Watershed

May 2022

Final Wild Rice River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

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Cover photo credit: MPCA

Document number: wq-ws4-89a

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Key terms and abbreviations

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

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

Aquatic recreation use 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 Basin is assigned a HUC-4 of 0902 and the Wild Rice River Watershed is assigned a HUC-8 of 09020108.

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

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

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

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

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

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

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

Executive summary

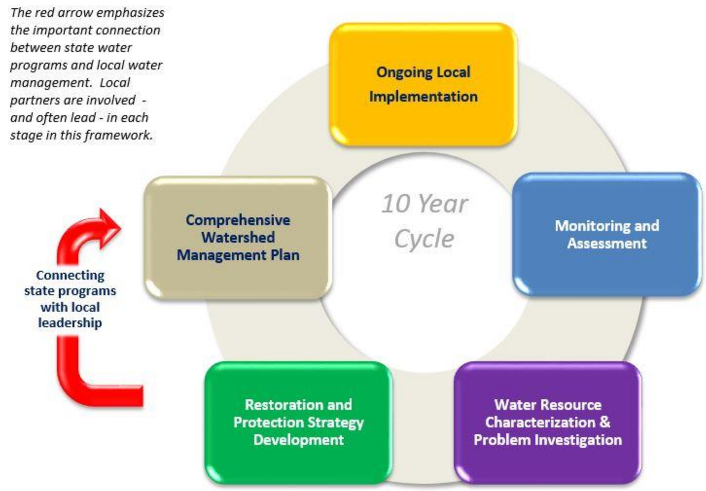
The Wild Rice River Watershed (WRRW), 8-digit hydrologic unit code (HUC-8) 09020108, encompasses approximately 1,636 square miles in northwestern Minnesota and is one of the most hydrologically and ecologically diverse tributaries of the Red River of the North Basin (HUC-4 0902). The watershed lies within six counties (listed in order of the percentage of watershed area): Mahnomen (32%), Norman (28%), Becker (13%), Clay (13%), Clearwater (13%), and Polk (<1%). Despite the large surface area of the watershed, the population density is low (21.2 residents per square mile). Approximately 76% of the land is privately owned, 18% is publicly owned, and 6% is owned by the White Earth Nation (NRCS, 2007). The eastern half of the watershed is located within the White Earth Reservation, a Tribal reservation that was established by treaty in 1867.

The eastern third of the watershed, which includes the headwaters area, is located within the Northern Lakes and Forests (NLF) and North Central Hardwood Forests (NCHF) ecoregions. The area is largely undeveloped except for lakeshore development. The shallow lakes and wetlands coupled with the hardwood forests are largely not suitable for cropping due to the drainage that would be required to convert the land to productive agricultural lands. The central third of the watershed lies primarily within the Lake Agassiz Plains (LAP) ecoregion. Transitional grasslands and woodlands were converted to agricultural production upon development, with drainage partially modifying the landscape to facilitate new land use practices. The western third of the watershed lies entirely in the LAP ecoregion. Historically, the grassland and wetland complexes within this portion of the watershed have largely been drained to permit cropping. The rich soils of the watershed support a large area of cultivated cropping systems (57.6% of total watershed area), with the remaining watershed comprised of forests/shrubs (19.8%), wetlands (13%), rangeland (3.5%) open water (3.1%), development (2.9%), and barren (0.1%) as of the 2016 National Land Cover Database (NLCD) (Yang, et al., 2018). The LAP ecoregion (65% of the watershed) employs extensive tiling and ditching to maintain adequate drainage for cultivation. Major crops grown throughout the watershed include soybeans, small grains, corn, and sugar beets (USDA-NASS, 2021) with the majority of the crops marketed outside of the watershed.

The diverse land cover/use of the WRRW is reflected in its water quality and is largely correlated with ecoregion. Water quality and habitat of the headwaters is ranked much higher than the western third of the watershed, reflecting land cover/use transition from natural lands in the east to intensely cultivated land in the west. Hydrologic connectivity for aquatic wildlife is a concern throughout the watershed due to both altered hydrologic conditions and physical barriers (e.g., culverts, dams, etc.) impeding the natural migration of several aquatic species. The resulting loss of aquatic habitat due to habitat connectivity disruptions is widespread, and management of these disruptors would reestablish corridors to high quality upstream habitats. Altered hydrology throughout the western two thirds of the WRRW also leads to the rapid movement of water from upland drainage ditches during wet times of the year. This can result in intensified bank erosion and subsequent fouling of aquatic habitats. Coupled with higher peak flows, the altered hydrology and lower water holding capacity of the landscape results in reduced flows during dry times of the year. In contrast to the western portions of the watershed, the hydrology of the eastern third of the WRRW largely reflects historical water holding capacity and conveyance due to fewer lake and stream controls and modifications.

The Minnesota Pollution Control Agency (MPCA) began its intensive two-year watershed monitoring within the WRRW in 2014. Data were compiled and analyzed by the MPCA to develop the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017) and the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018). Determinations and findings from those reports, in conjunction with the concurrent development of total maximum daily loads (TMDLs) for impaired waterbodies within the WRRW, are compiled within this WRAPS report to summarize water resources assessments conducted over the past 10 years and to review strategies to protect and restore impaired waters.

What is the WRAPS report?



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

As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds. This process is called Watershed Restoration and Protection Strategy (WRAPS) development. The WRAPS reports have two components: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

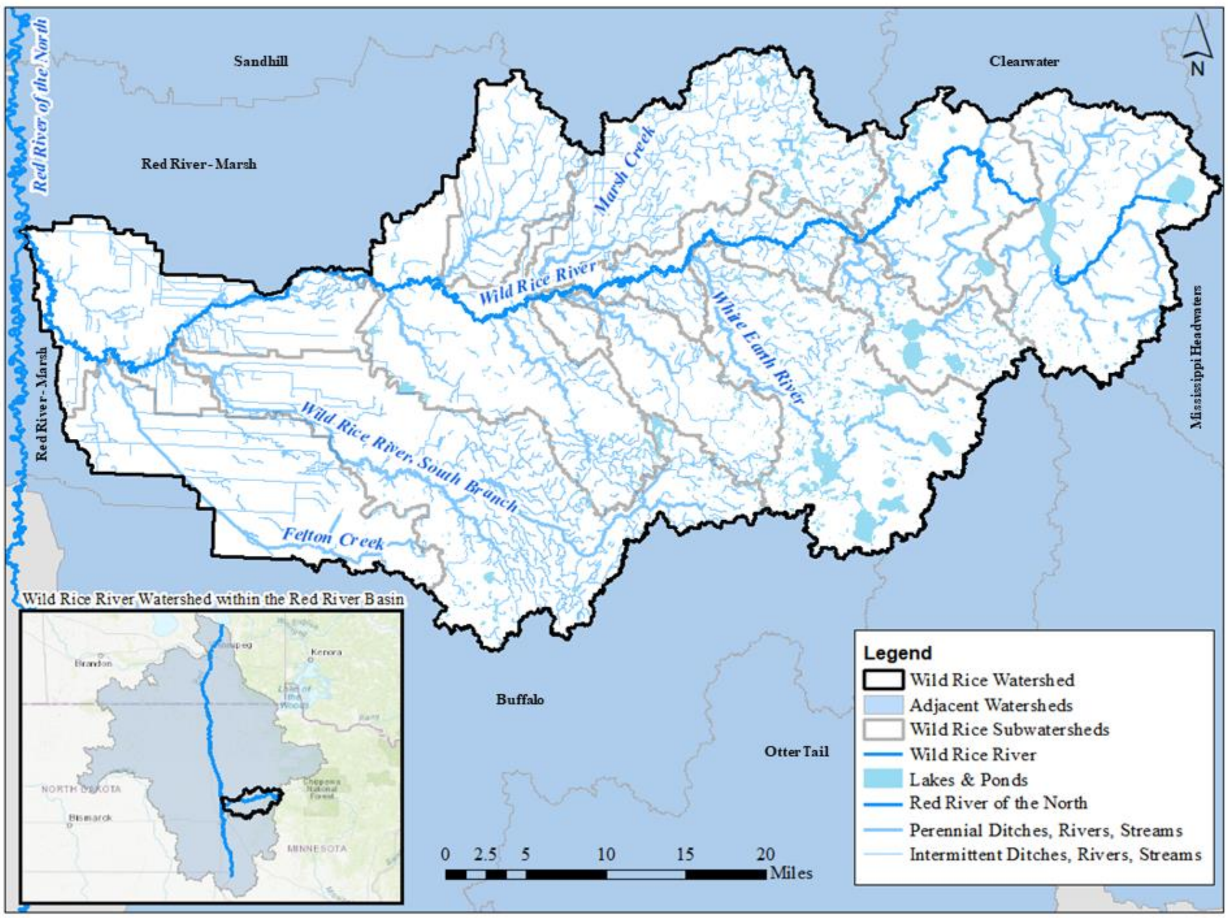
Waters not meeting state standards are listed as impaired, and TMDL studies are developed for them. The TMDLs are incorporated into the WRAPS reports. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple waterbodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and use watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, the WRAPS report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. The WRAPS report also serves as the building block 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: •*Wild Rice River Watershed Monitoring and Assessment*; •*Wild Rice River Watershed Stressor Identification*; and •*Final Wild Rice River 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 (local governments, SWCDs, watershed districts, etc.) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The WRRW, 8-digit hydrologic unit code (HUC-8) 09020108, is the third largest, and one of the most ecologically diverse, major watersheds in the Red River Basin (HUC-4 0902) (**Figure 1**). The watershed drains approximately 1,636 square miles (1,047,069 acres) across six counties of northwest Minnesota (listed in order of the percentage of watershed area): Mahnomen (32%), Norman (28%), Becker (13%), Clay (13%), Clearwater (13%), and Polk (<1%). Overall, the watershed has a relatively low population of 13,564 people (NRCS, 2007). About 40% of the population resides in municipalities, the largest of which are Mahnomen, Twin Valley, White Earth, Ulen, Waubun, and Hendrum. Developed land covers only 2.9% of the watershed and is widely-distributed throughout.

Figure 1: Location of the Wild Rice River Watershed in the Red River Basin.

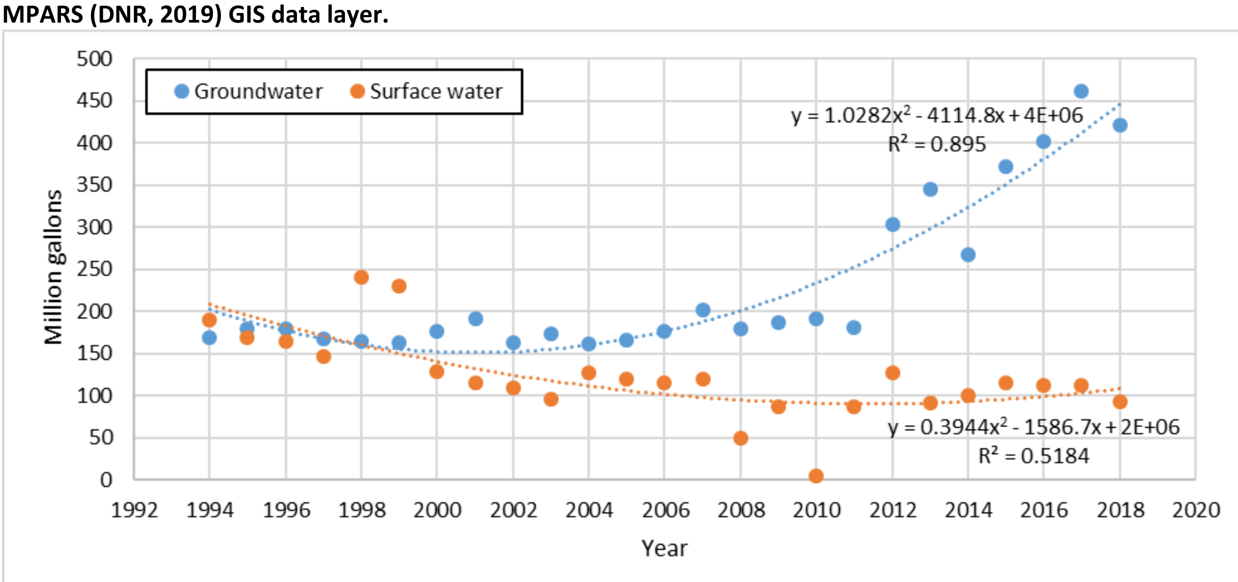


The WRRW has 475 miles of perennial streams and rivers. Tributaries to perennial stream and rivers includes 882 miles of intermittent stream, 643 miles of intermittent drainage ditch, and 50 miles of perennial drainage ditch, for a total of 2,050 miles of watercourses in the watershed (DNR, 2020). The main perennial river in the watershed, the Wild Rice River, originates from Upper Rice Lake, approximately 10 miles southeast of Bagley, and flows generally east to west for 168 miles to its confluence with the Red River near Hendrum. The Wild Rice River passes through the White Earth Reservation shortly before entering Lower Rice Lake, a 2,000-acre lake with abundant stands of wild rice. Major tributaries to the Wild Rice River include (upstream to downstream) Heir Creek, Buckboard Creek, Auganash Creek, Mosquito Creek, Roy Creek, Schermerhorn Creek, Twin Lake Creek, White Earth

River, Spring Creek, Marsh Creek, Mashaug Creek, Coon Creek, South Branch Wild Rice River, and Felton Creek. Notable ditch systems in the western two-thirds of the watershed include Project 24 – Norman County Ditch No. 12, Project No. 19 – Norman County Ditch No. 35, Project No. 9 –South Branch/Felton Ditch, Project No. 3 – Norman County Ditch No. 20, Judicial Ditch No. 56, and Dalton Coulee. East of Ada, a United States Army Corps of Engineers Flood Control Project connects the Wild Rice River to the headwaters of the Marsh River to the north. During high flow events when the Wild Rice River reaches flood stage, excess water leaves the Wild Rice River and flows into the Marsh River. The WRRW also has more than 440 waterbodies greater than 10 acres in size that are classified as a lake or pond by the Minnesota Department of Natural Resources (DNR) protected waters inventory (PWI) (MPCA, 2017).

Groundwater and surface water withdrawal to support industrial processing, public water supply, agricultural irrigation, etc. in the WRRW has also been assessed based on the DNR Permitting and Reporting System (MPARS) (DNR, 2019) geographic information system (GIS) data layer. Groundwater and surface water withdraw has generally exhibited an inverted pattern from 1994 to 2018 (**Figure 2**), with groundwater withdrawals increasing, largely driven by large agricultural demand since drought conditions in 2012 (**Figure 3**), whereas surface water withdrawals have consistently decreased during the same period, mainly due to less surface water usage for industrial processing (**Figure 4**). The vast majority of groundwater usage from 1994 to 2011 was for water supply (e.g., municipal), after which (2012 through 2018) agricultural irrigation accounted for approximately half of groundwater usage (**Figure 3**). In general, industrial processing demand has comprised the vast majority of surface water use from 1994 to 2018, but demand of surface water for agricultural irrigation increased from 2015 to 2018 (**Figure 4**).

Figure 2: Total groundwater and surface water usage in the Wild Rice River Watershed based on data from the MPARS (DNR, 2019) GIS data layer.



Note that the trendlines are calculated from 2nd order polynomial equations.

Figure 3: Groundwater usage by category in the Wild Rice River Watershed based on data from the MPARS (DNR, 2019) GIS data layer.

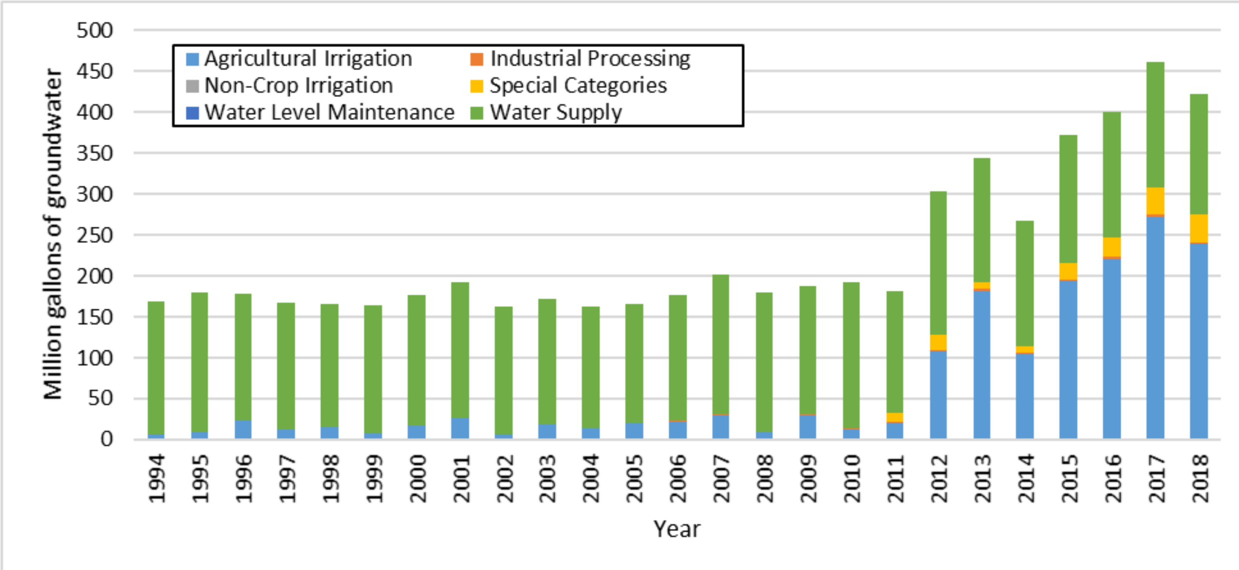
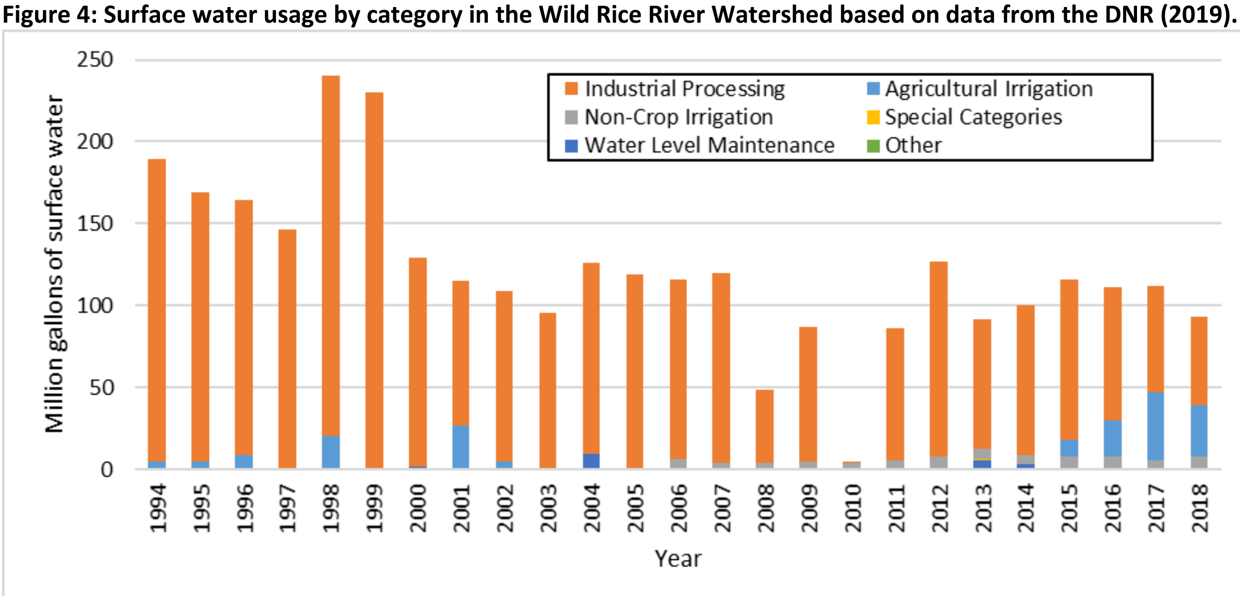


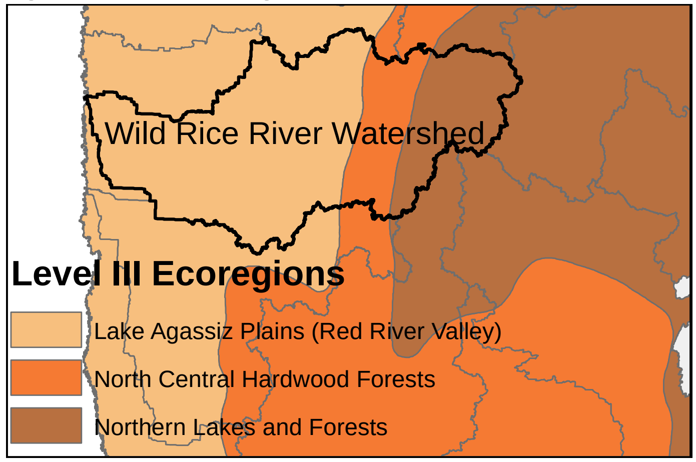
Figure 4: Surface water usage by category in the Wild Rice River Watershed based on data from the DNR (2019).



Attributes of the WRRW are highly variable, especially when comparing the eastern third of the watershed to the western two-thirds. Some of these attributes include level III ecoregions, soils, land cover/use, topography/elevation, hydrologic and stream alteration, and land ownership.

The WRRW is located within three level III ecoregions (**Figure 5**). The eastern third of the watershed is located within the NLF and NCHF ecoregions, while the western two-thirds is located within the LAP ecoregion. Each ecoregion is characterized by a combination of differences among climate, soils, geology, land cover/use, topography/elevation, etc., some of which are described further below.

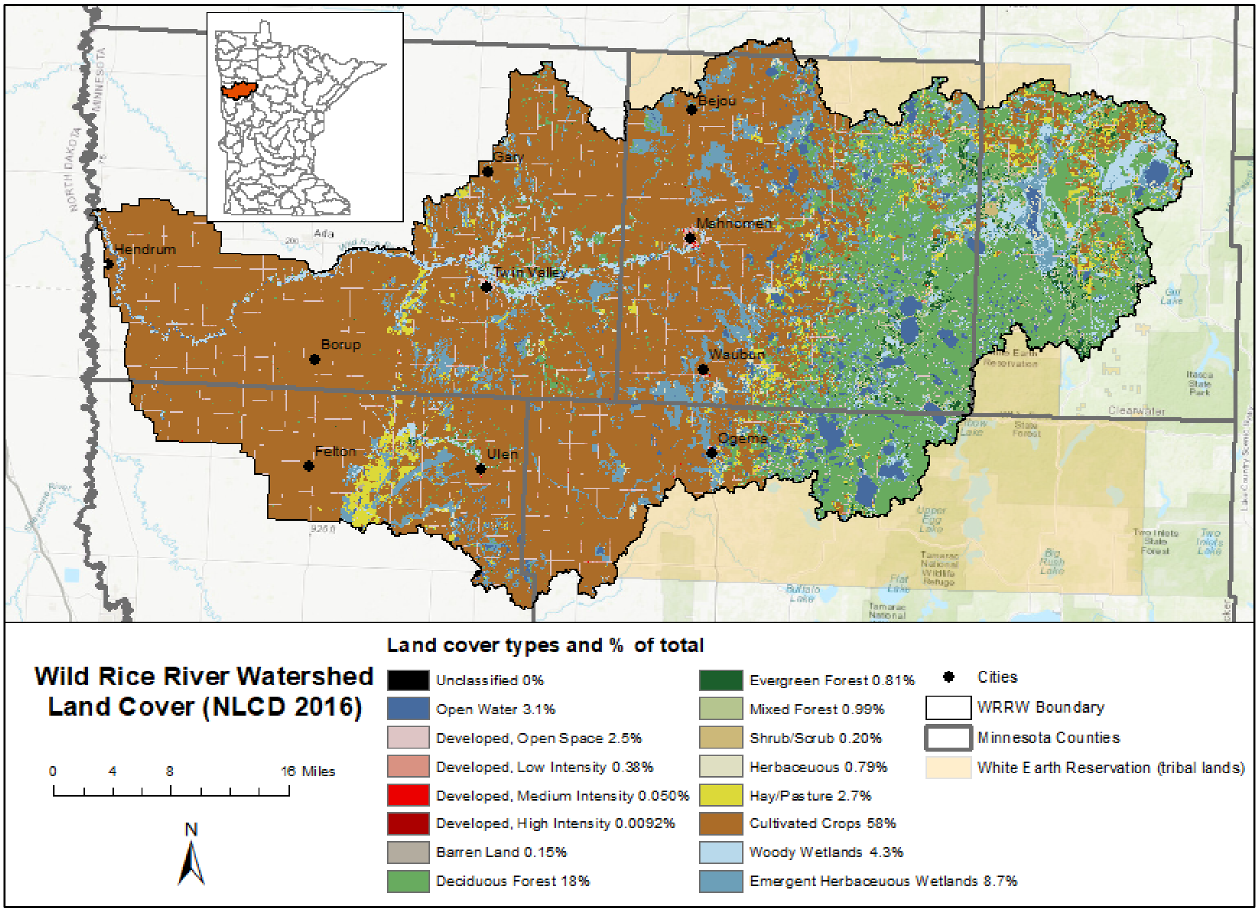
Figure 5: Level III ecoregions in the Wild Rice River Watershed



Soils in the WRRW tend to follow the same general boundaries as the ecoregions. In the eastern third, the NLF ecoregion has fairly nutrient-poor glacial soils that are sandy and loamy and generally lack arability, while soils in the NCHF ecoregion are slightly more nutrient-rich and arable. Soils in the western two-thirds (the LAP ecoregion) are characterized by thick, arable, and nutrient-rich lacustrine sediments above glacial till.

Land cover/use in the eastern third of the watershed is mostly deciduous forest, lakes, and wetlands (**Figure 6**). Over 80% of the lakes in the WRRW are found here, which increases opportunities there for recreation, primarily boating and fishing. Very little conversion from one land cover/use to another has historically occurred in this area, especially compared to the western two-thirds of the watershed, which has been predominantly converted to cultivated crops/agriculture with a smaller proportion being covered by hay/pasture lands and wetlands, among other land cover types.

Figure 6: Wild Rice River Watershed land cover (Yang, et al., 2018) and major cities.



The eastern third of the watershed has a higher elevation and more hills compared to the western two-thirds. As the Wild Rice River flows from the NLF ecoregion into the NCHF, it begins a relatively steep descent in elevation. Then the grade of the Wild Rice River lessens as it flows throughout the LAP ecoregion. This ancient glacial lakebed in the LAP has an incredibly flat topography and is comprised of thick beds of lake sediments and clays.

Manipulation of hydrology and streams in the eastern third of the watershed is minimal, thus allowing the majority of surface water to maintain its natural flow regime and water-holding capacity. The hydrology in the western third of the basins has been significantly changed, in part due to physical alterations of streams (i.e., channelized, ditched, or impounded) (MPCA, 2013). Altered watercourses are generally prone to elevated flows that rise quickly in response to precipitation, and are subsequently subject to periods of prolonged low discharge during drier periods. The channelization of stream reaches and ditching was done to facilitate drainage of the low-relief landscape for agricultural use.

Land ownership in the WRRW is predominantly private (76%), while 18% is publicly owned and 6% is owned by the White Earth Nation (NRCS, 2007). Public and White Earth Nation land ownership is primarily concentrated in the eastern third of the watershed, and the vast majority of the land in the western two-thirds is privately owned.

Many of these attributes in the WRRW have a direct or indirect effect on the quality of surface water as will be discussed in more detail in the next section.

Additional Wild Rice River Watershed resources

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Wild Rice River Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021583.pdf

Minnesota Department of Natural Resources (DNR) Watershed Health Assessment Framework for the Wild Rice River Watershed. Context Report:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/context_report_major_60.pdf

Report Card: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_60.pdf

2. Watershed conditions

This section describes the conditions of streams and lakes within the WRRW that are impaired and in need of restoration, or unimpaired and in need of protection based on water quality data. The determination of whether streams and lakes in the watershed were supportive of (i.e., unimpaired for) or not supportive of (i.e., impaired for) their beneficial uses (aquatic life and aquatic recreation [direct human contact with the water]) was completed by comparing data from surface waters to state standards.

In 2014, the MPCA began intensive watershed monitoring (IWM) in the WRRW, collecting biological and chemistry data from surface water, completing IWM at the end of the 2015 field season. Sampling during IWM was conducted in a manner to prioritize the sampling of streams at outlets of HUC-12 subwatersheds greater than 40 square miles, and lakes in the NLF and NCHF ecoregions, where the vast majority of the lakes in the WRRW are located. All data collected in 2006 through 2015, mostly by MPCA, Wild Rice Watershed District (WRWD), soil and water conservation districts (SWCDs), local citizens (as part of the Citizen Stream and Lake Monitoring Program), and the DNR, were assessed in early 2016 to determine whether streams and lakes were supportive of their beneficial uses (aquatic life and aquatic recreation). To determine whether a stream or lake can support aquatic life, biological and chemistry data are compared against state standards (i.e., acceptable limits). Streams and lakes considered impaired for either aquatic life use or aquatic recreation use should be targeted with restoration practices, while the waterbodies that currently meet aquatic life use and aquatic recreation use criteria should be the focus of protection efforts.

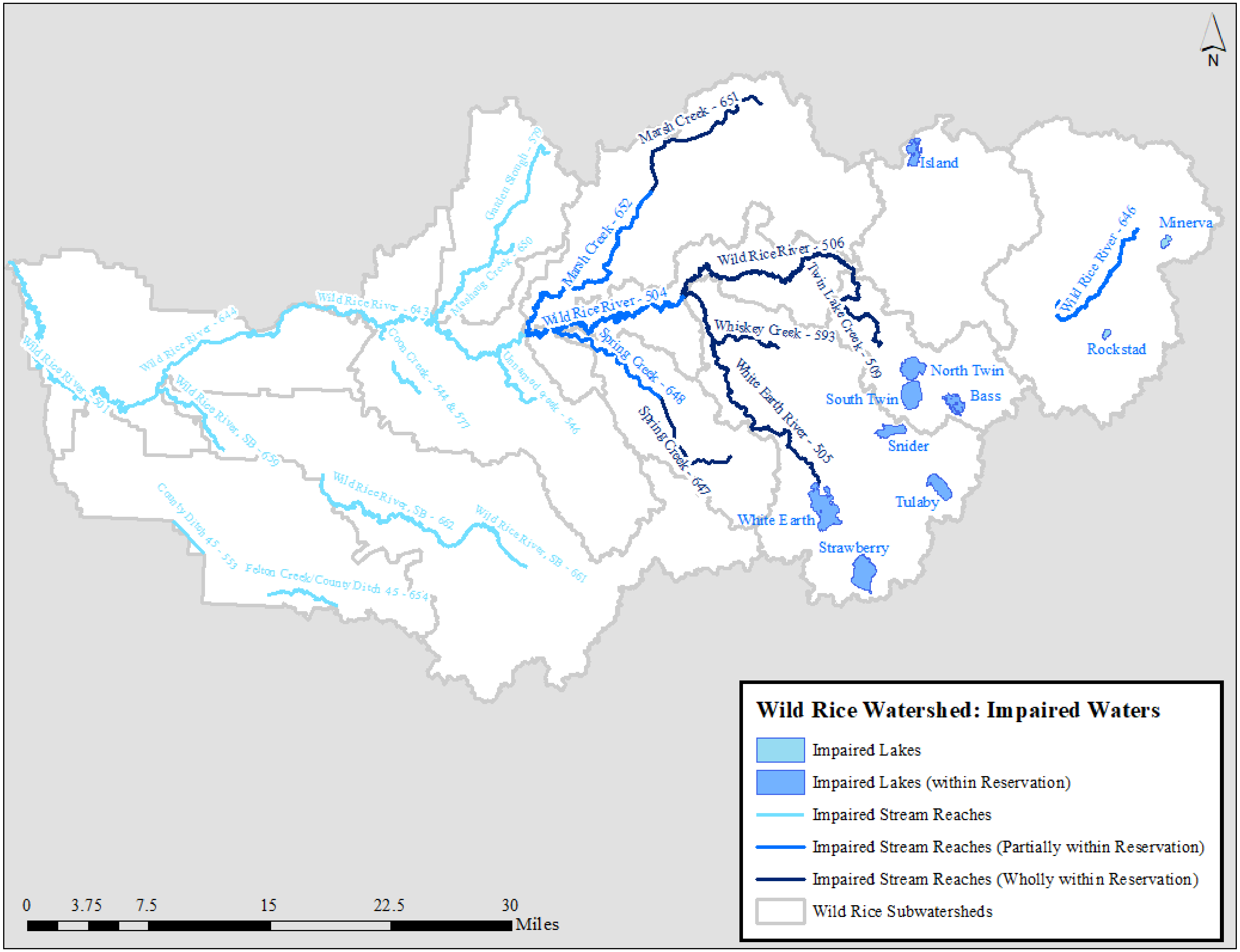
Another resource that is useful for describing watershed conditions is the Watershed Health Assessment Framework (WHAF) that was developed by the DNR (2021). The WHAF assessed the ecological health of the WRRW by ranking the health of five components from 0 to 100 (0 – low and 100 – high). The five components were hydrology, geomorphology, biology, connectivity, and water quality with the five health scores averaged to establish a mean watershed score. Connectivity and biology scored the lowest throughout the watershed (31 and 41, respectively), while geomorphology, hydrology, and water quality scored higher (64, 70, and 77, respectively) with the watershed receiving a mean health score of 57. Each of the five components were composed of several subcomponents. The subcomponents scores that brought down the connectivity and biology component scores were terrestrial habitat connectivity (16) and terrestrial habitat quality (20), which were low due to the highly altered landscape in the western two-thirds of the watershed. While the health scores for the five components were calculated to represent the entire watershed, several of the subcomponent scores were calculated at the HUC-12 catchment scale that differed greatly due to the land use and ecoregion patterns within the watershed.

An attribute of the watershed that can affect water quality conditions is the presence of sites that are potentially contaminated and sites with environmental permits and/or registrations as inventoried by MPCA's *What's in My Neighborhood* (MPCA, 2022). The MPCA lists 345 currently active environmental permitted/registered or contaminated locations within the WRRW. Active sites identified include: 86 tanks (46 underground and 40 aboveground tanks), 42 hazardous waste sites, 146 feedlots sites, 22 water quality sites, 3 air quality sites, 56 stormwater sites (8 industrial, 48 construction), 21 subsurface sewage treatment system (SSTS) sites, 14 investigation and cleanup sites, and 6 solid waste site. The number of sites exceeds the number of locations by 51, because there are situations where a single location is listed as a site under more than one program.

Twenty of the 22 water quality sites listed in *What in My Neighborhood* (MPCA, 2022) are attributed to the 10 municipal wastewater treatment plants (WWTPs) within the WRRW. There is one WWTP in each of the following cities: Bejou, Borup, Felton, Gary, Hendrum, Mahnomen, Ogema, Twin Valley, Ulen, and Waubun (mapped in **Figure 6**). None of the cities in the watershed require a Municipal Separation Storm Sewer System (MS4) permit.

A more detailed analysis of the quality of the waters within the WRRW can be found in the *Wild Rice River Monitoring and Assessment Report* (MPCA, 2017) and the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018). More specific information on the watershed and surface water conditions, and associated pollutant sources of lakes and streams impaired or unimpaired for aquatic life use or recreation, are summarized in the following sections.

Figure 7: Impaired waters in the Wild Rice River Watershed.



2.1 Condition status

Of the 44 stream reaches that were assessed in early 2016, all had at least some data that were used to attempt assessments for aquatic life use, and 27 of those 44 were also assessed for aquatic recreation use. Twenty-one of the 44 assessed reaches supported aquatic life, 14 did not, while the remaining 9 had some data but not enough to be fully assessed. Ten of the 27 assessed reaches supported aquatic recreation, 15 did not, and the remaining 2 had limited data. Note that stream reaches are often referred to by the unique 3-digit suffix portion of their assessment unit identifier or AUID (e.g., 09020108-**501**).

Of the 19 lakes with monitoring data, assessments of aquatic life use and aquatic recreation use was attempted on 15 and 18 of them, respectively. Ten lakes met aquatic life use standards and data was too limited for a full assessment of the remaining 5 lakes. Only 2 lakes, Rockstad and Tulaby, failed to meet aquatic recreation use standards due to excessive nutrient levels which can cause nuisance algal blooms; 11 lakes were supportive of aquatic recreation and 5 did not have enough data for full assessments.

Like the many attributes of the watershed discussed in **Section 1**, assessments show that water quality is also distinctively different between the eastern third of the watershed and the western two-thirds. Restoration efforts are needed most in the western portion of the watershed where there are significantly more water quality impairments, especially for sediment and *Escherichia coli* (*E. coli*), for several reasons. Extensive alterations to watercourses in the central and western portions of the watershed (mainly channelizing and ditching, but also impounding to a lesser extent) in combination with a predominantly agricultural land cover/use have had negative, albeit unintended, consequences for aquatic life. The ditches and straightened channels (especially those that completely lack meanders) and agricultural land (especially if tiled and lacking vegetation) promote drainage and result in very limited water holding capacity and flashy flows. These flashy flows are characterized by high and quick peak flows that contribute to increased sediment, nutrient, and *E. coli* loading to ditches, streams, and rivers, followed by very low or nonexistent baseflow for an extended period of time, placing greater stress on fish and aquatic macroinvertebrates (bugs). Water control structures such as dams and culverts in this area of the watershed, while providing drainage and flood control benefits, also stress fish as they are barriers to fish passage and spawning.

In contrast to the western two-thirds, the headwaters region of the watershed (approximately the eastern third) has many lakes and streams that support healthy fish populations as well as aquatic recreation, making this a prime location for protection efforts. The nutrient-poor soils and hilly topography are generally not suitable for cultivation, so the majority of the headwaters region remains in a natural, vegetated state with little alteration to hydrology or watercourses. Thus, water holding capacity is much higher, watercourses are less flashy, and water control structures are fewer, resulting in reduced loading of pollutants and less stress to aquatic life. As development and associated impervious surfaces increase on lakeshores, protecting the vitality of the headwaters region is paramount to maintaining waters supportive of aquatic life and recreation by decreasing sediment runoff that can result in turbid conditions or algal blooms. There are also several lakes near the impaired level where protective efforts would be more cost-efficient and timely to address water quality concerns than restoration efforts.

Impaired stream reaches and lakes are mapped in **Figure 7**. Statewide impaired waterbodies are summarized in Minnesota's impaired waters list (MPCA, 2021).

Several waterbodies in the WRRW are impaired for aquatic consumption use caused by excessive mercury (MPCA, 2021). Eight lakes are impaired due to excessive mercury in fish tissue. Seven of the lakes (Bass, Island, North Twin, Snider, South Twin, Strawberry, and White Earth) are located fully within the White Earth Reservation (i.e., outside of MPCA and EPA authority), while Minerva is located east of the reservation boundary and its impairment has been addressed by the statewide mercury TMDL. The one stream impaired due to excessive mercury (both in fish tissue and in the water column) is the most downstream reach of the Wild Rice River that outlets to the Red River of the North. No waters in the WRRW are listed as impaired by PCBs in fish tissue. However, aquatic consumption use impairments and toxic pollutants are not discussed further as they are not covered in this report. For more information on mercury impairments, see the statewide mercury TMDL documents on MPCA's statewide mercury reduction plan website (MPCA, 2020).

Streams

This section describes the streams within the WRRW that are impaired and in need of restoration, or unimpaired and in need of protection. Impairment classification is based on determining if a stream can meet aquatic life use and/or aquatic recreation use standards. To determine whether a stream can support aquatic life, data on nonpollutant parameters such as biological life (fish and aquatic macroinvertebrate indices of biotic integrity [F-IBI and M-IBI] scores), five-day biochemical oxygen demand (BOD_5), chlorophyll-*a* (Chl-*a*), dissolved oxygen (DO), DO flux (the difference between the daily minimum and maximum DO), and pH and pollutant parameters such as chloride, *E. coli*, total phosphorus (TP), total suspended solids (TSS), and un-ionized ammonia (NH_3) are compared against state standards (i.e., acceptable limits) for each parameter. The BOD_5, Chl-*a*, DO flux, pH, and TP, parameters are further assessed against eutrophication standards. A stream is considered impaired due to eutrophication if the causative parameter (TP) and at least one response parameter (BOD_5, Chl-*a*, DO flux, and/or pH) exceed state standards. To determine whether a stream can support aquatic recreation (i.e., direct contact of humans with the water), *E. coli* data are compared against state standards. Elevated *E. coli* is an indication that human health may be at risk from pathogens associated with fecal contamination in the water. Note that a minimum number of samples collected during a certain range of months over a minimum number of years are needed to assess each parameter. Streams considered impaired for either aquatic life use or aquatic recreation use will be targeted with restoration practices, while the streams that currently meet aquatic life use and aquatic recreation use criteria will be the focus of protection efforts.

In most cases, a parameter has more than one numeric standard and which numeric standard applies to a stream reach (or individual station along a reach) depends on a variety of factors. For example, numeric standards for TSS and for parameters related to eutrophication (other than pH) are dependent on the classification of the stream reach (i.e., class 2A [cold water] or 2B [cool or warm water]) and within which nutrient region (i.e., northern, central, or southern) a stream reach is located. Another example is the numeric standards for the biological parameters, F-IBI and M-IBI, are determined on a station by station basis, not a stream reach basis. The F-IBI and M-IBI standards that apply to a station are dependent on which fish class (e.g., southern rivers, northern streams, low gradient, northern coldwater, etc.) or aquatic macroinvertebrate class (e.g., northern forest rivers, prairie forest rivers, southern coldwater, etc.) the station is located within and which tiered aquatic life use (TALU) designation (i.e., exceptional, general, and modified) has been applied to the section of stream in which the station is located. The fish classes and aquatic macroinvertebrate classes are based on stream characteristics such as morphology, structure, water temperature, and gradient. As a final example, the numeric standards for parameters such as DO, NH_3, and pH that apply to a stream reach is dependent on its classification (i.e., class 2A [cold water] or 2B [cool or warm water]). More specific information on assessment protocols and state standards for each parameter can be found in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* (MPCA, 2018), the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017), and in Minn. R. 7050.0222 (2018).

The assessed stream reaches are listed in **Table 1** along with tribal, class 2, and TALU designations, and 2016 assessment results based on 10 years of data (2006 through 2015) for each reach. **Table 1** was summarized using the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017). Stream reaches are grouped by HUC-10 subwatersheds and are generally summarized from upstream to downstream (top to bottom of **Table 1**).

Of the 44 stream reaches listed in **Table 1** that were assessed in early 2016, all had at least some data that were used to attempt assessments for aquatic life use and 27 of those 44 were also assessed for aquatic recreation use. Twenty-one of the 44 assessed reaches supported aquatic life, 14 did not, and the remaining 9 had some data but not enough to be fully assessed. Ten of the 27 assessed reaches supported aquatic recreation use, 15 did not, and the remaining 2 had limited data.

Table 1: Water quality status of stream reaches (presented mostly from upstream to downstream) in the Wild Rice River Watershed based on assessments of 10 years of data (2006 through 2015) (MPCA, 2017).

HUC-10 subwatershed	AUID (last 3 digits)	Stream name	Reach Description [a]	Class 2 designation [b]	TALU designation [c]	Tribal designation [d]	Aquatic life use indicators [e]								Aq. rec. use (*E. coli*)
							F-IBI	M-IBI	DO	Secchi tube and/or Turbidity/TSS	Chloride	pH	NH_3 [f]	Eutrophication	
Headwaters Wild Rice River (0902010801)	551	Heir Creek	Unnamed cr to Wild Rice R	2B	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
	646	Wild Rice River	Unnamed cr to Lower Rice Lk	2B	g	partial	EX	MTS	MTS	MTS	MTS	MTS	MTS	IF [h]	MTS
	534	Buckboard Creek	Headwaters to T144 R38W S11, N line	2A	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
	591	Mosquito Creek	Unnamed ditch to Unnamed ditch	2B	g	partial	NA	–	IF	IF	–	IF	IF	IF	–
	657	Mosquito Creek	Unnamed cr to Unnamed cr	2B	m		–	–	IF	MTS	MTS	MTS	MTS	IF	MTS
Upper Wild Rice River (0902010802)	512	Wild Rice River	Lower Rice Lk to Roy Lake Cr	2B	g		MTS	IF	IF	MTS	MTS	MTS	MTS	IF	MTS
	510	Wild Rice River	Roy Lake Cr to Twin Lake Cr	2B	g		MTS	MTS	IF	MTS	MTS	MTS	MTS	IF [h]	MTS
Twin Lake Creek (0902010803)	532	Unnamed creek	T144 R39W S34, E line to Bad Boy Cr	2A	g		NA	NA	IF	IF	–	IF	IF	IF	–
	509	Twin Lake Creek	Sargent Lk to Wild Rice R	2B	g	wholly	MTS	–	IF	EX	MTS	MTS	MTS	MTS	EX
White Earth River (0902010804)	505	White Earth River	White Earth Lk to Wild Rice R	2B	g	wholly	MTS	MTS	IF	IF [g]	MTS	MTS	MTS	MTS	EX
	593	Whiskey Creek	Unnamed cr to White Earth R	2B	g	wholly	–	–	IF	MTS	MTS	MTS	MTS	IF [h]	EX
	569	Gull Creek	Unnamed cr to White Earth Lk	2B	g		–	–	--	MTS	MTS	–	–	MTS	MTS
Spring Creek (0902010805)	647	Spring Creek	Headwaters to 140th Ave	2B	m	wholly	MTS	EX	IF	IF	–	IF	IF	IF	–
	648	Spring Creek	140th Ave to Wild Rice R	2B	g	partial	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	EX
Middle Wild Rice River (0902010806)	506	Wild Rice River	Twin Lake Cr to White Earth R	2B	g	wholly	MTS	MTS	IF	IF [g]	MTS	MTS	MTS	MTS	EX
	504	Wild Rice River	White Earth R to Marsh Cr	2B	g	partial	MTS	MTS	IF	EX	MTS	MTS	MTS	MTS	MTS
	640	Unnamed creek	Unnamed cr to Wild Rice R	2B	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
Marsh Creek (0902010807)	519	Marsh Creek	Blair Lk to Beaulieu Lk	2B	m		MTS	--	IF	IF	–	IF	IF	IF	–
	651	Marsh Creek	Beaulieu Lk to -95.9973, 47.4054	2B	m	wholly	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	EX
	598	Unnamed creek	Unnamed ditch to Unnamed cr	2B	m		MTS	MTS	IF	IF	–	IF	IF	IF	–
	652	Marsh Creek	-95.9973, 47.4054 to Wild Rice R	2B	g	partial	MTS	MTS	IF	IF [g]	MTS	MTS	MTS	MTS	MTS
	579	Garden Slough	Headwaters to Mashaug Cr	2B	g		EX	–	IF	IF	–	IF	IF	IF	–

HUC-10 subwatershed	AUID (last 3 digits)	Stream name	Reach Description [a]	Class 2 designat-ion [b]	TALU designat-ion [c]	Tribal designat-ion [d]	Aquatic life use indicators [e]								Aq. rec. use (*E. coli*)
							F-IBI	M-IBI	DO	Secchi tube and/or Turbidity/TSS	Chloride	pH	NH_3 [f]	Eutrophication	
Mashaug Creek (0902010808)	656	County Ditch 42	Co Rd 151 to Unnamed cr	2B	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
	650	Mashaug Creek	T-92 to Wild Rice R	2B	g		EX	EX	MTS	MTS	MTS	MTS	MTS	MTS	EX
Lower Wild Rice River (0902010809)	643	Wild Rice River	Marsh Cr to Unnamed cr	2B	g		MTS	MTS	MTS	EX	MTS	MTS	MTS	MTS	EX
	577	Coon Creek	Unnamed cr to Unnamed cr	2B	g		MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	EX
	578	Coon Creek	Unnamed cr to Unnamed cr	2B	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
	544	Coon Creek	Unnamed cr to Wild Rice R	2B	g		MTS	MTS	MTS	IF [g]	MTS	MTS	MTS	IF [h]	EX
	639	Unnamed creek	Headwaters to Unnamed cr	2B	g		–	–	NA	MTS	MTS	MTS	MTS	IF [h]	MTS
	545	Unnamed creek	Unnamed cr to Unnamed cr	2B	g		MTS	MTS	IF	IF	MTS	MTS	MTS	IF	IF
	546	Unnamed creek	Unnamed cr to Wild Rice R	2B	g		MTS	MTS	IF	IF	MTS	MTS	MTS	IF	EX
South Branch Wild Rice River (0902010810)	662	South Branch Wild Rice River	Unnamed cr to Unnamed cr	2B	g		MTS	EX	MTS	IF	MTS	MTS	MTS	IF [h]	EX
	557	Unnamed creek	Unnamed ditch to S Br Wild Rice R	2B	g		–	–	IF	–	–	IF	–	–	–
	659	South Branch Wild Rice River	T-246 to Wild Rice R	2B	g		MTS	MTS	IF	MTS	MTS	MTS	MTS	IF	EX
	540	Spring Creek	Headwaters to S Br Wild Rice R	2B	g		MTS	MTS	IF	IF	–	IF	IF	IF	–
	660	South Branch Wild Rice River	Otto Lk to -96.1406, 47.0658	2B	g		–	–	–	–	–	–	–	–	–
	661	South Branch Wild Rice River	-96.1406, 47.0658 to Unnamed cr	2B	m		EX	IF	IF	IF	–	IF	IF	IF	–
	542	Stiner Creek	Unnamed cr to S Br Wild Rice R	2B	g		MTS	MTS	IF	IF	MTS	MTS	MTS	IF	IF
Felton Creek (0902010811)	653	Felton Creek / County Ditch 19	Headwaters (Unnamed lk 14-0082-00) to 200th St	2A	g		–	–	NA	–	–	IF	–	–	–
	654	Felton Creek / County Ditch 45	200th St to T141 R46W S14, W line	2A	g		EX	EX	IF	IF	–	MTS	MTS	IF	–
	553	County Ditch 45	Unnamed ditch to Unnamed ditch	2B	m		MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	EX
	541	Unnamed creek	Unnamed ditch to Wild Rice R	2B	m		MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	MTS

HUC-10 subwatershed	AUID (last 3 digits)	Stream name	Reach Description [a]	Class 2 designation [b]	TALU designation [c]	Tribal designation [d]	Aquatic life use indicators [e] F-IBI	M-IBI	DO	Secchi tube and/or Turbidity/TSS	Chloride	pH	NH_3 [f]	Eutrophication	Aq. rec. use (*E. coli*)
Outlet Wild Rice River (0902010812)	644	Wild Rice River	Unnamed cr to S Br Wild Rice R	2B	g		MTS	MTS	IF	EX	MTS	MTS	MTS	MTS	EX
	501	Wild Rice River	S Br Wild Rice R to Red R of the N	2B	g		MTS	MTS	MTS	EX	MTS	MTS	MTS	IF [h]	MTS

MTS = 2006 through 2015 data met the water quality standard(s); EX = 2006 through 2015 data exceeded the water quality standard(s); NA = 2006 through 2015 data was sufficient for assessment but was not assessed due to influence from wetlands or beavers; IF = the 2006 through 2015 data was insufficient to make a finding; – = no data.

Existing indication of impairment prior to assessments in 2016, new indication of impairment as of 2016 assessments, meets water quality standard(s) based on 2016 assessments and is not an indicator of impairment.

[a] Ave = Avenue, Br = Branch, cr/Cr = creek/Creek, lk/Lk = lake/Lake, R = River, St = Street, N = North, S = South, E = East, W = West.

[b] Class 2 streams are those that are assessed for aquatic life use and aquatic recreation use. Streams classified as 2A are cold water and those classified as 2B are cool or warm water

[c] g (general) and m (modified) are two of the three TALU designations.

[d] partial = stream reach is partially located with White Earth Reservation, wholly = stream reach is located completely (i.e., wholly) within White Earth Reservation, (blank) = stream reach is located completely outside of a tribal reservation.

[e] F-IBI = fish index of biotic integrity, M-IBI = macroinvertebrate index of biotic integrity, DO = dissolved oxygen, TSS = total suspended solids, and NH_3 = un-ionized ammonia.

[f] This is the form of nitrogen that is harmful to aquatic life and for which there are state standards for class 2 waters.

[g] TSS and Secchi tube had conflicting assessment determinations (i.e., TSS exceeds standards, but Secchi tube meets standards or vice versa), so results in the table are reported as IF.

[h] IF because the causative parameter (TP) exceeded standards but the response variables (BOD_5, Chl-*a*, DO flux, and/or pH) either met standards or had insufficient information for assessments.

Table 2 shows the 31 aquatic life use or aquatic recreation use impairments on 23 stream reaches in the WRRW that are listed on Minnesota's impaired waters list (MPCA, 2021). The 23 stream reaches are either wholly within (*n* = 6), partially within (*n* = 4), or completely outside (*n* = 13) White Earth Reservation. Stream reaches that are wholly within White Earth Reservation on Minnesota's impaired waters list (MPCA, 2021) are advisory to EPA only, as EPA has no authority to approve or disapprove listings of wholly tribal streams on Minnesota's impaired waters list (MPCA, 2021). There are 16 aquatic life use impairments (as indicated by poor benthic macroinvertebrate bioassessments scores (*n* = 4), poor fish bioassessments scores (*n* = 5), excessive TSS (*n* = 2), and excessive turbidity (*n* = 5) in 14 stream reaches and 15 aquatic recreation use impairments (as indicated by excessive *E. coli* in 15 stream reaches) in the WRRW listed on Minnesota's Impaired Waters List (MPCA, 2021). Only 5 of the impairments (those caused by excessive turbidity) in 5 stream reaches were already on the list prior to assessments in 2016, and the remaining 26 impairments in 21 stream reaches were added to the list in 2018 as a results of the 2016 assessments. No stream or river reaches were delisted as a result of the 2016 assessments.

Table 2: Aquatic life use and aquatic recreation use impairments in Wild Rice River Watershed streams on Minnesota's impaired waters list (MPCA, 2021). [a]

AUID (last 3 digits)	Stream name (reach description [b])	Class 2 and TALU designations [c]	Tribal designation [d]	Listing Year	Affected designated use [e]	Indicator / parameter	EPA category [f]
501	Wild Rice River (S Br Wild Rice R to Red R)	2Bg		2006	AQL	Turbidity	4A
504	Wild Rice River (White Earth R to Marsh Cr)	2Bg	Partial	2018	AQL	TSS	5
505	White Earth River (White Earth Lk to Wild Rice R)	2Bg	Wholly	2008	AQL	Turbidity	N/A
				2018	AQR	*E. coli*	N/A
506	Wild Rice River (Twin Lake Cr to White Earth R)	2Bg	Wholly	2018	AQR	*E. coli*	N/A
509	Twin Lake Creek (Sargent Lk to Wild Rice R)	2Bg	Wholly	2018	AQL	TSS	N/A
				2018	AQR	*E. coli*	N/A
544	Coon Creek (Unnamed cr to Wild Rice R)	2Bg		2018	AQR	*E. coli*	5
546	Unnamed creek (Unnamed cr to Wild Rice R)	2Bg		2018	AQR	*E. coli*	5
553	County Ditch 45 (Unnamed ditch to Unnamed ditch)	2Bm		2018	AQR	*E. coli*	5
577	Coon Creek (Unnamed cr to Unnamed cr)	2Bg		2018	AQR	*E. coli*	5
579	Garden Slough (Headwaters to Mashaug Cr)	2Bg		2018	AQL	Fishes bioassessments	5
593	Whiskey Creek (Unnamed cr to White Earth R)	2Bg	Wholly	2018	AQR	*E. coli*	N/A
643	Wild Rice River (Marsh Cr to Unnamed cr)	2Bg		2010	AQL	Turbidity	5
				2018	AQR	*E. coli*	5
644	Wild Rice River (Unnamed cr to S Br Wild Rice R)	2Bg		2010	AQL	Turbidity	5
				2018	AQR	*E. coli*	5
646	Wild Rice River (Unnamed cr to Lower Rice Lk)	2Bg	Partial	2018	AQL	Fishes bioassessments	5
647	Spring Creek (Headwaters to 140th Ave)	2Bm	Wholly	2018	AQL	Benthic macroinvertebrates bioassessments	N/A
648	Spring Creek (140th Ave to Wild Rice R)	2Bg	Partial	2018	AQR	*E. coli*	5
650	Mashaug Creek (T-92 to Wild Rice R)	2Bg		2018	AQL	Benthic macroinvertebrates bioassessments	5
				2018	AQL	Fishes bioassessments	5
				2018	AQR	*E. coli*	5
651	Marsh Creek (Beaulieu Lk to -95.9973 47.4054	2Bm	Wholly	2018	AQR	*E. coli*	N/A

AUID (last 3 digits)	Stream name (reach description [b])	Class 2 and TALU designations [c]	Tribal designation [d]	Listing Year	Affected designated use [e]	Indicator / parameter	EPA category [f]
652	Marsh Creek (-95.9973 47.4054 to Wild Rice R)	2Bg	Partial	2008	AQL	Turbidity	5
654	Felton Creek/County Ditch 45 (200th St to T141 R46W S14, W line)	2Ag		2018	AQL	Benthic macroinvertebrates bioassessments	5
				2018	AQL	Fishes bioassessments	5
659	South Branch Wild Rice River (T-246 to Wild Rice R)	2Bg		2018	AQR	*E. coli*	5
661	South Branch Wild Rice River (-96.1406 47.0658 to Unnamed cr)	2Bm		2018	AQL	Fishes bioassessments	5
662	South Branch Wild Rice River (Unnamed cr to Unnamed cr)	2Bg		2018	AQL	Benthic macroinvertebrates bioassessments	5
				2018	AQR	*E. coli*	5

[a] Excludes aquatic consumption use impairments and impairments in lakes.

[b] Ave = Avenue, Br = Branch, cr/Cr = creek/Creek, Lk = Lake, R = River, St = Street, S = South, W = West.

[c] Class 2 streams are those that are assessed for aquatic life use and aquatic recreation use. Streams classified as 2A are cold water and those classified as 2B are cool or warm water. g (general) and m (modified) are two of the three TALU designations.

[d] partial = stream reach is partially located with White Earth Reservation, wholly = stream reach is located completely (i.e., wholly) within White Earth Reservation, (blank) = stream reach is located completely outside of a tribal reservation.

[e] AQL = aquatic life, AQR = aquatic recreation.

[f] 4a = waterbody is impaired, but a TMDL study has been approved by EPA, 5 = waterbody is impaired, and a TMDL study has not been approved by EPA, N/A = waterbody is located wholly within a tribal reservation, so this listing is advisory to EPA only.

Lakes

This section describes the lakes within the WRRW that are impaired and in need of restoration, or unimpaired and in need of protection. Impairment classification is based on determining if a lake can meet aquatic life use and/or aquatic recreation use standards. To determine whether a lake can support aquatic life, data on pollutant parameters such as chloride and pesticides and nonpollutant parameters such as biological life (i.e., F-IBI scores) are compared against state standards (i.e., acceptable limits) for each parameter. DNR staff assessed lakes using the current F-IBI assessment, specifically Tool 2. The method uses 15 metrics to assess changes in the trophic state, floristic quality, land use, and dock density. The following metrics are assessed to comprise the F-IBI: total numbers of native, intolerant, tolerant, insectivorous, omnivorous, cyprinid, small benthic-dwelling, and vegetation-dwelling species caught collectively in nearshore gears, standard trap nets, and standard gill nets; proportions of intolerant and small benthic-dwelling individuals caught in nearshore gears; proportion of insectivores, omnivores, and tolerant species by biomass in standard trap nets; and proportion of top carnivores by biomass and presence or absence of intolerant species in gill nets. F-IBI scores were subsequently assessed using thresholds and confidence intervals (higher score indicates that the fish community has not been substantially altered).

To determine whether a lake can support aquatic recreation (i.e., direct contact of humans with the water), data on nonpollutant parameters such as Chl-*a* and Secchi depth and pollutant parameters such as TP, are compared against state standards (i.e., acceptable limits) for each parameter. The TP, Chl-*a*, and Secchi depth parameters are further assessed against lake nutrient (i.e., eutrophication) standards. A lake is considered impaired due to nutrients if the causative parameter (TP) and at least one response parameter (Chl-*a* and/or Secchi depth) exceed state standards. When the causative and response parameters exceed standards, it is an indication that human health may be at risk from harmful algae in the lake. This algae may also lead to harmful algal blooms in the lakes. Lakes considered impaired for either aquatic life use or aquatic recreation use should be targeted with restoration practices, while the lakes that currently meet aquatic life use and aquatic recreation use criteria should be the focus of protection efforts.

In most cases, a parameter has more than one numeric standard and which numeric standard applies to a lake depends on a variety of conditions such as the classification of the lake (i.e., class 2A [cold water] or 2B [cool or warm water]), depth of the lake (i.e., shallow or deep), and/or within which ecoregion a lake is located. Also, a minimum number of samples collected during a certain range of months over a minimum number of years are needed to assess each parameter. More specific information on assessment protocols and state standards for each parameter can be found in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* (MPCA, 2018), the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017), and in Minn. R. 7050.0222 (2018).

Nineteen of the assessed lakes are listed in **Table 3,** along with 2016 assessment results based on 10 years of data (2006 through 2015) for each lake. **Table 3** was summarized using the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017). Lakes are grouped by HUC-10 subwatersheds, and the HUC-10 subwatersheds and lakes listed within each HUC-10 are generally summarized from west to east (top to bottom of **Table 3**).

Of the 19 lakes listed in **Table 3** that were assessed in early 2016, most had at least some data that were used to attempt assessments for aquatic life use (*n* = 16) and aquatic recreation use (*n* = 18), respectively. None of the lakes were found to be impaired for aquatic life use and 2 were found to be impaired for aquatic recreation use due to nutrients. DNR assessed 11 of the lakes using F-IBI scores. While 1 lake had some F-IBI data but not enough for assessment, 10 lakes met F-IBI standards, including Tulaby Lake, but it scored only one point higher than the impairment threshold, making it a high priority for protection.

Table 3. Water quality status of lakes (presented mostly from west to east) in the Wild Rice River Watershed based on assessments of 10 years of data (2006 through 2015) (MPCA, 2017).

HUC-10 subwatershed	DNR Lake ID	Lake name	Area (acres)	Max Depth (ft)	Lake depth (assessment method)	Ecoregion [a]	Tribal Designation [b]	Secchi Trend [c]	Aquatic life Indicators			Aquatic Recreation indicators [d]			Aq. Rec. Use (nutrients)
									Fish IBI	Chloride	Pesticides	Total Phosphorus	Chlorophyll-*a*	Secchi depth	
Headwaters Wild Rice River (0902010801)	15-0059-00	Upper Rice	1338	15	Deep Lake	NLF			–	–	–	MTS	MTS	MTS	MTS
	15-0075-00	Rockstad	136	16	Shallow Lake	NLF			IF	–	–	EX	EX	EX	EX
	15-0079-00	Minerva	202	15	Deep Lake	NLF			–	MTS	–	MTS	EX	MTS	IF
	15-0124-00	McKenzie	73	17	Shallow Lake	NLF	wholly		–	MTS	–	MTS	MTS	MTS	MTS
	15-0128-00	Waptus	47	48	Deep Lake	NLF	wholly		–	MTS	–	MTS	MTS	MTS	MTS
	44-0001-00	Roy	679	15	Deep Lake	NLF	wholly	D	MTS	MTS	–	MTS	IF	EX	IF
	44-0038-00	Island	600	43	Deep Lake	NCHF	wholly	NT	MTS	MTS	–	IF	IF	MTS	IF
Twin Lake Creek (0902010803)	44-0006-00	Bass	632	20	Deep Lake	NLF	wholly	NT	MTS	MTS	–	MTS	MTS	MTS	MTS
	44-0014-00	South Twin	1101	29	Deep Lake	NLF	wholly	NT	MTS	MTS	–	MTS	MTS	MTS	MTS
	44-0023-00	North Twin	954	16	Shallow Lake	NLF	wholly	I	MTS	MTS	–	MTS	MTS	MTS	MTS
	44-0108-00	Sargent	139	15	Shallow Lake	NCHF	wholly		MTS	–	–	–	–	–	–
White Earth River (0902010804)	03-0323-00	Strawberry	1445	40	Deep Lake	NLF	wholly	NT	MTS	–	–	MTS	MTS	MTS	MTS
	03-0328-00	White Earth	1980	120	Deep Lake	NCHF	wholly		MTS	–	–	MTS	MTS	MTS	MTS
	44-0003-00	Tulaby	817	43	Deep Lake	NLF	wholly	NT	MTS	–	–	EX	EX	MTS	EX
	44-0045-00	Snider	617	25	Deep Lake	NCHF	wholly	NT	MTS	MTS	–	MTS	MTS	MTS	MTS
	44-0080-00	McCraney	270	40	Deep Lake	NLF	wholly		–	MTS	–	MTS	MTS	MTS	MTS
Marsh Creek (0902010807)	44-0169-00	Little Vanose	138	28	Deep Lake	NCHF	wholly		–	–	–	–	–	MTS	IF
South Branch Wild Rice River (0902010810)	03-0653-00	Rustad	136	6	Shallow Lake	NCHF			–	–	–	IF	–	–	IF
	14-0004-00	Tilde	248	13	Shallow Lake	NCHF			–	MTS	–	MTS	MTS	MTS	MTS

MTS = 2006 through 2015 data met the water quality standard(s); EX = 2006 through 2015 data exceeded the water quality standard(s); IF = the 2006 through 2015 data was insufficient to make a finding; – = not assessed.

Existing indication of impairment prior to assessments in 2016, new indication of impairment as of 2016 assessments, meets water quality standard(s) based on 2016 assessments and is not an indicator of impairment.

[a] NLF = Northern Lakes and Forests, NCHF = North Central Hardwood Forests.

[b] wholly = lake is located completely (i.e., wholly) within White Earth Reservation, (blank) = lake is located completely outside of a tribal reservation.

[c] D = decreasing, I = increasing, NT = no trend, (blank) = lake did not have adequate Secchi depth data for a trend analysis.

[d] The 3 aquatic recreation use indicators (TP, Chl-*a*, and Secchi depth) are further assessed to determine if the lake is impaired for aquatic recreation use due to nutrients, the results of which are listed in the last column of the table.

Table 4 shows the two aquatic recreation use impairments (both due to nutrients) in two lakes in the WRRW that are listed on Minnesota's impaired waters list (MPCA, 2021). There are no aquatic life use impairments in WRRW lakes listed on Minnesota's impaired waters list (MPCA, 2021). Tulaby Lake is located wholly within White Earth Reservation, while Rockstad Lake is not located within tribal lands. Lakes that are wholly within White Earth Reservation on Minnesota's impaired waters list (MPCA, 2021) are advisory to EPA only, as EPA has no authority to approve or disapprove listings of wholly tribal lakes on Minnesota's impaired waters list (MPCA, 2021). The impairment in Tulaby Lake was already on the list prior to assessments in 2016, and the impairment in Rockstad Lake was added to the list in 2018 as a results of the 2016 assessments. No lakes were delisted as a result of the 2016 assessments

Table 4: Aquatic life use and aquatic recreation use impairments in Wild Rice River Watershed lakes on Minnesota's impaired waters list (MPCA, 2021). [a]

DNR Lake ID	Lake name	Class 2 designation [b]	Tribal designation [c]	Listing Year	Affected designated use [d]	Indicator / parameter	EPA category [e]
15-0075-00	Rockstad	2B		2018	AQL	Nutrients	5
44-0003-00	Tulaby	2B	Wholly	2010	AQR	Nutrients	N/A

[a] Excludes aquatic consumption use impairments and impairments in streams.

[b] Class 2 lakes are those that are assessed for aquatic life use and aquatic recreation use. Lakes classified as 2A are cold water and those classified as 2B are cool or warm water.

[c] partial = stream reach is partially located with White Earth Reservation, wholly = stream reach is located completely (i.e., wholly) within White Earth Reservation, (blank) = stream reach is located completely outside of a tribal reservation.

[d] AQL = aquatic life, AQR = aquatic recreation.

[e] 5 = waterbody is impaired, and a TMDL study has not been approved by EPA, N/A = waterbody is located wholly within a tribal reservation, so this listing is advisory to EPA only.

2.2 Water quality trends

While there were not enough water quality data in streams to perform trend analyses on specific parameters, there were two sites in the WRRW with long term flow data adequate to analyze trends in annual mean discharge and summer monthly (July and August) mean discharge (MPCA, 2017). Mean discharge for water years 1995 through 2014 in the Wild Rice River at Twin Valley (U.S. Geological Survey [USGS] ID 05062500) shows an insignificant decreasing trend annually, a significant ($p < 0.1$) decreasing trend in July, and no trend in August. Mean discharge for water years 1994 through 2014 (with the exception of 2002 due to lack of data) in the Wild Rice River at Hendrum (USGS ID 05064000) shows insignificant decreasing trends annually and monthly (July and August).

Lake monitoring in the region has been more extensive than streams due to the relative ease and consistency of monitoring protocols throughout the WRRW. Of the 19 lakes assessed for aquatic life and/or recreation use, 8 have adequate data to assess long-term Secchi trends (**Table 3**). Six lakes (Bass, Island, Snider, South Twin, Strawberry, and Tulaby) have exhibited no significant, long-term trends in Secchi depth while one lake (North Twin) shows an increasing trend (i.e., increasing clarity) and one lake (Roy) shows a decreasing trend (i.e., decreasing clarity). Roy and Island lakes both lie within the Headwaters Wild Rice River HUC-10 (0902010801).

2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Stressor identification (SID) was conducted for streams with impairments that were identified by poor assemblages of fish and/or aquatic macroinvertebrates and encompassed the evaluation of both pollutant (e.g., TSS) and nonpollutant (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments were conducted where the SID process identified a pollutant as a stressor, as well as for the typical pollutant impairment listings.

Candidate causes of stressors considered in the WRRW were based on the *Red River Valley Biotic Impairment Assessment* by EOR (2009), as well as other SID reports in the state. A total of nine candidate causes were identified (**Table 5**), of which six were identified for causal analysis for the seven stream reaches within the WRRW that are impaired based on F-IBI or M-IBI scores. The stressor that were not considered to be candidate causes included nitrate-nitrite, pH, and pesticide toxicity as data for these stressors met state standards (nitrate-nitrite and pH) or no data was available (pesticide toxicity). Amongst the stressors that were candidate causes, flow regime instability was the most impactful in the WRRW. Periods of quick and high peak flows contribute to high turbidity and sediment loading (this sediment can bury what would otherwise be good habitat), and extended periods of low flow frequently result in elevated water temperatures and low DO concentrations. Flow remediation activities that mitigate the flashiness, extreme high flows and sustained low flows, are likely to reduce other candidate causes examined in this assessment. Further detail on stressors and pollutant sources are reviewed in **Section 3**.

Table 5: Summary of biotic stressors that were evaluated as potential candidate causes for biologically impaired reaches within the WRRW (MPCA, 2018).

	Candidate Cause Identification	
Stressor	Summary of available information	Candidate cause (Yes/No)
Loss of longitudinal connectivity	Several of the biologically impaired reaches have connectivity barriers (e.g., dams and private road crossings) that are potential obstructions to fish passage.	Yes
Flow regime instability	Many of the biologically impaired reaches are prone to high and quick peak flows, along with prolonged periods of very low discharge.	Yes
Insufficient physical habitat	Several of the biologically impaired reaches have insufficient in-stream habitat to support a healthy and diverse biotic community.	Yes
High suspended sediment	Several of the biologically impaired reaches have discrete total suspended solids (TSS) values that exceed the applicable state	Yes
Low dissolved oxygen	Several of the biologically impaired reaches have discrete and/or continuous DO values that are below the applicable state standard. Eutrophication may be a contributing factor to these low DO values.	Yes
High temperature	AUID 654 (Felton Creek / County Ditch 45) only. This is a cold water stream that experiences high temperature values.	Yes
High nitrate-nitrite	Nitrate-nitrite concentrations associated with the biologically impaired reaches were generally well below the level expected to cause stress to aquatic biota (<10 mg/L).	No
pH	Nearly all of the pH values associated with the biologically impaired reaches were within the state standard range (6.5-9.0).	No

Stressor	Candidate Cause Identification	
	Summary of available information	Candidate cause (Yes/No)
Pesticide toxicity	There is no pesticide data for the biologically impaired reaches. As a result, there is insufficient information to declare pesticide toxicity as a candidate cause at this time.	No

Stressors of biologically-impaired river reaches

Causes of poor fish and aquatic macroinvertebrate assessment scores that indicated aquatic life use impairments in streams, with reach-specific stressors, were assessed by the MPCA and reported in the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018). Within the WRRW, 9 impairments in 7 stream reaches were identified by poor fish assessment scores (*n* = 5) and aquatic macroinvertebrate assessment scores (*n* = 4). The candidate causes analyzed as potential stressors to fish and aquatic macroinvertebrates within the seven stream reaches include loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, low DO, and high temperature. High temperature was considered a candidate cause only for Felton Creek/County Ditch 45 (AUID 654), because it is classified as cold water. The degree to which each candidate cause stresses biological communities are summarized in **Table 6**. The candidate causes that were found to be the most stressful to aquatic life within the seven impaired stream reaches were flow regime instability and insufficient physical habitat.

Table 6: Primary stressors to aquatic life in biologically-impaired reaches in the Wild Rice River Watershed.

Stream name	AUID (last 3 digits	Biological impairment(s)	Candidate Causes					
			Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen	High Temperature
Wild Rice River	646	F-IBI	++	0	0	NE	+	NA
Spring Creek	647	M-IBI	NE	+	++	+	0	NA
Garden Slough	579	F-IBI	+++	++	++	0	++	NA
Mashaug Creek	650	F-IBI	0	++	+	+	+	NA
		M-IBI	NE	+	+	+	+	NA
South Branch Wild Rice River	661	F-IBI	0	++	++	+	+	NA
South Branch Wild Rice River	662	M-IBI	NE	+	+	+	+	NA
Felton Creek / County Ditch 45	654	F-IBI	++	+	++	+	++	+++
		M-IBI	NE	+	++	++	+	++

Key: +++ the available evidence convincingly supports the case for the candidate cause as a stressor, ++ the available evidence strongly supports the case for the candidate cause as a stressor, + the available evidence somewhat supports the case for the candidate cause as a stressor, 0 neither supports nor weakens the case for the candidate cause as a stressor, NE no evidence is available to support the case for the candidate cause as a stressor, and NA not applicable.

Six of the seven biologically-impaired stream reaches are located in the western two-thirds of the WRRW within the LAP ecoregion that has been heavily drained to facilitate row crop agriculture. Stream channels throughout that region have been straightened, drainage ditches constructed, and subsurface tile installed to facilitate farming of these low-relief soils. The altered hydrology of the region contributes to flow regime instability that has degraded in-stream habitat at the reach-scale, though remediation efforts are likely to improve other biological impairments (i.e., thermal impairments, DO, physical habitat, suspended sediment load). However, longitudinal connectivity within the WRRW will require regional efforts to address the altered flow regimes and associated ecological impacts associated with perched culverts, private road crossings, or beaver dams.

A goal of SID is to identify which stressors, if any, are subject to load quantification (e.g., TSS, TP [as it relates to low DO stressor]) and therefore require a TMDL. No TMDLs were developed to address the biological impairments because 1) the stressors identified were not those for which a TMDL can be developed (AUID 579 and 646), 2) a pollutant that was identified as a stressor meets standards (AUID 650), or 3) data for a pollutant that was identified as a stressor were too limited to assess the pollutant against state standards (AUID 654, 661, and 662).

Additional stressors and potential restorative actions are reviewed further in **Section 3.3** (Restoration and protection strategies) of this report.

Stressors of biologically-impaired lakes

While none of the 11 lakes within the WRRW that were assessed by the DNR for biological impairment were impaired, Tulaby Lake (located wholly within the White Earth Reservation) met standards by only 1 F-IBI point above the impairment threshold, so DNR further assessed Tulaby Lake with lake-specific stressors, the results of which are reported in the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018).

Identifying stressors in a lake close to the impairment threshold may prevent subsequent degradation of it and other lakes within the WRRW, as protective efforts are much more cost-effective to implement than remediation practices. Since Tulaby Lake was listed as impaired for aquatic recreation use in 2010 due to excess nutrients, efforts that can both restore nutrient conditions as well as protect or increase F-IBI scores would be the most advantageous. Causative (TP) and response variable (Chl-*a* and Secchi depth) measurements in excess of state standards (indicators of the impairment due to excess nutrients) have been found to be correlated with a change in lake trophic state and fish assemblage. There are several possible mechanisms that can result in the fish assemblage change, but it is highly likely that the aquatic recreation use impairment is related to F-IBI scores being near the impairment threshold. Lakeshore development is the secondary cause for change in the fish assemblage as the shoreline is significantly developed. Other candidate causes for impairment (e.g., connectivity; fish regulations, management, and angling pressure; fish stocking; sedimentation; global climate change) are examined in the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018), but the aquatic recreation use impairment due to nutrients and lakeshore development are the likely primary drivers.

Establishing native vegetation (e.g., native bulrush) around Tulaby Lake, along both undeveloped and developed shorelines, would enhance in-lake habitat and create fishery habitat. Lakeshore and littoral management for woody debris will also promote long-term habitat complexity that have been shown to improve conditions for aquatic life. Nutrient loading could be assessed through a TMDL, but the lake falls outside EPA and MPCA jurisdiction, so no exploration of the source(s) of excess nutrients has been conducted.

Pollutant sources

Pollutant sources vary by subwatershed and ecoregion depending on National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) dischargers, upstream loading conditions, and nonpoint sources within the watershed. 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.

Point sources in the WRRW are listed in **Table 7** as well as *E. coli* and TSS loads, if applicable. Loads for other pollutants were not calculated as there were no TMDLs for which wasteload allocations were required for pollutants other than *E. coli* and TSS (see **Section 2.4**). There are six NPDES/SDS permitted municipalities outside tribal lands and four NPDES/SDS permitted municipalities within tribal lands that operate WWTPs and four tribal wastewater stabilization lagoons that are NPDES-permitted. Rather than list individual industrial stormwater and construction stormwater permittees, these point sources are listed categorically in **Table 7**. Note that *E. coli* is not a typical pollutant from industrial or construction stormwater sites in the WRRW. Also listed are the five NPDES/SDS permitted confined animal feeding operations (CAFOs) which do not have loads calculated, because these permitted sites are designed to have zero discharge.

Table 7: Point sources in the Wild Rice River Watershed and *E. coli* and TSS loads.

HUC-8 / HUC-10	Facility	Permit	Permit type	Point source type	Downstream impaired AUIDs with TMDLs	*E. coli*		TSS	
						Maximum allowed concentration (org/100 mL)	Load (billion org/day)	Discharge Limit: Calendar month avg (mg/L)	Load (US tons/day)
0902010810	Borup WWTP	MN0022853	NPDES/SDS	Municipal WW	501, 659	126	0.6450	45	0.0254
0902010811	Felton WWTP	MNG585149	NPDES/SDS	Municipal WW	501	126	2.5955	45	0.1022
0902010808	Gary WWTP	MNG585175	NPDES/SDS	Municipal WW	501, 643, 644, 650	126	1.1656	45	0.0459
0902010812	Hendrum WWTP	MNG585176	NPDES/SDS	Municipal WW	501	126	3.6290	45	0.1429
0902010809	Twin Valley WWTP	MNG585137	NPDES/SDS	Municipal WW	501, 643, 644	126	4.2740	45	0.1683
0902010810	Ulen WWTP	MNG585088	NPDES/SDS	Municipal WW	501, 659, 662	126	4.0797	45	0.1606
0902010807	Bejou WWTP	MNT064688	NPDES/SDS	Municipal / Tribal WW	501, 643, 644, 652	126	0.7149	45	0.0281
0902010806	Mahnomen WWTP	MNT024066	NPDES/SDS	Municipal / Tribal WW	501, 504, 643, 644	126	19.7382	45	0.7771
0902010810	Ogema WWTP	MNT049794	NPDES/SDS	Municipal / Tribal WW	501, 659, 662	126	0.9869	45	0.0389
0902010805	Waubun WWTP	MNT022110	NPDES/SDS	Municipal / Tribal WW	501, 504, 643, 644, 648	126	2.9996	45	0.1181
0902010802	Big Rice Lake Wastewater Lagoon	MN-0068438-3	NPDES	Tribal WW	501, 504, 643, 644	126	1.0102	45	0.0398
0902010803	Chippewa Ranch WWSL	MN-0059404-5	NPDES	Tribal WW	501, 504, 643, 644	126	0.7382	45	0.0291
0902010803	Nay-Tah-Waush WWSL	MN-0064154-4	NPDES	Tribal WW	501, 504, 643, 644	126	4.6626	45	0.1836
0902010810	White Earth WWSL	MN-0064173-4	NPDES	Tribal WW	501, 659, 662	126	1.1656	45	0.0459
09020108	Various	MNR050000	NPDES/SDS	Industrial SW	All	N/A	N/A	N/A	varies

HUC-8 / HUC-10	Facility	Permit	Permit type	Point source type	Downstream impaired AUIDs with TMDLs	*E. coli*		TSS	
						Maximum allowed concentration (org/100 mL)	Load (billion org/day)	Discharge Limit: Calendar month avg (mg/L)	Load (US tons/day)
09020108	Various	MNR100001	NPDES/SDS	Construction SW	All	N/A	N/A	N/A	varies
0902010810	Briard's Hog Farm – Ulen 8	MNG441126	NPDES/SDS	CAFO	659, 662 [a]	Zero discharge permit			
0902010809	Bennefeld Cattle Company	MNG441113	NPDES/SDS	CAFO	643, 644 [a]				
0902010810	Greenstreak Dairy	MNG441199	NPDES/SDS	CAFO	659 [a]				
0902010809	Jennie-O Turkey Store – Twin Valley	MNG450111	NPDES/SDS	CAFO	643, 644 [a]				
0902010810	BGR Dairy LLP	MNG440311	NPDES/SDS	CAFO	659, 662 [a]				

CAFO = confined animal feeding operation, N/A = not applicable, NPDES = National Pollutant Discharge Elimination System, SDS = State Disposal System, SW = stormwater, WLA = wasteload allocation, WW = wastewater, WWSL = wastewater stabilization lagoon, WWTP = wastewater treatment plant.

[a] Only AUIDs with *E. coli* TMDLs are listed.

Table 8 lists impaired waterbodies, pollutants/stressors, and nonpoint sources of those pollutants/stressors. Primary nonpoint pollutants within the WRRW include TP, TSS, and *E. coli*. Sources of TSS and TP are similar, primarily via erosion, while *E. coli* is attributed mainly to manure runoff and SSTSs. Noncompliant SSTS density was estimated for determining TMDL loads but are not considered in the nonpoint assessment in this report. DO is listed in **Table 8** for stream reaches where low DO was determined to stress aquatic life. Nonpoint sources of low DO reflect the negative effects of excessive nutrient and organic matter enrichment on DO concentrations.

Table 8: Nonpoint sources of impaired waterbodies in the Wild Rice River Watershed.

HUC-10 Subwatershed	Stream (AUID) or Lake (DNR ID)	Pollutant / stressor	Nonpoint pollutant sources											
			Fertilizer and/or manure run-off	Livestock overgrazing in riparian	Noncompliant septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank Erosion/ excessive peak flow	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
Headwaters Wild Rice River (0902010801)	Wild Rice River (646)	DO							○	○	○			
	Rockstad (15-0075-00)	TP			○	○							○	○
Twin Lake Creek (0902010803)	Twin Lake Creek (509)	*E. coli*	⭘	○	○	○								
		TSS					○	●	●	●	⭘			
White Earth River (0902010804)	White Earth River (505)	*E. coli*	⭘	⭘	○	○	⭘		○					
		TSS		⭘			⭘	●	○		⭘			
	Whiskey Creek (593)	*E. coli*	⭘	⭘	○	○	⭘		○					
	Tulaby (44-0003-00)	TP			○	○							⭘	⭘
Spring Creek (0902010805)	Spring Creek (647)	TSS					○	●	○	●	⭘			
	Spring Creek (648)	*E. coli*	⭘	○	○	○								
Middle Wild Rice River (0902010806)	Wild Rice River (506)	*E. coli*	⭘	○	○	○								
	Wild Rice River (504)	TSS						●	○		●			
Marsh Creek (0902010807)	Marsh Creek (651)	*E. coli*	⭘	○	○	○								
	Marsh Creek (652)	TSS					○	●	○	○	⭘			
Mashaug Creek (0902010808)	Garden Slough (579)	DO					○			●	●			
	Mashaug Creek (650)	*E. coli*	⭘	○	○	○								
		TSS					○	⭘	●	●	⭘			
		DO						⭘			●			
Lower Wild Rice River (0902010809)	Wild Rice River (643)	*E. coli*	⭘	○	○	○								
		TSS					○	⭘		○	⭘			
	Coon Creek (577)	*E. coli*	⭘	○	○	○								
	Coon Creek (544)	*E. coli*	⭘	○	○	○								
	Unnamed Creek (546)	*E. coli*	⭘	○	○	○								

HUC-10 Subwatershed	Stream (AUID) or Lake (DNR ID)	Pollutant / stressor	Nonpoint pollutant sources											
			Fertilizer and/or manure run-off	Livestock overgrazing in riparian	Noncompliant septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank Erosion/ excessive peak flow	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
South Branch Wild Rice River (0902010810)	South Branch Wild Rice River (662)	*E. coli*	◉	○	○	○								
		TSS					◉	○	●	●	◉			
		DO					○				◉			
	South Branch Wild Rice River (659)	*E. coli*	◉	○	○	○								
	South Branch Wild Rice River (661)	TSS					○	●	○	●	◉			
		DO					○			◉	●			
Felton Creek (0902010811)	Felton Creek - County Ditch 45 (654)	TSS					○	●	○	◉	◉			
		DO					○			○				
	County Ditch 45 (553)	*E. coli*	◉	○	○	○								
Outlet Wild Rice River (0902010812)	Wild Rice River (644)	*E. coli*	◉	○	○	○								
		TSS					○	●	◉	○	●			
	Wild Rice River (501)	TSS					○	●	◉	○	●			

Key: ● = High, ◉ = Moderate, ○ = Low

Upstream loading, upland loading, and bank failure are common drivers of pollutant loading that together characterize watershed-scale land use change impacts on hydrology and water quality. Fertilizer and livestock management also are high to moderate predictors of impairment with 116 feedlots that are active, registered, and have greater than 0 animal units (AUs) within the WRRW. Eleven, 24, and 81 of the feedlots are located in the NLF, NCHF, and LAP ecoregions, respectively. There are approximately 32,218 AUs among the 116 animal feedlots, 4 of which exceed 1,000 AUs (MPCA, 2020). The primary animal types among the 116 animal feedlots are bovine (78%) and birds (15%).

2.4 TMDL summary

Sixteen TMDL studies were developed to address 16 impairments in 13 impaired stream reaches and 1 impaired lake in the WRRW. The 10 *E. coli* TMDLs address all 10 of the aquatic recreation use impairments in streams that are not wholly within tribal land, the 5 TSS TMDLs address all 5 of the aquatic life use impairments identified by excessive turbidity/TSS in streams that are not wholly within tribal land, and the 1 TP TMDL addresses the sole aquatic life use impairment in a lake that is not wholly within tribal land.

Table 9 shows each stream TMDL and components, including the maximum allowable load of the specified pollutant that will keep the stream in compliance (loading capacity) and the allowable amounts of the pollutant that can come from nonpoint sources (load allocation) and point sources (wasteload allocation). Eleven of the TMDLs have boundary conditions which are proportions of the loading capacities allocated to White Earth Nation. The boundary conditions are equal to the percentage of tribal land located within the drainage area of each impaired reach. A portion of the loading capacity (10%) is also placed in the margin of safety category, reflecting a level of uncertainty in the analysis. Observed loads/concentrations and estimated percent reductions are also presented in the table for each TMDL. See **Table 7** for a breakdown of the WWTPs that contribute to each WWTP WLA in **Table 9**.

The TMDL for Rockstad Lake is shown in **Table 10** and has no wasteload allocation (i.e., point sources), but the load allocation is divided up between several nonpoint sources. Land cover change to developments, pasture, and cultivated crops has occurred on approximately 25% of the contributing lakeshed, which is the likely cause for excess TP loading.

Further details on the development of the TMDLs can be found in the *Wild Rice River Watershed TMDL Report* (MPCA, 2022). Recommended restoration and protection strategies for both lakes and streams to achieve load reductions for waterbodies with TMDLs, or to protect at risk waterbodies, are discussed in **Section 3**.

Table 9: Summaries of stream TMDLs included in the Wild Rice River Watershed TMDL Report (MPCA, 2022).

HUC-10 subwatershed	AUID (last 3 digits)	Stream name (reach description)	Pollutant	Flow zone	Total loading capacity (LC)	Boundary condition (BC) – White Earth Nation LC [a]	Minnesota LC	Wasteload Allocation			Load Allocation	Margin of safety	Observed load	Observed load minus BC	Estimated percent reduction	Overall observed concentration *E. coli*: org/100 mL, TSS: mg/L [c]	Overall estimated percent reduction
								WWTP(s)	Construction / Industrial Stormwater [b]	MS4s							
					E. coli: billion org/day, TSS: U.S. tons/day												
Spring Creek (0902010805)	648	Spring Creek (140th Ave to Wild Rice R)	*E. coli*	Very High	411.1	401.6	9.5	-	-	-	8.55	0.95	-	-	-	383	67
				High	100.7	98.4	2.3	-	-	-	2.07	0.23	141	42.6	95		
				Mid-Range	43.9	42.9	1.0	-	-	-	0.9	0.10	111	68.1	99		
				Low	21.34	20.85	0.49	-	-	-	0.441	0.049	66	45.15	99		
				Very Low	9.48	9.26	0.22	-	-	-	0.198	0.022	15	5.74	96		
Middle Wild Rice River (0902010806)	504	Wild Rice River (White Earth R to Marsh Cr)	TSS	Very High	110	91	19	-	0.019	-	17.081	1.9	709	618	97	122	75
				High	35.4	29.3	6.1	-	0.0061	-	5.4839	0.61	210	180.7	97		
				Mid-Range	16.7	13.8	2.9	-	0.0029	-	2.6071	0.29	43	29.2	90		
				Low	8.5	7.0	1.5	-	0.0015	-	1.3485	0.15	8.2	1.2	0		
				Very Low	3.16	2.62	0.54	-	0.00054	-	0.48546	0.054	1.5	-1.12	0		
Marsh Creek (0902010807)	652	Marsh Creek (-95.9973 47.4054 to Wild Rice R)	TSS (Turbidity)	Very High	29.2	24.7	4.5	-	0.0045	-	4.0455	0.45	-	-	-	102	71
				High	6.7	5.7	1.0	-	0.0010	-	0.899	0.10	81	75.3	99		
				Mid-Range	2.91	2.46	0.45	-	0.00045	-	0.40455	0.045	1.4	-1.06	0		
				Low	1.31	1.11	0.20	-	0.00020	-	0.1798	0.020	0.62	-0.49	0		
				Very Low	0.589	0.498	0.091	-	0.000091	-	0.081809	0.0091	-	-	-		
Mashaug Creek (0902010808)	650	Mashaug Creek (T-92 to Wild Rice R)	*E. coli*	Very High	430	-	-	1.2	-	-	385.8	43	-	-	-	236	47
				High	91	-	-	1.2	-	-	80.7	9.1	87	-	0		
				Mid-Range	38	-	-	1.2	-	-	33	3.8	21	-	0		
				Low	18	-	-	1.2	-	-	15	1.8	22	-	18		
				Very Low	7.7	-	-	1.2	-	-	5.73	0.77	1.5	-	0		
Lower Wild Rice River (0902010809)	643	Wild Rice River (Marsh Cr to Unnamed cr)	TSS (Turbidity)	Very High	104	70	34	0.216	0.034	-	30.35	3.4	1,705	1,635	98	330	91
				High	44	30	14	0.216	0.014	-	12.37	1.4	411	381	96		
				Mid-Range	18.4	12.4	6.0	0.216	0.0060	-	5.178	0.60	28	15.6	62		
				Low	7.3	4.9	2.4	0.216	0.0024	-	1.9416	0.24	3.9	-1	0		
				Very Low	2.01	1.35	0.66	0.216	0.00066	-	0.37734	0.066	0.37	-0.98	0		
			E. coli	Very High	3,915	2,635	1,280	5.5	-	-	1,146.5	128	8,020	5,385	76	137	8.0
				High	1,574	1,059	515	5.5	-	-	457.5	52	1,074	15	0		
				Mid-Range	610	411	199	5.5	-	-	173.5	20	395	-16	0		
				Low	254	171	83	5.5	-	-	69.2	8.3	135	-36	0		
				Very Low	73	49	24	5.5	-	-	16.1	2.4	-	-	-		
	577	Coon Creek (Unnamed cr	*E. coli*	Very High	163	-	-	-	-	-	147	16	-	-	-	652	81
				High	19	-	-	-	-	-	17.1	1.9	64	-	70		
				Mid-Range	4.8	-	-	-	-	-	4.32	0.48	43	-	89		

HUC-10 subwatershed	AUID (last 3 digits)	Stream name (reach description)	Pollutant	Flow zone	Total loading capacity (LC)	Boundary condition (BC) – White Earth Nation LC [a]	Minnesota LC	Wasteload Allocation: WWTP(s)	Wasteload Allocation: Construction / Industrial Stormwater [b]	Wasteload Allocation: MS4s	Load Allocation	Margin of safety	Observed load	Observed load minus BC	Estimated percent reduction	Overall observed concentration *E. coli*: org/100 mL, TSS: mg/L [c]	Overall estimated percent reduction
					E. coli: billion org/day, TSS: U.S. tons/day												
		to Unnamed cr)		Low	0.87	-	-	-	-	-	0.783	0.087	-	-	-		
				Very Low	0.011	-	-	-	-	-	0.0099	0.0011	-	-	-		
	544	Coon Creek (Unnamed cr to Wild Rice R)	*E. coli*	Very High	163	-	-	-	-	-	147	16	-	-	-	262	52
				High	19	-	-	-	-	-	17.1	1.9	23	-	17		
				Mid-Range	4.8	-	-	-	-	-	4.32	0.48	6.5	-	26		
				Low	0.87	-	-	-	-	-	0.783	0.087	0.65	-	0		
				Very Low	0.011	-	-	-	-	-	0.0099	0.0011	0.011	-	0		
	546	Unnamed creek (Unnamed cr to Wild Rice R)	*E. coli*	Very High	387	185	202	-	-	-	182	20		-		891	86
				High	50	24	26	-	-	-	23.4	2.6	117	93	72		
				Mid-Range	8.5	4.1	4.4	-	-	-	3.96	0.44	38	33.9	87		
				Low	0.067	0.032	0.035	-	-	-	0.0315	0.0035	0.56	0.528	93		
				Very Low	0.0027	0.0013	0.0014	-	-	-	0.00126	0.00014	-	-	-		
South Branch Wild Rice River	662	South Branch Wild Rice River (Unnamed cr to Unnamed cr)	*E. coli*	Very High	1,306	324	982	4.1	-	-	879.9	98	-	-	-	193	35
				High	158	39	119	4.1	-	-	102.9	12	287	248	52		
				Mid-Range	32.4	8.0	24.4	4.1	-	-	17.9	2.4	32	24	0		
				Low	7.1	1.8	5.3	4.1	-	-	0.67	0.53	6.2	4.4	0		
				Very Low	0.50	0.12	0.38	[d]	-	-	0.342	0.038	-	-	-		
	659	South Branch Wild Rice River (T-246 to Wild Rice R)	*E. coli*	Very High	955	177	778	4.75	-	-	695.25	78	591	414	0	296	57
				High	189	35	154	4.75	-	-	134.25	15	239	204	25		
				Mid-Range	71	13	58	4.75	-	-	47.45	5.8	53	40	0		
				Low	22.4	4.1	18.3	4.75	-	-	11.75	1.8	12	7.9	0		
				Very Low	7.8	1.4	6.4	4.75	-	-	1.01	0.64	-	-	-		
Felton Creek (0902010811)	553	County Ditch 45 (Unnamed ditch to Unnamed ditch)	*E. coli*	Very High	320	-	-	-	-	-	288	32	-	-	-	600	79
				High	26	-	-	-	-	-	23.4	2.6	135	-	81		
				Mid-Range	6.1	-	-	-	-	-	5.49	0.61	36	-	83		
				Low	1.3	-	-	-	-	-	1.17	0.13	6.2	-	79		
				Very Low	0.19	-	-	-	-	-	0.171	0.019	-	-	-		
Outlet Wild Rice River (0902010812)	644	Wild Rice River (Unnamed cr to S Br Wild Rice R)	TSS (turbidity)	Very High	121	78	43	0.216	0.043	-	38.441	4.3	1,010	932	95	216	86
				High	55	35	20	0.216	0.020	-	17.764	2.0	156	121	83		
				Mid-Range	26.9	17.3	9.6	0.216	0.0096	-	8.4144	0.96	86	68.7	86		
				Low	10.1	6.5	3.6	0.216	0.0036	-	3.0204	0.36	7.4	0.9	0		
				Very Low	1.62	1.04	0.58	0.216	0.00058	-	0.30542	0.058	-	-	-		
			E. coli	Very High	4,602	2,959	1,643	5.5	-	-	1,473.5	164	3,325	366	0	176	28
				High	2,005	1,289	716	5.5	-	-	638.5	72	898	-391	0		

HUC-10 subwatershed	AUID (last 3 digits)	Stream name (reach description)	Pollutant	Flow zone	Total loading capacity (LC)	Boundary condition (BC) – White Earth Nation LC [a]	Minnesota LC	Wasteload Allocation			Load Allocation	Margin of safety	Observed load	Observed load minus BC	Estimated percent reduction	Overall observed concentration *E. coli*: org/100 mL, TSS: mg/L [c]	Overall estimated percent reduction
								WWTP(s)	Construction / Industrial Stormwater [b]	MS4s							
					E. coli: billion org/day, TSS: U.S. tons/day												
				Mid-Range	918	590	328	5.5	-	-	289.5	33	952	362	9		
				Low	316	203	113	5.5	-	-	96.5	11	251	48	0		
				Very Low	59	38	21	5.5	-	-	13.4	2.1	45	7.0	0		
	501	Wild Rice River (S Br Wild Rice River to Red R of the N)	TSS (turbidity)	Very High	416	198	218	0.641	0.22	-	195.139	22	2,552	2,354	91	320	80
				High	140	67	73	0.641	0.073	-	64.986	7.3	671	604	88		
				Mid-Range	68	32	36	0.641	0.036	-	31.723	3.6	233	201	82		
				Low	21	10	11	0.641	0.011	-	9.248	1.1	40	30	63		
				Very Low	5.3	2.5	2.8	0.641	0.0028	-	1.8762	0.28	5.0	2.5	0		

Ave = Avenue, Br = Branch, cr/Cr = creek/Creek, MS4 = municipal separate storm sewer system, N = North R = River, S = South, W = West, WWTP = wastewater treatment plant.

[a] No TMDL reductions are assigned to the BC for White Earth Nation which includes the percent of tribal government land located in the impaired stream reach drainage area.

[b] Calculated as 0.1% of the Minnesota LC.

[c] The overall observed concentration for *E. coli* is the highest observed monthly geometric mean from the months that the standard applies using *E. coli* data from 2007 through 2016. Five or more samples were needed in a month to be considered the highest observed monthly geometric mean. The overall observed centration for TSS is the 90th percentile of observed concentration.

[d] The permitted wastewater design flow exceeds the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x 126 org/100 mL (or NPDES/SDS permit concentration).

Table 10: Total phosphorus TMDL for Rockstad Lake (15-0075-00).

Rockstad (15-0075-00)		Observed TP Load		Allowable TP Load		Estimated TP Load Reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year	%
Wasteload Allocation	**Total WLA**	**0.121**	**0.000332**	**0.121**	**0.000332**	**0**	**0**
	Construction/Industrial Stormwater	0.121	0.000332	0.121	0.000332	0	0
Load Allocation	**Total LA**	**234**	**0.641**	**109**	**0.298**	**125**	**53**
	Watershed Runoff	195	0.533	71.8	0.197	123	63
	Atmosphere	31.7	0.0868	31.7	0.0868	0	0
	Excess internal load [a]	N/A	N/A	N/A	N/A	N/A	N/A
	SSTS	7.60	0.0208	5.26	0.0144	2.34	31
Margin of Safety (MOS)		**N/A**	**N/A**	**12.1**	**0.0332**	**N/A**	**N/A**
Loading Capacity		**234**	**0.641**	**121**	**0.332**	**113**	**48%**

[a] This is internal loading that occurs in excess of what is intrinsically included in the BATHTUB model.

2.5 Protection considerations

Preventing the degradation of waterbodies that are nearing an impaired state can be as important as achieving water quality standards in those waterbodies that are already impaired. Preventing further degradation of a waterbody can prevent its addition to Minnesota's impaired waters list (MPCA, 2021), but more importantly avoid loss of benefits of clean water and what are frequently more costly restoration efforts. In fact, restoration efforts might never result in the return of a stream or lake to conditions that meet aquatic life use or aquatic recreation use standards, such as has been the case for some shallow lakes and wetlands. Strategies to protect and restore degraded waterbodies identified in **Section 3** are critical to ensuring that water quality goals are achieved and sustain continued use of the resources.

Streams

The MPCA has developed a 'Streams Protection Strategy' to help watershed stakeholders set protection goals for streams that meet standards for fish and/or macroinvertebrates. In addition to how close fish and macroinvertebrate IBIs are to the standards, the 'Streams Protection Strategy' considers other water "values" such as the density of roads, percent of disturbed land, and percent of public or easement protected land. While the 'Streams Protection Strategy' and a 'Stream Prioritization Spreadsheet' are available from MPCA to manually determine stream protection, a shapefile was created that has already determined stream prioritization for waterbodies that do not have impairments caused by poor biota (DNR and MPCA, 2019). **Table 11** shows the stream protection prioritization results for the 22 stream reaches that support aquatic life. Fourteen stream reaches were determined to have the highest priority class (A), and the priority rank suggests that County Ditch 42 (AUID 656) is the highest priority for protection, followed by Coon Creek (AUIDs 544 and 577). Seven stream reaches were in the middle priority class (B), and only one, Wild Rice River (AUID 510) was in the lowest priority class (C).

Table 11: Stream protection prioritization for streams in the Wild Rice River Watershed not impaired for biota.

AUID (last 3 digits)	TALU [a]	Vulnerable? [b]	Cold or warm	Biota nearly impaired?	Riparian risk [c]	Watershed risk [c]	Current protection risk [d]	Priority rank [e]	Priority class [f]
Wild Rice River (504)	g	N	warm	neither	med/high	medium	med/low	15	B
Wild Rice River (506)	g	N	warm	neither	med/high	medium	med/low	15	B
Wild Rice River (510)	g	N	warm	neither	med/low	medium	medium	19.5	C
Wild Rice River (512)	g	N	warm	one	low	medium	medium	14	B
Marsh Creek (519)	m	N	warm	neither	med/high	med/high	medium	15	B
Buckboard Creek (534)	g	N	warm	both	med/low	med/low	high	8	A
Unnamed creek (541)	m	N	warm	neither	high	high	low	9	A
Stiner Creek (542)	g	N	warm	one	med/high	high	low	7	A
Coon Creek (544)	g	N	warm	one	high	high	low	6	A
Unnamed creek (545)	g	Y	warm	one	high	med/high	low	7	A
Unnamed creek (546)	g	N	warm	neither	medium	med/high	low	13.5	B
Hier Creek (551)	g	N	warm	neither	medium	medium	medium	18	B
County Ditch 45 (553)	m	N	warm	neither	high	med/high	low	10.5	A
Coon Creek (577)	g	N	warm	one	high	high	low	6	A
Coon Creek (578)	g	N	warm	neither	medium	high	low	12	B
Unnamed creek (598)	m	N	warm	one	med/high	med/high	low	8	A
Unnamed creek (640)	g	N	warm	one	med/high	med/high	low	8	A
Spring Creek (648)	g	N	warm	neither	high	high	low	9	A
Marsh Creek (651)	m	N	warm	one	med/high	med/high	low	8	A
Marsh Creek (652)	g	N	warm	one	med/high	med/high	low	8	A
County Ditch 42 (656)	g	N	warm	both	med/high	high	low	3.5	A
S Br Wild Rice River (659)	g	N	warm	one	med/high	high	low	7	A

[a] The 3 possible tiered aquatic life use (TALU) designations are exceptional (e), general (g), and modified (m).
[b] Indicates whether the fish and/or macroinvertebrate biota were determined to be vulnerable to indicating an impairment.
[c] low = low density of roads and low percent disturbed land, med = both risk factors intermediate or one factor high and one low, and high = high density of roads and high percent disturbed land.
[d] low = high percent of public and easement protected land in riparian and watershed area, med - both protective factors intermediate or one factor high and one low, high = low percent of public and easement protected land in riparian and watershed area
[e] The lower the value, the higher the priority.
[f] Possible priority classes are A (highest priority), B, and C (lowest priority).

Since the MPCAs 'Streams Protection Strategy' is based primarily on biological data for waterbodies that support aquatic life, another separate analysis was done for stream reaches that have existing water quality data with which to prioritize and classify stream reaches.

Designation of streams as candidates for protection or restoration is important in aligning with the Board of Water and Soil Resources' (BWSR) Nonpoint Priority Funding Plan for Clean Water Funding Implementation and Minnesota's Clean Water Roadmap. For this reason, assessed streams are designated as either "protection" or "restoration" based on water quality data. 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. This more refined categorization reflects priorities in the Nonpoint Priority Funding Plan for Clean Water Funding

Implementation. Each stream reach receives a classification for each measured water quality parameter (e.g., TP– low restoration effort, *E. coli* – potential impairment risk, etc.).

All unassessed streams currently supporting aquatic life and aquatic recreation in the WRRW are also candidates for protection. Over time, if these waters are not subject to protection strategies, they may become impaired. For these streams, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Protection strategies include improving upland and field surface runoff (RO) controls and improving livestock and manure management. Strategies for addressing protection of these waters are discussed in more detail in **Section 3** of this report.

A brief summary of the protection or restoration classification for the stream reaches with water quality data in the WRRW is shown in **Table 12**. Inconsistencies between the results in **Table 12** and MPCA assessments results in **Table 1** are due to differences between the years of data analyzed, the minimum number of samples needed, etc. Maps of the results and a more detailed explanation for determining protection and restoration designations for streams with water quality data within the WRRW are included in **Appendix A**.

Table 12: Protection and restoration classification of streams reaches in the Wild Rice River Watershed based on water quality data from 2007 through 2016.

AUID (last 3 digits)	Stream name (reach description [a])	Above Average Quality	Probable Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
501	Wild Rice River (S Br Wild Rice R to Red R of the N)	DO, N	*E. coli*			TP, TSS
504	Wild Rice River (White Earth R to Marsh Cr)	DO, N, TP			*E. coli*	TSS
505	White Earth River (White Earth Lk to Wild Rice R)	DO, N, TP			*E. coli*	TSS
506	Wild Rice River (Twin Lake Cr to White Earth R)	DO, N, TP			*E. coli*	TSS
509	Twin Lake Creek (Sargent Lk to Wild Rice R)	DO, N		TP		*E. coli*, TSS
510	Wild Rice River (Roy Lake Cr to Twin Lake Cr)	DO, N, TP, TSS		*E. coli*		
512	Wild Rice River (Lower Rice Lk to Roy Lake Cr)	*E. coli*, TP, TSS	DO	*E. coli*		
541	Unnamed creek (Unnamed ditch to Wild Rice R)	DO, N, TP		*E. coli*		TSS
542	Stiner Creek (Unnamed cr to S Br Wild Rice R)	*E. coli*, N, TSS	DO			TP
543	Unnamed creek (Unnamed cr to Unnamed cr)	TSS				
544	Coon Creek (Unnamed cr to Wild Rice R)	DO, N				*E. coli*, TP, TSS
545	Unnamed creek (Unnamed cr to Unnamed cr)	TSS	DO, *E. coli*			TP
546	Unnamed creek (Unnamed cr to Wild Rice R)	DO, N, TSS				*E. coli*, TP

AUID (last 3 digits)	Stream name (reach description [a])	Above Average Quality	Probable Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
553	County Ditch 45 (Unnamed ditch to Unnamed ditch)	DO			TSS	*E. coli*, TP
557	Unnamed creek (Unnamed ditch to S Br Wild Rice R)				DO	
565	Tulaby Creek (Tulaby Lk to McCraney Lk)					
567	Unnamed creek (McCraney Lk to Gull Cr)					
569	Gull Creek (Unnamed cr to White Earth Lk)	*E. coli*, N, TP, TSS				
577	Coon Creek (Unnamed cr to Unnamed cr)	TSS	DO			*E. coli*, TP
589	Unnamed creek (Gull Lk to McCraney Lk)					
593	Whiskey Creek (Unnamed cr to White Earth R)	DO, TSS				*E. coli*, TP
639	Unnamed creek (Headwaters to Unnamed cr)	TSS		*E. coli*		DO, TP
643	Wild Rice River (Marsh Cr to Unnamed cr)	DO, N		TP		*E. coli*, TSS
644	Wild Rice River (Unnamed cr to S Br Wild Rice R)	DO, N, TP				*E. coli*, TSS
646	Wild Rice River (Unnamed cr to Lower Rice Lk)	N, TP, TSS	DO	*E. coli*		
648	Spring Creek (140th Ave to Wild Rice R)	DO, N, TSS		TP		*E. coli*
650	Mashaug Creek (T-92 to Wild Rice R)	N, TSS	DO			*E. coli*, TP
651	Marsh Creek (Beaulieu Lk to -95.9973 47.4054)	DO		TSS		*E. coli*, TP
652	Marsh Creek (-95.9973 47.4054 to Wild Rice R)	DO, N			*E. coli*	TP, TSS
653	Felton Creek / County Ditch 19 (Headwaters [Unnamed lk 14-0082-00] to 200th St)					DO
657	Mosquito Creek (Unnamed cr to Unnamed cr)	*E. coli*, N, TSS		DO		TP
659	South Branch Wild Rice River (T-246 to Wild Rice R)	N	DO	TSS		*E. coli*, TP
660	South Branch Wild Rice River (Otto Lk to -96.1406 47.0658)					
662	South Branch Wild Rice River (Unnamed cr to Unnamed cr)	DO, N				*E. coli*, TP, TSS

DO = dissolved oxygen, *E. coli* = *Escherichia coli*, N = nitrogen, TP = total phosphorus, and TSS = total suspended solids.
[a] Ave = Avenue, Br = Branch, cr/Cr = creek/Creek, lk/Lk = lake/Lake, N = North, R = River, St = Street, S = South, W = West.

Lakes

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the north-central and northeastern parts of the state. The WRRW is no different within the NCLF ecoregion, because it includes several lakes with water quality that is much better than the standard. Environmental Analysis and Outcomes staff at the MPCA has collected data for a large number of lakes by region, which supports empirical relationships between lake TP concentration and response variables (i.e., Chl-*a* and Secchi depth) by lake use and depth. The comparison of current lake TP concentrations to an ecoregion specific standard facilitates protection of lakes by offering protection from future degradation in addition to ensuring that lakes meet water quality goals.

To ensure that impaired and unimpaired lakes alike are protected from further degradation, the degree of sensitivity to change should be considered when determining a protection strategy to implement. Protection for lakes that meet water quality standards can be prioritized based on 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.

Nutrient reduction goals for TP for each lake, both impaired and unimpaired, are summarized in **Table 13** relative to the lake standard (depth and ecoregion), as well as the current condition and targeted goals. Data used to create the table was sourced from the *Lakes of Phosphorus Sensitivity Significance* GIS data layer (DNR, 2021).

Table 13: Prioritization summary for lakes in the Wild Rice River Watershed based on total phosphorus risk (DNR, 2021).

Lake (DNR ID)	Eco-region	Depth class	AQL / AQR impaired (Y/N)?	TP standard (µg/L)	Current condition (µg/L) [a]	Target mean TP (µg/L) [b]	Target TP load reduction (lbs/yr) [c]	Priority class [d]
Big Rat (03-0246-00)	NLF	Shallow	N	30	26.5	13	486	High
Strawberry (03-0323-00)	NLF [e]	Deep	N	30	16.2	12	306	Higher
White Earth (03-0328-00)	NCHF	Deep	N	40	9.4	9.4	821	Higher
Rustad (03-0653-00)	LAP [f]	Shallow	N	60	180	141	204	High
Tilde (14-0004-00)	LAP [f]	Shallow	N	60	32.2	35	27	Highest
Upper Rice (15-0059-00)	NLF	Deep	N	30	22.1	20	131	Highest
Rockstad (15-0075-00)	NLF	Shallow	Y	30	54.6	38	134	Impaired
Minerva (15-0079-00)	NLF	Deep	N	30	28.6	27	47	Highest
McKenzie (15-0124-00)	NLF	Shallow	N	30	15.9	15	37	High
Waptus (15-0128-00)	NLF	Deep	N	30	11.9	11	85	High
Jackson (15-0131-00)	NLF	Shallow	N	30	10.2	8.0	8.4	Higher
Roy (44-0001-00)	NLF	Deep	N	30	26	25	89	Highest
Tulaby (44-0003-00)	NLF	Deep	Y	30	32.5	27	70	Impaired

Lake (DNR ID)	Eco-region	Depth class	AQL / AQR impaired (Y/N)?	TP standard (µg/L)	Current condition (µg/L) [a]	Target mean TP (µg/L) [b]	Target TP load reduction (lbs/yr) [c]	Priority class [d]
Bass (44-0006-00)	NLF	Deep	N	30	16.1	15	28	Higher
South Twin (44-0014-00)	NLF	Deep	N	30	14.5	13	105	Higher
North Twin (44-0023-00)	NLF [e]	Shallow	N	30	18.4	14	421	High
Island (44-0038-00)	NCHF	Deep	N	40	34.1	33	104	Highest
Snider (44-0045-00)	NLF [e]	Deep	N	30	24	16	461	High
McCraney (44-0080-00)	NCHF [e]	Deep	N	40	10.4	9.0	155	High
Aspinwall (44-0223-00)	NCHF [e]	Shallow	N	60	31	24	59	Highest
Chief (44-0224-00)	NCHF [e]	Shallow	N	60	43	34	11	Higher
Beaulieu (44-0242-00)	LAP [f]	Shallow	N	60	60	47	303	High

[a] Values are those that MPCA used to compare (or attempt a comparison) against standards for assessments in early 2016.

[b] This was calculated as the difference between the predicted load and target load.

[c] Calculated independently of the TP standard, as it is based on an estimate of the 25th percentile of the summer mean TP concentration.

[d] Priority classes are High, Higher, and Highest for unimpaired lakes.

[e] The lake is located within 2 ecoregions, but only one is listed, because the standards of that ecoregion were used for MPCA assessments.

[f] The lake is located completely within the LAP ecoregion (i.e., Red River Valley), but standards of the NCHF ecoregion were used for MPCA assessments.

3. Strategies for restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS contain strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including water quality goals, strategies, and targets by parameter of concern, and an example of the scales and timeline of adoption to meet water quality protection and restoration goals. This section of the WRAPS report provides the results of 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 (trust, networks, and positive relationships) with those who will be needed to voluntarily implement best management practices (BMPs). Thus, effective ongoing public participation is fully a part of the overall plan for moving forward.

The successful implementation of restoration and protection strategies also requires a combined effort from multiple jurisdictions and agencies. The WRWD has actively engaged with state agencies (MPCA, DNR, and BWSR) and local SWCDs during the decision-making process to ensure transparency of the strategy and to improve the eventual success upon implementation. The WRWD should continue to facilitate outreach and work with landowners to identify and implement priority projects. Collaboration with partners during the One Watershed, One Plan (1W1P) process has ensured that priority objectives are incorporated into local and regional plans, applicable budgets, and grant development that result in the implementation of practices and projects.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts using the Hydrological Simulation Program – Fortran (HSPF) model and the Prioritize, Target, Measure Application (PTMApp) and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

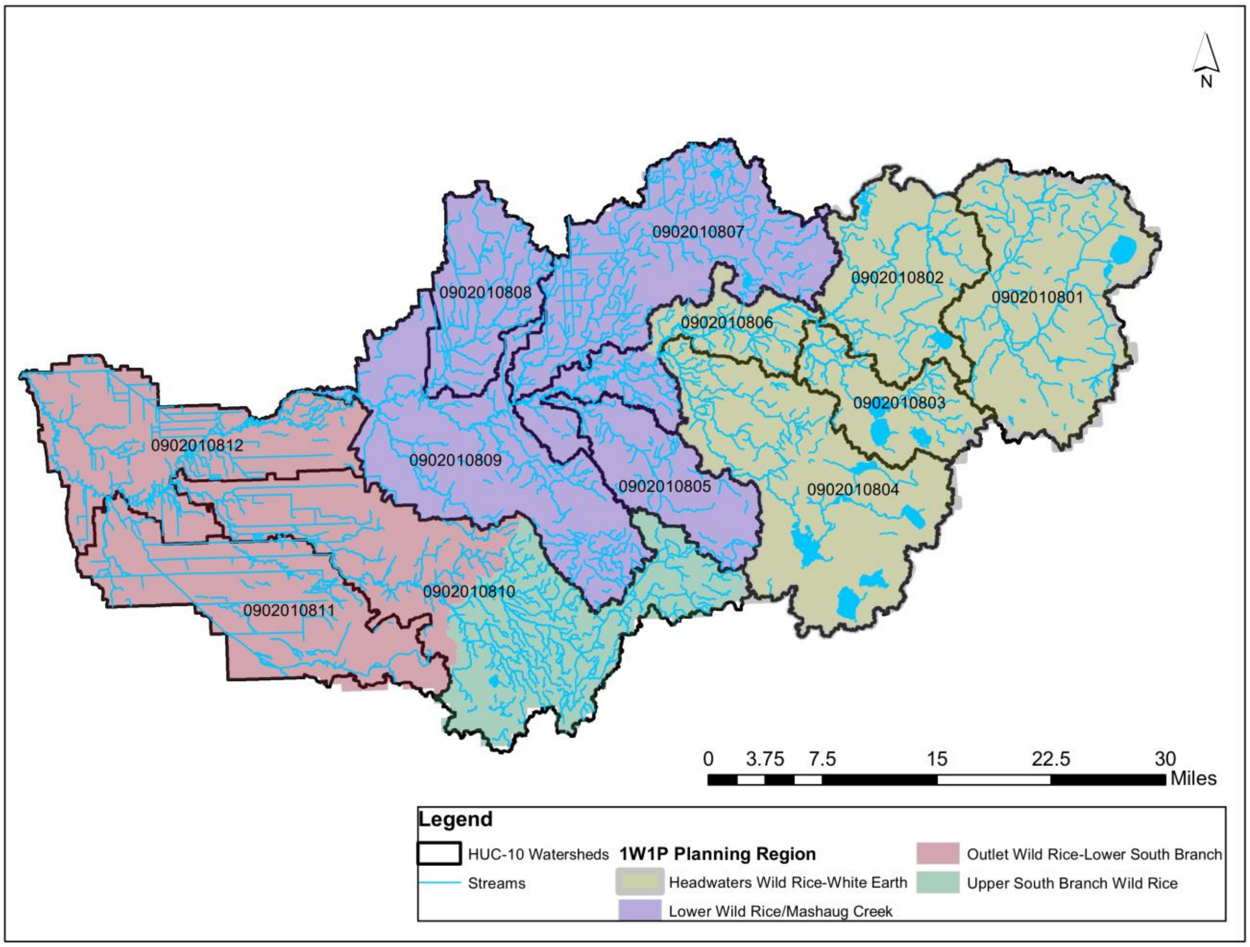
3.1 Targeting of geographic areas

There has been a significant amount of effort put into monitoring and protecting the WRRW over the past several decades. Some of the leaders in this effort have been the WRWD and the SWCDs of counties that overlap with the boundary of the WRRW. Those counties include Becker, Clay, Clearwater, Mahnomen, Norman, and Polk. All counties have one SWCD except for Polk, which has two, East Polk County SWCD and West Polk County SWCD; only East Polk County SWCD overlaps with the WRRW boundary.

Pursuant to Minnesota Statute, the WRWD and SWCDs are required to prepare Watershed or Water Management Plans (WMPs) for the WRRW or respective county, and to continually update and revise the plans every 10-years. A WMP is an important tool for identifying problems and issues, goals, and short and long-term strategies to address these issues and attain the goals. A WMP also inventories resources, assesses resource quality, and establishes regulatory controls, programs, or infrastructure improvements needed to manage the resources within the watershed or county. The WMPs provide guidance for the WRWD and counties to manage the water and natural resources throughout the WRRW.

The WMPs were most recently updated by the WRWD in 2003, Becker County SWCD in 2017, Clay County SWCD in 2017, Mahnomen County SWCD in 2008, Norman County SWCD in 2017, and East Polk County SWCD in 2012. A comprehensive watershed management plan (CWMP) was completed in December 2020 for the Wild Rice – Marsh planning region as part of the 1W1P effort. It was led by the WRWD, but all of the aforementioned SWCDs also took very active roles in the process. The CWMP was developed to inform local decisions and engage residents to inventory resources, assess the quality of resources, establish regulatory controls, develop programs, and prioritize infrastructure improvements to best manage resources within the watershed. The planning regions for the 1W1P process are identified in conjunction with subwatersheds (HUC-10) in **Figure 8** as this WRAPS was used to inform action steps for the CWMP to facilitate practice implementation and improvement of the aquatic resources of the watershed. This CWMP can serve as a substitute for the watershed district's and SWCDs' WMPs.

Figure 8: HUC-10 watersheds within the WRRW (by unique ID) overlain with 2019 1W1P planning regions.



Additional Tools to Target Protection and Restoration Strategies

As part of past and current local planning within the watershed, water quality models and enhanced geospatial water quality products (EGWQP) were developed. Advances in watershed assessment tools allow for the rapid identification of at-risk areas for natural resource degradation, as well as feasible placement locations for cost-effective BMPs and structural conservation practices (CPs). These models are used to analyze runoff quantity; target sources of sediment, total nitrogen (TN), and TP; and identify opportunities for BMP and CP implementation.

The watershed-based results developed under this WRAPS effort utilized the following geospatial products to assess water quality:

- HSPF model and its Scenario Application Manager (SAM) tool
- PTMApp model
    - Light Detection and Ranging (LiDAR) terrain analysis
    - EGWQP
    - BMP Suitability Analysis

Future use and updates of the CWMP will continue to include integration of these resources in conjunction with additional modelled water quality and quantity data. This breadth of available resources will be used to efficiently and effectively manage the waterbodies and contributing lands within the WRRW. The CWMP will provide the management and guidance framework under which these resources can be used to the greatest benefit.

Hydrological Simulation Program – Fortran Model

The HSPF model was chosen as the primary watershed modelling tool to simulate hydrology and water quality for this WRAPS assessment. The HSPF model combines both the WRRW and Marsh River Watershed (MRW) into one model, but data from the WRRW portion of the WRRW/MRW HSPF model was used to target geographic areas for this WRAPS report. The HSPF model assessed hydrology as the total runoff denoted by the unit runoff (RO) that includes surface flow, interflow, and active groundwater flow within subwatersheds. RO was used in conjunction with land use/soil classes to assess total sediment (TS) and nutrient (TN and TP) export for the modelled time period (1996 through 2009). Average load and yield exports were estimated and extracted by subwatershed to generate prioritization maps. Prioritization maps directly facilitate the identification and prioritization of subwatersheds with the greatest opportunity to improve water quality and quantity. This can aid in the effort to identify areas within the WRRW where restoration and protection strategies would be most beneficial.

Multiple HSPF data products are available to facilitate assessment of the watershed (**Appendix B**). Load and yield losses for TS, TN, TP, and RO have been ranked to facilitate greater ease of assessment of major subwatersheds. Examples of products of the HSPF model for the WRRW is shown in **Figure 9** through **Figure 12**. Note that the AUIDs specified in the maps are those that are impaired due to excessive turbidity or TSS, but AUID -503 has since been split into -644 and -643 and AUID -521 has been split into -652 and -651. Ranking of subwatersheds is as follows: lowest priority (lowest 10%), low priority (10% to 25%), moderate priority (25% to 75%), high priority (75% to 90%), and highest priority (highest 10%). Individual impaired AUIDs assessments using HSPF are shown in **Appendix B**. Integrated assessments for loss of habitat through elevated turbidity, an assessment of DO and TS, as well as watershed indices [e.g., water quality index (WQI)] are also available in **Appendix B**.

Multiple memos in support of the WRRW HSPF Priority Maps (**Appendix B**) are available from the MPCA, which discuss modeling methodologies, data used, and calibration results in the WRRW in great detail

(*Wild Rice and Marsh Rivers HSPF Model Hydrologic Calibration Technical Memorandum* [2015], *Wild Rice River and Marsh River Watersheds Hydrological Simulation Program - Fortran Technical Memorandum* [2016], *Wild Rice and Marsh Rivers HSPF Modeling Final Report* [2016], and *Wild Rice River and Marsh River Watersheds HSPF Model Development Technical Memorandum* [2016]).

Figure 9: Map of prioritized subwatersheds for implementation to address altered hydrology in the Wild Rice River Watershed, based on average (1996 through 2009) annual runoff (of water).

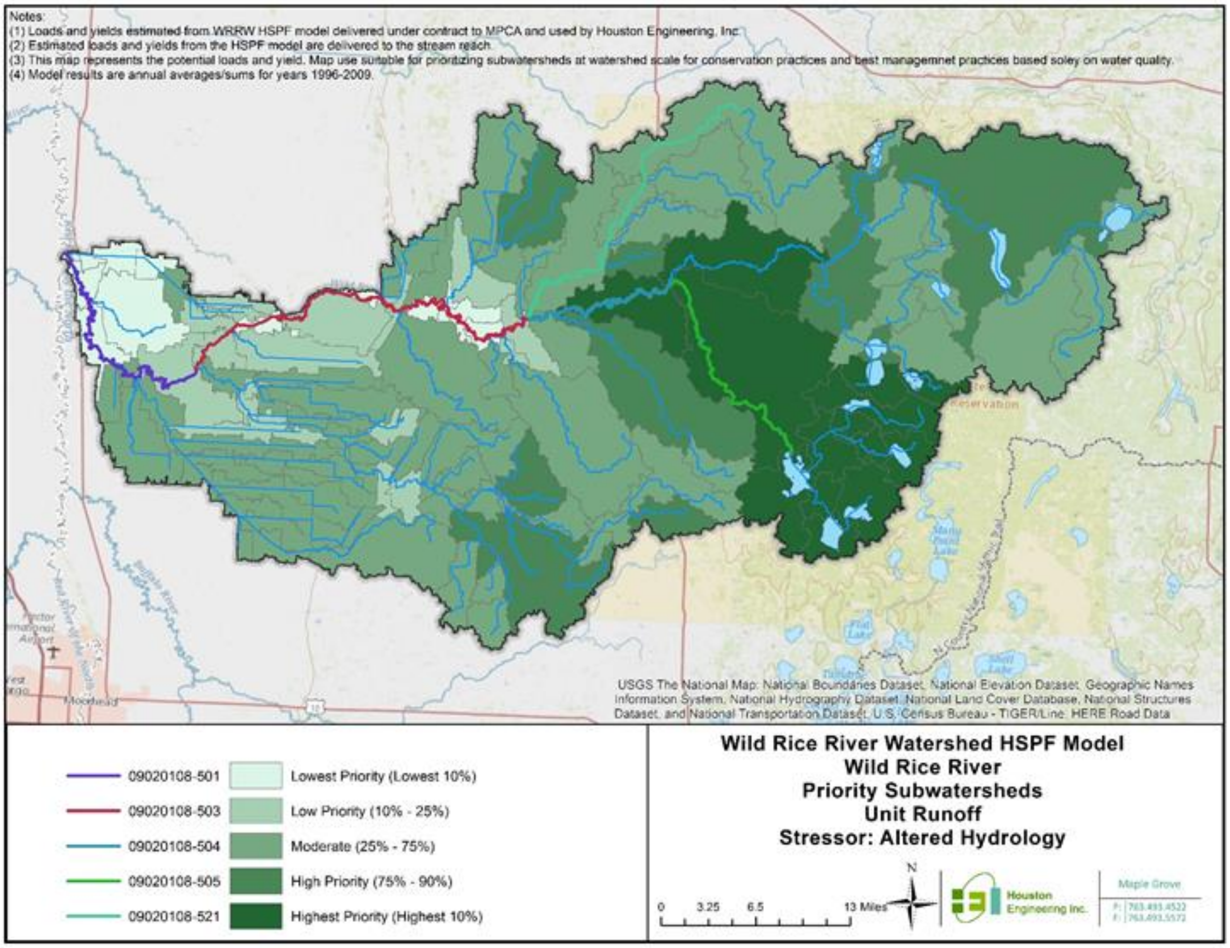


Figure 10: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the Wild Rice River Watershed, based on average (1996 through 2009) annual total sediment yields.

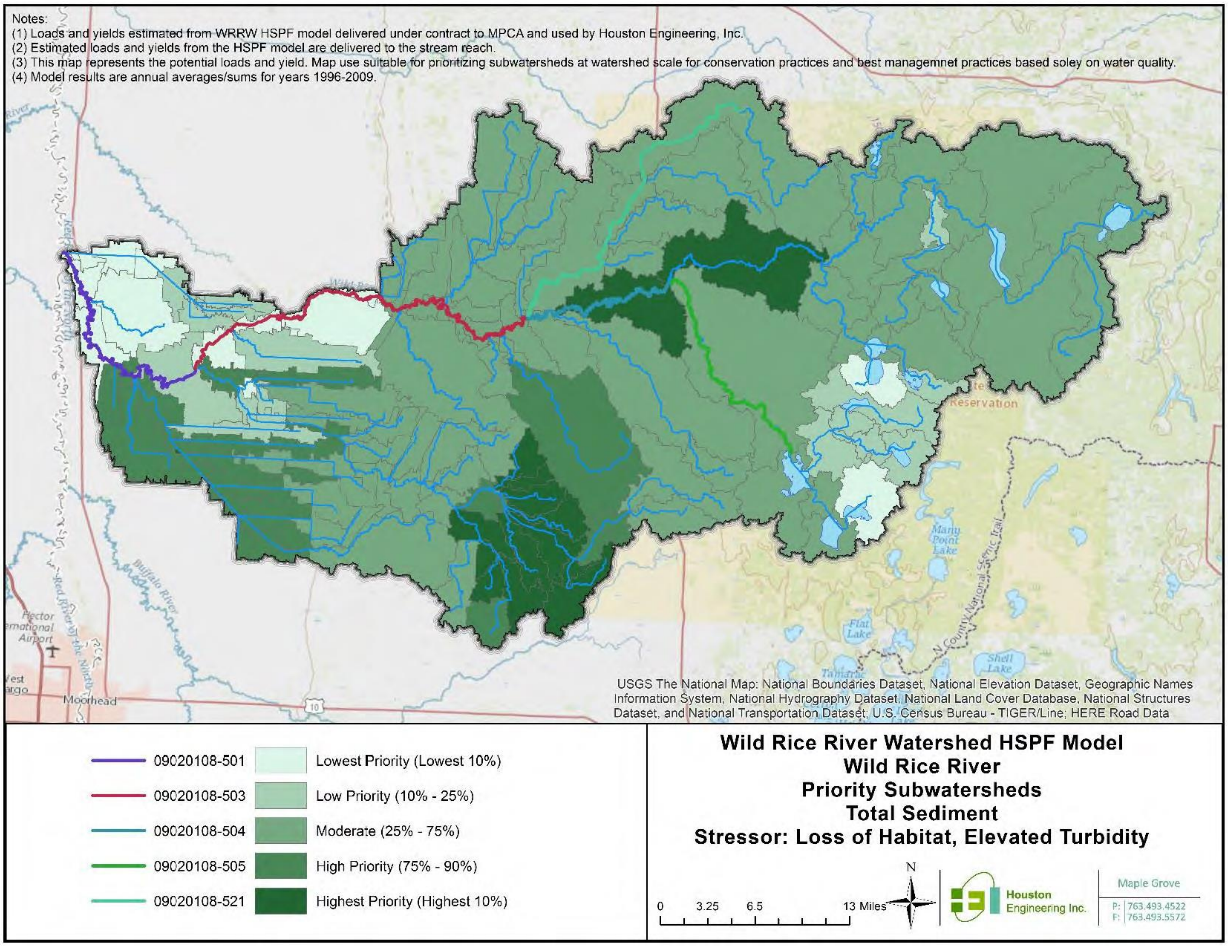


Figure 11: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River Watershed, based on average (1996 through 2009) annual total nitrogen yields.

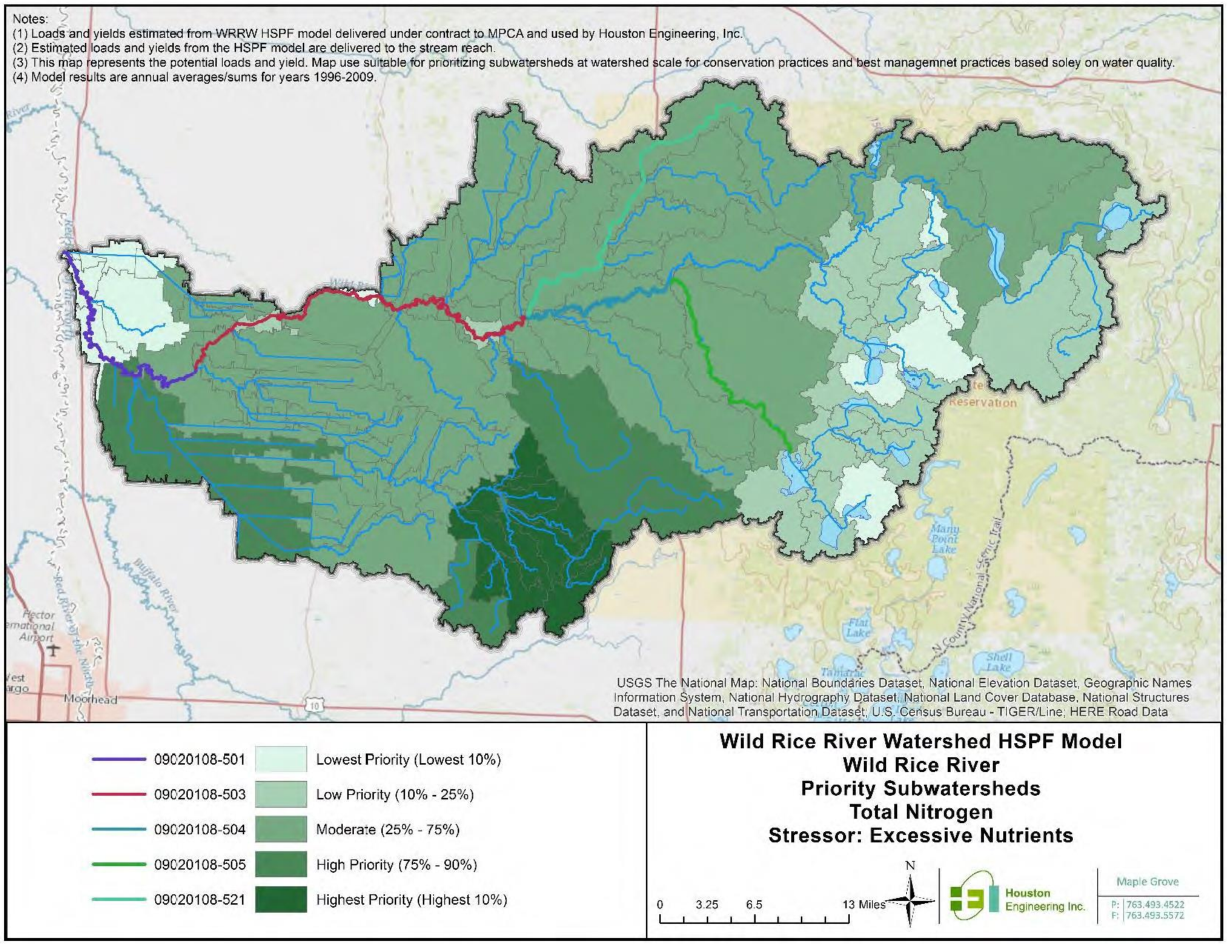
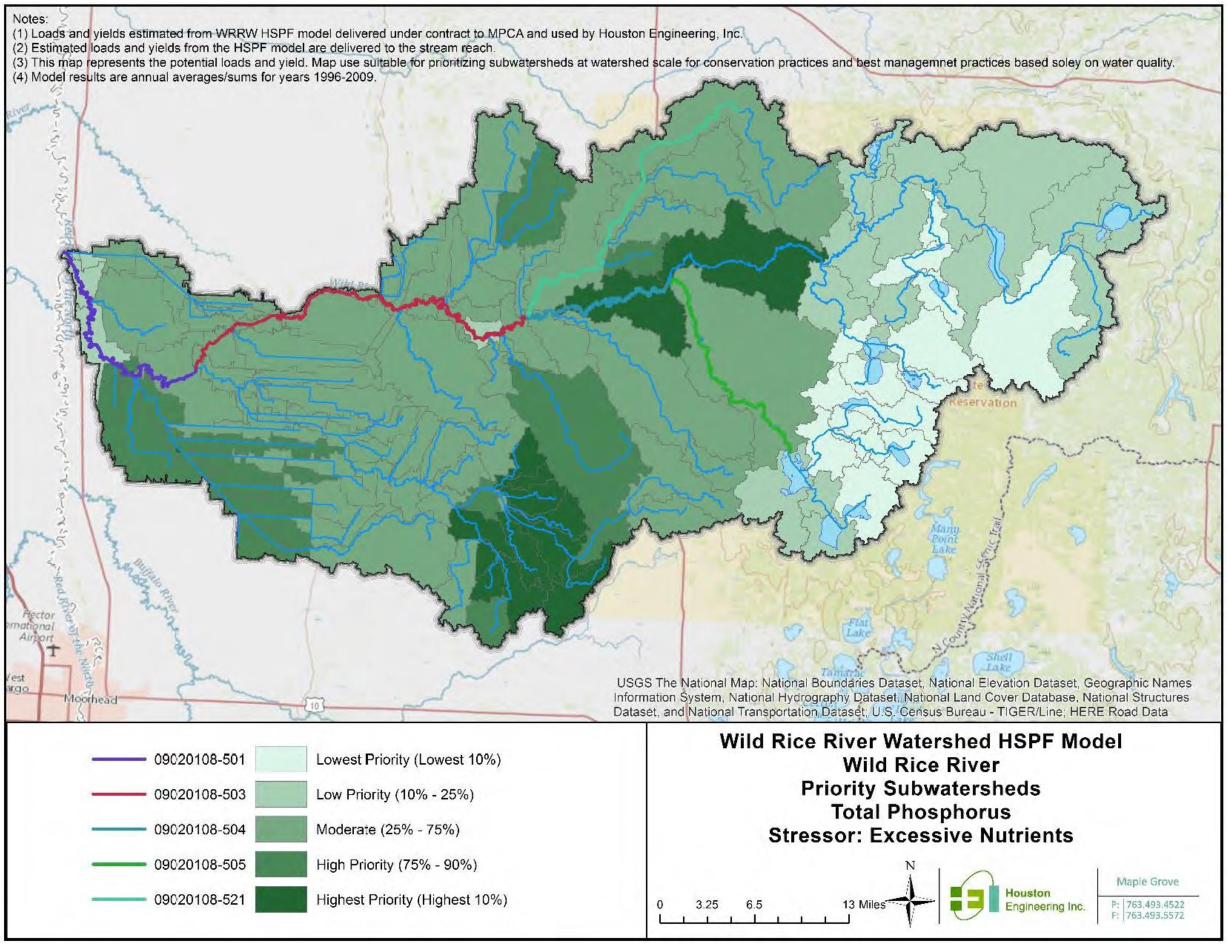


Figure 12: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River Watershed, based on average (1996 through 2009) annual total phosphorus yields.



Prioritize, Target, Measure Application

In addition to generally targeting areas within the watershed for restoration and protection based solely on the yield of water quality constituents (e.g., TS, TP, etc.) delivered to the stream outlet, individual fields were also targeted more explicitly for opportunities to place specific types of BMPs based on the feasibility and estimated benefit of those BMPs. For instance, a field may deliver a moderate to high amount of sediment to a stream but have limited opportunities to implement BMPs to reduce sediment delivery because of the physical setting (i.e., ability of the landowner and productivity of land). For this reason, the PTMApp was also included as part of the Wild Rice River WRAPS Report development.

PTMApp results can be used to locate areas within the watershed where BMPs and CPs are feasible and will be the most beneficial to water quality goals, while also being the most cost effective (i.e., provide the highest water quality benefit for the smallest dollar investment).

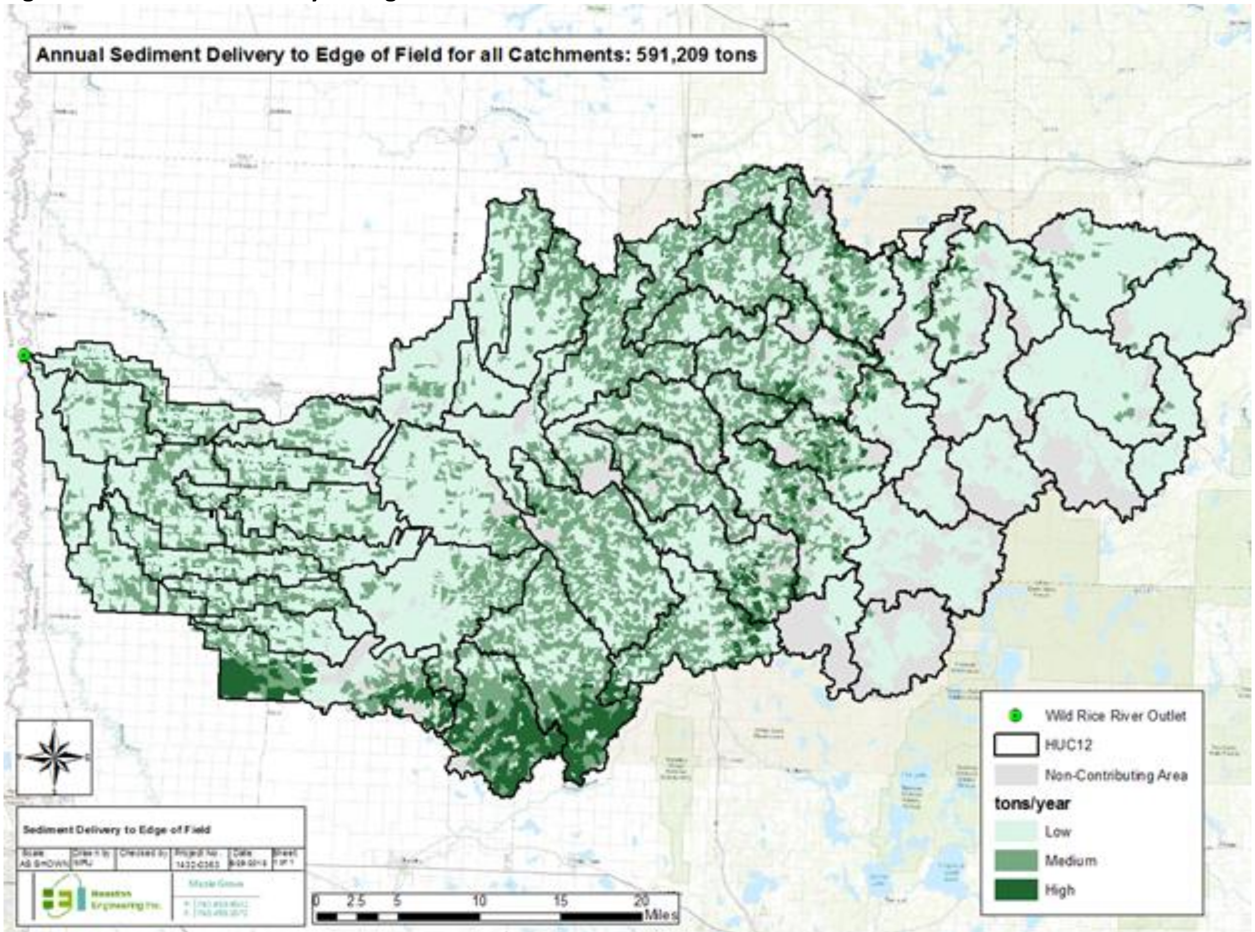
PTMApp utilizes LiDAR information to create a digital elevation model (DEM) for GIS analysis within the application. Within PTMApp, the DEM is first hydro-conditioned, a process that analyzes and modifies the original DEM to ensure that hydrologic flow lines generated through the use of PTMApp match the flow of water on the landscape. Infrastructure items such as culverts are not identified during the LiDAR data collection, and thus are not represented in the DEM. The absence or presence of a culvert can have a dramatic effect on water flow and accumulation within a watershed. Hydro-conditioning artificially adds flow diversions (like culverts) to the original DEM, resulting in a more hydrologically accurate DEM (hDEM).

The hDEM, along with Soil Survey Geographic Database (SSURGO) data, runoff curve number estimates, Revised Universal Soil Loss Equation (RUSLE) parameters, and land cover data are used to rank and classify portions of the watershed that are suitable for BMP and CP installation to improve water quality by reducing sediment and nutrient loss to streams.

For the WRRW, this form of BMP suitability analysis was purposefully focused on those BMPs and CPs used most often within the watershed area. The analysis focused on identifying potential locations believed suitable for BMPs and CPs based on various design criteria and landscape conditions. The implementation of BMPs and CPs are largely dependent upon a site's suitability for a given practice based on U.S. Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) guidelines and topographic characteristics, soils, and land use. Many other factors such as landowner willingness are also important criteria. The high spatial resolution hDEM makes it possible to identify potential locations to place BMPs based on topography and other design factors. The locations can then be reviewed and screened to assist in targeting the implementation of practices. The approach identifies preliminary locations to target BMP placement. As such, field verification is required to confirm the opportunities. The analysis excludes whether a practice is already constructed at the location.

The full results of the PTMApp analysis have been provided in **Appendix C**. An example of sediment delivery to the edge of field (EOF) using PTMApp for the WRRW (relative loading) is shown in **Figure 13**. Fields with the greatest sediment loss can be prioritized to slow water conveyance from the field and in doing so, reduce sediment mobilization and loss from a field.

Figure 13: Sediment Delivery to Edge of Field for the Wild Rice River Watershed.



This data product can be paired with the HSPF catchments that were ranked as high priorities based on their delivery of water quality constituents to identify opportunities to implement BMPs in the locations that are contributing the highest amounts of pollutants to downstream resources. The PTMApp data products can be used to precisely locate areas on the landscape where various types of management practices will be the most beneficial at reducing TS, TP, or TN. HSPF results can then be used to determine the areas that may be better suited for in-stream management practices. Together, the results from HSPF and PTMApp, as well as professional knowledge and experience can be used to inform placement of protection and restoration strategies within the WRRW.

Additional Tools

Statewide resources to assess the environmental benefits, hydrology, and other associated data to inform watershed plans are available online and by download. Available resources are summarized in **Table 14**.

Table 14: Additional tools available online or by download to assist with watershed or project analysis within the WRRW.

Tools	Description	How can the tool be used?	Notes	Link to information and data
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the Board of Water and Soil Resources (BWSR) website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions. Various data sets described or available.	Landscape Resiliency - Water Planning [a] Landscape Resiliency - Agricultural Landscapes [b] MPCA data download [c]
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.	Software [d] Examples Pine River Watershed [e] Cannon River Watershed [f]
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 U.S. Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface 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' website.	Restorable Wetlands [g]

Tools	Description	How can the tool be used?	Notes	Link to information and data
National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams, and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS [h]
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 (MGIO) website.	MGIO [i]
Hydrological Simulation Program – Fortran (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds of adoption rates of BMPs 2) effects of proposed or hypothetical land use changes.	EPA Models [j] USGS [k]

[a] https://bwsr.state.mn.us/practices/climate_change/Water_Planning.pdf

[b] https://bwsr.state.mn.us/practices/climate_change/Agricultural_Landscapes.pdf

[c] https://www.pca.state.mn.us/data/spatial-data

[d] https://www.helsinki.fi/en/researchgroups/metapopulation-research-centre/software

[e] https://www.pca.state.mn.us/water/watersheds/pine-river

[f] https://www.pca.state.mn.us/water/watersheds/cannon-river

[g] http://www.mnwetlandrestore.org/links-contact/data-download/

[h] http://nhd.usgs.gov/

[i] http://www.mngeo.state.mn.us/chouse/elevation/lidar.html

[j] https://www.epa.gov/exposure-assessment-models/hspf

[k] http://water.usgs.gov/software/HSPF/

3.2 Public participation

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful public participation. A specific goal of the public participation 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 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. This is especially true in the WRRW, as the vast majority of the land is privately owned (76%). In a watershed with differing private, public, and tribal land ownership (reflective of the habitat of each ecoregion in the WRRW), the public participation process included two primary components: technical stakeholder engagement and citizen engagement.

The WRWD and SWCDs (hereafter referred to as local government units [LGUs]) engage with property owners in the WRRW, encompassing private property owners as well as state, federal, and tribal representatives. LGU personnel engage with property stakeholders in addition to regional technical stakeholders including the Nature Conservancy, Ducks Unlimited, the Red River Basin Commission, the Red River Basin Institute, and many more wildlife and conservation oriented organizations. The WRWD has also worked alongside the Minnesota Center for Environmental Advocacy to address natural resource issues (MCEA, 2005; WRWD, 2002). Continued stakeholder engagement continues to ensure projects are developed in a manner that is mutually beneficial.

The LGUs recognize the importance of informing citizens of current watershed activities and educating the citizens in the benefits of conservation, preservation, and enhancement of natural resources. LGUs realize that optimum water management practices result when people affected by a water resources issue are sufficiently educated. An example of a result of this realization is the WRWD has taken an active position in publicizing its activities and educating the public. A professional publicist has been retained by the Board to prepare press releases on WRWD activities. From the standpoint of education, staff and managers of the WRWD have appeared before other governmental boards and organizations to inform them about activities and programs that are being implemented within the watershed. Engagement and participation by LGUs in state, regional, and basin functions ensures that the group as a whole is aware of water resources risks and can educate residents regarding existing and potential risks to the community.

LGUs have also been instrumental in garnering citizen involvement. Stakeholder groups are used to identify natural resource problems within the WRRW. Garnering support and gathering information from the public is often accomplished through a series of mailers, workshops, discussions, and meetings. In addition, the WRWD also has the goal of involving citizens in water quality monitoring across the watershed. Local residents have the opportunity to serve on the Wild Rice Watershed District Advisory Committee, helping to guide decisions within the watershed. A number of local citizens are also part of River Watch, a program that engages citizens and students to help with monitoring the health of the watershed. River Watch also works closely with WRWD staff, residents, and local schools (Mahnomen, Ulen, and Twin Valley) to monitor waters within the district and to educate the general public on water related issues affecting their community.

The public participation efforts related to the Wild Rice River WRAPS project were overseen and carried out by the WRWD. A public meeting and open house event for the WRAPS project was held at the Twin Valley Community Hall on May 30, 2018. This event took place during the early stages of drafting the WRAPS report and the purpose was to update stakeholders on the WRAPS efforts, as well as receive input and guidance on water quality values and concerns in the area. A 1W1P kickoff meeting for the Wild Rice – Marsh planning region was held at the WRWD office in July 2019. At this meeting, participants indicated priority areas on wall maps and completed a survey to share their priority issues and concerns. This public survey was also shared online via email for anyone who could not attend the meeting. These priorities were incorporated into the WRAPS report, which was being drafted at the time of the kickoff meeting.

Accomplishments and future plans

Since water quality is among the priorities of the LGUs management activities, future public participation will continue to be coordinated by them. The LGUs will update, educate, and engage stakeholders on water quality issues through the typical LGU communications, including plan update events and on their websites. A primary objective of this public participation is to create understanding of water quality problems and solutions that are available, and to build motivation to make changes with those who will be needed to voluntarily implement BMPs. As trusted authorities on water issues in the area, the LGUs are uniquely suited to provide information and leadership on this topic.

Public and private partnerships have focused on flooding and sediment control. These efforts are largely regional through the Red River Basin Commission and the USDA - NRCS. Efforts prior to 2015 are summarized in the *Wild Rice River and Marsh River Watersheds Bibliography* (Houston Engineering, Inc., 2015). More recent projects to engage communities and residents in the watershed are summarized in **Table 15**.

Table 15: Partial review of ongoing or recently completed projects by the WRWD.

Project	Goal	Partners
Green Meadow Watershed Regional Conservation Partnership Program	Red River Basin Commission – Basin-wide Flow Reduction Strategy project with a goal to reduce Red River main-stem flows by 20%. Project components include dam stabilization, grade control, and the re-establishment of grass buffers.	Red River Basin Commission; USDA - NRCS
Moccasin Creek Watershed Plan and Environmental Assessment	Primary Goal: Inform flood damage reduction from a 10-year, 24-hour storm in the watershed, and Secondary Goal: Contribute to Red River Basin Commission to reduce main-stem flows by 20%.	USDA - NRCS
South Branch Wild Rice River Watershed Plan and Environmental Assessment	Primary Goal: Inform flood damage reduction from a 10-year, 24-hour storm in the watershed, and Secondary Goal: Contribute to Red River Basin Commission to reduce main-stem flows by 20%.	USDA - NRCS

Project	Goal	Partners
Goose Prairie WMA Enhancement Project	Install a water control structure to improve control over lake water levels and maintain regional drainage.	Red River Watershed Management Board; Lessard-Sams Outdoor Heritage Council; State of Minnesota - Flood Hazard Mitigation Program; DNR; USFWS
Rural Ring Dike Program	Funding assistance for the construction and repair of ring dikes to protect homes and farmsteads from flooding.	Red River Watershed Management Board; State of Minnesota
Ring dikes for Hendrum and Perley	Levee segment upgraded to FEMA certification requirements. Additional road surface improvements are addressed in subsequent phases.	US Army Corps of Engineers; Perley
Lower Wild Rice Corridor Restoration and Setback	Set back levees to encompass historical meander belt and convey flow from a two-year event.	Lessard-Sams Outdoor Heritage Council and others

Expectations are that future implementation will occur either through the existing water-related plans, implementing a 1W1P, and/or through the Red River Basin Flood Damage Reduction Workgroup. Past and ongoing efforts have primarily focused on flood control projects with funding including local funds, match from the Red River Basin Flood Damage Reduction Workgroup and the Red River Watershed Management Board, grants such as the Regional Conservation Planning Partners and other funding sources to address flooding, sediment delivery and conveyance, and water quality within the greater Red River Basin.

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 March 14, 2022 to April 13, 2022. No comments were received during the public comment period.

3.3 Restoration and protection strategies

The WRRW has several impaired stream reaches and lakes in need of restoration with many additional waterbodies that would benefit from protection activities. The collaborative efforts fostered during this WRAPS process (and earlier reports) by local and state partners have led to the identification and prioritization of water quality restoration and protection strategies for the watershed that seek to decrease stressors and pollutants contributing to impairments observed within the watershed. Consistent stressors to aquatic life (some of which are pollutants such as TSS) in stream reaches in the WRRW are a function of altered hydrology and the lack of lateral connectivity to floodplains (causes of impaired biological communities are further identified in **Table 6**). Modified stream channels that are designed to move water quickly have created unstable flow regimes. During times of low flow, water can stagnate and sediment settles out, conditions commonly correlated with low DO and in-stream habitat disruption. High peak flows and concurrent high suspended solids are consistently observed throughout the WRRW. Overland soil erosion and channel degradation during these peak flows are believed to be the primary sources of sediment to impaired waterbodies. Restoration of impaired waterbodies within the WRRW will not be simple due to widespread channel embeddedness and either high TSS concentrations or indications of recent high TSS concentrations (interstitial packing of gravel and cobble substrate). Conservation practice adoption (e.g., side inlets and conservation cover) could stabilize sensitive areas or reduce sediment runoff to rivers and streams. In-channel mitigation of sediment from bank erosion or scouring is also needed to reduce the impacts on biotic communities. Also, improvements in the riparian corridor habitat structure, specifically an improvement in the lateral connectivity and vegetation are great opportunities to protect and restore impaired streams reaches.

Table 16 and **Table 17** contain more complete lists of the strategies to restore impaired streams and protect unimpaired streams in the WRRW. Included in the tables are water quality goals for restoration, suggested implementation strategies to achieve those goals, estimated necessary adoption rates, units/metrics to track progress towards goals, governmental unit(s) responsible for implementation, and the timeline to achieve those goals. All other waters (lakes included) in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies. Given the heterogeneity of the watershed, protection strategies are identified by the 1W1P planning region and the major HUC-10 watershed to facilitate comparison between this plan and the CWMP.

Interim 10-year milestones are identified in **Table 16** so that incremental progress is measured and achieved. Ongoing 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.

Table 16: Strategies and actions proposed for the Wild Rice River Watershed.

Parameter	Planning region (1W1P)	HUC-10 subwatershed	Impaired waterbody (AUID) relevant to parameter [a]	Identified conditions (see key below) [b]	Water quality goal (summarized)	Pollutant / stressor sources		Watershed-wide goal for parameter	10-yr target to meet by 2029	Restoration and protection strategies estimated rate of adoption: All= >90%, Most= >60%, Many/much= >30%, Some= >10%, Few= <10%	Estimated years to reach goal from 2019
						Land Use	Pathway				
Sediment	Headwaters Wild Rice - White Earth	0902010801	09020108-646	3 / 6 / 3 (TSS) 2 / 13 / - (Secchi)	90% of TSS concentrations below 15, 30, or 65 mg/L (North, Central, or South River Nutrient Region, resp.) in class 2B streams and 10 mg/L in class 2A streams. Average Secchi depth measurements greater than 2.0, 1.4, or 1.0 meters (NLF ecoregion, deep lake in the NCHF ecoregion, and shallow lake in the NCHF ecoregion, resp.) in class 2B lakes. Aquatic life populations in streams and lakes are not stressed by sediment.	Streambank erosion, Timber harvest, Cropping	Water quantity; Surface runoff; Open tile intakes	Protect	Protect	**Most** fields are managed to mitigate erosion associated with land use change following timber harvest and pastures are managed to prevent overgrazing and direct stream access by livestock. **Most** lakes have shoreline protection efforts in place (impervious surface practices, shoreline protection, etc.).	NA
		0902010802									
		0902010803	09020108-509								
		0902010804	09020108-505								
		0902010806	09020108-506								
	Lower Wild Rice / Mashaug Creek	0902010805	09020108-647	6 / 5 / 7 (TSS) - / 1 / - (Secchi)		Cropping (tiled and not tiled)	Surface runoff; Open tile intakes	45% Reduction	10% Reduction	**Most** fields use surface sediment controls to prevent erosion including conservation tillage, removing open intakes, cover crops, etc. **Many** fields trap/settle eroded sediment at edge of field with buffers, sediment basins, etc. Address altered hydrology in contributing areas as discussed below under 'Habitat.' Stabilize **few** streambanks/ravines - those that threaten high value property.	50
		0902010806	09020108-504								
		0902010807	09020108-652								
		0902010808	09020108-579 09020108-650								
		0902010809	09020108-544 09020108-643								
	Upper South Branch Wild Rice	0902010810	09020108-661 09020108-662	2 / - / 2 (TSS) - / 1 / - (Secchi)							
	Outlet Wild Rice - Lower South Branch	0902010810	09020108-662	4 / 2 / 1 (TSS) - / - / - (Secchi)							
		0902010811	09020108-654								
		0902010812	09020108-501 09020108-644								
Hydrology	Headwaters Wild Rice - White Earth	0902010801	09020108-646	Streams: 6 / 1 / 0 [c] While the impaired AUIDs to the left and numbers above reflect poor biological communities and stress caused by flow regime instability, resp., other parameters such as sediment, phosphorus, habitat, and DO can be affected by hydrology.	Aquatic life populations are not stressed by altered hydrology and flow regime instability (too high or too low river flow). Hydrology is not accelerating other parameters (e.g., excessive sedimentation, high phosphorus levels, insufficient habitat, low DO)	Timber harvest; Cropping (tiled and not tiled); All other land use	Lower water holding capacity; Surface runoff; tile drainage; All	Protect	Protect	**Most** timbers and pastures improve vegetation through management to increase water holding capacity.	NA
		0902010802									
		0902010803									
		0902010804									
		0902010806									
	Lower Wild Rice / Mashaug Creek	0902010805	09020108-647			Cropping (tiled and not tiled); All other land use	Surface runoff; tile drainage; All			**Most** drainage projects are hydrologically mitigated to protect from further degradation. **Most** crops and pastures improve vegetation by using cover crops, buffers, grasses, etc. **Many** fields have increased soil water holding capacity from increased soil organic matter due to conservation/no tillage, increased vegetation, etc. **Most** field drainage incorporates conservation drainage principles and/or is intercepted by ponds, wetlands, etc. that allow for evapotranspiration and infiltrate. **Most** drainage and ditch projects incorporate multi-benefits including maintaining vegetation and natural stream features. **Some** nonag land use areas add wetlands, perennial vegetation, and urban/ residential stormwater management. **Some** channel restorations and floodplain reconnection projects, starting in headwaters.	
		0902010806									
		0902010807									
		0902010808	09020108-579 09020108-650								
		0902010809									
	Upper South Branch Wild Rice	0902010810	09020108-661 09020108-662								
	Outlet Wild Rice - Lower South Branch	0902010810	09020108-662								
		0902010811	09020108-654								
		0902010812									

Parameter	Planning region (1W1P)	HUC-10 subwatershed	Impaired waterbody (AUID) relevant to parameter [a]	Identified conditions (see key below) [b]	Water quality goal (summarized)	Pollutant / stressor sources		Watershed-wide goal for parameter	10-yr target to meet by 2029	Restoration and protection strategies estimated rate of adoption: All= >90%, Most= >60%, Many/much= >30%, Some= >10%, Few= <10%	Estimated years to reach goal from 2019
						Land Use	Pathway				
Nitrogen	Headwaters Wild Rice - White Earth	0902010801, 0902010802, 0902010803, 0902010804, 0902010806	None; Note that the nitrogen-related parameter assessed in streams in early 2016 was unionized ammonia (NH_3), the conditions of which are recorded to the right. Nitrogen was not assessed in lakes. High nitrate-nitrite were not considered to be candidate causes of poor biological communities.	0 / 8 / 4 (NH_3)	Waterbodies continue to meet standards for NH_3 (16 and 40 µg/L in Class 2A and 2B waterbodies, resp.). Aquatic life populations continue to not be stressed by nitrate-nitrite. Reduce to support statewide and downstream goals (MPCA, 2014).	Cropping (All); Developed	Surface, tile, and groundwater runoff; City stormwater	13% Reduction (MPCA, 2014)	6% Reduction	**Much** of the urban/residential runoff is prevented or treated. Hydrology practices as discussed above are implemented, including design parameters for nitrogen removal.	25
	Lower Wild Rice / Mashaug Creek	0902010805, 0902010806, 0902010807, 0902010808, 0902010809		0 / 11 / 7 (NH_3)						**All** fields incorporate nutrient management principles for fertilizer and manure use. Hydrology practices as discussed above are implemented, including design parameters for nitrogen removal. Sediment practices as discussed above are implemented, including design parameters for nitrogen removal. **Much** of the urban/residential runoff is prevented or treated.	
	Upper South Branch Wild Rice	0902010810		0 / 2 / 2 (NH_3)							
	Outlet Wild Rice - Lower South Branch	0902010810, 0902010811, 0902010812		0 / 7 / 0 (NH_3)							
Phosphorus	Headwaters Wild Rice - White Earth	0902010801	15-0075-00	3 / 4 / 5 2 / 12 / 1	Average TP concentrations below 50, 100, or 150 µg/L (North, Central, or South River Nutrient Region, resp.) in Class 2A and 2B streams. Average TP concentrations below 30, 40, or 60 µg/L (NLF ecoregion, deep lake in the NCHF ecoregion, and shallow lake in the NCHF ecoregion, resp.) in class 2B lakes. Aquatic life populations are not stressed by phosphorus and its role in eutrophication and low DO. Reduce to support state-wide and lake-specific protection goals.	Cropping (All); Pasture (overgrazed); Developed	Surface, tile, and groundwater runoff; Surface runoff; Sanitation (WWTPs and SSTS) and Surface runoff	10% Reduction (MPCA, 2014)	5% Reduction	**All** fields incorporate nutrient management principles for fertilizer and manure use. **Some** ditch/stream water has improved treatment via stream/ditch vegetative improvements. **Much** of the urban/residential runoff is prevented or treated. **Most** failing SSTSs are fixed. **Some** WWTPs upgrades to reduce phosphorus are made. **All** internal lake loads are assessed.	25
		0902010802									
		0902010803									
		0902010804	44-0003-00								
		0902010806									
	Lower Wild Rice / Mashaug Creek	0902010805, 0902010806, 0902010807, 0902010808, 0902010809		2 / 7 / 9 - / - / -						**All** fields incorporate nutrient management principles for fertilizer and manure use. Sediment practices as discussed above are implemented. **Many** fields treat tile drainage water to remove phosphorus using treatment wetlands, vegetative filters, etc. **Some** ditch/stream water has improved treatment via stream/ditch vegetative improvements. **Much** of the urban/residential runoff is prevented or treated. **Most** failing SSTSs are fixed. **Some** WWTPs upgrades to reduce phosphorus are made. Sediment practices for streambanks/ravines as discussed above are implemented. Address internal lake loads.	
	Upper South Branch Wild Rice	0902010810		1 / - / 3 - / 1 / 1							
	Outlet Wild Rice - Lower South Branch	0902010810, 0902010811, 0902010812		2 / 3 / 2 - / - / -							
E. coli	Headwaters Wild Rice - White Earth	0902010801		Streams: 4 / 5 / -	Average monthly geomean of *E. coli* samples from Class 2 waterbodies is below 126 org/100mL. Fewer than 10% of individual *E. coli* samples from Class 2 waterbodies exceed 1,260 org/100mL.	Crops (with manure application); Pasture (overgrazed); Developed	Surface and feedlot runoff; Pasture runoff; Sanitation (failing SSTS and WWTPs)	25% Reduction	10% Reduction	**Most** failing SSTSs are fixed. **Some** WWTPs upgrades to reduce *E. coli* are made. **Much** pasture management is improved to reduce surface manure runoff.	50
		0902010802									
		0902010803	09020108-509								
		0902010804	09020108-505 09020108-593								
		0902010806	09020108-506								
	Lower Wild Rice / Mashaug Creek	0902010805	09020108-648	Streams: 7 / 3 / 1				45% Reduction	25% Reduction	**All** manured fields incorporate best manure management practices. **Many** manured fields	35
		0902010806									

Parameter	Planning region (1W1P)	HUC-10 subwatershed	Impaired waterbody (AUID) relevant to parameter [a]	Identified conditions (see key below) [b]	Water quality goal (summarized)	Pollutant / stressor sources: Land Use	Pollutant / stressor sources: Pathway	Watershed-wide goal for parameter	10-yr target to meet by 2029	Restoration and protection strategies estimated rate of adoption: All= >90%, Most= >60%, Many/much= >30%, Some= >10%, Few= <10%	Estimated years to reach goal from 2019
		0902010807	09020108-651							incorporate infield and edge of field vegetative practices to capture manure runoff including cover crops, buffer strips, etc. **Most** manure feed lot pile runoff is controlled. **Most** failing SSTSs are fixed. **Some** WWTPs upgrades to reduce *E. coli* are made.	
		0902010808	09020108-650								
		0902010809	09020108-544 09020108-546 09020108-577 09020108-643								
	Upper South Branch Wild Rice	0902010810	09020108-662	Streams: 1 / - / 1							30
	Outlet Wild Rice - Lower South Branch	0902010810	09020108-659 09020108-662	Streams: 4 / 2 / -							30
		0902010811	09020108-553								
		0902010812	09020108-644								
Habitat	Headwaters Wild Rice - White Earth	0902010801	09020108-646	Streams: 6 / 1 / 0 [d] While the impaired AUIDs to the left and numbers above reflect poor biological communities and stress caused by insufficient physical habitat, resp., other parameters such as sediment and hydrology can affect habitat.	Aquatic life populations are not stressed by lack of habitat (can be caused by parameters such as sediment and hydrology) or impeded passage (i.e., perched culverts, beaver dams, lake outlet structures).	Degraded riparian corridor; Altered hydrology		10% Increase	5% Increase	**All** streams have adequate buffer size and vegetation to meet shading, woody debris, geomorphology, and other habitat needs. Implement hydrology and sediment practices as discussed above.	60
		0902010802									
		0902010803									
		0902010804									
		0902010806									
	Lower Wild Rice / Mashaug Creek	0902010805	09020108-647					15% Increase	5% Increase		40
		0902010806									
		0902010807									
		0902010808	09020108-579 09020108-650								
		0902010809									
	Upper South Branch Wild Rice	0902010810	09020108-661 09020108-662								30
	Outlet Wild Rice - Lower South Branch	0902010810	09020108-662					25% Increase	10% Increase		30
		0902010811	09020108-654								
		0902010812									
DO	Headwaters Wild Rice - White Earth	0902010801	09020108-646	Streams: 1 / 0 / 10	Concentrations are above 5 or 7 mg/L for Class 2B or 2A streams, resp., with DO flux less than or equal to 3.0, 3.5, or 4.5 mg/L (North, Central, or South River Nutrient Region, resp.) in Class A streams and 3.0, 3.5, or 5.0 mg/L (North, Central, or South River Nutrient Region, resp.) in Class B streams.	Land use stressors (Phosphorus, altered hydrology, degraded riparian corridor)		Meet eutrophication standard (function of TP, hydrology, and habitat)	Meet Phosphorus, hydrology, and habitat goals	Address hydrology, phosphorus, and habitat practices as discussed above.	50
		0902010802									
		0902010803									
		0902010804									
		0902010806									
	Lower Wild Rice / Mashaug Creek	0902010805	09020108-647	Streams: 2 / 3 / 12							35
		0902010806									
		0902010807									
		0902010808	09020108-579 09020108-650								
		0902010809									

Parameter	Planning region (1W1P)	HUC-10 subwatershed	Impaired waterbody (AUID) relevant to parameter [a]	Identified conditions (see key below) [b]	Water quality goal (summarized)	Pollutant / stressor sources		Watershed-wide goal for parameter	10-yr target to meet by 2029	Restoration and protection strategies estimated rate of adoption: All= >90%, Most= >60%, Many/much= >30%, Some= >10%, Few= <10%	Estimated years to reach goal from 2019
						Land Use	Pathway				
	Upper South Branch Wild Rice	0902010810	09020108-661 09020108-662	Streams: 2 / - / 2							25
	Outlet Wild Rice - Lower South Branch	0902010810	09020108-662	Streams: 2 / 1 / 5							25
		0902010811	09020108-654								
		0902010812									

[a] AUIDs listed are those for which the parameter is contributing to an impairment and/or evaluated as a stressor to aquatic life.

[b] ## / ## / ## = # of waterbodies where parameter is stressing aquatic life (+, ++, or +++ in **Table 6**) and/or contributing to an impairment (i.e., does not meet standards) / # of waterbodies where parameter is not stressing aquatic life (0 or NE in **Table 6**) and/or is not contributing to an impairment (i.e., meets standards) / # of waterbodies sampled for parameter, but more data is needed and stressor identification was not conducted. Streams are listed in the top row, the second row summarizes lakes.
When data was insufficient for assessment in 2016, but the parameter had been previously identified as contributing to an impairment, the latter is represented in this column. In situations where a parameter is a stressor, but assessments determined the parameter meets standards, the former is represented in this column. Finally, if a parameter was evaluated as a stressor, but more data was needed for assessments, the results of the former is represented in this column.

[c] Hydrology was investigated in the stressor ID report as flow regime instability so AUIDs with impairments identified by poor biological communities are considered in this column and the column to the left. However, see other parameters such as sediment, phosphorus, habitat, and DO, because hydrology can influence these as well.

[d] Habitat was investigated in the stressor ID report as insufficient physical habitat so AUIDs with impairments identified by poor biological communities are considered in this column and the column to the left. However, see other parameters such as sediment and hydrology, because these can affect habitat as well.

Table 17: Strategies that can be implemented to help meet water quality goals in the Wild Rice River Watershed.

Land use	Restoration and Protection Strategies [a] Common management practices by land use	BMP mode of action By pollutant or stressor [b]						Responsibility Practice design, construction, and maintenance																						
		Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Farm Owners	Farm Operators	Residents	Conservation Nonprofit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Eng.
Cultivated Crops	Improved fertilizer management	-	-	X	X	-		•	•		•			•	•		•		•			•		•	•	•	•	•		
	Grassed waterway	X	-	X	-	-		•	•		•				•		•	•				•		•	•			•		
	Conservation tillage	X	-	-	X			•	•		•			•	•		•							•	•		•	•		
	Crop rotation (including small grain)			X	-			•	•		•			•	•		•		•					•	•		•	•		
	Improved manure field application	-	-	X	-	-		•	•		•			•			•	•	•	•		•		•			•	•		
	Cover crops	X	-	-	X	-		•	•		•			•	•		•						•	•	•		•	•		
	WASCOBS, terraces, flow-through basins	X	X	-	X	-		•	•								•					•		•	•			•		
	Buffers, border filter strips		-	X	-	X	X	•	•	•	•			•	•	•	•	•		•		•	•	•	•		•	•	•	
	Contour strip cropping (50% crop in grass)	X	X	X	X	X	-	•	•					•	•		•							•	•		•	•		
	Wind Breaks	-			-			•	•	•	•						•							•				•		
	Conservation cover (replacing marginal farmed areas)	X	X	X	X	X	-	•	•		•				•		•			•		•	•	•				•	•	
	In/near ditch retention/treatment	-	-	-	-	-		•	•		•		•	•	•	•	•							•				•		
	Alternative tile intakes	X			X	-		•	•		•			•	•	•	•		•	•		•		•	•		•	•		
	Treatment wetland (for tile drainage system)		-	X	-			•	•	•	•		•		•	•	•	•		•		•	•	•	•	•	•	•	•	
	Controlled drainage, drainage design		X	X	-			•	•		•			•	•	•	•							•				•		
	Saturated buffers		-	X	-			•	•		•				•	•	•							•	•			•		
	Wood chip bioreactor			X	-			•	•		•				•	•	•							•	•			•		
	Wetland Restoration	X	X	X	X	X	X	•	•	•	•				•	•	•						•	•				•	•	•
	Retention Ponds	X	X	X	X	X	-	•	•	•	•				•		•							•				•		
	Mitigate agricultural drainage projects	X	X	X	X	X	-	•	•		•				•		•	•					•	•				•		•
	Maintenance and new enrollment of BMPs, CRP, RIM, etc.	X	X	X	X	X	-	•	•	•	•						•	•					•	•				•	•	
Pastures	Rotational grazing/improved pasture vegetation management	X			X	X	X	•	•		•				•		•	•	•				•	•	•			•	•	
	Livestock stream exclusion and watering facilities	X			X	X	X	•	•		•				•		•	•	•				•	•	•			•	•	
Cities & yards	Nutrient/fertilizer and lawn mgt.	-	-	-	-	-				•	•	•	•		•		•	•		•					•		•			
	Infiltration/retention ponds, wetlands	-	-	X	-					•	•	•	•					•		•	•				•		•			•
	Rain gardens, rain barrels		-							•	•	•	•		•			•		•		•		•			•			

Land use	Restoration and Protection Strategies [a] Common management practices by land use	**BMP mode of action** By pollutant or stressor [b]						**Responsibility** Practice design, construction, and maintenance																						
		Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Farm Owners	Farm Operators	Residents	Conservation Nonprofit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Eng.
	Street sweeping & storm sewer mgt.	-								●	●	●	●		●			●		●	●	●					●			
	Trees/native plants	-			-					●	●	●	●		●		●						●				●		●	
	Snow pile management		-							●		●	●					●		●	●									
	Permeable pavement for new construction	-	-							●		●	●		●					●	●									
	Construction site erosion control	X	X	-	X		-			●		●	●					●		●	●	●								
SSTS	Maintenance and replacement/upgrades			X	X	X		●		●		●	●	●	●			●		●	●	●	●	●	●	●	●			
Feedlots	Feedlot runoff controls including: buffer strips, clean water diversions, etc. on feedlots with runoff			X	X	X		●	●		●			●	●		●	●	●	●		●		●	●	●	●	●		
Streams, ditches, & ravines	Protect and restore buffers, natural features	X	X	X			X	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●			●	●		
	Reduce or eliminate ditch clean-outs	X		X			X	●					●		●	●	●	●		●			●	●						
	Bridge/culvert design	X	X				X										●			●	●		●							●
	Streambank stabilization	X		X	X		-	●	●		●		●	●	●	●	●			●	●		●	●			●	●		
	Ravine/stream (grade) stabilization	X		X	X			●	●		●		●	●	●	●	●			●	●		●	●			●	●		
	Stream channel restoration and floodplain reconnection	X		X	X		X	●	●		●		●	●	●	●	●			●	●		●	●			●	●		●
Lakes & Wetlands	Near-water vegetation protection and restoration	X		X	X		X	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	In-water management and species control			X	-		X			●	●	●			●		●	●		●		●	●	●			●		●	
Grassland & Forest	Protect and restore areas in these land uses, increase native species populations	X	-	X	X		X	●	●	●	●		●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	

[a] **Table 18** includes additional information regarding specific restoration and protection strategies.

[b] "X" – strong benefit to water quality improvement as related to the specified parameter, "-" – moderate benefit to water quality as related to the specified parameter, blank – little benefit to water quality as related to the specified parameter.

Table 18: Additional information for restoration and protection strategies.

Parameter	Strategy key	
	Description	**Example BMPs/actions**
Total Suspended Solids (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

Parameter	Strategy key	
	Description	Example BMPs/actions
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology and 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 and post-harvest
		Location and 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
Total 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 and 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).

Parameter	Strategy key	
	Description	**Example BMPs/actions**
Total 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 and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	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. 7020 rules
		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 7020 rule 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.

Parameter	Strategy key	
	Description	**Example BMPs/actions**
	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

Parameter	Strategy key	
	Description	**Example BMPs/actions**
Chloride	Road salt management	See strategies in the *Twin Cities Metro Area Chloride Management Plan* (MPCA, 2016)
Altered hydrology; peak flow and / or low baseflow (Fish / Macroinvert. 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 and buffers of native grass and 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 / Macroinvert. 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 waterbodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
		Retrofit dams with multi-level intakes

Parameter	Strategy key	
	Description	**Example BMPs/actions**
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	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)	**Remove 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

4. Monitoring plan

It is the intent of the implementing organizations in this watershed to make steady progress improving water quality. Accordingly, as a very general guideline, progress benchmarks are established for this watershed that assume improvements will occur resulting in pollutant reductions and less stress to aquatic life each year as identified in **Section 3.3**. Factors that may lead to slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species), and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

Across the WRRW, improvement is assumed to occur at a rate of 0.5% to 1% improvement (reduction or increase) per year. For instance, if the overall TP reduction goal is 13% and the 10-year reduction goal is a 5% reduction, the ideal load reduction for year one would be a 0.5% reduction, with equivalent reductions occurring year over year. However, subregions within the watershed will differ with local water quality and flood control needs advancing strategies at a different rate. Planning regions identified within the 1W1P coincide with WRWD planning efforts. Ongoing projects reflect those local needs in conjunction with other regional goals such as achieving the 20% reduction of the 100-year main stem peak flow in the Red River of the North (BWSR and JOR Engineering, Inc., 2004).

Progress toward water quality goals can be monitored and compared against modeled results from an existing HSPF – SAM study (**Appendix D**). HSPF-SAM was used to estimate improvements in water quality based on three scenarios representing different levels of BMP implementation. Scenario 1 represented the most conservative implementation effort (suggesting slower progress toward water quality goals), Scenario 2 represents moderate implementation effort, and Scenario 3 represents aggressive implementation of BMPs (suggesting more rapid progress toward water quality goals). The greatest return in nutrient and sediment load reduction occurs in Scenario 1, with load reduction increasing by only a few percent for both Scenarios 2 and 3. This is indicative that the greatest overland sources are being reduced through the implementation of priority CPs.

The foundation of effective water quality monitoring is the collection and analysis of water samples. Although the historical water quality measurement record for the WRRW dates back to 1962, the available data is sparse, both spatially and temporally. The WRRW WRAPS focuses on the 10-year assessment period (2006 through 2015). During the final years of the WRAPS assessment period (2014 through 2015), an IWM program was performed to fill in several data gaps. In spite of this effort, more data is still needed to initially assess impairment within a majority of waterbodies in the watershed. Continued monitoring efforts for streams and lakes within the WRRW will facilitate greater assessment and protection of them throughout the region in the future.

Stream monitoring within the WRRW will continue primarily through the efforts of the Wild Rice Watershed District and the MPCA. As outlined in the Section 5.2.3 of the WRWD WMP, the WRWD has established current and future monitoring goals for water quality throughout the watershed. This effort is aimed at collecting current measurements of water quality parameters and building a more robust data set for analyzing long-term trends in water quality within the watershed. This includes the District's involvement in the River Watch program, which involves citizens in monitoring local waterbodies.

In addition to the stream monitoring supported by the WRWD, the MPCA also has ongoing monitoring in the watershed in the form of three water quality monitoring programs with the purpose of collecting data to create a long-term data set to track progress towards water quality goals and enable water quality condition assessments to be completed. These programs will continue to collect and analyze data in the WRRW as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA, 2011; MPCA, 2021). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. The three monitoring programs are the IWM Program, Watershed Pollutant Load Monitoring Network, and Citizen Stream and Lake Monitoring Program.

Intensive Watershed Monitoring (IWM) (MPCA, 2020) data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at stream monitoring stations across the watershed for a period of 2 years, on a 10-year cycle. The most recent IWM occurred in 2014 and 2015. To measure pollutant trends and conditions across the watershed, the MPCA will re-visit and re-assess the watershed, as well as monitor new sites in areas of interest. This work is scheduled to start its second iteration in the WRRW in 2025.

Watershed Pollutant Load Monitoring Network (MPCA, 2021) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the WRRW, there are four load monitoring sites: E60112001 (Wild Rice River by Hendrum), E60088001 (Wild Rice River by Twin Valley), H60029001 (Wild Rice River near Mahnomen), and E60124001 (South Branch Wild Rice River near Felton).

Citizen Stream and Lake Monitoring Program (MPCA, 2021) data provide a continuous record of waterbody transparency throughout much of the watershed. This program, much like the District River Watch Program, relies on a network of private citizen volunteers who make monthly lake and river measurements. There are currently 14 stations (7 in lakes and 7 in streams) in the WRRW where citizen volunteers collect transparency data.

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Wild Rice River Watershed Reports

All Wild Rice River Watershed reports produced for this WRAPS project are available at MPCA's Wild Rice River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/wild-rice-river

6. Appendices

Appendix A: Nearly/barely impaired analysis

Based on a technical memorandum by Houston Engineering, Inc. (HEI) that was provided to MPCA on August 6, 2019.

Introduction

All lakes and streams currently supporting aquatic life and aquatic recreation in the WRRW are candidates for protection. Over time, these waters could be subjected to land uses or stressors that could cause them to become impaired. Watershed managers and stakeholders should seek opportunities to identify and implement protection strategies on all unimpaired waterbodies. For streams 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 BWSR Nonpoint Priority Funding Plan for Clean Water Funding Implementation (BWSR, 2018) and Minnesota's Clean Water Roadmap (Minnesota Interagency Team, 2014). For this reason, assessed streams are designated as either “protection” or “restoration” based on water quality data. Once designated as protection or restoration, 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 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.

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 MPCA staff developed in the course of formulating the state's lake water quality standards. 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.

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the north-central and northeastern parts of the state. The WRRW is no different within the NCLF ecoregion, because it includes several lakes with water quality that well-exceeds the standard. 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 and/or restoration strategies for impaired waters and protection strategies for unimpaired waters. **Table A-1** lists the protection status of the WRRW's assessed lakes and their 'Priority Class', based on analyses of phosphorus sensitivity and lake risk. Data used to create the table was sourced from the *Lakes of Phosphorus Sensitivity Significance* GIS data layer (DNR, 2021).

Table A-1: Prioritization summary for lakes in the Wild Rice River Watershed based on total phosphorus risk (DNR, 2021).

Lake (DNR ID)	Eco-region	Depth class	AQL / AQR impaired (Y/N)?	TP standard (µg/L)	Current condition (µg/L) [a]	Target mean TP (µg/L) [b]	Target TP load reduction (lbs/yr) [c]	Priority class [d]
Big Rat (03-0246-00)	NLF	Shallow	N	30	26.5	13	486	High
Strawberry (03-0323-00)	NLF [e]	Deep	N	30	16.2	12	306	Higher
White Earth (03-0328-00)	NCHF	Deep	N	40	9.4	9.4	821	Higher
Rustad (03-0653-00)	LAP [f]	Shallow	N	60	180	141	204	High
Tilde (14-0004-00)	LAP [f]	Shallow	N	60	32.2	35	27	Highest
Upper Rice (15-0059-00)	NLF	Deep	N	30	22.1	20	131	Highest
Rockstad (15-0075-00)	NLF	Shallow	Y	30	54.6	38	134	Impaired
Minerva (15-0079-00)	NLF	Deep	N	30	28.6	27	47	Highest
McKenzie (15-0124-00)	NLF	Shallow	N	30	15.9	15	37	High
Waptus (15-0128-00)	NLF	Deep	N	30	11.9	11	85	High
Jackson (15-0131-00)	NLF	Shallow	N	30	10.2	8.0	8.4	Higher
Roy (44-0001-00)	NLF	Deep	N	30	26	25	89	Highest
Tulaby (44-0003-00)	NLF	Deep	Y	30	32.5	27	70	Impaired
Bass (44-0006-00)	NLF	Deep	N	30	16.1	15	28	Higher
South Twin (44-0014-00)	NLF	Deep	N	30	14.5	13	105	Higher
North Twin (44-0023-00)	NLF [e]	Shallow	N	30	18.4	14	421	High
Island (44-0038-00)	NCHF	Deep	N	40	34.1	33	104	Highest
Snider (44-0045-00)	NLF [e]	Deep	N	30	24	16	461	High

Lake (DNR ID)	Eco-region	Depth class	AQL / AQR impaired (Y/N)?	TP standard (µg/L)	Current condition (µg/L) [a]	Target mean TP (µg/L) [b]	Target TP load reduction (lbs/yr) [c]	Priority class [d]
McCraney (44-0080-00)	NCHF [e]	Deep	N	40	10.4	9.0	155	High
Aspinwall (44-0223-00)	NCHF [e]	Shallow	N	60	31	24	59	Highest
Chief (44-0224-00)	NCHF [e]	Shallow	N	60	43	34	11	Higher
Beaulieu (44-0242-00)	LAP [f]	Shallow	N	60	60	47	303	High

[a] Values are those that MPCA used to compare (or attempt a comparison) against standards for assessments in early 2016.

[b] This was calculated as the difference between the predicted load and target load.

[c] Calculated independently of the TP standard, as it is based on an estimate of the 25th percentile of the summer mean TP concentration.

[d] Priority classes are High, Higher, and Highest for unimpaired lakes.

[e] The lake is located within 2 ecoregions, but only one is listed, because the standards of that ecoregion were used for MPCA assessments.

[f] The lake is located completely within the LAP ecoregion (i.e., Red River Valley), but standards of the NCHF ecoregion were used for MPCA assessments.

Streams

Stream reaches were prioritized and classified into Protection or Restoration classes based on existing water quality data. 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 and restoration categories

Stream protection and restoration categories were determined based on 10 years of water quality data from 2007 through 2016 for five parameters: DO, TSS, TP, nitrogen (N), and *E. coli*. The lower limit on the number of samples required for this analysis is five for DO, TSS, TP, and N and three in a given month for *E. coli*. This is lower than what is required for MPCA to assess streams against state standards in order to categorize more stream reaches and parameters into protection/restoration subcategories. Depending on the parameter, there may be further limitations and requirements for assessments that were not considered for this analysis (which also allowed for more streams and parameters to be categorized). The standard (i.e., concentration) for each parameter that are used for assessments are the same ones used for this analysis. However, while the nitrogen-related parameter assessed by MPCA in Class 2 surface waters in early 2016 was ammonia (NH_3), this nearly/barely analysis used inorganic nitrogen (nitrate) and its standards of 10 mg/L, which MPCA uses to assess drinking water in Class 1B and 1C surface waters.

The following is a sampling of some of the limitations and requirements needed for MPCA assessments. Class 2 stream assessments require 12 (for TP) or 20 (for DO and TSS) samples over two years and at least five samples in a given month for *E. coli*. Determining whether an impairment caused by eutrophication is present requires assessment of not only TP, but response parameters as well (Chl-*a*, BOD_5, diel DO flux, and/or pH levels). For MPCA's drinking water assessments in Class 1B and 1C waters, instead of a minimum number of samples being required for assessment against state standards for nitrate nitrogen, samples collected within the same 24-hour period are averaged; a stream is listed as impaired if the nitrate nitrogen average of 2 or more 24-hour periods over 3 years exceed the standard.

Due to there being so many differences between methods used for this analysis and those used for assessments, 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 classification are provided below, followed by maps of the stream classifications by water quality parameter (**Figure A-1** for Above Average Quality, **Figure A-2** for Potential Impairment Risk, **Figure A-3** for Threatened Impairment Risk, **Figure A-4** for Low Restoration Effort, and **Figure A-5** for High Restoration Effort) and a list of classifications in **Table A-2**.

Protection categories

All streams currently supporting aquatic life and aquatic recreation 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 analysis, streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk.

Above Average Quality

A reach of a stream (i.e., Assessment Unit Identification Number [AUID]) is exhibiting Above Average Quality for a water quality parameter if one of the following conditions are met:

1. The data requirements of MPCA assessment methods are met, there is no impairment, and the 90th percentile (TSS, DO), average (TP, N), or the geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), no samples exceed the numeric water quality standard, and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard.

Surface waters exhibiting Above Average Quality for one (or more) water quality parameter are shown in **Figure A-1**. **Table A-2** lists the water quality parameters classified as Above Average Quality by AUID.

Potential Impairment Risk

An AUID is exhibiting Potential Impairment Risk for a water quality parameter if water quality conditions are "near" but not exceeding the numeric water quality standard as determined by meeting one of the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, N), or the geometric mean (*E. coli*) of concentrations equals or exceeds 75% but is less than 90% of the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, N),

or geometric mean (*E. coli*) of concentrations equals or exceeds 75% of the numeric water quality standard but is less than 90% of the numeric water quality standard.

Surface waters exhibiting Potential Impairment Risk for one (or more) water quality parameter are shown in **Figure A-2**. **Table A-2** lists the water quality parameters classified as Potential Impairment Risk by AUID.

Threatened Impairment Risk

An AUID is exhibiting Threatened Impairment Risk for a water quality parameter if water quality conditions are "very near", and which periodically exceed, the numeric water quality standard as determined by meeting at least one the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations equals or exceeds 90% but is less than the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations equals or exceeds 90% of the numeric water quality standard but is less than the numeric water quality standard.

Surface waters exhibiting Threatened Impairment Risk for one (or more) water quality parameter are shown in **Figure A-3**. **Table A-2** lists the water quality parameters classified as Threatened Impairment Risk by AUID.

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 were discussed previously in the main body of the *Wild Rice River WRAPS Report*.

Restoration categories

AUIDs in the "restoration" categories fail to achieve some minimum threshold water quality condition. Example minimum threshold conditions include failure to achieve numeric water quality standards or a condition considered degraded or unstable such as areas of accelerated streambank erosion, which can further contribute to degradation of water quality. The restoration category is further divided into two subcategories: Low Restoration Effort and High Restoration Effort.

Low Restoration Effort

Low Restoration Effort is defined as a degraded condition, but a condition near the designated minimum threshold, for a given parameter. An example is an AUID where the numeric water quality standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard for the parameter as determined by meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met, there is an impairment, and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard; or

2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli* and TP) and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard.

Surface waters exhibiting Low Restoration Effort for one (or more) water quality parameter are shown in **Figure A-4**. **Table A-2** lists the water quality parameters classified as Low Restoration Effort by AUID.

High Restoration Effort

High Restoration Effort AUIDs are degraded and are no longer near the designated threshold for a given parameter. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. Classifying a parameter for an AUID as High Restoration Effort is contingent on meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met, there is an impairment, and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations equals or exceeds 125% of the water quality standard.
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*) and the 90th percentile (TSS, DO), average (TP, N), or geometric mean (*E. coli*) of concentrations equals or exceeds 125% of the water quality standard or 25% of those samples exceed the water quality standard.

Surface waters exhibiting High Restoration Effort for one (or more) water quality parameters are shown in **Figure A-5**. **Table A-2** lists the water quality parameters classified as High Restoration Effort by AUID.

Figure A-1: Streams reaches with at least one water quality parameter in the protection category: above average quality.

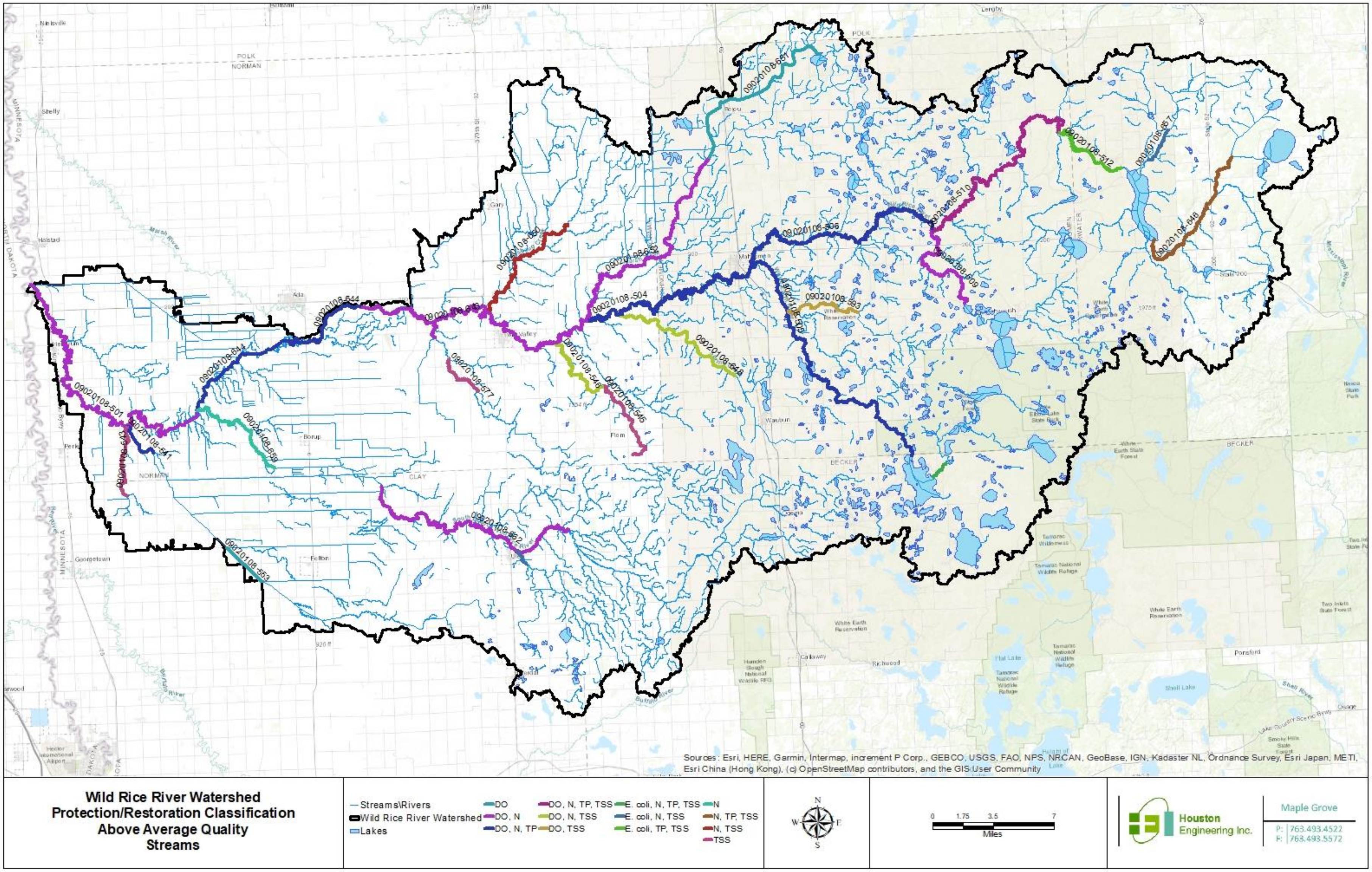


Figure A-2: Streams reaches with at least one water quality parameter in the protection category: potential impairment risk.

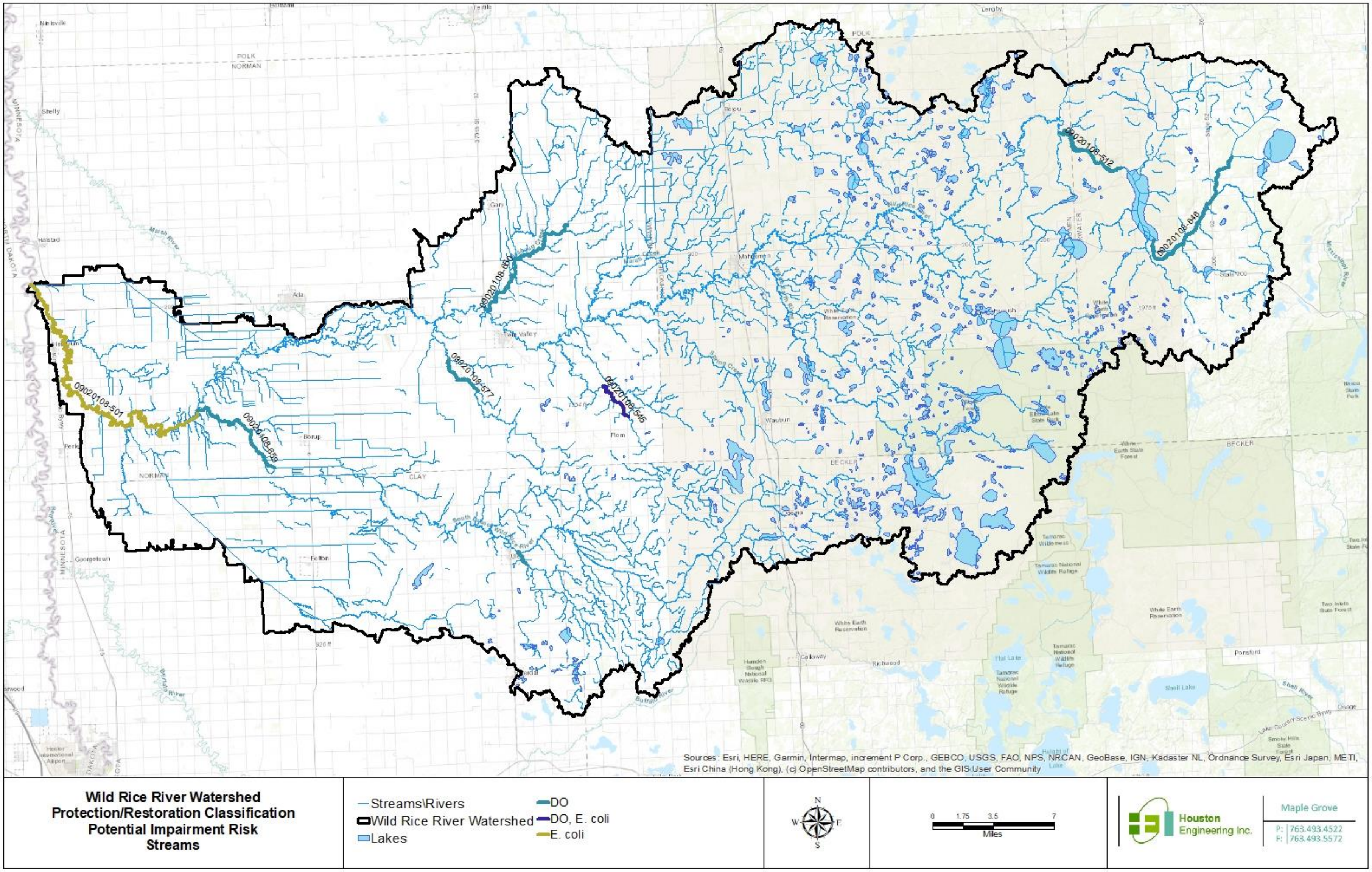


Figure A-3: Streams reaches with at least one water quality parameter in the protection category: threatened impairment risk.

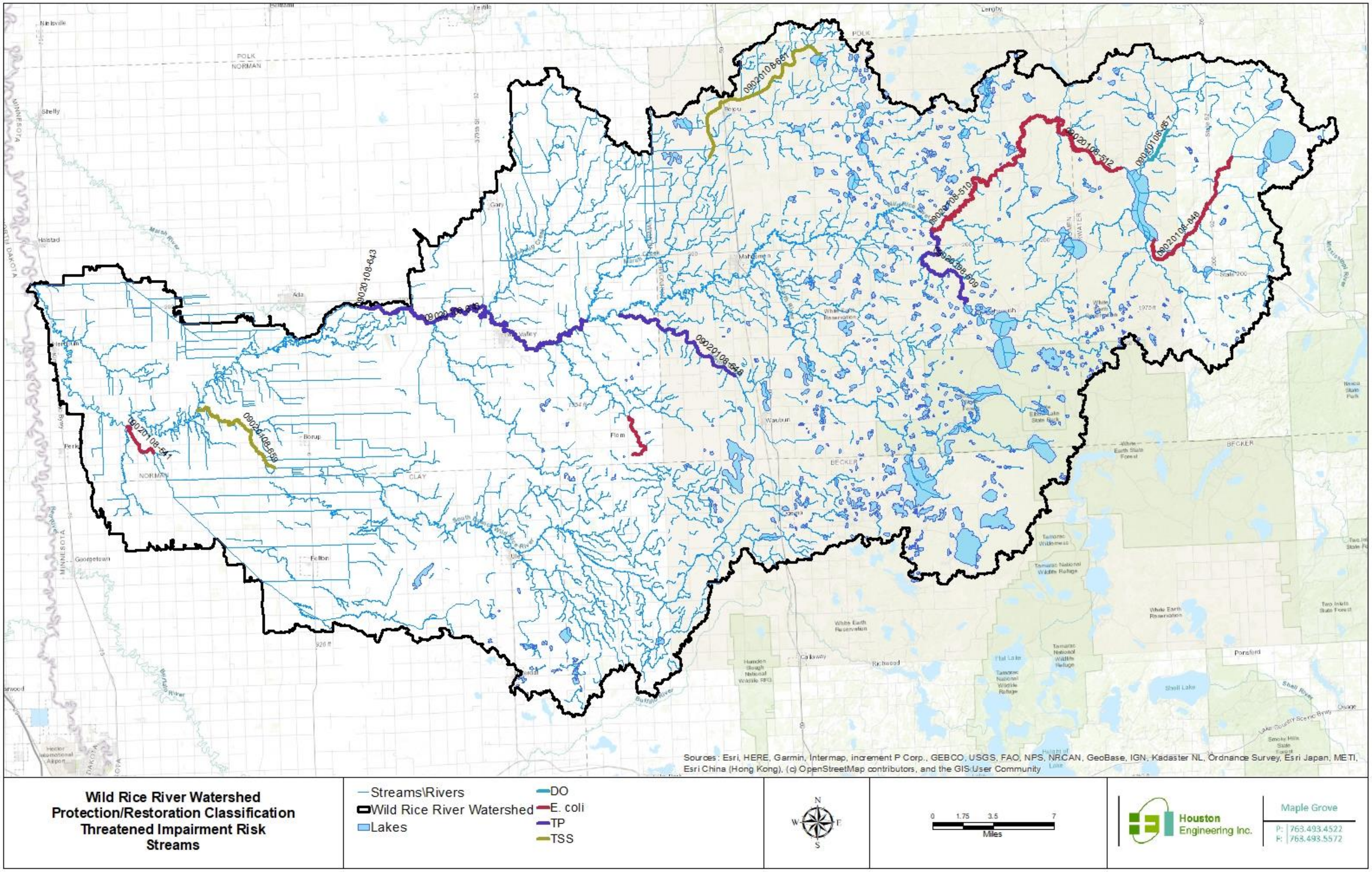


Figure A-4: Streams reaches with at least one water quality parameter in the restoration category: low restoration effort.

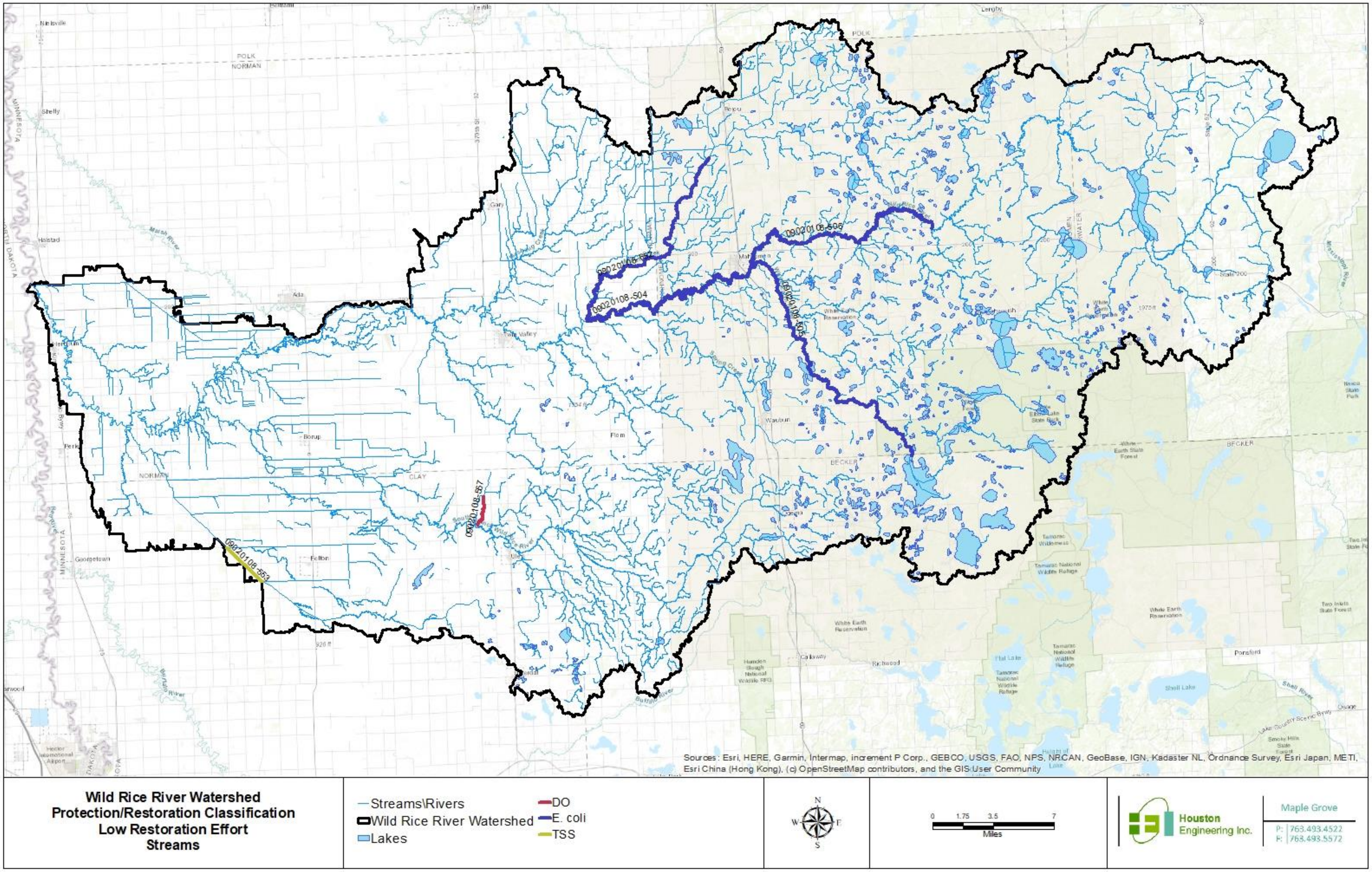


Figure A-5: Streams reaches with at least one water quality parameter in the restoration category: high restoration effort

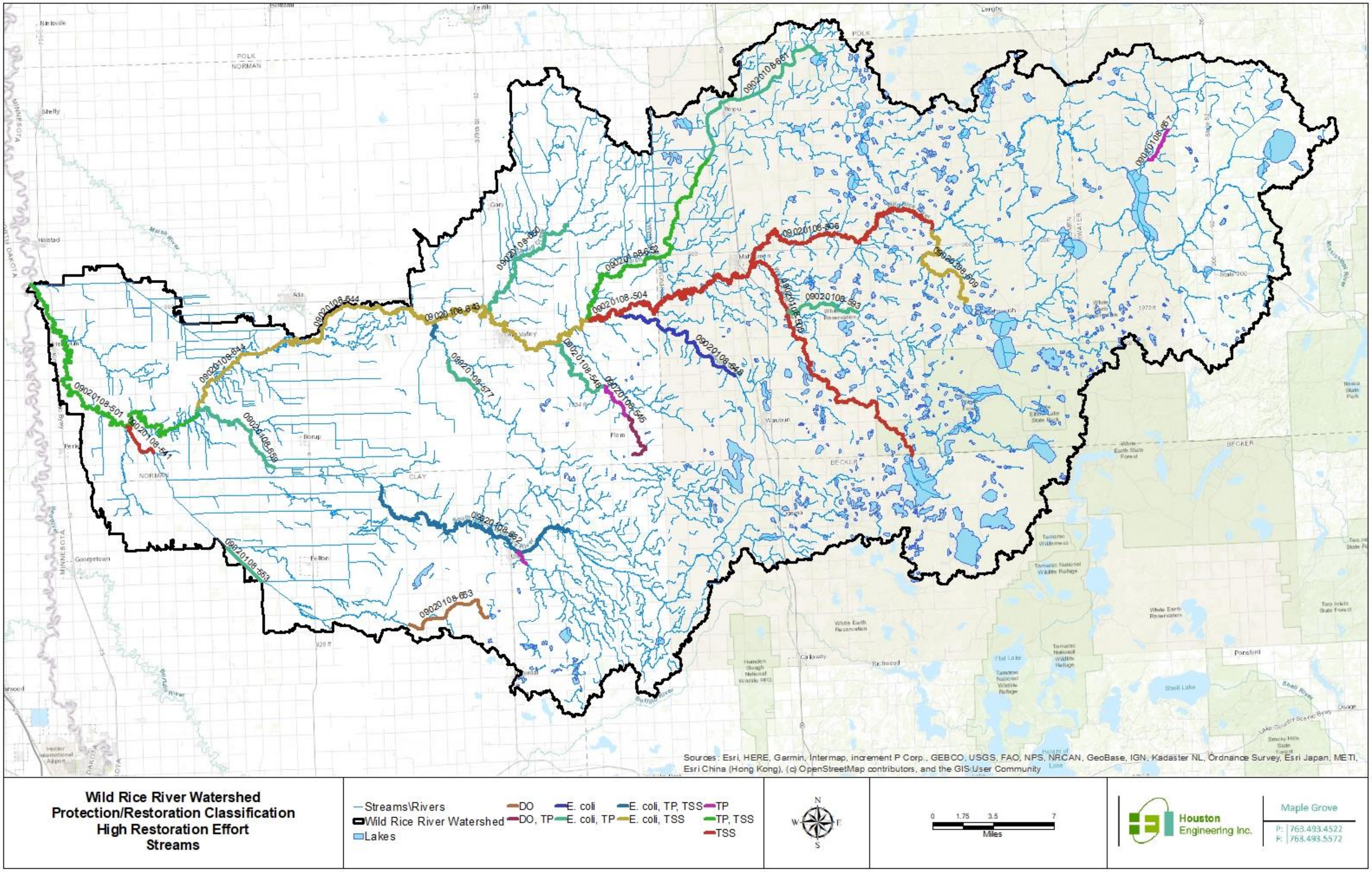


Table A-2: Protection and restoration categorization of streams reaches in the Wild Rice River Watershed.

AUID (last 3 digits)	Stream name (reach description [a])	Protection			Restoration	
		Above Average Quality	Potential Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
501	Wild Rice River (S Br Wild Rice R to Red R of the N)	DO, N	*E. coli*			TP, TSS
504	Wild Rice River (White Earth R to Marsh Cr)	DO, N, TP			*E. coli*	TSS
505	White Earth River (White Earth Lk to Wild Rice R)	DO, N, TP			*E. coli*	TSS
506	Wild Rice River (Twin Lake Cr to White Earth R)	DO, N, TP			*E. coli*	TSS
509	Twin Lake Creek (Sargent Lk to Wild Rice R)	DO, N		TP		*E. coli*, TSS
510	Wild Rice River (Roy Lake Cr to Twin Lake Cr)	DO, N, TP, TSS		*E. coli*		
512	Wild Rice River (Lower Rice Lk to Roy Lake Cr)	*E. coli*, TP, TSS	DO	*E. coli*		
541	Unnamed creek (Unnamed ditch to Wild Rice R)	DO, N, TP		*E. coli*		TSS
542	Stiner Creek (Unnamed cr to S Br Wild Rice R)	*E. coli*, N, TSS	DO			TP
543	Unnamed creek (Unnamed cr to Unnamed cr)	TSS				
544	Coon Creek (Unnamed cr to Wild Rice R)	DO, N				*E. coli*, TP, TSS
545	Unnamed creek (Unnamed cr to Unnamed cr)	TSS	DO, *E. coli*			TP
546	Unnamed creek (Unnamed cr to Wild Rice R)	DO, N, TSS				*E. coli*, TP
553	County Ditch 45 (Unnamed ditch to Unnamed ditch)	DO			TSS	*E. coli*, TP
557	Unnamed creek (Unnamed ditch to S Br Wild Rice R)				DO	
565	Tulaby Creek (Tulaby Lk to McCraney Lk)					
567	Unnamed creek (McCraney Lk to Gull Cr)					
569	Gull Creek (Unnamed cr to White Earth Lk)	*E. coli*, N, TP, TSS				
577	Coon Creek (Unnamed cr to Unnamed cr)	TSS	DO			*E. coli*, TP
589	Unnamed creek (Gull Lk to McCraney Lk)					
593	Whiskey Creek (Unnamed cr to White Earth R)	DO, TSS				*E. coli*, TP
639	Unnamed creek (Headwaters to Unnamed cr)	TSS		*E. coli*		DO, TP
643	Wild Rice River (Marsh Cr to Unnamed cr)	DO, N		TP		*E. coli*, TSS
644	Wild Rice River (Unnamed cr to S Br Wild Rice R)	DO, N, TP				*E. coli*, TSS
646	Wild Rice River (Unnamed cr to Lower Rice Lk)	N, TP, TSS	DO	*E. coli*		

AUID (last 3 digits)	Stream name (reach description [a])	Protection			Restoration	
		Above Average Quality	Potential Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
648	Spring Creek (140th Ave to Wild Rice R)	DO, N, TSS		TP		*E. coli*
650	Mashaug Creek (T-92 to Wild Rice R)	N, TSS	DO			*E. coli*, TP
651	Marsh Creek (Beaulieu Lk to -95.9973 47.4054)	DO		TSS		*E. coli*, TP
652	Marsh Creek (-95.9973 47.4054 to Wild Rice R)	DO, N			*E. coli*	TP, TSS
653	Felton Creek / County Ditch 19 (Headwaters [Unnamed lk 14-0082-00] to 200th St)					DO
657	Mosquito Creek (Unnamed cr to Unnamed cr)	*E. coli*, N, TSS		DO		TP
659	South Branch Wild Rice River (T-246 to Wild Rice R)	N	DO	TSS		*E. coli*, TP
660	South Branch Wild Rice River (Otto Lk to -96.1406 47.0658)					
662	South Branch Wild Rice River (Unnamed cr to Unnamed cr)	DO, N				*E. coli*, TP, TSS

DO = dissolved oxygen, *E. coli* = *Escherichia coli*, N = nitrogen, TP = total phosphorus, and TSS = total suspended solids.

[a] Ave = Avenue, Br = Branch, cr/Cr = creek/Creek, lk/Lk = lake/Lake, N = North, R = River, St = Street, S = South, W = West.

Appendix B: HSPF priority maps

Based on a technical memorandum by Houston Engineering, Inc. (HEI) that was provided to MPCA on March 26, 2018.

Introduction

Using results from the WRRW/MRW HSPF model, areas within the WRRW were prioritized 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), TP, TN, and TS. Prioritization is based solely on the potential mass leaving the landscape; considerations of other factors across the landscape (e.g., existing BMPs, travel time) could change the outcome of prioritizations.

The HSPF model

The HSPF model combines both the WRRW and MRW into one model and will be referred to as the WRRW/MRW HSPF model for the remainder of this document. In the HSPF model, a watershed is divided into "model segments", usually called hydrozones, based on the location 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 feature (lake, reservoir, or stream reach). 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 differs between subwatersheds based on differing acreage of each PERLND/IMPLND type.

The WRRW/MRW HSPF model is composed of 11 modeling segments (**Figure B-1**), or hydrozones, with 10 covering the WRRW and 3 covering the MRW (2 of the hydrozones span both watersheds). The model is further divided into 172 subwatersheds with 144 subwatersheds in the WRRW and 28 in the MRW. Each modeling segment, and therefore subwatershed, is divided by up to 10 land use/soil classes (PERLNDs), or land segments, and one impervious land segment class (IMPLND), for a total of 120 possible land segments in the HSPF model (see **Figure B-2**). The land segment classes include urban, forest-low runoff potential (A/B soils), forest-high runoff potential (C/D soils), cropland-high till, cropland- low till, pasture-low runoff potential (A/B soils), pasture-high runoff potential (C/D soils), grasslands-low runoff potential (A/B soils), grassland-high runoff potential (C/D soils), and wetland. Cropland-high till and cropland- low till are jointly represented as cropland in **Figure B-2**).

Figure B-1: Hydrozones of the Wild Rice River Watershed/Marsh River Watershed HSPF model.

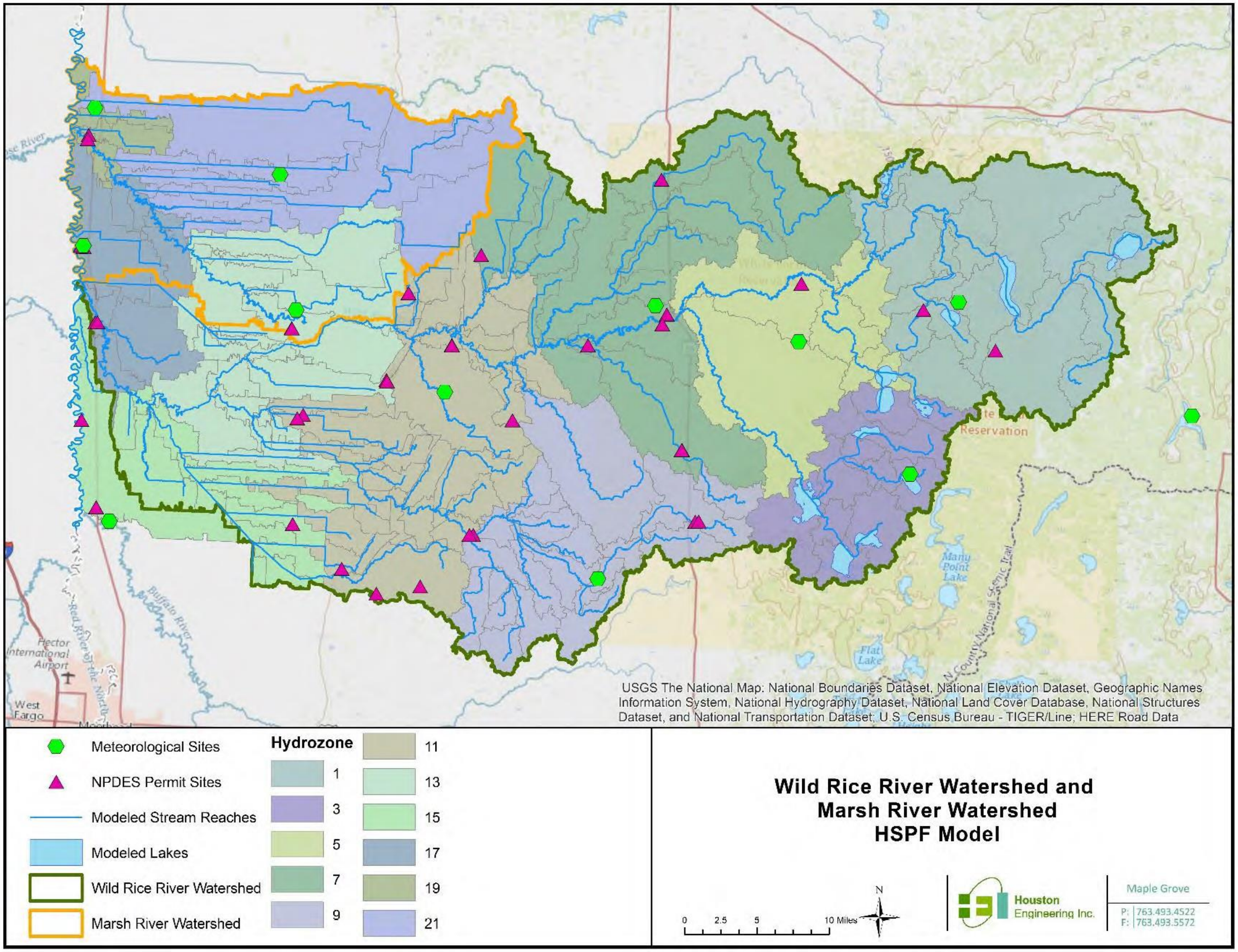
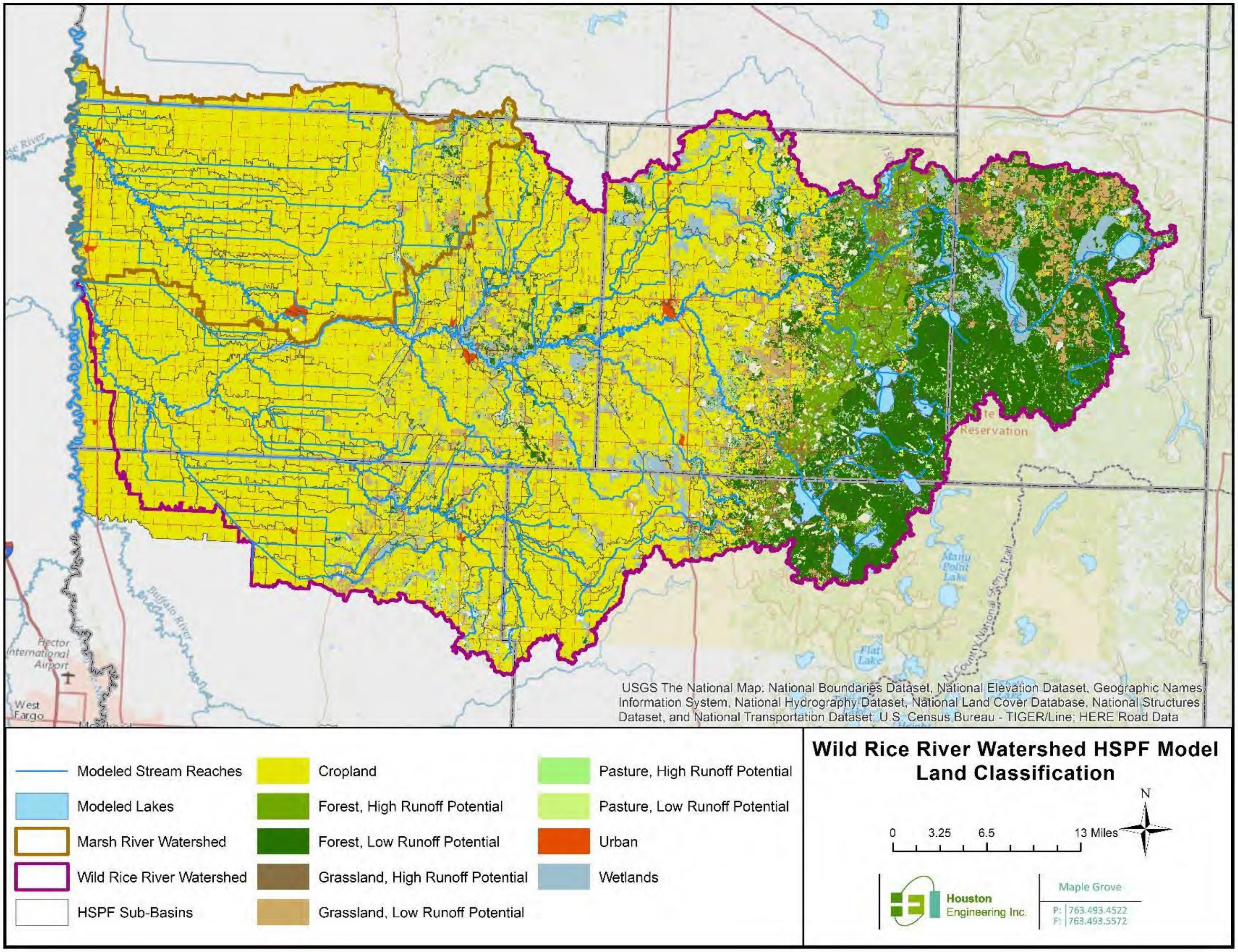


Figure B-2: Land classifications (pervious lands [PERLNDs] / impervious lands [IMPLNDs]) in the Wild Rice River Watershed/Marsh River Watershed HSPF model.



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 (TS). **Supplementary Table B-1** shows the required outputs, by constituent and land class (PERLND, IMPLND, or RCHRES), in the HSPF model. The following is a brief description of the components used to develop the maps and shown in **Supplementary Table B-1.**

In an HSPF model, 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 the output. 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 is 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 are used for surface runoff, interflow, and active groundwater flow (see **Supplementary Table B-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 (NH_3), nitrate-nitrite (NO_2-NO_3), and organic nitrogen loadings. NH_3 and NO_2-NO_3 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 **Supplementary Table B-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 TS 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.

Developing subwatershed priority maps using yields

The prioritization of subwatersheds occurred at two scales, the entire watershed and major tributary (see **Figure B-19**). Prioritization at multiple scales is necessary because the results change depending upon the location of the impaired resource in the watershed. Prioritization maps were generated using results extracted from the WRRW/MRW HSPF model for the period of 1996 through 2009. Average yields and loads were extracted, summarized, and used to generate the prioritization maps. Prioritization maps were developed for unit RO, TP, TN, and TS based on related stressors used in the SID work for biological impairments. The stressors include altered hydrology (using RO), excessive nutrients (using TN and TP), loss of habitat (using TS), and elevated turbidity (using TS).

The priority rankings maps are developed by ranking the average subwatershed yields to identify specific priority subwatersheds which should be preferentially considered for targeting fields for practice implementation. The rankings are from largest to smallest yields and are used to calculate their percentile rank. The ranks are then summarized as the lowest priority (lowest 10%), low priority (10% to 25%), moderate priority (25% to 75%), high priority (75% to 90%), and highest priority (highest 10%). The highest priority subwatersheds with the highest yields will likely benefit the most from implementation 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 WQI map was generated. The WQI (e.g., **Figure B-15**) represents the combined importance of nutrients and sediment and is estimated using:

WQI = 0.5*TS 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 priority mapping in WRRW is divided into three sections: 1) WRRW yields maps, which provides watershed-scale maps of the average yields used to develop the prioritizations maps for the landscape yields (land segment scale) and average subwatershed scale (average yields across the subwatershed or delivered to the channel); 2) WRRW prioritization mapping, which provide prioritization maps at the watershed-scale and field-stream index mapping; and 3) major tributary scale prioritization mapping, which provide prioritization maps for the drainage areas of several impaired reaches.

Wild Rice River Watershed yields

The following maps provide the yields extracted from WRRW portion of the WRRW/MRW HSPF model, including yield leaving the landscape (at the land segment or PERLND scale) (**Figure B-3** through **Figure B-6**) and yields entering the channel (at the subwatershed scale) (**Figure B-7** through **Figure B-10**). The yields leaving the landscape are the annual average yields by land segment (PERLND/IMPLND) for RO, TP, TN, and TS. The yields entering the channel (subwatershed scale) are the area-weighted average landscape yields within the subwatershed. The yield maps can be used to complete pollutant sources assessments. They show which subwatersheds are the largest sources of RO, TP, TN, and TS per area delivered to the channel (EOF). The yield maps are used to generate the prioritization maps.

Figure B-3 provides the average annual (1996 through 2009) unit RO (in/yr) yield leaving the landscape for each land segment in the HSPF model. **Figure B-4** provides the average annual (1996 through 2009) TP (lbs/ac/yr) yield leaving the landscape for each land segment in the HSPF model. **Figure B-5** provides the average annual (1996 through 2009) TN (lbs/ac/yr) yield leaving the landscape for each land segment in the HSPF model. **Figure B-6** provides the average annual (1996 through 2009) TS (lbs/ac/yr) yield leaving the landscape for each land segment in the HSPF model. **Figure B-7** provides the average annual (1996 through 2009) unit RO (in/yr) yield entering the channel for each subwatershed in the HSPF model. **Figure B-8** provides the average annual (1996 through 2009) TP (lbs/ac/yr) yield entering the channel for each subwatershed in the HSPF model. **Figure B-9** provides the average annual (1996 through 2009) TN (lbs/ac/yr) yield entering the channel for each subwatershed in the HSPF model. **Figure B-10** provides the average annual (1996 through 2009) TS (lbs/ac/yr) yield entering the channel for each subwatershed in the HSPF model.

The numeric values extracted from HSPF for each land segment and subwatershed used to develop the yield maps are provided in **Supplementary Table B-2.**

Figure B-3: Average (1996 through 2009) unit runoff (of water) leaving the landscape from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

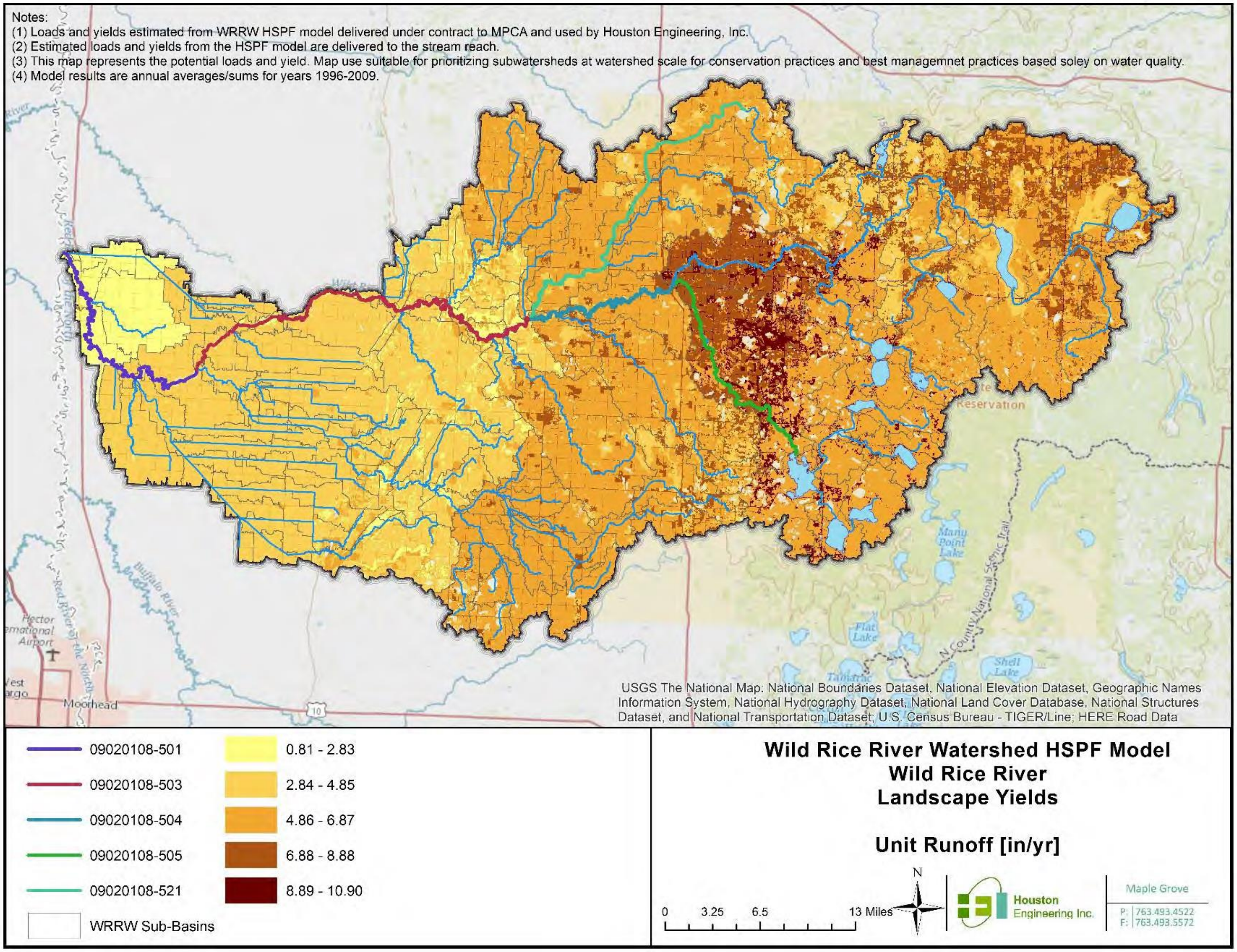


Figure B-4: Average (1996 through 2009) total phosphorus yield leaving the landscape from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

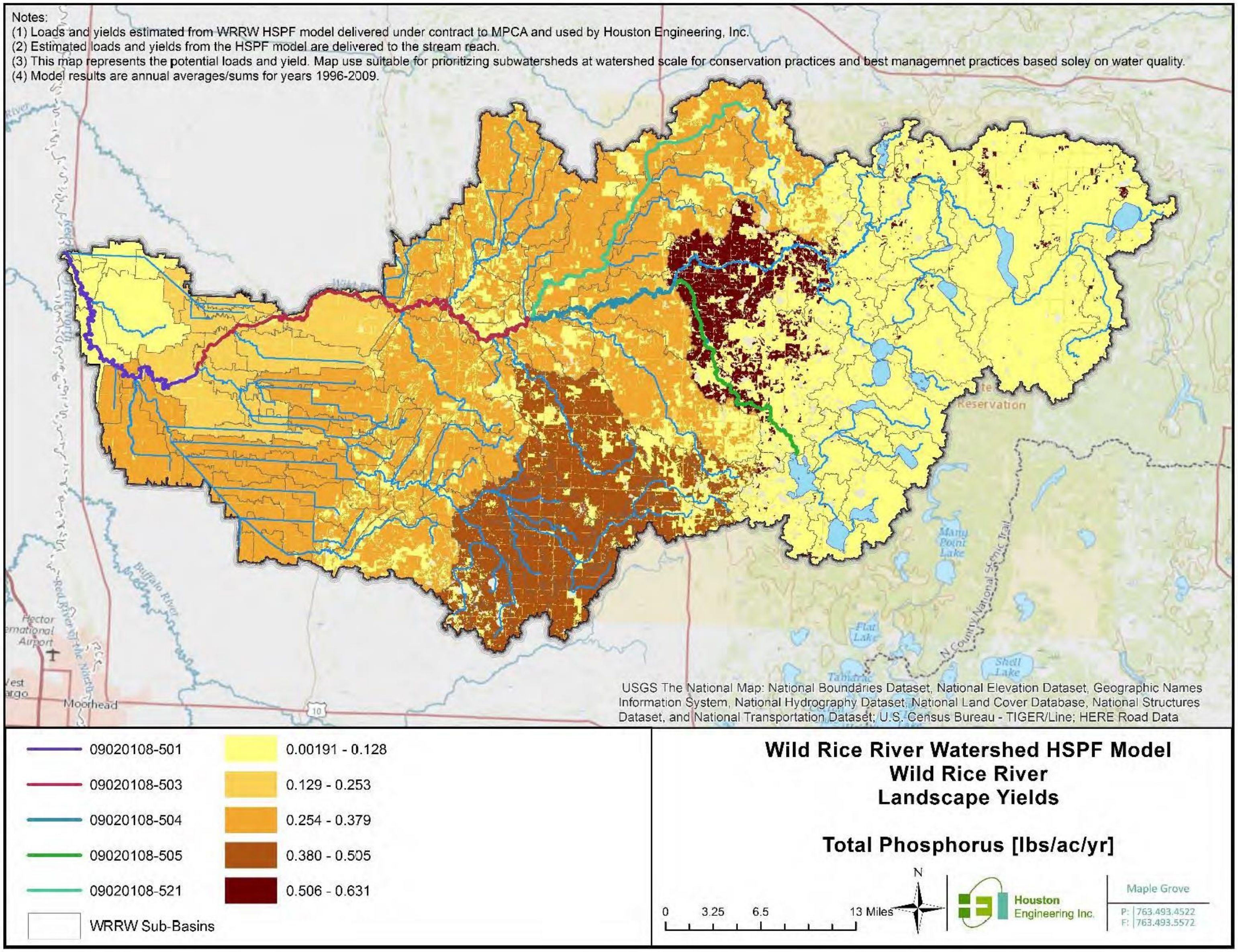


Figure B-5: Average (1996 through 2009) total nitrogen yield leaving the landscape from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

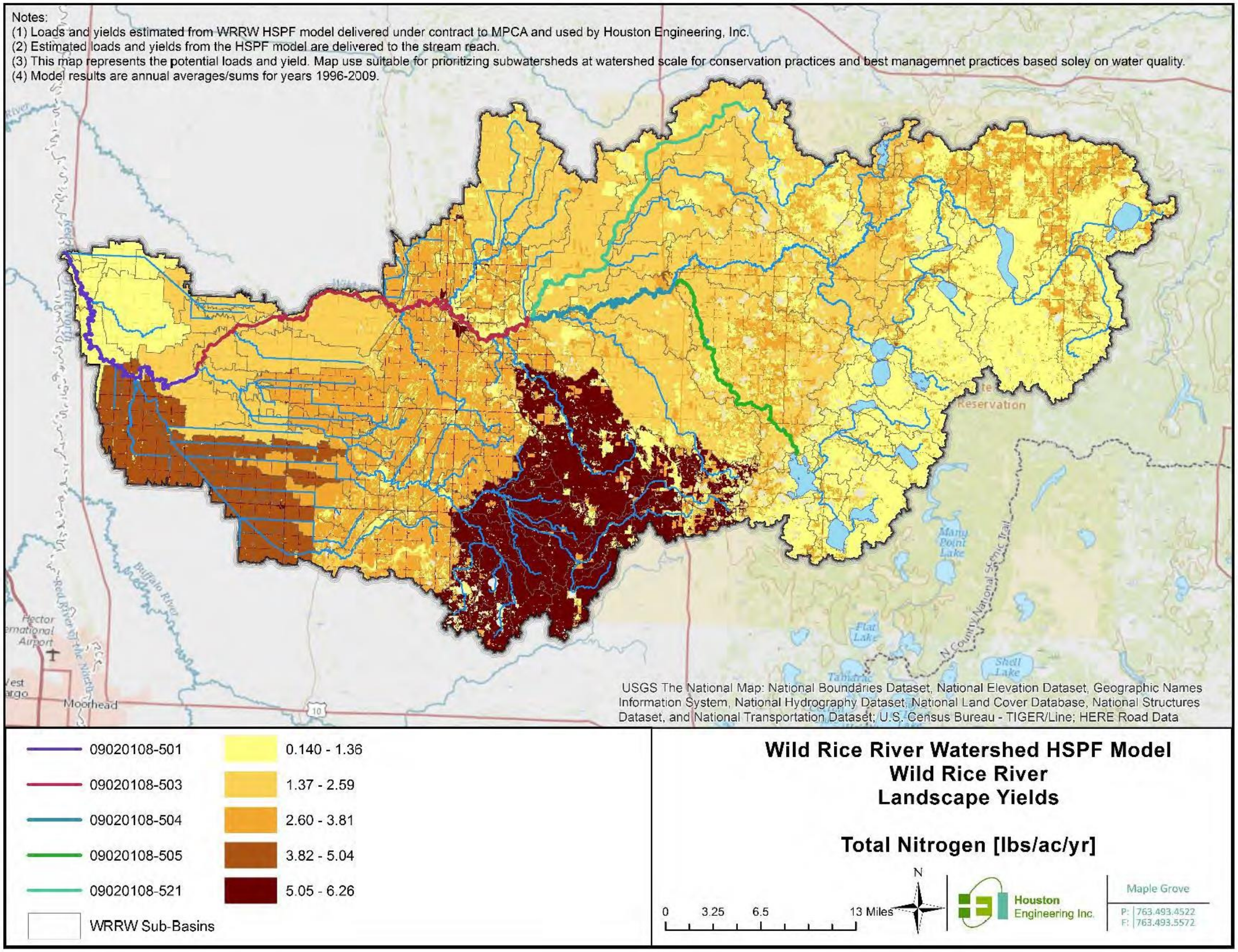


Figure B-6: Average (1996 through 2009) total sediment yield leaving the landscape from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

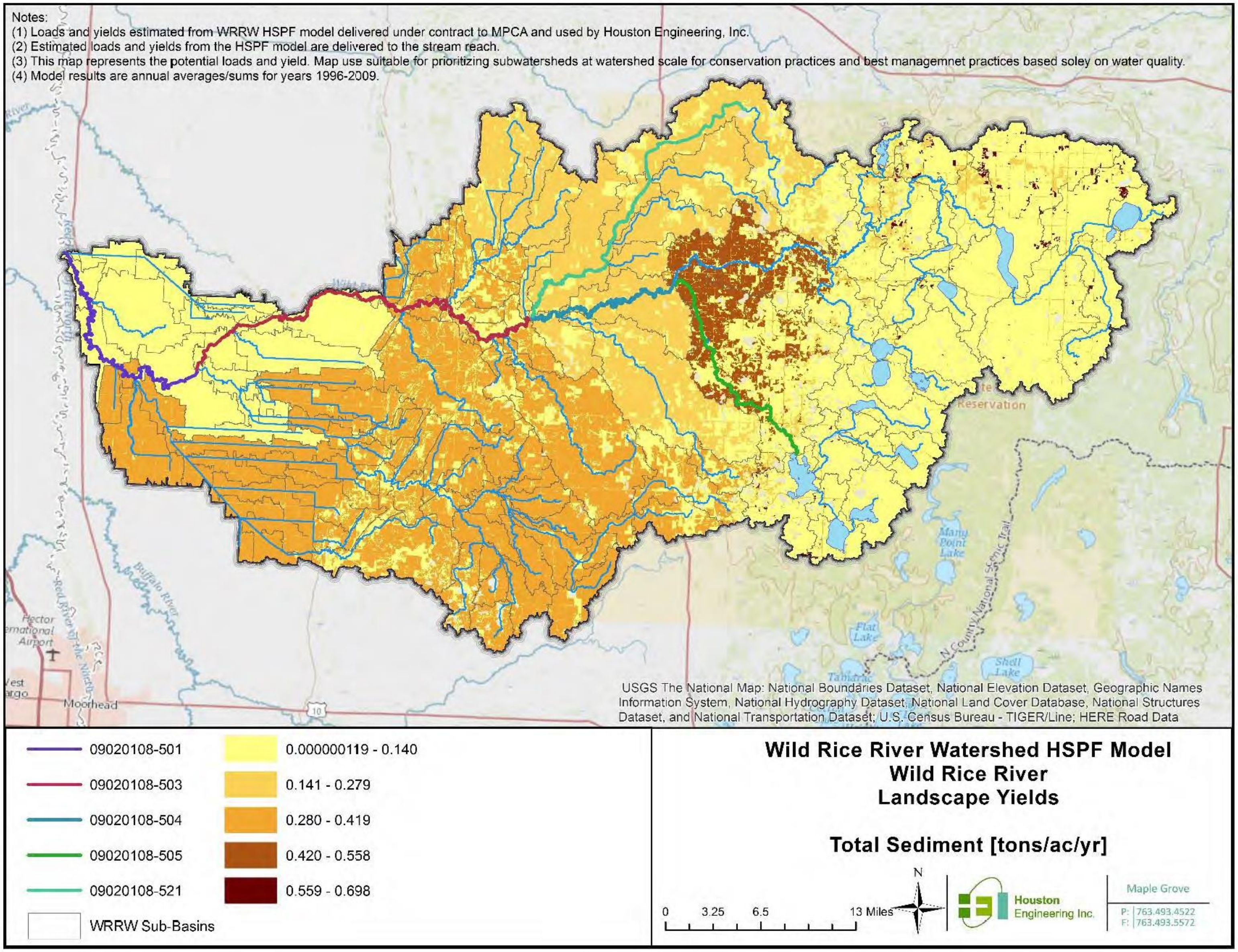


Figure B-7: Average (1996 through 2009) unit runoff (of water) delivered to the channel by subwatershed from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

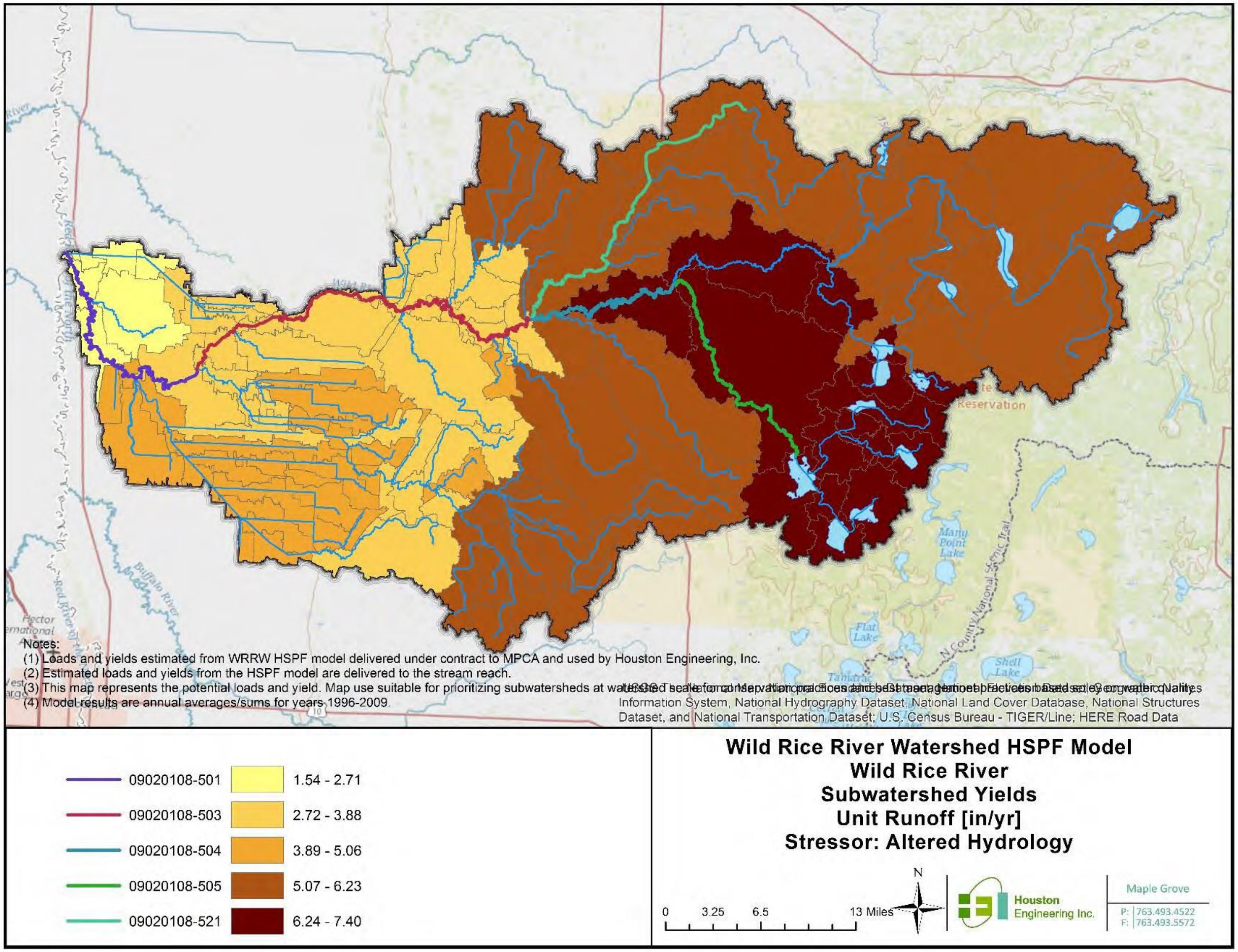


Figure B-8: Average (1996 through 2009) total phosphorus yield delivered to the channel by subwatershed from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

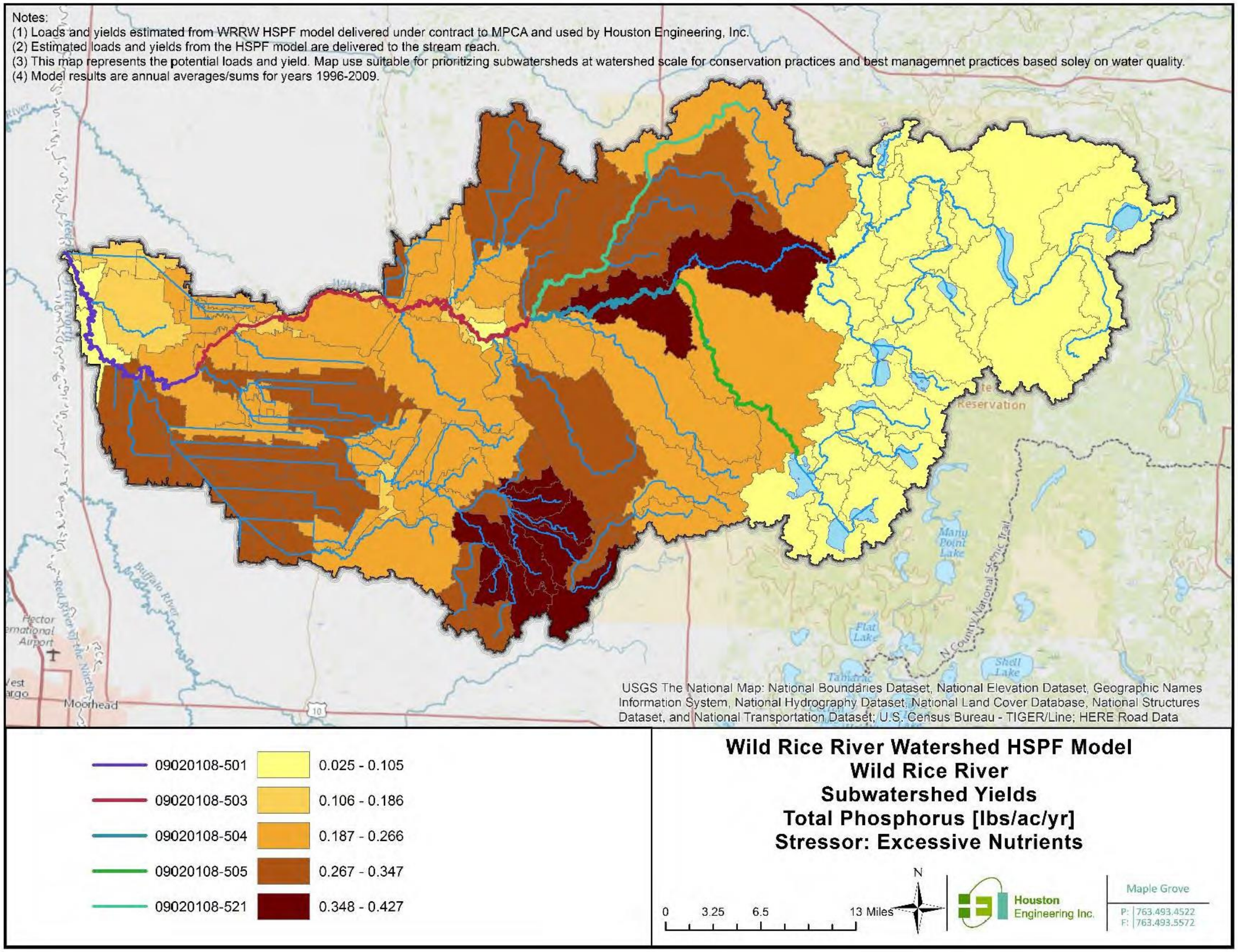


Figure B-9: Average (1996 through 2009) total nitrogen yield delivered to the channel by subwatershed from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

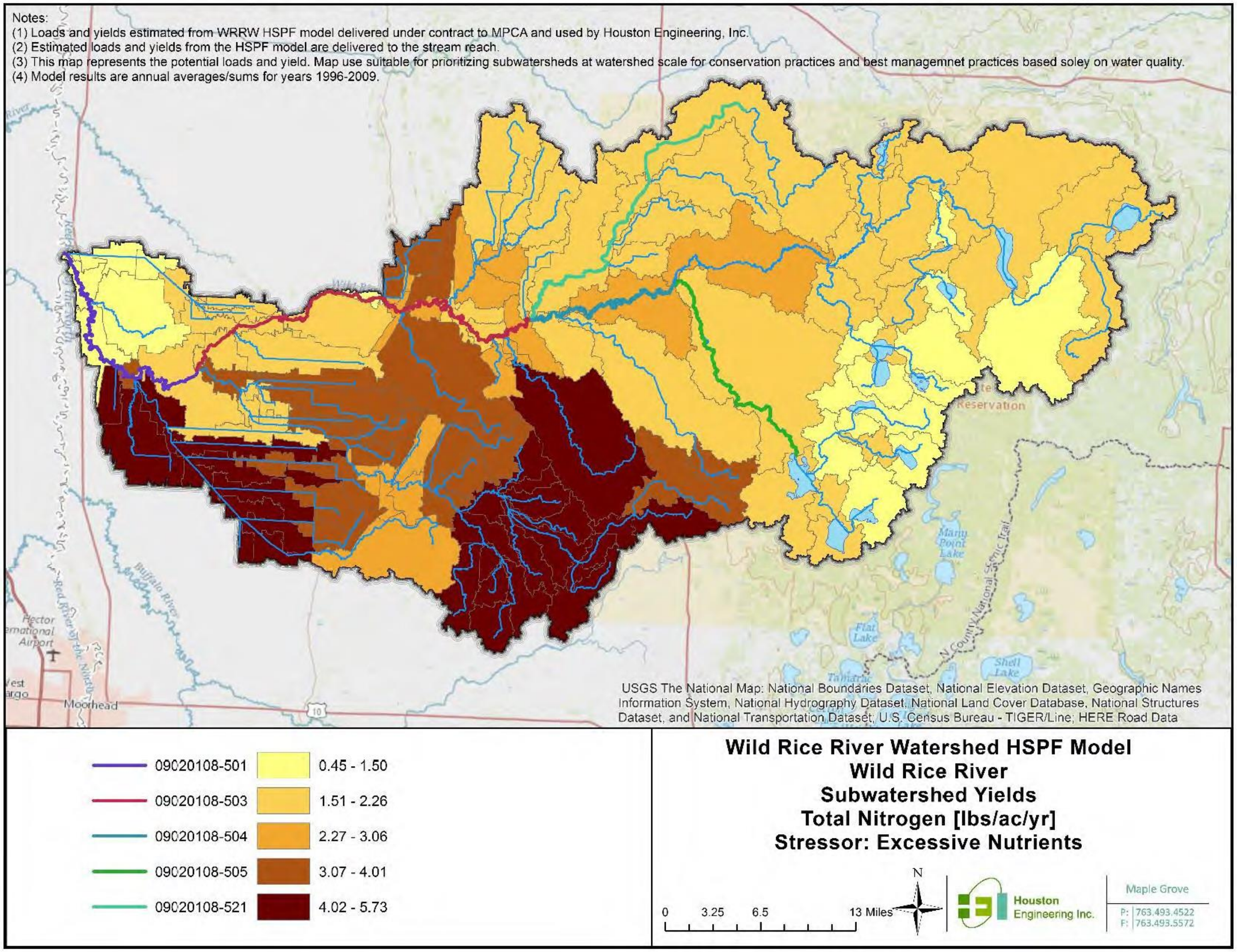
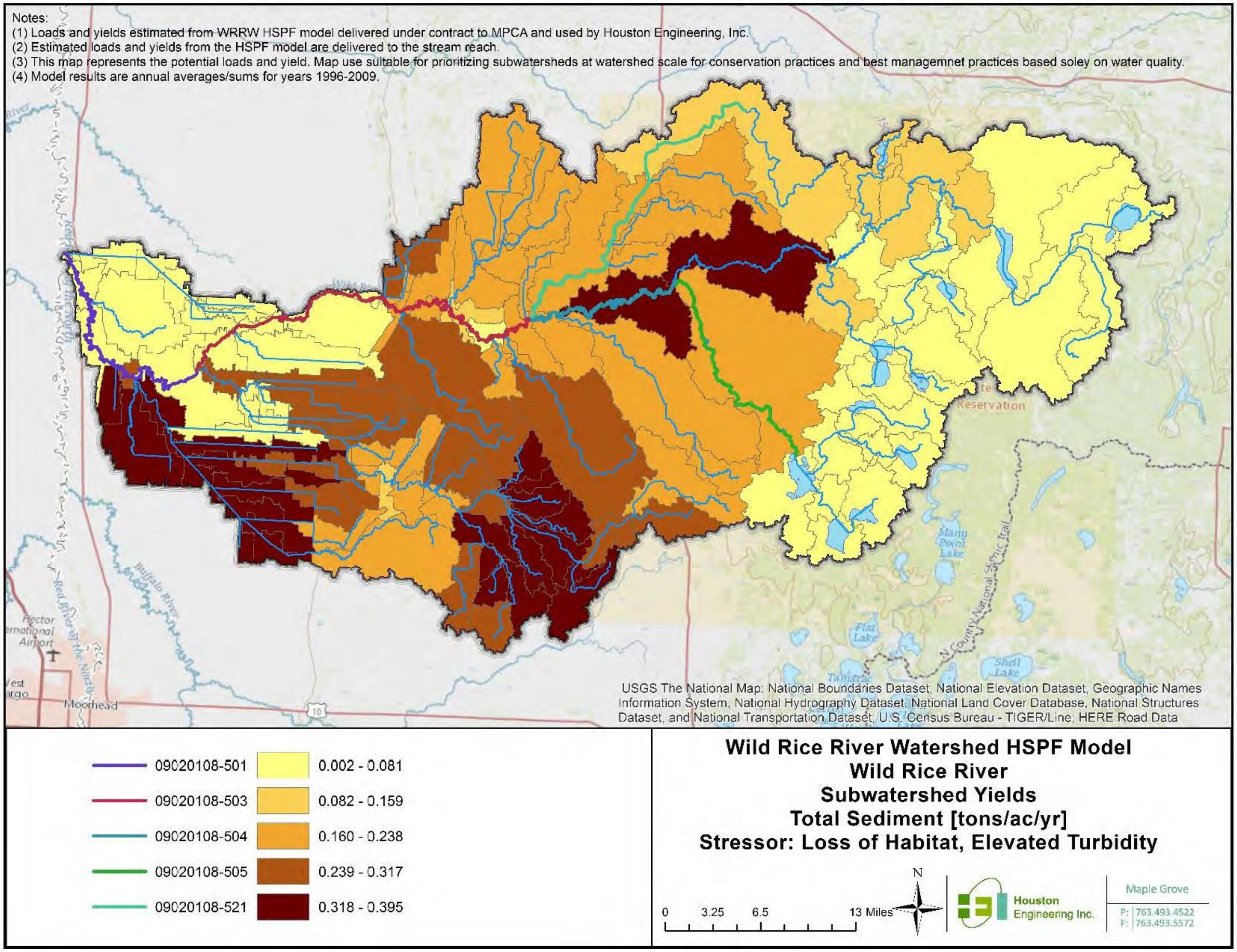


Figure B-10: Average (1996 through 2009) total sediment yield delivered to the channel by subwatershed from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.



Wild Rice River Watershed prioritization

The following maps provide subwatershed prioritization at the watershed scale for RO, TP, TN, and TS based on the subwatershed yields and represent different stressors, which can lead to impairments. The priority rankings maps are developed by ranking the average subwatershed yields to identify specific priority subwatersheds which should be preferentially considered for targeting fields for practice implementation. The rankings are from largest to smallest yields and are used to calculate their percentile rank. The ranks are then summarized as the lowest priority (lowest 10%), low priority (10% to 25%), moderate priority (25% to 75%), high priority (75% to 90%), and highest priority (highest 10%). The highest priority subwatersheds with the highest yields will likely benefit the most from implementation and protective strategy management. In addition, a watershed scale WQI is included to summarize the watershed conditions.

Figure B-11 provides the subwatershed prioritization for the stressor altered hydrology using average annual (1996 through 2009) unit RO of water entering the channel. **Figure B-12** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TP yield delivered to the channel. **Figure B-13** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TN yield delivered to the channel. **Figure B-14** provides the subwatershed prioritization for the stressor loss of habitat and elevated turbidity using average annual (1996 through 2009) TS yield delivered to the channel. **Figure B-15** provides the watershed scale subwatershed prioritization from the WQI. The dark green in the figures represent the highest priority subwatersheds (top 10%) with the highest yields and most likely would benefit the most from implementation and protective strategy management. The lightest green in the figures represent the lowest priority subwatersheds (bottom 10%) with the lowest yields and most likely would benefit the least from implementation and protective strategy management at the watershed scale.

In addition to the watershed scale prioritization maps, watershed scale Field Stream Index (FSI) maps are provided. The FSI maps provide guidance, subject to field verification, about where field practices rather than in-stream implementation activities, provide the largest 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 B-16** provides the FSI for the stressor excessive nutrients based on TP. **Figure B-17** provides the FSI for the stressor excessive nutrients based on TN. **Figure B-18** provides the FSI for the stressor loss of habitat and elevated turbidity based on TS. The information shown in the FSI mapping does not change for the major tributary prioritization mapping, therefore it is only included for the watershed-scale prioritization mapping.

Figure B-11: Map of prioritized subwatersheds for implementation to address altered hydrology in the Wild Rice River Watershed, based on average annual (1996 through 2009) unit runoff (of water).

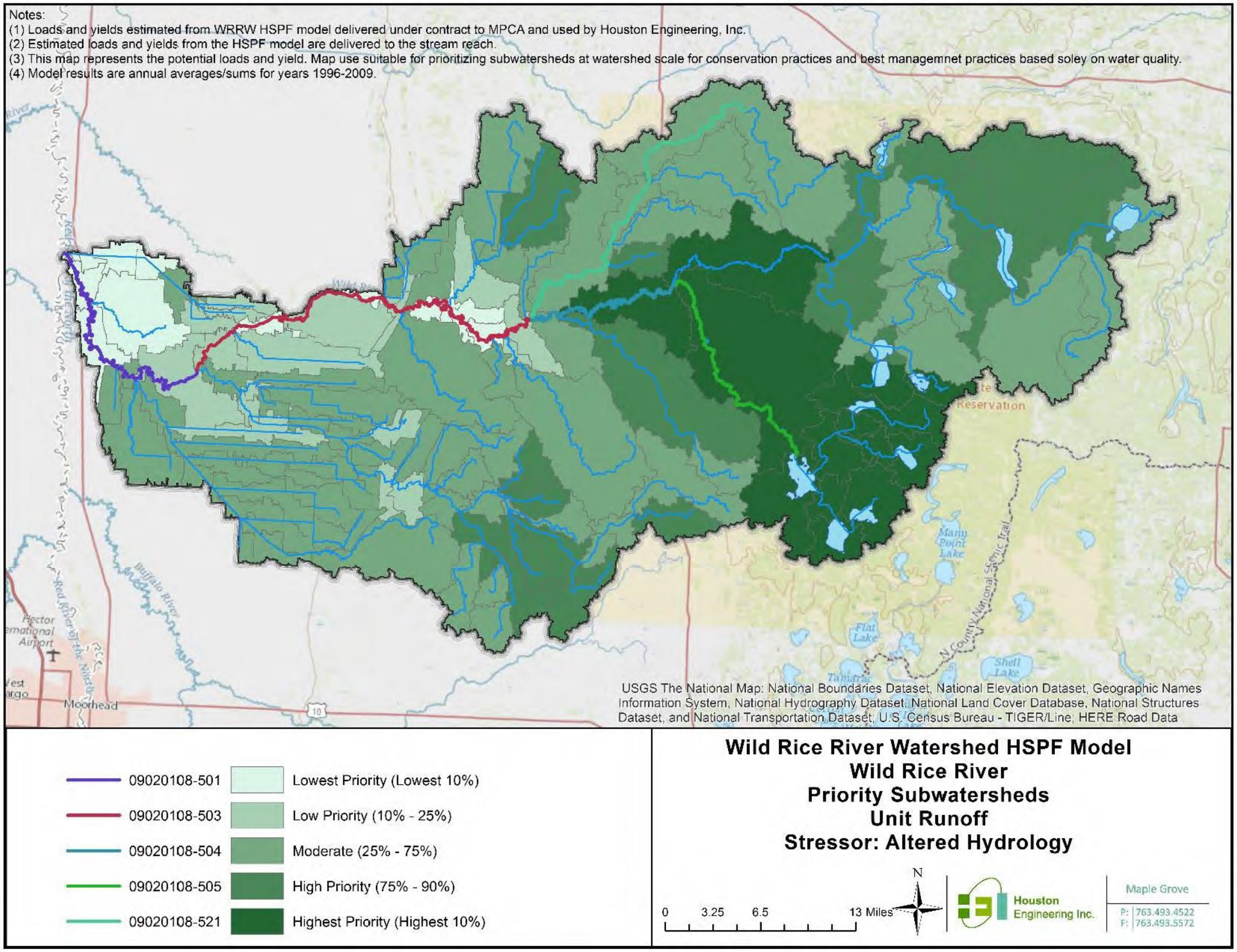


Figure B-12: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River Watershed, based on average annual (1996 through 2009) total phosphorus yields.

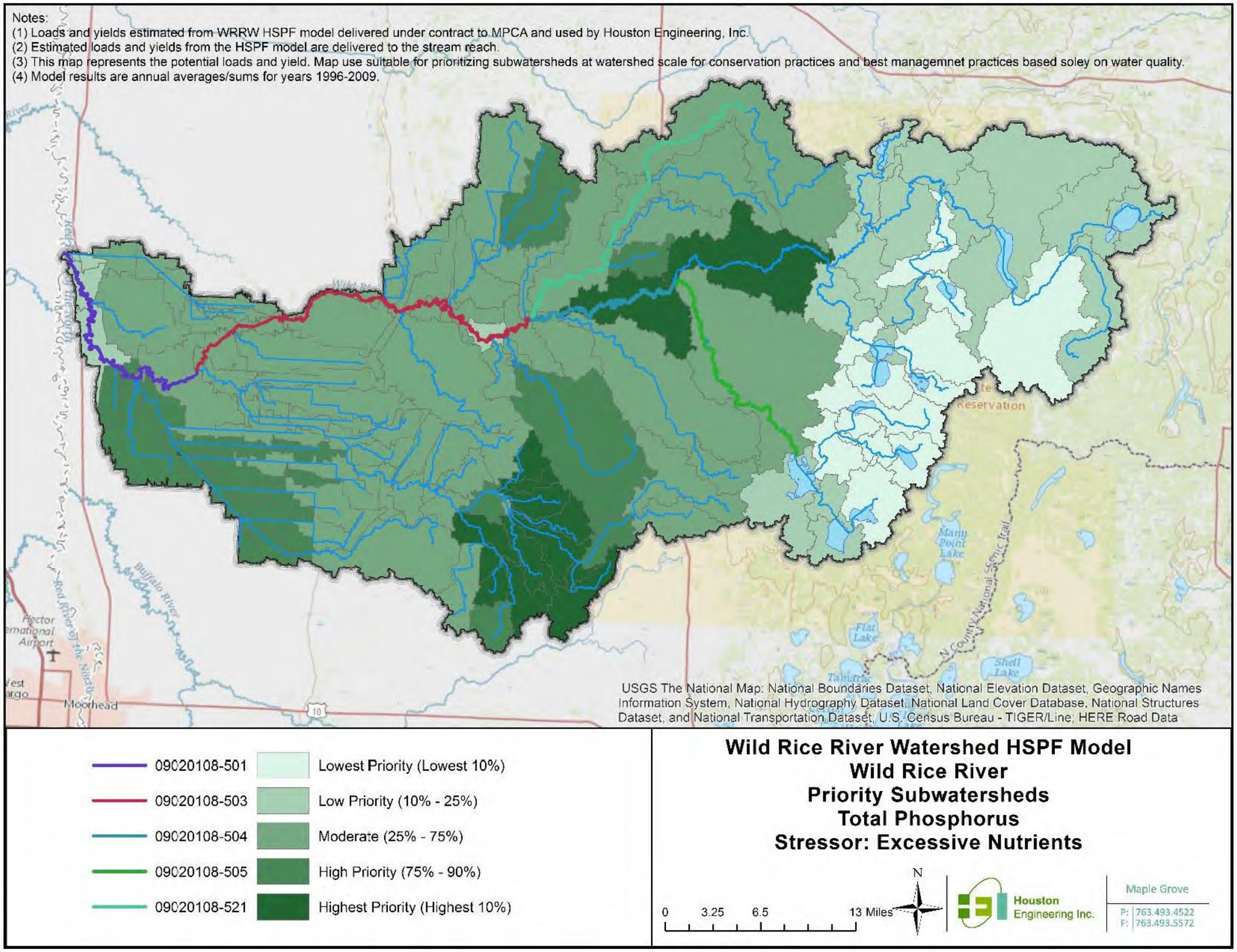


Figure B-13: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River Watershed, based on average annual (1996 through 2009) total nitrogen yields.

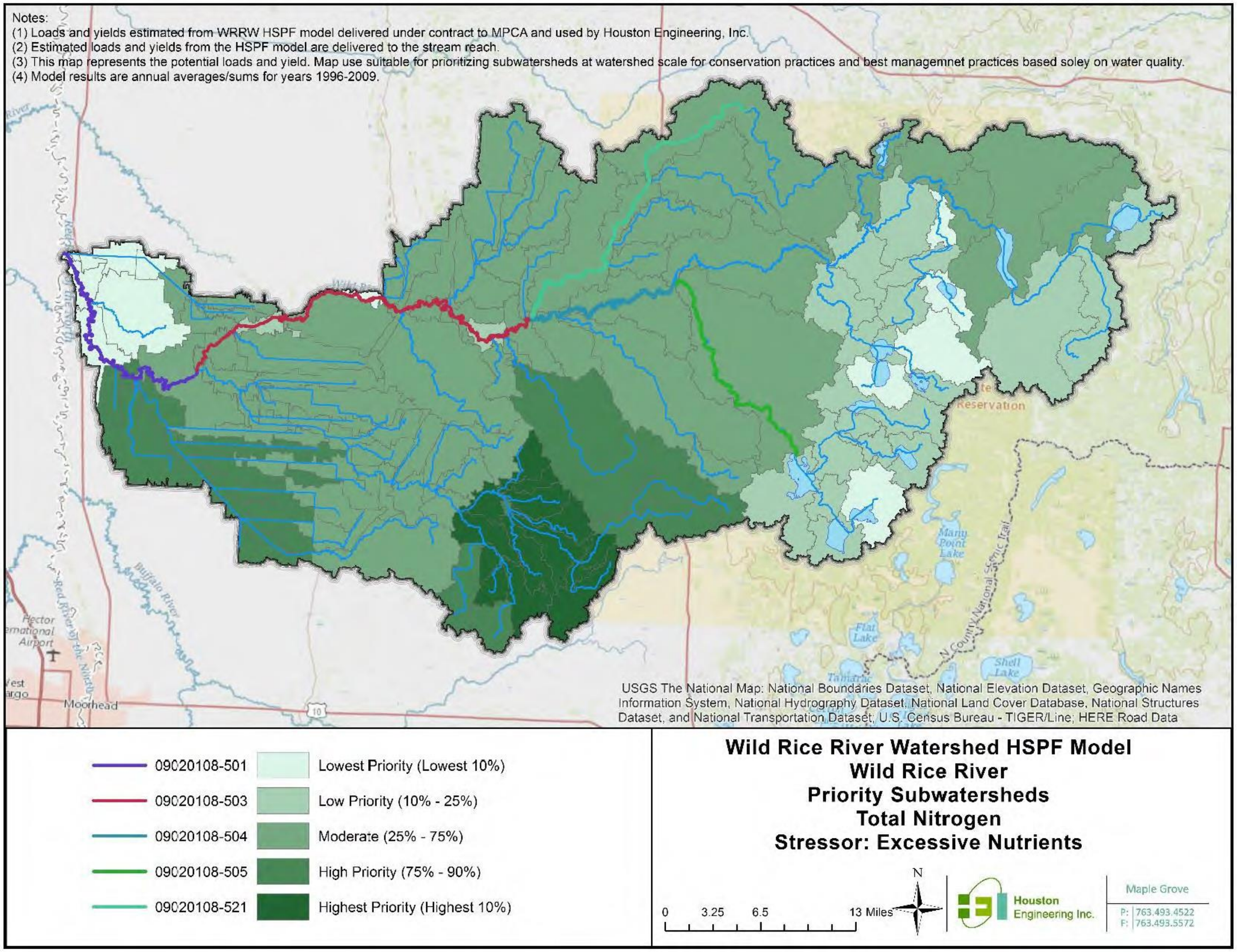


Figure B-14: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the Wild Rice River Watershed, based on average annual (1996 through 2009) total sediment yields.

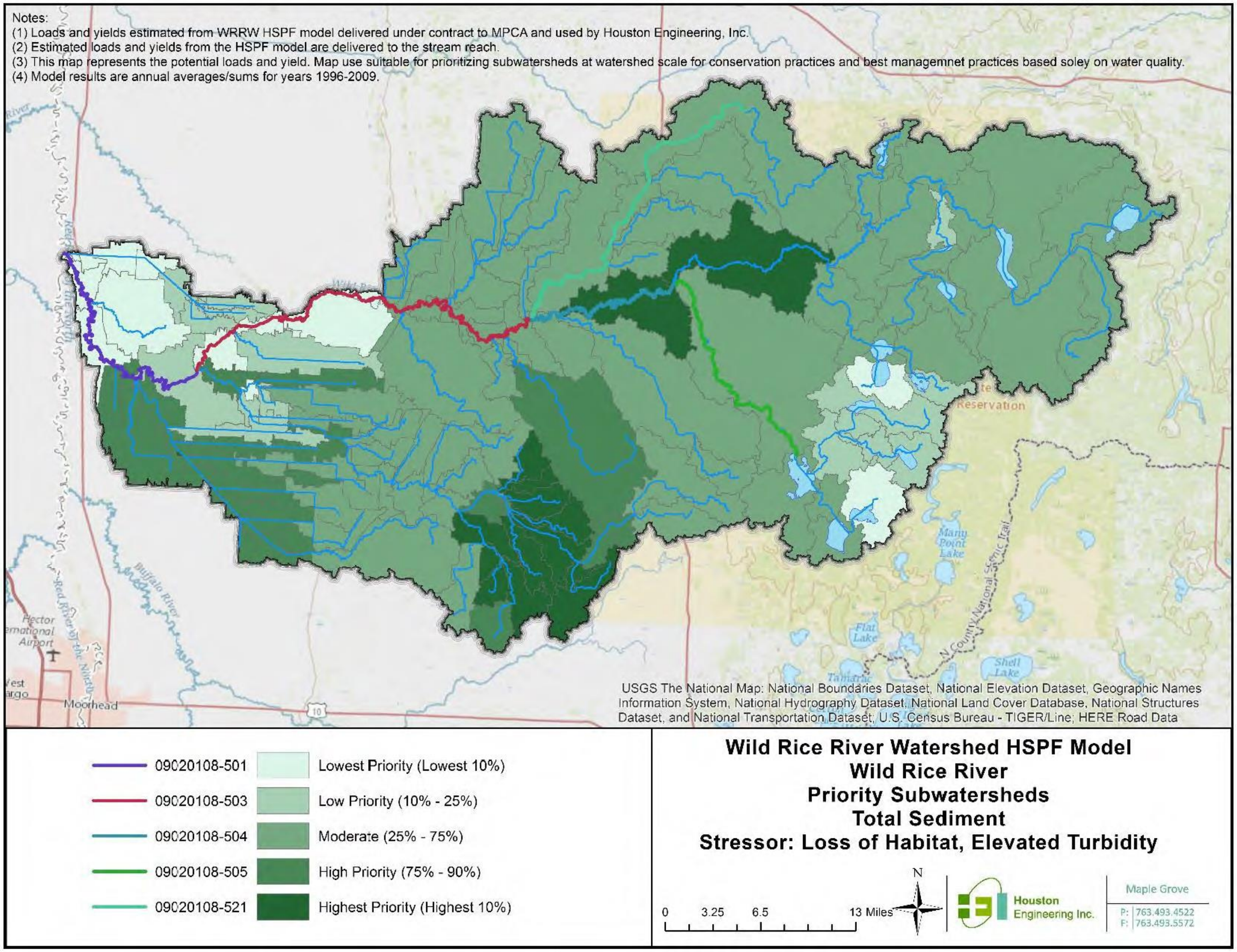


Figure B-15: Map of prioritized subwatersheds for implementation in the Wild Rice River Watershed, using the average (1996 through 2009) water quality index.

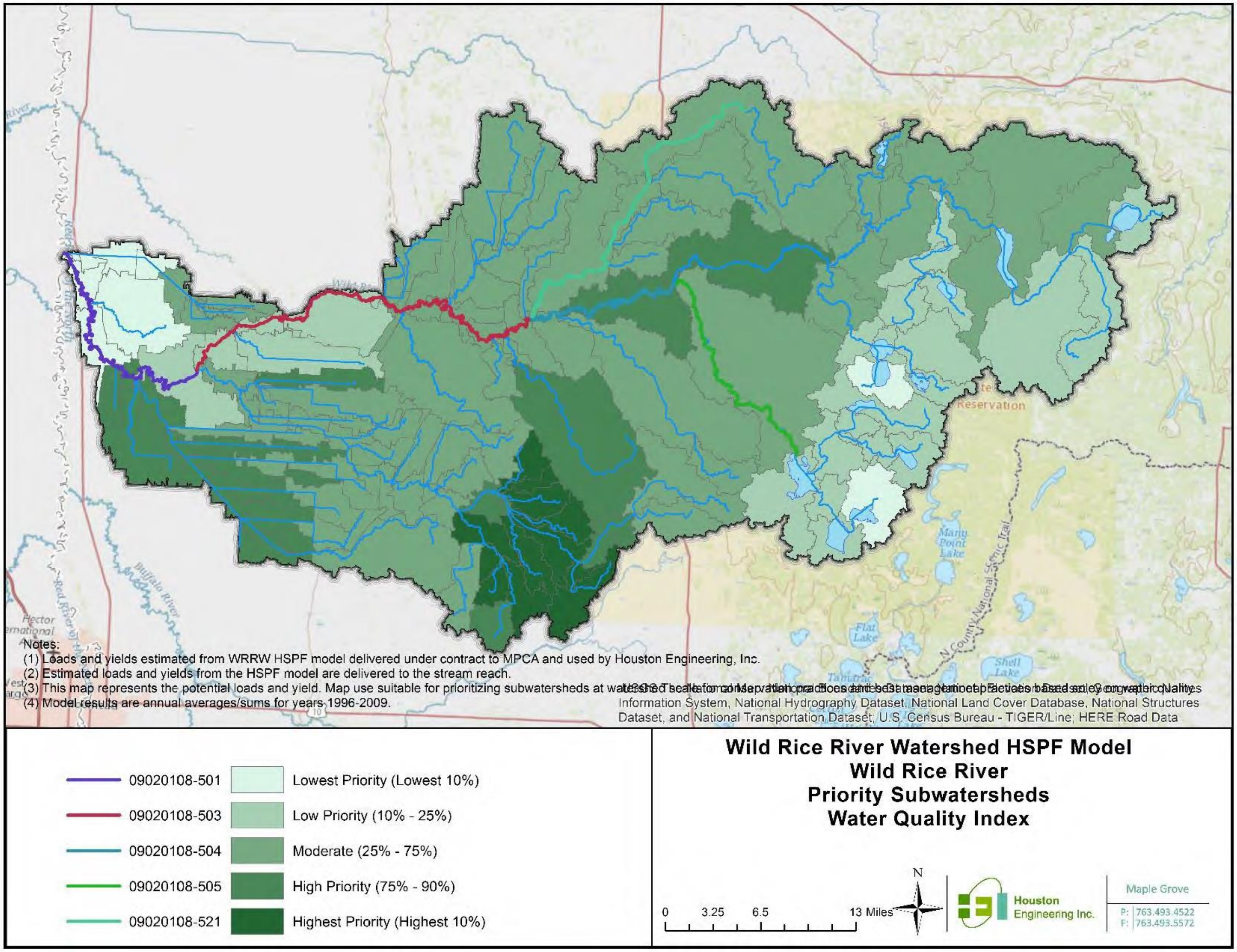


Figure B-16: Map of prioritized subwatersheds for implementation of field and stream practices (Field Stream Index) to address excessive nutrients, based on average annual (1996 through 2009) total phosphorus load.

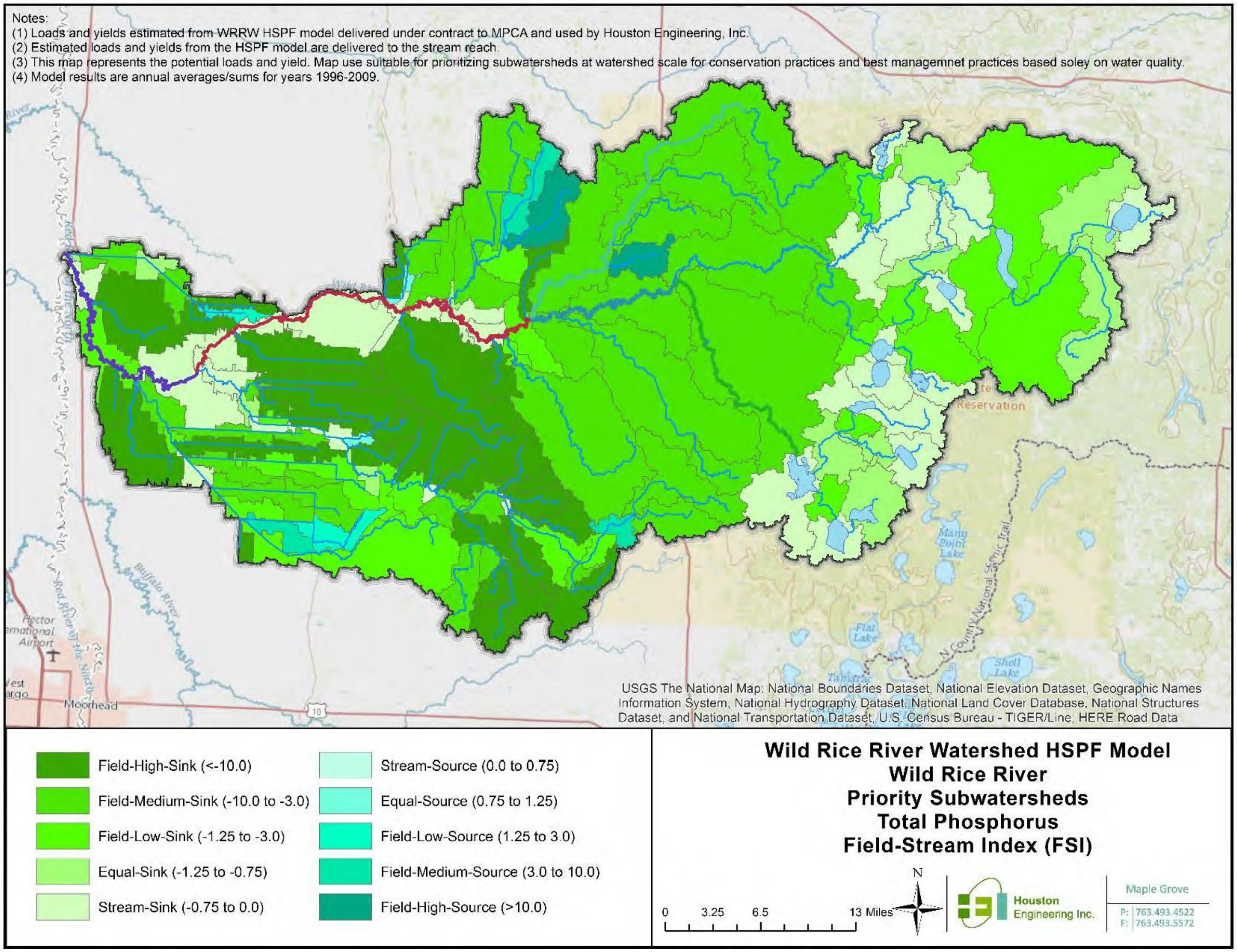


Figure B-17: Map of prioritized subwatersheds for implementation of field and stream practices (Field Stream Index) to address excessive nutrients, based on average annual (1996 through 2009) total nitrogen load.

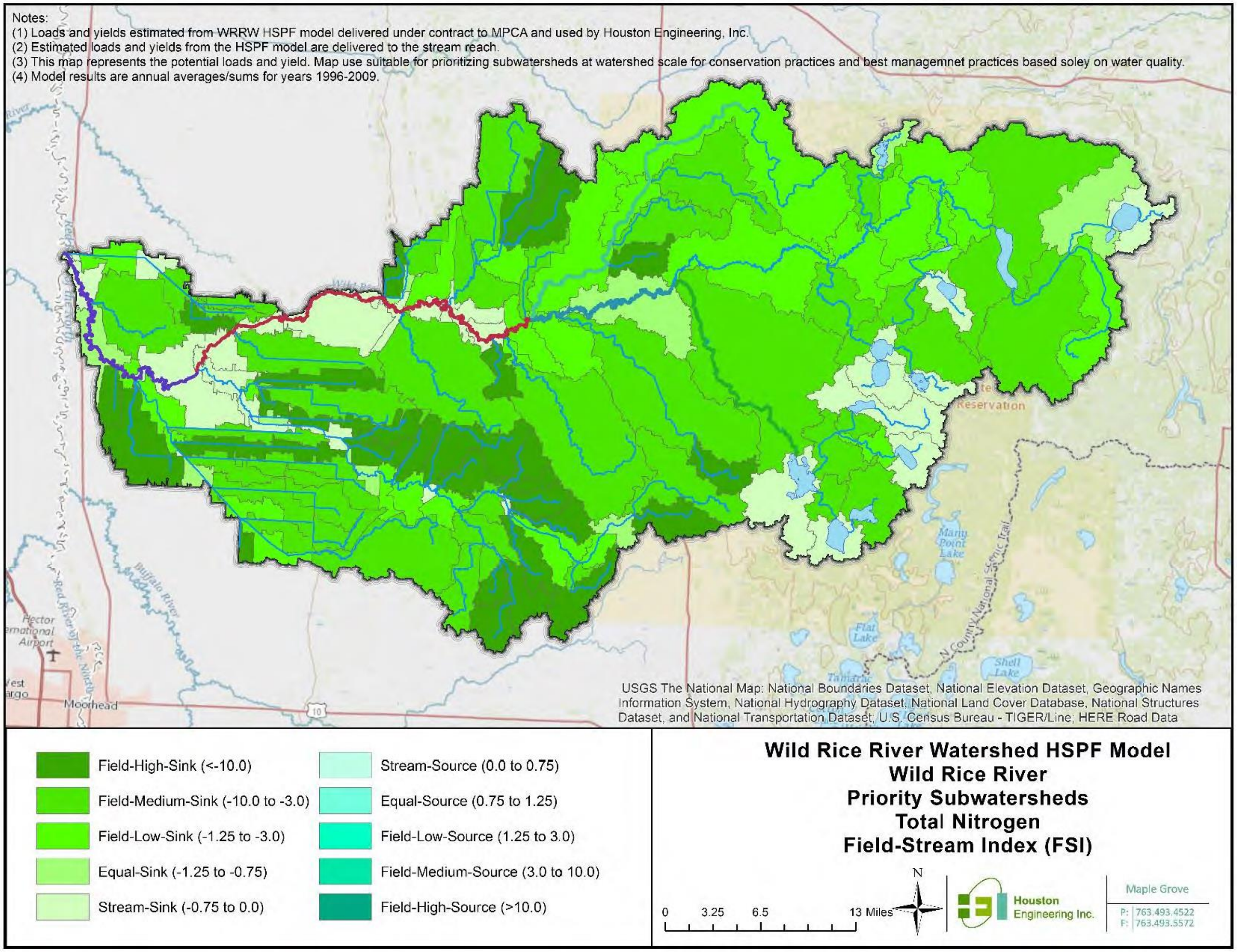
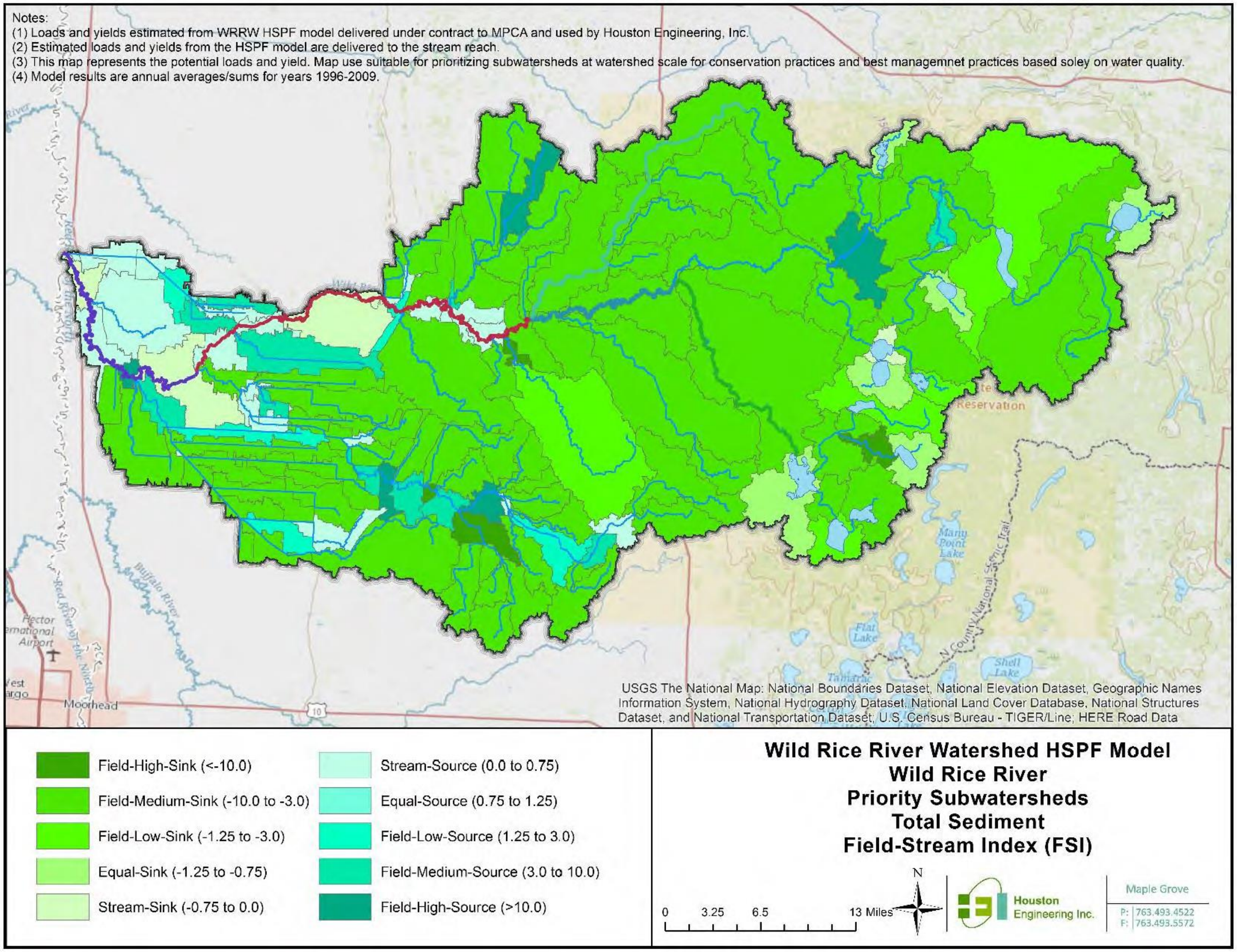


Figure B-18: Map of prioritized subwatersheds for implementation of field and stream practices (Field Stream Index) to address loss of habitat and elevated turbidity, based on average annual (1996 through 2009) total sediment.



Tributary scale prioritization

The prioritization mapping changes based on the subwatersheds included in the drainage area. Therefore, prioritization maps were produced for several tributary drainage areas for RO, TP, TN, and TS. This will be referred to as major tributary prioritization. **Figure B-19** provides the drainage areas for the various tributaries. It should be noted that drainage areas for the downstream reaches include the drainage areas for any upstream reaches within its boundaries.

Similar to the watershed scale maps, the following maps provide subwatershed prioritization at the tributary scale for RO, TP, TN, and TS based on the subwatershed yields and represent different stressors, which can lead to impairments. In addition, tributary scale WQI are include for each drainage area.

Wild Rice River, S Br Wild Rice R To Red R (AUID 09020108-501)

AUID 09020108-501 includes the outlet of the Wild Rice River; all of the subwatersheds in the WRRW are included in its drainage area and the maps are the exact same as the watershed scale maps. Therefore, see the watershed scale maps (**Figure B-11** through **Figure B-15**) for this drainage areas prioritization mapping.

Wild Rice River, Marsh Cr To S Br Wild Rice R (AUID 09020108-503)

Figure B-20 provides the subwatershed prioritization for the stressor altered hydrology using average annual (1996 through 2009) unit RO of water entering the channel for AUID 09020108-503. **Figure B-21** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TP yield delivered to the channel for AUID 09020108-503. **Figure B-22** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TN yield delivered to the channel for AUID 09020108-503. **Figure B-23** provides the subwatershed prioritization for the stressor loss of habitat and elevated turbidity using average annual (1996 through 2009) TS yield delivered to the channel for AUID 09020108-503. **Figure B-24** provides the tributary scale subwatershed prioritization from the WQI.

Wild Rice River, White Earth R To Marsh Cr (AUID 0902018-504)

Figure B-25 provides the subwatershed prioritization for the stressor altered hydrology using average annual (1996 through 2009) unit RO of water entering the channel for AUID 09020108-504. **Figure B-26** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TP yield delivered to the channel for AUID 09020108-504. **Figure B-27** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TN yield delivered to the channel for AUID 09020108-504. **Figure B-28** provides the subwatershed prioritization for the stressor loss of habitat and elevated turbidity using average annual (1996 through 2009) TS yield delivered to the channel for AUID 09020108-504. **Figure B-29** provides the tributary scale subwatershed prioritization from the WQI.

White Earth River, White Earth Lk To Wild Rice R (AUID 09020108-505)

Figure B-30 provides the subwatershed prioritization for the stressor altered hydrology using average annual (1996 through 2009) unit RO entering the channel for AUID 09020108-505. **Figure B-31** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TP yield delivered to the channel for AUID 09020108-505. **Figure B-32** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TN yield delivered to the channel for AUID 09020108-505. **Figure B-33** provides the subwatershed prioritization for the stressor loss of habitat and elevated turbidity using average annual (1996 through 2009) TS yield delivered to the channel for AUID 09020108-505. **Figure B-34** provides the tributary scale subwatershed prioritization from the WQI.

Marsh Creek, Beaulieu Lk To Wild Rice R (AUID 09020108-521)

Figure B-35 provides the subwatershed prioritization for the stressor altered hydrology using average annual (1996 through 2009) unit RO entering the channel for AUID 09020108-521. **Figure B-36** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TP yield delivered to the channel for AUID 09020108-521. **Figure B-37** provides the subwatershed prioritization for the stressor excessive nutrients using average annual (1996 through 2009) TN yield delivered to the channel for AUID 09020108-521. **Figure B-38** provides the subwatershed prioritization for the stressor loss of habitat and elevated turbidity using average annual (1996 through 2009) TS yield delivered to the channel for AUID 09020108-521. **Figure B-39** provides the tributary scale subwatershed prioritization from the WQI.

Figure B-19: Major tributary scale drainage areas in the Wild Rice River Watershed.

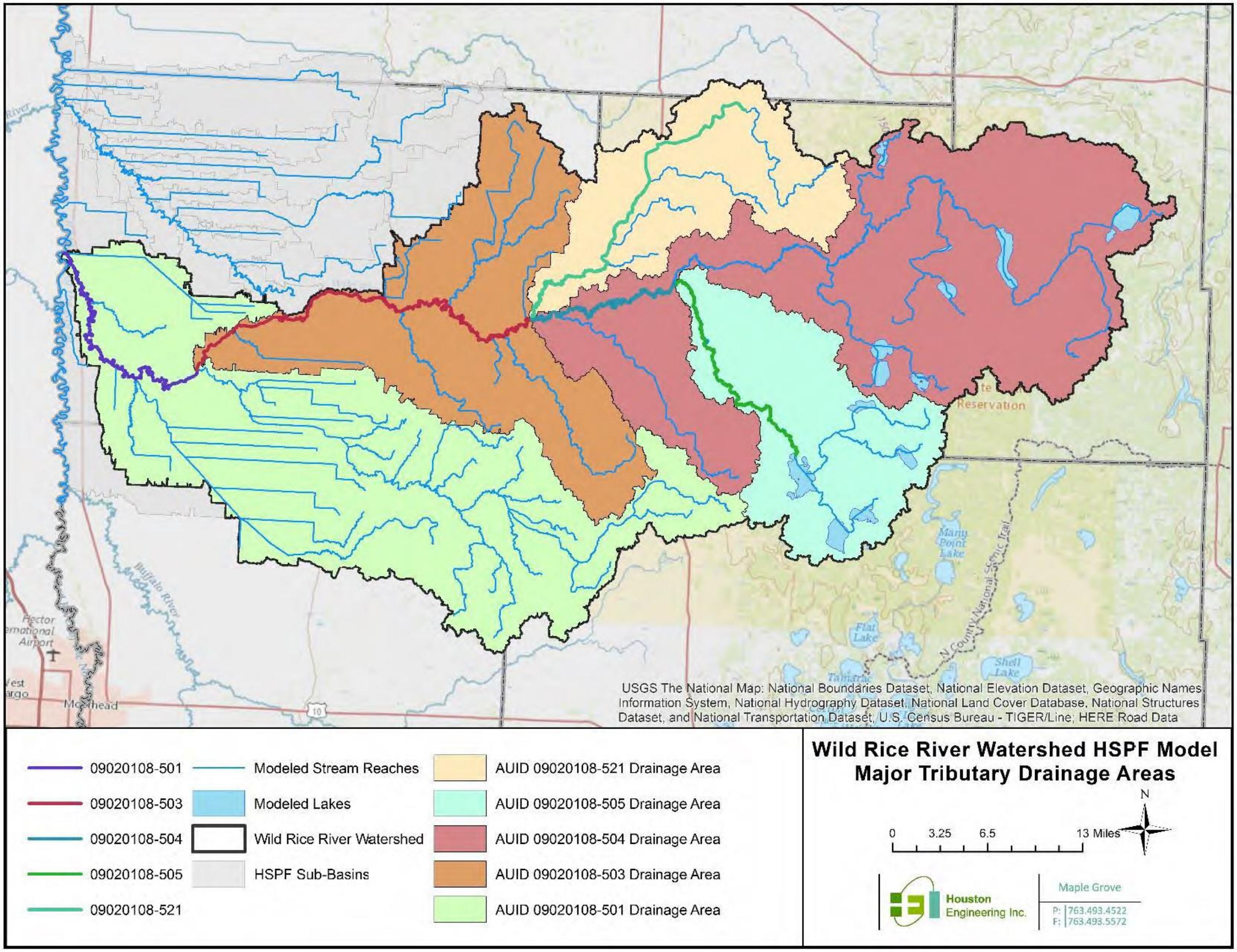


Figure B-20: Map of prioritized subwatersheds for implementation to address altered hydrology in the Wild Rice River, Marsh Cr to S Br Wild Rice R (AUID 09020108-503), based on average annual (1996 through 2009) unit runoff.

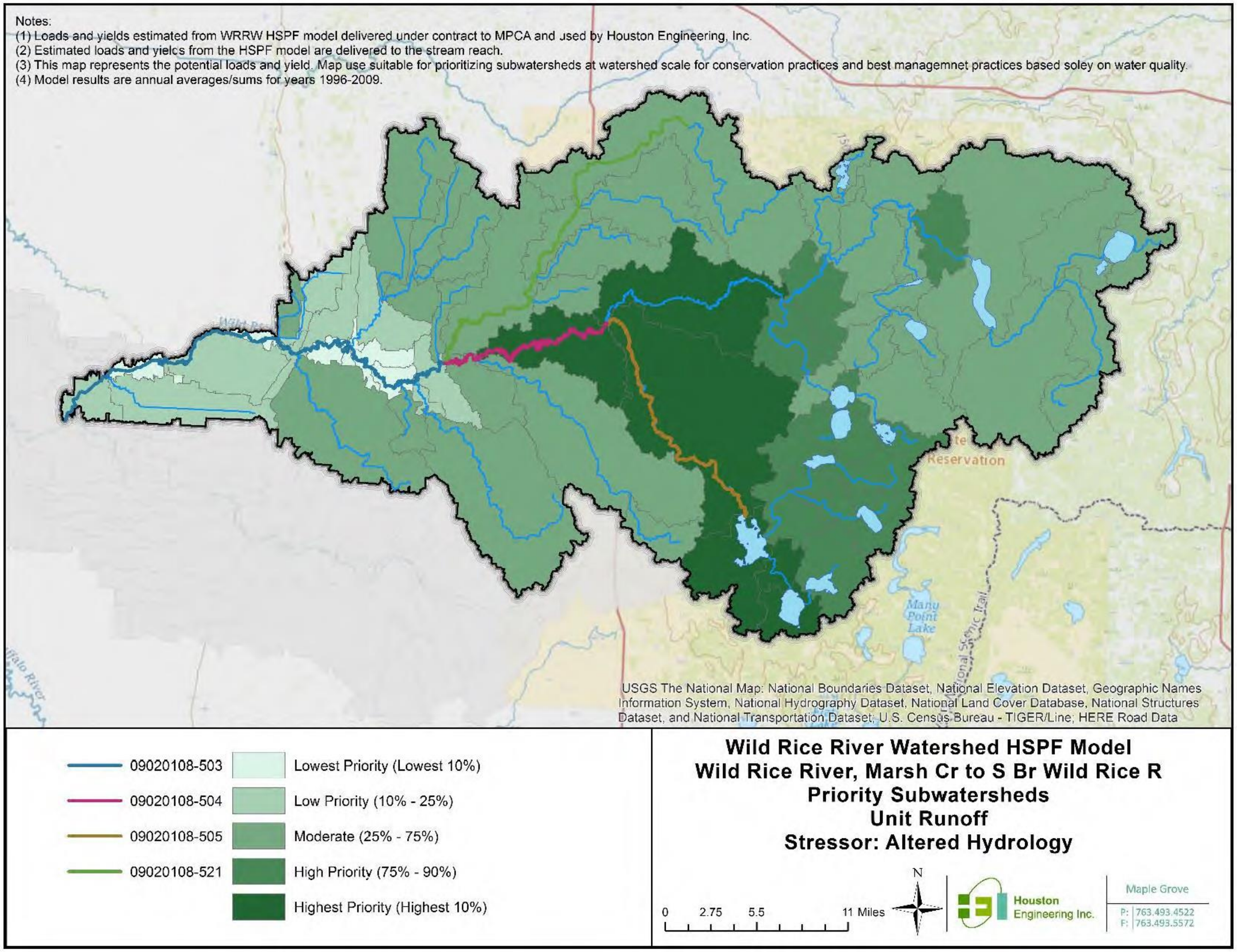


Figure B-21: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River, Marsh Cr to S Br Wild Rice R (AUID 09020108-503), based on average annual (1996 through 2009) total phosphorus yields.

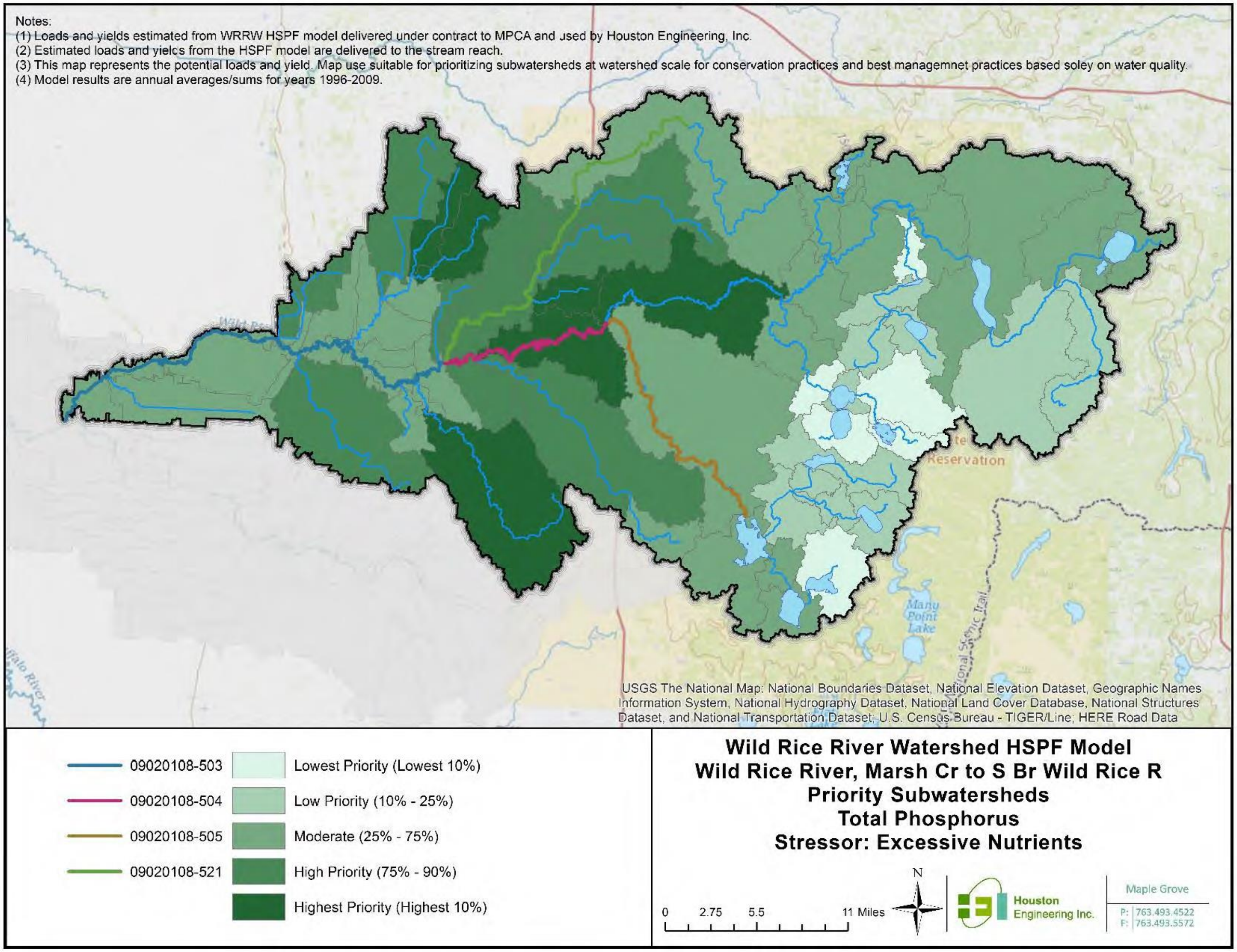


Figure B-22: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River, Marsh Cr to S Br Wild Rice R (AUID 09020108-503), based on average annual (1996 through 2009) total nitrogen yields.

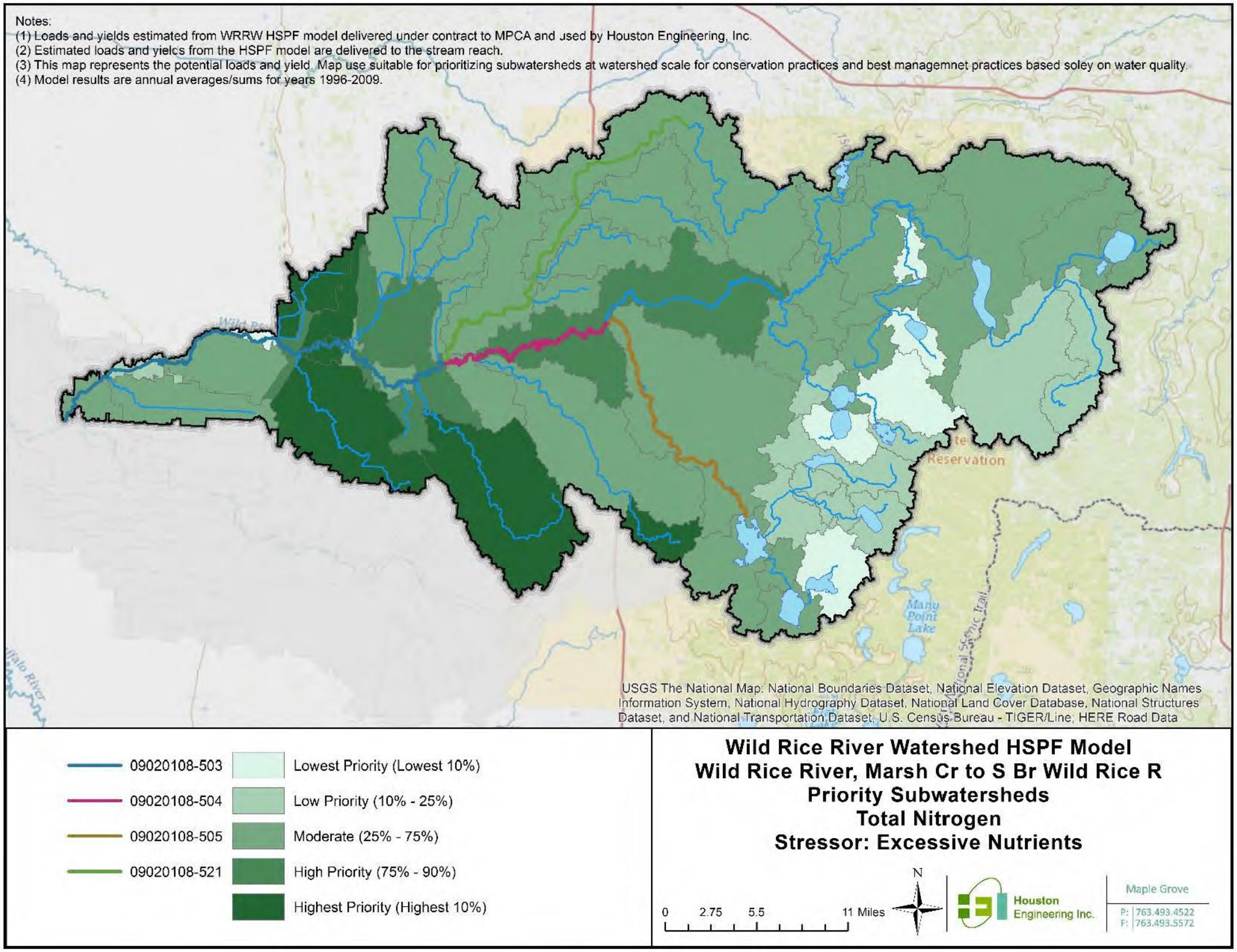


Figure B-23: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the Wild Rice River, Marsh Cr to S Br Wild Rice R (AUID 09020108-503), based on average annual (1996 through 2009) total sediment yields.

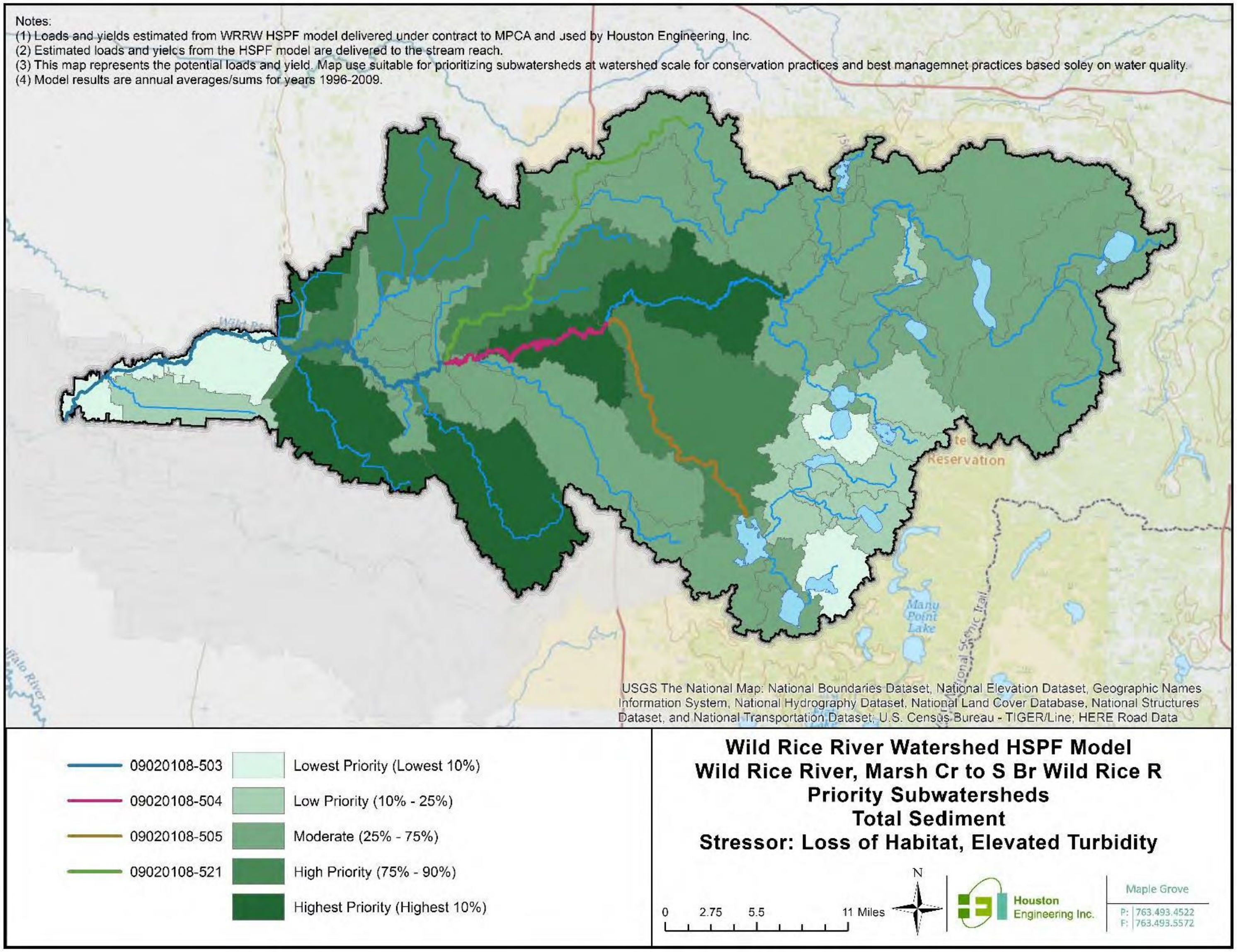


Figure B-24: Map of prioritized subwatersheds for implementation in the Wild Rice River, Marsh Cr to S Br Wild Rice R (AUID 09020108-503), based on the average (1996 through 2009) water quality index.

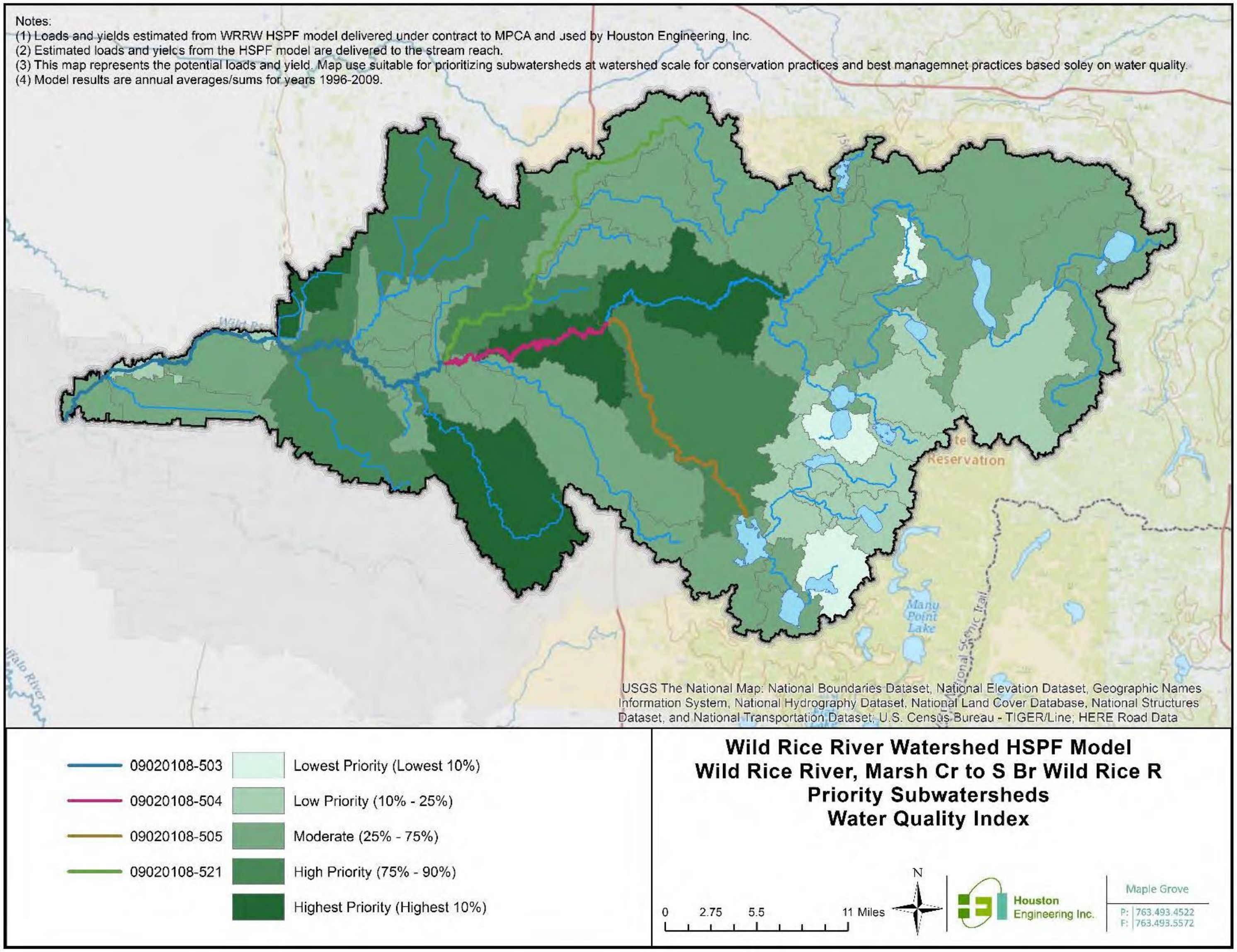


Figure B-25: Map of prioritized subwatersheds for implementation to address altered hydrology in the Wild Rice River, White Earth R to Marsh Cr (AUID 0902018-504), based on average annual (1996 through 2009) unit runoff.

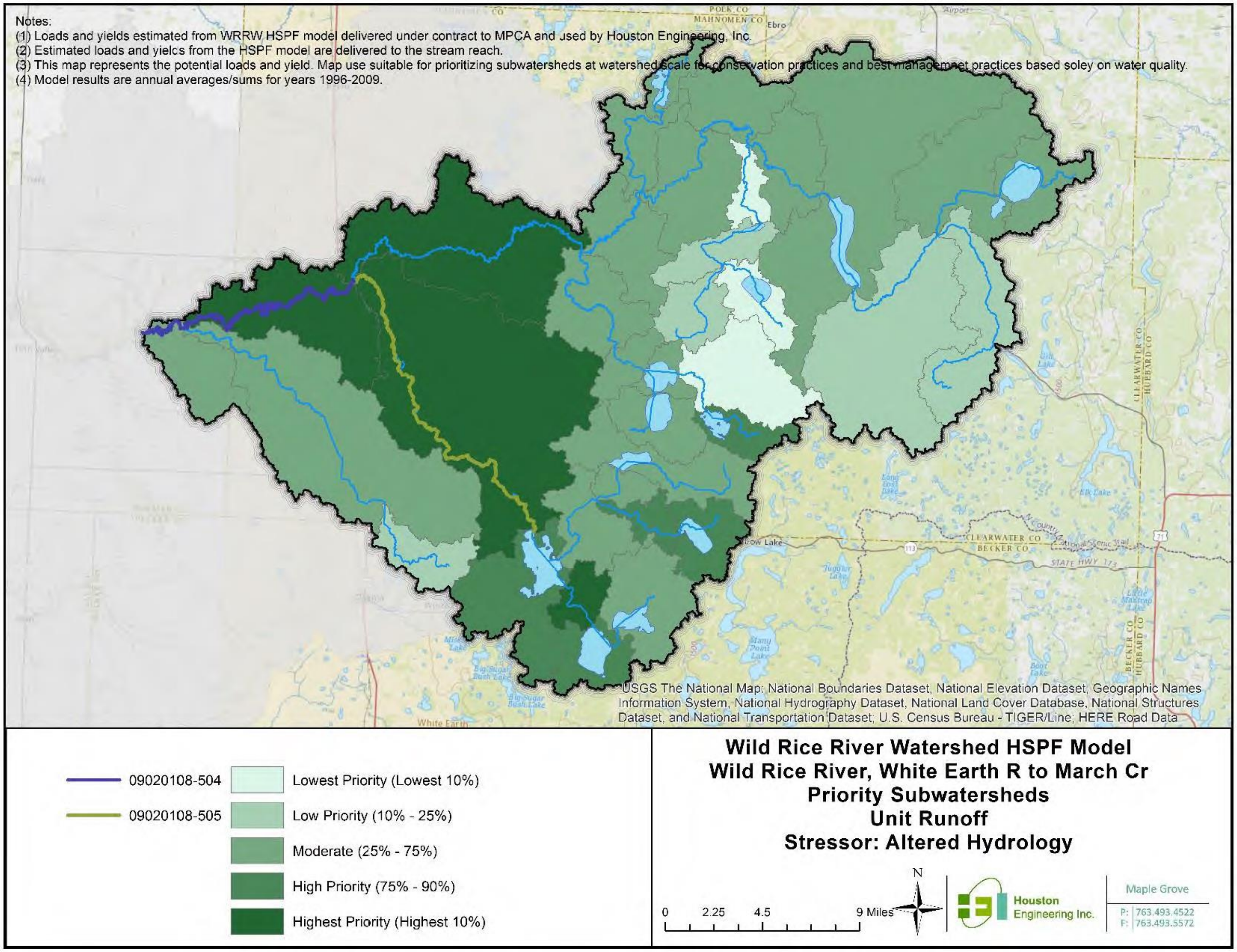


Figure B-26: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River, White Earth R to Marsh Cr (AUID 0902018-504), based on average annual (1996 through 2009) total phosphorus yields.

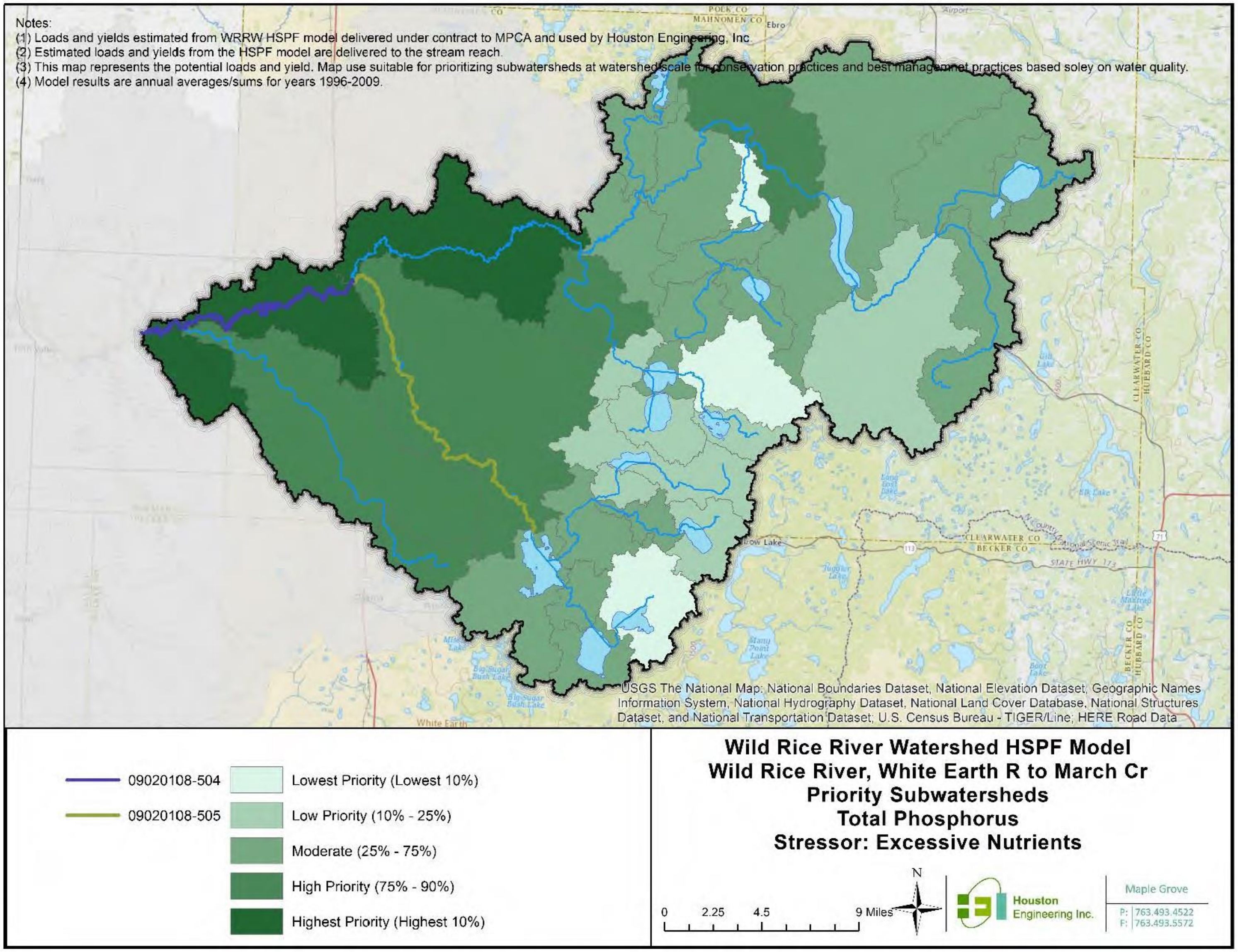


Figure B-27: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Wild Rice River, White Earth R to Marsh Cr (AUID 0902018-504), based on average annual (1996 through 2009) total nitrogen yields.

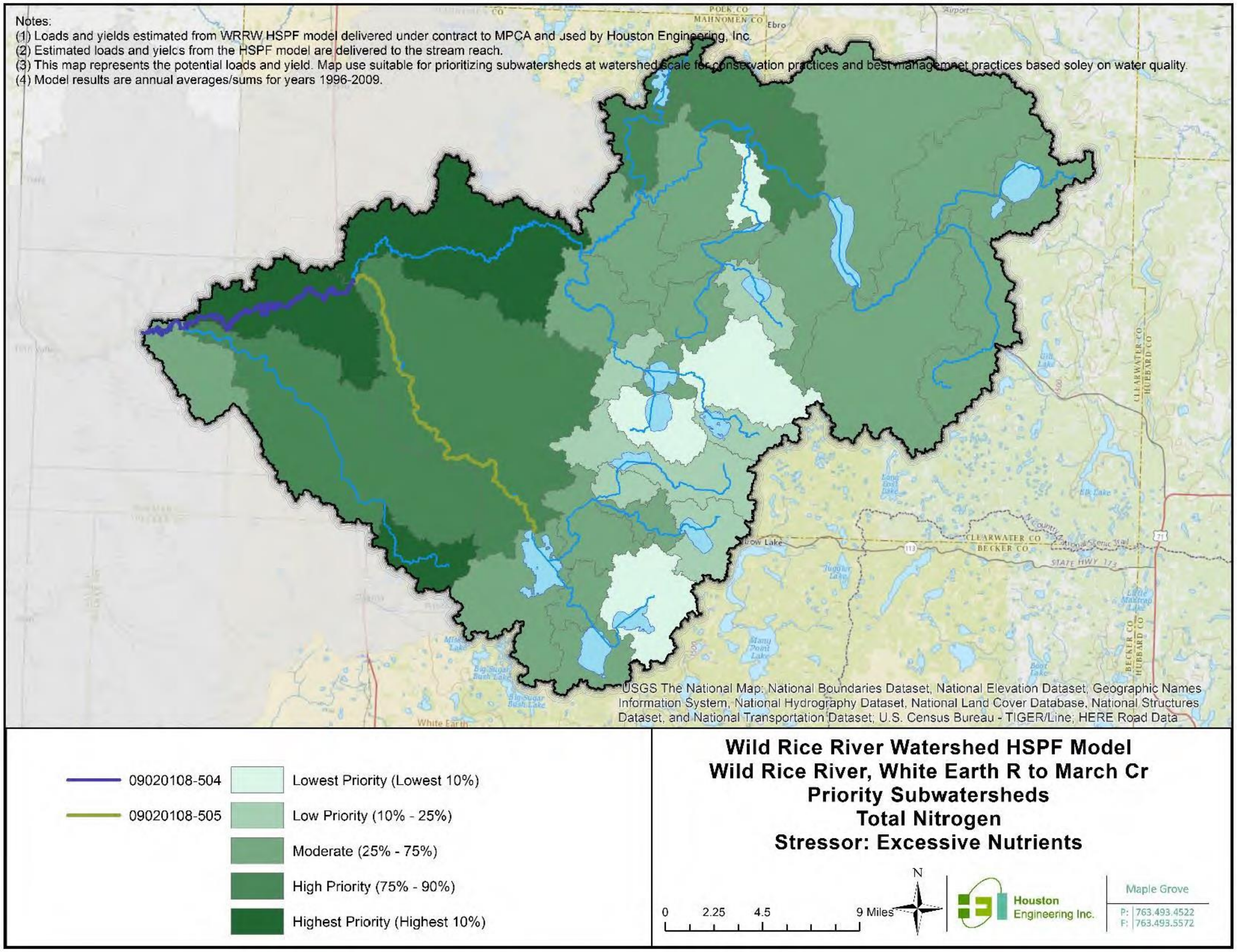


Figure B-28: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the Wild Rice River, White Earth R to Marsh Cr (AUID 0902018-504), based on average annual (1996 through 2009) total sediment yields.

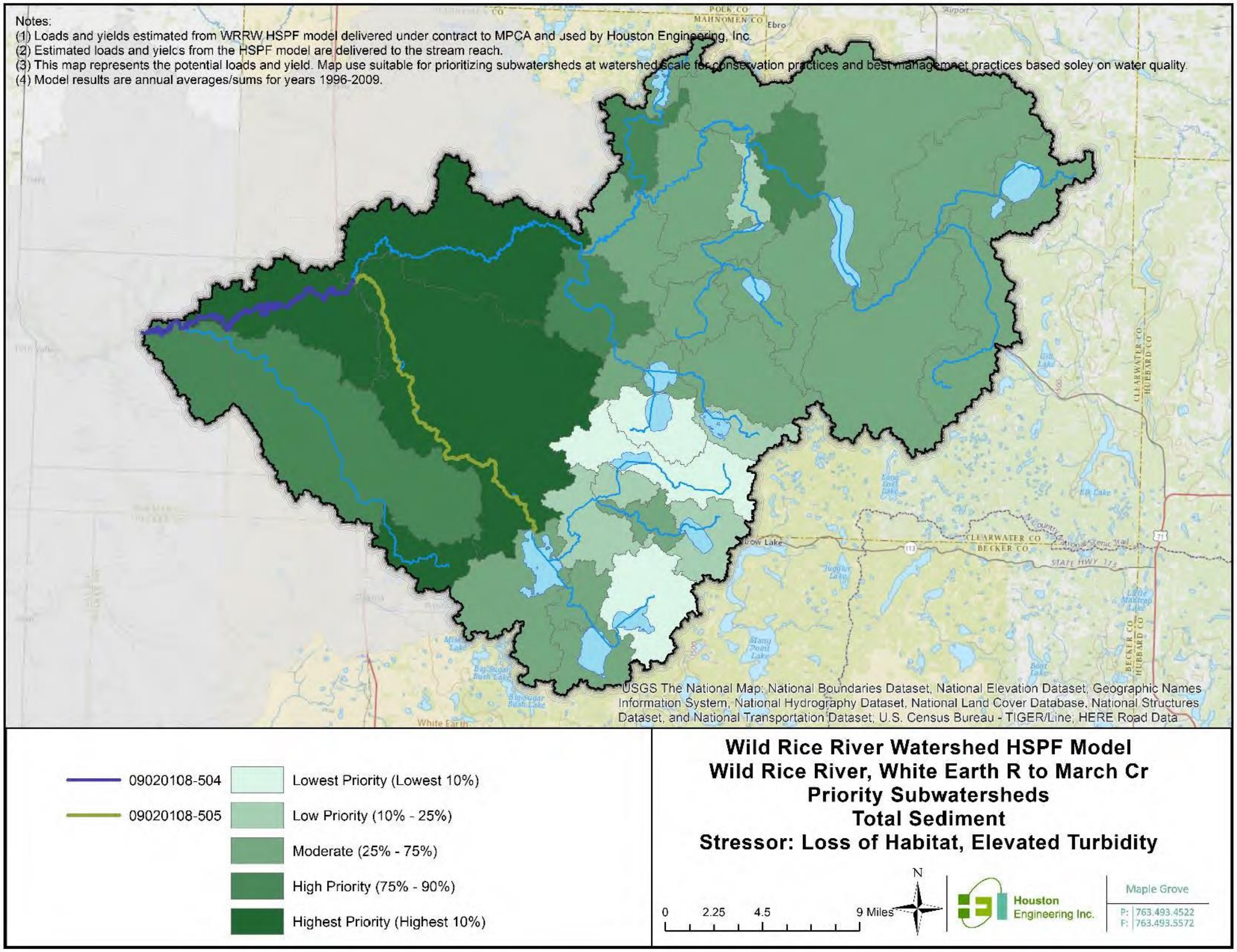


Figure B-29: Map of prioritized subwatersheds for implementation in the Wild Rice River, White Earth R to Marsh Cr (AUID 0902018-504), based on the average (1996 through 2009) water quality index.

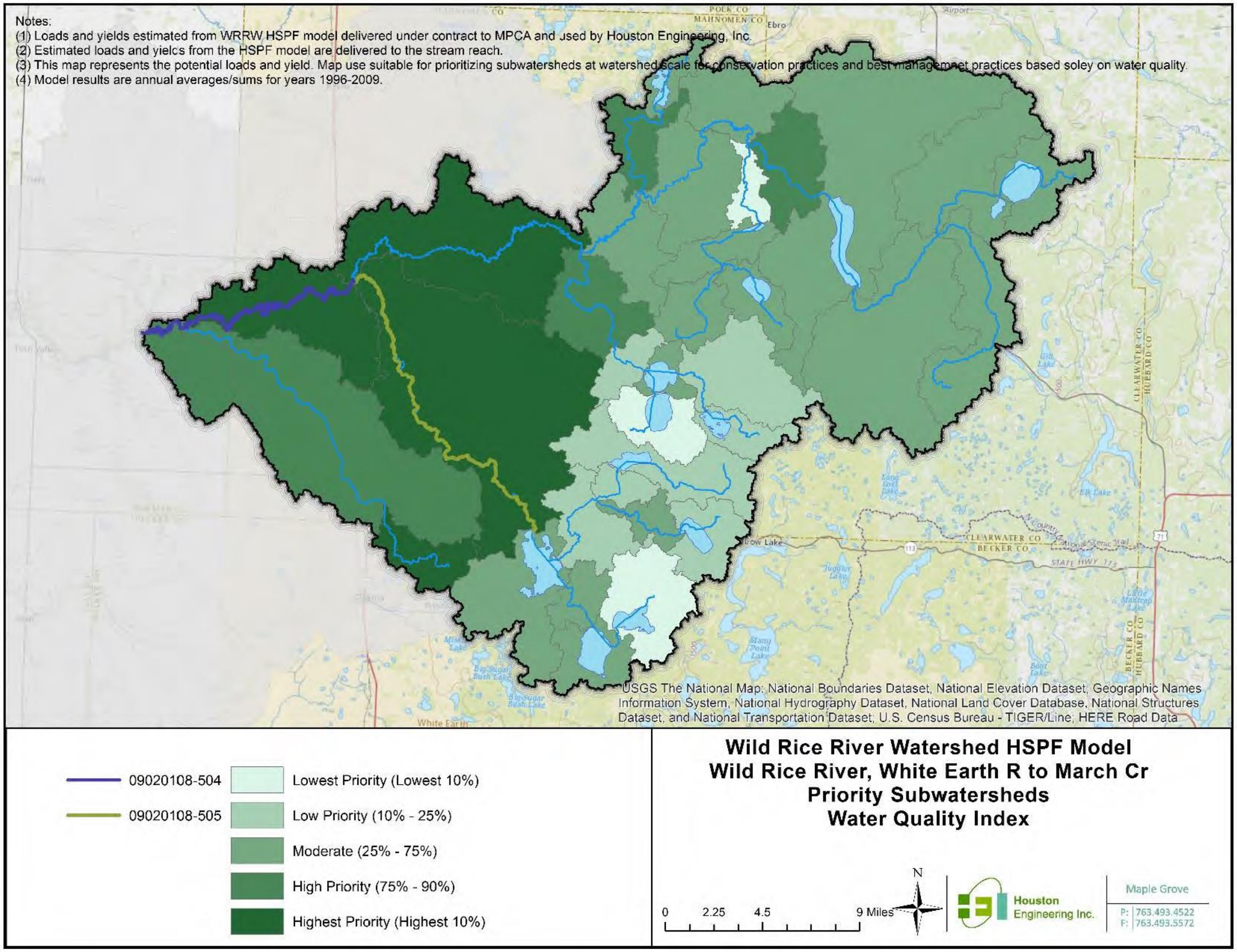


Figure B-30: Map of prioritized subwatersheds for implementation to address altered hydrology in the White Earth River, White Earth Lk to Wild Rice R (AUID 09020108-505), based on average annual (1996 through 2009) unit runoff.

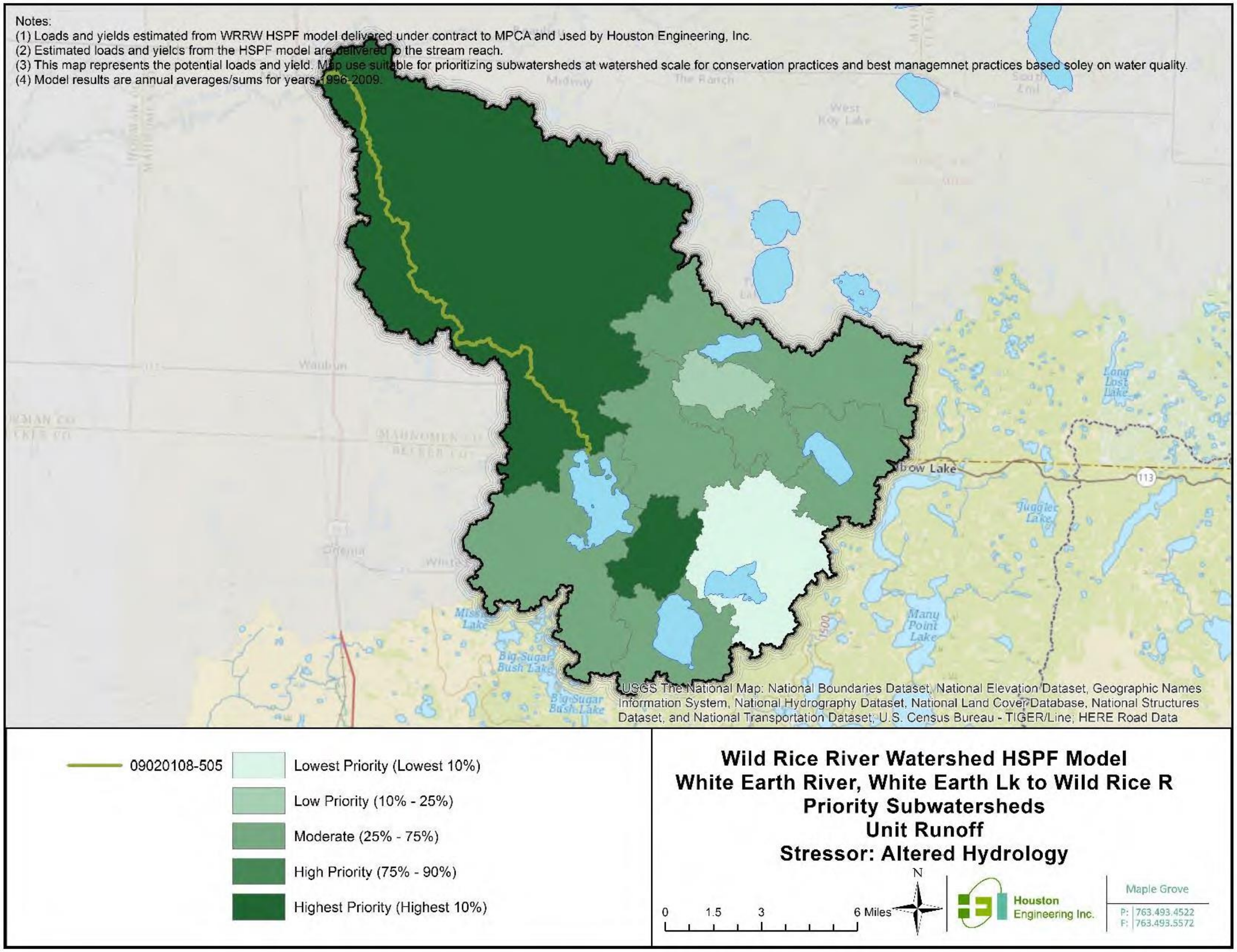


Figure B-31: Map of prioritized subwatersheds for implementation to address excessive nutrients in the White Earth River, White Earth Lk to Wild Rice R (AUID 09020108-505), based on average annual (1996 through 2009) total phosphorus yields.

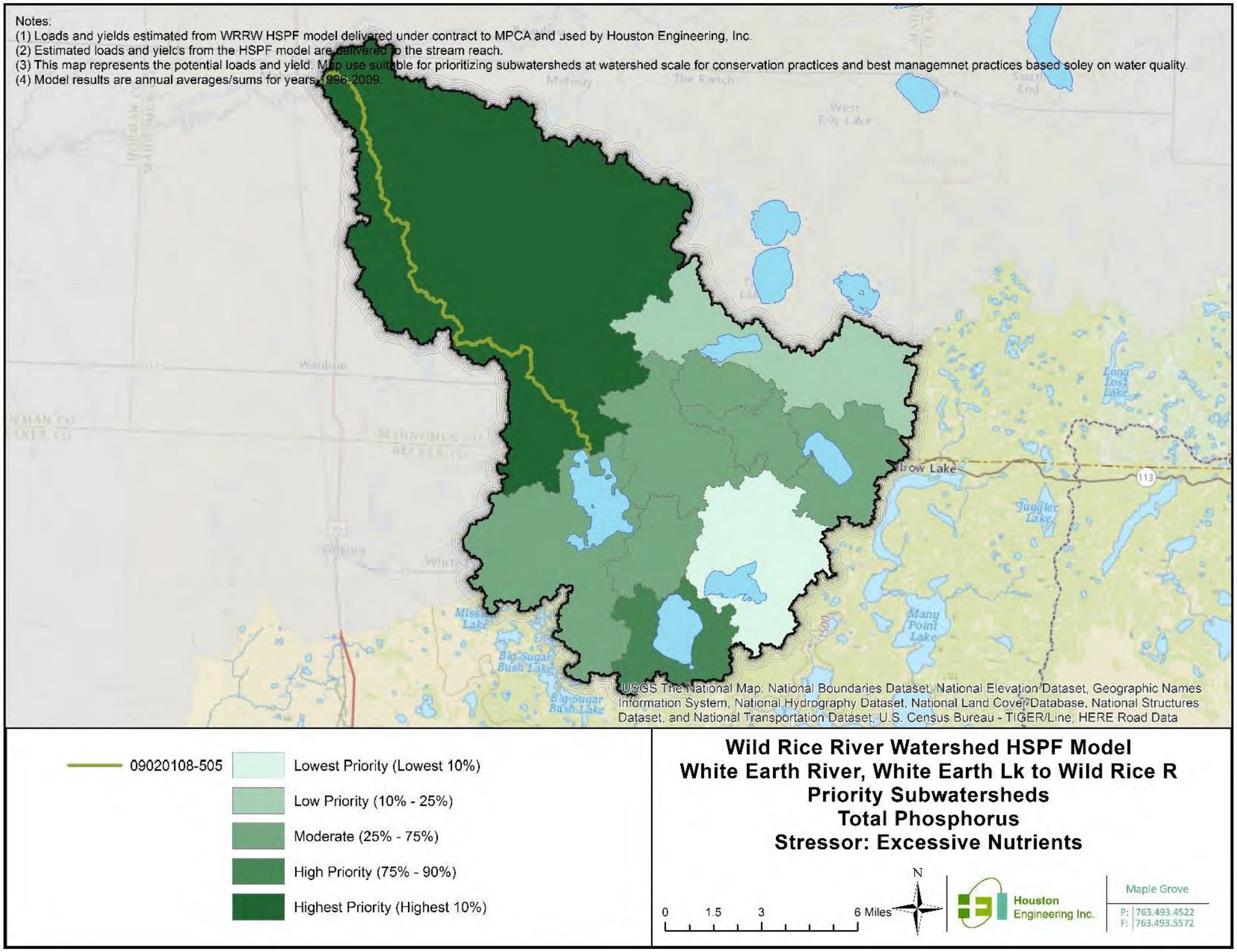


Figure B-32: Map of prioritized subwatersheds for implementation to address excessive nutrients in the White Earth River, White Earth Lk to Wild Rice R (AUID 09020108-505), based on average annual (1996 through 2009) total nitrogen yields.

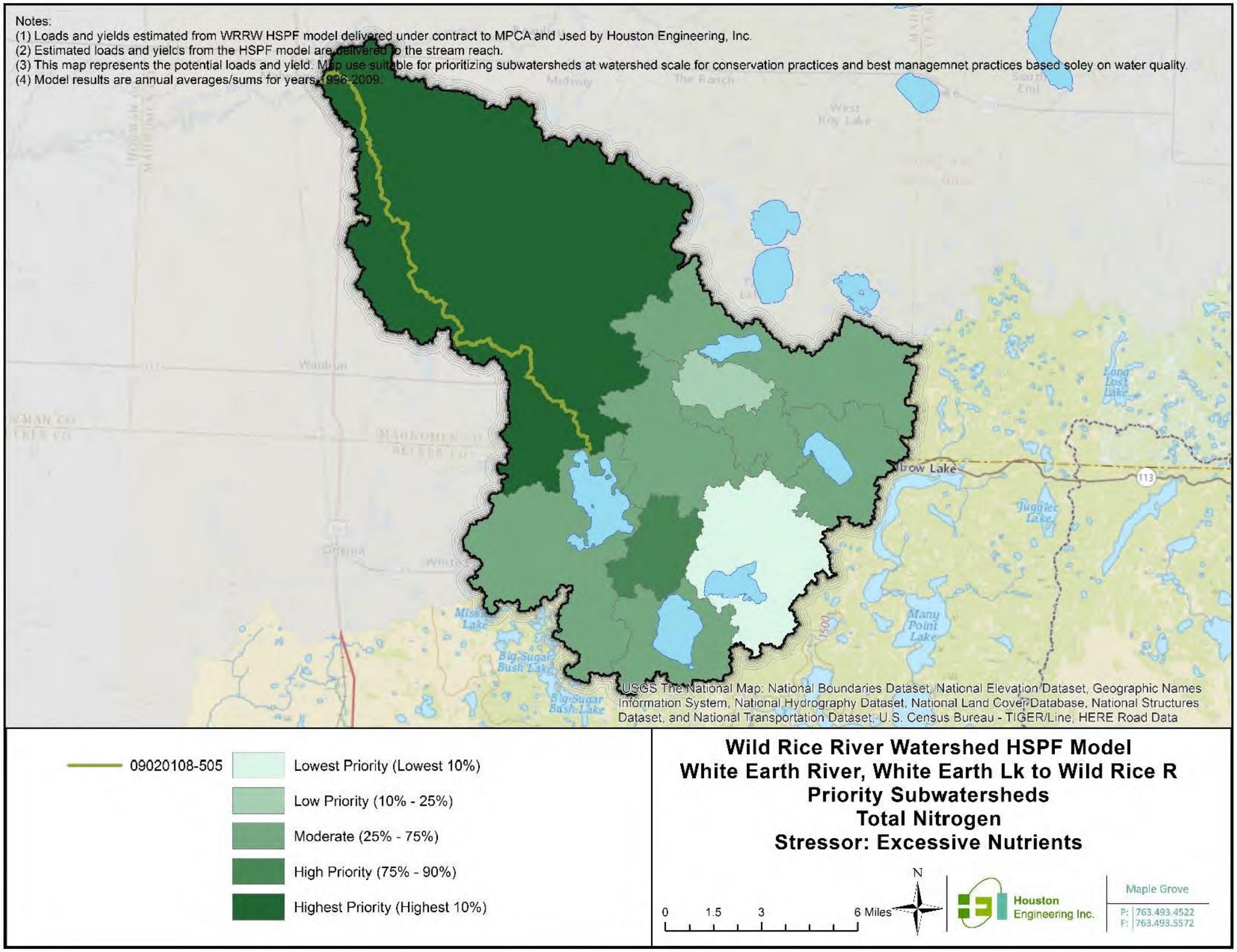


Figure B-33: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the White Earth River, White Earth Lk to Wild Rice R (AUID 09020108-505), based on average annual (1996 through 2009) total sediment yields.

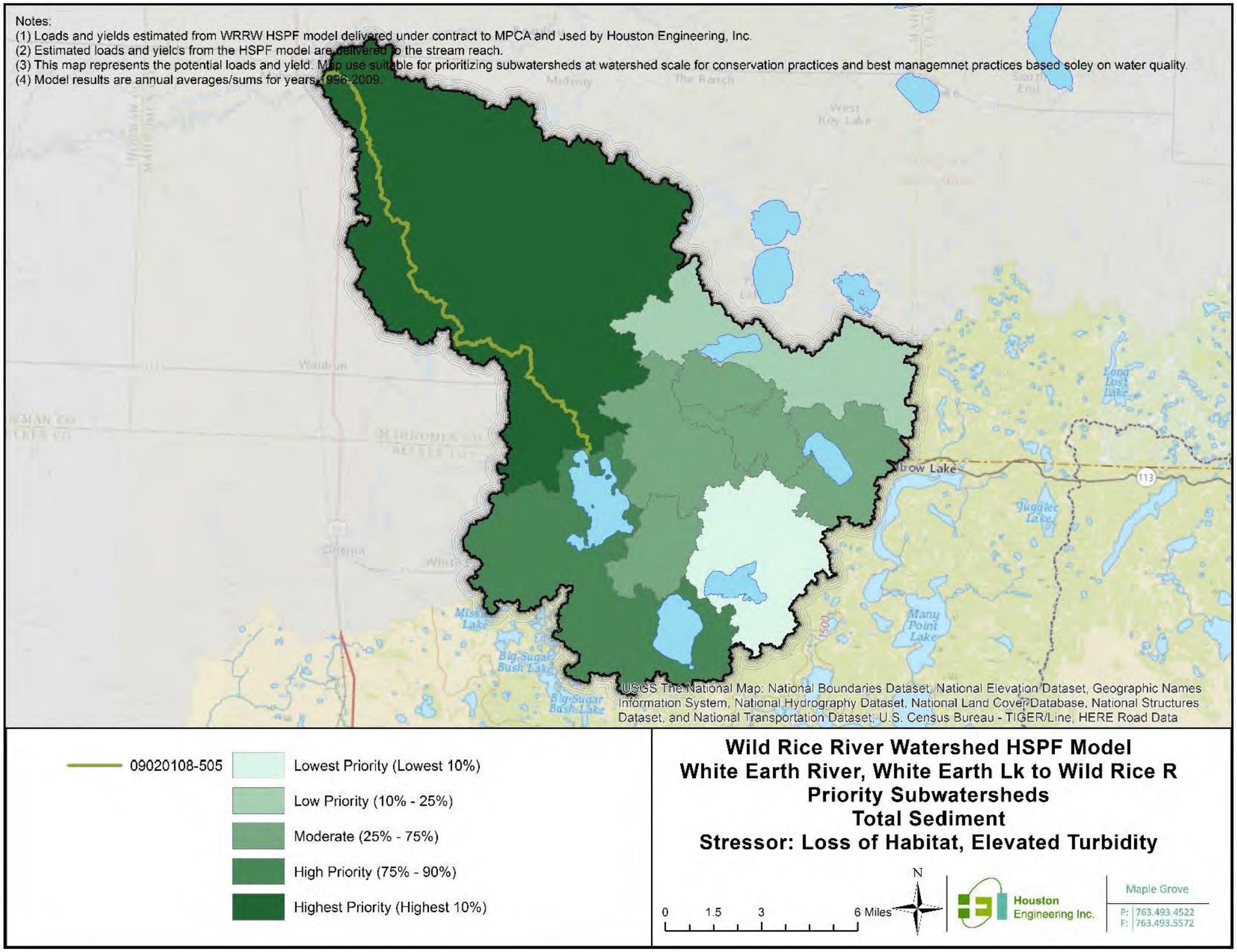


Figure B-34: Map of prioritized subwatersheds for implementation in the White Earth River, White Earth Lk to Wild Rice R (AUID 09020108-505), based on the average (1996 through 2009) water quality index.

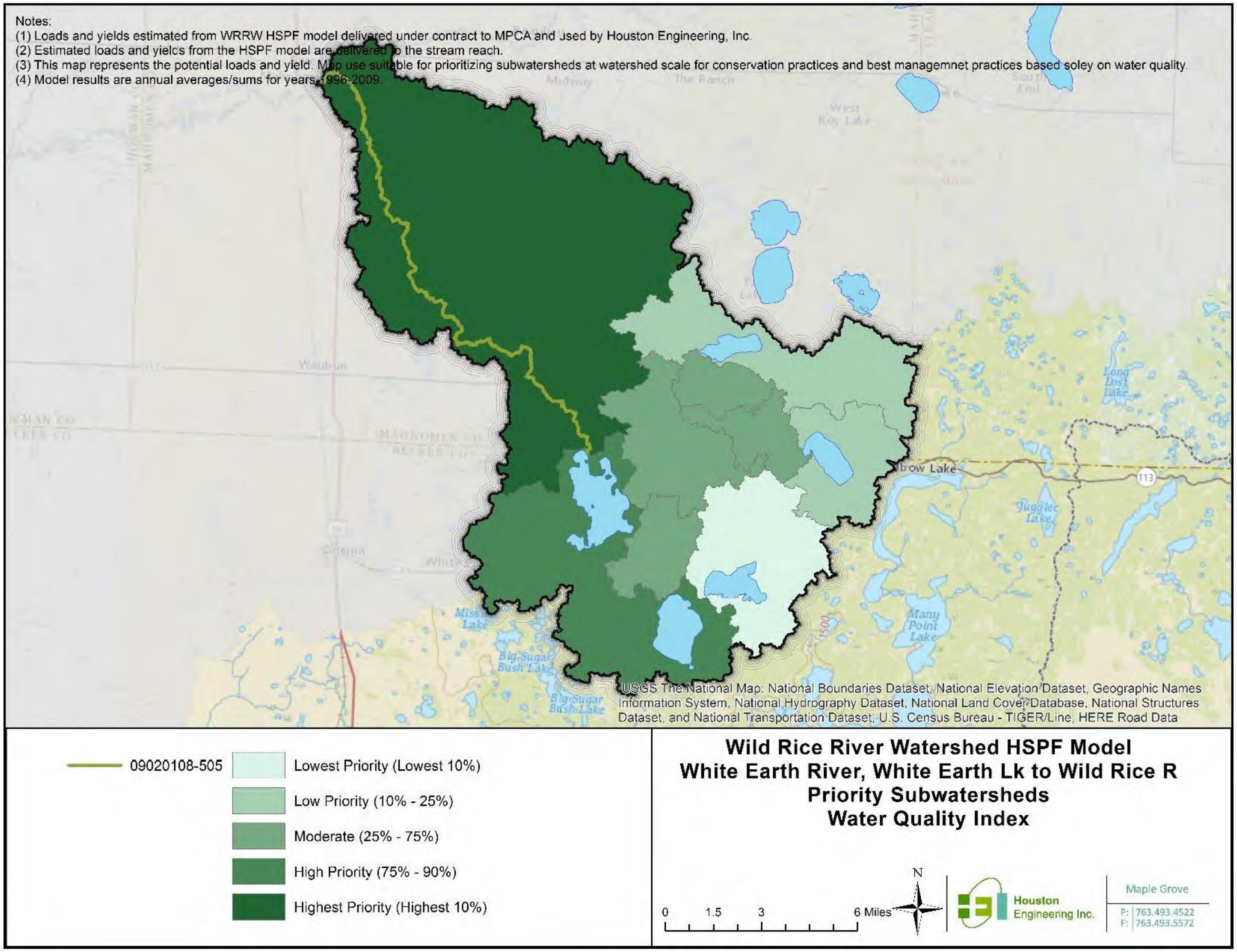


Figure B-35: Map of prioritized subwatersheds for implementation to address altered hydrology in the Marsh Creek, Beaulieu Lk to Wild Rice R (AUID 09020108-521), based on average annual (1996 through 2009) unit runoff.

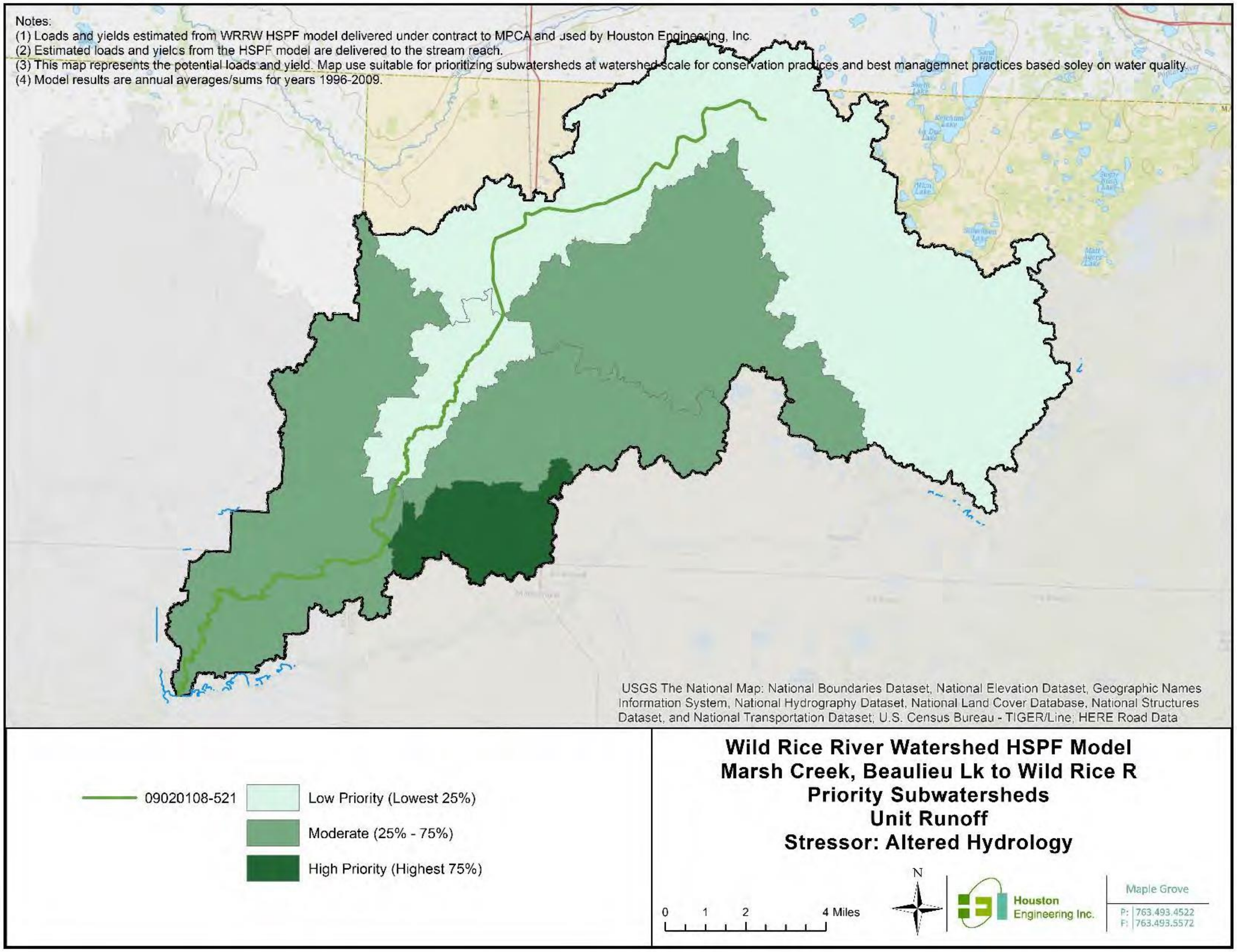


Figure B-36: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Marsh Creek, Beaulieu Lk to Wild Rice R (AUID 09020108-521), based on average annual (1996 through 2009) total phosphorus yields.

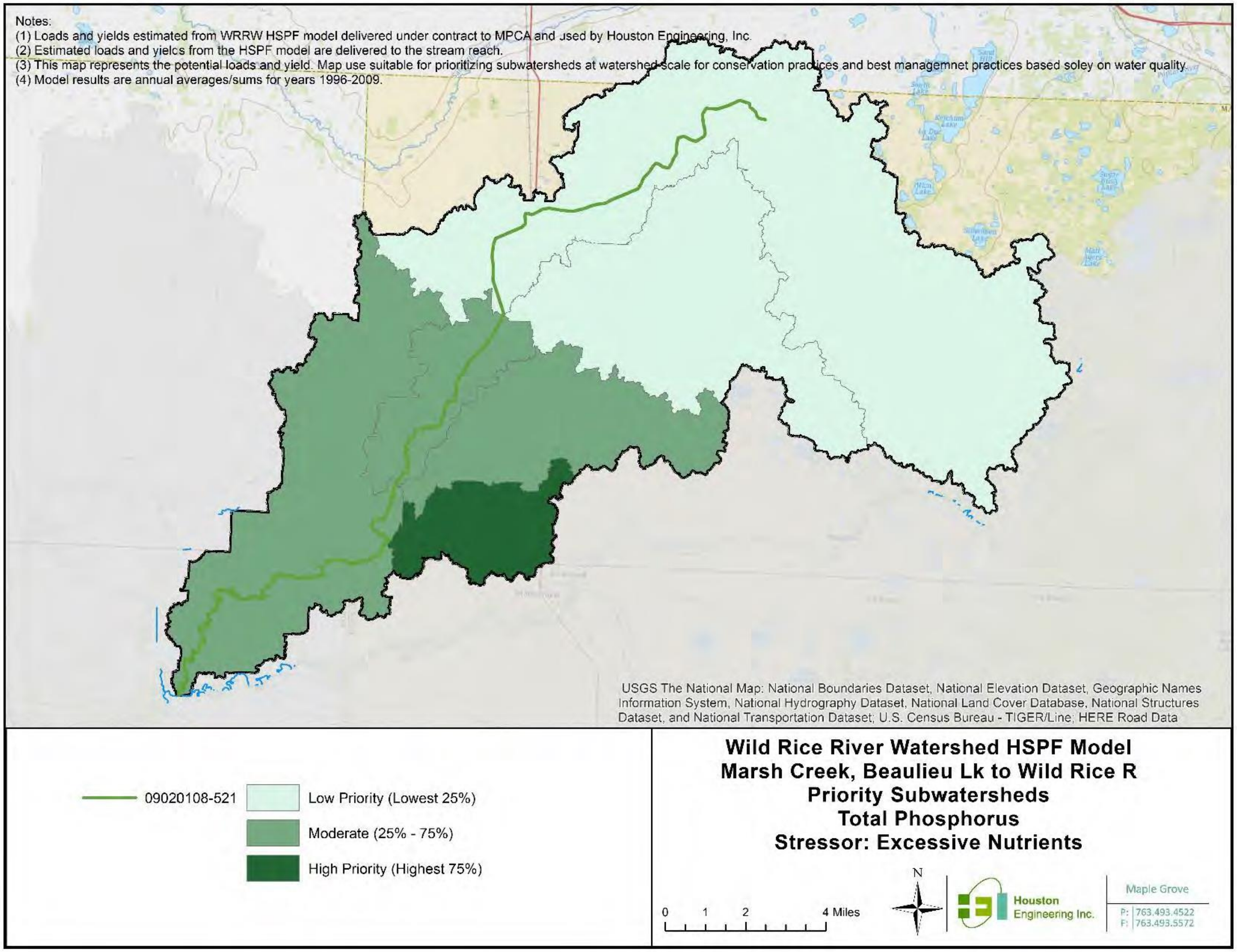


Figure B-37: Map of prioritized subwatersheds for implementation to address excessive nutrients in the Marsh Creek, Beaulieu Lk to Wild Rice R (AUID 09020108-521), based on average annual (1996 through 2009) total nitrogen yields.

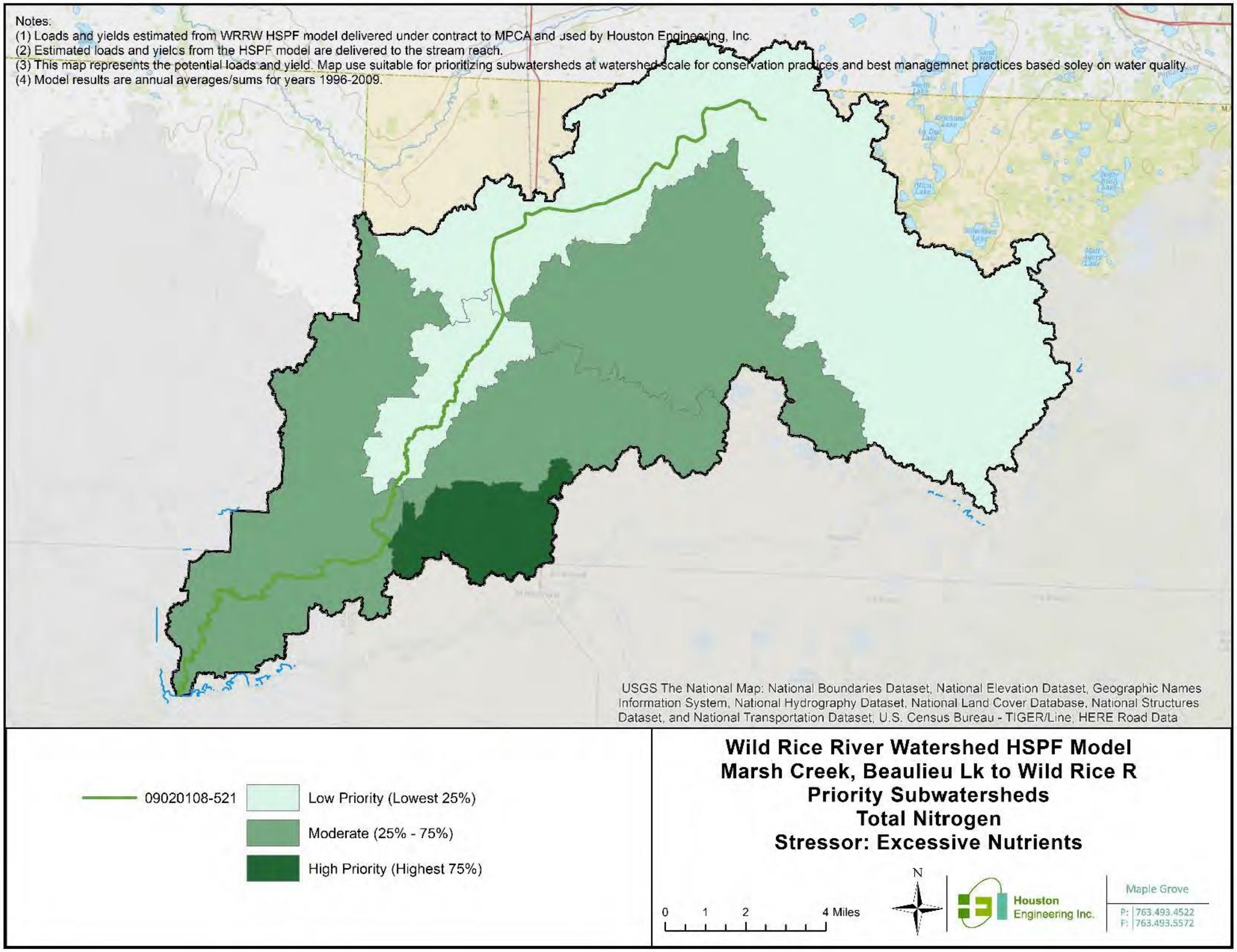


Figure B-38: Map of prioritized subwatersheds for implementation to address elevated turbidity and loss of habitat in the Marsh Creek, Beaulieu Lk to Wild Rice R (AUID 09020108-521), based on average annual (1996 through 2009) total sediment yields.

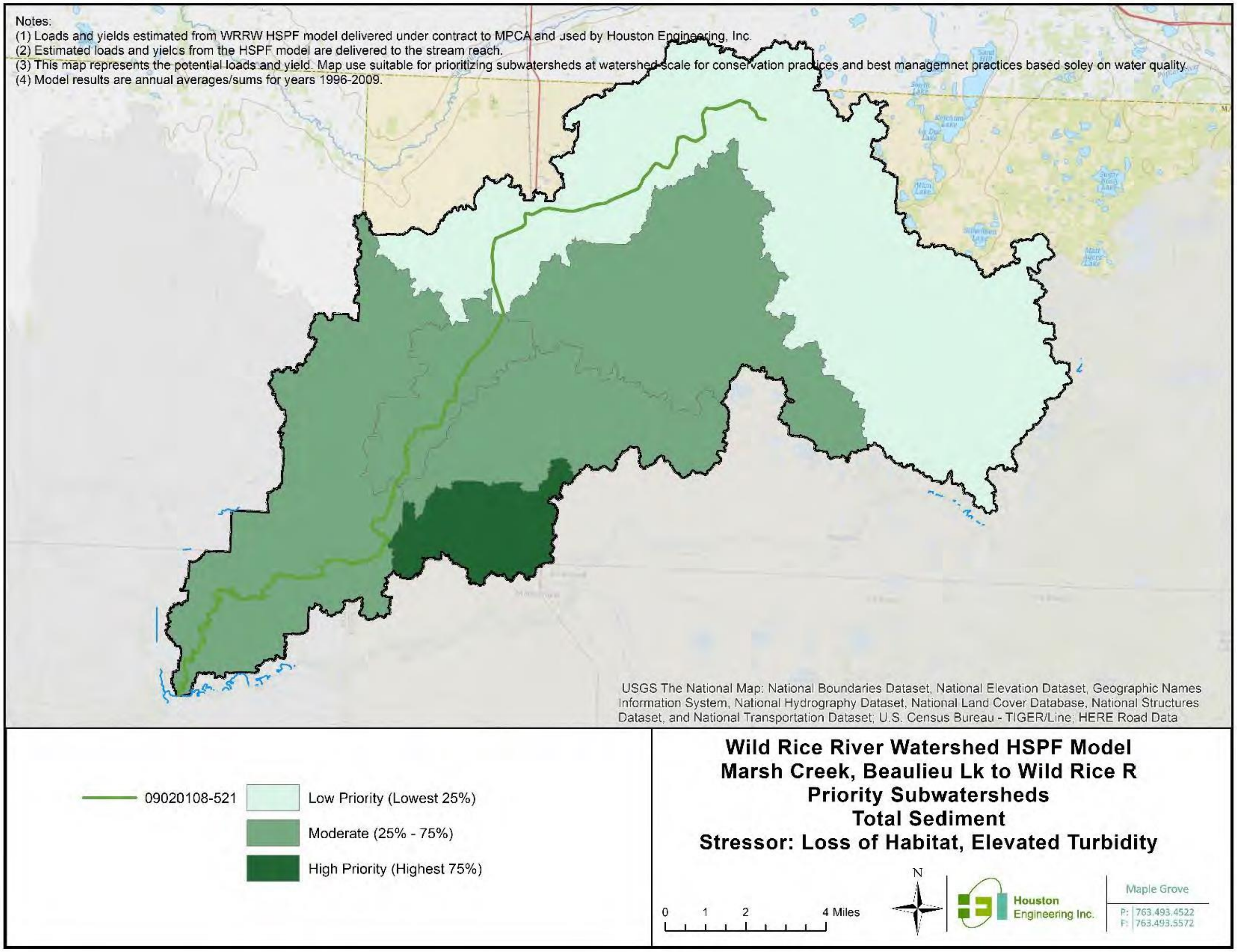
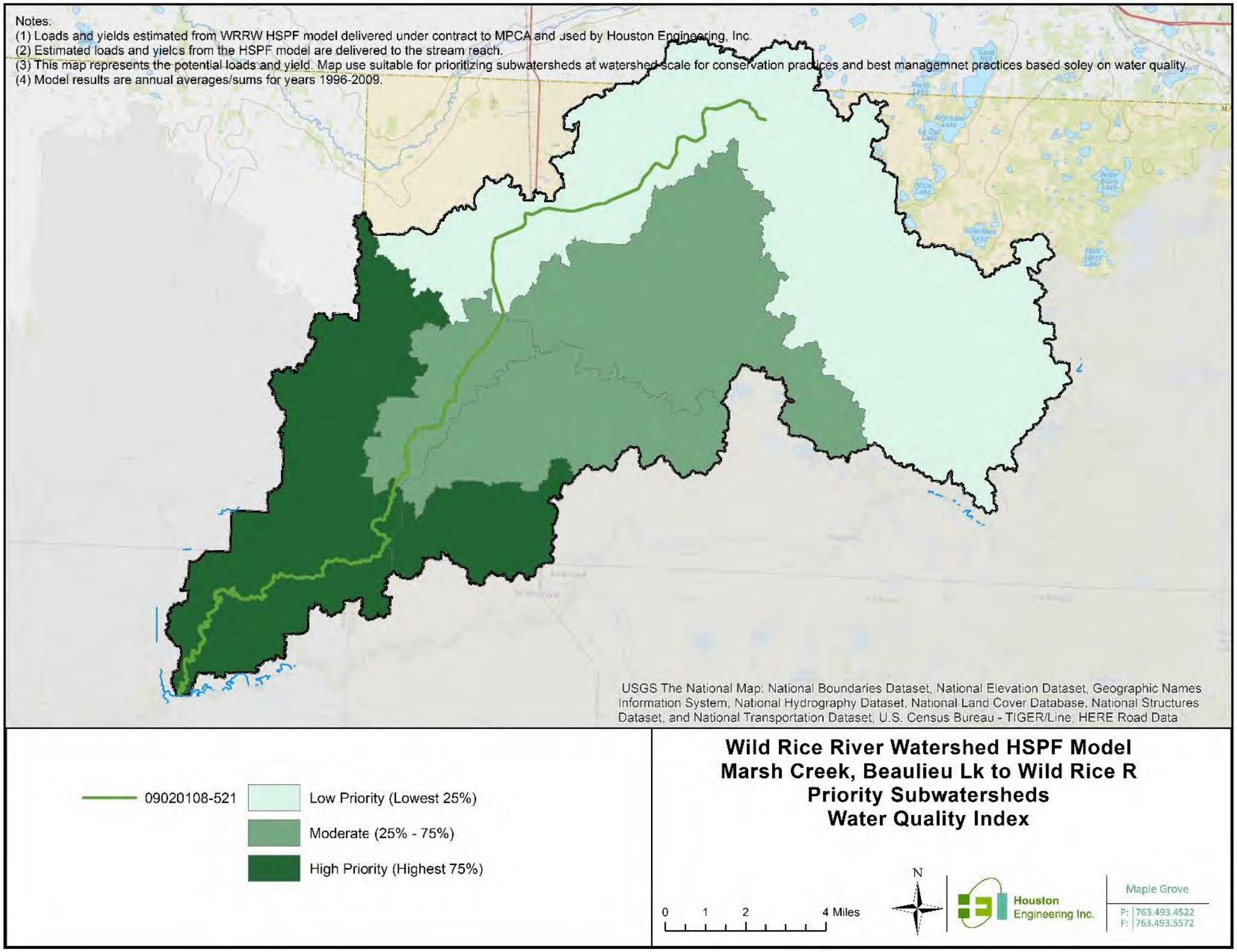


Figure B-39: Map of prioritized subwatersheds for implementation in the Marsh Creek, Beaulieu Lk to Wild Rice R (AUID 09020108-521), based on the average (1996 through 2009) water quality index.



Supplementary Table B-1: HSPF model outputs for runoff (RO), total phosphorus (TP), total nitrogen (TN), and total sediment (TS) used to prioritize subwatersheds for implementation.

WQ Parameter	Description	Volume	Group	Variable	x1	x2	Factor
RO	Total runoff from pervious areas	PERLND	PWATER	PERO	1	1	
	Surface water runoff for impervious areas	IMPLND	IWATER	SURO	1	1	
TP	Total flux of inorganic P (PO_4)	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 (PO_4)	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	
TN	Total flux of Ammonia (NH_3)	PERLND	PQUAL	POQUAL	2	1	
	Total flux of Nitrate-Nitrite (NO_2-NO_3)	PERLND	PQUAL	POQUAL	3	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 (NH_3)	IMPLND	IQUAL	SOQUAL	2		
	Total flux of Nitrate-Nitrite (NO_2-NO_3)	IMPLND	IQUAL	SOQUAL	3		
	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	
TS	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	

Supplementary Table B-2: Water quality yields by subwatershed from the Wild Rice River Watershed portion of the WRRW/MRW HSPF model.

HSPF RCHRES	Unit Runoff [in/yr]	Total Nitrogen [lbs/ac/yr]	Total Phosphorus [lbs/ac/yr]	Total Sediment [tons/ac/yr]	WQI	FSI TN	FSI TP	FSI TS
4	5.70	1.69	0.045	0.064	0.20	-0.71	-0.39	-1.03
10	5.95	1.84	0.060	0.078	0.24	-1.09	-0.88	-3.59
19	5.54	1.56	0.037	0.054	0.18	-2.73	-1.15	-5.68
30	5.45	1.49	0.032	0.046	0.16	-4.19	-1.27	-4.90
40	5.96	1.84	0.056	0.077	0.23	-5.32	-2.85	-2.91
50	6.21	2.07	0.060	0.103	0.25	-1.57	-0.67	-4.40
64	5.37	1.45	0.036	0.051	0.17	-0.71	-0.38	-1.10
67	5.45	1.64	0.037	0.060	0.20	-3.93	-1.50	-4.64
68	5.56	1.67	0.036	0.056	0.19	-2.71	-0.92	-4.63
69	5.14	1.32	0.025	0.031	0.15	-1.33	-0.45	6.92
70	6.00	1.97	0.065	0.101	0.25	-1.61	-0.84	-5.09
80	5.61	1.77	0.053	0.089	0.24	-1.58	-0.75	-3.62
86	5.73	2.01	0.048	0.103	0.25	-0.80	-0.43	-1.06
88	6.01	2.11	0.054	0.111	0.26	-3.67	-1.73	-4.32
90	6.11	1.69	0.051	0.073	0.22	-1.28	-0.68	40.02
98	6.65	1.47	0.029	0.029	0.14	-0.60	-0.23	-1.56
99	5.23	1.35	0.026	0.038	0.16	-8.13	-2.21	-4.02
104	6.53	1.41	0.028	0.024	0.07	-0.60	-0.25	-1.24
106	6.23	1.62	0.037	0.051	0.18	-0.13	-0.06	-0.28
107	5.71	1.46	0.029	0.046	0.16	-9.44	-2.84	-3.75
109	6.25	1.79	0.087	0.108	0.25	-3.91	-3.17	-3.97
110	7.40	2.36	0.357	0.338	0.52	-1.63	-4.19	-3.17
114	6.61	1.48	0.029	0.028	0.13	-0.65	-0.27	-1.41
115	6.56	1.47	0.032	0.030	0.14	-5.89	-1.81	-3.54
116	6.64	1.48	0.031	0.028	0.14	-0.61	-0.27	-1.21
117	6.73	1.56	0.034	0.034	0.16	-2.89	-0.96	-26.86
119	6.62	1.50	0.033	0.032	0.15	-3.35	-0.99	-5.78
122	6.49	1.40	0.027	0.024	0.07	-3.32	-0.80	-6.69
124	7.10	1.76	0.049	0.054	0.19	-0.24	-0.12	-1.69
125	7.18	1.80	0.046	0.047	0.17	-5.20	-1.60	-8.73
128	6.90	1.70	0.047	0.056	0.19	-0.30	-0.18	-0.78
129	7.19	2.25	0.226	0.226	0.37	-4.21	-6.82	-3.27
130	7.20	2.40	0.427	0.395	0.54	-1.11	-3.31	-3.42
147	5.56	3.79	0.203	0.191	0.31	-10.27	-8.14	-3.67
149	5.89	2.05	0.250	0.173	0.29	-3.12	-5.92	-3.54
150	5.75	1.97	0.264	0.182	0.29	-1.87	-3.86	-5.04
153	5.78	2.01	0.273	0.186	0.30	-3.65	-7.85	-3.29
155	5.53	1.81	0.213	0.145	0.27	-2.70	-5.41	-3.55
157	5.66	1.94	0.280	0.189	0.30	-2.01	-3.73	-5.50

HSPF RCHRES	Unit Runoff [in/yr]	Total Nitrogen [lbs/ac/yr]	Total Phosphorus [lbs/ac/yr]	Total Sediment [tons/ac/yr]	WQI	FSI TN	FSI TP	FSI TS
159	5.73	2.00	0.294	0.199	0.33	-3.57	-8.58	-3.41
163	6.01	2.18	0.310	0.215	0.36	-13.01	47.79	-7.77
165	5.78	2.03	0.298	0.203	0.33	-1.86	-4.64	-3.19
169	5.76	2.00	0.287	0.195	0.32	-6.68	-15.28	-3.27
170	3.52	2.61	0.192	0.182	0.29	-1.46	-1.62	-4.27
183	5.76	5.01	0.313	0.295	0.45	-4.50	-3.08	-2.31
185	3.59	2.84	0.216	0.206	0.34	-1.95	-2.03	-35.95
189	3.91	2.75	0.192	0.175	0.29	-13.28	-16.54	-4.03
190	3.06	1.60	0.089	0.077	0.23	-0.14	-0.12	0.26
210	3.40	2.26	0.137	0.128	0.27	-0.29	-0.32	0.53
230	3.47	2.20	0.126	0.117	0.27	-0.08	-0.09	0.10
233	6.01	2.17	0.313	0.215	0.36	-18.69	109.18	-4.67
237	5.86	2.09	0.313	0.214	0.35	-56.22	9.79	697.09
239	3.77	2.84	0.207	0.195	0.31	-2.46	-2.57	-3.59
245	5.77	2.02	0.298	0.202	0.33	-3.21	-7.81	-3.39
247	3.67	2.70	0.198	0.184	0.30	-3.72	-4.30	-3.67
249	3.06	1.90	0.120	0.112	0.26	-0.73	-0.81	7.82
250	3.51	2.84	0.220	0.212	0.34	-0.16	-0.26	0.28
270	3.77	3.14	0.234	0.226	0.36	-2.95	-4.62	-7.36
289	3.81	3.26	0.254	0.245	0.39	-8.75	-10.51	-3.82
290	3.59	2.82	0.214	0.204	0.33	-0.53	-0.74	2.54
303	3.70	3.25	0.262	0.254	0.40	-5.44	-6.46	-3.79
305	3.62	2.77	0.201	0.191	0.31	-0.82	0.86	0.15
309	3.84	3.39	0.273	0.263	0.41	-13.60	-22.29	-3.99
310	3.10	1.30	0.139	0.016	0.06	-0.10	-0.09	-0.01
330	3.57	1.81	0.228	0.025	0.09	-0.70	-0.68	-0.07
350	3.33	1.57	0.181	0.021	0.07	-0.01	-0.01	0.01
369	3.63	1.87	0.237	0.026	0.10	-6.74	-14.01	3.15
370	3.58	1.82	0.231	0.025	0.09	-0.05	-0.10	0.02
381	5.87	4.52	0.259	0.244	0.39	-13.06	-9.77	-3.21
385	5.55	3.98	0.221	0.206	0.34	-9.77	-7.29	-3.39
387	5.58	4.86	0.306	0.290	0.44	-1.03	3.07	0.26
389	5.74	5.16	0.326	0.310	0.46	-1.37	-1.36	3.53
397	5.83	5.42	0.348	0.331	0.52	-20.44	-16.63	-3.10
399	6.05	5.42	0.340	0.322	0.50	-9.85	-9.00	-3.90
401	5.92	5.53	0.353	0.336	0.53	-1.88	-2.57	1.94
405	5.91	5.73	0.373	0.357	0.54	-14.18	-11.88	-3.30
407	5.80	5.42	0.349	0.332	0.52	-12.10	-10.27	-3.41
411	5.49	4.83	0.303	0.289	0.43	-0.25	-0.29	0.17
419	5.88	5.60	0.359	0.343	0.53	-16.62	-14.00	-3.26

HSPF RCHRES	Unit Runoff [in/yr]	Total Nitrogen [lbs/ac/yr]	Total Phosphorus [lbs/ac/yr]	Total Sediment [tons/ac/yr]	WQI	FSI TN	FSI TP	FSI TS
421	5.36	4.61	0.292	0.277	0.42	-0.14	-0.18	0.08
427	5.90	5.42	0.342	0.327	0.51	-21.95	-18.60	-3.19
429	5.86	5.59	0.360	0.345	0.54	-28.10	-26.72	-3.27
431	5.82	5.16	0.328	0.304	0.46	-4.23	-5.12	47.88
433	5.71	5.00	0.316	0.294	0.44	-17.54	-14.32	-3.21
435	5.86	5.59	0.361	0.345	0.54	-14.61	-11.95	-3.16
437	5.74	5.37	0.352	0.330	0.51	-15.37	-12.64	-3.47
439	5.87	5.42	0.353	0.328	0.51	-6.01	-4.80	-3.31
445	5.58	4.57	0.279	0.257	0.41	-9.73	-7.86	-3.70
449	5.86	5.50	0.360	0.335	0.52	-6.74	-10.28	-16.60
451	3.81	3.21	0.234	0.226	0.37	-2.39	-3.20	8.96
455	3.96	3.30	0.255	0.243	0.39	-14.44	-20.72	-3.72
461	4.52	3.80	0.241	0.221	0.36	-0.71	-0.52	-10.96
469	3.84	3.33	0.264	0.255	0.40	-10.62	-45.96	-7.04
471	3.56	2.75	0.205	0.195	0.31	-1.48	-1.76	4.16
489	3.73	3.06	0.237	0.226	0.37	-15.54	-22.64	-3.66
491	3.53	2.36	0.160	0.147	0.28	-2.77	-2.98	58.43
511	3.90	2.97	0.212	0.199	0.32	-1.18	-1.25	3.55
519	3.94	3.23	0.252	0.237	0.38	-18.14	-28.91	-3.64
527	3.66	3.15	0.258	0.248	0.39	-16.90	-29.44	-3.70
529	3.81	3.23	0.252	0.241	0.38	-10.94	1.09	0.51
531	3.96	3.61	0.293	0.283	0.43	-0.56	-0.45	-7.17
551	3.60	1.85	0.242	0.025	0.10	-0.24	-0.37	0.11
567	3.95	3.61	0.292	0.283	0.42	-19.33	-33.37	-3.63
569	3.68	1.93	0.241	0.028	0.13	-1.09	-1.35	0.60
571	3.64	1.90	0.238	0.027	0.13	-0.67	-0.99	0.52
573	3.89	3.53	0.284	0.275	0.42	-9.28	-16.91	-5.95
577	3.69	1.95	0.239	0.028	0.16	-11.54	-25.87	8.64
579	3.63	1.88	0.245	0.026	0.11	-1.80	-6.26	0.19
585	3.91	3.66	0.303	0.295	0.44	-15.83	-27.15	-3.77
589	3.61	1.86	0.247	0.025	0.09	-1.78	-4.33	0.32
591	3.85	3.60	0.302	0.293	0.44	-0.70	-0.60	-4.10
610	3.61	1.86	0.234	0.026	0.11	-0.28	-0.32	-0.04
617	3.83	2.93	0.217	0.203	0.33	-3.41	-2.55	-4.06
619	4.35	4.26	0.333	0.319	0.47	-2.81	-2.41	-3.76
623	4.07	3.16	0.239	0.221	0.36	-3.34	2.56	0.63
625	4.39	4.32	0.332	0.319	0.48	-5.04	5.00	1.33
629	4.37	4.30	0.330	0.318	0.47	-34.40	-78.73	-3.42
631	4.41	4.35	0.331	0.319	0.48	-2.95	-2.31	-4.47
649	3.90	3.39	0.271	0.259	0.41	-5.21	-3.86	-3.14

HSPF RCHRES	Unit Runoff [in/yr]	Total Nitrogen [lbs/ac/yr]	Total Phosphorus [lbs/ac/yr]	Total Sediment [tons/ac/yr]	WQI	FSI TN	FSI TP	FSI TS
651	4.40	4.34	0.332	0.319	0.48	-4.80	-3.63	-3.37
671	4.36	4.30	0.333	0.320	0.49	-0.76	-0.55	-5.09
675	3.99	3.51	0.281	0.269	0.41	-3.63	-2.83	-3.32
679	4.36	4.30	0.333	0.320	0.49	-6.33	-4.69	-3.16
681	4.29	4.26	0.341	0.326	0.50	-0.19	-0.16	0.52
689	4.35	4.29	0.333	0.320	0.49	-13.78	-23.53	-4.12
691	4.33	4.27	0.333	0.320	0.48	-1.57	-1.31	-8.66
695	4.35	4.27	0.331	0.318	0.47	-12.49	-16.08	-3.85
699	3.63	1.88	0.242	0.026	0.11	-4.57	-9.18	1.67
701	4.35	4.27	0.328	0.317	0.46	-2.62	-3.46	9.82
710	4.20	4.01	0.307	0.296	0.45	-1.50	-1.60	268.69
729	4.38	4.31	0.332	0.321	0.50	-22.05	-29.38	-3.39
730	1.67	0.73	0.103	0.008	0.03	-0.91	-2.65	0.05
749	1.63	0.71	0.112	0.007	0.03	-5.49	-25.85	0.53
750	1.74	0.79	0.098	0.010	0.04	-0.18	-0.26	-0.03
751	3.62	1.87	0.242	0.026	0.11	-5.98	-10.10	3.02
753	3.67	1.92	0.238	0.028	0.13	-3.87	2.57	0.09
755	3.68	1.93	0.238	0.028	0.14	-3.58	-7.45	0.78
759	3.64	1.89	0.244	0.026	0.12	-12.85	-33.44	5.22
761	3.69	1.94	0.241	0.028	0.14	-5.12	-9.32	2.90
763	1.62	0.70	0.114	0.007	0.02	-0.69	-1.20	0.47
765	1.61	0.69	0.114	0.006	0.02	-1.99	-5.65	0.33
767	1.70	0.78	0.112	0.009	0.04	-1.35	-3.36	0.31
769	1.79	0.86	0.108	0.011	0.05	-0.54	-0.92	0.28
770	1.54	0.45	0.050	0.002	0.01	-0.08	-0.17	0.00

Appendix C: Wild Rice River Watershed PTMApp

Based on a technical memorandum by Houston Engineering, Inc. (HEI) that was provided to MPCA on July 5, 2018.

Introduction

Using results from the MRW and WRRW Prioritize, Target, and Measure Application (PTMApp), a hydrologically-conditioned digital elevation model (hDEM) and a suite of water quality datasets were generated to help identify and target locations at the field-scale for BMPs and CPs. This memo summarizes PTMApp data output products, including field-scale sources of sediment, TP, and TN, as well as prioritized locations for BMPS for addressing pollutants of concern. These data can be used for standalone implementation planning or within the framework of CWMP.

Development of the derived water quality data products utilized the desktop version of PTMApp, (https://ptmapp.bwsr.state.mn.us/). PTMApp can be used in rural settings to: 1) identify the field-scale source locations and amounts of sediment, TP, and TN that leave the landscape and enter a downstream lake or river; 2) target specific fields on the landscape (based upon USDA - NRCS design standards, landscape characteristics, land productivity, and/or landowner preference) for the potential implementation of nonpoint source BMPs and CPs; and 3) estimate the benefits of single or multiple BMPs and CPs to one or more streams, rivers, and lakes within a watershed, where the benefits are expressed as the downstream load reduction and the annual estimated cost/unit load reduction. For a specific type of CP or BMP (called "treatment groups" within PTMApp), an optimization curve showing the relationship between the estimated implementation cost and the reduction in annual load for a single watershed or multiple watersheds can be obtained. These tools allow water quality practitioners to target solutions to the identified priorities and develop tailor-made implementation plans. Products developed by using PTMApp are also useful in making day-to-day implementation decisions and communicating needs and benefits with landowners.

PTMApp has desktop (PTMApp – Desktop) and web (PTMApp Web) components. PTMApp – Desktop (https://ptmapp.bwsr.state.mn.us//User/PTMAppDesktop) consists of a toolbar for use within ESRI's ArcGIS technology. Once created, the geo-spatial data products can be shared using PTMApp Web (https://ptmapp.bwsr.state.mn.us/User/PTMAppWeb). The application was developed to meet the specific daily business needs of local water quality practitioners (https://ptmapp.bwsr.state.mn.us/User/Documentation). The intended audiences within Minnesota for using PTMApp and its products are SWCDs, watershed district, and County water planning staff.

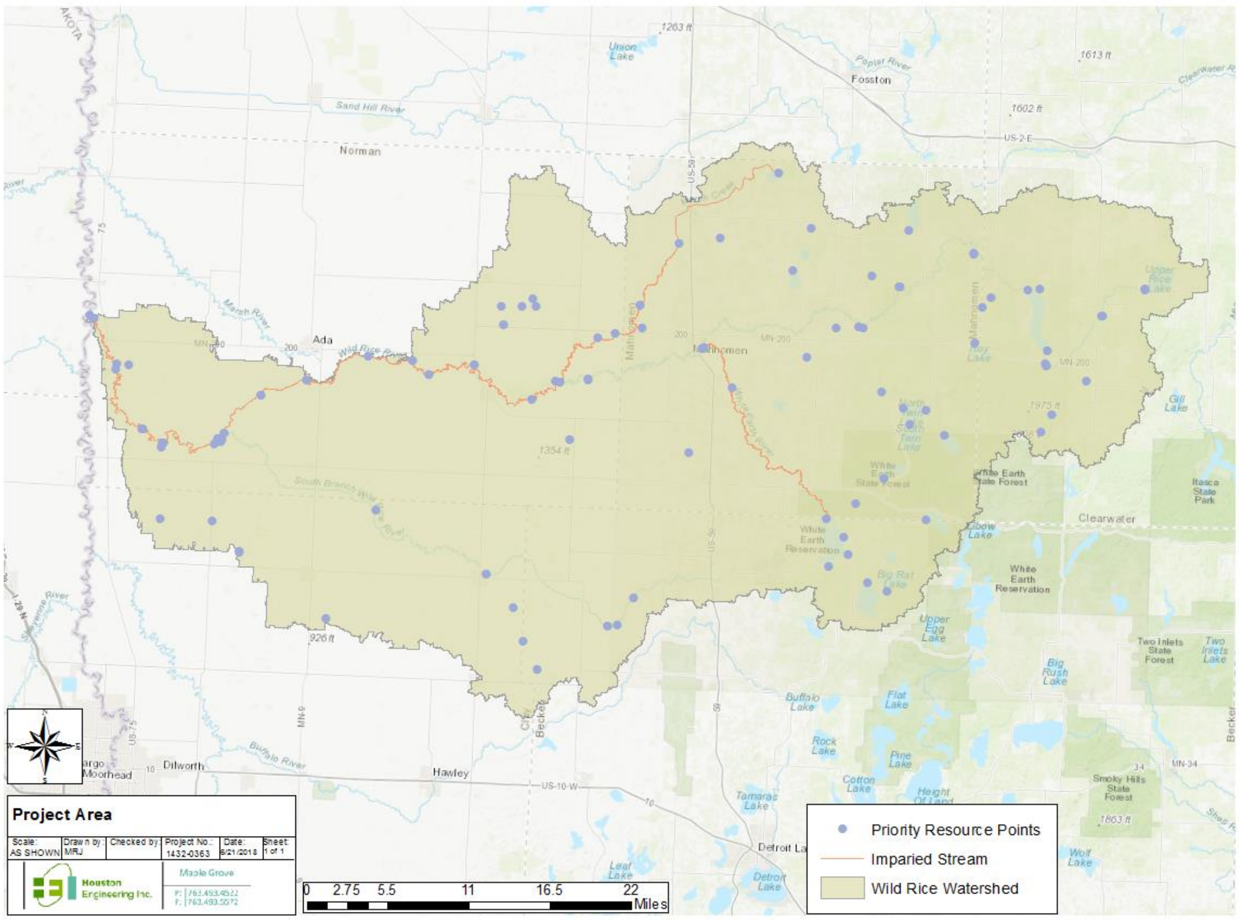
Project area

The WRRW, HUC-8 09020108 PTMApp project area (**Figure C-1**) is approximately 1,651 square miles (1,056,320 acres) and includes the following twelve HUC-10 subwatersheds:

- Felton Creek (0902010811)
- Headwaters Wild Rice River (0902010801)
- Lower Wild Rice River (0902010809)
- Marsh Creek (0902010807)

- Mashaug Creek (0902010808)
- Middle Wild Rice River (0902010806)
- Outlet Wild Rice River (0902010812)
- South Branch Wild Rice River (0902010810)
- Spring Creek (0902010805)
- Twin Lake Creek (0902010803)
- Upper Wild Rice River (0902010802)
- White Earth River (0902010804)

Figure C-1: Wild Rice River Watershed project area.



Summary of data sources

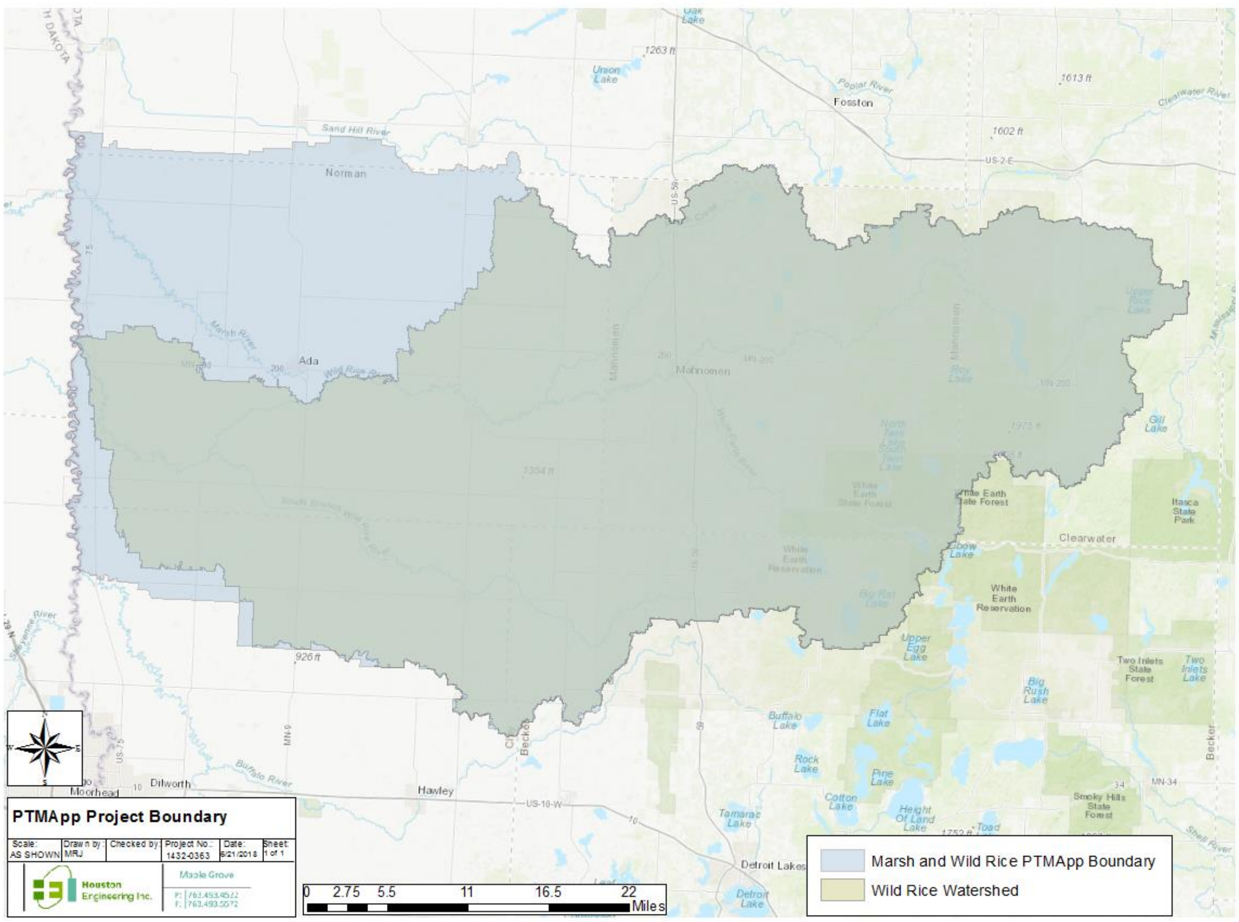
Several data sources are required to run PTMApp – Desktop. Summarized below are the data sources that serve as, or enable development of, the required inputs for PTMApp – Desktop, which are documented in the PTMApp – Desktop User Guide (available online: https://ptmapp.bwsr.state.mn.us/User/Documentation).

Plan boundary and priority resource points

The plan boundary is the extent of the study area for which PTMApp – Desktop is run. The extent could include an existing watershed boundary, watershed district boundary, or other boundary defining a project area. For purposes of this project the entire MRW and WRRW were combined into one PTMApp project (**Figure C-2**). The entire MRW/WRRW PTMApp project boundary is based on a union of the watersheds delineated from the hDEM and the legal boundary of the WRWD, at the request of the WRWD, to ensure the most complete spatial coverage. The priority resource catchment representing the WRRW was extracted from the PTMApp output data and used as the project area for this appendix (**Figure C-2**).

Priority resource points are the locations at which sediment, TP, and TN source loads are routed and where source load reductions can be summarized for potential BMPs and CPs. There are 112 priority resource points in the WRRW (**Figure C-1**). These priority resource locations were selected based on the HUC-10 and HUC-12 outlets, WRWD important lakes, MPCA IWM lakes, and input from WRWD staff.

Figure C-2: Wild Rice River Watershed within the PTMApp project boundary.



Topographic data

This project utilizes the State of Minnesota's Elevation Mapping Project's (http://www.mngeo.state.mn.us/committee/elevation/mn_elev_mapping.html) LiDAR elevation data collected to a vertical root mean square error (RMSE) of plus or minus six inches. For purposes of this work, the bare earth LiDAR points were interpolated into a DEM at a 5 meter by 5-meter resolution.

Rainfall frequency/duration data

The National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation data were used for the rainfall depths for the 2-year, 24-hour event and 10-year, 24-hour event to generate runoff volume and peak discharge estimates.

Land use/cover

The 2011 National Land Cover Dataset (NLCD) (Homer, et al., 2015) was used to develop runoff curve numbers, and to generate estimates of TN and TP loading. The National Agricultural Statistics Service (NASS) (http://www.nass.usda.gov/) 2014 Cropland Data Layer (CDL) was used for assigning cover management values for various land cover types in the RUSLE.

Soils

Hydrologic soil group designations from the USDA - NRCS SSURGO database was also used in developing curve numbers for hydrologic conditioning of the DEM. Soil Erodibility Factors (K_w) from these data were used as inputs for the RUSLE. SSURGO hydric rating, crop productivity index, and minimum depth to groundwater data were also used for identifying potential BMP and CP locations.

Rainfall-runoff (R-Factor) values

Information on R-factors used in RUSLE is available from the USDA - NRCS Minnesota Field Guide. The R-factor accounts for the impact of meteorological characteristics on erosion rates.

Methods

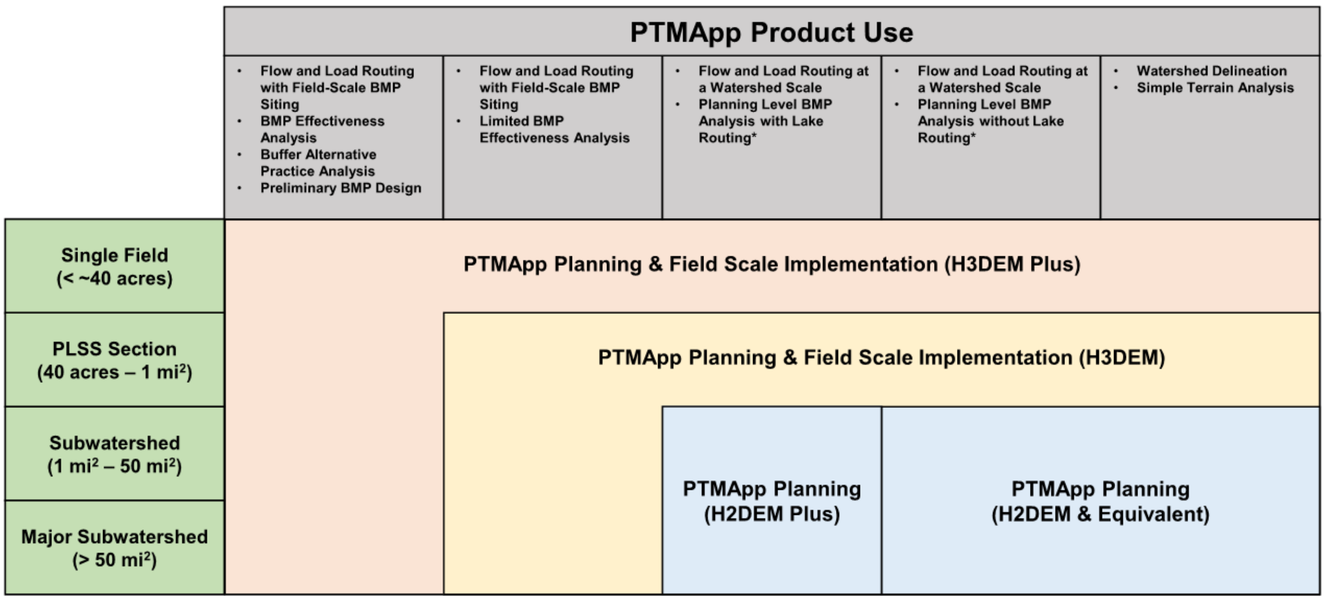
Hydrologic conditioning

Hydrologic conditioning is the process of modifying the topographic data represented as the raw or "bare earth" DEM through a series of GIS processing steps to represent the movement of surface water on the landscape more accurately. Upon completion of the hydrologic conditioning process, the DEM becomes modified to reflect the movement of water not only based on topography, but the presence of other factors affecting water movement like the locations of culverts, drains, or other structures. The hydrologic conditioning process used for this analysis was to enforce (with burnlines) waterways from manual aerial photo interpretation and watershed boundaries (with wall lines) from the Watershed Boundary Dataset (WBD).

The level of detail in the conditioning process can vary significantly depending on the purpose and need of the conditioned DEM's uses. **Figure C-3** displays the range of conditioning scale and a basic explanation of their differences. The WRRW was previously conditioned at a H3DEM standard to allow for planning and field scale catchment accuracy. This level of hydro conditioning provides flow and load routing with field sale BMP suitability and limited BMP effectiveness analysis. Modifications were made to the hydro conditioned products to account for lakes routing. Lakes routing is a technical process within PTMApp that simulates the effect of large wetlands, lakes, and reservoir systems on suspended sediment, TP, and TN loads. The theory and technical information of lakes routing is available as a technical memorandum on the BWSR PTMApp website (https://ptmapp.bwsr.state.mn.us/files/Technical_Memo_LakeRouting.pdf). In total, 51 lakes (**Figure C-4**) were included for lakes routing in the WRRW based on the following criteria:

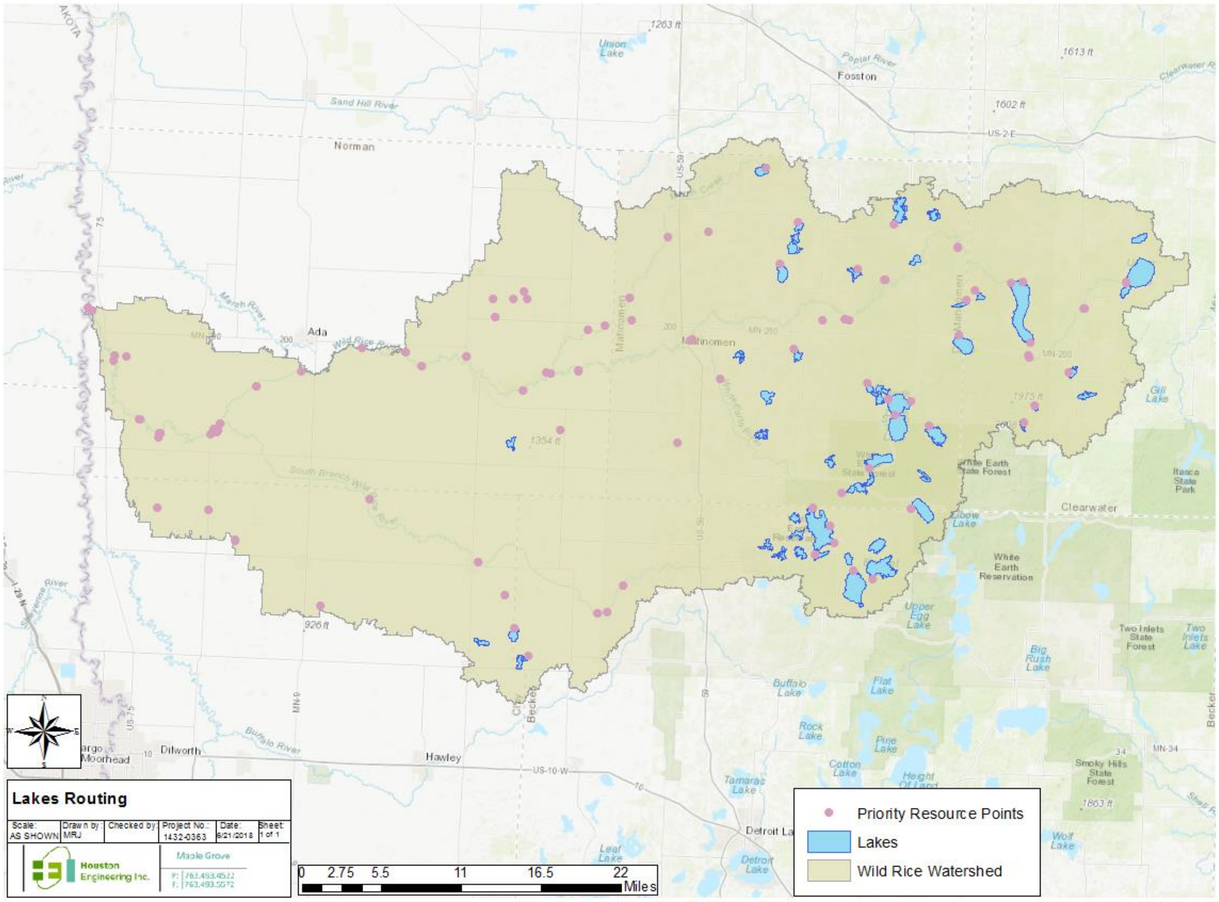
- Lake area > 160 acres
- Lake monitored during the MPCA IWM process
- WRWD Important Lakes
- Lakes included in the DNR Lakes of Phosphorus Sensitivity Significance

Figure C-3: Hydrologic DEM conditioning and data product scale.



* Lake routing is an analysis technique that adjusts sediment, total nitrogen, and total phosphorus loads based on dead storage within the lakes.

Figure C-4: WRRW lakes included in the PTMApp lakes routing process.



Travel time

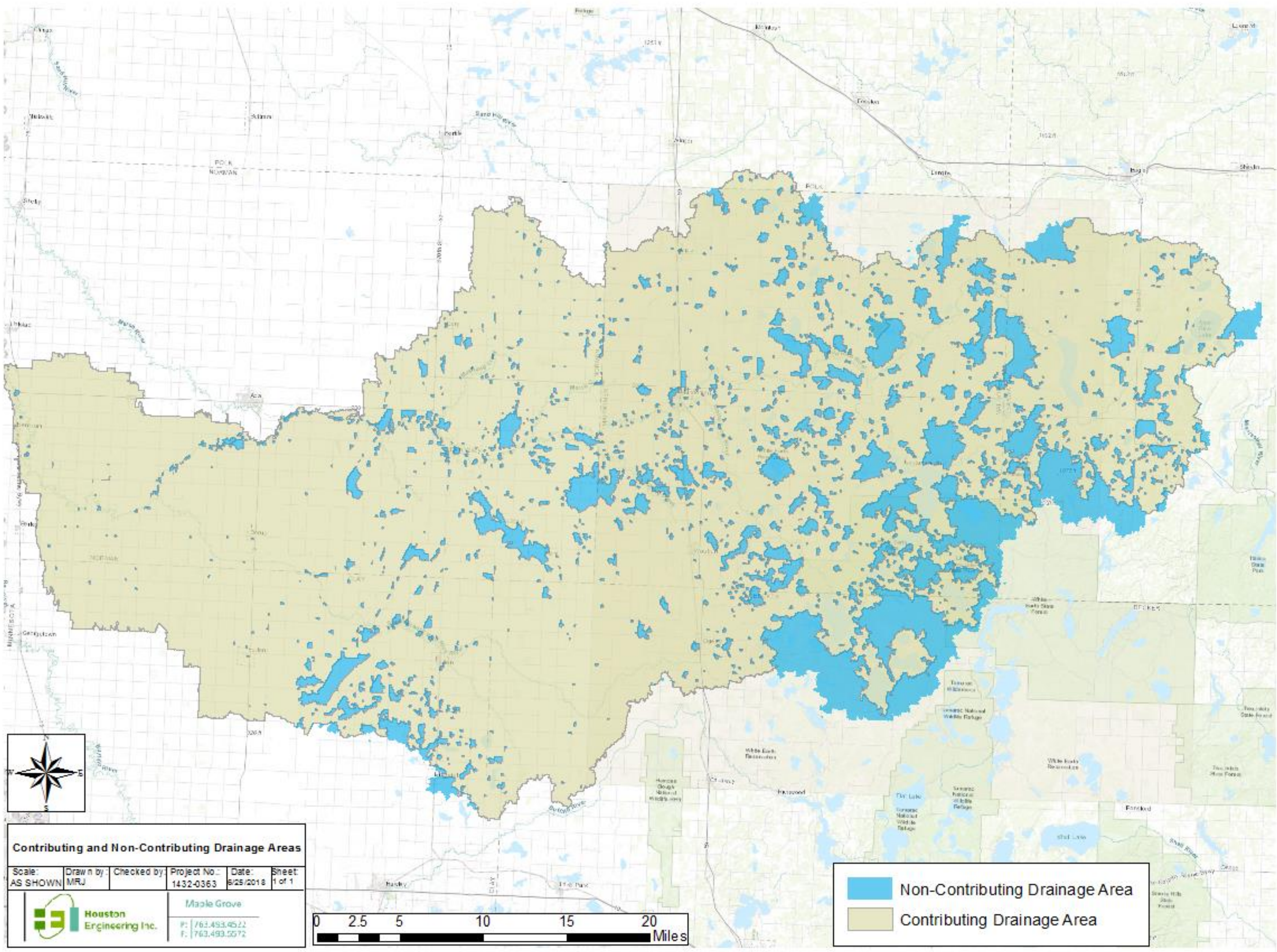
The travel time tool was created by HEI to develop downstream travel time rasters for each cell in a watershed. The travel time tool uses Manning's equation to determine flow velocity across a cell and then uses cell to cell flow lengths to determine the travel time across the cell. Once individual flow times across each cell have been estimated, travel times are accumulated in the downstream direction throughout the raster. Several pieces of input data must be created to run the travel time tool and are generated as outputs during the hydrologic conditioning process.

Noncontributing analysis

Depressional areas (e.g., sinks, wetlands, potholes) are a naturally-occurring features in many landscapes. During runoff events, the runoff volume reaching a depressional area is not contributed downstream until the runoff volume exceeds the depressional area's volume. If the runoff volume does not exceed the depressional area volume, the area is categorized as "noncontributing". This determination is dependent on the size of the runoff event analyzed. For the purposes of this study, noncontributing areas were defined as areas that contain the runoff volume corresponding to the 10-year, 24-hour precipitation event. For the study area, this event ranged from 3.69 to 3.81 inches of precipitation across the watershed, as defined by the NOAA in the Atlas 14 Precipitation-Frequency Atlas of the United States. The noncontributing determination was performed using a series of iterative GIS processes in which the available storage of a depressional area was compared to the runoff volume generated from the contributing watershed of the depressional area. This is an iterative “fill and spill” process in which the excess runoff of contributing areas is routed through subsequent downstream depressional areas until no excess runoff was produced. This process resulted in an hDEM that accounts for noncontributing areas. All depressional areas determined to be contributing were “filled” by adjusting their elevation values to equal the surface spill out elevation to create a continuous flow path that traverses the depressional area. Flow paths terminate at the minimum elevation cell within each noncontributing depressional area. All depressional areas deemed to be noncontributing were incorporated “as is” into the hydrologically conditioned DEM.

Some areas in the watershed that have an agricultural land use may be tile drained. Because there is not adequate data to know where private tile drainage exists, the assumption was made to leave the noncontributing depressions in the final data products. This dataset is useful for identifying restorable wetland projects and characteristics like volume of water that can be stored by the depression. Contributing and noncontributing areas in the WRRW are shown in **Figure C-5**.

Figure C-5: Contributing and Noncontributing Drainage Areas in the Wild Rice River Watershed.



Processing data in PTMApp - Desktop

The science and theory used to process data in PTMApp – Desktop are well documented through a series of technical memoranda, available at https://ptmapp.bwsr.state.mn.us/User/Documentation. These documents describe all the technical aspects of the processing performed to generate the output products for this project. In addition, these methods have been described in a series of free webinars that can be viewed at the aforementioned website. Rather than describe these methods in detail in this appendix, the website has been referenced.

This WRRW analysis used PTMApp desktop version 2.3.87. More detail about version releases can be found at https://ptmapp.bwsr.state.mn.us//files/VerionsUpdates_PubliclyReleased.pdf.

In summary, PTMApp – Desktop generates estimates of annual loads (sediment, TP, and TN) based upon empirical methods. The loads are then routed to downstream locations, via concentrated flow paths, to priority resource points, using a sediment delivery ratio for sediment and first order decay equations for TP and TN.

Priority resource points are points on the landscape for which informational products are generated including load reductions, cost benefit analysis, and routing for sediment, TN, and TP. Locations for priority resource points are guided by project stakeholder input and are typically placed at lake or stream outlets that are impaired or the focus of a protection strategy, or at the pour points of catchments or subwatersheds. **Figure C-1** shows the locations of priority resource points within the WRRW.

During development of the geospatial products, criteria were used to screen BMPs and CPs considered technically feasible for implementation. Locations of BMPs and CPs deemed technically feasible were created for six different treatment groups (protection, storage, infiltration, filtration, biofiltration, and source reduction) within PTMApp – Desktop.

Potential locations for BMPs and CPs are identified based upon USDA - NRCS design standards. The BMP and CP locations are then integrated with the source load data and surface hydrology calculations to estimate the BMP and CP efficiency and source load reductions. Finally, the cost of potential BMPs and CPs can be estimated based upon 2017 Minnesota Environmental Quality Incentives Programs (EQIP) payment schedules.

Local knowledge is still critical for ensuring that the data generated from this desktop analysis identify locations that are practical and feasible for implementing projects and practices. For example, land owner willingness and existing practices are two factors that cannot be accounted for in this project. Local knowledge can be incorporated and used to adjust for these factors.

PTMApp results

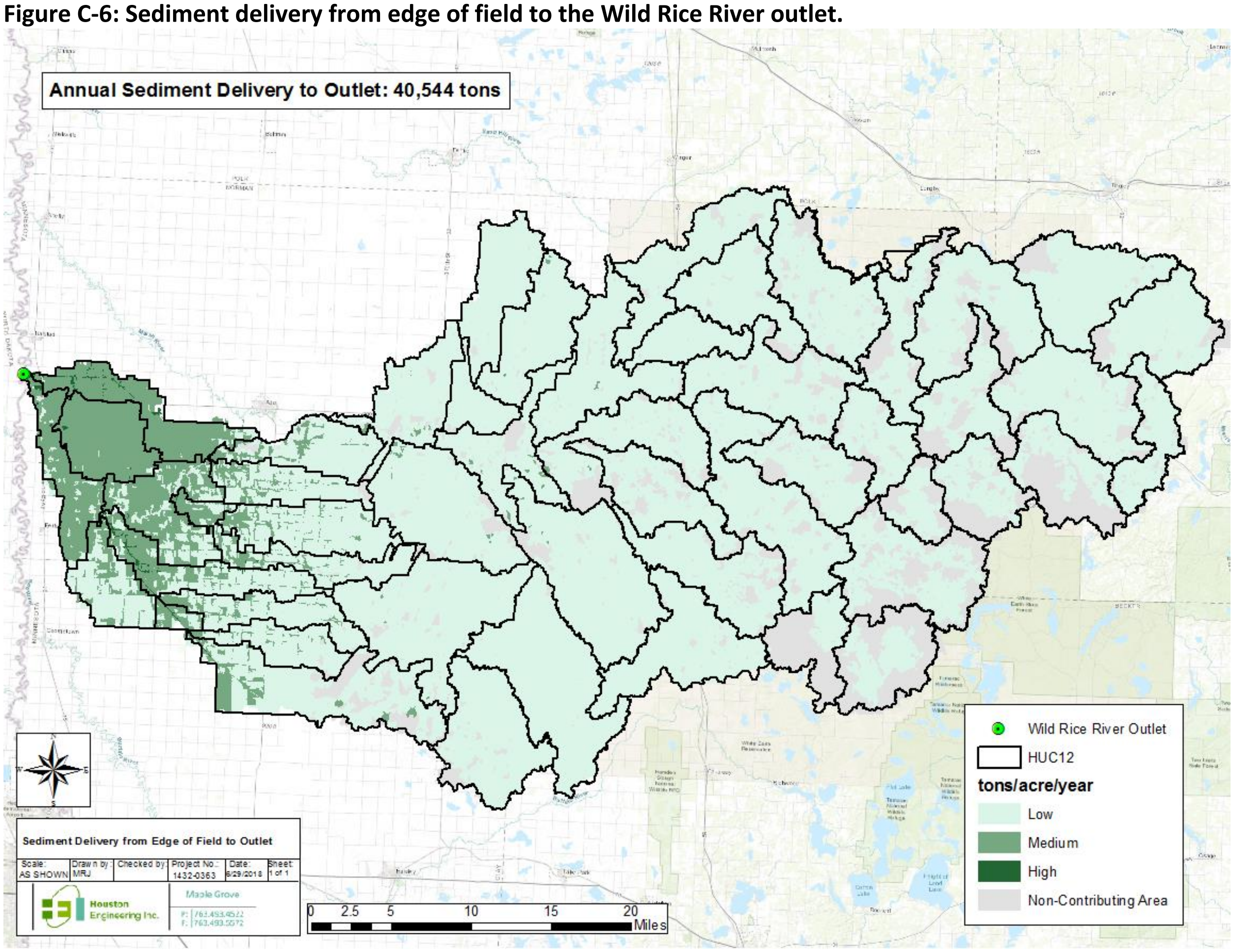
Prioritize resource concerns – source assessment

Prioritizing resource concerns is a term used to describe the process by which practitioners establish the relative importance of resources within their area of management. Frequently in Minnesota, surface water quality is a potential resource concern included in the prioritization processes. Products from PTMApp can be used in conjunction with other information, such as HSPF models and zonation, to aid in the process of prioritizing resource concerns.

Prioritization of the WRRW is described in **Appendix B** for runoff, sediment, TP, and TN. While the HSPF model is useful for estimating continuous overland and in-channel pollutant loading at a larger subwatershed scale, PTMApp estimates event-based (2-year and 10-year, 24-hour rainfall events) pollutant loading at a finer catchment or field scale, for overland sources. This field scale data allows for further prioritization and targeting based on critical areas within subwatersheds or priority resource catchments.

There is currently one approved TMDL in the WRRW (MPCA, 2009). The reach of the Wild Rice River from South Branch Wild Rice River to Red River of the North (AUID 09020108-501), also known as the Lower Wild Rice River, was listed for turbidity in 2006. The *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017) and the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018) cite high levels of TSS as a contributor to aquatic life use impairments in the WRRW. Sediment sources are in-channel and overland soil erosion, due to highly erosive soils, that occurs primarily during spring runoff and rain events (MPCA, 2017). **Figure C-6** depicts sediment delivery from EOF, referred to as catchment in PTMApp, to the Wild Rice River outlet at the Red River of the North.

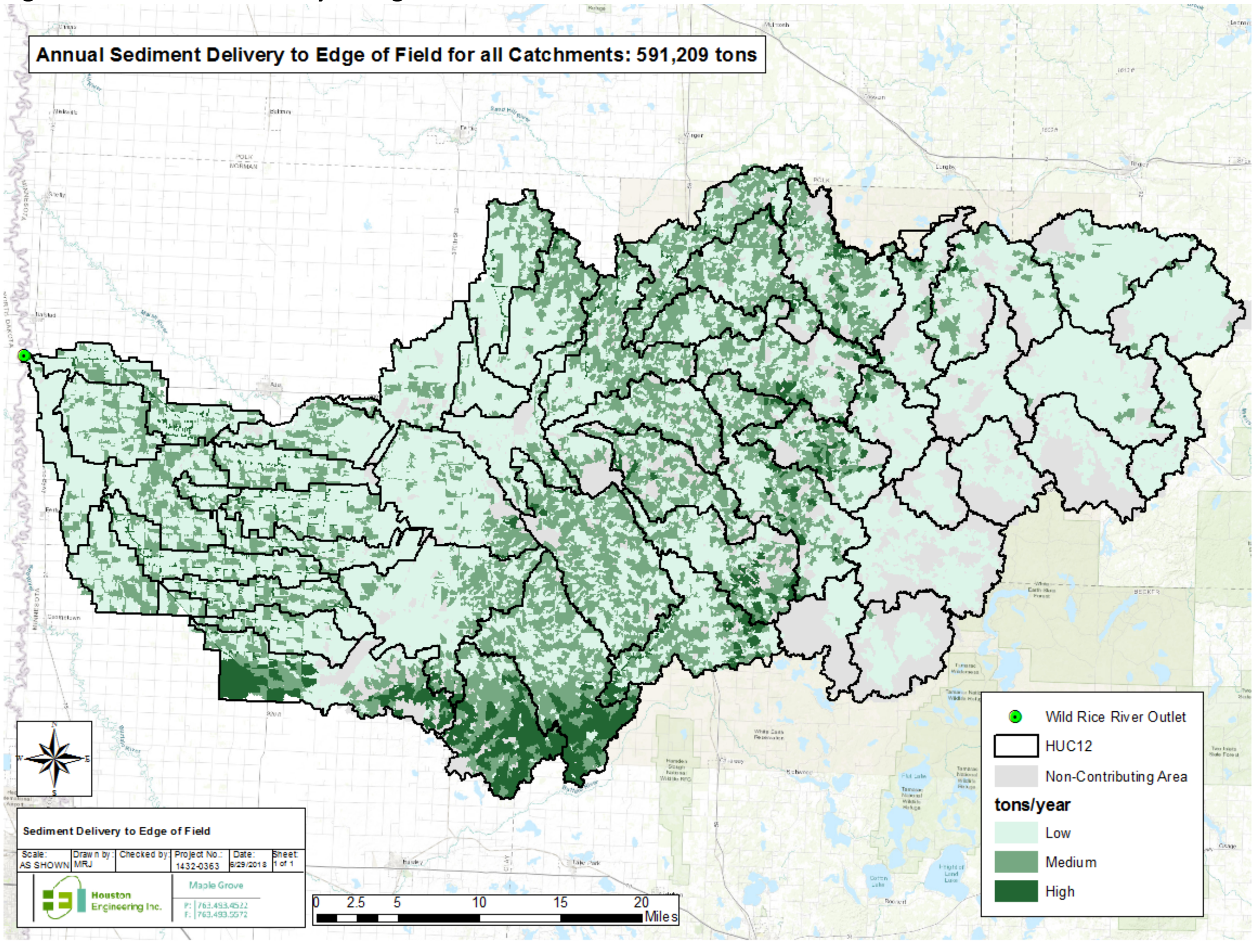
Figure C-6: Sediment delivery from edge of field to the Wild Rice River outlet.



Due to the sediment delivery ratio function of routing sediment downstream in PTMApp, source loads tend to be clustered near the priority resource outlet where loads are routed.

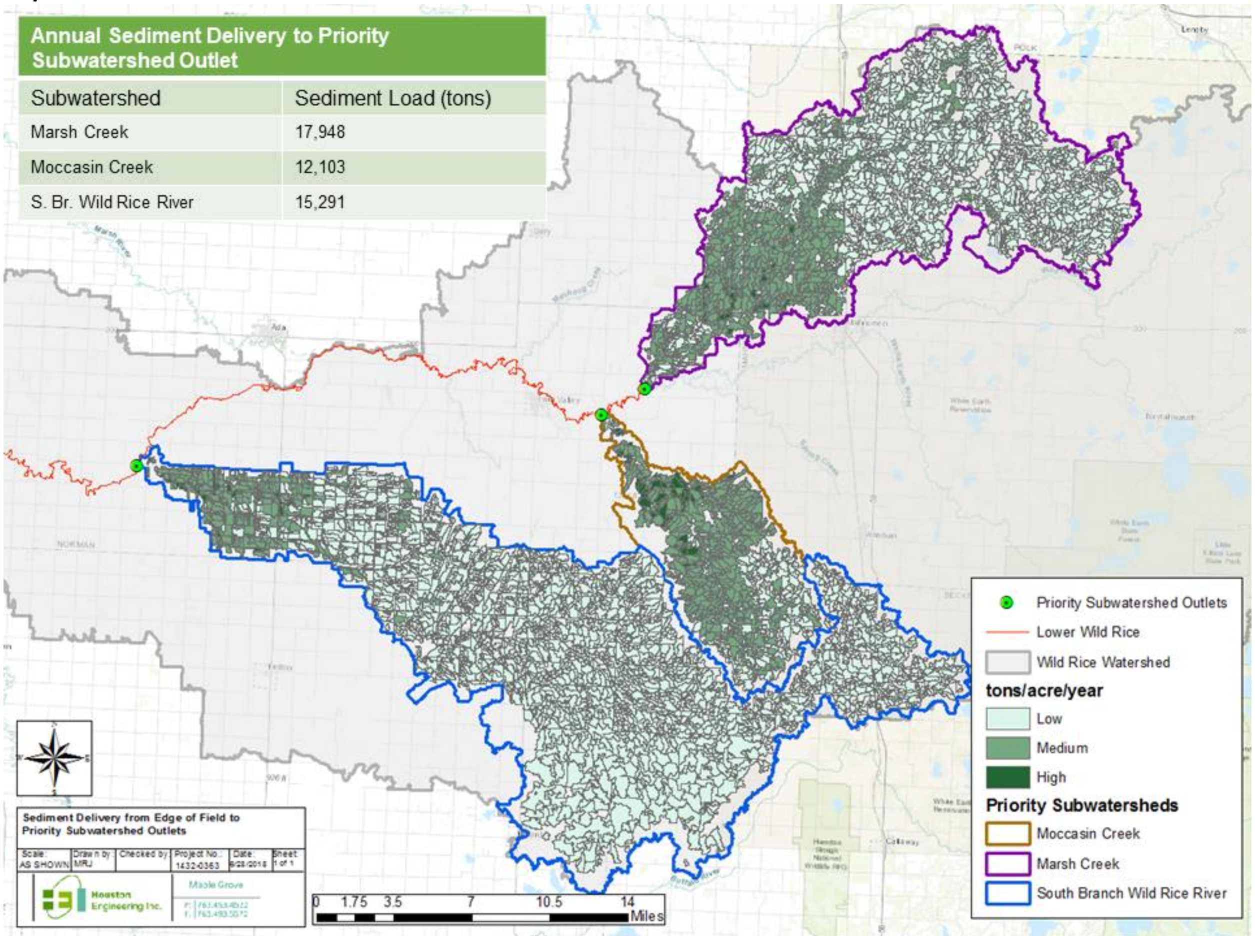
Another way to source sediment in PTMApp is to identify loading to the EOF or catchment outlet. This method provides a more localized assessment of sediment sources. This assessment if beneficial to practitioners whose intent is to keep sediment at the source and out of waterways. **Figure C-7** depicts sediment delivery to the EOF.

Figure C-7: Sediment delivery to edge of field.



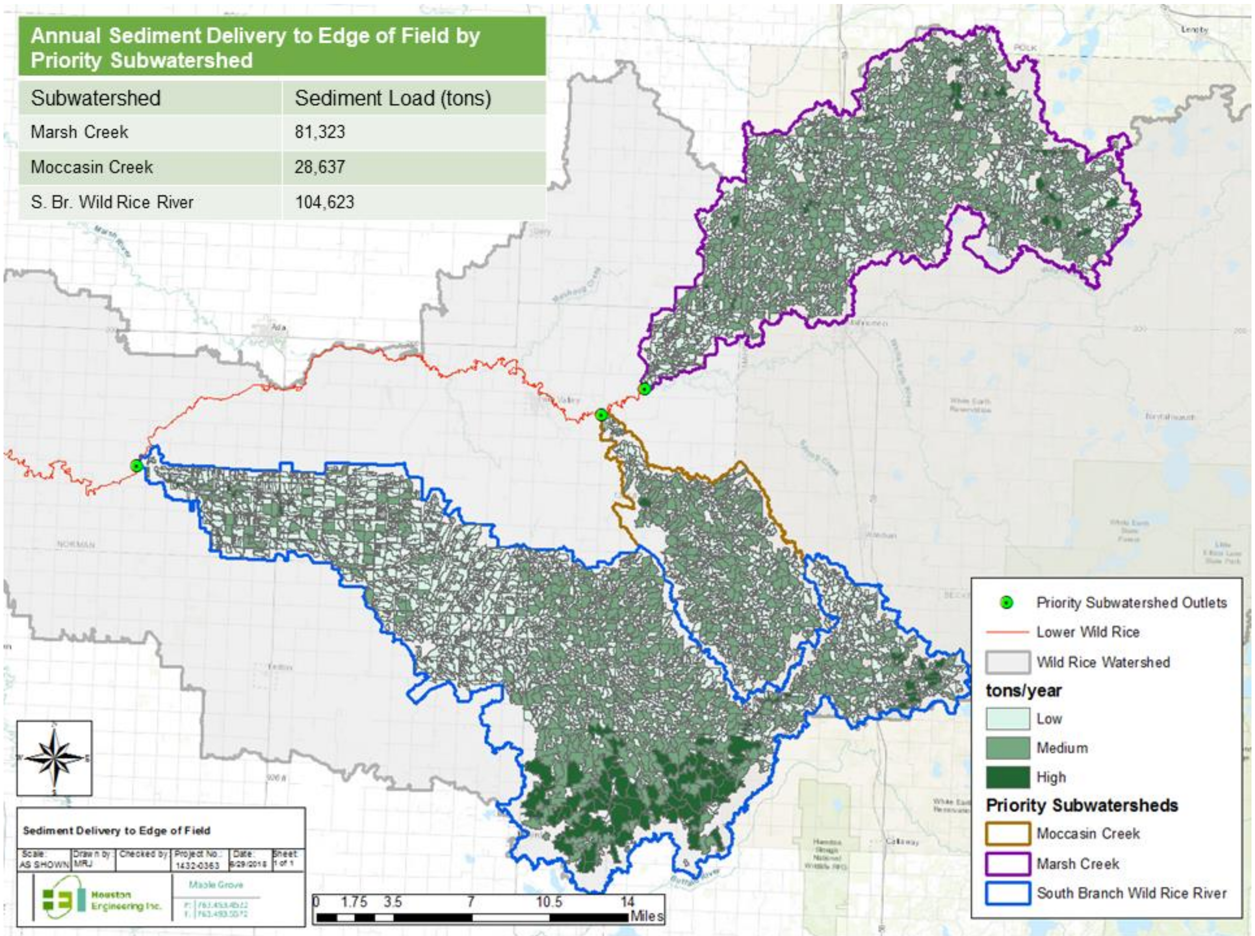
Overland source loading of sediment can further be refined by priority resource points placed in more upstream locations of the watershed. The *Lower Wild Rice Turbidity TMDL Implementation Plan* identifies three priority HUC-10s for implementation to address the turbidity TMDL: South Branch of the Wild Rice River (HUC 0902010810), Moccasin Creek (Apple Lake HUC 090201080901), and Marsh Creek (HUC 0902010807) (WRWD; Becker, Clay, Norman, and Mahnomen SWCDs, 2011). One of the initial implementation activities identified in the implementation plan is a basin-wide sediment source assessment. The HSPF model that includes the WRRW provides a subwatershed scale assessment across the entire watershed for sediment yields from in-channel and overland sources. PTMApp data provides a field-scale estimate of source loads for sediment across the entire watershed. By focusing on the three priority HUC-10s, the estimation of source loads at the field scale can further refine targeting actions for implementation. **Figure C-8** shows sediment delivery from the EOF to the outlets of the three priority HUC-10s. Sediment loading to these outlets contribute to overall sediment loading to most downstream reach of the Wild Rice River (AUID 09020108-501).

Figure C-8: Sediment delivery from edge of field to the outlets of HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Source loads delivered to the EOF can also be estimated to identify areas on the landscape where sediment could be prevented from reaching the outlets of the three priority HUC-10s and eventually the lower reaches of the Wild Rice River. **Figure C-9** provides a field-scale estimate of sediment delivery to the EOF.

Figure C-9: Sediment delivery to edge of field in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Evaluate Practice Feasibility

The feasibility of placing a BMP or CP on the landscape depends on several factors. These factors include land use, the size of the contributing drainage area, the land slope, the type of flow regime, and local topography. Detailed information on the theory and criteria for evaluating practice feasibility are documented in the *BMP Suitability Enhancement Technical Memorandum* (https://ptmapp.bwsr.state.mn.us/files/BMP_Suitabilty_Memo.pdf). Practice feasibility is based solely on technical factors largely based on field office technical guides developed by the USDA - 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. BMPs and CPs are categorized into five treatment groups consisting of structural practices and one treatment group of management practices. Treatment groups are shown in **Table C-1**.

Table C-1: PTMApp BMP and CP treatment groups.

Treatment Group	BMP Type (NRCS Practice Code)
Structural	
Biofiltration	Denitrifying Bioreactor (605)
	Saturated Buffer (604)
Filtration	Grassed Waterway (412)
	Filter Strip (393)

Treatment Group	BMP Type (NRCS Practice Code)
Structural	
Infiltration	Multi-Stage Ditch (N/A)
	Infiltration Trench or Small Basin (N/A)
Protection	Grade Stabilization (410)
	Grassed Waterway (412)
	Critical Planting Areas (342)
	Shoreline Restoration/Protection (580)
Storage	WASCOB (638)
	Drainage Water Management/Controlled Drainage (554)
	Farm Pond/Wetland (378,657,658,659)
	Regional Pond/Wetland (656)
	Regional Nutrient Reduction Wetland (656)
Management	
Source Reduction	Cover Crops (340)
	Perennial Crops (327)
	Nutrient Management of Groundwater for Nitrate (590)

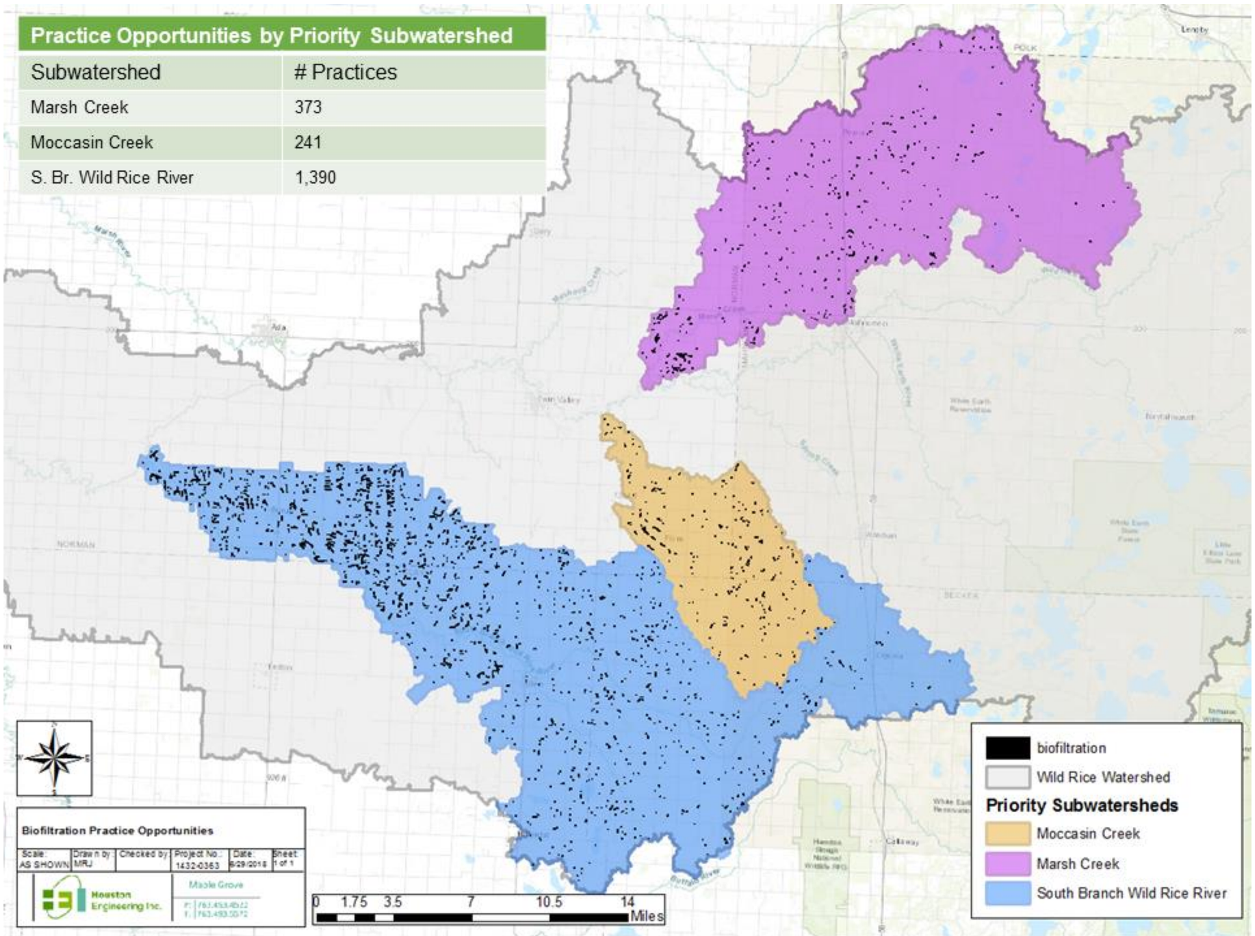
BMPs can be categorized as structural or management practices. These two categorizes generally represent different approaches to implementation. However, a mix of both structural and management practices is essential to ensuring a diverse and effective implementation approach.

The potential opportunities for structural and management BMPs and CPs, by treatment group within the WRRW, are described below. It is important to note that that these are only potential locations at this point in the implementation planning. Local knowledge is still needed to refine the locations to identify a realistic set of targeted practices. Practices can also be targeted by applying a set of screening criteria based on size, runoff volume delivery, constituent removal efficiency, and reduction magnitude to identify preferred practices and locations. 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.

Biofiltration

The biofiltration treatment group is comprised of two USDA - NRCS practices: denitrifying bioreactor (practice code 605) and saturated buffer (practice code 604). PTMApp identified opportunities for biofiltration practices in the HUC-10s identified as priority areas for implementation to address TSS in AUID 501 (**Figure C-10**). Biofiltration practices are not commonly implemented in the Red River Basin as nitrogen is typically not a pollutant of concern and their ability to treat sediment and phosphorus is limited.

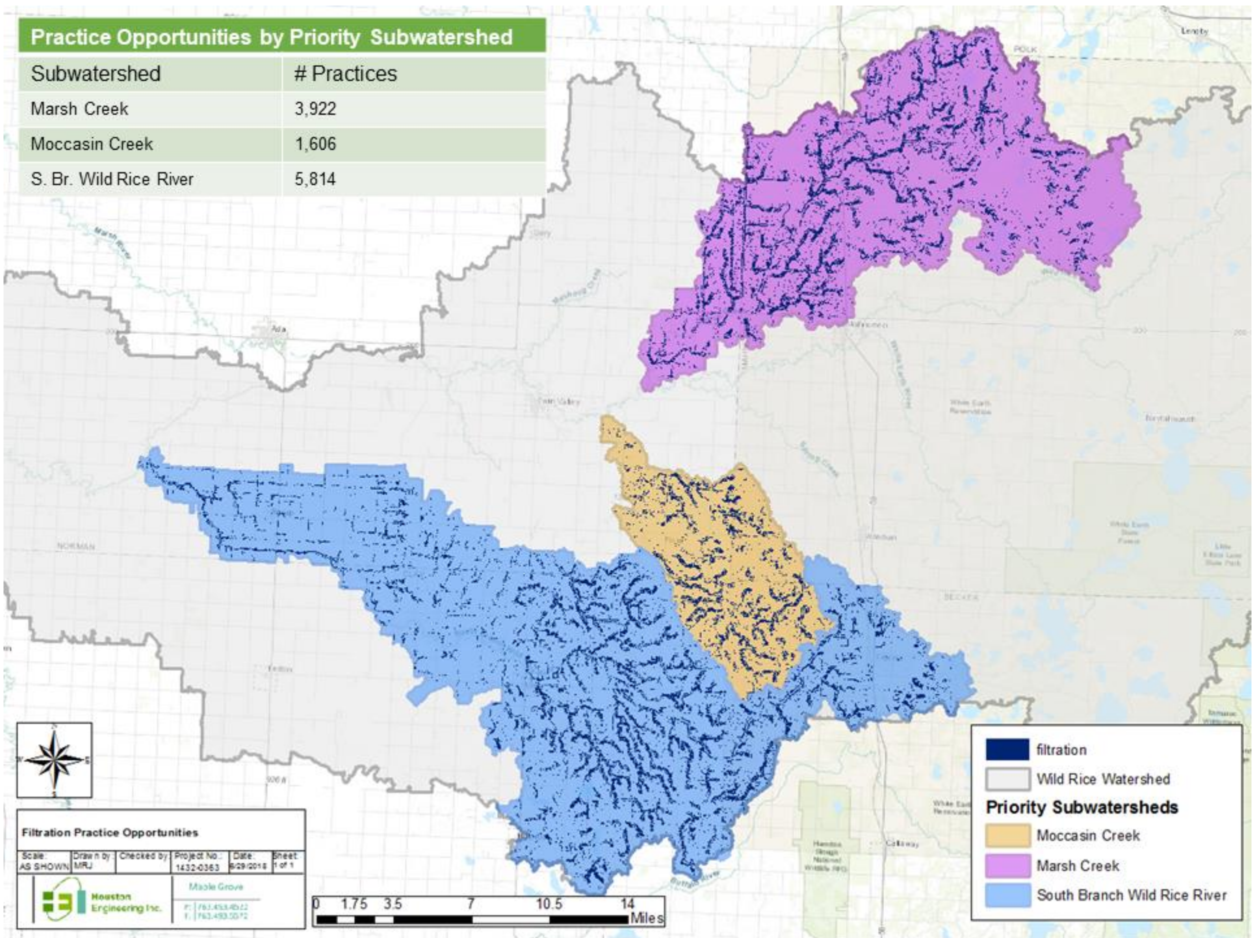
Figure C-10: Biofiltration practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Filtration

The filtration treatment group is comprised of two USDA - NRCS practices: grassed waterway (practice code 412) and filter strip (practice code 393). PTMApp identified opportunities for filtration practice implementation in the HUC-10s identified as priority areas for implementation to address TSS in AUID 501 (**Figure C-11**). Filtration practices are common due to their cost-effectiveness and abundance of opportunities.

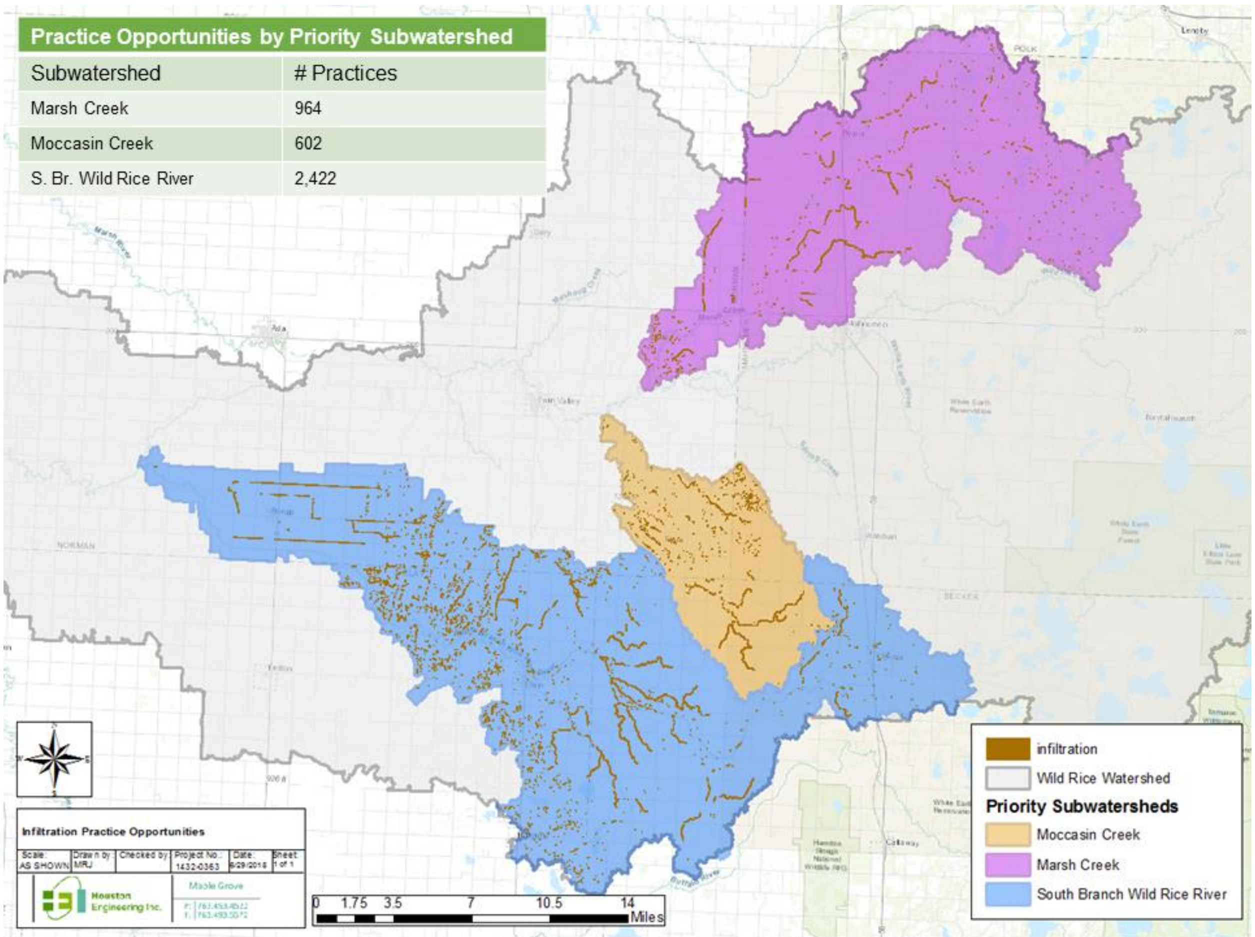
Figure C-11: Filtration practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Infiltration

The infiltration treatment group is comprised of two USDA - NRCS practices: multi-stage ditch and infiltration trench or small basin. PTMApp identified practice opportunities in the HUC-10s identified as priority areas for implementation to address TSS in AUID 501 (**Figure C-12**). Multi-stage ditches, commonly known as two-stage ditches provide bank stabilization by slowing the velocity of water and increasing the area of water to move through the ditch. Due to the highly erodible soils, extensive ditch network, and bank stability issues, this treatment group should be considered for implementation in the Wild Rice priority subwatersheds where ditching is extensive.

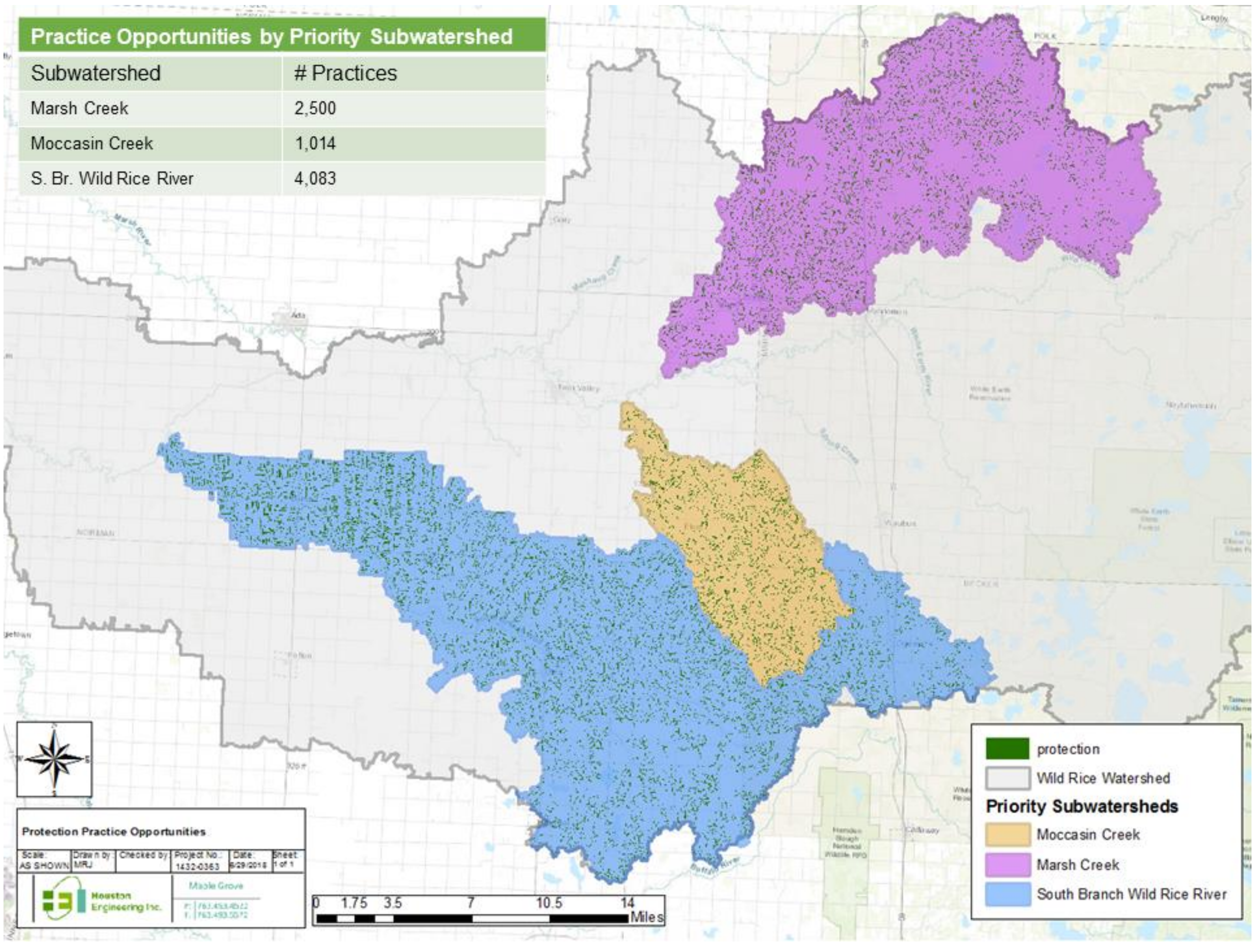
Figure C-12: Infiltration practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Protection

The protection treatment group is comprised of four USDA - NRCS practices: grade stabilization (practice code 410), grassed waterway (practice code 412), critical planting areas (practice code 342), and shoreline restoration/protection (practice code 580). PTMApp identified practice opportunities in the HUC-10s identified as priority areas for implementation to address TSS in AUID 501 (**Figure C-13**). Protection practices, particularly critical area plantings, are identified in the *Wild Rice River Watershed Monitoring and Assessment Report* as a recommended action to increase species abundance and diversity as well as reduce sediment loading into streams (MPCA, 2017). Protection practices have value in the three priority HUC-10s due to the abundance of opportunities for implementation and their ability to mitigate soil loss in highly erosive areas.

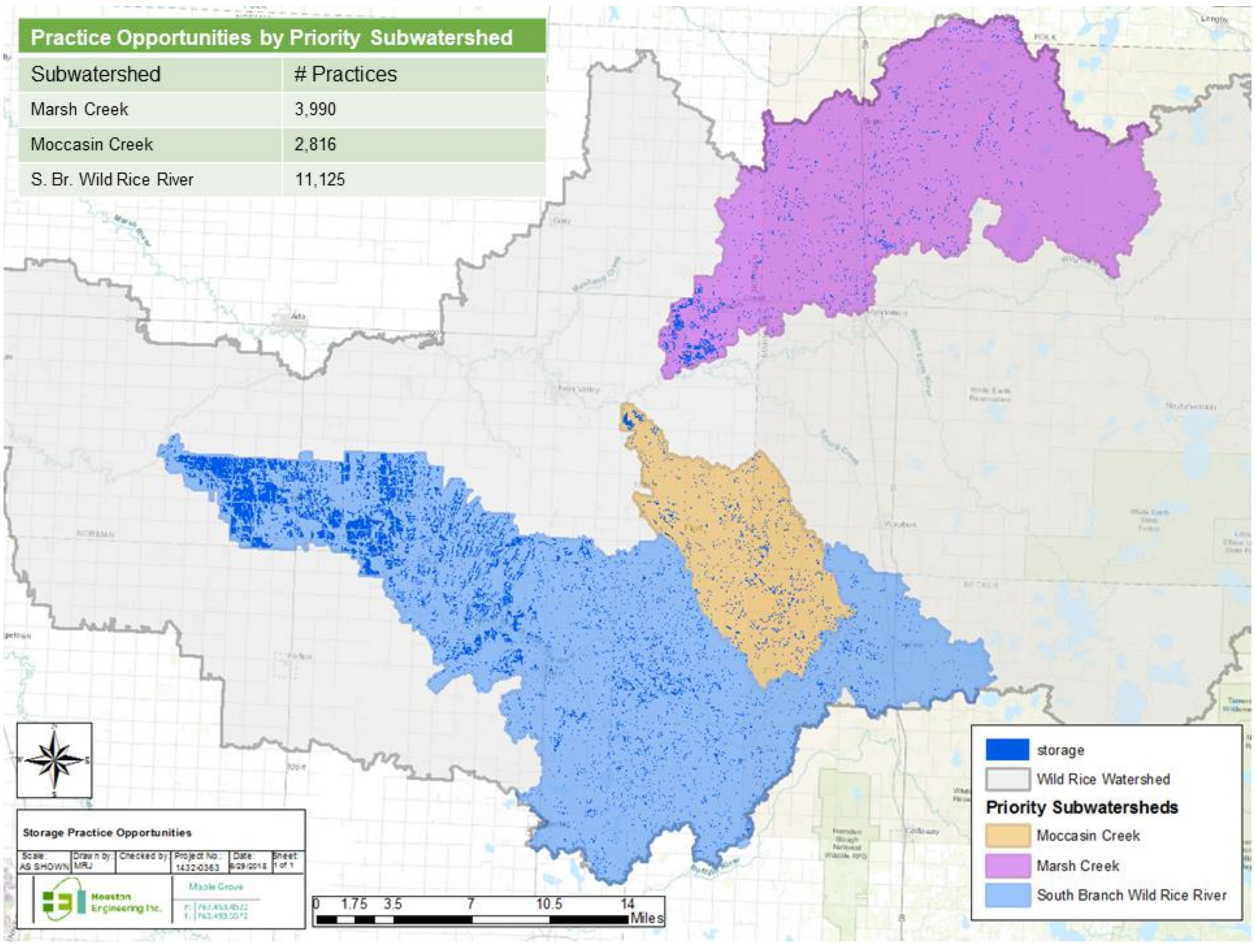
Figure C-13: Protection practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Storage

The storage treatment group is comprised of five USDA - NRCS practices: WASCOB (practice code 638), drainage water management/controlled drainage (practice code 554), farm pond/wetland (practice codes 378,657,658,659), regional pond/wetland (practice code 656), and regional nutrient reduction wetland (practice code 656). PTMApp identified practice opportunities in the HUC-10s identified as priority areas for implementation to address TSS in AUID 501 (**Figure C-14**). Storage practices are identified in the *Wild Rice River Watershed Stressor Identification Report* as a recommended action to improve flow regime stability and reduce excess sedimentation (MPCA, 2018).

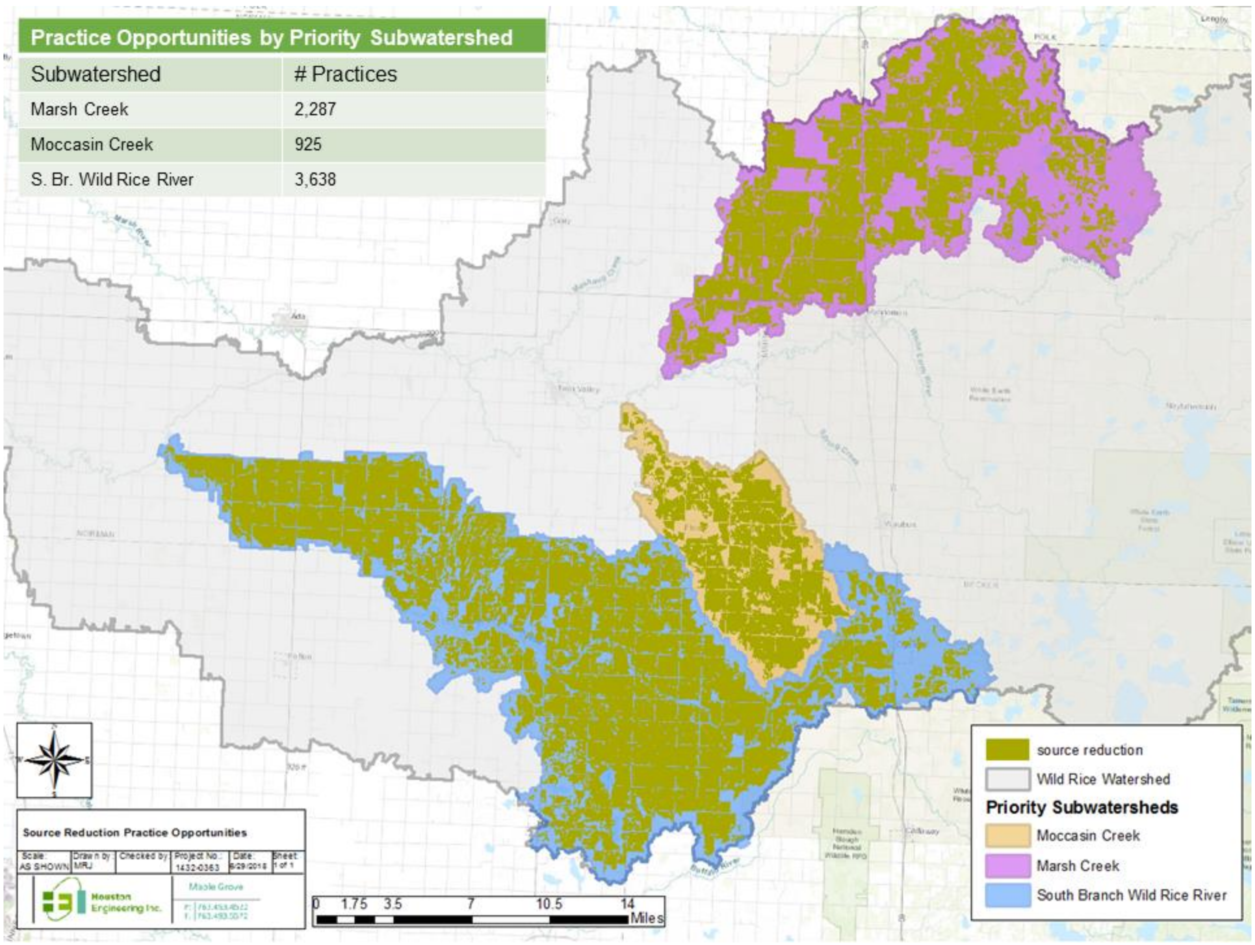
Figure C-14: Storage practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Source reduction

The source reduction treatment group differs from the treatment groups outlined above as it is comprised of three USDA - NRCS management practices: cover crops (practice code 340), perennial crops (practice code 327), and nutrient management of groundwater for nitrate (practice code 590); implemented by producers and operators on cultivated crop land. Because land use in the three priority HUC-10s is predominately agricultural, opportunities for this treatment group are nearly ubiquitous on the landscape (**Figure C-15**). Source reduction practices that curtail soil loss are recommended in the *Wild Rice River Watershed Stressor Identification Report* (MPCA, 2018).

Figure C-15: Source reduction practice opportunities in HUC-10s identified as priority areas for implementation to address TSS in AUID 501.



Appendix D: Wild Rice River Watershed HSPF-SAM BMP scenarios

Based on a technical memorandum by Houston Engineering, Inc. (HEI) that was provided to MPCA on August 13, 2019.

Introduction

This appendix describes estimated load reduction benefits for three BMP scenarios in the WRRW. The benefits of the scenarios were evaluated using the HSPF-SAM (https://www.respec.com/product/modeling-optimization/scenario-application-manager/), informed by the BMP suitability processes in the PTMApp.

The BMP scenarios were developed, and the benefits estimated, to guide local implementation efforts as part of the WRAPS project. The intent of this appendix is to provide 1) greater clarity with regard to the technical feasibility of achieving various nutrient and sediment load reductions and therefore the WRRW water quality goals (i.e., load allocations); 2) more detailed guidance to those responsible for implementation including the numbers and types of BMPs which should be placed on the landscape; and 3) the information expectations memorialized in the Clean Water Accountability Act (https://www.revisor.mn.gov/statutes/cite/114D).

The three scenarios developed and simulated using HSPF-SAM are intended to represent a range of potential implementation efforts and include: 1) a low BMP implementation scenario; 2) an intermediate BMP implementation scenario, and 3) a high BMP implementation scenario. The low BMP implementation scenario represents a targeted implementation approach where BMPs are located and constructed to treat 5% to 10% of cropland acres in subwatersheds where practices are feasible. The intermediate BMP implementation scenario also represents a targeted implementation approach where BMPs are located and constructed to treat 10% to 25% of cropland acres in subwatersheds where practices are feasible. The high BMP implementation scenario represents an upper limit on what can be achieved in terms of the load reduction by assuming up to half of the cropland acres in the watershed are treated with BMPs. Further discussion of the scenarios is provided below.

Scenario development

Three BMP scenarios were developed and simulated using two programs, PTMApp to develop BMP feasibility, and HSPF-SAM, a BMP scenario tool for the watershed-wide HSPF model.

PTMApp best management practices feasibility

BMP feasibility was conducted utilizing PTMApp. An hDEM and a suite of water quality datasets were generated to help identify and target locations at the field-scale for BMPs and CPs. PTMApp is used in rural settings to: 1) identify the field-scale source locations and amounts of sediment, TP, and TN that leave the landscape and enter a downstream lake or stream; 2) target specific fields on the landscape (based upon USDA - NRCS design standards, landscape characteristics, land productivity, and/or landowner preference) for the potential implementation of nonpoint source BMPs and CPs; and 3) estimate the benefits of single or multiple BMPs and CPs to one or more streams and lakes within a watershed, where the benefits are expressed as the downstream load reduction and the annual estimated cost/unit load reduction. These tools allow water quality practitioners to target solutions to the identified priorities and develop tailor-made implementation plans. Products developed by using PTMApp are also useful in making day-to-day implementation decisions and communicating needs and benefits with landowners.

BMP suitability

The feasibility of placing a BMP or CP on the landscape depends on several factors. These factors include land use, the size of the contributing drainage area, the land slope, the type of flow regime, and local topography. Detailed information on the theory and criteria for evaluating practice feasibility are documented in the BMP Suitability Enhancement Technical Memorandum (https://ptmapp.bwsr.state.mn.us/files/BMP_Suitabilty_Memo.pdf). Practice feasibility is based solely on technical factors largely based on field office technical guides developed by the USDA - 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. BMPs and CPs are categorized into five treatment groups consisting of structural practices and one treatment group of management practices. Treatment groups and a sampling of BMP types in each group are shown in **Table D-1**.

The structural practices opportunities in the WRRW include biofiltration (**Figure D-1**), filtration (**Figure D-2**), infiltration (**Figure D-3**), protection (**Figure D-4**), and storage (**Figure D-5**). **Figure D-6** shows the management practice group opportunities in the WRRW.

Table D-1: Treatment Groups included in PTMApp and types of practices each treatment group represents.

Treatment Group	Primary Treatment Process	Form of Treatment	Practices
Structural Practice Groups			
Biofiltration	Sedimentation & biological	Particulate	Saturated buffers Denitrifying Bioreactor
Filtration	Sedimentation	Particulate	Grassed Waterways Filter Strips Conservation Cover Easements
Infiltration	Volume abstraction	Dissolved	Alternative Tile Intakes
Protection	Physical protection of the landscape	Total (Dissolved & Particulate)	Grade Stabilization Structure Critical Area Planting Streambank and Shoreline Protection
Storage	Sedimentation	Particulate	WASCOB Wetland Restoration Pond for Water Use
Management Practice Group			
Source Reduction	Reduction of Mass Potential	Total (Dissolved & Particulate)	Conservation Tillage Nitrogen Management Plan

Table D-2 shows the total number of locations feasible for each treatment group at the field scale with a drainage area treated by the BMP greater than one acre. It should be noted, the BMPs listed in **Table D-2** and shown in **Figure D-1** through **Figure D-6**, are opportunities were the landscape fits design criteria of each treatment group and field verification may be necessary if a BMP area is selected for implementation.

Table D-2: Number of practices in the Wild Rice River Watershed.

PTMApp Structural Practice Treatment Group	Total Number of Practices
Biofiltration	4,539
Filtration	4,355
Infiltration	86
Protection	267
Storage	12,221
PTMApp Management Practice Treatment Group	**Total Acres of Practices**
Source Reduction	406,570

Figure D-1: Feasible locations for PTMApp's biofiltration practices treatment group in the Wild Rice River Watershed.

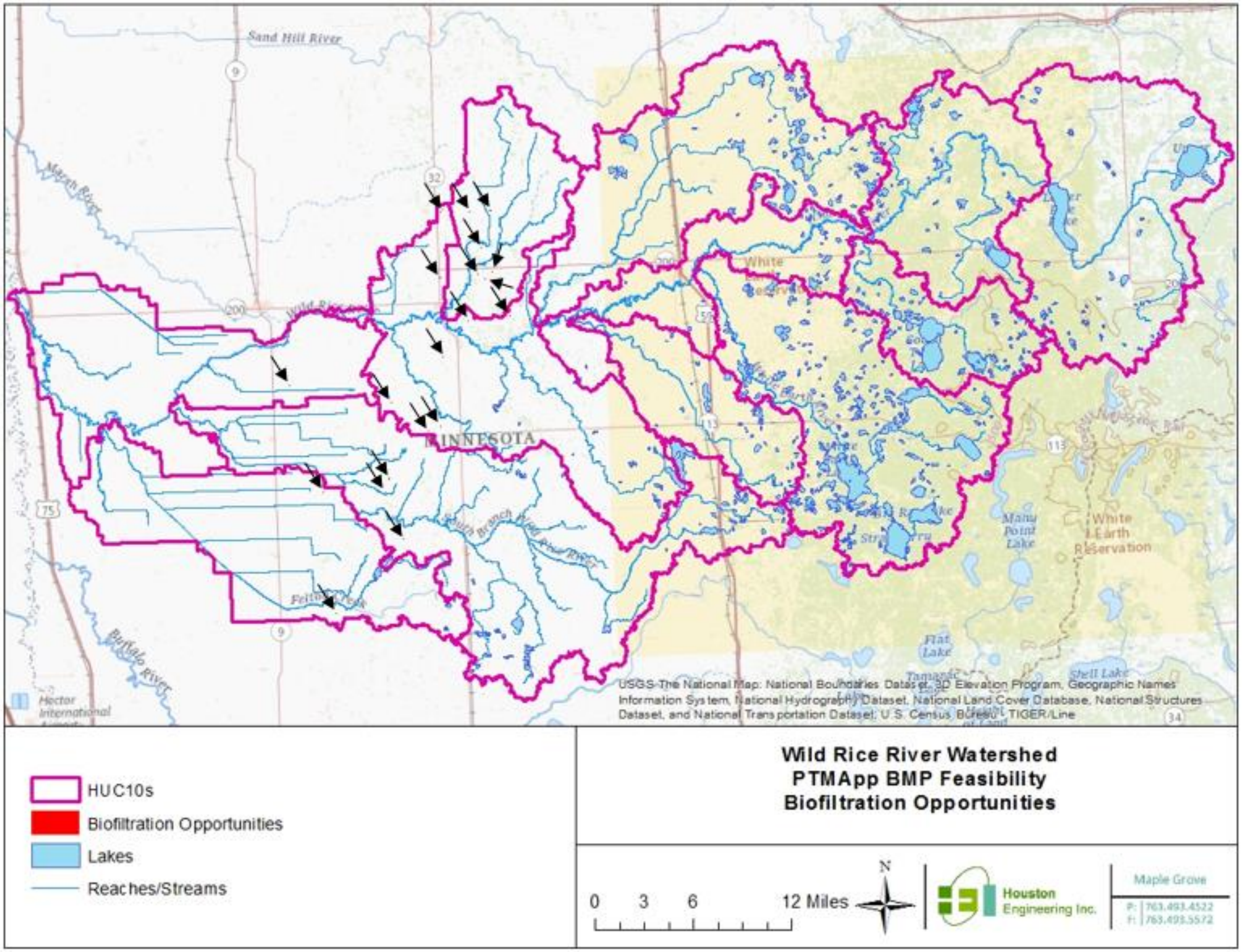


Figure D-2: Feasible locations for PTMApp's filtration practices treatment group in the Wild Rice River Watershed.

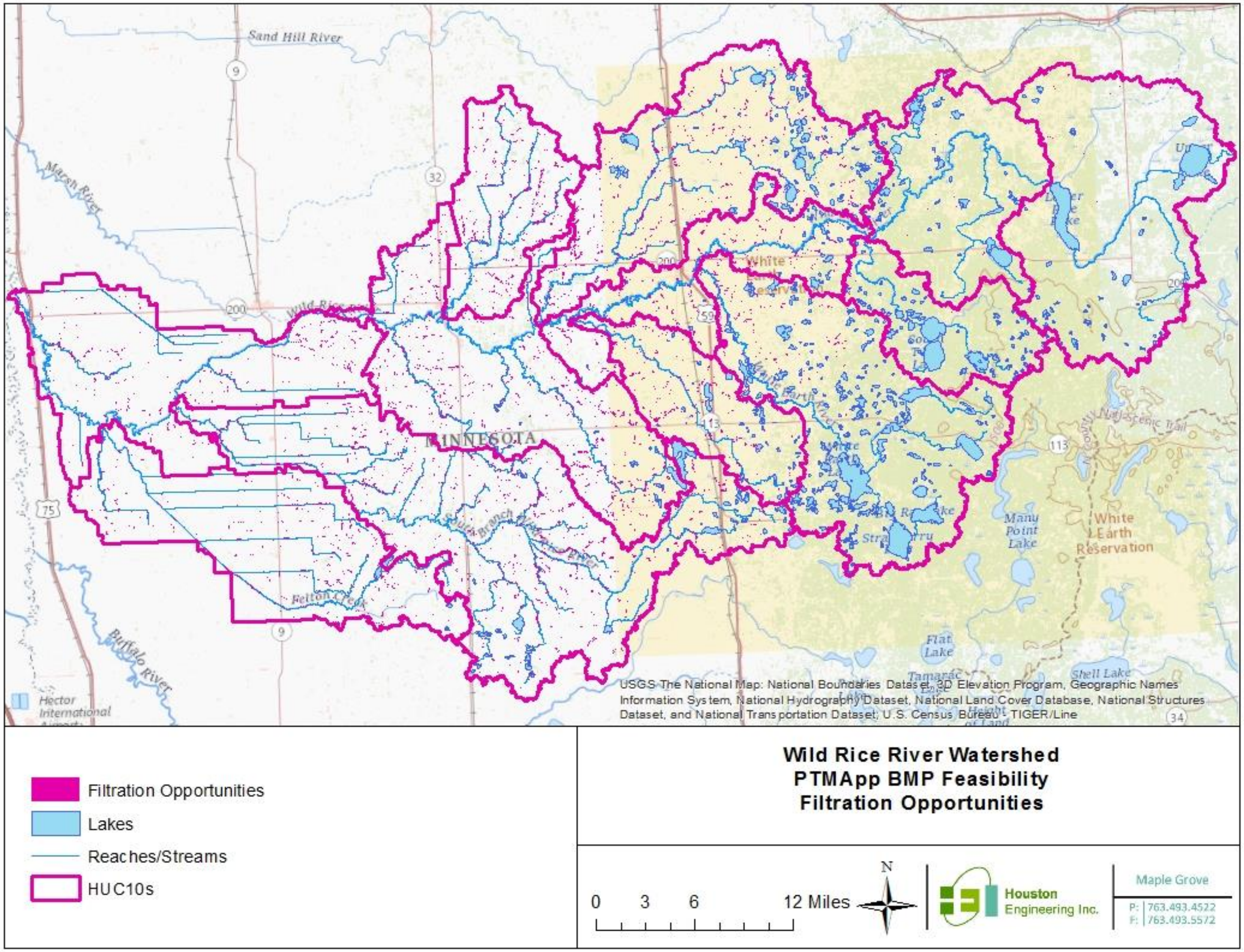


Figure D-3: Feasible locations for PTMApp's infiltration practices treatment group in the Wild Rice River Watershed.

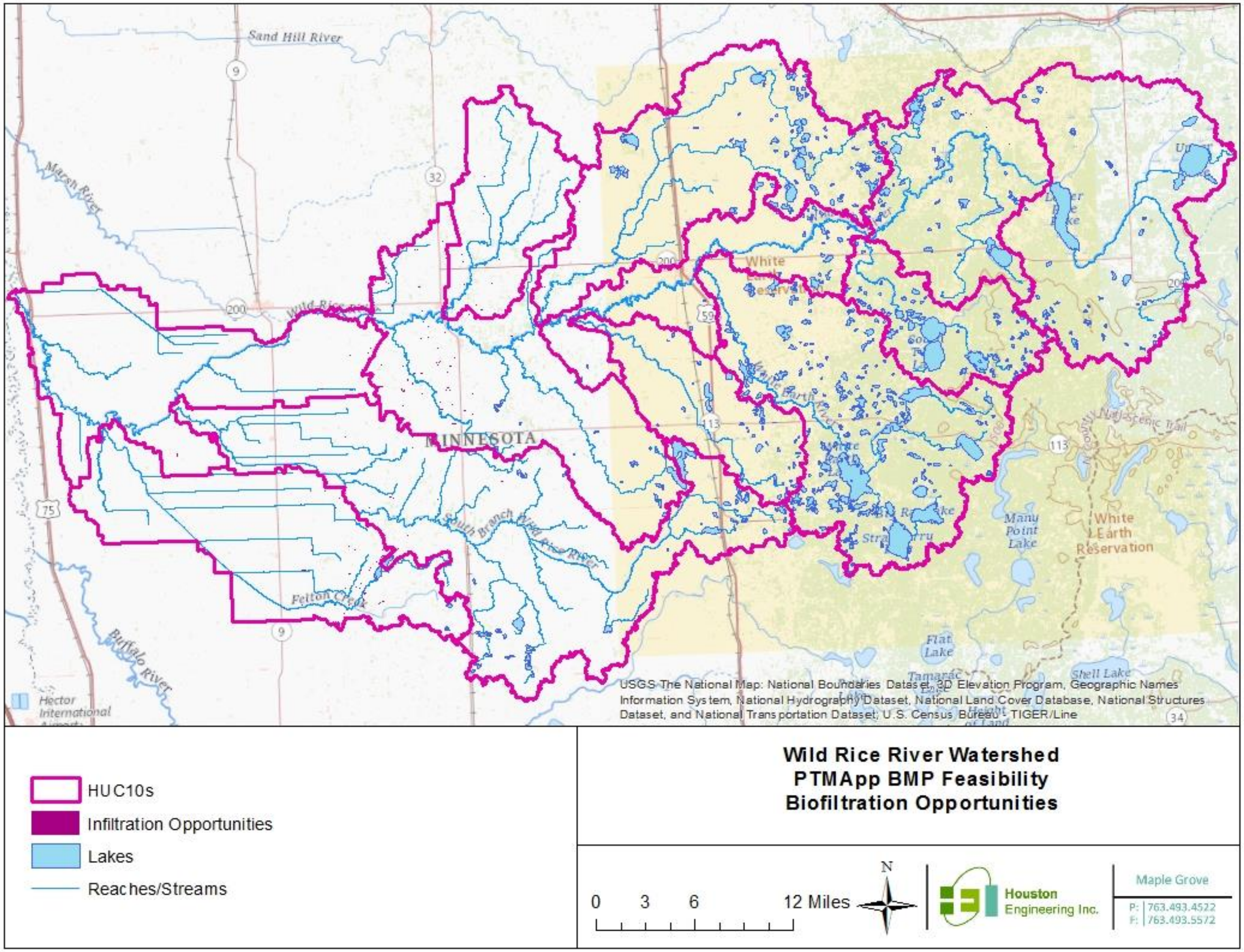


Figure D-4: Feasible locations for PTMApp's protection practices treatment group in the Wild Rice River Watershed.

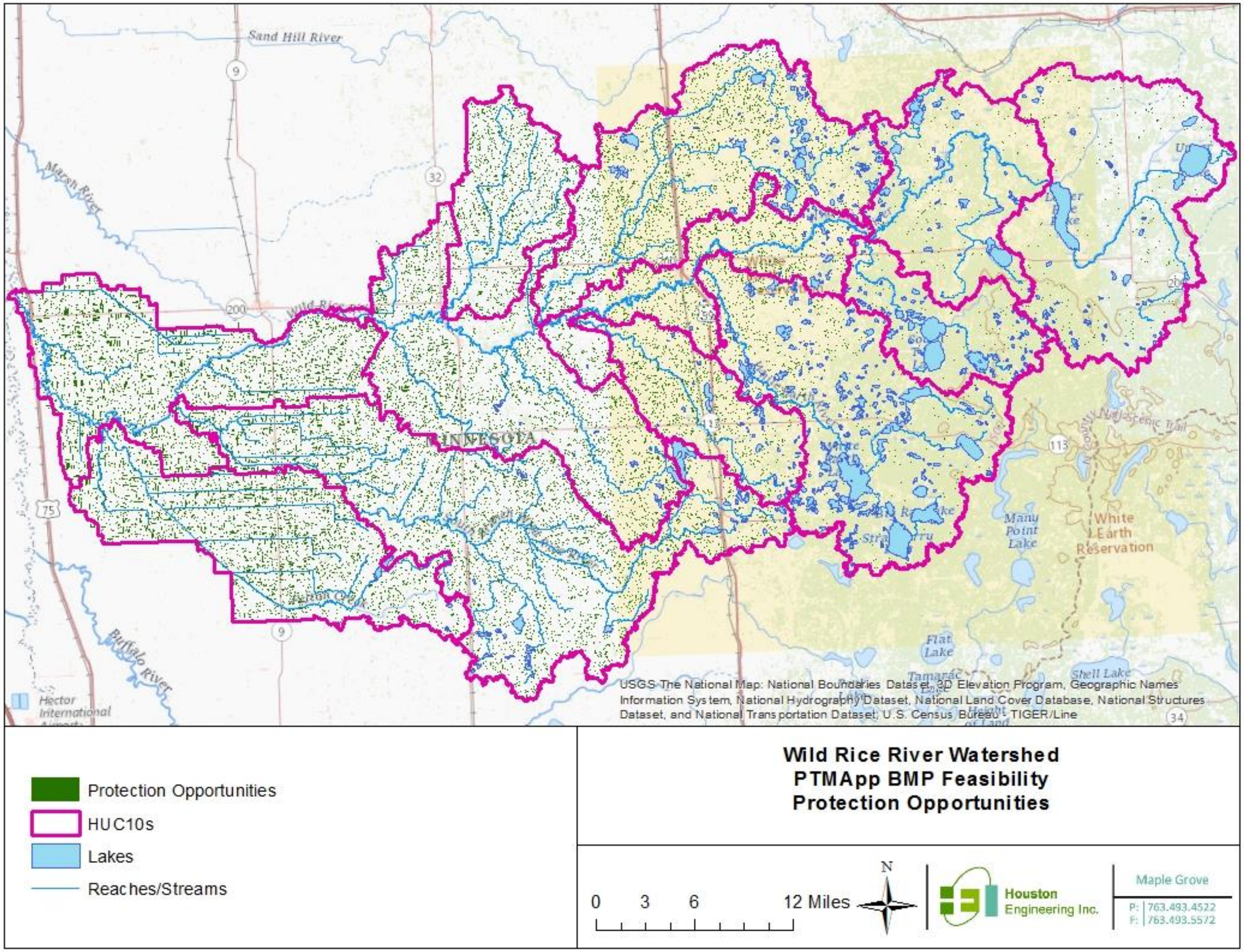


Figure D-5: Feasible locations for PTMApp's storage practices treatment group in the Wild Rice River Watershed.

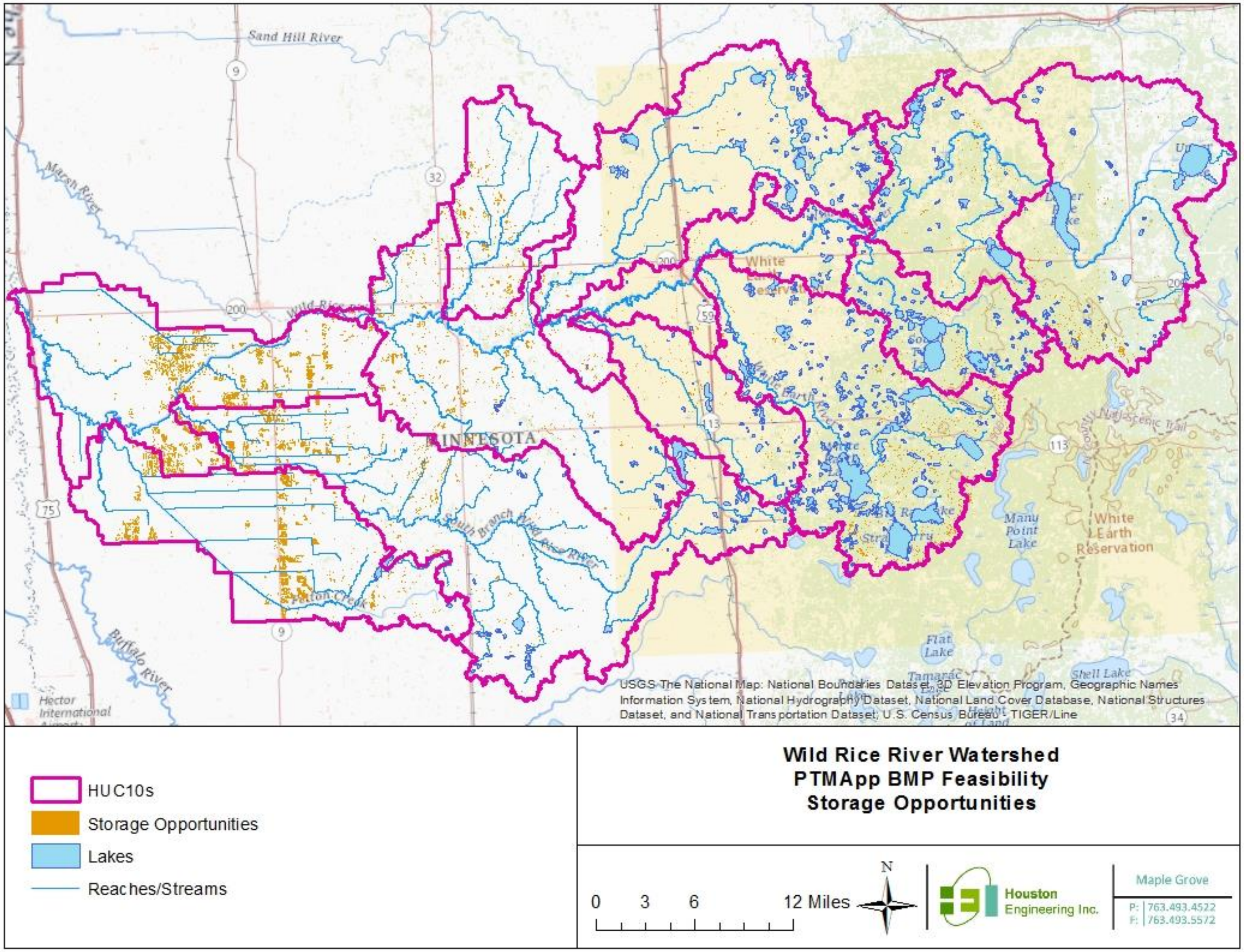
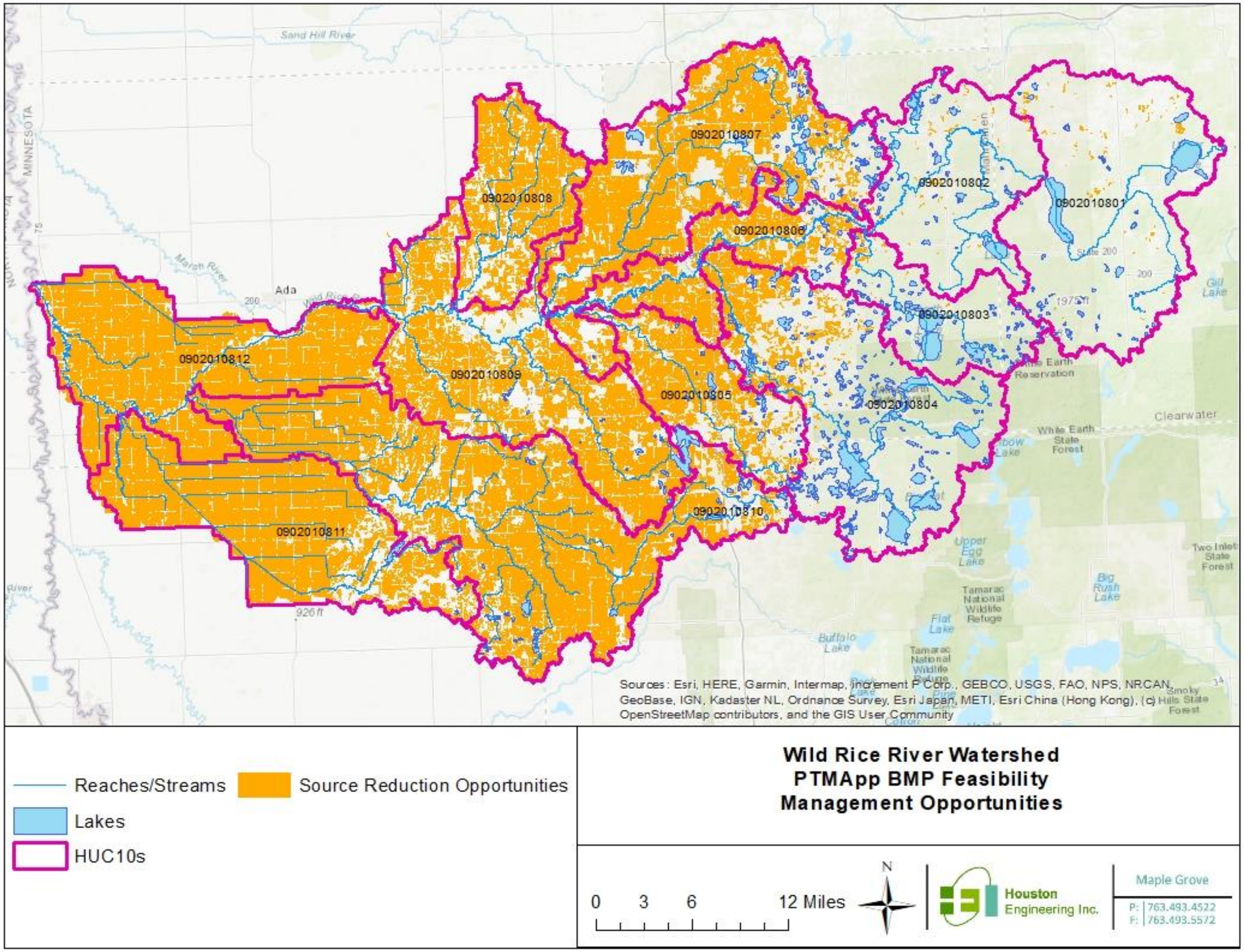


Figure D-6: Feasible locations for PTMApp's management practices treatment group in the Wild Rice River Watershed.



Scenario Application Manager

HSPF-SAM is a watershed scale tool that consists of GIS for subwatershed selection, HSPF to simulate the transport and fate of pollutants, and a BMP database. The tool assists in developing custom implementation plans by combining individual and/or suites of BMPs that are simulated and applying reduction efficiencies to the appropriate source loads represented in the HSPF model. **Table D-3** lists the BMPs included in the HSPF-SAM software and their associated PTMApp treatment group.

Table D-3: HSPF-SAM BMPs and associated PTMApp treatment groups.

HSPF-SAM BMP Name	Minnesota Agricultural BMP Handbook Practice	NRCS EQIP Practice	NRCS Practice Code	PTMApp Treatment Group [a]
Nutrient Management	Nutrient Management (590)	Nutrient Management	590	6
Nutrient Management + Manure Incorporation	Nutrient Management (590)	Nutrient Management	590	6
Restore Tiled Wetlands (cropland)	Wetland Restoration (651)	Wetland Restoration	657	6
Tile Line Bioreactors	Woodchip Bioreactor (Denitrification Beds)	Denitrifying Bioreactor	747	3
Controlled Tile Drainage	Controlled Drainage (554)	Drainage Water Management	554	1
Riparian Buffers, 16 ft wide (replacing row crops)	Riparian and Channel Vegetation (322/390)	Conservation Cover	327	2
Riparian Buffers, 50 ft wide (replacing row crops)	Riparian and Channel Vegetation (322/390)	Conservation Cover	327	2
Riparian Buffers, 100 ft wide (replacing row crops)	Riparian and Channel Vegetation (322/390)	Conservation Cover	327	2
Filter Strips, 50 ft wide (cropland field edge)	Filter Strips (393) and Field Borders (386)	Conservation Cover	327	2
Conservation Crop Rotation	Conservation Crop Rotation (328)	Conservation Crop Rotation	328	6
Conservation Cover Perennials	Conservation Cover (327)	Conservation Cover	328	6
Corn & Soybeans to Cover Crop	Cover Crops (340)	Cover Crop	340	6
Reduced Tillage (30% + residue cover)	Cover Crops (340)	Cover Crop	340	6
Short-Season Crops to Cover Crop	Conservation Tillage (329, 345, and 346)	Residue and Tillage Management-Reduced Till	329	6
Reduced Tillage (no till)	Conservation Tillage (329, 345, and 346)	Residue and Tillage Management-Reduced Till	329	6
Alternative Tile Intakes	Alternative Tile Intakes	Subsurface Drain	606	4
Riparian Buffers, 50 ft wide (replacing pasture)	Riparian and Channel Vegetation (322/390)	Conservation Cover	327	2
Corn & Soybeans to Rotational Grazing	Rotational Grazing	Conservation Cover	327	6
Water and Sediment Control Basin (cropland)	Water and Sediment Control Basin (638)	Water and Soil Control Basin	638	1

[a] PTMApp treatment groups: 1-storage, 2-filtration, 3-biofiltration, 4-infiltration, 5-protection, and 6-source reduction.

The three BMPs highlighted in green were used to develop the three scenarios. The three scenarios represent an increasing implementation of BMPs and are used to gage the level of effort needed to meet the TMDL reduction goals and aid watershed managers in developing implementation strategies. The three BMP scenarios are:

Scenario 1-Low BMP implementation effort:

- Nutrient Management strategies are applied to 10% of the cropland within the watershed, equaling 58,882 treated acres.
- Water and Sediment Control Basins treat 5% of the cropland in subwatersheds where they are feasible, equaling 1,652 treated acres (**Figure D-5**).
- Filter Strips, 50ft wide, treat 10% within the watershed, equaling 58,882 treated acres.

Scenario 2-Intermediate BMP implementation effort:

- Nutrient Management strategies are applied to 25% of the cropland within the watershed, equaling 147,210 treated acres.
- Water and Sediment Control Basins treat 10% of the cropland in subwatersheds where they are feasible, equaling 3,305 treated acres (**Figure D-5**).
- Filter Strips, 50ft wide, treat 25% of the cropland within the watershed, equaling 147,210 treated acres.

Scenario 3-High BMP implementation effort:

- Nutrient Management strategies are applied to 50% of the cropland within the watershed, equaling 294,411 treated acres.
- Water and Sediment Control Basins treat 20% of the cropland in subwatersheds where they are feasible, equaling 6,610 treated acres (**Figure D-5**).
- Filter Strips, 50ft wide, treat 50% of the cropland within the watershed, equaling 294,411 treated acres.

Scenario results

The following provides a summary of the base conditions and the percent load reductions for the three BMP scenarios for TSS, TP, and TN. The base conditions are represented as the simulated annual average loads for 1996 through 2009 that are contributed directly to each reach (**Figure D-7**) and the annual average loads at the outlets of each HUC-10 (**Table D-4**). For each scenario, the percent load reductions in each reach is shown in **Figure D-8** through **Figure D-10** and percent load reductions at the HUC-10 outlets are summarized in **Table D-5** through **Table D-7**.

Base

Figure D-7: Base conditions of TSS, TP, and TN (in-channel annual average loads) for each reach in the WRRW HSPF model for 1996 through 2009.

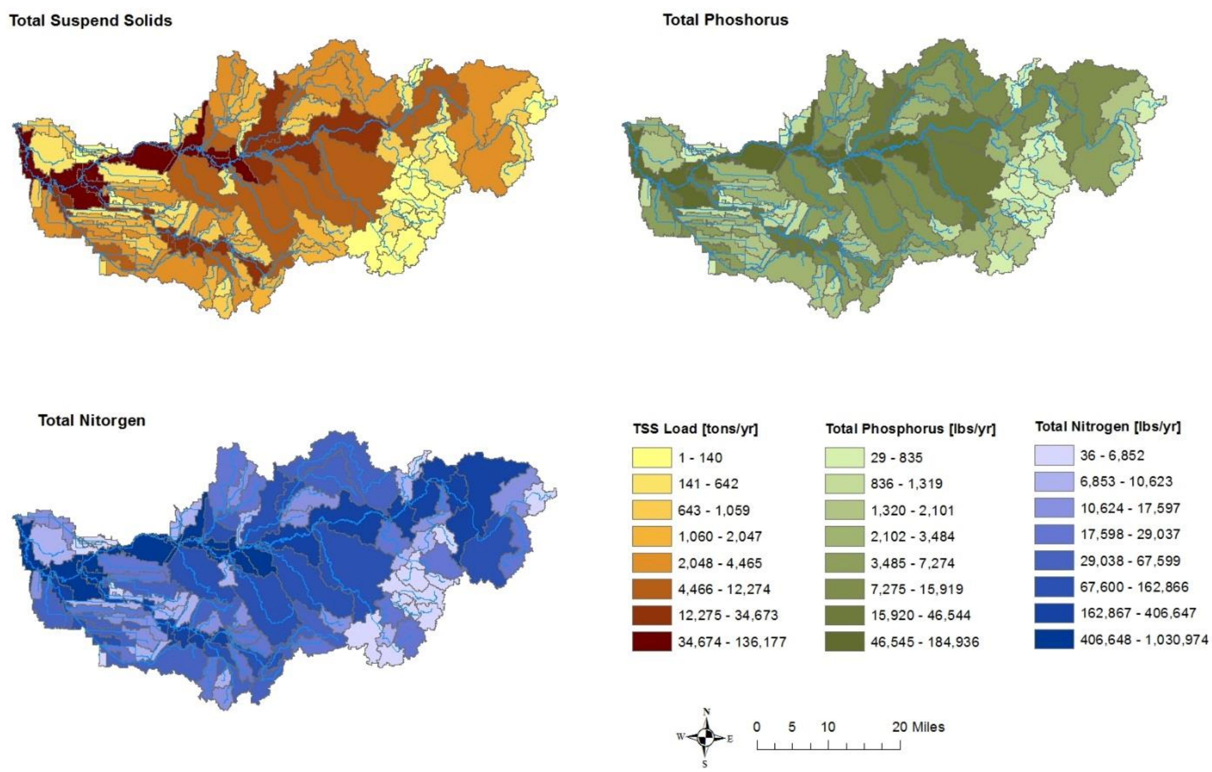


Table D-4: Base conditions of TSS, TP, and TN (in-channel annual average loads) at each HUC-10 outlet from the WRRW HSPF model for 1996 through 2009.

HUC-10	HSPF Sub-basin	TSS Load [tons/yr]	TP Load [lbs/yr]	TN Load [lbs/yr]
0902010801	40	4,465	11,044	167,039
0902010802	90	8,216	14,864	228,281
0902010803	109	904	2,172	22,067
0902010804	129	7,828	17,596	114,301
0902010805	149	5,186	12,155	79,395
0902010806	150	33,747	66,559	496,655
0902010807	165	12,970	29,754	149,510
0902010808	249	7,477	15,138	84,317
0902010809	310	74,022	133,006	880,500
0902010810	591	40,210	46,544	423,241
0902010811	701	18,928	21,297	179,286
0902010812	770	136,177	184,936	1,030,974

Scenario 1

Figure D-8: Scenario 1's percent load reductions of TSS, TP, and TN for each reach in the WRRW HSPF model for 1996 through 2009.

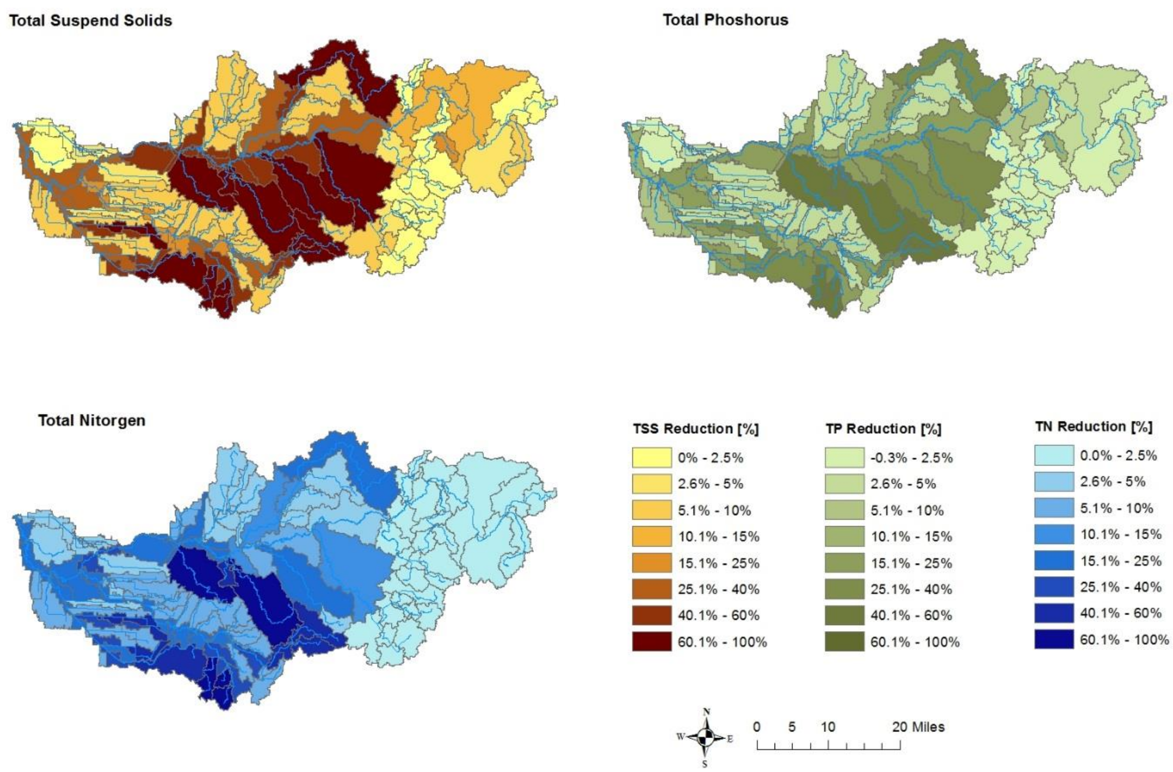


Table D-5: Scenario 1's percent load reductions of TSS, TP, and TN at each HUC-10 outlet from the WRRW HSPF model for 1996 through 2009.

HUC-10	HSPF Subbasin	TSS Reduction [%]	TP Reduction [%]	TN Reduction [%]
0902010801	40	11.9%	4.1%	0.6%
0902010802	90	11.1%	5.5%	0.9%
0902010803	109	4.0%	1.8%	0.5%
0902010804	129	68.9%	27.4%	11.4%
0902010805	149	65.8%	25.9%	18.4%
0902010806	150	46.7%	21.6%	9.2%
0902010807	165	30.8%	13.5%	11.6%
0902010808	249	6.7%	3.9%	4.2%
0902010809	310	41.6%	21.9%	23.7%
0902010810	591	19.1%	11.6%	18.0%
0902010811	701	27.5%	11.9%	18.3%
0902010812	770	29.7%	14.4%	20.8%

Scenario 2

Figure D-9: Scenario 2's percent load reductions of TSS, TP, and TN for each reach in the WRRW HSPF model for 1996 through 2009.

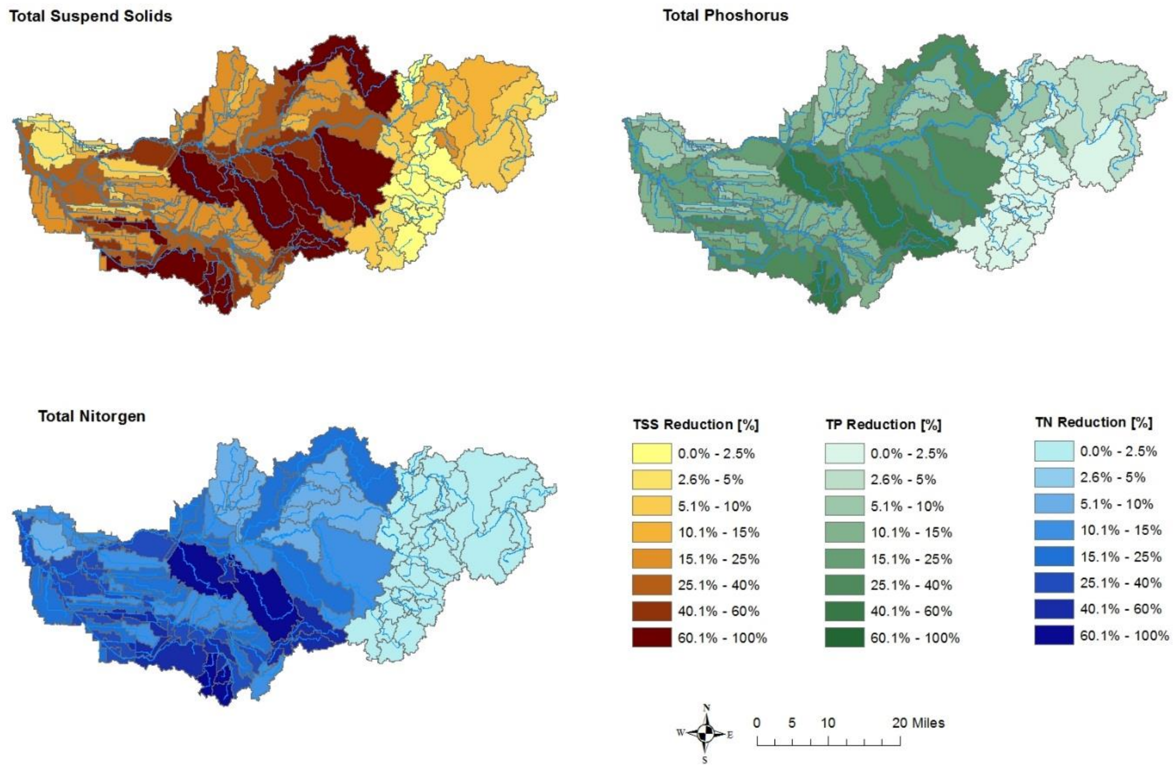


Table D-6: Scenario 2's percent load reductions of TSS, TP, and TN at each HUC-10 outlet from the WRRW HSPF model for 1996 through 2009.

HUC-10	HSPF Subbasin	TSS Reduction [%]	TP Reduction [%]	TN Reduction [%]
0902010801	40	12.6%	4.5%	0.7%
0902010802	90	11.8%	6.0%	1.0%
0902010803	109	8.5%	3.8%	1.2%
0902010804	129	69.8%	29.3%	12.4%
0902010805	149	68.1%	28.7%	21.2%
0902010806	150	49.3%	24.0%	10.6%
0902010807	165	38.2%	18.0%	15.5%
0902010808	249	16.7%	9.8%	10.5%
0902010809	310	45.7%	25.2%	26.3%
0902010810	591	26.1%	17.4%	26.1%
0902010811	701	33.7%	16.9%	25.8%
0902010812	770	34.7%	18.5%	27.2%

Scenario 3

Figure D-10: Scenario 3's Percent load reductions of TSS, TP, and TN for each reach in the WRRW HSPF model for 1996 through 2009.

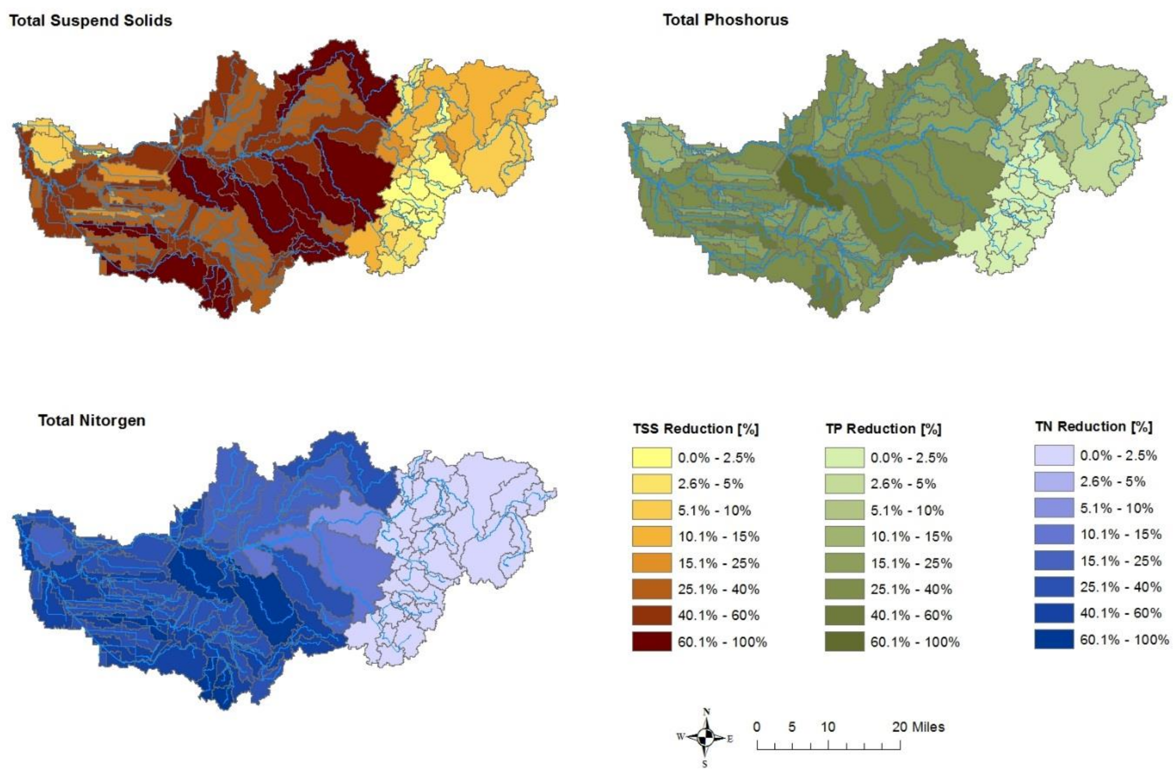


Table D-7: Scenario 3's percent load reductions of TSS, TP, and TN at each HUC-10 outlet from WRRW HSPF for 1996 through 2009.

HUC-10	HSPF Subbasin	TSS Reduction [%]	TP Reduction [%]	TN Reduction [%]
0902010801	40	13.8%	5.3%	0.8%
0902010802	90	12.8%	6.9%	1.1%
0902010803	109	16.2%	6.2%	2.3%
0902010804	129	71.3%	32.6%	14.6%
0902010805	149	72.2%	34.7%	26.6%
0902010806	150	54.7%	29.1%	13.4%
0902010807	165	50.4%	25.5%	22.1%
0902010808	249	38.5%	23.8%	25.1%
0902010809	310	53.8%	32.1%	31.7%
0902010810	591	39.4%	29.0%	41.5%
0902010811	701	45.2%	27.1%	40.1%
0902010812	770	44.4%	27.1%	40.1%

Impaired reaches

The following provides information for TSS impaired reaches or biologically-impaired reaches with TSS as a stressor in the WRRW. **Table D-8** provides the needed load reduction in TSS, the modeled average annual load in tons per year, and load reduction for each BMP scenarios.

Table D-8: Percent load reductions for BMP scenarios in impaired reaches.

AUID	HSPF Subbasin	Need Load Reduction	Base TSS Load [tons/yr]	Scenario 1	Scenario 2	Scenario 3
09020108-504	150	25%	33,747	46.7%	49.3%	54.7%
09020108-643	310	87%	74,022	41.6%	45.7%	53.8%
09020108-644	370	59%	79,540	36.3%	39.9%	47.0%
09020108-652	165	76%	12,970	30.8%	38.2%	50.4%
09020108-650	249	24%	7,477	6.7%	16.7%	38.5%
09020108-662	511	14%	32,052	22.2%	28.7%	40.1%

Discussion

HSPF-SAM provides limited implementation practices to treat overland sources of pollutants and does not allow for near channel or in-channel implementation strategies to be simulated. The three scenarios show increasing treatment in the watershed as the area of treatment increases. The most efficient scenario is Scenario 1, where the largest incremental load reductions occur. As the treatment area doubles from Scenario 1 to Scenario 2, the load reduction percentages only increase by a few percent, same with the doubling of treatment area from Scenario 2 to Scenario 3. This is most likely because most of the excessive overland sources are being removed in Scenario 1. This also means that additional overland treatment may not produce much gains in load reductions and practices that target other sources (i.e., streambank erosion and in-channel sources) may be needed to achieve additional load reductions.