Upper Red River of the North Watershed Restoration and Protection Strategy Report

December 2017

MINNESOTA POLLUTION CONTROL AGENCY

BUFFALO-RED RIVER WATERSHED DISTRICT

CLEAN WATER LAND & LEGACY AMENDMENT

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Table of Contents

Authors and contributors 2

Key Terms 4

Executive Summary 5

What is the WRAPS Report? 7

1. Watershed Background & Description **9**

2. Watershed Conditions **10**

2.1 Condition Status 11

2.2 Water Quality Trends 16

2.3 Stressors and Sources 16

2.4 TMDL Summary 18

2.5 Protection Considerations 20

3. Prioritizing and Implementing Restoration and Protection **20**

3.1 Targeting of Geographic Areas 21

3.2 Civic Engagement 32

3.3 Restoration & Protection Strategies 33

4. Monitoring Plan **48**

5. References and Further Information **48**

Appendix A: **50**

Appendix B: **51**

Key Terms

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

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

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

Best Management Practice (BMP): A practice that is determined to be an effective and practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of a substance in excess of background levels, generated by nonpoint sources.

Conservation Practice (CP): A BMP implemented in an agricultural setting with additional planned benefits of protecting soil health, reducing erosion, and enhancing habitat.

Hydrologic Unit Code (HUC): An HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

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

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

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

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

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

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

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

Executive Summary

The Upper Red River of the North Watershed (URRW) is located in northwestern Minnesota and covers approximately 581 square miles within Clay, Wilkin, and Otter Tail counties and a portion of North Dakota. It is located in the Red River of the North Basin (i.e., Red River Basin) and spans two ecoregions: the Lake Agassiz Plain and the North Central Hardwood Forests. Land use within the URRW is predominantly agricultural, occurring in the west and central portions, with the eastern portion of the watershed being partially forested. Municipalities located within the URRW include Rothsay, Kent, Comstock, Wolverton, Dilworth, and Moorhead.

In general, water quality conditions in the URRW are generally poor and reflect the intensely cultivated land use, altered watercourses, altered hydrology, intensive drainage, and a consistent lack of riparian cover (buffers) around many of the wetlands and streams in the watershed. Total Suspended Solids (TSS) and *E. coli* levels are elevated in most of the watershed, with the Wolverton Creek and Whiskey Creek Subwatersheds assessed as impaired. The sources of sediment and turbidity, in addition to the susceptibility of naturally occurring fine silts and clays, are overland runoff, field erosion, wind erosion, and stream bank scouring from hydrologic modifications in the watershed. Elevated bacteria levels were found in many of the monitored streams. Aquatic life and recreation use impairments were found throughout the watershed.

While the URRW includes a segment of the Red River mainstem, this report includes only data and findings collected from the tributary streams. The Red River mainstem impairments will be addressed in a Total Maximum Daily Load (TMDL) at a later date. The URRW contains 7 lakes and 32 stream reaches that are defined by the state of Minnesota (i.e., have an Assessment Unit ID – AUID – or DNR lake number). Of these, not all were assessed for impairment due to reasons including extensive modification, channelization, insufficient flows, impoundments, no channel or water body present, and limited resource value waters. Of 33 stream reaches monitored, only five had sufficient data to be able to be assessed, and were determined to have impairments. These waterbodies (Wolverton and Whiskey Creeks) contain five impairment listings: one for *E. coli*, one for fecal coliform, one for turbidity, one for aquatic macroinvertebrate bioassessment, and one for dissolved oxygen (DO). The URRW TMDL study (https://www.pca.state.mn.us/water/watersheds/upper-red-river-north) addresses three of those impairments: one stream reach for turbidity, and two stream reaches for bacteria (*E. coli*).

For the seven lakes within the watershed, only Nelson Lake (56-1015-00) has been assigned an identification number. Lake and wetland identifiers are assigned by the Minnesota Department of Natural Resources (DNR). The Protected Waters Inventory provides the identification numbers for lake, reservoirs, and wetlands. These identification numbers serve as the AUID and are composed of an eight-digit number indicating county, lake, and bay for each basin. It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. Due to the watershed's limited natural ability for water retention, extensive drainage system, lack of lake monitoring data, and no assigned AUIDs, there are no assessable lakes within the URRW. Therefore, no lake water chemistry sampling was conducted during the intensive watershed monitoring of the URRW.

The nature of the impairments leading to the lack of support for aquatic life and recreation are those commonly occurring in highly modified landscapes, including an overabundance of sediment, excessive bacteria in the water, and reduced biological abundances (low fish or macroinvertebrate numbers).

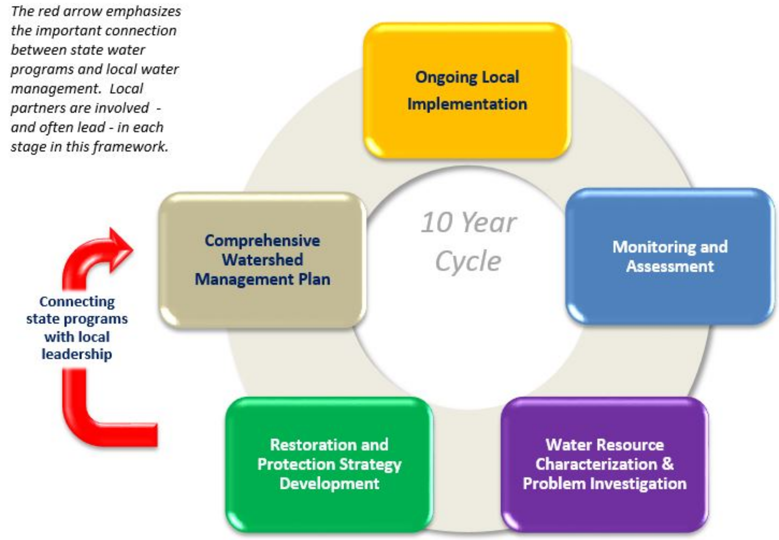
Pollutant reductions needed to correct impaired waters are large and will be challenging to accomplish. A coordinated, long term, sustained effort will be needed to both restore the impaired waters and to protect the others from being degraded down to an impaired condition. Required reductions for sediment (TSS) values range from 7% on the low end to as high as 29% for impaired stream segments. Required reductions for bacteria are even higher, ranging from 17 to 64% depending on stream flow conditions.

Common stressors that contribute to poor fish and aquatic insect populations include lack of fish passage (connectivity) and altered hydrology. Some examples of connectivity problems in the URRW include migration barriers that are both naturally occurring (beaver dams) and manmade (e.g., perched culverts and control structures). Examples of the results of altered hydrology include increases in peak discharge and loss of base flow, as shown by a "flashy" hydrograph in many streams. This is a common occurrence in artificially-drained agricultural areas.

To correct impairments and protect further degradation of aquatic resources, increased use of best management practices (BMPs) will be required for the working lands in the watershed and the management of the drainage systems. Examples for the landscape include, but are not limited to livestock management, nutrient management, field windbreaks, cover crops and perennial vegetation, residue management, riparian buffers, shoreline buffers, and ditch buffers. Examples for the waters themselves include engineered hydrologic controls, regional water retention, stream channel restoration, culvert resizing and replacement, and restoration of unconnected streams. In addition, maintenance and upgrades of individual onsite septic systems and compliance with National Pollutant Discharge Elimination System (NPDES) Permits (Permit) for municipal stormwater and wastewater is required.

What is the WRAPS Report?

The State of Minnesota has adopted a watershed approach to address the state's 80 major watersheds, denoted by an 8-digit hydrologic unit code or HUC. The Minnesota Watershed Approach incorporates **water quality assessment, watershed analysis, civic engagement, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection.



Along with the watershed approach, the Minnesota Pollution Control Agency (MPCA) developed a process to identify and address threats to water quality in each of these major watersheds. This process is called WRAPS or the Watershed Restoration and Protection Strategy. WRAPS reports have two parts: impaired waters will have strategies for restoration, and waters that are not impaired will have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are performed, as they have been in the past. TMDLs are developed for impaired waters in each watershed as part of Minnesota's watershed approach and folded into WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies and actions for point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves to at least partially address U.S. Environmental Protection Agency's (EPA's) Nine Minimum Elements, helping to 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:
	    • *Upper Red River of the North Watershed Monitoring and Assessment*
	    • *Upper Red River of the North Watershed Biotic Stressor Identification*
	    • *Upper Red River of the North Watershed Total Maximum Daily Load*

Scope	• Impacts to aquatic recreation and impacts to aquatic life in streams
Audience	• Local working groups (local governments, watershed district, SWCDs, watershed management groups, etc.) • State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed Background & Description

The URRW is located in western Minnesota, and borders North Dakota. The Minnesota portion of the watershed comprises approximately 499 square miles within Clay, Otter Tail, and Wilkin counties. All 499 square miles of the URRW lie within the current boundaries of the Buffalo-Red River Watershed District (BRRWD). The URRW is located in the Red River of the North Basin (i.e., Red River Basin) and spans two ecoregions: Lake Agassiz Plain and North Central Hardwood Forests. Land use within the watershed is predominantly agricultural. Municipalities within the URRW include Georgetown, Dilworth, Moorhead, Sabin, Comstock, Wolverton, Rothsay, Kent, and Breckenridge. Additional background information and description of the URRW can be found in the resources listed below.

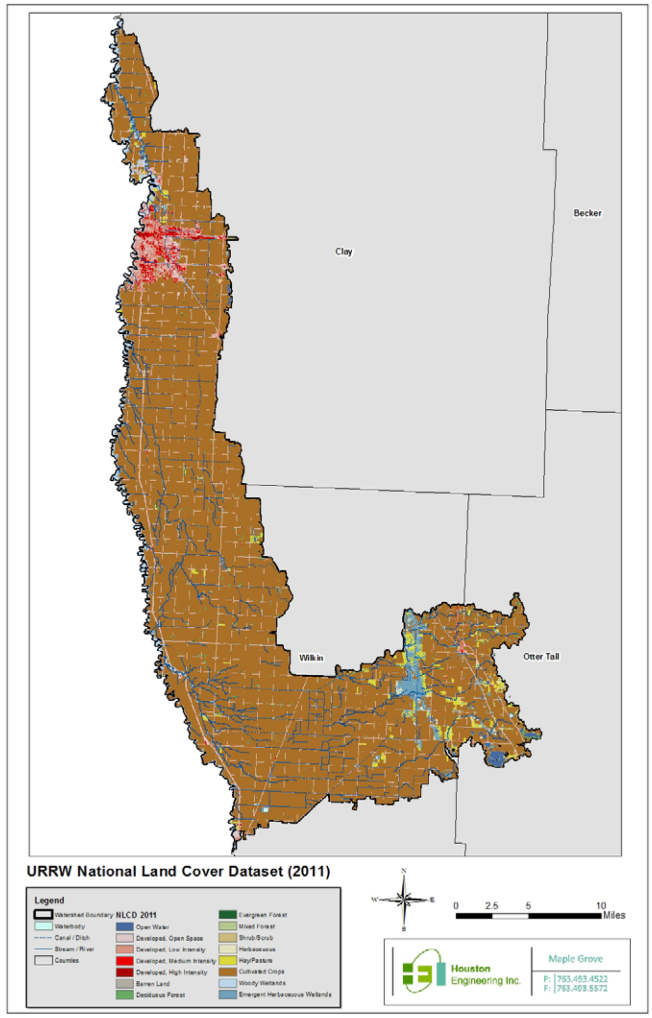


Figure 1: Land use in the URRW (NCLD 2011)

Additional Upper Red River of the North Watershed Resources

Upper Red River Watershed Conditions Report (HEI, 2012)

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Upper Red River of the North Watershed:
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021580.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Upper Red River of the North Watershed:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/wsmb57.pdf

2. Watershed Conditions

Water resources within the URRW include the Red River, its tributaries, a few lakes, wetlands, and an extensive drainage network. While the URRW includes a segment of the Red River mainstem, this report will include only the tributary streams. The Red River mainstem impairments will be addressed in a TMDL at a later date with the Large River Monitoring process.

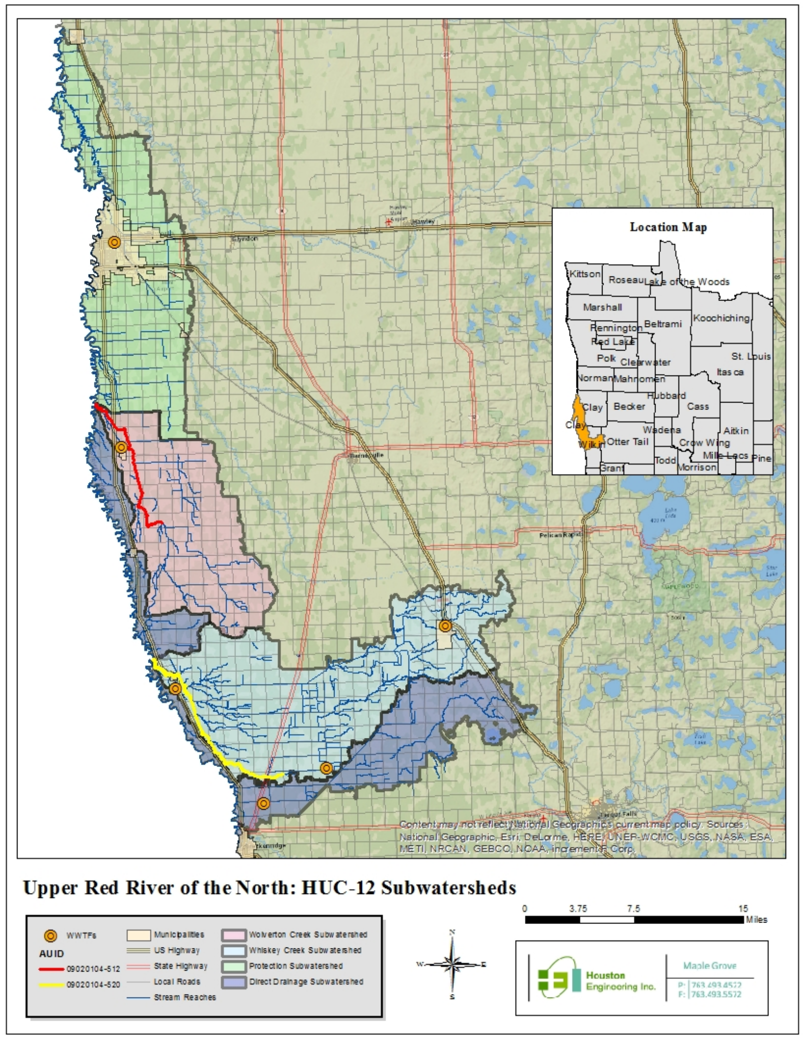


Figure 2: Upper Red River of the North Watershed regulated and impaired waters

Excluding the mainstem of the Red River of the North, the URRW contains 7 lakes and 32 stream reaches that are defined by the state of Minnesota (i.e., have an Assessment Unit ID – AUID – or DNR lake number). Of these, not all were able to be assessed for impairment due to reasons including extensive modification, channelization, insufficient flows, impoundments, no channel or water body present, and limited resource value waters. Of the 32 stream reaches (AUIDs), only three were fully assessable (09020104-516, 09020104-520, and 09020104-512) for aquatic life or aquatic recreation. Of those three, two have sufficient data to determine whether the segment is impaired. Of the two AUIDs with sufficient data, one does not support aquatic life, and both do not support aquatic recreation. The nature of the impairments leading to the lack of support for aquatic life and recreation are those commonly occurring in highly modified landscapes, including an overabundance of sediment, excessive bacteria in the water, and reduced biological abundances (low fish or macroinvertebrate numbers). Due to the watershed's limited natural ability for water retention, there are no assessable lakes within the URRW. Therefore, no lake water chemistry sampling was conducted.

There are four "minor" wastewater treatment facilities (WWTFs) and two "major" WWTFs in the URRW; however, both major facilities contribute flow to channels within the city of Moorhead and then directly into the Red River, which will be addressed in a TMDL at a later date with the Large River Monitoring process. As the focus of this analysis was on rural nonpoint sources within subwatersheds contributing to impaired reaches, the two major WWTFs were not considered. In addition, there are 29 permitted feedlots, 121 Construction Stormwater Permits, and 21 Industrial Stormwater Permits, none of which require individual NPDES Permits (HEI 2012). The City of Moorhead is an MS4 permittee, however it is not located within any of the impaired subwatersheds of the URRW. Nonpoint sources and stressors in the watershed are typical of the agricultural setting of the Red River Basin.

A more detailed analysis of the quality of the waters within the URRW can be found in the Watershed Conditions Report (HEI 2012), the Monitoring and Assessment Report (MPCA 2014), and the Biotic SID Report (MPCA 2015). The conditions and associated pollutant sources of these individual streams are summarized in the following sections.

2.1 Condition Status

This section describes the streams and lakes within the URRW that are impaired or in need of protection. Impaired waters are targets for restoration efforts while waters currently supporting aquatic life and recreation are subject to protection efforts.

Water quality conditions in the URRW are generally poor and reflect the highly altered landscape. Much of the land use is in agricultural production, waterways are channelized or straightened, hydrology has been modified, and a lack of riparian cover is found around many of the streams in the watershed. Excess bacteria and reduced biological assemblages are problems in the assessed waterways.

Factors used to determine whether a waterway is capable of supporting and harboring aquatic life (generally fish and aquatic insects) include the fish and macroinvertebrate index of biological integrity (IBI), the concentration of DO, and the sediment level, expressed as TSSs. Factors used to assess the suitability of a water body for aquatic recreation include the amount of bacteria and the levels of nutrients.

Some of the waterbodies in the URRW are impaired by mercury; however, this report does not cover toxic pollutants. For more information on mercury impairments, see the statewide mercury TMDL at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Streams

A range of parameters were used to assess URRW streams including fish and macroinvertebrate IBI, and the concentrations of DO, turbidity/suspended solids, and bacteria. Water quality measures were compared to the state standards as well as the normal range for the ecoregion where the stream is located. The aquatic life standards are based on the IBI scores, DO, and turbidity/suspended solids, while the aquatic recreation standard is based on bacteria.

The URRW's AUID stream segments are listed in **Table 1**, with stream condition summaries provided for each of the segments. Excluding the mainstem of the Red River of the North, the URRW contains 32 stream reaches with unique AUIDs, three of which have been assessed for aquatic life or aquatic recreation (**Figure 3**). Of those three, two have sufficient data to determine whether the segment is impaired. Of the two AUIDs with sufficient data, one does not support aquatic life, and both do not support aquatic recreation. Information used to create this table was summarized using the Minnesota Pollution Control Agency's (MPCA) Watershed Monitoring and Assessment Report (MPCA 2014), as well as the MPCA's Watershed Biotic SID Report (MPCA 2015).

Table 1: Assessment status of stream reaches in the Upper Red River of the North Watershed, presented (mostly) from north to south

HUC-12 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
Protection Area 090201040501	514	County Ditch 32	T138 R48W S13, south line to T138 R48W S18, north line	NA	NA	NA	NA	NA
	536	Unnamed creek	T138 R48W R7, south line to Red R	NA	NA	NA	NA	NA
	539	County Ditch 41	Unnamed ditch to CD 47	NA	NA	NA	NA	NA
	540	County Ditch 41	CD 47 to CD 50	NA	NA	NA	NA	NA
	541	County Ditch 41	CD 50 to Unnamed cr	NA	NA	NA	NA	NA
	542	County Ditch 41	Unnamed ditch to Red R	NA	NA	NA	NA	NA
Wolverton Creek 090201040304	512	Wolverton Creek	Unnamed cr to Red R	EXS	EXS	EXS	EXP	Imp
	513	Unnamed creek	Headwaters to Wolverton Cr	NA	NA	NA	NA	NA
	519	Wolverton Creek	T135 R48W S12, east line to Unnamed cr	NA	NA	NA	NA	NA
	538	County Ditch 22	Unnamed Crr to Wolverton Cr	NA	NA	NA	NA	NA
Whiskey Creek 090201040203	515	County Ditch 6A	CD 23 to Unnamed cr	NA	NA	NA	NA	NA
	516	Unnamed Creek	CD 6A to Whiskey Cr	Sup	EXS	NA	NA	NA
	517	Unnamed ditch (County Ditch 6A- 2)	Unnamed ditch to Unnamed ditch	NA	NA	NA	NA	NA

HUC-12 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
	518	Unnamed creek	T135 R45W S25, north line to Unnamed ditch	NA	NA	NA	NA	NA
	520	Whiskey Creek	T133 R47W S13, east line to Red R	Sup	Imp	Imp	Imp	Imp
	521	Whiskey Creek	T133 R47W S13, east line to Red R	NA	NA	NA	NA	NA
	522	Whiskey Creek	Headwaters to T133 R46W S18, west line	NA	NA	NA	NA	NA
	523	Unnamed ditch (County Ditch 6A)	Unnamed cr to Unnamed cr	NA	NA	NA	NA	NA
	524	County Ditch 6A	Unnamed cr to Unnamed cr	NA	NA	NA	NA	NA
	525	County Ditch 6A	Unnamed cr to Unnamed ditch	NA	NA	NA	NA	NA
	526	County Ditch 6A	Unnamed ditch to Unnamed ditch	NA	NA	NA	NA	NA
	527	County Ditch 6A	Unnamed ditch to CD 23	NA	NA	NA	NA	NA
	528	Unnamed creek	Headwaters to Unnamed cr	NA	NA	NA	NA	NA
	529	Unnamed creek	Unnamed cr to Unnamed cr	NA	NA	NA	NA	NA
	530	Unnamed creek	Unnamed cr to Unnamed cr	NA	NA	NA	NA	NA
	531	County Ditch 1A	Unnamed cr to CD 1B	NA	NA	NA	NA	NA
	532	Unnamed creek	CD 1B to Unnamed cr	NA	NA	NA	NA	NA
	533	Unnamed creek	Unnamed cr to Whisky Cr	NA	NA	NA	NA	NA
	534	Unnamed creek	Headwaters to Unnamed cr	NA	NA	NA	NA	NA
	535	Unnamed creek	Unnamed cr to Whiskey Cr	NA	NA	NA	NA	NA

HUC-12 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
Direct Drainage 090201040401	505	Unnamed ditch	Unnamed ditch to Red R	NA	NA	NA	NA	NA
	537	Unnamed ditch	Unnamed ditch to Red R	NA	NA	NA	NA	NA

Sup = found to meet the water quality standard, Imp = does not meet the water quality standard and therefore, is impaired, NA = not assessed, EXS = Exceeds criteria, potential severe (new) impairment, EXP = Exceeds criteria, potential (new) impairment.

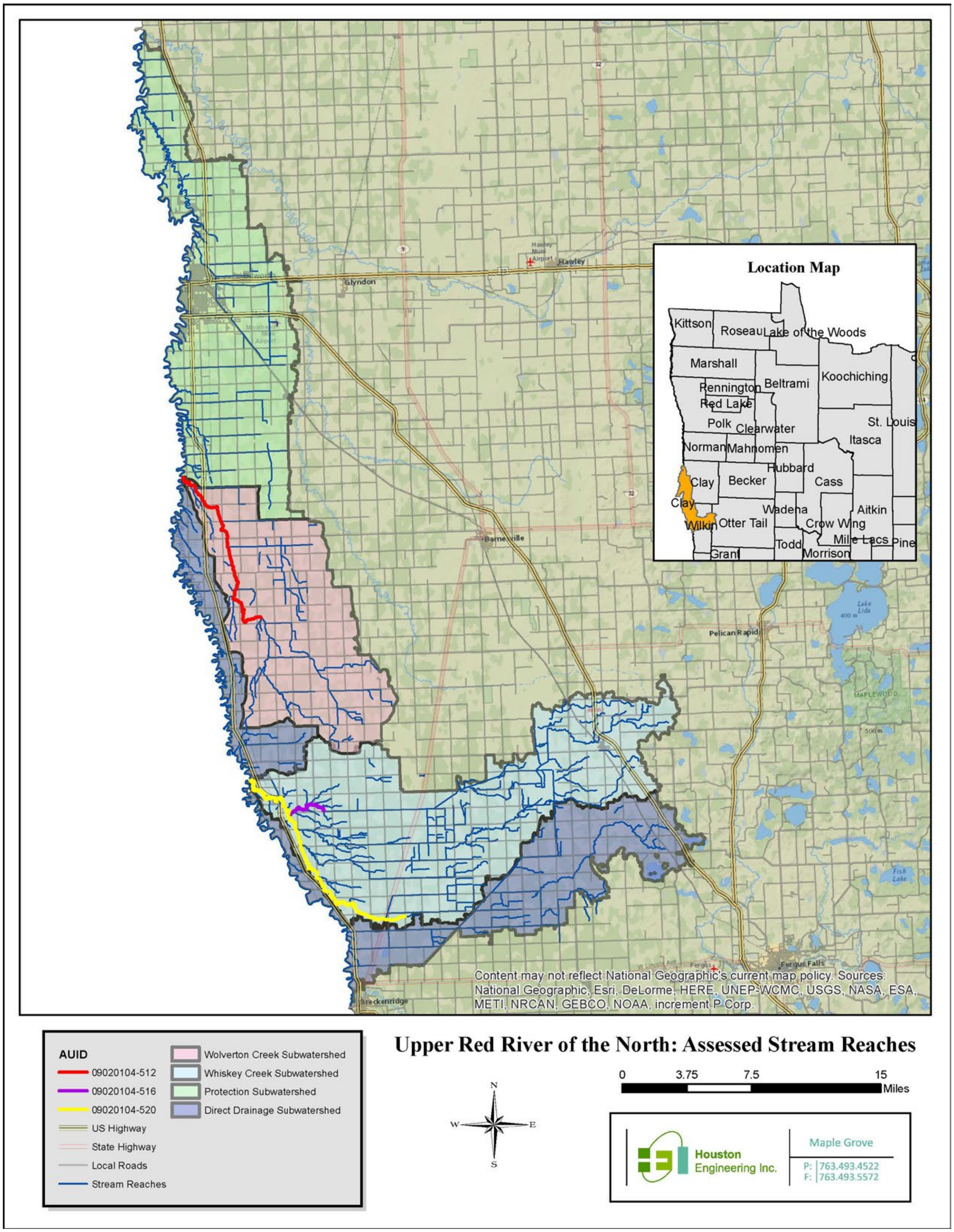


Figure 3: Assessed stream reaches within the Upper Red River of the North Watershed

Lakes

For the seven lakes within the watershed, only Nelson Lake (56-1015-00) has been assigned an identification number. Lake and wetland identifiers are assigned by the DNR. The Protected Waters Inventory provides the identification numbers for lake, reservoirs, and wetlands. These identification numbers serve as the AUID and are composed of an eight-digit number indicating county, lake, and bay for each basin. It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. Due to the watershed's limited natural ability for water retention, extensive drainage system, lack of lake monitoring data, and no assigned AUIDs, there are no assessable lakes within the URRW. Therefore, no lake water chemistry sampling was conducted during the intensive watershed monitoring of the URRW.

Only one lake within the watershed is classified as protected by the DNR. Nelson Lake (56-1015-00) lies in the eastern tip of the Whiskey Creek Subwatershed. Neither assessment level data nor Citizen Lake Monitoring Program (CLMP) trend data is available for this lake. No lake water chemistry sampling was conducted and there will be no further discussion regarding lakes in this report (MPCA 2014). The URRW will be reassessed in 2019 to 2020.

2.2 Water Quality Trends

There is currently no long-term water quality trend data available for the URRW.

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. Biological stressor identification (SID) is done for streams with either fish or macroinvertebrate biota impairments and encompasses both evaluation of pollutants (e.g., sediment and pesticides) and non-pollutant-related (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments are done for pollutants identified as biological stressors, as well as for any conventional pollutant impairment. **Section 3** provides further detail on stressors and pollutant sources.

Stressors of Biologically-Impaired Stream Reaches

The primary stressors for the biological impairment in the URRW are listed in **Table 2**. Evidence indicates that the biological impairment associated with Whiskey Creek is likely the result of altered hydrology, low DO, lack of in-stream habitat, and excess suspended sediment. The primary stressor is altered hydrology (MPCA 2015). Altered hydrology acts as a biological stressor though increased peak flows and rapid post-event reduction of flow to dry conditions. This stressor is in a large part driving the low DO stressor, and appears to be having the most direct impact on the poor macroinvertebrate community inhabiting Whiskey Creek. Both excess suspended sediment and lack of in-stream habitat appear to be impacting the stream organisms, however, these are, in part, follow-on effects of altered hydrology (MPCA 2015).

Further detailed SID information can be found in the MPCA's Watershed Biotic SID Report (MPCA 2015).

Table 2: Primary stressors to aquatic life in the biologically-impaired reach in the Upper Red River of the North Watershed

HUC-12 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Biological Impairment	Stressors				
					Flow Alteration	Habitat	Suspended Sediment	Dissolved Oxygen	Pesticide Toxicity
Whiskey Creek	520	Whiskey Creek	T133 R47W S13, east line to Red R	Macroinvertebrate Bioassessments	●	●	●	●	

* ˜ = high risk, › = medium risk, ™ = low risk

Currently, there is no numeric standard for altered hydrology. No flow devices have tracked historical flow patterns in the URRW. For this reason, there is no capacity to identify changes in hydrology between historic and modern records. Goals and associated management strategies for altered hydrology are provided below in **Section 3.3**.

Pollutant sources

Point and nonpoint sources of pollutants are identified in **Table 3** and **Table 4**, respectively. **Table 3** and **Table 4** are summarized from the MPCA's SID Report (MPCA 2015) and the URRW TMDL (HEI 2017). More specific information regarding the geographic location of nonpoint source locations and prioritization is detailed in **Section 3** where various methods of targeting and evaluating geographic areas are described.

Table 3: Point Sources in the Upper Red River of the North Watershed.

HUC-12 Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Direct Drainage (090201040401)	Breckenridge WWTF	MN0022900	Municipal wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
Wolverton Creek (090201040304)	Comstock WWTF	MNG580131	Municipal wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
Whiskey Creek (090201040203)	Rothsay WWTF	MNG580064	Municipal wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
Protection Area (090201040501)	Sabin WWTF	MNG580133	Municipal wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL

Table 4: Nonpoint Sources in the Upper Red River of the North Watershed. Relative magnitudes of contributing sources are indicated.

HUC-12 Subwater-shed	Stream/Reach (AUID) or Lake (ID)	Pollutant	Pollutant Sources									
			Fertilizer & manure run-off	Livestock grazing	AFO Open Lots	Failing septic systems	Wildlife	Domestic animals	Flow Alteration	Lack of Riparian Vegetation	Bank erosion	Farmed first order streams
Wolverton Creek	Wolverton Creek (512)	Bacteria	›	˜	˜	™	›	™				
Whiskey Creek	Whiskey Creek (520)	Bacteria	˜	˜	˜	™	›	™				
		TSS							˜	˜	˜	˜

* ˜ = high risk, › = medium risk, ™ = low risk

2.4 TMDL Summary

Two of the stream reaches are impaired, requiring a TMDL and reduction in the current loading to achieve the numeric water quality standards, and therefore, the water quality goals. The following tables show the maximum allowable load (loading capacity), and the amount which comes from nonpoint sources (load allocation) and point sources (wasteload allocation). The tables also show the reduction from the existing load needed based on load duration curves. A portion of the allowable load (10%) is placed in the "margin of safety" category, reflecting a level of uncertainty in the analysis. The critical duration period for each of the waterbodies is provided in Section 4 of the draft TMDL.

Escherichia coli

The existing bacteria contributions expressed as *Escherichia coli*, along with the wasteload and load allocations to meet the standard for portions of the URRW, are shown in the following tables (**Tables 5 and 6**). The analysis is based on the load duration curve method. The loading capacity is established using the flow condition requiring the greatest estimated load reduction.

Table 5: *E. coli* loading capacities and allocations for AUID 09020104-512.

E. coli		Flow Condition				
		Very High	High	Mid	Low	Very Low
		Geometric Mean (Billion organisms per day)				
Loading Capacity		**7,583.18**	**2,117.74**	**450.06**	**104.81**	**5.55**
Waste Load Allocation	**Total WLA**	**0.93**	**0.93**	**0.93**	**0.93**	**0.93**
	Comstock WWTF	0.93	0.93	0.93	0.93	0.93
Load Allocation	**Total LA**	**6,823.93**	**1,905.04**	**404.12**	**93.40**	**4.06**
Margin of Safety (MOS)		**758.32**	**211.77**	**45.01**	**10.48**	**0.55**
Existing Load		**9,118.27**	**3,056.77**	**735.69**	**160.28**	**10.91**
Unallocated Load		**0**	**0**	**0**	**0**	**0**
Estimated Load Reduction		**17%**	**31%**	**39%**	**35%**	**49%**

Table 6: *E. coli* loading capacities and allocations for AUID 09020104-520.

E. coli		Flow Condition				
		Very High	High	Mid	Low	Very Low
		Geometric Mean (Billion organisms per day)				
Loading Capacity		**2,224.09**	**570.28**	**204.99**	**83.23**	**14.80**
Waste Load Allocation	**Total WLA**	**2.33**	**2.33**	**2.33**	**2.33**	**2.33**
	Rothsay WWTF	2.33	2.33	2.33	2.33	2.33
Load Allocation	**Total LA**	**1,999.35**	**510.92**	**182.16**	**72.58**	**10.99**
Margin of Safety (MOS)		**222.41**	**57.03**	**20.50**	**8.32**	**1.48**
Existing Load		**6,250.73**	**58.50**	**233.06**	**76.13**	**30.60**
Unallocated Load		**0.00**	**454.75**	**0.00**	**0.00**	**0.00**
Estimated Load Reduction		**64%**	**0%**	**12%**	**0%**	**52%**

Total Suspended Solids

In January 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the historically used turbidity standard with TSS standards. The existing TSS contributions, along with the wasteload and load allocations to meet the standard for the URRW, are shown in the following tables. The analysis is based on using the concentrations of TSS using load duration curves. The loading capacity is established using the flow condition requiring the greatest estimated load reduction.

Table 7: TSS loading capacities and allocations for AUID 09020104-520.

TSS		Flow Condition				
		Very High	High	Mid	Low	Very Low
		Tons per day				
Loading Capacity		**129.54**	**34.71**	**13.15**	**4.91**	**0.77**
Wasteload Allocation	**Total WLA**	**0.21**	**0.12**	**0.10**	**0.09**	**0.09**
	Rothsay WWTF	0.09	0.09	0.09	0.09	0.09
	Construction/ Industrial Stormwater	0.12	0.03	0.01	0.004	0.001
Load Allocation	**Total LA**	**116.38**	**31.12**	**11.73**	**4.32**	**0.60**
Margin of Safety (MOS)		**12.95**	**3.47**	**1.31**	**0.49**	**0.08**
Existing Load		**171.4**	**48.9**	**14.1**	**3.4**	**---**
Unallocated Load		**0**	**0**	**0**	**1.05**	**---**
Estimated Load Reduction		**24%**	**29%**	**7%**	**0%**	**---**

2.5 Protection Considerations

All streams and lakes currently supporting aquatic life and aquatic recreation in the URRW are candidates for protection. Over time, if these waters are not subject to protection strategies, they may or may not become impaired. For streams, rivers, and lakes, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Protection strategies for urban areas include volume control and stream channel restorations. Protection strategies for non-urban areas include improving upland / field surface runoff 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.

3. Prioritizing and Implementing Restoration and Protection

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

This section of the report provides the prioritization and strategy development results. Because much 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 readiness and capacity (including understanding of the problems and solutions that are available, as well as motivation to make changes; strategies emphasize trust, networks, and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective ongoing civic engagement is a part of the overall plan for moving forward.

The successful implementation of restoration and protection strategies requires a combined effort from multiple entities within the URRW, including local and state partners [i.e., soil and water conservation districts (SWCDs), BRRWD, MPCA, DNR, and the Board of Water and Soil Resources (BWSR)]. By bringing these groups together in the decision making process, it will increase the transparency and eventual success of the implementation. The BRRWD will also work with landowners within the URRW through typical education and outreach programs to help identify implementation priorities. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

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

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

3.1 Targeting of Geographic Areas

The URRW lacks the Hydrologic Simulation Program-Fortran (HSPF) model, which can be used to evaluate the potential sources of pollutants. For this reason, several watershed modeling tools were used for the purpose of simulating and evaluating hydrology and water quality (sediment, nutrients, and bacteria) within the URRW. Tools developed under this WRAPS effort include:

- Enhanced Geospatial Water Quality Products (EGWQP);
- BMP suitability analysis; and
- SID studies.

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

Enhanced Geospatial Water Quality Products

Light Detection and Ranging (LiDAR) is a remote sensing technology that uses laser light to detect and measure surface features on the earth. The resulting data can be converted into elevation data and used to create a digital elevation model (DEM) for geographic information system (GIS) analysis. LiDAR data has been used in many ways to protect water quality in Minnesota, including erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping (MNGeo 2015).

As part of local planning in the watershed, EGWQP were developed for targeting fields based on yields (mass/acre/time) of sediment, total nitrogen (TN) and total phosphorus (TP) and identifying opportunities for BMP and Conservation Practice (CP) implementation. A bacteria risk assessment was also completed to identify areas in the watershed that pose the greatest risk for contributing bacteria to surface water resources.

The EGWQP was developed from derivatives of a hydrologically-conditioned 3-meter DEM for the URRW. Key processing steps involved the development of travel time data, and sediment, TN, and TP yield. Sediment yields leaving a landscape were estimated based on the application of the Revised Universal Soil Loss Equation (RUSLE). RUSLE accounts for land cover, soil type, topography, and management practices to determine an average annual sediment yield estimate. The sediment reaching a channel at the overland catchment outlet was then estimated using a sediment delivery ratio (SDR). Four products are ultimately produced: 1) sediment yield leaving the landscape; 2) sediment yield reaching the overland catchment outlet; 3) sediment yield delivered to a user defined downstream subwatershed outlet; and 4) sediment yield reaching the watershed outlet.

Whiskey Creek (AUID 09020104-520) is impaired by sediments. As such, the EGWQP was utilized to target field-scale (less than 140 acres) catchments contributing to the Whiskey Creek subwatershed outlet based upon sediment delivery to the outlet. **Figure 4** demonstrates use of this product. The Highest Priority (Highest 90% - darkest green) areas are the catchments delivering the highest yield (mass per unit area) of sediment to the Whiskey Creek subwatershed outlet. Non-contributing areas (no green) are also identified. This map and data can be used to target fields that deliver the largest amount of sediment to the subwatershed outlet for placing practices within the drainage area.

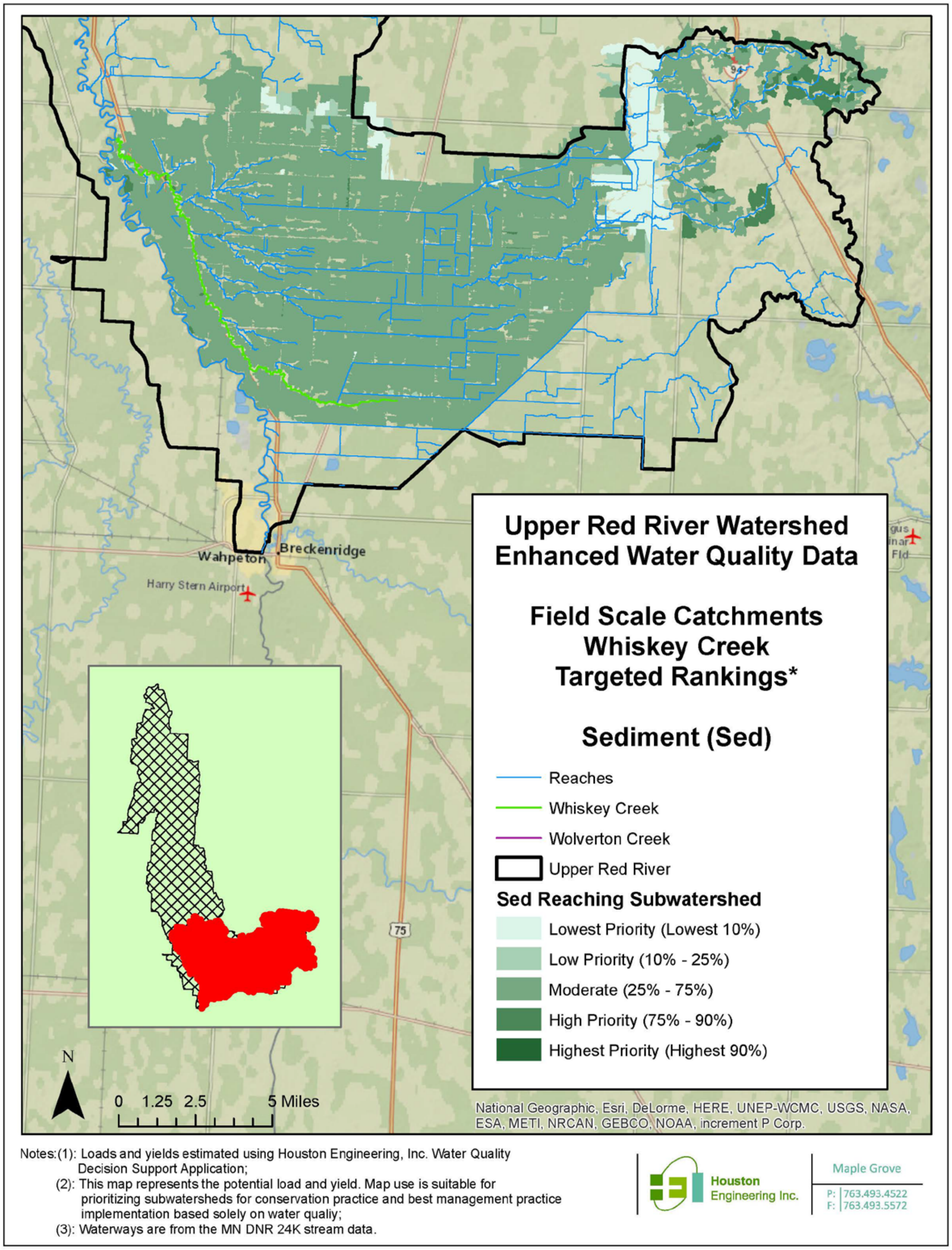


Figure 4: Targeting field scale catchments within Whiskey Creek based upon sediment delivery to the TSS impaired subwatershed outlet.

Nutrient annual yields leaving a landscape are estimated using a method similar to sediment. Yields for TP and TN follow an empirical approach using land use export coefficients from literature values. GIS layers for sediment, TP and TN were individually analyzed and given a percentile ranking. A Water Quality Index (WQI) value was then created to combine the sediment, TP and TN ranked yields into one composite ranking, giving equal weight to both sediments and nutrients to identify areas contributing relatively high proportions of both sediment and nutrients downstream. Field scale (less than 140 acres) catchments within each major tributary (i.e. Protection Area, Direct Drainage, Whiskey Creek, and Wolverton Creek – see Figure 3) were ranked based upon the annual delivery of TP, TN, and sediment mass from the landscape, to a waterway (i.e., flow line), subwatershed outlet, and to the outlet of the URRW, and were used to inform protection and restoration strategies (**Table 10)**. The full results of the field scale targeting are provided in **Appendix A.**

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

The risk rankings of potential sources of bacteria in the URRW by subwatershed are shown in **Table 8**. Livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the URRW. Human and wildlife sources of bacteria posed relatively lower risks, with the exception of ducks in the Protection Area, Whiskey Creek, and Wolverton Creek, and geese in the area draining directly to the Red River. This information can be used to prioritize management efforts for the potential sources of bacteria that pose the greatest risk of impacting surface waters in the URRW.

Table 8: Relative Sources of *E. coli*.

HUC-12 Subwatershed	Humans			Livestock			Wildlife			
	WWTF Effluent	Septic Systems	Domestic Animals	Grazing	Manure	AFO Open Lots	Deer	Ducks	Geese	Other
Protection	™	™	™	›	˜	˜	™	›	™	™
Direct	™	™	™	˜	™	™	™	™	˜	™
Whiskey	™	™	™	˜	˜	˜	™	›	™	™
Wolverton	™	™	™	˜	›	˜	™	›	™	™

* ˜ = high risk, › = medium risk, ™ = low risk

Figure 5 shows the HUC 12 ranks based on the magnitude of bacterial delivery to URRW outlet. Higher rates equate to a greater risk of bacterial delivery from the HUC 12 to the outlet of the URRW. Similar to the results shown in **Table 8**, livestock sources consistently posed the greatest risk of bacterial delivery. In addition, the results indicated that wildlife posed a moderate risk of delivery within the Wolverton and Whiskey Creek subwatersheds. This information can be used to inform the prioritization of local management efforts aimed at reducing bacterial delivery to surface waters in the URRW. In addition, **Figure 5** can also be used to begin targeting specific HUC12 watersheds for bacterial restoration and protection strategies.

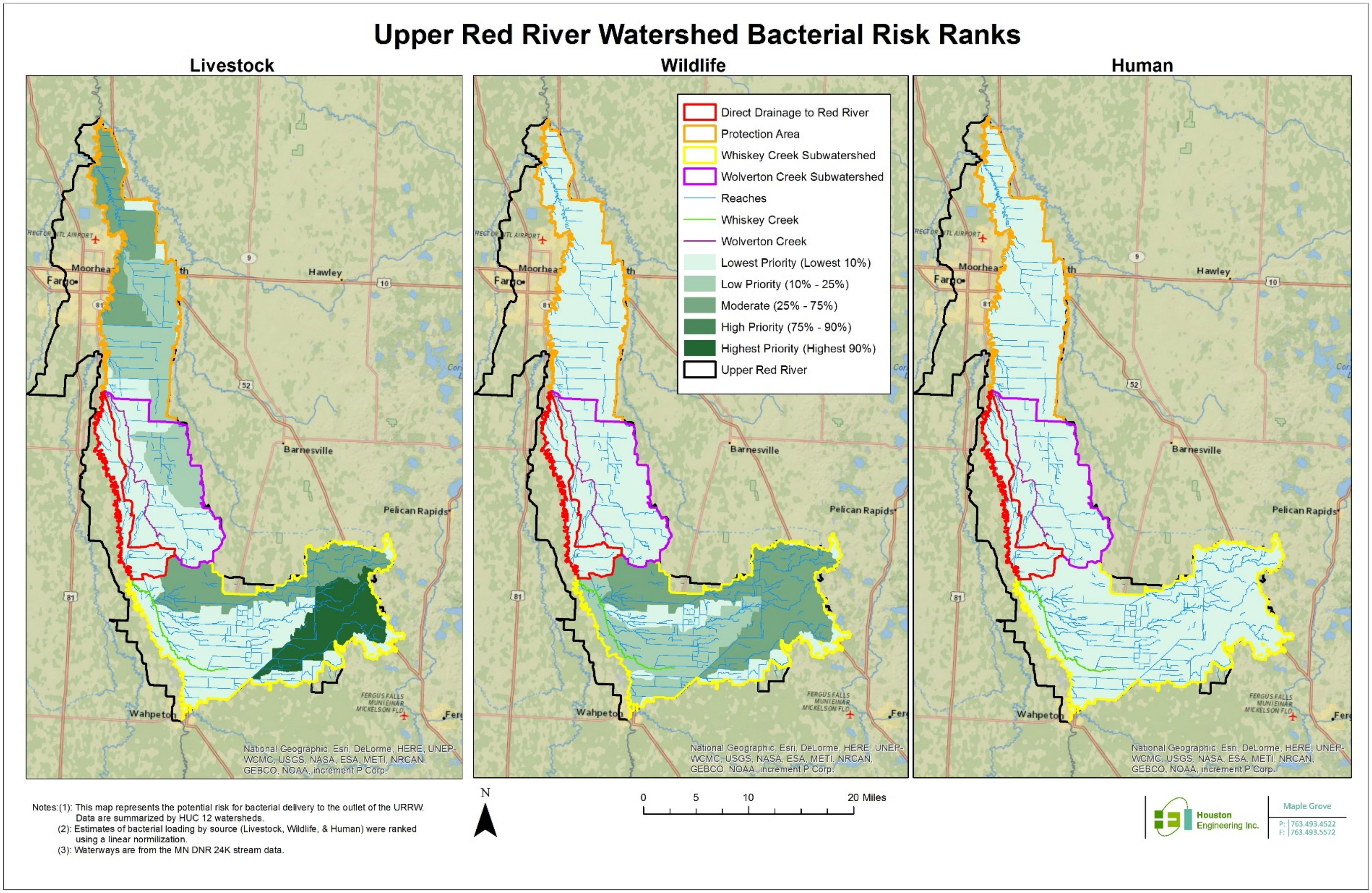


Figure 5. Ranked HUC 12 subwatersheds based upon magnitude of bacterial delivery to the outlet of the URRW.

BMP Suitability Analysis

In addition to targeting fields based on the delivery of water quality constituents, fields also can be targeted for opportunities to place BMPs. For instance, a field may produce a moderate to high amount of sediment, 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). As such, field scale opportunities to implement BMPs were targeted across the URRW watershed.

The BMP suitability analysis for the URRW was purposefully focused on those BMPs[1] and CPs[2] 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 NRCS guidelines and topographic characteristics, soils, and land use. Many other factors such as landowner willingness and the proximity to priority water resources are also important criteria. The high spatial resolution hydro conditioned DEM 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 BMP targeting have been provided in **Appendix B. Figure 6** shows an example of field scale catchments that have been targeted for opportunities to place filter strips. This data product can be paired with the 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.

[1] Best Management Practice (BMP) – Means a practice that is determined to be an effective and practicable (including technological, economic and institutional considerations) means of preventing or reducing the amount of a substance in excess of background levels, generated by nonpoint sources.
[2] Conservation Practices (CPs) – Means a BMP implemented in an agricultural setting with additional planned benefits of protecting soil health, reducing erosion, and enhancing habitat.

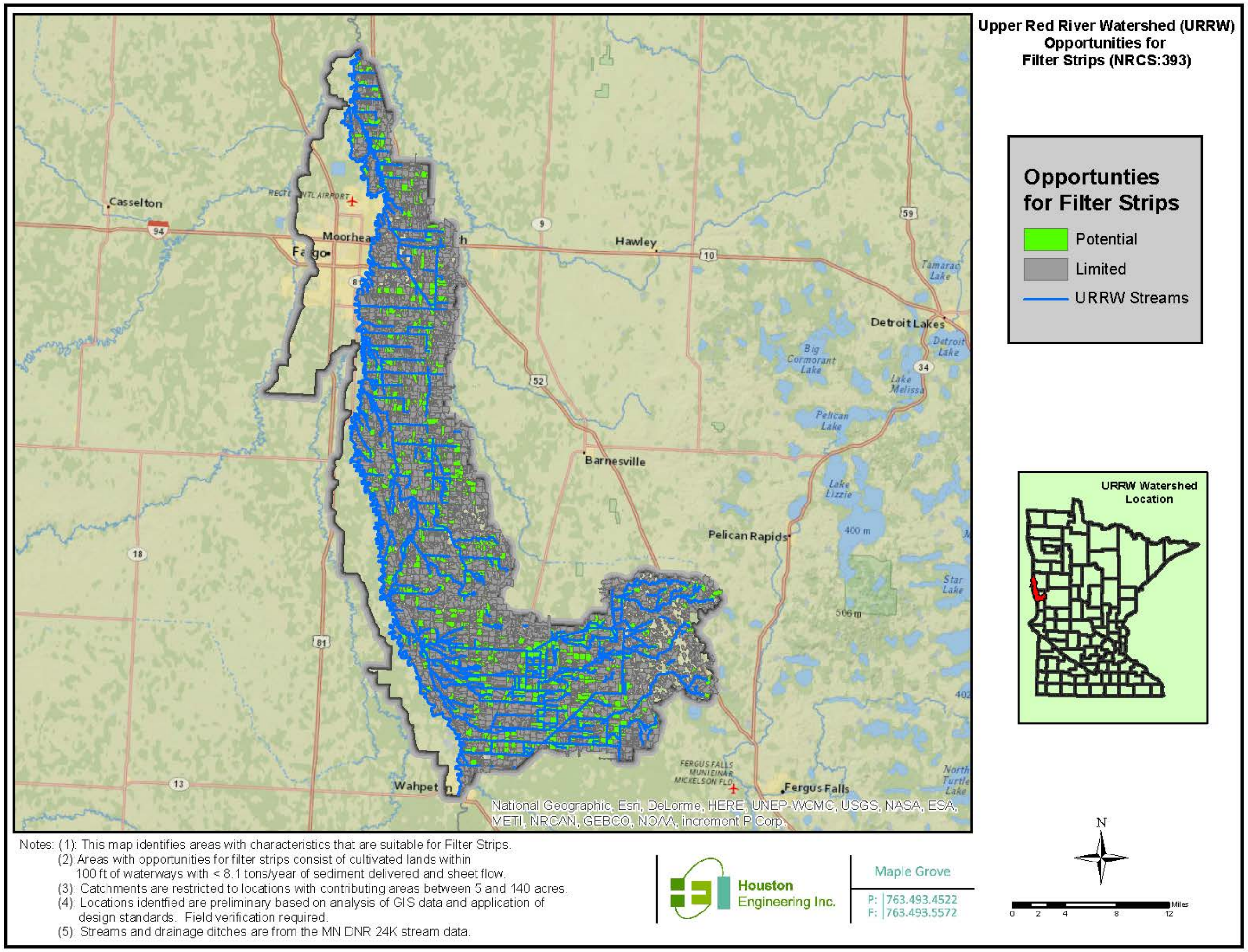


Figure 6: Targeting field scale catchments within Whiskey Creek based upon sediment delivery to the subwatershed outlet.

Buffalo Red River Watershed Management Plan

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

The BRRWD WMP was most recently updated in June of 2010. In the updated plan, great efforts have been made to quantify the goals and suggest implementation strategies of the BRRWD for managing water quantity and quality, as well as natural resource enhancement. The WMP is currently being updated to include the 2012 newly added areas in Wilkin and Otter Tail Counties, with an estimated completion date of December 2017.

Future use of the BRRWD WMP in water quality restoration and protection efforts will include integrating the principles, goals, and policies of the BRRWD into the work and providing a management framework under which it can occur.

Additional Tools

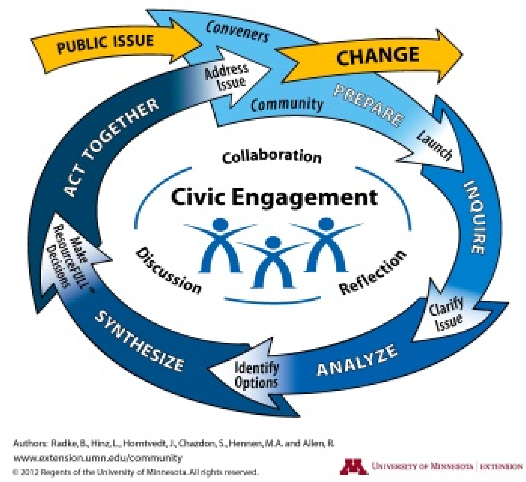
A number of additional tools are available for use in restoration and protection of impaired waters in the URRW. A non-exhaustive list of some of these tools, their description, and how they may be utilized is listed in **Table 9.**

Table 9: Additional Tools Available for Restoration and Protection of Impaired Waters.

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Prioritize, Target and Measure Application (PTMA)	The Prioritize, Target, and Measure Application (PTMAP) for implementing water quality improvement plans is being developed as part of BWSR's One Watershed: One Plan initiative.	The tool will enable local practitioners to prioritize subwatersheds for BMPs and CPs based upon outputs of HSPF models, target specific fields for implementation based upon contaminant flux estimated with terrain analysis techniques and suitability for BMPs and CPS, and measure the likelihood of success by estimating the costs (construction and maintenance) and benefits (reduction in contaminants) of BMPs and CPs.	Application is being developed for statewide use through the International Water Institute.	NA
Ecological Ranking Tool (Environmental Benefit Index - EBI)	Three GIS layers containing soil erosion risk, water quality risk, and habitat quality. Locations on each layer are assigned a score from 0-100. The sum of all three layer scores (max of 300) is the EBI score. This higher the score, the higher the value in applying restoration or protection.	Any one of the three layers can be used separately or the sum of the layers (EBI) can be used to identify areas that are in line with local priorities. Raster calculator allows a user to make their own sum of the layers to better reflect local values.	GIS layers are available on the BWSR website.	BWSR
Zonation	A framework and software for large-scale spatial conservation prioritization; it is a decision support tool for conservation planning. This values-based model can be used to identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.)	Zonation
Restorable Depressional Wetland Inventory	A GIS layer representing drained, potentially restorable wetlands in agricultural landscapes. Created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May 1991 and 1992.	Identify restorable wetland areas with an emphasis on: wildlife habitat, surface and ground water quality, reducing flood damage risk. To see a comprehensive map of restorable wetlands, must display this dataset in conjunction with the USGS National Wetlands Inventory (NWI) polygons that have a 'd' modifier in their NWI classification code	The GIS layer is available on the DNR Data Deli website.	DNR

National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data has been used for: fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of the data set is to identify buffers around riparian areas.	The layers are available on the USGS website.	*USGS*
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	*MGIO*

3.2 Civic Engagement



A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a more interactive level of involvement. The MPCA has coordinated with the University of Minnesota Extension Service for years on developing and implementing civic engagement approaches and efforts for the Watershed Approach. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." Extension defines a resourceFULL decision as one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www1.extension.umn.edu/community/civic-engagement/.

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

An Open House style "kickoff meeting" was held at the Barnesville office of the BRRWD on June 14, 2012, for interested stakeholders and resource managers to become familiar with the WRAPS and TMDL process for the URRW. Similarly, another Open House was held on January 7, 2016, for reviewing findings of and draft documents for the WRAPS and TMDLs. A Technical Stakeholder Group (TSG) was developed to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. The WRAPS TSG included representatives from the BRRWD, the SWCDs, and state agencies. This group was primarily engaged to discuss potential products developed to identify geographic areas for implementing projects.

Accomplishments and Future Plans

The civic engagement efforts related to the URRW WRAPS have been overseen and carried out by the BRRWD. Two public meetings and open house events were held at key points in the WRAPS process to update stakeholders on the WRAPS efforts as well as receive input and guidance on water quality values and concerns in the area. In addition, the BRRWD posted project updates on their website (http://www.brrwd.org/) and a core team, including BRRWD board members and local/state agency partners, was established, meeting quarterly to stay current on technical components of the work.

Since water quality is among the priorities of the BRRWD's management activities, future civic engagement will continue to be coordinated by the District. The BRRWD will update, educate, and engage stakeholders on water quality issues through the typical District communications, including plan update events and on their website. A primary objective of this civic engagement is to create understanding of water quality problems and solutions that are available, and build motivation to make changes with those who will be needed to voluntarily implement BMPs. As one of most trusted authorities on water issues in the area (U of MN WRC 2012), the BRRWD is uniquely suited to provide information and leadership on this topic.

Expectations are that future implementation will occur either through the existing water related plans, implementing One Watershed, One Plan, and/or through the flood damage reduction workgroup.

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the State Register from July 24, 2017 to August 23, 2017.

3.3 Restoration & Protection Strategies

Water quality restoration and protection strategies within the URRW were identified through collaboration with local and state partners (i.e., SWCDs, BRRWD, MPCA, DNR, and BWSR). Due to the homogeneous nature of the watershed, most of the suggested strategies are applicable throughout the watershed.

Altered hydrology has been cited as a primary stressor to the biological impairment in the URRW (MPCA 2015). Based on the results of the URRW SID Report (MPCA 2015), restoration and protection strategies can be developed to prevent or mitigate activities that further alter the hydrology of the watershed, and improve storage capacity in an effort to restore the hydrology of the URRW.

A study has already been completed for the URRW that identifies areas that are suitable for BMPs, based on sediment, TP, and TN delivery (HEI 2014). Bacteria risk areas have also been identified (HEI 2014). Based upon the HEI (2014) study, the subwatersheds where BMP projects could be implemented are defined in **Table 10** and **Table 11.**

Table 10 contains a list of the impaired waters of the URRW, along with goals for restoration, suggested implementation strategies, estimated adoption rates, units/metrics to track progress towards goals, the governmental unit responsible for implementation, and the timeline to achieve those goals. All other waters in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies. Given the homogeneity of the watershed, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams.

The BRRWD and the Wilkin, Clay, and West Otter Tail SWCDs have a long history of improving water quality. All three have been actively seeking grants to improve local water quality before and since the passage of the Clean Water, Land and Legacy Amendment.

In 2007, the Clay SWCD received funds to work on installing sediment controls along Wolverton Creek. In partnership with the BRRWD and Wilkin SWCD, the Clay SWCD grant was used to install a series of 13 grade control rock riffles, nine stream barbs, and four side inlet structures along the portion of Wolverton Creek downstream of Highway No. 75. The lower reach of Wolverton Creek was downcutting and this project prevented additional downcutting of the channel. As part of that grant, the Wolverton Creek channel was surveyed for future restoration work.

Through the 2011 Clean Water Fund grant, the BRRWD partnered again with the Wilkin and Clay SWCDs to complete work along Wolverton Creek. The funding was used to install a number of side inlet structures, buffer strips, and outlet grade control on public drainage systems within the Wolverton Creek subwatershed. Based on the previous survey, the BRRWD developed a plan to restore over 26 miles of the Wolverton Creek. The expected sediment loading reduction is in the range of 6,000 to 7,000 tons/year. The BRRWD is currently seeking outside funding to complete this $8 to $10 million dollar project.

In 2014, Otter Tail County started their buffer initiative. The County planned to buffer all streams over the course of five years. In 2015, the West Otter Tail SWCD was granted $290,616 to assist with that effort through a Clean Water Fund Soil Erosion and Drainage Law Compliance grant. The 2015 Governor's Buffer Initiative signed into law during the 2015 Special Session will result in additional funding to all SWCDs within the URRW (and statewide) to accelerate implementation of buffers along all legal ditches and Public Waters. All public drainage systems must be buffered by November 2018 and all Public Waters must be buffered by November 2017.

The Wilkin County SWCD has received grant funding for retrofitting legal ditch systems within the Whiskey Creek Watershed. A 2010 CWF grant for $256,410 was leveraged with $119,500 in local funds to install 14 miles of buffer strips and berms and 56 side inlet sediment control structures along 14 miles of ditch system with an expected sediment reduction of 300 tons/year. A 2012 CWF grant for $294,506 was leveraged with $240,500 to install 6.5 miles of berms and side inlet sediment controls and 25 acres of buffer strips along the Connelly Ditch (Wilkin County Ditch No. 31). This project is expected to reduce sediment by 335 tons per year and reduce peak flows by 50% to 75%. A 2014 CWF grant is being used to install grade control on gullies flowing to the Red River.

The success of the ditch retrofit BMP projects installed by Wilkin County has resulted in the county moving forward with completing the retrofits on all ditch systems within the URRW in Wilkin County regardless of whether outside CWF grant were available. As of 2015, Wilkin County had two remaining systems in the Whiskey Creek Watershed that needed retrofits: Wilkin County Ditches Nos. 34 and 1-C. These systems are currently under construction.

In 2012, the BRRWD completed a redetermination of benefits for Clay County Ditches Nos. 40, 11 (North and South), 36, and 60. As part of this work, buffer strips and side inlet culverts were installed. The BRRWD plans to install buffers on Wilkin County Ditch No. 22 Laterals Nos. 1 and 2, and Wilkin County Ditches No. 5A and 26 in 2015.

In 2013, the BRRWD was awarded a $333,590 CWF grant to retrofit Clay County Ditches Nos. 9, 32, and 33. The grant funding was supplemented with an additional $256,120 of local funding for the work as well. The work resulted in 40 acres of new buffer strips and 179 side inlet sediment control structures, which are expected to reduce sediment loss to the Red River by 1,942 tons per year and phosphorus loss by 2,729 lbs. per year.

These ditch retrofit projects reduce the amount of sediment loading reaching Whiskey Creek, Wolverton Creek, and the Red River and will help address the turbidity/TSS impairments throughout the watershed and reduce the elevated turbidity stressors on biological impairments. In addition, the berms and side inlet culverts installed as part of these projects temporarily detain surface runoff, helping reduce the altered hydrology stressors identified in the SID Report (MPCA 2014b).

In addition to the Clean Water Fund supported efforts in the URRW, in 2013, the BRRWD in partnership with the Wilkin and West Otter Tail SWCDs, agreed to submit the Whiskey Creek/Wilkin County Ditch No. 31 watershed as a pilot for the Minnesota Agricultural Water Quality Certification Program. The program encourages farm producers to implement conservation BMPs that will improve the water quality of runoff leaving their fields. Using existing USDA Farm Bill programs and state cost share, a number of conservation practices have been installed. As of June 2017, thirteen agricultural producers have been certified, along with 9,424 certified acres in the URRW.

In 2015 in partnership with Wilkin County, the BRRWD completed a one-mile restoration of Whiskey Creek. This restoration created a two-stage natural design channel with a permanently protected expanded riparian buffer. Side inlet sediment controls also were installed along the channel. Cost for this restoration was $60,000.

The BRRWD has identified three regional retention sites within the URRW. These sites have been identified and preliminary hydrologic design work has been completed. The sites have been located to provide flood damage reduction benefits, which would address the altered hydrology identified in the SID Report for the URRW. Significant effort and funding would be required to implement these sites. Each site would have an approximate cost of $10 to $15 million dollars.

Interim 10-year milestones are identified in **Table 10** for each impaired subwatershed so incremental progress is measured and achieved. On-going water quality monitoring data will be used in future components of the WRAP process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals. The timeline for the identified protection strategies is on-going.

It is important to note that loading reduced from some implementation actions listed in **Table 10** is creditable to the load allocation and some to the wasteload allocation. Examples of non-WLA creditable projects include strategies aimed at reducing in-stream loading (e.g., streambank and shoreline protection/stabilization). For clarification on a particular project, proposers should contact the MPCA Stormwater Program.

Table 10: Strategies and actions proposed for the Upper Red River of the North Watershed.

HUC-12 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	Estimated Year to Achieve Water Quality Target
						NPDES Permit Compliance								•				
All	Unimpaired streams	All	TSS	Varies	Upper 10th percentile not to exceed 65 mg/L	Maintain riparian vegetation	One rod ditch buffers	90%	100%	100%	% of stream miles	•	•					2025 per Nutrient Reduction Strategy
							Maintain buffers meeting 50-ft requirement on all streams	30%	100%	100%	% of streams	•	•					
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	10000	25000	Feet of ditch	•				•		
							Install rock barb structures	1000	2500	5000	Feet of streambank protected	•	•					
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	1	10	stream miles	•				•		
						Improve upland / field surface runoff controls	Cover crops	5%	15%	25%	% of watershed area		•					
							Rotations including perennials	5%	10%	12%	% of watershed area		•					
							Conservation cover easements	2%	4%	5%	% of watershed area		•					
							Grassed waterways	0.05	0.1	0.1	% of watershed area		•					
							Side Inlet or similar grade and rate control	80%	95%	100%	% of field ditches entering waterways and ditches	•	•					
							Residue management - conservation tillage	30%	50%	80%	% of watershed area		•					
							Field edge buffers, borders, windbreaks and/or filter strips	1%	2%	2%	% of watershed area		•					
						Reduce Flashiness of Waterways	Construct Floodwater Impoundments / Reduce flood volume	0	5,000	10,000	Acre-feet of storage impoundments		•					

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

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				
						Implement volume control / limited-impact development	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php							•				2055
			Biological Habitat	Varies	Varies	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•					
							One rod ditch buffers	90%	100%	100%	% of stream miles	•	•					
							Increase conservation cover easements	2%	4%	5%	% of watershed area	•	•					
							Streambank and shoreline protection/stabilization	0	5000	20000	Feet of shoreline	•	•					
							Accurately size bridges and culverts to improve stream stability	80	90	100%	% complete	•	•					
							Tree planting to increase shading and for stabilization	0	2	5	stream miles	•	•					
						Restore / enhance channel	Install two-stage ditches on drainage ditches	0	10000	25000	Feet of ditch	•						
							Restore natural meander and complexity	0	10000	25000	stream miles					•		
						Improve upland / field surface runoff controls	Open tile inlets with either riser pipes, rock inlets or other protection	95	100	100%	% of open tile inlets	•	•					
			E. coli	Varies	Geometric mean ≤ 126 org/100mL	**Address failing septic systems**	Replace failing septic (SSTS) systems	0	0	0	# of noncompliant septic systems				•			
							Maintain septic (SSTS) systems	0	0	0	# of noncompliant septic systems				•			
						Improve livestock and manure management	Rotational grazing / Livestock exclusion on pastured stream miles	75%	100%	100%	% of priority sites		•				•	
							Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•				•	
							All Minn. R. Ch. 7020 manure spreading setbacks are met	100%	100%	100%	% of priority sites		•				•	

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				
			Total Phosphorus (TP)	Varies	10% reduction from 2003 conditions per Nutrient Reduction Strategy	Improve fertilizer and manure application management	Soil P testing and applying nutrients on fields needing phosphorus	95%	100%	100%	% of watershed area		•				•	2025 per Nutrient Reduction Strategy
							Incorporating/injecting nutrients below the soil	95%	100%	100%	% of watershed area		•				•	
						Improve livestock and manure management	Rotational grazing / Livestock exclusion on pastured stream miles	75%	100%	100%	% of priority sites		•				•	
							Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•				•	
							All Minn. R. Ch. 7020 manure spreading setbacks are met	100%	100%	100%	% of priority sites		•				•	
						Improve upland / field surface runoff controls	Strategies to reduce sediment from fields (see above - upland field surface runoff)					•	•					
							Constructed wetlands	0	100	200	acres of wetland		•					
							Pasture management	0.5	0.5	0.5	% of watershed area		•				•	
						Store and treat tile drainage waters	Saturated buffers	10	200	500	acres of drained cropland acres going into treatment systems		•					
							Controlled drainage	10%	50%	75%	% of watershed area	•	•					
			Nitrogen (TN) or Nitrate	Varies	13% load reduction from 2003 conditions per Nutrient Reduction Strategy	Improve fertilizer and manure application management	Soil N testing and applying nutrients on fields needing nitrogen	95%	100%	100%	% of watershed area		•				•	
							Incorporating/injecting nutrients below the soil	95%	100%	100%	% of watershed area		•				•	
							Strategies to reduce sediment from fields (see above - upland field surface runoff)					•	•					

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				
						Improve upland / field surface runoff controls	Constructed wetlands	0	100	200	acres of wetland		•					
							Pasture management	0.5	0.5	0.5	% of watershed area		•				•	
						Store and treat tile drainage waters	Saturated buffers	10	200	500	acres of drained cropland acres going into treatment systems		•					
							Controlled drainage	10%	50%	75%	% of watershed area	•	•					
Wolverton Creek HUC 090201040304	Wolverton Creek: Unnamed cr to Red R (09020104-512)	Clay, Wilkin	*E. coli*	High = 152 org/100mLMoist = 182 org/100mLAvg = 206 org/100mLDry = 193 org/100mLLow = 248 org/100mL	Geometric mean ≤ 126 org/100mL, April - October	**Address failing septic systems**	Maintain septic (SSTS) systems	0	0	0	# of noncompliant septic systems				•			2055
						Improve livestock and manure management	Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•				•	
							All Minn. R. ch. 7020 manure spreading setbacks are met	100%	100%	100%	% of priority sites		•				•	
Whiskey Creek HUC 090201040203	Whiskey Creek: T133 R47W S13, east line to Red R (09020104-520)	Wilkin	*E. coli*	High = 354 org/100mL Moist = 13 org/100mL Avg = 143 org/100mL Dry = 115 org/100mL Low = 261 org/100mL	Geometric mean ≤ 126 org/100mL, April - October	**Improve livestock and manure management**	Animal mortality storage areas consistent with Bd. Animal Health rules and feedlot permits.	0	0	0	# noncompliant mortality storage sites		•				•	2055
							All Minn. R. ch. 7020 manure spreading setbacks are met	100%	100%	100%	% of priority sites		•				•	
							Inject or immediately incorporate manure where currently surface applied	95%	100%	100%	% of priority sites		•				•	
						Address failing septic systems	Maintain septic (SSTS) systems	0	0	0	# of noncompliant septic systems				•			

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				
			Dissolved Oxygen	< 5 mg/L	5+ mg/L	Reduce phosphorus	See Nutrients strategies											2055
			Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Macro-Invertebrate IBI = 40	Macro-Invertebrate IBI = 40	**Increase living cover** [to increase infiltration and evapotranspiration]	Grassed waterways	0.05%	0.10%	0.10%	% of watershed area		•					2055
							Cover crops	5%	15%	25%	% of watershed area		•					
							Conservation cover (easements & buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•					
							Rotations including perennials	5%	10%	12%	% of watershed area		•					
						Reduce Flashiness of Streams	Construct Floodwater Impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•					
						Improve drainage management [to store and control the release of tile drainage water]	Controlled drainage	10%	50%	75%	% of watershed area	•	•					
							Restored / Treatment wetlands	0	100	200	acres of wetland		•					
						Reduce rural runoff by increasing infiltration, residue management	80 % row cropland at 30% residue cover	30	50	80	% row cropland at 30% residue cover		•					
							Water and sediment basins, terraces	100	500	1500	acres	•	•					

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				
						Improve urban stormwater management [to decrease urban stormwater volume]	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs							•				
			Poor Habitat (Fish/Macroinvertebrate IBI)	Macro-Invertebrate IBI = 9.39	Macro-Invertebrate IBI = 40	**Improve riparian vegetation**	50-ft buffers on all streams and all buffer requirements met	30%	100%	100%	% of streams	•	•					2055
							One rod setback from all ditches, where required	90%	100%	100%	% of stream miles	•	•					
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•					
							Improve/increase natural habitat in riparian, control invasive species	0	2	2	% of watershed area addressed	•	•					
							Streambank and shoreline protection/stabilization	0	5000	10000	Feet of shoreline	•	•					
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•					
						Restore/enhance channel	Dam removals and dam improvements to mimic natural conditions	0	0	0	# dam improvements					•		
							Install two-stage ditches on drainage ditches	0	20000	100000	Feet of ditch	•						
							Restore natural meander and complexity	0	25	30	stream miles	•						
			TSS	High =86 mg/L Moist = 92 mg/L Avg = 70 mg/L Dry = 45 mg/L Low = N/A	Upper 10th percentile not to exceed 65 mg/L	**Improve riparian vegetation**	50' vegetated buffer on waterways	30%	100%	100%	% of streams	•	•					2055
							One rod ditch buffers	90%	100%	100%	% of stream miles	•	•					
							Increase conservation cover: in/near water bodies, to create corridors	9%	12%	15%	% of watershed area	•	•					
							Improve/increase natural habitat in riparian, control invasive species	0%	2%	2%	% of watershed area addressed	•	•					
							Streambank and shoreline protection/stabilization	0	5000	10000	Feet of shoreline	•	•					
							Wetland restoration	0	100	200	acres of wetland	•	•					

HUC-12 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.: Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal	Estimated Adoption Rate: Units / Metric	Governmental Units with Primary Responsibility: Watershed District	SWCD	MPCA	County	DNR	MDA	Estimated Year to Achieve Water Quality Target
						NPDES Permit Compliance								•				
							Accurately size bridges and culverts to improve stream stability	80%	90%	100%	% complete	•	•					
						Reduce Flashiness of Streams (to reduce instream sediment loading)	Construct Floodwater Impoundments	0	10,000	25,000	Acre-feet of storage impoundments		•					
						Improve upland / field surface runoff controls	Water and sediment basins	100	500	1500	acres		•					
							Residue management - conservation tillage	10	20	25	% of watershed area		•					
							Side Inlet or similar grade and rate control	80%	95%	100%	% of field ditches entering waterways and ditches	•	•					
							Field wind breaks	1.5%	3%	5%	% of watershed area		•					
						Stream channel restoration	Install two-stage ditches on drainage ditches	0	20000	100000	Feet of ditch	•						
							Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)	0	25	30	stream miles					•		
						Increase vegetative cover	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)	9%	12%	15%	% of watershed area		•					
							Perennials grown on marginal lands and riparian lands	1%	2%	2%	% of watershed area		•					
							Cover crops	5%	15%	25%	% of watershed area		•					
							Rotations that include perennials	5%	10%	12%	% of watershed area		•					
							Crop conversion to low nutrient-demanding crops (e.g., hay).	3%	4%	5%	% of watershed area		•					

HUC-12 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.					Governmental Units with Primary Responsibility						Estimated Year to Achieve Water Quality Target
							Strategy Type	Estimated Adoption Rate										
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal	Units / Metric	Watershed District	SWCD	MPCA	County	DNR	MDA	
						NPDES Permit Compliance								•				

	Restoration
	Protection
	Point Sources

Table 11: Key for Strategies Column

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
TSS	Improve upland/field surface runoff controls: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow- some of flow reduction strategies should be targeted to ravine subwatersheds
		Residue management - conservation tillage
		Forage and biomass planting
		Open tile inlet controls - riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks and/or filter strips
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion - controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also, may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks and/or filter strips
		Contour farming and contour buffer strips
		Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management - conservation tillage
	Stream Channel Restoration	Addressing road crossings (direct erosion) and floodplain cut-offs
		Clear water discharge: urban areas, ag tiling etc. – direct energy dissipation
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology & sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Improve forestry management	Proper Water Crossings and road construction
		Forest Roads - Cross-Drainage
		Maintaining and aligning active Forest Roads
		Closure of Inactive Roads & Post-Harvest
		Location & Sizing of Landings
		Riparian Management Zone Widths and/or filter strips

	Improve urban stormwater management [to reduce sediment and flow]	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
Nitrogen (TN) or Nitrate	Increase fertilizer and manure efficiency: Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at Maximum Return to Nitrogen (U of MN recommendations)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	Improve upland/field surface runoff controls: Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass & trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	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 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.
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	Reducing livestock bacteria in surface runoff: Preventing manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce Industrial/Municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTP untreated (emergency) releases
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate
Chloride	Road salt management	[Strategies currently under development within Twin Cities Metro Area Chloride Management Plan]

Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	Increase living cover: Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements & buffers of native grass & trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins, terraces
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management
Poor Habitat (Fish/Macroinvertebrate IBI)	Improve riparian vegetation: Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants and increase biodiversity	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water Temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	Removal 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

Continued stream monitoring within the URRW will continue primarily through the efforts of the BRRWD. As outlined in the Section 4.2 of the BRRWD WMP (HEI 2010b), the BRRWD has established regional assessment locations (RALs) in streams throughout the BRW and are currently employing a water quality monitoring program that consists of financial support to the River Watch Program and International Water Institute. Samples are collected on (at least) a monthly basis from April through September. The samples are analyzed for turbidity, temperature, pH, DO, connectivity, chloride, nutrients, TSS and *E. coli*. In addition to the stream monitoring sponsored by the BRRWD, the MPCA also has on-going monitoring in the watershed. Their major watershed outlet monitoring will continue to provide a long-term on-going record of water quality at the BRW outlet.

The MPCA will return to the watershed under their Intensive Watershed Monitoring program in 2019 through 2020.

5. References and Further Information

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Minnesota Pollution Control Agency (MPCA). 2015. Upper Red River of the North Watershed Biotic Stressor Identification Report. April, 2015.

University of Minnesota Water Resources Center (U of MN WRC). 2012. BRRWD Social Indicators Survey Final Report. May 30, 2012.

Upper Red River of the North Watershed Reports

All Upper Red River of the North Watershed reports referenced in this watershed report are available at the Upper Red River of the North Watershed webpage: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/upper-red-river-of-the-north.html

Appendix A:

TECHNICAL MEMORANDUM

To: Tara Mercil, Minnesota Pollution Control Agency

From: Houston Engineering, Inc.

Cc: Bruce Albright, Buffalo Red River Watershed District
Erik Jones, Houston Engineering, Inc.
File 1915-204

Subject: Technical Memorandum - PTMA BMPs and Measurement Methods

Date: January 5, 2015

Project: 1915-204

INTRODUCTION

This Technical Memorandum (TM) describes the methods employed to create and then use Enhanced Geospatial Water Quality Products (EGWQP) for targeting fields based on yield (mass/area/time) of sediment, total nitrogen (TN) and total phosphorus (TP) and identifying opportunities for Best Management Practice (BMP) and Conservation Practice (CP) implementation. This work is one component of the Upper Red River Watershed (URRW), Watershed Restoration and Protection Strategy (WRAPS). The URRW lacks other water quality models, such as Hydrologic Simulation Program-Fortran (HSPF), for completing their Total Maximum Daily Load (TMDL) and Watershed Restoration and Protection Strategy (WRAPS) studies, driving the use of the EGWQP for source assessments and restoration and protection strategies.

This TM describes the methods used to create the EGWQP products which include raster and catchment (generally described as field scale contributing drainage areas ranging in size up to 140 acres) sediment, TN and TP mass leaving the landscape, delivered to a waterway or flowline, and delivered to user defined locations within the watershed. These user defined locations can include lakes and rivers of interest (resources of concern) and the outlet (i.e., pour point) of specific subwatersheds and the watershed. The information is useful in assessing the locations which are the greatest sources of sediment, total phosphorus and total nitrogen, at a very fine field scale. These data can also be used to target specific fields as opportunities based solely on pollutant source magnitude to place CPs and BMPs. Potential locations where CPs and BMPs appear suitable (BMP suitability products) based on Natural Resources Conservation Service (NRCS) design practice standards are also presented. Finally, results of a bacteria risk assessment are presented which can be used to identify areas in the watershed that pose the greatest risk for contributing bacteria to surface water resources.

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

METHODS

Bacteria Sources and Risks

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

1. Identify and estimate magnitude (i.e., production rate) of potential bacteria sources that may contribute *E. coli* in the watershed. These sources include humans (subsurface sewage treatment systems [SSTS], wastewater treatment facilities [WWTF]), companion animals (cats and dogs), livestock (cows, chickens, goats, hogs, horses, sheep, and turkeys), and wildlife (deer, ducks, geese, and others). Once the population contributing bacteria had been identified, population estimates were obtained from the various sources provided in the following sections.

2. Each source is assigned a bacteria production rate (see **Table 1**), based on literature values. These bacteria yields are then applied to the relevant areas, described in the following sections.

3. Estimate an empirical downstream delivery factor representing die-off and based on water travel time was then applied to the bacteria production rates across the watershed. This delivery factor accounts for the fate and transport of bacteria from the source to the impaired waterbody.

4. Finally, the total bacteria load was estimated by summing the bacteria production with the delivery factor applied to estimate the relative loads for each identified source. A ranking was applied based on percentage of total bacteria load.

Production Rates

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

Table 1: Bacteria production rates by source

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Humans	Humans	2	1.3	Metcalf and Eddy 1991
Livestock	Domestic Animals	5	3.2	Horsley and Witten 1996
	Cattle	5.4	3.4	Metcalf and Eddy 1991
	Hogs	8.9	5.6	Metcalf and Eddy 1991
	Sheep and Goats	18	11.3	Metcalf and Eddy 1991
	Poultry	0.24	0.15	Metcalf and Eddy 1991

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
	Horses	4.2	2.6	ASAE 1998
Wildlife	Deer	0.36	0.2	Zeckoski et al 2005
	Geese	4.9	3.1	LIRPB 1978
	Ducks	11	6.9	Metcalf and Eddy 1991
	Other (e.g. feral cats, raccoons, etc.)	5	3.2	Yaggow 1991

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

Permitted Sources

Wastewater Treatment Facilities

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

The URRW contains four “minor” (as defined by the MPCA) WWTFs. These facilities are all pond-type treatment plants with primary and secondary treatment lagoons. In addition, the URRW also has two “major” WWTFs located in the watershed. However, both of these major facilities are within the City of Moorhead. The focus of this analysis was on rural non-point sources and therefore the two major WWTFs were not considered. The general operation of these facilities is to discharge their treated waste into the surface water system in the spring/early summer and again in the late fall of each year (HEI, 2013). The most typical windows for releases are in April-June and then again in September-November. **Table 2** identifies the four permitted WWTF in the URRW, and their permitted daily discharge flow and permitted daily bacteria load.

Table 2. WWTFs, permitted flows and bacteria loads for minor facilities in the URRW**.**

Facility	Permit Number	12-Digit HUC	Discharges to	City / Township	System Type	Permitted Daily Flow [mgd]	Equivalent Bacteria Load as E. coli: 126 org/100mL [billion org/day]
Breckenridge	MN0022900	090201040401	Direct	Breckenridge	WWTF	0.5	22.21
Comstock	MNG580131	090201040304	Wolverton Creek	Comstock	WWTF	0.021	1.48
Rothsay	MNG580064	090201040203	Whiskey Creek	Rothsay	WWTF	0.056	3.70
Sabin	MNG580133	090201040501	Protection Area	Sabin	WWTF	0.0985	5.02

* These NPDES permitted facilities contribute flow to channels within the city of Moorhead and then directly into the Red River, therefore they were not considered for the remainder of this assessment.

NPDES Permitted Concentrated Animal Feeding Operation

The Minnesota Pollution Control Agency (MPCA) regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation wastes (MPCA, 2011). The MPCA currently uses the federal definition of a Concentrated Animal Feeding Operation (CAFO) in its regulation of animal facilities. In Minnesota, the following types of livestock facilities are issued, and must operate under, a National Pollutant Discharge Elimination System (NPDES) permit: a) all federally defined (CAFOs); and b) all CAFOs and non-CAFOs which have 1,000 or more animal units (MPCA, 2010). There are no CAFOs requiring NPDES permits in the URRW.

Non-permitted Sources

Humans - Subsurface Sewage Treatment Systems

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

Humans - Companion Animals

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

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

Bacteria Source	Distribution
Unsewered Communities-Failing and IPHT SSTS Population in unsewered communities based on 2010 Census Block information. Number of failing and IPHT SSTS from County estimates (MPCA, 2011).	The population of unsewered communities were estimated, based on 2010 Census Block data. Production rates of 1.3×10^9 cfu/day/person was used. Total bacteria was applied to Developed land use classes in the NLCD 2011 dataset.
Companion Animals (Dogs only) 34.3% of households own dogs, 1.4 dogs in households with dogs. Populations of dogs was based on the 2010 Census Block data.	An estimated 38% of dog owners do not depose of waste properly (**TBEP, 2011**). Population distributions are based on 2010 Census Blocks. Production rates of 3.2×10^9 cfu/day/dog was used. Total bacteria was distributed among all land use classes in the NLCD 2011 dataset except open water.

Livestock - Populations

The USDA National Agricultural Statistics Service (NASS) provides livestock numbers, by county. Estimates numbers are available for cattle, hogs, horses, sheep, goats, and poultry (chicken and turkey) through the U.S. Census of Agriculture. County livestock populations were distributed across the watershed in an area-weighted basis. For example, if County A is 100 square miles and has 100 head of cattle within Wolverton Creek, the population density of cattle is 1 head per square mile. If 60 square miles of County A is located in Wolverton Creek, then an estimated 60 head of cattle would be in the watershed. Livestock waste is distributed throughout the watershed in three main categories: grazing animals, animal feedlot operations, and land application of manure. Discussion of each of these categories follows.

Livestock - Grazing

Grazing occurs on pastured areas where concentrations of animals allow grasses or other vegetative cover to be maintained during the growing season. Grazing pasture is neither permitted nor registered in the State of Minnesota. Agricultural areas adjacent to lakes, rivers, and streams require a buffer strip of permanent vegetation that is 50feet wide unless the areas are part of a resource management system plan (MN Rule 6120.330 Subp. 7). It should be noted, it is commonly believed that these rules have limited enforcement statewide. Grazing cattle were assumed to be the total cattle population from the Census of Agriculture (see *Livestock Populations*) minus the cattle of feed.

Livestock - Animal Feedlot Operations

Animal feedlot operations (AFOs) with less than 1,000, but more than 50, animal units (and are outside of shoreland areas) are regulated by MPCA under a registration program. AFOs with more than 10 animal units and inside shoreland areas are also regulated under this program. Shoreland is defined in MN Statute § 103F.205 to include: land within 1,000 feet of the normal high-watermark of lakes, ponds, or flowages; land within 300 feet of a river or stream; and designated floodplains (MPCA, 2009). These smaller facilities are subject to state feedlot rules which include provisions for registration, inspection, permitting, and upgrading.

Livestock - Land Application of Manure

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

Livestock – Small Operations

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

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

Bacteria Sources	Distribution
Grazing Grazing populations estimates for cattle, horses, goats, and sheep were based on USDA 2007 Census of Agriculture (USDA NASS 2009).	Bacteria form grazing animals was applied to grasslands and pasture classes in the NLCD 2011 dataset.

Bacteria Sources		Distribution
Animal Feeding Operation (AFO) AFO populations for cattle, goats, hogs, horses, poultry, and sheep are based on the 2011 Census of Agriculture (USDA NASS 2009).	**Partially Housed or Open Lot without Runoff Controls**[1] The proportion of AFO animals that are partially housed or in open lots without runoff controls: - Cattle 50% - Poultry 8% - Goats 42% - Sheep 42% - Hogs 15%	Bacteria from Open Lot AFOs was applied to barren, scrub/shrub, grassland, and pasture classes of the NLCD 2011 dataset.
	Land Application of Manure[1] - Cattle 50% - Poultry 92% - Goats 58% - Sheep 58% - Hogs 85%	Land application of manure was distributed across the cropland class of the NLCD 2011 dataset.

Wildlife

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

Fate and transport mechanisms differ between wildlife that live in surface waters (e.g. ducks, geese, and beavers) where bacteria are directly delivered to waters and wildlife that live in upland areas (e.g. deer) where bacteria delivery is primarily driven by washoff and surface runoff. The wildlife considered as potential sources of bacteria include deer, ducks, geese, and others. Data sources and assumptions for wildlife populations are shown in **Table 5**. In addition, a category called “other wildlife” was added to the source summary. These other animals include all other wildlife that may dwell in the watershed, such as beaver, raccoons, coyote, foxes, squirrels, etc.

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

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

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

Natural/Background Sources

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

Fate and Delivery of Bacteria

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

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

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

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

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

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

Generating Enhanced Geospatial Water Quality Products

The EGWQP were developed from derivatives of a hydrologically conditioned 3 m digital elevation model for the URRW. Key processing steps, described in detail below, involved the development of travel time data, and sediment, TN and TP yield.

Sediment Yields

Sediment yields are estimated based on the implementation of the RUSLE. RUSLE accounts for land cover, soil type, topography, and management practices to determine an average annual sediment yield estimate as a result of rill and interrill flow. RUSLE requires several input parameters to be developed and multiplied in the equation to form the estimated annual sediment yield. The following section summarizes the development of input variables to RUSLE. The RUSLE was calculated as:

$$A = R\ x\ K\ x\ LS\ x\ C\ x\ P$$

where, R is the Rainfall and Runoff Factor, K is the Soil Erodibility Factor, LS is the Length-Slope Factor, C is the Cover and Management Factor, and P is the Support Practice Factor. Figures are included in Appendix A that show the input variables and their variation across the project area.

RUSLE Inputs

Rainfall and Runoff Factor (R-factor) – The R-factor accounts for the impact of meteorological characteristics of the watershed on erosion rates. Information on R-factors across the State of Minnesota is available from the NRCS Field Guide, on a county-by-county basis (NRCS, 1996)

Soil Erodibility Factor (K-factor) – Soil erodibility factors used in this analysis were taken directly from the NRCS's SSURGO Database. The K factor accounts for the effects of soil characteristics on erosion rates.

Length-Slope Factor (LS-factor) – The LS-factor accounts for physical characteristics of the landscape on erosion rates. The US Department of Agriculture's (USDA) Predicting Soil Erosion by Water: A Guide to

Conservation Planning with RUSLE, Agricultural Handbook No. 703 summarizes the methodology used to derive the LS-factors for this work. Length data was derived from the conditioned DEM and slope data was derived from the raw “bare earth” DEM.

Cover and Management Factor (C-factor) – The C-factor accounts for land cover effects on erosion rates. C-values in the NRCS’s MN Field Office Technical Guide and were used as the basis for developing the values used in this analysis. The USDA’s 2013 National Agricultural Statistics Service’s (NASS) Cropland Data Layer (CDL) was used to define land cover and crop type in the study area. Table 6 summarizes 2013 NASS land cover classification in the study area and the corresponding C-factors used.

The C-factors used in this project were generalized due to the scale of the project watershed. Since future crop rotations are unknown and outputs of this project are planned to be used for future implementation, C-factors were generalized under the assumption that row crops will typically be rotated with other row crops. These types of crops were given a common value. Other crops and land cover types were given the appropriate C-factor. Because of this generalization, it is recommended that the RUSLE analysis be used mainly in comparison to other areas in the project watershed for purposes of prioritizing land use management.

Table 6: Cover and Management Factors for NASS Cropland Data Layer Categories

C- Factor	NASS CDL Classification
0.200	Corn, Soybeans, Sunflower, Barley, Spring Wheat, Durum Wheat, Winter Wheat, Rye, Oats, Canola, Flaxseed, Peas, Herbs, Dry Beans, Potatoes, Other Crops, Fallow/Idle Cropland
0.100	Alfalfa, Other Hay/Non Alfalfa, Sod/Grass Seed, Herbs
0.005	Clover/Wildflowers
0.003	Developed/Open Space, Developed/Low Intensity, Developed/Medium Intensity, Developed/High Intensity, Barren
0.002	Deciduous Forest, Evergreen Forest, Shrubland, Mixed Forest
0.001	Grassland Herbaceous, Woody Wetlands, Herbaceous Wetlands
0.000	Open Water

Support Practice Factor (P-factor) – The P-factor accounts for the impact of support practices on erosion rates. Examples of support practices include contour farming, cross-slope farming, and buffer strips. For the purposes of this analysis, variations in P-factors across the study area were not accounted for since there is not sufficient information to derive P-factors at the scale required for this analysis. Support practice P-factors are typically less than one and result in lower estimates of sediment yield than if the support practices were not accounted for. As such, the results of the RUSLE analysis in this work are conservative estimates of soil erosion, not accounting for support practices that may be in-place.

Downstream Sediment Delivery

Once the sediment yield leaving the landscape is estimated for a cell, the sediment reaching a channel at the overland catchment outlet is estimated using a sediment delivery ratio (SDR). The estimated SDR for the catchment is a function of area (Maidment, 1993).

$$Overland\ SDR = 0.41 * catchment\ drainage\ area\ (sq.km)^{-0.3}$$

The SDR for each cell within an overland catchment is estimated as a function of the catchment SDR adjusted by the distance from a cell to the flowline.

$$Overland\ SDR\ Adjustment\ Factor = 1 - \frac{\frac{Flow\ Length}{Maximum\ Flow\ Length\ in\ Catchment}}{0.75 + \frac{Flow\ Length}{Maximum\ Flow\ Length\ in\ Catchment}}$$

Therefore, the SDR for each cell is computed as Overland SDR (for the catchment) multiplied by Overland SDR Adjustment Factor (for the cell).

The sediment transported downstream to subwatershed and watershed outlets is further reduced using a first-order transport function. In-channel downstream transport and loss follows an exponential decay function (i.e., first order loss) using travel time and median diameter of sediment:

$$SY = Ye^{-\beta T\sqrt{d_{50}}}$$

Where Y is sediment yield from sub-basin, β is transport coefficient, T is travel time, d_{50} is mean sediment diameter. Values of 0.2 and 0.1 are used for β and the d_{50}, respectively.

Essentially, four products were produced for each cell in the raster: 1) sediment yield leaving the landscape; 2) sediment yield reaching the overland catchment outlet; 3) sediment yield delivered to a user defined downstream subwatershed outlet; and 4) sediment yield reaching the watershed outlet.

Total Phosphorus and Total Nitrogen Yield

Nutrient annual yields leaving the landscape are estimated using a method similar to sediment (i.e., they are computed for each cell in the raster). Yields for TP and TN follow an empirical approach using land use export coefficients from literature values. TP and TN annual yields are estimated using the values in **Table 7** and **Table 8** applied to each National Land Cover Dataset (NLCD) land use class.

Table 7: Total Phosphorus Loading for NLCD Land Use Classifications

NLCD Classification	Description	TP Loading [kg/ha/yr]	Source
11	Open Water	0	
21	Developed, Open Space	1	
22	Developed, Low Intensity	0.91	LimnoTech 2007
23	Developed, Medium Intensity	1.15	LimnoTech 2007
24	Developed, High Intensity	1.5	LimnoTech 2007
31	Barren Land	1.35	
41	Deciduous Forest	0.075	LimnoTech 2007
42	Evergreen Forest	0.075	LimnoTech 2007
43	Mixed Forest	0.075	LimnoTech 2007
52	Shrub/Scrub	0.075	LimnoTech 2007
71	Grassland/Herbaceous	0.17	LimnoTech 2007
81	Pasture/Hay	0.17	LimnoTech 2007
82	Cultivated Crops	0.38	LimnoTech 2007
90	Woody Wetlands	0	LimnoTech 2007
95	Emergent Herbaceous Wetlands	0	LimnoTech 2007

Table 8: Total Nitrogen Loading for NLCD Land Use Classifications

NLCD Classification	Description	TN Loading [kg/ha/yr]	Source
11	Open Water	3.5	MPCA 2013
21	Developed, Open Space	3.5	MPCA 2013
22	Developed, Low Intensity	5.4	US EPA 1983
23	Developed, Medium Intensity	9.6	US EPA 1983
24	Developed, High Intensity	18.0	US EPA 1983
31	Barren Land	3.5	MPCA 2013
41	Deciduous Forest	2	US EPA 1999
42	Evergreen Forest	2	US EPA 1999
43	Mixed Forest	2	US EPA 1999
52	Shrub/Scrub	2	US EPA 1999
71	Grassland/Herbaceous	1.3	USDA MANAGE[2] database
81	Pasture/Hay	2.4	USDA MANAGE[5] database
82	Cultivated Crops	7.8	USDA MANAGE[5] database
90	Woody Wetlands	3.5	MPCA 2013
95	Emergent Herbaceous Wetlands	3.5	MPCA 2013

Downstream Total Phosphorus and Total Nitrogen Delivery

The mass leaving each cell comprising the raster can be "routed" downstream to: 1) the overland catchment outlet 2) a subwatershed outlet and 3) the watershed outlet, using a first order decay computed as a function of overland and in-channel flow travel times. The decay or loss of mass after leaving the landscape is used to represent the reduction in mass from physical, chemical and biological processes. The computed travel time raster is used in estimating the first order loss coefficient. The calculation methods for downstream routing can be subdivided into two parts 2) transport to the channel, and 3) an in-channel routing routine.
The nutrient mass loss as it is transported downstream was represented using a first order loss equation for both, as a function of travel time:

$$W = \exp(-kT)$$

where W is the portion of the yield leaving the landscape and delivered to the downstream, k is the decay rate and T is travel time from one location to the next The default values used for k was 0.1 for travel to the overland catchment outlet and 0.4 for in-channel transport. The delivery raster was created using the travel time raster to determine the portion of the mass reaching the overland catchment, subwatershed, and watershed outlets.

Ranking Methods to Target Field for Implementing Practices

GIS layers for sediment, TP and TN were individually analyzed and given a percentile ranking using a log-normal distribution. The percentile ranking represented a cell's relative rank for potential erosion, sediment, TP or TN loading. The result of the percentile ranking provide context for the various parameters by showing the severity of the values relative to others in the study area. Rankings were computed for 4 scenarios: 1) sediment, TP and TN yields leaving the landscape; 2) sediment, TP and TN yields reaching the overland catchment outlet; 3) sediment, TP and TN yields reaching subwatershed outlets; 4) sediment, TP and TN yields reaching URRW.

A Water Quality Index (WQI) value was created that combines the sediment, TP and TN ranked rasters into one composite ranking computed as follows.

$$Water\ Quality\ Index\ (WQI) = 0.5\ x\ Sediment\ Rank + (0.25\ x\ TN\ Rank + 0.25\ x\ TP\ Rank)$$

[2] U.S. Department of Agriculture – Agricultural Research Station. Nutrient Loss Database for Agricultural Fields in the US. (http://www.ars.usda.gov/Research/docs.htm?docid=11079)

This formula gives equal weighting to both sediments and nutrients to identify areas contributing relatively high proportions of both sediment and nutrients downstream.

Targeting Fields for Water Quality Improvement

For the purposes of making the results more easily interpretable and useable, the water quality products and the derived ranking and index raster layers were summarized by overland catchment areas. Overland catchments are hydrologic boundaries between 5 and 124 acres in size and therefore contain only areas of overland flow and represent a field scale calculation. Summary statistics calculated within overland catchments include sums of sediment, TP and TN loads leaving the landscape and yields delivered to the overland catchment, subwatershed outlets, and URRW. These loads where ranked using the same log-normal distribution described above. A separate ranking was performed for each of the four major subwatershed areas in the URRW. Additionally the mean Water Quality Index were computed for overland catchments. Similar tabulations could be performed with the provided layers for other subdivided watershed areas such as other subwatershed boundaries, PLSS sections, 1/4 sections or parcels.

Identifying Potential Locations for Siting Best Management and Conservation Practices

This analysis is purposely focused on those BMPs and CPs used most often within the URRW area. (Analysis of all NRCS practices is not possible because of the large number of practices.) Specifically, 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 such as Sediment Basins, Grassed Waterways, Riparian Buffers, Cover Crops, and others are largely dependent upon a site's suitability to a given practice based on topographic characteristics, soils, and land use. Many other factors such as land owner willingness and the proximity to priority water resources are also important criteria. The high spatial resolution hydro conditioned DEM 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. **Table 9** identifies the criteria used to identify potential locations for specific practice types and their NRCS and Minnesota Board of Water and Soil Resources (BWSR) practice code. Where possible, these criteria were based on NRCS design standards and experience with practice implementation. 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.

Table 9: Criteria Used in Identifying Potential Practice Locations

BMP	Suitability Criteria	NRCS Code	BWSR Code
Sediment Basin/ WASCOB	• High sediment yield: accumulated sediment delivered to flow line; percentile rank > 90; • Contributing drainage area < 40 acres; • National Land Cover Dataset (NLCD) (2006) land cover is cultivated lands • ≥ 0.25 acres of the catchment has opportunities for Sediment Basin/WASCOBs	350/638	350/638
Filter Strips	• Land Within 100 ft. of flowline • NLCD 2011 data classified as cultivated • < 8.1 tons/year of sediment • Contributing Area < 124 acres;	393	393
Controlled Drainage	• Slope ≤ 1% • NLCD 2011 data classified as cultivated • ≥ 80% of catchment has opportunities for controlled drainage	554	554
De-nitrifying Bioreactors	• Slope ≤ 1% • NLCD 2011 data classified as cultivated	747	747

BMP	Suitability Criteria	NRCS Code	BWSR Code
	• ≥ 50% of catchment has opportunities for Bioreactors		
Cover crops	• ≥ 20% of catchment is NLCD 2011 cultivated lands	340	340
Perennials	• Low crop productivity: SSURGO Crop Productivity Index ≤ 61 • NLCD 2011 data classified as cultivated • ≥ 5 acres of catchment has opportunities for perennials	327	327
Grassed Waterways	• Channelized flow path • NLCD 2011 data classified as cultivated • Slope ≥ 3% and ≤ 12% • Flow Length ≤ 750 ft • Drainage area ≤ 7 acres • ≥ 0.5 acres of catchment has opportunities for grassed waterways	412	412
Saturated Buffers	• Within 100 ft of waterway • SSURGO minimum depth to water table ≤ 2ft • NLCD 2011 data classified as cultivated	NA	NA
Two-stage Ditch	• NLCD 2011 data classified as cultivated • Drainage ditch based on MN DNR 24K streams • bank heights ≤ 10 ft	NA	NA

Field Validation

The accuracy of the EGWQP and the potential locations for BMPs and CPs were checked by conducting field visits on October, 24 2014. A random sample of catchments was selected (10 High, 10 Moderate, 10 Low) from within the Whiskey Creek watershed based upon their rank for sediment delivery to the outlet of Whiskey Creek. For each catchment a field validation sheet (Appendix A) was completed. At each catchment we determined if the EGWQP sediment erosion ranks were appropriate, if areas of likely erosion were missed, and if areas of likely erosion already had management practices applied. In addition, for each BMP type it was document if there was an opportunity for the practice, if potential locations for practices were missed, and if the practices was already present.

RESULTS

While initial information was extracted on a County basis, all results have been summarized by subwatersheds including the Protection Area, Direct Drainage to the Red River, Whiskey Creek Subwatershed, and Wolverton Creek Subwatershed. The Protection Area, is the subwatershed in the Northern portion of the URRW that lack surface water impairments. Direct Drainage to the Red River are the areas in the central and Southern portions of the watershed that drain directly to the Red River. The subwatershed designations were segmented primarily by waterways with and without impairements.

Bacteria Sources and Risks

Humans - Subsurface Sewage Treatment Systems

Of the rural population in the URRW, an estimated 615 people - or 14.2 percent - have inadequate treatment of their household wastewater. This includes individual residences and any un-sewered communities. An MPCA document (MPCA, 2011) reports numbers from 2000-2009 on the total number of SSTSs by county, along with the average estimated percent of SSTSs that are failing versus the percent that are considered IPHTs. The total numbers of SSTSs per county were multiplied by the estimated percent IPHT and percent failing within each area (MPCA, 2011) to compute the number of potential IPHTs and potentially failing SSTSs per county and in the URRW overall. **Table 10** summarizes the results.

Table 10: SSTS compliance status in the URRW.

	Protection Area	Direct Drainage to Red River	Whiskey Creek Subwatershed	Wolverton Creek Subwatershed
Identified # of SSTSs	309	73	625	175
# of potentially failing SSTSs	89	21	273	70
# of potential IPHTs	38	9	90	25

Livestock - Populations

Livestock populations were estimated for cattle, chickens, goats, horses, sheep, and turkeys for each major subwatershed and are provided in **Table 11**. Although the MPCA's geographic feedlot database developed for registered and NPDES permitting provide location and allowable populations of animals, these populations are the maximum allowable populations under the permits and are not the actual populations at these sites. Therefore, the USDA census data was used to estimate livestock populations.

Table 11 Livestock Population Estimates (numbers) in the URRW.

Animal	Type	Wolverton Creek Subwatershed	Whiskey Creek Subwatershed	Protection Area	Direct Drainage to Red River
Cattle	All				
	Beef	554	2,209	1,093	256
	Cattle on Feed	32	131	132	31
Other	Pigs	1,031	575	4,207	987
	Sheep and Goats	5	45	19	5
	Horses	33	74	76	18
Poultry	Layers	43,750	234	178,218	41804
	Boilers	110	203	242	57
	Turkey	15,456	56,438	17,980	4217
	Ducks and other	8	324	1	0

Fate and Delivery of Bacteria

Table 12 shows the risk rankings of potential sources of bacteria in the URRW by subwatershed. Livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the URRW. Human and wildlife sources of bacteria posed relatively lower risks, with the exception of Ducks in the Protection Area, Whiskey Creek, and Wolverton Creek, and Geese in the area draining directly to the Red River. This information can be used to prioritize management efforts for the potential sources of bacteria that pose the greatest risk of impacting surface waters in the URRW. It should be noted that there are potential sources of E. coli. that were not accounted for in this analysis due to a lack of data. For instance, Cliff Swallows often colonize under bridges along waterways in this area and would be a potentially high source of direct E. coli contributions to surface waters in the area.

Table 12. Relative Sources of E. coli.

Watershed	Humans			Livestock			Wildlife			
	WWTF Effluent	Septic Systems	Domestic Animals	Grazing	Manure	AFO Open Lots	Deer	Ducks	Geese	Other
Protection	○*	○	○	⭘	●	●	○	⭘	○	○
Direct Drainage to Red River	○	○	○	●	○	○	○	○	●	○
Whiskey Creek Subwatershed	○	○	○	●	●	●	○	⭘	○	○
Wolverton Creek Subwatershed	○	○	○	●	⭘	●	○	⭘	○	○

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

Figure 1 shows the HUC 12 ranks based on the magnitude of bacterial delivery to URRW outlet. Higher rates equate to a greater risk of bacterial delivery from the HUC 12 to the outlet of the URRW. Similar to the results shown in **Table 12**, livestock sources consistently posed the greatest risk of bacterial delivery. In addition, the results indicated that Wildlife posed a moderate risk of delivery within the Wolverton Creek Subwatershed. This information can be used to inform the prioritization of local management efforts aimed at reducing bacterial delivery to surface waters in the URRW. In addition, **Figure 1** can also be used to begin targeting specific HUC 12 watersheds for bacterial restoration and protection strategies.

<u>Targeting Fields with Enhanced Water Quality Data</u>

Field scale (< 140 acres) catchments within each major tributary (e.i. Protection Area, Direct Drainage, Whiskey Creek, and Wolverton Creek) were ranked based upon the annual delivery of TP, TN, and sediment mass from the landscape, to a waterway (i.e., flow line), subwatershed outlet, and to the outlet of the URRW. The full results of the field scale targeting are provided in **Appendix B**. **Figure 2** shows an example of field scale catchments that have been ranked based on their delivery of sediment to the sub watershed outlet of Whiskey Creek. The Highest Priority (Highest 90%) areas are the catchments delivering the highest yield (mass per unit area) of sediment to the subwatershed outlet. This map and data can be used to target fields for placing practices within the drainage area to Whiskey Creek which deliver the largest amount of sediment to its outlet.

Figure 1. Ranked HUC 12 subwatersheds based upon magnitude of bacterial delivery to the outlet of the URRW.

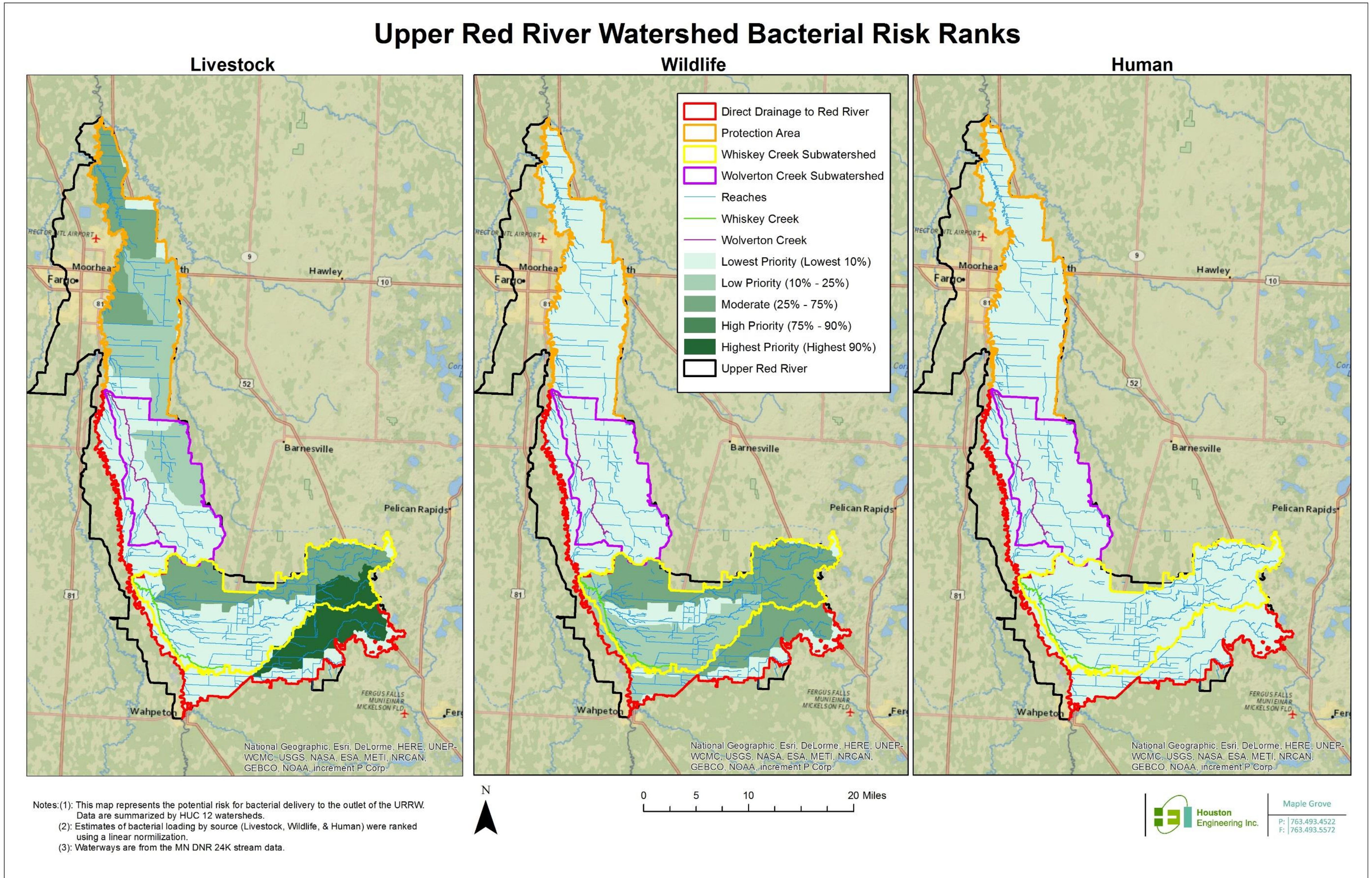
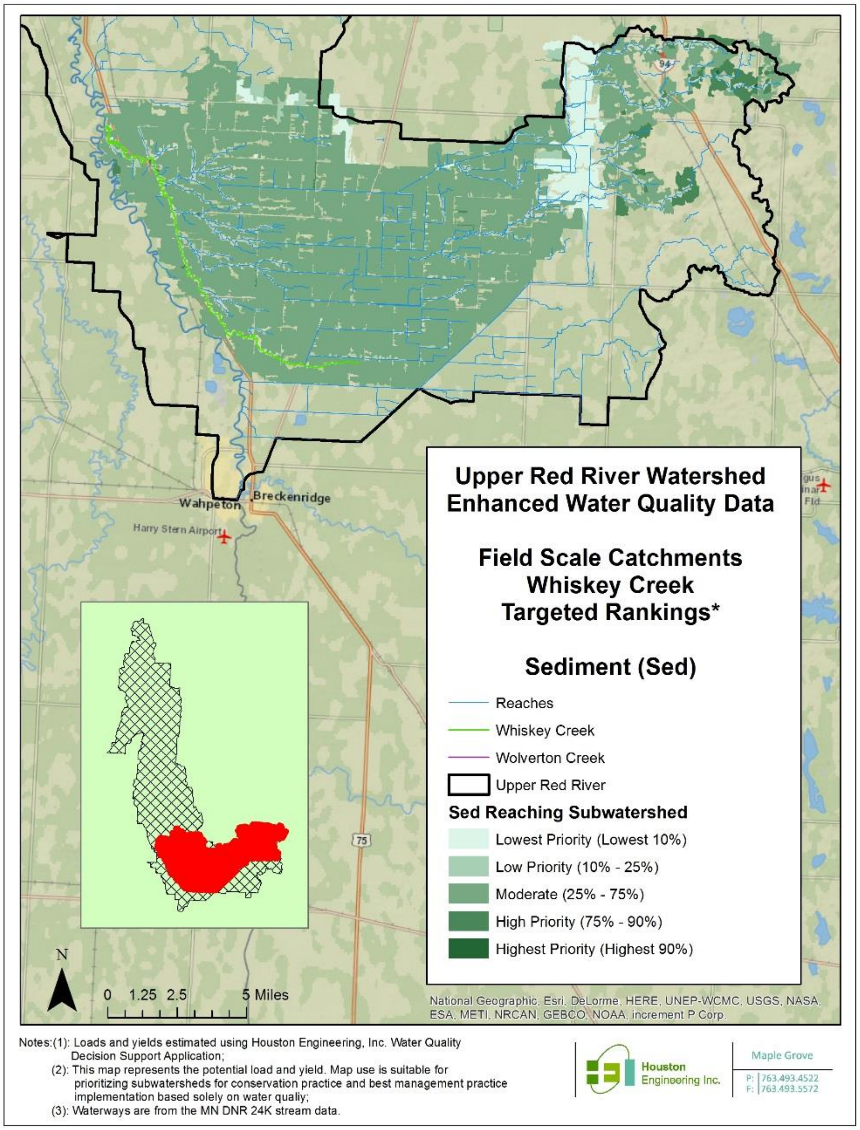


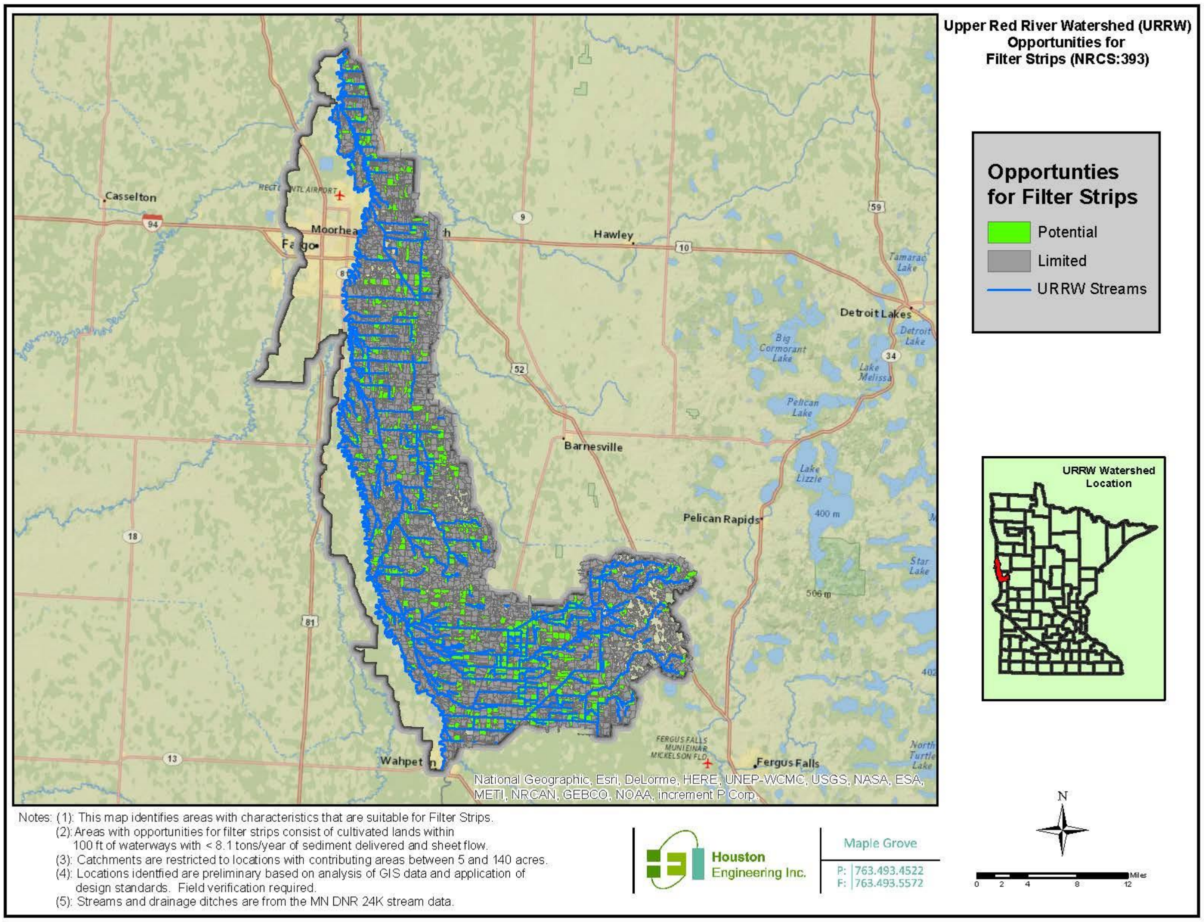
Figure 2. Targeting field scale catchments within Whiskey Creek based upon sediment delivery to the subwatershed outlet.



Opportunities for Best Management Practices

In addition to targeting based on the delivery of water quality constituents, fields also can be targeted for opportunities to place BMPs. For instance, a field may produce a moderate to high amount of sediment, but have limited opportunities to implement BMPs to reduce sediment delivery because of the physical setting. As such, field scale opportunities to implement BMPs were targeted across the URRW watershed. The full results of the BMP targeting have been provided in **Appendix C**. **Figure 3** shows an example of field scale catchments that have been targeted for opportunities to place filter strips. This data product can be paired with the 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.

Figure 3. Targeting field scale catchments within Whiskey Creek based upon sediment delivery to the subwatershed outlet.



Field Validation

The EGWQP missed very few areas showing signs of erosion. Overall, the field validation revealed that the EGWQP performed well for ranking catchments for potential erosion, although in some instances the EGWQP ranks seemed higher than justified by conditions in the field (i.e. over predicting erosion potential). However, due to the timing of the field visits most of the sites visited had already been tilled, so it is possible that areas of moderate to high erosion were covered. We suggest that future field work be targeted to shortly after spring runoff and/or shortly after spring planting.

The BMP and CP analysis performed well in identifying locations that held potential for implementation. However, the BMP and CP analysis did, at times, over predict (i.e. false positives) potential opportunities for BMPs and CPs, but missed very few locations that were suitable for BMPs and CPs. False positives appeared to be driven primarily by the lack of a minimum slope requirement. In other words, areas would be identified as having the potential for a BMP, but the lack of slope would make the location unpractical for BMP implementation. Future versions of this analysis will incorporate minimum slope requirements to refine the targeting of locations that are suitable for BMPs and CPs. The field work identified that this desktop analysis identified locations for potential implementation that need field validation to confirm the opportunities.

CONCLUSIONS

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

The results of the field validation work confirmed that the EGWQP and target opportunities for BMPs and CPs show probable locations of high sediment, TN, and TP loading and potential locations from BMPs and CPs. However, field site visits are needed to confirm the results.

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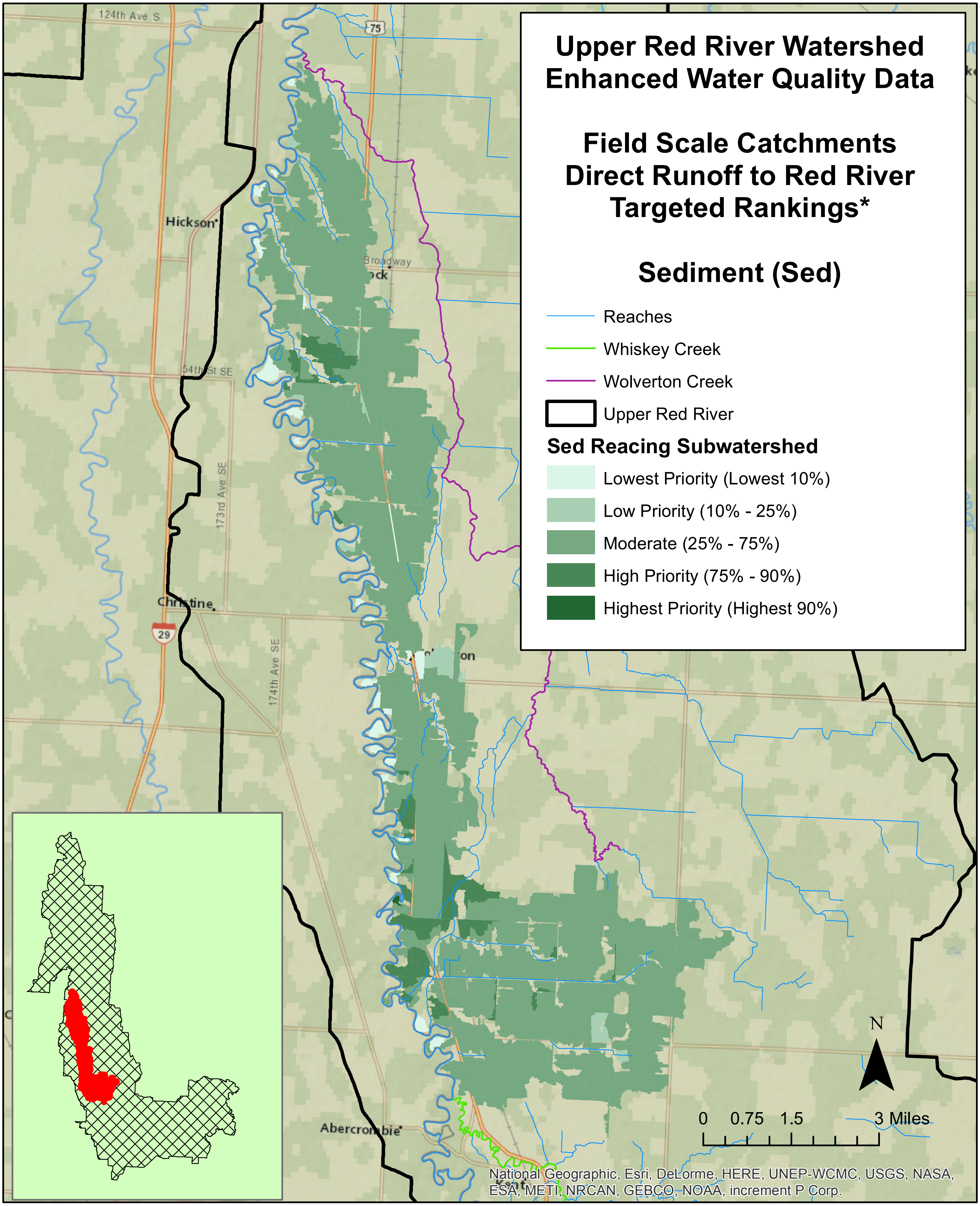
APPENDIX A: FIELD SCALE TARGETING OF CATCHMENTS BASED UPON DELIVERY OF WATER QUALITY CONSITUTENTS TO DOWNSTREAM RESOURCES



Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data.

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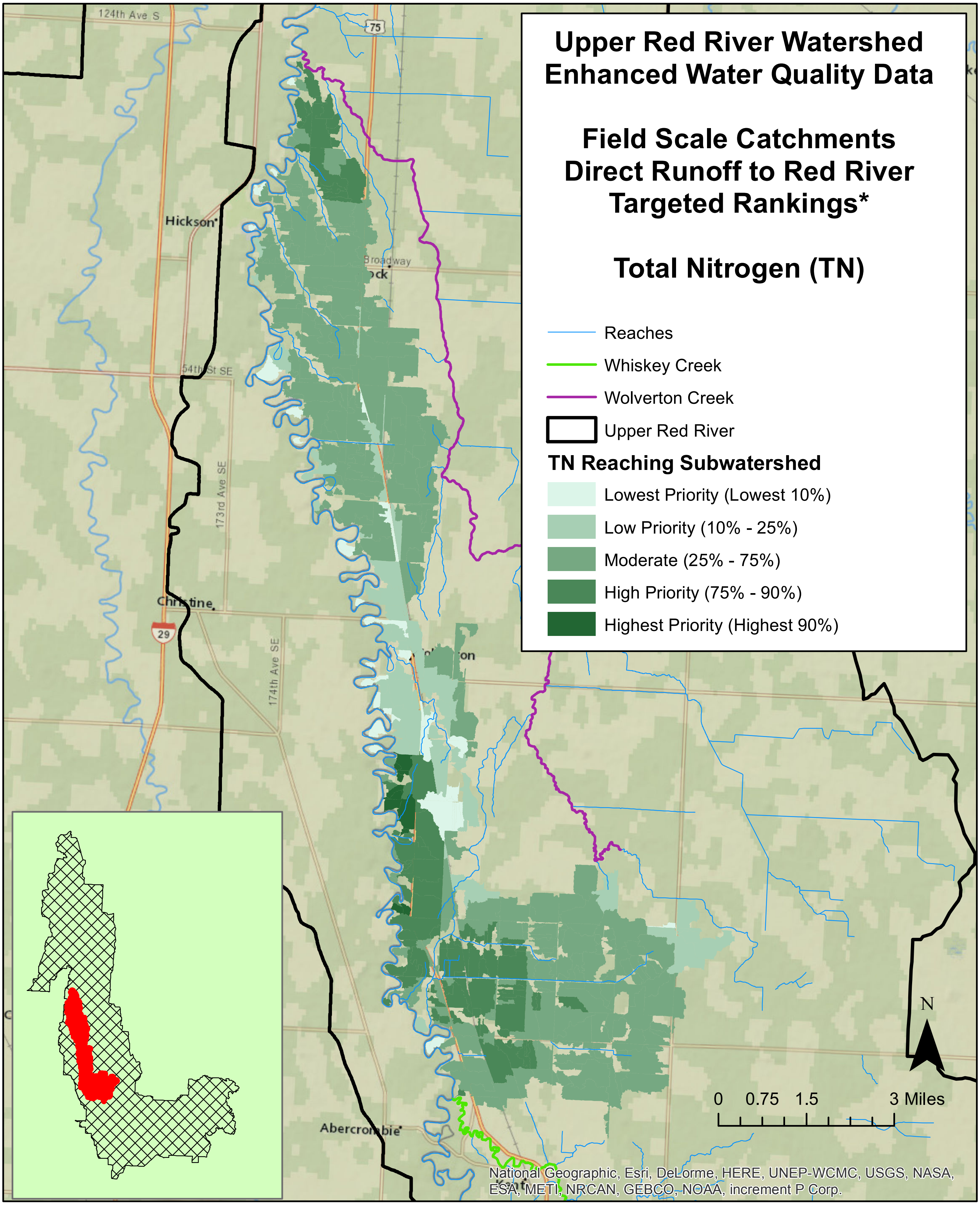

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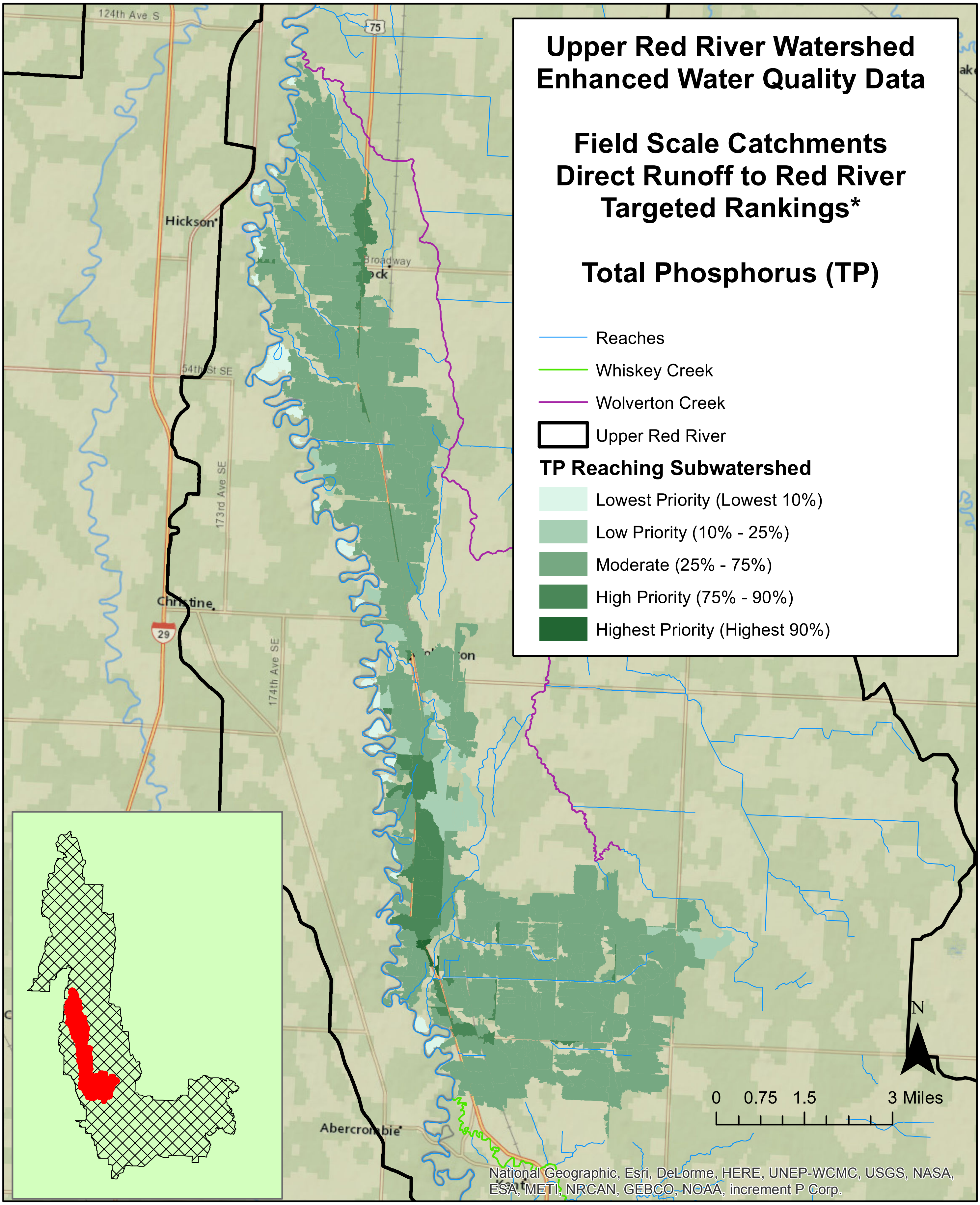

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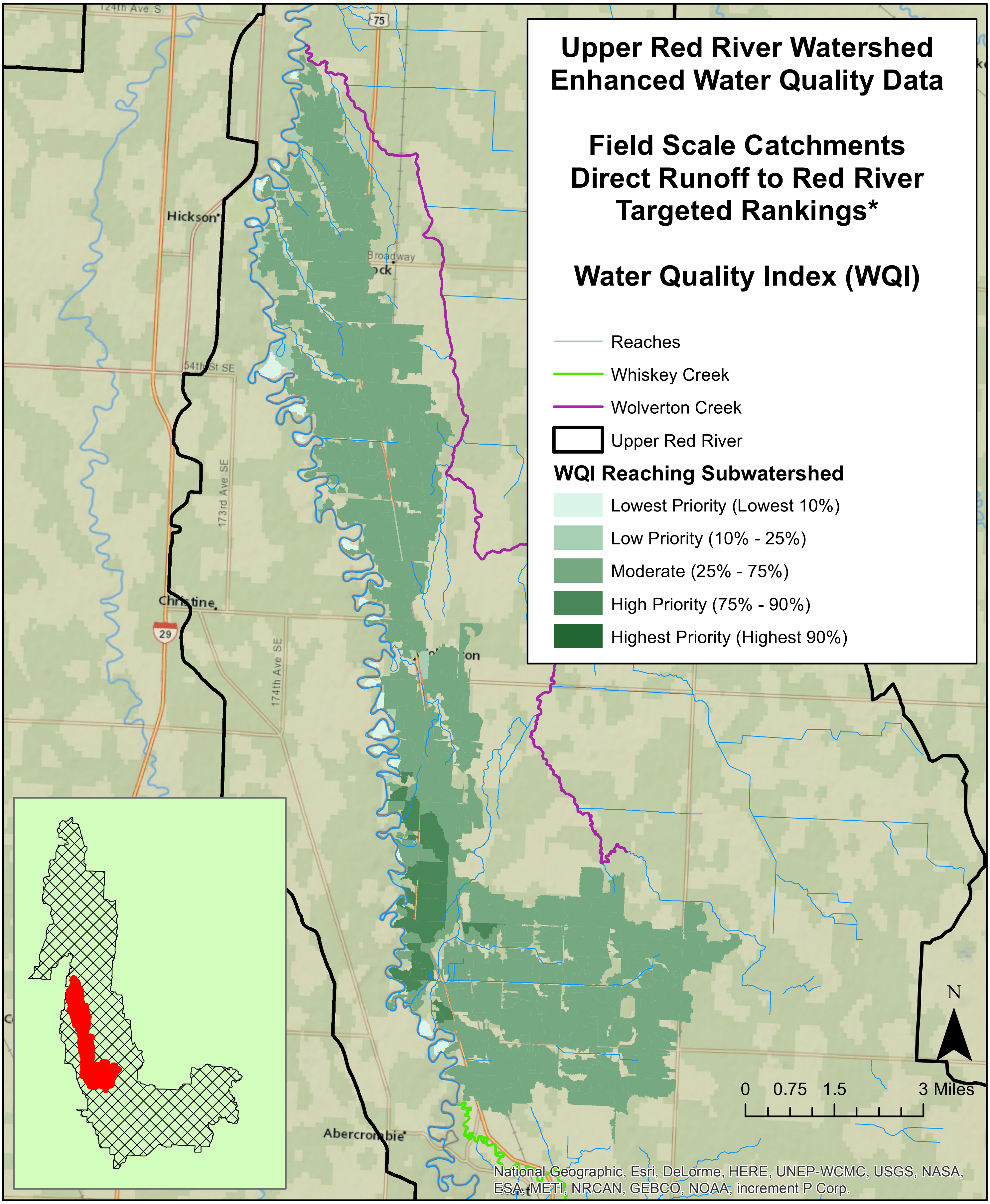

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(4): WQI is an equally weighted aggregate of Nutrients and Sediment.

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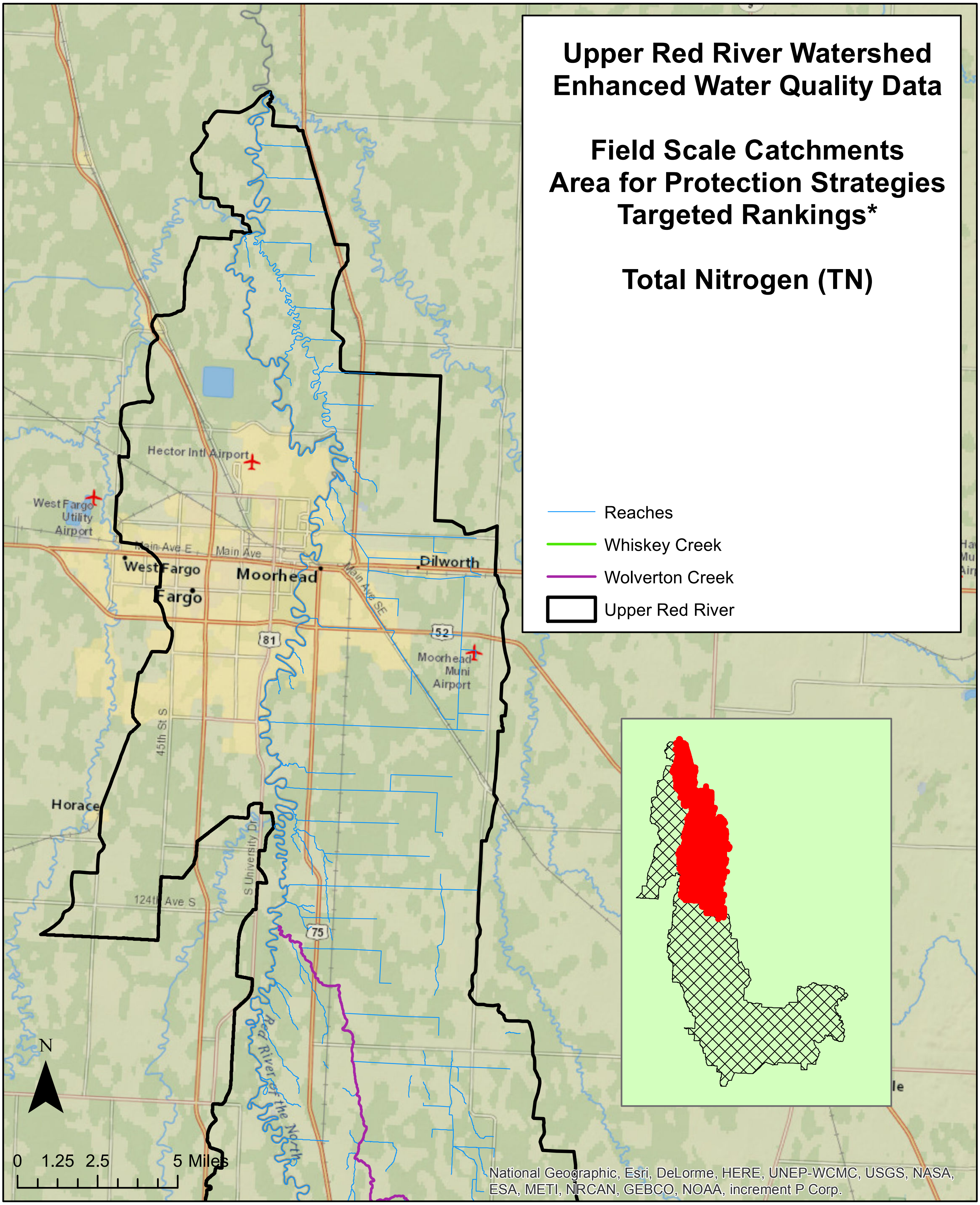

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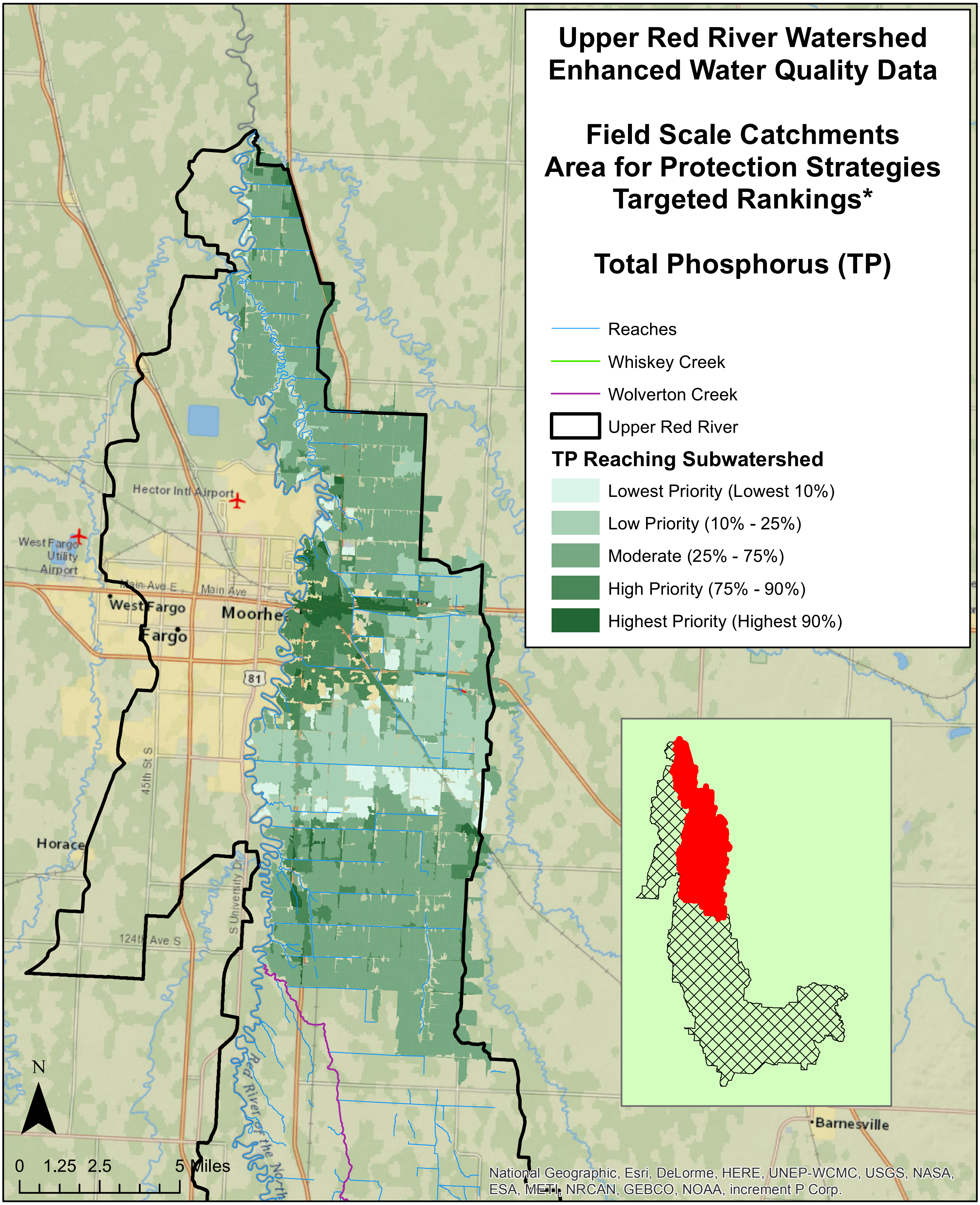

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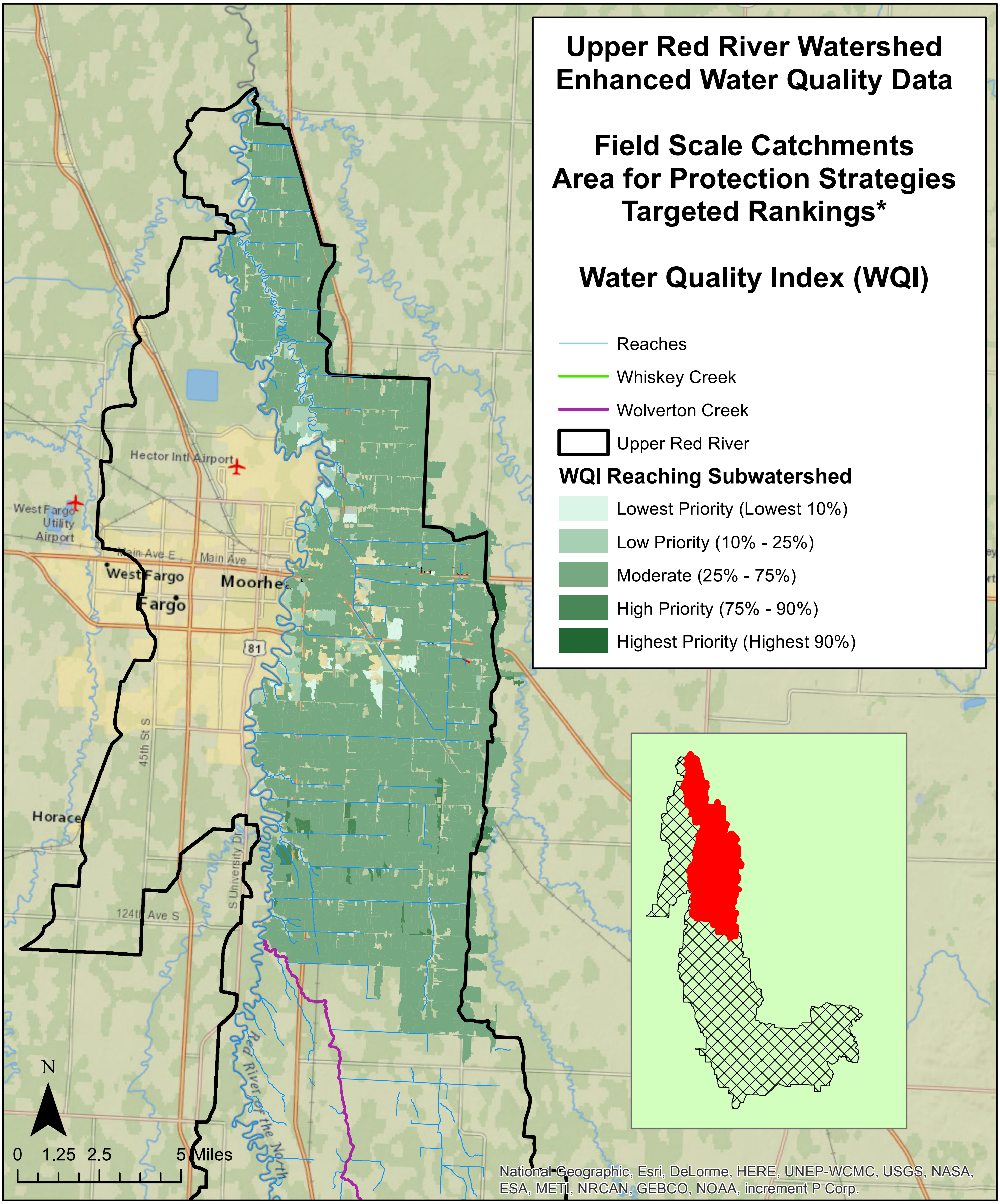

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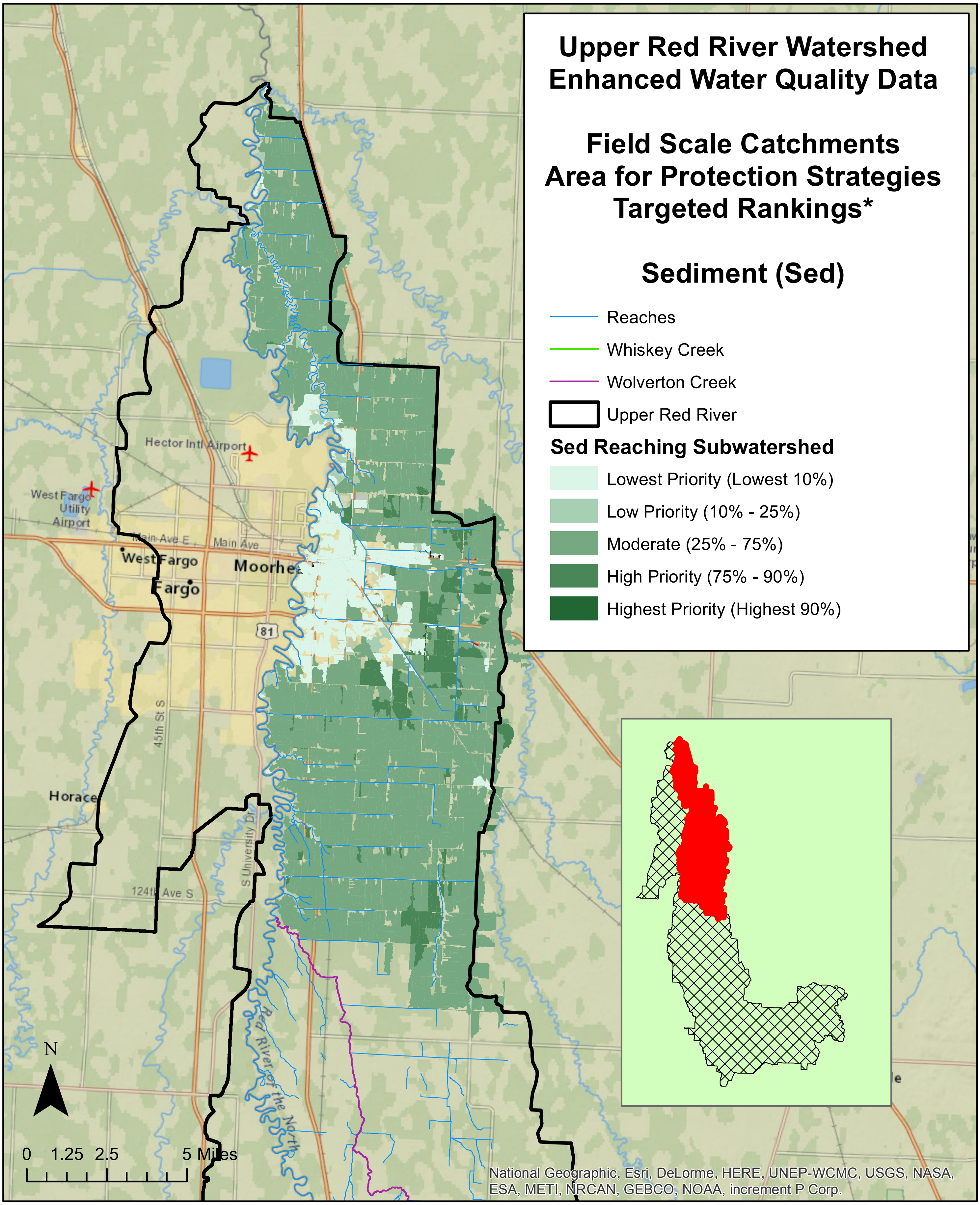

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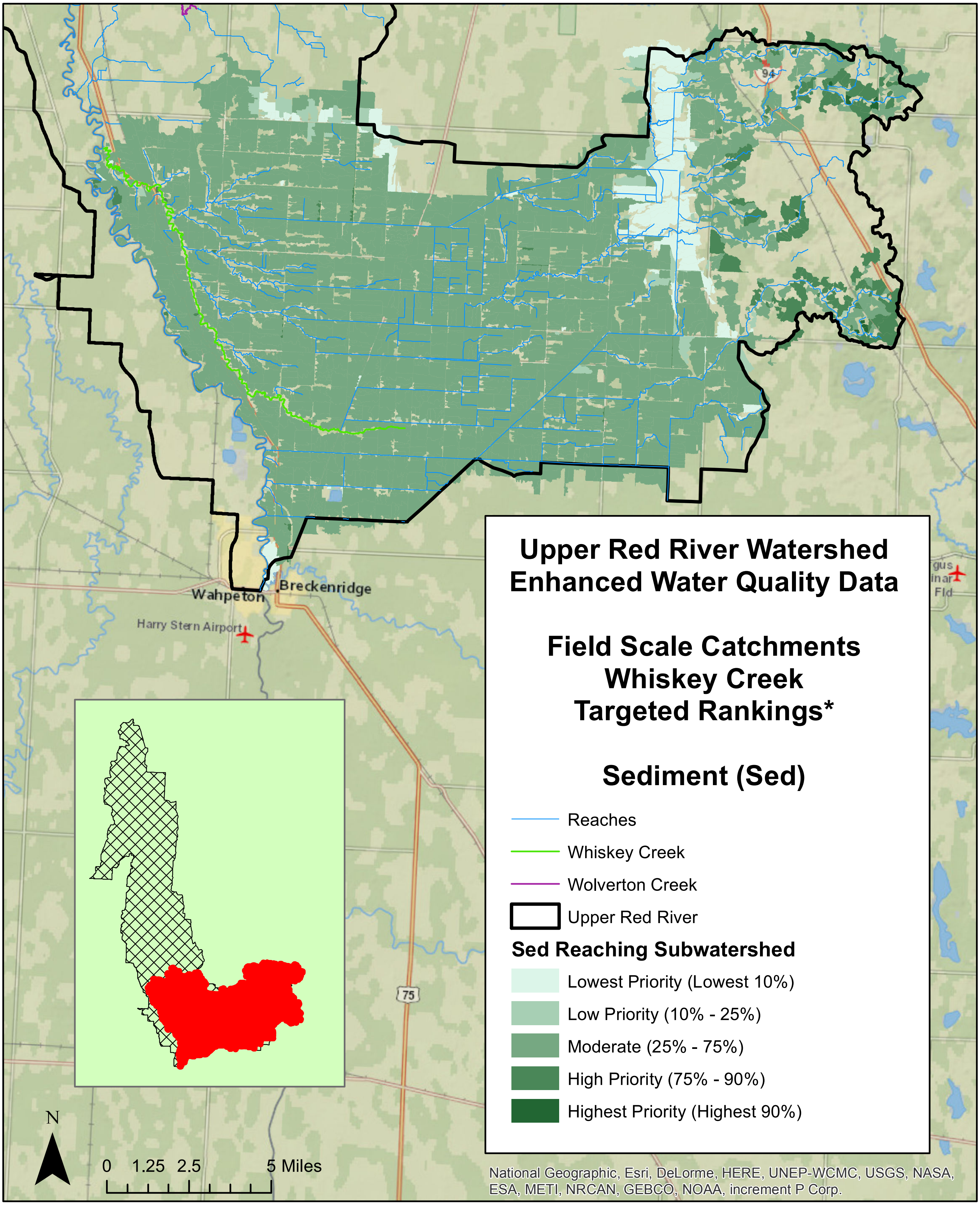

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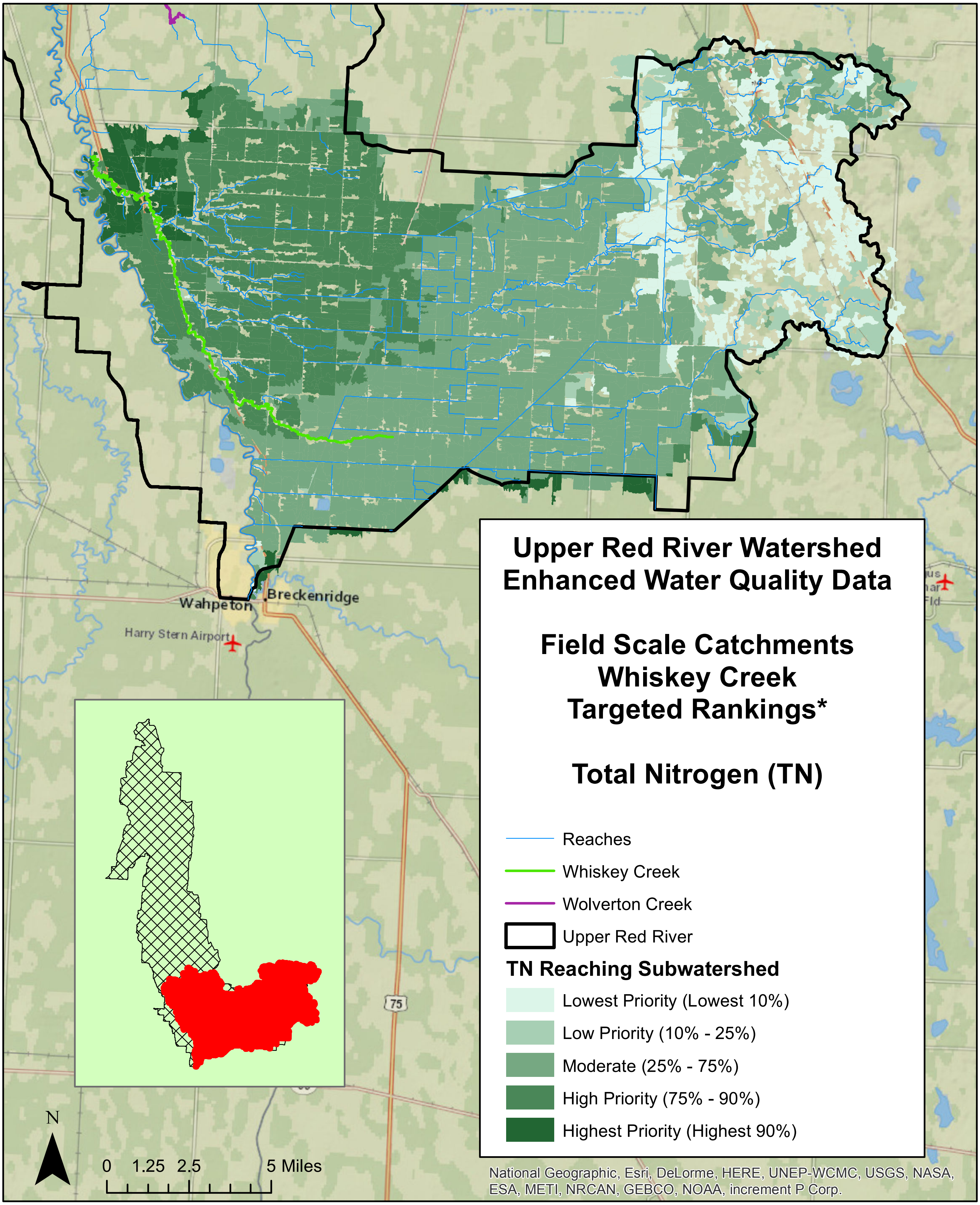
F: 763.493.5572



Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data.

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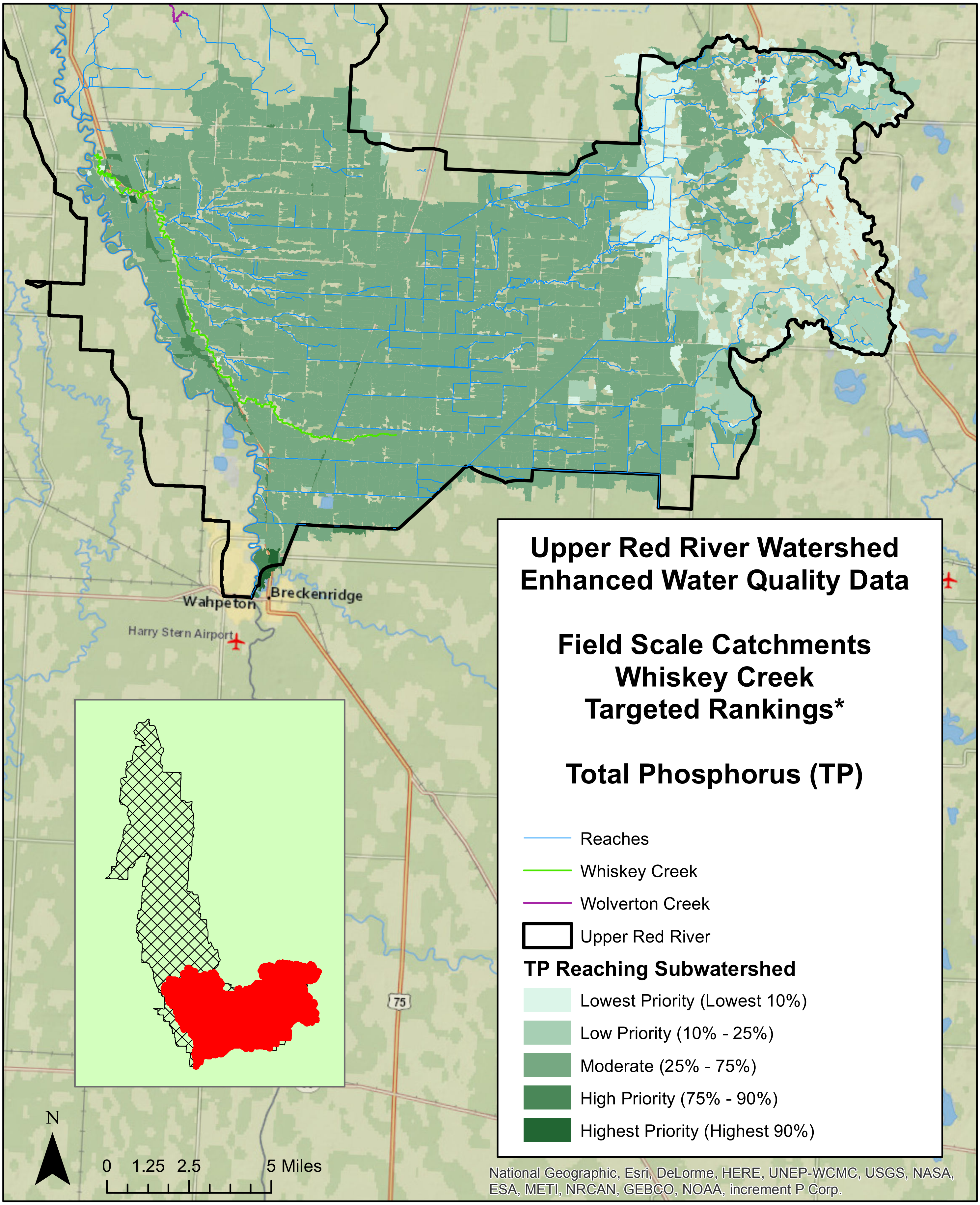

Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
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(3): Waterways are from the MN DNR 24K stream data.

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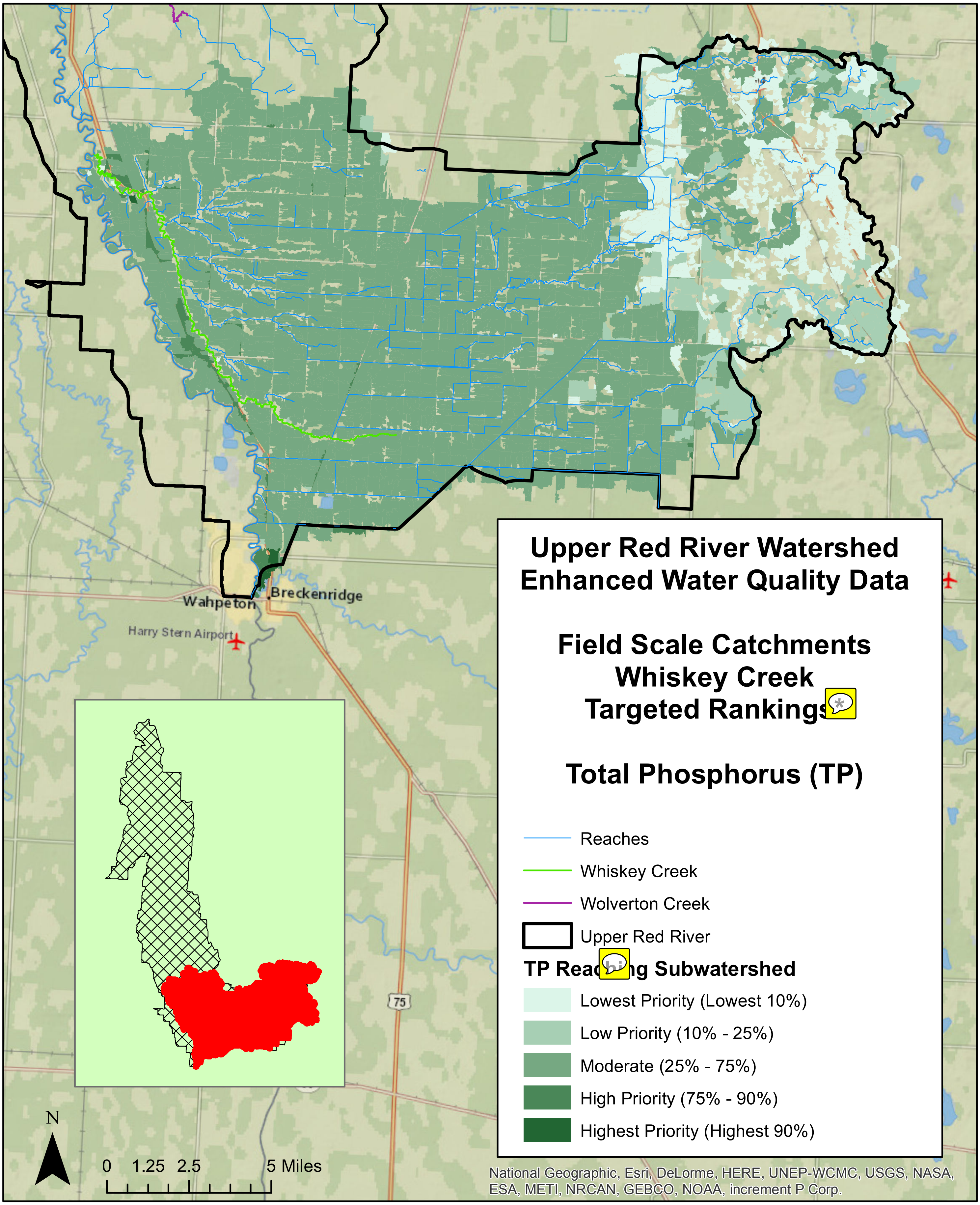

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(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practices and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data.

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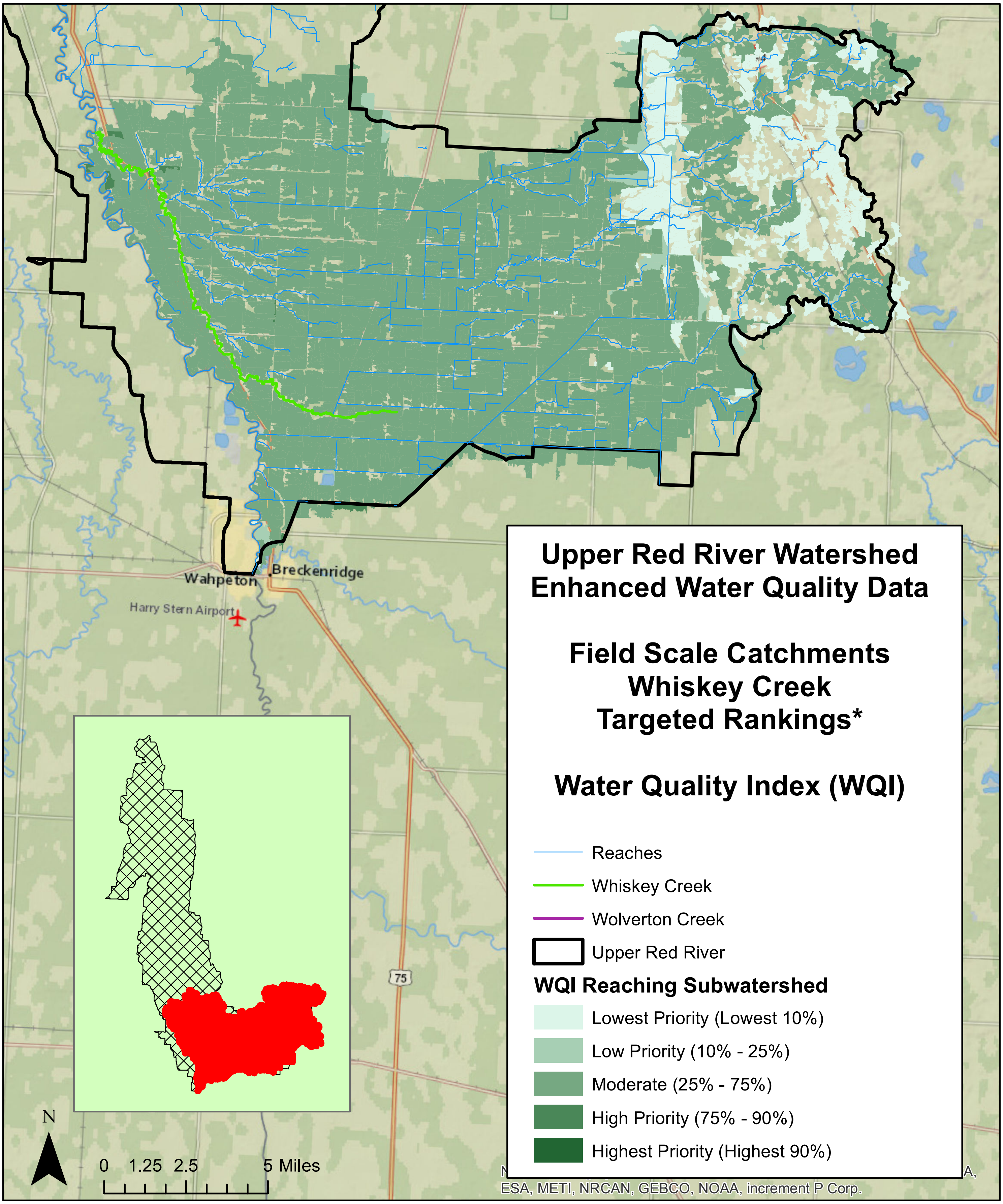
Upper Red River Watershed Enhanced Water Quality Data

Field Scale Catchments Whiskey Creek Targeted Rankings*

Water Quality Index (WQI)



Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;

(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;

(3): Waterways are from the MN DNR 24K stream data;

(4): WQI is an equally weighted aggregate of Nutrients and Sediment.

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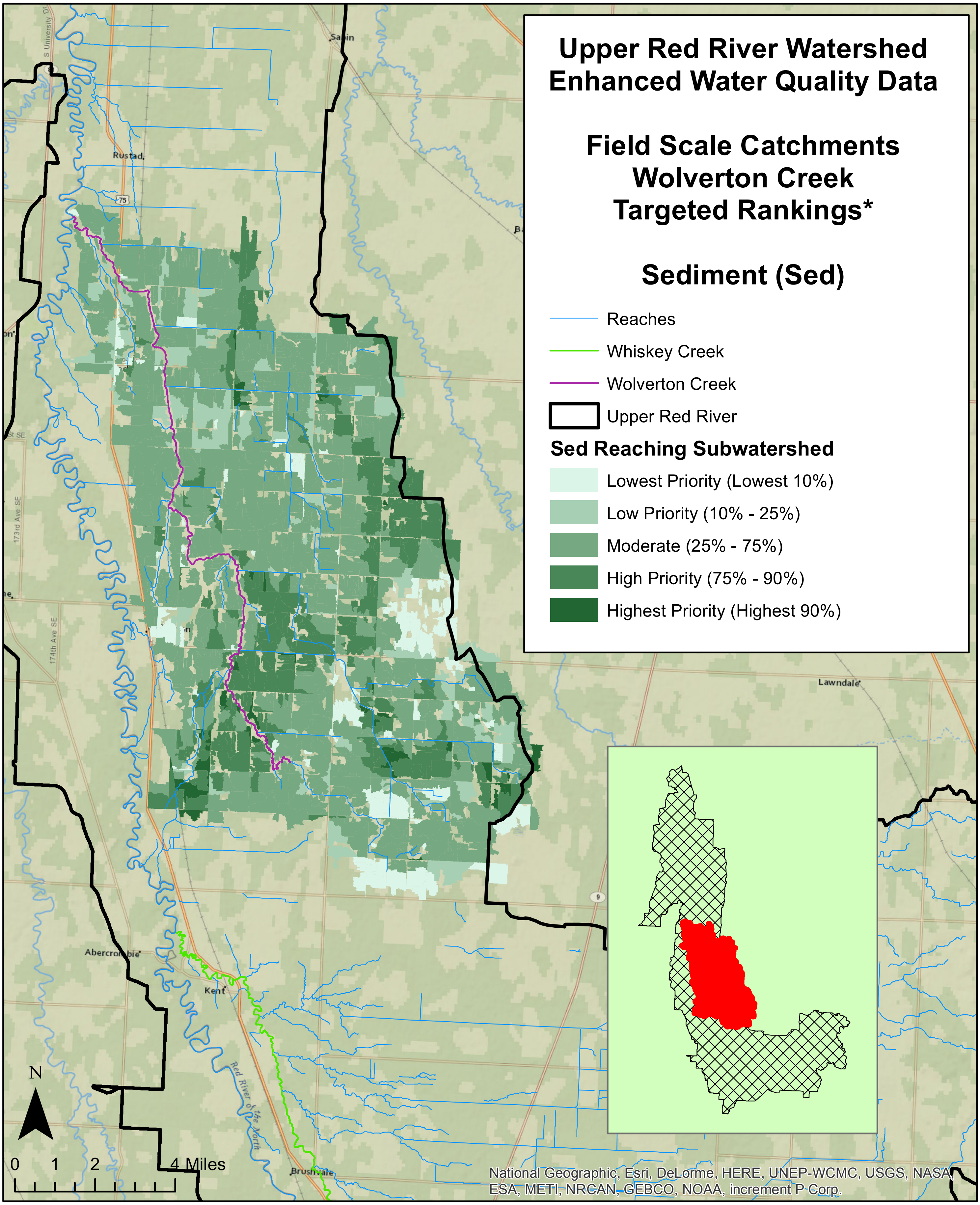

Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data.

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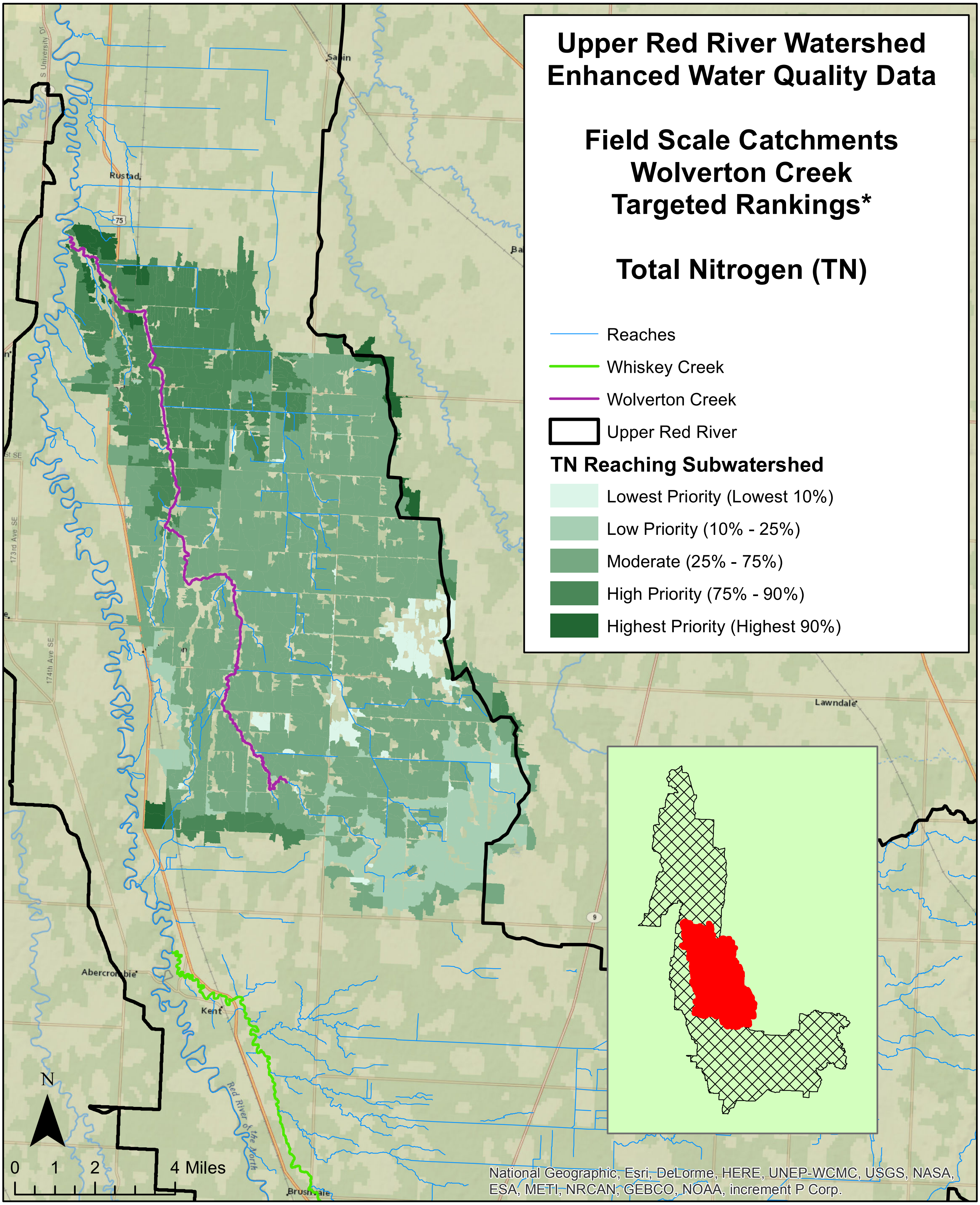
F: 763.493.5572



Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data.

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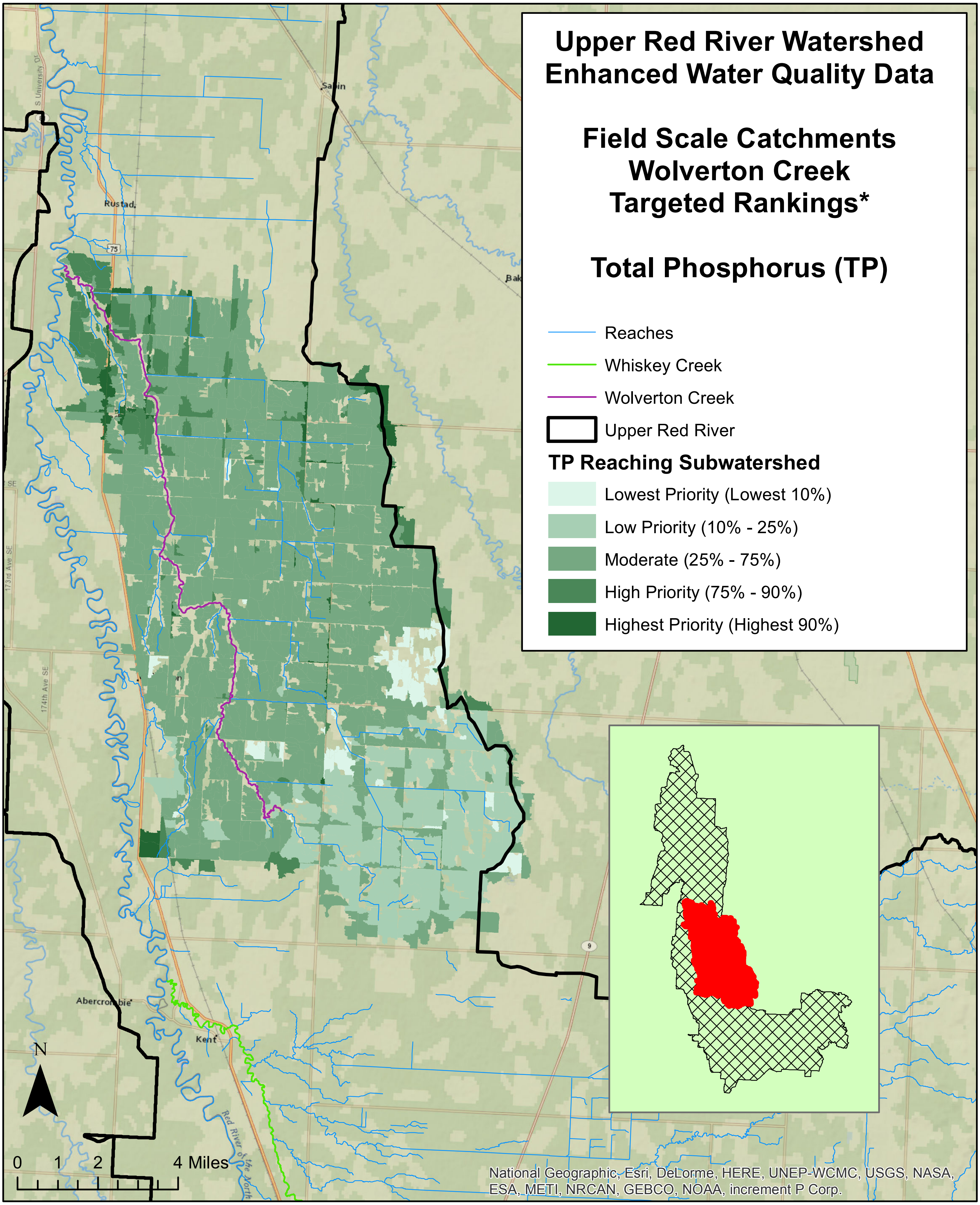

Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;

(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;

(3): Waterways are from the MN DNR 24K stream data.

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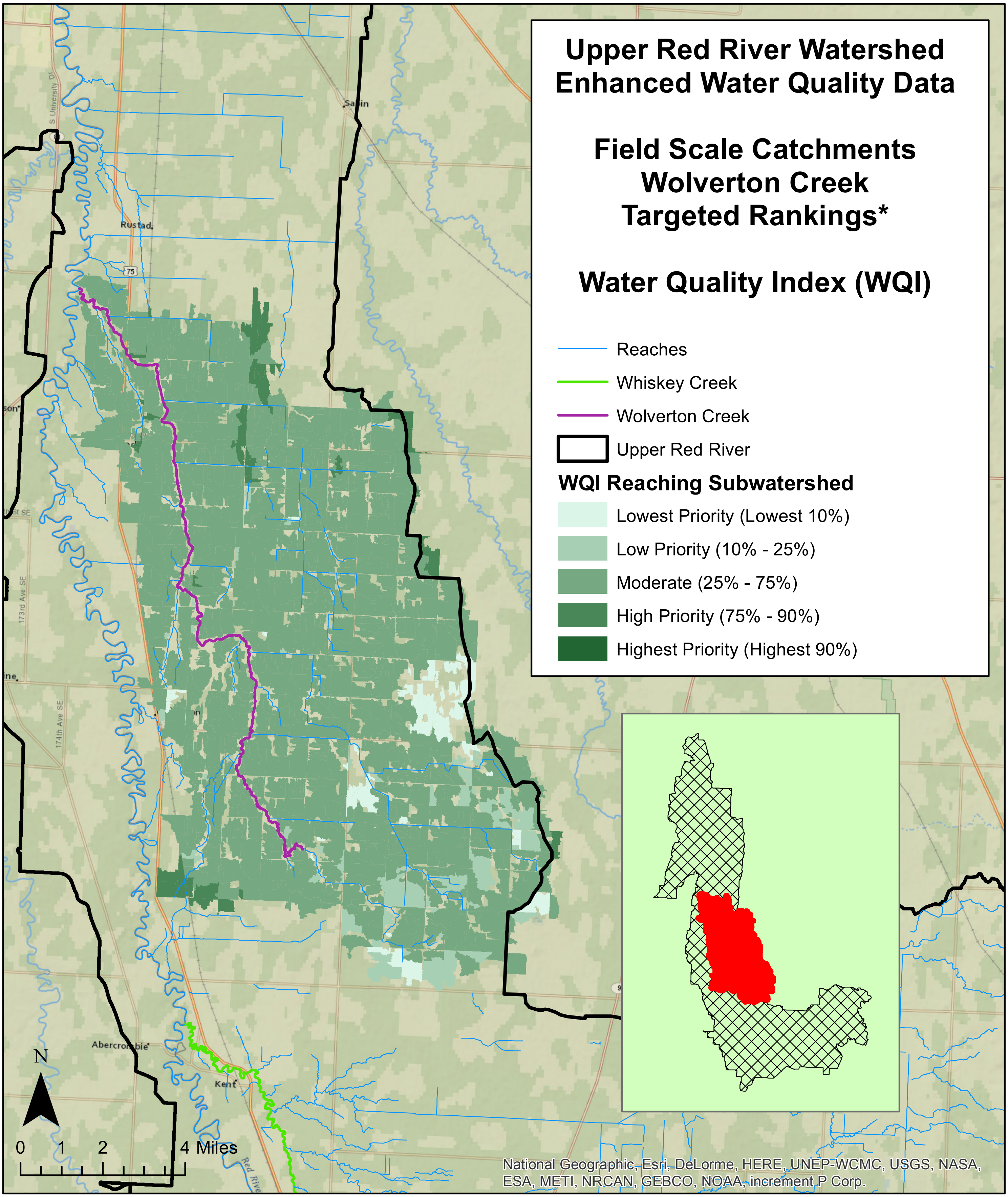

Notes:(1): Loads and yields estimated using Houston Engineering, Inc. Water Quality Decision Support Application;
(2): This map represents the potential load and yield. Map use is suitable for prioritizing subwatersheds for conservation practice and best management practice implementation based solely on water qualiy;
(3): Waterways are from the MN DNR 24K stream data;
(4): WQI is an equally weighted aggregate of Nutrients and Sediment.

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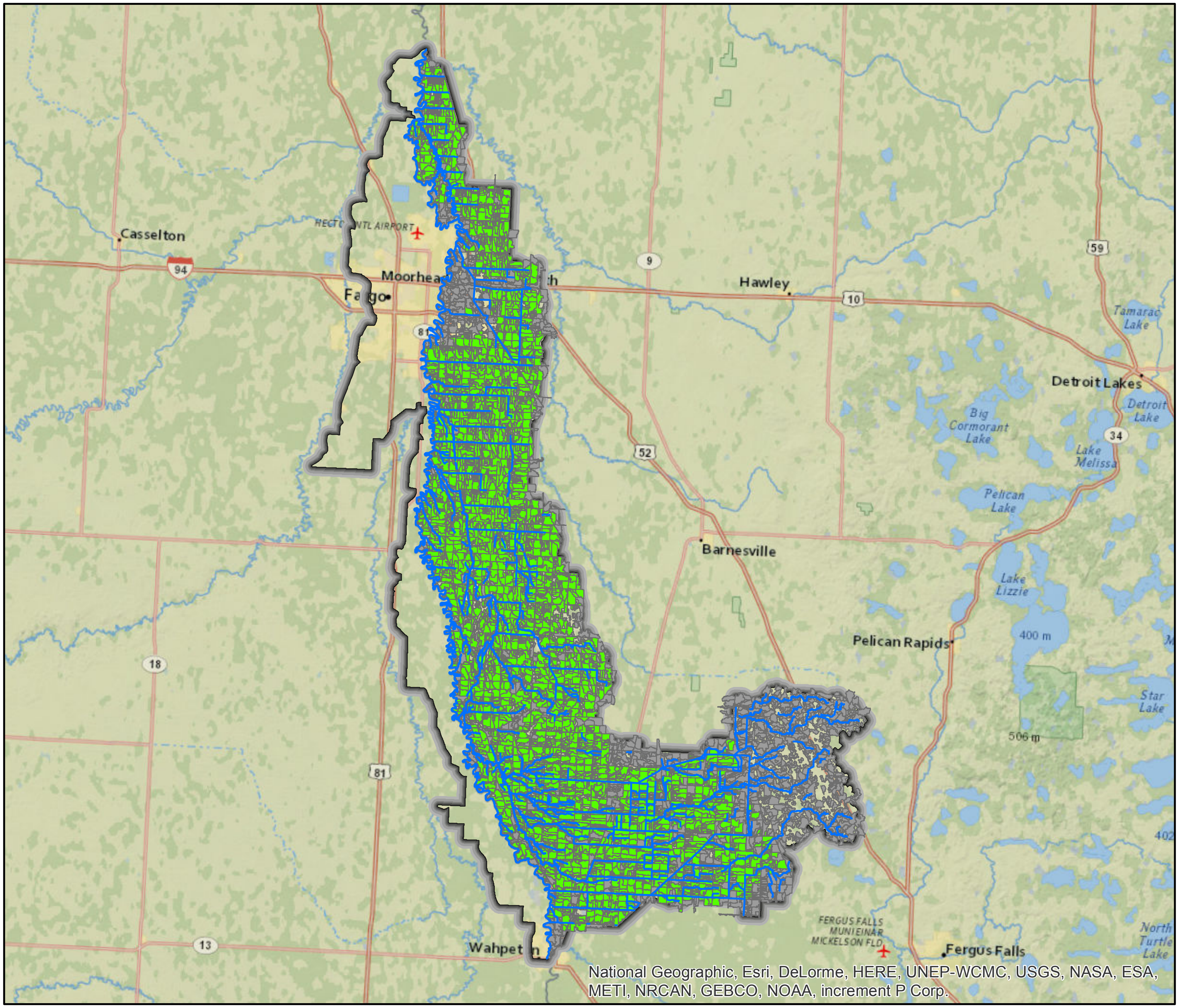
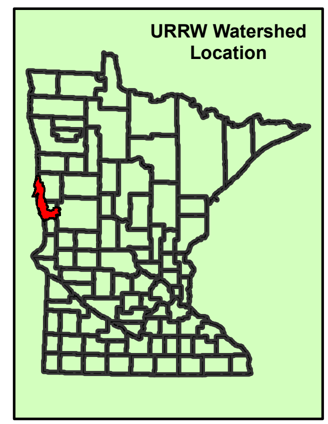
APPENDIX B: FIELD SCALE TARGETING OF CATCHMENTS FOR OPPORTUNITIES TO IMPLMENT BMPS TO IMPROVE WATER QUALITY

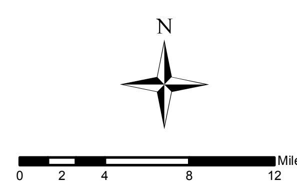
Upper Red River Watershed (URRW) Opportunities for Bioreactors (NRCS: 747)



Opportunties for Bioreactors

- Potential
- Limited
- URRW Streams





Notes: (1): This map identifies catchments with characteristics that are suitable for bioreactors.
(2): Catchments with bioreactor opportunities have at least 50% of the area consiting of slopes < 1% and agricultural lands use.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.

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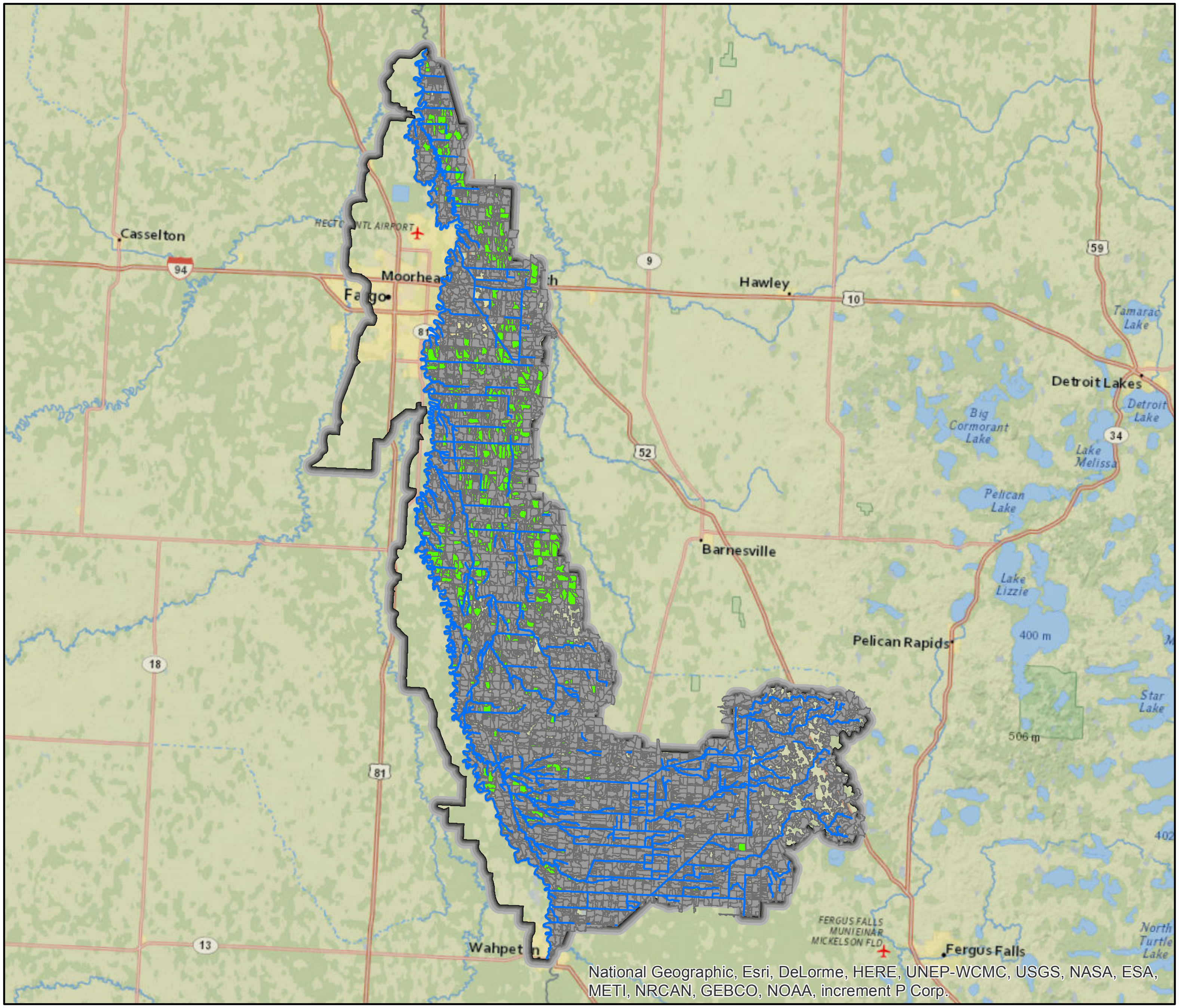
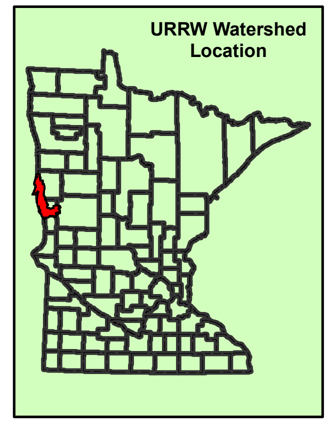
Upper Red River Watershed (URRW) Opportunities for Controlled Drainage (NRCS: 554)



Opportunties for Controlled Drainage

- Potential
- Limited
- URRW Streams



N

Miles 0 2 4 8 12

Notes: (1): This map identifies areas with characteristics that are suitable for controlled drainage.
(2):Areas with opportunities for controlled drainage consist of cultivated lands with slopes < 2% occuping at least 80% of a catchment.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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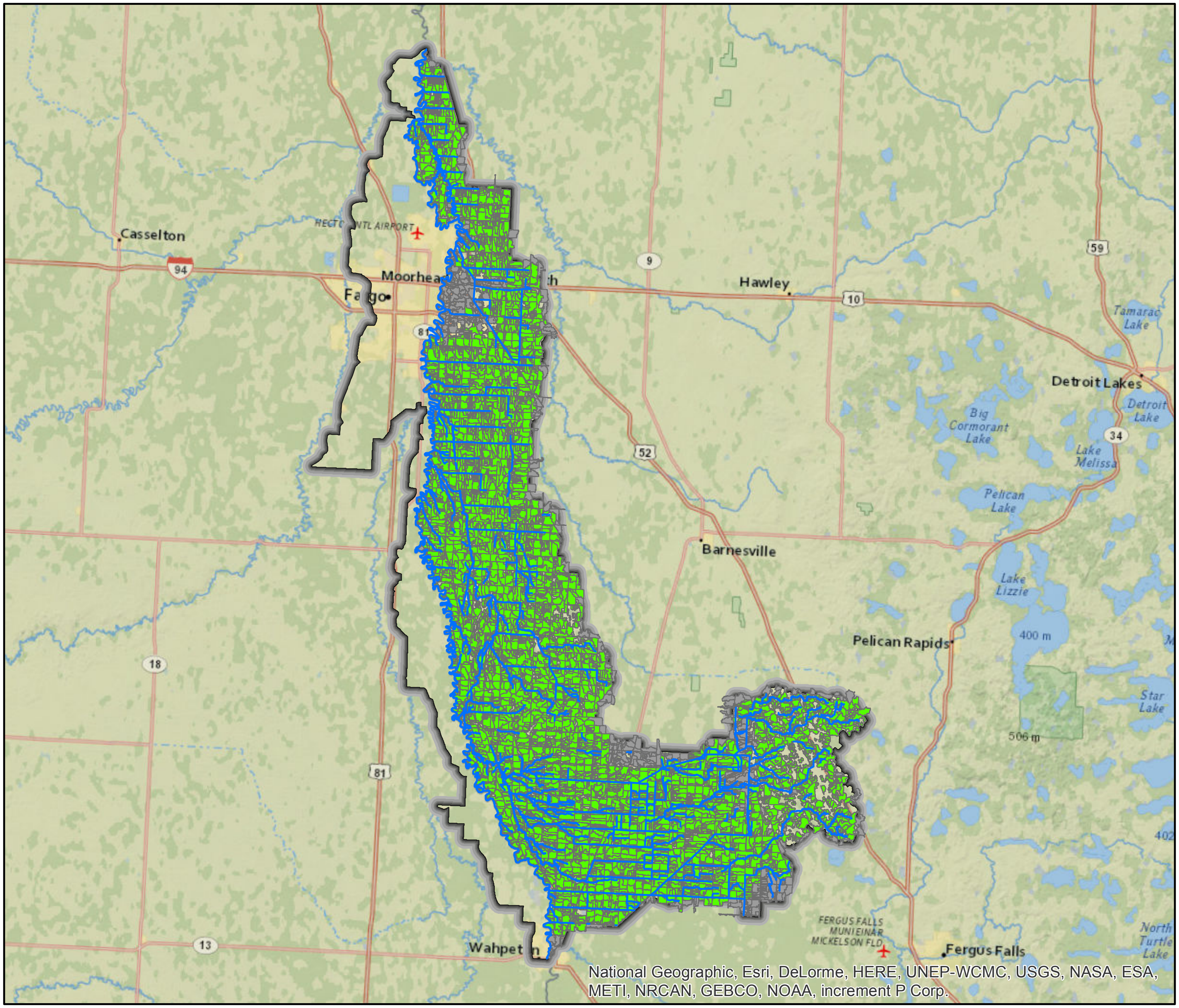
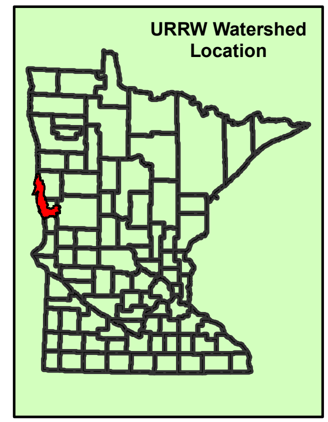
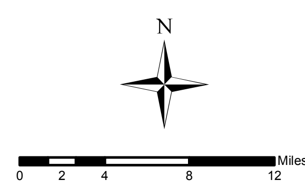
Upper Red River Watershed (URRW) Opportunities for Cover Crops (NRCS:340)



Opportunties for Cover Crops

- Potential
- Limited
- URRW Streams





Notes: (1): This map identifies areas with characteristics that are suitable for cover crops.
(2):Areas with opportunities for cover crops consist of areas under cultivated land.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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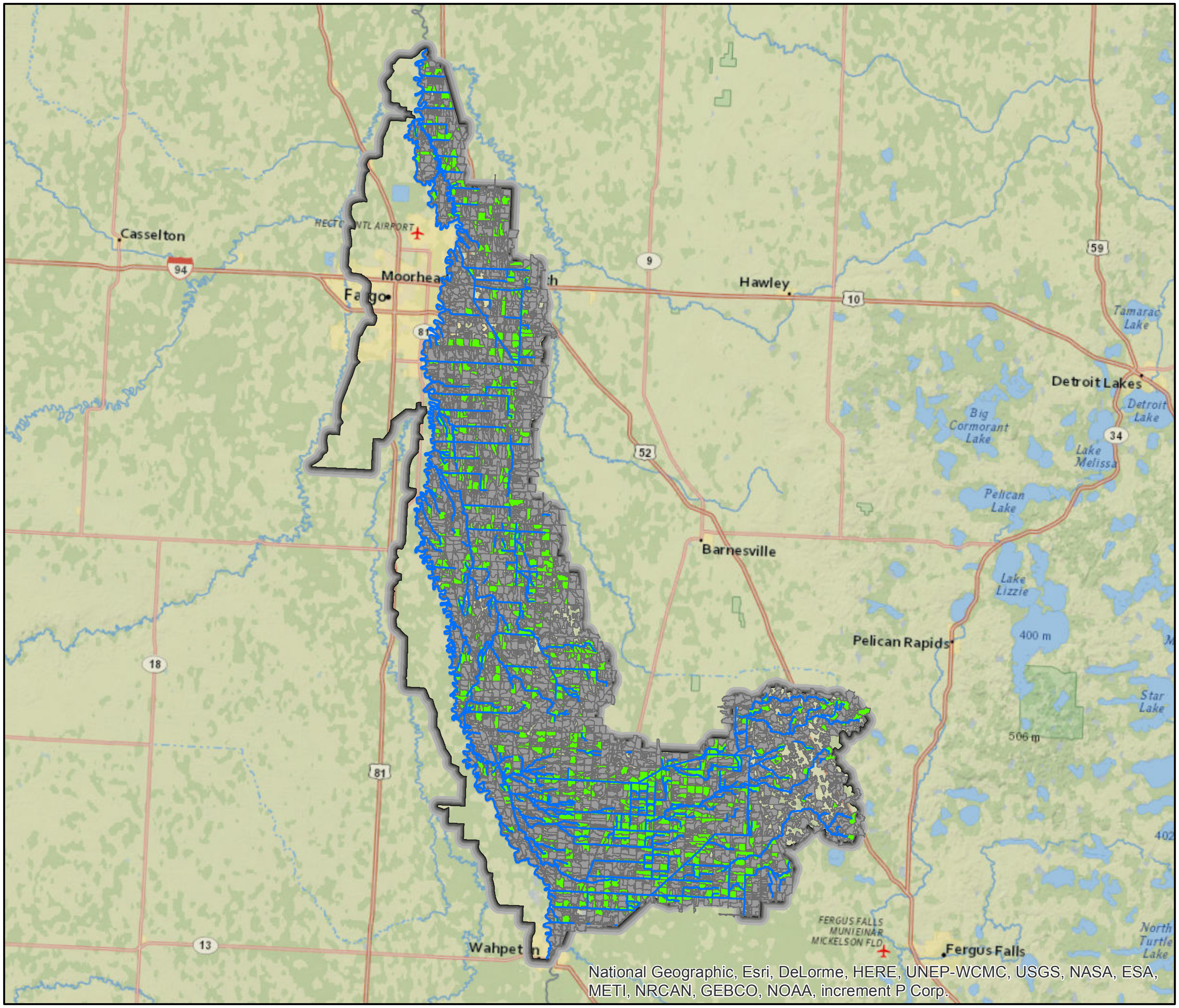
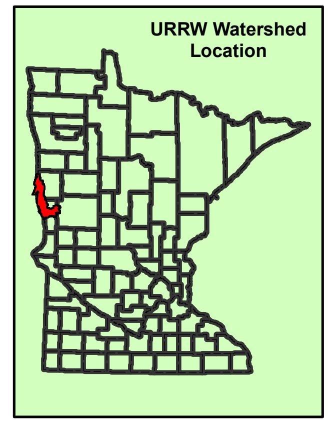
Upper Red River Watershed (URRW)
Opportunities for
Filter Strips (NRCS:393)



Opportunities for Filter Strips

- Potential
- Limited
- URRW Streams



N

Miles: 0 2 4 8 12

Notes: (1): This map identifies areas with characteristics that are suitable for Filter Strips.
(2):Areas with opportunities for filter strips consist of cultivated lands within 100 ft of waterways with < 8.1 tons/year of sediment delivered and sheet flow.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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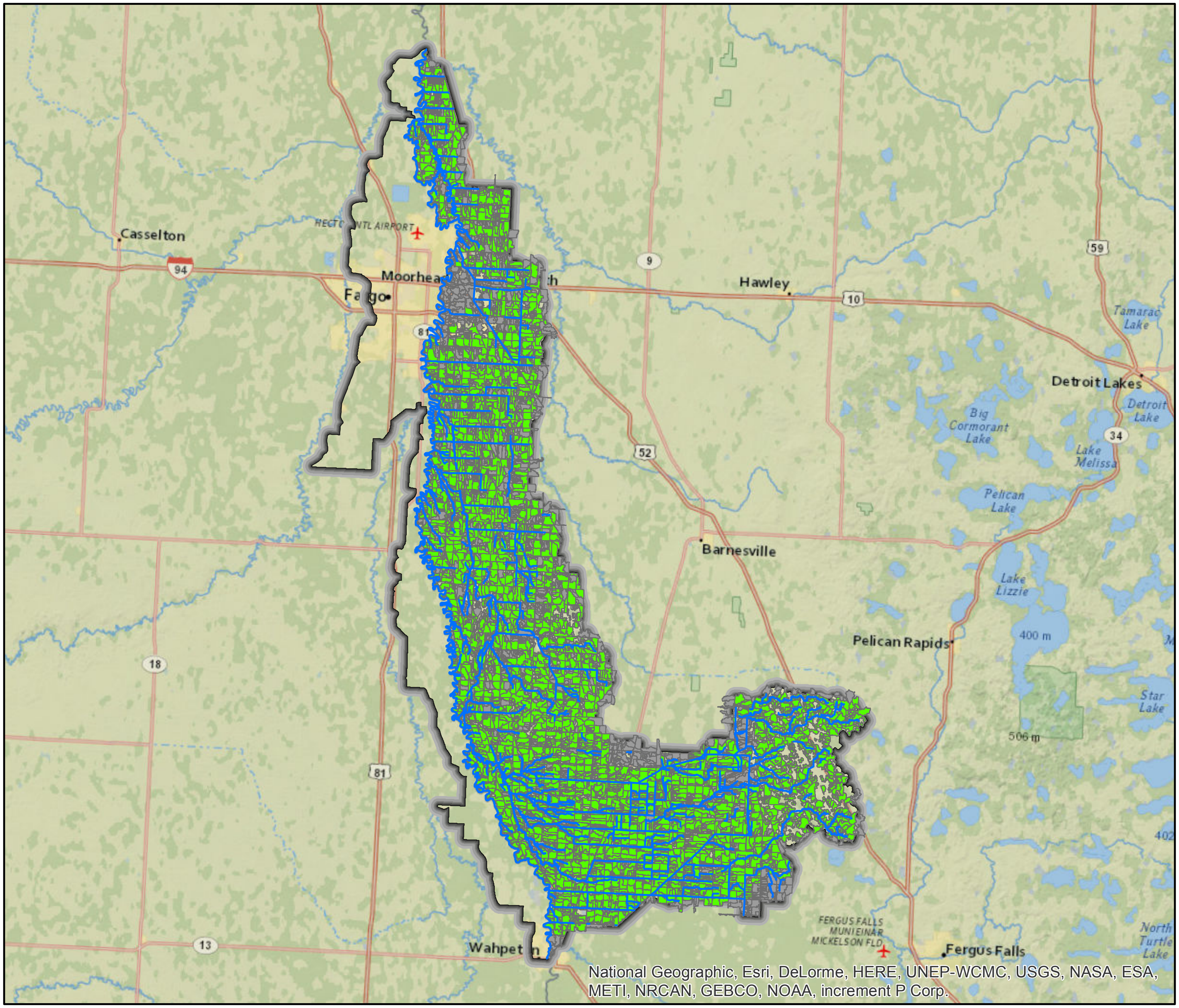
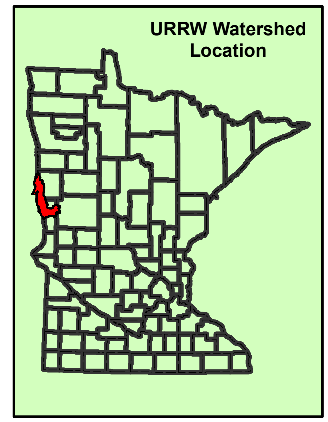
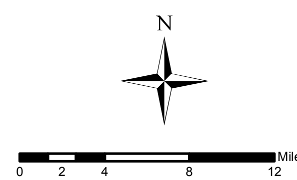
Upper Red River Watershed (URRW)
Opportunities for
Grassed Waterways (NRCS:412)



Opportunties for Grassed Waterways

- Potential
- Limited
- URRW Streams





Notes: (1): This map identifies areas with characteristics that are suitable for grassed waterways.
(2):Areas with opportunities for grassed waterways consist of concentrated flow paths currently under cultivation with slopes between 3% to 12% and flow lengths < 750 ft.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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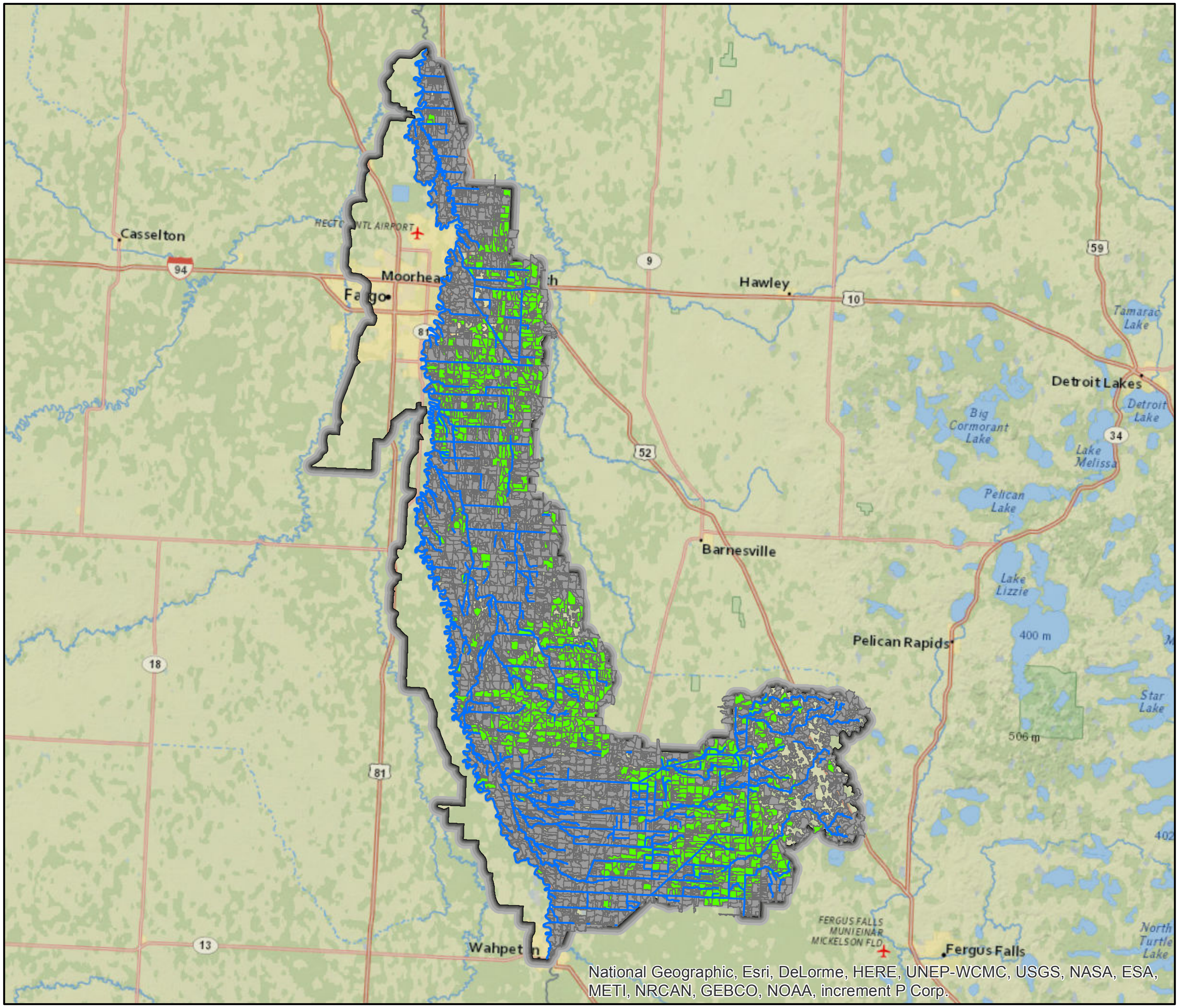
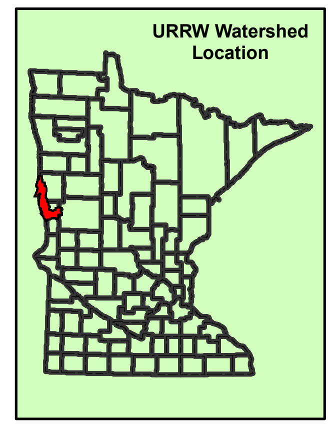
Upper Red River Watershed (URRW)
Opportunities for
Perennials



Opportunties for Perennials

- Potential
- Limited
- URRW Streams



Notes: (1): This map identifies areas with characteristics that are suitable for perennials.
(2):Areas with opportunities for perennials consist of crop productivity indices < 61 and currently cultivated lands.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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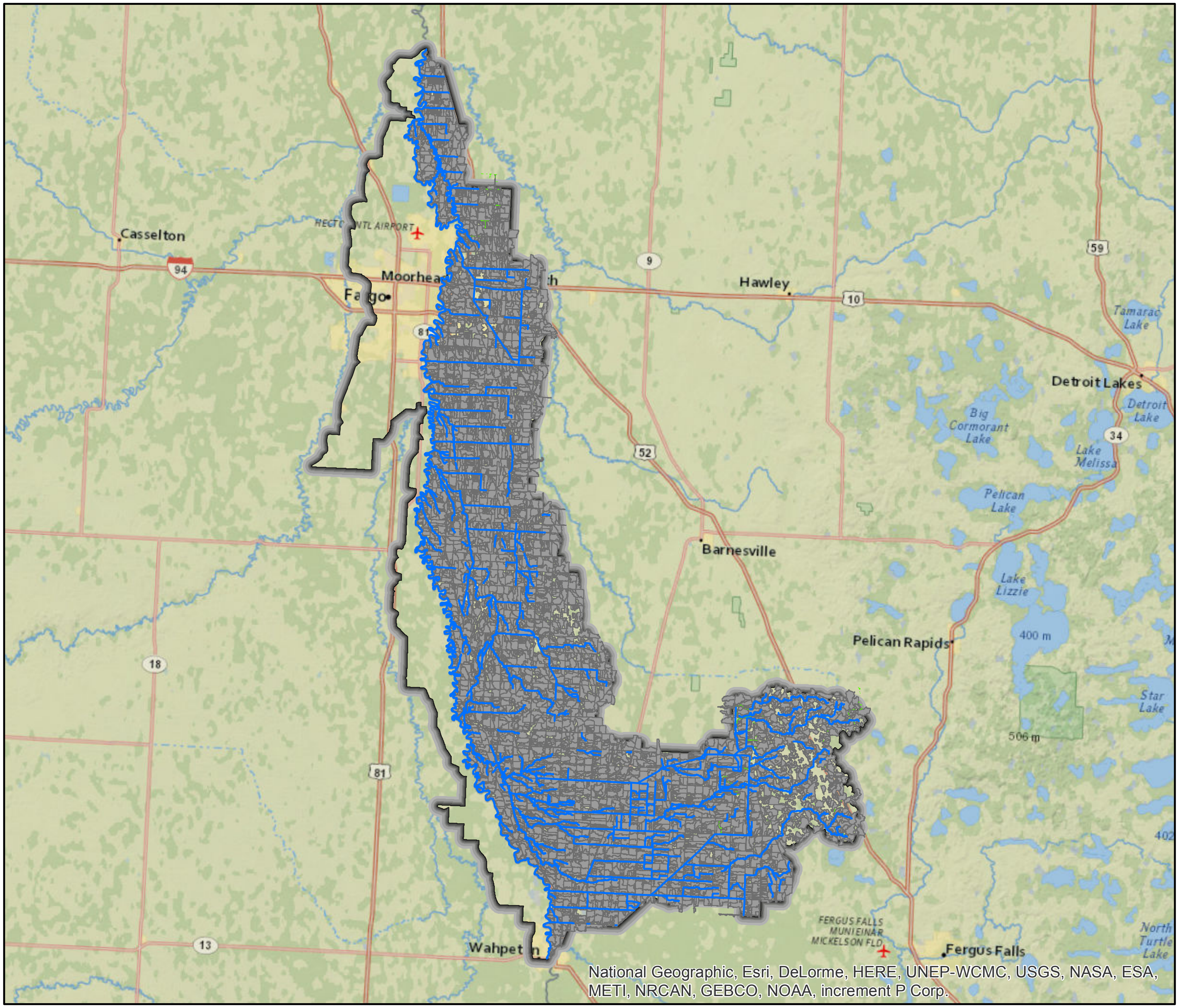
N

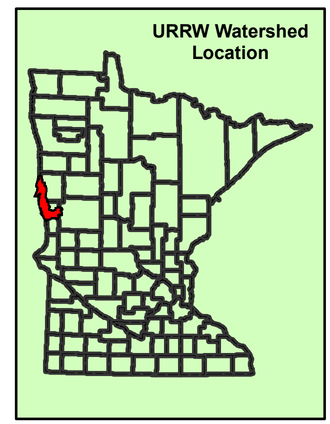
Miles 0 2 4 8 12

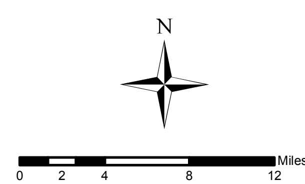
Upper Red River Watershed (URRW)
Opportunities for
Saturated Buffers



Opportunties for Saturated Buffers

- Potential
- Limited
- URRW Streams





Notes: (1): This map identifies areas with characteristics that are suitable for saturated buffers.
(2):Areas with opportunities for saturated buffers consit riparian areass with water table depths < 2 ft
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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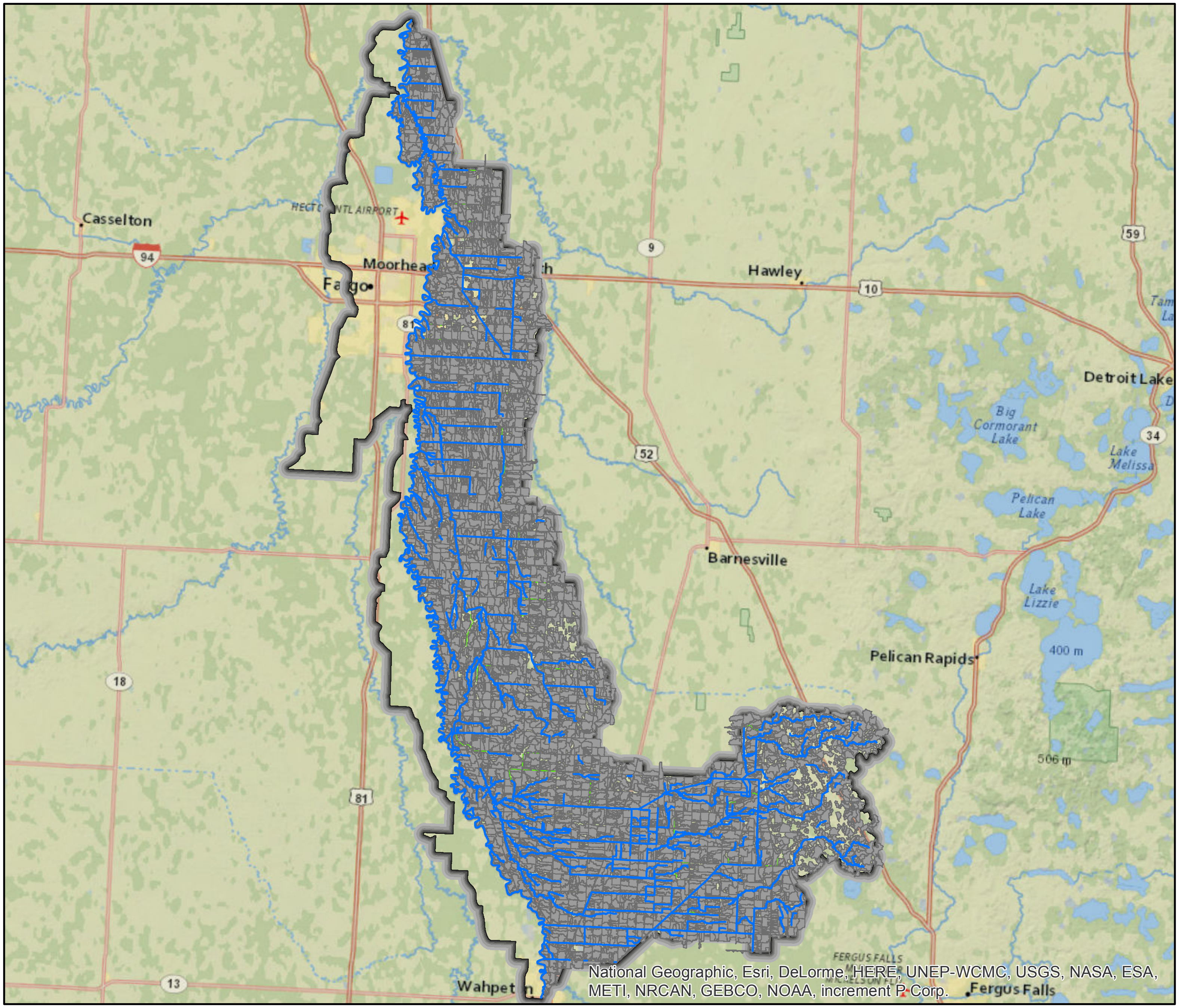
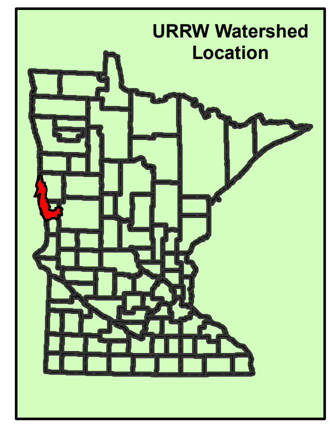
Upper Red River Watershed (URRW)
Opportunities for
Two Stage Ditches (NRCS: 582)



Opportunties for Two Stage Ditches

- Potential
- Limited
- URRW Streams



Notes: (1): This map identifies areas with characteristics that are suitable for two-stage ditches.
(2):Areas with opportunities for two-stage ditches consist of dtiches with top of bank heights within 3 m of the ditch minimum elevation.
(3): Catchments are restricted to locations with contributing areas between 2 and 40 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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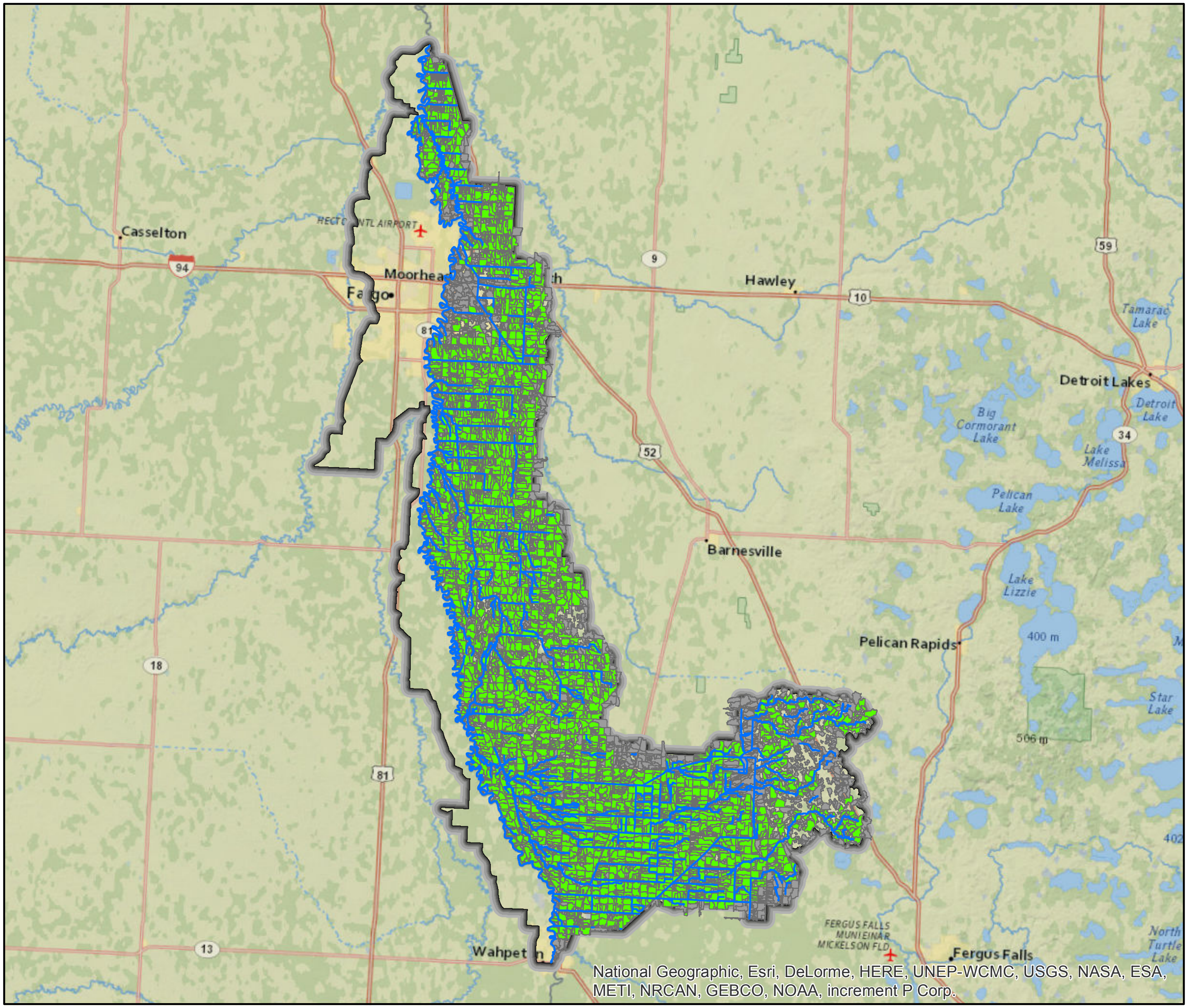
N

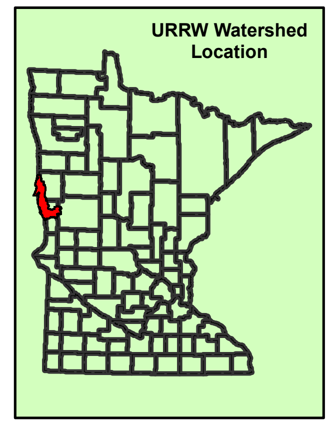
0 2 4 8 12 Miles

Upper Red River Watershed (URRW) Opportunities for WASCOB (NRCS: 638)



Opportunties for WASCOB

- Potential
- Limited
- URRW Streams



N

Miles 0 2 4 8 12

Notes: (1): This map identifies areas with characteristics that are suitable for water and sediment control basins (WASCOBS).
(2):Areas with opportunities for WASCOBS consit of flow paths with contributing areas of < 40 acres and high ratings for sediment accumulation.
(3): Catchments are restricted to locations with contributing areas between 5 and 140 acres.
(4): Locations identfied are preliminary based on analysis of GIS data and application of design standards. Field verification required.
(5): Streams and drainage ditches are from the MN DNR 24K stream data.

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Appendix B:

MEMO

(External Correspondence)

To:	Bruce Albright, BRRWD Cary Hernandez, MPCA	**From:**	Stephanie Johnson, PhD, PE
Date:	January 14, 2014	**Subject:**	Upper Red River Watershed GIS Terrain Analysis Results
File:	1915-204		

The following memorandum is intended to summarize the GIS (geographic information systems) terrain analysis work completed in the Upper Red River Watershed (URRW) (HUC 09020104) for the purpose of prioritizing nonpoint source priority management areas. This work was performed under Objective 1 of Phase II of the URRW Watershed Restoration and Protection (WRAP) project. The work was completed using a GIS terrain analysis dataset developed for the entire Buffalo-Red River Watershed District (BRRWD), under a separate effort. The methodology used to create the terrain analysis datasets is consistent with work completed in the Upper South Branch of the Buffalo River Watershed and detailed in the Upper South Branch BMP Strategic Plan report (HEI, 2011). The report is attached at the end of this memorandum for reference.

One of the main water quality concerns in the URRW is elevated turbidity levels, reflecting an overloading of sediment into the system. GIS terrain analysis uses highly-accurate light detection and ranging (LiDAR) data, combined with information on soils and land use, and advanced geospatial analysis techniques to identify locations on the landscape that are highly erosive and susceptible to erosive flows. Landscape erosivity is computed using the Revised Universal Soil Loss Equation (RUSLE) and erosive flow patterns are identified through use of the Stream Power Index (SPI).

The results of GIS terrain analysis are intended for use in preliminary site selection and project evaluation for controlling nonpoint sources of sediment (and its associated pollutants) in the URRW. RUSLE and SPI values are computed on a three meter grid scale and then ranked to identify locations with high vs. low priority for best management practice (BMP) implementation. A combined score is computed for each grid cell, reflecting locations with a highly erosive landscape/practices and also a high potential for erosive flows. To summarize results on a larger scale, the gridded RUSLE, SPI, and combined scores are averaged across the overland catchments (HEI, 2011).

Figure 1 shows the mean RUSLE scores for the overland catchments of the URRW. Results have been color-coded to highlight areas of high vs. low priority for BMP implementation and nonpoint source management. Results show erosive landscapes/practices throughout the watershed, with areas of high management priority clustered in the south-central portion.

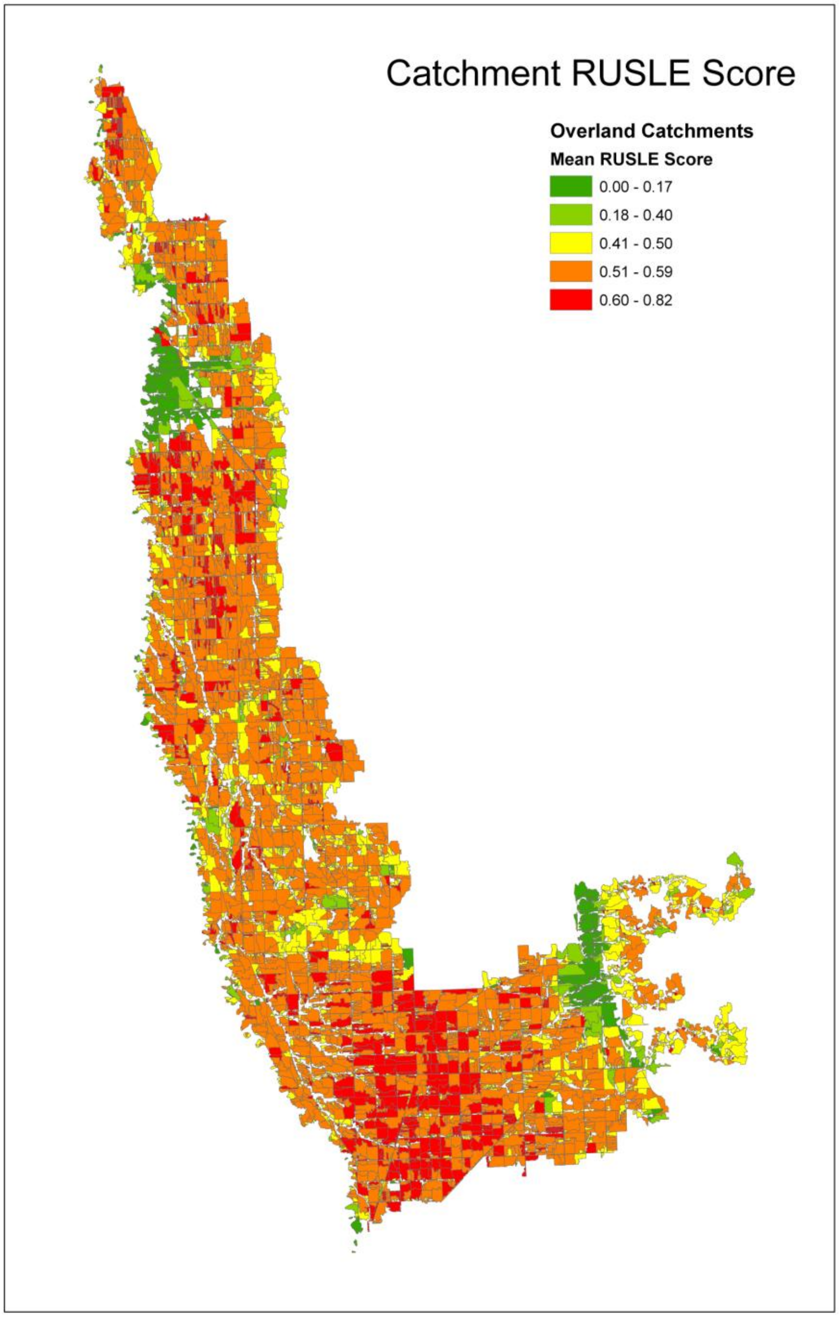

Figure 1. Mean RUSLE Scores by Overland Catchment

Figure 2 shows the mean SPI scores for the overland catchments of the URRW. Again, there's a cluster of catchments with high priority for management in the south-central portion of the watershed.

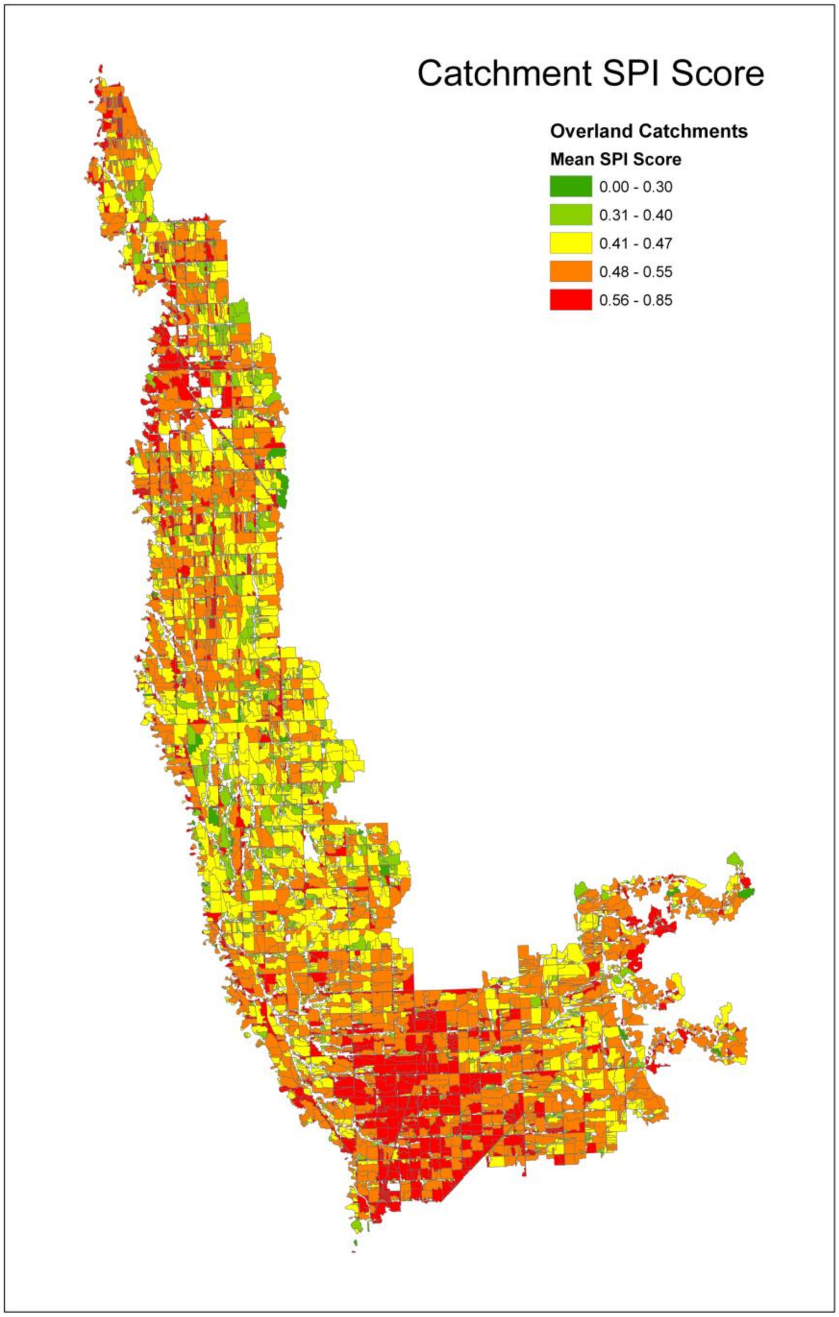

Figure 2. Mean SPI Scores by Overland Catchment

Figure 3 shows the combination of RUSLE and SPI scores, showing the mean combined scores for the watershed. As expected, results show that the south-central portion of the watershed should be prioritized for nonpoint source BMP implementation.

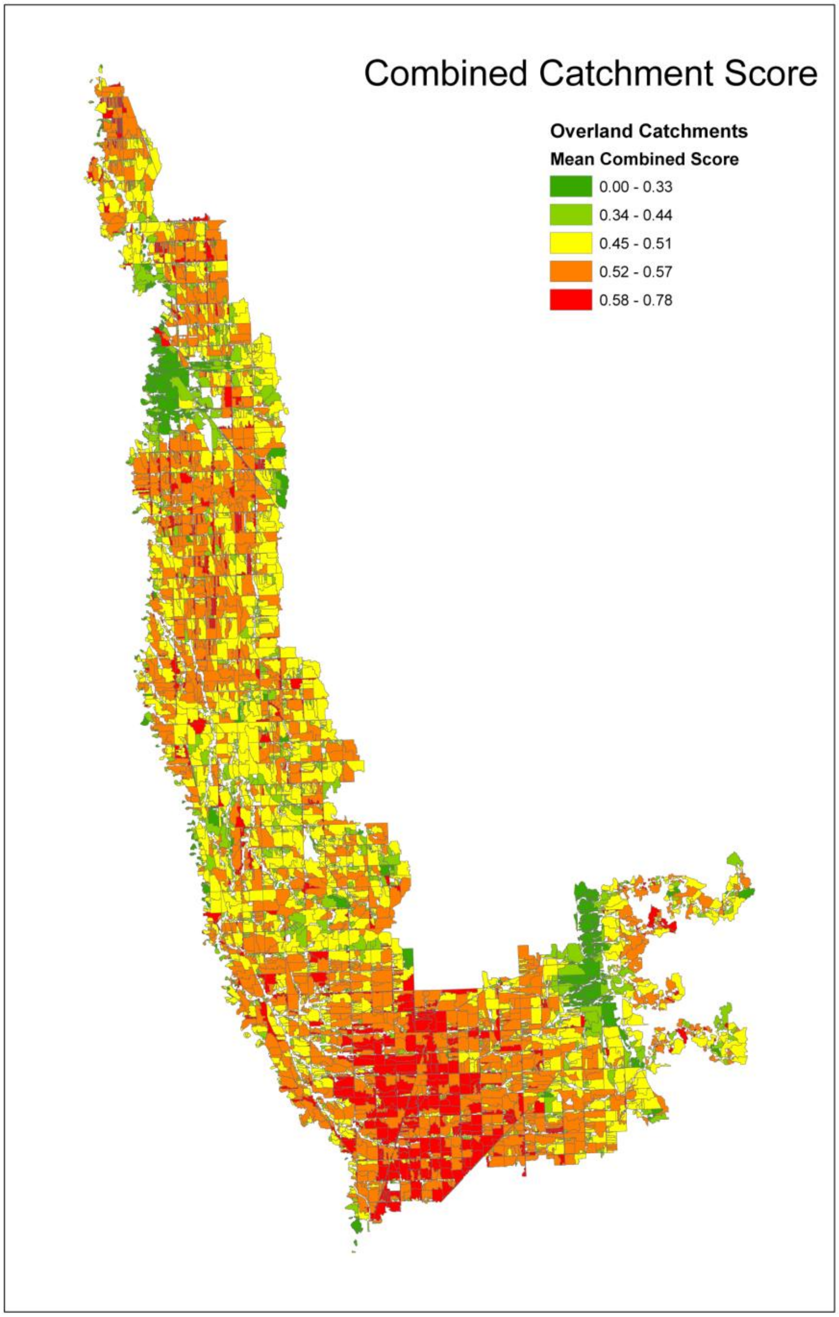

Figure 3. Mean Combined Scores by Overland Catchment

In addition to summarizing the GIS terrain analysis results by overland catchment, the combined scoring raster was also ranked and scored along flow paths in the watershed. These results help to identify flow paths where highly erosive flows are intersecting a highly erodible landscape. Figure 4 shows an example of the ranked flow path results in the subbasins that contribute directly to the upper portion of Whiskey Creek.

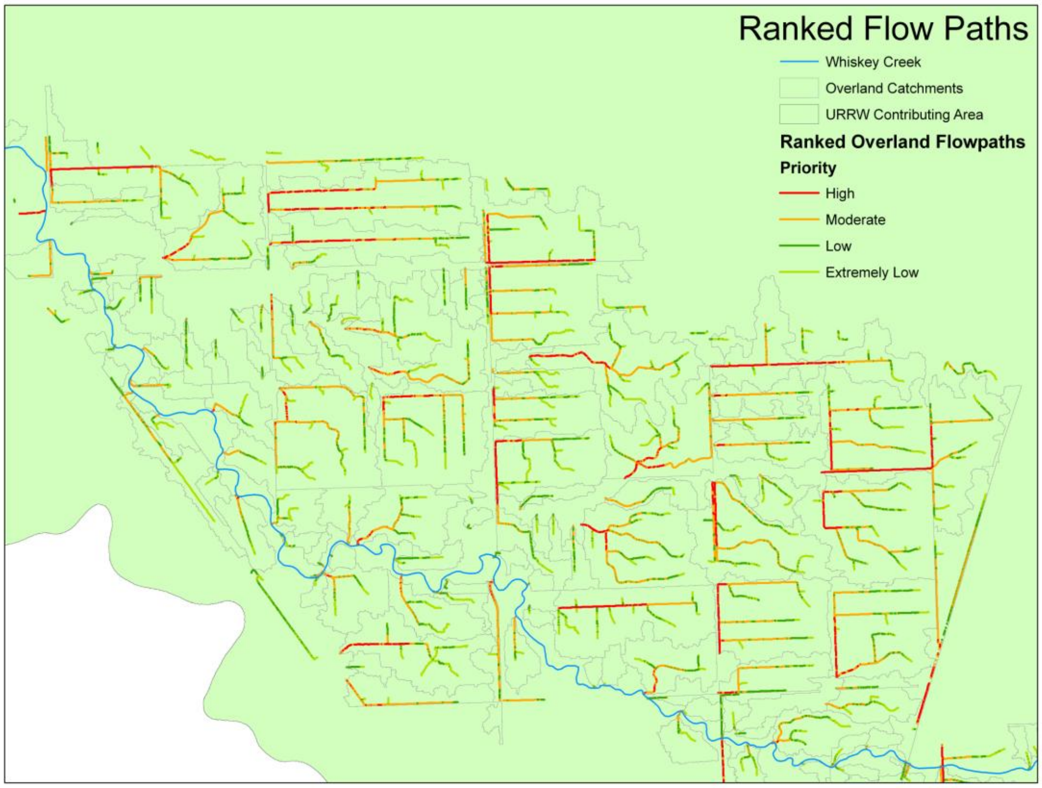

Figure 4. Ranked Flowpaths in the Upper Whiskey Creek Contributing Drainage Area

Details of the various GIS datasets created under this work and provided as deliverables follow.

1. **RUSLE_rank**
   a. *Data type:* Raster
   b. *Summary:* Ranking of the accumulated effective load raster (i.e., RUSLE loading multiplied by Sediment Delivery Ratio) for areas of channelized overland flow (upstream flow length > 300 feet and contributing area > 0.5 sq. km.). Cumulative percentile rank uses log-normal distribution.

2. **SPI_rank**
    a. *Data type:* Raster
    b. *Summary:* SPI percentile ranking for areas of channelized overland flow (upstream flow length > 300 feet and contributing area > 0.5 sq. km.). Cumulative percentile rank uses log-normal distribution.
3. **Score**
    a. *Data type:* Raster
    b. *Summary:* Combined scoring of the SPI and RUSLE percentile rankings. The score is based on equal weighting between the SPI and RUSLE percentile rank for channelized overland flow.
4. **Overland_Catchments.shp**
    a. *Data type:* Polygon Shapefile
    b. *Summary:* Contributing areas for overland flow for drainage areas between 0.5 square kilometers and 5 acres.
    c. *Attributes*
        i. *GRIDCODE* – Common ID corresponding to Overland_Pourpoint.shp
        ii. *TonPerYr* – Total amount of sediment loss predicted from RUSLE for the overland catchment.
        iii. *MeanSPI* - Mean value of the SPI_ranks raster dataset for the overland catchment areas in the URRW.
        iv. *MeanRUSLE* – Mean value of the RUSLE_ranks raster dataset for the overland catchment areas in the URRW.
        v. *MeanScore* – Mean value of the score raster dataset for the overland catchment areas in the URRW.
5. **Overland_Pourpoints.shp**
    a. *Data type:* Point Shapefile
    b. *Summary:* Outlet locations of overland flow to in-channel flow using drainage areas thresholds between 0.5 square kilometers and 5 acres.
    c. *Attributes*
        i. *GRIDCODE* – Common ID corresponding to Overland_Pourpoint.shp
6. **Ranked_Overland_Flowpaths.shp**
    a. Data type: Polyline Shapefile
    b. *Summary:* Overland flowpaths were classified into priority categories based on the score raster dataset.
    c. *Attributes:*
        i. *SedBasin:* Areas generally acceptable for sediment control basins

1. *Value = 1:* Contributing area is less than 40 acres (ideal for sediment control basins.
2. *Value = 2:* Contributing area is greater than 40 acres (not ideal for sediment control basins.

ii. *MinScore:* Minimum score of range used for priority classification. Source data is from the score raster dataset.

iii. *MaxScore:* Maximum score of range used for priority classification. Source data is from the score raster dataset.

iv. *Priority:* Priority classification for implementation based on the range established in the MinScore and MaxScore fields.

1. *Extremely Low* (score < 75)
2. *Low* (75 < score < 85)
3. *Moderate* (85 < score < 95)
4. *High* (score > 95)

7. Project_Watershed_Contributing.shp

a. *Data type:* Polygon Shapefile

b. *Summary:* Total project area including only contributing areas.

c. *Attributes:*

i. *Area_SqMi:* Total area in square miles.

ii. *Acres:* Total area in acres

These results are delivered in a geospatial database along with this memorandum and are intended for use in prioritizing and planning rural nonpoint source management in the URRW.

REFERENCES

Houston Engineering, Inc. (HEI) 2011. Upper South Branch BMP Strategic Plan.

Upper South Branch BMP Strategic Plan

Minnesota BSWR Clean Water Fund FY2011

Project Sponsors:
Buffalo – Red River Watershed District
Wilkin County SWCD
West Otter Tail County SWCD

October 4, 2011

HoustonEngineering Inc.

Upper South Branch BMP Strategic Plan

Minnesota BSWR Clean Water Fund FY2011

Project Sponsors:
Buffalo – Red River Watershed District
Wilkin County SWCD
West Otter Tail County SWCD

October 4, 2011

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Registered Engineer under the laws of the State of Minnesota.

Erik S. Jones

Erik S. Jones, P.E.
MN Reg. No. 41161

Date: 10/04/2011

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Table of Contents

Section	Page No.
1. INTRODUCTION	
A. Scope and Purpose	2
2. LiDAR TERRAIN ANALYSIS	
A. Data Summary	2
B. DEM Reconditioning	3
C. Non-Contributing Analysis	3
D. Hydrographic Characteristics	4
3. REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)	
A. Process Summary	4
B. Input Variables	4
C. Analysis	6
4. STREAM POWER INDEX (SPI)	
A. Process Summary	7
5. SUMMARY	
A. Watershed Scoring	8
B. Current Conditions Summary	8
C. Guidance for BMP Activities	8
D. Limitation of Data	9
References	9

Appendix A - Figures

Figure 1: Location Map
Figure 2: DEM Reconditioning
Figure 3: LiDAR Derived Slope
Figure 4: 2010 National Agricultural Statistics Service (NASS)
Figure 5: RUSLE Cover and Management Factor "C"
Figure 6: Kw Value - SSURGO Soils Database
Figure 7: RUSLE Length/Slope Factor "LS"
Figure 8: RUSLE Total Sediment Load Per Cell
Figure 9: Sediment Delivery Ratio (MN P-Index)
Figure 10: RUSLE Effective Source Loading at Pour Point
Figure 11: RUSLE Total Sediment Load Per Overland Catchment Area
Figure 12: Mean SPI Value for Overland Catchments
Figure 13: Mean Score for Overland Catchments
Figure 14: Applicable Locations for Sediment Control Basins
Figure 15: Example SWCD Map

Appendix B – GIS Data Summary

1. INTRODUCTION

A. Scope and Purpose

Portions of the South Branch of the Buffalo River are currently overloaded with sediment. Two primary waterways in the watershed, Deerhorn Creek and the South Branch, are listed on the 2010 Draft 303d list as impaired for turbidity. Due to sediment deposition in the channel, the waterways have lost much of their historic capacity. Attempts in the past by landowners and the Buffalo-Red River Watershed District to restore the capacity of the channel by removing sediment have had limit success due to additional excess sediment being washed into the channel.

The Buffalo-Red River Watershed District has partnered with the Wilkin and West Otter Tail Soil and Water Conservation Districts (SWCDs) to develop a strategic plan for determining locations for Better Management Practices (BMP) implementation in the upper watershed of the South Branch of the Buffalo River. The study area and watershed of the Upper South Branch includes the portions of the watershed upstream of the Clay – Wilkin County line. The total watershed area is 154 square miles (including the non-contributing portions of the watershed). The BMP Strategic Plan is being developed using advanced GIS techniques using LiDAR, Soils, and Landcover data. The Plan ranks the watershed by analyzing and scoring the results of the Stream Power Index (SPI) and a spatial application of the Revised Universal Soil Loss Equation (RUSLE). This analysis is being conducted on the portion of the South Branch Watershed that lies upstream (South) of the Clay/Wilkin County boundary.

Development of this plan is funded through the Technical Assistance portion of the Board of Soil and Water Resources (BSWR) Clean Water Fund (FY2011). Funding for this phase of the project includes completing the analysis, as well as marketing and implementation of BMPs within the project watershed. This initial phase of the project will potentially lead to additional phases geared towards marketing and implementation of additional BMPs in high priority areas as determined by the results of the BMP Strategic Plan. This report summarizes methods and results of the BMP Strategic Plan.

2. LiDAR TERRAIN ANALYSIS

A. Data Summary

This study utilizes the International Water Institute's (IWI) LiDAR data, collected in the fall of 2008. IWI has collected LiDAR data for the United States portion of the Red River Basin to enhance water management capabilities. All data has been collected to a maximum error of plus or minus six inches. The bare earth LiDAR points were generalized into a digital elevation model (DEM) at 3 meter by 3 meter resolution. This 3 meter by 3 meter "bare earth" DEM served as the base of all terrain analysis related to the BMP Strategic Plan.

B. DEM Reconditioning

The project-wide 3 meter by 3 meter “bare earth” DEM was hydrologically reconditioned to determine accurate physical hydrologic characteristics within the project watershed. Reconditioning the DEM is an iterative process that requires user interpretation of runoff characteristics within the watershed. The “bare earth” DEM fails to account for sub-surface drainage structures, such as culverts and flood control structures, and creates false digital dams in the DEM. Reconditioning the DEM consists of interpreting these structures and accounting for them by “burning in” these locations into the “bare earth” DEM. The term “burning in” refers to artificially lowering the DEM along the alignment of the subsurface drainage structure to allow flow accumulation through the digital dam during terrain processing. . The resultant DEM after the “burning in” process has taken place is referred to as the AgreeDEM. The AgreeDEM is then processed through a series of GIS Terrain Analysis techniques to determine drainage lines and catchment polygons for the project watershed. These drainage lines and catchment polygons are then interpreted by the user to verify the results. This process is repeated until the results of the GIS Terrain Analysis processing on the AgreeDEM match the user’s interpretation of the DEM. Figure 2 illustrates the extent of “burning in” that was required across the project watershed.

In some instances, walls were also required to achieve the required results. Walls are used to artificially raise the DEM and create a hydrologic divide. This process was used extensively in areas where “bare earth” LiDAR DEM data falsely interprets heavy vegetation as high ground elevations. Another example of this is extremely flat topography where the 3 meter by 3 meter resolution DEM becomes too general to determine accurate flow split locations in shallow field ditches.

To assist in determining the appropriate “burn in” locations, several sources of data were analyzed:

- Drainage structure surveys and inventories (Where available)
- Aerial Photography
- LiDAR data

C. Non-Contributing Analysis

For the purposes of this study, non-contributing areas are defined as areas that contain the 10-yr recurrence, 24-hour duration runoff event, as defined by *Technical Paper No. 40: Rainfall Frequency Atlas of the United States.* The determination of contributing versus non-contributing areas was done using a series of GIS processes in which the available storage of a depressed area on the AgreeDEM is compared to the runoff volume generated from the contributing watershed of the depressed area. This is an iterative process in which the excess runoff of contributing areas is accumulated with downstream non-contributing areas until no excess runoff is produced. The output of this process is a hydrologically reconditioned DEM that accounts for non-contributing areas, referred to as the HydroDEM. Figure 2 illustrates the results of the non-contributing analysis.

D. Hydrographic Characteristics

Once the HydroDEM was created, various characteristics of the watershed could be derived. These characteristics would be used later for the RULSE and SPI analyses. One of the most critical hydrologic properties of the watershed for the purposes of this analysis is determining the contributing area threshold that will be used to define the transition from overland flow to in-channel flow. Based on a review of 2010 NAIP Aerial photography, a threshold of 0.5 square kilometers was used to define this transition. The SPI and RUSLE analyses are not applicable to in-channel erosion, therefore flowpaths with a contributing area greater than this were not considered in the analyses.

Using the HydroDEM, other characteristics were developed as needed for the analysis. These characteristics include:

- Upstream and Downstream Flow Length
- Flow Accumulation (Contributing Area)
- Flow Direction
- Slope (Illustrated in Figure 3)
- Overland flowpaths
- Overland Pour Points
- Overland Catchments

3. <u>REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)</u>

A. Process Summary

The Revised Universal Soil Loss Equation (RUSLE) accounts for land cover, soil types, topography, and management practices to determine an average annual sediment load as a result of rill and interrill flow. RULSE has traditionally been applied as a means to quantify benefits for individual projects. For the purposes of this project, RUSLE has been applied in a spatial setting using GIS data. The data below summarizes the development of input variables and application RUSLE in a spatial GIS setting.

B. Input Variables

RUSLE requires several parameters to be developed, and then multiplied to form the estimated annual sediment load. Several of the input variables were derived from the National Agricultural Statistics Service (NASS) 2010 Cropland Data Layer. 2010 NASS data for the project area is illustrated in Figure 4. Below is a summary of the input variables and how they were developed for this project:

1. *Support Practice Factor (P-value)* – The P-value accounts for the impact of support practices on erosion rates. Examples of support practices include contour farming, cross-slope farming, and buffer strips. For the purposes of this analysis, variations in the P-value were not accounted for. Currently, there is not sufficient information to derive P-values at the scale required for this analysis. Users of the data may apply the appropriate P-value to the results to account for site conditions.
2. *Cover and Management Factor (C-value)* – The C-value accounts for land cover characteristics on erosion rates. C-values were derived using 2010 NASS land cover data. Table 1 summarizes 2010 NASS land cover classification and the corresponding C-value. Figure 5 illustrates the C-values assigned to the watershed.
3. *Rainfall and Runoff Factor (R-value)* – The R-value accounts for meteorological characteristics of the watershed on erosion rates. The NRCS Minnesota Field Guide has already accounted for this factor on a county basis. Values for Clay, Otter Tail, and Wilkin County for each respective area were used.
4. *Soil Erodibility Factor (Kw-value)* – This value is attributed in the SSURGO Soils Database, and accounts for the effects of soil characteristics on erosion rates. Kw-values used for this analysis were extracted directly from the SSURGO Soils Database and are illustrated in Figure 6.
5. *Slope Length Factor (LS-value)* – The LS-value accounts for physical characteristics of the landscape on erosion rates. The USDA's Agricultural Handbook No. 703 summarizes the methodology to derive the LS-value. Length data was derived from the HydroDEM and the slope data was derived from the raw "bare earth" DEM (Figure 2). Both of these values were applied to methodology specified in the USDA's Agricultural Handbook No. 703 to calculate the LS-values for the project watershed. Figure 7 illustrates the LS-values for the project watershed.

Table 1: Summary of 2010 NASS Cropland Data Layer

2010 NASS Classification	Cover and Management Factor
Corn	0.200
Soybeans	0.200
Sunflower	0.200
Barley	0.200
Spring Wheat	0.200
Winter Wheat	0.200
Rye	0.200
Oats	0.200
Alfalfa	0.100
Other Hay	0.100
Sugarbeets	0.200
Dry Beans	0.200
Potatoes	0.200
Other Crops	0.200
Clover/Wildflowers	0.005
Sod/Grass Seed	0.100

Fallow/Idle Cropland	0.200
Pasture/Grass	0.005
Woodland	0.002
Wetlands	0.001
Open Water	0.000
Developed/Open Space	0.003
Developed/Low Intensity	0.003
Developed/Medium Intensity	0.003
Developed/High Intensity	0.003
Barren	0.003
Deciduous Forest	0.002
Evergreen Forest	0.002
Mixed Forest	0.002
Shrubland	0.002
Grassland Herbaceous	0.001
Pasture/Hay	0.005
Woody Wetlands	0.001
Herbaceous Wetlands	0.001
Vetch	0.200
Dbl. Crop Soybeans/Oats	0.200

The C-value was generalized because of the scale of the project watershed. Since future crop rotations are unknown and outputs of this project are planned to be used for future implementation, C-values were generalized under the assumption that row crops will be rotated with other row crops. These types of crops were given a common C-value. Other crops and land covers were given the appropriate C-value. Because of this generalization, it is recommended that the RUSLE analysis is used to provide results for comparison to other areas for prioritization.

C. Analysis

Once all of the required input variables were derived for RUSLE, the values were multiplied to determine the total sediment loads. Only areas of the watershed that are estimated to exhibit rill and interrill flow types were considered for the analysis. The HydroDEM was used to estimate areas of rill and interrill flow based on an upstream flow length less than 500 feet. The total sediment loading occurring per grid cell in these regions is illustrated in Figure 8 for the project watershed.

In order to determine the amount of sediment from each grid cell that reaches the overland pour point into in-channel areas, a Sediment Delivery Ratio (SDR) was applied as defined based on the Minnesota Phosphorus Index (MN P-Index). This relates the flow length between the source of sediment loading and the point of interest. In this case, the point of interest is defined as the overland pour point. The flow length component of the SDR relationship was derived from the HydroDEM. Figure 9 illustrates the higher SDR for areas adjacent to in-channel areas and a reduced SDR as distance from in-channel areas increases. The SDR was applied to the total sediment loss per grid cell to determine how much of the total sediment loss within a grid cell reaches the in-channel areas. Figure 10 illustrates the effective sediment loading originating from each grid cell.

Values presented in Figure 10 were accumulated downstream to create a raster dataset that summarizes the total sediment load passing through each grid cell that reaches the pour point. This allowed for the total sediment load for each overland catchment area to be determined. Figure 11 illustrates the total sediment load of each overland catchment of the project watershed.

Total effective RUSLE sediment load passing through each grid cell were then scored by ranking each value against all other grid cell values in the project watershed using a cumulative log-normal distribution. Because total effective sediment loading for overland sheet flow areas is minimal, areas where the upstream flow length is less than 300 feet were eliminated. This provided a wider range of ranked values for overland channelized areas. Since RUSLE is a method for determining the potential for surface water erosion occurring in overland flow areas, in-channel areas as described in Section 2.D were also removed.

4. STREAM POWER INDEX (SPI)

A. Process Summary

The Stream Power Index (SPI) method accounts for the physical characteristics of the landscape to quantify the likelihood of surface water erosion. SPI methodology consists of multiplying the slope of a point by the contributing area to that same point. The higher the value, the greater the probability that surface water erosion will occur at that location.

SPI was applied to the project watershed using GIS raster data. Slope was derived from the raw “bare earth” DEM. Figure 3 illustrates the slope values generalized into 3 meter by 3 meter raster data. In general, the project watershed is consists of higher slopes to the east with slopes moderating further to the west. The contributing area was derived in raster format for each 3 meter by 3 meter grid cell using the HydroDEM. These two rasters were then multiplied to determine SPI for the watershed. Because the likelihood of gully erosion is generally low where rill and interrill flow occurs areas where the upstream flow length is less than 300 feet were eliminated. Since SPI is a method for determining the potential for surface water erosion for overland flow, in-channel areas as described in Section 2.D were also removed. Raw SPI values were then scored by ranking each value against all other values in the project watershed using a cumulative log-normal distribution. Figure 12 illustrates the mean SPI rank for each of the overland catchment areas.

5. SUMMARY

A. Watershed Scoring

The ranked values of RUSLE and SPI were combined to create a scoring system for the project watershed. This scoring system is on a scale of 100, with 100 being highest priority. The scoring system assumes an equal weight for SPI and RUSLE. SPI provides an index of erosion at the location, while RUSLE provides an index of the erosion for the upstream watershed. High scores correlate to areas where a high likelihood of erosion exists at that location as well as from the upstream contributing area. Figure 14 illustrates the mean score for overland catchments within the project watershed.

B. Current Conditions Summary

In general, the most significant surface water erosion appears to occur in the eastern third of the project watershed where high slopes are combined with a high percentage of land is in row crops. Minimal erosion appears to be occurring in the middle third of the watershed due to a high percentage of land in grass within this region. The western third of project watershed appears to have moderate erosion occurring. Despite flat landscapes, land use in the western third of the project watershed is predominantly row crops. The provided data and supplemental maps illustrate this at a much finer scale.

C. Guidance for BMP Implementation

Results will be provided to Clay County SWCD and Wilkin County SWCD to aid in marketing of BMPs within the project watershed. Results will be provided at a scale that will allow SWCD staff to determine where exactly to place BMPs on the landscape to maximize benefit. The provided data will also allow SWCD staff to quantify a percent reduction in overland sediment loading as a result of individual BMP projects within the project watershed.

Based on previous installations of sediment control basins in the region, SWCD staff indicated that this type of BMP practice is no longer feasible for contributing areas greater than 40 acres. Areas that have a contributing area less than 40 acres have been delineated using the HydroDEM and is illustrated in Figure 14.

A series of tools has been made available for SWCD staff to utilize for marketing BMP practices in the project area. These tools are summarized below:

- Results Mapping – Results have been mapped and attributed in a series of maps that encompass the entire project area. These maps have been generated at a 1:7000 scale.
- ArcMap Document – This is similar to the results maps. This will allow SWCD staff to customize maps to specific areas. An example map that can be generated with the ArcMap Document is presented in Figure 15.

- GIS Dataset – Various datasets have been generated from the results of the analysis. An in depth summary of data available to SWCD staff is contained in Appendix B.

D. Limitations of Data

This data is intended to provide a means for preliminary site selection and project evaluation. The analysis has been conducted as a desktop GIS exercise and has not been field verified. The results of this analysis should not be used as a substitute for detailed design procedures. It is strongly recommended to perform a field review of potential project sites before implementation to ensure the accuracy of the analysis.

References

1. U.S. Weather Bureau, Rainfall Frequency Atlas of the United States, Technical Paper No. 40
2. Natural Resource Conservation Service (NRCS), USDS. Soil Survey Geographic Database (SSURGO). Website: http://soildatamart.nrcs.usda.gov/
3. U.S. Department of Agriculture, Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE), Agricultural Handbook No. 703.
4. Natural Resource Conservation Service (NRCS), NRCS Minnesota Technical Guide, Section 1-C.
5. National Agricultural Statistics Service (NASS), 2010 Cropland Data Layer (CDL), Website: http://www.nass.usda.gov/

Appendix A

Figures

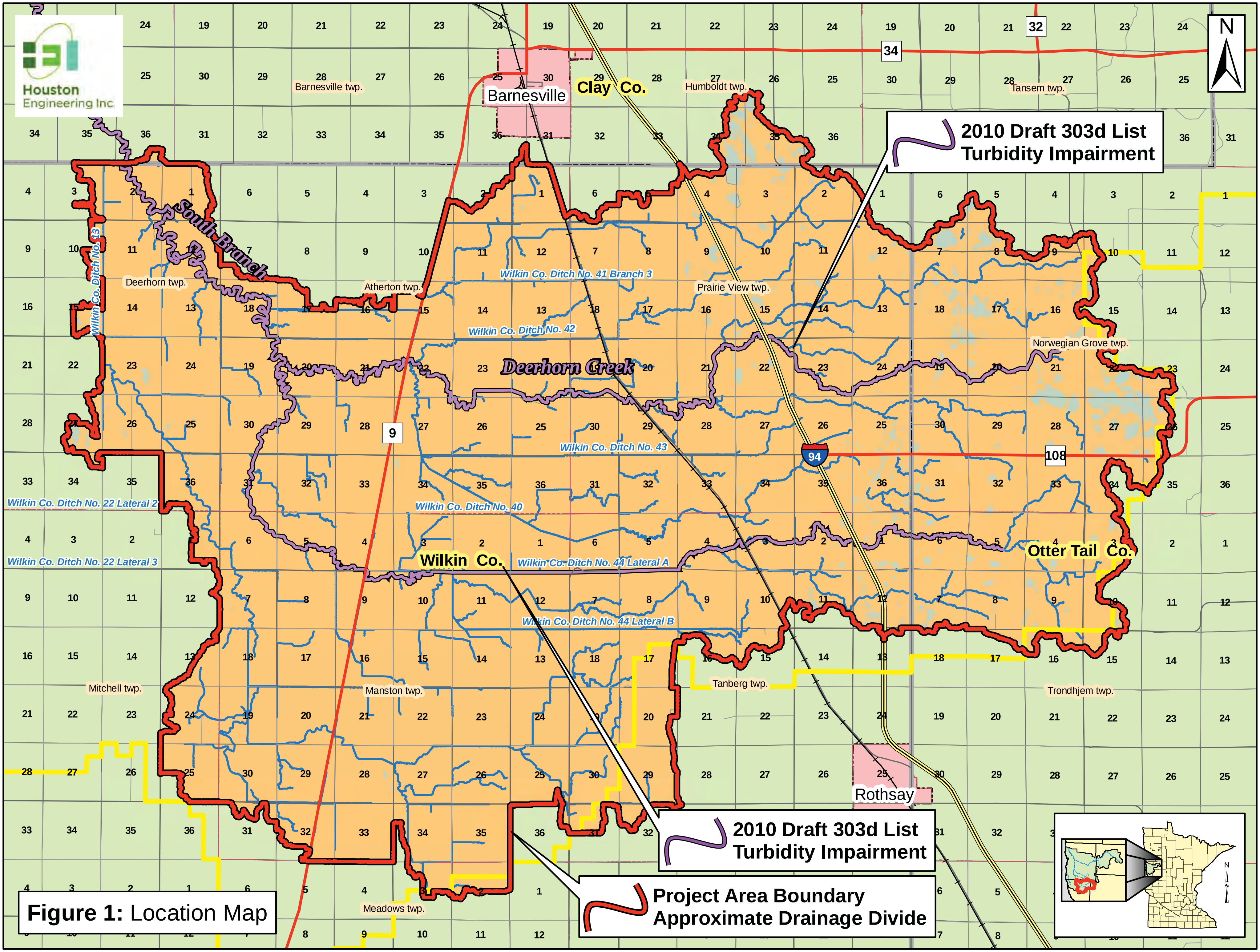

Figure 1: Location Map

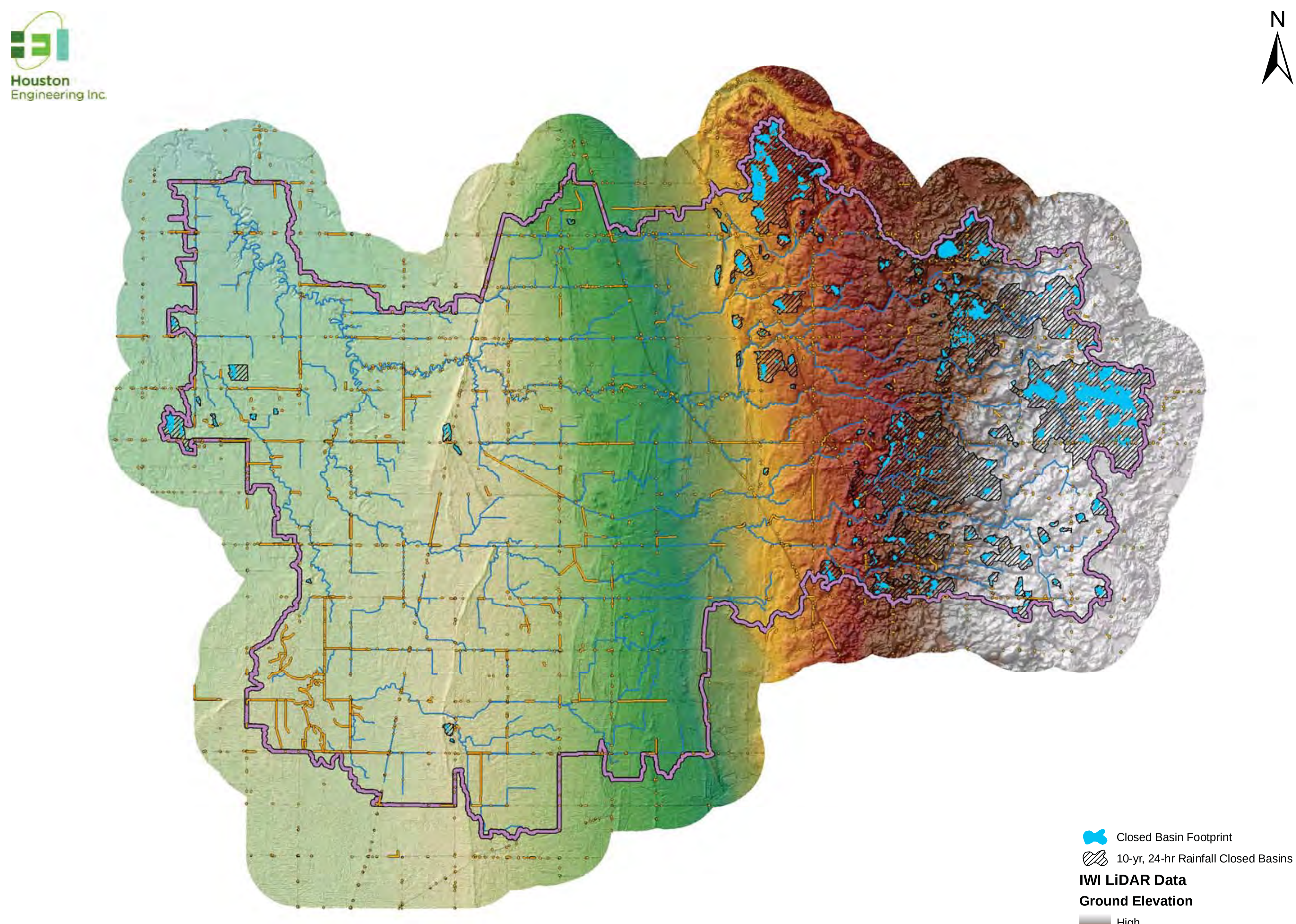

Figure 2: DEM Reconditioning

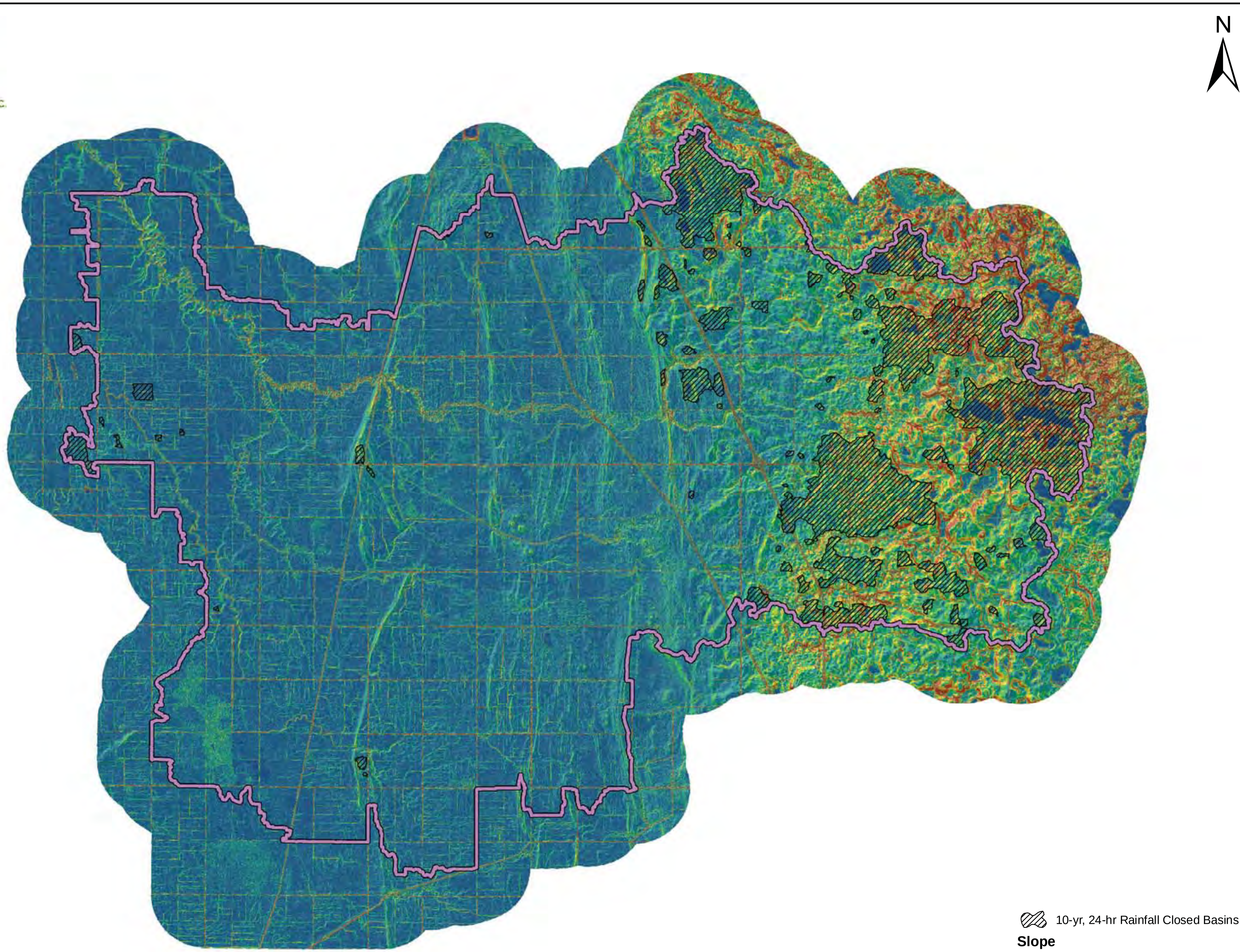

Figure 3: LiDAR Derived Slope

Figure 4: 2010 NASS Data

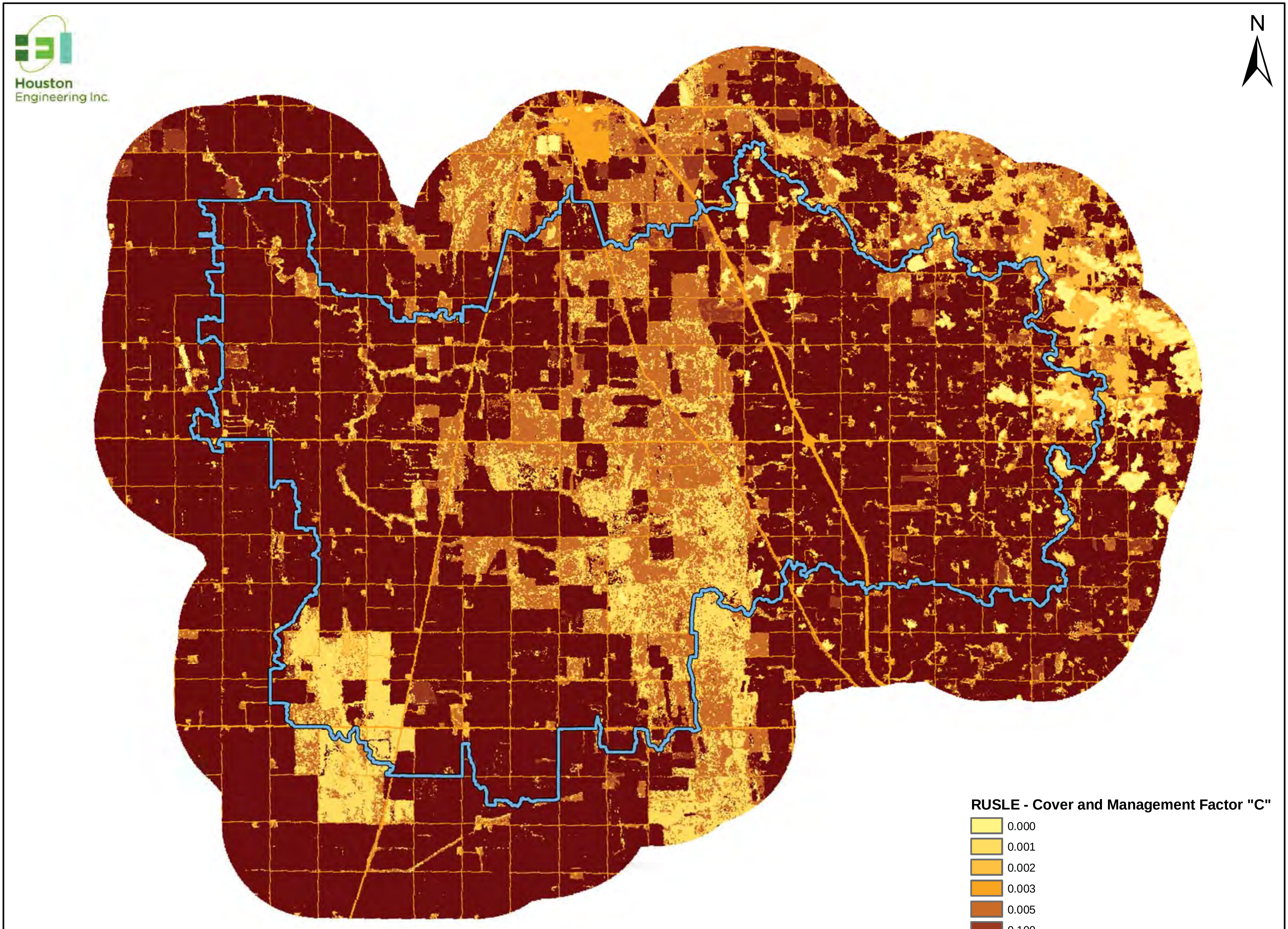

Figure 5: RUSLE Cover and Management Factor "C"

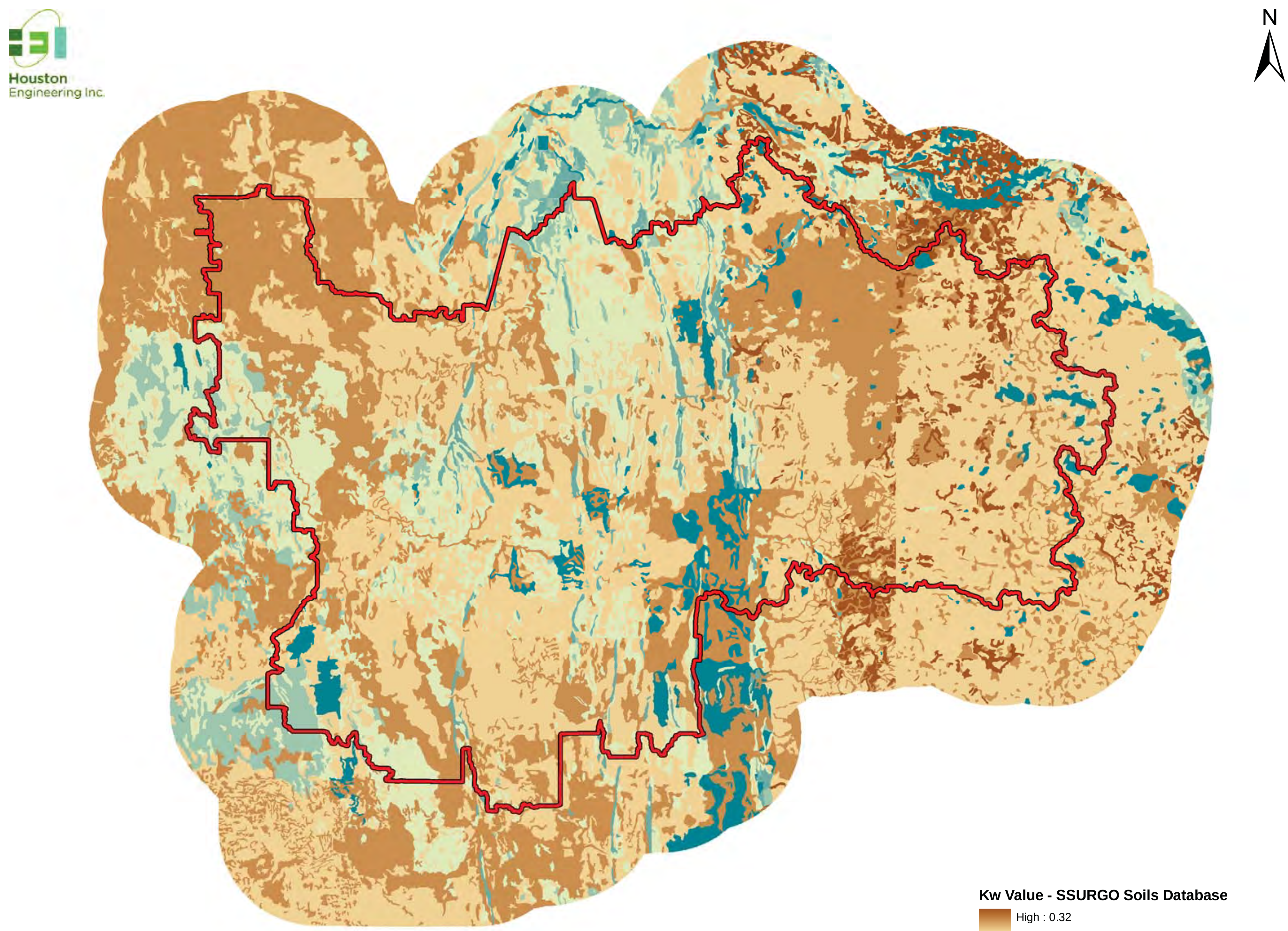

Figure 6: Kw Value - SSURGO Soils Database

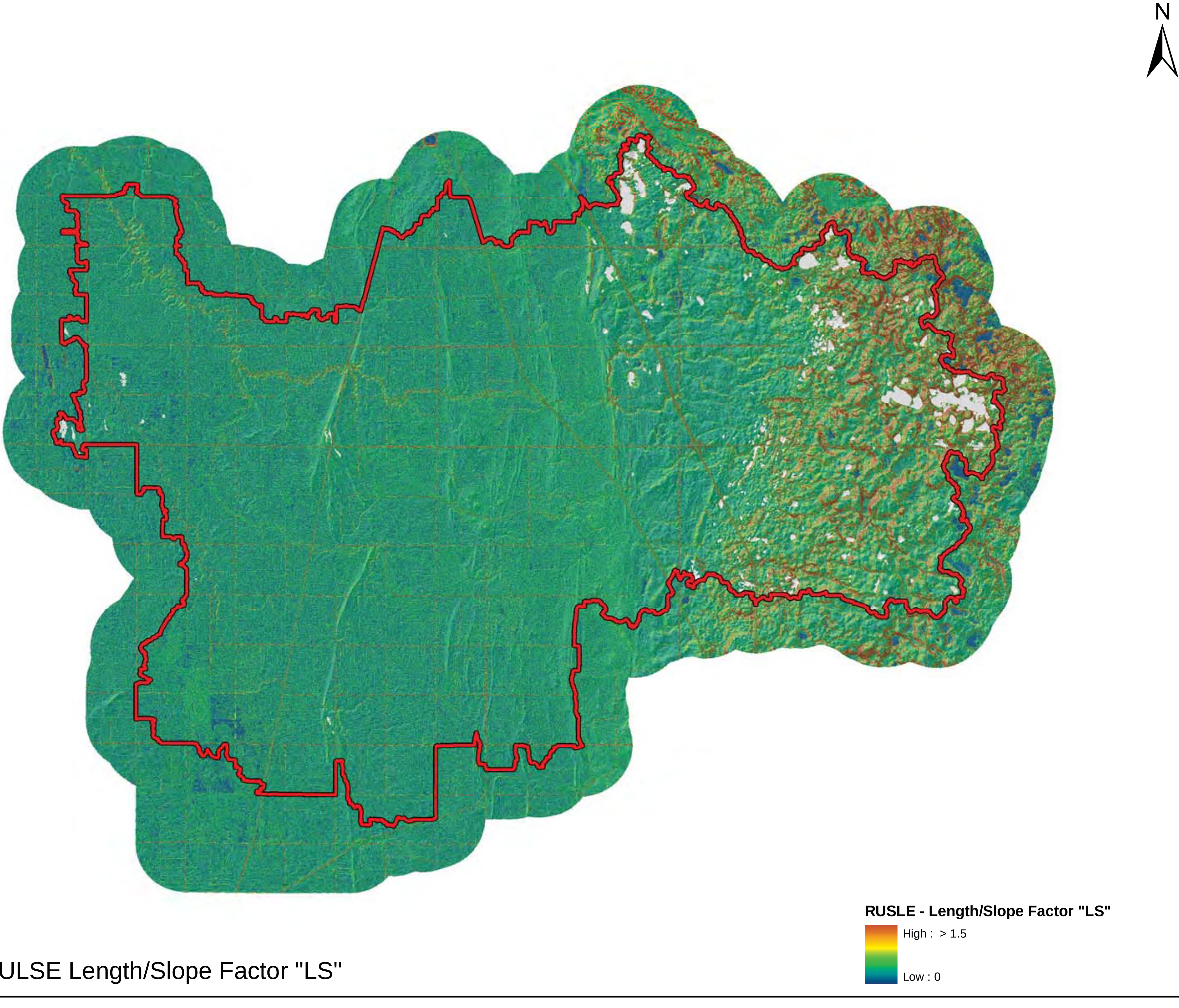

Figure 7: RULSE Length/Slope Factor "LS"

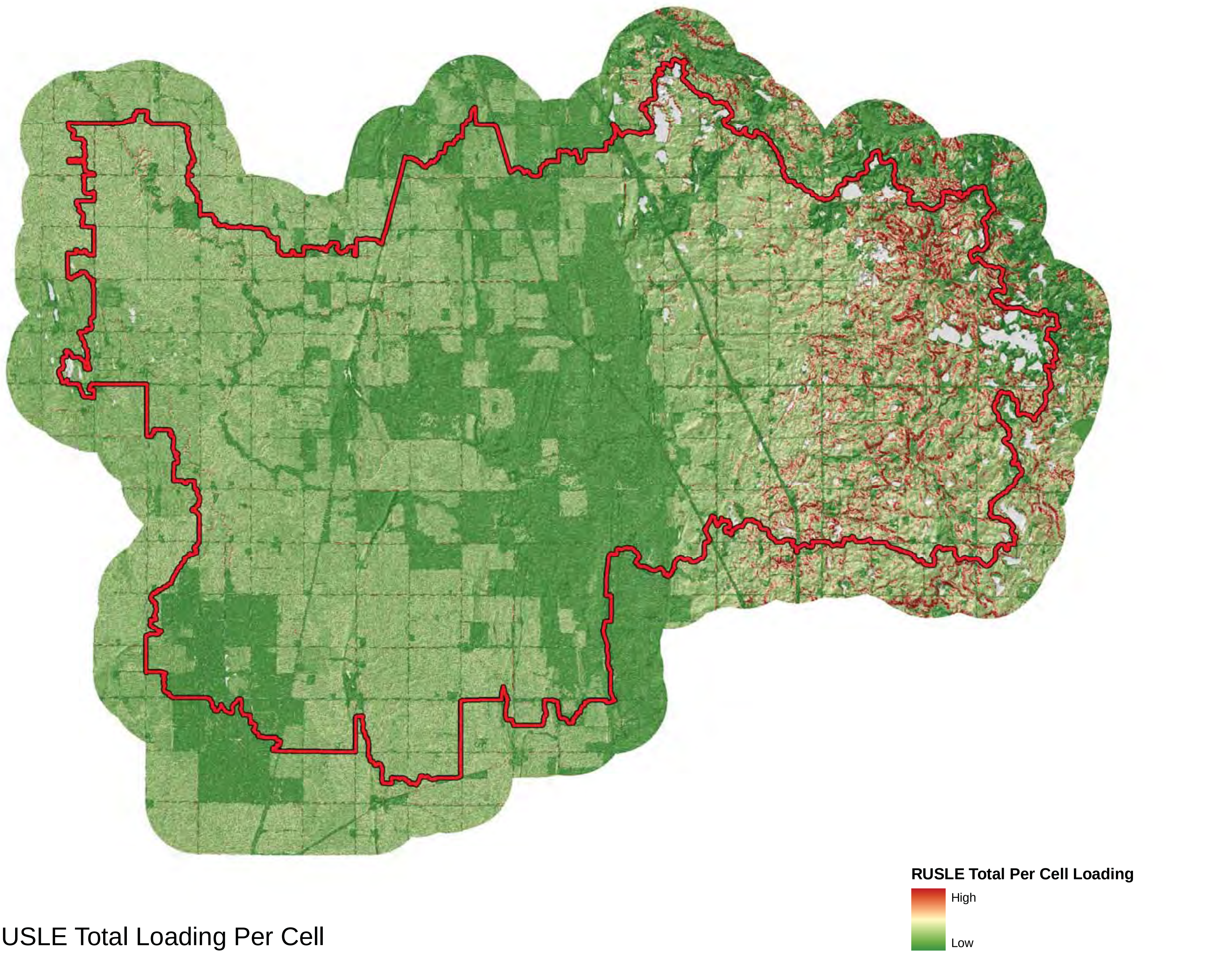

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Figure 8: RUSLE Total Loading Per Cell

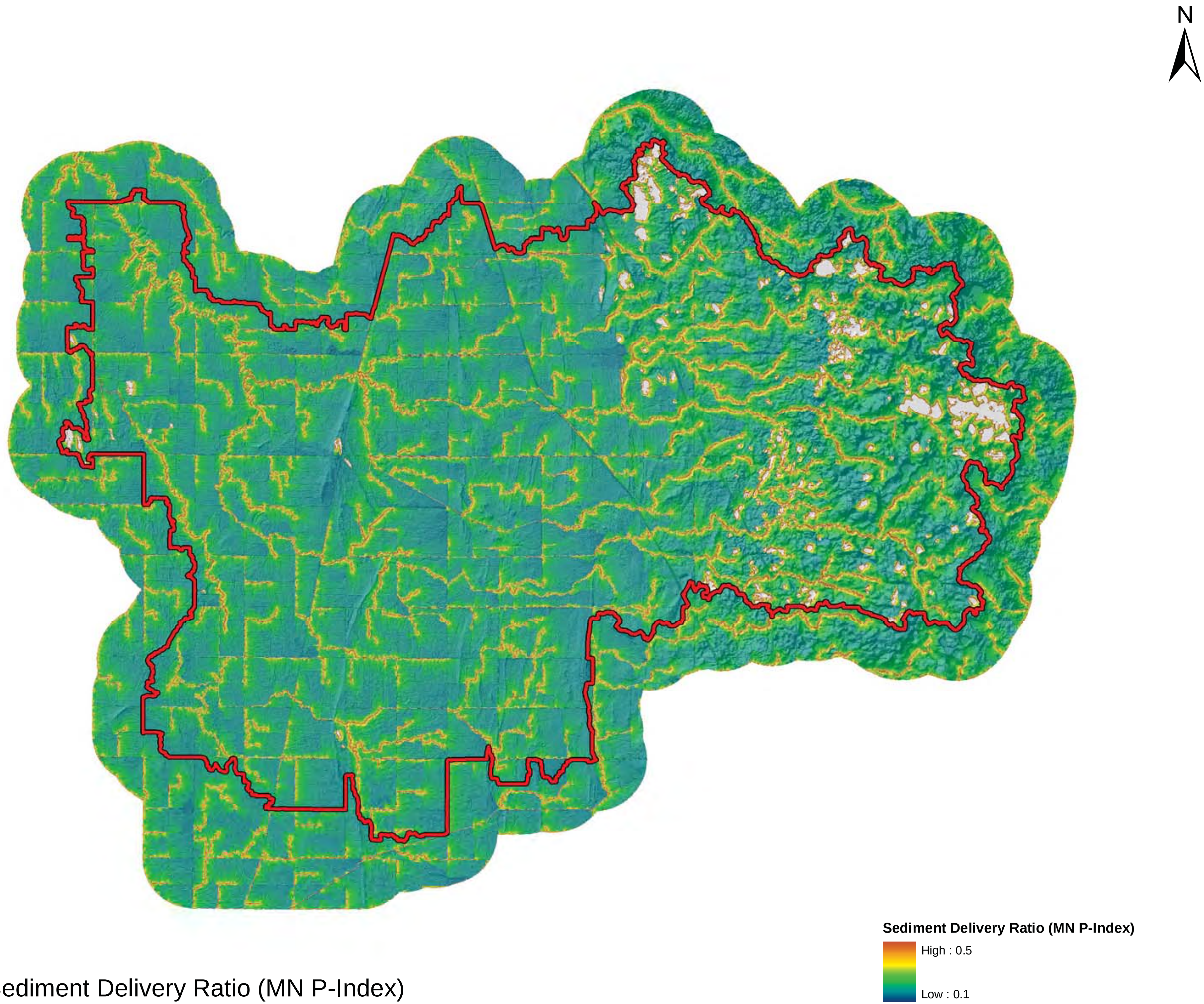

Figure 9: Sediment Delivery Ratio (MN P-Index)

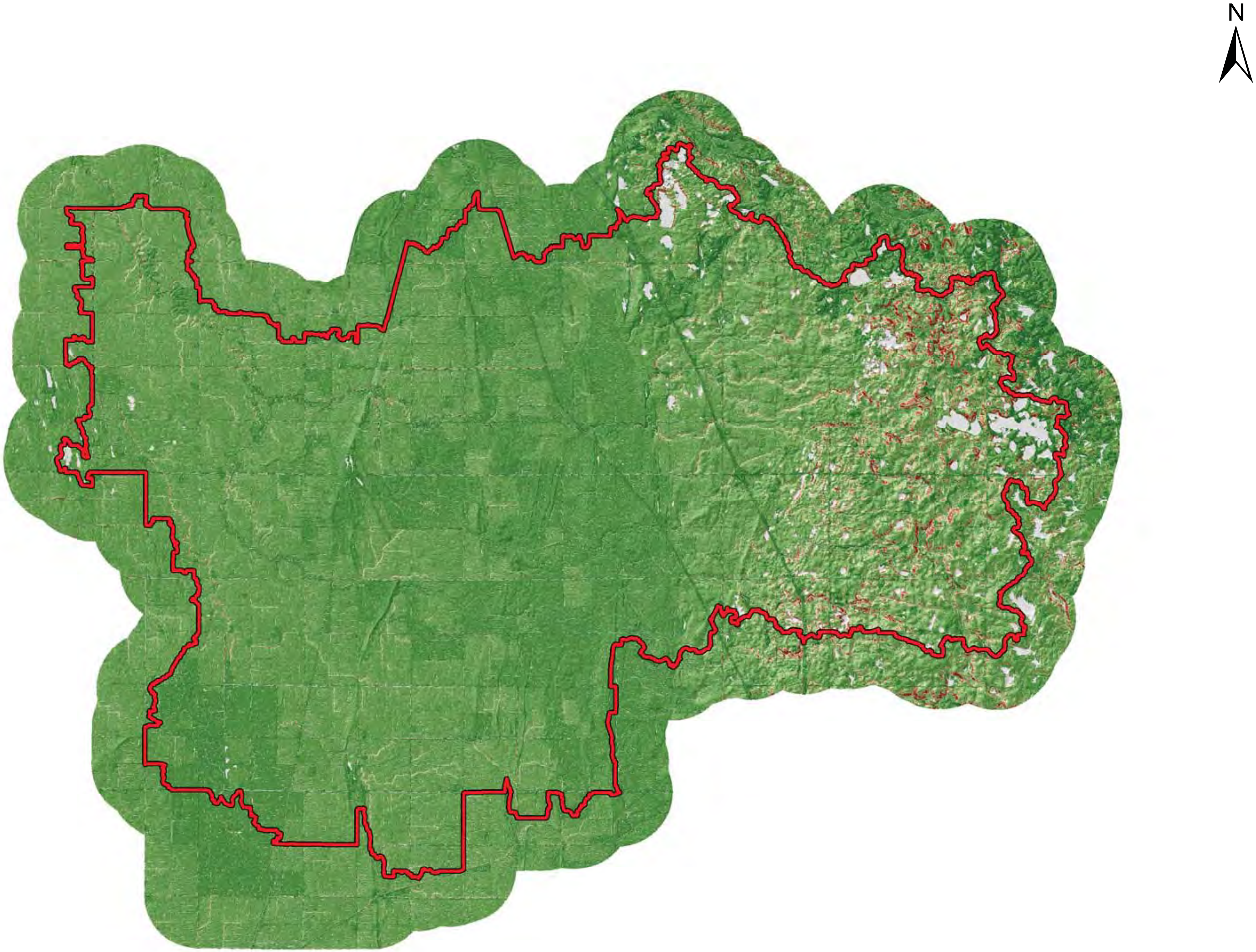

Figure 10: RUSLE Effective Source Loading at Pour Point

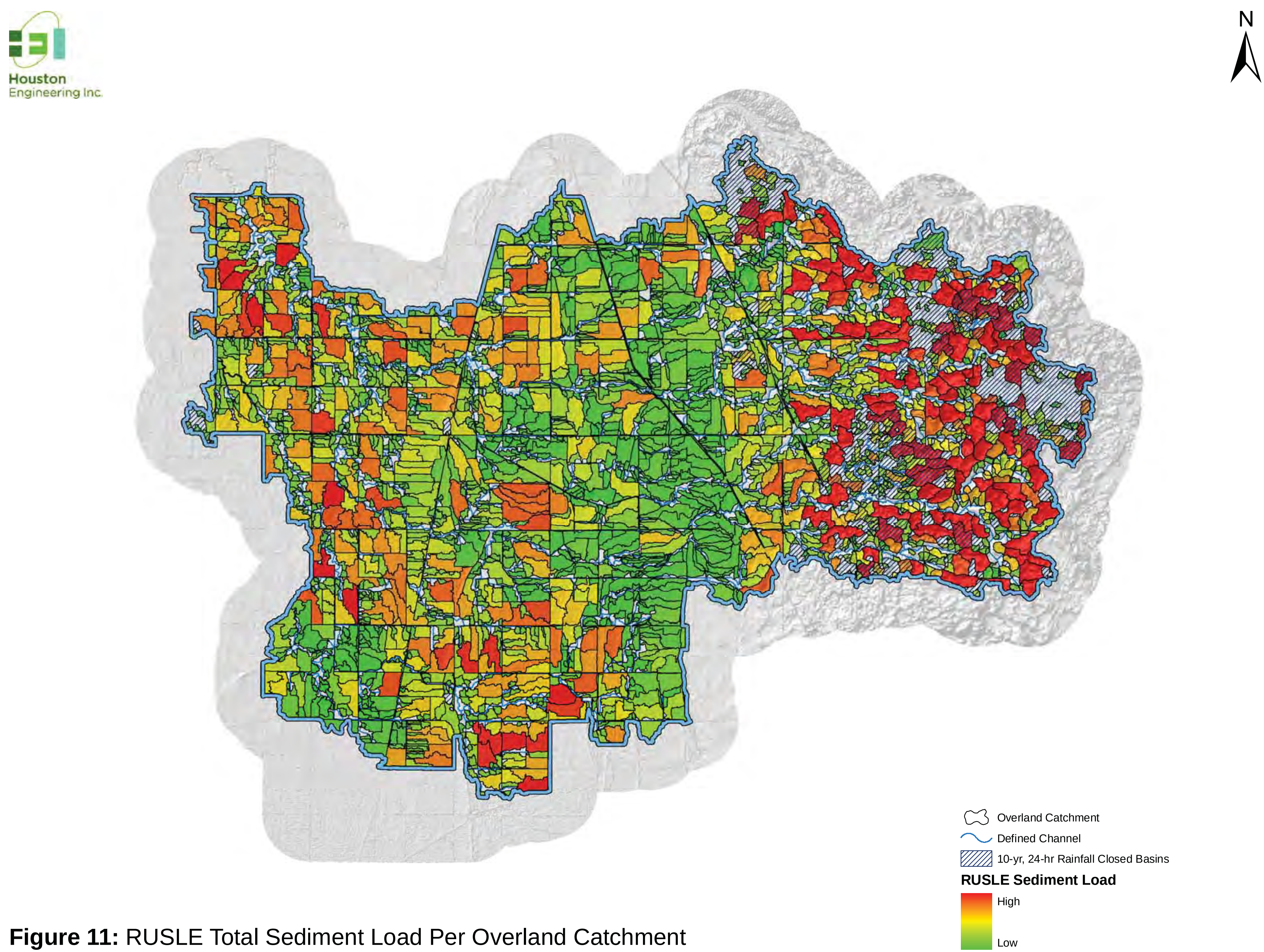

Figure 11: RUSLE Total Sediment Load Per Overland Catchment

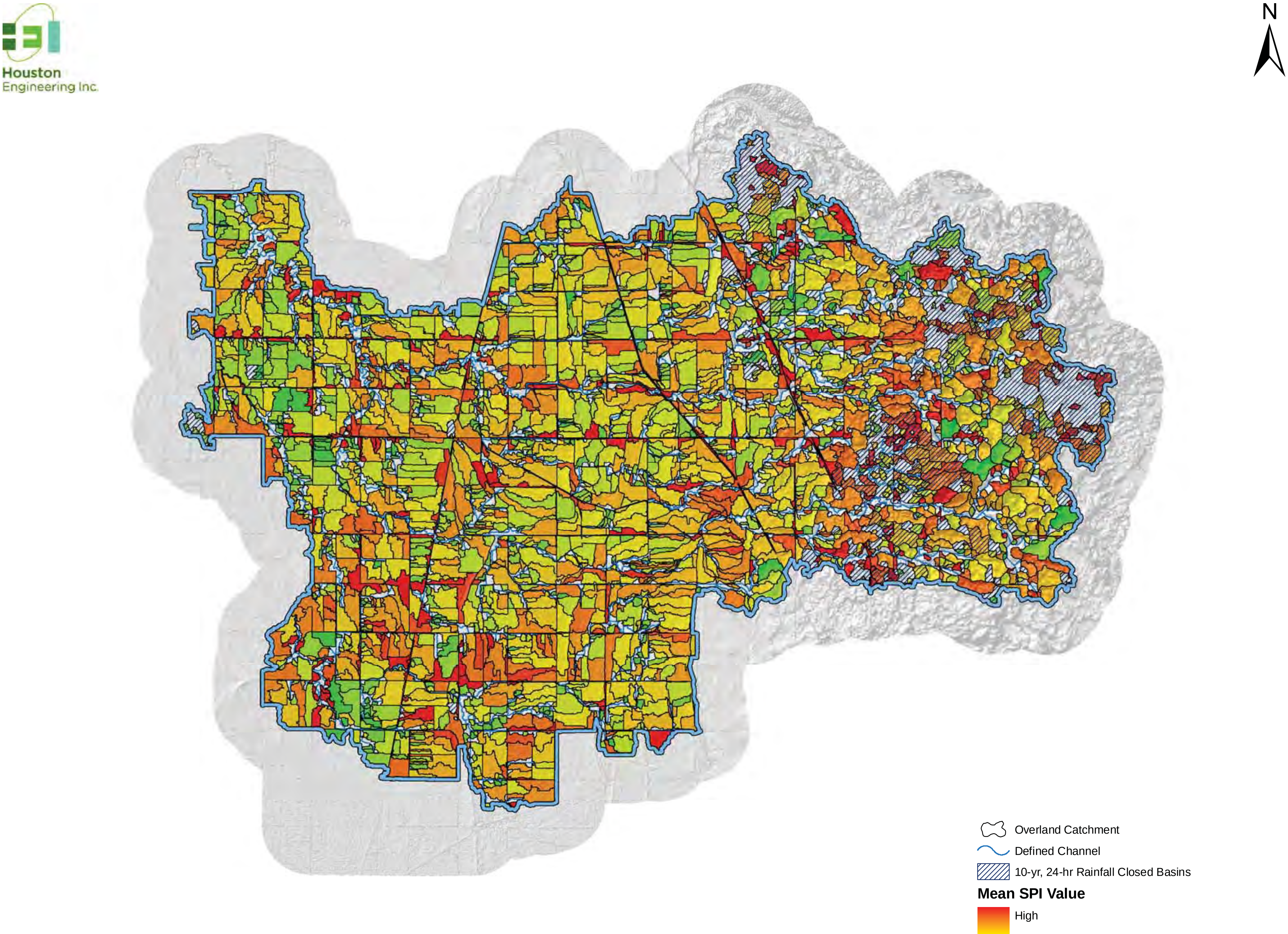

Figure 12: Mean SPI Value for Overland Catchments

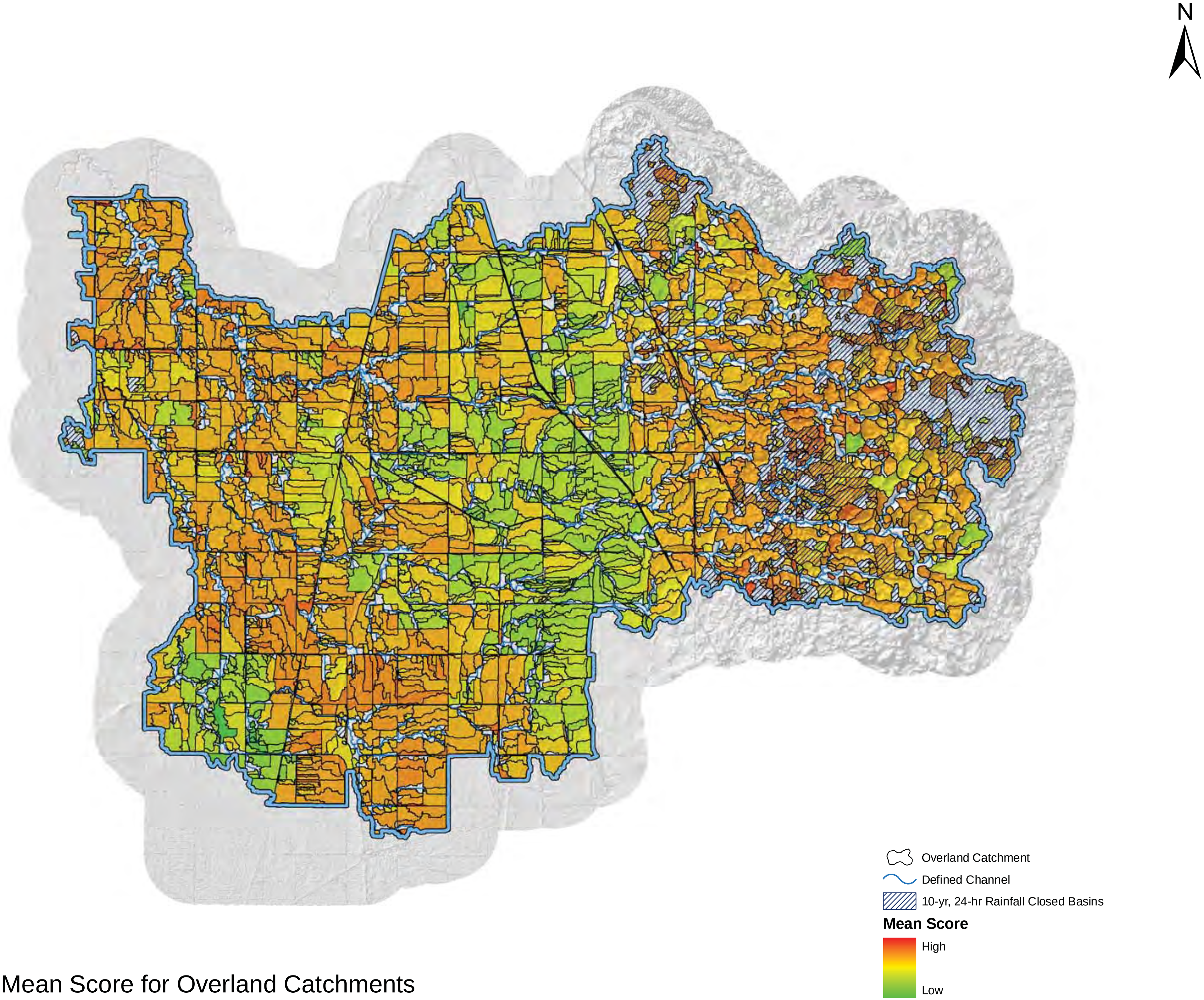

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Figure 13: Mean Score for Overland Catchments

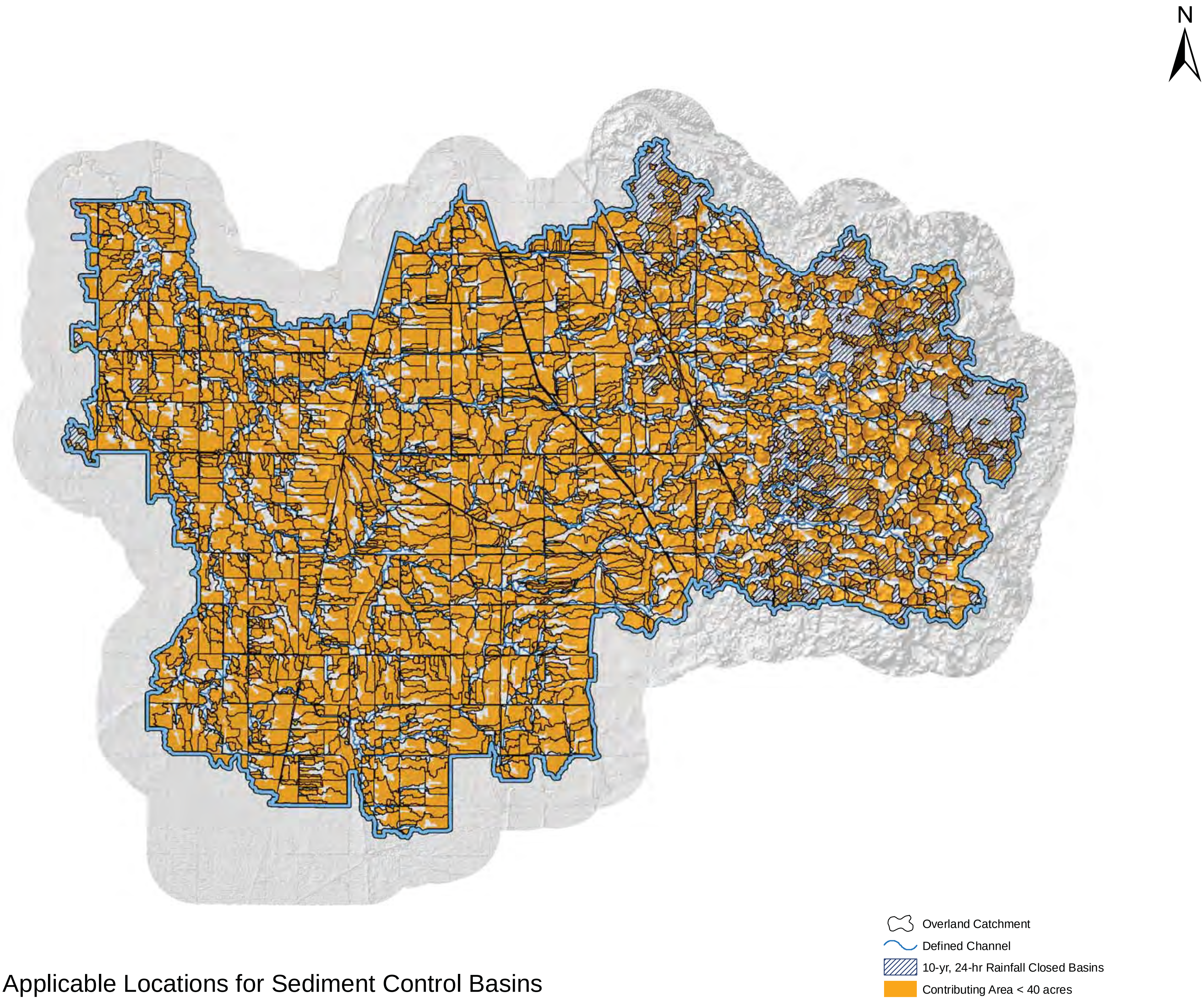

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Figure 14: Applicable Locations for Sediment Control Basins

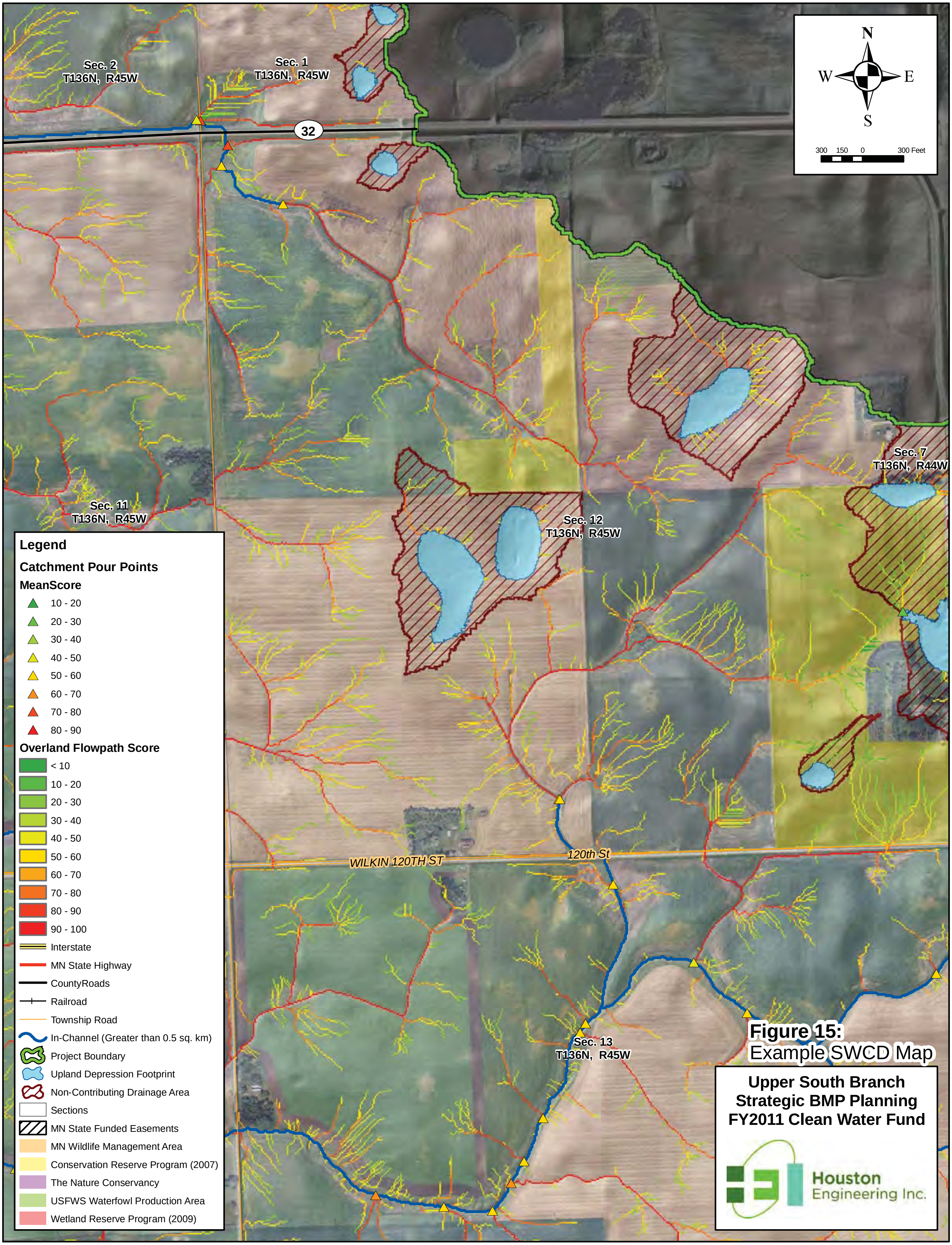

Figure 15:
Example SWCD Map

Appendix B

GIS Data Summary

GIS Data Summary

1. **Usb_DEM**
   a. *Data type*: Raster
   b. *Summary*: Raw LiDAR derived DEM. 3 meter by 3 meter resolution. Elevation units are in feet (NAVD88).
2. **Score**
   a. *Data type*: Raster
   b. *Summary*: Combined scoring of the Stream Power Index and the Revised Universal Soil Loss Equation. Based on a 50/50 split of the percentile rank of SPI and RUSLE for channelized overland flow. (Upstream flow length > 300 feet and contributing area < 0.5 sq. km). High score equates to high priority.
3. **Ls_factor**
   a. *Data type*: Raster
   b. *Summary*: RULSE Length/Slope factor. Calculated using the HydroDEM. Methodology from USDA Agricultural Handbook No. 703.
4. **Rusle_percell**
   a. *Data type*: Raster
   b. *Summary*: The total sediment loading passing through the grid cell on the pour point. Values are in total tons.
5. **Rusle_eff**
   a. *Data type*: Raster
   b. *Summary*: The effective sediment loading passing through the grid cell on the pour point. Values are in total tons reaching the corresponding pour point.
6. **Rusle_rank**
   a. *Data type*: Raster
   b. *Summary*: RUSLE_eff raster accumulated in a downstream direction to create a total effective sediment loading as a result of the upstream area.
7. **Rusle_rank**
   a. *Data type*: Raster
   b. *Summary*: Ranking of the Rusle_eff grid for areas of channelized overland flow (upstream flow length > 300 feet and contributing area < 0.5 sq. km). Sheet flow was eliminated from dataset (upstream flow length < 300 ft). Cumulative percentile rank using log-normal distribution.
8. **Spi_rank**
   a. *Data type*: Raster
   b. *Summary*: Stream Power Index percentile ranking for areas of channelized overland flow (upstream flow length > 300 feet and contributing area < 0.5 sq. km). Cumulative percentile rank using log-normal distribution.

9. **Flowpaths.shp**
   a. *Data Type*: Polyline Shapefile
   b. *Summary*: LiDAR derived flowpaths.
   c. *Attributes*:
      i. *Type*: Defines in-channel or overland.
         1. Overland (Greater than 5 acres)
         2. In-Channel (Greater than 0.5 sq. km)
      ii. *CloseBasin*: Defines if flowpath is in a closed basin based on a 10-year, 24-hour rainfall event (TP-40).
         1. *Value = 1*: Contained within a closed basin
         2. *Value = 0*: Within the Contributing Watershed

10. **Overland_Catchment.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Contributing areas for overland flow for drainage areas ranging from contributing areas < 0.5 sq. km and contributing areas > 5 acres.
   c. *Attributes*:
      i. *CatID*: Common ID with corresponding Overland_Pourpoint.shp
      ii. *Catch_Acre*: Total Contributing area to the pour point
      iii. *MeanScore*: Mean value of the Score raster dataset for the corresponding overland catchment area.
      iv. *RUSLE_Rank*: Mean value of the Rusle_rank raster dataset for the corresponding overland catchment area.
      v. *SPI_Rank*: Mean value of the spi_rank raster dataset for the corresponding overland catchment area.
      vi. *RUSLE_SedL*: Total Sediment load reaching the pour point from the corresponding overland catchment area.
      vii. *CloseBasin*: Defines if corresponding catchment is in a closed basin based on a 10-year, 24-hour rainfall event (TP-40).
         1. *Value = 1*: Contained within a closed basin
         2. *Value = 0*: Within the Contributing Watershed

11. **Overland_Pourpoint.shp**
   a. *Data Type*: Point Shapefile
   b. *Summary*: Outlet locations of overland flow into in-channel flow. Defined as contributing areas greater than 5 acres and less than 0.5 sq. km.
   c. *Attributes*:
      i. *CatID*: Common ID with corresponding Overland_Catchment.shp
      ii. *Catch_Acre*: Total Contributing area to the pour point
      iii. *MeanScore*: Mean value of the Score raster dataset for the corresponding overland catchment area.

iv. *RUSLE_Rank*: Mean value of the Rusle_rank raster dataset for the corresponding overland catchment area.
v. *SPI_Rank*: Mean value of the spi_rank raster dataset for the corresponding overland catchment area.
vi. *RUSLE_SedL*: Total Sediment load reaching the pour point from the corresponding overland catchment area.
vii. *CloseBasin*: Defines if corresponding catchment is in a closed basin based on a 10-year, 24-hour rainfall event (TP-40).
   1. *Value = 1*: Contained within a closed basin
   2. *Value = 0*: Within the Contributing Watershed

12. Ranked_Overland_Flowpaths.shp

a. *Data Type*: Polyline Shapefile
b. *Summary*: Overland flowpaths ranked based on the score raster dataset. Also prioritizes reaches for Sediment Control Basins based on contributing area. Areas that are ideal for sediment control basins consist of locations where the contributing area is less than 40 acres. The overland flowpaths consist of areas where the contributing area ranges from a minimum of 5 acres and a maximum of 0.5 sq. km.
c. *Attributes*:
   i. *SedBasin*: Areas acceptable for Sediment Control Basins
      1. *Value = 1*: Contributing area less than 40 acres (ideal for sed basins)
      2. *Value = 0*: Contributing area greater than 40 acres (not ideal for sed basins)
   ii. *MinScore*: Minimum score of range used for priority field. Source data from the score raster dataset.
   iii. *MaxScore*: Maximum score of range used for priority field. Source data from the score raster dataset.
   iv. *Priority*: Priority for implementation. Based on the range established from the MinScore and MaxScore fields.
      1. *Extremely Low* (score < 75)
      2. *Low* (75 < score < 85)
      3. *Moderate* (85 < score < 95)
      4. *High* (score > 95)
   v. *CloseBasin*: Defines if flowpath is in a closed basin based on a 10-year, 24-hour rainfall event (TP-40).
      1. *Value = 1*: Contained within a closed basin
      2. *Value = 0*: Within the Contributing Watershed

13. ContribWatershed_10yr24hr_rainfall.shp

a. *Data Type*: Polygon Shapefile
b. *Summary*: Total contributing area for the project. Contributing area is defined as areas that would contribute to the South Branch at the Clay/Wilkin county line for a 10-year, 24-hour rainfall event (TP-40).

   c. *Attributes*:
      i. *Area_SqMi*: Contributing area in square miles
      ii. *Acres*: Contributing area in acres

14. **NonContribAreas_10yr24hr_rainfall.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Non-contributing area for the project. Non-contributing area is defined as areas that would not contribute to the South Branch at the Clay/Wilkin county line for a 10-year, 24-hour rainfall event (TP-40).
   c. *Attributes*:
      i. *Area_SqMi*: Non-contributing area in square miles
      ii. *Acres*: Non-contributing area in acres

15. **ProjectWatershed.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Total area to the South Branch at the Clay/Wilkin county line based assuming everything contributes.
   c. *Attributes*:
      i. *Area_SqMi*: Total area in square miles
      ii. *Acres*: Total area in acres.

16. **SedBasin_Areas.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Areas that would be considered more ideal for sediment control basin BMP practices. These areas are defined as the contributing watershed for regions of contributing areas less than 40 acres.
   c. *Attributes*:
      i. *CloseBasin*: Defines if the area is in a closed basin based on a 10-year, 24-hour rainfall event (TP-40).
         1. *Value = 1*: Contained within a closed basin
         2. *Value = 0*: Within the Contributing Watershed

17. **Final_10year_Depressions.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Footprint of non-contributing basins at the spill out elevation for the depressed area.
   c. *Attributes*:
      i. *GridID*: Common ID with GridID field from Final_10year_DepressionDA.shp.
      ii. *FillElev*: Elevation in feet of the spill out elevation of the depression
      iii. *FillArea*: Surface area in acres
      iv. *DrainArea*: Contributing area in acres

18. **Final_10year_DepressionDA.shp**
   a. *Data Type*: Polygon Shapefile
   b. *Summary*: Corrisponding contributing area of Final_10year_Depressions.shp.
   c. *Attributes*:

i. *GridID*: Common ID with GridID field from Final_10year_Depressions.shp.
ii. *DrainArea*: Contributing area in acres

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