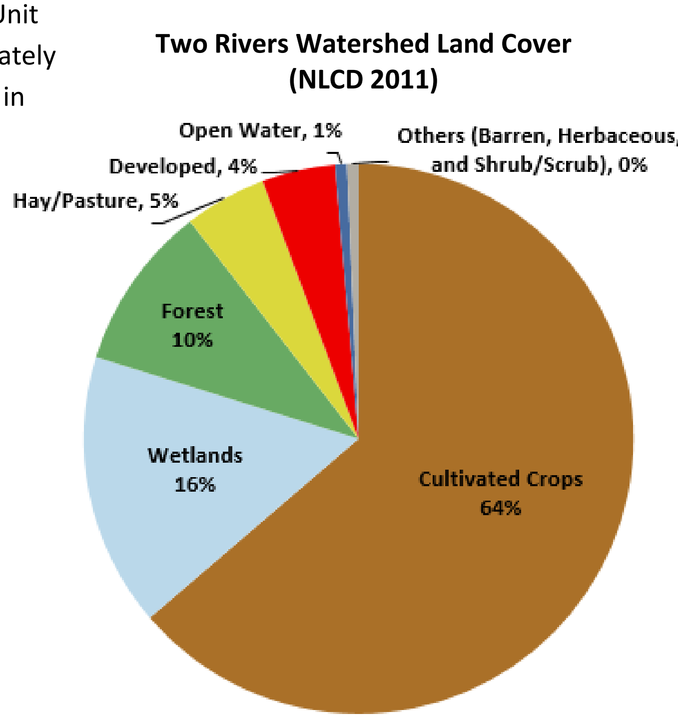
Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and non-pollutant 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

The Two Rivers Watershed (TRW) (Hydrologic Unit Code [HUC] 09020312) encompasses approximately 1,098 square miles in northwestern Minnesota in portions of Kittson, Roseau, and Marshall Counties. Land cover within the TRW is predominantly crops, comprising 64% of the landscape (pie chart at right). The Two Rivers Watershed Restoration and Protection Strategy (WRAPS) Project included and built upon public participation, collaboration with local working/government groups, sampling waterbodies, assessing the ability of waterbodies to support designated uses, identifying stressors to biological communities, writing Total Maximum Daily Loads (TMDLs), and identifying implementation strategies to protect and restore waterbodies. This document, the WRAPS Report, summarizes the condition of surface water, the scale and types of changes needed to restore and protect waters, and options and available tools to prioritize and target conservation work on the landscape in the TRW. The focus of this report is on the three branches of the Two Rivers and their tributaries, all water from which flows into the main channel of the Red River of the North (Red River) via the Two River. Water quality in the main channel of the Red River is not addressed in this WRAPS Report.



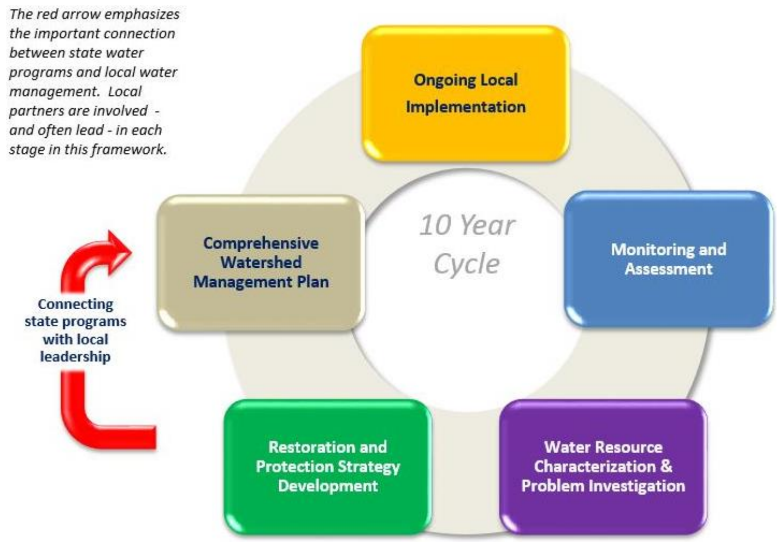
Information from multiple resources was used to evaluate the potential point and nonpoint sources of pollutants and ultimate health of waterbodies, including (but not limited to): stressor identification (SID) studies, HSPF modeling, analysis of the available water quality data for the last 10 years, and Geographic Information System (GIS) analyses. In 2015, assessments of water quality data from the previous 10 years showed that total suspended solids (TSS) and *Escherichia coli* (*E. coli*) were exceedingly high and dissolved oxygen (DO) was exceedingly low in some waters in the TRW; and a report published in 2017 shows that the following stressors are adversely affecting poor biological communities in multiple stream reaches: low DO, altered hydrology, poor habitat, and lack of connectivity (TSS was listed as a stressor as well, but to a much lesser extent).

Strategies to reduce pollutants/stressors listed above and restore waterbodies to conditions where they are able to support their designated uses are identified in this document. Some examples of restoration strategies include restoring over-widened reaches/ditches, increasing living cover, constructing floodwater impoundments, restoring wetlands, and removing dams. All waterbodies in the TRW that already support their designated use(s) have strategies of protection in this document that aim to prevent them from degrading in condition. Many of the restoration strategies are applicable as protection strategies as well with the overall goal of no net increase in water volume or pollutants.

The TRW TMDL Report was concurrently developed with the WRAPS Report and the seven TMDLs that address seven impairments are summarized in this document. There are 23 additional impairments in the TRW that are listed on the approved 2018 303(d) list as impaired but have not been addressed with a TMDL, because more information is needed or because the impairments are not caused by conventional pollutants.

Following completion of the WRAPS process, the WRAPS report, as well as other technical reports referenced in this document, will be publicly available on the MPCA's Two Rivers Watershed website located at https://www.pca.state.mn.us/water/watersheds/two-rivers.

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.

Along with the watershed approach, the Minnesota Pollution Control Agency (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. 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 TMDL studies are developed for them. TMDLs are incorporated into the WRAPS project. 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, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This 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 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:
  - *Two Rivers Watershed Monitoring and Assessment*
  - *Two Rivers Watershed Stressor Identification*
  - *Two Rivers Watershed Total Maximum Daily Load*

Scope

- Impacts to aquatic recreation and impacts to aquatic life in streams
- Impacts to aquatic recreation in lakes

Audience

- Local working groups (watershed districts, SWCDs, watershed management groups, etc.)
- State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The Two Rivers Watershed (TRW) is located in the far northwestern portion of Minnesota, bordering both North Dakota and Canada. The TRW has a drainage area of approximately 1,098 square miles within portions of Kittson, Roseau, and Marshall Counties. There are an additional 3.6 square miles of this watershed that extend into Canada that is not addressed by the Two Rivers WRAPS project. The TRW is located in the Red River of the North Basin (Red River Basin) and is almost entirely contained within the boundaries of the Two Rivers Watershed District (TRWD). Historically, land cover in the TRW during European settlement times (mid-late 1800s) consisted almost entirely of prairies in the western half of the watershed and a mix of mainly prairies and aspen-oak land in the eastern half (**Figure** 1). Current land cover within the TRW is predominantly agricultural (**Figure** 2). Municipalities within the TRW include Badger, Greenbush, Hallock, Halma, Lake Bronson, Lancaster, and Strathcona.

The TRW includes portions of two Level III ecoregions as defined by the EPA: The Glacial Lake Agassiz Plains and Northern Minnesota Wetlands Ecoregions. The majority of the TRW is located in the Lake Agassiz Plain (greater than 80%). The EPA defines an ecoregion as a relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. Much of the Lake Agassiz Plain has been drained for agricultural use. The drainage network in place today in the Red River Basin "has thousands of miles of principal drains and probably tens of thousands of miles of small laterals and on-farm channels." (Carlyle 1984). The Red River Valley is among the world's largest artificially drained landscapes.

Additional Two Rivers Watershed Resources

Two Rivers Watershed Conditions Report (HEI 2014a):

Two Rivers Watershed Monitoring and Assessment Report (MPCA 2016a): https://www.pca.state.mn.us/sites/default/files/wq-ws3-09020312b.pdf

Two Rivers Watershed Stressor Identification Report (MPCA 2016b): https://www.pca.state.mn.us/sites/default/files/wq-ws5-09020312a.pdf

Two Rivers Watershed District Management Plan: http://www.tworiverswd.com/overall_plan.html

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Two Rivers Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021815.pdf

Minnesota Department of Natural Resources (DNR) Watershed Health Assessment Framework (WHAF) for the Two Rivers Watershed: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_70.pdf

The Minnesota Nutrient Reduction Strategy (September 2014 [MPCA 2014b]): https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf

Minnesota Nutrient Planning Portal: http://mrbdc.mnsu.edu/mnnutrients/

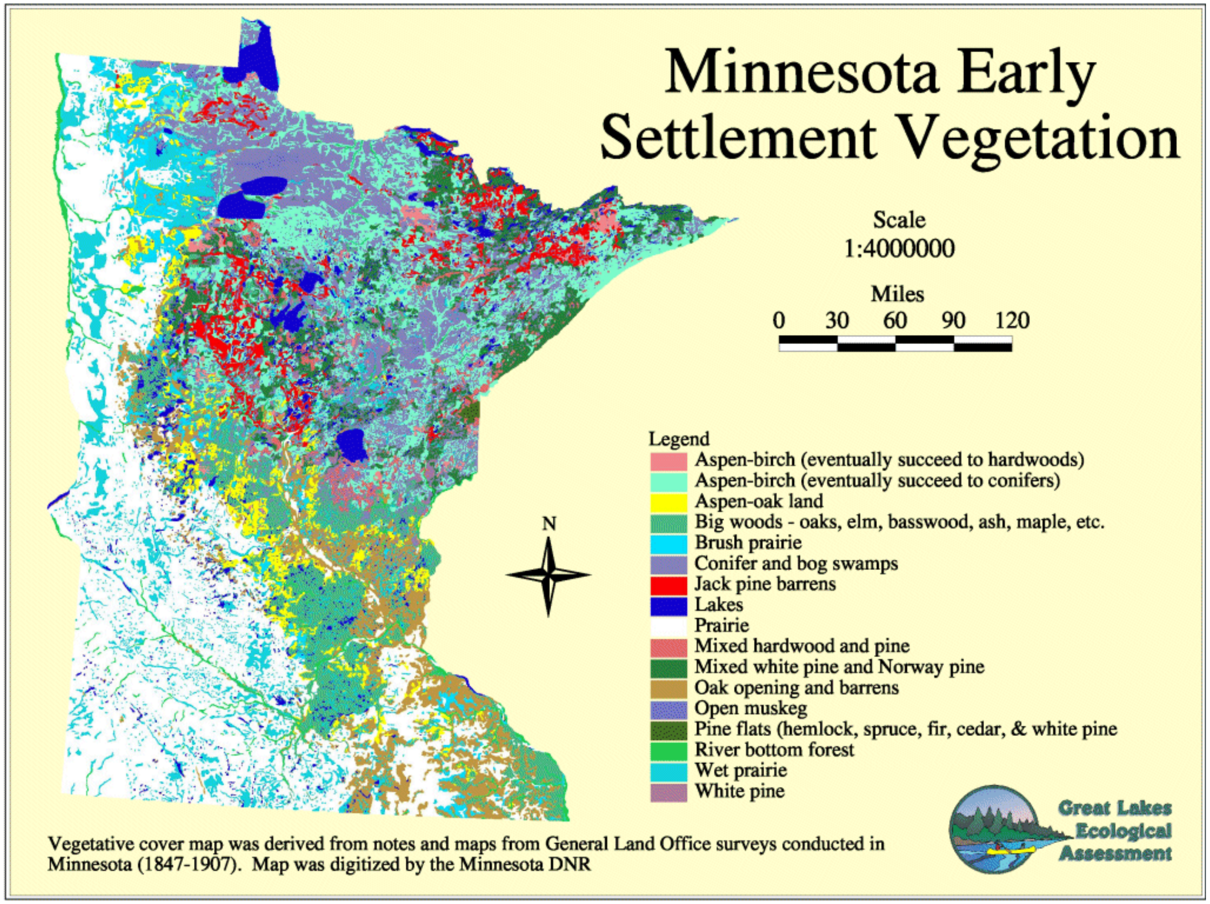


Figure 1: Historical map of land cover in Minnesota based on European settlement data. The original version is the "Marschner's Map", created by Francis J. Marschner in 1930.[1]

[1] For more information see http://www.mngeo.state.mn.us/chouse/land_use_historic.html

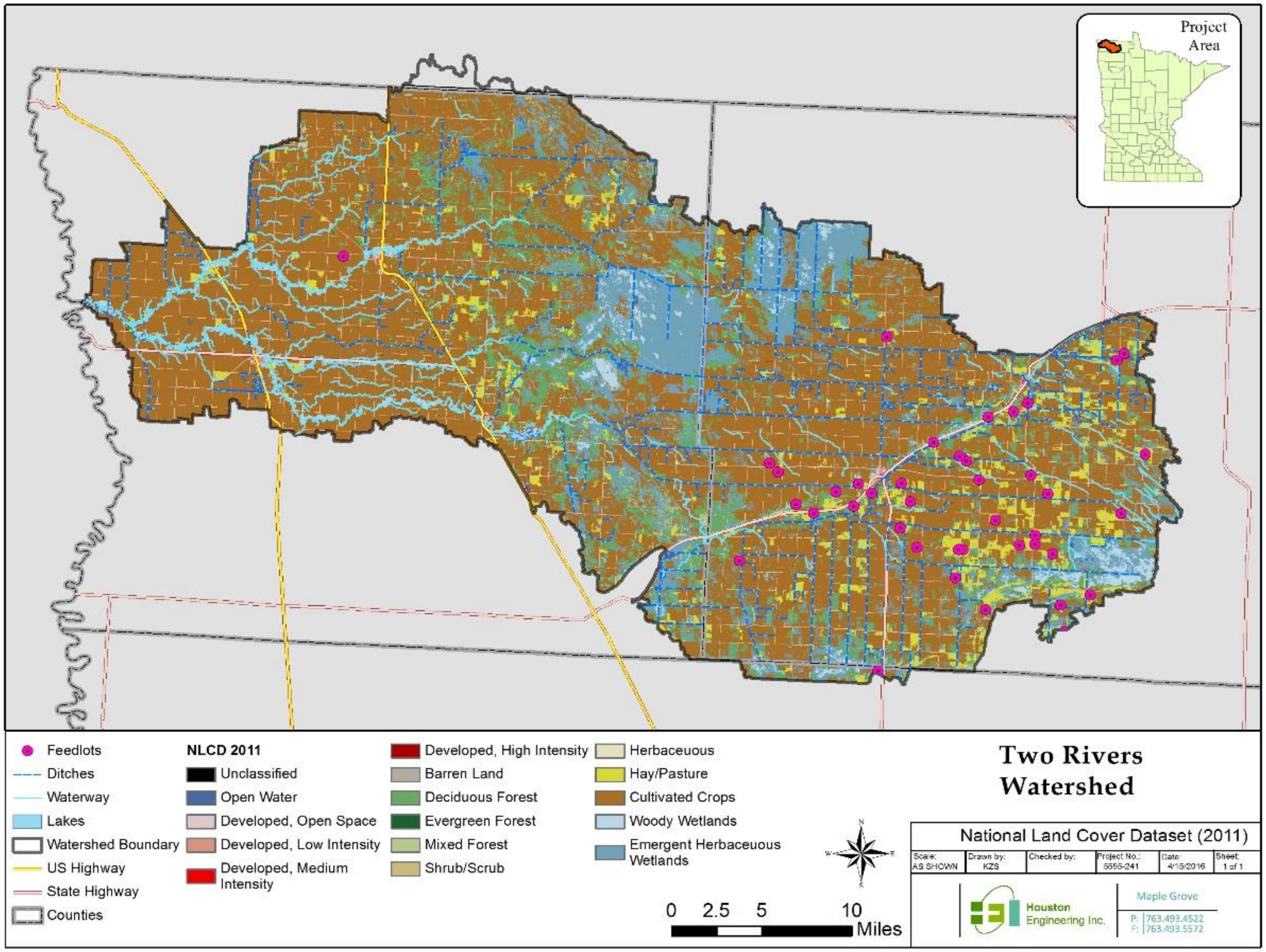


Figure 2: Land cover in the Two Rivers Watershed using the National Land Cover Database (NLCD) 2011 (Homer et al. 2015).

2. Watershed conditions

Prominent water resources within the TRW include three branches of the Two Rivers; the North Branch, Middle Branch, and South Branch. The confluence of the North and South Branches form the main stem Two River, three miles east of its outlet to the Red River. The TRW contains an estimated 510 miles of intermittent drainage system, 315 miles of intermittent stream, 182 miles of perennial stream and river, and 152 miles of perennial drainage system (DNR 2003). Lake Bronson, a 300-acre man-made reservoir, is the most prominent local water resource (MPCA 2016a).

The TRW has 54 basins (waterbodies) with a Minnesota Department of Natural Resources (DNR) lake ID (greater than 10 acres) and 52 stream segments/reaches with an assessment unit identification (AUID) number, in addition to approximately 769 miles of unassessed stream reaches. Of these, not all were able to be assessed for impairment due to one or more of the following reasons: extensive modification, channelization, insufficient flows, impoundments, no channel or waterbody present, and/or limited resource value waters. In 2013, the MPCA conducted an intensive watershed monitoring (IWM) effort of the TRW, after which 23 AUIDS were assessed for aquatic life and/or aquatic recreation beneficial uses. Sixteen AUIDs were found to be non-supportive of at least one beneficial use (see **Figure** 3); 15 were non-supportive of aquatic life use and 5 were non-supportive of aquatic recreation use. The conditions that lead to non-support of aquatic life use include a low fish index of biological integrity (IBI) score, a low aquatic macroinvertebrate IBI score, high total suspended solids (TSS), and low dissolved oxygen (DO). The condition that lead to non-support of aquatic recreation is excess bacteria (*Escherichia coli* [*E. coli*]). All of these are officially listed as impaired on the approved 2018 303(d) list. Aquatic consumption impairments caused by toxic pollutants (e.g., mercury) are not covered in this report.

According to the MPCA, as of December 2013, there are 73 permitted facilities currently active in the TRW and covered either under state-wide National Pollutant Discharge Elimination System (NPDES) permits (feedlots, industrial stormwater, or construction stormwater) or individual NPDES permits (wastewater treatment facility [WWTF]). Active permits include 40 feedlots, 6 industrial stormwater permits, and 5 wastewater permits. Of the seven municipalities in the TRW, all but Halma and Strathcona are listed as having permitted WWTF in the TRW. Construction permits are not included here as they are continuously being issued and deactivated (HEI 2014a). Nonpoint sources and stressors in the TRW are typical of the agricultural setting of the Red River Basin.

A more detailed analysis of the quality of the waters within the TRW can be found in the Watershed Conditions Report (HEI 2014a) and the TRW SID Report (MPCA 2016b). The conditions and associated pollutant sources of these individual streams are summarized in the following sections.

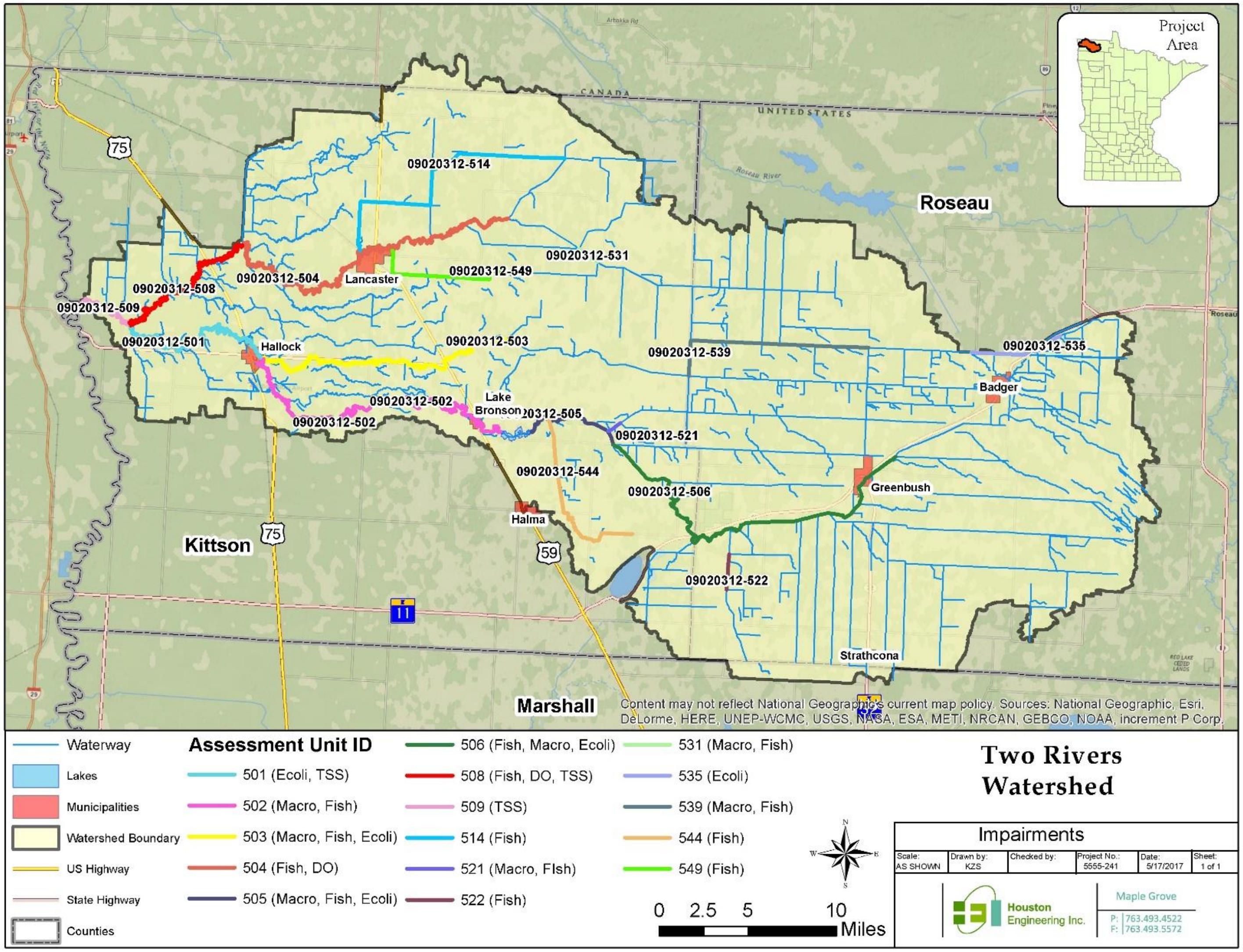


Figure 3: Aquatic life use and aquatic recreation use impairments in the Two Rivers Watershed that are listed on Minnesota's approved 2018 305(b) Impaired Waters List.

2.1 Condition status

This section describes the streams and lakes within the TRW that are impaired and unimpaired. Impaired waters are targets for restoration efforts, while unimpaired waters currently supporting aquatic life and/or recreation are subject to protection efforts (**Section 2.5**).

Factors used to determine whether a river or stream in the TRW is capable of supporting and harboring aquatic life (generally fish and aquatic insects) include the fish and macroinvertebrate indices of biological integrity (IBI), DO, chloride, pH, ammonia (NH_3), and the sediment level, expressed as TSS. Factors used to assess the suitability of a TRW waterbody for aquatic recreation include the amount of bacteria and the levels of nutrients; excessive nutrients can lead to algal blooms (MPCA 2016a).

Streams

The parameters used to assess whether TRW streams achieve aquatic life beneficial use include fish and macroinvertebrate IBIs, DO, chloride, pH, ammonia (NH_3), and total suspended solids (TSS), while aquatic recreation beneficial use was assessed using bacteria (*E. coli*). Assessment involved comparing the values of these parameters to the state standards as well as the normal range for the ecoregion where the stream is located. Values of fish and/or macroinvertebrate IBIs and DO below state standards were not supportive of aquatic life use, while values of chloride, ammonia (NH3), TSS, and *E. coli* above state standards were non supportive of their respective beneficial uses. State standards for pH is a range of values, so pH values in the TRW above or below the range were considered unsupportive of aquatic life use. The TRW AUID stream segments are listed in **Table 1**, with stream condition summaries provided for each of the segments.

The TRW contains 52 stream reaches with unique AUIDs, 23 of which have been assessed for aquatic life and/or aquatic recreation (**Figure** 3; **Table 1**). Sixteen AUIDs were found to be non-supportive of at least one beneficial use; 15 were non-supportive of aquatic life use and 5 were non-supportive of aquatic recreation use. Information used to create **Table 1** was summarized using the Watershed Conditions Report (HEI 2014a) and the TRW Monitoring and Assessment Report (MPCA 2016a).

Table 1: Assessment status of stream reaches in the Two Rivers Watershed, presented by 10-digit HUC.

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life							Aq. Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Chloride	pH	Ammonia (NH_3)	Bacteria (*E. coli*)
State Ditch No 91 (0902031201)	507	Two River, South Branch	Headwaters to SD 91 Lat 2	Sup	NA	IF	IF	NA	IF	IF	NA
	515	Lateral Ditch 4 of State Ditch 91	Headwaters to Lateral Ditch 12 SD 91	Sup	Sup	IF	IF	NA	IF	IF	NA
	516	Lateral Ditch 4 of State Ditch 91	Lateral Ditch 12 SD 91 to S Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	522	County Ditch 4	Unnamed ditch to Unnamed ditch	Imp	Sup	IF	IF	NA	IF	IF	NA
	523	County Ditch 4	Unnamed ditch to S Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	546	State Ditch 90	Upper Twin Lk (35-0001-00) to S Br Two R	Sup	NA	IF	IF	NA	IF	IF	NA
	548	Unnamed ditch	Unnamed Cr to S Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	550	Unnamed ditch (along 210th Ave)	110th St to Lat Ditch 12 SD 91	Sup	Sup	IF	IF	NA	IF	IF	NA
	551	Unnamed ditch (along 190th Ave)	110th St to Lat Ditch 4 SD 91	Sup	IF	IF	IF	NA	IF	IF	NA
	552	Unnamed creek	Unnamed ditch to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
State Ditch No 95 (0902031202)	505	Two River, South Branch	Lateral Ditch 2 to Lk Bronson	Imp	Imp	Sup	Sup	Sup	Sup	Sup	Imp
	506	Two River, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	Imp	Imp	IF	Sup	Sup	Sup	Sup	Imp
	513	Lateral Ditch 2 of State Ditch 95	Headwaters to S Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	521	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 95	Imp	Imp	IF	Sup	Sup	Sup	Sup	Sup
	526	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 50	NA	NA	NA	NA	NA	NA	NA	NA
	527	Unnamed ditch	Headwaters to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	534	Badger Creek	Headwaters to County Ditch 13	NA	NA	NA	NA	NA	NA	NA	NA
	535	County Ditch 13	Unnamed ditch to Badger Cr (disconnected portion)	NA	NA	IF	Sup	IF	Sup	Sup	Imp
	536	County Ditch 13	Unnamed ditch to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	537	County Ditch 13	Unnamed ditch to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	538	Lateral Ditch 1 of State Ditch 95	CD 13 to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	539	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 50	Imp	Imp	IF	IF	IF	IF	IF	NA
	540	Unnamed ditch	Headwaters to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	541	Unnamed ditch	Unnamed ditch to CD 13	NA	NA	NA	NA	NA	NA	NA	NA
	542	Lateral Ditch 1 of State Ditch 95	State Ditch 50 to Lateral Ditch 1 Br 4	NA	NA	NA	NA	NA	NA	NA	NA

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life							Aq. Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Chloride	pH	Ammonia (NH_3)	Bacteria (*E. coli*)
State Ditch No 95 (0902031202) (cont.)	543	Lateral Ditch 1 of State Ditch 95	Lateral Ditch 1 Br 4 to Unnamed ditch	NA	NA	NA	NA	NA	NA	NA	NA
	545	State Ditch 95	Headwaters to S Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
Middle Branch Two Rivers (0902031203)	503	Two River, Middle Branch	CD 23 to S Br Two R	Imp	Imp	IF	Sup	Sup	Sup	Sup	Imp
	517	State Ditch 50	SD 95 Lat 1 to Unnamed cr	NA	NA	NA	NA	NA	NA	NA	NA
	518	County Ditch 15	Unnamed cr to CD 23	NA	NA	NA	NA	NA	NA	NA	NA
State Ditch No 85 (0902031204)	528	State Ditch 72	Unnamed ditch to Unnamed ditch	NA	NA	NA	Sup	IF	Sup	Sup	Sup
	529	State Ditch 72	Unnamed ditch to Unnamed cr	NA	NA	NA	NA	NA	NA	NA	NA
	530	State Ditch 72	Unnamed cr to JD 31	NA	NA	NA	NA	NA	NA	NA	NA
	531	State Ditch 72	JD 31 to State Ditch 85	Imp	Imp	IF	IF	NA	IF	IF	NA
	547	State Ditch 85	Headwaters to N Br Two R	Sup	Sup	IF	IF	NA	IF	IF	NA
Little Joe River (0902031205)	510	Little Joe River/ County Ditch 22	Headwaters to N Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	519	Unnamed creek	Headwaters to T163 R48W S30, west line	NA	NA	NA	NA	NA	NA	NA	NA
	520	Unnamed creek	T163 R49W S25, east line to Little Joe R	NA	NA	NA	NA	NA	NA	NA	NA
North Branch Two Rivers (0902031206)	504	Two River, North Branch	Headwaters to CD 22	Imp	Sup	Imp	Sup	NA	Sup	Sup	Sup
	508	Two River, North Branch	CD 22 to Two R	Imp	Sup	Imp	Sup	Sup	Sup	Sup	Sup
	514	State Ditch 84	Headwaters to N Br Two R	Imp	NA	IF	IF	NA	IF	IF	NA
	524	County Ditch 13	CD 29 to N Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	532	County Ditch 11	State Ditch 85 to N Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	533	County Ditch 14	Unnamed ditch to N Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	549	Judicial Ditch 31	Unnamed cr to N BR Two R	Imp	NA	IF	IF	NA	IF	IF	NA
South Branch Two Rivers (0902031207)	501	Two River	M Br Two R to N Br Two R	Sup	IF	IF	Imp	Sup	Sup	Sup	Imp
	502	Two River, South Branch	Lk Bronson to M Br Two R	Imp	Imp	IF	Sup	Sup	Sup	Sup	Sup
	509	Two River	N Br Two R to Red R	Sup	IF	IF	Imp	Sup	Sup	Sup	Sup
	511	Two River, South Branch (Lake Bronson)	Lk Bronson (35-0003-00)	NA	NA	NA	NA	NA	NA	NA	NA
	512	Unnamed ditch	Headwaters to Two R	NA	NA	NA	NA	NA	NA	NA	NA
	525	County Ditch 12	CD 29 to N Br Two R	NA	NA	NA	NA	NA	NA	NA	NA
	544	State Ditch 49	Headwaters to S Br Two R	Imp	NA	IF	IF	NA	IF	IF	NA

Sup = 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

Lakes

The only lake assessed in the TRW was Lake Bronson (35-0003-00). Total phosphorus (TP) in Lake Bronson was found to exceed the TP standard for the Western Cornbelt Plains (WCBP) eco-region (65 ug/L) for deep lakes, but response parameters (chlorophyll-a [Chl-*a*] and Secchi) had mean values meeting their respective numeric standards. Therefore, Lake Bronson has insufficient information to determine aquatic recreation use support as the response variables meet the standard but TP does not (MPCA 2016a). Lake Bronson's assessment is listed in **Table 2**.

Lake Bronson is impaired by mercury in fish tissue; however, this report does not cover toxic pollutants. For more information on mercury impairments see the statewide mercury TMDL at: https://www.pca.state.mn.us/water/statewide-mercury-reduction-plan.

Table 2: Assessment status of Lakes in the Two Rivers Watershed.

HUC-10 Subwatershed	Lake ID	Lake	Aquatic Life	Aquatic Recreation
South Branch Two Rivers (0902031207)	35-0003-00	Lake Bronson	IF	IF

Imp = impaired for impacts to aquatic recreation, **Sup** = fully supporting aquatic recreation, **IF** = insufficient data to make an assessment, **NA** = not assessed.

2.2 Water quality trends

To investigate long-term water quality trends, a seasonal Kendall test (Hirsch et al. 1982) was used to evaluate trends in flow, *E. coli*, TSS, TP, DO, and pH. The seasonal Kendall test indicates whether water quality concentrations are increasing, declining, or remaining the same within the TRW. The seasonal Kendall trend analysis was conducted using daily flow statistics from South Branch Two Rivers at Hallock, MN175 (United States Geological Survey [USGS] ID: 05095000; DNR ID: 70018001) and monthly water quality measurements from MPCA gage S000-186 near Hallock. The gage sites provided the only locations in the TRW where long-term water quality data were available that corresponded with long-term flow data ranging from 1937 to 2011. Summary statistics for the data used in the trend analysis for monthly precipitation, daily flow, and water quality constituents are shown in **Table 3**. The maximum monthly precipitation in the study period was 10.9 inches and the minimum was 0.0 inches. Daily flow ranged from 0.0 cubic feet per second (cfs) to 5,290 cfs with a daily mean flow of 125.5 cfs. Mean TSS, DO, and TP were 31 milligrams per liter (mg/L), 9.1 mg/L, and 0.2 mg/L, respectively. Mean *E. coli* measurements were 147.4 colony forming units (cfu)/100 ml and mean pH was 8.1 (HEI 2015).

Table 3: Summary statistics for precipitation, flow, and water quality measurements near Hallock, MN in the TRW.

Variable	Time	n	Mean	Median	Range	Min.	Max.	STD
Monthly Precip., in	1890 to 2010	1452	1.7	1.2	10.9	0	10.9	1.5
Daily flow, cfs	1937-2011	22,998	125.5	7.6	5,290	0	5,290	364.3
TSS, mg L^{-1}	1972-2011	165	31	20	198	2	200	33.3
DO, mg L^{-1}	1972-2011	229	9.1	9	18	2	19.6	2.4
E. coli, cfu/100 ml	1972-2008	133	147.4	11	2399	0.6	2400	379.3
TP, mg L^{-1}	1972-2011	167	0.2	0.1	3	0	3.5	0.5
pH	1972-2011	282	8.1	8.1	3	6.5	9.3	0.3

The seasonal Kendall trend analysis was performed on flow-weighted monthly concentrations following methods similar to Johnson et al. (2009) and techniques recommended by the USGS (Helsel and Hirsch 2002). The monthly flow-weighted concentrations were calculated by pairing the water quality measurements with the daily flow statistic from the sampling day. Results from the seasonal Kendall trend analysis are provided in **Table 4**.

Table 4: Results of the seasonal Kendall trend analysis of monthly flow-weighted concentrations for South Branch Two Rivers at Hallock, MN175 (USGS #05095000) and MPCA gage S000-186.

Water quality constituent	Trend intervals	N	tau	Final Durbin-Watson	Sen's slope (unit $year^{-1}$)	Seasonal Kendall p-value	Trend?
Flow	1928 to 2013	795	0.03	2.08†	0.87	0.27	Increasing
TSS	1972 to 2011	140	0.01	1.91†*	0.11	0.83	Increasing
DO	1972 to 2011	169	0.01	2.21†*	< -0.01	> 0.99	No change
E. coli	1972 to 2008	105	<0.01	1.85†	-0.04	0.96	Decreasing
	1986 to 2008	62	0.02	1.98†*	0.04	0.79	Increasing
TP	1972 to 2011	137	-0.01	1.82*	<-0.01	0.82	No change
	1986 to 2011	86	0.02	1.82†	<0.01	0.82	No change
pH	1972 to 2011	177	0.02	2.04†*	0.01	0.67	Increasing

† - monthly flow-weighted constituent concentrations were flow-adjusted

*** -** AR(1) pre-whitening used to remove serial autocorrelation

While the seasonal Kendall trend analysis found that flow, TSS, *E. coli*, and pH have either an increasing or decreasing trend in the long-term, flow-adjusted water quality concentrations in the South Branch of Two Rivers near Hallock, none of these trends were statistically significant (a p-value of less than 0.05 is considered significant; see seventh column of **Table 4**). Data limitations prevented conducting analysis on all stream segments within the TRW. These findings align well with the findings of the Milestones Site Analysis (Christopherson 2014), with two exceptions. The Milestone Site Analysis showed a decreasing trend in TP (where no statistically significant trend was found in this study) and a decreasing trend in Biochemical Oxygen Demand (not analyzed for Two Rivers). The different outcomes in TP trends between Two Rivers analysis (no trend) and the Milestone Site Analysis (decreasing trend) may be the result of flow weighting of concentrations and pre-whitening (the removal of serial autocorrelation; i.e., the value depends on a previous value) performed in this analysis (see Helsel and Hirsh[2] 2002). Future water quality sampling efforts should attempt to obtain consistent samples for all seasons and, whenever possible, collect flow data alongside water quality samples. Although flow-adjusted concentrations have remained unchanged, annual flow appears to be increasing. If this trend in increasing annual flow continues, it could have impacts on future water quality management strategies and efforts. In summary, the results of this analysis (HEI 2015) indicate:

- An analysis of 120 years of precipitation data (1890 through 2010) shows a trend of increasing annual precipitation;
- Annual flow appears to be increasing;

[2] https://pubs.usgs.gov/twri/twri4a3/html/toc.html

- Increased annual flows appear to be driven by increasing annual precipitation;
- Water quality trends have not undergone any statistically significant changes since 1972 on the South Branch of Two Rivers near Hallock;
- Water quality sample frequency has been fairly evenly distributed across flow regimes;
- Water quality sample frequency is weighted more heavily towards summer months; and
- Future water quality sampling efforts could be improved by collecting flow data in conjunction with water quality samples and by distributing sampling events more evenly across seasons.

2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening the waterbodies must be identified and evaluated. Biological SID is done for streams with either fish or macroinvertebrate biota impairments, and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g., altered hydrology, fish passage, habitat). Pollutant source assessments are done where a biological stressor ID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings. **Section 3** provides further detail on stressors and pollutant sources.

Stressors of biologically-impaired stream reaches

The primary stressors for biological impairments within the TRW are listed in **Table 5.** The MPCA examined five candidate causes as potential stressors, which can contribute to the biological impairments in the watershed: loss of longitudinal connectivity, insufficient physical habitat, high suspended sediment, low DO, and instability in flow regimes defined as the seasonal and annual flow patterns of a stream. Loss of longitudinal connectivity caused by the Hallock Dam, Lake Bronson Dam, and Northcote Dam obstruct fish passage and limit the potential of the fish community (MPCA 2016b). Historical changes in land cover and drainage have led to flow instability in the form of high and quick peak flows and/or prolonged periods of low or no flow. These anthropogenic alterations have led to habitat degradation within several biologically impaired reaches, in addition to excess suspended sediment. Hydrologic alteration, in the form of low flow or lentic conditions, has also coincided with low DO conditions.

Further, detailed SID information can be found in the TRW SID Report (MPCA 2016b).

Table 5: Primary stressors to aquatic life in biologically-impaired reaches in the Two Rivers Watershed (MPCA, 2016b).

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Biological Impairment	Primary Stressor*				
					Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
State Ditch No 91 (0902031201)	522	County Ditch 4	Unnamed ditch to Unnamed ditch	Fish	◉	◉	◉		◉
State Ditch No 95 (0902031202)	505	Two Rivers, South Branch	Lateral Ditch 2 to Lk Bronson	Fish	◉	◉	○		○
				Macroinvert.		○	○	○	
	506	Two Rivers, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	Fish	◉	◉	○		○
				Macroinvert.		○	○	○	○
	521	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 95	Fish	◉	◉	◉		◉
				Macroinvert.		◉	○		○
	539	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 50	Fish	○	◉	◉		◉
				Macroinvert.		○	○	○	◉
State Ditch No 85 (0902031204)	503	Two Rivers, Middle Branch	CD 23 to S Br Two R	Fish	○	○	○		○
				Macroinvert.		○	○	○	○
	531	State Ditch 72	JD 31 to State Ditch 85	Fish	○	◉	○		○
				Macroinvert.		◉	○		○
North Branch Two Rivers (0902031206)	504	Two Rivers, North Branch	Headwaters to CD 22	Fish	◉	◉	○		◉
	508	Two Rivers, North Branch	CD 22 to Two R	Fish	●	◉	◉	○	◉
	514	State Ditch 84	Headwaters to N Br Two R	Fish	◉	◉	◉		◉
	549	Judicial Ditch 31	Unnamed cr to N BR Two R	Fish	◉	◉	◉		◉
South Branch Two Rivers (0902031207)	502	Two Rivers, South Branch	Lk Bronson to M Br Two R	Fish	●	◉	◉		
				Macroinvert.		○	○		
	544	State Ditch 49	Headwaters to S Br Two R	Fish	○	◉	◉		◉

*● = high risk, ◉ = medium risk, ○ = low risk

Altered hydrology

Altered hydrology is frequently cited as a primary biological stressor of reaches with fish IBI or macroinvertebrate IBI impairments in the TRW (MPCA 2016b) and elsewhere (e.g., MPCA 2014a). However, rarely is altered hydrology defined or a quantitative goal established. Using daily flow data from the USGS gage at South Branch Two Rivers at Lake Bronson, Minnesota (USGS ID: 05094000), flow duration curves and flow return periods were developed for the periods 1940 to 1975 and 1980 to 2015 to identify changes in hydrology between historical and modern records. Studies have identified the mid-1970s as an inflection point in the hydrologic conditions in the Upper Midwest, driven by a combination of changes in precipitation and land use/land cover (Frans et al. 2013; Schottler et al. 2013). Both flow duration curves (Figure 4) and peak flow return periods (Figure 5) indicate a change in hydrology for (1.5-year to 200-year return periods) channel forming flows, which can lead to geomorphic instability and habitat loss. Currently, there is no agreed upon method for detecting or setting targets for mitigating the effects of altered hydrology. Based upon this analysis (i.e., Figure 4 and Figure 5), hydrologic management goals were developed for the TRW for critical channel forming flows. The differences between the solid lines in Figure 4 and the lines in Figure 5 indicate the magnitude of flow increases. The hydrologic management goals and associated management strategies are provided below in **Section 3.3**.

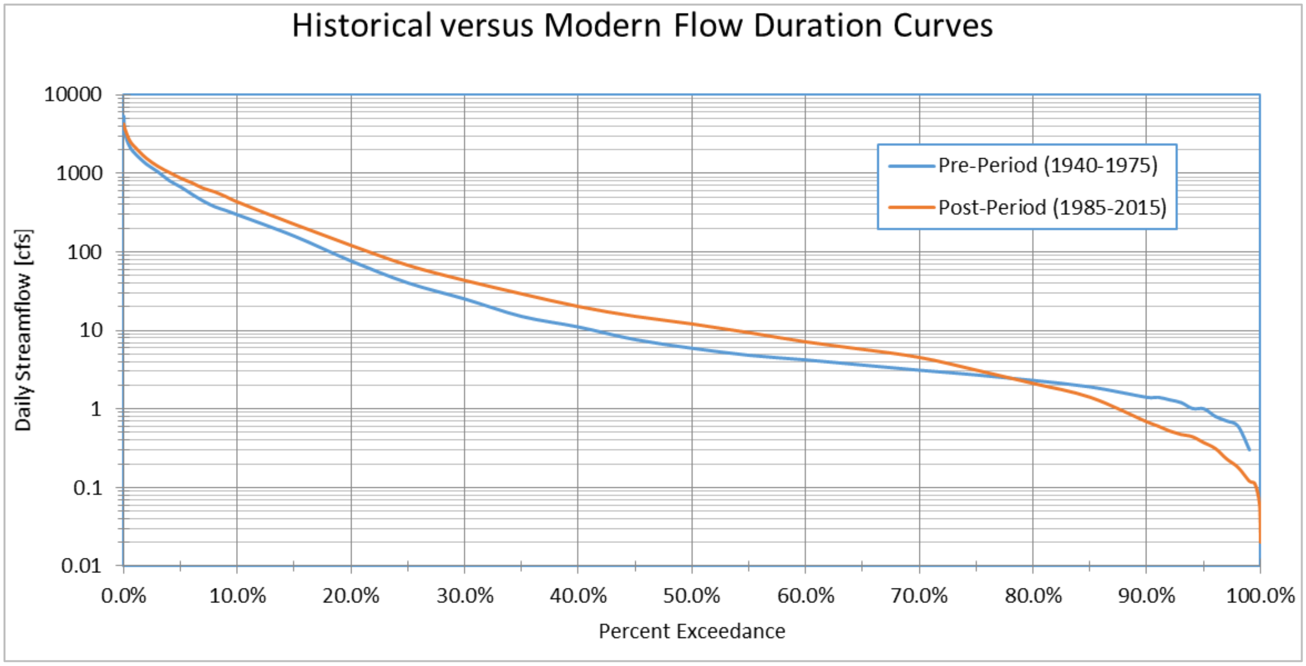


Figure 4: Historical (1940-1975) versus modern (1980-2015) flow duration for South Branch Two Rivers at Lake Bronson, Minnesota (USGS ID: 05094000).

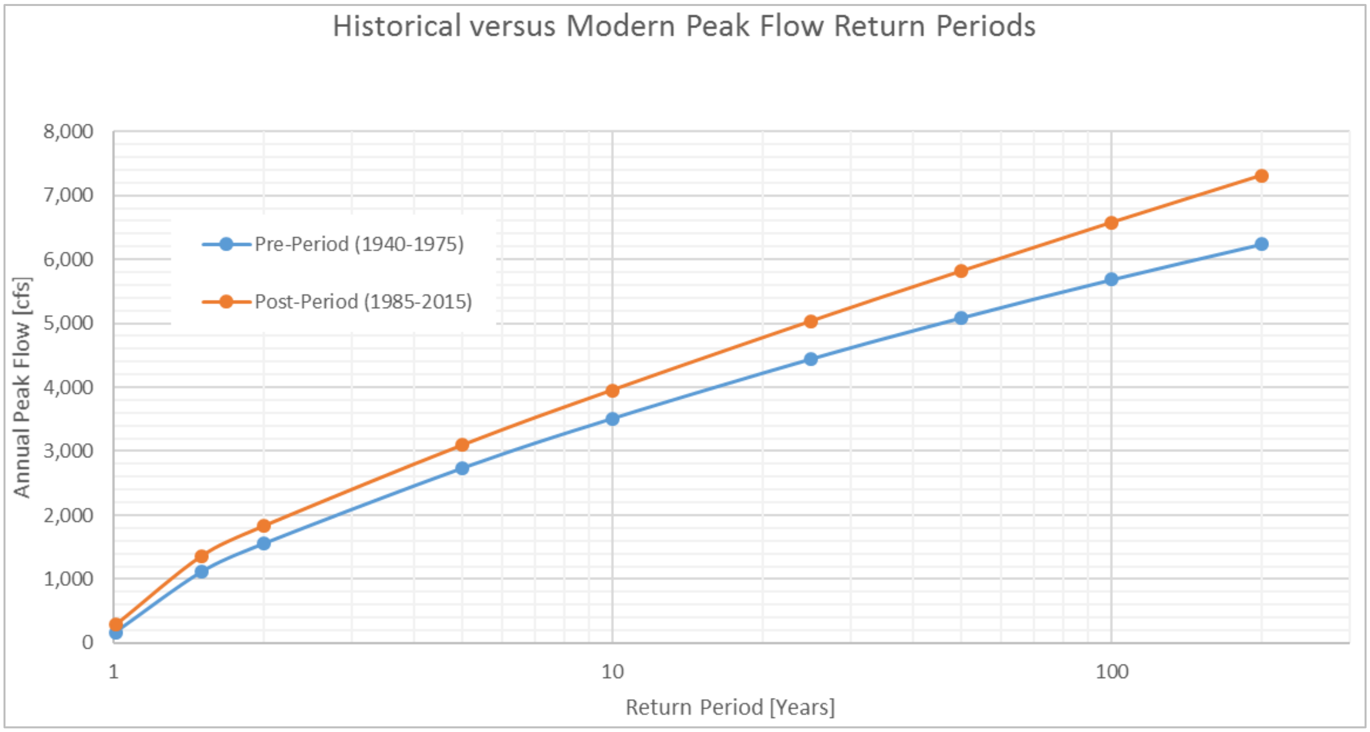


Figure 5: Historical (1940-1975) versus modern (1980-2015) peak flow return periods for South Branch Two Rivers at Lake Bronson, Minnesota (USGS ID: 05094000).

One possible goal for mitigating the effects of altered hydrology would be for the daily mean discharges, used to develop the flow duration curve, to match between the two time periods. This presumes the 1940 through 1975 period represents the desired condition.

Pollutant sources

Point and nonpoint sources of pollutants are identified in **Table 6** and **Table 7**, respectively. **Table 5** (above) and **Table 6** (below) are summarized from the MPCA's TRW SID Report (MPCA 2016b) and the TRW TMDL Report (HEI 2019). More specific information regarding the geographic location of nonpoint source locations and prioritization is detailed in **Section 3** where various methods of targeting and evaluating geographic areas are described.

Table 6: Point Sources in the Two Rivers Watershed.

HUC-10 Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
State Ditch No 95 (0902031202)	Badger WWTF	MNG580155	Municipal wastewater	No	WLAs based on current permitted "Calendar Month Average" TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Greenbush WWTF	MNG580156	Municipal wastewater	No	WLAs based on current permitted "Calendar Month Average" TSS limit of 45 mg/L and fecal

HUC-10 Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
					coliform limit of 200 organisms/100 mL
North Branch Two Rivers (0902031206)	Lancaster	MNG580066	Municipal stormwater	No	WLAs based on current permitted "Calendar Month Average" TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
South Branch Two Rivers (0902031207)	Hallock WWTF	MNG580147	Municipal stormwater	No	WLAs based on current permitted "Calendar Month Average" TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Lake Bronson WWTF	MNG580029	Municipal stormwater	No	WLAs based on current permitted "Calendar Month Average" TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL

A nonpoint source that is deserving of explanation is natural background. Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions that occur outside of human influence. Minn. R. 7050.0150, subp. 4, defines the term "Natural causes" as the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence. Natural background sources can include inputs from natural processes such as soil loss from upland erosion and stream development and movement, atmospheric deposition, and loading from forested land, natural decomposition of vegetation, wildlife defecation, etc.

For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment and therefore natural background is accounted for and addressed through MPCA's waterbody assessment process. Not enough data were available to evaluate natural background conditions explicitly to determine whether natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. The position of the MPCA is that source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, WWTFs, failing SSTSs, and other anthropogenic sources.

Table 7: Nonpoint Sources in the Two Rivers Watershed. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	Stream/Reach (AUID)	Pollutant	Pollutant Sources								
			Fertilizer & manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank erosion/excessive peak flows	Channelization	Upstream influences
State Ditch No 95 (0902031202)	09020312-505	Bacteria	●	**O**	○	○					
	09020312-506	Bacteria	●	**O**	○	○					
North Branch Two Rivers (0902031206)	09020312-508	TSS					●	●	●	●	**O**
South Branch Two Rivers (0902031207)	09020312-501	Bacteria	●	**O**	○	○					
		TSS					●	●	●	●	**O**
	09020312-509	Bacteria	●	**O**	○	○					
		TSS					●	●	●	●	**O**
	09020312-535	Bacteria	●	**O**	○	○					
Middle Branch Two Rivers (0902031203)	09020312-503	Bacteria	●	**O**	○	○					

Key: ● = High **O** = Moderate ○ = Low

2.4 TMDL summary

Six stream reaches within the TRW are impaired where the pollutant is a parameter with a numeric standard and, therefore, require TMDLs. **Table 8** through **Table 14** show the maximum allowable load (loading capacity) and the amount that comes from nonpoint sources (load allocation) and point sources (wasteload allocation). The tables also show the reduction from the existing load needed, based on load duration curves (LDCs). No reductions are required from point sources beyond what is set as limits in the wastewater and stormwater permits, thus the reductions should come from nonpoint sources. A portion of the allowable load (10%) is placed in the "margin of safety" category reflecting a level of uncertainty in the analysis. The critical duration period (i.e., the flow regimes for which the water quality standard is exceeded) for each of the waterbodies is provided elsewhere (see the Load Duration Curve Memo [Appendix A] at the end of the TRW TMDL Report [HEI 2019]).

Escherichia coli

The existing bacteria contributions (expressed as *E.coli*), the loading capacity, allocations, and the reduction in *E. coli* needed to meet the *E. coli* standard for the impaired reaches are shown in **Table 8** through **Table 12**. The various components of these allocations were developed as described in Section 4.1 of the TMDL (HEI 2019). All *E. coli* TMDLs apply to the geometric mean standard. In addition to the TMDL components, the existing load (current conditions), the unallocated load (if applicable, if current load is under numeric standard for specified flow regime), and the estimated load reduction as a percentage (if current load is over numeric standard under specified flow regime) are given for each flow regime. The existing load is based on existing water quality data; the unallocated load is the potential load available if the existing load is less than the loading capacity for a given flow regime (i.e., the loading capacity minus the existing load). The existing load and unallocated load are only provided if water quality data are available for the stated flow regime. The unallocated load is only provided if the existing load is less than the loading capacity, i.e. there is reserve capacity in the TMDL. The estimated load reduction is the required reduction in load, expressed as a percentage of existing load, needed to meet the loading capacity (TMDL) and is only provided if a load reduction is needed.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (**Table 8** through **Table 12**), only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by EPA. The LDCs used to develop the loading capacities and allocations can be found in Appendix A of the TRW TMDL Report (HEI 2019).

It should be noted that rounding errors may result in small differences between the reported values and the summation in values.

Table 8: *E. coli* TMDL summary for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501).

Escherichia coli		**Flow Regime**				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		[Billions CFU/day]				
Loading Capacity		**5,737**	**1,304**	**398**	**122**	**25**
Wasteload Allocation	**Total WLA**	**22.2**	**22.2**	**22.2**	**22.2**	**22.2**
	Badger WWTF	1.8	1.8	1.8	1.8	1.8
	Greenbush WWTF	10.9	10.9	10.9	10.9	10.9
	Hallock WWTF	7.5	7.5	7.5	7.5	7.5
	Lake Bronson WWTF	2.1	2.1	2.1	2.1	2.1
Load Allocation	**Total LA**	**5,141**	**1,151**	**336**	**88**	**0.3**
Margin of Safety (MOS)		**574**	**130**	**40**	**12**	**2.5**
Existing Load		**9,562**	**409**	**197**	**119**	**20.0**
Unallocated Load		**0**	**894**	**201**	**3**	**5**
Estimated Load Reduction		**40%**	**0%**	**0%**	**0%**	**0%**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 9: *E. coli* TMDL summary for Middle Branch Two Rivers, CD 23 to South Branch Two Rivers (AUID 09020312-503).

Escherichia coli		Flow Regime				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		[Billions CFU/day]				
Loading Capacity		**474.1**	**90.9**	**26.8**	**7.4**	**0.90**
Wasteload Allocation	**Total WLA**	**1.8**	**1.8**	**1.8**	**1.8**	***
	Badger WWTF	1.8	1.8	1.8	1.8	***
Load Allocation	**Total LA**	**424.9**	**80.0**	**22.4**	**4.9**	**0.81**
Margin of Safety (MOS)		**47.4**	**9.1**	**2.7**	**0.7**	**0.09**
Existing Load		**112.7**	**45.6**	**18.1**	**11.0**	**ND[1]**
Unallocated Load		**361.4**	**45.3**	**8.7**	**0.0**	**Unk**
Estimated Load Reduction		**0%**	**0%**	**0%**	**33%**	**Unk**

***Outflow from WWTF will be larger than flow during this flow regime, therefore no WLA from the WWTF was established for the flow regime.

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 10: *E. coli* TMDL summary for South Branch Two Rivers, Lateral Ditch 2 to Lake Bronson (AUID 09020312-505).

Escherichia coli		Flow Regime				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		[Billions CFU/day]				
Loading Capacity		**4,595**	**1,000**	**303.8**	**99.3**	**19.7**
Wasteload Allocation	**Total WLA**	**10.9**	**10.9**	**10.9**	**10.9**	**10.9**
	Greenbush WWTF	10.9	10.9	10.9	10.9	10.9
Load Allocation	**Total LA**	**4,125**	**889**	**262.5**	**78.5**	**6.9**
Margin of Safety (MOS)		**459.5**	**100**	**30.4**	**9.9**	**2.0**
Existing Load		**88,242**	**631**	**190.9**	**24.2**	**ND[1]**
Unallocated Load		**0.0**	**369**	**112.9**	**75.1**	**Unk**
Estimated Load Reduction		**95%**	**0.0**	**0.0**	**0.0**	**Unk**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 11: *E. coli* TMDL summary for South Branch Two Rivers, Unnamed ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		2,773.6	614.0	191.3	60.7	11.7
Wasteload Allocation	Total WLA	0.00	0.00	0.00	0.00	0.00
Load Allocation	Total LA	2,496	553	172	54.6	10.5
Margin of Safety (MOS)		277.4	61.4	19.1	6.1	1.2
Existing Load		ND[1]	567.7	63.8	209.5	ND[1]
Unallocated Load		Unk	46.3	127.5	0.0	Unk
Estimated Load Reduction		Unk	0%	0%	71%	Unk

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 12: *E. coli* TMDL summary for County Ditch 13, Unnamed ditch to Badger Creek (disconnected portion) (AUID 09020312-535).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		201.7	41.3	11.38	3.21	0.58
Wasteload Allocation	Total WLA	1.8	1.8	1.8	1.8	***
	Badger WWTF	1.8	1.8	1.8	1.8	***
Load Allocation	Total LA	179.8	35.4	8.45	1.09	0.52
Margin of Safety (MOS)		20.2	4.1	1.1	0.32	0.06
Existing Load		ND[1]	10.3	10.4	12.4	ND[1]
Unallocated Load		Unk	31.0	1.0	0.0	Unk
Estimated Load Reduction		Unk	0%	0%	74%	Unk

***Outflow from WWTF will be larger than flow during this flow regime, therefore no WLA from the WWTF was established for the flow regime.

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Total suspended solids (TSS)

In January 2015, EPA approved MPCA's adoption of the TSS standards to replace the turbidity numeric standard. The existing TSS contributions, the loading capacity, and the reductions needed to meet the TSS standard for portions of the TRW are shown in the following tables. The analysis is based on the concentrations of TSS using the LDCs. The critical condition is established using the flow regime requiring the greatest estimated load reduction. As indicated, the greatest estimated load reduction is required during the higher flow regimes, indicating that large sediment loading occurs during flooding events.

Table 13 and **Table 14** show the computed loading capacities and allocations for the TRW streams, which are currently listed for turbidity, using the TSS standard. The various components of these allocations were developed as described in Section 4.2 of the TRW TMDL (HEI 2019). The LDCs used to develop the loading capacities and allocations are provided in Appendix A of the TRW TMDL (HEI 2019). It should be noted that rounding errors may result in the sum of some of the TMDL calculations not matching the loading capacity of the AUID.

In addition to the TMDL components, the existing load, the unallocated load (if applicable), and the estimated load reduction (expressed as a percentage of existing load) are given for each flow regime. The existing load is based on existing water quality data; the unallocated load is the potential load available if the existing load is lower than the loading capacity for a given flow regime (i.e., the loading capacity minus the existing load). The existing load and unallocated load are only provided if water quality data is available in the stated flow regime. In addition, an unallocated load is only provided if the existing load is lower than the loading capacity. The estimated load reduction is the required load reduction, as a percentage of existing load, to meet the loading capacity. A load reduction is only provided if the loading capacity is less than the existing load.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (**Table 13** and **Table 14**), only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by EPA. The LDCs used to develop the loading capacities and allocations are provided in Appendix A of the TRW TMDL Report (HEI 2019).

Table 13: Total Suspended Solids TMDL for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501).

Total Suspended Solids		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[tons/day]				
Loading Capacity		**347.9**	**87.8**	**28.81**	**9.20**	**1.64**
Wasteload Allocation	**Total WLA**	**1.22**	**0.96**	**0.90**	**0.88**	**0.87**
	Badger WWTF	0.07	0.07	0.07	0.07	0.07
	Greenbush WWTF	0.43	0.43	0.43	0.43	0.43
	Hallock WWTF	0.29	0.29	0.29	0.29	0.29
	Lake Bronson WWTF	0.08	0.08	0.08	0.08	0.08
	Construction/Industrial Stormwater	0.35	0.09	0.03	0.009	0.002
Load Allocation	**Total LA**	**311.9**	**78.0**	**25.0**	**7.40**	**0.60**
Margin of Safety (MOS)		**34.8**	**8.8**	**2.9**	**0.92**	**0.16**
Existing Load		**820.9**	**131.5**	**28.4**	**6.13**	**0.89**
Unallocated Load		**0.0**	**0.0**	**0.4**	**3.07**	**0.75**
Estimated Load Reduction		**58%**	**33%**	**0%**	**0%**	**0%**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 14: Total Suspended Solids TMDL for Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509).

Total Suspended Solids		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[tons/day]				
Loading Capacity		**520.7**	**130.3**	**45.0**	**14.4**	**2.79**
Wasteload Allocation	**Total WLA**	**1.47**	**1.08**	**0.99**	**0.96**	**0.95**
	Badger WWTF	0.07	0.07	0.07	0.07	0.07
	Greenbush WWTF	0.43	0.43	0.43	0.43	0.43
	Hallock WWTF	0.29	0.29	0.29	0.29	0.29
	Lake Bronson WWTF	0.08	0.08	0.08	0.08	0.08
	Lancaster WWTF	0.08	0.08	0.08	0.08	0.08
	Construction/Industrial Stormwater	0.52	0.13	0.04	0.014	0.003
Load Allocation	**Total LA**	**467.2**	**116.2**	**39.5**	**12.0**	**1.56**
Margin of Safety (MOS)		**52.1**	**13.0**	**4.5**	**1.44**	**0.28**
Existing Load		**1509.3**	**579.5**	**154.0**	**26.6**	**2.2**
Unallocated Load		**0.0**	**0.0**	**0.0**	**0.0**	**0.59**
Estimated Load Reduction		**65%**	**78%**	**71%**	**46%**	**0%**

Loading capacity, wasteload allocation, load allocation, and margin of safety are part of the TMDL equation (HEI 2019). The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

2.5 Protection considerations

All lakes and streams currently supporting aquatic life and aquatic recreation in the TRW are candidates for protection efforts. Over time, these waters could be subjected to land uses or stressors that could cause them to become impaired. Watershed stakeholders should seek opportunities to identify and implement protection strategies on all unimpaired waterbodies. For streams, rivers, and lakes, the protection strategy consists of working toward ensuring that the existing loads for the critical duration periods are not exceeded.

Designation of streams as candidates for protection or restoration is important in aligning with the Board of Soil and Water Resources' (BWSR) Nonpoint Priority Funding Plan for Clean Water Funding Implementation (http://www.bwsr.state.mn.us/planning/npfp/NPFP_2018.pdf) and Minnesota's Clean Water Roadmap (https://www.pca.state.mn.us/sites/default/files/wq-gov1-07.pdf). For this reason, assessed streams within the TRW are designated as either "protection" or "restoration" based on water quality data. Once designated as protection or restoration, TRW streams and lakes are further divided into subcategories based on water quality monitoring data to reflect priorities in the Nonpoint Priority Funding Plan for Clean Water Funding Implementation.

Lakes

Protecting the quality of lakes and rivers that meet water quality standards is an important consideration in watershed restoration and protection projects being carried out through Minnesota's Clean Water, Land and Legacy Amendment. The protection of lakes exhibiting high water quality and those which are at risk of becoming impaired can be as important as restoring impaired waters. Protecting current water quality is essential to avoid degradation and impairment of Minnesota's waters.

Healthy watersheds provide a variety of ecological services that have high value and may be challenging to reestablish once compromised. Research continually demonstrates that protecting healthy watersheds can reduce capital costs for water treatment plants and reduce damage to property and infrastructure due to flooding, thereby avoiding future costs. Additionally, protecting healthy watersheds can generate revenue through property value premiums, recreation, and tourism.

All lakes that currently meet water quality standards should be protected from future water quality degradation to maintain beneficial uses. These lakes vary in their degree of sensitivity to change and this should be considered when implementing a protection strategy. Protection for lakes that meet water quality standards can be prioritized considering the following attributes:

- waters meeting water quality standards but with downward trends in water quality;
- waters having known or anticipated future water quality threats;
- waters with suspected but not confirmed impairments;
- shallow lakes, which are especially sensitive to nutrient loading or watershed activities; and

- high-quality or unique waters deserving special attention.

Several state agencies have developed a "Lakes Protection Strategy" to help watershed stakeholders set water quality protection goals for unimpaired waters. In addition to lake water quality data, the Lakes Protection Strategy considers other water "values" such as economic value, aesthetics, and tourism. The Lakes Protection Strategy and a "Lake Prioritization Spreadsheet" is now available and can be requested from the MPCA watershed staff.

An important aspect of protection strategies in Minnesota is the reliance on empirical relationships between lake TP concentration and the "response variables" (i.e. chl-*a* and Secchi depth) that the MPCA staff developed in the course of formulating the state's lake water quality standards. The MPCA's Environmental Analysis and Outcomes staff developed these relationships based on a substantial body of Minnesota lake data sorted by ecoregion and (for some ecoregions) by lake depth. These relationships determined the response-variable standards that correspond to each ecoregion/depth class TP standard. The MPCA relies on the above empirical relationships to ensure that the response variable standards are met when the TP standard is met.

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially in the north-central and northeastern parts of the state. Many other lakes meet the standards but may exhibit declining water quality. The high-quality lakes and other lakes that meet water quality standards require protection from future degradation. The WRAPS process aims to address all waters in a major watershed, providing TMDL studies for impaired waters and protection strategies for non-impaired waters.

Assessment of Lake Bronson, the TRW's only assessed lake, shows that although TP concentrations are above the numeric standard, but neither of the response variables (chl-*a* or Secchi disk) exceed their respective standards. Therefore, Lake Bronson is not listed as impaired due to excessive nutrients (MPCA 2016a). **Table 15** lists the Protection Status of Lake Bronson, and its 'Protection Priority Class', based on analysis of phosphorus sensitivity and lake risk. This analysis results in an estimate that TP load needs to be reduced by 30% to meet the target mean TP.

Table 15: Two Rivers Watershed Lake Prioritization Summary Table.

Lake Name (AUID)	Depth	Lake Area Acres	Phosphorus Standard	Current Condition	Target Mean TP[a]	Target Load Reduction	Priority Class[b]
Lake Bronson (35-0003-00)	DEEP	312	65 µg/L	94.1 µg/L	65.6 µg/L	1061 lb/year	High

[a] Calculated independently of the TP standard of 65 µg/L, as it is based on an estimate of the 25th percentile of the summer mean TP concentration.

[b] Priority classes are High, Higher, and Highest.

See https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity for additional information.

Streams

Stream reaches in the TRW were prioritized and classified into Protection or Restoration classes based on existing water quality. Both protection and restoration classes are further divided into subclasses. Streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk. Streams within the "restoration" category are subdivided into two subcategories: Low Restoration Effort and High Restoration Effort.

Stream protection categories

Stream protection categories are based on existing water quality data for the most recent assessment period (2006 through 2015). In order to categorize more stream reaches, the lower limit on the number of observations used is lower than required for assessments. Stream assessments typically require 20 samples over two years (five samples in a given month for *E. coli*), whereas, the below stream categories are divided into protection/restoration classes using a lower limit of five samples (three for *E coli.*). This allows for more stream reaches to be included in the stream categories. Descriptions of the stream categories and water quality attributes for each class follows.

Stream categories were compiled for TSS, TP, Inorganic Nitrogen (NO2+NO3) (as a surrogate for total nitrogen; TN), and *E. coli*. It should be noted that there is no NO2+NO3 water quality standard for Class 2 streams. In order to include nitrogen in the protection strategies, streams where benchmarked utilizing the secondary standard for drinking water, Class 1 (Minn. R. 7050) water quality standard for inorganic nitrogen of 10 mg/L. In addition, for TP assessment and impairments, secondary water quality parameters (chl-*a*, five-day biochemical oxygen demand (BOD), diel DO flux, or pH levels) need to be considered. For TP stream classification, only the TP concentrations are considered. Due to these limiting factors and the lower limit on the number of samples used to qualify for a stream classification, a restoration classification may not mean a waterbody is impaired by a specific parameter.

Descriptions of the stream categories and water quality attributes for each class are provided below, followed by maps of the stream classifications by water quality parameter (**Figure 6** for Above Average Quality, **Figure 7** for Potential Impairment Risk, **Figure 8** for Threatened Impairment Risk, **Figure 9** for Low Restoration Effort, and Figure 10 for High Restoration Effort).

Protection categories

All streams currently supporting aquatic life and aquatic recreation in the TRW are candidates for protection. Over time, these waters could be subjected to land uses or stressors that could cause them to become impaired. For purposes of this assessment, TRW streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk.

Surface waters exhibiting Above Average Quality for a water quality parameter are defined as those portions of a river or stream (i.e., AUID Number) which:

1. Have no impairments and meet the full MPCA assessment methods for determining whether an impairment exists and the 90th percentile (TSS, TP, NO2+NO3) or the geometric mean (*E. coli*) are less than 75% of the numeric standard; or

2. Do not meet the data requirements of the MPCA assessment methods (have less than 20 samples, or 5 samples per month for *E. coli*) yet still have a minimum of 5 samples for the AUID Number (or 3 samples per month for *E. coli*), no samples exceed the numeric water quality standard for the AUID Number, and the 90th percentile concentration (geometric mean for *E. coli*) of a water quality parameter is less than 75% of the numeric water quality standard.

Surface waters in the TRW exhibiting Above Average Quality for a water quality parameter are shown in **Figure 6.**

Potential Impairment Risk for a water quality parameter is defined as those portions of a river or stream (i.e., AUID) with water quality conditions "near" but not exceeding the numeric water quality standard for a given parameter. Surface waters exhibiting Potential Impairment Risk are defined by the following circumstances:

1. When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), surface waters are placed in the Potential Impairment Risk subcategory for *E. coli*, inorganic nitrogen, TP, or TSS if the 90th percentile (geometric mean for *E. coli*) concentration exceeds 75%, but is less than 90% of the numeric water quality standard; or
2. When the data requirements of the MPCA assessment methods are not met (number of samples is less than 20, but greater than 5; or less than 5 but at least 3 samples per month for *E. coli*), a Potential Impairment Risk is defined as the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75% of the water quality standard, but not exceeding the water quality standard for a given water quality parameter.

Surface waters in the TRW exhibiting Potential Impairment Risk for a water quality parameter are shown in **Figure 7**.

Surface waters exhibiting Threatened Impairment Risk are defined as those portions of a river or stream (i.e., AUID Number) with water quality conditions "very near" and which periodically exceed numeric standards, but the number of samples are insufficient to meet the MPCA assessment criteria (i.e., the number of samples are less than 20, or less than 5 per month for *E. coli*). Surface waters are categorized as Threatened Impairment Risk if:

1. The data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*) and the 90th percentile (geometric mean for *E. coli*) concentration exceeds 90%, but is less than the numeric water quality standard; or
2. The 90th percentile (or geometric mean for *E. coli*) concentration is below 110% of the water quality standard when an AUID Number has more than 10 samples but less than 20; or
3. The number of samples is less than 10 but greater than 5, and the 90th percentile (or geometric mean for *E. coli*) concentration is less than 120% of the water quality standard. This limits the number of exceedances to one or two observations.

Surface waters in the TRW exhibiting Threatened Impairment Risk for a water quality parameter are shown in **Figure 8.**

For streams and rivers, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Strategies for addressing protection of these waters are discussed in more detail in **Section 3** of this report.

Restoration categories

TRW streams in the "restoration" categories fail to achieve some minimum threshold water quality condition. Example minimum threshold conditions include failure to achieve a water quality standard or a condition considered degraded or unstable, such as areas of accelerated stream bank erosion, which can further contribute to degradation of water quality. Restoration classifications are further divided into Low Restoration Effort and High Restoration Effort.

Low Restoration Effort needed is defined as a degraded condition, but a condition near the designated minimum threshold. An example is a portion of a river or stream where the numeric standard is exceeded (and therefore is “impaired”), but with restoration has a high probability of attaining the numeric water quality standard. Surface waters are defined as a Low Restoration Effort if more than five samples are collected, of which no more than 25% of the samples exceed the water quality standard. Surface waters may also be in the Low Restoration Effort category if the 90th percentile of the samples (five or more required) is within 125% of the water quality standard. Surface waters in the TRW in the Low Restoration Effort category are shown in **Figure 9**.

Surface waters in the High Restoration Effort category are degraded, and are further away from the designated threshold than the Low Restoration Effort. These surface waters have a lower probability of attaining the numeric water quality standard and may require a larger effort to attain water quality compliance. High Restoration Effort surface waters are impaired, with the 90th percentile of at least five samples exceeding 125% of the water quality standard. Impaired waters are also defined in the High Restoration Effort category if more than 25% of samples (five or more required) exceed the water quality standard. Surface waters in the TRW in the High Restoration Effort category are shown in Figure 10.

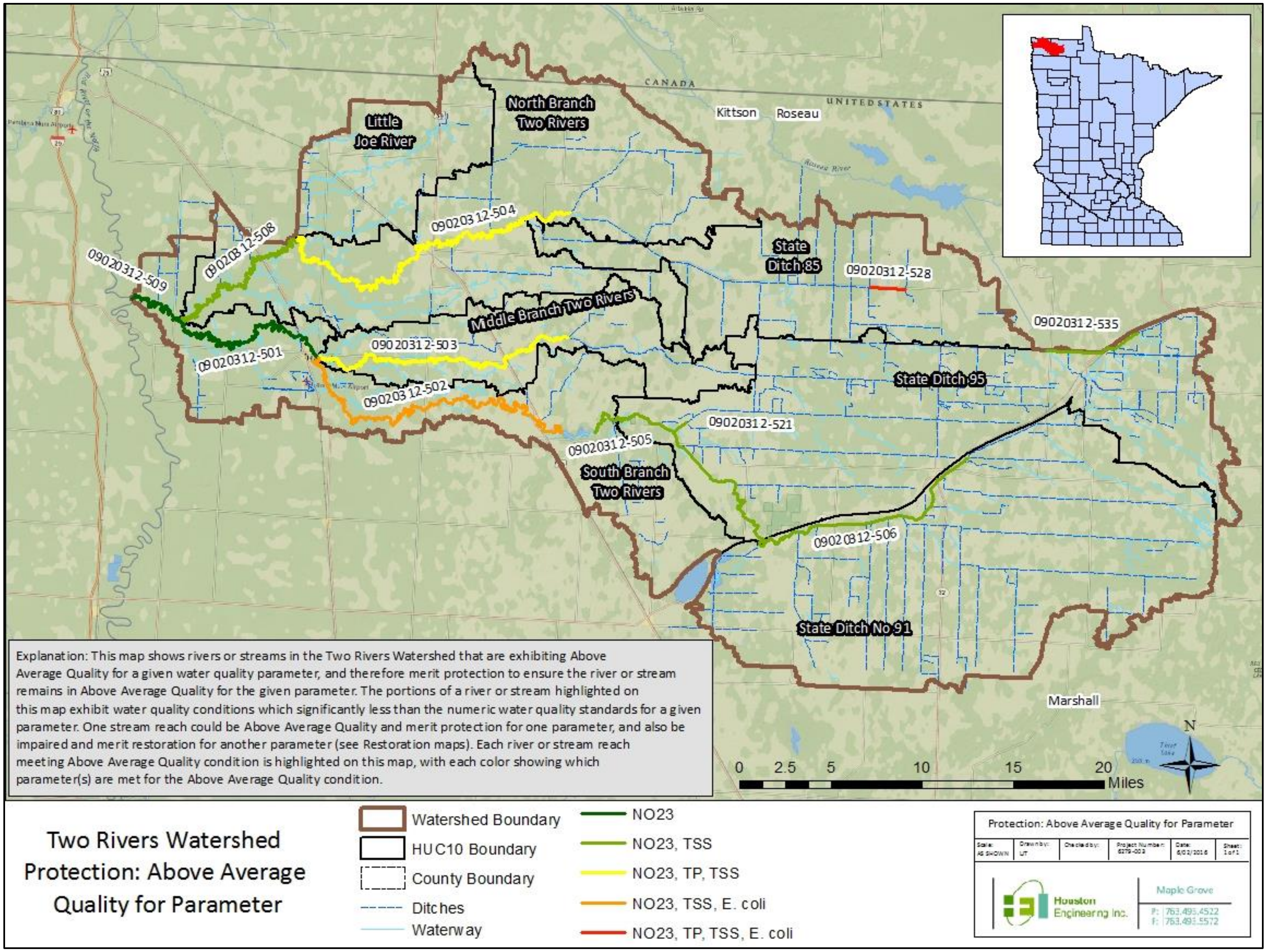


Figure 6: Surface waters exhibiting Above Average Quality for a given water quality parameter, and therefore merit protection.

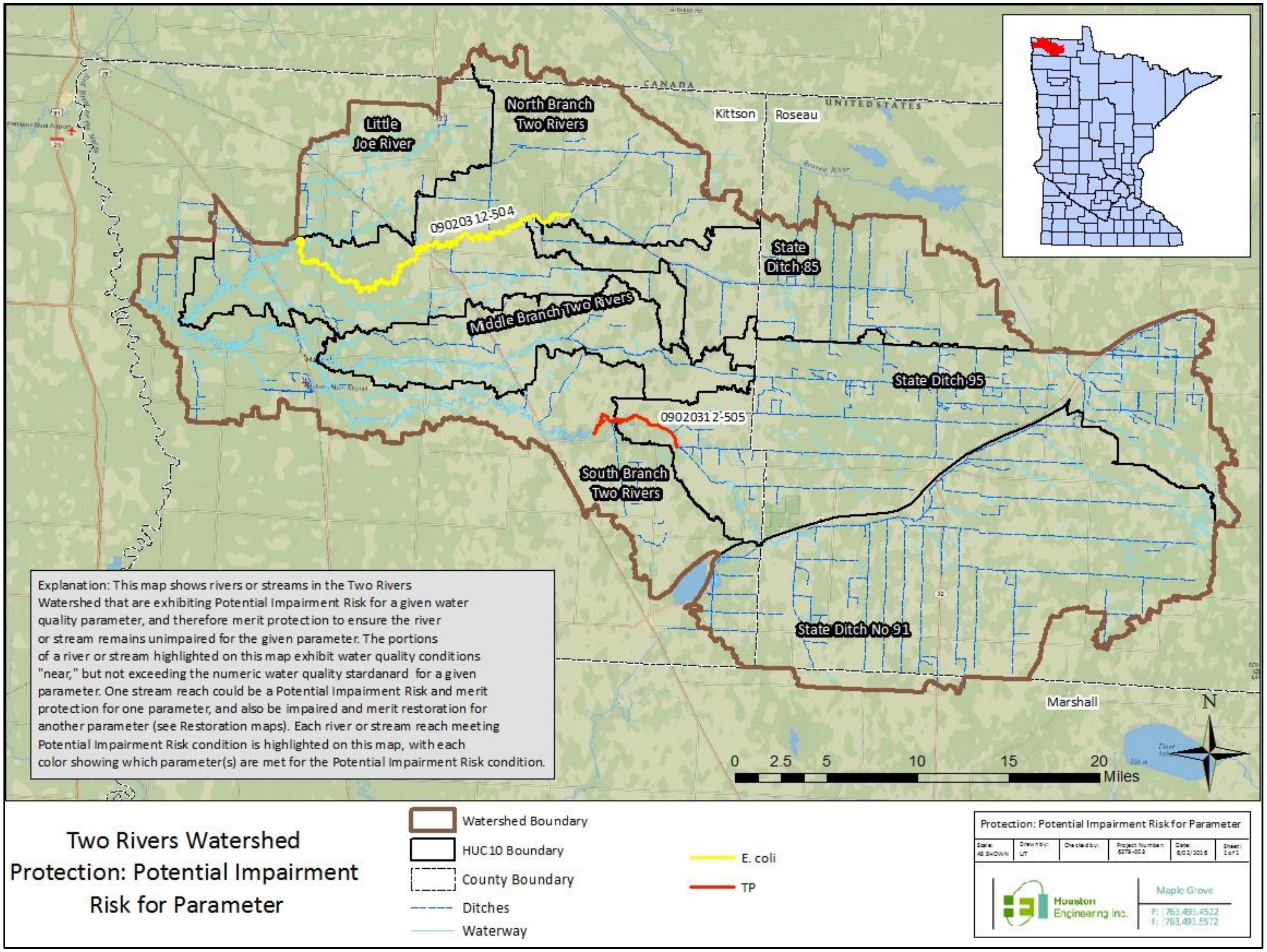


Figure 7: Surface waters exhibiting Potential Impairment Risk for a given water quality parameter, and therefore merit protection.

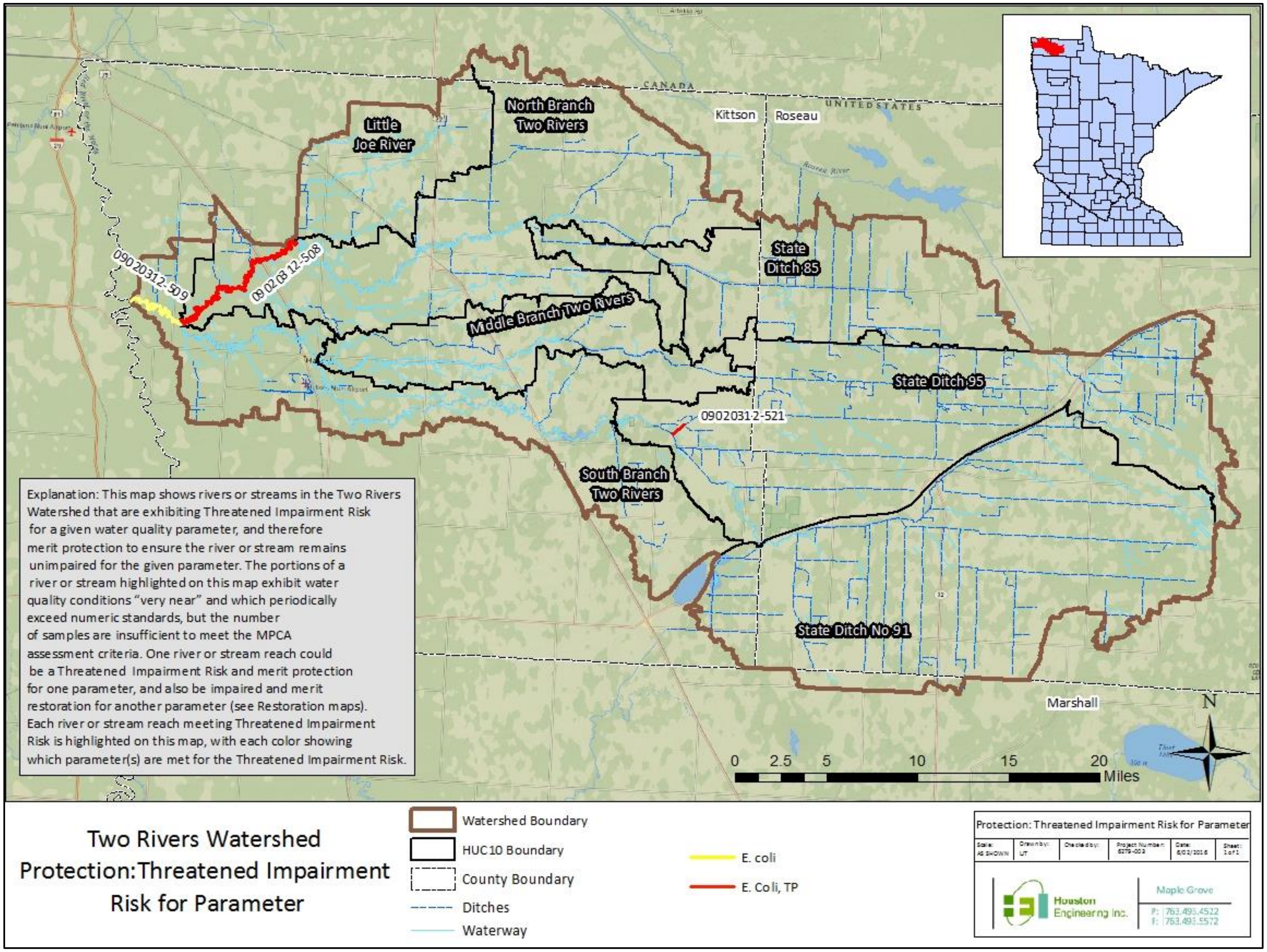


Figure 8: Surface waters exhibiting Threatened Impairment Risk for a given water quality parameter, and therefore merit protection.

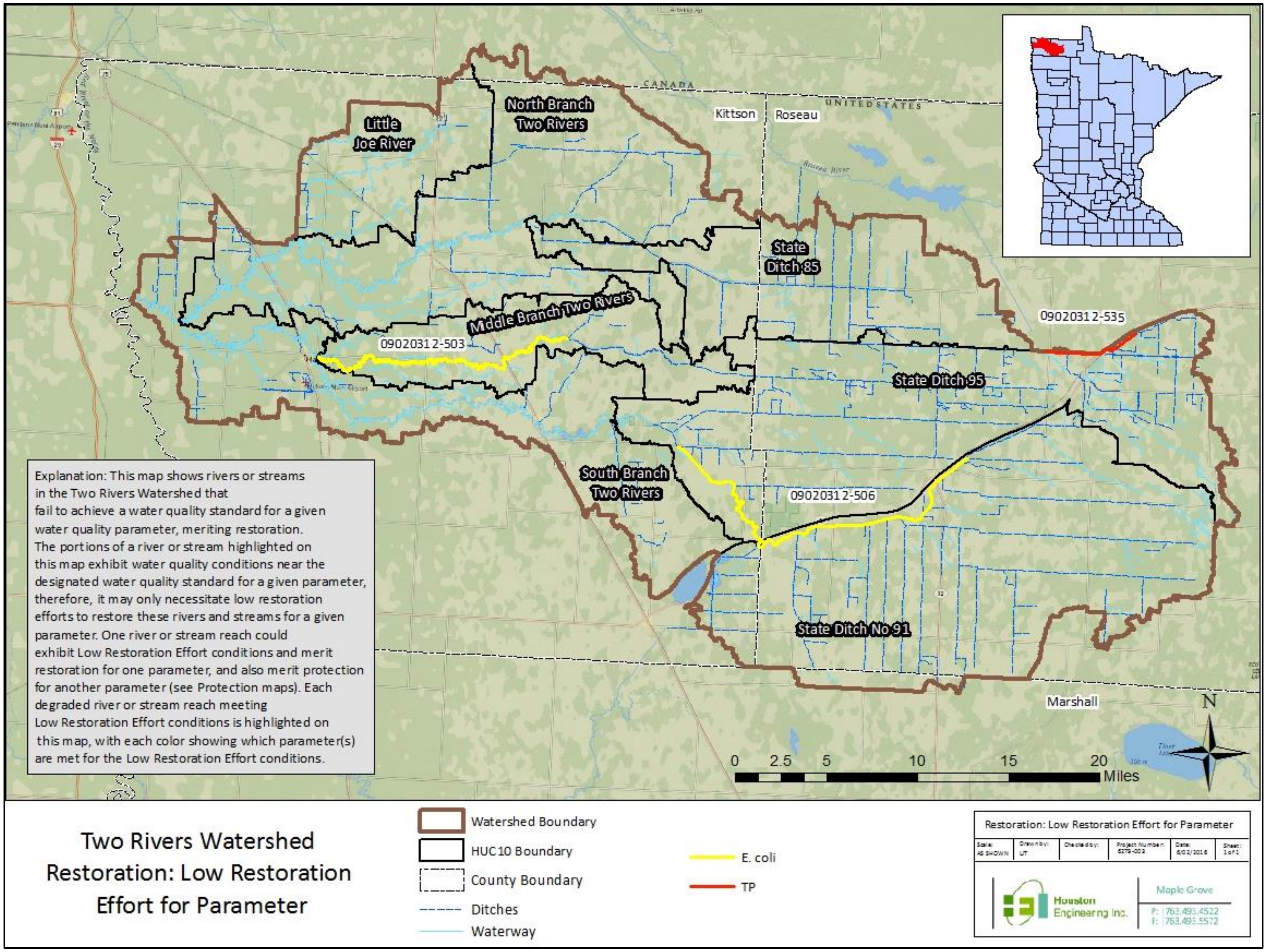


Figure 9: Surface waters classified as Restoration: Low Restoration Effort by water quality parameter.

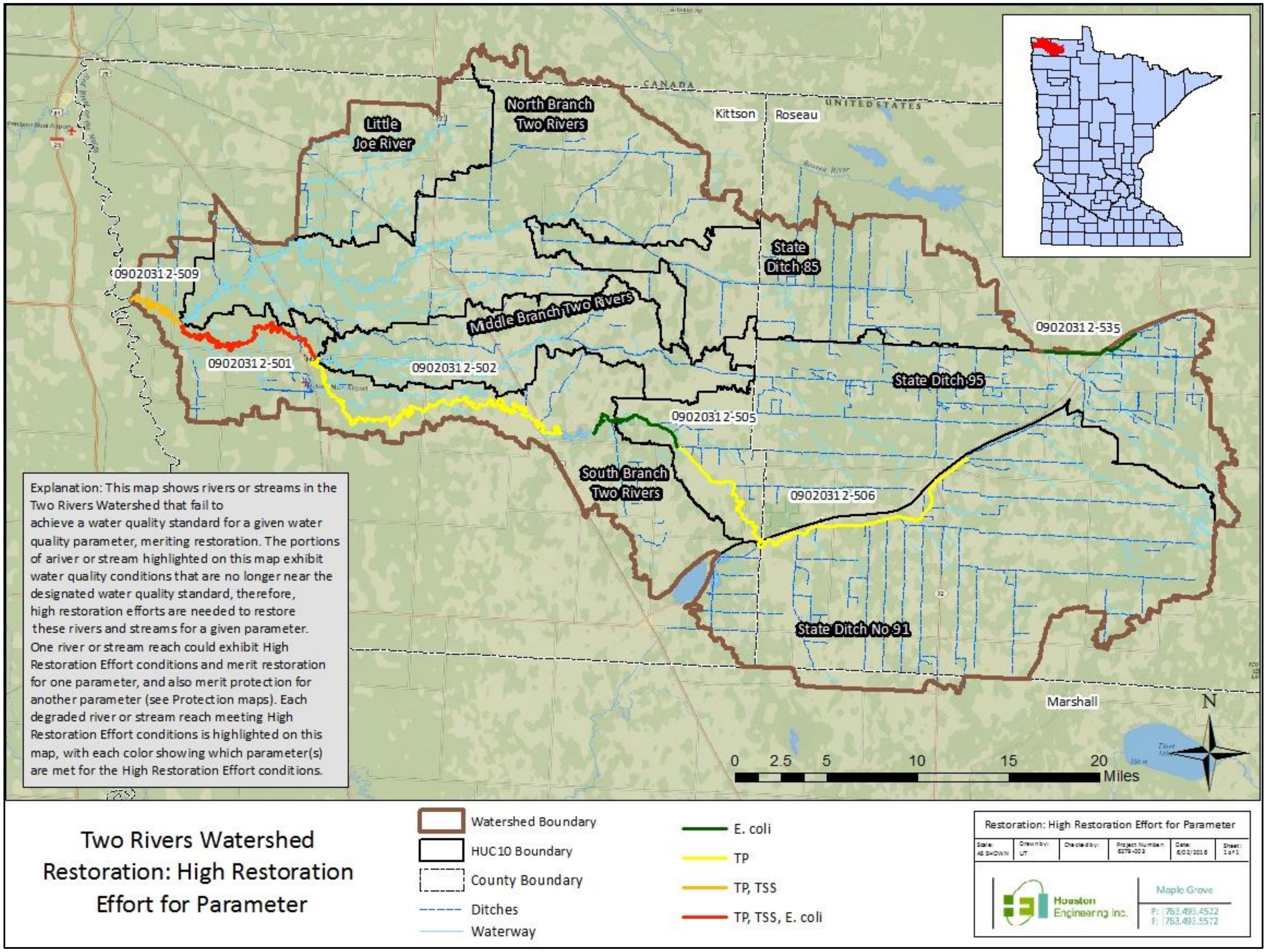


Figure 10: Surface waters classified as Restoration: High Restoration Effort by water quality parameter.

In addition to mapping stream categories, the loading capacity, existing loads, and remaining loading capacity were calculated for any stream reach with water quality data and that were explicitly represented in the Hydrological Simulation Program – FORTRAN (HSPF) model or had observed daily streamflows. Loading capacities and existing loads were calculated for each of the parameters (TSS, TP, NO2+NO3, and *E. coli*) and the Tables can be found in Appendix A of the TRW TMDL Report (HEI 2019). A summary of the results is provided in **Table 16**. **Table 16** shows the critical flow regime with the lowest percentage of remaining load (i.e., before the load resulting in a standards exceedance occurs). A negative value is assigned should either of the following two conditions apply. The first condition is that the current load exceeds the loading capacity; i.e., it is impaired. The second condition is that there are insufficient data to formally assess for impairment, but the available data suggests it may be impaired.

As seen in **Table 16**, coverage of the available water quality data is primarily restricted to the main channels of the North, Middle, and South Branches of the Two Rivers and sampling has focused primarily on the impaired reaches. Limited sampling has occurred in the tributary and small stream reaches, feeding the main channels, as shown by the numerous AUIDs without water quality data. As a protection strategy, it is recommended that future monitoring plans cover a greater area of the watershed, contingent on available resources. It should be noted that the existing loads shown in **Table 16** may be estimated based on one sample. No considerations for the number of water quality samples were given and official assessment by MPCA is needed to confirm impairment. For TSS, most stream reaches exceed the TSS load capacity (based on the 65 mg/L numeric standard) for at least one flow regime. For TP, all stream reaches with water quality data (where an existing load can be computed) have at least one flow regime exceeding the load capacity (based on the 0.15 mg/L numeric standard). All stream reaches show good water quality relating to inorganic nitrogen (NO2+NO3) and are well below the loading capacity (based on the Class 1 numeric standard of 10 mg/L).

The results shown in **Table 16** and the protection/restoration category maps (**Figure 6** through Figure 10) should be used to provide guidance for the prioritization of protection strategies. A summary of water quality data used to develop the maps and **Table 16** is provided in **Appendix C**, as well as the estimated existing load, loading capacity, and protection/restoration classification for each parameter shown. It should be noted that the existing loads and loading capacity in the tables in **Appendix C** are dependent on availability of flows from the HSPF model. Therefore, the time-period for the existing loads and loading capacity is 1996 through 2009. The water quality data summary provided in the tables extends the time period through the current assessment period (through 2015).

Table 16: Critical flow regimes and percentage of remaining load capacity of stream reaches in the Two Rivers Watershed.

HUC-10 Subwatershed	AUID (Last 3 digits)	TSS		TP		NO2+NO3		*E. coli*	
		Critical Flow Regime	Unallocated Load (%)[a]	Critical Flow Regime	Unallocated Load (%)	Critical Flow Regime	Unallocated Load (%)	Critical Flow Regime	Unallocated Load (%)
State Ditch No 91 (0902031201)	507	--	--	--	--	--	--	--	--
	515	Very Low	99%	Very Low	99%	--	--	Very Low	99%
	516	--	--	--	--	--	--	--	--
	522	--	--	--	--	--	--	--	--
	523	--	--	--	--	--	--	--	--
	546	--	--	--	--	--	--	--	--
	548	--	--	--	--	--	--	--	--
	550	--	--	--	--	--	--	--	--
	551	--	--	--	--	--	--	--	--
	552	--	--	--	--	--	--	--	--
State Ditch No 95 (0902031202)	505	Very Low	0%	Very High	0%	High	98%	High	35%
	506	Very High	53%	Very High	0%	Very High	95%	Low	0%
	513	--	--	--	--	--	--	--	--
	521	--	--	--	--	--	--	--	--
	526	--	--	--	--	--	--	--	--
	527	--	--	--	--	--	--	--	--
	534	--	--	--	--	--	--	--	--
	535	Very Low	68%	Very High	0%	Very High	97%	Low	0%
	536	Very Low	99%	Very Low	99%	--	--	Very Low	99%
	537	--	--	--	--	--	--	--	--
	538	--	--	--	--	--	--	--	--
	539	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--
	541	--	--	--	--	--	--	--	--
	542	--	--	--	--	--	--	--	--
	543	--	--	--	--	--	--	--	--
	545	--	--	--	--	--	--	--	--
Middle Branch Two Rivers (0902031203)	503	Very High	82%	Mid	50%	Very Low	97%	Low	0%
	517	Very Low	99%	Very Low	99%	--	--	Very Low	99%
	518	--	--	--	--	--	--	--	--
State Ditch No 85 (0902031204)	528	Very Low	60%	Low	30%	Very High	100%	Low	60%
	529	--	--	--	--	--	--	--	--
	530	--	--	--	--	--	--	--	--
	531	--	--	--	--	--	--	--	--
	547	--	--	--	--	--	--	--	--
Little Joe River (0902031205)	510	--	--	--	--	--	--	--	--
	519	--	--	--	--	--	--	--	--
	520	--	--	--	--	--	--	--	--
	504	Very High	47%	Very Low	20%	Very High	96%	Low	23%
	508	Very High	0%	Very Low	0%	High	97%	High	73%

HUC-10 Subwatershed	AUID (Last 3 digits)	TSS		TP		NO2+NO3		*E. coli*	
		Critical Flow Regime	Unallocated Load (%)[a]	Critical Flow Regime	Unallocated Load (%)	Critical Flow Regime	Unallocated Load (%)	Critical Flow Regime	Unallocated Load (%)
North Branch Two Rivers (0902031206)	514	Very Low	99%	Very Low	99	--	--	Very Low	100%
	524	--	--	--	--	--	--	--	--
	532	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--
	549	--	--	--	--	--	--	--	--
South Branch Two Rivers (0902031207)	501	Very High	0%	Very High	0%	High	96%	Very High	0%
	502	Very High	30%	Very High	0%	Very High	96%	Low	74%
	509	High	0%	Very High	0%	Very High	95%	Low	19%
	511	--	--	--	--	--	--	--	--
	512	--	--	--	--	--	--	--	--
	525	--	--	--	--	--	--	--	--
	544	--	--	--	--	--	--	--	--

[a] The unallocated load is the load not assigned to a wasteload allocation, load allocation, or the margin of safety. Sometimes referred to as the reserve capacity.

3. Strategies for restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, identify point sources, and identify nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

This section of the report provides the results of such strategy 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 (knowledge, assistance, trust, networks, and positive relationships) with those who will be needed to voluntarily implement best management practices (BMPs). Thus, effective ongoing civic engagement is fully a part of the overall plan for moving forward.

The successful implementation of restoration and protection strategies requires a combined effort from multiple entities within the TRW, including local and state partners (i.e., soil and water conservation districts [SWCDs], TRWD, MPCA, DNR, and the BWSR). Bringing these groups together in the decision-making process will increase the transparency and eventual success of the implementation. To this end, the TRWD received a One Watershed, One Plan (1W1P) grant in 2018. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

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 the availability of needed funding. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

The TRW WRAPS effort has been led by the TRWD. The TRWD has a long history of collaborating with local and state partners (i.e., SWCDs, MPCA, DNR, and BWSR) to prioritize, implement, and fund restoration and protection activities within its jurisdiction. Future restoration and protection work in the area will benefit from these relationships, building on previous successes.

3.1 Targeting of geographic areas

The TRW's hydrology and water quality (i.e., sediment, nutrients, and bacteria) were simulated and evaluated using watershed modeling tools and plans. Tools and plans used in this WRAPS effort include:

- HSPF model
- Prioritize, Target, and Measure Application (PTMApp)
- Overall Plan of the TRWD (2004)

This section gives an overview of the development of these tools and plans, their results, and an outline of how the tools and plans can be used in identifying restoration and protection target areas in the watershed.

HSPF model

HSPF is a watershed-scale model that simulates hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. The model incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. HSPF 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. The output from the HSPF model is used to identify those locations where yields are greatest on average at the subwatershed outlet. More information on the TRW HSPF model's development and calibration can be found in the modeling reports (RESPEC 2014). The full results of the priority ranking of subwatersheds in the TRW using HSPF results have been provided in **Appendix A** and **Appendix D** provides discussion on simulating BMP scenarios in HSPF.

Prioritize, Target, and Measure Application (PTMApp)

The PTMApp for implementing water quality improvement plans was developed as part of BWSR's 1W1P initiative. The PTMApp enables local practitioners to do the following: prioritize subwatersheds for **BMPs** and **Conservation Practice** (CP) implementation based upon outputs of HSPF models; target specific fields for implementation based on yield (mass/area/time) of sediment, TN, and TP estimated with terrain analysis techniques; assess technical feasibility for placing BMPs and CPs on the landscape; and measure the water quality benefits of potential BMPs and CPs.

Future use of PTMApp in local planning of restoration and protection efforts will include the identification of field-scale priority management areas within the TRW. These products are especially helpful for understanding the delivery of loads to specific waterbodies and targeting specific fields for placing implementation practices. As part of the WRAPS process, PTMApp products aided in identifying broader needs and expectations, while on-going local water planning processes will describe more specific action plans over the next 10-year period. **Appendix B** summarizes results from PTMApp.

Prioritized and targeted implementation scenario

A bacteria risk assessment was completed to identify areas in the TRW that pose the greatest risk for contributing bacteria to surface water resources (**Appendix B**). To identify high-risk areas, sources of bacteria in the TRW were identified. Malfunctioning **Subsurface Sewage Treatment Systems** (SSTSs) can be an important source of fecal contamination to surface waters; thus, the number of potential **Imminent Public Health Threats** (IPHTs) and potentially failing SSTSs were computed per county and in the TRW overall. Livestock populations for cattle, chickens, goats, horses, sheep, and turkeys were also estimated for each county within the TRW.

The risk rankings of potential sources of bacteria in the TRW, by subwatershed, are shown in **Table 17**. Livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the TRW. Human and wildlife sources of bacteria posed relatively lower risks. This information can be used to prioritize management efforts for the potential sources of bacteria that pose the greatest risk of impacting surface waters in the TRW. A complete discussion on the methodology and data used to develop this analysis is provided in **Appendix B**.

Table 17: Relative Sources of *E. coli* by stream reach.

Stream Reach	Humans			Livestock			Wildlife			
	WWTF Effluent	Septic Systems	Domestic Animals	Grazing	Manure	AFO Open Lots	Deer	Ducks	Geese	Other
Little Joe Diversion	○	○	○	●	●	**O**	○	○	○	○
Main Stem Two Rivers	○	○	○	●	●	○	**O**	○	○	○
Middle Branch Two Rivers	○	○	○	●	**O**	**O**	○	○	○	○
North Branch Two Rivers	○	○	○	●	●	**O**	○	○	○	○
South Branch Two Rivers	○	○	○	●	●	●	○	○	○	○

*● = high risk, **O** = medium risk, ○ = low risk

Figure 11 shows ranks based on the area weighted magnitude of bacterial delivery for major stream branches within the TRW. Higher rates equate to a greater risk of bacterial delivery from each subwatershed to the outlet of the TRW. Similar to the results shown in **Table 17**, livestock sources consistently posed the greatest risk of bacterial delivery. The results in **Figure 11** are area weighted, so comparisons can be made between subwatersheds. This information can be used to inform the prioritization of local management efforts aimed at reducing bacterial delivery to surface waters in the TRW. In addition, **Figure 11** can also be used to begin targeting specific subwatersheds for bacterial restoration and protection strategies. It is important to note that the data used to develop **Figure 11** is based on county-wide data that was aggregated to subwatersheds within the study area. Therefore, the source magnitudes should not be interpreted to represent the source loading of specific fields within the subwatersheds. For example, Marshall County only occupies a small portion of the study area, but was aggregated into the South Branch Subwatershed (see **Figure 11**) which was ranked higher relative to other subwatersheds. However, the portion of Marshall County contributing bacteria to the South Branch Subwatershed is likely minor. This result is driven by the county-wide scale of the bacteria input data.

A source assessment was also completed to identify the magnitude and spatial distribution of sediment and nutrient sources across the landscape. PTMApp – Desktop creates three source assessment products: load and yields leaving the landscape; load and yields delivered to a waterway; and loads and yields delivered to a downstream resource of interest (e.g., lake or river reach). By completing a source assessment, an understanding of how various parts of the watershed affect a resource is obtained. The sediment yield (tons/acre/year) delivered to the outlet of TRW for the study area is shown in **Figure 12**. Similar products can be developed for TN and TP for any priority resource point input during processing. The results indicate that the highest areas of overland sediment loading to the outlet of TRW are concentrated near the outlet of the watershed. For strategies aimed at reducing sediment delivered to the outlet of TRW, the "High" sediment yield areas would provide ideal locations to target practices. However, the feasibility of implementing BMPs and CPs in those areas must be evaluated. In other words, the highest loading (sediment, TN, or TP) areas on the landscape might have limited opportunities for implementing a practice to address the issue.

The feasibility of placing a BMP or CP on the landscape depends on several factors. These factors include the size of the contributing drainage area, the land slope, the type of flow regime, and local topography. Practice feasibility is based solely on technical factors largely based on field office technical guides developed by the NRCS, and excludes social factors like landowner willingness. Locations shown as "feasible" are candidates for implementing practices and require further technical evaluation to confirm feasibility. The potential opportunities for BMPs and CPs within the TRW study area are shown in **Figure 13**. The opportunities are displayed by PTMApp treatment group (Appendix B). It is important to note that that these are only potential locations at this point in the business workflow. Local knowledge is still needed to refine the locations to identify a realistic set of targeted practices. These BMP and CP opportunities can be combined with the source assessment data in PTMApp to estimate the "measurable" water quality benefits for implementing the practices.

One of the means of selecting specific practices for implementation is based on their probable benefits. The probable benefits of a practice can be described by either the amount of a parameter like sediment or phosphorus removed, or the cost to remove one unit of the parameter (e.g., dollars per pound of phosphorus annually reduced). Practice benefits can be estimated at the location of the practice or the resource. The estimated benefits at a lake or river are more valuable from a decision making perspective. The estimated sediment load reduction, tons/year, for reducing sediment using storage practices at the outlet of TRW is shown in **Figure 14**. The areas providing the largest load reduction are in the High category. These results can be used to target practice locations to implement BMPs and CPs that provide the largest sediment load reductions to make progress towards local, state, and regional water quality management goals.

Including all BMPs and CPs into the PTMApp is not practical or feasible because of the large number of them. Therefore, the "most commonly used" non-urban non-point source BMPs and CPs are included based upon statewide analysis of the e-link database. These practices are categorized into the treatment groups of Filtration, Infiltration, Storage, Protection and Source Reduction. Examples of filtration include grassed waterways and filter strips; examples of infiltration include alternative tile intakes; examples of storage include water and sediment control basins (WASCOB), pond for water use, wetland restoration or drainage water management; examples of protection include grade stabilization structures and critical area planting; and an example of source reduction includes nutrient management.

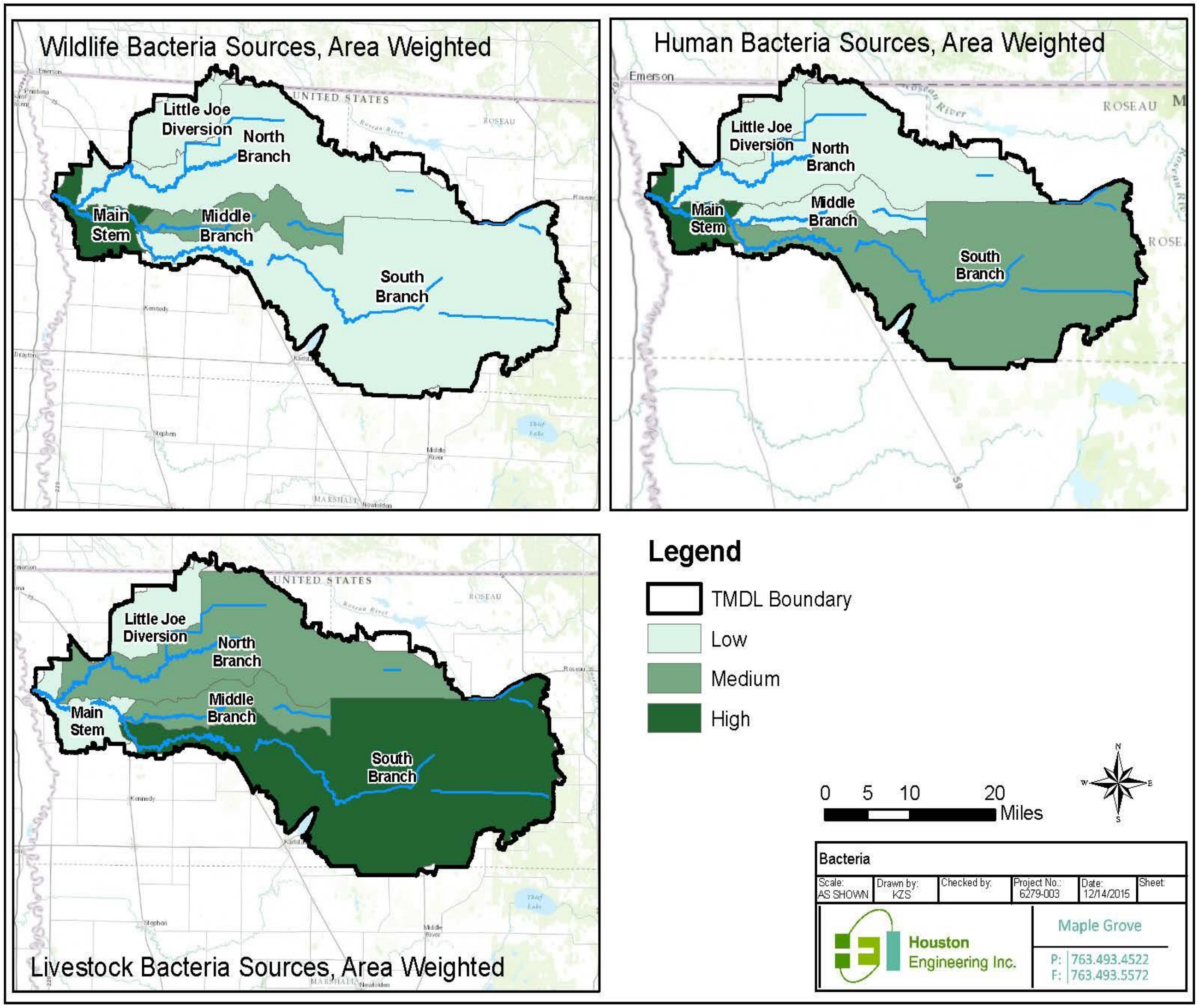


Figure 11: Ranked HUC 10 subwatersheds based upon magnitude of bacterial delivery to the outlet of the TRW.

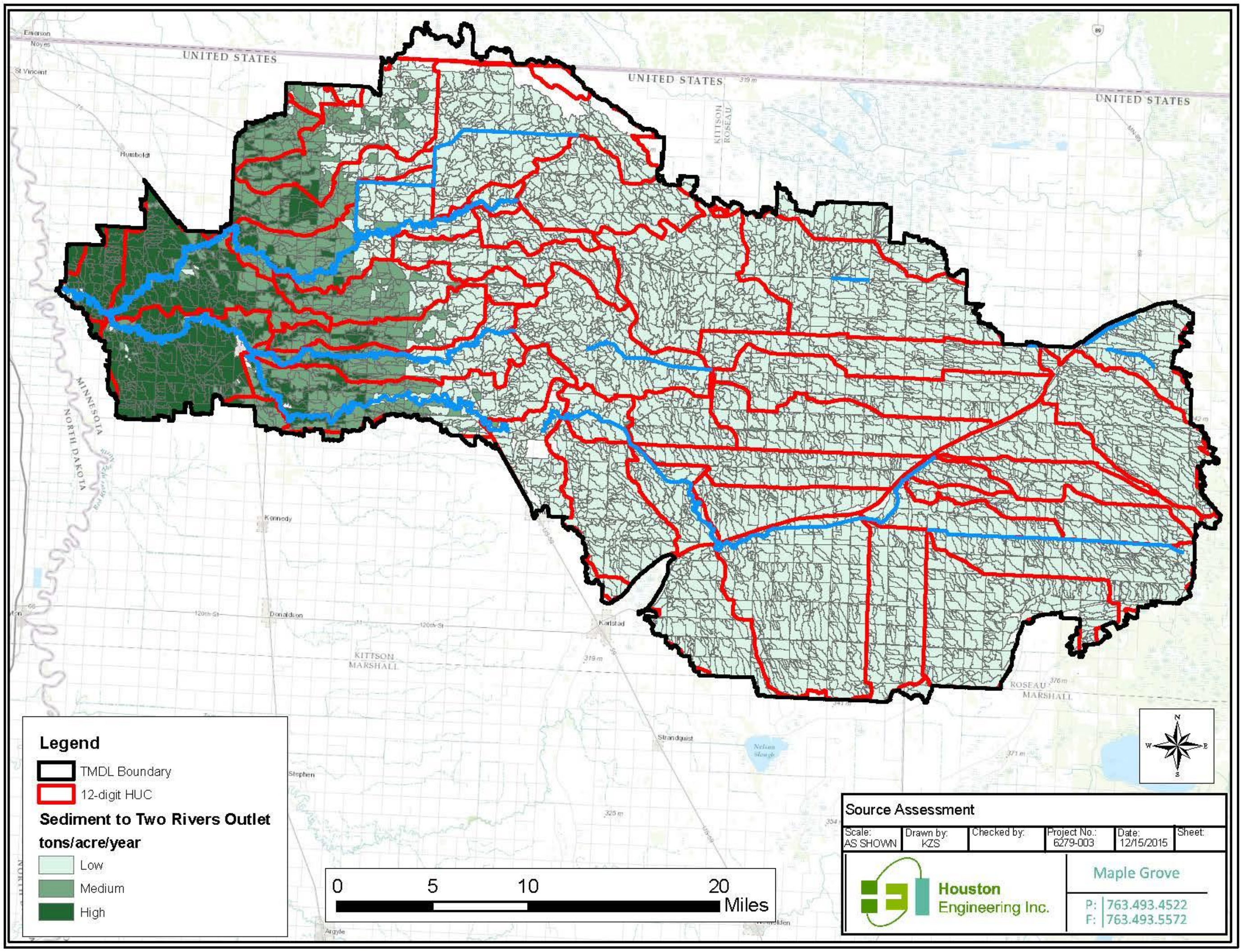


Figure 12: Two Rivers Watershed source assessment for sediment yield delivered to the outlet of Two Rivers. Analyses for Total Nitrogen and Total Phosphorus were also completed (not shown in map).

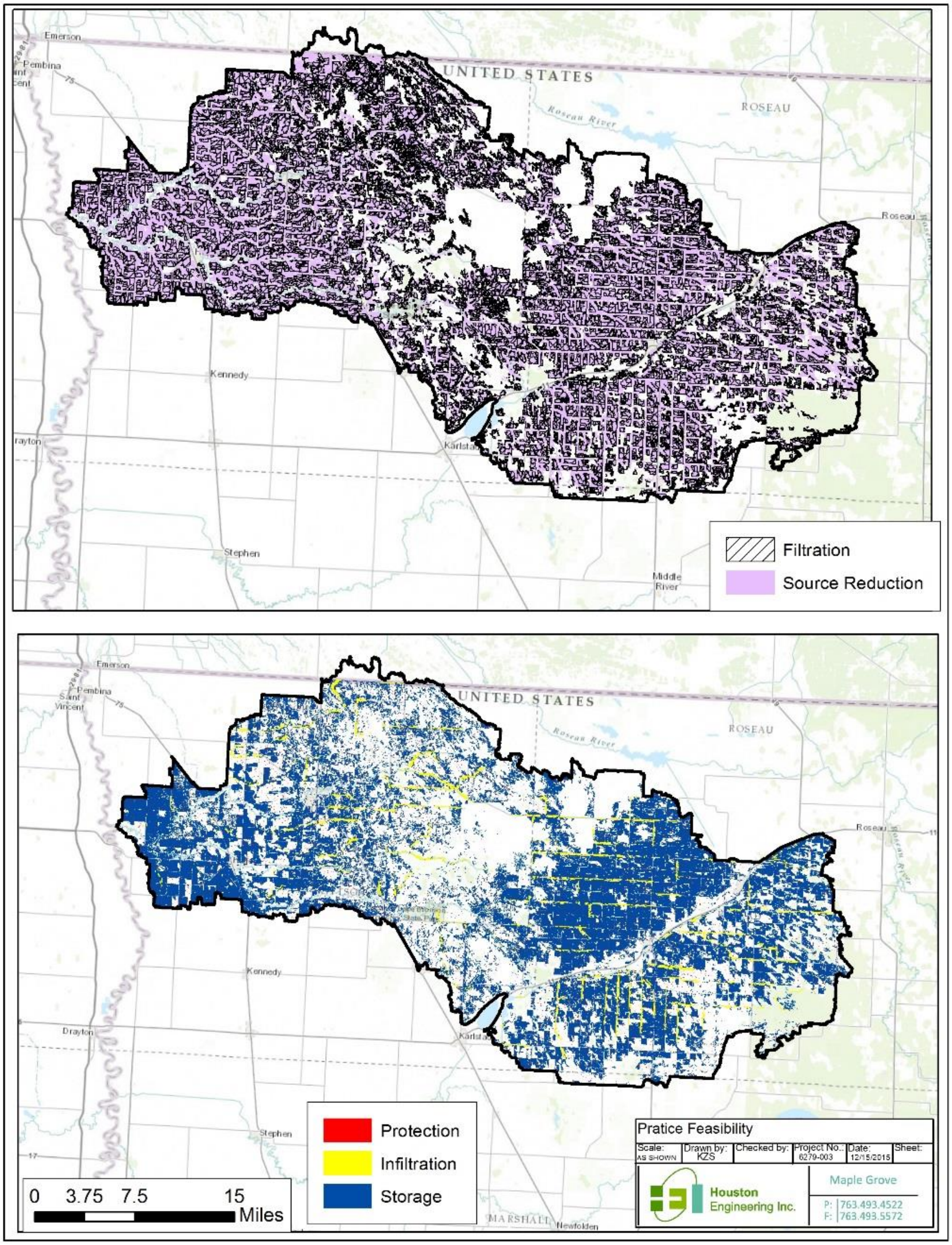


Figure 13: Potential opportunities for BMPs and CP within the Two Rivers Watershed Study Area, based solely on technical feasibility.

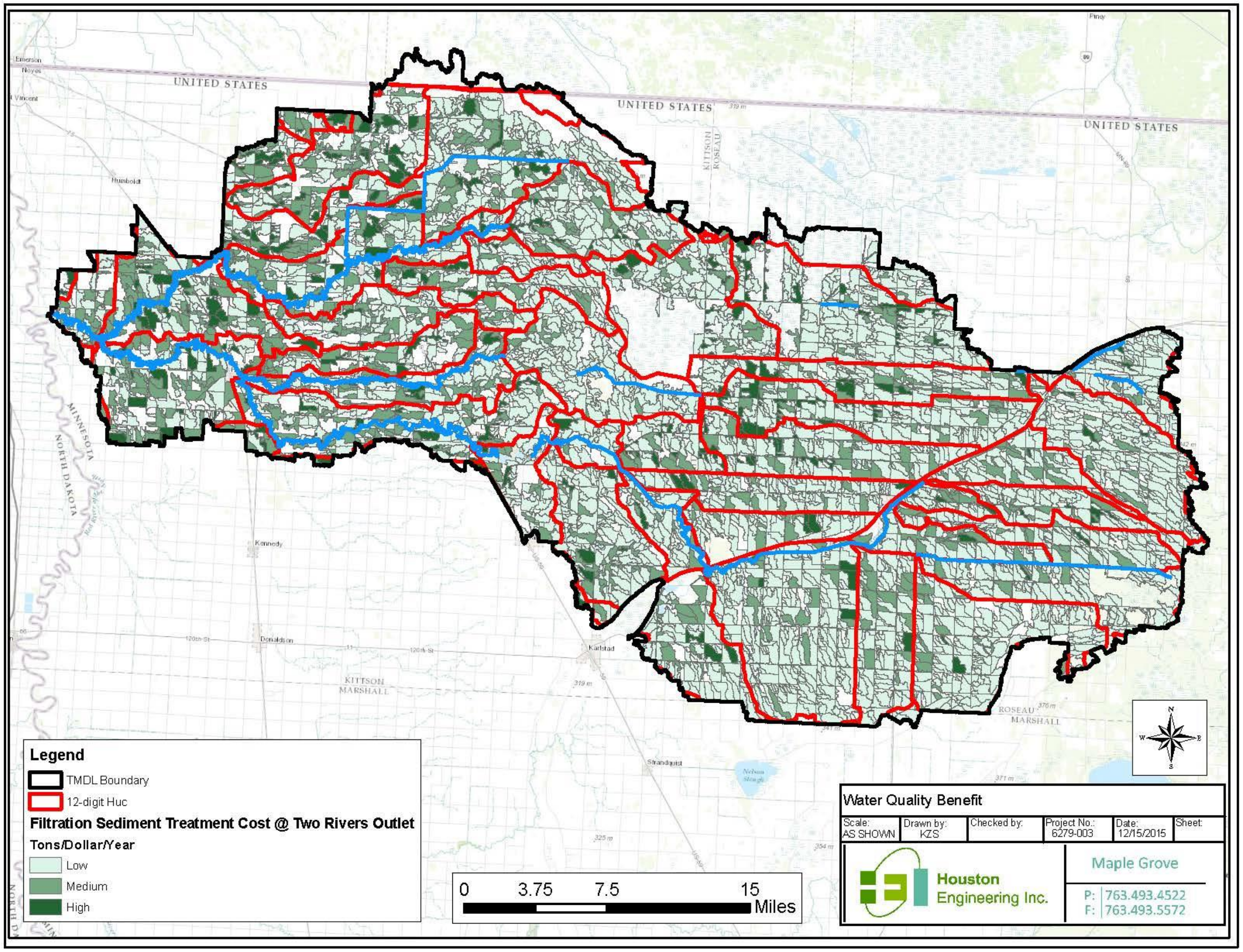


Figure 14: The estimated treatment cost (tons/year/dollar spent) of reducing sediment delivered to the outlet of the Two Rivers Watershed study area using filtration practices. Similar products are available for total nitrogen and total phosphorus.

Watershed management plans

Pursuant to Minnesota Statute, TRWD is required to prepare a Watershed Management Plan (WMP) and to continually update and revise the plan every 10 years. The WMP is an important tool for identifying problems, issues, and goals and developing long and short-term strategies to address these issues and attain the goals. The WMP also inventories resources, assesses resource quality, and establishes regulatory controls, programs, or infrastructure improvements needed to manage the resources within the watershed. The WMP provides guidance for each county to manage the water and natural resources within the watershed boundary.

The TRWD Overall Plan was most recently updated in 2004 (TRWD 2004). The TRWD was granted an extension on their 2004 WMP until December 31, 2022, by which time, a 1W1P will be completed. In the 2004 plan, great efforts were made to quantify the goals and suggest implementation strategies for managing water quantity and quality, as well as natural resource enhancement. Results of the WRAPS will be directly incorporated into the next scheduled update of the TRWD overall plans and 1W1P. Future use of the watershed district plan, in water quality restoration and protection efforts, will include integrating the principles, goals and policies of the TRWD into ongoing implementation activities and providing a management framework under which these efforts will occur.

Additional tools

HSPF – SAM (Scenario Application Manager) has been developed for virtually the entire state and is available for the TRW. SAM is a user-friendly platform, which pulls data from the HSPF model and allows local resource managers to run various implementation strategies and evaluate their effectiveness in addressing restoration or protection objectives. The following features characterize the SAM platform.

- Localize those scenarios to specific areas within a watershed
- Multiple, literature-based BMP options available for scenario development
- Can help inform nutrient reduction strategies and watershed planning
- Allows staff without formal modeling training to utilize HSPF hydrologic models

A number of additional tools are available for use in the restoration of impaired waters and protection of threatened waters in the TRW. A non-exhaustive list of some of these tools, their description and how they may be utilized is provided in **Table 18.**

Table 18: Additional Tools Available for Restoration and Protection of Waters within the TRW.

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Ecological Ranking Tool (Environmental Benefit Index - EBI)	This dataset consists of three GIS raster data layers including soil erosion risk, water quality risk, and habitat quality. The 30-meter grid cells in each layer contain scores from 0-100. The sum of all three scores is the EBI score (max of 300). A higher score indicates a higher priority for restoration or protection.	The three layers can be used separately, or the sum of the layers (EBI) can be used to identify priority areas for restoration or protection projects. The layers can be weighted or combined with other layers to better reflect local values.	These data layers are available on the BWSR website. In addition, a GIS data layer that shows the 5% of each 8-digit watershed in Minnesota with the highest EBI scores is available for viewing in the MPCA 'water quality targeting' web map, and download from MPCA.	*BWSR* *MPCA Web Map* *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* *Examples*
Restorable Wetland Inventory	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 USDA NRCS 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 and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' web site.	*Restorable Wetlands*
National Hydrography Dataset (NHD) & 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 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 website.	*MGIO*

3.2 Civic engagement and Public Participation

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'Resourceful' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." A resourceful decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www.extension.umn.edu/community-development/leadership-and-civic-engagement.

A specific goal of the civic engagement process for this WRAPS was to work closely with the residents, cities, counties, businesses, and other stakeholders to ensure that their ideas, concerns, and visions for future conditions were understood and utilized throughout the WRAPS study process. The WRAPS process is most likely to be successful when average citizens play a greater role in helping to frame the water quality issues in their own community as well as in the creation of the solutions to those problems. Given this, the civic engagement process included two primary components: technical stakeholder engagement and citizen engagement.

A Technical Stakeholder Group (TSG) was developed to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. The WRAPS TSG included representatives from the TRWD, the SWCDs, and state agencies. This group was primarily engaged to discuss potential products developed to identify geographic areas for implementing projects.

Accomplishments and future plans

The civic engagement efforts related to the TRW WRAPS were overseen and carried out by the TRWD. Numerous public meetings and open house events were held at key points in the WRAPS process to update stakeholders on the WRAPS efforts as well as receive input and guidance on water quality values and concerns in the area.

Since water quality is among the priorities of the TRWD's management activities, future civic engagement will continue to be coordinated by the district. The TRWD will update, educate, and engage stakeholders on water quality issues through the normal district communications, including plan update events and on their website. A primary objective of this civic engagement is to create understanding of water quality problems and solutions that are available, and build motivation to make changes with those who will be needed to voluntarily implement BMPs. As one of the most trusted authorities on water issues in the area, the TRWD is uniquely suited to provide information and leadership in this area.

Periodically and throughout the year, the TRWD conducts public outreach activities to provide information on programs, policies, and initiatives. News releases are submitted to various radio, television, and print media. Also, the TRWD has prepared a fact sheet regarding its *Rules* and permit procedures and sends this out to counties, cities, and townships each year. Since 1998, the TRWD has participated jointly with the Kittson SWCD to publish a quarterly newsletter, *Northland Conservation News*, focusing on watershed and SWCD programs and projects. The newsletter is mailed out to all farm operators, government agencies, farm related businesses, and others within the TRWD.

Expectations are that future implementation efforts will be carried out either through the existing water-related plans, implementing 1W1P, and/or through the flood damage reduction workgroup.

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 24, 2018, through January 23, 2019. There was one comment letter received and responded to as a result of the public comment period.

3.3 Restoration and protection strategies

TRW water quality restoration and protection strategies were identified through collaboration with state and local partners. Due to the homogeneous nature of the TRW, most of the suggested strategies are applicable throughout the watershed. One exception to that is residue management, which is not practical for implementation in the Lake Plain Region due to the low permeability and cohesive nature of the soils. Similarly, side inlet controls are effective in the Lake Plain Region, but WASCOB are a more appropriate practice than side inlet controls in the eastern portions of the watershed.

Based on an analysis of flow statistics for the USGS gage South Branch Two Rivers at Lake Bronson, Minnesota (USGS ID: 05094000), the 1.5-year, 2-year, 10-year, and 25-year return period peak flows have increased by 248 cfs, 276 cfs, 441 cfs, and 587 cfs, respectively (**Table 19**). These changes may be indicative of altered hydrology (cause undefined) that has been cited as a stressor to biological impairments in the TRW (MPCA 2016b) and in other watersheds in Minnesota (MPCA 2014a). Based on the results of this analysis (see **Table 19**), restoration and protection strategies can be developed to reduce flows for critical channel-forming return periods in an effort to restore the hydrology of the TRW. Water detention basins can also aid in restoring surface waters impacted by sediment and nutrients (Tomer et al. 2013), providing an opportunity to address multiple stressors.

Table 19: Return periods for flows for the South Branch, Two Rivers at Lake Bronson, Minnesota (USGS ID: 05094000).

Return Period	1980-2015	1940-1975	+Change
years	-------------------Flow, cfs----------------		
1.5	1,358	1,110	248
2	1,829	1,553	276
10	3,954	3,513	441
25	5,031	4,444	587

Table 20 contains a list of the impaired waters of the TRW, along with goals for restoration and suggested implementation strategies to achieve those goals. Biological impairments (fish and aquatic

macroinvertebrates) are addressed with restoration strategies for stressors. Fish passage has been cited as a primary stressor to the biological impairments in the TRW (MPCA 2016b). The natural flow regime of the impaired reach has been substantially altered resulting in "flashy" flow regimes, which is largely responsible for the degradation of physical habitat, high suspended sediment, and low DO conditions that are also limiting the fish and macroinvertebrate communities within the impaired reach (MPCA 2016b). Based on the results of the TRW SID Report (MPCA 2016b), restoration and protection strategies can be used to prevent or mitigate activities that further alter the hydrology of the TRW, improve upland storage capacity, restore connectivity to allow for greater fish passage, and improve riparian condition in an effort to restore the hydrology of the TRW.

Analyses have been completed for the TRW that identifies areas that are suitable for BMPs, based on TP, TN, and sediment delivery from priority ranking of subwatersheds in the TRW using HSPF and PTMApp-Desktop Results (**Appendix A** and **Appendix B**). Subwatershed priority rankings were also developed for several stressors including altered hydrology (expressed as run off [RO]), excess nutrients (TP, TN) and turbidity and habitat alteration/geomorphology (total sediment) (**Appendix A**). Bacteria risk areas have also been identified (**Appendix B**). Also, three scenarios representing a range of BMP implementation strategies were developed for TP, TN, and sediment and the load reduction benefits of the scenarios were then estimated using the HSPF model (**Appendix D**). Based upon these HEI studies, the subwatersheds where BMP projects could be implemented and the strategies that were determined to be most beneficial are defined in **Table 20**.

In addition, **Table 20** contains estimated adoption rates needed to achieve milestones (or alternatively, outcome benchmarks), units/metrics to track progress towards goals, the governmental unit responsible for implementation, and the timeline to achieve those goals. Interim 10-year milestones are identified in for each impaired subwatershed, so incremental progress can be tracked as achieved. On-going water quality monitoring data will be used in future components of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals.

It is important to note that load reductions from some implementation actions listed in **Table 20** are creditable to the load allocation and some to the wasteload allocation. Examples of non-WLA creditable projects include strategies aimed at reducing in-stream loading (e.g., streambank and shoreline protection/stabilization). For clarification on a particular project, proposers should contact the MPCA Stormwater Program.

All other waters in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies (see **Section 2.5** for protection considerations). Given the homogeneity of the TRW, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes. The approach for the identified protection strategies implementation is on an on-going basis.

Table 21 provides a description of the possible restoration strategies that address the various impairments and stressors, and examples of BMPs that could help achieve the restoration goals. Not all of the strategies or BMPs have been used in the creation of **Table 20**. Alternatively, some of the strategies and BMPs listed in **Table 20** may be more specific than those listed in **Table 21** as some have been customized to better pertain to the impaired waterbody.

Table 20: Strategies and actions proposed for the Two Rivers Watershed.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.: Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Governmental Units with Primary Responsibility: Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
All	All	All	Parameters cited in permit	-	-	Wastewater facilities -- compliance with NPDES permits								●							-
			Parameters cited in permit	-	-	Construction and Industrial Stormwater permittees -- compliance with general permits								●							-
			Nitrogen (TN) or Nitrate		13% load reduction per Nutrient Reduction Strategy	**Increase fertilizer and manure efficiency**	Increase row crop acres utilizing U of MN recommendations for the economic optimal nitrogen rate after crediting all legumes and manure, varying with level of adoption of vegetative cover BMP.	20%	50%	100%	% row crop acres		●					●			2040 per Nutrient Reduction Strategy (MPCA 2014b)
						Store and treat tile drainage waters	Treat tiled cropland using constructed/restored wetlands or other practices	2%	5%	10%	% of agricultural areas	●							●		
							Controlled drainage on tile-drained row cropland	3%	15%	30%	% of tiled acres								●		
						Increase vegetative cover/root duration [to reduce nitrate leaching]	Cover crops on a) earlier harvest crops (EHC) and b) corn and soybean lands (C/S)	<1% EHC <1% C&S	5% of EHC 5% of C/S	10% of EHC 10% of C/S	% of crop land in each category (EHC and C/S)		●						●		
							Convert marginal lands to perennial cover (marginal lands as determined by Crop Productivity Index)		80%	100%	acres							●			
			TSS, TP	(See watersheds below)		**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams		●				●				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								●		
							0pen tile inlets with either riser pipes, rock		70	100%	% of open tile inlets where applicable										

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							inlets or other protection														
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
			TSS, TP, Altered hydrology			**Increase vegetative cover/root duration**	Cover crops on early harvest crops and fallow land	0%	5%	15%	% of early harvest and fallow lands with cover		•						•		
			TP, *E. coli*			**Prevent feedlot runoff**	Fix open lot runoff problems per 7020 rules and open lot agreement.	80%	90%	100%	# open lots in compliance										
						Improve fertilizer and manure application management	Applying P fertilizer only on fields needing P for optimal crop growth		70%	90%	% of agricultural acres										
							Fertilizer and manure injected or immediately incorporated		70%	90%	% of agricultural acres										
						Improve livestock and manure management	All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Winter manure spreading reduced		40%	60%	% of agricultural acres								•		
							Inject or immediately incorporate manure where currently surface applied		40%	60%	% of agricultural acres								•		
State Ditch No 91 (0902031201)	County Ditch 4 (09020312-522)	Roseau	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 15	Fish IBI ≥ 42	**Increase living cover** [to increase	Increase living cover in watershed through cover crops, perennials	5%	15%	25%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						infiltration and evapotranspiration]	and well-managed pastures														
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
			Poor Habitat (Fish IBI)	Fish IBI = 15	Fish IBI ≥ 42	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 15	Fish IBI ≥ 42	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
State Ditch No 95 (0902031202)	Two River, South Branch (09020312-505)	Kittson	***E. coli***	Very High=88,242 Bil. org/day High=631 Bil. org/day	Geometric mean ≤ 126 org/100ml	**Improve livestock and manure management**	*See strategies to reduce field TSS (applied to manured fields)*														
							Livestock exclusion on pastured stream miles	0.01%	0.01%	5%	% of stream miles		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
				Mid=191 Bil. org/day Low=24.2 Bil. org/day Very Low=ND			Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•								
							All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage		•	•							
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•								
						Address failing septic systems	Maintain septic (SSTS) systems	90%	100%	100%	# of noncompliant septic systems			•	•					•	
			Macroinvertebrate IBI - TSS	Macro IBI = 29	Macro IBI ≥ 37	**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology;*														

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
								Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units										
							peak flow (Fish/Macroinvertebrate IBI)"														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	60%	70%	100%	% sediment reduction for unpermitted areas			•	•						
			Dissolved Oxygen	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 36 Macro IBI = 29	20% reduction in peak flows; Fish IBI ≥ 47 Macro IBI ≥ 37	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or	30%	60%	100%	% of qualifying acres		•								

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility: Watershed District, SWCD, MPCA, County, DNR, BWSR, MDA, NRCS, MDH

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							other BMPs (to store and infiltrate water)														
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			●							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	●	●								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 36 Macro IBI = 29	Fish IBI ≥ 47 Macro IBI ≥ 37	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	●	●								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	●	●								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	●	●								
							Restore riparian wetlands		100	500	acres of wetland		●								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	●	●								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		●								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					●					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	●	●								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 36	Fish IBI ≥ 47	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	Two River, South Branch (09020312-506)	Roseau	***E. coli***	Very High=ND High=568 Bil. org/day Mid=63.8 Bil. org/day Low=209 Bil. org/day Very Low=ND	Geometric mean ≤ 126 org/100ml	**Improve livestock and manure management**	*See strategies to reduce field TSS (applied to manured fields)*														
							Livestock exclusion on pastured stream miles	0.01%	0.01%	5%	% of stream miles		•								
							Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•								
							All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage		•	•							
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•								
						Address failing septic systems	Maintain septic (SSTS) systems	90%	100%	100%	# of noncompliant septic systems			•	•					•	
			Macroinvertebrate IBI - TSS	Macro IBI = 30, 32, 42	Macro IBI ≥ 41, 37, 41, resp.	**Improve upland/field surface runoff controls** [to reduce	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						or intercept farm field erosion]	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow (Fish/Macroinvertebrate IBI)"*														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.														
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	60%	70%	100%	% sediment reduction for unpermitted areas			•	•						
			Dissolved Oxygen	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 38, 38, 49 Macro IBI = 30, 32, 42	20% reduction in peak flows; Fish IBI ≥ 47 Macro IBI ≥ 41, 37, 41, resp.	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate				Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
								Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units										
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 38, 38, 49 Macro IBI = 30, 32, 42	Fish IBI ≥ 47 Macro IBI ≥ 41, 37, 41, resp.	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in	0	2%	2%	% of watershed	•	•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									
							riparian, control invasive species				area addressed										
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 38, 38, 49	Fish IBI ≥ 47	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	Lateral Ditch 1 of State Ditch 95 (09020312-521)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 0, 55 Macro IBI = 44	20% reduction in peak flows; Fish IBI ≥ 47 Macro IBI ≥ 41	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.						Governmental Units with Primary Responsibility									
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		●								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	●	●								
							Restored / treatment wetlands	0	100	200	acres of wetland		●								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	●	●								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		●								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		●								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		●								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			●							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	●	●								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 0, 55 Macro IBI = 44	Fish IBI ≥ 47 Macro IBI ≥ 41	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	●	●								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.: Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Governmental Units with Primary Responsibility: Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 0, 55	Fish IBI ≥ 47	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	County Ditch 13 (09020312-535)	Roseau	***E. coli***	Very High=ND High=10.3 Bil. org/day Mid=10.4 Bil. org/day Low=12.4 Bil. org/day Very Low=ND	Geometric mean ≤ 126 org/100ml	**Improve livestock and manure management**	*See strategies to reduce field TSS (applied to manured fields)*														
							Livestock exclusion on pastured stream miles	0.01%	0.01%	5%	% of stream miles		•								
							Animal mortality storage areas consistent with Bd. Animal Health	0	0	0	# noncompliant		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							rules and feedlot permits.				mortality storage sites										
							All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage		•	•							
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•								
						Address failing septic systems	Maintain septic (SSTS) systems	90%	100%	100%	# of noncompliant septic systems			•	•					•	
	Lateral Ditch 1 of State Ditch 95 (09020312-539)	Roseau	**Macroinvertebrate IBI - TSS**	Macro IBI = 10	Macro IBI ≥ 22	**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow*														

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							(Fish/Macroinvertebrate IBI)"														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.: Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Governmental Units with Primary Responsibility: Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	60%	70%	100%	% sediment reduction for unpermitted areas			•	•						
			Dissolved Oxygen	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 8 Macro IBI = 10	20% reduction in peak flows; Fish IBI ≥ 35 Macro IBI ≥ 22	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or	30%	60%	100%	% of qualifying acres		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							other BMPs (to store and infiltrate water)														
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 8 Macro IBI = 10	Fish IBI ≥ 35 Macro IBI ≥ 22	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 8	Fish IBI ≥ 35	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
Middle Branch Two Rivers (0902031203)	Two River, Middle Branch (09020312-503)	Kittson	***E. coli***	Very High=112.7 Bil. org/day High=45.6 Bil. org/day Mid=18.1 Bil. org/day Low=11.0 Bil. org/day Very Low=ND	Geometric mean ≤ 126 org/100ml	**Improve livestock and manure management**	*See strategies to reduce field TSS (applied to manured fields)*														
							Livestock exclusion on pastured stream miles	0.01%	0.01%	5%	% of stream miles		•								
							Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•								
							All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage		•	•							
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•								
						Address failing septic systems	Maintain septic (SSTS) systems	90%	100%	100%	# of noncompliant septic systems			•	•					•	
			Maroinvertebrate IBI - TSS	Macro IBI = 33, 50, 53	Macro IBI ≥ 41	**Improve upland/field surface runoff controls** [to reduce	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						or intercept farm field erosion]	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow (Fish/Macroinvertebrate IBI)"*														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	60%	70%	100%	% sediment reduction for unpermitted areas			•	•						
			Dissolved Oxygen	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 42, 79, 0, 12 Macro IBI = 33, 50, 53	20% reduction in peak flows; Fish IBI ≥ 42, 50, 50, 50, resp. Macro IBI ≥ 41	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 42, 79, 0, 12 Macro IBI = 33, 50, 53	Fish IBI ≥ 42, 50, 50, 50, resp. Macro IBI ≥ 41	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in	0	2%	2%	% of watershed	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							riparian, control invasive species				area addressed										
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 42, 79, 0, 12	Fish IBI ≥ 42, 50, 50, 50, resp.	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
State Ditch No 85 (0902031204)	State Ditch 72 (09020312-531)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Fish IBI = 33 Macro IBI = 34	20% reduction in peak flows; Fish IBI ≥ 47 Macro IBI ≥ 41	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 33 Macro IBI = 34	Fish IBI ≥ 47 Macro IBI ≥ 41	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 33	Fish IBI ≥ 47	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
North Branch Two Rivers (0902031206)	Two River, North Branch (09020312-504)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.	Estimated Adoption Rate				Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 37, 53, 48, 39, 57	20% reduction in peak flows; Fish IBI ≥ 47, 47, 47, 47, 50, resp.	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		●								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		●								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	●	●								
							Restored / treatment wetlands	0	100	200	acres of wetland		●								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	●	●								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		●								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		●								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		●								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			●							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	●	●								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
			Poor Habitat (Fish IBI)	Fish IBI = 37, 53, 48, 39, 57	Fish IBI ≥ 47, 47, 47, 47, 50, resp.	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 38	Fish IBI ≥ 47	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	Two River, North Branch (09020312-508)	Kittson	Dissolved Oxygen	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Fish IBI - TSS	Fish IBI = 39, 39, 66	Fish IBI ≥ 49	**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow (Fish/Macroinvertebrate IBI)"*														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	60%	70%	100%	% sediment reduction for unpermitted areas			•	•						
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 39, 39, 66	Fish IBI ≥ 49	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control	Increase tile drainage waters draining into wetlands, saturated	5%	10%	15%	% of drained cropland acres going into	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						the release of tile drainage water]	buffers and other practices				treatment systems										
							Restored / treatment wetlands	0	100	200	acres of wetland		●								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	●	●								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		●								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		●								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		●								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			●							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	●	●								
			Poor Habitat (Fish IBI)	Fish IBI = 39, 39, 66	Fish IBI ≥ 49	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	●	●								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	●	●								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	●	●								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 39, 39, 66	Fish IBI ≥ 49	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	State Ditch 84 (09020312-514)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 0, 35	Fish IBI ≥ 42	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish IBI)	Fish IBI = 0, 35	Fish IBI ≥ 42	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in	0	2%	2%	% of watershed	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							riparian, control invasive species				area addressed										
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 0, 35	Fish IBI ≥ 42	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	Judicial Ditch 31 (09020312-549)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 0, 0	20% reduction in peak flows; Fish IBI ≥ 42	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish IBI)	Fish IBI = 0, 0	Fish IBI ≥ 42	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 0, 0	Fish IBI ≥42	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
South Branch Two Rivers (0902031207)	Two River (09020312-501)	Kittson	***E. coli***	Very High=9,562 Bil. org/day High=409 Bil. org/day Mid=197 Bil. org/day Low=119 Bil. org/day	Geometric mean ≤ 126 org/100ml	**Improve livestock and manure management**	*See strategies to reduce field TSS (applied to manured fields)*														
							Livestock exclusion on pastured stream miles	0.01%	0.01%	5%	% of stream miles		•								
							Animal mortality storage areas consistent with Bd. Animal Health	0	0	0	# noncompliant		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
				Very Low=20 Bil. org/day			rules and feedlot permits.				mortality storage sites										
							All Minn. R. ch. 7020 manure spreading setbacks are met		90%	100%	% of agricultural acres		•	•	•						
							Total containment of manure storage	50%	75%	100%	% of animal units with manure going to storage		•	•							
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•								
						Address failing septic systems	Maintain septic (SSTS) systems	90%	100%	100%	# of noncompliant septic systems			•	•					•	
			TSS	Very High=820.94 tons/day High=131.50 tons/day Mid=28.37 tons/day Low=6.13 tons/day Very Low=0.89 tons/day	TSS ≤ 65 mg/L	**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							Open tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow*														

Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.

Governmental Units with Primary Responsibility

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							(Fish/Macroinvertebrate IBI)"														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
							Stabilization within ravines--vegetative practices and/or engineered structures	[X%]	[XX%]	100	% High-priority ravines addressed		•			•					
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	[X%]	[XX%]	100%	% sediment reduction for unpermitted areas			•							
	Two River, South Branch (09020312-502)	Kittson	**Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)**	Fish IBI = 37, 50, 51, 59 Macro IBI = 30, 58, 70	20% reduction in peak flows; Fish IBI ≥ 49, 49, 38, 38, resp. Macro IBI ≥ 31	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater	Reduce post-construction	60%	80%	100%	Percent flow reduction for			•							

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						management [to decrease urban stormwater volume]	stormwater volume for redevelopment projects				unpermitted areas										
						Improve irrigation water management [to decrease ground water withdrawals]	Irrigation water management plans to minimize water withdrawals on irrigated crops	10%	20%	50%	Adoption rate	•	•								
			Poor Habitat (Fish/Macroinvertebrate IBI)	Fish IBI = 37, 50, 51, 59 Macro IBI = 30, 58, 70	Fish IBI ≥ 49, 49, 38, 38, resp. Macro IBI ≥ 31	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 37, 50, 51, 59	Fish IBI ≥ 49, 49, 38, 38, resp.	**Remove fish passage barriers**	Dam removal or fish passage project	0	2	3	# of dam improvements					•					

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
				Macro IBI = 30, 58, 70	Macro IBI ≥ 31		Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
	Two River (09020312-509)	Kittson	**TSS**	Very High=1509.27 tons/day High=579.54 tons/day Mid=154.03 tons/day Low=26.60 tons/day Very Low=2.21 tons/day	TSS ≤ 65 mg/L	**Improve upland/field surface runoff controls** [to reduce or intercept farm field erosion]	Increase living cover through cover crops, perennials and well-managed pastures	15%	20%	30%	% of watershed area		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•				•				
							HEL lands and >3% sloped cropland at ≥30% residue cover or equivalent	80%	90%	100%	% of priority lands with residue protection								•		
							0pen tile inlets with either riser pipes, rock inlets or other protection		70	100%	% of open tile inlets where applicable										
							Tilled sloping row-cropped lands protected with grassed waterways, WASCOBs, contour farming and/or other BMPs		80%	100%	% of applicable lands with listed BMPs	•	•					•	•		
						Protect/stabilize banks/bluffs	*See all examples for "Altered hydrology; peak flow (Fish/Macroinvertebrate IBI)"*														
							Highly-eroding banks identified and stabilized	20%	40%	100%	% of banks identified and stabilized		•								
							50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•								
							Livestock exclusion on pastures near streams	0.01%	0.01%	5%	% of stream miles		•								
							Construct floodwater impoundments	0	10000	25000	Acre-feet of storage impoundments		•								

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	Estimated Year to Achieve Water Quality Target
							Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•								
							Tree and grass planting for stabilization on streams	0	2	5	stream miles		•								
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10,000	25,000	Feet of ditch	•	•			•					
							Re-meander channelized stream reaches	2	10	30	stream miles		•			•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•					
						Stabilize ravines	*See all examples for TSS - reducing upland/field surface runoff*														
							Stabilization within ravines--vegetative practices and/or engineered structures	[X%]	[XX%]	100	% High-priority ravines addressed		•			•					
						Improve urban stormwater management [to reduce sediment and flow]	Combination of practices to achieve sediment reduction from baseline levels	[X%]	[XX%]	100%	% sediment reduction for unpermitted areas			•							
	State Ditch 49 (09020312-544)	Kittson	**Dissolved Oxygen**	<5 mg/L during low flow	5+ mg/L	**Reduce phosphorus**	*See TP strategies*						•								
						Increase river flow during low flow years	*See Altered hydrology; low base flow strategies*					•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						Restore stream channel	Restore over-widened reaches	2	10	30	stream miles	•								•	
			Altered hydrology; peak flow and/or low base flow (Fish IBI)	Fish IBI = 0, 0	20% reduction in peak flows; Fish IBI ≥ 42	**Increase living cover** [to increase infiltration and evapotranspiration]	Increase living cover in watershed through cover crops, perennials and well-managed pastures	5%	15%	25%	% of watershed area		•								
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•								
						Improve drainage management [to store and control the release of tile drainage water]	Increase tile drainage waters draining into wetlands, saturated buffers and other practices	5%	10%	15%	% of drained cropland acres going into treatment systems	•	•								
							Restored / treatment wetlands	0	100	200	acres of wetland		•								
							Controlled drainage on suitable tile-drained row cropland	10%	50%	75%	% of watershed area	•	•								
						Reduce flashiness of waterways	Construct floodwater impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•								
						Reduce rural runoff by increasing infiltration, residue management	80% row cropland at 30% residue cover	30%	50%	100%	% row cropland at 30% residue cover		•								
							Tilled sloping lands with WASCOBs, terraces, contour farming and/or other BMPs (to store and infiltrate water)	30%	60%	100%	% of qualifying acres		•								
						Improve urban stormwater management [to decrease urban stormwater volume]	Reduce post-construction stormwater volume for redevelopment projects	60%	80%	100%	Percent flow reduction for unpermitted areas			•							
						Improve irrigation water management [to	Irrigation water management plans to minimize water	10%	20%	50%	Adoption rate	•	•								

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						decrease ground water withdrawals]	withdrawals on irrigated crops														
			Poor Habitat (Fish IBI)	Fish IBI = 0, 0	Fish IBI ≥ 42	Improve riparian vegetation	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of stream miles	•	•								
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•								
							Improve/increase natural habitat in riparian, control invasive species	0	2%	2%	% of watershed area addressed	•	•								
							Restore riparian wetlands		100	500	acres of wetland		•								
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•								
							Streambank protection / stabilization	0	5000	10000	Feet of shoreline		•								
						Restore/enhance channel	Dam removals, dam improvements, or fish passage to mimic natural conditions	0	1	2	# dam improvements					•					
							Install two-stage ditches on drainage ditches	0	20,000	100,000	Feet of ditch	•	•								
							Apply habitat improvement work [per Trout Unlimited habitat improvement methods, NRCS practices and DNR stream restoration principles]	0	5,000	10,000	Feet of stream					•					
			Connectivity (Fish IBI)	Fish IBI = 0, 0	Fish IBI ≥ 42	Remove fish passage barriers	Dam removal or fish passage project	0	2	3	# of dam improvements					•					
							Replace hanging/undersized culverts	80%	90%	100%	% complete					•					
All			All			Implement volume control / limited-	Apply to all projects when developing undeveloped land to	60%	80%	100%	% in compliance with MS4										

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units	Watershed District	SWCD	MPCA	County	DNR	BWSR	MDA	NRCS	MDH	
						impact development	provide no net increase in volume and pollutants				permit conditions										
	Note: Many entries from the above restoration rows may be translated for use in protection rows. Additional protection-related guidance is in development.																				

	Point Sources
	Strategies to address downstream impairments
	Restoration
	Protection

Table 21: Key for Strategies Column.[3]

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
TSS	Improve upland/field surface runoff controls: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow- some of flow reduction strategies should be targeted to ravine subwatersheds
		Residue management - conservation tillage
		Forage and biomass planting
		Open tile inlet controls - riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks, and/or filter strips
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion - controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also, may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks, and/or filter strips
		Contour farming and contour buffer strips
		Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management - conservation tillage
	Stream Channel Restoration	Addressing road crossings (direct erosion) and floodplain cut-offs
		Clear water discharge: urban areas, ag tiling, etc. – direct energy dissipation
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Improve forestry management	Proper Water Crossings and road construction
		Forest Roads - Cross-Drainage
		Maintaining and aligning active Forest Roads
		Closure of Inactive Roads & Post-Harvest
		Location & Sizing of Landings
		Riparian Management Zone Widths and/or filter strips
	Improve urban stormwater management [to reduce sediment and flow]	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
Nitrogen (TN) or Nitrate	Increase fertilizer and manure efficiency: Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at Maximum Return to Nitrogen (U of MN rec's)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	Improve upland/field surface runoff controls: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials

[3]For more information on these practices, please see the MDA Agricultural Best Management Practice (BMP) Handbook for Minnesota at: https://bbe.umn.edu/sites/bbe.umn.edu/files/agricultural-best-management-practices-handbook-for-minnesota-second-edition.pdf

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
	Preventing feedlot runoff: Using manure storage, water diversions, reduced lot sizes, and vegetative filter strips to reduce open lot phosphorus losses	Open lot runoff management to meet Minn. R. Ch. 7020
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto soils where it is most needed using techniques that limit exposure of phosphorus to rainfall and runoff.	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil
		Manure application meeting all Minn. R. Ch. 7020 setback requirements
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering around lakes
		Eliminating straight pipes, surface seepages
	Reduce in-water loading: Minimizing the internal release of phosphorus within lakes	Rough fish management
		Curly-leaf pondweed management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Improve forestry management	See forest strategies for sediment control
	Reduce Industrial/Municipal wastewater TP	Municipal and industrial treatment of wastewater P
		Upgrades/expansion. Address inflow/infiltration.
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	Reducing livestock bacteria in surface runoff: Preventing manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce Industrial/Municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTP untreated (emergency) releases
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate
Chloride	Road salt management	[Strategies currently under development within Twin Cities Metro Area Chloride Management Plan]
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Increase living cover: Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements & buffers of native grass & trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins, terraces
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management
Poor Habitat (Fish/Macroinvertebrate IBI)	Improve riparian vegetation: Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants, and increase biodiversity	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	**Example BMPs/actions**
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water Temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	Removal of fish passage barriers: Identify and address barriers.	Remove impoundments
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All [protection-related]	Implement volume control / limited-impact development: This is aimed at development of undeveloped land to provide no net increase in volume and pollutants	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs

4. Monitoring plan

Continued monitoring within the TRW will be addressed primarily through the efforts of the TRWD. A summary of scheduled water quality sampling, in addition to recommendations for additional sampling needs, is outlined in the Two Rivers Watershed Restoration and Protection Strategy Data Review and Sampling Plan (HEI 2014b). Ongoing and historical water quality monitoring actions taken by the TRWD are also outlined within the Overall Plan of the TRWD (TRWD 2004).

Four monitoring components are outlined within the Two Rivers WRAPS Data Review and Sampling Plan (HEI 2014b), including water chemistry (quality) sampling, biological sampling and flow monitoring. Ongoing water quality sampling occurs at 25 river/stream sites within the TRW that are sampled primarily between June 1 and September 30, with the majority of the data collected for DO, *E. coli*, eutrophication, pH, turbidity, and TSS. Minimum sample sizes for these parameters are determined by the data requirements for select water quality parameters in Minnesota's rivers and streams. Twelve citizen groups and LGU programs performed water chemistry sampling during the past 10-year assessment period, which are anticipated to have continued involvement in future water chemistry sample collection.

Future biological assessment sampling within the TRW includes resampling of seven locations for fish and four locations for macroinvertebrates (Dingmann 2014). Five long-term flow monitoring stations will continue to operate as permanent long-term stations, which will be visited every 30 to 40 days with additional visits during high flows (HEI 2014b). Section 7 of the Overall Plan of the TRWD (TRWD 2004), outlines additional details of historical and ongoing TRWD water quality and flow monitoring program actions.

5. References and further information

Carlyle, W. J. 1984. Water in the Red River Valley of the North. Geographical Review, 74(3): 331-358.

Christopherson, D. 2014. Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites. Report by the Minnesota Pollution Control Agency (MPCA).

Dingmann, T. 2014. Personal Communication. Minnesota Pollution Control Agency, North Biological Monitoring Unit. Baxter, MN.

Frans, C.; E. Istandbullouglu; V. Mishra; F. Munoz-Arriola; and D. P. Lettenmaier. 2013. Are climatic or land cover changes the dominant cause of runoff trends in the Upper Mississippi River Basin? Geophysical Research Letters, 40:1-7.

Helsel, D. R. and R. M. Hirsch. 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. 522 pages.

Hirsch, R. M.; J. R. Slack; and R. A. Smith. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research, 18(1):107-121.

Homer, C. G.; J. A. Dewitz; L. Yang; S. Jin; P. Danielson; G. Xian; J. Coulston; N. D. Herold; J. D. Wickham; and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, 81(5): 345-354.

Houston Engineering, Inc. (HEI). 2014a. Two Rivers Watershed Watershed Restoration and Protection Strategy Watershed Conditions Report. April, 2014.

Houston Engineering, Inc. (HEI). 2014b. Two Rivers Watershed Watershed Restoration and Protection Strategy Data Review and Sampling Plan. June, 2014.

Houston Engineering, Inc. (HEI). 2015. Long Term Trend Analysis Memo, Two Rivers Advanced Statistical Analysis.

Houston Engineering, Inc. (HEI). 2019. Two Rivers Watershed Total Maximum Daily Load (TMDL). June 2019.

Johnson, H. O.; S. C. Gupta; A. V. Vecchia; and F. Zvomuya. 2009. Assessment of water quality trends in the Minnesota River using non-parametric and parametric methods. Journal of Environmental Quality, 38: 1018-1030.

Minnesota Department of Natural Resources (DNR). 2003. DNR 24k Streams [Online]. Available at https://catalog.data.gov/dataset/dnr-24k-lakes (verified 22 May 2019).

Minnesota Pollution Control Agency (MPCA). 2012. Shapefile: Assessed waters (2012) [Online] Available at https://www.pca.state.mn.us/data/spatial-data (downloaded 15 January 2014, verified 24 May 2019).

Minnesota Pollution Control Agency (MPCA). 2014a. Sand Hill River Watershed Biotic Stressor Identification Report [Online]. June 2014. Available at http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/red-river-of-the-north-sandhill-river.html (verified 24 May 2019).

Minnesota Pollution Control Agency (MPCA). 2014b. The Minnesota Nutrient Reduction Strategy. St. Paul, MN. June, 2016. Available at https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf (verified 24 May 2019).

Minnesota Pollution Control Agency (MPCA). 2016a. Two Rivers Watershed Monitoring and Assessment Report. St. Paul, MN. June, 2016.

Minnesota Pollution Control Agency (MPCA). 2016b. Two Rivers Watershed Stressor Identification Report. St. Paul, MN. June, 2016.

RESPEC. (2014). Two Rivers Model Development Revision 1. Memorandum to Michael Vavricka, MPCA. March, 2014.

Schottler, S. P.; J. Ulrich; P. Belmont; R. Moore; J. W. Lauer; D. R. Engstrom; and J. E. Almendinger. 2013. Twentieth century agricultural drainage creates more erosive rivers. Hydrological Processes, DOI:10.1002/hyp.9738.

Tomer, M. D.; W. G. Crumpton; R. L. Bingner; J. A. Kostel; D. E. James. 2013. Estimate nitrate load reductions from placing constructed wetlands in a HUC-12 watershed using LiDAR data. Ecological Engineering, 56: 69-78.

Two Rivers Watershed District (TRWD). 2004. Overall Plan of the Two Rivers Watershed District. July, 2004.

Two Rivers Watershed Reports

All Two Rivers Watershed reports referenced in this watershed report are available at the Two Rivers Watershed webpage: https://www.pca.state.mn.us/water/watersheds/two-rivers.

6. Appendices

Appendix A: Technical Memorandum – Priority Ranking of Subwatershed in the Two Rivers Watershed Using HSPF Results.

Appendix B: Technical Memorandum – PTMApp to aid in the development of WRAPS Strategies.

Appendix C: Existing Water Quality, Existing Loads, and Loading Capacity for Stream Reaches in the TRW.

Appendix D: Technical Memorandum – BMP Implementation Scenarios using HSPF Objective 8 Hydrologic Simulation Program – FORTRAN (HSPF) Model Development Assistance and Incorporation.

See Appendix A in the Two River Watershed Total Maximum Daily Load (TMDL) Report (HEI 2019) for information about the load duration curves (LDCs).

Appendix A: Priority Ranking of Subwatershed in the Two Rivers Watershed Using HSPF Results.

Using results from the Two Rivers Watershed (TRW) Hydrologic Simulation Program - FORTRAN (HSPF) model, areas within the watershed were prioritized based upon the magnitude of nonpoint sources to identify subwatersheds where restoration and protection strategies would be most beneficial. Subwatersheds were prioritized by ranking the area-averaged yields (pounds/acre/year) from the HSPF model for unit runoff (RO), total phosphorus (TP), total nitrogen (TN), and total sediment. Prioritization is based solely on the estimated mass leaving the landscape. The consideration of other factors could change the prioritization outcome.

The TRW HSPF Model

The TRW HSPF model was constructed to inform the Watershed Restoration and Protection Strategy (WRAPS) and watershed-wide Total Maximum Daily Load (TMDL) Projects currently being undertaken by the Minnesota Pollution Control Agency (MPCA) and Houston Engineering Inc (HEI). The TRW HSPF model simulates hydrology and water quality for the TRW 8-digit Hydrologic Unit Code (HUC) 9020312 (see **Figure A-1**).

In HSPF, a watershed is divided into “model segments”, usually called hydrozones, based on the locations of the climate stations. Each model segment uses a unique set of climate data. Each model segment is further divided into subwatersheds with each subwatershed containing one hydrologic reach (lake, reservoir, or river). Each modeling segment is composed of multiple land segments called PERLNDs (pervious areas) and IMPLNDs (impervious areas). These PERLNDs and IMPLNDs are typically based on land uses and soil types and a subwatershed can be composed of multiple PERLND/IMPLND types. Runoff and water quality loadings are simulated for each PERLND/IMPLND in a modeling segment, i.e. the same flows and loadings are used across all subwatersheds in a modeling segment for each individual PERLND/IMPLND type. The amount of runoff and loading differ between subwatersheds based on differing acreage of each PERLND/IMPLND type.

The TRW HSPF model is composed of 11 modeling segments, or hydrozones (**Figure A-1**) and further divided into 90 subwatersheds (**Figure A-1**). Each modeling segment, and therefore subwatershed, is divided by up to 9 land-use/soil classes (PERLNDs) and one impervious land use class (IMPLND), for a total of 99 possible PERLNDs in the HSPF model (see **Figure A-2**). The PERLND classes include urban, forest with A/B soils (soil is type A [sand, loamy sand, or sandy loam] when drained, type B [silt loam or loam] when undrained), forest with C/D soils (soil is type C [sandy clay loam] when drained, type D [clay loam, silty clay loam, sandy clay, silty clay, or clay] when undrained), cropland-high tillage, cropland-low tillage, grasslands, pasture, wetlands, and feedlots. It should be noted, feedlots are taken as a portion of cropland and are not represented as a land segment in **Figure A-2**.

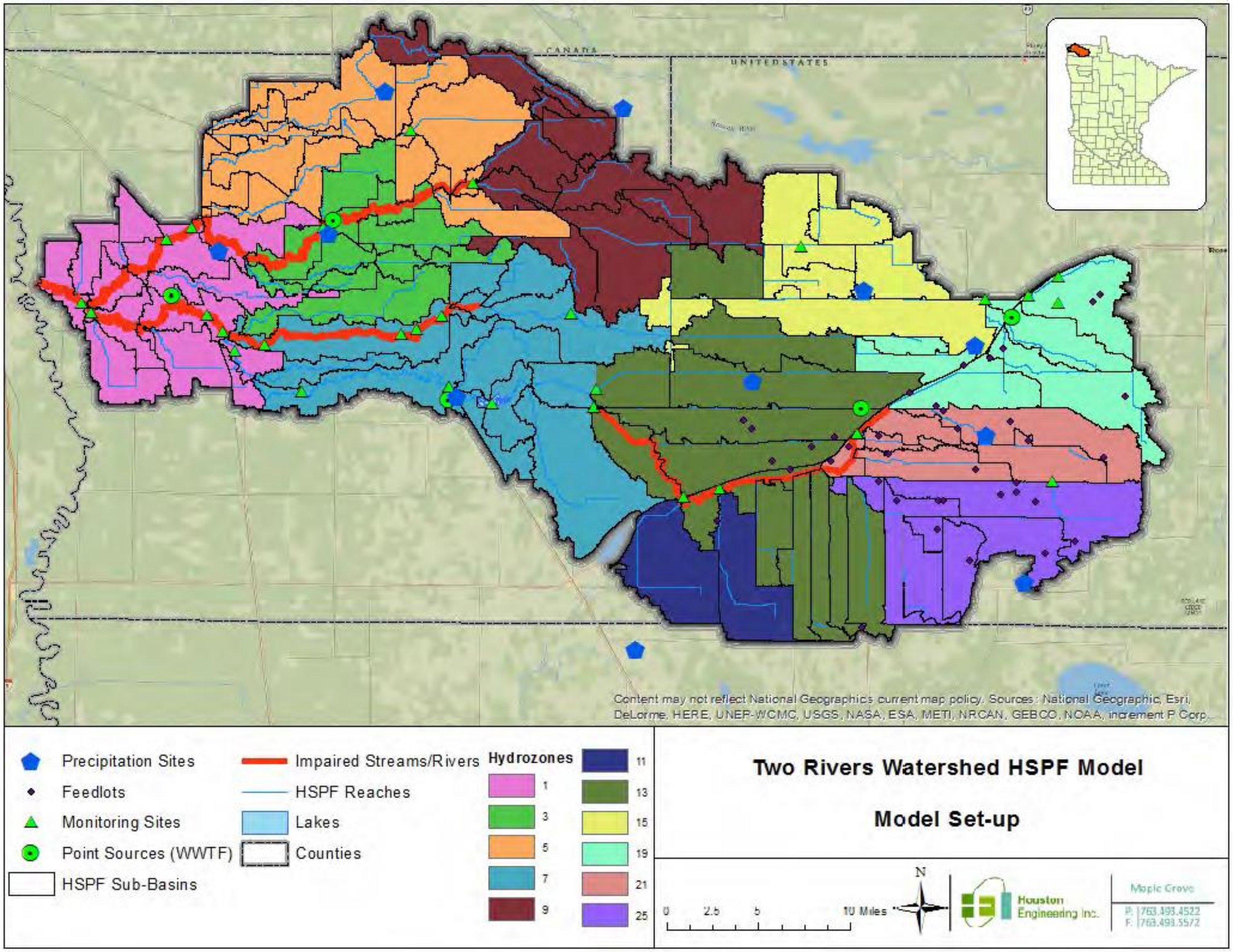


Figure A-1: Set-up for the Two Rivers Watershed HSPF model.

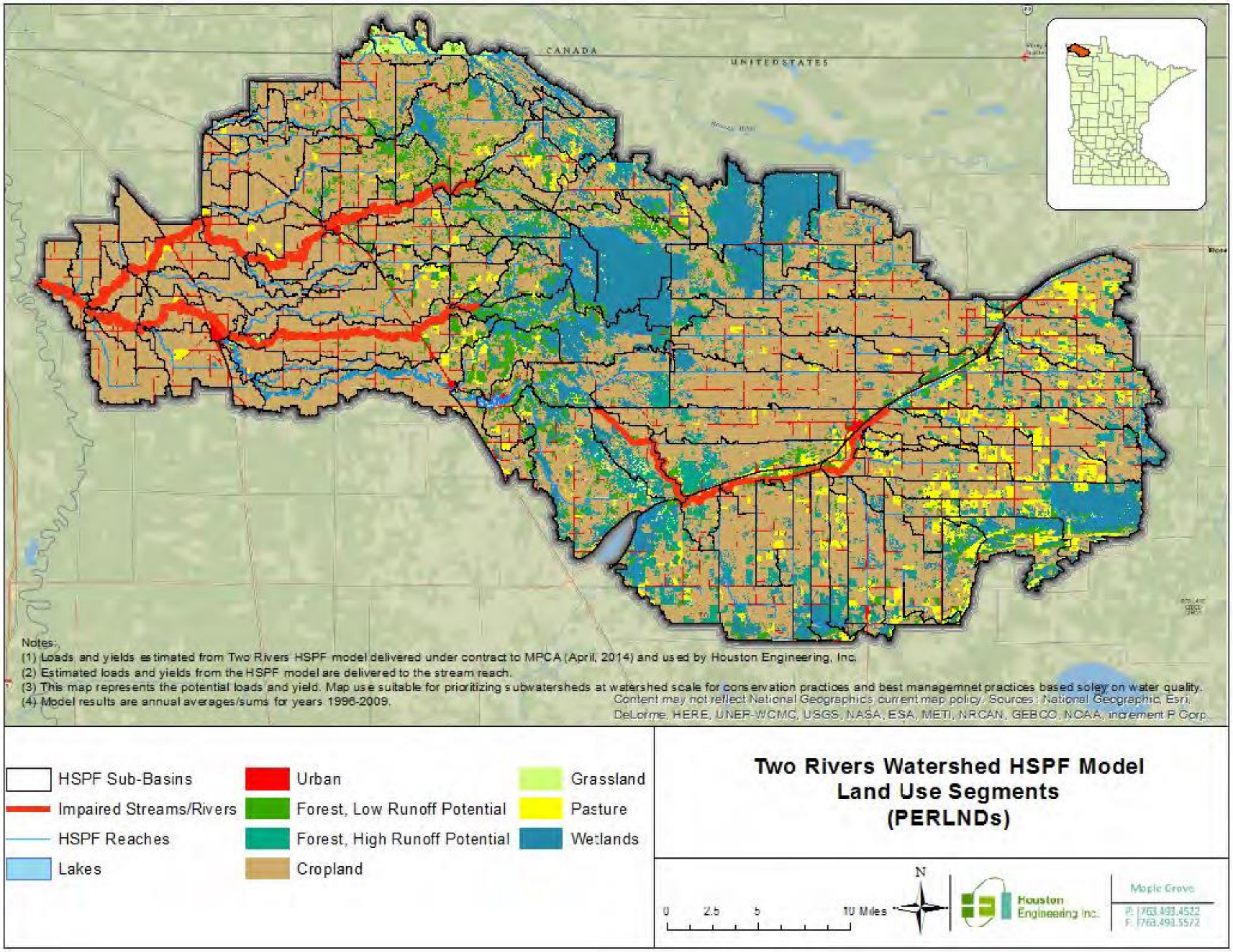


Figure A-2: Land Classifications (PERLNDs) in the TRW HSPF model.

Using the HSPF Model Output for Prioritization

Subwatershed priority rankings were developed for several stressors including altered hydrology (expressed as RO), excess nutrients (TP, TN) and turbidity and habitat alteration/geomorphology (total sediment). **Table A-1** shows the required outputs, by constituent and land class (PERLND, IMPLND, or RCHRES [reach reservoir]), in the HSPF model. The following is a brief description of the components used to develop the maps and shown in **Table A-1**.

In HSPF, RO from a land segment has three components: surface runoff, interflow, and active groundwater flow. For PERLNDs, RO is taken as the sum of the three flow components and is outputted. RO from IMPLNDs only has a surface runoff component. In-channel (RCHRES) streamflow was not used in this analysis.

Overland TP loading is the sum of inorganic phosphorus loading and organic phosphorus loading. Inorganic phosphorus in simulated directly using the PQUAL group. Inorganic phosphorus is taken as a fraction of the organic material simulated as biological oxygen demand (BOD). For pervious land segments (PERLNDs), differing factions of organic phosphorus is used for surface runoff, interflow, and active groundwater flow (see **Table A-1**). In channel TP loading has various forms but can be extracted from HSPF as TP using the PLANK group. In channel TP flux is taken as the difference between TP inflow and TP outflow for the hydrologic reach.

Like phosphorus, overland TN has multiple forms and is taken as the summation of ammonia (NH3), nitrate-nitrite (NO2NO3), and organic nitrogen loadings. NH3 and NO2NO3 are simulated directly using the PQUAL group. Organic nitrogen is taken as a fraction of the organic material simulated as BOD with varying fractions for different flow types (surface runoff, interflow, and active groundwater) (see **Table A-1**). In channel TN loading has various forms but can be extracted from HSPF as TN using the PLANK group. In channel TN flux is taken as the difference between TN inflow and TN outflow for the hydrologic reach.

Overland sediment can be extracted directly from the HSPF model as total sediment from overland sources using the SEDMNT group for PERLNDs and SOLIDS group for IMPLNDs. In channel sediment loading and sediment flux can be extracted directly using the SEDTRN group. In channel sediment flux can be taken as the change in bed storage.

Table A-1: HSPF Model Outputs for RO, TP, TN, and Total Sediment Used to Prioritize Subwatersheds for Implementation.

WQ Parameter	Description	Volume	Group	Variable	x1	x2	Factor
Unit Runoff	Total runoff from pervious areas	PERLND	PWATER	PERO	1	1	
	Surface water runoff for impervious areas	IMPLND	IWATER	SURO	1	1	
Total Phosphorus	Total flux of inorganic P (PO4)	PERLND	PQUAL	POQUAL	3	1	
	Portion of BOD composed of organic P in Surface runoff	PERLND	PQUAL	SOQUAL	4	1	0.0005
	Portion of BOD composed of organic P in active groundwater	PERLND	PQUAL	AOQUAL	4	1	0.0004
	Portion of BOD composed of organic P in interflow	PERLND	PQUAL	IOQUAL	4	1	0.0005
	Total flux of inorganic P (PO4)	IMPLND	IQUAL	SOQUAL	3	1	
	Portion of BOD composed of organic P in Surface runoff	IMPLND	IQUAL	SOQUAL	4	1	0.0005
	Total inflow of TP	RCHRES	PLANK	TPKIF	5	1	
	Total outflow of TP	RCHRES	PLANK	TPKCF1	5	1	
Total Nitrogen	Total flux of Ammonia (NH3)	PERLND	PQUAL	POQUAL	1	1	
	Total flux of Nitrate-Nitrite (NO2NO3)	PERLND	PQUAL	POQUAL	2	1	
	Portion of BOD composed of organic N in Surface runoff	PERLND	PQUAL	SOQUAL	4	1	0.0407
	Portion of BOD composed of organic N in active groundwater	PERLND	PQUAL	AOQUAL	4	1	0.0488
	Portion of BOD composed of organic N in interflow	PERLND	PQUAL	IOQUAL	4	1	0.0407
	Total flux of Ammonia (NH3)	IMPLND	IQUAL	SOQUAL	1		
	Total flux of Nitrate-Nitrite (NO2NO3)	IMPLND	IQUAL	SOQUAL	2		
	Portion of BOD composed of organic N in Surface runoff	IMPLND	IQUAL	SOQUAL	4	1	0.0407
	Total inflow of TN	RCHRES	PLANK	TPKIF	4	1	
	Total outflow of TN	RCHRES	PLANK	TPKCF1	4	1	
Total Sediment	Total Sediment	PERLND	SEDMNT	SOSED	1	1	
	Total Solids	IMPLND	SOLIDS	SOSLD	1	1	
	Inflow of Sediment	RCHRES	SEDTRN	ISED	4	1	
	Outflow Sediment	RCHRES	SEDTRN	ROSED	4	1	
	Sediment Flux/Change in Storage	RCHRES	SEDTRN	DEPSCR	4	1	

Developing Subwatershed Priority Maps Using Yields

The prioritization of subwatersheds based on nonpoint source loads, occurred at two scales; i.e., the entire watershed and major tributary (**Figure A-3**). Prioritization at multiple scales is necessary because the results change depending upon the location of the impaired resource (or resource being protected) in the watershed. Subwatershed priority maps were generated using results extracted from the TRW HSPF model. Maps were developed for RO, TP, TN, and total sediment. Maps generated at the watershed scale using the entire simulation period (i.e., multiple years, 1996-2009) included average land segment yield maps (**Figures A-4** through **A-7**), averaged subwatershed yield maps (**Figures A-8** through **A-11),** subwatershed priority rankings maps (**Figures A-12** through **A-15**), water quality index (WQI) map (**Figure A-16**), and field stream index maps (**Figures A-17** through **A-19**). Five sets of maps were also generated at the major tributary drainage scale for the three main branches of in the TRW (**Figure A-3**); the south branch was split into two map sets (upstream and downstream of Lake Bronson) and a map set of the drainage to AUID 09020312-501 (Two Rivers upstream of the North Branch confluence) was also generated. Map sets for each of major tributary drainage include the subwatershed priority ranks (Two Rivers, North Branch-**Figures A-20** through **A-23**; Two Rivers, Middle Branch -**Figures A-25** through **A-28**; Two Rivers, South Branch upstream of Lake Bronson -**Figures A-30** through **A-33,** Two Rivers, South Branch downstream of Lake Bronson -**Figures A-35** through **A-38,** Two Rivers, upstream of the confluence with the North Branch-**Figures A-40** through **A-43**) and the water quality index maps (Two Rivers, North Branch-**Figure A-24**; Two Rivers, Middle Branch –**Figure A-29**; Two Rivers, South Branch upstream of Lake Bronson –**Figure A-34,** Two Rivers, South Branch downstream of Lake Bronson –**Figure A-39,** Two Rivers, upstream of the confluence with the North Branch –**Figure A-44**).

The yield maps (**Figures A-4** through **A-11**) can be used to complete pollutant sources assessments. They show which land segments and subwatersheds are the largest sources of runoff, nutrients and sediment per area and time (annual average) delivered to the channel (edge of field). Maps represent different stressors that can lead to impairment. The maps show those subwatersheds having the greatest unit area, average annual yields of each subwatershed for RO (**Figure A-8**), TP (**Figure A-9**), TN (**Figure A-10**), and total sediment (**Figure A-11**). These maps were generated by extracting the flow and loadings from each PERLND and IMPLND (**Figures A-4** through **A-7**), averaging the annual total flows and loads over the modeling period (1996-2009) for each PERLND/IMPLND, and using the areas of each PERLND/IMPLND in each subwatershed to get a subwatershed unit area, annual average yield. The numeric values for each subwatershed are provided in **Supplemental Table 1**.

The priority rankings maps (**Figures A-12** through **A-15**) use the information in the yield maps to identify specific priority subwatersheds which should be preferentially considered for targeting fields for practice implementation based solely on water quality. These maps were developed by taking the yields at the watershed and major tributary scales and ranking them smallest to largest and calculating their percentile rank. The ranks are summarized as the lowest implementation priority (lowest 10%), low priority (10%-25%), moderate priority (25%-75%), high priority (75%-90%), and highest priority (highest 10%). The highest priority subwatersheds with the highest yields and most likely would benefit the most from implantation and protective strategy management. For the major tributary maps, the yields were re-ranked, only using the subwatersheds draining to the tributary.

In addition to the priority rankings maps, an overall water quality index (WQI) map was generated. The WQI (**Figure A-16**) represents the combined importance of nutrients and sediment and is estimated using:

WQI = 0.5*Sediment Ranking + 0.25*TP Ranking + 0.25*TN Ranking

These maps should be used when the practitioner wishes to consider establishing priority based on both excess nutrients and sediment as stressors.

The Field Stream Index maps (**Figures A-17** through **A-19**) provide guidance, subject to field verification, about where field practices rather than in-stream implementation activities, provide the largest potential water quality benefit. These maps show the magnitude of field source loads relative to in-stream sources and are taken as the overland field load divided by the in-channel flux. Positive numbers represent a source of in-stream materials and a negative number represents a sink for in-stream materials. If the FSI is between -1 and 1, the dominate processes in the subwatershed are in-channel, meaning the in-channel flux is larger than the overland sources. If the FSI is less than -1 or greater than 1, field sources are larger than the in-stream sources.

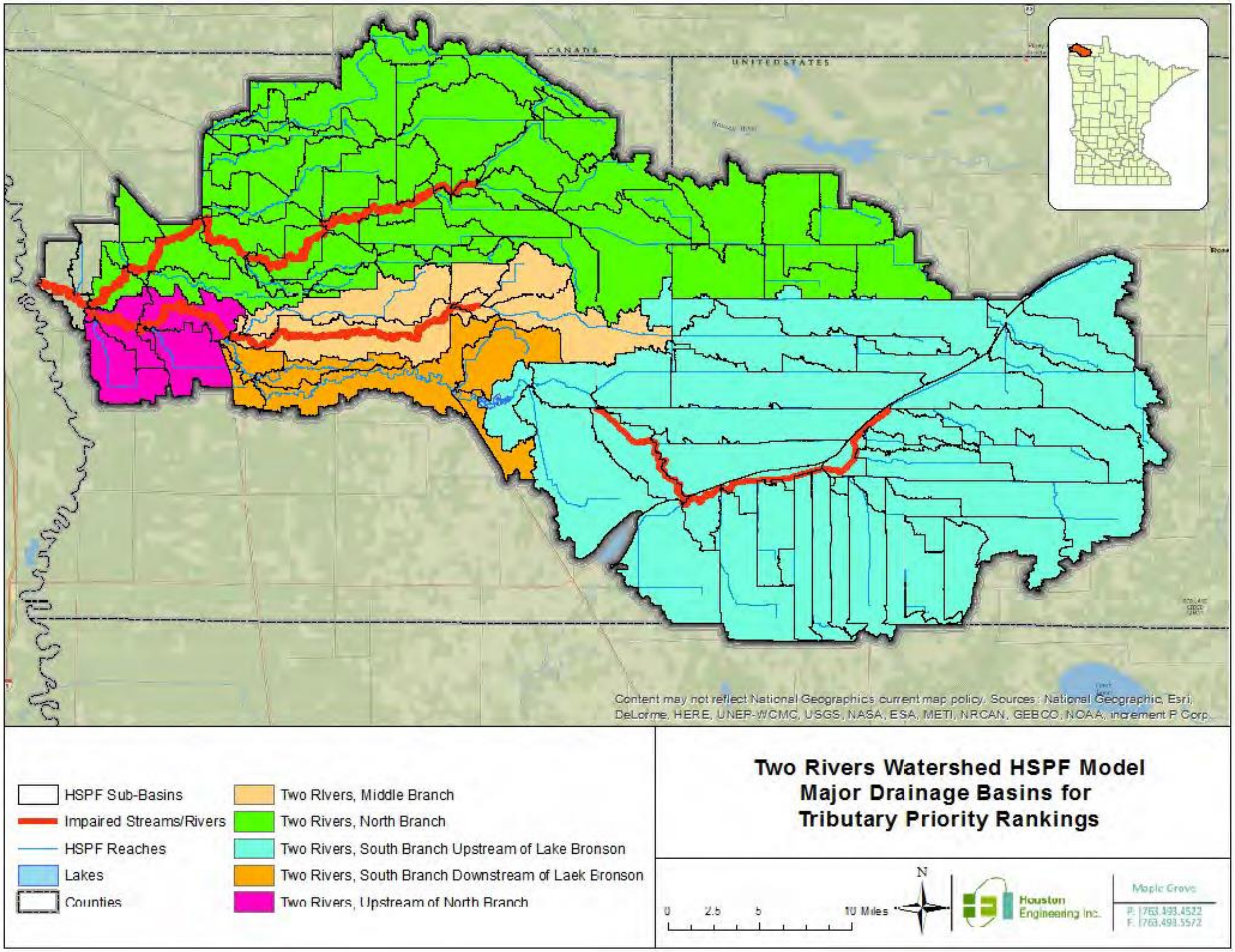


Figure A-3: Major drainage basins for tributary priority rankings in the Two Rivers Watershed.

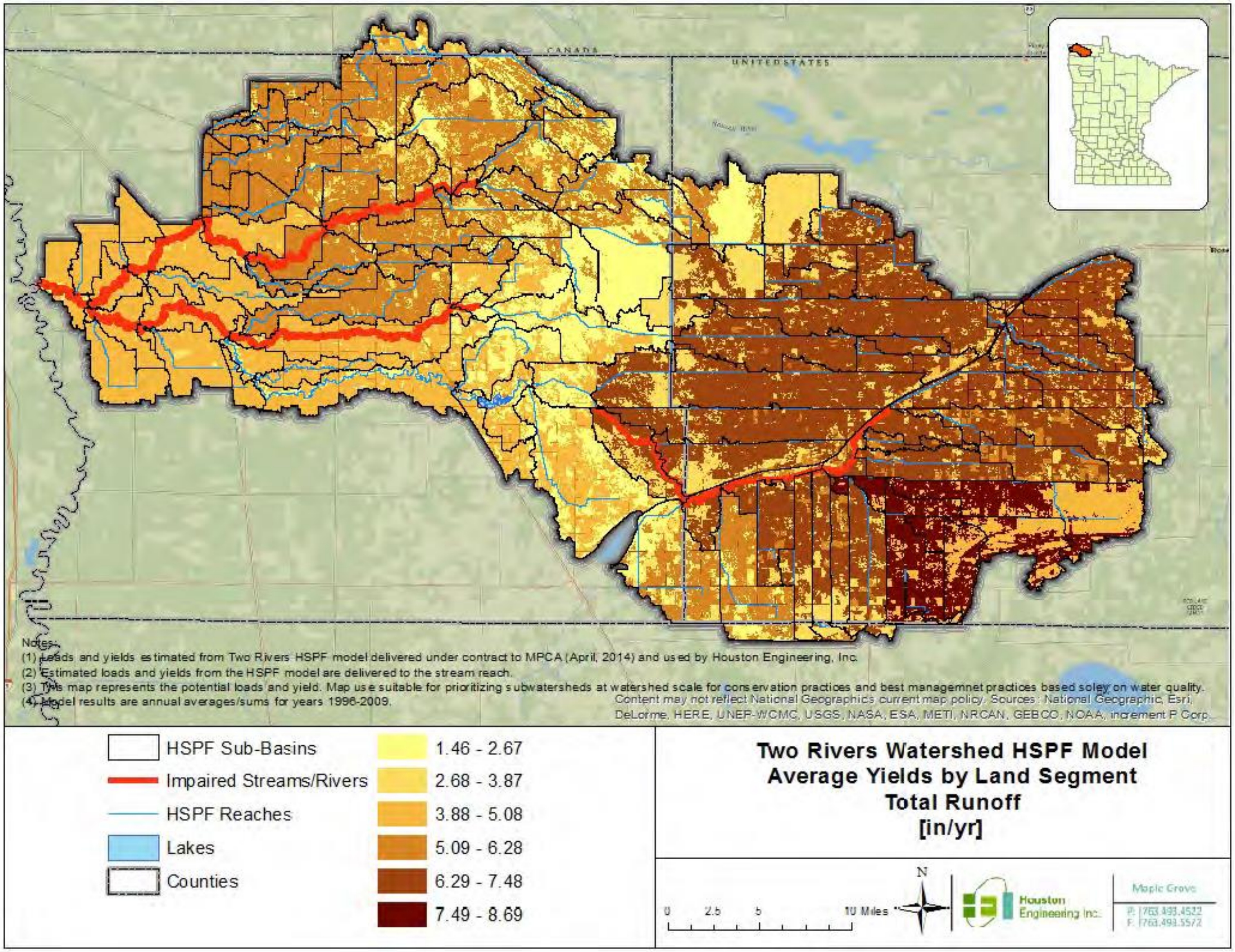


Figure A-4: Average (1996-2009) Unit Runoff delivered to the channel from the TRW HSPF model by land segment.

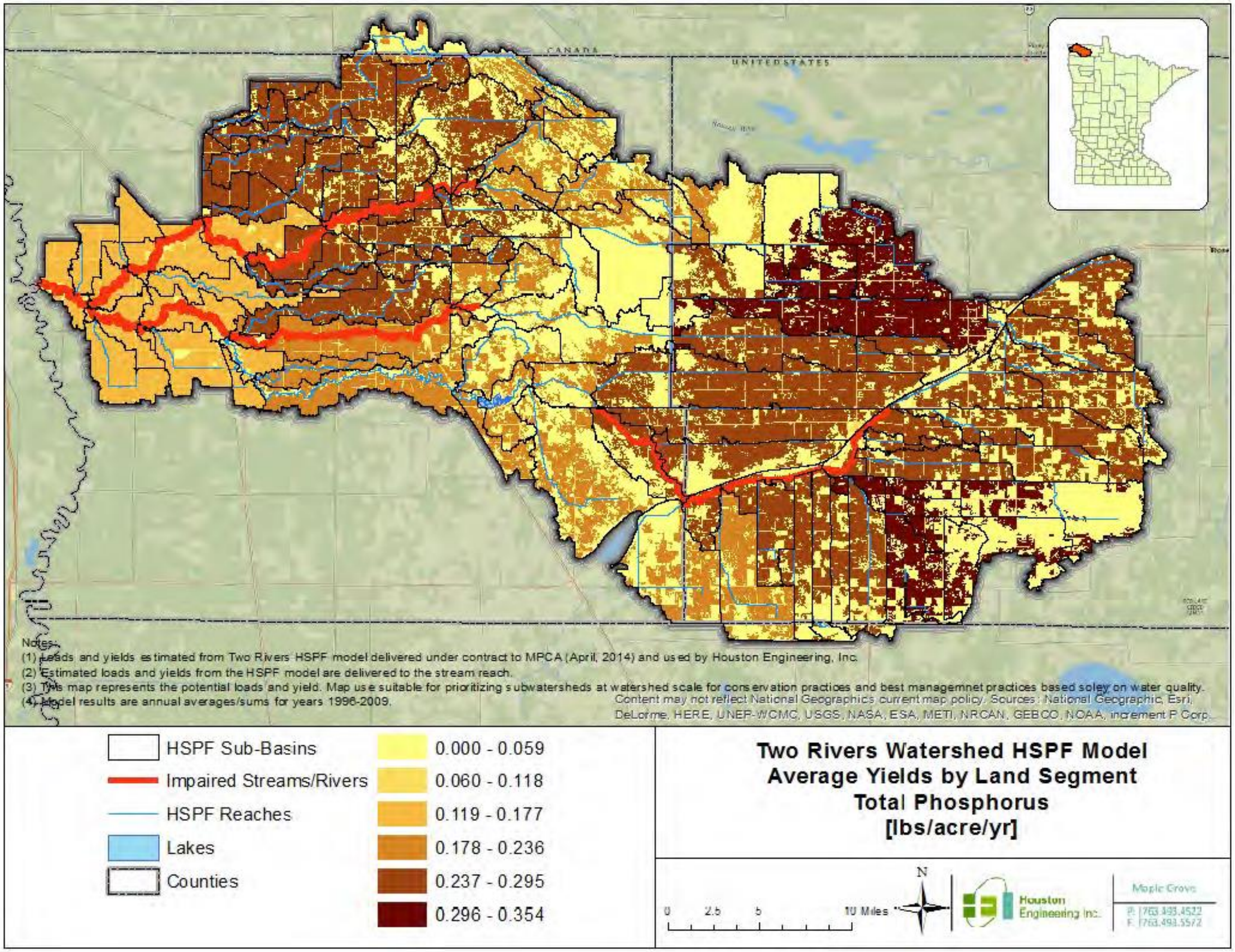


Figure A-5: Average (1996-2009) Total Phosphorus Yield delivered to the channel from the TRW HSPF model by land segment.

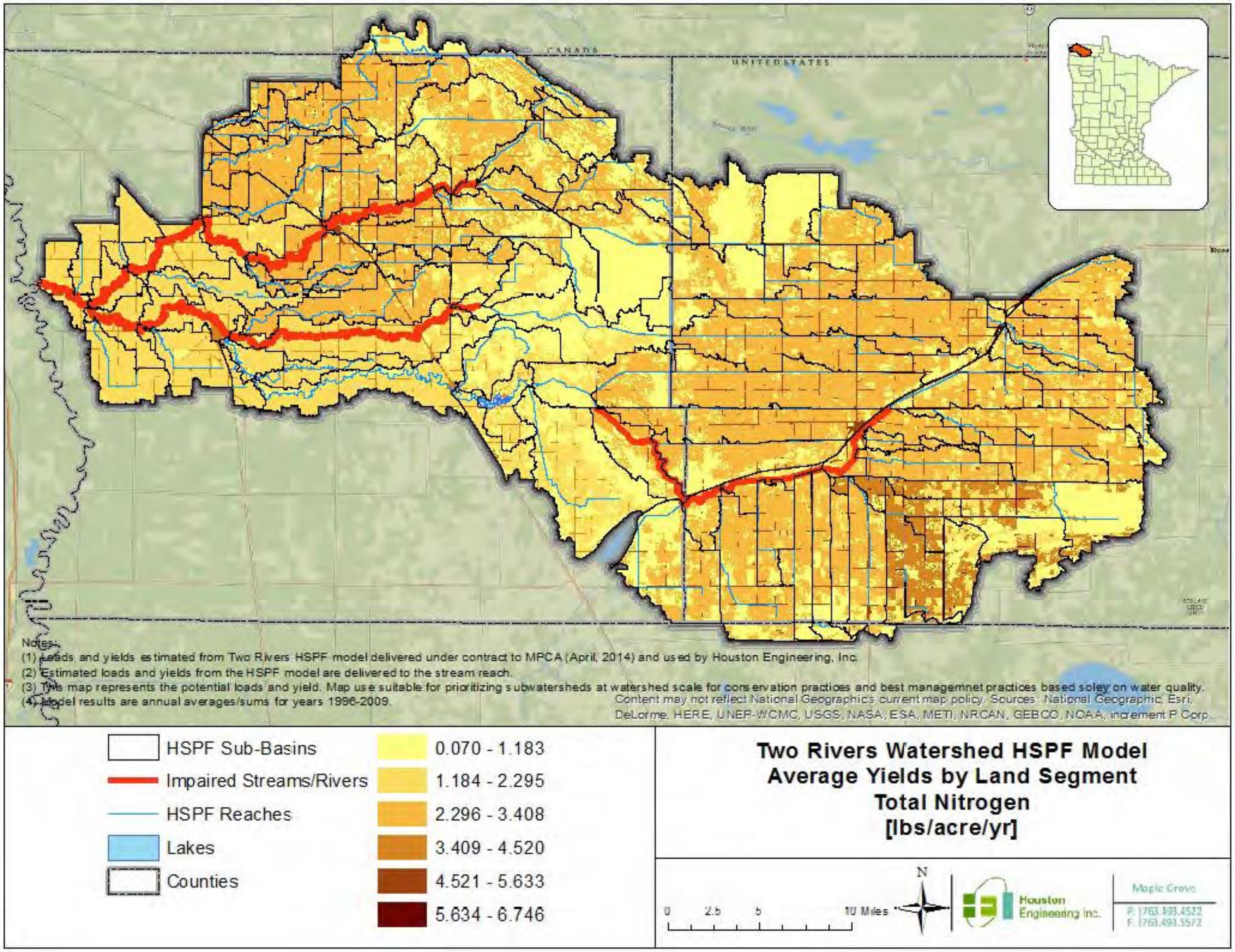


Figure A-6: Average (1996-2009) Total Nitrogen Yield delivered to the channel from the TRW HSPF model by land segment.

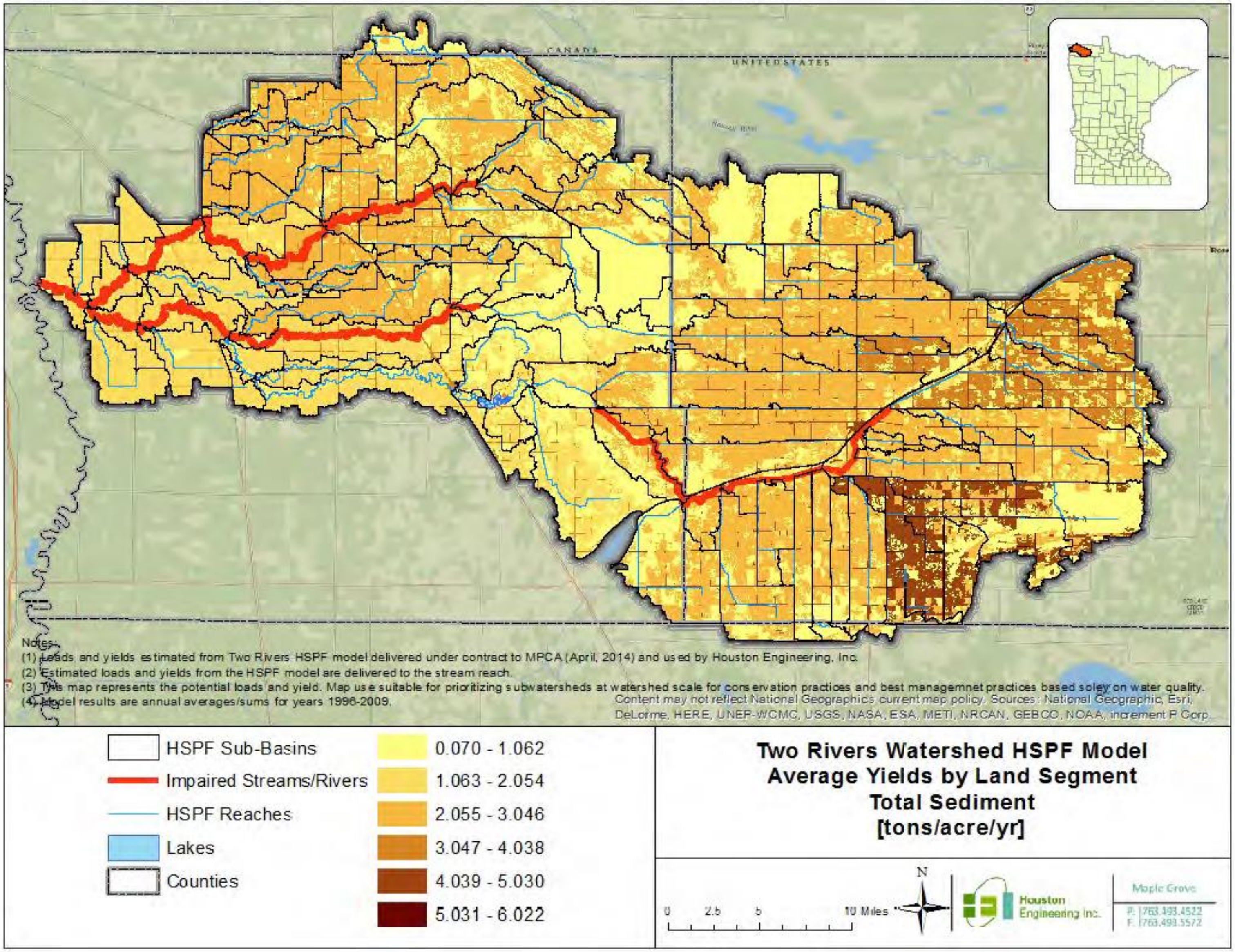


Figure A-7: Average (1996-2009) Total Sediment Yield delivered to the channel from the LRW HSPF model by land segment.

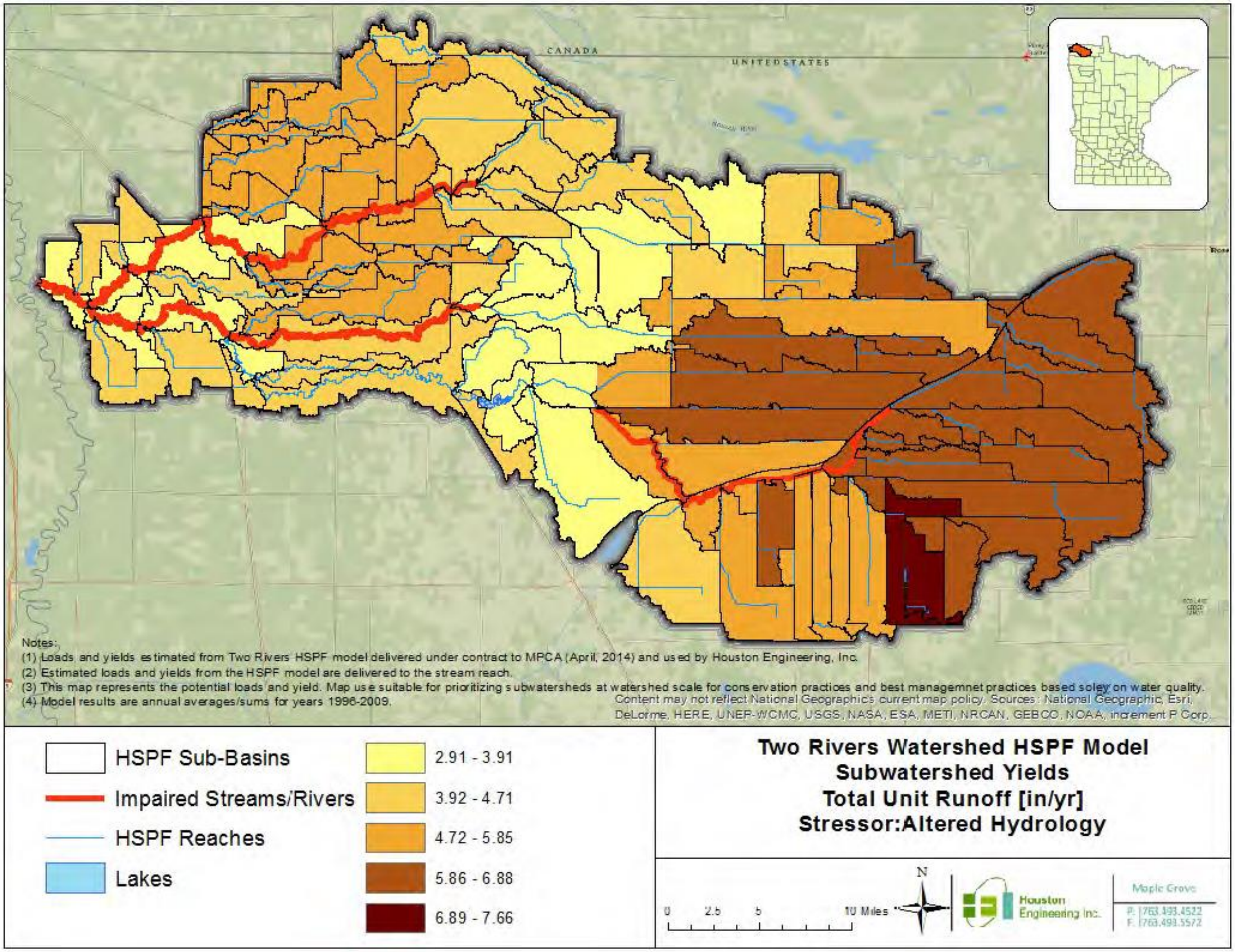


Figure A-8: Average (1996-2009) Unit Runoff delivered to the channel from the TRW HSPF model by subwatershed.

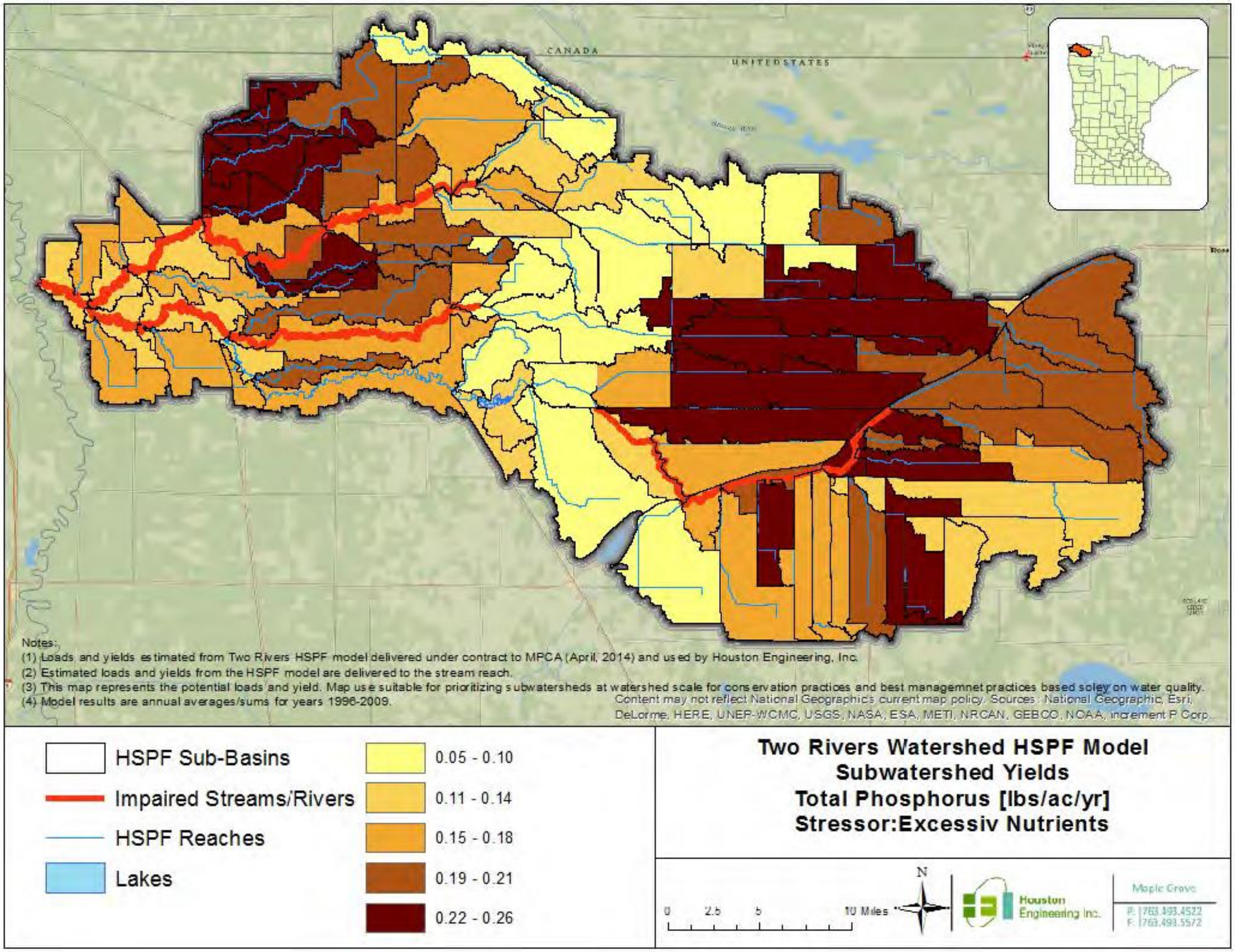


Figure A-9: Average (1996-2009) Total Phosphorus Yield delivered to the channel from the TRW HSPF model by subwatershed.

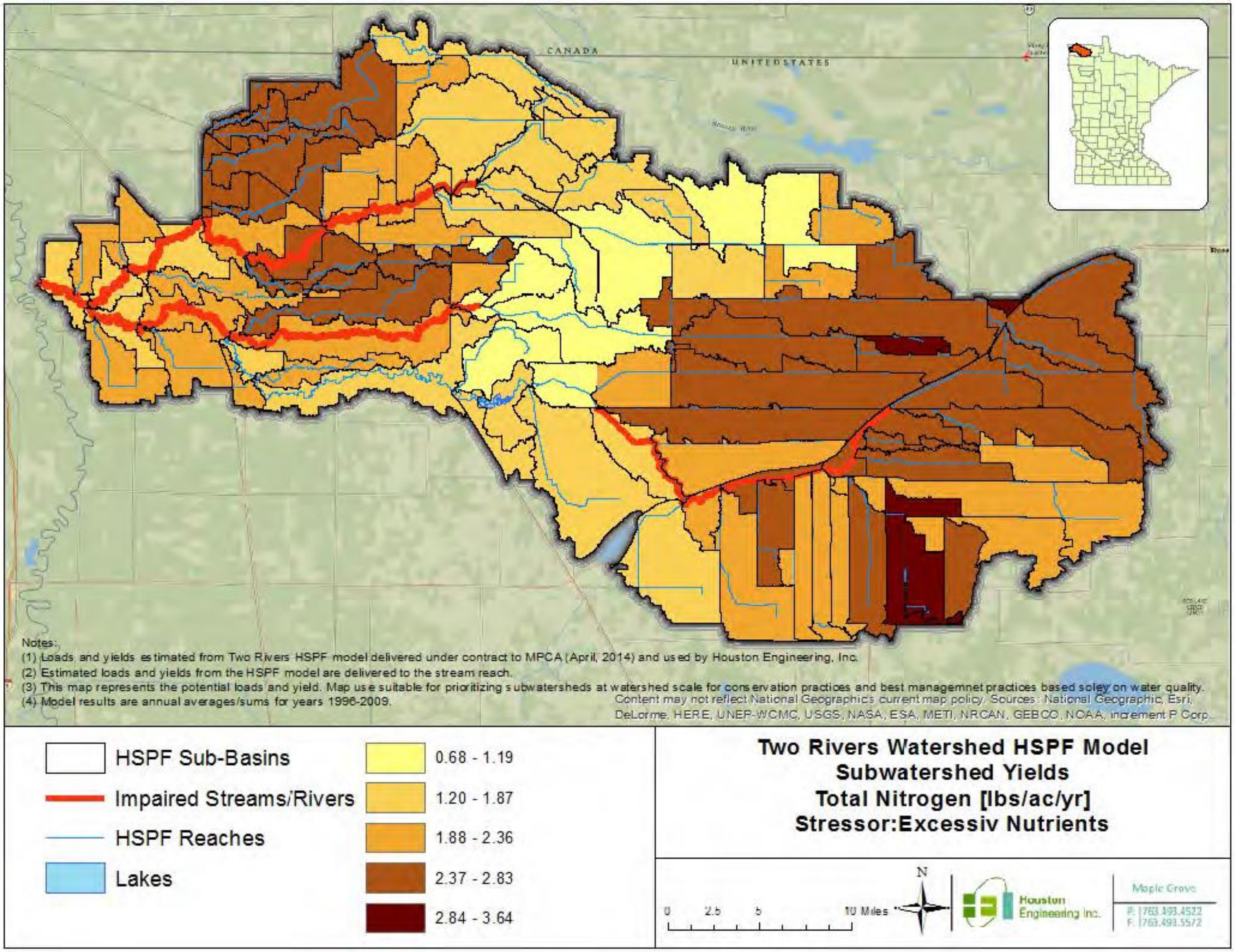


Figure A-10: Average (1996-2009) Total Nitrogen Yield delivered to the channel from the TRW HSPF model by subwatershed.

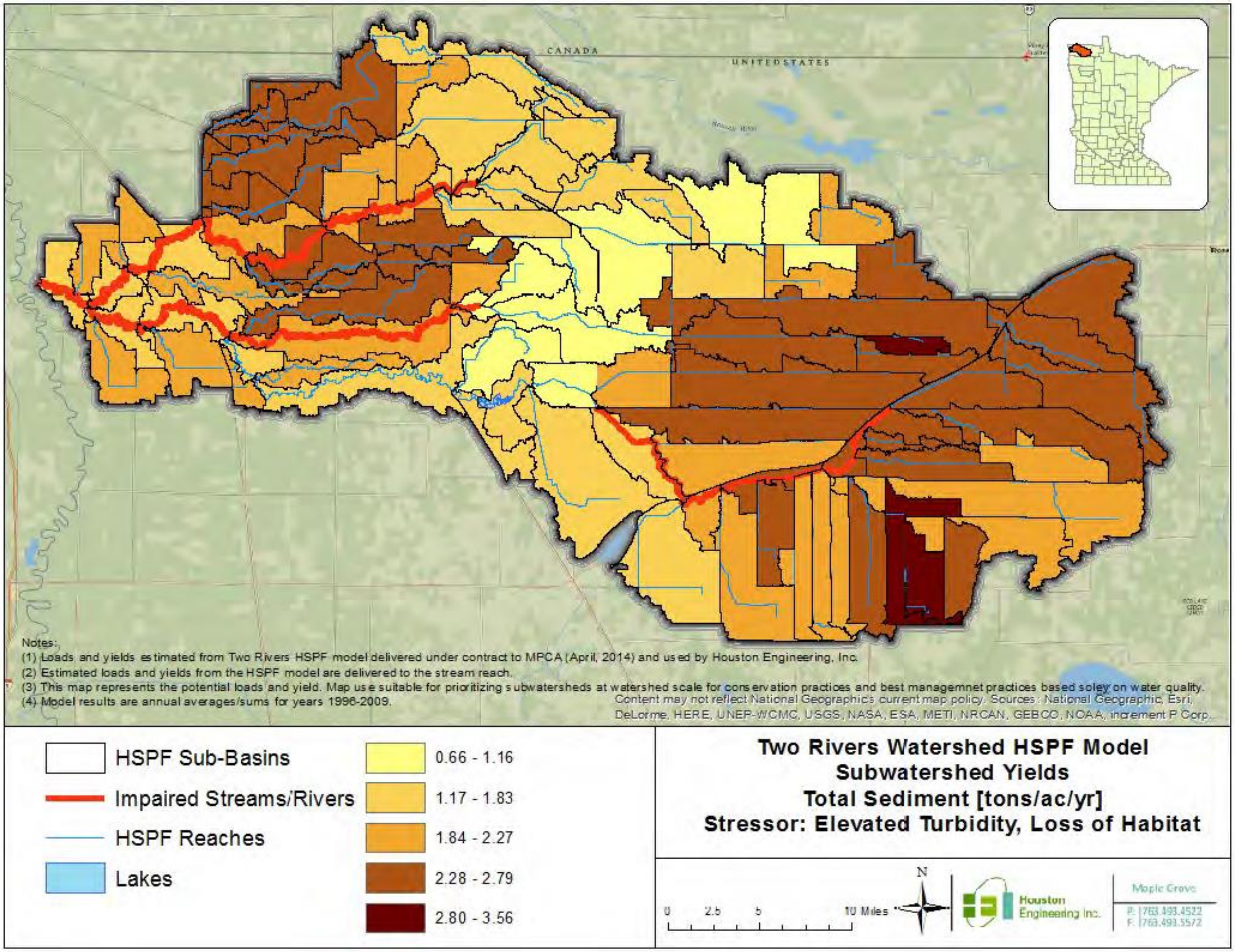


Figure A-11: Average (1996-2009) Total Sediment Yield delivered to the channel from the TRW HSPF model by subwatershed.

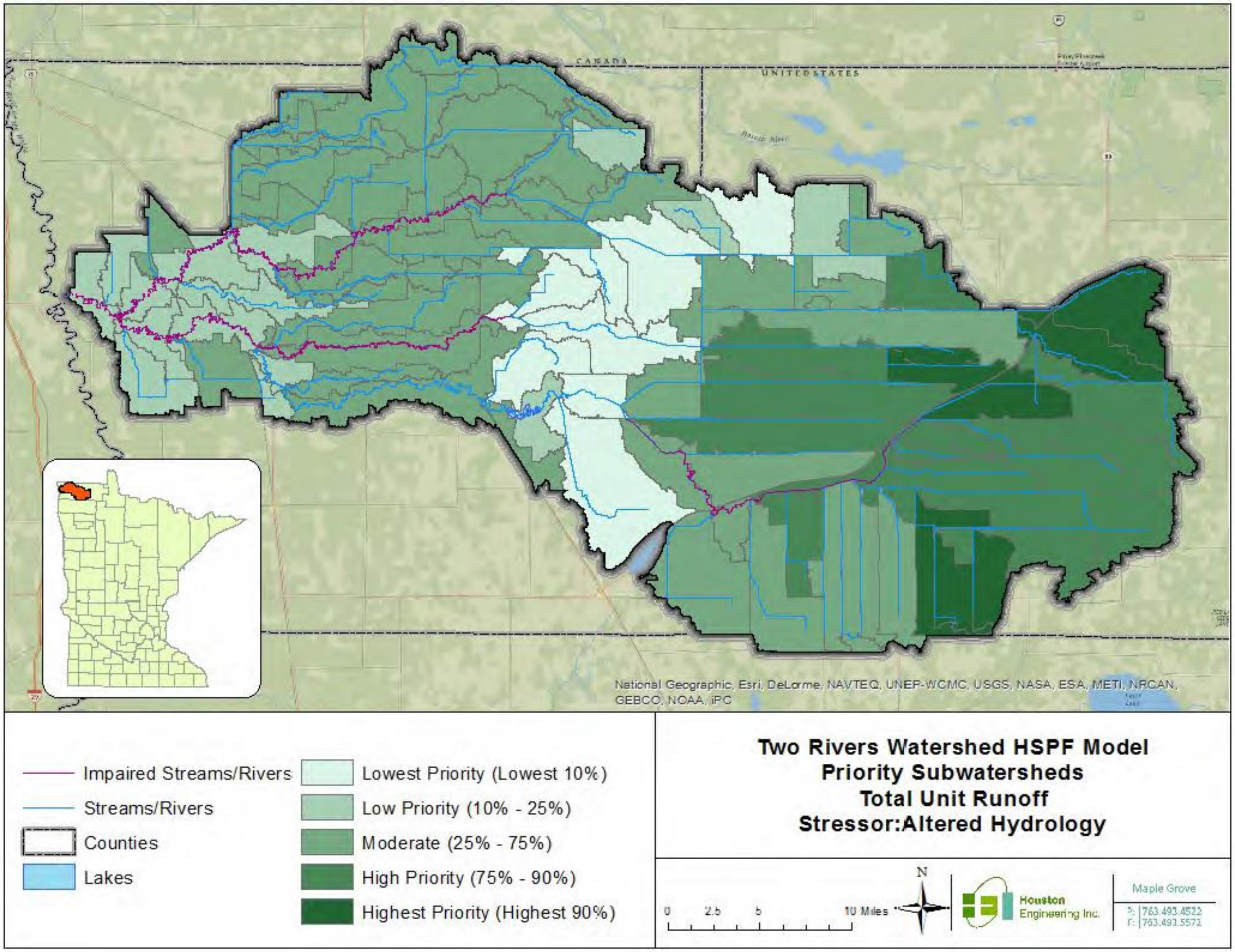


Figure A-12: Watershed scale subwatershed priority for implementation for the stressor altered hydrology, using average (1996-2009) annual unit runoff.

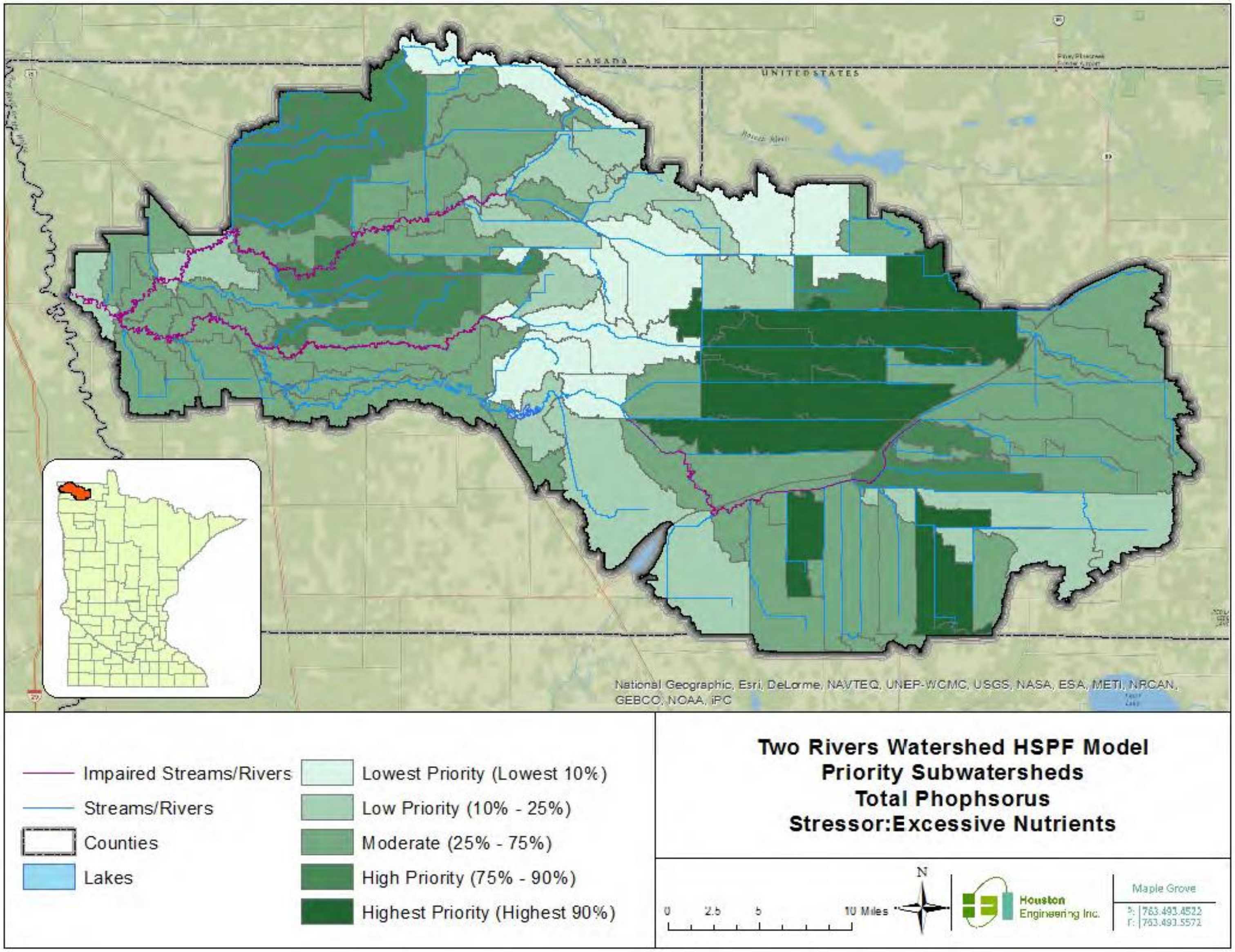


Figure A-13: Watershed scale subwatershed priority for implementation for the stressor excessive nutrients, using average (1996-2009) total phosphorus yields.

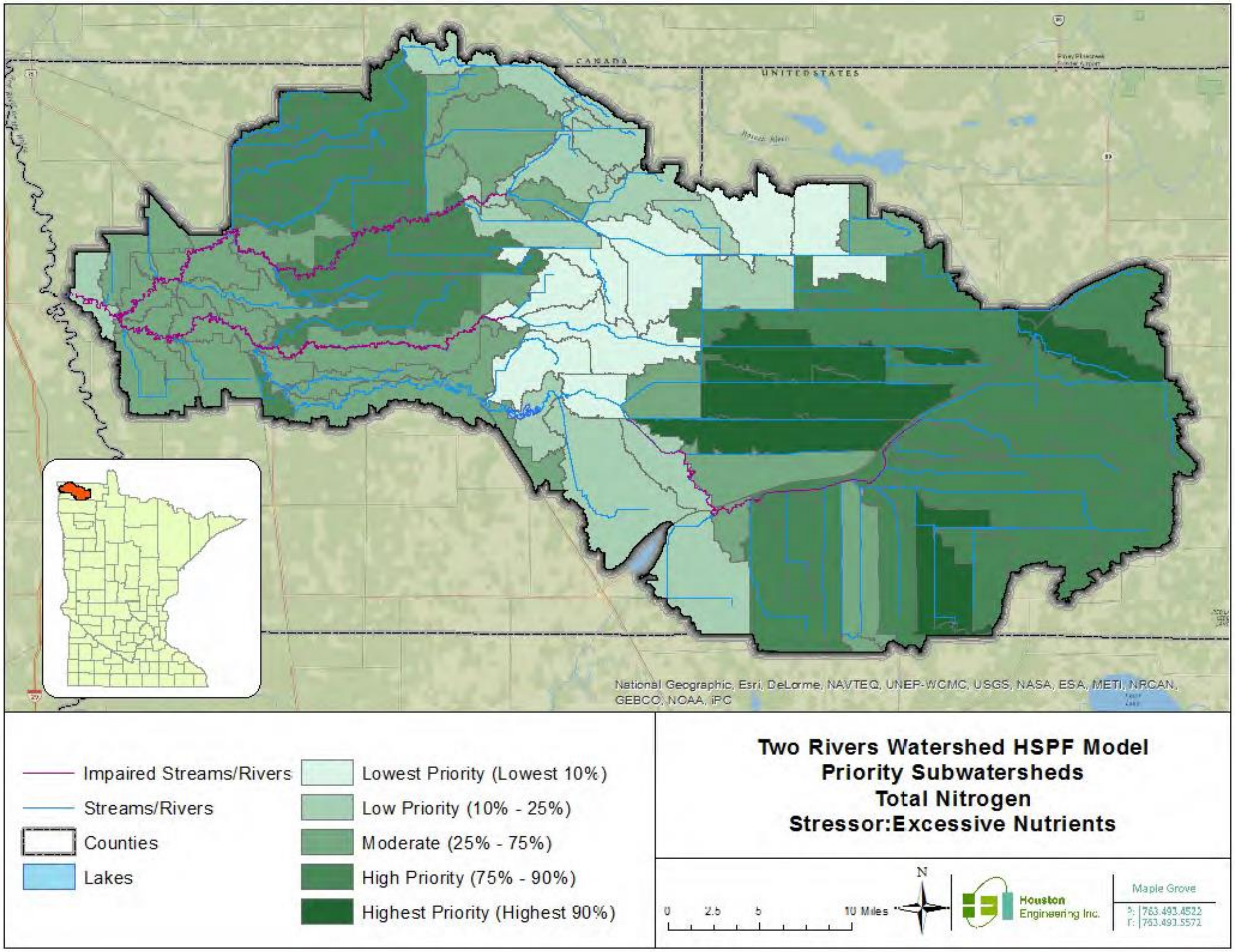


Figure A-14: Watershed scale subwatershed priority for implementation for the stressor excessive nutrients, using average (1996-2009) total nitrogen yields.

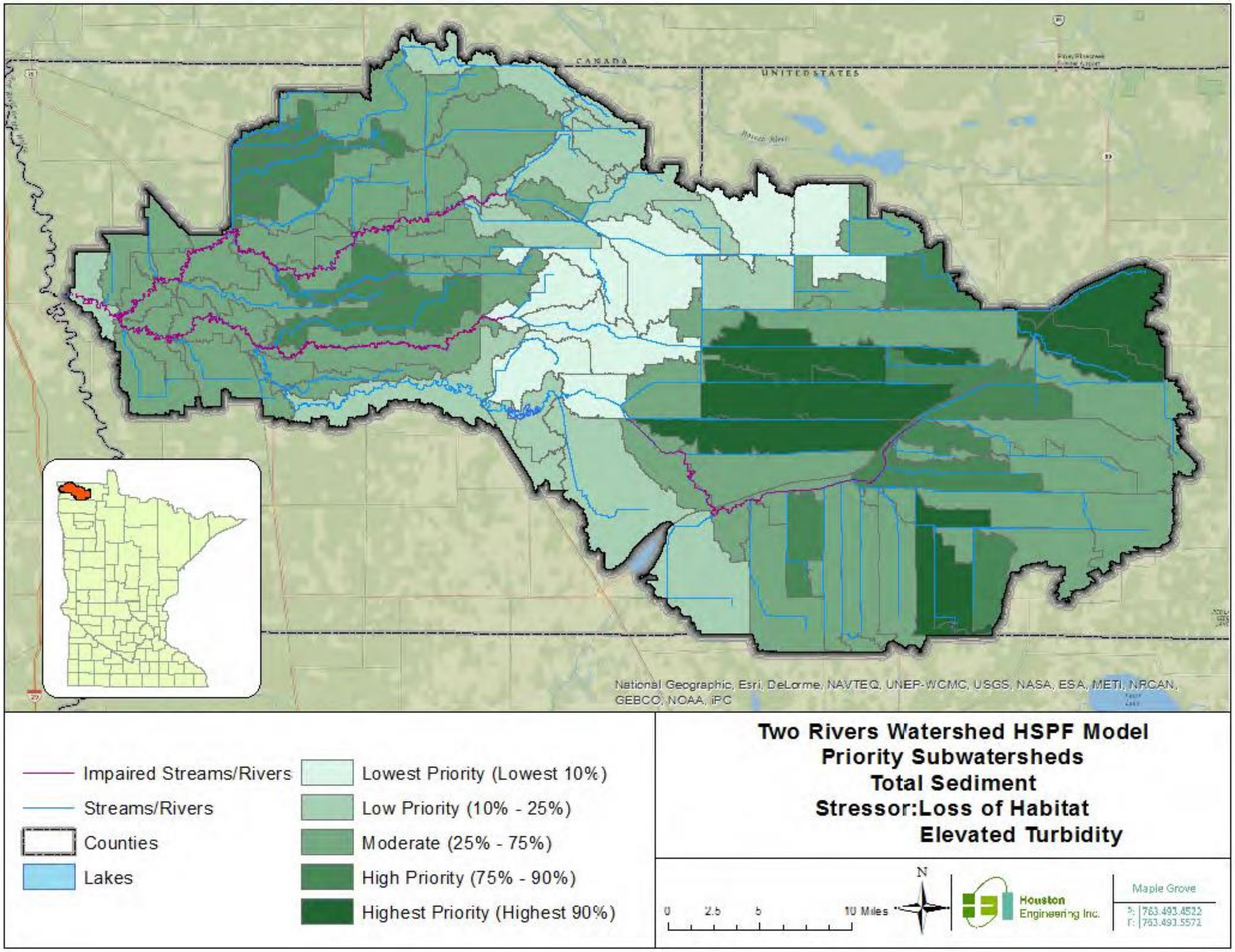


Figure A-15: Watershed scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat, using average (1996-2009) total sediment yields.

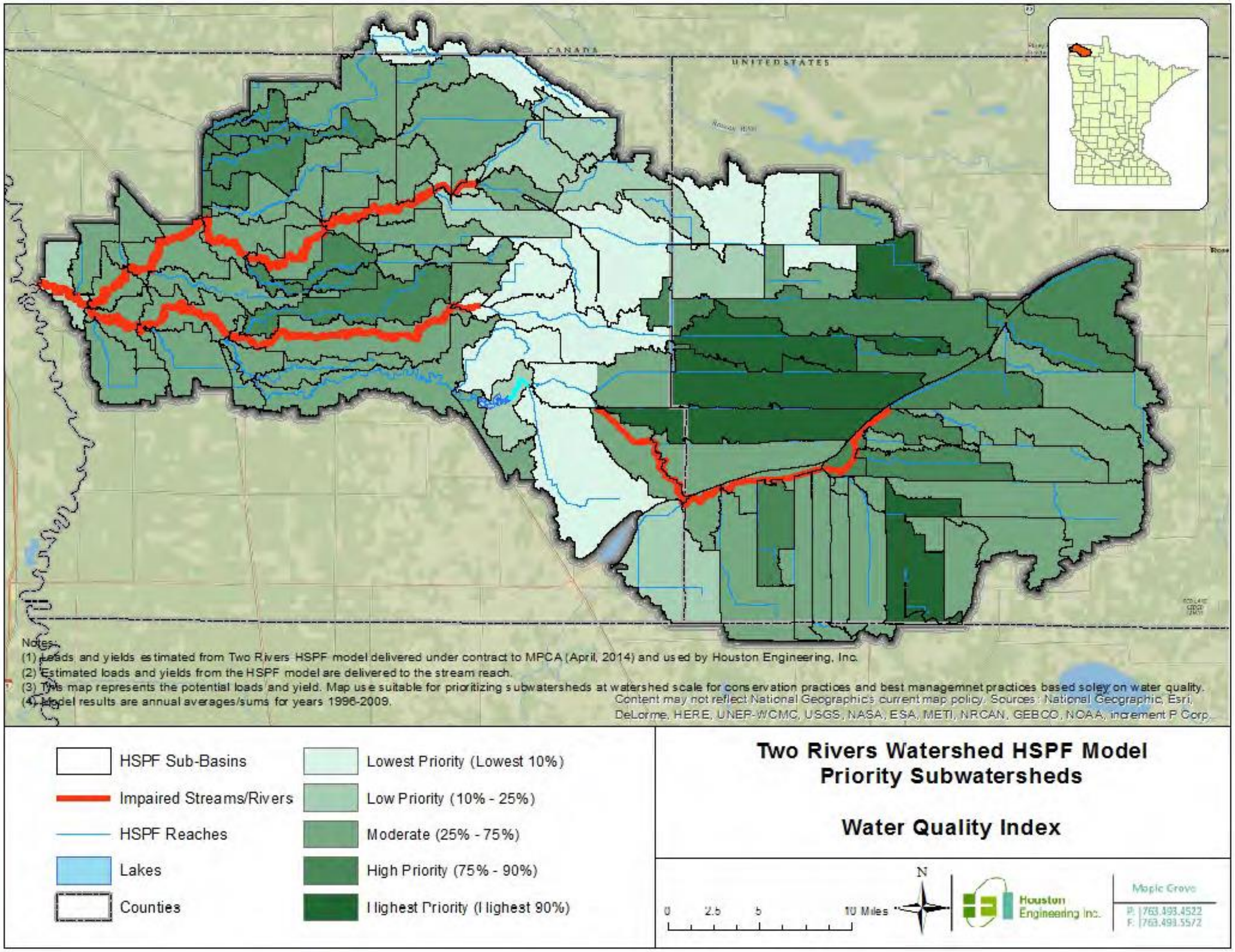


Figure A-16: Watershed scale subwatershed priority for implantation, using the average (1996-2009) water quality index.

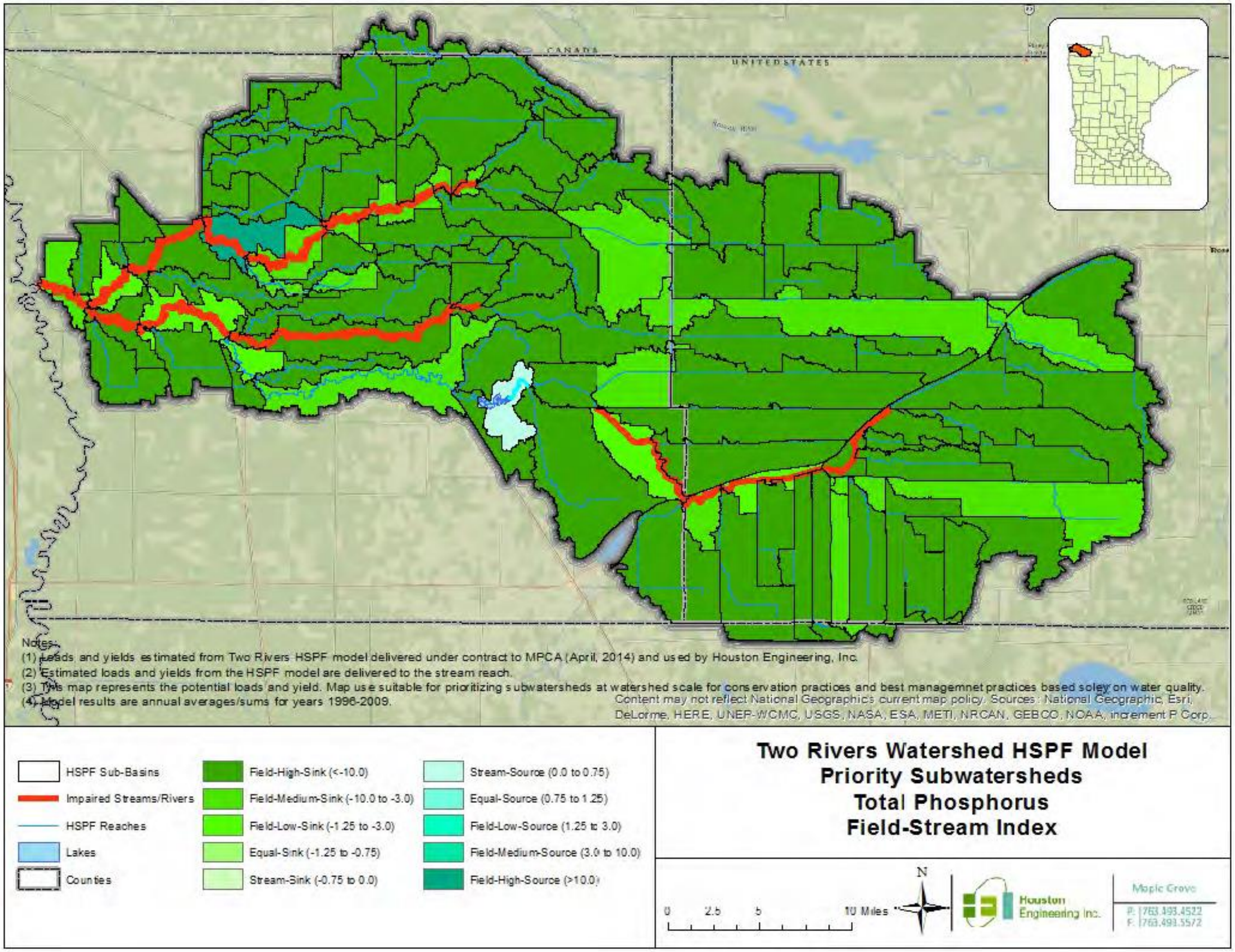


Figure A-17: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor excess nutrients using total phosphorus (1996-2009) annual average load.

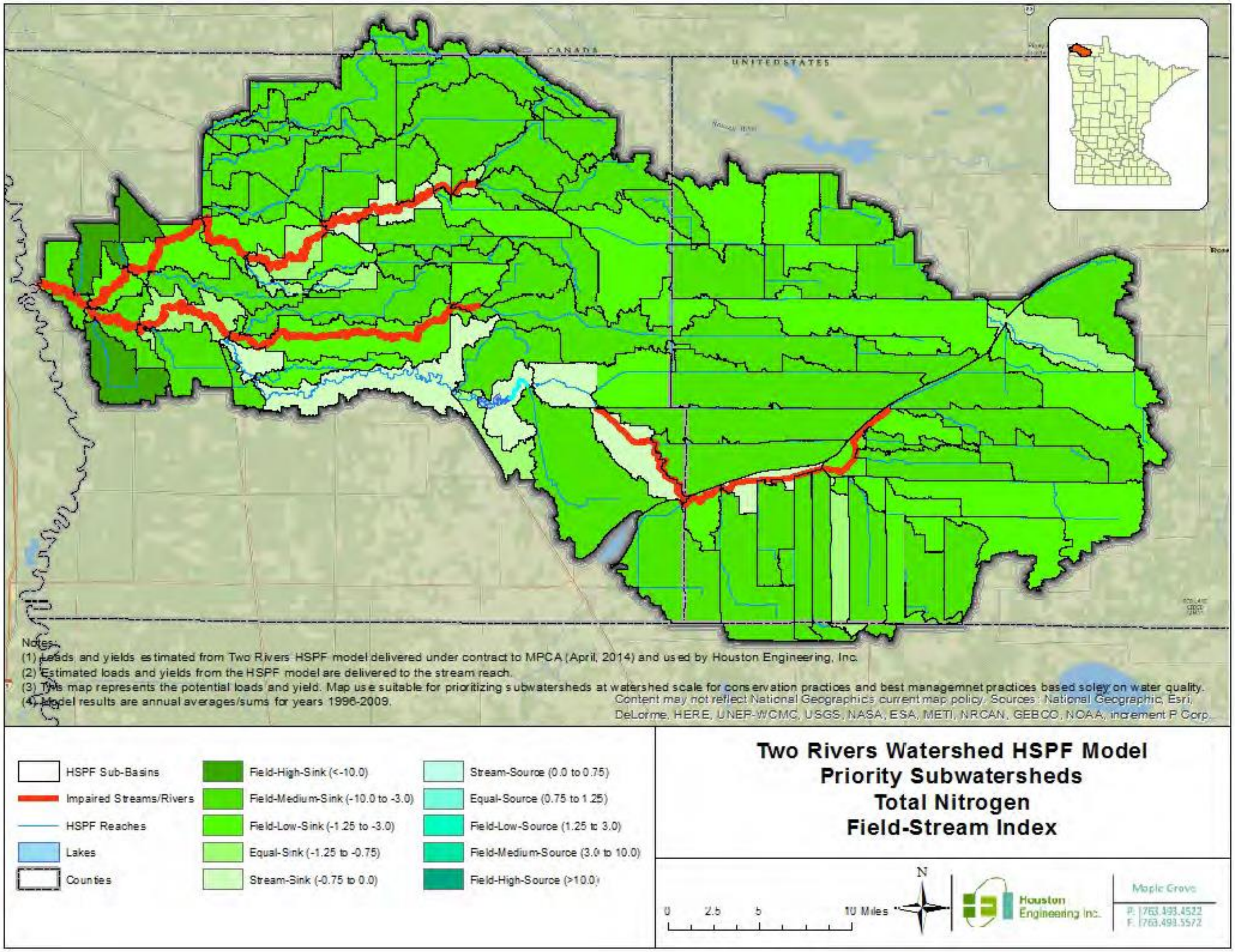


Figure A-18: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor excess nutrients using total nitrogen (1996-2009) annual average load.

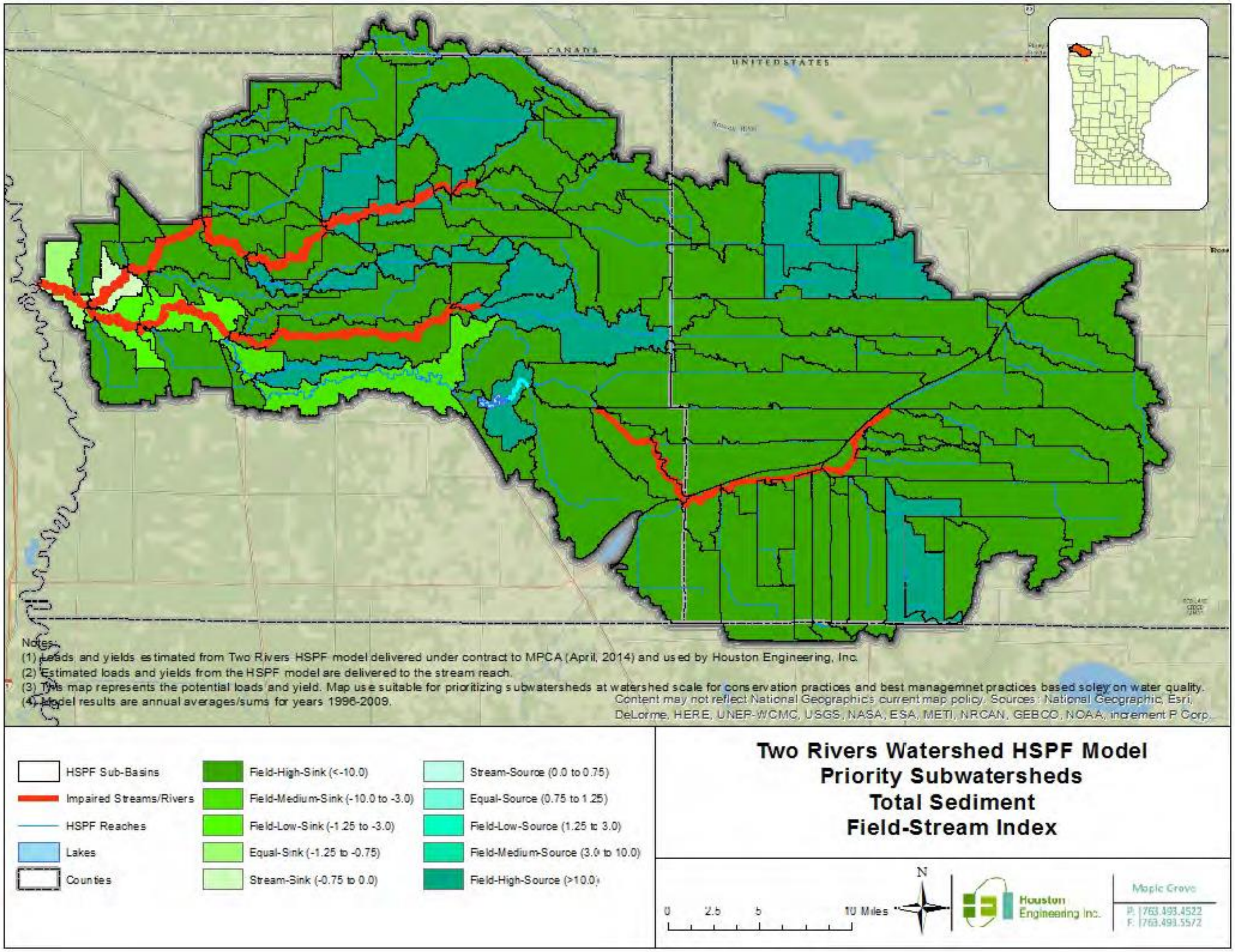


Figure A-19: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor elevated turbidity using total sediment (1996-2009) annual average load. .

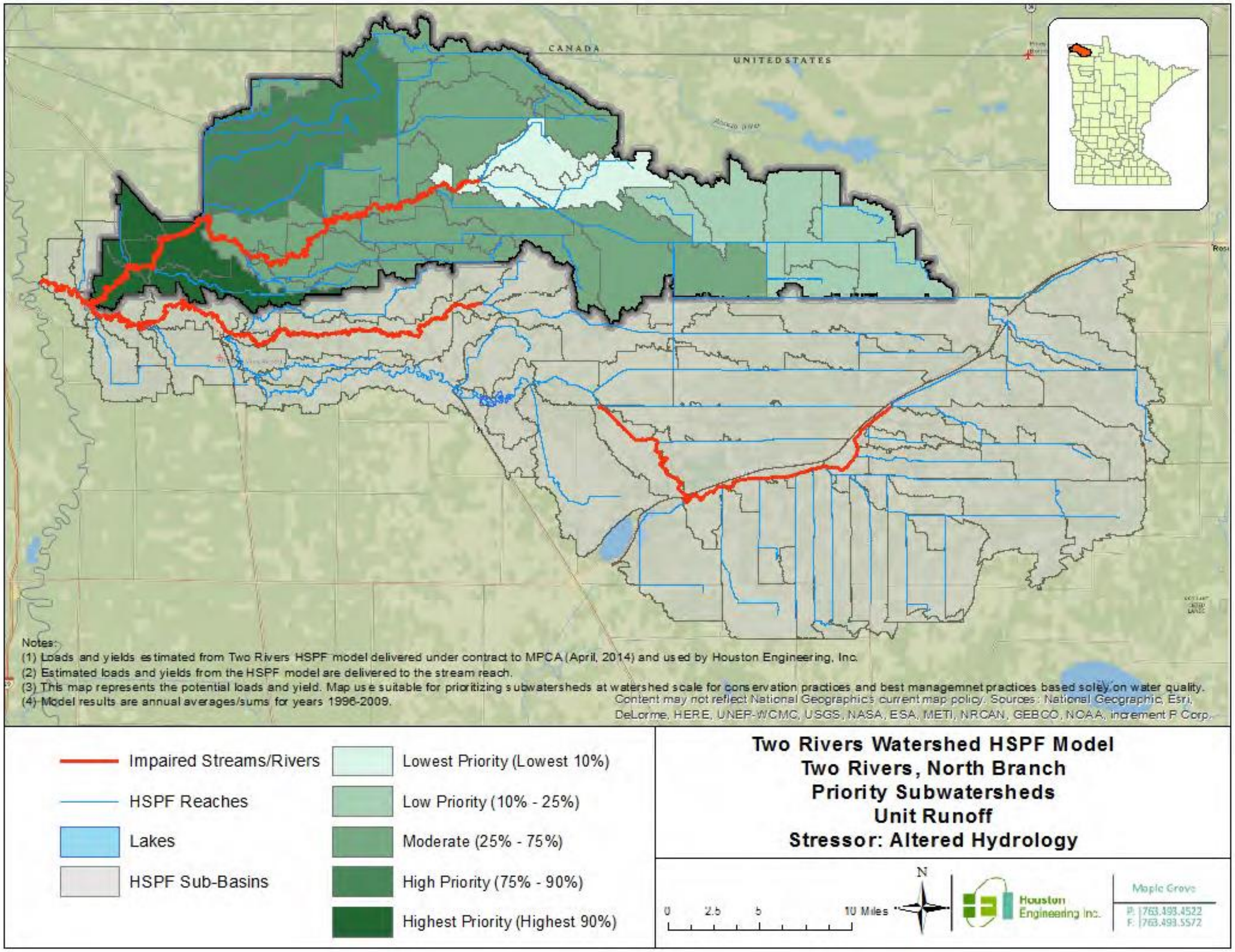


Figure A-20: Tributary scale subwatershed priority for implementation for the stressor altered hydrology for Two Rivers, North Branch, using average (1996-2009) annual unit runoff.

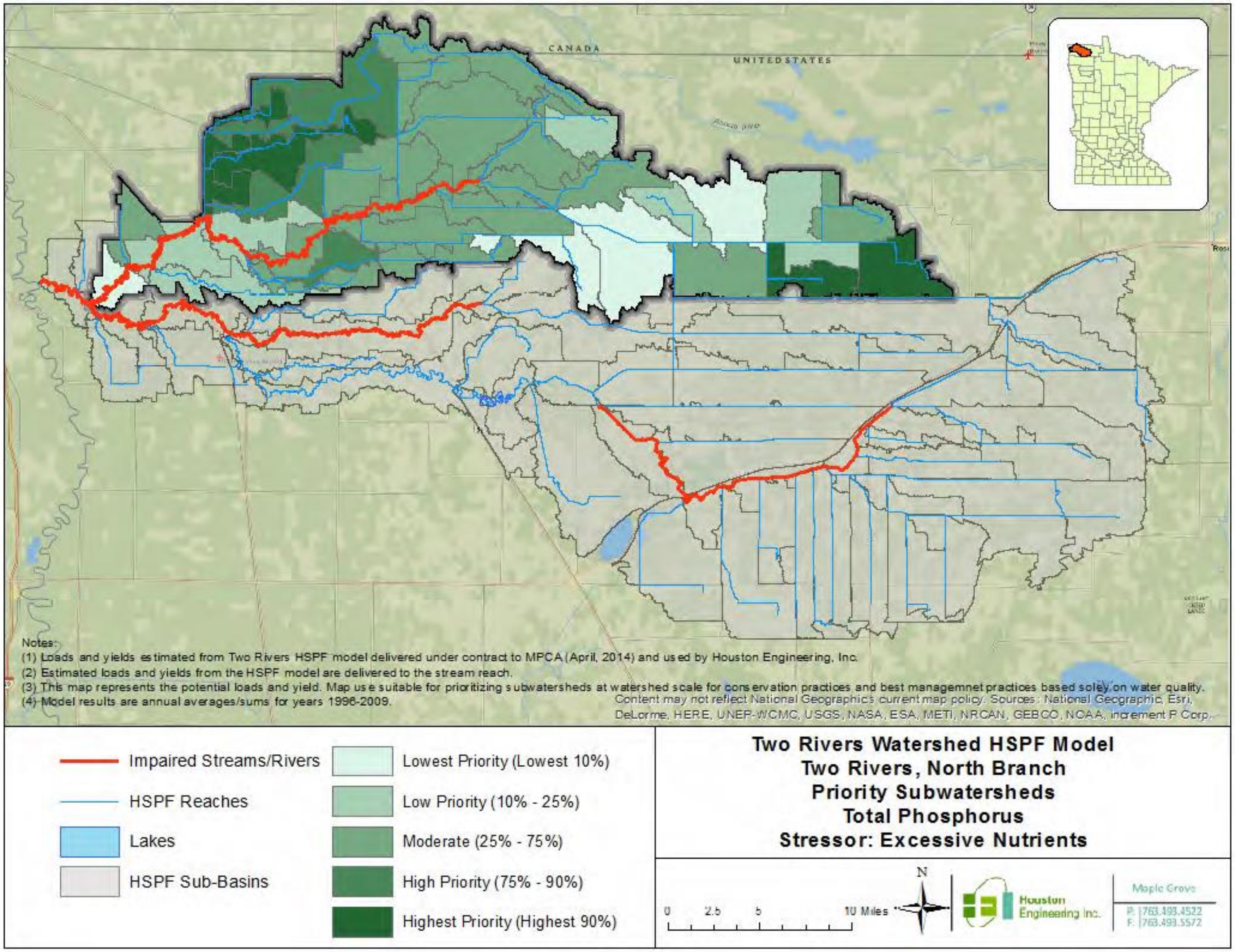


Figure A-21: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers, North Branch, using average (1996-2009) annual total phosphorus yields.

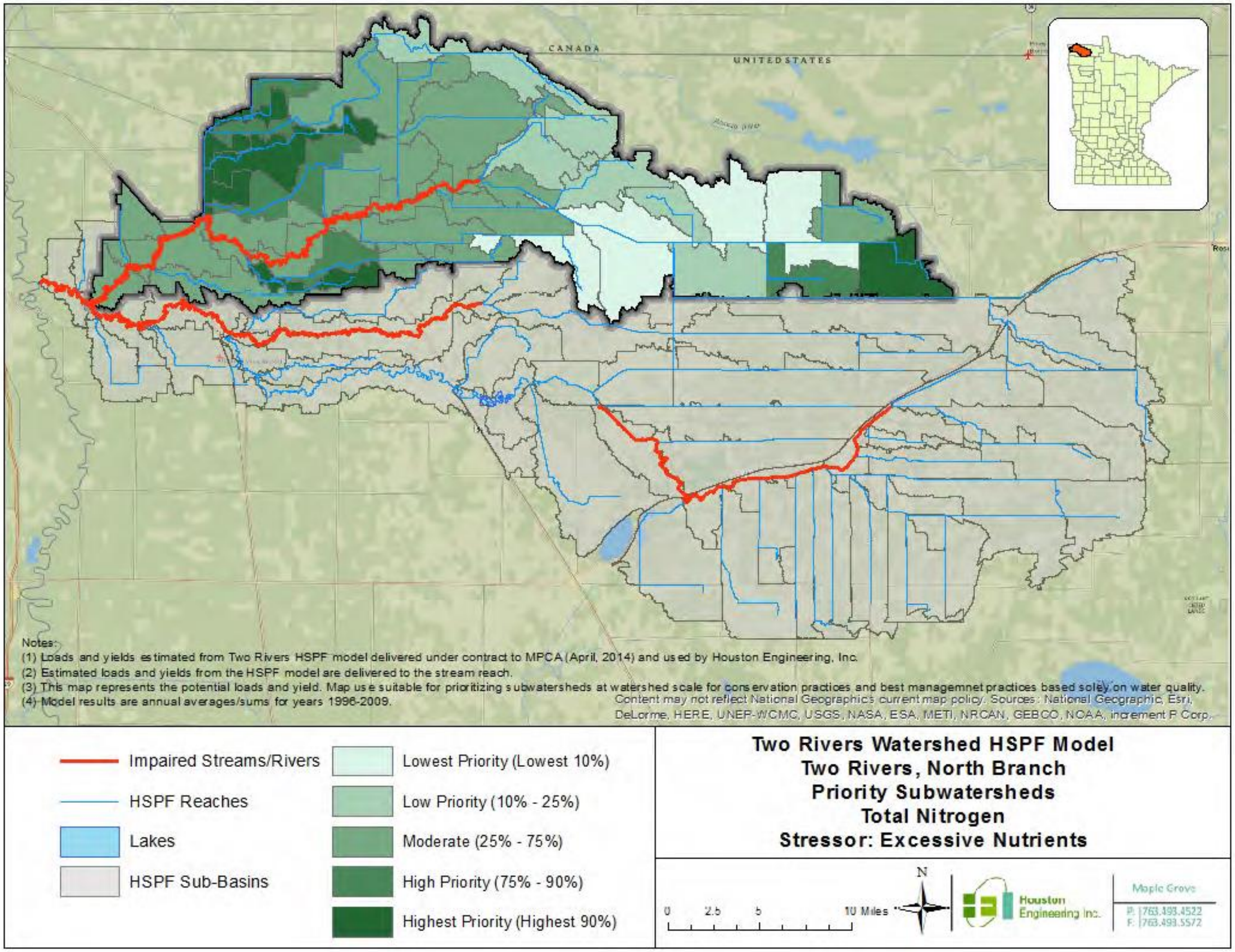


Figure A-22: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers, North Branch, using average (1996-2009) annual total nitrogen yields.

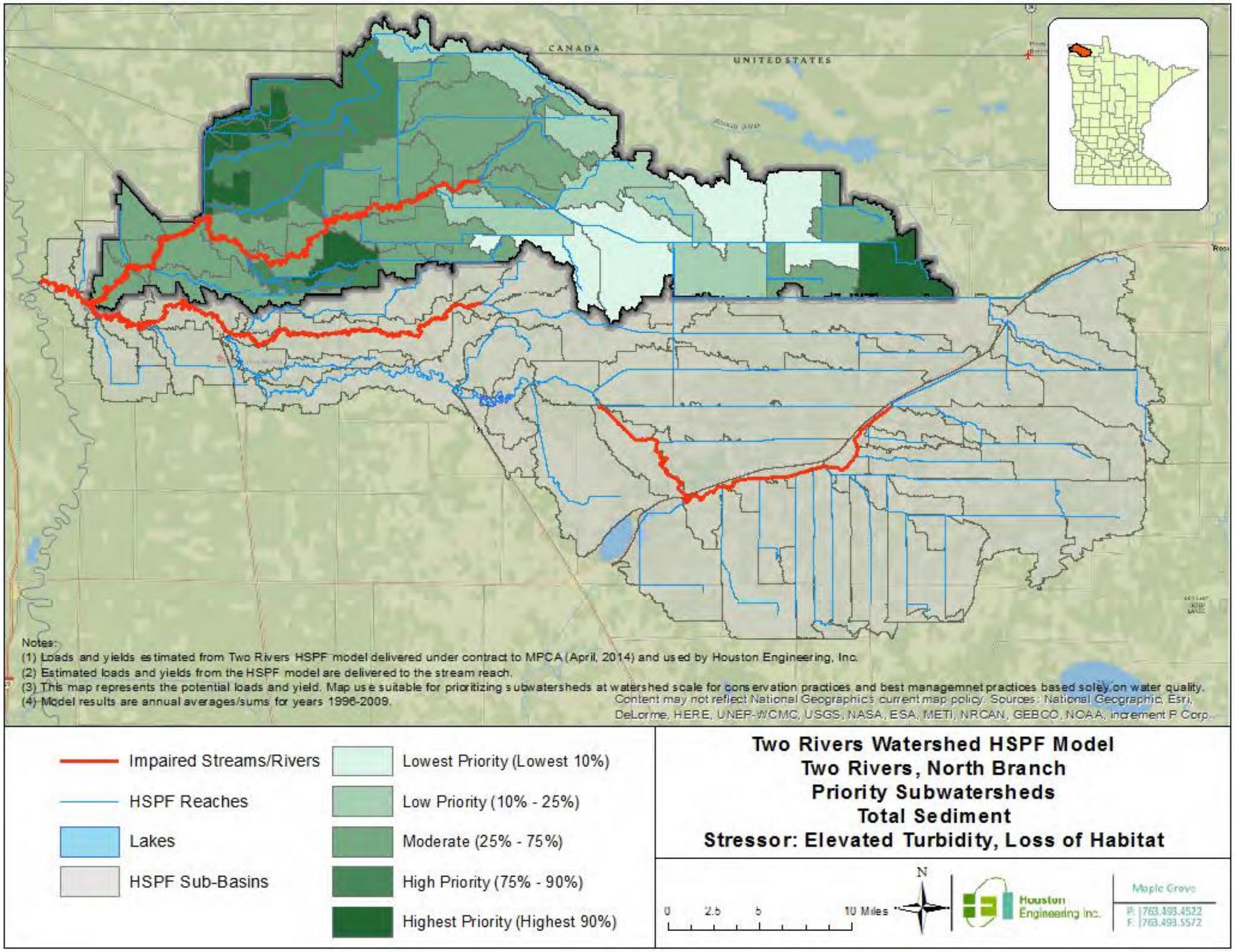


Figure A-23: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat Two Rivers, North Branch, using average (1996-2009) annual total sediment yields.

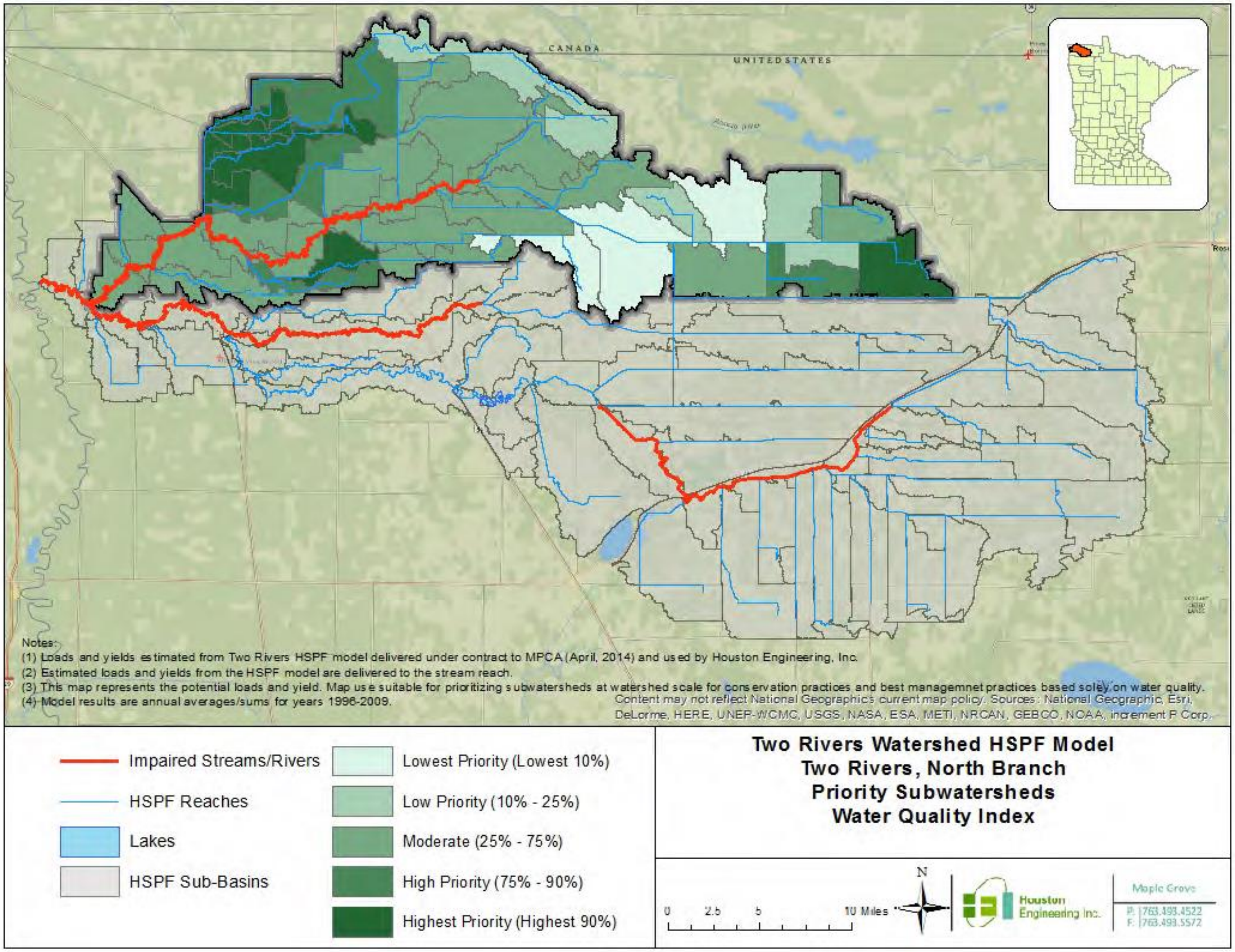


Figure A-24: Tributary scale subwatershed priority for implantation for Two Rivers, North Branch, using the average (1996-2009) water quality index.

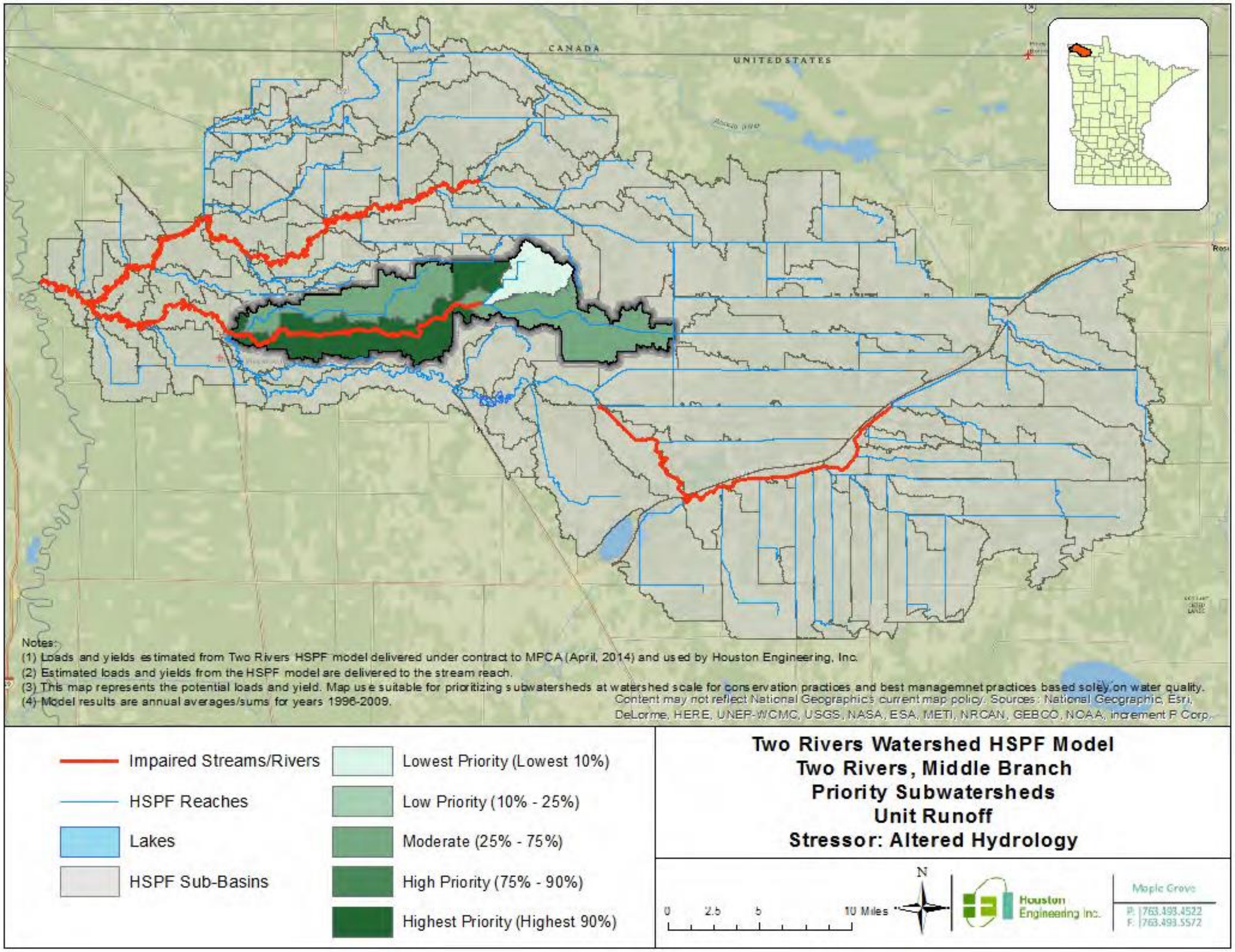


Figure A-25: Tributary scale subwatershed priority for implementation for the stressor altered hydrology for Two Rivers, Middle Branch, using average (1996-2009) annual unit runoff.

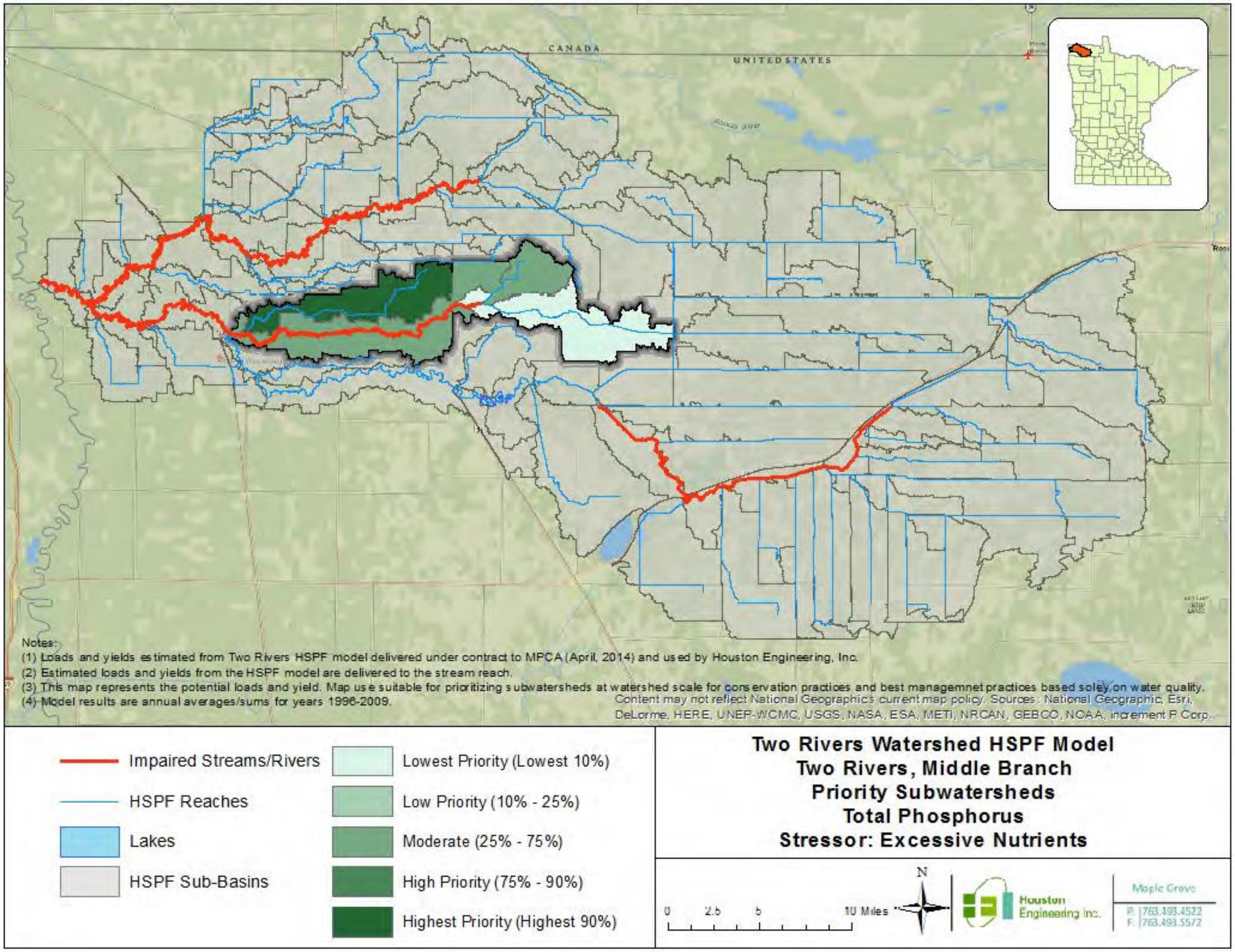


Figure A-26: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for Two Rivers, Middle Branch, using average (1996-2009) annual total phosphorus yields.

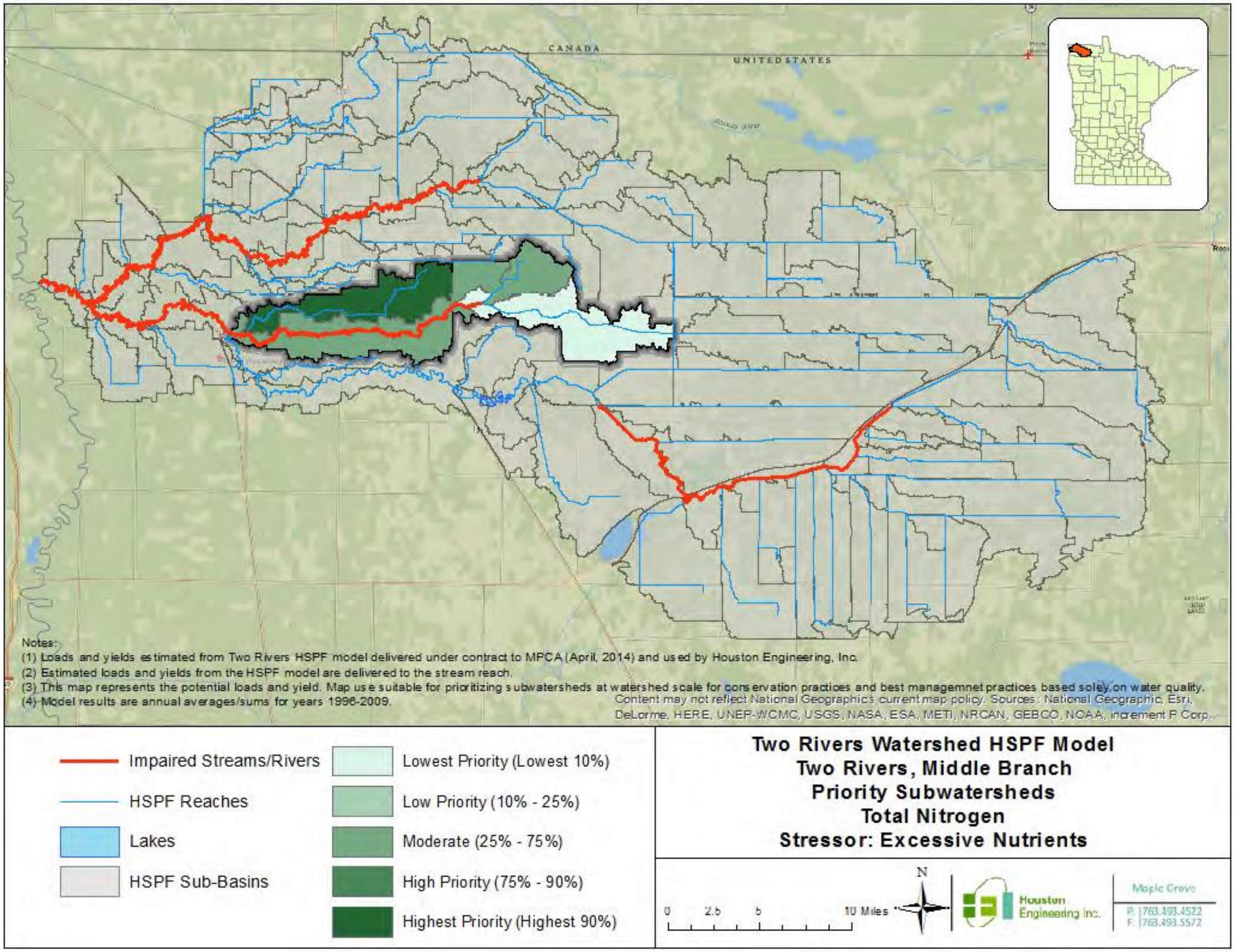


Figure A-27: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for Two Rivers, Middle Branch, using average (1996-2009) annual total nitrogen yields.

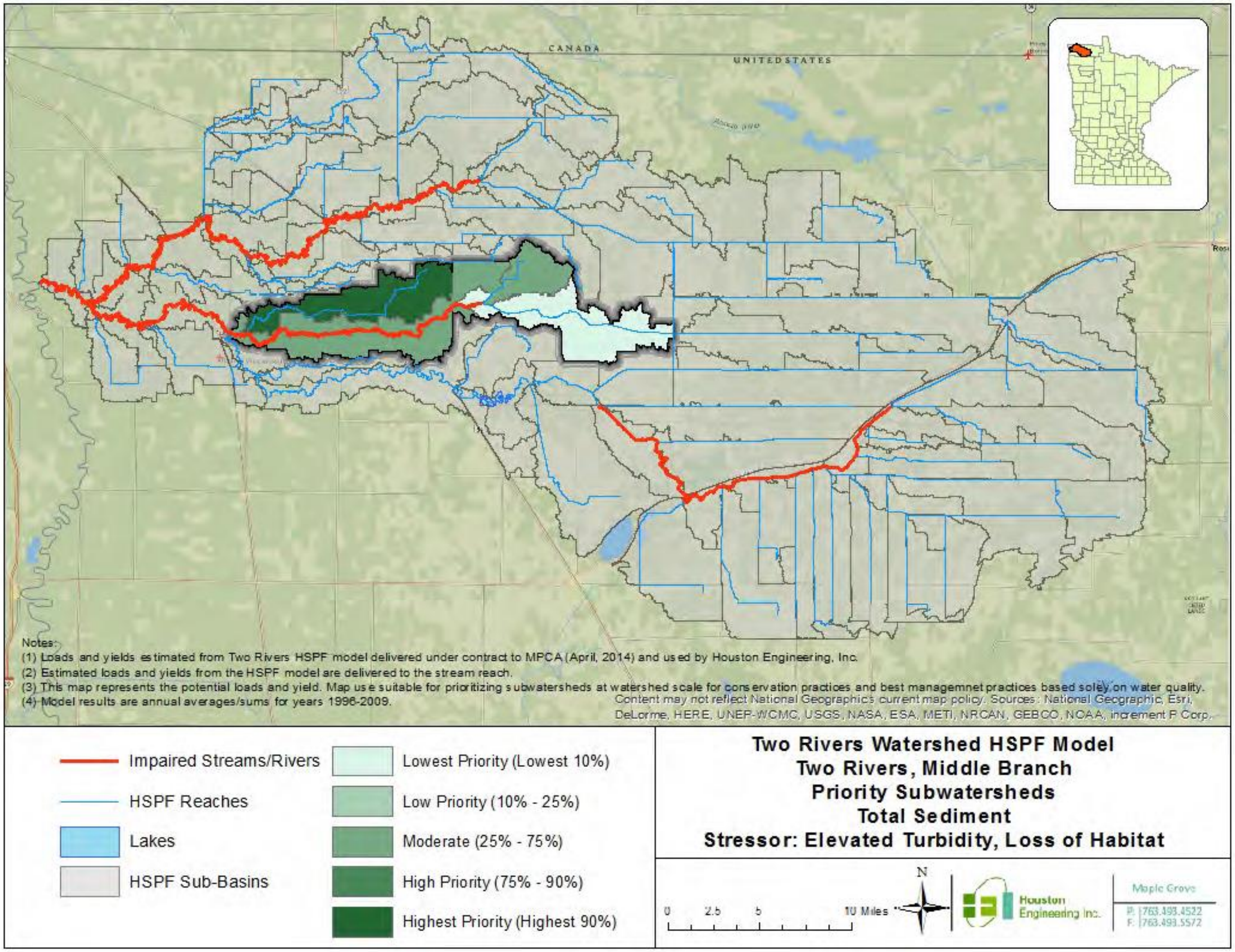


Figure A-28: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for Two Rivers, Middle Branch, using average (1996-2009) annual total sediment yields.

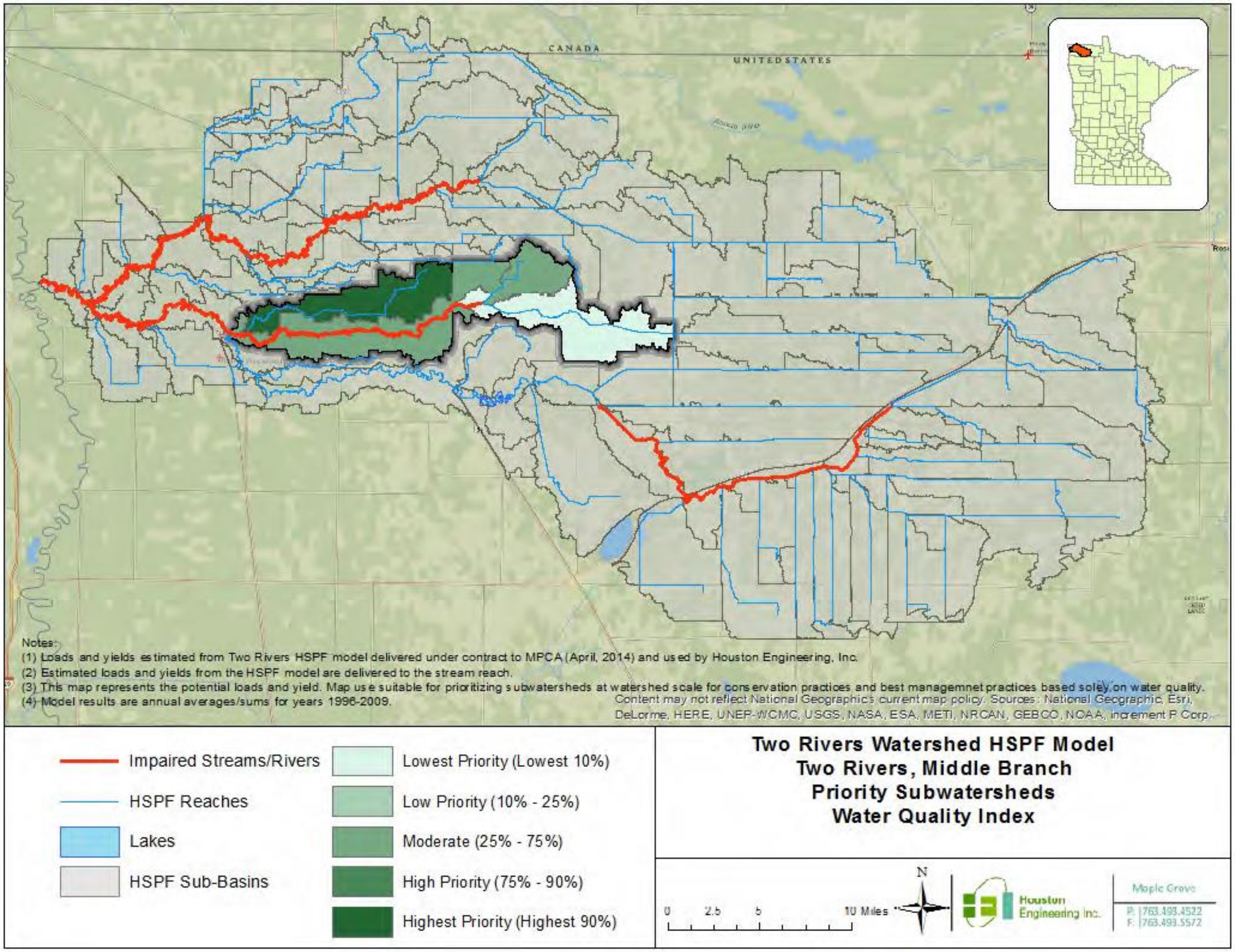


Figure A-29: Tributary scale subwatershed priority for implantation for Two Rivers, Middle Branch, using the average (1996-2009) water quality index.

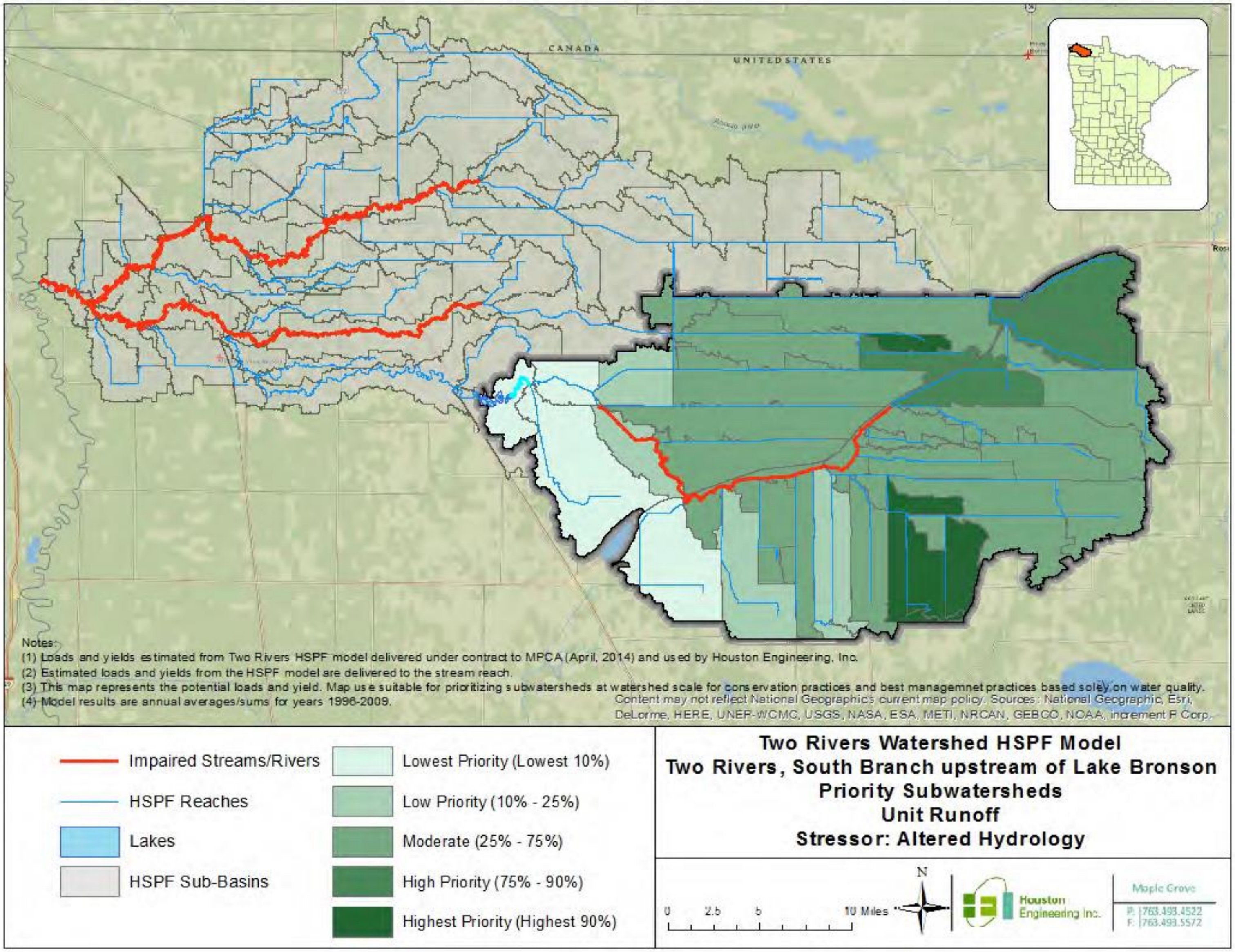


Figure A-30: Tributary scale subwatershed priority for implementation for the stressor altered hydrology for Two Rivers, South Branch upstream of Lake Bronson, using average (1996-2009) annual unit runoff.

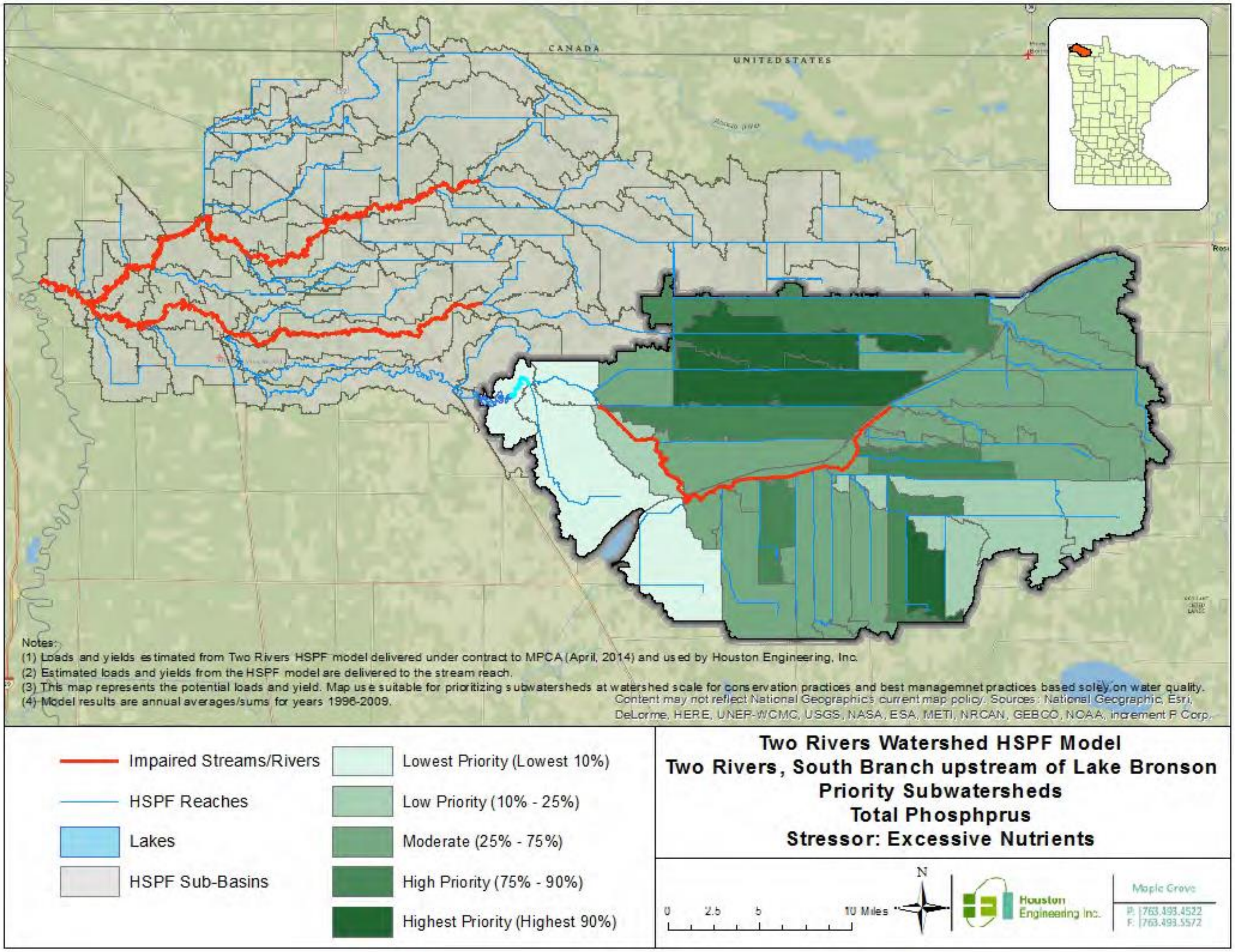


Figure A-31: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers, South Branch upstream of Lake Bronson, using average (1996-2009) annual total phosphorus yields.

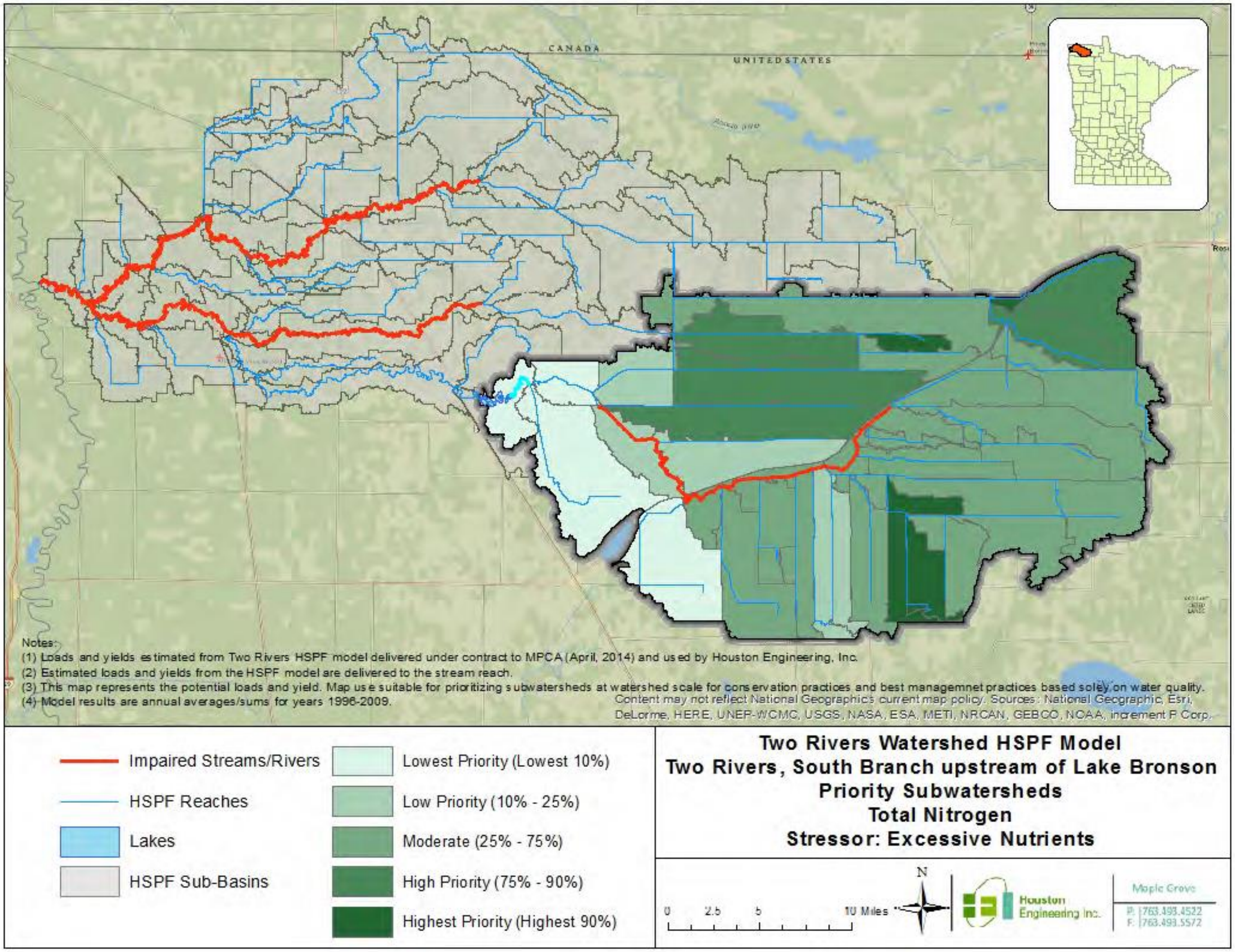


Figure A-32: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers, South Branch upstream of Lake Bronson, using average (1996-2009) annual total nitrogen yields.

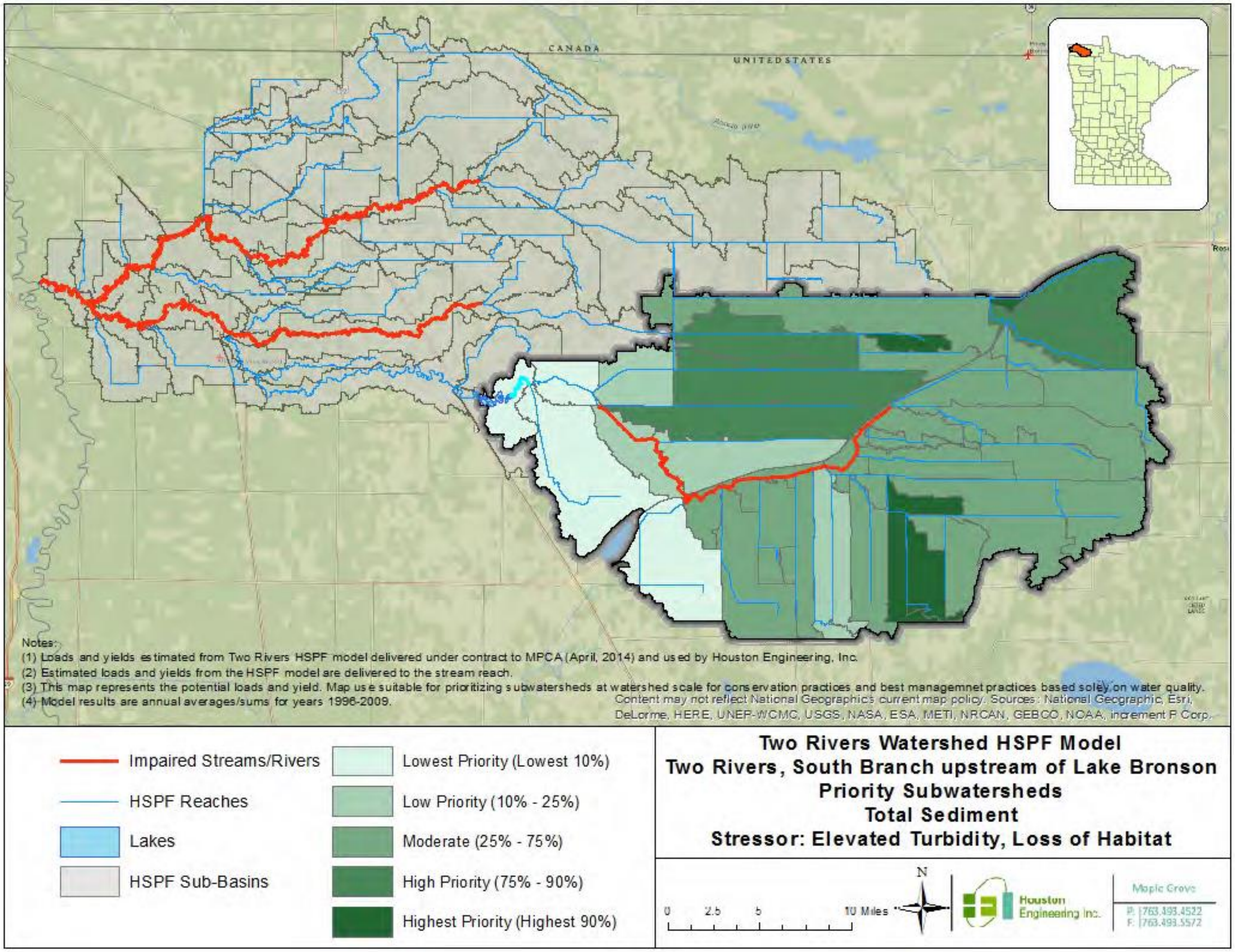


Figure A-33: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat Two Rivers, South Branch upstream of Lake Bronson, using average (1996-2009) annual total sediment yields.

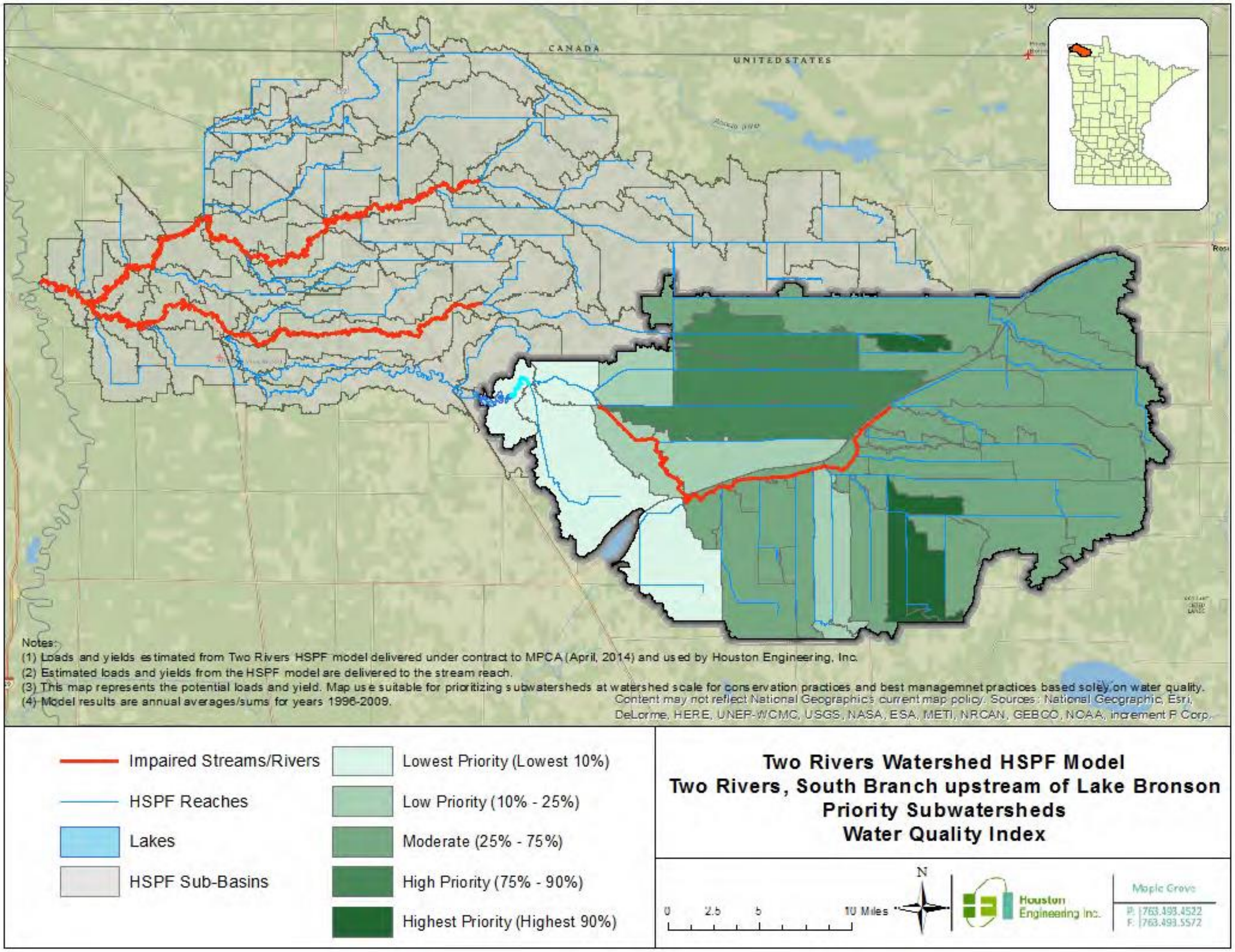


Figure A-34: Tributary scale subwatershed priority for implantation for Two Rivers, South Branch upstream of Lake Bronson, using the average (1996-2009) water quality index.

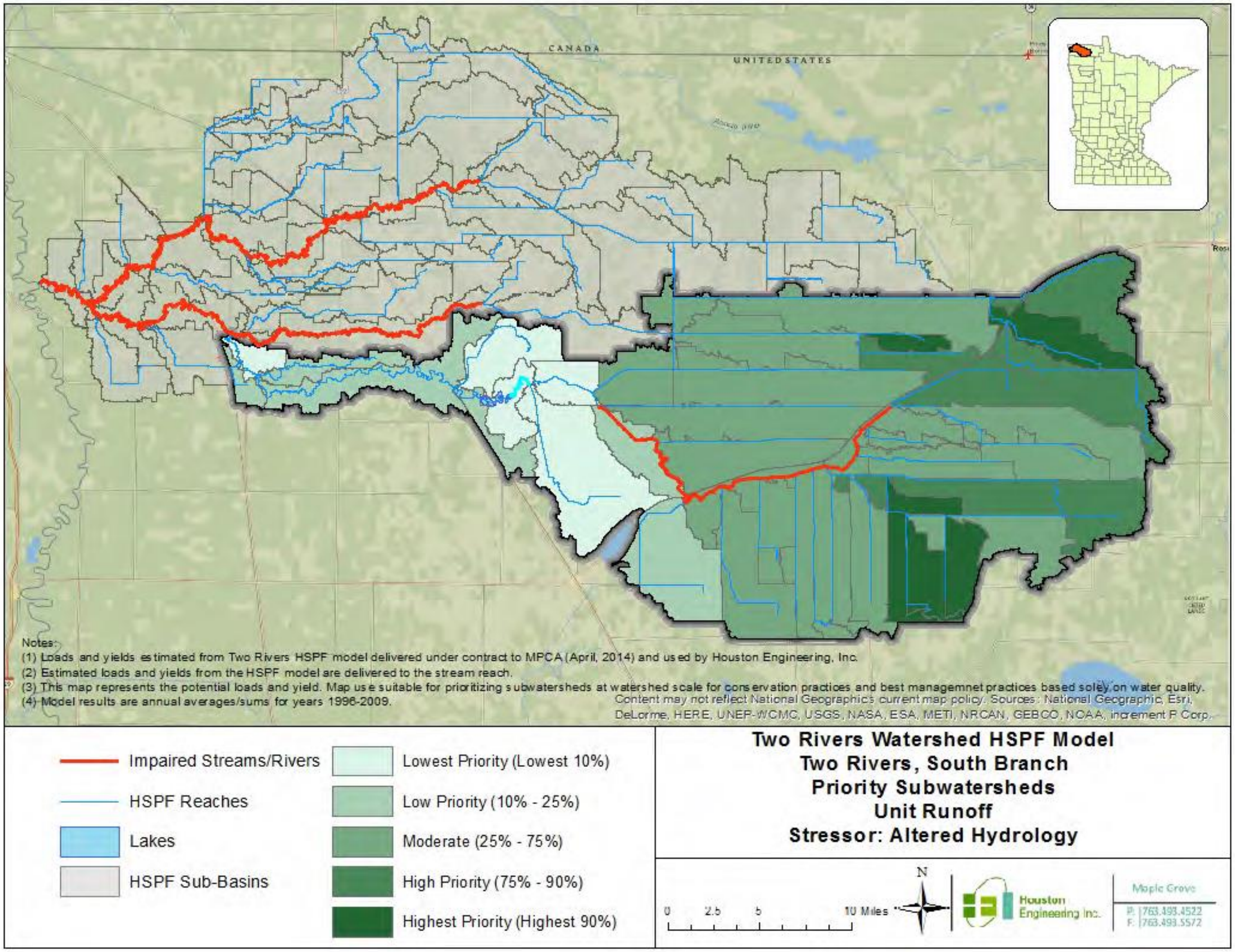


Figure A-35: Tributary scale subwatershed priority for implementation for the stressor altered hydrology for Two Rivers, South Branch downstream of Lake Bronson, using average (1996-2009) annual unit runoff.

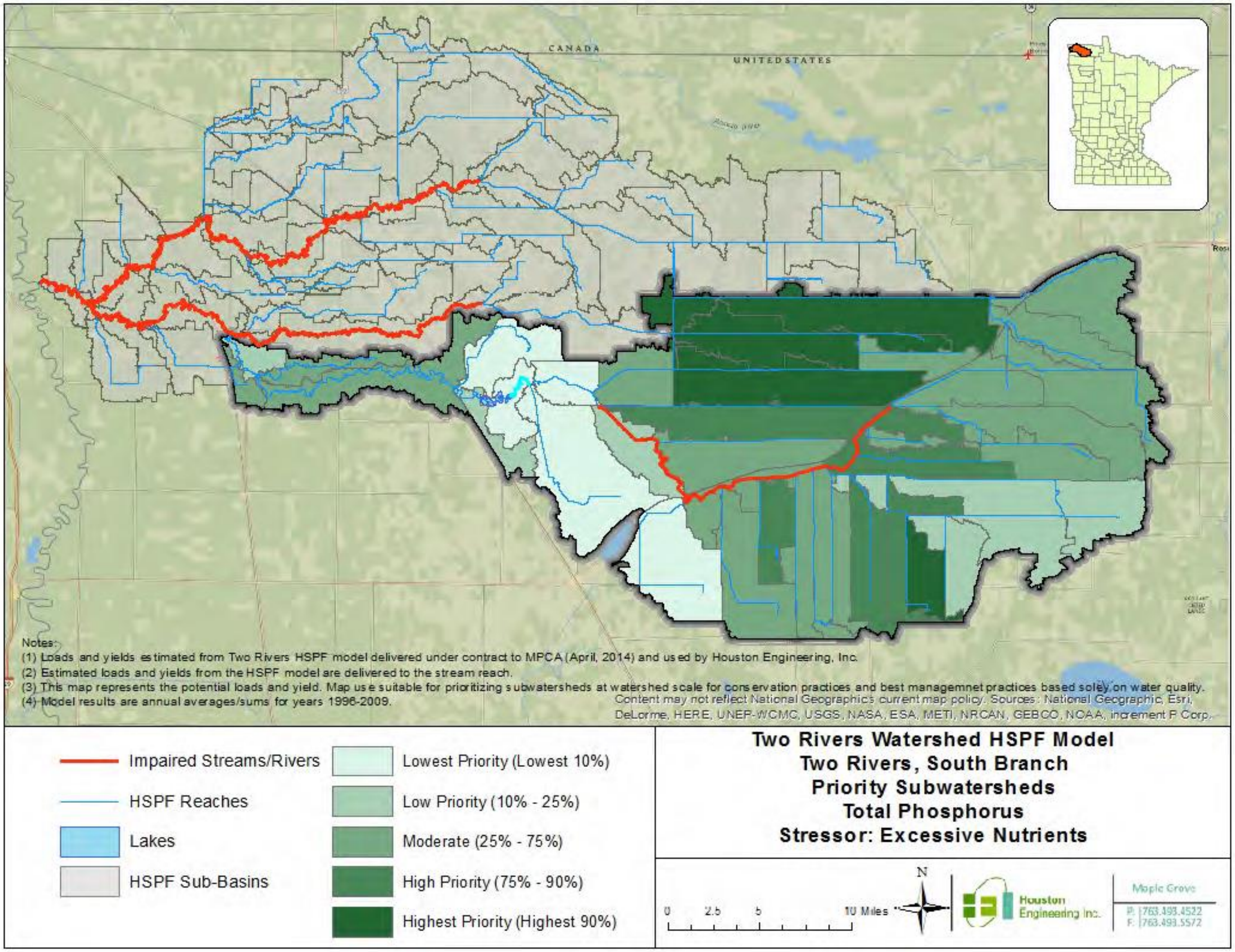


Figure A-36: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for Two Rivers, South Branch downstream of Lake Bronson, using average (1996-2009) annual total phosphorus yields.

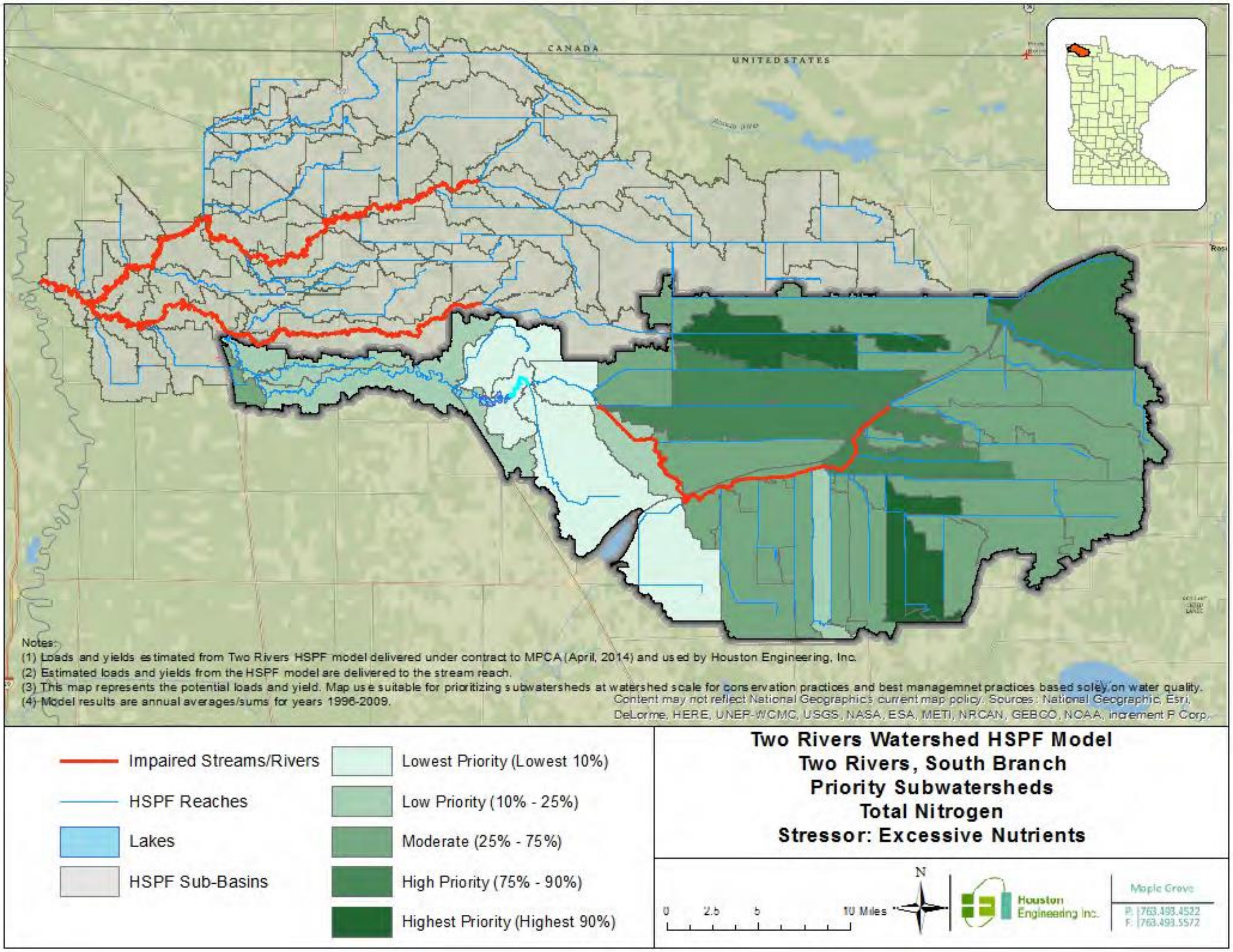


Figure A-37: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for Two Rivers, South Branch downstream of Lake Bronson, using average (1996-2009) annual total nitrogen yields.

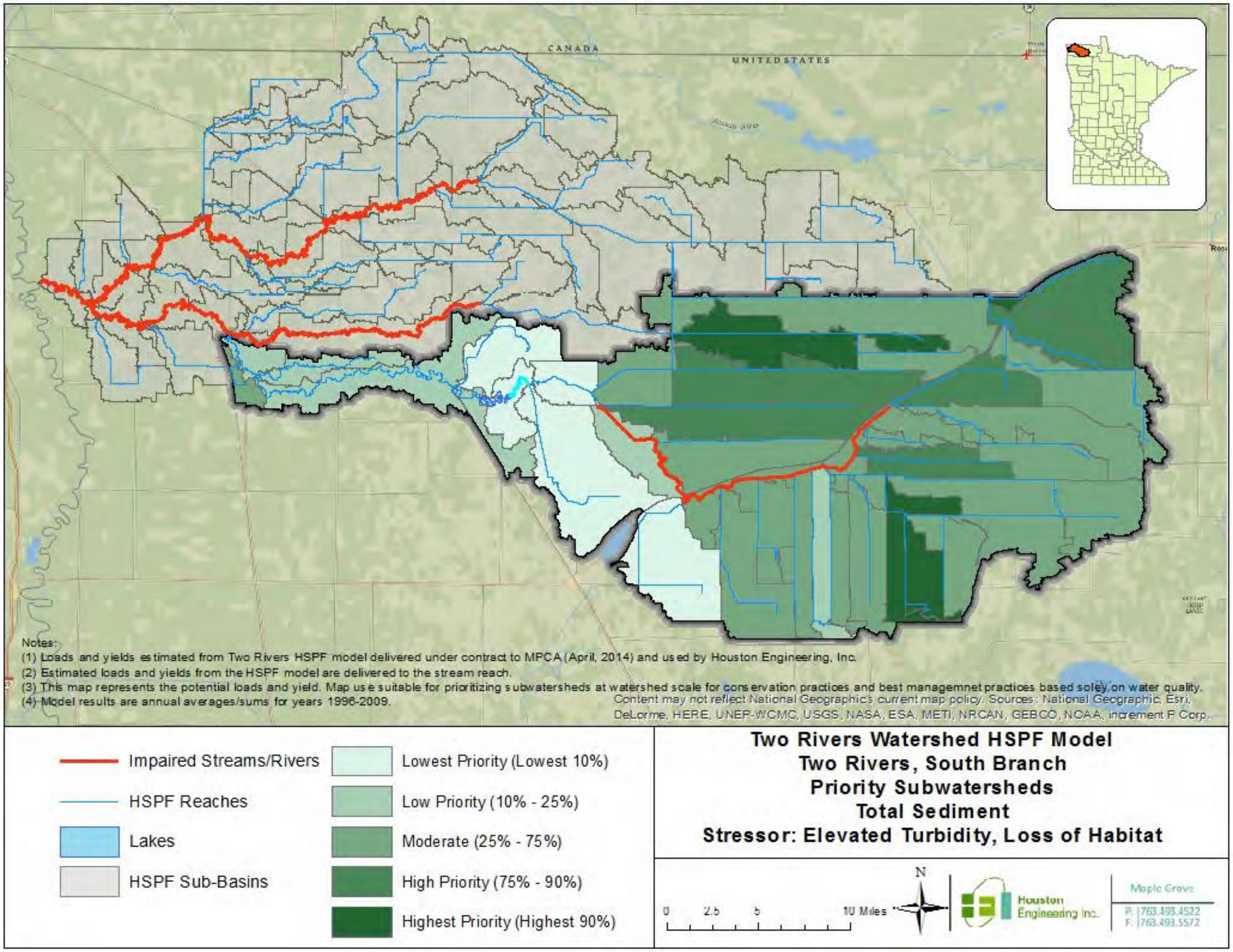


Figure A-38: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for Two Rivers, South Branch downstream of Lake Bronson, using average (1996-2009) annual total sediment yields.

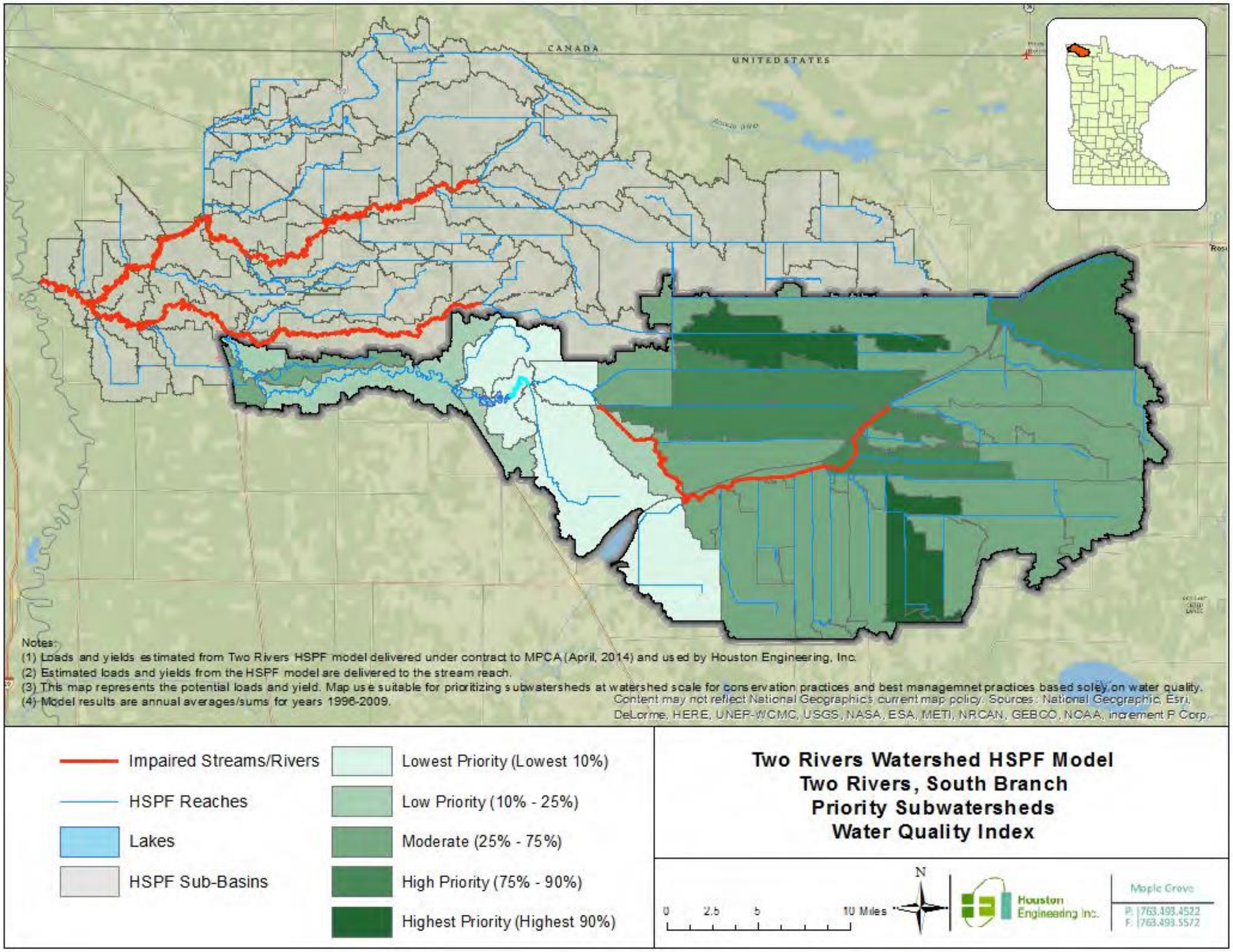


Figure A-39: Tributary scale subwatershed priority for implantation for Two Rivers, South Branch downstream of Lake Bronson, using the average (1996-2009) water quality index.

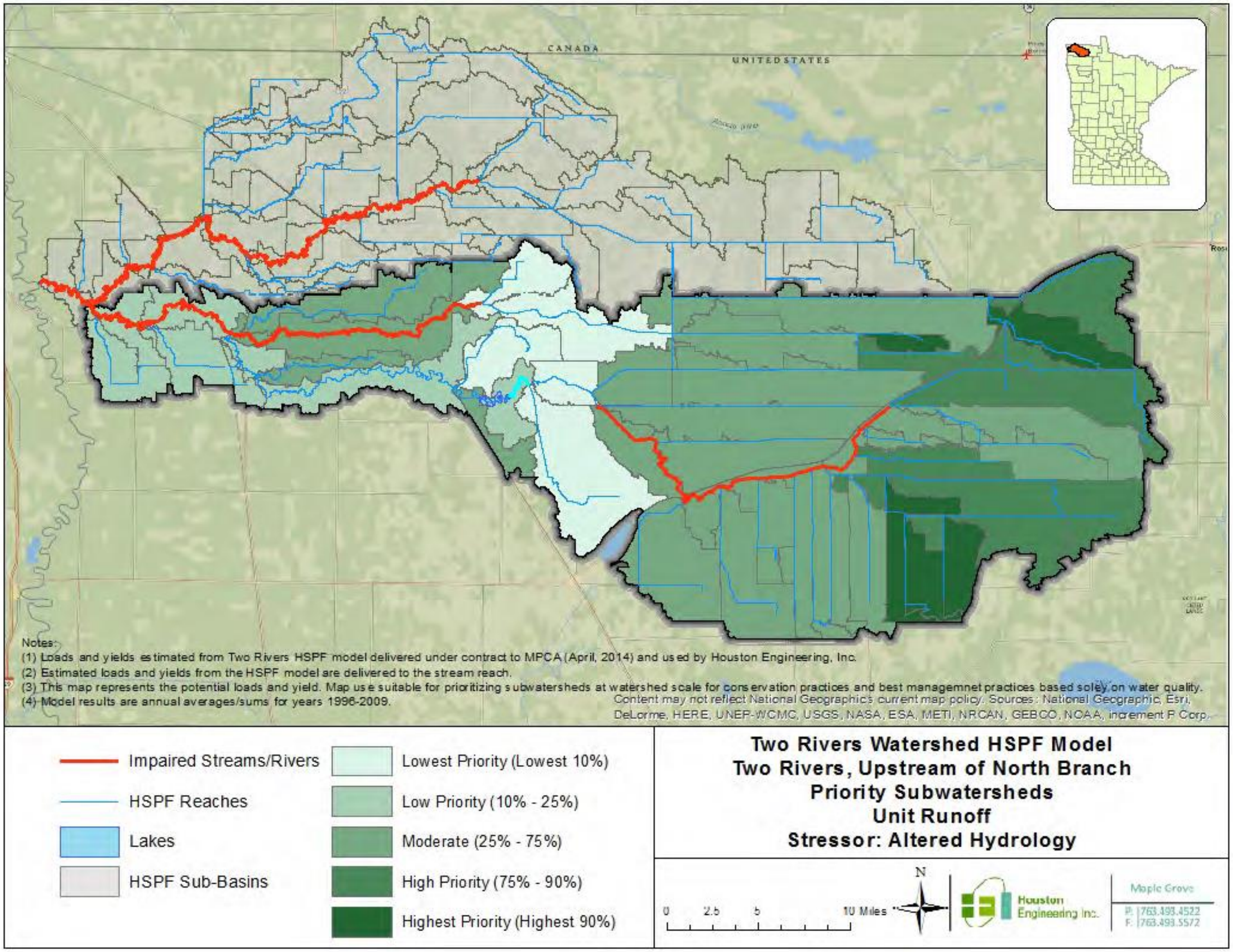


Figure A-40: Tributary scale subwatershed priority for implementation for the stressor altered hydrology for Two Rivers upstream of the confluence of North Branch, using average (1996-2009) annual unit runoff.

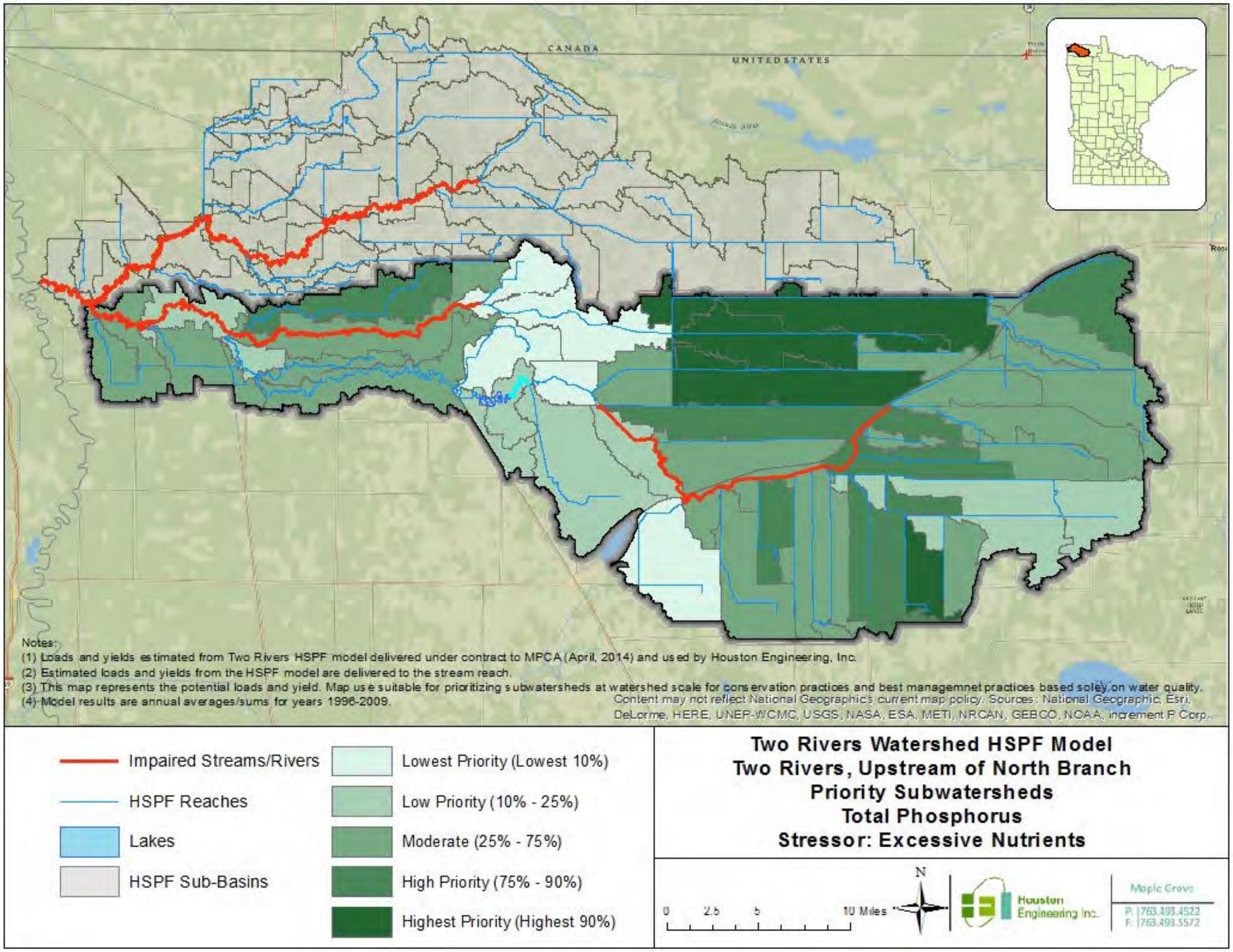


Figure A-41: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers upstream of the confluence of North Branch, using average (1996-2009) annual total phosphorus yields.

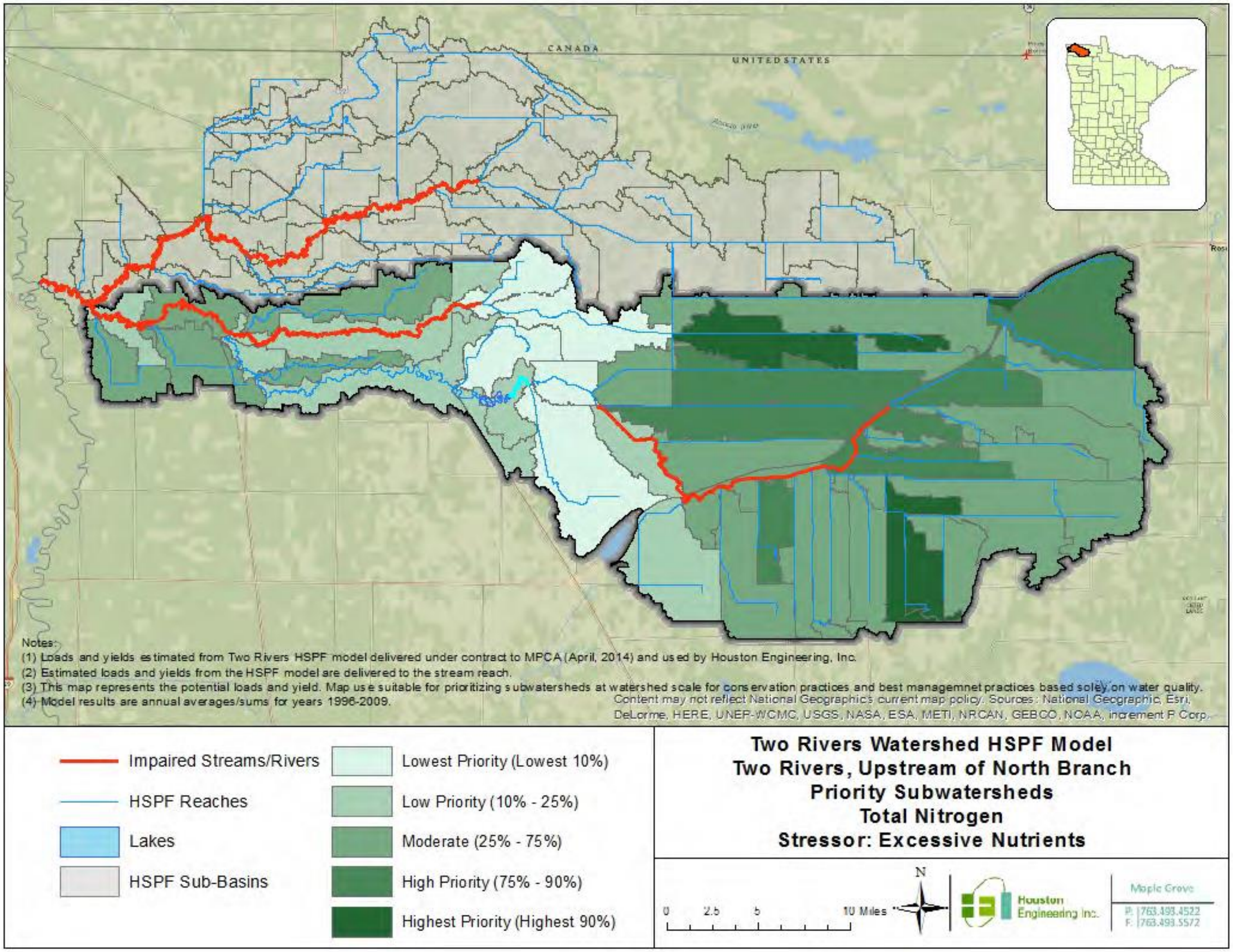


Figure A-42: Tributary scale subwatershed priority for implementation for the stressor excessive nutrients for Two Rivers upstream of the confluence of North Branch, using average (1996-2009) annual total nitrogen yields.

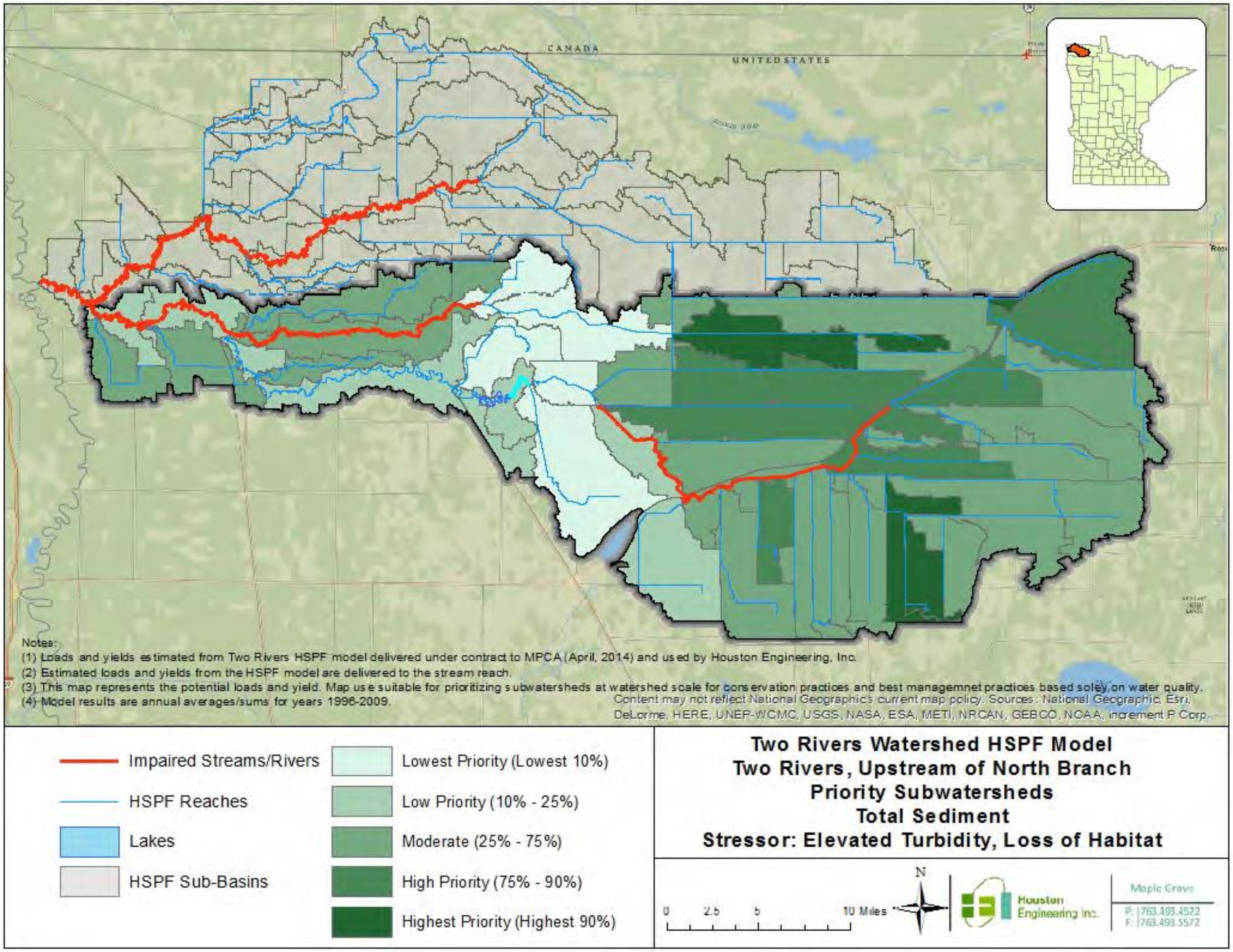


Figure A-43: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat Two Rivers upstream of the confluence of North Branch, using average (1996-2009) annual total sediment yields.

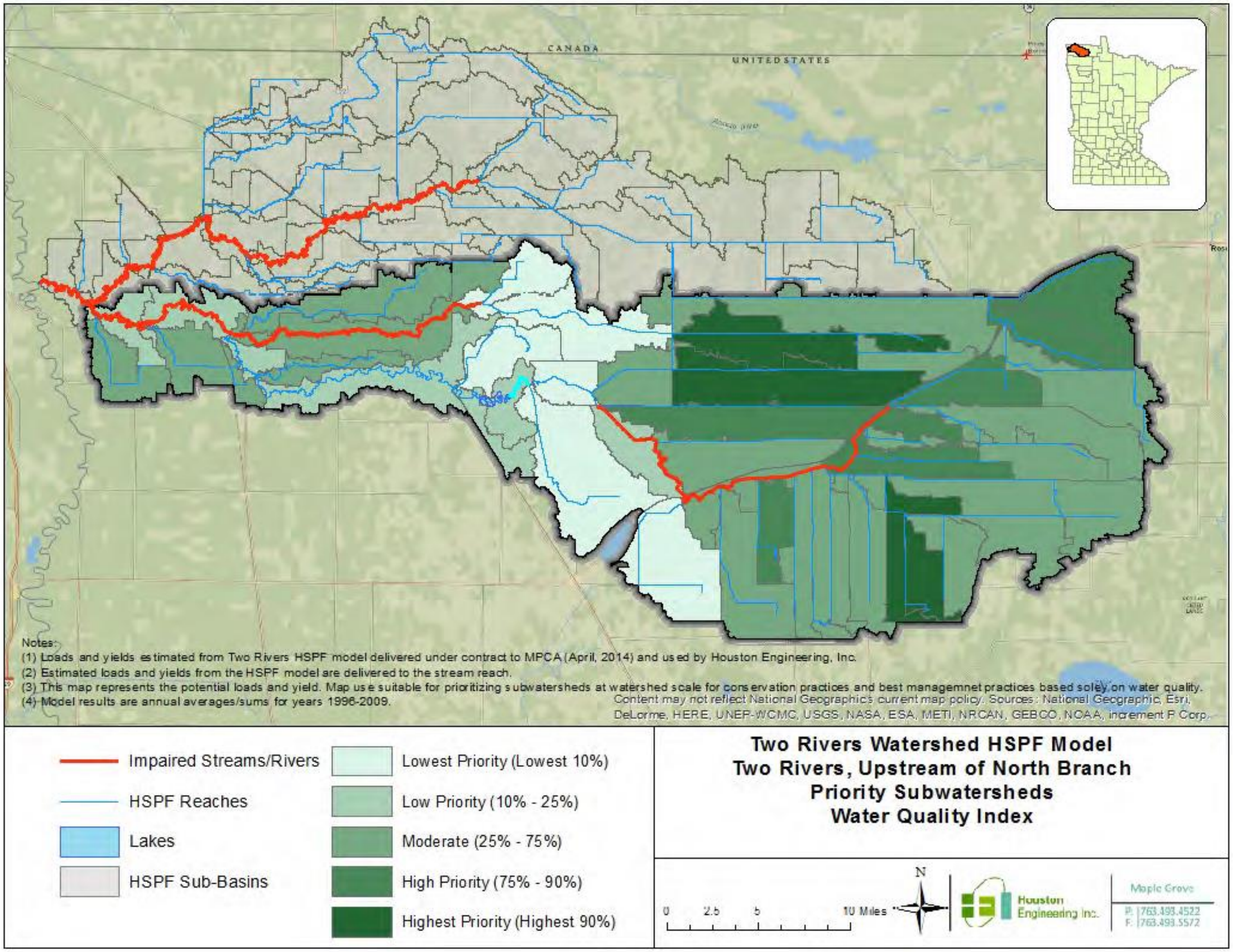


Figure A-44: Tributary scale subwatershed priority for implantation for Two Rivers upstream of the confluence of North Branch, using the average (1996-2009) water quality index.

Supplemental Information: HSPF Results

Supplemental Table 1: Water Quality Yields by Subwatersheds (RCHRES).

HSPF	Runoff		TP		TN		Sediment		WQI
RCHRES	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Rank
30	6.49	8%	0.190	31%	2.69	15%	2.60	13%	18%
31	6.08	24%	0.165	51%	2.31	40%	2.24	40%	43%
33	6.07	25%	0.191	30%	2.45	34%	2.37	33%	32%
35	6.30	16%	0.183	40%	2.51	29%	2.42	29%	32%
37	6.33	13%	0.222	11%	2.69	13%	2.62	12%	12%
50	6.22	20%	0.211	20%	2.74	11%	2.59	15%	15%
51	6.78	4%	0.143	67%	2.54	22%	2.47	24%	34%
53	6.32	15%	0.117	83%	2.18	47%	2.11	48%	57%
55	7.66	2%	0.258	1%	3.64	1%	3.56	1%	1%
57	7.66	1%	0.229	8%	3.47	2%	3.38	2%	4%
59	5.85	27%	0.198	27%	2.51	27%	2.40	30%	29%
71	6.33	12%	0.128	79%	2.19	46%	2.12	45%	54%
73	5.51	38%	0.160	58%	2.11	54%	2.04	55%	56%
75	5.44	40%	0.161	56%	2.07	61%	2.00	61%	60%
77	5.53	35%	0.176	43%	2.17	48%	2.10	49%	47%
79	6.13	21%	0.223	10%	2.65	17%	2.58	16%	15%
90	5.85	26%	0.183	38%	2.48	33%	2.36	34%	35%
91	5.43	44%	0.163	53%	2.20	45%	2.13	43%	46%
110	5.54	34%	0.169	46%	2.13	51%	2.06	51%	49%
111	4.62	61%	0.101	89%	1.53	84%	1.48	85%	86%
113	5.51	37%	0.161	57%	2.12	53%	2.05	53%	54%
115	6.23	19%	0.229	9%	2.83	7%	2.72	8%	8%
130	5.16	53%	0.138	73%	1.76	76%	1.73	74%	74%
131	6.65	7%	0.198	28%	2.75	10%	2.67	10%	15%
133	6.38	9%	0.144	65%	3.13	3%	2.79	4%	19%
135	6.37	11%	0.179	42%	2.51	26%	2.44	26%	30%
137	6.69	6%	0.188	33%	2.80	9%	2.69	9%	15%
139	6.38	10%	0.191	29%	2.61	19%	2.53	19%	22%
151	6.88	3%	0.243	6%	3.07	4%	3.00	3%	4%
153	6.26	17%	0.243	4%	2.83	6%	2.76	6%	5%
155	5.81	28%	0.234	7%	2.51	30%	2.43	27%	23%
157	6.23	18%	0.244	3%	2.82	8%	2.75	7%	6%
159	5.43	43%	0.173	44%	2.08	56%	2.04	54%	52%
170	3.28	96%	0.083	93%	1.04	93%	1.01	93%	93%
171	3.63	92%	0.104	88%	1.32	91%	1.27	91%	90%
200	3.91	83%	0.115	84%	1.55	83%	1.48	83%	83%
210	4.21	71%	0.141	70%	1.85	70%	1.73	75%	72%
211	3.34	94%	0.075	94%	1.03	94%	0.99	94%	94%
230	4.17	72%	0.151	63%	1.80	74%	1.72	76%	72%
231	4.62	62%	0.187	36%	2.07	60%	2.03	57%	53%
233	4.15	75%	0.162	55%	2.22	44%	2.13	44%	47%

HSPF RCHRES	Runoff		TP		TN		Sediment		WQI
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Rank
250	3.81	88%	0.139	72%	1.87	67%	1.78	69%	69%
251	3.49	93%	0.099	91%	1.19	92%	1.16	92%	92%
253	2.91	100%	0.059	98%	0.76	99%	0.73	99%	99%
255	5.40	46%	0.206	22%	2.51	28%	2.45	25%	25%
257	4.40	66%	0.165	48%	1.95	65%	1.88	64%	60%
259	4.16	74%	0.159	60%	2.13	52%	2.03	58%	57%
270	3.85	85%	0.139	71%	1.99	64%	1.77	70%	69%
271	4.14	76%	0.170	45%	2.09	55%	2.05	52%	51%
290	3.79	90%	0.144	66%	1.83	72%	1.79	67%	68%
291	4.51	63%	0.122	81%	1.71	79%	1.66	80%	80%
293	4.29	69%	0.120	82%	1.62	82%	1.58	82%	82%
295	4.71	57%	0.153	61%	1.85	69%	1.83	66%	65%
297	4.50	64%	0.130	78%	1.67	81%	1.63	81%	80%
299	6.11	22%	0.251	2%	2.71	12%	2.63	11%	9%
311	5.32	48%	0.187	35%	2.05	62%	1.99	63%	56%
313	4.07	80%	0.073	96%	0.96	96%	0.89	96%	96%
315	5.77	29%	0.209	21%	2.33	39%	2.27	39%	35%
317	3.19	97%	0.064	97%	0.92	97%	0.85	97%	97%
319	4.06	81%	0.105	87%	1.48	87%	1.42	87%	87%
331	4.66	58%	0.114	85%	1.40	88%	1.35	89%	88%
333	2.91	99%	0.047	100%	0.68	100%	0.66	100%	100%
335	4.33	67%	0.123	80%	1.51	85%	1.48	84%	83%
337	4.02	82%	0.100	90%	1.38	89%	1.35	88%	88%
339	4.48	65%	0.137	74%	1.71	80%	1.68	78%	77%
351	4.66	60%	0.151	62%	1.80	73%	1.76	72%	70%
353	5.11	54%	0.183	39%	2.15	49%	2.11	46%	45%
355	3.10	98%	0.056	99%	0.79	98%	0.77	98%	98%
357	5.21	51%	0.188	34%	2.36	38%	2.30	38%	37%
359	5.03	55%	0.184	37%	2.28	42%	2.22	42%	40%
371	4.89	56%	0.165	49%	2.23	43%	2.11	47%	47%
373	5.20	52%	0.201	25%	2.37	37%	2.33	37%	34%
375	5.27	49%	0.199	26%	2.40	36%	2.34	36%	33%
377	5.43	42%	0.216	17%	2.67	16%	2.57	17%	17%
379	5.40	47%	0.218	13%	2.54	24%	2.49	20%	19%
391	3.90	84%	0.147	64%	1.92	66%	1.84	65%	65%
393	5.47	39%	0.211	18%	2.52	25%	2.40	31%	26%
395	4.28	70%	0.090	92%	1.37	90%	1.34	90%	90%
397	5.42	45%	0.202	24%	2.42	35%	2.34	35%	32%
399	5.55	33%	0.216	16%	2.60	20%	2.48	22%	20%
411	5.56	31%	0.216	15%	2.57	21%	2.48	21%	20%
413	5.52	36%	0.211	19%	2.50	31%	2.43	28%	27%
415	5.69	30%	0.221	12%	2.63	18%	2.55	18%	17%
417	4.13	79%	0.162	54%	2.04	63%	1.99	62%	60%
419	3.84	87%	0.135	76%	1.84	71%	1.77	71%	72%

HSPF RCHRES	Runoff		TP		TN		Sediment		WQI
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Rank
431	4.17	73%	0.164	52%	2.08	57%	2.01	60%	57%
433	3.79	89%	0.141	69%	1.77	75%	1.74	73%	72%
435	4.14	78%	0.168	47%	2.08	58%	2.04	56%	54%
450	3.68	91%	0.135	75%	1.72	78%	1.68	79%	78%

Appendix B: PTMApp to aid in the development of WRAPS Strategies

TECHNICAL MEMORANDUM

To: Dan Money, Two Rivers Watershed District

Cary Hernandez, Minnesota Pollution Control Agency

From: Drew Kessler, Houston Engineering, Inc.

Through: Mark Deutschman, Houston Engineering, Inc.

Date: January 7, 2016

Project: 6279-003

Introduction

This Technical Memorandum (TM) describes the results of a bacteria risk assessment which can be used to identify areas in the watershed that pose the greatest risk for contributing bacteria to surface water resources and the use of the Prioritize, Target and Measure Application (PTMApp) for targeting fields based on yield (mass/area/time) of sediment, total nitrogen (TN) and total phosphorus (TP) and identifying opportunities for Best Management Practice (BMP) and Conservation Practice (CP) implementation and then measuring the water quality benefits of potential BMPs and CPs. This work is one component of the Two Rivers Watershed (TRW), Watershed Restoration and Protection Strategy (WRAPS).

This TM describes the methods used to create the PTMApp Desktop data products which include sediment, TN and TP mass leaving the landscape and delivered to downstream, user defined, priority resources summarized at landscape (i.e. 3-m raster) and catchment scales[4]. These user defined priority resource locations can include lakes and rivers of interest (resources of concern) and/or the outlet (i.e., pour point) of specific subwatersheds. This information is useful in assessing the locations, which are the greatest sources of sediment, TP, and TN, at a very fine field scale. These data can also be used to target specific fields as opportunities to place CPs and BMPs, based solely on pollutant source magnitude. Potential locations where CPs and BMPs appear suitable are also presented along with potential load reductions at the CP/BMP and any downstream priority resources.

This TM is intended to serve as a guide for TRW practitioners to utilize PTMApp Desktop output products to identify potential opportunities in specific fields for BMP implementation in areas that are likely to result in the greatest potential water quality improvements for the TRW. The data presented within this TM are a beginning point. The data requires further evaluation including field verification to select specific locations for implementing BMPs and CPs.

[4] Catchments are generally described as field scale contributing drainage areas with and average size of 40 acres.

Methods

Bacteria Sources and Risks

The relationship between bacterial sources and bacterial concentrations found in streams is complex, driven in part by the amount of precipitation and runoff, surface water temperature, the type of livestock management practices, wildlife population abundance and spatial distribution, bacterial survival rates, land use practices, and other environmental factors. These relationships were evaluated to determine the sources of bacteria. To evaluate the potential sources of bacteria delivered to waterbodies, a bacteria source investigation was conducted based on population production estimates and delivery mechanics. The bacteria source investigation included the following steps:

1. Identify and estimate magnitude (i.e., production rate) of potential bacteria sources that may contribute *E. coli* in the TRW. These sources include humans (subsurface sewage treatment systems [SSTS], WWTF), companion animals (cats and dogs), livestock (cows, chickens, goats, hogs, horses, sheep, and turkeys), and wildlife (deer, ducks, geese, and others). Once the population contributing bacteria have been identified, population estimates were obtained from the various sources provided in the following sections.
2. Each source is assigned a bacteria production rate (see **Table B-1**), based on literature values. These bacteria yields are then applied to the relevant areas, described in the following sections.
3. Apply an empirical downstream delivery factor, representing die-off and based on water travel time, to the bacteria production rates across the TRW. This delivery factor accounts for the fate and transport of bacteria from the source to the impaired waterbody.
4. Finally, the total bacteria load was estimated by summing the bacteria production with the delivery factor applied to estimate the relative loads for each identified source. A ranking was applied based on percentage of total bacteria load.

Production Rates

The EPA's *Protocols for Developing Pathogen TMDLs* (EPA 2001) provides estimates for bacteria production rates for most animals shown in **Table B-1**. Bacteria production rates were based on estimated bacteria content in feces and average excretion rates, expressed as units of colony forming units (cfu) per day per head (individual). Production rates are usually provided as fecal coliform; therefore, a conversion factor of 0.63 was used to convert fecal coliform to *E. coli*. The conversion factor is based on the ratio of the previous fecal coliform standard (200 org/100 mL) to the current *E. coli* standard (126 org/100 mL).

Table B-1: Bacteria production rates by source

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Humans	Humans	2	1.3	Metcalf and Eddy 1991
	Domestic Animals	5	3.2	Horsley and Witten 1996

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Livestock	Cattle	5.4	3.4	Metcalf and Eddy 1991
	Hogs	8.9	5.6	Metcalf and Eddy 1991
	Sheep and Goats	18	11.3	Metcalf and Eddy 1991
	Poultry	0.24	0.15	Metcalf and Eddy 1991
	Horses	4.2	2.6	ASAE 1998
Wildlife	Deer	0.36	0.2	Zeckoski et al. 2005
	Geese	4.9	3.1	LIRPB 1978
	Ducks	11	6.9	Metcalf and Eddy 1991
	Other (e.g. feral cats, raccoons, etc.)	5	3.2	Yagow 2001

[1]Literature rates are provided as fecal coliform, estimates for *E. coli* rates are based on fecal coliform estimates and conversion factor of 0.63, based on the conversion of the fecal coliform standard and *E. coli* standard.

Permitted Sources

Wastewater Treatment Facilities

Permitted WWTFs in the State of Minnesota are required to monitor their effluent to ensure that concentrations of specific pollutants remain within levels specified in their National Pollutant Discharge Elimination System (NPDES) discharge permit. In Minnesota, WWTFs are permitted based on fecal coliform, not *E. coli*. Effluent limits require that fecal coliform concentrations remain below 200 organisms/100 mL (MPCA 2002). Based on the previous fecal standard and the current *E. coli* standard, a ratio of 200:126 (0.63) is used to convert fecal coliform to *E. coli*. Therefore, the effluent limit for *E. coli* concentrations remains below 126 organisms/100 mL.

The TRW contains five "minor" (as defined by the MPCA) WWTFs. These facilities are all pond-type treatment plants with primary and secondary treatment ponds. **Table B-2** identifies the five permitted WWTFs in the TRW, and their permitted daily discharge flow and permitted daily bacteria load.

Table B-2: Wastewater treatment facilities, permitted flows, and bacteria loads for minor facilities in the TRW.

Facility	Permit Number	Discharges to	City / Township	System Type	Permitted Daily Discharge Flow [mgd]	Equivalent Bacteria Load as *E. coli*: 126 org/100mL [billion org/day]
Badger	MNG580155	Unnamed ditch	Badger	Class D: 3-cell pond	0.37	1.79
Greenbush	MNG580156	Lateral Ditch #2	Greenbush	Class D: 2-cell pond	2.28	10.88
Hallock	MNG580147	Unnamed Ditch	Hallock	Class D: 3-cell pond	1.56	7.46
Lake Bronson	MNG580029	Two Rivers, South Branch	Lake Bronson	Class D:2-cell pond	0.44	2.10
Lancaster	MNG580066	Coulee Creek	Lancaster	Class D: 2-cell pond	0.41	1.94

NPDES Permitted Concentrated Animal Feeding Operation

The MPCA regulates the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes (MPCA 2011). The MPCA currently uses the federal definition of a CAFO in its regulation of animal facilities. In Minnesota, the following types of livestock facilities are issued, and must operate under a NPDES Permit: (a) all federally defined (CAFOs); and (b) all CAFOs and non-CAFOs, which have 1,000 or more AUs (MPCA 2010). There is one permitted CAFO requiring an NPDES permit in the TRW. High Prairie Dairy has 2,240 AUs of dairy cows and holds NPDES Permit MNG440499. It is located in the North Branch Two Rivers Subwatershed (0902031206), which is within the drainage basin of one of the AUIDs that has an impairment addressed in this report (09020312-509). However, this is a zero discharge facility and therefore it is not given a WLA in the TMDL.

Non-permitted Sources

Humans - Subsurface Sewage Treatment Systems

Malfunctioning SSTSs can be an important source of fecal contamination to surface waters, especially during dry periods when these sources continue to discharge and surface water runoff is minimal. Malfunctioning SSTSs are commonly placed in two categories: Imminent Public Health Threat (IPHTs) or failing to protect groundwater (i.e., failing). IPHT indicates the system has a sewage discharge to surface water; sewage discharge to ground surface; sewage backup; or any other situation with the potential to immediately and adversely affect or threaten public health or safety. Failing to protect groundwater indicates the bottom of the system does not have the required separation to groundwater or bedrock.

Humans - Companion Animals

Companion animals, such as dogs and cats, can contribute bacteria to a watershed when their waste is not disposed of properly. Dog waste can be a significant source of bacteria to water resources (Geldreich 1996) at a local level when in the immediate vicinity of a waterbody. It was estimated that 34.3% of households own dogs and each dog-owning households has 1.4 dogs (AVMA 2007). Waste from domestic cats is usually collected by owners in the form of litter boxes. Therefore, it is assumed that domestic cats do not supply significant amounts of bacteria on the watershed scale. Feral cats may supply a significant source of bacteria and are accounted for under wildlife. Population estimates of domestic dogs were taken from the 2010 Census as a function of number of households per census block. Distribution of bacteria from companion animals is applied to all land uses in the NLCD land cover layer except open water. The bacteria sources, assumptions, and distribution used to estimate the potential source of bacteria related to humans are listed in **Table B-3**.

Table B-3. Data sources, assumptions, and distribution of bacteria attributed to humans.

Bacteria Source	Distribution
Unsewered Communities-Failing and IPHT SSTS Population in unsewered communities based on 2010 Census Block information. Number of failing and IPHT SSTS from County estimates (MPCA 2011).	The population of unsewered communities were estimated based on 2010 Census Block data. Production rates of 1.3×10^9 cfu/day/person was used. Total bacteria was applied to Developed land use classes in the NLCD 2011 dataset.
Companion Animals (Dogs only)	An estimated 38% of dog owners do not dispose of waste properly (TBEP 2011). Population distributions are based on 2010 Census Blocks. Production rates of

Bacteria Source	Distribution
34.3% of households own dogs, 1.4 dogs in households with dogs. Populations of dogs was based on the 2010 Census Block data.	3.2×10^9 cfu/day/dog was used. Total bacteria was distributed among all land use classes in the NLCD 2011 dataset except open water.

Livestock - Populations

The United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) provides livestock numbers, by county. Estimated numbers are available for cattle, hogs, horses, sheep, goats, and poultry (chicken and turkey) through the U.S. Census of Agriculture. County livestock populations were distributed across the TRW in an area-weighted basis. Livestock waste is distributed throughout the TRW in four main categories: grazing animals, animal feedlots, land application of manure, and small operations. Discussion of each of these categories follows.

Livestock - Grazing

Grazing occurs on pastured areas where concentrations of animals allow grasses or other vegetative cover to be maintained during the growing season. The state of Minnesota does not require permitting or registration of grazing pastures. Grazing cattle were assumed to be the total cattle population from the Census of Agriculture (see *Livestock Populations*) minus the cattle of feed.

Livestock - Animal Feedlots

Animal feedlots with less than 1,000, but more than 50, AUs (and are outside of shoreland areas) are regulated by the MPCA under a registration program. Animal feedlots with more than 10 AUs and inside shoreland areas are also regulated under this program. Shoreland is defined in Minn. Stat. § 103F.205 to include: land within 1,000 feet of the normal high-watermark of lakes, ponds, or flowages; land within 300 feet of a river or stream; and designated floodplains (MPCA 2010). These smaller facilities are subject to state feedlot rules, which include provisions for registration, inspection, permitting, and upgrading.

Livestock - Land Application of Manure

Manure is often surface applied or incorporated into fields as a fertilizer and soil amendment. The land application of manure has the potential to be a substantial source of fecal bacteria, transported to waterbodies from surface runoff and drain tile intakes. Minn. R. ch. 7020 contains manure application setbacks based on research related to nutrient transport, but the effectiveness of these setbacks on bacteria transport to surface waters is unknown. A portion of the livestock population was assumed to supply manure for land application (see **Table B-4**).

Livestock – Small Operations

Small-scale animal operations do not require registration and are not included in the MPCA's geographic feedlots database, but should be included in the Census of Agriculture (see *Livestock Populations*). All cattle, goats, horses, sheep, and poultry were treated as partially housed or open lot operations, and literature estimates were used to identify the number of animal feedlots without runoff controls (see **Table B-4**). The geographic areas for stockpiling or spreading of manure from these small, partially housed or open lot operations is based on NLCD 2011 *Pasture/Hay* and *Grassland/Herbaceous* land covers.

Table B-4: Data sources, assumptions, and watershed distribution of bacteria from livestock.

<table>
<tr><th colspan="2">Bacteria Sources</th><th>Distribution</th></tr>
<tr><td colspan="2">Grazing
Grazing populations estimates for cattle, horses, goats, and sheep were based on NASS Quick Stats (http://www.nass.usda.gov/Quick_Stats/).</td><td>Bacteria from grazing animals was applied to grasslands and pasture classes in the NLCD 2011 dataset.</td></tr>
<tr><td rowspan="2">Animal Feedlots
Animal feedlot populations for cattle, goats, hogs, horses, poultry, and sheep are based on NASS Quick Stats (http://www.nass.usda.gov/Quick_Stats/)</td><td>Partially Housed or Open Lot without Runoff Controls[1]
The proportion of feedlot animals that are partially housed or in open lots without runoff controls:
- Cattle 50%
- Poultry 8%
- Goats 42%
- Sheep 42%
- Hogs 15%</td><td>Bacteria from open lot animal feedlots was applied to barren, scrub/shrub, grassland, and pasture classes of the NLCD 2011 dataset.</td></tr>
<tr><td>Land Application of Manure
- Cattle 50%
- Poultry 92%
- Goats 58%
- Sheep 58%
- Hogs 85%</td><td>Land application of manure was distributed across the cropland class of the NLCD 2011 dataset.</td></tr>
</table>

[1] Estimates based on Mulla et al. 2001.

Wildlife

Wildlife, especially waterfowl, contribute bacteria to the watershed by directly defecating into waterbodies and through runoff from wetlands and fields adjacent to waterbodies, which are used as feeding grounds. In the TRW, land cover that could potentially attract wildlife includes: herbaceous wetlands and row crops adjacent to streams and lakes, wildlife management areas (WMA), and open water. Wildlife contribute bacteria to surface waters by living in waterbodies, living near conveyances to waterbodies, or when their waste is delivered to waterbodies during storm runoff events. Areas such as WMAs, state parks, national parks, national wildlife refuges, golf courses, state forest, and other conservation areas provide habitat for wildlife and are potential sources of bacteria due to high densities of animals. Additionally, private land managed for wildlife with practices such as food-plotting or supplemental feeding can concentrate wildlife and have the potential to be a source of bacteria from wildlife sources.

Fate and transport mechanisms differ between wildlife that live in/on surface waters (e.g., ducks, geese, cliff swallows, shorebirds, and beavers) where bacteria are directly delivered to waters and wildlife that live in upland areas (e.g., deer) where bacteria delivery is primarily driven by washoff and surface runoff. The wildlife considered as potential sources of bacteria include deer, ducks, geese, and others. Data sources and assumptions for wildlife populations are shown in **Table B-5**. In addition, a category called "other wildlife" was added to the source summary. These other animals include all other wildlife that may dwell in the watershed, such as beaver, raccoons, coyote, foxes, squirrels, etc. It is possible that the "other wildlife" category may at times be a significant source of bacteria, which lacks the data needed to account for it in this assessment. An example might be cliff swallows nesting under bridges, which may be in close proximity to sampling sites. The lack of data needed for this source assessment is a limitation of this technique.

Table B-5: Data Sources and Assumption for Wildlife Population and Bacteria Delivery.

Bacteria Source	Delivery
Deer The DNR report "Status of Wildlife populations, Fall 2009" includes a collection of studies that estimate wildlife populations of various species (Dexter 2009). Pre-fawn deer densities (in deer per square mile) were reported by DNR deer permit area.	Bacteria from deer were applied to all land use classes in the NLCD 2011 dataset except for open water and developed land use classes.
Ducks Populations of breeding ducks was taken from the U.S. Fish and Wildlife "Thunderstorm" Maps for the Prairie Pothole Region of Minnesota and Iowa	The USFW "Thunder Maps" are spatially distributed and were used once a bacteria production rate was applied.
Geese Population estimates were taken from the state-wide DNR's Minnesota Spring Canada Goose Survey, 2009 (Rave 2009). Counts were reported by Level I Ecoregion. An area-weighted estimate was taken from the state-wide data, resulting in an estimate of 1,568 geese in the TRW.	Bacteria from geese were distributed to areas within a 100 ft buffer of and including wetlands and open water classes in the NLCD 2011 dataset.
Other Wildlife Other wildlife in the TRW includes such animals as swallows, beaver, raccoons, coyote, foxes, and squirrels. Instead of estimating individual populations of each type of wildlife within the TRW. The bacteria production was assumed to be the same as the bacteria production from deer. Therefore, the bacteria production from deer was doubled to account for all other wildlife in the watershed that are not accounted for explicitly.	Same as deer.

Natural/Background Sources

Three Minnesota studies described the potential for the presence of "naturalized" or "indigenous" *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Sadowsky et al. 2010; Chandrasekaran et al. 2015). Sadowsky et al. (2010) conducted DNA fingerprinting of *E. coli* in sediment and water samples from Seven Mile Creek, located in south-central Minnesota. They concluded that roughly 63.5% of the bacteria were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period, but results might not be transferable to other locations without further study. Although the result may not be transferable to other locations, they do suggest the presence of natural background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies.

Fate and Delivery of Bacteria

A delivery factor was developed to account for the fate and transport of bacteria from the landscape to the impaired waterbody. The delivery factor accounts for factors such as proximity to surface waters, landscape slope, imperviousness, and the probable bacteria die-off rate (bacteria cannot survive outside of a warm-blooded host). Therefore, the die-off rate is known to follow an exponential (first-order) loss rate. The bacteria delivery factor assumed delivery to the waterbody is dependent on water travel time and a bacteria die-off rate.

The EPA's *Protocols for Developing Pathogen TMDLs* provides a methodology for estimating bacteria die-off and lists coefficients for die-off calculations (EPA 2001). The die-off equation was given as:

$$C = C_0 exp(-KT_t)$$

Where *C* is the concentration of bacteria (cfu/day), C_0 is the initial concentration of bacteria (cfu/day), *K* is the decay (die-off) coefficient (1/day), and T_t is travel time (days). The die-off coefficient for natural surface water used in the TRW was 0.202 $days^{-1}$ (essentially meaning about 20% per day). The die-off equation was applied to a water travel-time grid for the watershed as a whole and each impaired reach to estimate the delivery factor. An assumption is that the time of travel through the watershed by bacteria is the same as water.

The magnitude of the bacteria sources were placed into one of three categories: low, medium, and high. The rankings are based on the percentage of total bacteria load for each potential source. The sources were categorized into 10 groups. If all 10 potential sources contributed equally, they should each contribute 10% of the total load. As such, we ranked potential sources contributing 5% to 20% of the total load as a medium risk, or half to twice the expected value. If the source of bacteria was less than 5% of the total load, a rank of low was assigned and if greater than 20% a rank of high was assigned. The rankings for the TRW were all relative to the delivery of *E. coli* to the TRW outlet.

The magnitude of bacterial source delivery was also summarized by 12-digit HUC watersheds (hereafter HUC-12) within the TRW. The bacterial source loading to the outlet of the TRW was calculated for each HUC-12. The bacterial sources were aggregated to Human (STSS; Pets), Livestock (Grazing; Manure; Animal Feedlots), and Wildlife (Deer; Ducks; Gees; Other). WWTF were excluded from the HUC-12 rankings as they are currently a regulated point source. The magnitudes of the three sources were then ranked using a linear normalization relative to the total magnitude of all sources.

Generating PTMApp Products

PTMApp was used to develop the following data products:

- *Catchments* – hydrologic boundaries that average 40 acres in size. Used to summarize PTMApp raster data products
- *Stream power index (SPI) and compound topographic index (CTI)* – SPI shows areas on the landscape of high flow accumulation and slope (i.e. areas of likely erosion). CTI shows areas on the landscape where water is likely to pond.
- *Source Assessment* - Sediment, TN, and TP yield and delivery downstream to catchment outlets and priority resource points.
- *Hydrology Data* – estimates of runoff depths, volumes, and peak discharge based upon the curve number method

- *BMP suitability* – areas on the landscape with potential for BMPs and CPs grouped into six categories (biofiltration, filtration, infiltration, protection, source reduction, storage).
- *BMP cost-effectiveness* – estimates of the cost and load reduction of potential BMPs. Load reductions are calculated at the BMP and downstream at the catchment outlet and priority resource points.

The methods used within PTMApp are peer reviewed and well documented. All PTMApp documentation can be obtained by entering “BWSR PTMApp Documentation” into a search engine.

Previous work had developed similar geospatial data products. This project has significantly increased the value of available geospatial data products for the TRW WRAPS by:

- Delineating catchment hydrologic boundaries for rivers, streams, and ditches.
- Identify potential locations for BMPs and CPs
- Estimated source delivery, load reductions, and cost effectiveness at downstream priority resource points. These points were selected based upon local input from TRWD.

Results

Bacteria Sources and Risks

Results for each potential source of bacteria are summarized by the portion of each county within TRW. The final risk assessment is then presented based upon subwatershed boundaries delineated by TRWD.

Humans - Subsurface Sewage Treatment Systems

Of the rural population in the TRW, an estimated 126 systems have inadequate treatment of household wastewater. This includes individual residences and any un-sewered communities. An MPCA document (MPCA 2011) reports numbers from 2000 through 2009 on the total number of SSTSs by county, along with the average estimated percent of SSTSs that are failing versus the percent that are considered IPHTs. The total numbers of SSTSs per county were multiplied by the estimated percent IPHT and percent failing within each area (MPCA 2011) to compute the number of potential IPHTs and potentially failing SSTSs per county and in the TRW overall. **Table B-6** summarizes the results.

Table B-6: SSTS compliance status in the TRW.

	Kittson	Roseau	Marshall
Identified # of SSTSs	538	1,165	14
# of potentially failing SSTSs	48	0	3
# of potential IPHTs	27	47	1

Livestock - Populations

Livestock populations were estimated for cattle, chickens, goats, horses, sheep, and turkeys for each county and are provided in **Table B-7**. The MPCA’s geographic feedlot database was developed for registered and NPDES-permitted animal feedlots; it provides the location and allowable populations of animals, but these populations are the maximum allowable populations under the permits and are not the actual populations at these sites. Therefore, the USDA census data was used to estimate livestock populations.

Table B-7: Livestock Population Estimates (numbers) in the TRW.

Animal	Type	Kittson	Marshal	Roseau
Cattle	Beef	6,128	52	4,759
	Cattle on Feed	221	2	198
Other	Pigs	20	0	2,531
	Sheep and Goats	140	10	610
	Horses	125	3	242
Poultry	Layers	118	4	216
	Boilers	82	2	70
	Turkey	0	0	70,832
	Ducks and other	1	0	4

Fate and Delivery of Bacteria

Table B-8 shows the risk rankings of potential sources of bacteria in the TRW by impaired AUID. These ranks are relative to the potential sources within each subwatersheds (i.e., ranks cannot be compared between subwatersheds, only within). Livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the TRW. This information can be used to prioritize management efforts for the potential sources of bacteria that pose the greatest risk of impacting surface waters in the TRW. It should be noted that there are potential sources of *E. coli* that were not accounted for in this analysis due to a lack of data. For instance, Cliff Swallows often colonize under bridges along waterways in this area and would be a potentially high source of direct *E. coli* contributions to surface waters in the area.

Table B-8: Relative Sources of *E. coli* in the TRW.

Assessment Unit Identification	Humans				Livestock				Wildlife					Upstream Sources	
	All	WWTF Effluent	Septic Systems	Domestic Animals	All	Grazing	Manure	Feedlot Open Lots	All	Deer	Ducks	Geese	Other	Level	Estimated Percentage
501	○	○	○	○	●	●	●	●	○	○	○	○	○	●	87%
503	○	○	○	○	●	●	◯	◯	○	○	○	○	○		NA
505	○	○	○	○	●	●	●	●	○	○	○	○	○	●	90%
506	○	○	○	○	●	●	●	●	○	○	○	○	○		NA
535	○	○	○	○	●	●	●	●	○	○	○	○	○		NA

Figure B-1 shows ranks based on the area weighted magnitude of bacterial delivery for major stream branches within TRW. Higher rates equate to a greater risk of bacterial delivery from the watershed to the outlet of the TRW. Similar to the results shown in **Table B-8**, livestock sources consistently posed the greatest risk of bacterial delivery. The results in **Figure B-1** are area weighted, so comparisons can be made between watersheds. This information can be used to inform the prioritization of local management efforts aimed at reducing bacterial delivery to surface waters in the TRW. In addition, **Figure B-1** can also be used to begin targeting specific watersheds for bacterial restoration and protection strategies.

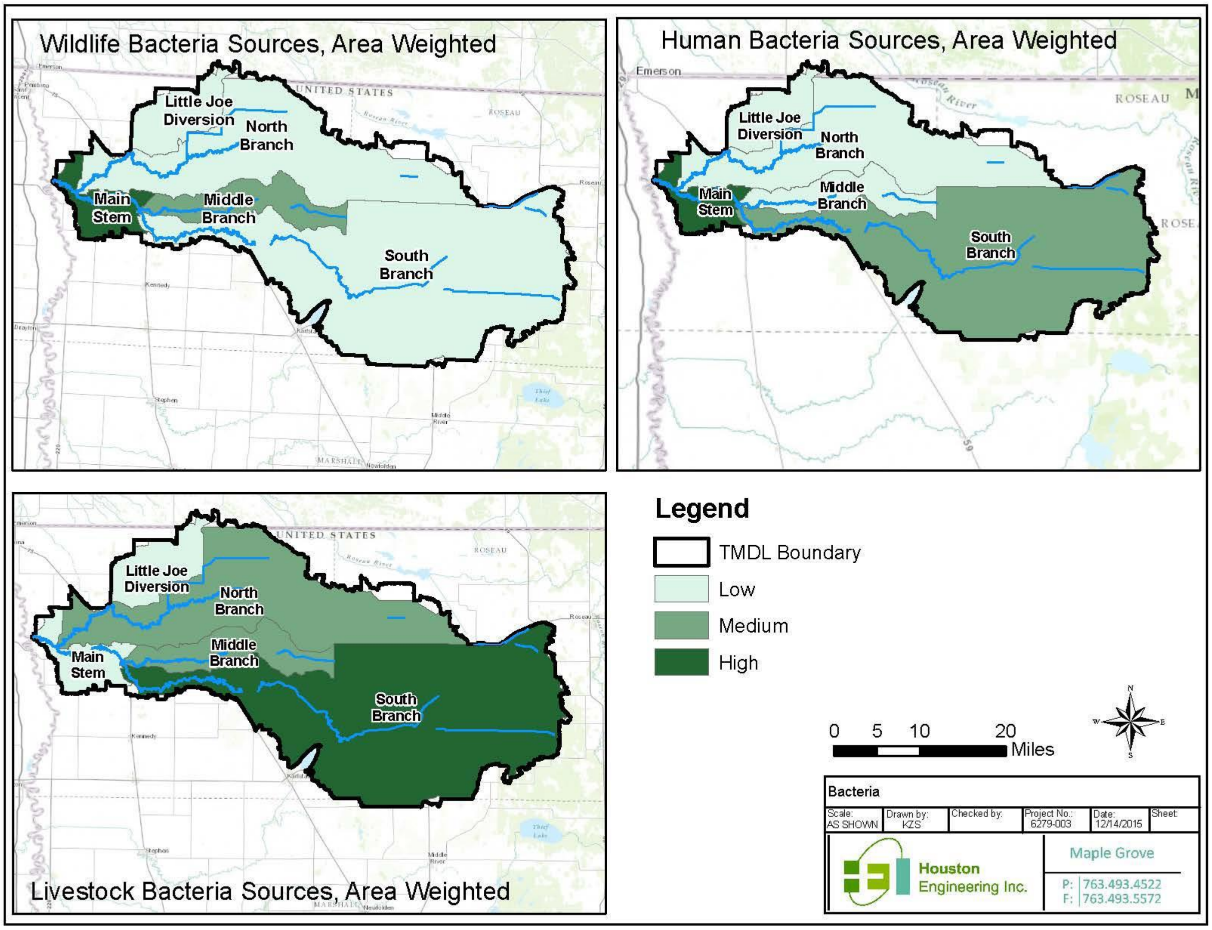


Figure B-1: Ranked HUC 12 subwatersheds based upon magnitude of bacterial delivery to the outlet of the TRW.

Targeting Fields with PTMApp

The output products from PTMApp Desktop can be used in a number of business workflows. The business workflows in **Figure B-2** are tasks staff might undertake as part of daily work to prioritize, target the locations of projects and practices that provide measurable water quality benefits. These workflows, or subset of the workflows, might be completed as part of implementation strategy development for an annual work plan, development of WRAPS, accelerated implementation grants (AIG) through BWSR, or federal 319 grants. This desktop analysis picked up beginning with the Complete Source Assessment step in **Figure B-2** and worked through:

- Evaluate Practice Feasibility
- Estimate Individual Practice Water Quality Benefits

The data developed through this study can continue to be used to develop numerous BMP and CP implementation scenarios. This data will be used to help inform the development of the final protection and restoration strategies for the TRW WRAPS. The sections below show an example of these products and how they can be used. The complete dataset used for generating these products was delivered with this technical memorandum.

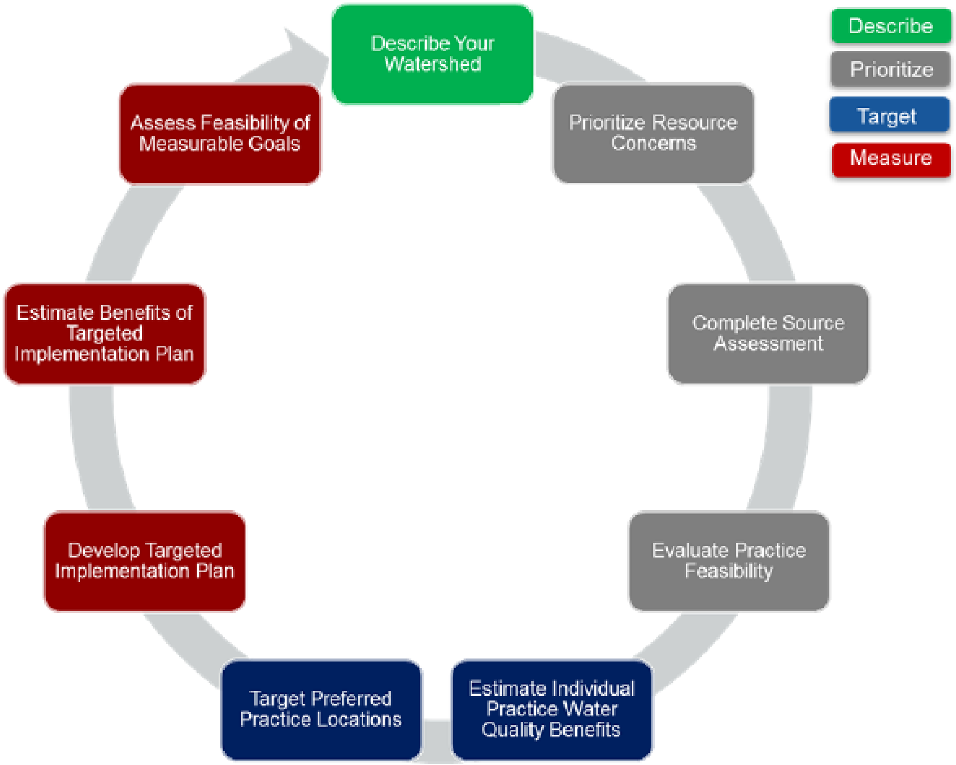
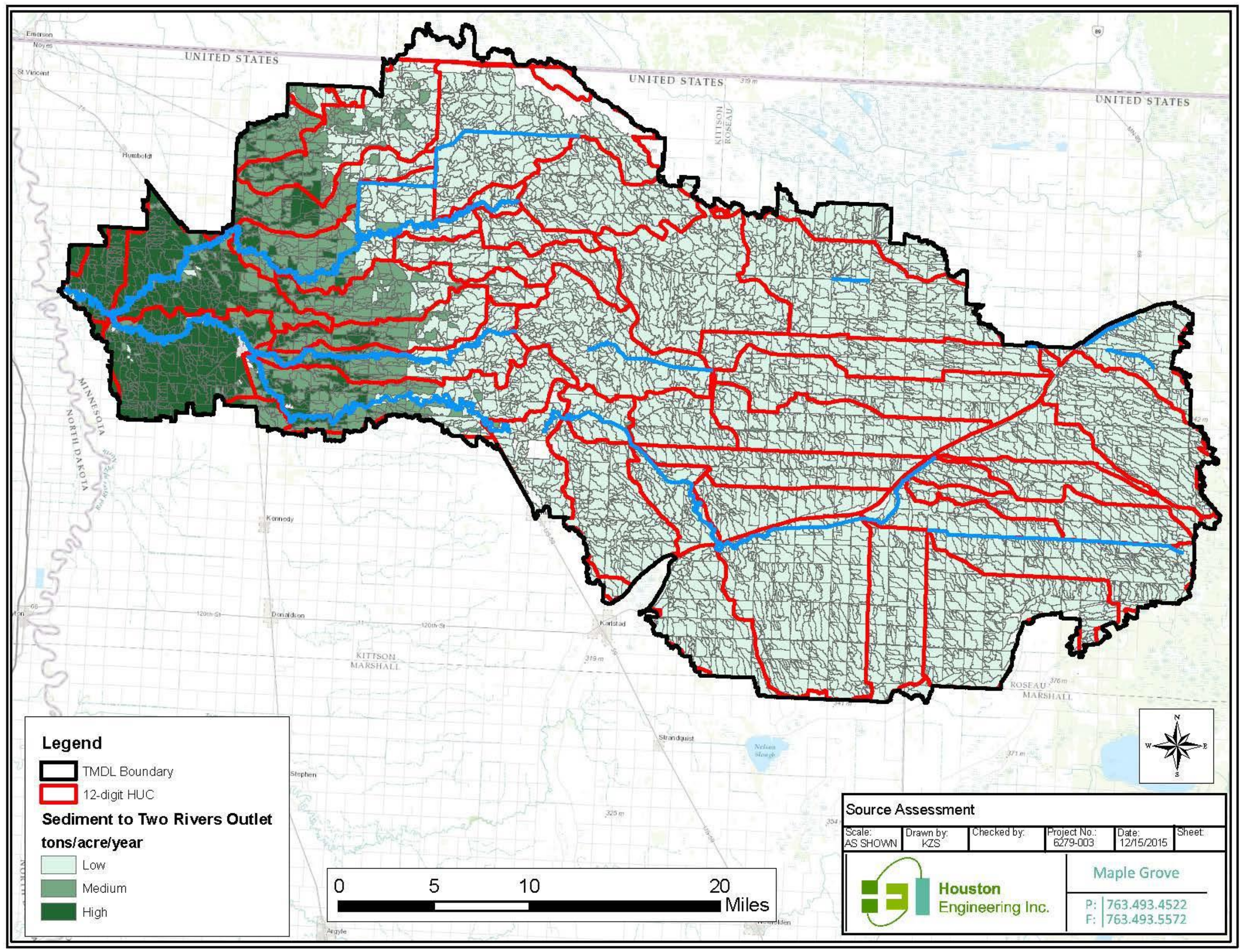


Figure B-2: Business workflows addressed by PTMApp Desktop.

Complete Source Assessment

The source assessment identifies the magnitude and spatial distribution of potential pollution sources across the landscape. PTMApp – Desktop creates three source assessment products; i.e., load and yields leaving the landscape, delivered to a waterway, and delivered to a downstream resource of interest (e.g., lake or river reach). By completing a source assessment, an understanding of how various parts of the watershed affect a resource is obtained. The sediment yield (tons/acre/year) delivered to the outlet of TRW for the study area is shown in **Figure B-3**. Similar products can be developed for TN and TP for any priority resource point input during processing. The results indicate that the highest areas of overland sediment loading to the outlet of TRW are concentrated near the outlet of the watershed. For strategies aimed at reducing sediment delivered to the outlet of TRW, the "High" sediment yield areas would provide ideal locations to target practices. However, we first must evaluate the feasibility of implementing BMPs and CPs in those areas. In other words, the highest loading (sediment, TN, or TP) areas on the landscape, might have limited opportunities for implementing a practice to address the issue.



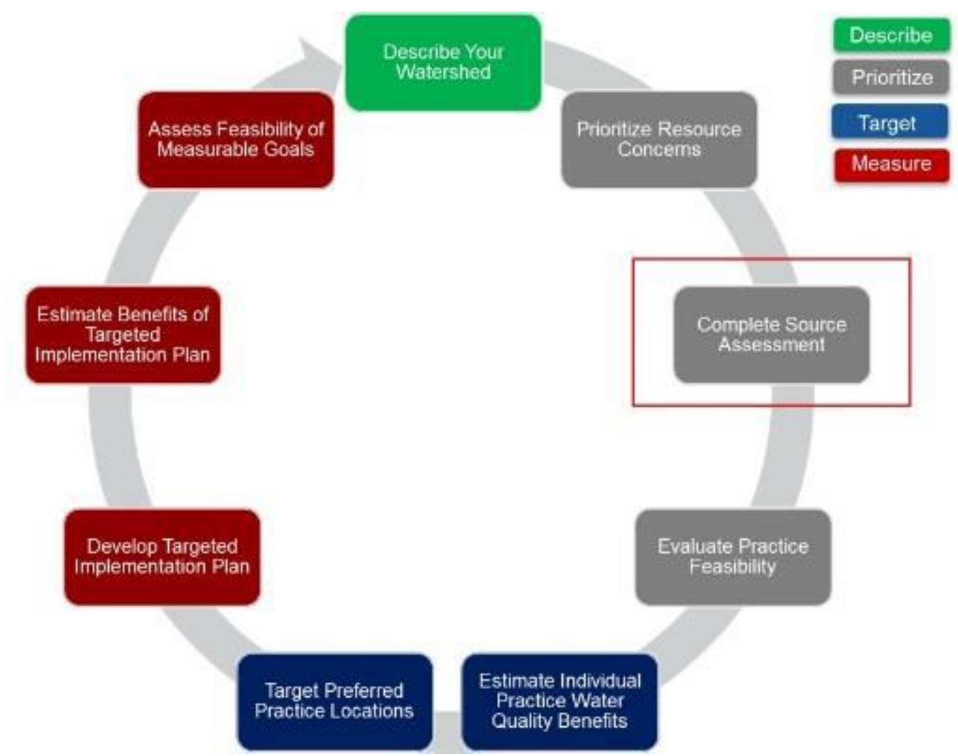
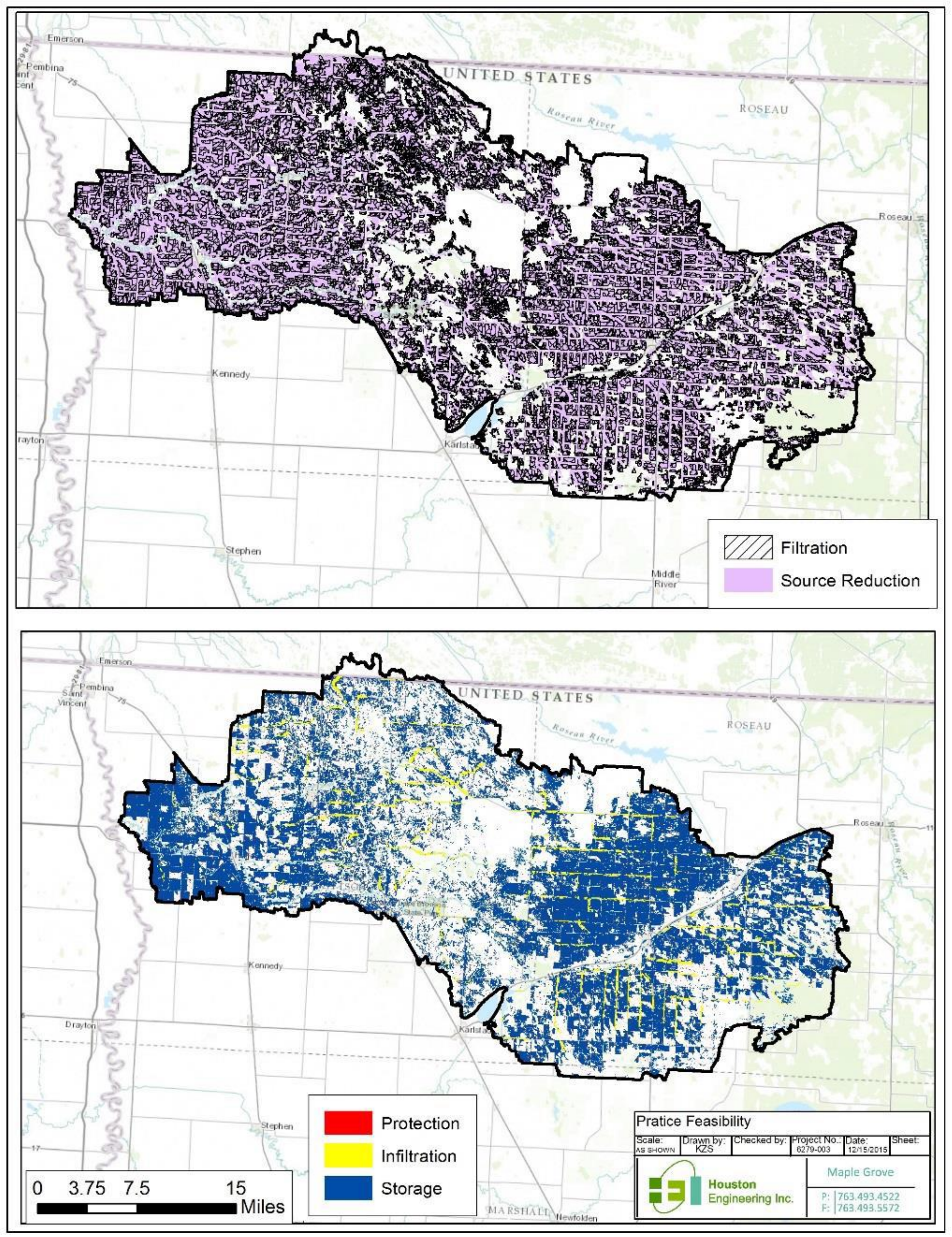


Figure B-3: Two Rivers Watershed source assessment for sediment yield delivered to the outlet of Two Rivers. Total Nitrogen and Total Phosphorus were also assessed (not shown in map).

Evaluate Practice Feasibility

The feasibility of placing a BMP or CP on the landscape depends on several factors. These factors include the size of the contributing drainage area, the land slope, the type of flow regime, and local topography. Practice feasibility is based solely on technical factors largely based on field office technical guides developed by the NRCS, and excludes social factors like landowner willingness. Locations shown as “feasible” are candidates for implementing practices and require further technical evaluation to confirm feasibility. The potential opportunities for BMPs and CPs within the TRW study area are shown in **Figure B-4**. The opportunities are displayed by PTMApp treatment group (HEI 2014). It’s important to note that that these are only potential locations at this point in the business workflow. Local knowledge is still needed to refine the locations to identify a realistic set of targeted practices. These BMP and CP opportunities can be combined with the source assessment data in PTMApp to estimate the “measurable” water quality benefits for implementing the practices.



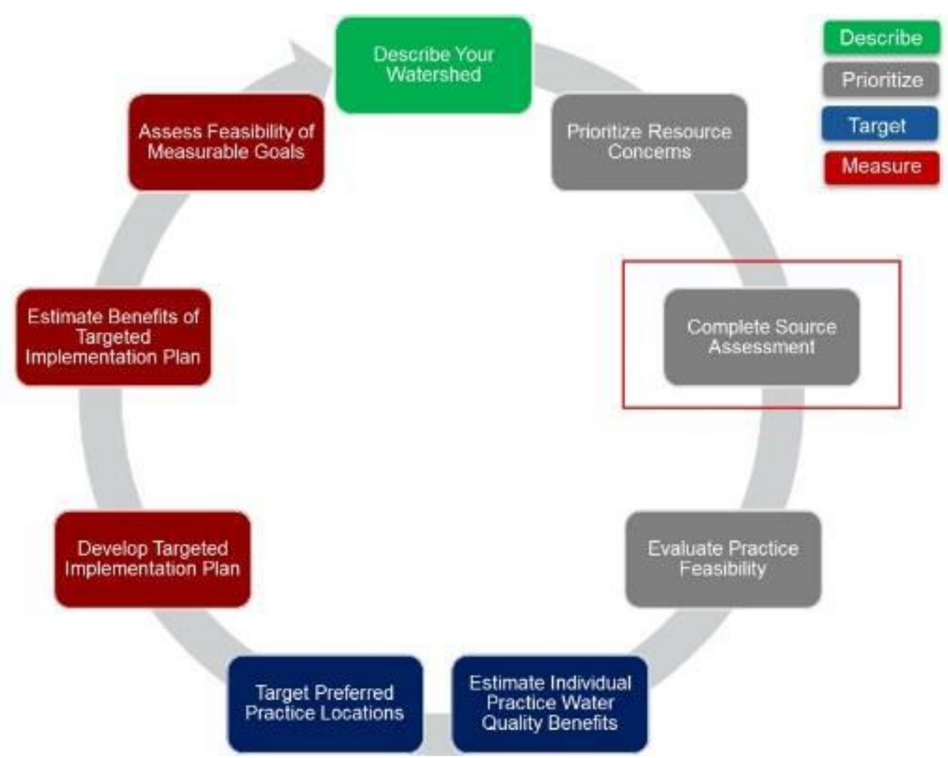
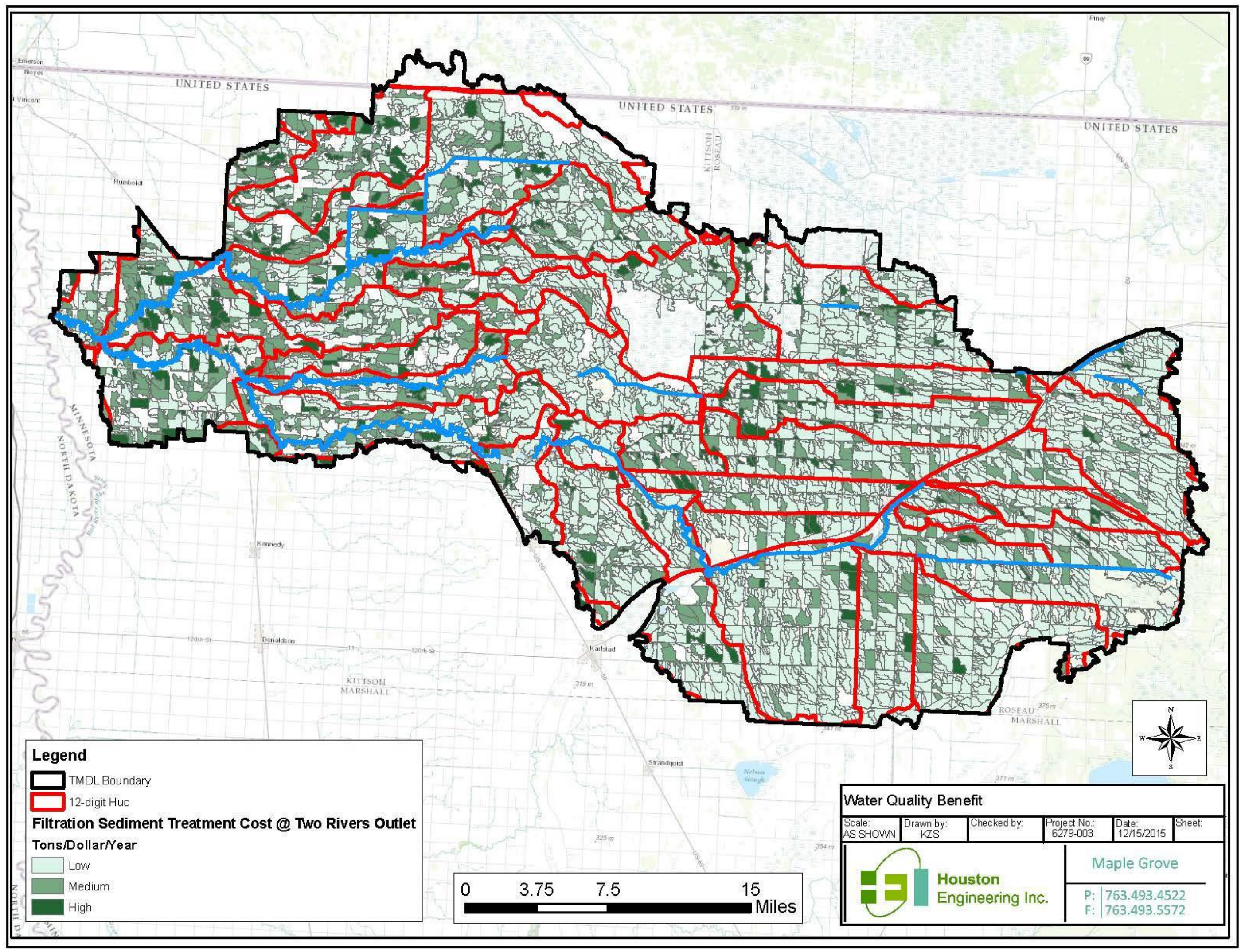


Figure B-4: Potential opportunities for BMPs and CP within the Two Rivers Watershed Study Area.

Estimate Water Quality Benefits

One of the means of selecting specific practices for implementation is based on their probable benefits. The probable benefits of a practice can be described by either the amount of a parameter like sediment or phosphorus removed, or the cost to remove one unit of the parameter (e.g., dollars per pound of phosphorus annually reduced). Practice benefits can be estimated at the location of the practice or the resource. The estimated benefits at a lake or river are more valuable from a decision making perspective. The estimated treatment cost, tons/year/dollar spent, for reducing sediment using filtration practices (e.g. filter strips and grassed waterways) to the outlet of TRW Is shown in **Figure B-5**. The areas providing the largest "bang for the buck" are in the High category. The most cost-effective areas for sediment reductions do not correspond exactly to the highest source load areas (see **Figure B-3**). These results can be used to target practice locations to implement BMPs and CPs that provide the most cost-effective avenue to make progress towards local, state, and regional water quality management goals.



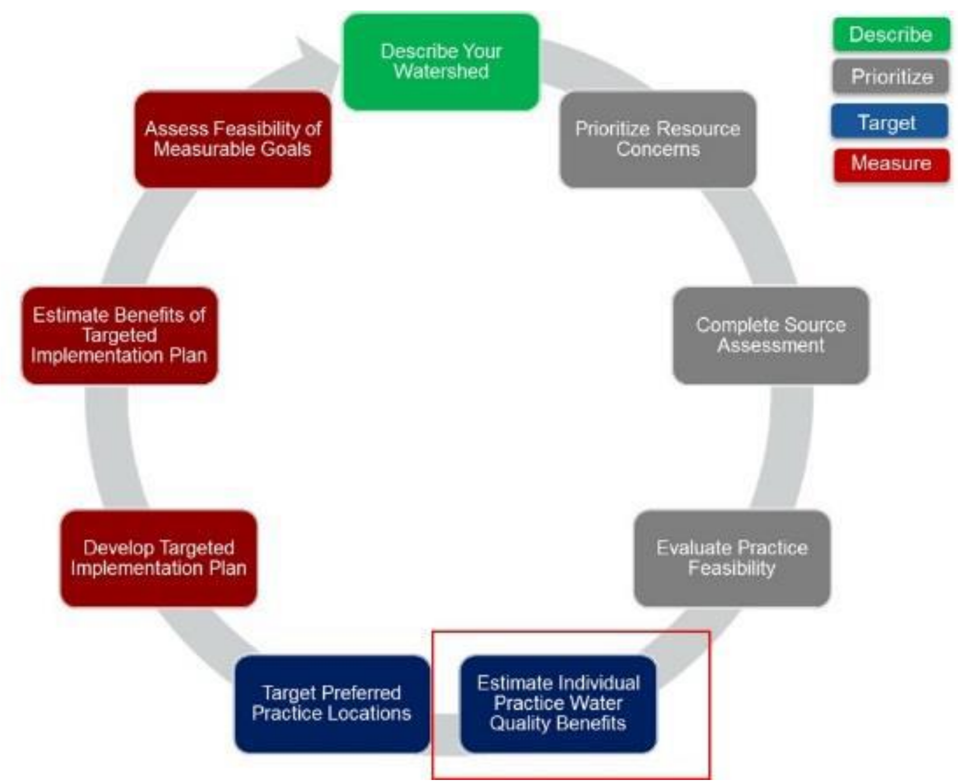


Figure B-5: The treatment cost (tons/year/dollar spent) of reducing sediment delivered to the outlet of the Two Rivers Watershed study area using filtration practices. Similar products can be developed for total nitrogen and total phosphorus

Conclusions

This TM describes a bacteria risk assessment for different potential sources, and use of data products for targeting fields and identifying opportunities for BMP implementation as part of the TRW WRAPS development. The bacteria risk assessment identify the potential sources that likely contribute the greatest amount of bacteria to the outlet of the TRW. The data products delivered with the TM are suitable for targeting fields for restoration and protection strategies based on the delivery of water quality constituents (e.g. TN, TP, sediment) to downstream resources and identification of opportunities to implement BMPs. As such, it is our intention to use the data products delivered with this TM to aid the development of the implementation table and source assessment as part of the TRW WRAPS. In addition, these data products can be used by local practitioners on an ongoing basis to target opportunities to implement BMPs that will be most beneficial too restoration and protection strategies aimed at improving water quality.

References

American Society of Agricultural Engineers (ASAE). 1998. *ASAE Standards,* 45th Edition. Standards, Engineering Practices, Data.

American Veterinary Medical Association (AVMA). 2007. *US Pet Ownership & Demographics Sourcebook*. Schaumburg, IL: American Veterinary Medical Association.

Chandrasekaran, R.; M. J. Hamilton; P. Wang; C. Staley; S. Matteson; A. Birr; M. J. Sadowsky. 2015. Geographic isolation of Escherichia coli genotypes in sediments and water of the Seven Mile Creek – A constructed riverine watershed. The Science of the Total Environment, 538:78-85.

Dexter, M.H., editor. 2009. Status of Wildlife Populations, Fall 2009. Unpublished report, Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 314 pp.

Geldreich, E. 1996. Pathogenic agents in freshwater resources. *Hydrologic Processes* 10(2):315-333.

Horsley and Witten, Inc. 1996. *Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine*. Final Report.

Houston Engineering, Inc. (HEI). 2014. Categorization of best management practices and conservation practices for estimating pollutant removal effectiveness part 1. Technical memorandum to the Minnesota Board of Water and Soil Resources.

Ishii, S., Ksoll, W.B., Hicks, R.E., and Sadowsky, M.J. 2006. Presence and growth of naturalized *Escherichia coli* in temperate soils from Lake Superior watersheds. *Applied Environmental Microbiology* 72(1): 612-621

Long Island Regional Planning Board (LIRPB). 1978. The Long Island Comprehensive Waste Treatment Management Plan: Volume II: Summary Documentation. Nassau-Suffolk regional Planning Board. Hauppauge, NY.

Metcalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. 3rd ed. McGraw-Hill, Inc., New York.

Minnesota Pollution Control Agency (MPCA). 2002. Septage and Restaurant Grease Trap Waste Management Guidelines. Water/Wastewater–ISTS #4.20. wq-wwists4-20.

Minnesota Pollution Control Agency (MPCA). 2010. NPDES/SDS Permitted Facilities. Accessed: October 2012: http://www.pca.state.mn.us/index.php/view-document.html?gid=3589

Minnesota Pollution Control Agency (MPCA). 2011. Recommendations and Planning for Statewide Inventories, Inspections of Subsurface Sewage Treatment Systems. Accessed: November 2012: http://www.pca.state.mn.us/index.php/view-document.html?gid=15476

Mulla, D. J., A. S. Birr, G. Randall, J. Moncrief, M. Schmitt, A. Sekely, and E. Kerre. 2001. Technical Work Paper: Impacts of Animal Agriculture on Water Quality. Final Report to the Environmental Quality Board. St. Paul, MN.

Rave, D. 2009. Spring Canada Goose Survey. Minnesota Department of Natural Resources. Status of Wildlife Populations, Fall 2009, pp. 140-143.

Sadowsky, M., Matteson, S., Hamilton, M., and Chandrasekaran, R. 2010. Growth, Survival, and Genetic Structure of *E. Coli* found in Ditch Sediments and Water at the Seven Mile Creek Watershed. Project Report to Minnesota Department of Agriculture. Mankato, MN. 45pp.

U.S. Environmental Protection Agency (EPA). 2001. Protocol for Developing Pathogen TMDLs. EPA 841-J-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC. 132 pp.

Tampa Bay Estuary Program (TBEP). 2011. Get the scoop on (dog) poop!

Yagow, B. (2001). Fecal Coliform TMDL Mountain Run Watershed Culpeper County, Virginia. Prepared for the Virginia Department of Environmental Quality, Richmond, Virginia. April 2001.

Zeckoski, R., B. Benham, s. shah, M. Wolfe, K. Branna, M. Al-Smadi, T. Dillaha, S. Mostaghimi, and D. Heatwole. 2005. BLSC: A tool for bacteria source characterization for watershed management. *Applied Engineering in Agriculture*. 21(5): 879-889.

Appendix C: Existing Water Quality, Existing Loads, and Loading Capacity for Stream Reaches in the TRW

Table C-1: Existing water quality, existing loads, and loading capacity for stream reaches in the TRW for Total Suspended Solids.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Suspended Solids				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
State Ditch No 91 (0902031201)	507	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	515	--	--	--	--	--	--	--	--	--	--	52.5	13.5	4.2	1.1	0.1	NA
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	522	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
State Ditch No 95 (0902031202)	505	S002-996	2002, 2009-2011, 2013	36	14.0	0	21.0	6.0	5.5	4.4	5.7	90.1	6.3	1.9	0.5	0.1	AAQ
	506	S002-364, S002-998, S002-373	1996, 1999, 2000-2002, 2009-2011	38	14.1	0	77.7	8.1	4.2	0.5	0.1	166.1	42.1	13.6	4.3	0.7	AAQ
	513	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	521	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	527	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	534	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	535	S003-452, S002-371	2003-2004, 2006-2011, 2013	48	13.0	0	3.8	0.3	0.1	0.0	0.0	12.2	2.6	0.8	0.2	0.0	AAQ
	536	--	--	--	--	--	--	--	--	--	--	11.4	2.5	0.8	0.2	0.0	NA
	537	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Suspended Solids				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
	538	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	541	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	542	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	543	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Middle Branch Two Rivers (0902031203)	503	S003-100, S003-103, S002-999, S002-360	1996-1997, 1999, 2002-2006, 2008-2010, 2013	55	13.2	0	5.5	0.5	0.3	0.1	--	30.4	6.5	1.9	0.6	0.1	AAQ
	517	--	--	--	--	--	--	--	--	--	--	9.8	1.6	0.4	0.1	0.0	NA
	518	--	--	--	--	--	--	--	--	--	--						
State Ditch No 85 (0902031204)	528	S002-361	2009	21	3.0	0	0.3	0.1	0.0	0.0	0.0	20.5	4.1	1.1	0.3	0.0	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	531	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Little Joe River (0902031205)	510	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	519	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	520	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
North Branch Two Rivers (0902031206)	504	S002-368, S002-369	1996-1997, 1999-2005, 2008-2009, 2011	82	14.5	0	62.3	7.6	1.1	0.4	0.0	116.9	27.6	8.5	2.4	0.5	AAQ
	508	S007-442, S002-370, S003-092	1996-1997, 1999-2005, 2008-2011, 2013-2014	75	45.9	4	165.3	25.3	9.1	1.9	0.6	164.8	39.8	12.6	3.6	0.7	AAQ

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Suspended Solids				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
	514	--	--	--	--	--	--	--	--	--	--	5.3	1.1	0.3	0.1	0.0	NA
	524	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	532	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
South Branch Two Rivers (0902031207)	501	S000-186, S003-102, S005-387	1996-1997, 1999-2011, 2014	104	92.0	27	860.5	108.8	25.0	6.8	0.9	347.9	87.8	28.8	9.2	1.6	HRE
	502	S002-365, S003-099	1996-1997, 1999-2006, 2008-2010, 2014	74	18.4	0	213.2	17.7	4.7	1.3	0.3	303.3	76.2	24.6	7.8	1.3	AAQ
	509	S000-569	1996-1997, 1999-2014	235	225.2	112	1328.2	473.7	128.8	26.3	2.2	520.7	130.3	45.0	14.4	2.8	HRE
	511	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	512	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	525	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	544	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: EWQ = Exceptional Water Quality, HIR = Heightened Impairment Risk, TIR = Threatened Impairment Risk, PRS = Probable Restoration Success, LRS = Low Restoration Success.

Table C-2: Existing water quality, existing loads, and loading capacity for stream reaches in the TRW for Total Phosphorus.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Phosphorus [mg/L]				Existing Conditions (Observed Data) [lbs/day] Flow Conditions					Loading Capacity (Flow Based) [lbs/day] Flow Conditions					Protection/Restoration Classification
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
State Ditch No 91 (0902031201)	507	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	515	--	--	--	--	--	--	--	--	--	--	242.5	62.1	19.2	5.0	0.6	NA
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	522	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
State Ditch No 95 (0902031202)	505	S002-996, S002-998,	2002, 2009-2010, 2013	24	0.1	2	1733.4	184.7	42.3	9.1	2.4	1287.2	316.9	101.6	32.3	6.0	PIR
	506	S002-364, S002-373, S002-998	1996, 2001-2202, 2009-2010	24	0.2	8	1074.1	267.6	35.0	4.0	3.4	766.5	194.4	62.5	20.1	3.4	HRE
	513	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	521	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HIR
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	527	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	534	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	535	S003-452, S002-371	2003-2004, 2006-2011	39	0.2	6	76.5	7.3	3.4	1.1	--	56.2	12.0	3.7	1.1	0.2	LRE
	536	--	--	--	--	--	--	--	--	--	--	--	11.4	3.5	1.0	0.2	NA
	537	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	538	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	541	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	542	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	543	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Phosphorus [mg/L]				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Middle Branch Two Rivers (0902031203)	503	S002-999, S003-100, S002-360, S007-441	1996-1997, 1999, 2002, 2008-2010, 2013	36	0.1	1	65.4	9.6	4.4	1.0	--	140.1	29.8	8.8	2.7	0.4	AAQ
	517	--	--	--	--	--	--	--	--	--	--	45.4	7.2	1.8	0.6	0.1	NA
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
State Ditch No 85 (0902031204)	528	S002-361	2009-2010	10	0.1	0	13.3	6.1	0.5	1.0	--	94.7	18.8	5.0	1.5	0.2	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	531	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Little Joe River (0902031205)	510	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	519	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	520	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
North Branch Two Rivers (0902031206)	504	S002-368, S002-369	1996-1997, 1999-2002, 2008, 2010	45	0.1	2	302.1	95.1	17.7	6.1	1.8	539.5	127.3	39.0	11.1	2.3	AAQ
	508	S002-370, S007-442	1996-1997, 1999-2002, 2008-2011, 2013-2014	61	0.2	7	1352.4	181.5	54.9	11.9	11.1	760.6	183.5	58.2	16.5	3.2	HIR
	514	--	--	--	--	--	--	--	--	--	--	24.5	5.1	1.5	0.4	0.1	NA
	524	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	532	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Total Phosphorus [mg/L]				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
South Branch Two Rivers (0902031207)	501	S000-186, S005-387	1996-1997, 1999-2002, 2005, 2007, 2009-2011, 2014	89	0.3	35	3141.4	745.8	176.9	44.4	3.6	1605.5	405.0	133.0	42.5	7.6	HRE
	502	S002-365	1996-1997, 1999-2002, 2008-2009, 2014	44	0.3	15	2156.6	183.7	122.8	42.4		1399.8	351.5	113.4	36.2	6.0	HRE
	509	S000-569	1996, 1997, 1999-2014	251	0.4	153	5460.3	1318.6	302.7	109.1	11.1	2403.3	601.2	207.7	66.5	12.9	HRE
	511	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	512	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	525	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	544	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: EWQ = Exceptional Water Quality, HIR = Heightened Impairment Risk, TIR = Threatened Impairment Risk, PRS = Probable Restoration Success, LRS = Low Restoration Success.

Table C-3: Existing water quality, existing loads, and loading capacity for stream reaches in the TRW for Inorganic Nitrogen.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Inorganic Nitrogen				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
State Ditch No 91 (0902031201)	507	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	515	--	--	--	--	--	--	--	--	--	--	12433.2	2067.4	463.9	84.0	10.5	NA
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	522	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
State Ditch No 95 (0902031202)	505	S002-996	2002, 2009-2010, 2013	24	0.5	0	472.5	189.8	18.6	1.1	--	67503.4	11298.1	2661.6	549.9	64.8	AAQ
	506	S002-364, S002-998, S002-373	1999-2002, 2009-2010	24	0.5	0	2060.3	127.9	27.4	7.9	--	40933.3	6883.3	1661.7	357.7	40.5	AAQ
	513	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	521	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	AAQ
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	527	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	534	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	535	S003-452, S002-371	2003-2004, 2006-2013	42	0.1	0	87.4	1.4	0.2	--	--	2912.1	466.5	105.1	19.0	1.5	AAQ
	536	--	--	--	--	--	--	--	--	--	--	2763.3	441.9	98.1	17.4	1.3	NA
	537	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	538	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	541	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	542	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	543	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Inorganic Nitrogen				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
Middle Branch Two Rivers (0902031203)	503	S002-999, S003-100, S002-360, S007-441	1999-2002, 2008-2010, 2013	36	0.0	0	18.4	1.8	0.9	0.9	--	6885.3	876.4	208.5	29.1	2.5	AAQ
	517	--	--	--	--	--	--	--	--	--	--	2028.0	221.2	50.4	7.4	0.7	NA
	518	--	--	--	--	--	--	--	--	--	--						
State Ditch No 85 (0902031204)	528	S002-361	2009-2010	10	0.0	0	8.8	1.3	0.3	0.0	--	4389.2	565.4	135.8	21.2	1.6	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	531	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Little Joe River (0902031205)	510	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	519	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	520	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
North Branch Two Rivers (0902031206)	504	S002-368, S002-369	1999-2002, 2008, 2010	49	0.8	0	1128.1	147.6	2.9	5.2	--	27323.5	4086.6	923.4	159.3	16.2	AAQ
	508	S002-370, S003-092, S007-442	1999-1002, 2008-2011, 2013-2014	64	0.5	0	591.0	150.5	6.6	4.8	--	39845.8	5931.0	1311.3	226.6	23.6	AAQ
	514	--	--	--	--	--	--	--	--	--	--	1228.6	152.4	31.4	5.0	0.3	NA
	524	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	532	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
South Branch Two Rivers (0902031207)	501	S000-186, S005-387	1997-2002, 2004-2007, 2009-2011, 2014	125	0.9	0	2807.0	570.0	42.5	17.2	0.8	83170.5	13955.9	3319.9	715.0	97.3	AAQ

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	Inorganic Nitrogen				Existing Conditions (Observed Data) [lbs/day]					Loading Capacity (Flow Based) [lbs/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	90th Percentile	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
	502	S002-365	1999-2002, 2008-2009, 2014	47	1.1	0	3036.5	266.9	34.9	19.7		72297.1	12194.3	2876.5	611.5	85.8	AAQ
	509	S000-569	1999-2014	298	1.1	0	6525.4	398.7	50.2	18.5	0.3	123028.1	20172.8	4927.2	1030.3	129.3	AAQ
	511	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	512	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	525	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	544	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: EWQ = Exceptional Water Quality, HIR = Heightened Impairment Risk, TIR = Threatened Impairment Risk, PRS = Probable Restoration Success, LRS = Low Restoration Success.

Table C-4: Existing water quality, existing loads, and loading capacity for stream reaches in the TRW for *Escherichia coli*.

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	*Escherichia coli* [org/100mL]				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	Geo.	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
State Ditch No 91 (0902031201)	507	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	515	--	--	--	--	--	--	--	--	--	--	869.4	194.1	58.4	15.0	2.0	NA
	516	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	522	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	523	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	505	S002-996	2009-2010, 2013-2014	30	80.8	9		646.0	117.5	24.2	--	4595.2	1000.0	303.8	99.3	19.7	HRE

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	*Escherichia coli* [org/100mL]				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	Geo.	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
State Ditch No 95 (0902031202)	506	S002-373	2009-2011	14	97.7	7	--	771.0	275.6	209.5	--	2773.6	614.0	191.3	60.7	11.7	LRE
	513	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	521	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	HIR
	526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	527	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	534	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	535	S002-371	2009-2010	15	91.2	6		13.8	9.1	12.4	--	201.7	41.3	11.4	3.2	0.6	HRE
	536	--	--	--	--	--	--	--	--	--	--	190.6	38.7	10.7	2.9	0.5	NA
	537	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	538	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	539	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	NA
	541	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	542	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	543	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Middle Branch Two Rivers (0902031203)	503	S003-100, S007-441	2008-2010, 2013-2014	38	85.3	17		46.5	11.0	11.0	--	474.1	90.9	26.8	7.4	0.9	LRE
	517	--	--	--	--	--	--	--	--	--	--	152.9	22.4	5.7	1.5	0.1	NA
	518	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
State Ditch No 85 (0902031204)	528	S002-361	2009-2010	14	39.6	1	--	9.9	4.2	1.7	--	338.2	60.0	15.4	4.3	0.6	AAQ
	529	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	531	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Little Joe River (0902031205)	510	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	519	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	520	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

HUC-10 Subwatershed	AUID (Last 3 digits)	WQ Sites	*Escherichia coli* [org/100mL]				Existing Conditions (Observed Data) [tons/day]					Loading Capacity (Flow Based) [tons/day]					Protection/Restoration Classification
							Flow Conditions					Flow Conditions					
			Sampling Years	n	Geo.	# of Exceedances	Very High	High	Mid	Low	Very Low	Very High	High	Mid	Low	Very Low	
North Branch Two Rivers (0902031206)	504	S002-368	2008-2009	20	57.4	4	--	122.8	39.5	22.9	--	1935.7	401.1	117.5	29.7	5.4	PIR
	508	S002-370, S007-442	2008-2009, 2013-2014	36	44.6	7	--	156.3	31.0	10.6	--	2751.2	580.2	175.8	43.4	8.0	HIR
	514	--	--	--	--	--	--	--	--	--	--	87.2	15.4	4.2	1.1	0.2	NA
	524	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	532	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	533	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
South Branch Two Rivers (0902031207)	501	S000-186	2000-2002, 2005-2008	47	79.3	17	9561.9	409.4	196.8	118.8	20.0	5737.1	1303.8	397.7	121.9	25.0	HRE
	502	S002-365	2008-2009	21	17.5	1	--	63.0	27.5	27.3	--	5046.3	1117.6	335.3	106.5	19.2	AAQ
	509	S000-569	2008-2010, 2013-2014	34	95.4	10	--	996.4	398.6	144.2	--	8659.1	1931.5	619.5	178.3	38.8	HIR
	511	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	512	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	525	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	544	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

--No Available Data

Protection/Restoration Classifications: EWQ = Exceptional Water Quality, HIR = Heightened Impairment Risk, TIR = Threatened Impairment Risk, PRS = Probable Restoration Success, LRS = Low Restoration Success.

Appendix D: BMP Implementation Scenarios using HSPF

Technical Memorandum

To: Daniel Money, Two Rivers Watershed District
Cary Hernandez, Minnesota Pollution Control Agency

From: Timothy Erickson, P.E., Houston Engineering, Inc.

Through: Mark Deutschman, Ph.D., P.E., Houston Engineering, Inc.

Date: January 11, 2017

Project: 6279-003

Introduction

This Technical Memorandum (TM) describes the estimated load reduction benefits for three best management practice (BMP) scenarios in the Two Rivers Watershed (TRW). The benefits of the scenarios were evaluated using the TRW's Hydrologic Simulation Program-FORTRAN (HSPF) model informed by the BMP Suitability Analysis from the Prioritize, Target, and Measure Application (PTMApp) (HEI 2015). The BMP scenarios were developed to guide local implementation efforts for use in the Watershed Restoration and Protection Strategy. The intent of preparing this memorandum is to provide 1) greater clarity with regard to the technical feasibility of achieving various nutrient and sediment load reductions and therefore the Two Rivers water quality goals (i.e., load allocations); 2) more detailed guidance to those responsible for implementing the TMDL including the numbers and types of BMPs which could be placed on the landscape; and 3) the information expectations memorialized in the Clean Water Accountability Act (https://www.revisor.leg.state.mn.us/statutes/?id=114D&view=chapter).

Through discussion with the Technical Advisory Committee for the TRW WRAPS project, three scenarios representing a range of BMP implementation strategies were conceptualized. The load reduction benefits of these scenarios were then estimated using the HSPF model (RESPEC 2014). The three scenarios developed and simulated using HSPF are intended to represent a range of potential strategies and include: (1) a Top 10% BMP implementation scenario, (2) a Top 25% BMP implementation scenario, and (3) Top 25% storage BMP implementation scenario. The Top 10% BMP and Top 25% BMP scenarios represent a targeted implementation approach where BMPs are located and constructed only for BMPs, which rank in the top 10% and 25%, respectively. The rankings are based on individual BMPs cost effectiveness (HEI 2015) for each of three constituents: i.e. Total Nitrogen, Total Phosphorus, and Total Sediment. The Top 25% storage scenario was developed by using the top 25% cost effective BMPs with a drainage area greater than 10 acres. This scenario looks at both hydrologic and water quality impacts versus the other two scenarios, which looks at water quality impacts only.

Methods

Best Management Practices

Table D-1 lists the BMPs used to develop the scenarios and simulated using the HSPF model. These BMP categories include (1) filtration, which includes filter strips and grass waterways, (2) protection, which includes water and sediment control basins (WASCOBs), and (3) upland storage. Additional BMPs were identified in the BMP suitability study (HEI 2015) but limitations within HSPF restricts the types of BMPs that can be simulated to the ones listed in **Table D-1**.

Table D-1: BMP Types Simulated in TRW HSPF Scenarios.

BMP	Type	Treatment	HSPF Notes
Filtration: Filter Strips/Grass Waterways	Surface BMP	Sediment, Nitrogen, Phosphorus	Applied to Cropland.
Protection: Sediment Control Basins (WASCOBs)	Surface BMP	Sediment, Nitrogen, Phosphorus	Applied to Cropland.
Upland Storage	Storage	NA	Added intermediate RCHRES

Grass waterways and filter strips were combined into one BMP for simulation in HSPF. These BMPs treat water in the same way, with the only difference being placement (filter strips are located at the edge of the field and grass waterways are located in small ephemeral channels and swales). Since HSPF does not distinguish between overland flow and small ephemeral channels within a subwatershed, these two BMPs were grouped. **Table D-2** provides the reduction efficiencies, by flow component, for filter strips used in the HSPF scenarios. For simplicity purposes, the reductions were only applied to the cropland in the BMPs drainage areas.

Table D-2: Nutrient and sediment reductions for Filter Strips and Grass Waterways (Wall, 2016).

Parameter	Surface Runoff	Interflow	Baseflow
Total Nitrogen	66%	66%	58%
Total Phosphorus	67%	28%	16%
Total Sediment	84%	84%	84%

Table D-3 provides the reduction efficiencies, by flow component, for WASCOBS. For simplicity purposes, the reductions were only applied to the cropland in the BMPs drainage areas.

Table D-3: Nutrient and sediment reductions for WASCOBs (Wall, 2016).

Parameter	Surface Runoff	Interflow	Baseflow
Total Nitrogen	82%	70%	17%
Total Phosphorus	82%	36%	21%
Total Sediment	90%	90%	90%

For the storage areas, no direct reductions were made to the overland loads. To simulate the storage areas in HSPF, intermediate storage devices (represented as RCHRES) were added in between the land segments (PERLNDs) and the channels (RCHRES). Since the actual dimensions of the storage BMPs are unknown, the surface area was assumed to be 1% of the drainage areas to the storage BMP and the volumes were calculated based on surface area and depth, assuming a cylinder shape. The outflows for each added RCHRES were developed by assuming at least a target “two week” drainage time for the storage volume, i.e. the outflow was taking as the flow required to drain to storage unit in two weeks. These storage RCHRES were treated as lakes for the parameterization of storage devices. All water quality benefits for the storage BMPs were based on the functionality of HSPF only, no straight percentage reductions.

Drainage Areas of the BMPs

Table D-4 shows the treated drainage acreage by BMP and scenario for the watershed as a whole (at the outlet of Two Rivers to the Red River of the North) and by major tributary (North Branch Two Rivers, Middle Branch Two Rivers, and South Brach Two Rivers. The total Two Rivers drainage area is 717,982.8 acres (based on the HSPF model) with a total cropland acreage of 455,697 acres.

Table D-4: Treated Areas (acres) of cropland by BMP and Scenario for Two Rivers HSPF model.

	Filtration: Grass Waterways/ Filter Strips		Protection: WASCOBs		Upland Storage
Major Tributary	Top 10% BMPs	Top 25% BMPs	Top 10% BMPs	Top 25% BMPs	Top 25% Storage Areas
Watershed	25,529	47,832	18,808	33,598	98,371
North Branch	7,373	15,192	6,865	14,395	46,624
Middle Branch	8,913	10,431	1,109	5,453	13,770
South Branch	5,607	17,400	10,834	13,716	26,374

The top 10% BMP scenario's total treated area is 25,529 acres of cropland, representing 9.7% of total cropland and 6.2% of total watershed area. The top 25% BMP scenario's total treated area is 81,429 acres of cropland, representing 17.9% of total cropland and 11.3% of total watershed area. The top 25% storage areas scenario's treated area is 98,371 acres of cropland, representing 21.6% of total cropland and 13.7% of total watershed area. Locations of the BMP practices are shown in the upper right-hand corner of the results figures for each scenario (**Figures D-1** through **D-3**) in the following section.

Results

Summary results from the TRW HSPF BMP Scenarios are provided in **Table D-5** for total nitrogen, **Table D-6** for total phosphorus, and **Table D-7** for total sediment. For each water quality parameter, the reductions in annual loads delivered to the outlet of the river reach are provided for each BMP scenario and the base simulation (without BMPs).

In addition to the tables, **Figures D-1** through **D-3** show the in-channel reductions of loads for the three scenarios (Top 10% BMPs, Top 25% BMPs, and Top 25% storage, respectively). **Figures D-1** through **D-3** provide the reduction in average annual loads at the outlets of each HSPF subbasin for total nitrogen (top right), total phosphorus (bottom left) and total sediment (bottom right). In addition, catchments with suitable BMPs used in the respected scenario are also shown (top left). It should be noted, the same scale (i.e. legend) is used for the water quality components in all three figures, except for total sediment in the storage scenario (which increased under the scenario). Total sediment under the storage scenario has a different color scheme for increasing values (that are discussed below)

Table D-5: Total Nitrogen-Average Annual Load (pounds/year) Reductions by Scenario.

Major Stream	Base Load	Top 10% BMPs		Top 25% BMPs		Upland Storage	
	Load (lbs/year)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)
Watershed	1,294,776	1,274,135	4.1%	1,256,868	7.2%	1,144,655	11.6%
North Branch	443,831	424,191	4.4%	407,713	8.1%	369,081	16.8%
Middle Branch	83,865	73,179	4.9%	69,012	5.0%	63,486	24.3%
South Branch	694,187	675,614	12.7%	662,122	17.7%	655,028	5.6%

Table D-6: Total Phosphorus-Average Annual Load (pounds/year) Reductions by Scenario.

Major Stream	Base Load	Top 10% BMPs		Top 25% BMPs		Upland Storage	
	Load (lbs/year)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)	Load (lbs/year)	Percent (%)
Watershed	119,868	118,342	1.3%	116,135	3.1%	114,863	4.2%
North Branch	37,711	36,902	2.1%	36,114	4.2%	35,201	6.6%
Middle Branch	6,807	6,445	5.3%	6,229	8.5%	6,172	9.3%
South Branch	67,096	66,827	0.4%	66,224	1.3%	65,791	1.9%

Table D-7: Total Sediment-Average Annual Load (tons/year) Reductions by Scenario.

Major Tributary	Base Load	Top 10% BMPs		Top 25% BMPs		Upland Storage	
	Load (tons/year)	Load (tons/year)	Percent (%)	Load (tons/year)	Percent (%)	Load (tons/year)	Percent (%)
Watershed	43,456	43,212	0.6%	42,989	1.1%	42,536	2.1%
North Branch	13,815	13,668	1.1%	13,540	2.0%	13,347	3.4%
Middle Branch	494	483	2.3%	479	3.0%	370	25.0%
South Branch	8,830	8,789	0.5%	8,744	1.0%	8,742	1.0%

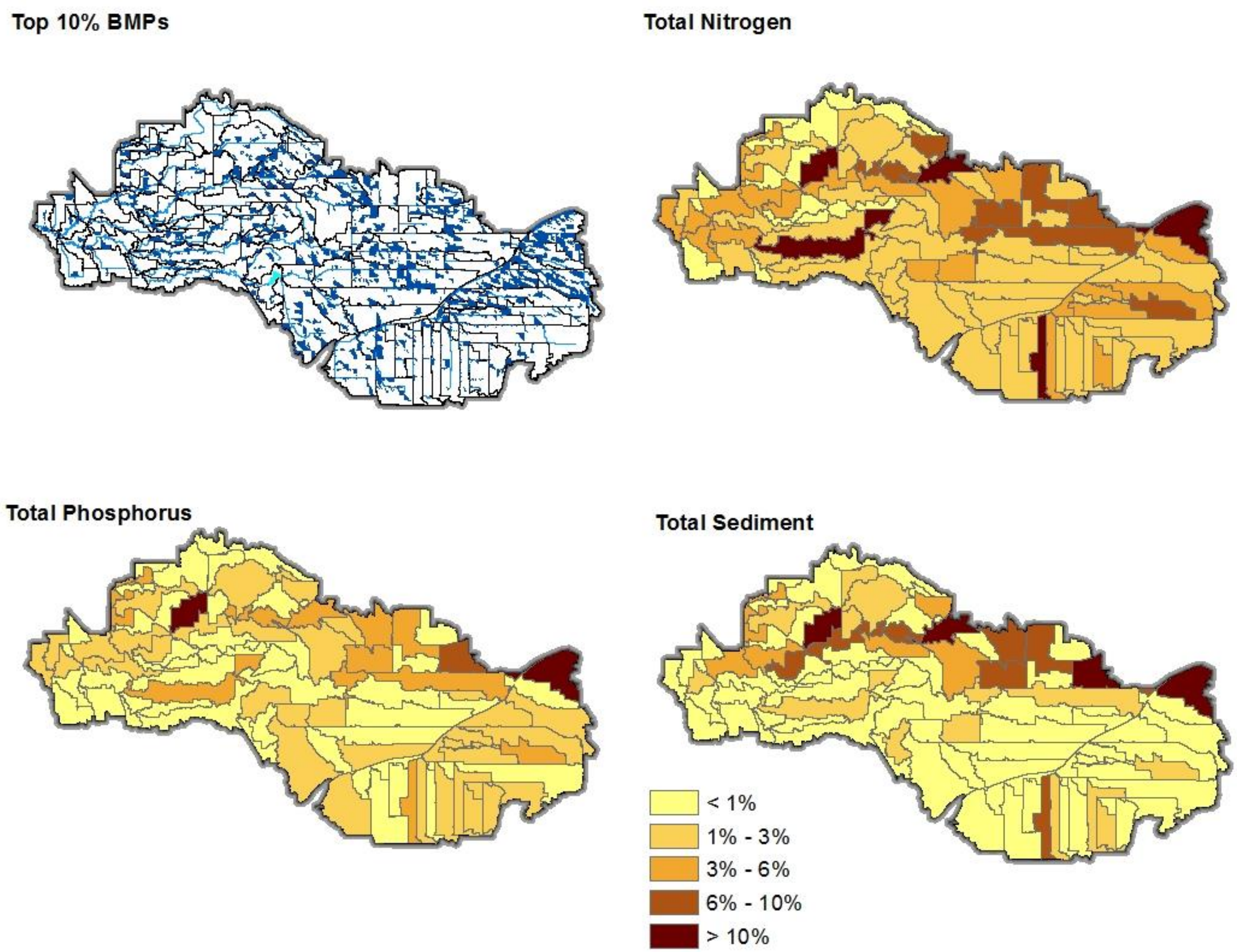


Figure D-1: Scenario 1 Results-Reductions in average annual loading rates for the Top 10% BMPs.

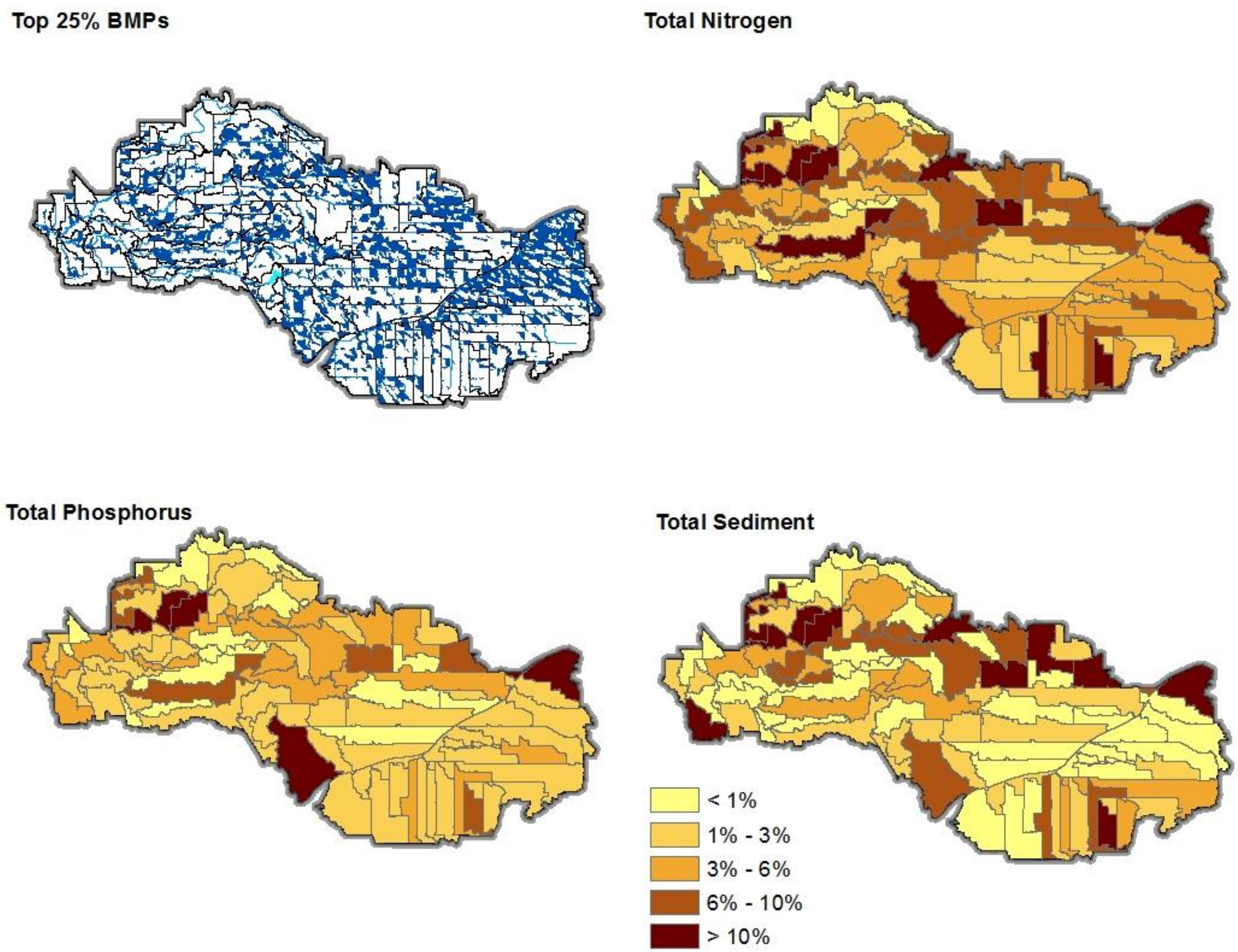


Figure D-2: Scenario 2 Results-Reductions in average annual loading rates for the Top 25% BMPs.

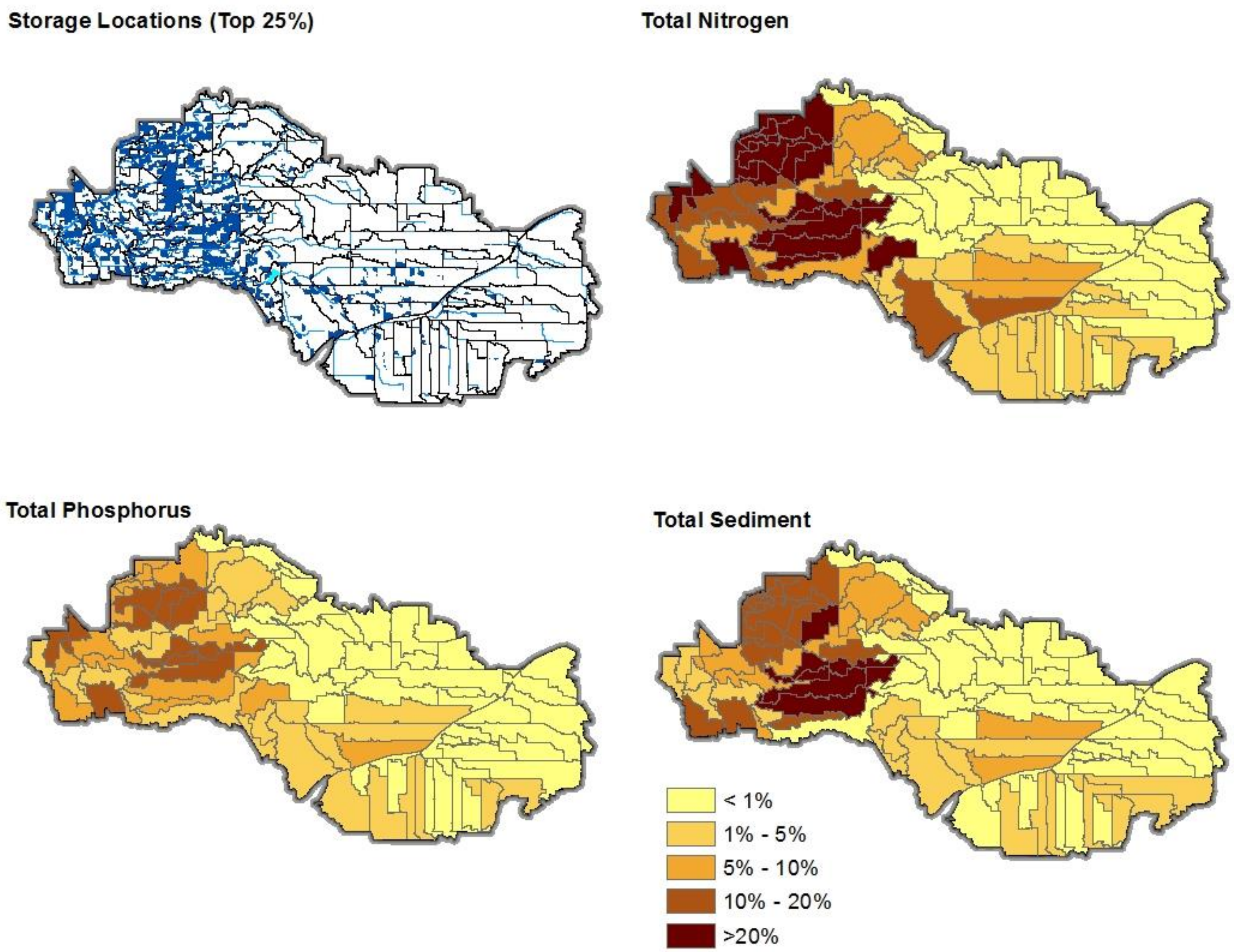


Figure D-3: Scenario 3 Results-Reductions in average annual loading rates for the Top 25% storage locations.

Results from the Top 10% scenario and Top 25% BMP scenario are consistent with results in other watersheds (HEI 2015). At the subwatershed scale, reduction in TN load ranged from 0.7% to 28.1% for the Top 10% BMP scenario and 0.8% to 33.8% for the Top 25% BMP scenario, depending on the level of treatment. For the main branches of Two Rivers, the TN reductions for the Top 10% scenario ranged from 4.4% in the North Branch to 12.7% in the South Branch, with a nitrogen reduction of 4.1% at the outlet. For the Top 25% scenario, the main branches ranged from 5.0% in the Middle Branch to 17.7% in the South Branch, with a nitrogen reduction of 7.2% at the outlet. Differences in the reduction rates are dependent on the level and type (BMP type) of treatment in each subwatershed and main branch drainage area.

For TP, the subwatershed scale reductions ranged from 0.14% to 20.1% for the Top 10% BMP scenario and 0.5% to 21.4% for the Top 25% BMP scenario, depending on the level of treatment. For the main branches of Two Rivers, the phosphorus reductions for the Top 10% scenario ranged from 0.4% in the South Branch to 5.3% in the Middle Branch, with a TP reduction of 1.3% at the outlet. For the Top 25% scenario, the main branches ranged from 1.3% in the South Branch to 8.5% in the Middle Branch, with a TP reduction of 3.1% at the outlet. Differences in the reduction rates are dependent on the level and type (BMP type) of treatment in each subwatershed and main branch drainage area. Reductions in TP loading were much less than TN. This is due to the lower reductions rates in interflow and groundwater flow of filter strips and grass waterways (**Table D-2**).

For sediment, the subwatershed scale reductions ranged from 0.0% (in areas with minimal treatment) to 34.2% (areas with a majority of WASCOBs as treatment) for the Top 10% BMP scenario and 0.0% to 34.4%. The subwatersheds on the low side of the reduction range in sediment load are areas where treatment is minimal. Subwatershed on the high side of the treatment range typically had more treated area with WASCOBs than filter strips. For the Top 25% BMP scenario, the subwatershed sediment reductions ranged from 0.0% to 34.4%. For the main branches of Two Rivers, the sediment reductions for the Top 10% scenario ranged from 0.5% in the South Branch to 2.3% in the Middle Branch, with a sediment reduction of 0.6% at the outlet. For the Top 25% scenario, the main branches ranged from 1.0% in the South Branch to 3.0% in the Middle Branch, with a sediment reduction of 1.1% at the outlet. Differences in the reduction rates are dependent on the level and type (BMP type) of treatment in each subwatershed and main branch drainage area.

The magnitude of water quality reductions for the storage scenario is much greater than the Top 10% BMP and Top 25% BMP scenarios for all three water quality parameters. This is partly due the number of treated acres being nearly double. The subwatershed reductions in TN loading ranged from 0.0% to 36.2%, TP loading, ranged from 0.0%% to 14.9%, and sediment ranging from 0.0% to 36.4%, with lower end of the ranges being in watersheds without treatment. For the major branches, TN reductions ranged 5.6% in the South Branch to 24.3% in the Middle Branch, with a reduction of 11.6% at the outlet of Two Rivers. TP reductions ranged 1.9% in the South Branch to 9.3% in the Middle Branch, with a reduction of 4.2% at the outlet of Two Rivers. Sediment reductions ranged 1.0% in the South Branch to 25.0% in the Middle Branch, with a reduction of 2.1% at the outlet of Two Rivers. Differences in the reduction rates are dependent on the level of treatment (acreage treated by upland storage) in each subwatershed and main branch drainage area.

Figures D-4 through **D-7** show the hydrologic impacts of the increased storage through changes in the flow duration curves. **Figures D-4** through **D-7** show that the hydrologic impacts from the increase storage is minimal. The largest change occur in the lower flow range, i.e. increased baseflow as the water slowly drains form the storage BMPs. A slight decrease in peak flows also occurs. The increase in baseflows are most likely the cause of the increases in sediment transport. In HSPF, a higher flow transports more sediment. It is unknown at this time if that is actually the case or if it is an issue with the calculations HSPF performs or how the storage was represented in the model.

Overall, the results suggest that the implementation of the Top 25% filter strips, grass waterways, and WASCOBs will only provide a reduction in average annual total nitrogen, total phosphorus, and total sediment loads of less than 7.2%. This suggests additional conservation practices (such as nutrient management or cover crops) will also be needed, in conjunction with the listed BMPs, to meet the desired water quality reductions in the TMDL.

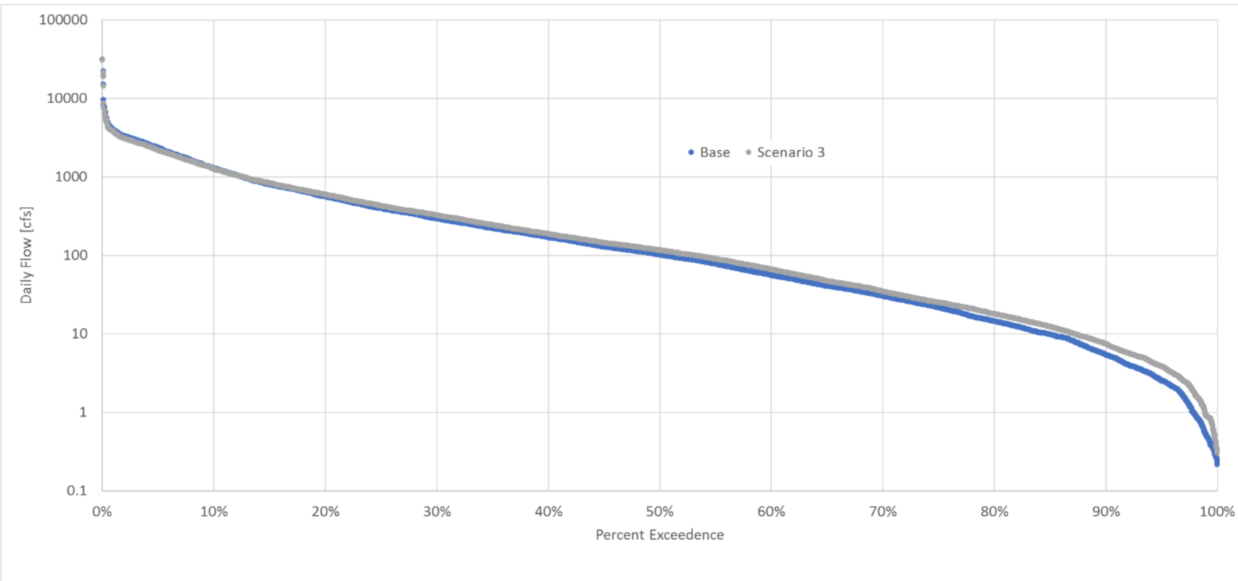


Figure D-4: Flow duration curve at the outlet of Two Rivers (RCHRES 450) for the increased storage BMP scenario.

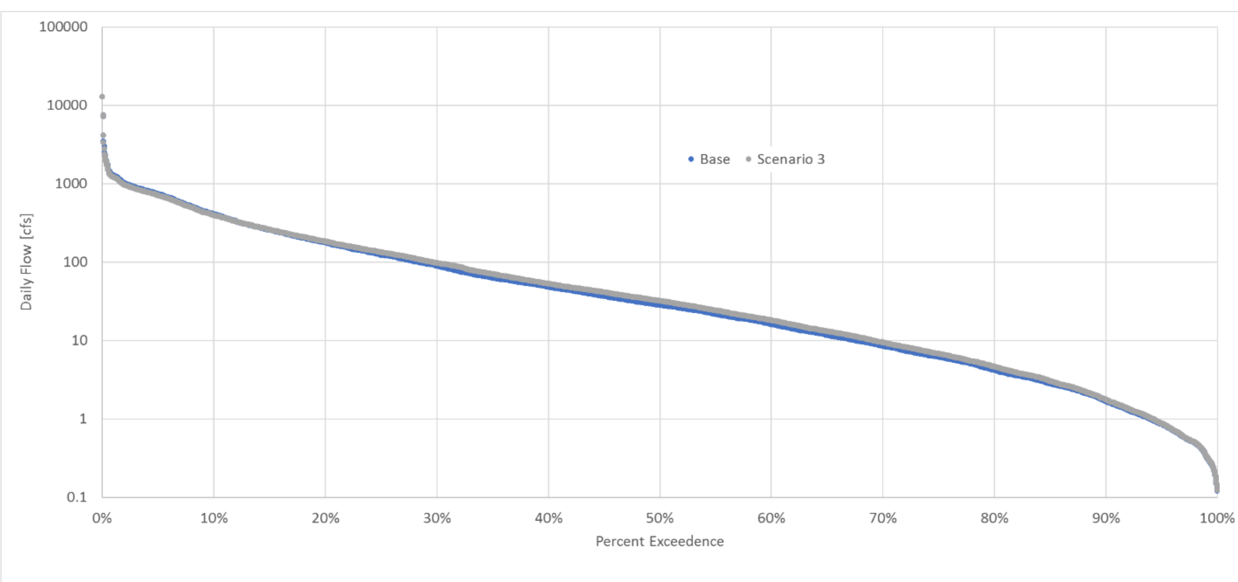


Figure D-5: Flow duration curve at the outlet of North Branch Two Rivers (RCHRES 433) for the increased storage BMP scenario.

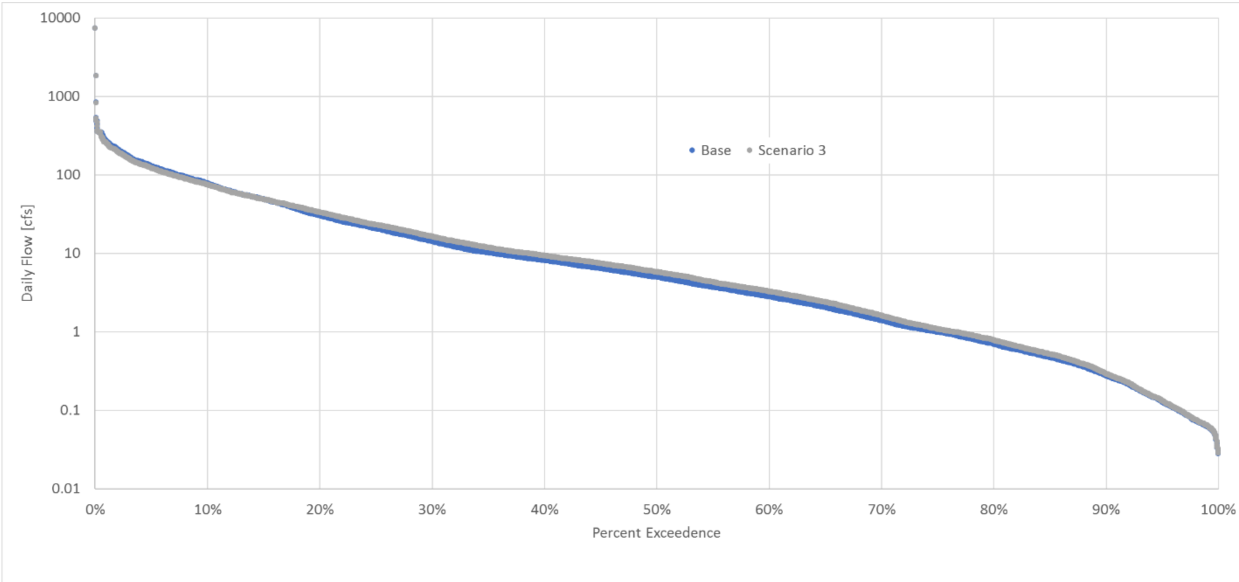


Figure D-6: Flow duration curve at the outlet of Middle Branch Two Rivers (RCHRES 257) for the increased storage BMP scenario.

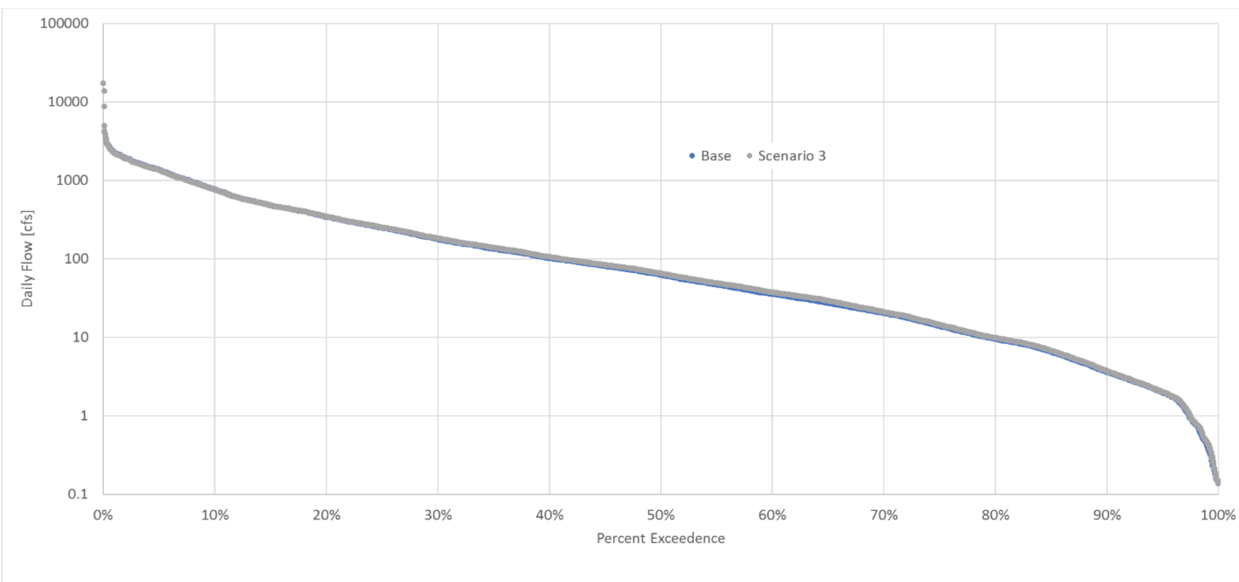


Figure D-7: Flow duration curve at the outlet of South Branch Two Rivers (RCHRES 250) for the increased storage BMP scenario.

References

Houston Engineering, Inc. (HEI). 2015. Technical Memorandum – BMP Implementation Scenarios using HSPF Objective 6 Hydrologic Simulation Program FORTRAN (HSPF) Model Development Assistance and Incorporation. February 2, 2015

Houston Engineering, Inc. (HEI). 2016. PTMApp to aid in the development of WRAPS strategies, Technical Memorandum. May, 2016.

RESPEC. (2014). Two Rivers Model Development Revision 1. March, 2014.