# Final Sand Hill River Watershed Restoration and Protection Strategy Report

*October 2017*

SAND HILL RIVER
WATERSHED DISTRICT

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY

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## Key Terms

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

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

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

**Hydrologic Unit Code (HUC):** A Hydrologic Unit Code (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.

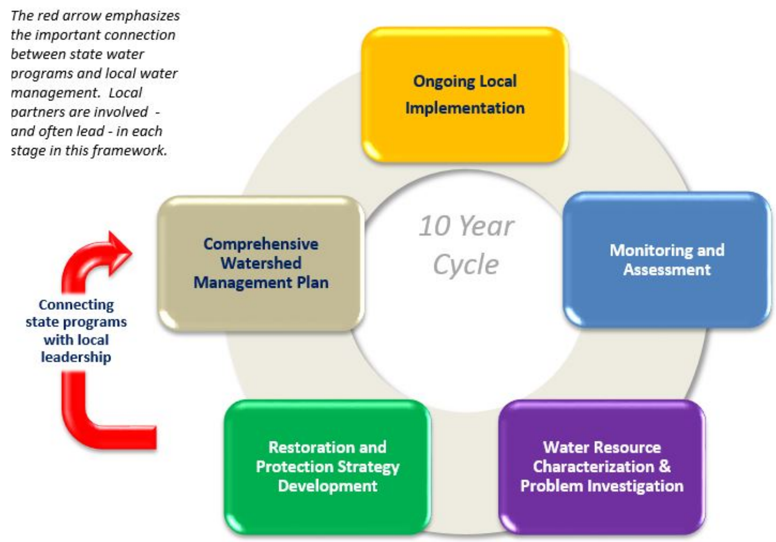
**Restoration:** This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

**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.

## What is the WRAPS Report?




The State of Minnesota has adopted a watershed approach to address the state's 80 major watersheds, denoted by 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 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 Total Maximum Daily Load (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 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<br>• Summarize Watershed Approach work done to date including the following reports:<br>  • *Sand Hill River Watershed Monitoring and Assessment*<br>  • *Sand Hill River Watershed Biotic Stressor Identification*<br>  • *Sand Hill River Watershed Total Maximum Daily Load Study* |
| Scope | • Impacts to aquatic recreation and to aquatic life in streams<br>• Impacts to aquatic recreation in lakes |
| Audience | • Local working groups (local governments, SWCDs, watershed management groups, etc.)<br>• State agencies (MPCA, DNR, BWSR, etc.) |

# 1. Watershed Background & Description

The Sand Hill River Watershed (SHRW) is located in northwest Minnesota and comprises approximately 495 square miles within Polk, Norman, and Mahnomen counties. The watershed 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, with some pasture and grasslands found in the central portion and forested areas in the eastern portion. Municipalities located within the SHRW include Beltrami, Climax, Fertile, Fosston, Nielsville, and Winger, which account for two-thirds of the watershed's population. Additional background information and descriptions of the SHRW can be found in the resources listed below.

***Additional Sand Hill River Watershed Resources***

Sand Hill River Watershed Conditions Report (HEI 2011a)

Sand Hill River Watershed Conditions Report Addendum (HEI 2014)

United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Sand Hill River Watershed:
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021584.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Sand Hill River Watershed:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/wsmb61.pdf

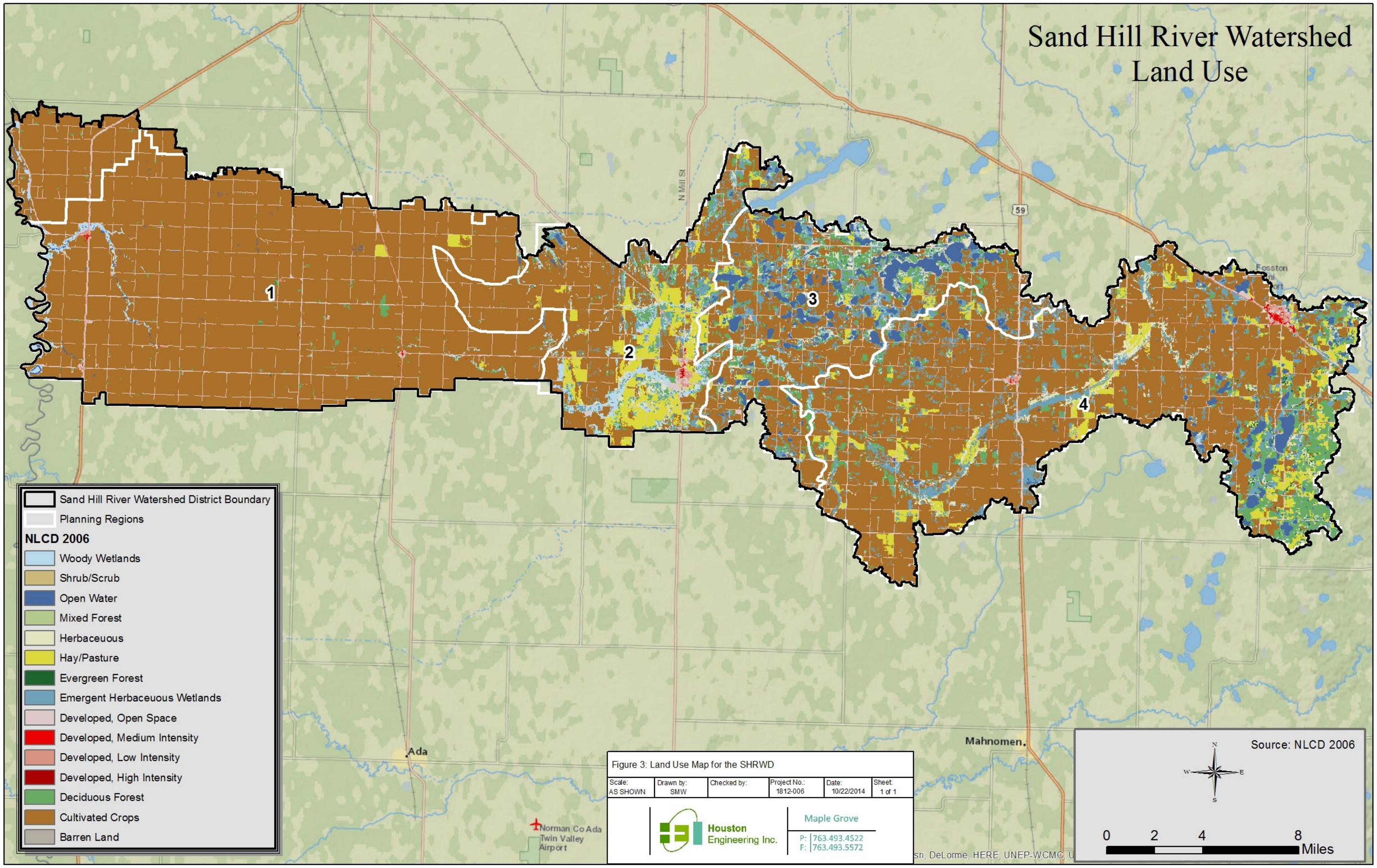



**Figure 1: Sand Hill River Watershed land use (NLCD 2006).**

## 2. Watershed Conditions

The water resources within much of the SHRW consist of rivers, streams, and ditches passing through a predominantly agricultural watershed draining west to the Red River of the North.

There are 16 lakes and 8 stream reaches in the SHRW that are defined by the State of Minnesota (i.e., have an Assessment Unit ID – AUID – or DNR lake number) and had their water quality assessed by the Minnesota Pollution Control Agency (MPCA). The Red River of the North mainstem, forming the boundary between Minnesota and North Dakota, is excluded from this Watershed Restoration and Protection Strategy (WRAPS). Not all of the assessed lakes and streams were fully assessed for impairment due to reasons including: insufficient monitoring data, limited resources waters, or predominantly channelized stream reaches. Of the eight assessed stream segments (i.e., AUIDs), two were not assessed for impairment because of insufficient information, six were assessed to some degree, and five of those were assessed as not supporting aquatic life or aquatic recreation (MPCA 2012). All 16 lakes were assessed and 4 of those were assessed as not supporting aquatic recreation. The nature of the impairments, leading to the lack of support for aquatic recreation, are those commonly occurring in in this region including: an overabundance of sediment, excessive bacteria levels, nutrient enrichment, and reduced biological abundances (low fish or macroinvertebrate numbers).

There are five National Pollutant Discharge Elimination system (NPDES) permitted point sources currently active in the SHRW, four municipal wastewater treatment facilities, and one industrial (i.e., food processing-potato washing) wastewater treatment facility . In addition, there are 46 registered feedlots, 47 Construction Stormwater Permits covered under Minnesota's NPDES/State Disposal System (SDS) Construction Stormwater (CSW) General Permit (MNR100001), and 10 Industrial Stormwater Permits covered under Minnesota's NPDES/SDS General Permit (MNR050000) for Industrial Stormwater Multi-Sector (IWS). There are no individual NPDES Permits for feedlots, CSW, or industrial stormwater in the SHRW. 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 SHRW can be found in the Watershed Conditions Report (HEI 2011) and its addendum (HEI 2014d), the Monitoring and Assessment Report (MPCA 2014a) and the Biotic Stressor Identification Report (SID) (MPCA 2014b). The conditions and associated pollutant sources of these individual streams and lakes are summarized in the following sections.

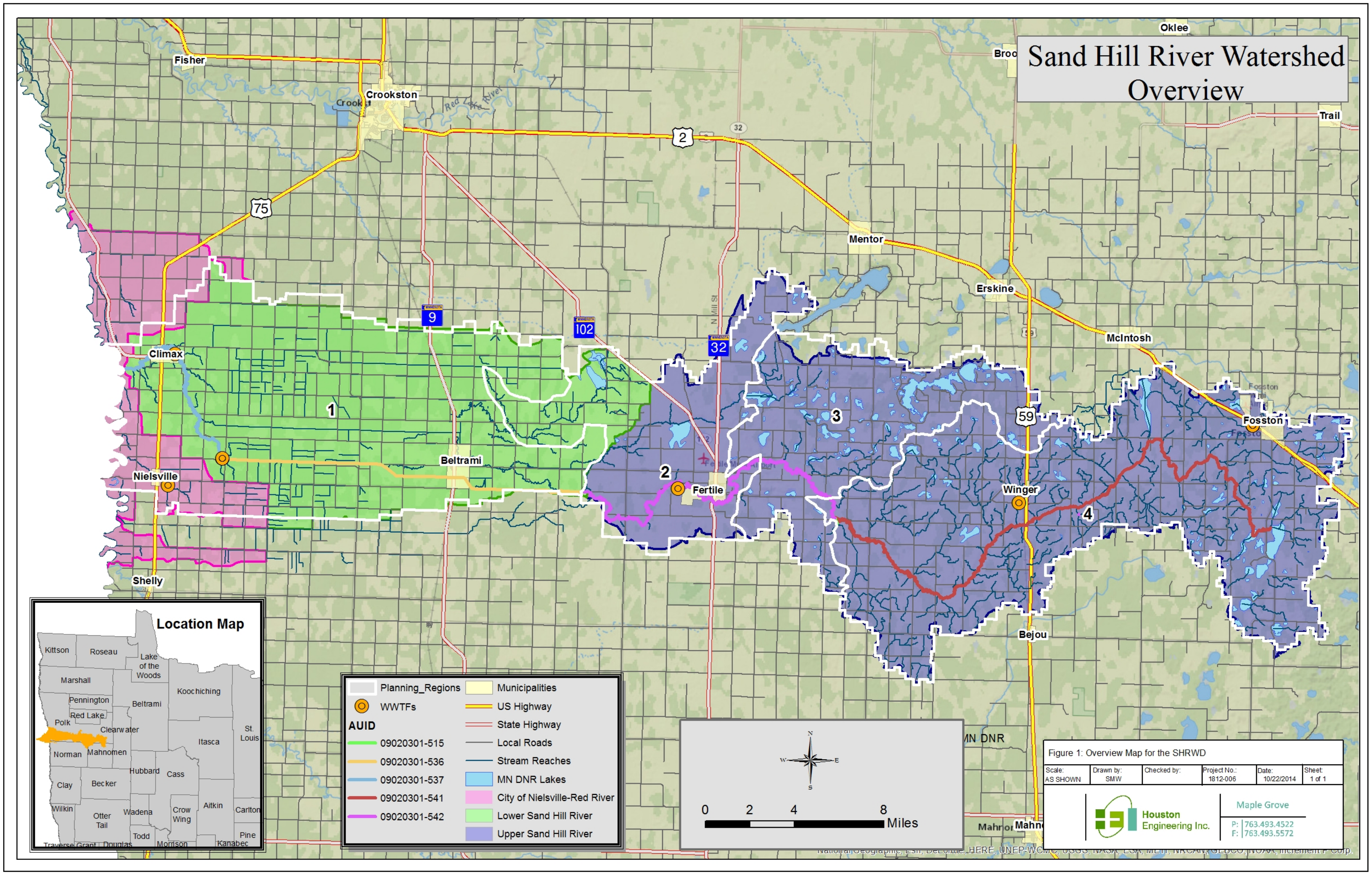



**Figure 2: Sand Hill River Watershed regulated and impaired water.**

## 2.1 Condition Status

This section describes the streams and lakes within the SHRW 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 SHRW are generally poor and are typical of this region. Much of the land use is in agricultural production, waterways are channelized or straightened, hydrology has been altered, and there is a lack of riparian cover around many of the lakes and streams in the watershed (MPCA 2014b). Excess bacteria and reduced biological assemblages are problems in most of the assessed waterways. However, most of the assessed lakes of the watershed are in good condition.

Factors considered in determining whether a stream is capable of supporting and harboring aquatic life (generally fish and aquatic insects) include the fish index of biological integrity (FIBI), macroinvertebrate index of biological integrity (MIBI), the concentration of dissolved oxygen (DO) and the turbidity/sediment level. Factors considered in assessing the suitability of a water body for aquatic recreation include the amount of bacteria and levels of nutrients.

Some of the waterbodies in the SHRW 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 SHRW streams including fish and macroinvertebrate IBI, DO concentrations, turbidity/suspended solids and bacteria. Water quality measurements and observations were compared to the state standards as well as the normal ranges 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 SHRW's AUID stream segments are listed in **Table 1**, with stream condition summaries provided for each of the segments. The SHRW contains thirty stream reaches with unique AUIDs, eight of which have been assessed. Of those eight, six have sufficient data to determine whether the segment is impaired. Of the six AUIDs with sufficient data, one does not support aquatic life, three do not support both aquatic life and aquatic recreation, and one does not support aquatic recreation. Information used to create this table was summarized using the MPCA's Watershed Monitoring and Assessment Report (MPCA 2014b), as well as the MPCA's Watershed Biotic SID Report (MPCA 2014a).

**Table 1: Assessment status of stream reaches in the Sand Hill River Watershed, presented by 10-digit HUC.**

| HUC-10 Subwatershed | AUID (Last 3 digits) | Stream | Reach Description | Aquatic Life | | | | Aq Rec |
|---|---|---|---|---|---|---|---|---|
| | | | | Fish Index of Biotic Integrity | Macroinvertebrate Index of Biotic Integrity | Dissolved Oxygen | Turbidity/TSS | Bacteria |
| Upper Sand Hill River | 541 | Sand Hill River | Headwaters to CD 17 | Imp | Imp | Imp | Imp | Imp |
| | 512 | County Ditch 16 | CD55 to Sand Hill R | IF | IF | IF | IF | NA |
| | 510 | Unnamed ditch | Headwaters to Sand Hill R | NA | NA | NA | NA | NA |
| | 513 | Unnamed creek | unnamed cr to Sand Hill R | NA | NA | NA | NA | NA |
| | 514 | Garden Slough | Unnamed cr to CD17 | NA | NA | NA | NA | NA |
| | 515 | County Ditch 17 | Garden Slough to Sand Hill R | Sup | Imp | NA | NA | NA |
| | 542 | Sand Hill River | CD 17 to Kittleson Cr | Imp | Sup | Sup | Sup | Imp |
| | 508 | Kittleson Creek | Headwaters to Sand Hill R. | Sup | Sup | Sup | Sup | NA |
| Lower Sand Hill River | 536 | Sand Hill River | Kittleson Cr to Unnamed cr | IF | IF | NA | Sup | Imp |
| | 522 | Unnamed ditch | Headwaters to CD 86 | NA | NA | NA | NA | NA |
| | 523 | County Ditch 86 | Unnamed ditch to Sand Hill R | NA | NA | NA | NA | NA |
| | 537 | Sand Hill River | Unnamed cr to Red R | Sup | Sup | Sup | Imp | Imp |
| | 520 | County Ditch 46 | Unnamed ditch to CD 90 | NA | NA | NA | NA | NA |
| | 521 | County Ditch 46 | CD 90 to Sand Hill R | NA | NA | NA | NA | NA |
| | 516 | County Ditch 73 | CD 86 to Sand Hill R | NA | NA | NA | NA | NA |
| | 524 | Maple Creek | Headwaters (Melvin Slough 60-0332-00) to Unnamed cr | NA | NA | NA | NA | NA |
| | 525 | Maple Creek | Unnamed cr to Unnamed cr | NA | NA | NA | NA | NA |
| | 526 | Maple Creek | Unnamed cr to CD 9 | NA | NA | NA | NA | NA |
| | 527 | County Ditch 9 | Maple Cr to CD 119 | NA | NA | NA | NA | NA |
| | 528 | County Ditch 6 | CD 119 to Unnamed ditch | NA | NA | NA | NA | NA |
| | 529 | County Ditch 9 | Unnamed ditch to CD 93 | NA | NA | NA | NA | NA |

| HUC-10 Subwatershed | AUID (Last 3 digits) | Stream | Reach Description | Aquatic Life | | | | Aq Rec |
|---|---|---|---|---|---|---|---|---|
| | | | | Fish Index of Biotic Integrity | Macroinvertebrate Index of Biotic Integrity | Dissolved Oxygen | Turbidity/TSS | Bacteria |
| Lower Sand Hill River (cont.) | 532 | County Ditch 57 | Unnamed ditch to CD 93 | NA | NA | NA | NA | NA |
| | 531 | County Ditch 93 | Unnamed ditch to CD 57 | NA | NA | NA | NA | NA |
| | 530 | County Ditch 93 | CD 57 to CD 9 | NA | NA | NA | NA | NA |
| | 519 | County Ditch 6 | CD 93 to Unnamed cr | NA | NA | NA | NA | NA |
| | 518 | County Ditch 6 | Unnamed cr to Sand Hill R | NA | NA | NA | NA | NA |
| | 533 | County Ditch 148 | CD 98 to CD 57 | NA | NA | NA | NA | NA |
| | 517 | County Ditch 98 | CD 148 to Sand Hill R | NA | NA | NA | NA | NA |
| | 539 | Unnamed creek | Perkins Lake to Muddy Creek | IF | IF | NA | NA | NA |
| City of Nielsville-Red River | 511 | County Ditch 77 | Headwaters 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, IF = the data collected was insufficient to make a finding, NA = not assessed

## Lakes

The SHRW lakes were assessed against Class 2B standards for deep and shallow lakes. The findings show that four lakes exceed the eutrophication standards for their respective ecoregion and are impaired for aquatic recreation use. **Table 2** below presents a summary of SHRW lake assessment findings indicating which lakes are: impaired, support aquatic recreations, lacked sufficient data for assessment, or were not monitored. Aquatic recreation impairments are based on the eutrophication levels of lakes, which is typically caused by excess nutrients. Parameters used in assessing the level of eutrophication with numeric standards include phosphorus, chlorophyll-*a* concentrations, and Secchi disc depths.

There are 17 lakes in the SHRW that have DNR ID numbers and 16 of those lakes were sampled to collect water quality data. Of the 16 sampled, 12 were fully assessed, with 8 of the lakes found to support aquatic recreation and four deemed impaired because the numeric standards were not achieved. Information used to create this table is based on the MPCA's Watershed Monitoring and Assessment Report (MPCA 2014b), as well as the Watershed Biotic SID Report (MPCA 2014a).

**Table 2: Assessment status of lakes in the Sand Hill River Watershed, presented by 10-digit HUC.**

| HUC-10 Subwatershed | Lake ID | Lake | Aquatic Recreation |
|---|---|---|---|
| Upper Sand Hill River | 44-0152-00 | Ketchum | Imp |
| | 44-0157-00 | Allen | Sup |
| | 44-0162-00 | Simonson | Sup |
| | 60-0069-00 | Sand Hill | Sup |
| | 60-0078-00 | Unnammed | IF |
| | 60-0093-00 | Hilligas | Sup |
| | 60-0119-00 | Uff | Imp |
| | 60-0202-00 | Sarah | Sup |
| | 60-0217-00 | Union | Sup |
| | 60-0228-00 | Halverson | Sup |
| | 60-0234-00 | Unnamed | IF |
| | 60-0236-00 | Unnamed | Imp |
| | 60-0238-00 | Rindahl | IF |
| | 60-0281-00 | Unnamed | IF |
| | 60-0309-00 | Arthur | Sup |
| | 60-0327-00 | Kittleson | Imp |
| Lower Sand Hill River | NA | NA | NA |

Imp = impaired for impacts to aquatic recreation, Sup = fully supporting aquatic recreation, IF = insufficient data to make an assessment

## 2.2 Water Quality Trends

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

## 2.3 Stressors and Sources

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

### Stressors of Biologically-impaired Stream Reaches

The primary stressors for biological impairments in the SHRW are listed in Table 3. Common stressors across the SHRW include loss of connectivity between the stream channel and the riparian area and between upstream and downstream reaches, altered hydrology (defined later), and a lack of in-stream habitat. Connectivity problems included natural barriers, such as beaver dams, and manmade structures such as dams. Altered hydrology acts as a biological stressor through increased peak flow and reduced base flow. Altered hydrology can subsequently lead to secondary impacts including loss of in-stream habitat resulting from bank erosion and scour. Loss of in-stream habitat was also frequently implicated as a biological stressor in the SHRW.

Further detailed stressor identification information can be found in the MPCA's Watershed Biotic Stressor Identification Report (MPCA2014b).

**Table 3: Primary stressors to aquatic life in biologically-impaired reaches in the Sand Hill River Watershed**

| Drainage Area | AUID (Last 3 digits) | Stream | Reach Description | Biological Impairment | Primary Stressor | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Low Dissolved Oxygen | Pesticide Toxicity | Phosphorus | Excessive Suspended Sediment (Turbidity) | Loss of Connectivity | Altered Hydrology | Lack of In-stream Habitat |
| Upper Sand Hill River | 515 | County Ditch 17 | Garden Slough to Sand Hill R | Macroinvert. | | | | | | ● | |
| | 541 | Sand Hill River | Headwaters to CD 17 | Fish | ● | | | | ● | ● | ● |
| | | | | Macroinvert. | ● | | | ● | | ● | |
| | 542 | Sand Hill River | CD 17 to Kittleson Cr | Fish | | | | | ● | ● | ● |

## Altered Hydrology

Altered hydrology is frequently cited as a Primary Biological Stressor of reaches with FIBI or MIBI impairments in the SHRW (MPCA 2014) and elsewhere (e.g., MPCA 2013). However, rarely is altered hydrology defined or a quantitative goal established. Using daily flow data from the Sand Hill River at Climax, Minnesota (USGS ID: 05095000), flow duration curves and flow return periods were developed for the periods 1945 to 1975 and 1980 to 2010 to identify changes in hydrology between historical and modern records. Studies have identified the mid-1970s as an inflection point in the hydrologic conditions in the Upper Midwest, driven by a combination of changes in precipitation and land use/land cover (Frans et al. 2013; Schottler et al. 2013). Both flow duration curves (**Figure 3**) and flow return periods (**Figure 4**) indicate a change in hydrology for (1.5-year to 10-year return periods) channel forming flows, which can lead to geomorphic instability and habitat loss. Currently, there is no numeric standard for altered hydrology. Based upon this analysis (i.e., **Figures 3 and 4**), hydrologic management goals were developed for the SHRW for critical channel forming flows. The difference between the solid and dashed lines indicated the magnitude of flow increases. These goals and associated management strategies are provided below in section *3.3 Restoration and Protection Strategies*.

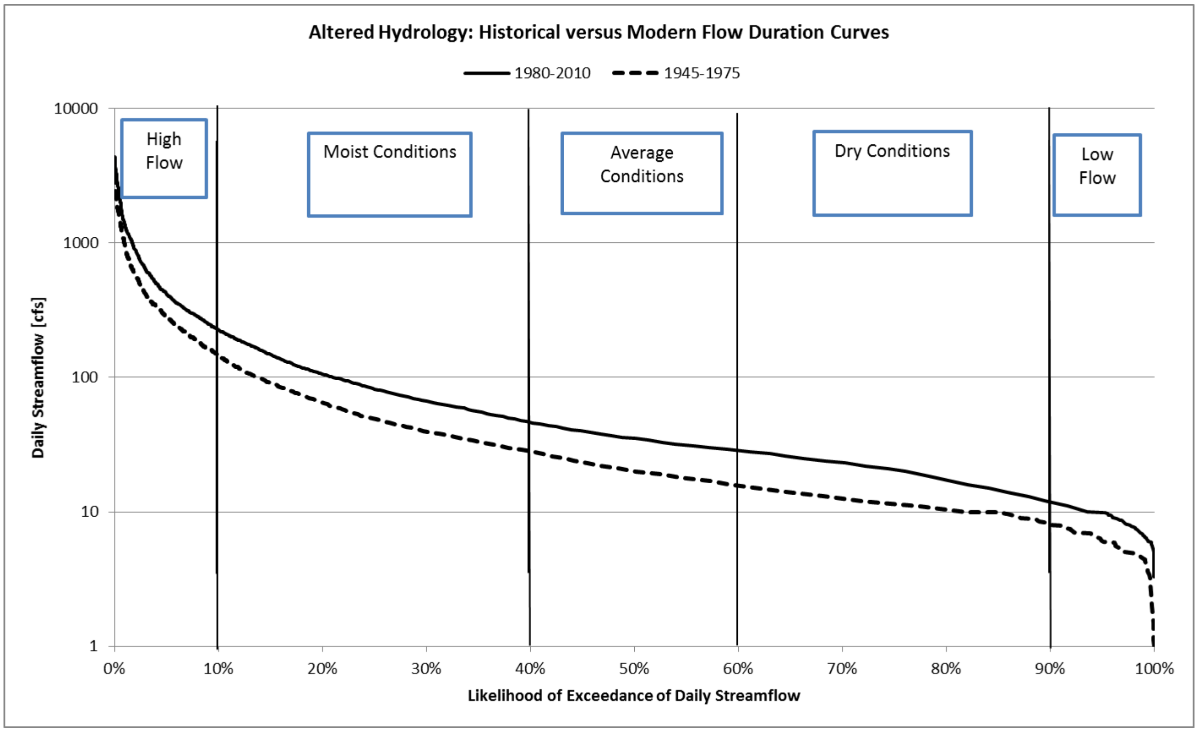



**Figure 3: Altered Hydrology: Historical (1945-1975) versus Modern (1980-2010) Flow Duration for the Sand Hill River at Climax, Minnesota (USGS ID: 05095000).**

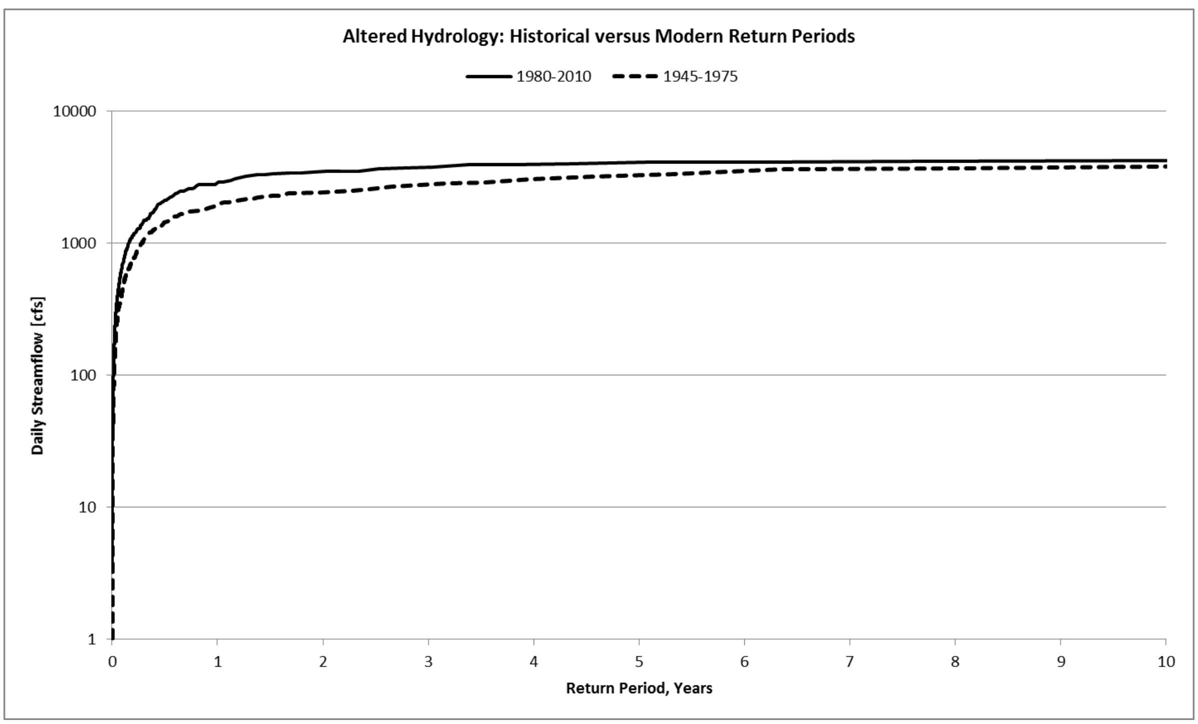



**Figure 4: Altered Hydrology: Historical (1945-1975) versus Modern (1980-2010) Return Periods for the Sand Hill River at Climax, Minnesota (USGS ID: 05095000).**

## Pollutant sources

Point and nonpoint sources of pollutants are identified in **Table 4** and **Table 5**, respectively. **Tables 4** and **5** are summarized from the MPCA's SID Report (MPCA 2014b) and the SHRW TMDL (HEI 2014c). 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 4: Point Sources in the Sand Hill River Watershed.**

| HUC-10 Subwatershed | Point Source | | | Pollutant reduction needed beyond current permit conditions/limits? | Notes |
|---|---|---|---|---|---|
| | Name | Permit # | Type | | |
| Upper Sand Hill River | Fertile WWTP | MNG580166 | Municipal wastewater | No | WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL |
| | Winger WWTP | MN0046671 | Municipal wastewater | No | WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL |
| Lower Sand Hill River | Climax WWTP | MNG580169 | Municipal wastewater | No | WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL |
| | Spokey Farms | MN0069981 | Wastewater-Potato Washing | No | WLAs based on current permitted TSS limit of 45 mg/L |
| City of Nielsville-Red River | Nielsville WWTP | MNG580166 | Municipal wastewater | No | WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL |

**Table 5: Nonpoint Sources in the Sand Hill River Watershed. Relative magnitudes of contributing sources are indicated.**

| HUC-10 Subwater-shed | Stream/Reach (AUID) or Lake (ID) | Pollutant | Pollutant Sources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer & manure run-off | Livestock overgrazing in riparian | Failing septic systems | Wildlife | Poor riparian vegetation cover | Upland soil erosion | Bank erosion/excessive peak flows | Channelization | Upstream influences | Farmed-through headwater streams | Poor shoreline buffer | Internal sources |
| Upper Sand Hill River | Sand Hill River (541) | Bacteria | ˜ | › | ™ | ™ | | | | | | | | |
| | | Turbidity/TSS | | | | | | ˜ | ˜ | ˜ | › | | | |
| | | Dissolved Oxygen | | | | | | | | | | | | |
| | Sand Hill River (542) | Bacteria | ˜ | › | ™ | ™ | | | | | ˜ | | | |
| | | Turbidity/TSS | | | | | ˜ | ˜ | ˜ | ˜ | › | | | |
| | Ketchum (44-0152-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Allen (44-0157-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Simonson (44-0162-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Sand Hill (60-0069-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Unnammed (60-0078-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Hilligas (60-0093-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| | Uff (60-0119-00) | Nutrients | ˜ | | › | | | | | | | | › | ˜ |
| | Sarah (60-0202-00) | Nutrients | ˜ | | › | | | | | | | | › | |
| Upper Sand Hill | Union (60-0217-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Halverson (60-0228-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |

| HUC-10 Subwater-shed | Stream/Reach (AUID) or Lake (ID) | Pollutant | Pollutant Sources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer & manure run-off | Livestock overgrazing in riparian | Failing septic systems | Wildlife | Poor riparian vegetation cover | Upland soil erosion | Bank erosion/excessive peak flows | Channelization | Upstream influences | Farmed-through headwater streams | Poor shoreline buffer | Internal sources |
| River (cont.) | Unnamed (60-0234-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Unnamed (60-0236-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Rindahl (60-0238-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Unnamed (60-0281-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Arthur (60-0309-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | |
| | Kittleson (60-0327-00) | Nutrients | ˜ | ˜ | › | | | | | | | | › | ˜ |
| Lower Sand Hill River | Sand Hill River (536) | Bacteria | ˜ | › | ™ | ™ | | | | | ˜ | | | |
| | Sand Hill River (537) | Bacteria | ˜ | › | ™ | ™ | | | | | › | | | |
| | | Turbidity/TSS | | | | | ˜ | ˜ | ˜ | ˜ | › | | | |

**Key:** ˜ = High › = Moderate ™ = Low

## 2.4 TMDL Summary

Several of the lakes and stream reaches are impaired and require a reduction in the current loading to achieve the state's numeric water quality standards. The following tables show the maximum allowable load (loading capacity) and the amounts that come from nonpoint sources (load allocation) and point sources (wasteload allocation). The tables also show the reduction, from the existing load, needed based on either modeling or the use of 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 elsewhere (HEI 2014a, b, and c.).

On June 27, 2017, the EPA issued the *Decision Document for the Approval of the Sand Hill River Watershed TMDL* (Decision Document). In the Decision Document, the EPA notes that the Sand Hill River – Headwaters to CD17 (09020301-541) and Ketchum Lake (44-0152-00) waterbodies are located on White Earth Reservation land; therefore they cannot be included in the state's TMDL approval. The TMDLs presented in Tables 6, 10, and 15 of this report are for informational and planning purposes only, and should not be construed as legally-approved TMDLs.

### Phosphorus

The existing phosphorus contributions, the maximum allowable phosphorus loading, and the estimated load reduction needed to meet the phosphorus standard for Ketchum Lake, Kittleson Lake, Uff Lake, and an unnamed lake are summarized in the following tables. The analysis assumes the net groundwater load is equal to zero (amount of groundwater entering the lake equals the amount leaving the lake).

**Table 6: Ketchum Lake TP TMDL and Allocations.**

| | | Existing Annual TP Load | | Maximum Allowable TP Load | | Estimated Load Reduction Needed | |
|---|---|---|---|---|---|---|---|
| | | lbs/yr | lbs/day | lbs/yr | lbs/day | lbs/yr | % |
| **TOTAL LOAD CAPACITY** | | **187** | **0.51** | **106** | **0.29** | **81** | **43%** |
| **Wasteload Allocation** | **Total WLA** | **0.106** | **0.0003** | **0.106** | **0.0003** | **0** | **0** |
| | *Construction/Industrial Stormwater* | *0.106* | *0.0003* | *0.106* | *0.0003* | *0* | *0* |
| **Load Allocation** | **Total LA** | **186.9** | **0.51** | **95.4** | **0.26** | **91.5** | **49%** |
| | *Direct runoff* | *144.9* | *0.40* | *53.4* | *0.15* | *91.5* | *63%* |
| | *Failing SSTS* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Upstream lakes* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Atmospheric deposition* | *42* | *0.11* | *42* | *0.11* | *0* | *0* |
| | *Groundwater* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Internal load* | *0* | *0* | *0* | *0* | *0* | *NA* |
| **MOS** | | | | **10.6** | **0.03** | | |

**Table 7: Kittleson Lake TP TMDL and Allocations.**

| | | Existing TP Load | | Maximum Allowable TP Load | | Estimated Load Reduction Needed | |
|---|---|---|---|---|---|---|---|
| | | lbs/yr | lbs/day | lbs/yr | lbs/day | lbs/yr | % |
| **TOTAL LOAD CAPACITY** | | **1863** | **5.10** | **540** | **1.48** | **1324** | **71%** |
| **Wasteload Allocation** | **Total WLA** | **0.539** | **0.0015** | **0.539** | **0.0015** | **0** | **0** |
| | *Construction/Industrial Stormwater* | *0.539* | *0.0015* | *0.539* | *0.0015* | *0* | *0* |
| **Load Allocation** | **Total LA** | **1862** | **5.11** | **485.1** | **1.33** | **1377** | **74%** |
| | *Direct runoff* | *623* | *1.71* | *31.1* | *0.09* | *592* | *95%* |
| | *Failing SSTS* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Upstream lakes* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Atmospheric deposition* | *79* | *0.22* | *79* | *0.21* | *0* | *0* |
| | *Groundwater* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Internal load* | *1160* | *3.18* | *375* | *1.03* | *785* | *68%* |
| **MOS** | | | | **53.9** | **0.15** | | |

**Table 8: Uff Lake TP TMDL and Allocations.**

| | | Existing TP Load | | Maximum Allowable TP Load | | Estimated Load Reduction Needed | |
|---|---|---|---|---|---|---|---|
| | | lbs/yr | lbs/day | lbs/yr | lbs/day | lbs/yr | % |
| **TOTAL LOAD CAPACITY** | | **105** | **0.287** | **40** | **0.101** | **65** | **62%** |
| **Wasteload Allocation** | **Total WLA** | **0.037** | **0.0001** | **0.037** | **0.0001** | **0** | **0** |
| | *Construction/Industrial Stormwater* | *0.037* | *0.0001* | *0.037* | *0.0001* | *0* | *0* |
| **Load Allocation** | **Total LA** | **105** | **0.29** | **38** | **0.10** | **67** | **67%** |
| | *Non-MS4 runoff* | *70* | *0.20* | *3* | *0.01* | *67* | *96%* |
| | *Failing SSTS* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Upstream lakes* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Atmospheric deposition* | *35* | *0.09* | *35* | *0.09* | *0* | *0* |
| | *Groundwater* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Internal load* | *0* | *0* | *0* | *0* | *0* | *NA* |
| **MOS** | | | | **2** | **0.005** | | |

**Table 9: Unnamed Lake TP TMDL and Allocations.**

| | | Existing TP Load | | Maximum Allowable TP Load | | Estimated Load Reduction Needed | |
|---|---|---|---|---|---|---|---|
| | | lbs/yr | lbs/day | lbs/yr | lbs/day | lbs/yr | % |
| **TOTAL LOAD CAPACITY** | | **287** | **0.79** | **205** | **0.56** | **82** | **29%** |
| **Wasteload Allocation** | **Total WLA** | **0.205** | **0.0006** | **0.205** | **0.0006** | **0** | **0** |
| | *Construction/Industrial Stormwater* | *0.205* | *0.0006* | *0.205* | *0.0006* | *0* | *0* |
| **Load Allocation** | **Total LA** | **287** | **0.79** | **184.5** | **0.51** | **102.3** | **36%** |
| | *Non-MS4 runoff* | *135* | *0.37* | *77* | *0.21* | *58.3* | *43%* |
| | *Failing SSTS* | *0* | *0* | *0* | *0* | *0* | *0* |
| | *Upstream lakes* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Atmospheric deposition* | *31* | *0.09* | *31* | *0.09* | *0* | *0* |
| | *Groundwater* | *0* | *0* | *0* | *0* | *0* | *NA* |
| | *Internal load* | *121* | *0.33* | *77* | *0.21* | *44.0* | *36%* |
| **MOS** | | | | **20.5** | **0.06** | | |

## Escherichia coli

The existing bacteria contributions, expressed as Escherichia coli (*E. coli*), the loading capacity and the reduction needed to meet the standard for portions of the Sand Hill River are shown in the following tables. The analysis is based on the load duration curves. The loading capacity is established using the flow condition requiring the greatest estimated load reduction.

**Table 10: Bacteria loading capacities and allocations for Sand Hill River, Headwaters to CD17 (AUID 09020301-541).**

| *E. coli* | | Flow Condition | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Geometric Mean (Billion organisms per day) | | | | |
| **Loading Capacity** | | **678.45** | **140.34** | **56.27** | **27.35** | **13.81** |
| **Waste Load Allocation** | **Total WLA** | **1.2** | **1.2** | **1.2** | **1.2** | **1.2** |
| | *Winger WWTF* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **Load Allocation** | **Total LA** | **609.41** | **125.11** | **49.44** | **23.42** | **11.23** |
| **Margin of Safety (MOS)** | | **67.84** | **14.03** | **5.63** | **2.73** | **1.38** |
| | | | | | | |
| **Existing Load** | | **797.76** | **75.57** | **84.12** | **9.16** | **3.52** |
| **Unallocated Load** | | **0.00** | **50.74** | **0.00** | **15.46** | **8.91** |
| **Estimated Load Reduction** | | **23%** | **0%** | **40%** | **0%** | **0%** |

**Table 11: Bacteria loading capacities and allocations for Sand Hill River, CD17 to Kittleson Cr (AUID 09020301-542).**

| *E. coli* | | Flow Condition | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Geometric Mean (Billion organisms per day) | | | | |
| **Loading Capacity** | | **1,046.2** | **229.7** | **91.4** | **43.4** | **20.6** |
| **Waste Load Allocation** | **Total WLA** | **5.9** | **5.9** | **5.9** | **5.9** | **5.9** |
| | *Fertile WWTF* | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| | *Winger WWTF* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **Load Allocation** | **Total LA** | **935.6** | **200.85** | **76.32** | **33.2** | **12.6** |
| **Margin of Safety (MOS)** | | **104.6** | **22.97** | **9.14** | **4.34** | **2.06** |
| | | | | | | |
| **Existing Load** | | --- | **158.00** | **126.17** | **24.66** | **15.47** |
| **Unallocated Load** | | --- | **48.75** | **0.00** | **14.44** | **3.05** |
| **Estimated Load Reduction** | | --- | **0%** | **35%** | **0%** | **0%** |

**Table 12: Bacteria loading capacities and allocations for Sand Hill River, Kittleson Cr to Unnamed Cr (AUID 09020301-536).**

| *E. coli* | | Flow Condition (Geomean Standard) | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Geometric Mean (Billion organisms per day) | | | | |
| **Loading Capacity** | | **1,595.7** | **346.1** | **133.5** | **63.0** | **29.9** |
| **Wasteload Allocation** | **Total WLA** | **5.9** | **5.9** | **5.9** | **5.9** | **5.9** |
| | *Fertile WWTF* | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| | *Winger WWTF* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **Load Allocation** | **Total LA** | **1,430.2** | **305.6** | **114.3** | **50.8** | **21.0** |
| **Margin of Safety (MOS)** | | **159.6** | **34.6** | **13.3** | **6.3** | **3.0** |
| | | | | | | |
| **Existing Load** | | -- | **659.6** | **240.7** | **72.3** | **23.1** |
| **Unallocated Load** | | -- | **0.0** | **0.0** | **0.0** | **3.8** |
| **Estimated Load Reduction** | | -- | **53%** | **50%** | **22%** | **0%** |

**Table 13: Bacteria loading capacities and allocations for Sand Hill River, Unnamed Cr to Red River (AUID 09020301-537).**

| *E. coli* | | Flow Condition | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Geometric Mean (Billion organisms per day) | | | | |
| **Loading Capacity** | | **2,371.3** | **475.5** | **209.6** | **104.8** | **55.5** |
| **Wasteload Allocation** | **Total WLA** | **7.2** | **7.2** | **7.2** | **7.2** | **7.2** |
| | *Climax WWTF* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| | *Fertile WWTF* | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| | *Winger WWTF* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **Load Allocation** | **Total LA** | **2127.00** | **420.80** | **181.40** | **87.10** | **42.80** |
| **Margin of Safety (MOS)** | | **237.1** | **47.5** | **21.0** | **10.5** | **5.5** |
| | | | | | | |
| **Existing Load** | | **--** | **121.9** | **282.4** | **159.3** | **100.5** |
| **Unallocated Load** | | **--** | **306.1** | **0.0** | **0.0** | **0.0** |
| **Estimated Load Reduction** | | **--** | **0%** | **33%** | **41%** | **50%** |

## Total Suspended Solids (TSS)

In August 2014, the MPCA adopted total suspended solids (TSS) standards with the intention of replacing the turbidity numeric standard after EPA final approval. The existing TSS contributions, the loading capacity, and the reductions needed to meet the standard for portions of the Sand Hill River are shown in the following tables. The analysis is based on the concentrations of TSS using the load duration curves. The loading capacity is established using the flow condition requiring the greatest estimated load reduction. As indicated, the greatest estimated load reduction is required during “very high” flow conditions, indicating that large sediment loading occurs during these flooding events.

Table 14: TSS loading capacities and allocations for Sand Hill River, Unnamed Cr to Red River (AUID 09020301-537).

| Total Suspended Solids | | Flow Condition | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Tons per day | | | | |
| **Loading Capacity** | | **156.7** | **30.3** | **13.7** | **6.5** | **3.16** |
| Wasteload Allocation | **Total WLA** | **0.42** | **0.31** | **0.29** | **0.29** | **0.28** |
| | *Climax WWTF* | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | *Fertile WWTF* | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| | *Winger WWTF* | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | *Construction/Industrial Stormwater* | 0.14 | 0.03 | 0.01 | 0.006 | 0.003 |
| **Load Allocation** | **Total LA** | **140.61** | **26.96** | **12.04** | **5.56** | **2.55** |
| **Margin of Safety (MOS)** | | **15.7** | **3.0** | **1.4** | **0.7** | **0.3** |
| | | | | | | |
| **Existing Load** | | **1,680** | **181** | **30** | **9.0** | **4.2** |
| **Unallocated Load** | | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| **Estimated Load Reduction** | | **92%** | **85%** | **59%** | **35%** | **32%** |

Table 15: TSS loading capacities and allocations for Sand Hill River, Headwaters to CD17 (AUID 09020301-541).

| Total Suspended Solids | | Flow Condition | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Tons per day | | | | |
| **Loading Capacity** | | **42.48** | **9.34** | **3.37** | **1.57** | **0.77** |
| **Wasteload Allocation** | **Total WLA** | **0.08** | **0.06** | **0.05** | **0.05** | **0.05** |
| | *Winger WWTF* | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | *Construction/Industrial Stormwater* | 0.03 | 0.008 | 0.002 | 0.0015 | 0.0007 |
| **Load Allocation** | **Total LA** | **38.15** | **8.35** | **2.98** | **1.36** | **0.64** |
| **Margin of Safety (MOS)** | | **4.25** | **0.93** | **0.34** | **0.16** | **0.08** |
| | | | | | | |
| **Existing Load** | | **29.0** | **7.6** | **1.5** | **1.7** | **0.6** |
| **Unallocated Load** | | **9.2** | **0.8** | **1.5** | **0.0** | **0.1** |
| **Estimated Load Reduction** | | **0%** | **0%** | **0%** | **16%** | **0%** |

## 2.5 Protection Considerations

Designation of streams and lakes as candidates for protection or restoration is important identifying resource management needs and for aligning with the Nonpoint Priority Funding Plan (NPFP) for Clean Water Funding Implementation (http://www.bwsr.state.mn.us/planning/npfp/NPFP%20Final.pdf) and Minnesota's Clean Water Roadmap (https://www.pca.state.mn.us/sites/default/files/wq-gov1-07.pdf). For this reason, assessed streams within the SHRW are designated as either “protection” or “restoration” based on the available water quality monitoring data. Once designated as protection or restoration, SHRW streams and lakes are further divided into subcategories to guide management efforts and reflect priorities in the NPFP for Clean Water Funding Implementation. For example, considerable energy and fiscal investment is needed to restore some resources. This energy and fiscal investment could be invested in other resources more likely to be successfully restored and attain water quality standards.

Streams, rivers, and lakes currently supporting aquatic life and aquatic recreation in the SHRW are candidates for protection. The purpose of the protection strategy is to reasonably ensure the beneficial uses are maintained into the future. Some of the implementation strategies are focused on “protecting” these waters. For streams, rivers, and lakes, the purpose of the protection strategy is reasonably ensuring the existing loads for the critical duration periods are maintained or reduced.

### Lakes

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

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

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

- waters meeting water quality standards but with downward trends in water quality;
- waters having known or anticipated future water quality threats;
- waters with suspected but not confirmed impairments;

- shallow lakes, which are especially sensitive to nutrient loading or watershed activities; and
- high quality or unique waters deserving special attention.

Several state agencies have jointly developed a “Lakes Protection Strategy” to help watershed stakeholders set water quality protection goals for unimpaired waters. In addition to lake water quality data, the Lakes Protection Strategy considers other water “values” such as economic value, aesthetics, and tourism. The Lakes Protection Strategy and a “Lake Prioritization Spreadsheet” became available in late 2016.

The “Lakes Protection Strategy” approach includes five discrete steps that are meant to be applied to any given WRAPS project. The following discussion outlines this 5-step approach.

Steps 1 and 2 deal primarily with the presentation and analysis of available historical water quality data (total phosphorus (TP), chlorophyll-a, and Secchi transparency) that are then used to examine trends and to set water quality goals for unimpaired lakes.

Step 3 establishes a score for each lake based on risk factors (proximity to the impairment threshold, long term trend data, sensitivity of the lake to future phosphorus inputs, and other factors) to produce a prioritized list of lakes for each watershed. The result of Step 3 is provided to watershed project teams during the assessment phase of each WRAPS project.

Step 4 brings additional information to the WRAPS protection strategy development, regarding the perceived value of individual aquatic resources for consideration alongside of the prioritization-based information from Step 3. The NPFP acknowledges that values are a part of the decision making process and specifically calls out recreation, aesthetic, and economic values as important considerations. Local partners, citizens and other stakeholders would provide key data layers and input during this step.

Step 5 uses the WQ data and values information collected in the first four steps to refine and present: 1) targeted protection strategies that will be particularly effective in a given watershed; 2) critical areas where they those strategies could be targeted; and 3) key linkages with other water quality/natural resource planning goals.

The Lakes Protection Strategy acknowledges that several similar water quality protection and risk management approaches have been or are being developed and some watersheds may already have tools in place that serve to identify and prioritize watershed protection efforts. The “Lakes Protection Strategy” is not intended to replace those systems but is offered as a model where it is needed to advance the state of water quality protection science in Minnesota.

Because development of the Lakes Protection Strategy occurred near the end of the first cycle of the Sand Hill River’s WRAPS development, the strategy will be useful during the implementation planning process and more fully incorporated into the Sand Hill River WRAPS during the second cycle.

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

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially in the north-central and northeastern parts of the state. Many other lakes meet the standards but may exhibit declining water quality. The high-quality lakes and other lakes that meet WQS require protection from future degradation. The WRAPS process aims to address all waters in a major watershed, providing TMDL studies for impaired waters and protection strategies for non-impaired waters. TMDLs for the four impaired lakes are provided in **Section 2.4. Table 18** lists Protection Status of the SHRW's four unimpaired lakes, ranked by 'Protection Priority Class', based on analysis of phosphorus sensitivity and lake risk.

**Table 16: Sand Hill River Watershed Lake Prioritization Summary Table**

| Lake Name | Lake I.D. # | Depth | Lake Area Acres | Phosphorus Standard | Current Condition | Priority Class |
|---|---|---|---|---|---|---|
| Union | 60-0217-00 | DEEP | 887.46 | 65 µg/L | 19 µg/L | Highest |
| Sara | 60-0202-00 | DEEP | 365.93 | 65 µg/L | 30 µg/L | Highest |
| Sand Hill | 60-0069-00 | DEEP | 479.2 | 40 µg/L | 36 µg/L | Highest |
| Halverson | 60-0228-00 | SHALLOW | 142.19 | 90 µg/L | 46.8 µg/L | Higher |

### Streams and Rivers

The MPCA is currently developing a "Streams Protection Strategy" to help watershed stakeholders set protection goals for unimpaired waters. In addition to stream water quality data, the Streams Protection Strategy will consider other water "values" such as economic value, aesthetics, and tourism. The Streams Protection Strategy and a 'Stream Prioritization Spreadsheet' will be available sometime in the future. Since the Streams Protection Strategy is not complete at the time of this publication, stream reaches in the SHRW were prioritized and classified into Protection or Restoration classes based on their existing water quality. Both protection and restoration classes are further broke down into subclasses. Streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Heightened Impairment Risk. Streams within the "restoration" category are subdivided into two subcategories: Low Restoration Effort and High Restoration Effort.

### Stream Classifications

Stream classification is based on existing water quality data for the most recent assessment period (2003 through 2012). In order to classify more stream reaches, the lower limit on the number of observation is lower than required for assessments. Stream assessments typically require 20 water quality samples over two years (five samples in a given month for *E. coli*), whereas, this method requires a minimum of five water quality samples (three for *E. coli*). This allows for more stream reaches to be included in the stream classification. Descriptions of the stream classes and water quality attributes for each class follows.

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

Descriptions of the stream classes and water quality attributes for each class is described below, followed by maps of the stream classifications by water quality parameter (**Figure 5** for TSS, **Figure 6** for TP, **Figure 7** for NO2+NO3, **Figure 8** for *E. coli*).

## Protection Classes

All streams currently supporting aquatic life and aquatic recreation in the SHRW are candidates for protection. Over time, if these waters are not subject to protection strategies, they may or may not become impaired. For purposes of this assessment, SHRW streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk.

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

1. Have no impairments and meet the full MPCA assessment methods for determining whether an impairment exists and the 90$^{th}$ percentile (TSS, TP, NO2+NO3) or the geometric mean (*E. coli*) are less than 75% of the numeric standard; or
2. Surface waters that do not meet the data requirements of the MPCA assessment methods (have less than 20 samples, or 5 samples per month for *E. coli*) yet still have a minimum of 5 samples for the AUID (or 3 samples per month for *E. coli*) may also be defined as having Above Average Quality, if no samples exceed the numeric water quality standard for the AUID, and the 90th percentile concentration (geometric mean for *E. coli*) of a water quality parameter is less than 75% of the numeric water quality standard.

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

1. When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), surface waters in the Potential Impairment Risk subcategory for *E. coli*, inorganic nitrogen, TP, or TSS are defined by the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75%, but less than 90% of the numeric water quality standard.

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

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

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

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

### Restoration Classification

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

Low Restoration Effort is defined as a degraded condition but a condition near the designated minimum threshold. An example is a portion of a river or stream where the numeric standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard. Surface waters are defined as a Low Restoration Effort if more than 5 samples are collected, of which no more than 25% of the samples exceed the water quality standard. Surface waters may also be in the Low Restoration Effort category if the 90th percentile of the samples (5 or more required) is within 125% of the water quality standard.

Surface waters in the High Restoration Effort category are degraded, and are no longer near the designated threshold. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. High Restoration

Effort surface waters are impaired, with the 90th percentile of at least 5 samples exceeding 125% of the water quality standard. Impaired waters are also defined in the High Restoration Effort category if more than 25% of samples (5 or more required) exceed the water quality standard.

Maps of the stream classifications by water quality parameter (**Figure 5** for TSS, **Figure 6** for TP, **Figure 7** for NO2+NO3, **Figure 8** for *E. coli*) follow.

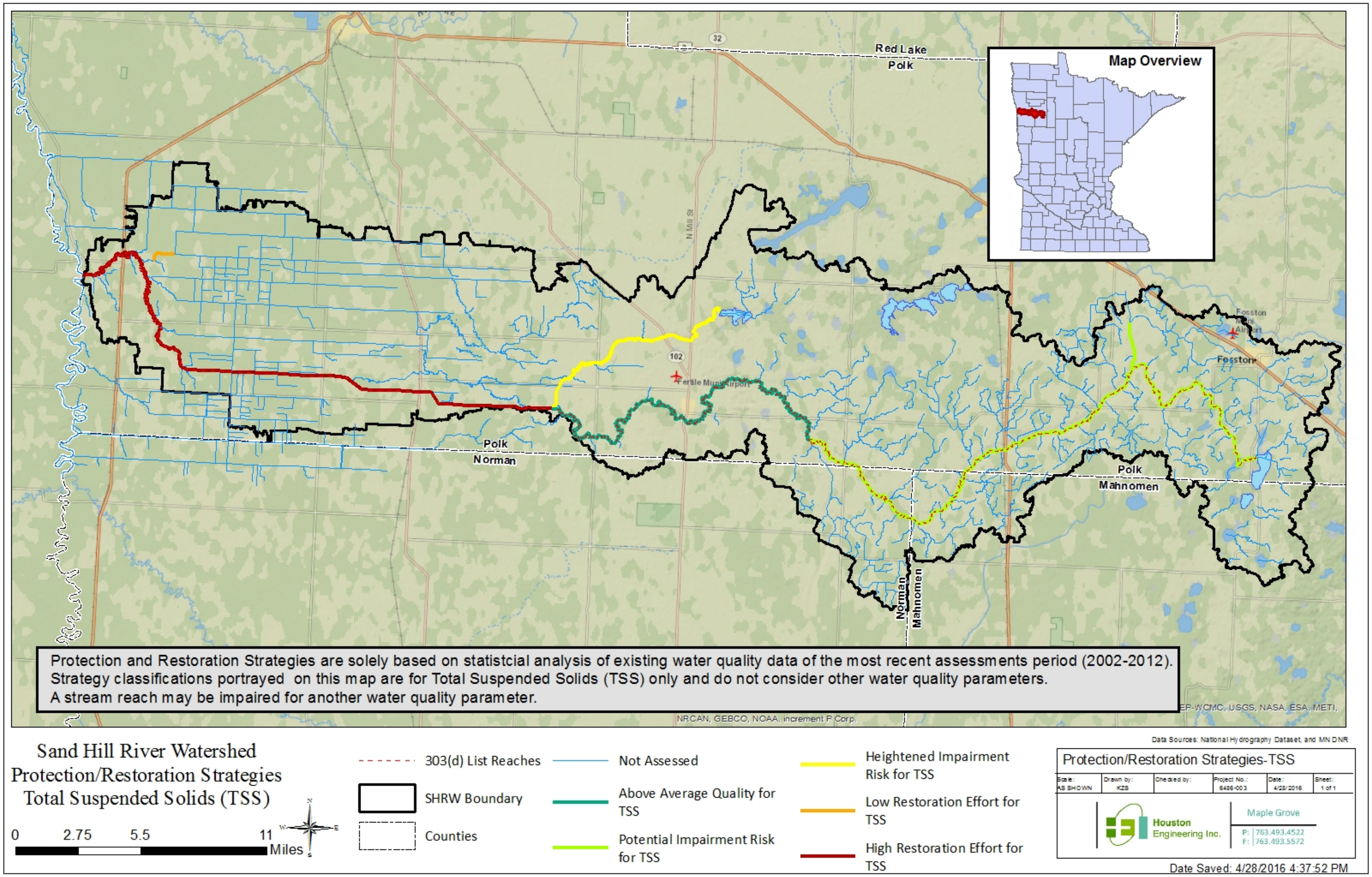



**Figure 5: Protection/Restoration Classifications for Total Suspended Solids of Stream Reaches in the Sand Hill River Watershed.**

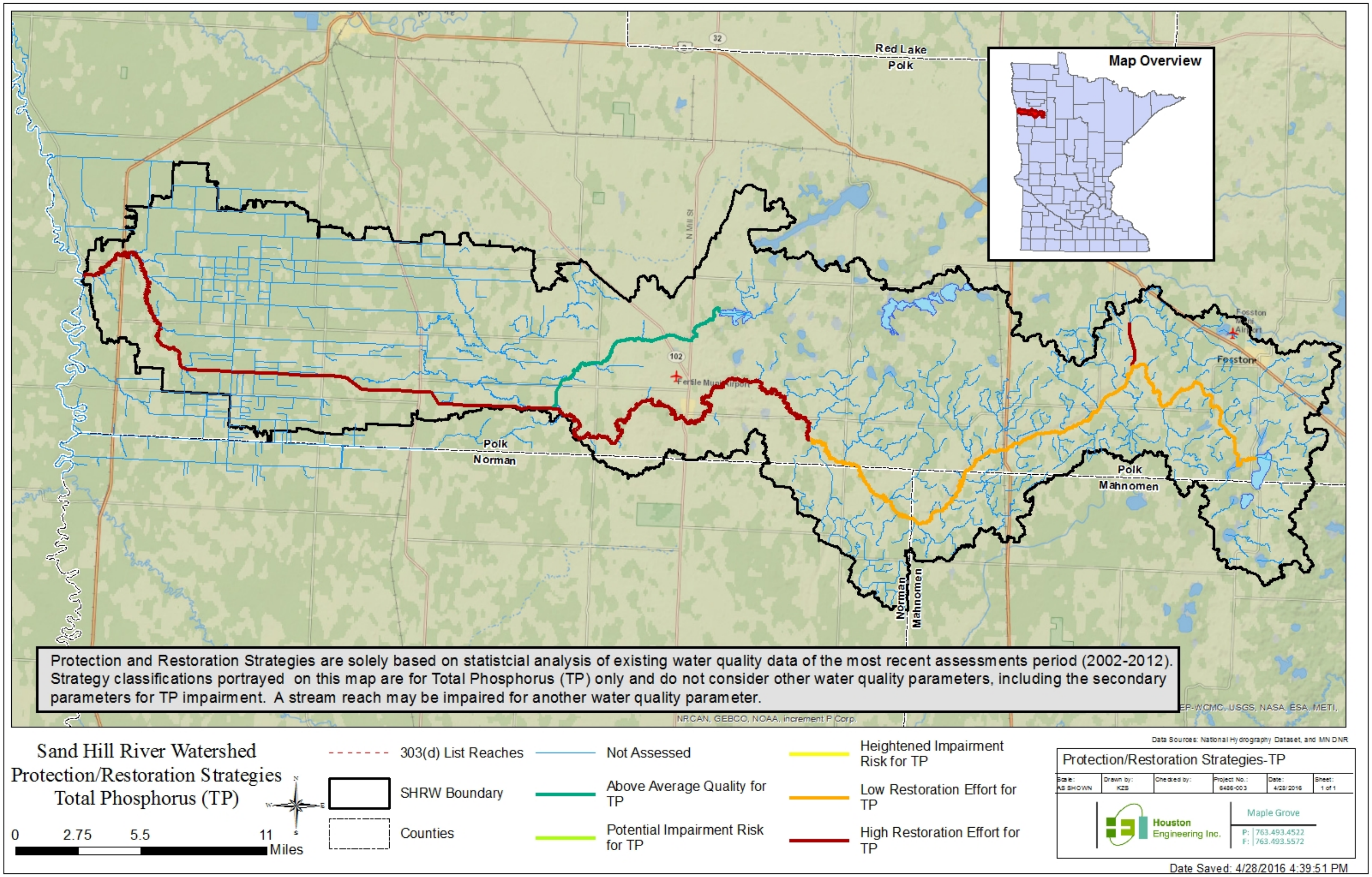



**Figure 6: Protection/Restoration Classifications for Total Phosphorus of Stream Reaches in the Sand Hill River Watershed.**

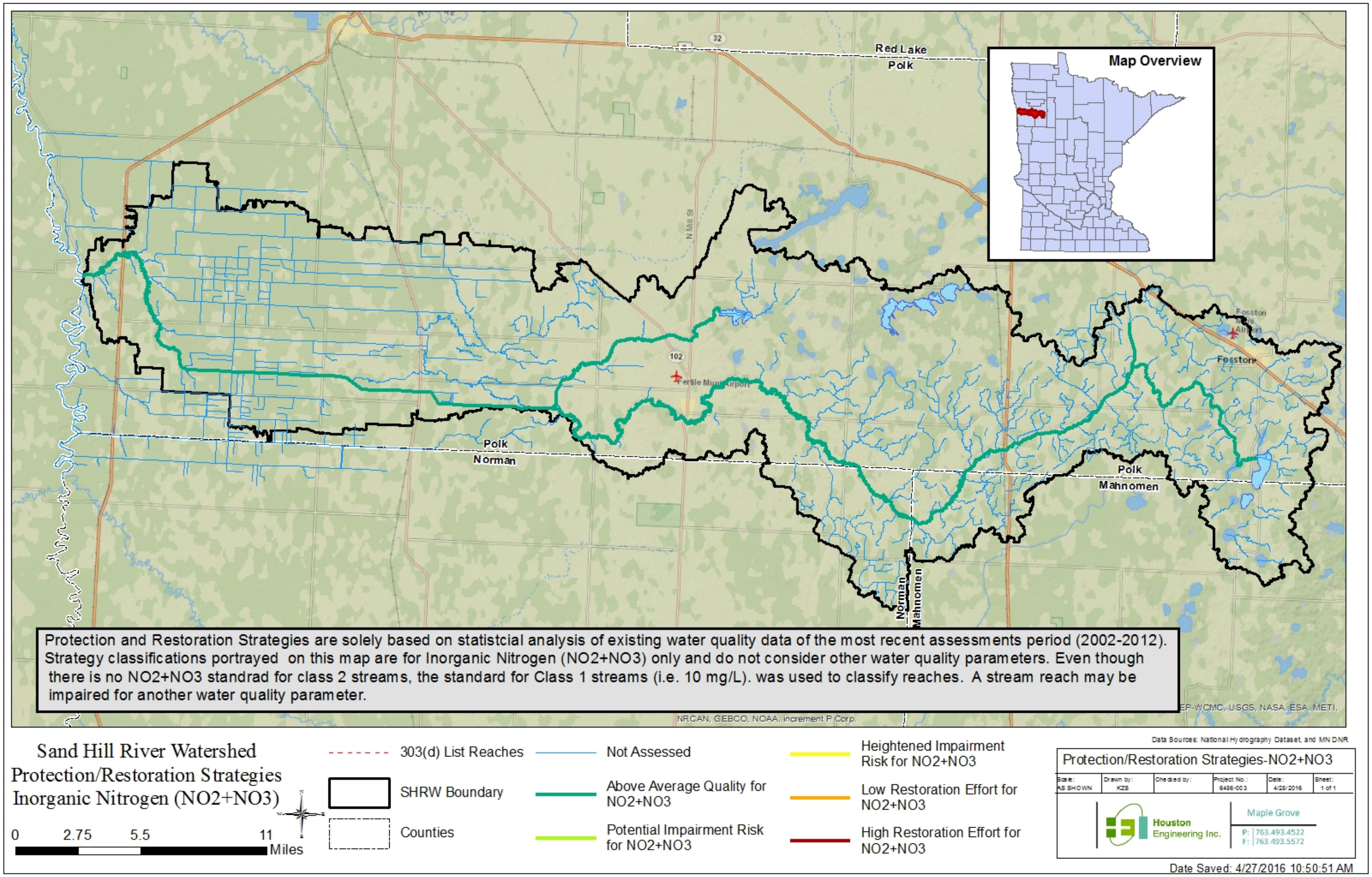



**Figure 7: Protection/Restoration Classifications for Inorganic Nitrogen of Stream Reaches in the Sand Hill River Watershed.**

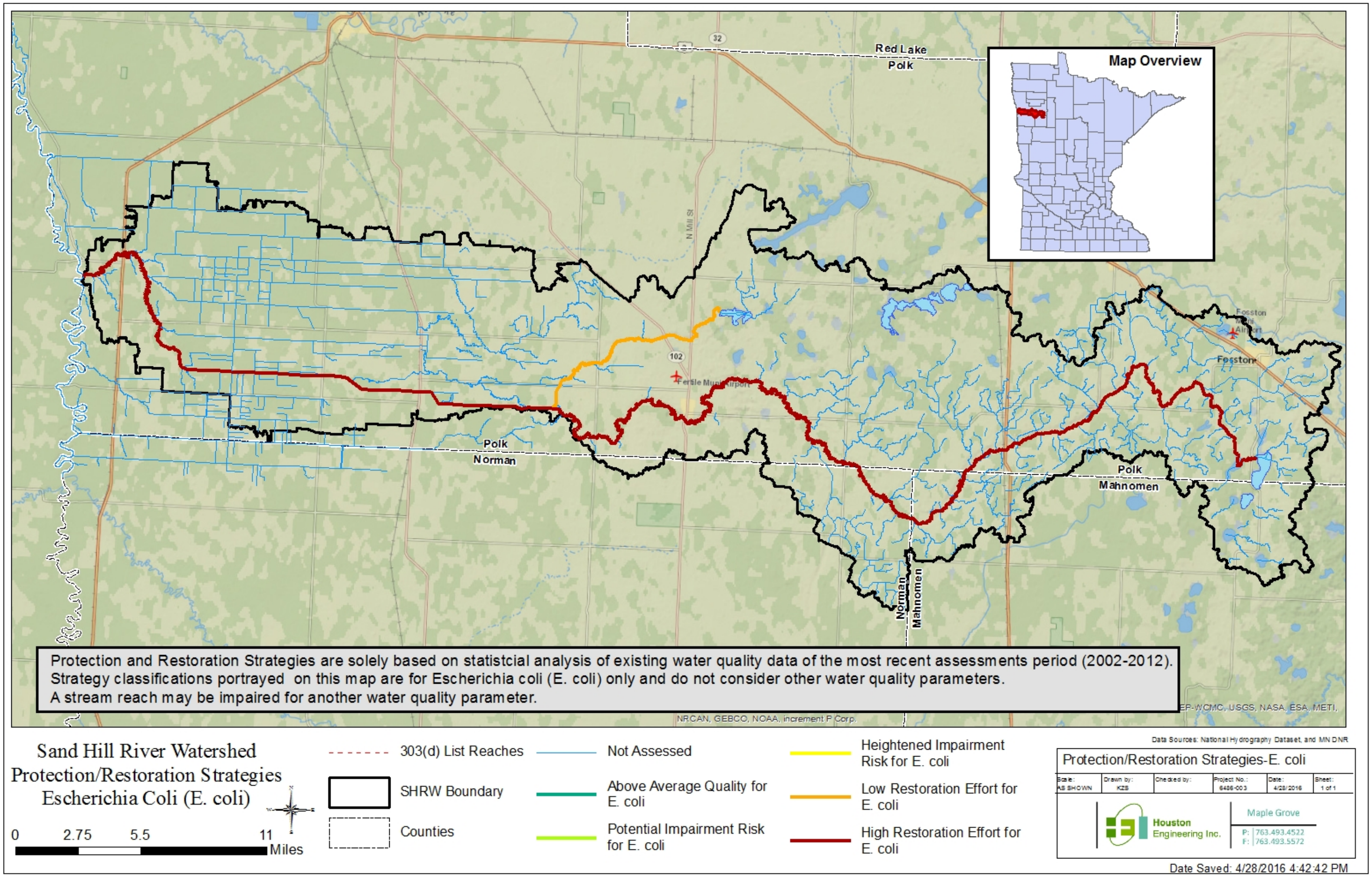



**Figure 8: Protection/Restoration Classifications for *E. coli* of Stream Reaches in the Sand Hill River Watershed.**

In addition to mapping stream classification, the loading capacity, existing loads, and remaining loading capacities were calculated for any stream reach with water quality data that were explicitly represented in the HSPF or had observed daily streamflows. Loading capacities and existing loads were calculated for each of the parameters (TSS, TP, NO2+NO3, and *E. coli*) and the **Tables** can be found in **Appendix D.** A summary of the results are provide as **Table 19**. **Table 19** shows the critical flow regime were the lowest percentage of remaining load occurs based on any existing loads and the calculate load capacities. If the percentage of remaining load is negative, the existing load exceeds the remaining load, therefore is either impaired for the parameter or existing data shows impairment but does not meet the assessment criteria.

As seen in **Table 19**, most of the available water quality data is located in the mainstem of the Sand Hill River and is measured in impaired reaches. As a protection strategy, it is recommended that greater coverage of the whole watershed be considered in future monitoring plans. It should be noted that the existing loads shown in **Table 19** may be estimated based on one sample; no consideration for the number of water quality samples was given and official assessment by MPCA is needed to confirm impairment. For TSS, most stream reaches exceed the TSS load capacity (based on the 65 mg/L numeric standard) for at least one flow regime. For TP, all stream reaches with water quality data (where an existing load can be computed) have at least one flow regime exceeding the load capacity (based on the 0.15 mg/L numeric standard). All stream reaches show good water quality relating to inorganic nitrogen (NO2+NO3) and are well below the loading capacity (based on the Class 1 numeric standard of 10 mg/L). The results shown in **Table 19** and the protection/restoration classification maps (**Figures 5** to **8**) should be used to provide guidance for the prioritization of protection strategies. A summary of water quality conditions used to develop the maps and **Table 19** are provide in Appendix D, as well as the estimated existing load, loading capacity, and protection/restoration classification for each parameter shown.

**Table 17: Critical flow regimes and percentage of remaining load capacity of stream reaches in SHRW.**

| HUC-10 Subwatershed | AUID (Last 3 digits) | TSS | | TP | | NO2+NO3 | | *E. coli* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Critical Flow Regime | Remaining Load (%)[1] | Critical Flow Regime | Remaining Load (%)[1] | Critical Flow Regime | Remaining Load (%)[1] | Critical Flow Regime | Remaining Load (%)[1] |
| Upper Sand Hill River | 508 | High | -2% | High | 37% | High | 99% | High | -111% |
| | 510 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 512 | Very High | -2% | Very High | -59% | Mid | 92% | -- | -- |
| | 513 | High | -49% | -- | -- | -- | -- | -- | -- |
| | 514 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 515 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 541 | Very Low | -17% | High | -127% | Very High | 94% | Mid | -49% |
| | 542 | Very High | -168% | Very High | -184% | Very High | 96% | Mid | -27% |
| Lower Sand Hill River | 516 | Very High | 54% | -- | -- | -- | -- | -- | -- |
| | 517 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 518 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 519 | High | -33% | -- | -- | -- | -- | -- | -- |
| | 520 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 521 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 522 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 523 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 524 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 525 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 526 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 527 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 528 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 529 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 530 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 531 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 532 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 533 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 536 | Very High | -458% | Very High | -175% | Very High | 94% | High | -91% |
| | 537 | Very High | -972% | Very High | -456% | Very High | 87% | Very Low | -81% |
| | 539 | -- | -- | -- | -- | -- | -- | -- | -- |
| City of Nielsville-Red River | 511 | -- | -- | -- | -- | -- | -- | -- | -- |

[1]Percentage of remaining load capacity, negative number means existing load exceeds load capacity

# 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 including an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

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

The successful implementation of restoration and protection strategies requires a combined effort from multiple entities within the SHRW, including local and state partners (i.e., the SHRWD, soil and water conservation districts [SWCDs], 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. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The SHRWD led the SHRW WRAPS effort. The SHRWD has a long history of collaborating with local and state partners to increase social capital with landowners, land users, and residents of the watershed. As a result of this, the SHRWD also has a long history of collaborating with local and state partners 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, and will build upon previous successes.

## 3.1 Targeting of Geographic Areas

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

- Hydrological Simulation Program – FORTRAN (HSPF) model
- In-lake (CNET) models
- Enhanced Geospatial Water Quality Products derived through hydrological conditioning
- Prioritized and Targeted Implementation Scenarios
- Sand Hill River Watershed Management Plan

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

### HSPF Model

HSPF is a watershed-scale model that simulates hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. The model incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. HSPF addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in-stream reaches. The output from the HSPF model is used to identify those locations where yields are greatest on average at the subwatershed outlet. More information on the SHRW HSPF model's development and calibration can be found in the modeling reports (RESPEC 2014a & b, respectively).

### In-Lake Models

Multiple CNET models were created for the impaired lakes in the SHRW. CNET is a modified spreadsheet version of the United States Army Core of Engineer's (USACE) BATHTUB model which, allows for Monte Carlo simulation. A Monte Carlo simulation approach uses selected modeling inputs that are allowed to vary within typical ranges, based upon known or assumed statistical distributions. The approach results in a statistical distribution of in-lake eutrophication conditions, based on the distributions of the input parameters. The approach is powerful because the results reflect the variability in model parameters inherent in natural systems (e.g., climate) and allows for a more realistic prediction of long-term water quality condition. A proprietary software program named "Crystal Ball[1]" was used to perform the Monte Carlo simulations. More information on the lake modeling in the SHRW can be found in the Sand Hill River Watershed Lakes Eutrophication Modeling Report (HEI 2014b).

These models produce results that include an in-lake response to nutrient loading, generally on an annual timescale. The models are developed utilizing stochastic Monte Carlo simulations to compute the likelihood of water quality outcomes. This allows for looking at lake impairments from a probabilistic standpoint, rather than as a single event.

The CNET models can be used for future lake planning by analyzing load reduction scenarios. In some cases this may include the use of other tools that provide input to the CNET models. For example, as outputs from the SHRW HSPF model change for various future scenarios, the outputs can be used with the accompanying CNET models to predict in-lake response to the changes in loading. **Figure 9** is an example of the results that the SHRW CNET models provide; highlighting the necessary reduction to meet the state water quality standard. Additional information, on the models created for the SHRW, can be found in the lakes modeling report (HEI 2014b).

[1] A proprietary software developed by Oracle;http://www.oracle.com/appserver/business-intelligence/crystalball/crystalball.html

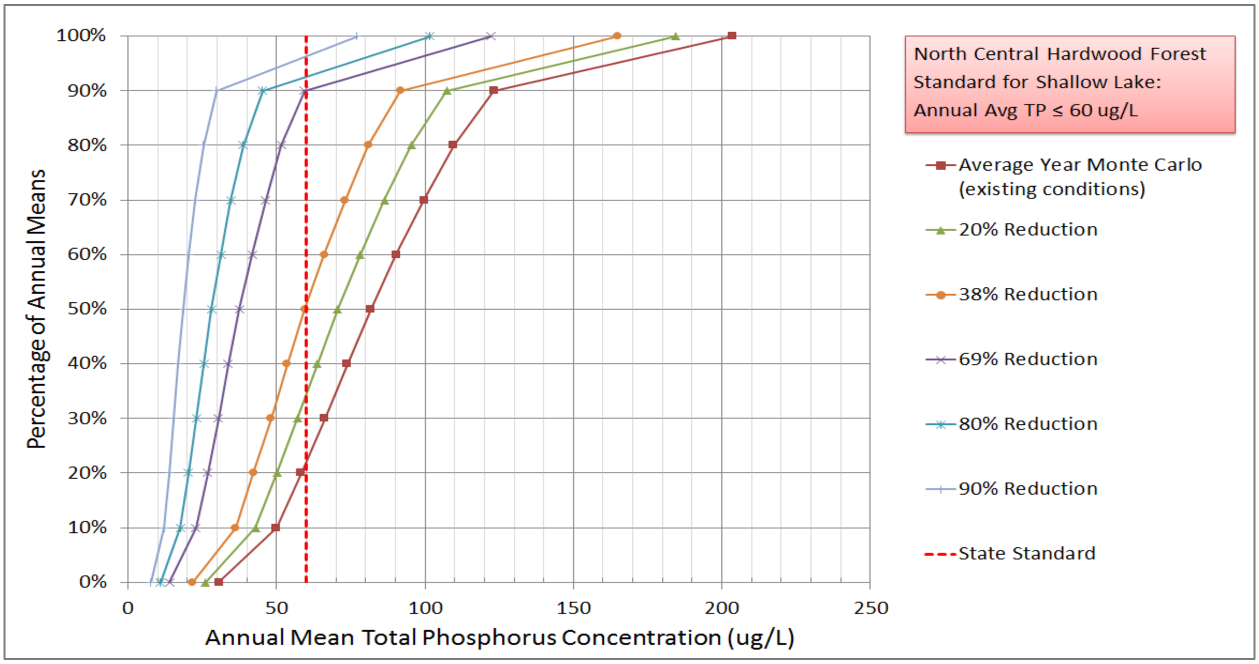



**Figure 9: Example of frequency distribution of mean annual TP concentrations resulting from select load reduction scenarios in Kittleson Lake (HEI 2014b).**

## Enhanced Geospatial Water Quality Products Derived Through Hydrological Conditioning

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. The general mapping and analysis of elevation/terrain has 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.

Excessive sediment loading in SHRW streams contributes to many of the turbidity impairments throughout the watershed. As part of local planning in the watershed, highly erosive portions of the watershed were ranked and classified using advanced, LiDAR-based GIS techniques and soils and land cover data sets. This methodology ranks basins, within 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 methodology identifies critical management areas for the prioritization and implementation of best management practices (BMPs). The methodology results in a detailed mapping of SPI values for the SHRW. This mapping provides a relative indication of the erosive power of the overland, concentrated, and surface water runoff at locations across the landscape. Additionally, this methodology results in a mapping of potential soil yields from overland flow areas, computed using the RUSLE. Priority management areas in the SHRW are identified by analyzing and combing the SPI and RUSLE results to locate those areas where the most erosive flows and highest predicted sediment yields overlap. An example of the types of products produced, for the Sand Hill River, is shown in **Figures 10** through **12**. The identified critical management areas undergo field verification by the local land managers. The main benefit of this work is the field-scale accuracy of the results.

Future use of the LiDAR terrain analysis, in restoration and protection efforts, will include the identification of field-scale priority management areas within the SHRW. These products are especially helpful for understanding the delivery of loads to specific waterbodies, downscaling of HSPF results, and targeting specific fields for placing implementation practices.

## Prioritized and Targeted Implementation Scenario

It is important to understand how the HSPF model results and the enhanced geospatial water quality products focus efforts, geographically. This section presents an example of their use. Expectations are that others may follow this same approach in the future to refine implementation and protection strategies.

The HSPF model results and Terrain Analysis Geospatial Water Quality Products were used to develop a *Prioritized and Targeted Implementation Scenario.* The Prioritized and Targeted Implementation Scenario identifies prioritized subwatersheds and restoration and protection strategies that can be carried out at the local level within those subwatersheds. Subwatersheds, within the HSPF model segments, represent the contributing drainage area to an individual reach (i.e., lake, reservoir, river, or stream). Subwatersheds were prioritized by ranking the yield from the HSPF model for various water quality constituents (i.e., Runoff, TP, TN, and Sediment) across the entire watershed. **Figure 10** shows an example of the priority rankings for a Water Quality Index based upon TP, TN, and Sediment, ranked across the entire watershed. However, many times local governmental unit (LGU) jurisdictional boundaries only encompass a portion of a watershed, or contributing area. Therefore, HSPF subwatershed prioritization was applied to the upstream contributing area of each impaired AUID to identify priority subwatersheds that are applicable to LGU jurisdictions and the resources of concern (see **Figure 10**).

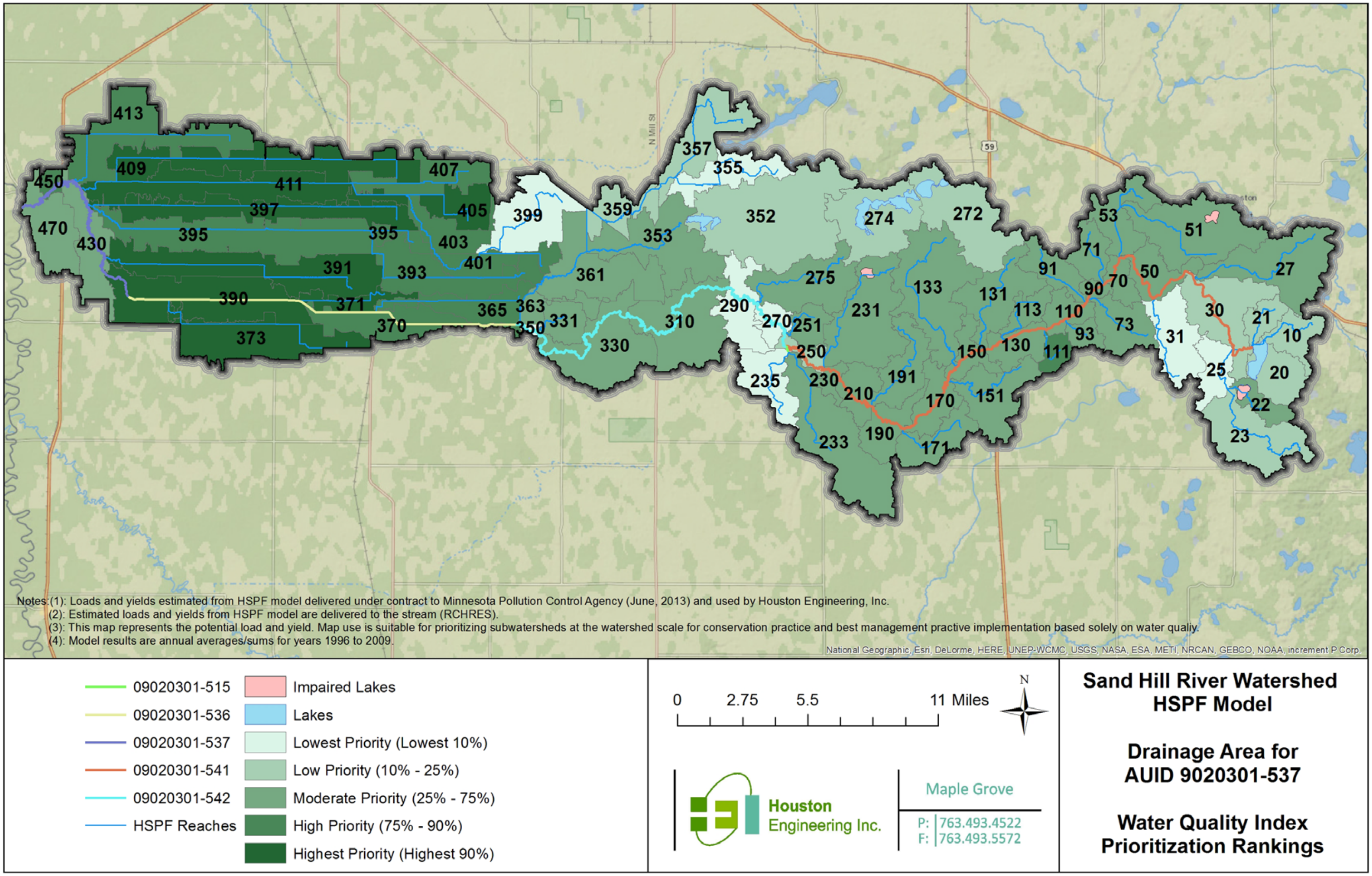



**Figure 10: HSPF subwatershed prioritization based on the Water Quality Index (WQI) calculated from TN, TP, and sediment yields.**

In addition, subwatersheds upstream of impaired AUIDs were analyzed to identify which subwatersheds held opportunities for the placement of Conservation Practices (CPs) and BMPs (**Table 18**). As shown in **Table 18**, subwatersheds which are upstream and contribute to impaired AUIDs are marked with an “x.” Suitable CPs and BMPs are highlighted in grey.

**Table 18: Suitability of Conservation Practices and Best Management Practices within HSPF subwatershed upstream of impaired stream segments.**

| HSPF Subwatershed | County Ditch 17, Garden Slough to Sandhill R (09020301-515) | Sand hill River (Kittleson Cr to unnamed Cr (0902301-536) | Sand Hill river, Unnamed Cr to Red River (09020301-537) | Sand Hill River, Headwaters to CD17 (09020301-541) | Sand Hill River, CD 17 to Kittleson Cr (09020301-542 | Temporary Water Storage (e.g. Sediment Control Basins and Storage without dead | Permanent Water Storage (i.e., with dead storage)* | Drainage Water Management | Bioreactor | *Filter Strips and Waterway Buffers | Multistage Drainage System | Saturated Buffer | Establishment of Perennials (Removal from Agricultural Production) | Cover Crop Planting | Grass Waterways |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | x | x | x | x | | | | | | | | | | |
| 20 | | x | x | x | x | | | | | | | | | | |
| 21 | | x | x | x | x | | | | | | | | | | |
| 22 | | x | x | x | x | | | | | | | | | | |
| 23 | | x | x | x | x | | | | | | | | | | |
| 25 | | x | x | x | x | | | | | | | | | | |
| 27 | | x | x | x | x | | | | | | | | | | |
| 30 | | x | x | x | x | | | | | | | | | | |
| 31 | | x | x | x | x | | | | | | | | | | |
| 50 | | x | x | x | x | | | | | | | | | | |
| 51 | | x | x | x | x | | | | | | | | | | |
| 53 | | x | x | x | x | | | | | | | | | | |
| 70 | | x | x | x | x | | | | | | | | | | |
| 71 | | x | x | x | x | | | | | | | | | | |
| 73 | | x | x | x | x | | | | | | | | | | |
| 90 | | x | x | x | x | | | | | | | | | | |
| 91 | | x | x | x | x | | | | | | | | | | |
| 93 | | x | x | x | x | | | | | | | | | | |
| 110 | | x | x | x | x | | | | | | | | | | |
| 111 | | x | x | x | x | | | | | | | | | | |
| 113 | | x | x | x | x | | | | | | | | | | |
| 130 | | x | x | x | x | | | | | | | | | | |
| 131 | | x | x | x | x | | | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 133 | | x | x | x | x | | | | | | | | | | |
| 150 | | x | x | x | x | | | | | | | | | | |
| 151 | | x | x | x | x | | | | | | | | | | |
| 170 | | x | x | x | x | | | | | | | | | | |
| 171 | | x | x | x | x | | | | | | | | | | |
| 190 | | x | x | x | x | | | | | | | | | | |
| 191 | | x | x | x | x | | | | | | | | | | |
| 210 | | x | x | x | x | | | | | | | | | | |
| 230 | | x | x | x | x | | | | | | | | | | |
| 231 | | x | x | x | x | | | | | | | | | | |
| 233 | x | x | x | | x | | | | | | | | | | |
| 235 | x | x | x | | x | | | | | | | | | | |
| 250 | | x | x | x | x | | | | | | | | | | |
| 251 | | x | x | | x | | | | | | | | | | |
| 270 | | x | x | | x | | | | | | | | | | |
| 272 | | x | x | | x | | | | | | | | | | |
| 274 | | x | x | | x | | | | | | | | | | |
| 275 | | x | x | | x | | | | | | | | | | |
| 290 | | x | x | | x | | | | | | | | | | |
| 310 | | x | x | | x | | | | | | | | | | |
| 330 | | x | x | | x | | | | | | | | | | |
| 331 | | x | x | | x | | | | | | | | | | |
| 350 | | x | x | | x | | | | | | | | | | |
| 352 | | x | x | | | | | | | | | | | | |
| 3 | | x | x | | | | | | | | | | | | |
| 355 | | x | x | | | | | | | | | | | | |
| 357 | | x | x | | | | | | | | | | | | |
| 359 | | x | x | | | | | | | | | | | | |
| 361 | | x | x | | | | | | | | | | | | |
| 363 | | x | x | | | | | | | | | | | | |
| 365 | | x | x | | | | | | | | | | | | |
| 370 | | x | x | | | | | | | | | | | | |
| 371 | | x | x | | | | | | | | | | | | |
| 373 | | x | x | | | | | | | | | | | | |
| 390 | | x | x | | | | | | | | | | | | |
| 391 | | | x | | | | | | | | | | | | |
| 393 | | | x | | | | | | | | | | | | |
| 395 | | | x | | | | | | | | | | | | |
| 397 | | | x | | | | | | | | | | | | |
| 399 | | | x | | | | | | | | | | | | |
| 401 | | | x | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 403 | | | x | | | | | | | | | | | | |
| 405 | | | x | | | | | | | | | | | | |
| 407 | | | x | | | | | | | | | | | | |
| 409 | | | x | | | | | | | | | | | | |
| 411 | | | x | | | | | | | | | | | | |
| 413 | | | x | | | | | | | | | | | | |
| 430 | | | x | | | | | | | | | | | | |
| 450 | | | x | | | | | | | | | | | | |
| 470 | | | x | | | | | | | | | | | | |

Within HSPF prioritized subwatersheds, Terrain Analysis Geospatial Water Quality Products were used to target specific fields (5 to 124 acres in area) based upon the predicted relative yield of sediment, TP, and Total Nitrogen (TN). In addition, high resolution topographic data, collected using LiDAR, and Terrain Analysis Geospatial Water Quality Products were used to identify the field scale suitability of Conservation Practices (CP) and Best Management Practices (BMP) within HSPF prioritized subwatersheds. This process of developing P*rioritized and Targeted Implementation Scenarios* can be facilitated with following data products:

- HSPF Subwatershed Prioritization based on the predicted yield of TN, TP, Sediment, and Unit Runoff
- Targeting of specific fields within priority subwatersheds based on LiDAR derived TN, TP, and Sediment ranks
- Targeting of specific fields within priority subwatersheds based upon CP and BMP suitability analysis

Below is an example of subwatershed prioritization using HSPF outputs and then field targeting, using Terrain Analysis Geospatial Water Quality Products, based upon sediment yield, and CP/BMP suitability for the Sandhill River Headwaters to County Ditch 17 (AUID #09020301-541; hereafter Sand Hill River Headwaters). Stressor identification work has indicated that excess sediment contributes to a M-IBI impairment within the reach (MPCA 2014). To aid in restoring this reach, non-point sources within the Sand Hill River Headwaters have been given TSS load allocations (see **Table 15**, HEI 2014c). These load allocations represent the minimum water quality goal for the Sand Hill River Headwaters.

Using HSPF model outputs, subwatersheds contributing to the Sand Hill River Headwaters were prioritized based upon their contribution of sediment to the impaired reach (**Figure 11**). From this prioritization scenario, subwatershed 111 (**Figure 11**) was selected to target field scale CP and BMP suitability for reducing sediment to the Sand Hill River Headwaters.

Within HSPF subwatershed 111 (**Figures 11** and **12**), specific fields were targeted for the placement of six different types of CPs and BMPs that could aid in reducing downstream sediment delivery and upstream sediment production (**Figure 12**). From the analysis targeting the placement of CPs and BMPs, a BMP Suitability Index was developed that identifies specific fields with the greatest number of potential restoration and protection opportunities (**Figure 12**). The areas with the highest levels of downstream sediment delivery were ranked using the Terrain Analysis Geospatial Water Quality Products analysis and methods developed in other research (HEI 2013b). The BMP Suitability Index and sediment ranking outputs were given equal weights and multiplied together to identify specific fields having the highest flux of sediment and greatest number of potential CPs and BMPs (**Figure 13**). The results of this type of analysis can be used to identify specific practices that can be targeted to fields, with the highest production of sediment, within HSPF prioritized subwatersheds.

The goal of this *Prioritized and Targeted Implementation Scenario* is to provide a direct method for LGUs to utilize the information developed through the WRAPS process to restore and protect water resources within the SHRW. This is accomplished by targeting the field scale placement of CPs and BMPs within HSPF high priority subwatersheds. An example of how to use the HSPF model results and Terrain Analysis Geospatial Water Quality Products is shown for a single watershed. However, subwatershed prioritization is a function of spatial scale (i.e., it is dependent upon the specific water body of interest and whether the water body is impaired or needs protection). The HSPF model results and Terrain Analysis Geospatial Water Quality Products needed to prioritize subwatersheds and target fields for any water body are included in **Appendix B**. Expectations are that the LGUs will use these data to develop *Prioritized and Targeted Implementation Scenario* for water bodies needing restoration and protection strategies.

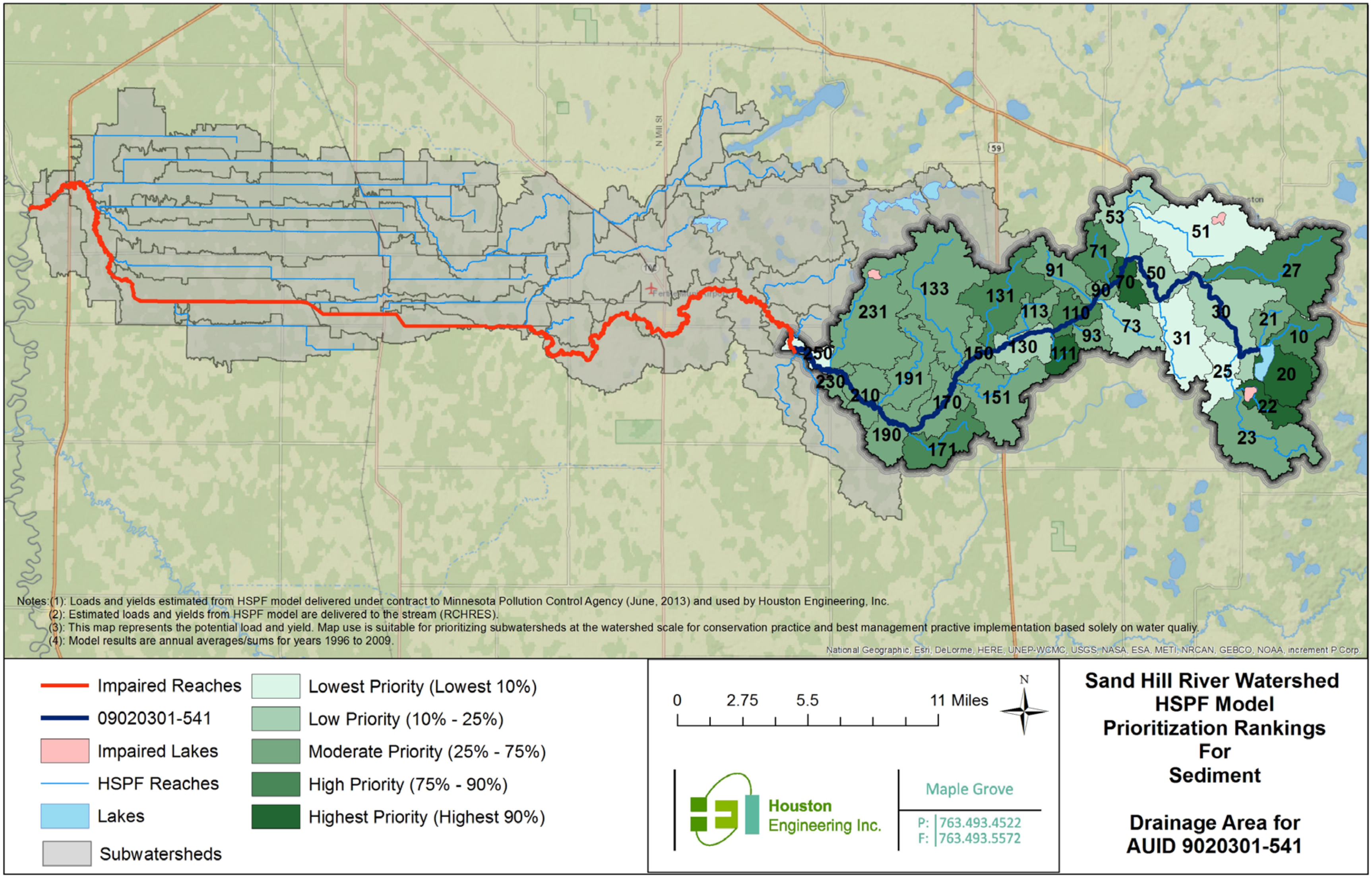



**Figure 11: Prioritization of HSPF subwatersheds contributing to AUID 9020301-541 based on sediment.**

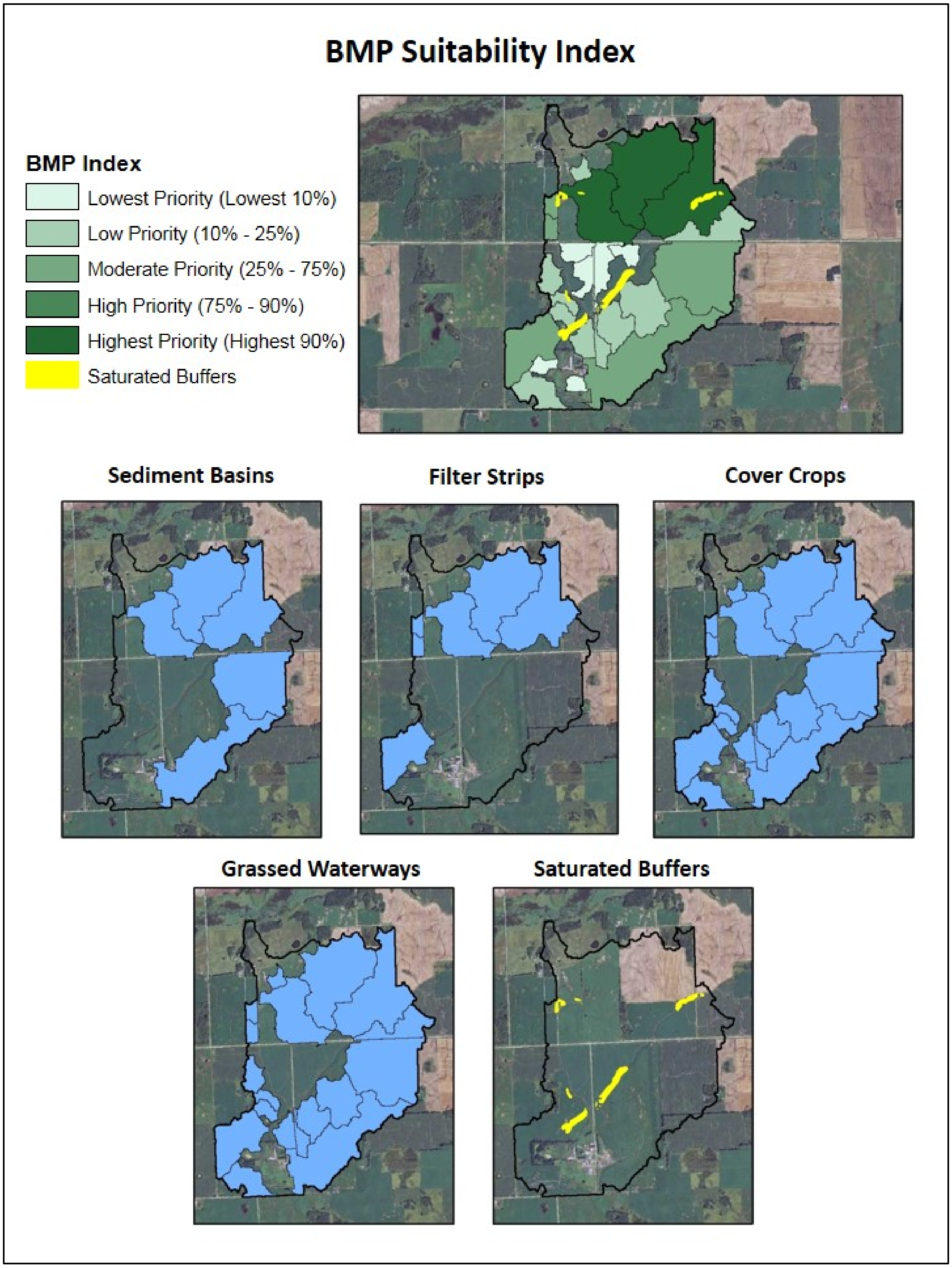



**Figure 12: Targeting the placement of Conservation Practices and Best Management Practices to specific fields within HSPF prioritized subwatershed 111.**

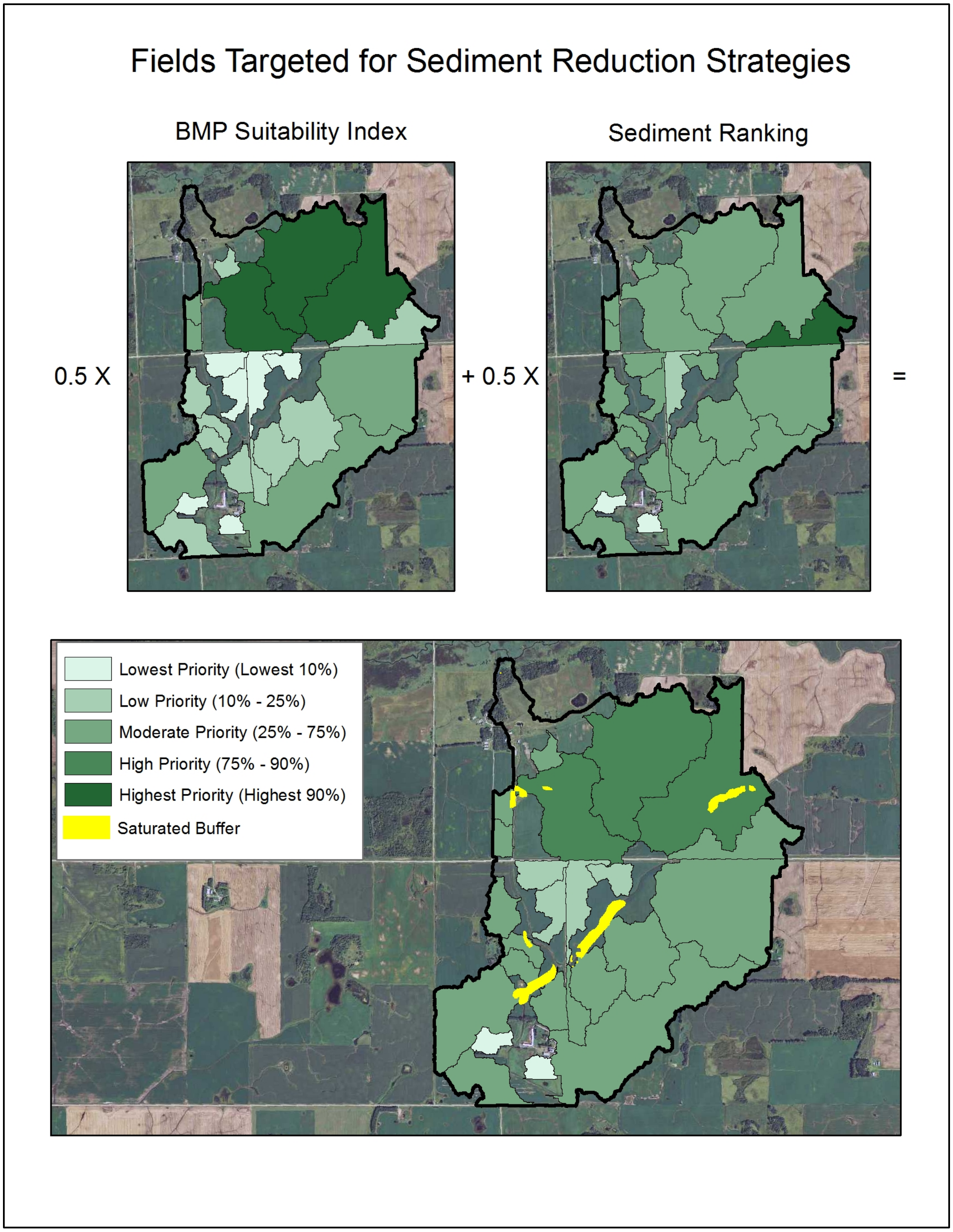



**Figure 13: Targeting specific fields based on sediment flux and, and Conservation Practices and Best Management Practices suitability for restoration and protection strategies within HSPF prioritized subwatershed 111.**

## Sand Hill River Watershed Management Plan

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

The SHRWD WMP was most recently updated in May of 2011. In the updated plan, great efforts were made to quantify the goals and suggest implementation strategies for managing water quantity and quality, as well as natural resource enhancement. The SHRWD WMP is scheduled for its next update in 2021. Results of the WRAPS will be directly incorporated into the updated Plan.

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

## Additional Tools

A number of additional tools are available for use in restoration and protection of impaired waters in the SHRW. A non-exhaustive list of some of these tools, their description and how they may be utilized is listed in **Table 19**.

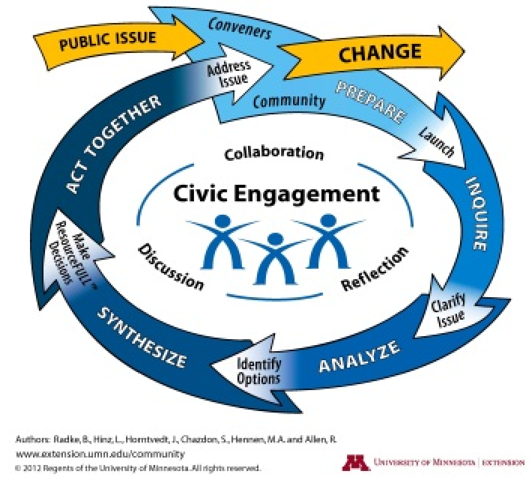
**Table 19: Additional Tools Available for Restoration and Protection of Impaired Waters.**

| Tool | Description | How can the tool be used? | Notes | Link to Information and data |
|---|---|---|---|---|
| **Prioritize, Target and Measure Application (PTMApp)** | The Prioritize, Target, and Measure Application (PTMA) 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 (discussed above) 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)** | This dataset consists of three GIS raster data layers including soil erosion risk, water quality risk, and habitat quality. The 30-meter grid cells in each layer contain scores from 0-100. The sum of all three scores is the EBI score (max of 300). A higher score indicates a higher priority for restoration or protection. | The three layers can be used separately, or the sum of the layers (EBI) can be used to identify priority areas for restoration or protection projects. The layers can be weighted or combined with other layers to better reflect local values. | These data layers are available on the BWSR website.<br><br>In addition, a GIS data layer that shows the 5% of each 8-digit watershed in Minnesota with the highest EBI scores is available for viewing in the MPCA 'water quality targeting' web map, and download from MPCA. | *BWSR*<br><br>*MPCA Web Map*<br><br>*MPCA download* |
| **Zonation** | This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration. | Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells). | The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.) | *Software*<br><br>*Examples* |

**Table 19: Additional Tools Available for Restoration and Protection of Impaired Waters (cont.)**

| Tool | Description | How can the tool be used? | Notes | Link to Information and data |
|---|---|---|---|---|
| **Restorable Wetland Inventory** | A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and USDA NRCS SSURGO soils with a soil drainage class of poorly drained or very poorly drained. | Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk. | The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' web site. | *Restorable Wetlands* |
| **National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)** | The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations. | General mapping and analysis of surface-water systems. These data 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* |
| **Hydrological Simulation Program – FORTRAN (HSPF) Model** | Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles). | Incorporates watershed-scale and non-point source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. | Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of BMPs, and 2) effects of proposed or hypothetical land use changes. | *USGS* |

## 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 higher, 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.

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 SHRWD, the SWCDs, and state agencies. This group was primarily engaged to discuss potential products developed to identify geographic areas for implementing projects to manage the watershed. A public meeting was held in March 22, 2012, to discuss Phase I of the WRAPS project.

The Sand Hill River WRAPS Report went through its 30-day public noticed review and comment period from May 31, 2016, through June 29, 2016. The MPCA received five comments regarding the WRAPS report, all of which were submitted by the Minnesota Department of Agriculture. All comments have been addressed in this final WRAPS report.

### Accomplishments and Future Plans

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.

## 3.3 Restoration & Protection Strategies

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

Based on an analysis of flow statistics for the Sand Hill River at Climax, Minnesota (USGS ID: 05095000), the 1.5-year, 2-year, and 10-year return period flows have increased by 1,069 cfs, 1,071 cfs, and 711 cfs, respectively (**Table 20**). These changes are indicative of altered hydrology that has been cited as a stressor to biological impairments in the SHRW (MPCA 2014a) and in other watersheds in Minnesota (e.g., MPCA 2013). Based on the results of this analysis (see **Table 20**), restoration and protection strategies can be developed to reduce flows for critical channel forming return periods in an effort to restore the hydrology of the SHRW. A study that identifies areas that are suitable for distributed water detention projects (HEI 2013) in the SHRW has already been completed. **Table 21** and **Table 22** identify the subwatersheds where distributed water retention projects could be implemented, based upon the results of the HEI 2013 study. In addition to restoring and protecting hydrology, water detention basins can also aid in restoring surface waters impacted by sediment and nutrients (Tomer et al. 2013), providing an opportunity to address multiple stressors.

**Table 20: Return periods for critical channel forming flows for the Sand Hill River at Climax, Minnesota (USGS ID: 05095000).**

| Return Period | 1980-2010 | 1945-1975 | Change |
|---|---|---|---|
| years | -------------------Flow, cfs---------------- | | |
| 1.5 | 3,355 | 2,286 | 1069 |
| 2 | 3,496 | 2,425 | 1071 |
| 10 | 4,227 | 3,516 | 711 |

**Table 21** contains a list of the impaired waters of the SHRW, along with goals for restoration and suggested implementation strategies to achieve those goals. All other waters in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies (see **Section 2.5** for protection considerations). Given the homogeneity of the watershed, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes.

The Sand Hill River Watershed District, the East Polk SWCD, and West Polk SWCD have a long history of improving water quality. All three have been seeking grants to improve local water quality since the passage of the Clean Water, Land Legacy Amendment. The SHRWD is a member district of the Red River Watershed Management Board and is also a member of the Minnesota Flood Damage Reduction Work Group. These entities are important partners in the Red River Basin for meeting both water quality and water storage goals. The following is a brief description of existing, planned, or proposed projects the SHRWD, East Polk SWCD, and West Polk SWCD are implementing to achieve the water quality targets listed in this document and the SHRW TMDL (HEI 2014c).

In 2010, the SHRWD and East Polk SWCD received funding to assist landowners with flood related projects. Some of these projects were water and sediment basins on cropland with slopes greater than 10%. A water and sediment basin is an earthen embankment built so that sediment-laden runoff is temporarily detained, allowing sediment to settle out before runoff is discharge. These are installed on agricultural cropland where erosion exceeds the allowable soil rate. Minimum detention time to store water is 36 hours for a 10-year, 24-hour runoff event. The average water/sediment basin costs approximately $6,000 and reduces sediment by 19.31 tons/yr and phosphorus by 20.66 lbs/yr, and saves approximately 33.16 tons/yr of soil.

The success of these BMPs had landowners requesting more funding than what the SWCD had available. In 2011, the East Polk SWCD received a Clean Water Act (CWA) grant to install 70 water and sediment basins. In 2012, the East Polk SWCD received a CWA grant to install approximately 80 water and sediment basins. In 2014, the SHRWD received a CWA grant. That money was used to install an additional 80 water and sediment basins. There remains a significant backlog of landowners requesting assistance. Because of this popular conservation practice, the SHRWD has landowners on a waiting list. Water and sediment basins are a practical practice landowners can install while at the same time addressing the impairments of the Sand Hill River. In 2015, The SHRWD submitted a request for a Targeted Watershed Program Grant to fund 60 sediment control basins and a coulee stabilization project in the watershed that contributes to AUID 09020301-541.

These sediment basins reduce the amount of overall sediment loading reaching the Sand Hill River and both help address the turbidity/TSS impairments throughout the watershed and reduce the elevated turbidity stressors on biological impairments. In addition, the sediment basins detain surface runoff up to 36 hours, helping reduce the altered hydrology stressors identified in the SID Report (MPCA 2014b).

The SHRWD, along with the West Polk SWCD, received a $475,000 grant in Clean Water Funds (CWF) and $100,000 from Enbridge., Inc. to install 16 rock riffles to assist with grade stabilization and facilitate fish passage for 3.5 miles of the channelized reach of the Sand Hill River (AUID 09020301-536), which contributes thousands of tons of sediment downstream. The total project length is five miles of channel located between the cities of Fertile and Beltrami in western Polk County. It has been estimated that the channelized reach bed and banks lose 2,270 tons of sediment, per mile, each year. Channelization of a watercourse decreases the stream length, increases the channel grade/slope and increases flow velocities, resulting in incision of the channel bed and destabilization of the banks. The Sand Hill River channelized reach has been experiencing channel bed incision, destabilized banks, and increased turbidity/sedimentation, which has led to the water quality impairment. To address this, several projects were completed to reduce in-channel sediment load and resulting turbidity in the Sand Hill River and will address the turbidity/TSS impairments in AUID 9020301-536 and any identified elevated turbidity stressor.

In addition, the SHRWD wants to install grade control measures in a 2.75 mile reach of the Polk County Ditch 122 and will complete as funds become available. The SHRWD is also providing stabilization to headcutting that is occurring along a tributary (Carlson Coulee) to the Sand Hill River. Carlson Coulee is also located within the Targeted Watershed Program area. If successful, the Targeted Watershed Program could fund the Carlson Coulee. The SHRWD also plans to install grade stabilization measures along an abandoned ditch near Winger (formerly known as County Ditch 133).

The SHRWD is also installing gully stabilization measures around the perimeter of Union Lake that will reduce sediment loading into the lake. This is expected to improve water quality by reducing TP and turbidity. Although not listed as impaired, Union Lake is a popular recreational lake in the district, and is a high priority for protection.

In 2016, the SHRWD secured funding for retrofitting the U.S. Army Corps of Engineers drop structures, located in the upper reaches of the Sand Hill River (AUID 9020301-541 and -542), with riprap to allow fish passage. This project was a high priority for the DNR and was federally funded with a 75% match. The project had a total estimated cost of $6.7 million. This project is expected to address the loss of connectivity stressors identified in the SID Report (MPCA 2014b).

The SHRWD is also developing regional detention facilities and strategy to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed. The SHRW has worked extensively on several potential facilities in the watershed, and will continue to build off these previous efforts. Natural Resource Enhancement features will be included, where applicable, to meet multiple goals and objectives for SHRWD Planning Region No. 4 (see **Figure 1**). The SHRWD will use required easement areas to restore natural vegetation to land used for runoff detention in Region 4. The SHRWD plans to complete one detention facility by 2016-17 at a cost of $3 million. This project, along with future facilities, will reduce sediment loading and address the turbidity/TSS impairment in AUID 9020301-541 and address the elevated turbidity and altered hydrology stressors indicated in the Stressor Identification Report (MPCA 2014b).

Past ditching and recent and ongoing increases in tile drainage have altered watershed runoff patterns and stream flow; in particular, increases in tile drainage are likely to result in increases in nitrates and reactive phosphorus concentrations in downstream waterbodies. As tile drainage is installed, it is important that new designs minimize potential downstream impacts.

The SHRWD will continue existing programs to install side water inlets and establish vegetated buffer strips adjacent to the Sand Hill Drainage System. These will reduce sediment and phosphorus loading from agricultural sources to the channel. These programs are ongoing with an estimated cost of $4 million and will address the turbidity and excessive nutrient impairments, as well as the elevated turbidity and excessive nutrients stressors.

Interim 10-year milestones are identified in **Table 21** for each impaired subwatershed, so incremental progress is achieved. On-going water quality monitoring data will be used in future components of the

WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals. The timeline for the identified protection strategies is on-going.

**Table 21: Strategies and actions proposed for the Sand Hill River Watershed.**

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All | All | All | Parameters cited in permit | - | - | Wastewater facilities -- compliance with NPDES permits | | | | | • | | | | - |
| | | | Parameters cited in permit | - | - | Construction and Industrial Stormwater permittees -- compliance with general permits | | | | | • | | | | - |
| Upper Sand Hill River (0902030102) | County Ditch 17-Garden Slough to Sand Hill R (09020301-515) | Norman, Polk | Biological-Macroinvertebrate IBI: Altered hydrology | Micro. IBI = 29.6 | Micro IBI >35.9 | Engineered hydrologic control structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | 2040 |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | Sand Hill River-Headwaters to CD 17 (09020301-541) | Mahnomen, Norman, Polk | Biological-Macroinvertebrate IBI: Low Dissolved Oxygen, Excessive Sediment, Altered hydrology | Micro. IBI = 29.6 | Micro IBI >35.9 | Engineered hydrologic control structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | 2040 |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | | | | | | Channel restoration | Install in- channel grade control measures to reduce sedimentation | Install grade control structures to reduce sediment erosion. | • | | | • | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | Turbidity/TSS | High = 40 mg/L<br>Moist = 60 mg/L<br>Avg = 26 mg/L<br>Dry = 65 mg/L<br>Low = 51 mg/L | 90% of samples ≤ 33.8 mg/L TSS<br>Reductions:<br>High = 23%<br>Moist = 49% | Improve upland/field surface runoff controls [to reduce or intercept farm field erosion] | Mixture of upland BMPs (incl grassed waterways, WASCOBs, contour farming) to reduce soil loss. | Install sediment control BMPs throughout the contributing drainage area | • | • | | | | | 2040 |
| Upper Sand Hill River | Sand Hill River-Headwaters | Mahnomen, Norman, Polk | Turbidity/TSS (cont.) | | Avg = 0%<br>Dry = 53%<br>Low = 40% | Improve upland/field surface runoff controls [to reduce or | Riparian and/or ditch system buffers on all streams and all buffer requirements met | Increase the number of buffers along streams and ditches | • | • | | | | | 2040 |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (0902030102) (cont.) | to CD 17 (09020301-541) (cont.) | | | | | intercept farm field erosion] (cont.) | Increase cover crops and/or perennial vegetation to reduce erosion | Review NRCS conservation plans to determine residue needs and focus areas | | • | | | | | |
| | | | | | | | Residue Management | Develop residue management plan | | • | | | | | |
| | | | | | | Engineered Hydrologic Control Structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | *E. coli* | High = 148 org/100mL Moist = 68 org/100mL Avg = 188 org/100mL Dry = 42 org/100mL Low = 32 org/100mL | Geometric mean ≤ 126 org/100mL Reductions: High = 23% Moist = 0% Avg = 40% Dry = 0% Low = 0% | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspections | | | | | • | | 2040 |
| | | | | | | Livestock Management | Control livestock access to streams | Implement at least one cattle exclusion plan | | • | | | | | |
| | | | | | | | Manure Management | Develop manure management plan , Identify areas where manure management BMPs could be placed | • | • | | | | | |
| Upper Sand Hill River (0902030102) (cont.) | Sand Hill River-Headwaters to CD 17 | Mahnomen, Norman, Polk | *E. coli* (cont.) | | | Riparian and/or ditch system buffers | Increase the amount of riparian and/or ditch system buffers | Identify areas to increase amount of buffers | • | • | | | | | 2040 |
| | | | | | | Nutrient Management | Develop field-scale nutrient management plans | Develop field-scale nutrient management plans | | • | | | | | |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (09020301-541) (cont.) | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | Biological-Fish IBI: Low Dissolved Oxygen, Loss of Connectivity, Altered hydrology, Lack of In-stream Habitat | Fish IBI = 8.5-37.8 | Fish IBI > 38.3-46.8 | Engineered hydrologic control structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | 2040 |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | | | | | | Channel restoration | Install in- channel grade control measures to reduce sedimentation | Install grade control structures to reduce sediment erosion. | • | | | • | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | | | | Fish passage(s) around dam(s) | Install fish passages to increase stream connectivity (completed in 2016) | Compliance with MS4 permit conditions | • | | | • | | | |
| | Sand Hill River-CD 17 to Kittleson Cr (09020301-542) | Mahnomen, Norman, Polk | *E. coli* | High = NA<br>Moist = 87 org/100mL<br>Avg = 174 org/100mL<br>Dry = 72 org/100mL<br>Low = 95 org/100mL | Geometric mean ≤ 126 org/100mL<br>Reductions:<br>High = NA<br>Moist = 0%<br>Avg = 35%<br>Dry = 0%<br>Low = 0% | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspections | | | | | • | | 2040 |
| | | | | | | Livestock Management | Control livestock access to streams | Implement at least one cattle exclusion plan | | • | | | | | |
| | | | | | | | Manure Management | Develop manure management plan , Identify areas where manure management BMPs could be placed | • | • | | | | | |
| Upper Sand Hill River (0902030102) (cont.) | Sand Hill River-CD 17 to Kittleson Cr (09020301-542) (cont.) | Mahnomen, Norman, Polk | *E. coli* (cont.) | | | Riparian and/or ditch system buffers | Increase the amount of riparian and/or ditch system buffers | Identify areas to increase amount of buffers | • | • | | | | | 2040 |
| | | | | | | Nutrient Management | Develop nutrient management plan | Develop nutrient management plan | | • | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | Biological-Fish IBI: Loss of Connectivity, Altered Hydrology, Lack of In-stream Habitat | Fish IBI = 31 - 46 | Fish IBI > 50 | Engineered hydrologic control structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | 2040 |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | | | | | | Channel restoration | Install in- channel grade control measures to reduce sedimentation | Install grade control structures to reduce sediment erosion. | • | | | • | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | | | | Fish passage(s) around dam(s) | Install fish passages to increase stream connectivity (completed in 2016) | Compliance with MS4 permit conditions | • | | | • | | | |
| | Ketchum Lake (44-0152-00) | Mahnomen | Excessive Nutrients-Phosphorus (TP) | 187 lbs TP Annual load; 130 ppb seasonal conc | 81 lbs TP annual load (43% Reduction); 60 ppb TP seasonal conc | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspection | • | | | | | | 2030 |
| | | | | | | Livestock Management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing, pasture runoff controls, buffers, heavy use protection-stream crossing areas, alternative watering sources, rotational grazing. | Develop grazing management plan for riparian zones | | • | | | | | |
| | | | | | | Shoreline Buffers | Implement or improve buffers along the shoreline | Work with land owners to install buffers along the shoreline | | • | | | | | |
| Upper Sand Hill River (0902030102) (cont.) | Ketchum Lake (44-0152-00) (cont.) | Mahnomen | Excessive Nutrients-Phosphorus (TP) (cont.) | | | Nutrient Management | Reduce watershed phosphorus loading by 43% | Develop nutrient management plan to identify, target and implement nutrient BMPs | | • | | | | • | 2030 |
| | | | | | | Diagnostic Study | Preform a diagnostic study to quantify any internal loading of phosphorus and identify sources. Develop implementation plan to reduce internal loading. | Complete diagnostic study and develop implementation plan (if applicable) | • | | • | • | | | |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kittleson Lake (60-0327-00) | Polk | Excessive Nutrients-Phosphorus (TP) | 1,863 lbs TP Annual load; 87 ppb seasonal conc | 1,324 lbs TP annual load (71% Reduction); 60 ppb TP seasonal conc | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspection | • | | | | | | 2030 |
| | | | | | | Livestock Management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing, pasture runoff controls, buffers, heavy use protection-stream crossing areas, alternative watering sources, rotational grazing. | Develop grazing management plan for riparian zones | | • | | | | | |
| | | | | | | Shoreline Buffers | Implement or improve buffers along the shoreline | Work with land owners to install buffers along the shoreline | | • | | | | | |
| | | | | | | Nutrient Management | Reduce watershed phosphorus loading by 71% | Develop nutrient management plan to identify, target and implement nutrient BMPs | | • | | | | • | |
| | | | | | | Diagnostic Study | Preform a diagnostic study to quantify internal loading of phosphorus rates and identify sources. Develop implementation plan to reduce internal loading. | Complete diagnostic study and develop implementation plan | • | | • | • | | | |
| | | | | | | In-lake Nutrient Management (Based on Diagnostic Study) | Rough fish management (if applicable) | Develop implementation plan based on diagnostic study | | | • | • | | | |
| | | | | | | | Curly-leaf pondweed management (if applicable) | | | | • | • | | | |
| | | | | | | | Alum treatment (if applicable) | | • | • | • | | | | |
| | Uff Lake (60-0119-00) | Polk | Excessive Nutrients-Phosphorus (TP) | 105 lbs TP annual load; 130.5 ppb seasonal TP conc | 65 lbs TP annual load (62% Reduction); 60 ppb TP seasonal conc | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspection | • | | | | | | 2030 |
| Upper Sand Hill River (0902030102) (cont.) | Uff Lake (60-0119-00) (cont.) | Polk | Excessive Nutrients-Phosphorus (TP) (cont.) | | | Livestock Management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing, pasture runoff controls, buffers, heavy use protection-stream crossing areas, alternative watering sources, rotational grazing. | Develop grazing management plan for riparian zones | | • | | | | | 2030 |
| | | | | | | Shoreline Buffers | Implement or improve buffers along the shoreline | Work with land owners to install buffers along the shoreline | | • | | | | | |
| | | | | | | Nutrient Management | Reduce watershed phosphorus loading by 62% | Develop nutrient management plan to identify, target and implement nutrient BMPs | | • | | | | • | |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Diagnostic Study | Preform a diagnostic study to quantify any internal loading of phosphorus and identify sources. Develop implementation plan to reduce internal loading. | Complete diagnostic study and develop implementation plan (if applicable) | • | | • | • | | | |
| | Unnamed Lake (60-0236-00) | Polk | Excessive Nutrients-Phosphorus (TP) | 287 lbs TP annual load; 68.7 ppb seasonal TP conc | 82 lbs TP annual load (29% Reduction); 60 ppb TP seasonal conc | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspection | • | | | | | | 2030 |
| | | | | | | Livestock Management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing, pasture runoff controls, buffers, heavy use protection-stream crossing areas, alternative watering sources, rotational grazing. | Develop grazing management plan for riparian zones | | • | | | | | |
| | | | | | | Shoreline Buffers | Implement or improve buffers along the shoreline | Work with land owners to install buffers along the shoreline | | • | | | | | |
| | | | | | | Nutrient Management | Reduce watershed phosphorus loading by 29% | Develop nutrient management plan to identify, target and implement nutrient BMPs | | • | | | | • | |
| | | | | | | Diagnostic Study | Preform a diagnostic study to quantify internal loading of phosphorus rates and identify sources. Develop implementation plan to reduce internal loading. | Complete diagnostic study and develop implementation plan | • | | • | • | | | |
| | | | | | | In-lake Nutrient Management (Based on Diagnostic Study) | Rough fish management (if applicable) | Develop implementation plan based on diagnostic study | | | • | • | | | |
| Upper Sand Hill River (0902030102) (cont.) | Unnamed Lake (60-0236-00) (cont.) | Polk | Excessive Nutrients-Phosphorus (TP) (cont.) | | | In-lake Nutrient Management (Based on Diagnostic Study) (cont.) | Curly-leaf pondweed management (if applicable) | Develop implementation plan based on diagnostic study | | | • | • | | | 2030 |
| | | | | | | | Alum treatment (if applicable) | | • | • | • | | | | |
| Lower Sand Hill River (0902030103) | Sand Hill River-Kittleson Crk to Unnamed Crk (09020301-536) | Mahnomen, Norman, Polk | *E. coli* | High = NA<br>Moist = 240 org/100mL<br>Avg = 227 org/100mL<br>Dry = 145 org/100mL<br>Low = 97 org/100mL | Geometric mean ≤ 126 org/100mL<br>Reductions:<br>High = NA<br>Moist = 53%<br>Avg = 50%<br>Dry = 22%<br>Low = 0% | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspections | | | | | • | | 2040 |
| | | | | | | Livestock Management | Control livestock access to streams | Implement at least one cattle exclusion plan | | • | | | | | |
| | | | | | | | Manure Management | Develop manure management plan , Identify areas where manure management BMPs could be placed | • | • | | | | | |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: Location and Upstream Influence Counties | Parameter (incl. non-pollutant stressors) | Water Quality: Current Conditions | Water Quality: Goals / Targets and Estimated % Reduction | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: SHRWD | SWCD | MPCA | DNR | County | MDA | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Sand Hill River (0902030103) (cont.) | | | | | | Riparian and/or ditch system buffers | Increase the amount of riparian and/or ditch system buffers | Identify areas to increase amount of buffers | • | • | | | | | |
| | | | | | | Nutrient Management | Develop nutrient management plan | Develop nutrient management plan | | • | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | Sand Hill River-Unnamed Crk to Red R (09020301-537) | Mahnomen, Norman, Polk | *E. coli* | High = NA<br>Moist = 32 org/100mL<br>Avg = 170 org/100mL<br>Dry = 191 org/100mL<br>Low = 228 org/100mL | Geometric mean ≤ 126 org/100mL<br>Reductions:<br>High = NA<br>Moist = 0%<br>Avg = 33%<br>Dry = 41%<br>Low = 50% | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | Conduct septic system inventory and inspections | | | | | • | | 2040 |
| | | | | | | Livestock Management | Control livestock access to streams | Implement at least one cattle exclusion plan | | • | | | | | |
| | | | | | | | Manure Management | Develop manure management plan , Identify areas where manure management BMPs could be placed | • | • | | | | | |
| | Sand Hill River-Unnamed Crk to Red R (09020301-537) (cont.) | Mahnomen, Norman, Polk | *E. coli* (cont.) | | | Riparian and/or ditch system buffers | Increase the amount of riparian and/or ditch system buffers | Identify areas to increase amount of buffers | • | • | | | | | 2040 |
| | | | | | | Nutrient Management | Develop nutrient management plan | Develop nutrient management plan | | • | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| | | | Turbidity/TSS | High = 436 mg/L<br>Moist = 190 mg/L<br>Avg = 78 mg/L<br>Dry = 76 mg/L<br>Low = 83 mg/L | 90% of samples ≤ 33.8 mg/L TSS<br>Reductions:<br>High = 93%<br>Moist = 84%<br>Avg = 61%<br>Dry = 60%<br>Low = 63% | Improve upland/field surface runoff controls [to reduce or intercept farm field erosion] | Mixture of upland BMPs (including grassed waterways, WASCOBs, contour farming) to reduce soil loss. | Install sediment control BMPs throughout the contributing drainage area | • | • | | | | | 2040 |
| | | | | | | | Riparian and/or ditch system buffers on all streams and all buffer requirements met | Increase the number of buffers along streams and ditches | • | • | | | | | |
| | | | | | | | Increase cover crops and/or perennial vegetation to reduce erosion | Review NRCS conservation plans to determine residue needs and focus areas | | • | | | | | |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter (incl. non-pollutant stressors) | Water Quality | | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | Location and Upstream Influence Counties | | Current Conditions | Goals / Targets and Estimated % Reduction | | | | SHRWD | SWCD | MPCA | DNR | County | MDA | |
| | | | | | | | Residue Management | Develop residue management plan | | • | | | | | |
| | | | | | | Engineered Hydrologic Control Structures | Grade stabilization structures | Install grade control structures to reduce sediment erosion. | • | • | | • | | | |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | Continue planning and development efforts and construct at least one detention facility. | • | | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | Ensure NPDES-permitted source comply with conditions of their permits. | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | Develop restoration and implementation strategies plan | • | • | • | | | | |
| All | Unimpaired streams[1] | Mahnomen, Norman, Polk | Turbidity/ TSS | Varies | 90% of samples ≤ 32 mg/L TSS | Improve upland/field surface runoff controls [to reduce or intercept farm field erosion] | Mixture of upland BMPs (incl grassed waterways, WASCOBs, contour farming) to reduce soil loss. | No waters that currently meet standards become impaired | • | • | | | | | |
| All | Unimpaired streams[1] (cont.) | Mahnomen, Norman, Polk | Turbidity/ TSS (cont.) | Varies | 90% of samples ≤ 32 mg/L TSS | Improve upland/field surface runoff controls [to reduce or intercept farm field erosion] (cont.) | Riparian and/or ditch system buffers on all streams and all buffer requirements met | No waters that currently meet standards become impaired | • | • | | | | | |
| | | | | | | | Increase cover crops and/or perennial vegetation to reduce erosion | | | • | | | | | |
| | | | | | | | Residue Management | | | • | | | | | |
| | | | | | | Engineered Hydrologic Control Structures | Grade stabilization structures | | • | • | | • | | | |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | | • | | | | | | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | | | | • | | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | | • | • | • | | | | |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter (incl. non-pollutant stressors) | Water Quality | | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | Location and Upstream Influence Counties | | Current Conditions | Goals / Targets and Estimated % Reduction | | | | SHRWD | SWCD | MPCA | DNR | County | MDA | |
| | | | Biological habitat | Varies | Varies | Engineered hydrologic control structures | Grade stabilization structures | No waters that currently meet standards become impaired | • | • | | • | | | |
| | | | | | | Regional retention project(s) | Develop regional detention facilities and strategies to reduce the magnitude of downstream flooding and restore the natural hydrology in the watershed | | • | | | | | | |
| | | | | | | Channel restoration | Install in- channel grade control measures to reduce sedimentation | | • | | | • | | | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | | • | • | • | | | | |
| All | Unimpaired streams[1] (cont.) | Mahnomen, Norman, Polk | Biological habitat (cont.) | Varies | Varies | Fish passage(s) around dam(s) | Install fish passages to increase stream connectivity (completed in 2016) | No waters that currently meet standards become impaired | • | | | • | | | |
| | | | *E. coli* | Varies | Geometric mean ≤ 126 org/100mL | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | No waters that currently meet standards become impaired | | | | | • | | |
| | | | | | | Livestock Management | Control livestock access to streams | | | • | | | | | |
| | | | | | | | Manure Management | | • | • | | | | | |
| | | | | | | Riparian and/or ditch system buffers | Increase the amount of riparian and/or ditch system buffers | | • | • | | | | | |
| | | | | | | Nutrient Management | Develop nutrient management plan | | | • | | | | • | |
| | | | | | | NPDES permit compliance | Ensure All NPDES-permitted source comply with conditions of their permits. | | | | • | | | | |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter (incl. non-pollutant stressors) | Water Quality | | Strategies (see key below) | Strategy types and estimated scale of adoption needed to meet final water quality target | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | Estimated Year to Achieve Water Quality Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | Location and Upstream Influence Counties | | Current Conditions | Goals / Targets and Estimated % Reduction | | | | SHRWD | SWCD | MPCA | DNR | County | MDA | |
| | | | | | | Restore upstream waters | Restore and protect any/all upstream waters | | • | • | • | | | | |
| | Unimpaired lakes[1] | Mahnomen, Norman, Polk | Nutrients | Varies | Varies | Septic system compliance | Ensure all septic systems are compliant to current standards and address all failing and IPHT systems. | No waters that currently meet standards become impaired | | • | | | | | |
| | | | | | | Livestock Management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing, pasture runoff controls, buffers, heavy use protection-stream crossing areas, alternative watering sources, rotational grazing. | | • | | | | | | |
| All | Unimpaired lakes[1] (cont.) | Mahnomen, Norman, Polk | Nutrients (cont.) | Varies | Varies | Shoreline Buffers | Implement or improve buffers along the shoreline | No waters that currently meet standards become impaired | | • | | | | | |
| | | | | | | Nutrient Management | Reduce watershed phosphorus loading by 71% | | | • | | | | • | |
| | | | | | | Diagnostic Study | Preform a diagnostic study to quantify internal loading of phosphorus rates and identify sources. Develop implementation plan to reduce internal loading. | | | | • | | | | |
| | | | | | | Restore Upstream Waters | Restore and protect any/all upstream waters | | • | • | | | | | |

**Table 22: Key for Strategies Column**

| Strategy | Description |
|---|---|
| **Nonpoint Source** | |
| Septic System Compliance | The counties will ensure all septic systems are compliant to current standards and ensure all failing and IPHT systems are addressed. |
| Livestock management | Ensure livestock do not enter waters of the state. Managed/restricted area fencing (382 and 472), pasture runoff controls, buffers (322/390), heavy use protection-stream crossing areas, alternative watering sources, rotational grazing |
| Riparian and/or ditch system buffers | Install side water inlets and establish vegetated buffer strips adjacent to Sand Hill River Drainage Systems. Reduce sediment and phosphorus loading from agricultural sources to the channel. Open tile-inlet controls (e.g., riser pipes, French drains). |
| Engineered hydrologic control structures | Install in channel grade control structures within a 3.5 mile reach of the Sand Hill River Drainage System. Reduce in-channel headcutting resulting in reduced sediment load and resulting turbidity. |
| Regional retention project(s) | Continue work installing sediment and water control basins throughout the watershed. Manage drainage waters in fields or at constructed control basins. Reduce sediment and phosphorus loading to lakes and the Sand Hill River. Release stored waters after peak flow periods. |
| Field wind breaks | Ensure proper wind breaks are implemented to reduce wind erosion of top soil. |
| Increased cover crops/perennial vegetation | Promote cover crops and perennial vegetation to reduce sediment erosion during non-growing season months. |
| Residue Management | Promote residue management practices throughout the watershed. |
| Channel Restoration | Install in-channel grade control measures within a 2.75 mile reach of the Polk County Ditch 122. Provide stabilization to headcutting that is occurring along Carlson Coulee, a tributary to the Sand Hill River. Reduce in-channel headcutting resulting in reduced sediment load and resulting turbidity in the Sand Hill River. |
| Fish passage(s) around dam(s) | Retrofit U.S. Army Corps of Engineers drop structures with riprap to allow for fish passage. |
| Shoreline Buffer | Install shoreline buffers around impaired and protected lakes. Install gully stabilization measures around perimeter of Union Lake. Reduce sediment loading into lake. Improve water quality by reducing total phosphorus and turbidity. |
| Nutrient Management | Chemical addition to manure, spreading in sensitive areas, soil P testing, nutrient management (590), conservation and reduced tilling methods (329, 345 and 346), sediment and water control structures and basins (350), cover crops (340), grassed waterways, lined waterways and channels, manure runoff control, manure storage facilities (313), use of bioreactors to treat tile drainage water for phosphorus. |
| Regional Storage Site(s) | Implementation of regional detention facilities to reduce the magnitude of downstream flooding and restore natural hydrology. Natural Resource Enhancement features will be included where applicable to meet multiple goals and objectives for SHRWD Planning Region No. 4. Use required easement areas to restore natural vegetation to land required to |

| Strategy | Description |
|---|---|
| | implement runoff detention in Region 4 of the Sand Hill River Watershed District for enhanced habitat, reduced contaminant loading, and reduced rate of runoff. |
| Restore upstream waters | Restoring upstream waters will have a positive impact on downstream waters |
| Culvert Replacement | Assess culverts/dams for sizing, retention, fish passage and hydrologic function |
| Support voluntary enrollment activities promoted by SWCDs | Provide support as needed for efforts led by SWCDs. These efforts include promoting and installation of sediment control basins, easement programs, and other BMPs. |
| **Point Source** | |
| NPDES point source compliance | All NPDES-permitted sources shall comply with conditions of their permits, which are written to be consistent with any assigned wasteload allocations |

# 4. Monitoring Plan

Stream monitoring within the SHRW will continue primarily through the efforts of the SHRWD. As outlined in the Section 7 of the SHRWD WMP (HEI 2011), the District has been actively involved in volunteer water quality monitoring since 1993 through the River Watch Program and has been involved in an ongoing citizen river monitoring project with the Red River Watershed Management Board, Agassiz Environmental Learning Center, and public schools in the SHRWD. These schools include Fosston, Win-E-Mac (Winter, Erskine, and McIntosh), Fertile-Beltrami, and Climax schools. The goals of this project are to develop baseline water quality data on the Sand Hill River, provide hands-on “real world” science opportunities for students and promote greater citizen awareness and understanding of the watershed and the role of the watershed district. The River Watch Program collects samples at 25 sites in the SHRWD.

In addition to the stream monitoring sponsored by the SHRWD and River Watch, the MPCA also has ongoing monitoring in the watershed. Their major watershed outlet monitoring will continue to provide a long-term ongoing record of water quality at the SHRW outlet. The lakes of the SHRW are not being routinely monitored at this time. The MPCA will return to the watershed and monitor lakes under their 10-year cycle Intensive Watershed Monitoring program in 2021 and 2022.

# 5. References and Further Information

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## *Sand Hill River Watershed Reports*

*All Sand Hill River Watershed Reports referenced in this watershed report are available at the Sand Hill River Watershed webpage:* http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/red-river-of-the-north-sandhill-river.html

# Appendix

**Appendix A. Subwatershed Prioritization in the Sand Hill River Watershed**

**Appendix B: Terrain Analysis Write-up**

**Appendix C: Lake Characteristics Table**

# Appendix A: Priority Ranking of Subwatershed in the Sand Hill River Watershed Using HSPF Results.

Using results from the Sand Hill River Watershed (SHRW) Hydrologic Simulation Program Fortran (HSPF) model (RESPEC, 2013), areas within the watershed were prioritized based upon the magnitude of nonpoint sources, to identify subwatersheds where restoration and protection strategies would be most beneficial. Subwatersheds were prioritized by ranking the area-averaged yields (pounds / acre / year) from the HSPF model for unit runoff (RO), total phosphorus (TP), total nitrogen (TN), and total sediment. Prioritization is based solely on the estimated mass leaving the landscape. The consideration of other factors could change the prioritization outcome.

## The SHRW HSPF Model

The SHRW HSPF model was constructed to inform the Watershed Restoration and Protection Strategy (WRAPS) and watershed-wide Total Maximum Daily Load (TMDL) Projects currently being undertaken by the Minnesota Pollution Control Agency (MPCA) and Houston Engineering Inc (HEI). The SHRW HSPF model simulates hydrology and water quality for the Sand Hill River Watershed 8-digit Hydrologic Code (HUC) 9020301(see **Figure 1**).

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

The SHRW HSPF model is composed of six modeling segments, or hydrozones (**Figure 1**) and further divided into 73 subwatersheds (**Figure 1**). Each modeling segment,  and therefore subwatershed, is divided by up to 10 land-use/soil classes (PERLNDs) and one impervious land use class (IMPLND), for a total of 60 possible PERLNDs in the HSPF model (see **Figure 2**).  The PERLND classes include urban, Forest, cropland-high tillage 1, cropland-low tillage 1, grasslands, pasture, wetlands, feedlots, cropland-high tillage 2, and cropland-low tillage 2. Although it is listed as a PERLND class, cropland-high tillage 2 and cropland-low tillage 2 are placeholders and not used (no area assigned to them) in the SHRW HSPF model.

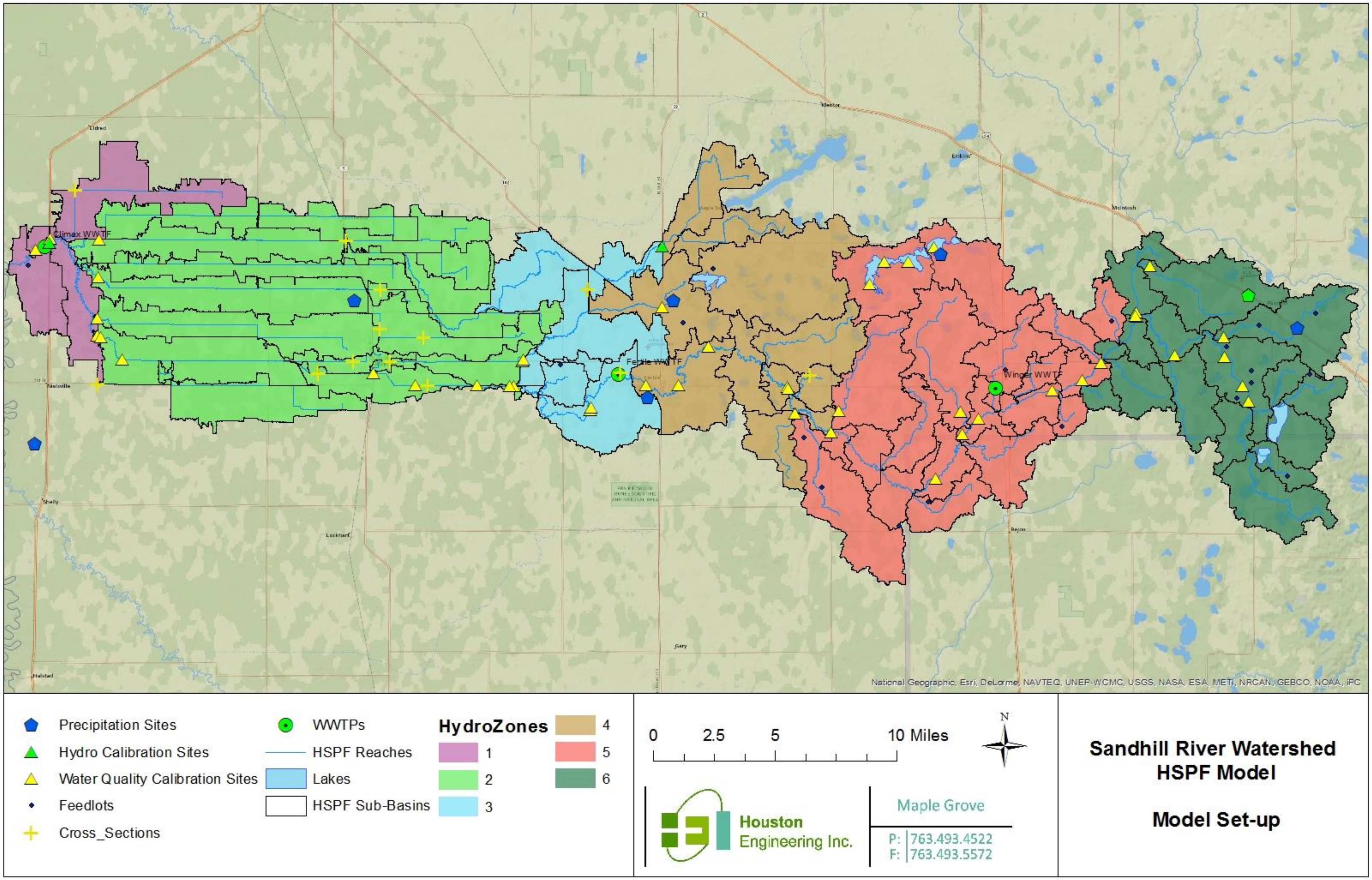


**Figure 1: Set-up for the Sand Hill River Watershed HSPF model.**

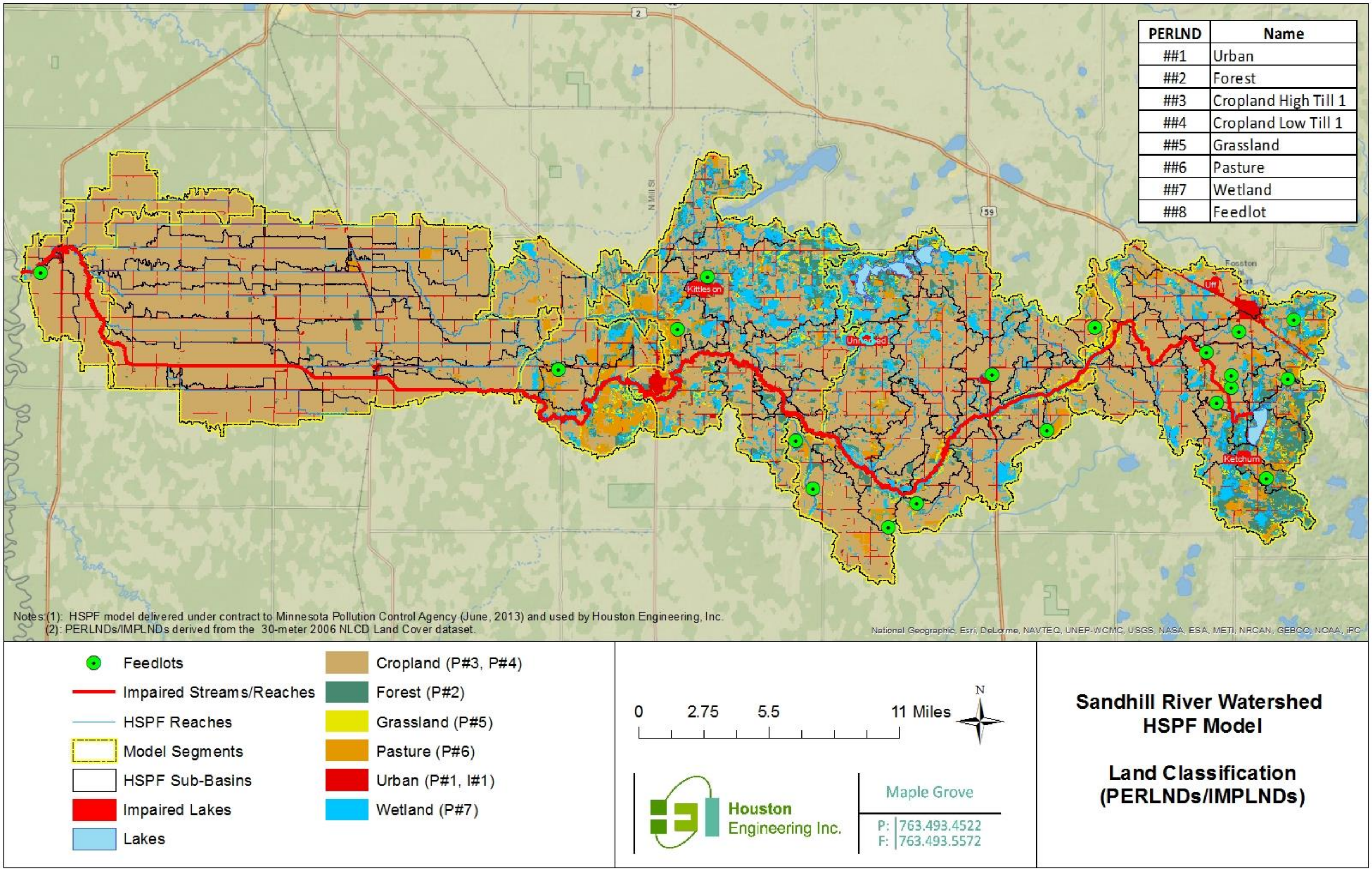


**Figure 2: Land Classifications (PERLNDs) in the SHRW HSPF model.**

## Using the HSPF Model Output for Prioritization

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

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

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

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

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

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

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

## Developing Subwatershed Priority Maps Using Yields

The prioritization of subwatersheds based on nonpoint source loads, occurred at two scales; i.e., the entire watershed and major tributary (**Figure 3**). Prioritization at multiple scales is necessary because the results change depending upon the location of the impaired resource (or resource being protected) in the watershed. Subwatershed priority maps were generated using results extracted from the SHRW HSPF model. Maps were developed for RO, TP, TN, and total sediment. Maps generated at the watershed scale using the entire simulation period (i.e., multiple years, 1996-2009) included average subwatershed yield maps (**Figure 4-7**), subwatershed priority rankings maps (**Figures 8-11**), water quality index (WQI) map (**Figure 12**), and field stream index maps (**Figure 13-16**). Maps were also generated at the AUID drainage scale for three of the four impaired AUIDs (09020301-536, -541, and -542) in the SHRW watershed (**Figure 3**). The remaining impaired AUID 09020301-537 is the most downstream reach of the modeled watershed and is represented by the maps covering the whole watershed. Map sets for each of AUID drainage include the subwatershed priority ranks (09020301-536-**Figures 16-19**; 09020301-542-**Figure 21-24**; 09020301-541-**Figures 26-29**) and the water quality index maps (09020301-536-**Figure 20**; 09020301-542-**Figure 25**; 09020301-541-**Figure 30**).

The yield maps (**Figure 4-7**) can be used to complete pollutant sources assessments. They show which subwatersheds are the largest sources of runoff, nutrients and sediment per area and time (annual average) delivered to the channel (edge of field). Maps represent different stressors which can lead to impairment. The maps show those subwatersheds having the greatest unit area, average annual yields of each subwatershed for RO (**Figure 4**), TP (**Figure 5**), TN (**Figure 6**), and total sediment (**Figure 7**). These maps were generated by extracting the flow and loadings from each PERLND and IMPLND, averaging the annual total flows and loads over the modeling period (1996-2009) for each PERLND/IMPLND, and using the areas of each PERLND/IMPLND in each subwatershed to get a subwatershed unit area, annual average yield. The numeric values for each subwatershed is provided in **Appendix A**.

The priority rankings maps (**Figures 8-11**) use the information in the yield maps to identify specific priority subwatersheds which should be preferentially considered for targeting fields for practice implementation based solely on water quality. These maps were developed by taking the yields at the watershed and major tributary scales and ranking them smallest to largest and calculating their percentile rank. The ranks are summarized as the lowest implementation priority (lowest 10%), low priority (10%-25%), moderate priority (25%-75%), high priority (75%-90%), and highest priority (highest 10%). The highest priority subwatersheds with the highest yields and most likely would benefit the most from implementation and protective strategy management. For the major tributary maps, the yields were re-ranked, only using the subwatersheds draining to the tributary.

In addition to the priority rankings maps, an overall water quality index (WQI) map was generated. The WQI (**Figure 12**) represents the combined importance of nutrients and sediment and is estimated using:

$$WQI = 0.5*\text{Sediment Ranking} + 0.25*\text{TP Ranking} + 0.25*\text{TN Ranking}$$

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

The Field Stream Index maps (**Figures 13-16**) provide guidance, subject to field verification, about where field practices rather than in-stream implementation activities, provide the largest potential water quality benefit. These maps show the magnitude of field source loads relative to in-stream sources and are taken as the overland field load divided by the in-channel flux. Positive numbers represent a source of in-stream materials and a negative number represents a sink for in-stream materials. If the FSI is between -1 and 1, the dominate processes in the subwatershed are in-channel, meaning the in-channel flux is larger than the overland sources. If the FSI is less than -1 or greater than 1, field sources are larger than the in-stream sources.

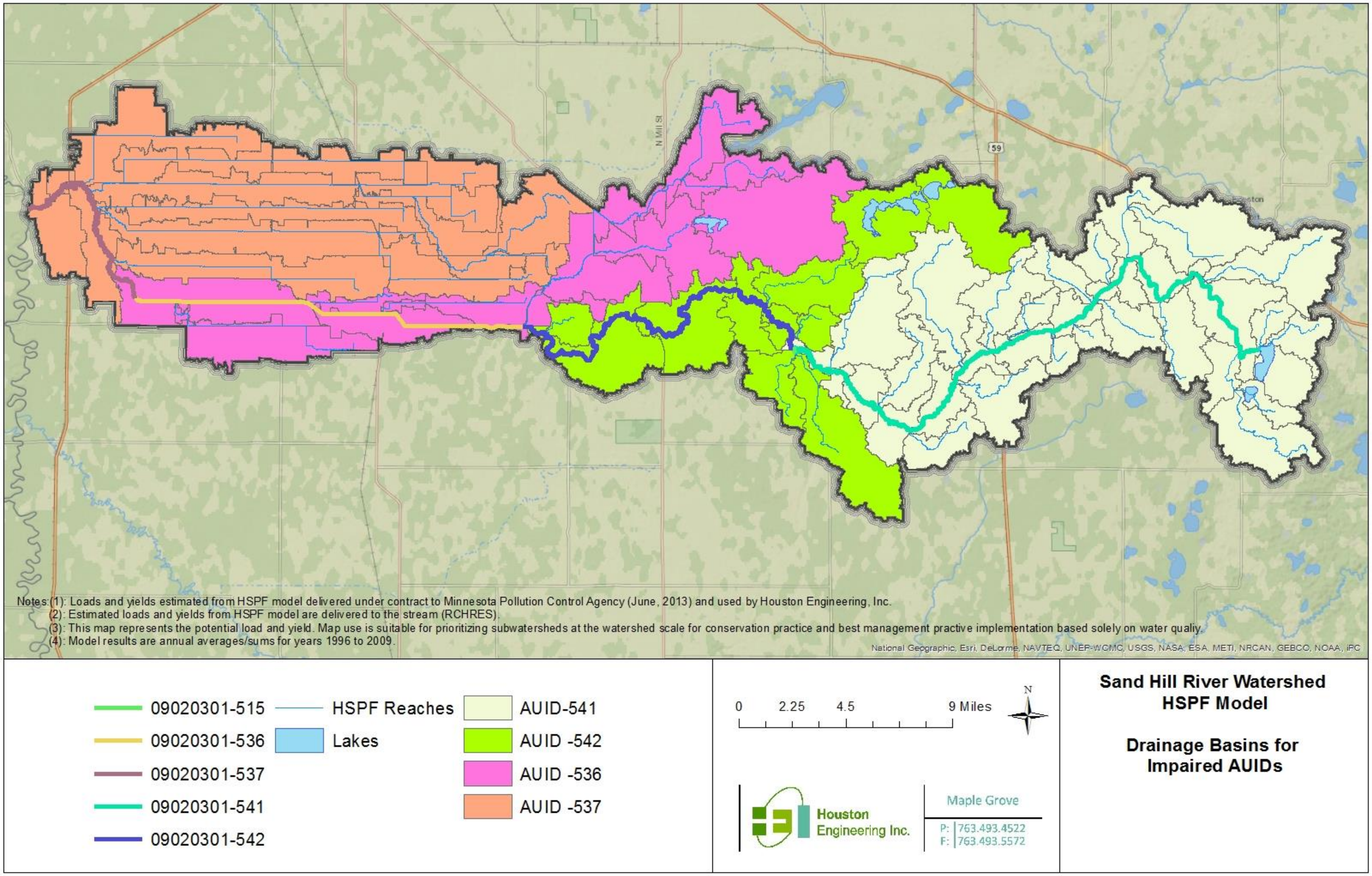


**Figure 3: Drainage basins of the impaired AUIDs in the Sand Hill River Watershed.**

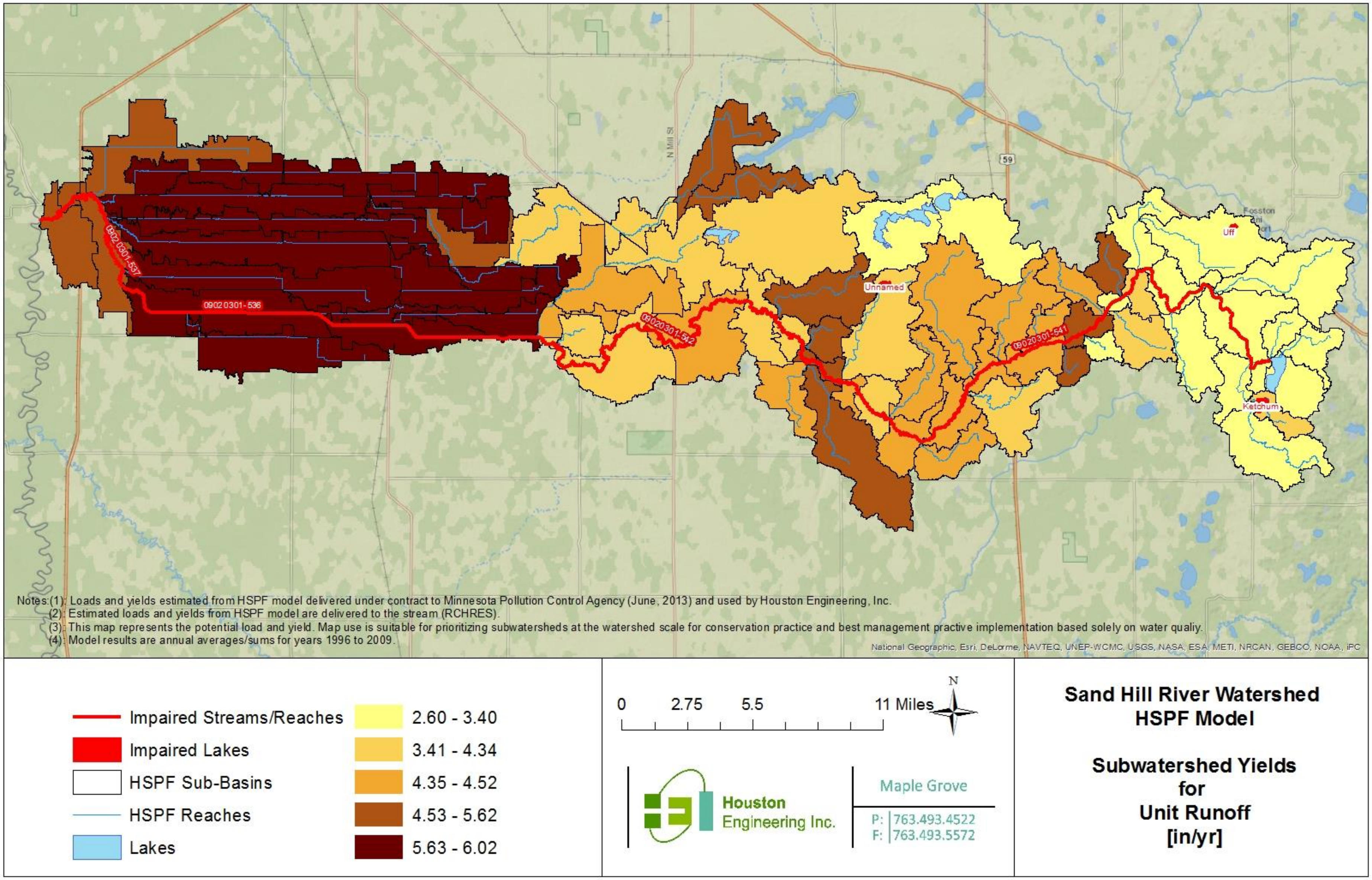


**Figure 4: Average (1996-2009) Unit Runoff delivered to the channel from the SHRW HSPF model by subwatershed.**

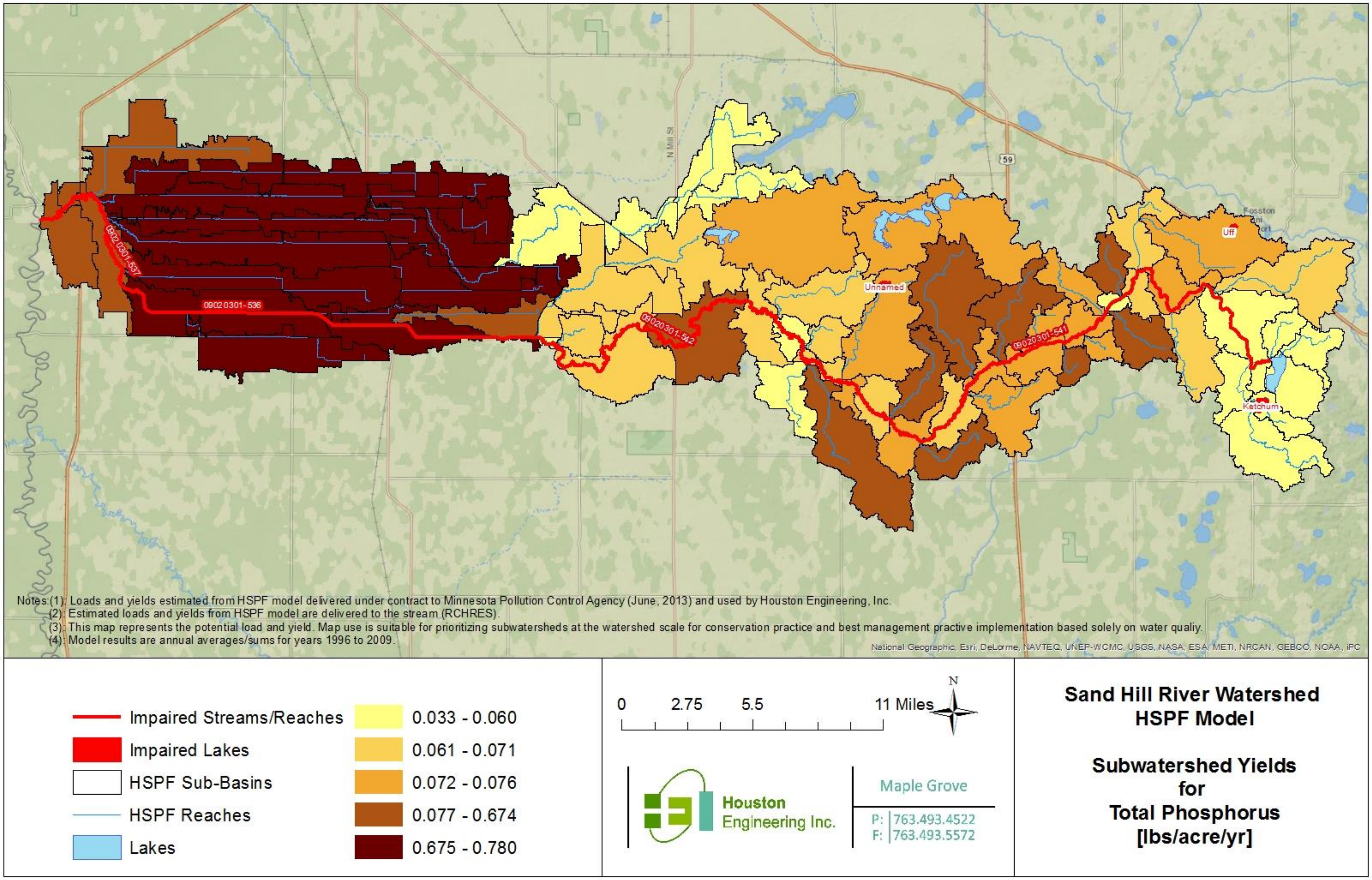


**Figure 5: Average (1996-2009) Total Phosphorus Yield delivered to the channel from the SHRW HSPF model by subwatershed.**

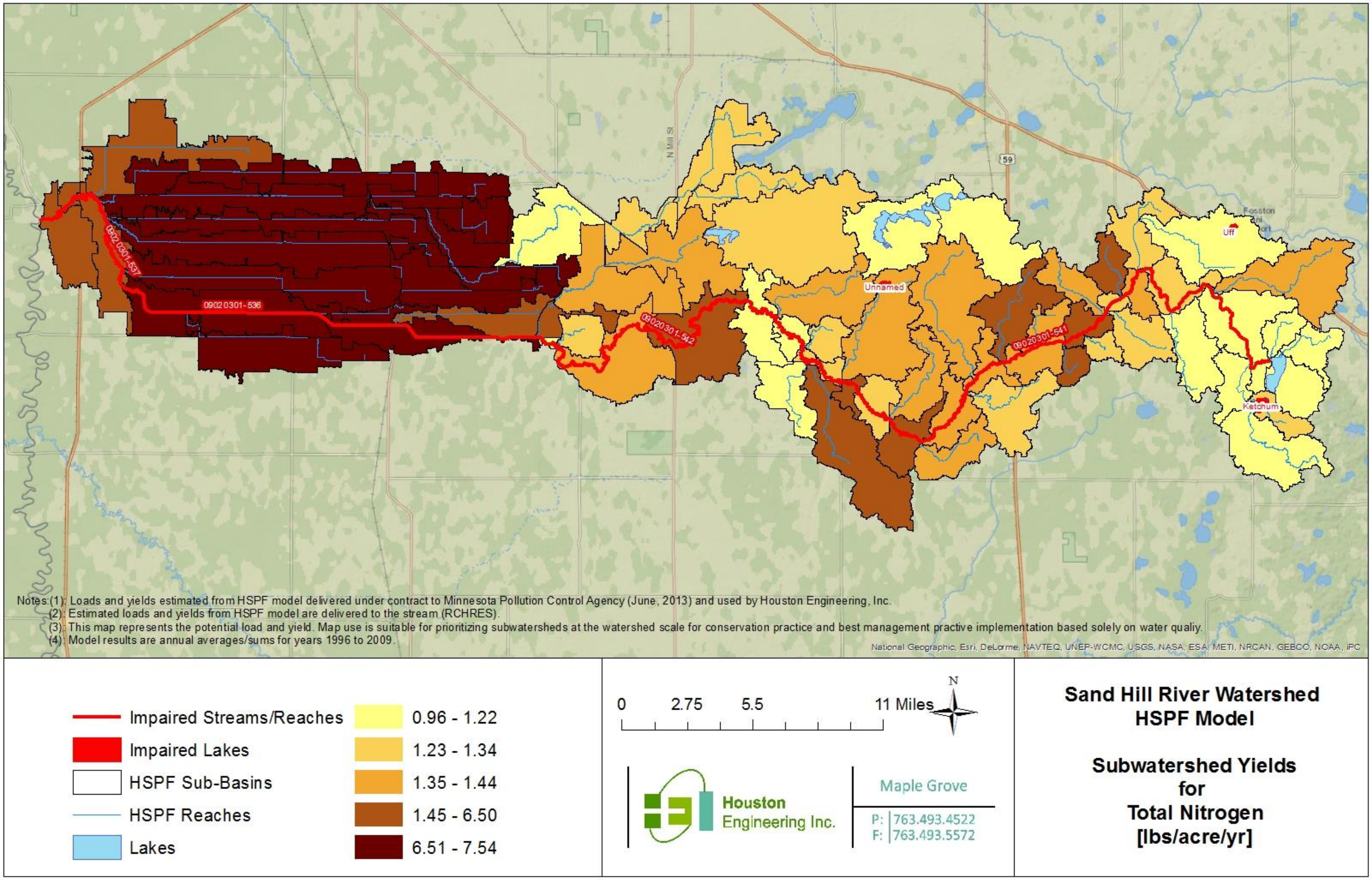


**Figure 6: Average (1996-2009) Total Nitrogen Yield delivered to the channel from the SHRW HSPF model by subwatershed.**

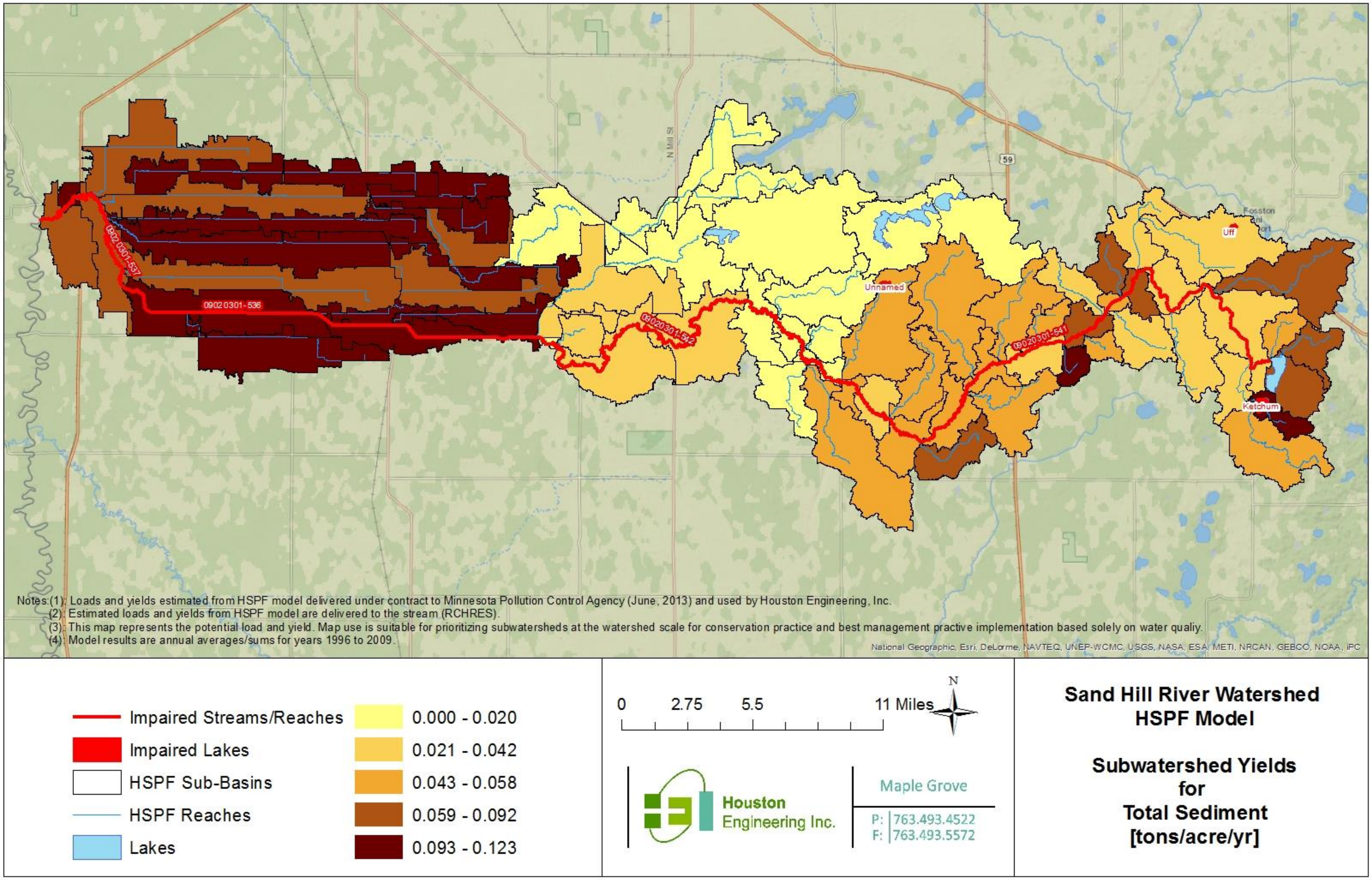


**Figure 7: Average (1996-2009) Total Sediment Yield delivered to the channel from the SHRW HSPF model by subwatershed.**

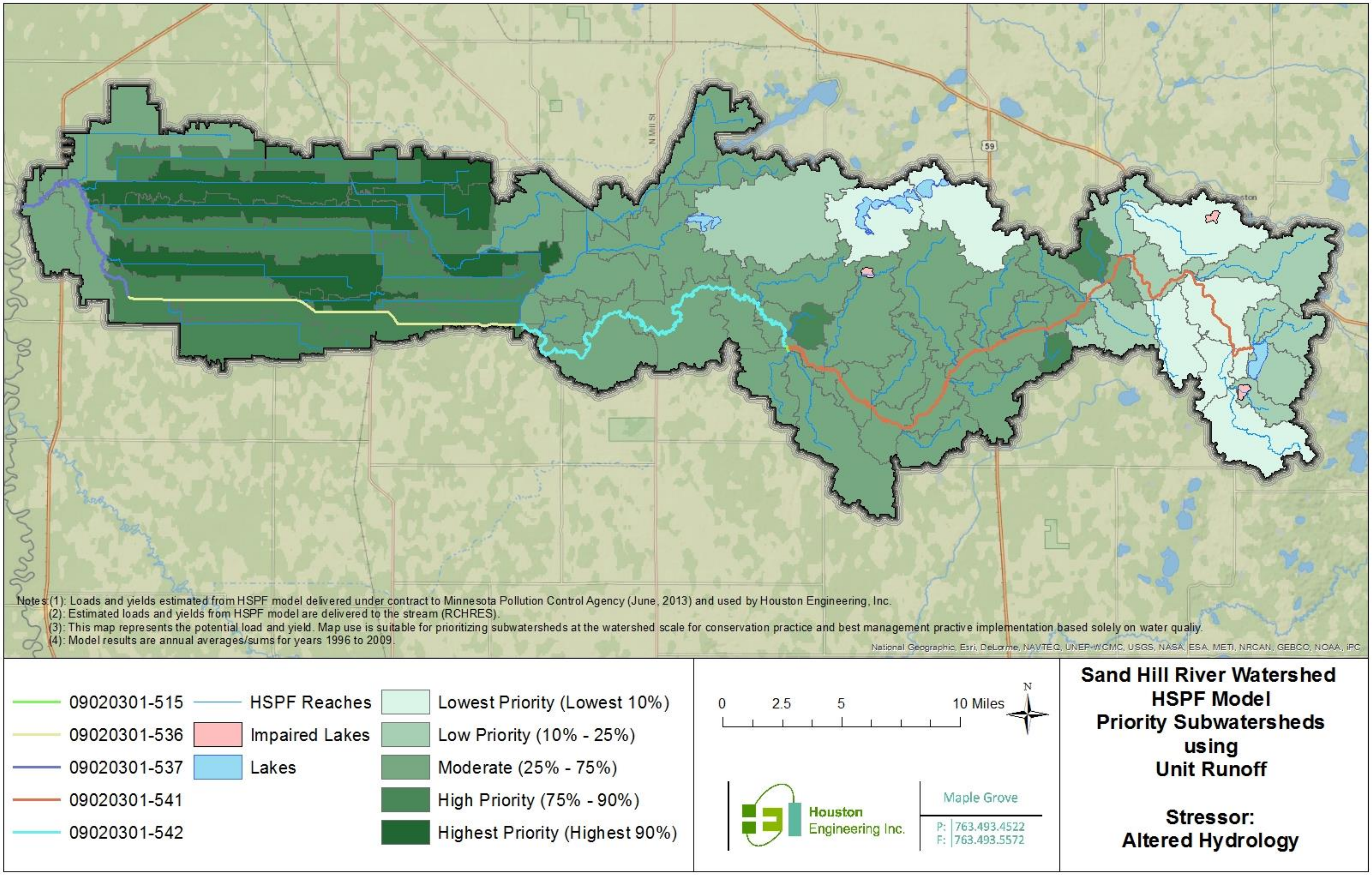


**Figure 8: Watershed scale subwatershed priority for implementation for the stressor altered hydrology, using average (1996-2009) annual unit runoff.**

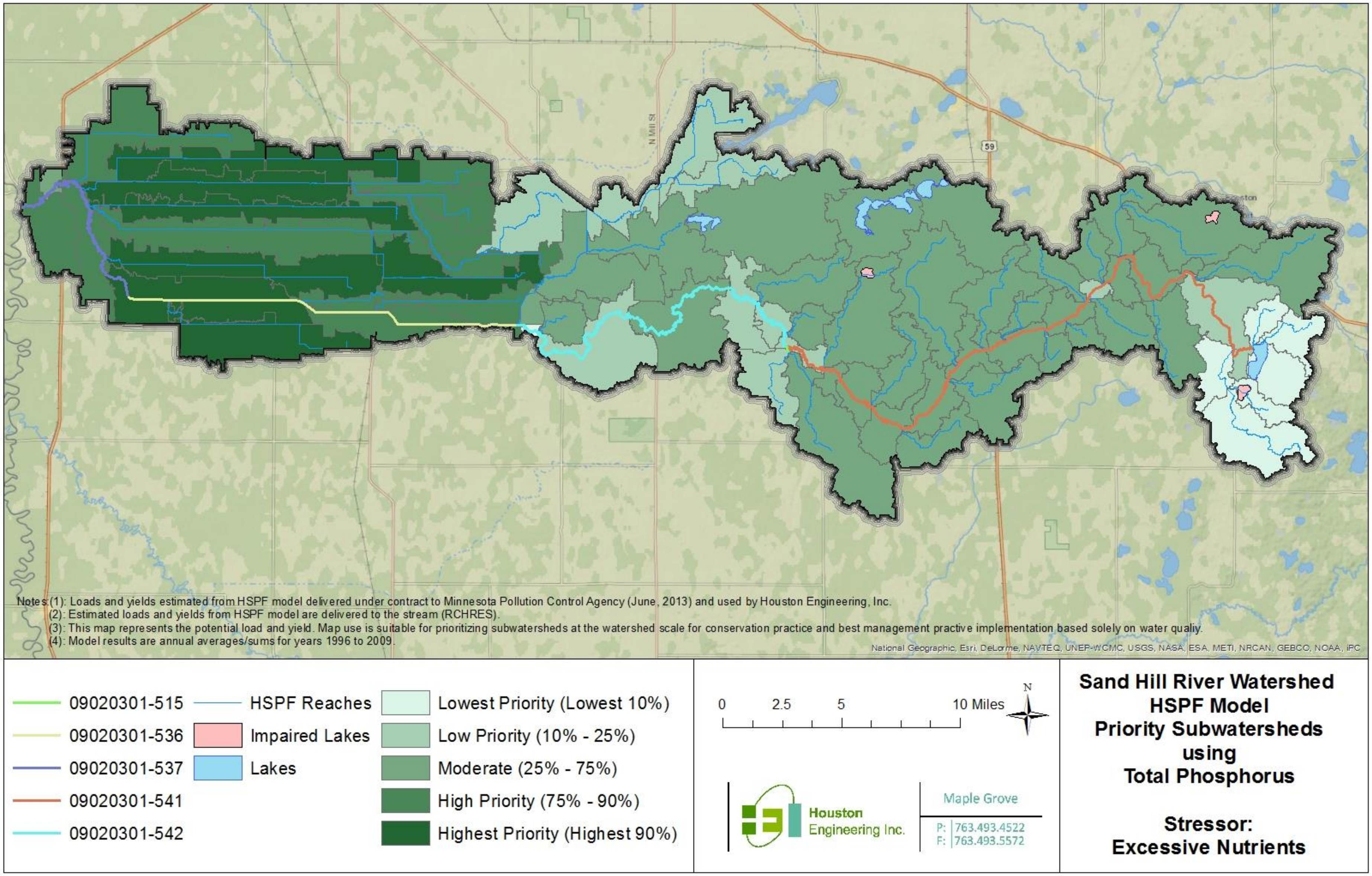


**Figure 9: Watershed scale subwatershed priority for implementation for the stressor excessive nutrients, using average (1996-2009) total phosphorus yields.**

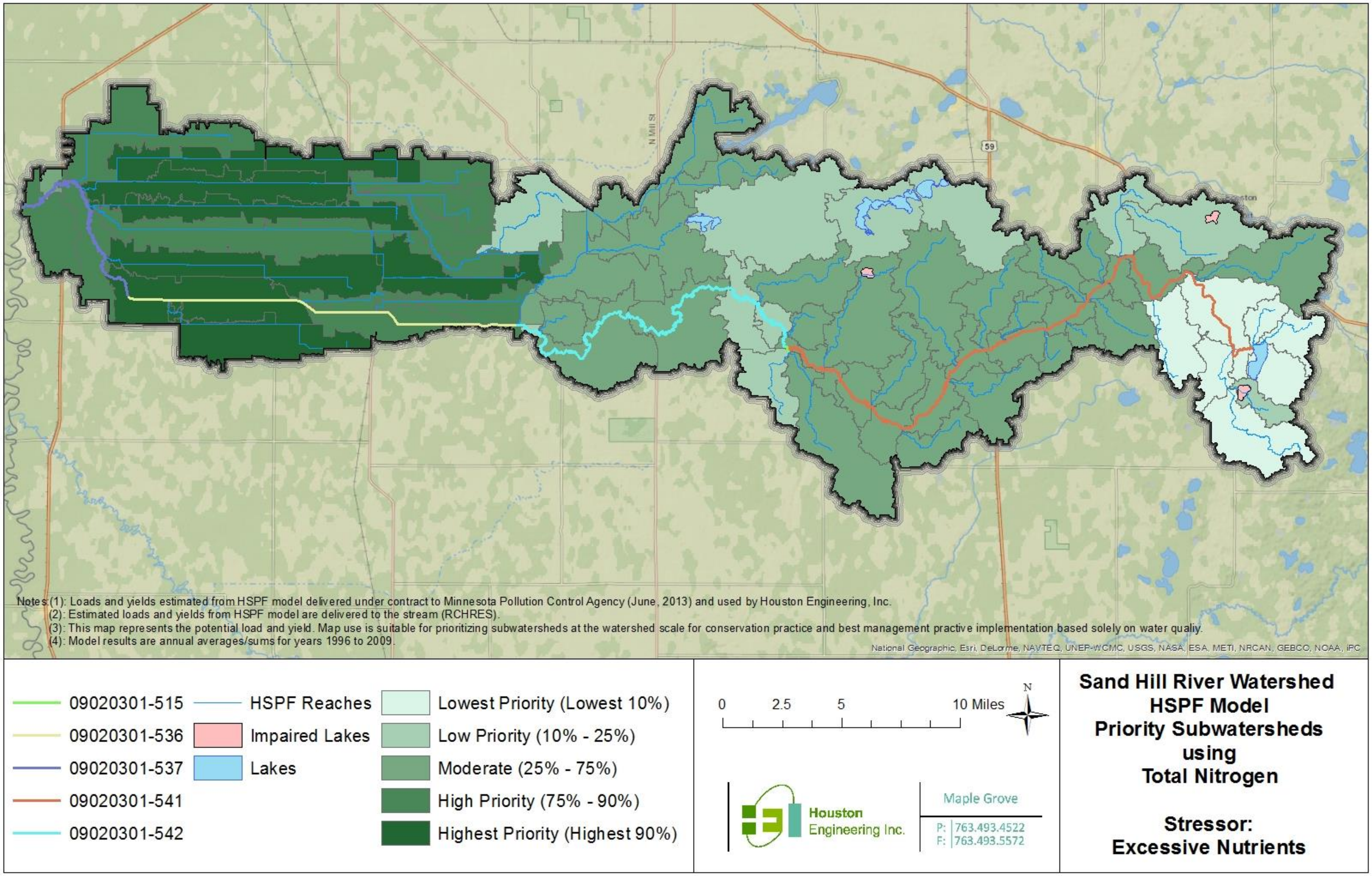


**Figure 10: Watershed scale subwatershed priority for implementation for the stressor excessive nutrients, using average (1996-2009) total nitrogen yields.**

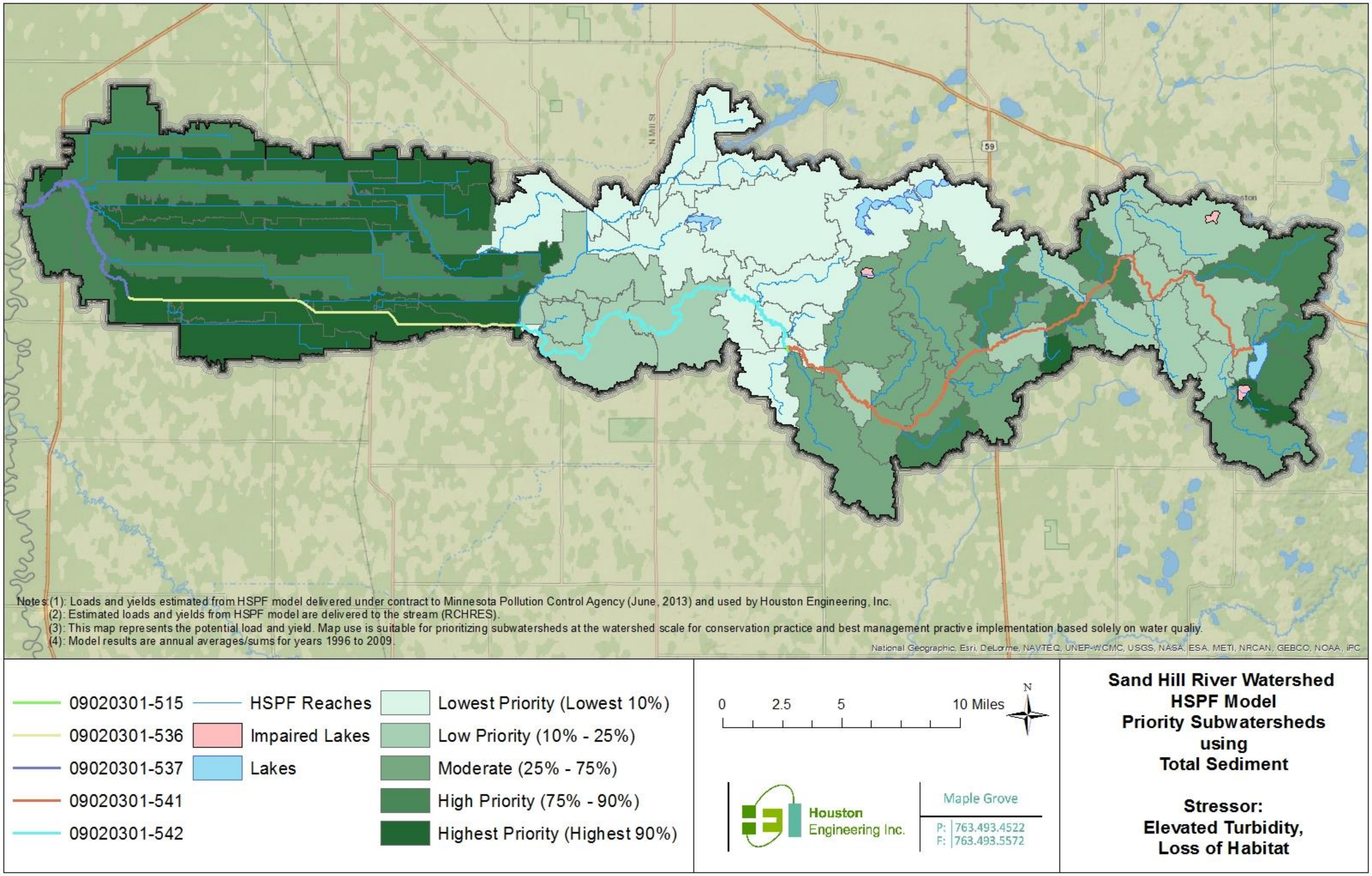


**Figure 11: Watershed scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat, using average (1996-2009) total sediment yields.**

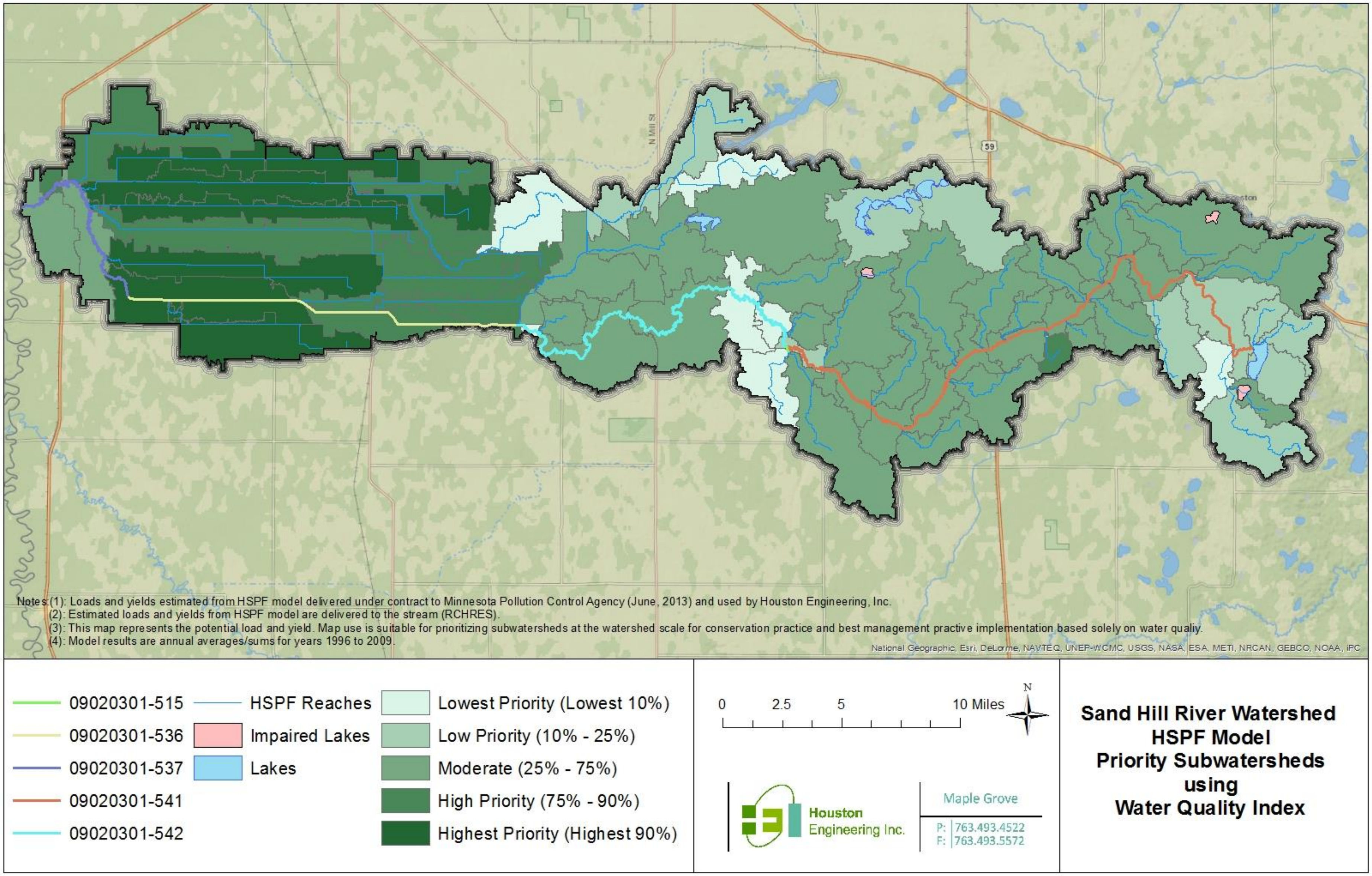


**Figure 12: Watershed scale subwatershed priority for implementation, using the average (1996-2009) water quality index.**

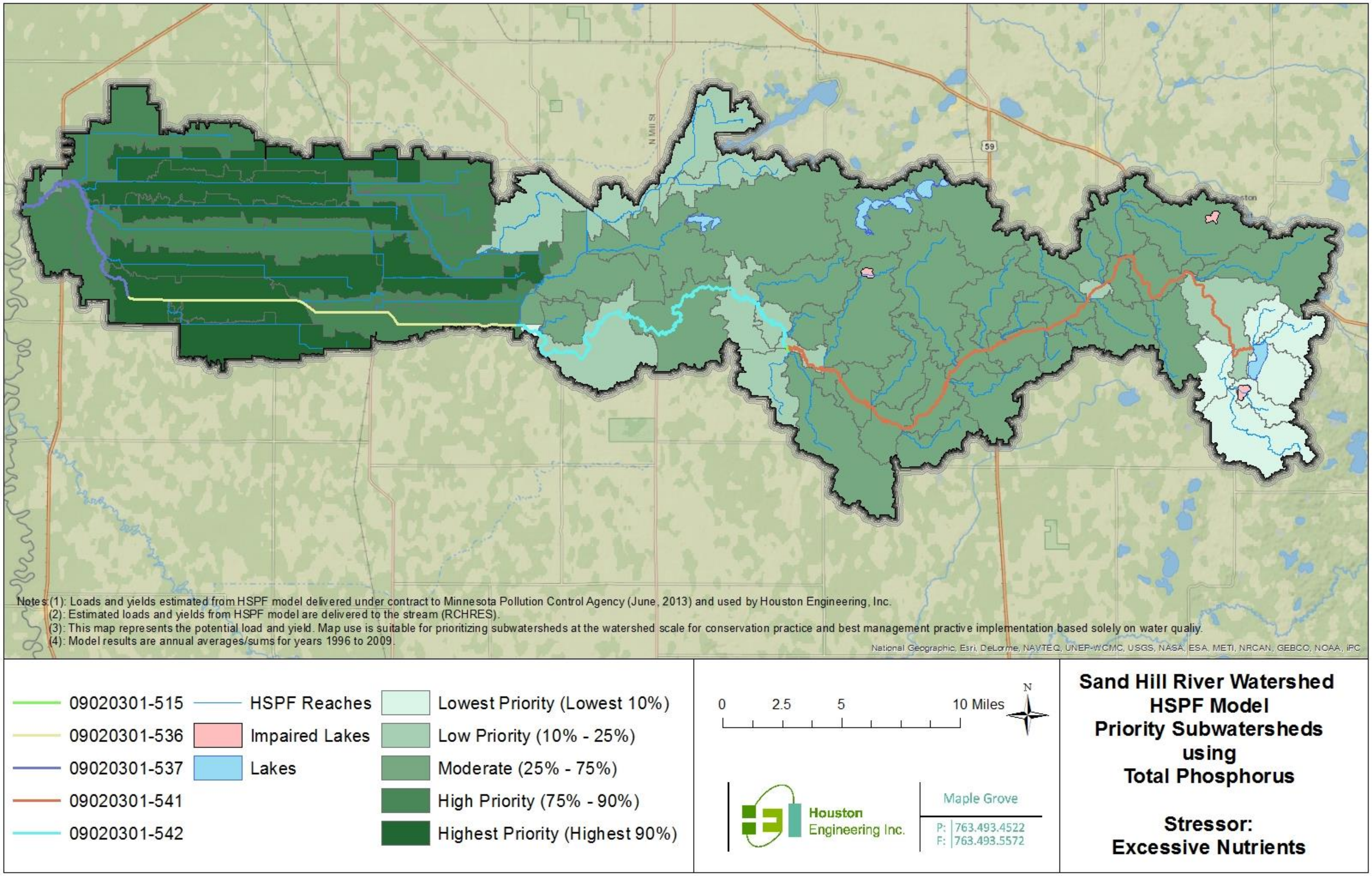


**Figure 13: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor excess nutrients using total phosphorus (1996-2009) annual average load**.

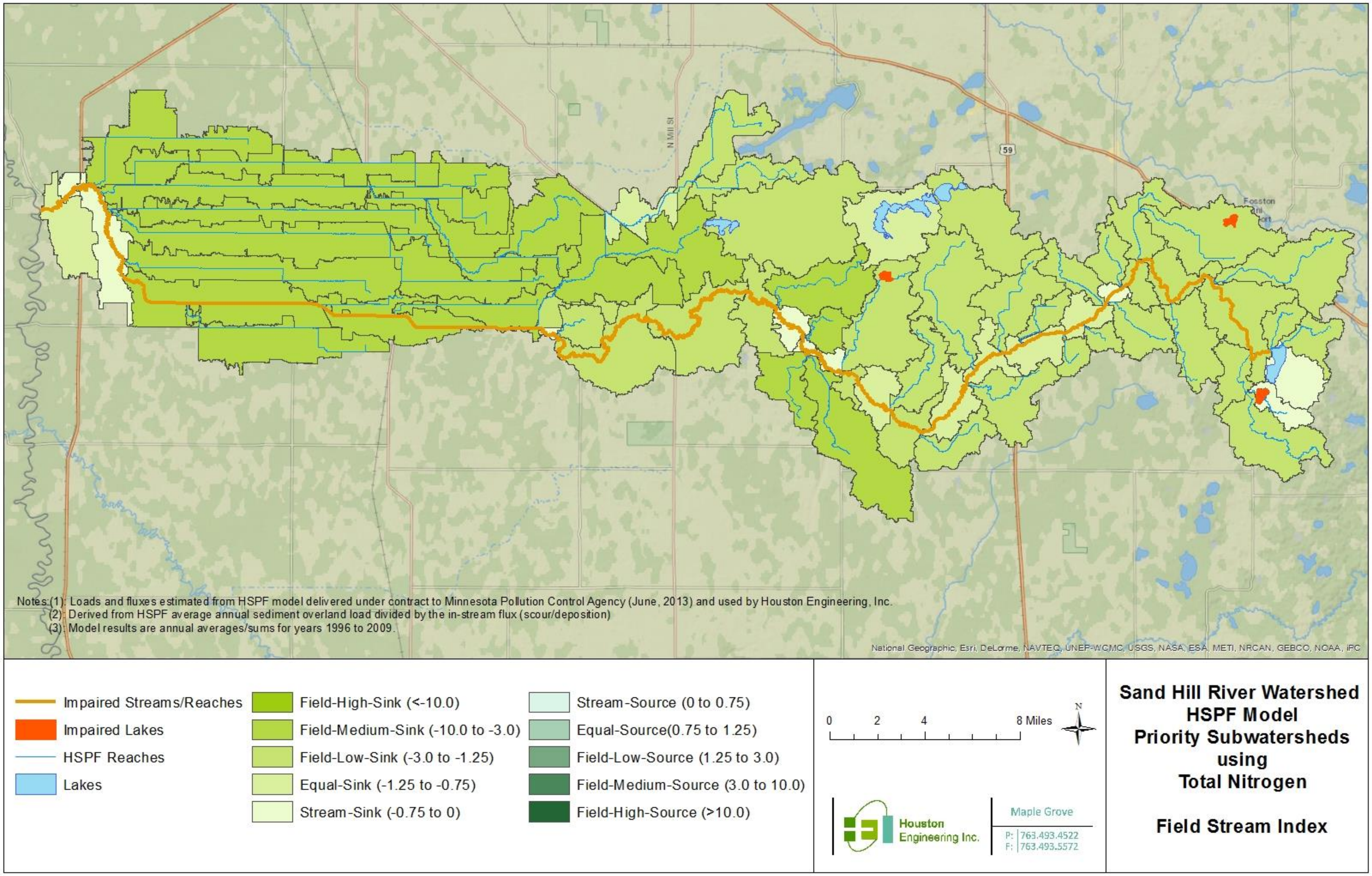


**Figure 14: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor excess nutrients using total nitrogen (1996-2009) annual average load.**

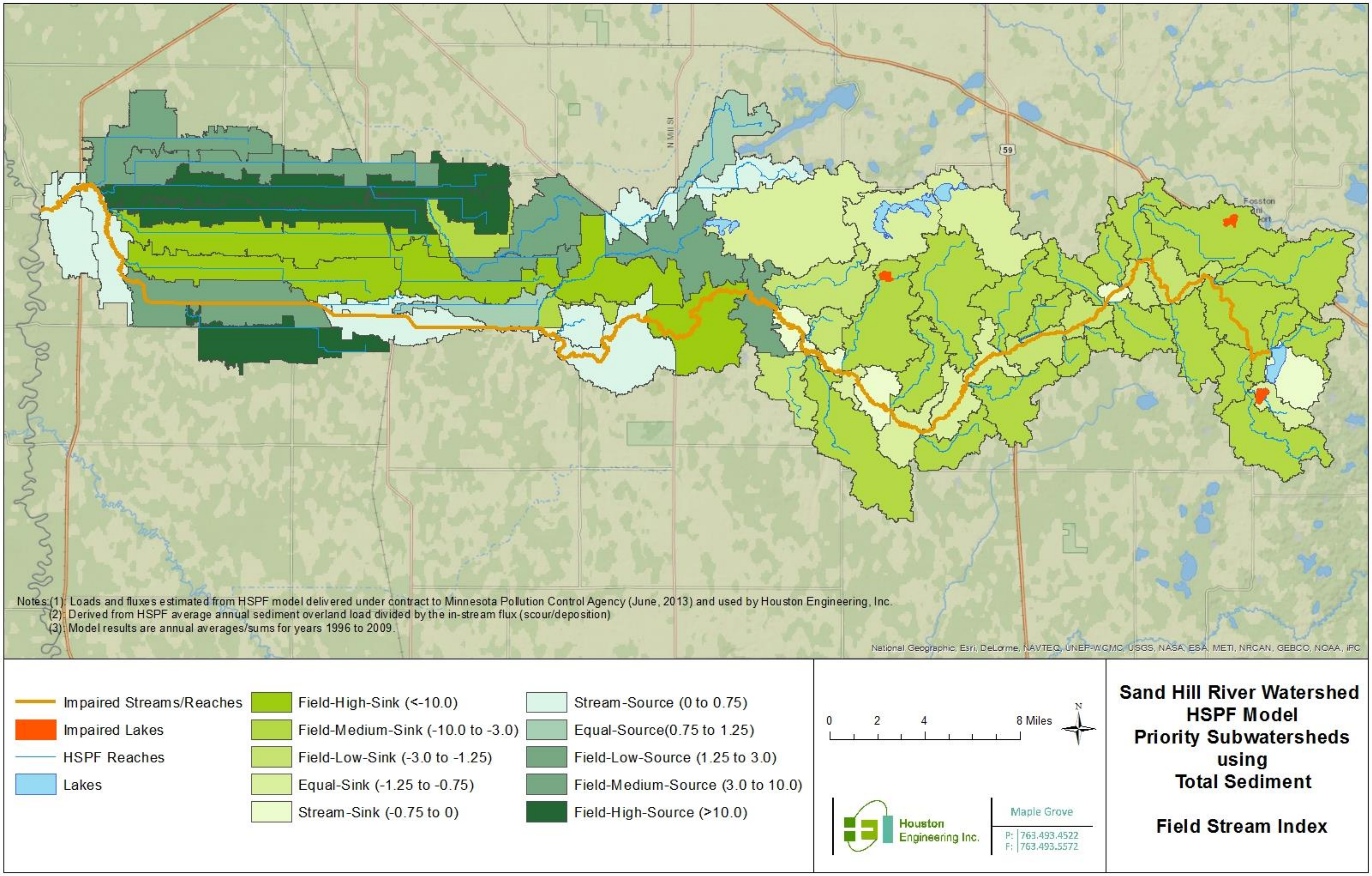


**Figure 15: Watershed scale subwatershed priority for implementation of field and stream practices (Field Stream Index) for the stressor elevated turbidity using total sediment (1996-2009) annual average load. .**

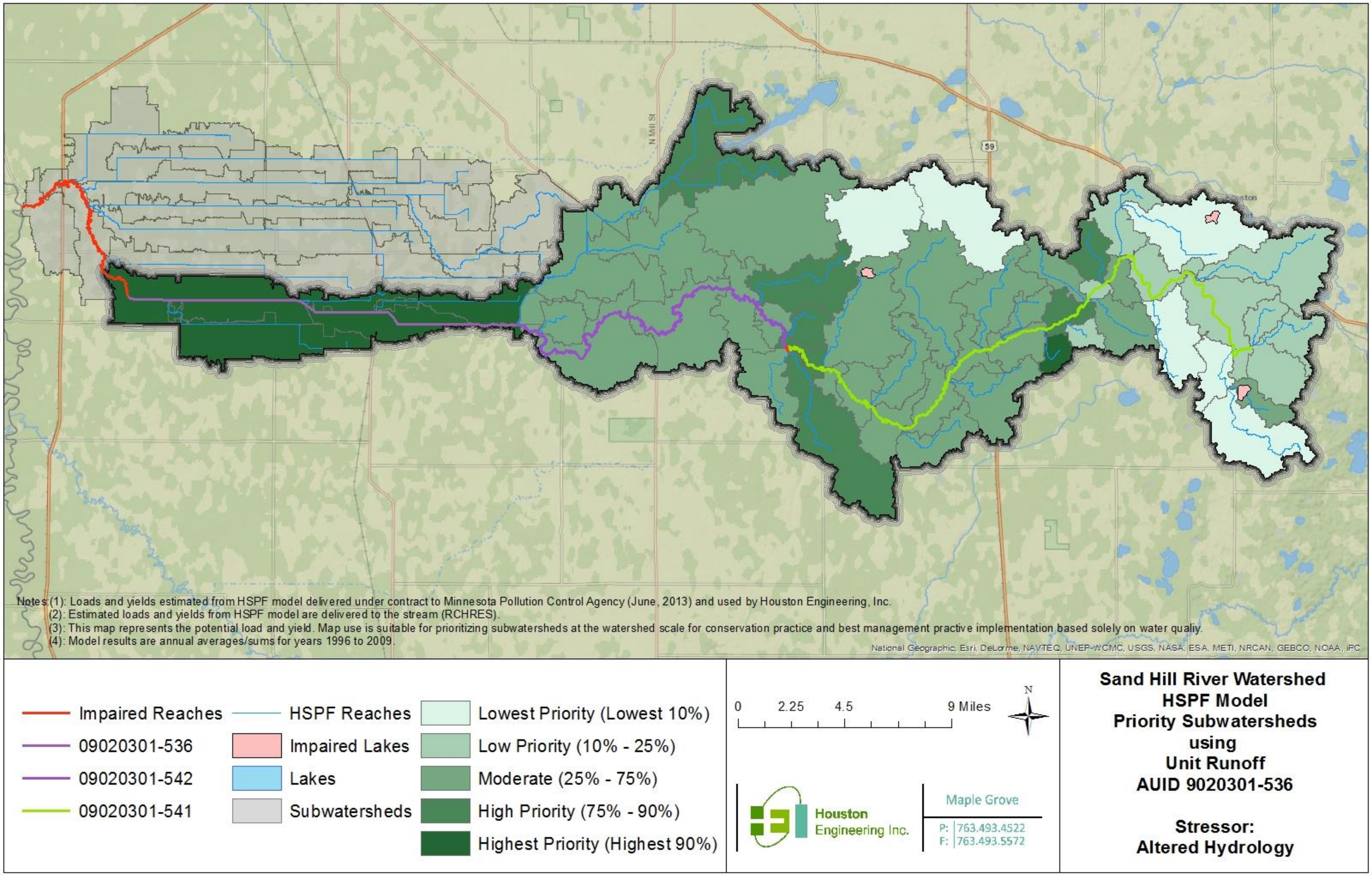


**Figure 16: AUID scale subwatershed priority for implementation for the stressor altered hydrology for AUID 9020301-536, using average (1996-2009) annual unit runoff.**

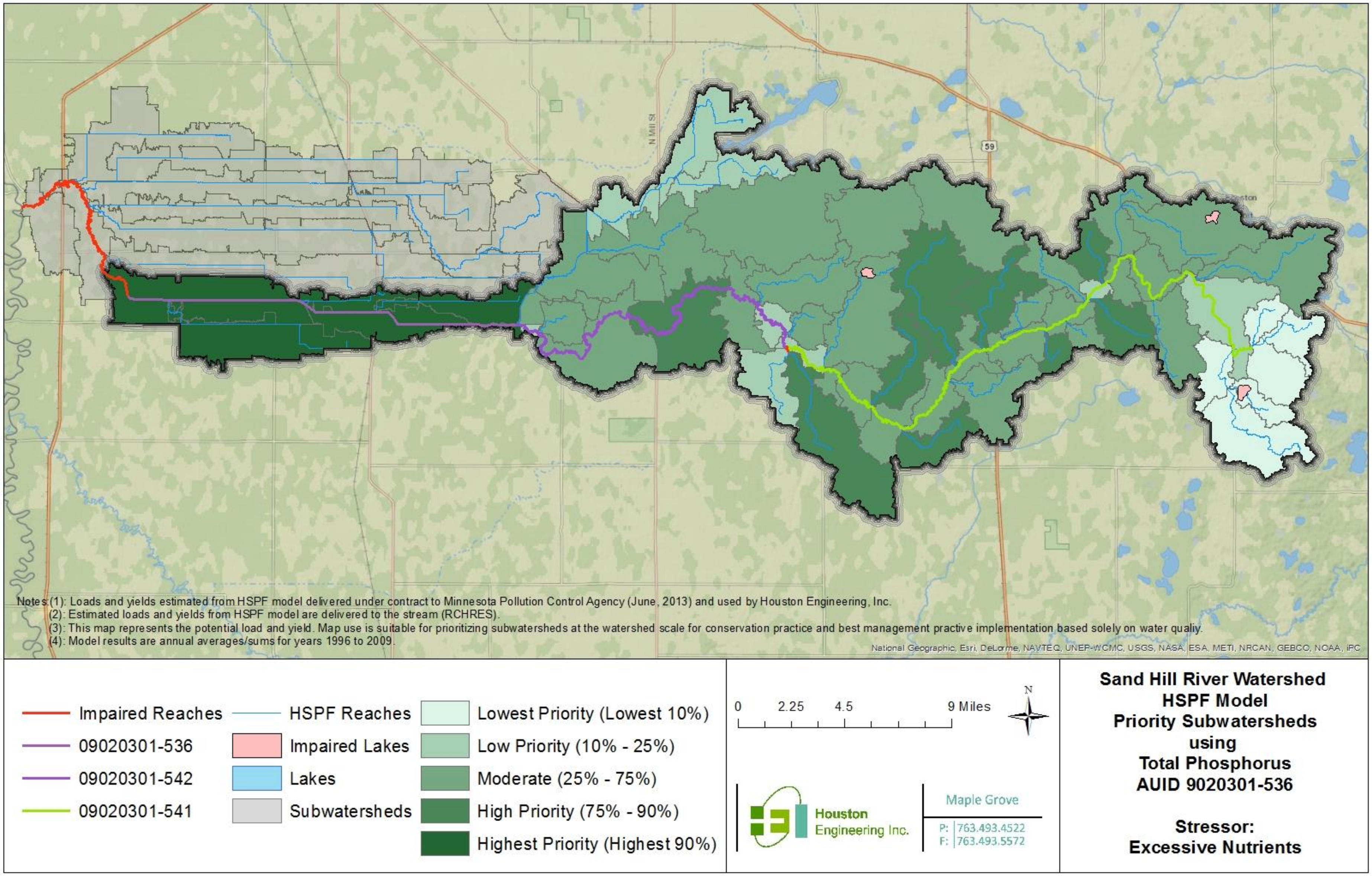


**Figure 17: AUID scale subwatershed priority for implementation for the stressor excessive nutrients for AUID 9020301-536, using average (1996-2009) annual total phosphorus yields.**

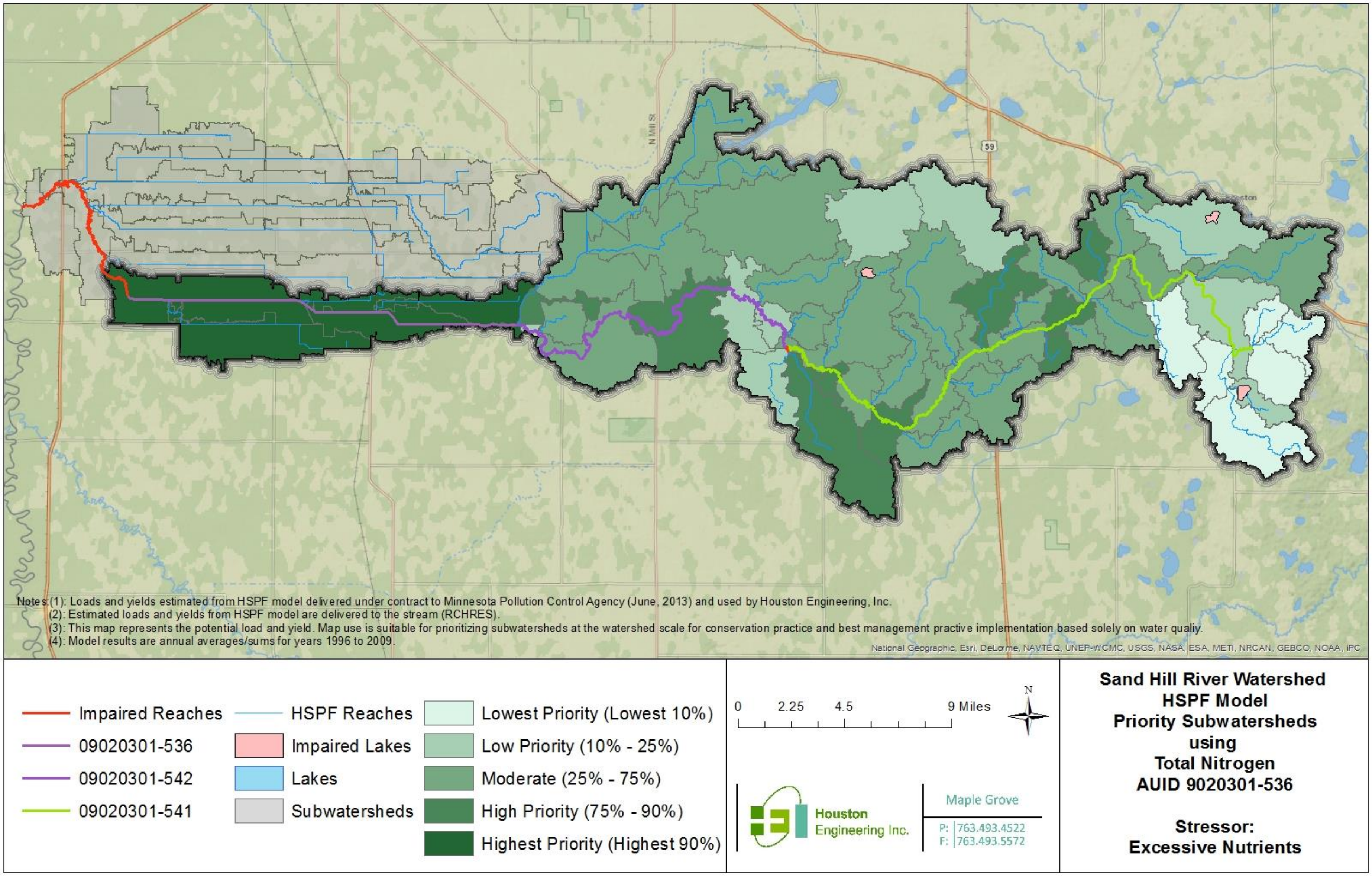


**Figure 18: AUID scale subwatershed priority for implementation for the stressor excessive nutrients for AUID 9020301-536, using average (1996-2009) annual total nitrogen yields.**

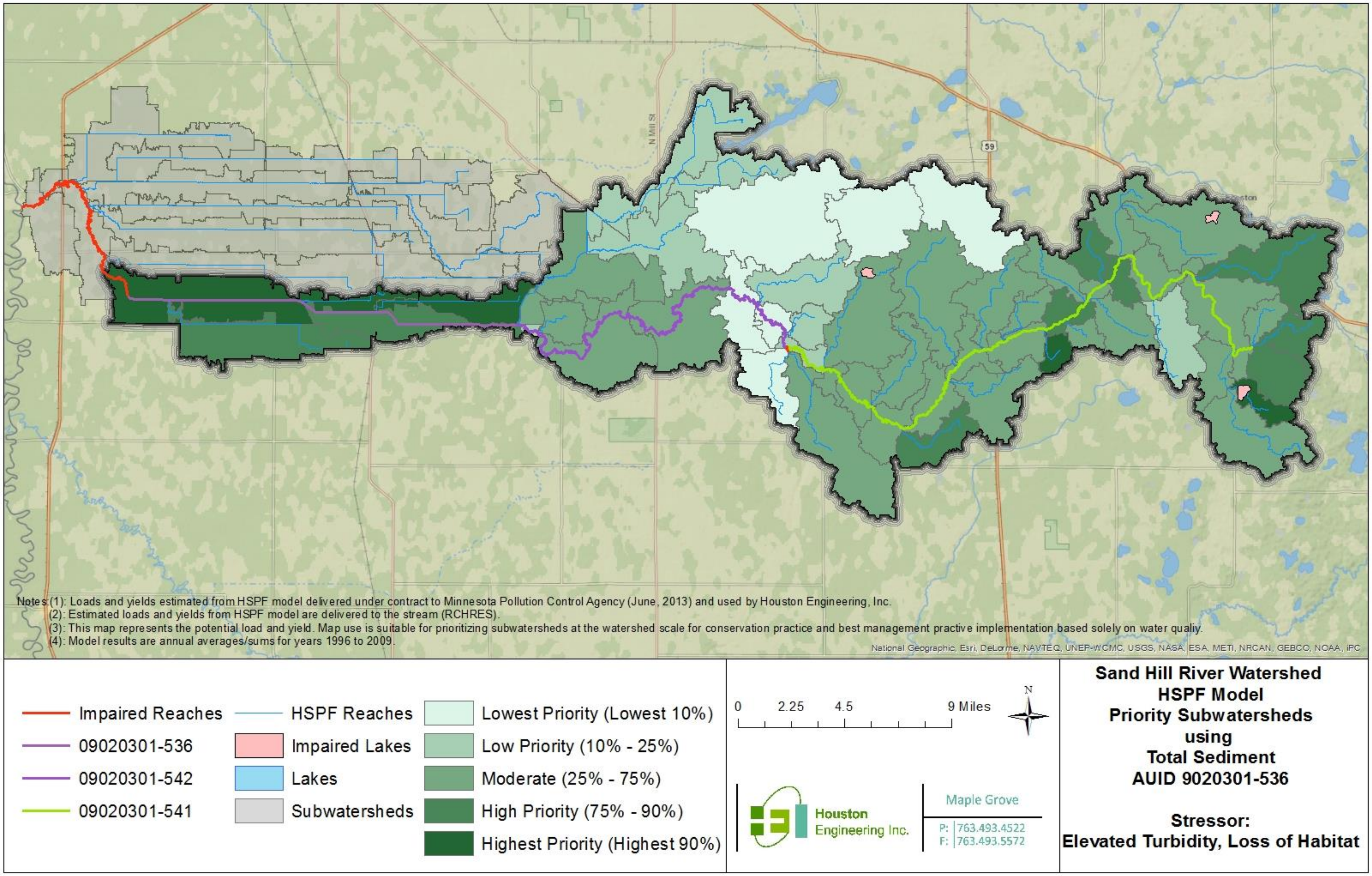


**Figure 19: AUID scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for AUID 9020301-536, using average (1996-2009) annual total sediment yields.**

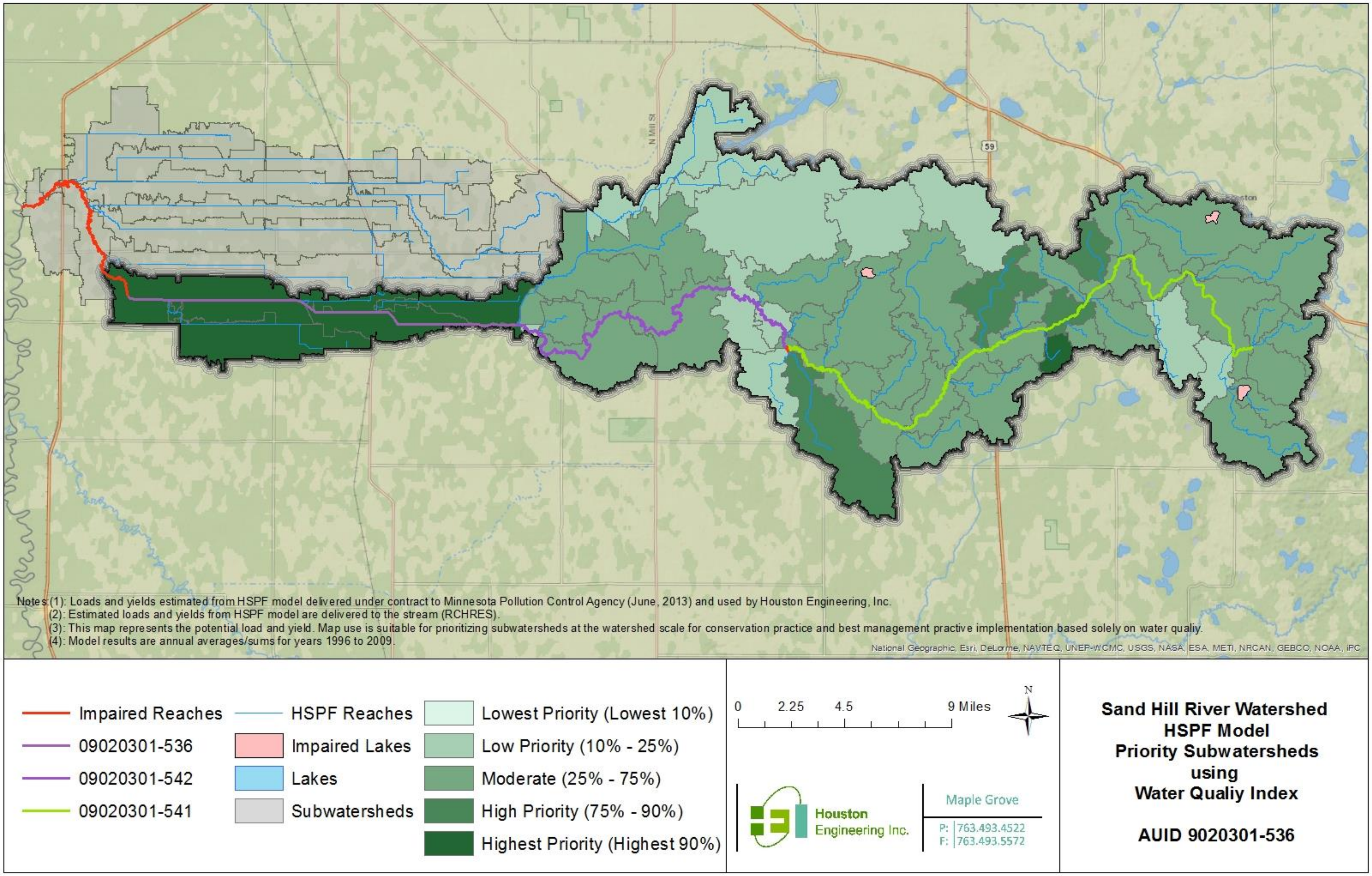


**Figure 20: AUID scale subwatershed priority for implementation for AUID 9020301-536, using the average (1996-2009) water quality index.**

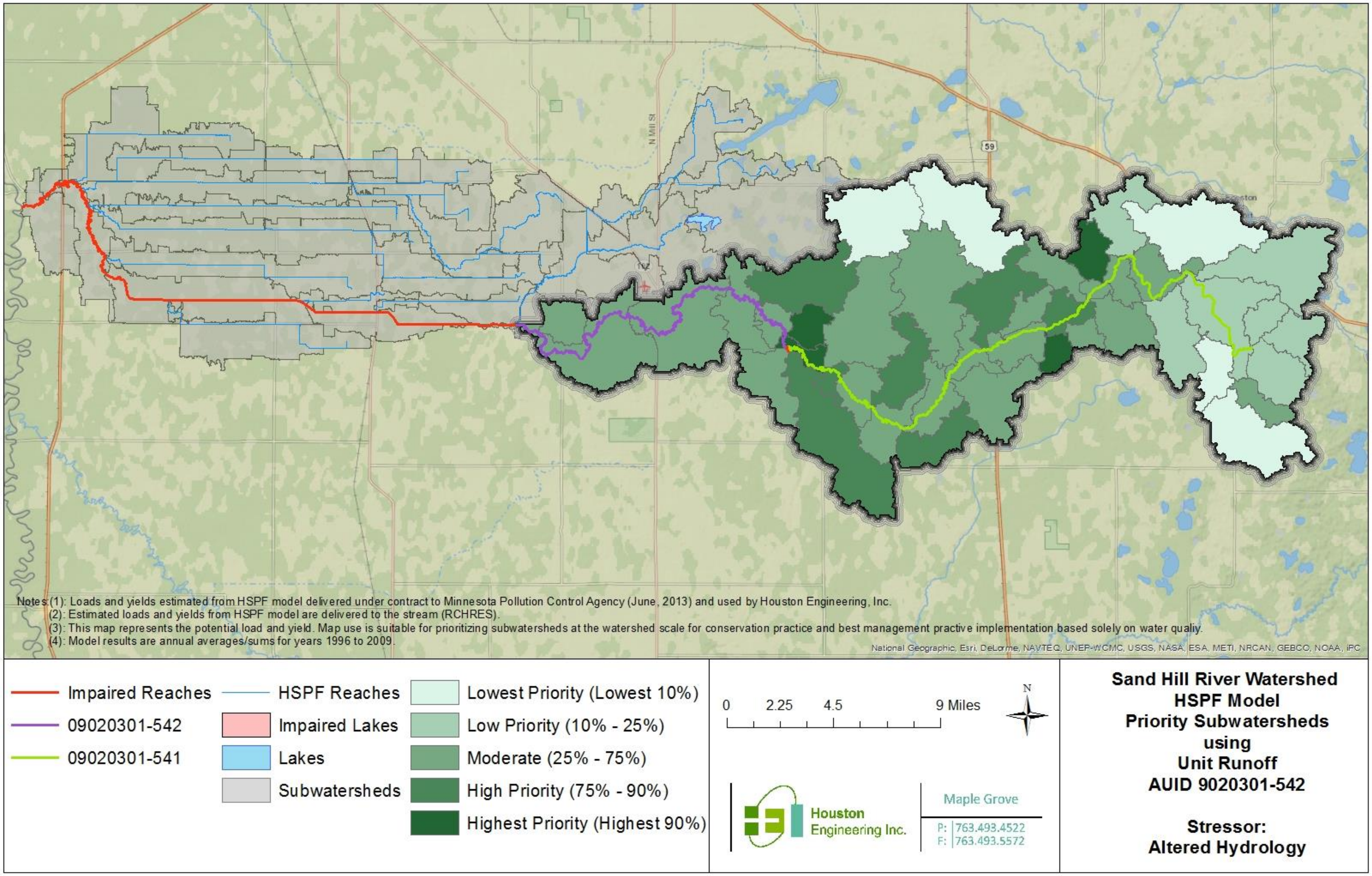


**Figure 21: AUID scale subwatershed priority for implementation for the stressor altered hydrology for AUID 9020301-542, using average (1996-2009) annual unit runoff.**

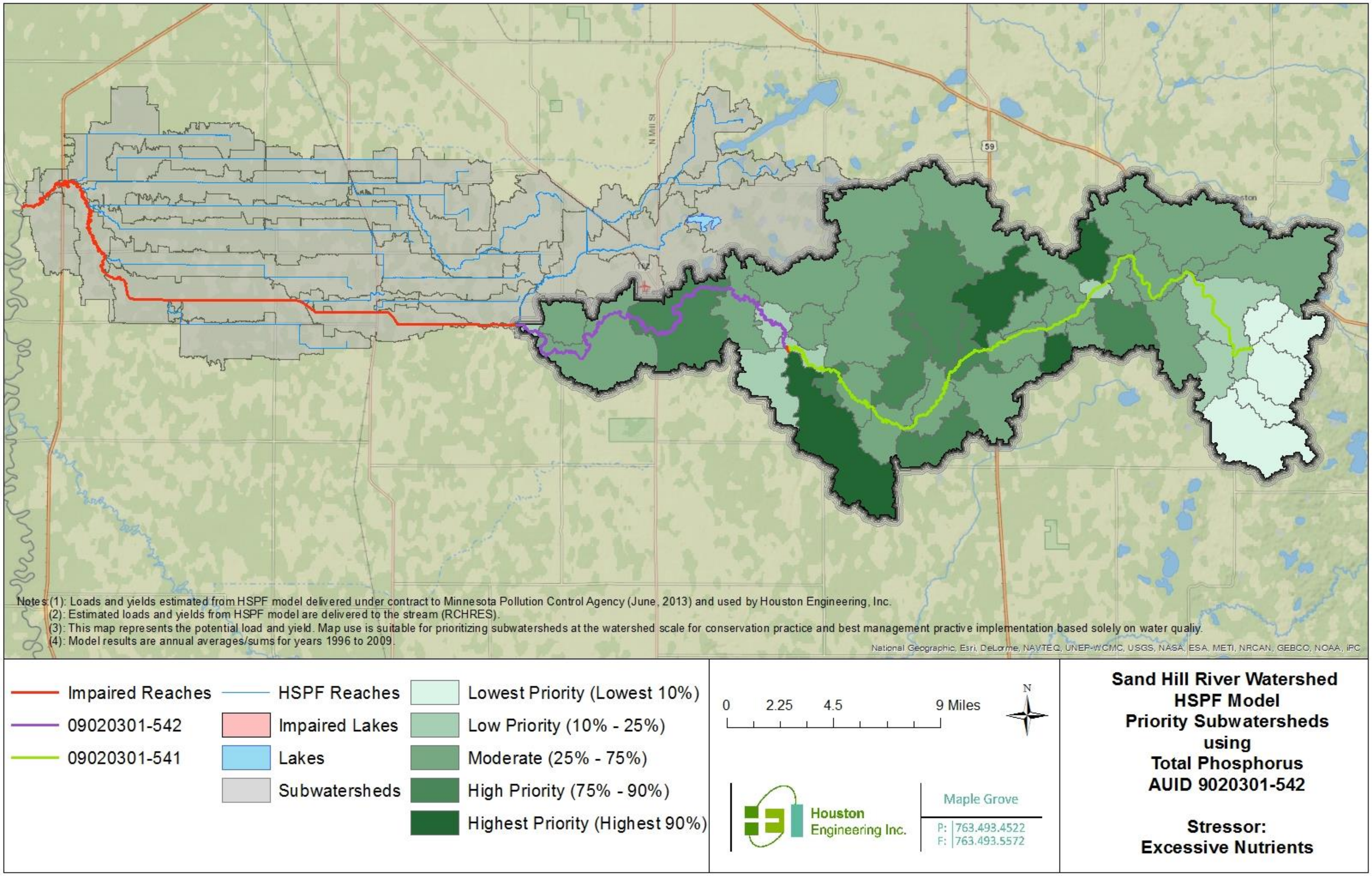


**Figure 22: AUID tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for AUID 9020301-542, using average (1996-2009) annual total phosphorus yields.**

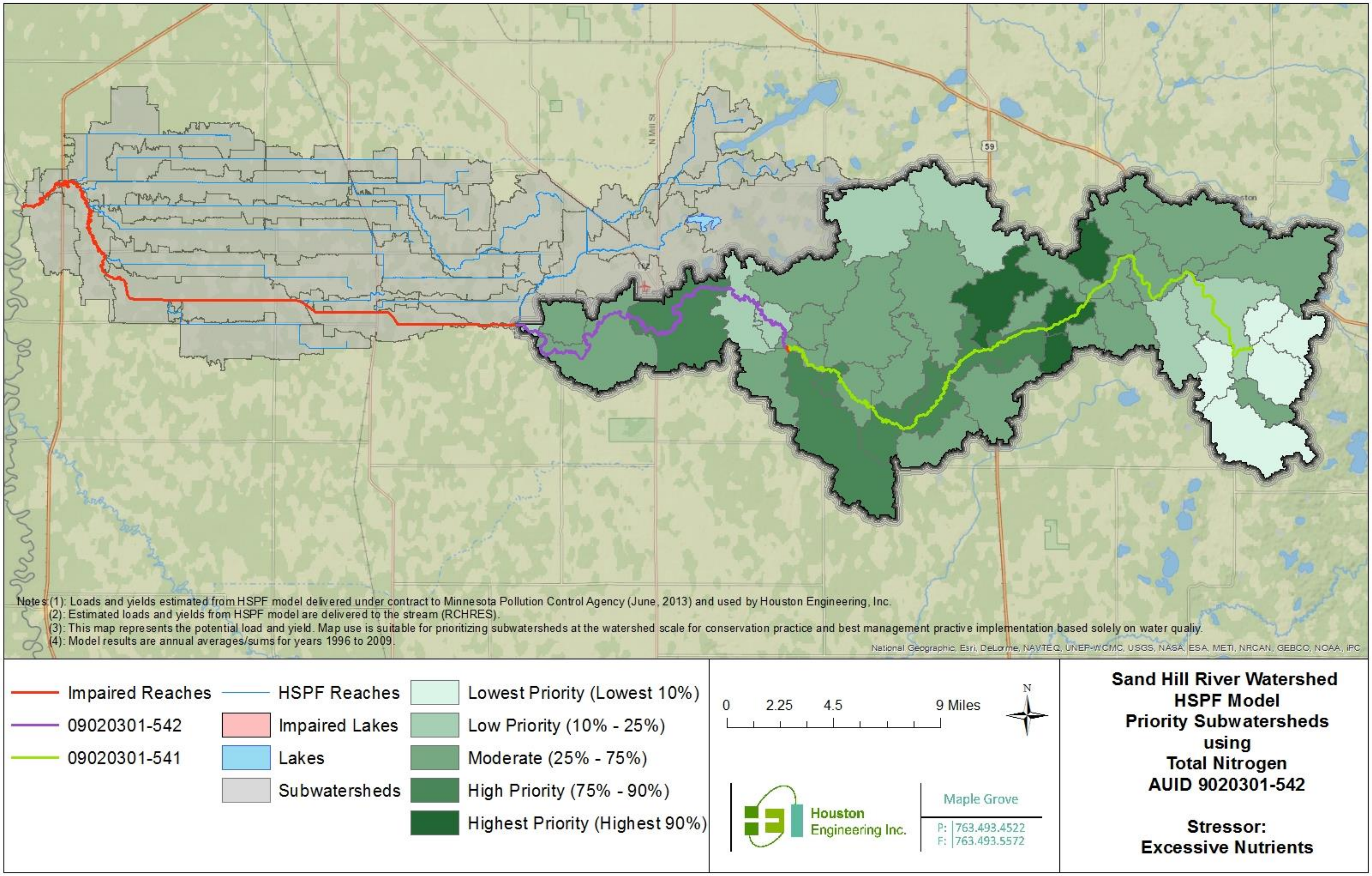


**Figure 23: AUID tributary scale subwatershed priority for implementation for the stressor excessive nutrients in for AUID 9020301-542, using average (1996-2009) annual total nitrogen yields.**

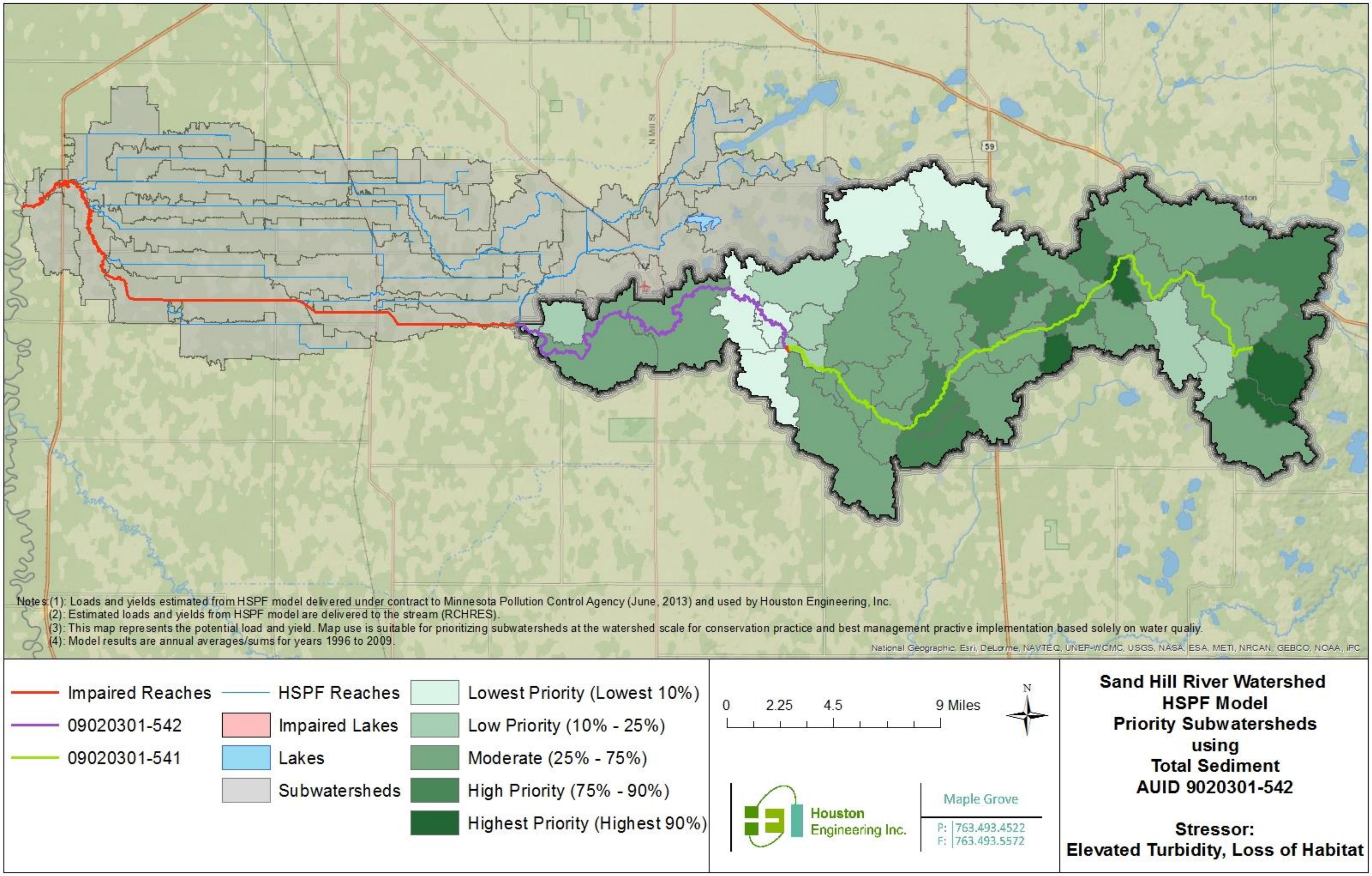


**Figure 24: AUID tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for AUID 9020301-542, using average (1996-2009) annual total sediment yields.**

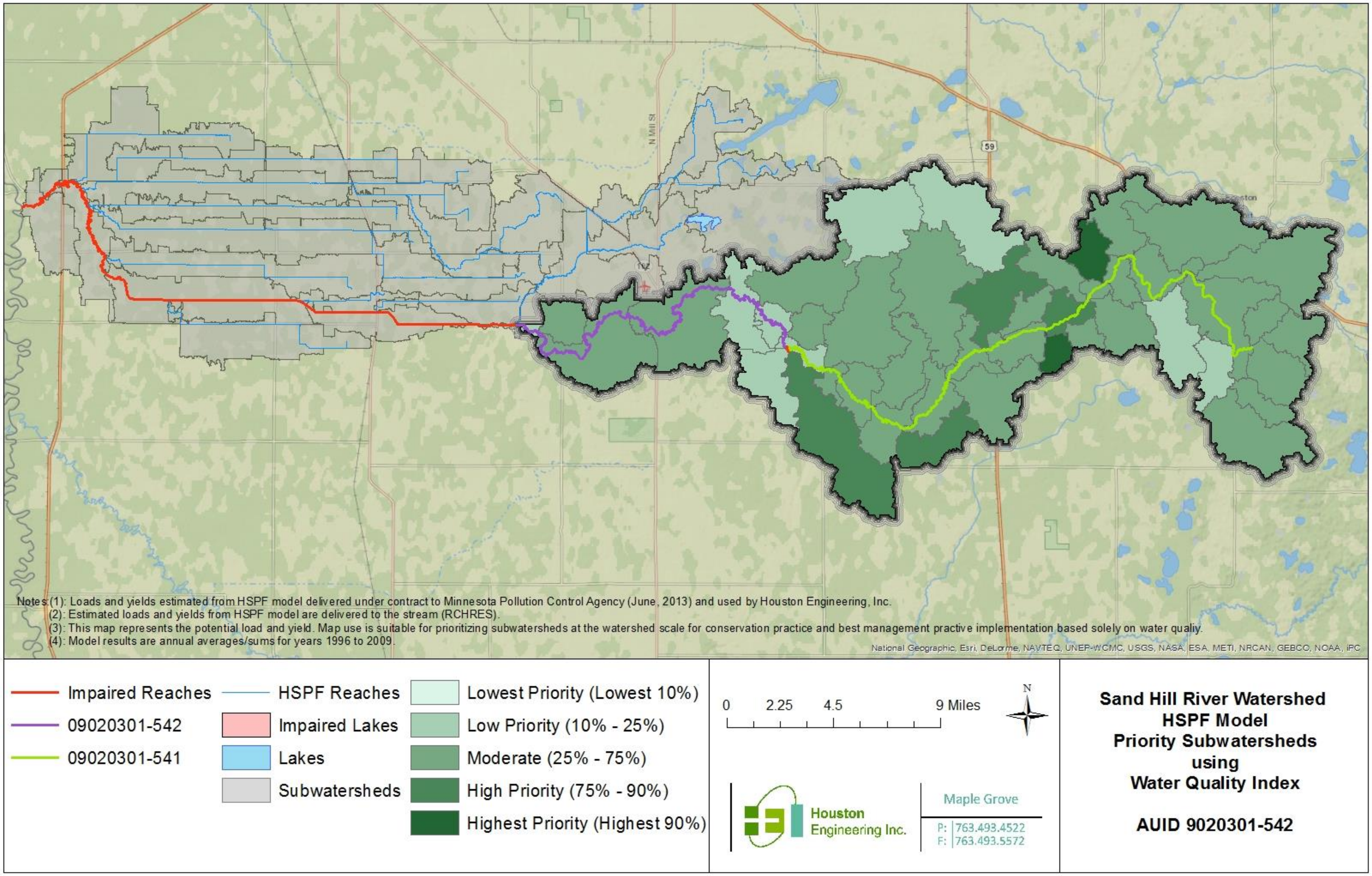


**Figure 25: AUID tributary scale subwatershed priority for implementation for AUID 9020301-542, using the average (1996-2009) water quality index.**

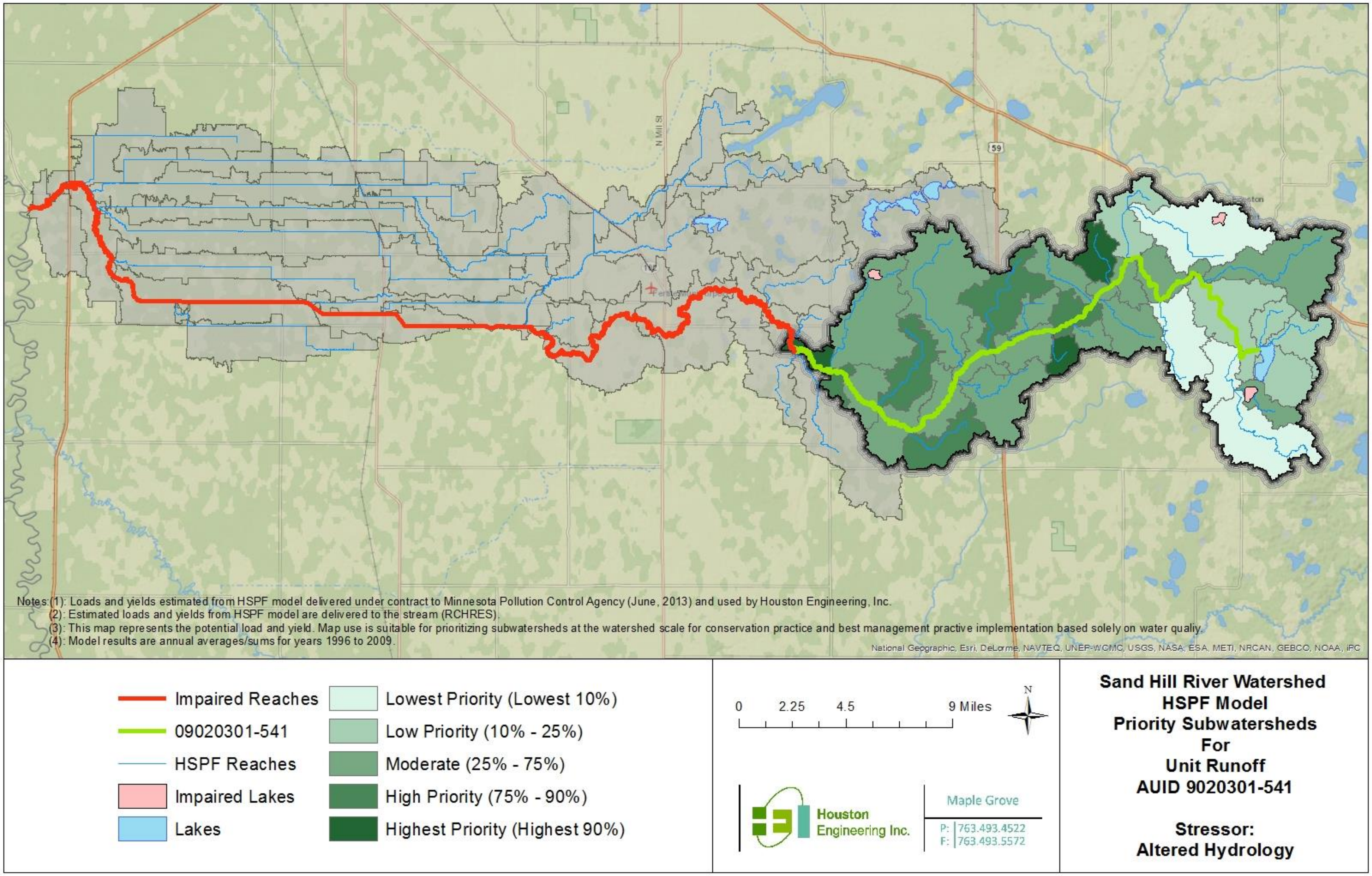


**Figure 26: AUID tributary scale subwatershed priority for implementation for the stressor altered hydrology for AUID 9020301-541, using average (1996-2009) annual unit runoff.**

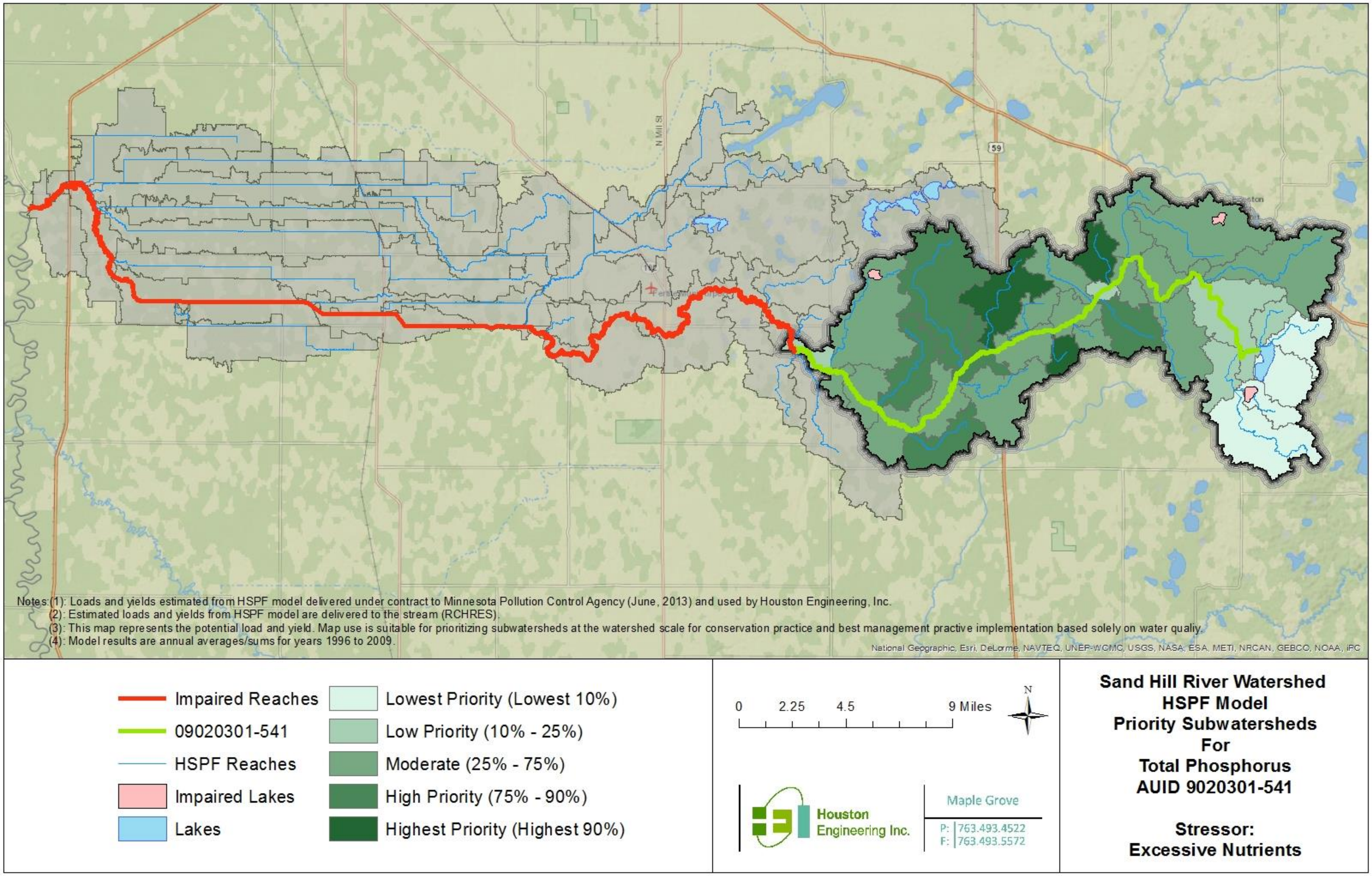


**Figure 27: AUID scale subwatershed priority for implementation for the stressor excessive nutrients for AUID 9020301-541, using average (1996-2009) annual total phosphorus yields.**

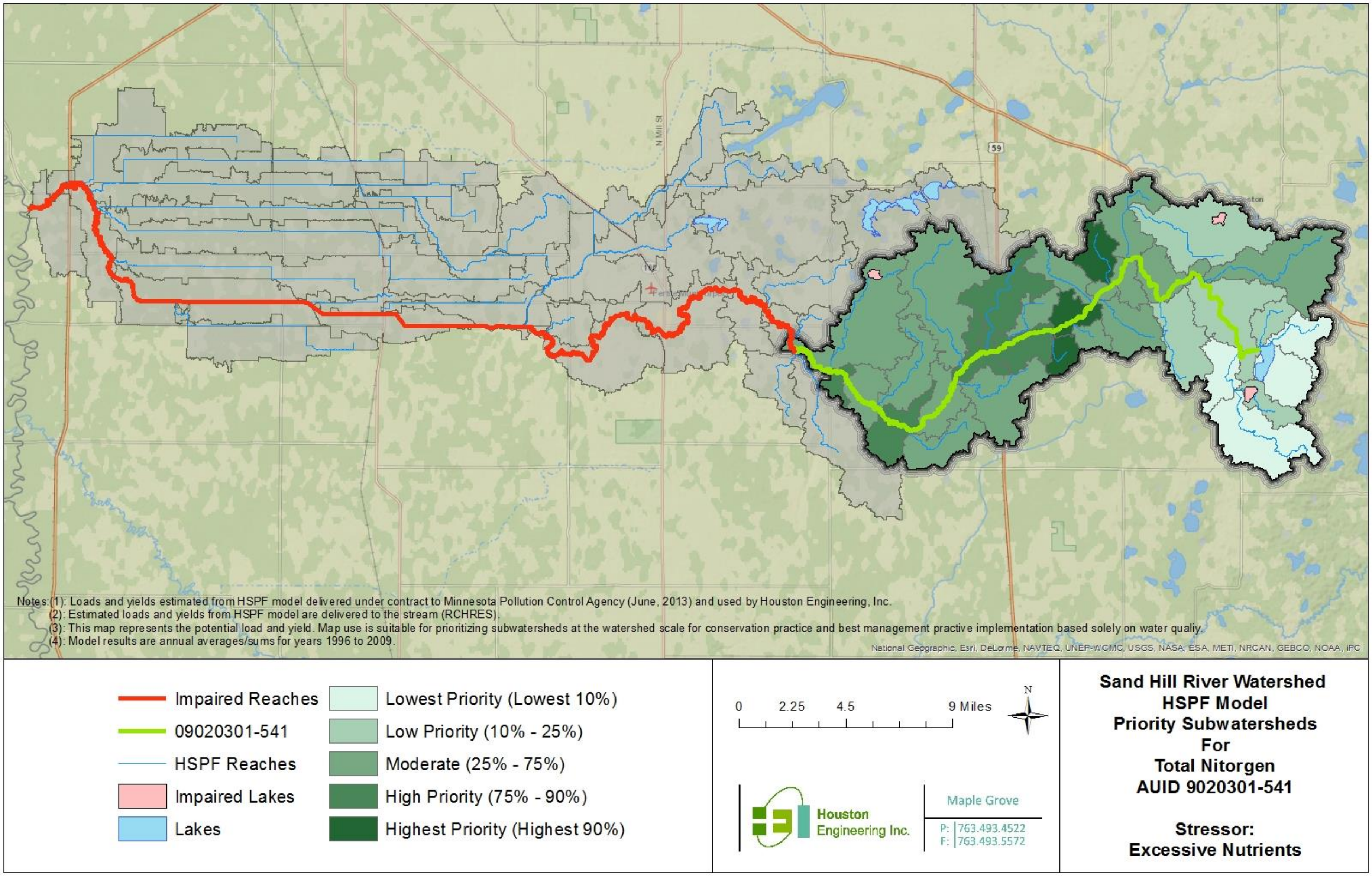


**Figure 28 AUID scale subwatershed priority for implementation for the stressor excessive nutrients for AUID 9020301-541, using average (1996-2009) annual total nitrogen yields.**

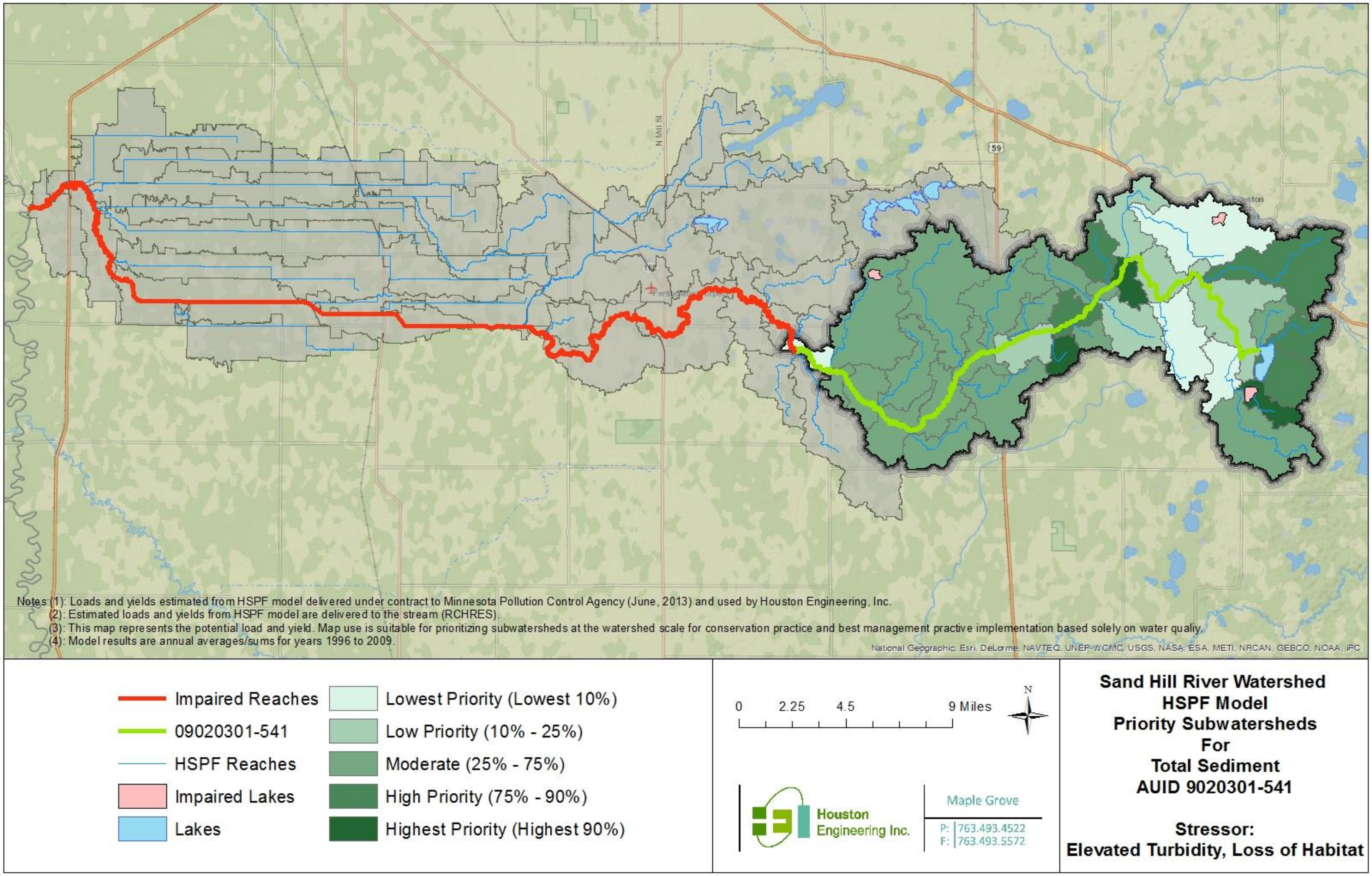


**Figure 29: AUID scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for AUID 9020301-541, using average (1996-2009) annual total sediment yields.**

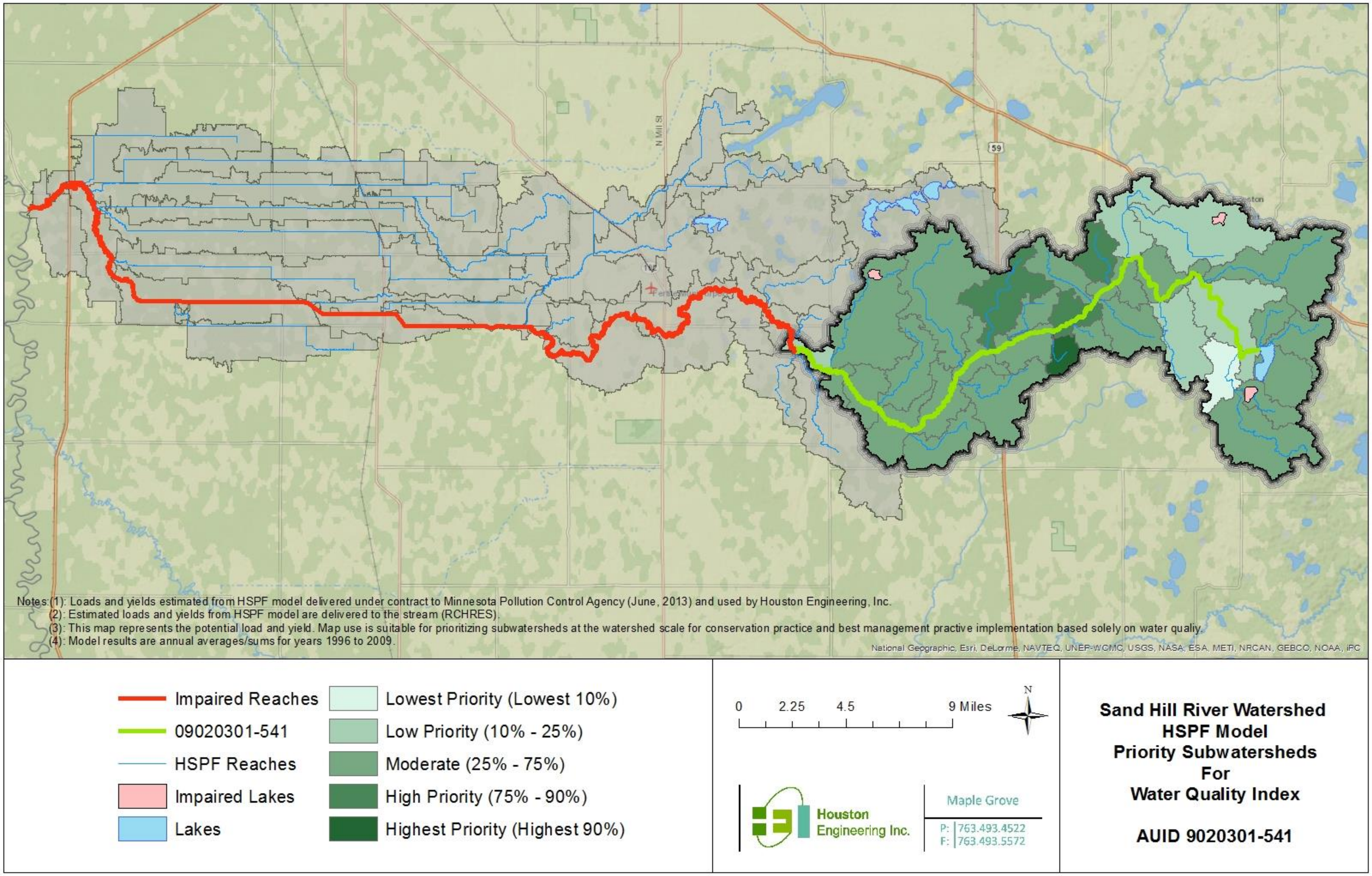


**Figure 30: AUID scale subwatershed priority for implementation for AUID 9020301-541, using the average (1996-2009) water quality index.**

# Appendix A: HSPF Results

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

| HSPF RCHRES | Runoff | | TP | | TN | | Sediment | | WQI |
|---|---|---|---|---|---|---|---|---|---|
| | Yield | Rank | Yield | Rank | Yield | Rank | Yield | Rank | Rank |
| 10 | 3.04 | 12% | 0.042 | 3% | 1.070 | 4% | 0.062 | 63% | 33% |
| 20 | 3.03 | 11% | 0.033 | 0% | 1.034 | 3% | 0.072 | 68% | 35% |
| 21 | 2.96 | 10% | 0.045 | 5% | 1.079 | 5% | 0.047 | 48% | 27% |
| 22 | 3.41 | 21% | 0.043 | 4% | 1.225 | 21% | 0.107 | 97% | 55% |
| 23 | 2.77 | 4% | 0.034 | 1% | 0.956 | 0% | 0.056 | 58% | 29% |
| 25 | 2.80 | 5% | 0.051 | 7% | 1.013 | 1% | 0.028 | 23% | 14% |
| 27 | 3.14 | 15% | 0.071 | 40% | 1.345 | 41% | 0.064 | 64% | 52% |
| 30 | 2.96 | 8% | 0.060 | 19% | 1.149 | 8% | 0.038 | 37% | 25% |
| 31 | 2.91 | 7% | 0.064 | 26% | 1.137 | 7% | 0.020 | 21% | 18% |
| 50 | 3.28 | 18% | 0.074 | 53% | 1.294 | 30% | 0.035 | 32% | 37% |
| 51 | 2.74 | 1% | 0.072 | 44% | 1.200 | 16% | 0.032 | 27% | 29% |
| 53 | 3.13 | 14% | 0.066 | 30% | 1.228 | 23% | 0.036 | 34% | 30% |
| 70 | 3.61 | 25% | 0.070 | 37% | 1.405 | 51% | 0.077 | 70% | 57% |
| 71 | 4.93 | 77% | 0.093 | 71% | 1.721 | 71% | 0.070 | 67% | 69% |
| 73 | 3.41 | 22% | 0.083 | 67% | 1.332 | 37% | 0.034 | 30% | 41% |
| 90 | 3.16 | 16% | 0.053 | 11% | 1.228 | 25% | 0.047 | 45% | 32% |
| 91 | 4.35 | 41% | 0.075 | 55% | 1.359 | 44% | 0.040 | 38% | 44% |
| 93 | 3.40 | 19% | 0.072 | 48% | 1.295 | 32% | 0.050 | 51% | 45% |
| 110 | 4.69 | 68% | 0.075 | 56% | 1.604 | 70% | 0.065 | 66% | 64% |
| 111 | 5.62 | 79% | 0.106 | 73% | 2.098 | 73% | 0.123 | 99% | 86% |
| 113 | 4.37 | 42% | 0.075 | 58% | 1.389 | 49% | 0.045 | 42% | 48% |
| 130 | 4.37 | 45% | 0.071 | 42% | 1.433 | 59% | 0.037 | 36% | 43% |
| 131 | 4.52 | 60% | 0.089 | 70% | 1.555 | 68% | 0.058 | 60% | 65% |
| 133 | 4.48 | 52% | 0.079 | 63% | 1.426 | 55% | 0.046 | 44% | 51% |
| 150 | 4.46 | 51% | 0.076 | 60% | 1.439 | 60% | 0.049 | 49% | 55% |
| 151 | 4.23 | 37% | 0.071 | 41% | 1.318 | 34% | 0.042 | 41% | 39% |
| 170 | 4.40 | 48% | 0.070 | 38% | 1.431 | 58% | 0.057 | 59% | 53% |
| 171 | 4.48 | 53% | 0.078 | 62% | 1.427 | 56% | 0.058 | 62% | 60% |
| 190 | 4.43 | 49% | 0.073 | 52% | 1.464 | 64% | 0.054 | 53% | 56% |
| 191 | 4.52 | 59% | 0.081 | 66% | 1.416 | 52% | 0.050 | 52% | 55% |
| 210 | 4.13 | 33% | 0.069 | 36% | 1.341 | 40% | 0.042 | 40% | 39% |
| 230 | 4.49 | 56% | 0.076 | 59% | 1.460 | 63% | 0.055 | 55% | 58% |
| 231 | 4.33 | 38% | 0.072 | 49% | 1.370 | 47% | 0.047 | 47% | 47% |
| 233 | 4.61 | 63% | 0.083 | 68% | 1.501 | 66% | 0.056 | 56% | 62% |
| 235 | 4.39 | 47% | 0.059 | 18% | 1.218 | 19% | 0.011 | 7% | 13% |
| 250 | 4.84 | 74% | 0.062 | 21% | 1.331 | 36% | 0.018 | 15% | 22% |
| 251 | 4.90 | 75% | 0.067 | 33% | 1.334 | 38% | 0.018 | 14% | 25% |

| HSPF RCHRES | Runoff | | TP | | TN | | Sediment | | WQI |
|---|---|---|---|---|---|---|---|---|---|
| | Yield | Rank | Yield | Rank | Yield | Rank | Yield | Rank | Rank |
| 270 | 4.34 | 40% | 0.057 | 15% | 1.196 | 15% | 0.009 | 5% | 10% |
| 272 | 2.76 | 3% | 0.072 | 47% | 1.179 | 14% | 0.000 | 1% | 16% |
| 274 | 2.60 | 0% | 0.072 | 45% | 1.169 | 12% | 0.000 | 3% | 16% |
| 275 | 4.65 | 66% | 0.065 | 29% | 1.348 | 42% | 0.017 | 12% | 24% |
| 290 | 3.72 | 27% | 0.063 | 23% | 1.168 | 11% | 0.004 | 4% | 11% |
| 310 | 4.37 | 44% | 0.080 | 64% | 1.528 | 67% | 0.028 | 25% | 45% |
| 330 | 3.86 | 29% | 0.062 | 22% | 1.387 | 48% | 0.031 | 26% | 30% |
| 331 | 3.70 | 26% | 0.067 | 32% | 1.302 | 33% | 0.022 | 22% | 27% |
| 350 | 4.04 | 30% | 0.052 | 8% | 1.155 | 10% | 0.014 | 10% | 9% |
| 352 | 3.45 | 23% | 0.073 | 51% | 1.225 | 22% | 0.000 | 0% | 18% |
| 353 | 4.23 | 36% | 0.065 | 27% | 1.360 | 45% | 0.019 | 18% | 27% |
| 355 | 4.72 | 70% | 0.054 | 14% | 1.269 | 27% | 0.016 | 11% | 16% |
| 357 | 4.76 | 71% | 0.052 | 10% | 1.281 | 29% | 0.018 | 16% | 18% |
| 359 | 4.11 | 32% | 0.053 | 12% | 1.240 | 26% | 0.020 | 19% | 19% |
| 361 | 4.49 | 55% | 0.064 | 25% | 1.417 | 53% | 0.033 | 29% | 34% |
| 363 | 4.49 | 58% | 0.067 | 34% | 1.456 | 62% | 0.035 | 33% | 40% |
| 365 | 5.68 | 81% | 0.674 | 79% | 6.502 | 79% | 0.095 | 90% | 85% |
| 370 | 5.84 | 88% | 0.766 | 89% | 7.336 | 88% | 0.092 | 82% | 85% |
| 371 | 5.92 | 93% | 0.745 | 85% | 7.215 | 85% | 0.098 | 95% | 90% |
| 373 | 5.84 | 86% | 0.769 | 90% | 7.343 | 92% | 0.093 | 85% | 88% |
| 390 | 5.86 | 89% | 0.771 | 93% | 7.382 | 93% | 0.093 | 86% | 90% |
| 391 | 5.97 | 95% | 0.778 | 97% | 7.526 | 97% | 0.092 | 78% | 88% |
| 393 | 5.80 | 84% | 0.770 | 92% | 7.343 | 90% | 0.092 | 79% | 85% |
| 395 | 5.73 | 82% | 0.754 | 86% | 7.153 | 82% | 0.092 | 81% | 83% |
| 397 | 6.00 | 97% | 0.780 | 99% | 7.535 | 99% | 0.095 | 88% | 93% |
| 399 | 4.15 | 34% | 0.059 | 16% | 1.203 | 18% | 0.012 | 8% | 13% |
| 401 | 5.98 | 96% | 0.743 | 84% | 7.227 | 86% | 0.095 | 92% | 88% |
| 403 | 5.56 | 78% | 0.735 | 81% | 6.912 | 81% | 0.089 | 75% | 78% |
| 405 | 5.89 | 92% | 0.765 | 88% | 7.339 | 89% | 0.095 | 89% | 89% |
| 407 | 6.02 | 99% | 0.738 | 82% | 7.173 | 84% | 0.100 | 96% | 89% |
| 409 | 5.81 | 85% | 0.776 | 95% | 7.392 | 95% | 0.092 | 84% | 89% |
| 411 | 5.86 | 90% | 0.777 | 96% | 7.438 | 96% | 0.092 | 77% | 86% |
| 413 | 4.63 | 64% | 0.600 | 78% | 5.444 | 78% | 0.079 | 73% | 75% |
| 430 | 4.59 | 62% | 0.540 | 75% | 5.009 | 75% | 0.078 | 71% | 73% |
| 450 | 4.79 | 73% | 0.483 | 74% | 4.696 | 74% | 0.096 | 93% | 84% |
| 470 | 4.68 | 67% | 0.558 | 77% | 5.175 | 77% | 0.084 | 74% | 75% |

February 10, 2013

# GIS TERRAIN ANALYSIS REPORT

## Sandhill River Watershed

## Major Watershed Restoration & Protection Plan

HoustonEngineering Inc.

**Submitted to:**

SAND HILL RIVER
WATERSHED DISTRICT

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## 1. INTRODUCTION

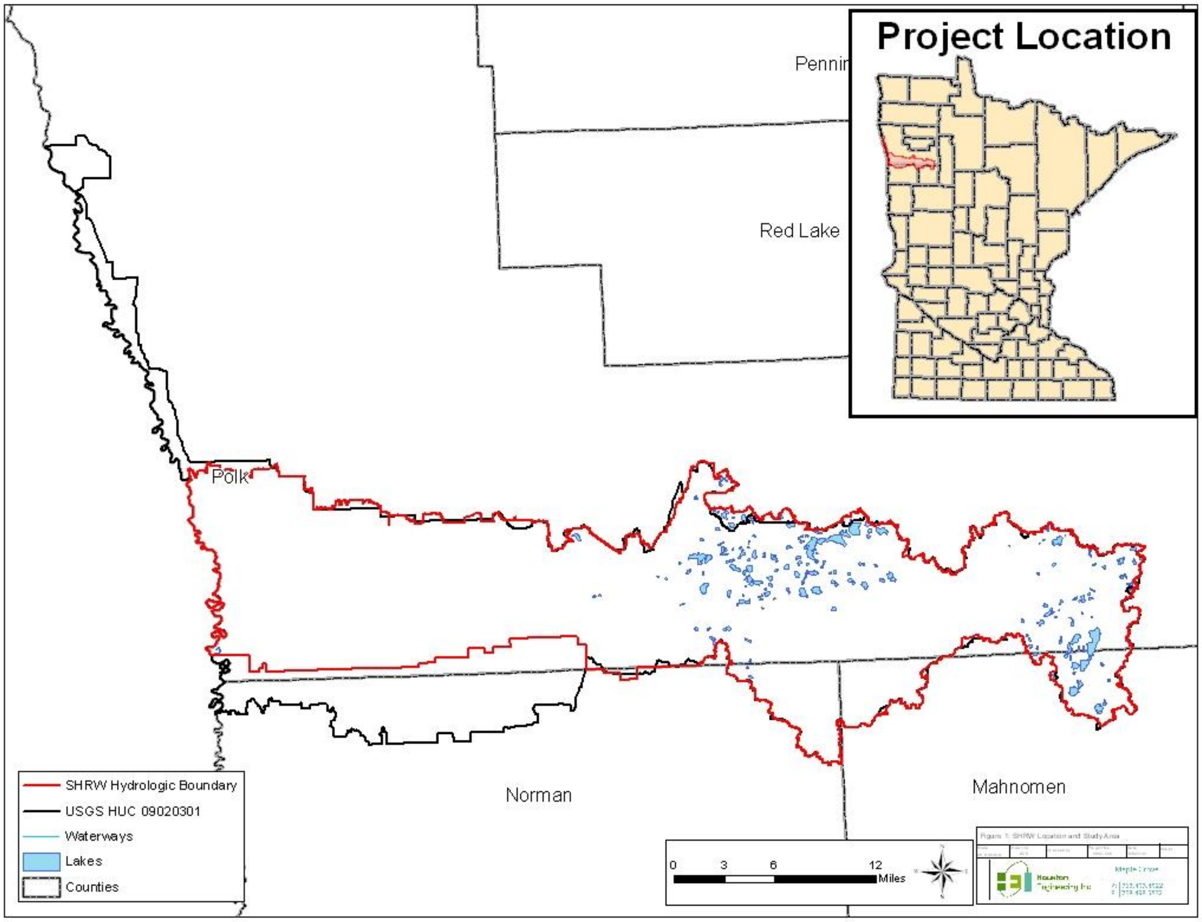
The Sand Hill River Watershed Restoration and Protection Plan (WRPP) project is currently underway. The goal of the project is to develop a comprehensive plan for managing surface water quality across the watershed, protecting waters where conditions meet water quality standards and restoring waters that are impaired. The MPCA has contracted the Sand Hill River Watershed District (SHRWD) to lead the WRPP effort.

A major goal of the WRPP effort is to identify areas across the landscape where surface water quality management should be prioritized. GIS (geographic information systems) terrain analysis is one way to identify these areas, using the power of computer-based analysis tools. Highly-accurate elevation data are combined with information on soils, land use, and the location of civil infrastructure to develop a series of GIS products. These products include a raster of Stream Power Index (SPI) values, which provide a (relative) indication of the erosive power of overland, concentrated, surface water runoff at locations across the landscape. Also included is a raster of potential soil yields from overland areas, computed using the Revised Universal Soil Loss Equation (RUSLE). Priority management areas in the watershed are identified by analyzing and combining the SPI and RUSLE results to locate those areas where the most erosive overland flows and high sediment yields combine. This report describes the work done to perform GIS terrain analysis in the Sand Hill River Watershed (SHRW) and provides information for use in prioritizing areas for water quality management in the study area.

## 2. STUDY AREA

The SHRW comprises an area of approximately 495 square miles in the northwestern Minnesota counties of Polk, Norman and Mahnomen. It's bordered on the north and east by the Red Lake Watershed and by the Wild Rice River Watershed on the south and east. The SHRW is contained within the larger US Geological Survey HUC (Hydrologic Unit Code) # 09020301. The remaining area of the 8-digit HUC (that which is not covered by the SHRW) includes areas drained by ditches that flow directly to the Red River of the North (**Figure 1**). The GIS products created under this project were created to cover the entire 8-digit HUC. However, the process of analyzing and scoring the SPI and RUSLE rasters to prioritize management areas focused only on the SHRW since that is the focus of the WRPP effort.

**Figure 1: SHRW Location and Study Area**




## 3. DATA SOURCES

A number of different data sources were used in the performance of the GIS terrain analysis work. Following are the main data sources used and a general description of their origin and content.

**Elevation data:** This study utilizes the International Water Institute's (IWI) Light Detection and Ranging (LiDAR) elevation data, which was collected in the SHRW area between 2008 and 2009. All data was collected to a maximum error of plus or minus six inches. For purposes of this work, the bare earth LiDAR points were generalized into a digital elevation model (DEM) at 3 meter by 3 meter resolution.

**Watershed District Permit Information:** Information from the SHRWD's permit program was available for reference during the creation of the hydrologically-corrected DEM. This data mainly consists of point locations of past permits and permit application forms describing the permitted project. This information was referenced in several instances where the drainage direction was in question during hydrologic correction.

**Rainfall Frequency/Duration data:** The hydrologic conditioning process included analysis to identify areas that do contribute runoff downstream. Runoff estimates from the 10-year recurrence, 24-hour runoff duration event, as defined by the US Weather Bureau's *Rainfall Frequency Atlas of the United Sates* (Technical Paper No. 40) were used to determine the non-contributing areas.

**Land Use/Land Cover:** The 2006 National Land Cover Dataset (NLCD) was used to develop a runoff Curve Number for assessing non-contributing areas when creating the hydrologically-conditioned DEM. The National Agricultural Statistics Service (NASS) 2011 Cropland Data Layer (CDL) was used for assigning C and P values for various land use practices in the RUSLE equation.

**Soils:** Hydrologic Soil Group designations from the Natural Resources Conservation Service's (NRCS) SSURGO database were also used in the developing the Curve Number for hydrologically conditioning the DEM. Soil Erodibility Factors ($K_w$) from these data were used as input to the RUSLE equation.

**Rainfall-Runoff (R-factor) Values:** Information on R-factors used in the RUSLE equation is available from the NRCS MN Field Guide. The R-factor accounts for the impact of meteorological characteristics on erosion rates.

## 4. METHODS

### 4.1. Hydrologic Conditioning

Hydrologic conditioning is the process of modifying the elevation values in a raw "bare earth" Digital Elevation Model (DEM) raster through GIS processing to make the DEM more suitable for most hydrologic analyses. The modification process typically involves breeching digital dams (lowering the outlet) and elevating user-defined sinks to ensure that water flow paths are accurately represented in the conditioned DEM. Hydrologic conditioning is sometimes referred to as hydrologic correction.

**"Burning in" Process**

Conditioning 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. Conditioning involves the interpretation of these structures and accounting for them by "burning in" their location to 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. The resultant DEM after the "burning in" process is referred to as the AgreeDEM. The AgreeDEM is then processed through a series of GIS watershed processing techniques to determine drainage lines and catchment polygons for the analyzed watershed. These drainage lines and catchment polygons are interpreted by the user to verify the results and in subsequent watershed analysis. This process is repeated until the results of the GIS watershed processing on the AgreeDEM match the user's interpretation of the DEM.

**Non-Contributing Analysis**

Depressional areas (e.g., sinks, wetlands, potholes) are a naturally occurring feature in most landscapes. During runoff events the runoff volume to the depressional areas is not contributed downstream until the runoff volume exceeds the depressional area volume.  If the runoff volume does not exceed the depressional area volume, the area is categorized as “non-contributing”. The determination is dependent on the size of the runoff event analyzed. For the purposes of this study, non-contributing areas were defined as areas that contain the 10-year recurrence, 24-hour runoff event, as defined by the US Weather Bureau’s *Rainfall Frequency Atlas of the United Sates* (i.e., Technical Paper No. 40). For the SHRW, this event was defined as 3.5 inches of precipitation. The non-contributing determination is done using a series of GIS processes in which the available storage of a depressional area is compared to the runoff volume generated from the contributing watershed of the depressional 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. All depressional areas determined to be contributing are adjusted by elevating their elevation values to create a continuous flow path that traverses the depressional area. Flow paths are allowed to terminate within non-contributing depressional areas.

### 4.2. Stream Power Index (SPI)

The Stream Power Index (SPI) accounts for physical characteristics of a landscape to estimate the potential of overland, concentrated surface water flow to cause erosion. SPI values are computed by multiplying the slope of a point on the landscape by its contributing drainage area.

$$SPI = ln[(flow\ accumulation)\ x\ (slope)]$$

The higher the SPI value, the greater the energy that surface water moving across the landscape at that point will potentially have to cause erosion. SPI is a simple analysis, not accounting for land cover, land use, soil type or other factors that impact surface water erosion. For this reason, it is best to compare SPI values across areas with similar land management practices, land covers, and soils.

SPI values were computed across the SHRW using the raster data discussed above. Landscape slope was determined from the raw “bare earth” DEM. Contributing areas were determined using the 3 meter by 3 meter flow accumulation raster created from the HydroDEM. SPI values across the 8-digit HUC were computed by multiplying the two rasters together.

A main focus of the SPI analysis is to locate areas with high potential for erosion due to gully formation. Since the likelihood of gully erosion is generally low where rill and interrill flow occurs, areas of the watershed where the upstream flow length is less than 300 feet were eliminated from the SPI analysis. In-channel flow areas were also removed from the SPI raster, since this method focuses on overland, not channelized, flow.

### 4.3. 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 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 discussion below summarizes the development of input variables to RUSLE. Figures are included in **Appendix A** that show the input variables and their variation across the project area.

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

Where, R = Rainfall and Runoff Factor
K = Soil Erodibility Factor
LS = Length-Slope Factor
C = Cover and Management Factor
P = Support Practice Factor

**Equation Input Descriptions**

*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 MN is available from the NRCS MN Field Guide, on a county-by-county basis. Values for Mahnomen, Norman and Polk Counties were used in this study.

*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 HydroDEM 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 2011 National Agricultural Statistics Service's (NASS) cropland data layer (CDL) were used to define land cover and crop type in the project area HUC. **Table 1** summarizes 2011 NASS land cover classification in the project HUC 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 covers 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 1** – Cover and Management Factors for NASS Cropland Data Layer Categories

| C- Factor | NASS CDL Classification |
|---|---|
| 0.200 | Corn, Soybeans, Sunflower, Barley, Spring Wheat, Winter Wheat, Rye, Oats, Millet, Canola, Flaxseed, Sorghum, Peas, Herbs, Sugarbeets, Dry Beans, Potatoes, Other Crops, Fallow/Idle Cropland, Vetch, Double Crop Soybean/Oats |
| 0.100 | Alfalfa, Other Hay, Sod/Grass Seed |
| 0.005 | Clover/Wildflowers, Pasture/Grass, Pasture/Hay |
| 0.003 | Developed/Open Space, Developed/Low Intensity, Developed/Medium Intensity, Developed/High Intensity, Barren |
| 0.002 | Woodland, Deciduous Forest, Evergreen Forest, Shrubland |
| 0.001 | Grass Herbaceous |
| 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 project 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 is conservative in its estimate of soil erosion, not accounting for support practices that may be in-place. If future users of this data have more information on support practices and desire to include those in their analysis, P-factors can be derived data and the analysis can be re-run to account for these practices in the estimation of soil erosion.

**Potential Sediment Yield**

Once all of the required input variables were derived for RUSLE, the values were multiplied to determine the potential sediment yield for each (3 meter by 3 meter) raster cell in the project area. 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 of less than 500 feet.

**Sediment Delivery Ratio**

To determine the amount of sediment yielded at each raster cell that actually reaches the downstream overland catchment (defined in **Section 4.4**) pour point, a Sediment Delivery Ratio (SDR) was applied. SDRs were developed following methods defined in the Minnesota Phosphorus Index (MN P-Index) which uses methodology based on previous sediment delivery analysis (Ouyang and Bartholic, 1997). The SDR is computed as a function of the flow length between the source of sediment loading and the downstream point of interest (in this case, the overland catchment pour point). Higher SDR values correspond to areas adjacent to in-channel areas and lower SDR values are found as distance from in-channel areas increases.

$$SDR = (downstream\ flow\ length)^{-0.2069}$$

The downstream flow length was derived from the HydroDEM. The SDR values are multiplied by the potential sediment yield results to estimate effective sediment yields.

**Effective Sediment Load at Overland Catchment Pour Point**

The effective sediment yield values were accumulated downstream to the overland catchment pour points to compute an estimated total sediment load (accounting for the SDR) from each overland catchment area.

### 4.4. Overland Catchment Definition

For the purposes of summarizing the results of the SPI and RUSLE analyses, overland catchment areas needed to be defined. As used in this work, the term overland catchment refers to the area that drains to the location where flow transitions from concentrated overland flow to in-channel flow. Based on a review of aerial photography in the Red River Basin, a drainage area threshold of 124 acres was used to define the transition from concentrated overland flow to in-channel flow. In addition, a minimum drainage area of 5 acres was assigned. The outlet from the overland catchment area is identified as the “overland catchment pour point”.

### 4.5. SPI and RUSLE Raster Scoring

As mentioned above, the results of the SPI and RUSLE analyses are most valuable when compared relative to one another across a similar landscape/soil/land management scenario. To do this for the HSRW, SPI raster values were exported to an Excel spreadsheet and analyzed to develop a percentile ranking for each SPI value in SHRW using a cumulative log-normal distribution. The corresponding percentile ranking for each SPI value was then joined back to the SPI raster to create a raster with values representing each cell value’s percentile rank from the log-normal distribution. The result of this was to provide context to each SPI, showing the severity of the values relative to others in the study area.

A similar process was repeated for the accumulated effective sediment yield raster from the RUSLE analysis. However, in this case, areas where upstream flow length is less than 300 feet were eliminated. This step was necessary due to the size of the effective sediment load raster (i.e., the number of values

that it contained) and introduces minimal error since effective sediment loading for overland sheet flow areas (areas where flow length <300 feet) is small. The result of this step was to highlight those areas in the SHRW where elevated sediment loadings from overland sources are occurring.
The rankings grids for the SPI values and accumulated effective sediment loading values were then averaged to create a grid of combined SPI/loading scores. Finally, a mean combined score value was computed for each overland catchment scale. This combined overland catchment score accounts for both the SPI's index of erosion potential and RUSLE's estimate of overland erosion. High scores correlate to overland catchments that have areas where a high likelihood of gully erosion exists as well as a high value of estimated sediment loading from overland flow.

$$Combined\ Overland\ Catchment\ Score = Average\ \ \frac{SPI\ Rank + RUSLE\ Rank}{2}$$

## 5. RESULTS

### 5.1. Hydrologically-Conditioned DEM

The result of the hydrologic conditioning process is a DEM (HydroDEM) from which accurate water flow paths can be developed. GIS processes are run on the HydroDEM to create rasters representing flow direction and upstream contributing cell count to each cell along with a stream network raster. These rasters are then used in the SPI and RUSLE analysis. **Figure 2** displays the HydroDEM and major drainage paths derived from the HydroDEM.

### 5.2. SPI Values

**Figure 3** shows the raster of mean SPI rankings for the overland catchments in the SHRW. In general, the project watershed consists of higher slopes to the east with slopes moderating further to the west causing a corresponding variation in the mean SPI values.

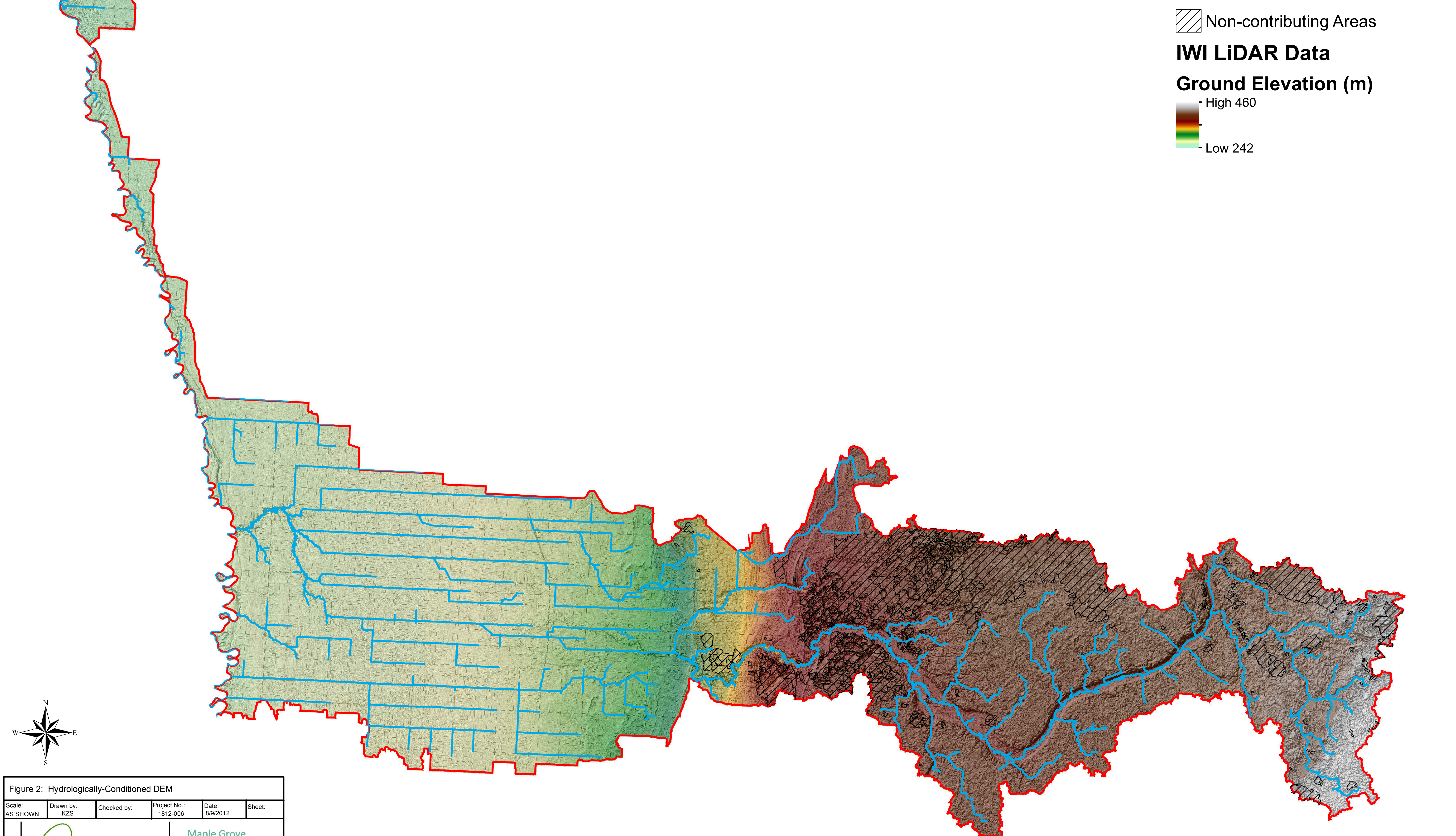
### 5.3. Accumulated Effective Sediment Loading

**Figure 4** shows the accumulated effective sediment load for each overland catchment in the SHRW.

### 5.4. Catchment Prioritization

**Figure 5** shows the combined overland catchment scores, computed as an average of the SPI and accumulated effective loading rankings, across the SHRW. The variation in scores indicates the relative difference in potential erosion from the combined effects of the SPI's prediction of erosive flows and RUSLSE's prediction of sediment yields. In general, areas with either relatively steep slopes and a high density of field drainage features causing high sediment delivery ratios result in higher catchment scores for the SHRW.

# Hydrologically-Conditioned DEM




| Figure 2: Hydrologically-Conditioned DEM | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 8/9/2012 | Sheet: |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# Mean SPI Value for Overland Catchments

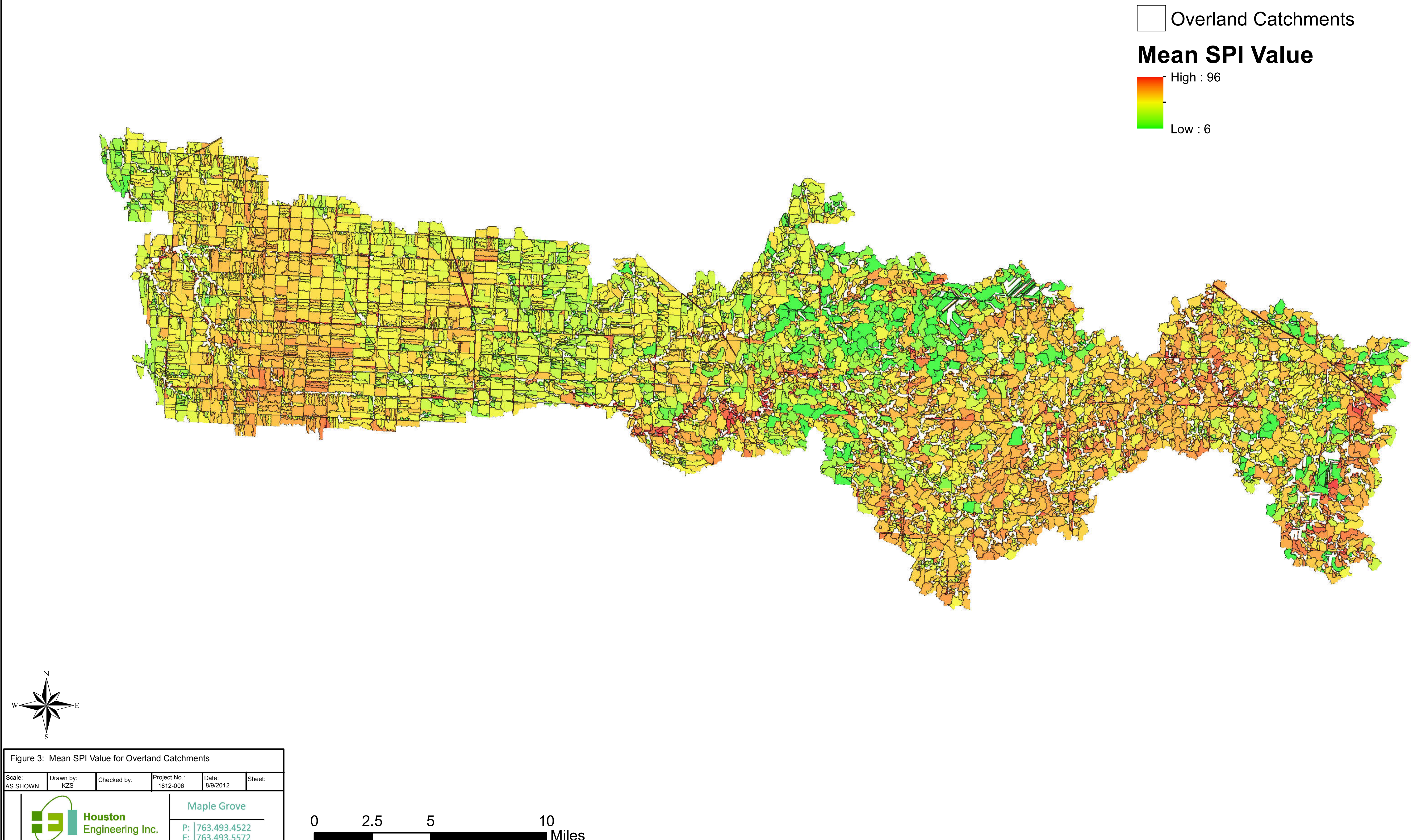


Figure 3: Mean SPI Value for Overland Catchments

| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 8/9/2012 | Sheet: |
|---|---|---|---|---|---|

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F: 763.493.5572

# Overland Catchment Average Sediment Load (tons/yr)

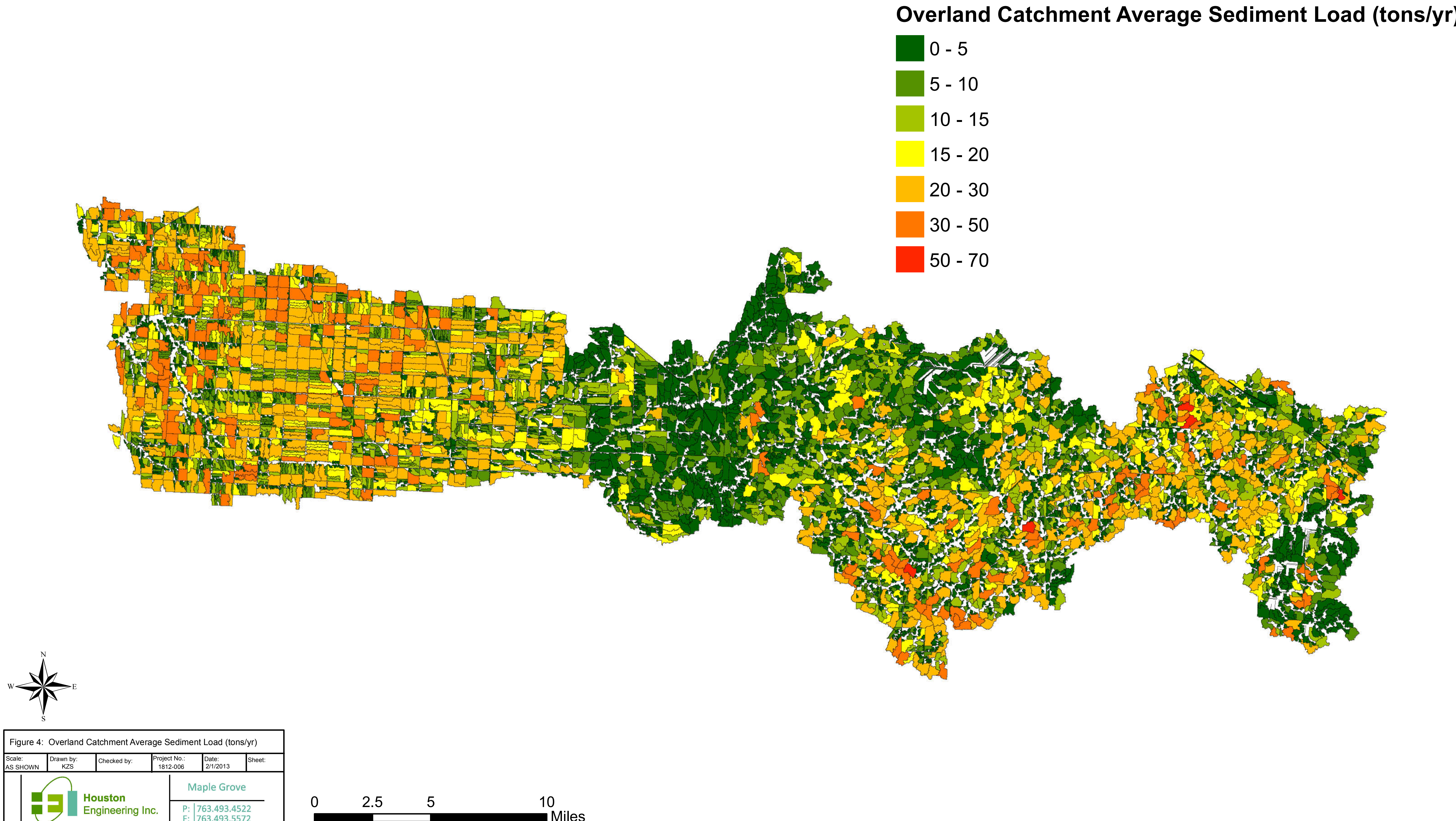


Figure 4: Overland Catchment Average Sediment Load (tons/yr)

| Scale: | Drawn by: | Checked by: | Project No.: | Date: | Sheet: |
| --- | --- | --- | --- | --- | --- |
| AS SHOWN | KZS | | 1812-006 | 2/1/2013 | |

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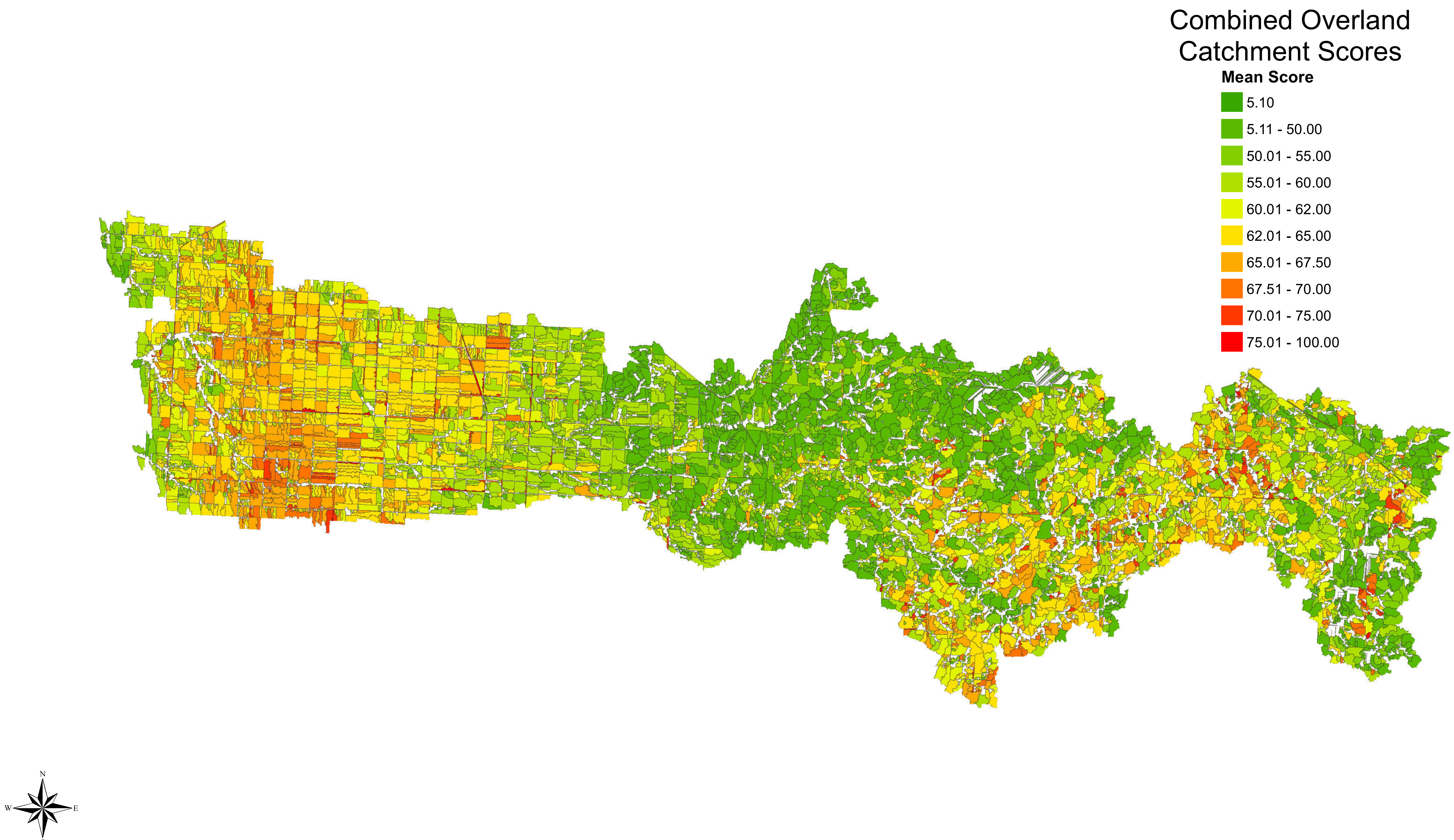


Figure 5: Combined Overland Catchment Scores

| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 2/1/2013 | Sheet: |
|---|---|---|---|---|---|


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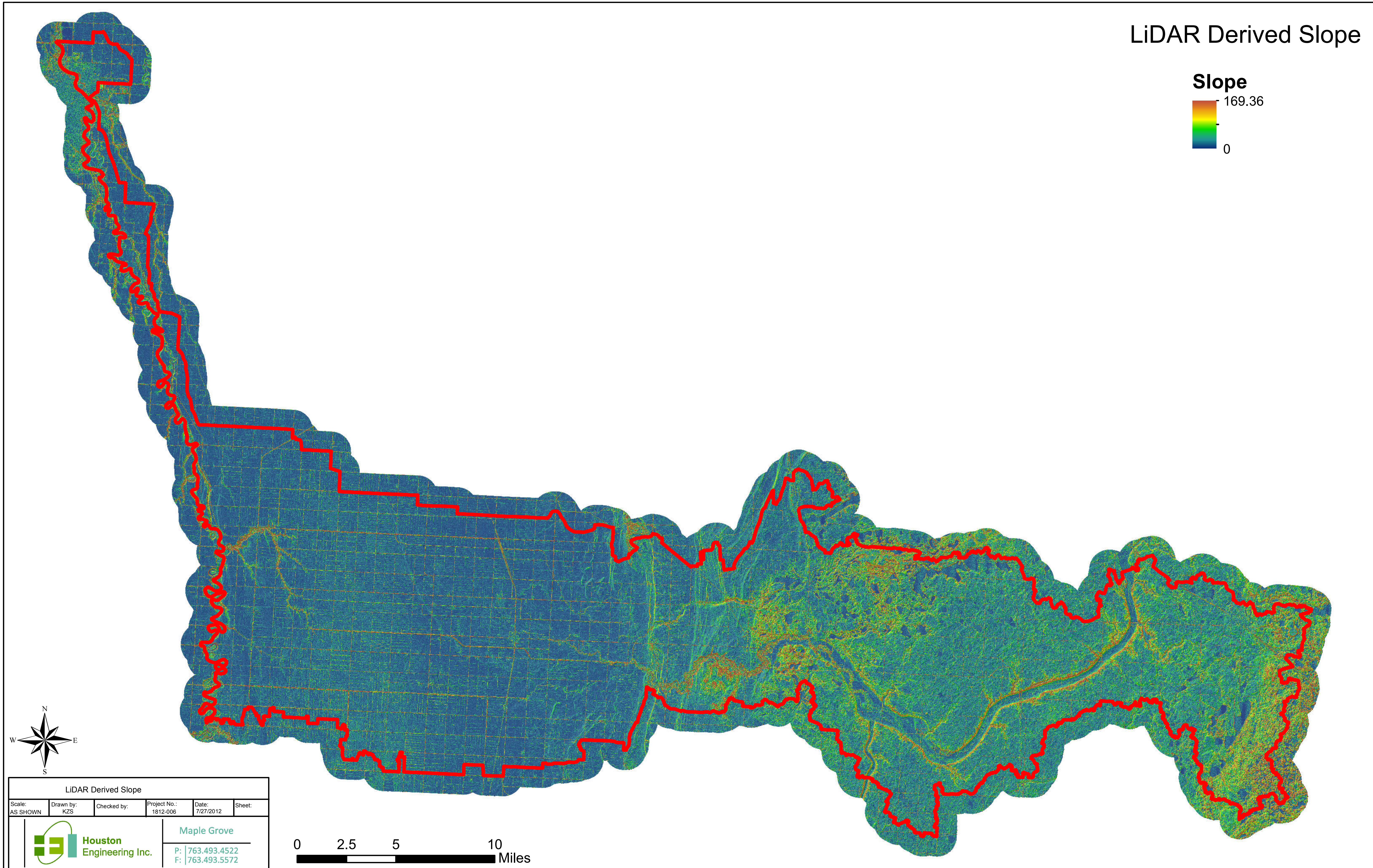
0 2.5 5 10 Miles

# APPENDIX A




| LiDAR Derived Slope | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 7/27/2012 | Sheet: |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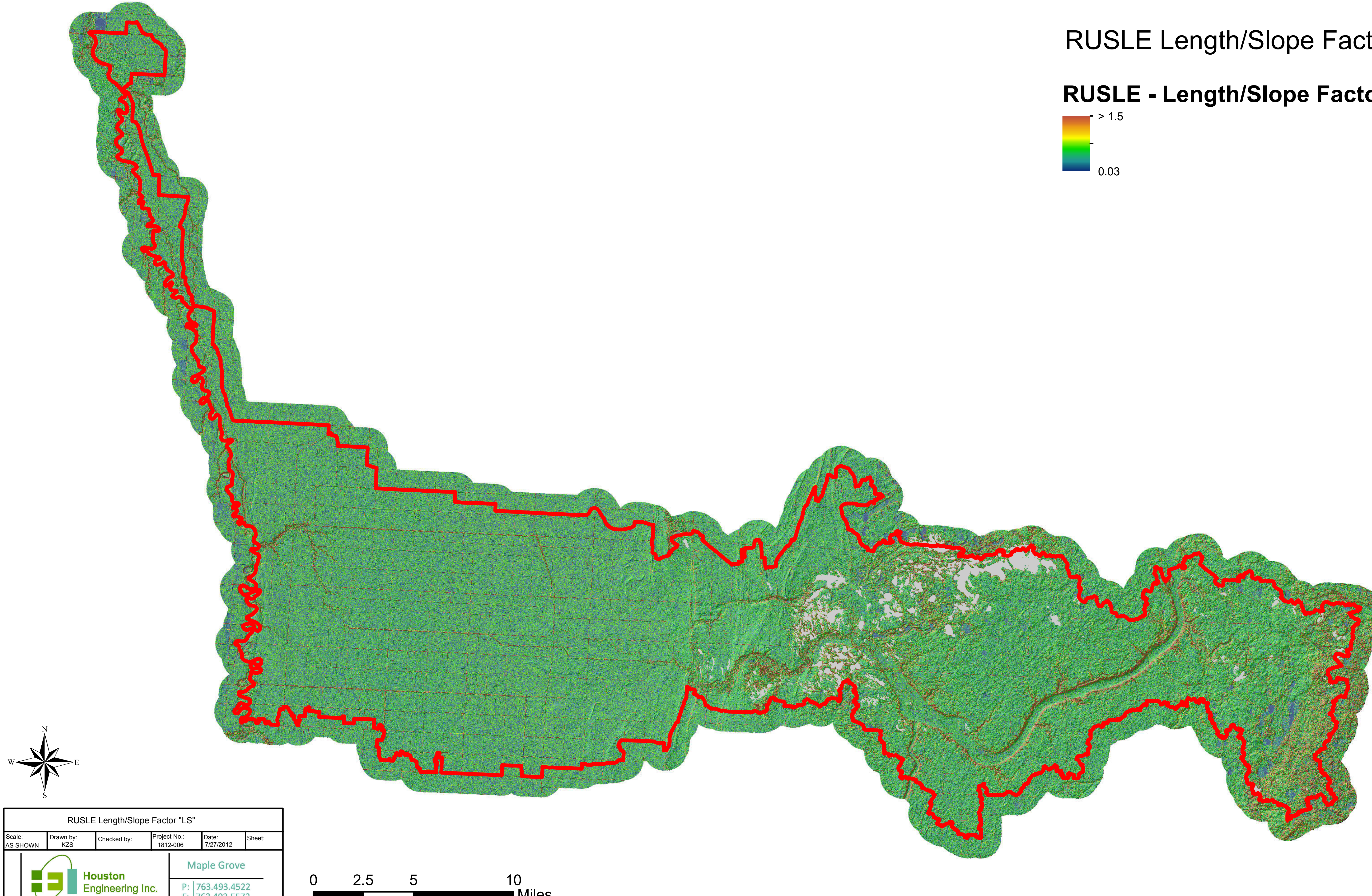
# RUSLE Length/Slope Factor "LS"




| RUSLE Length/Slope Factor "LS" | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 7/27/2012 | Sheet: |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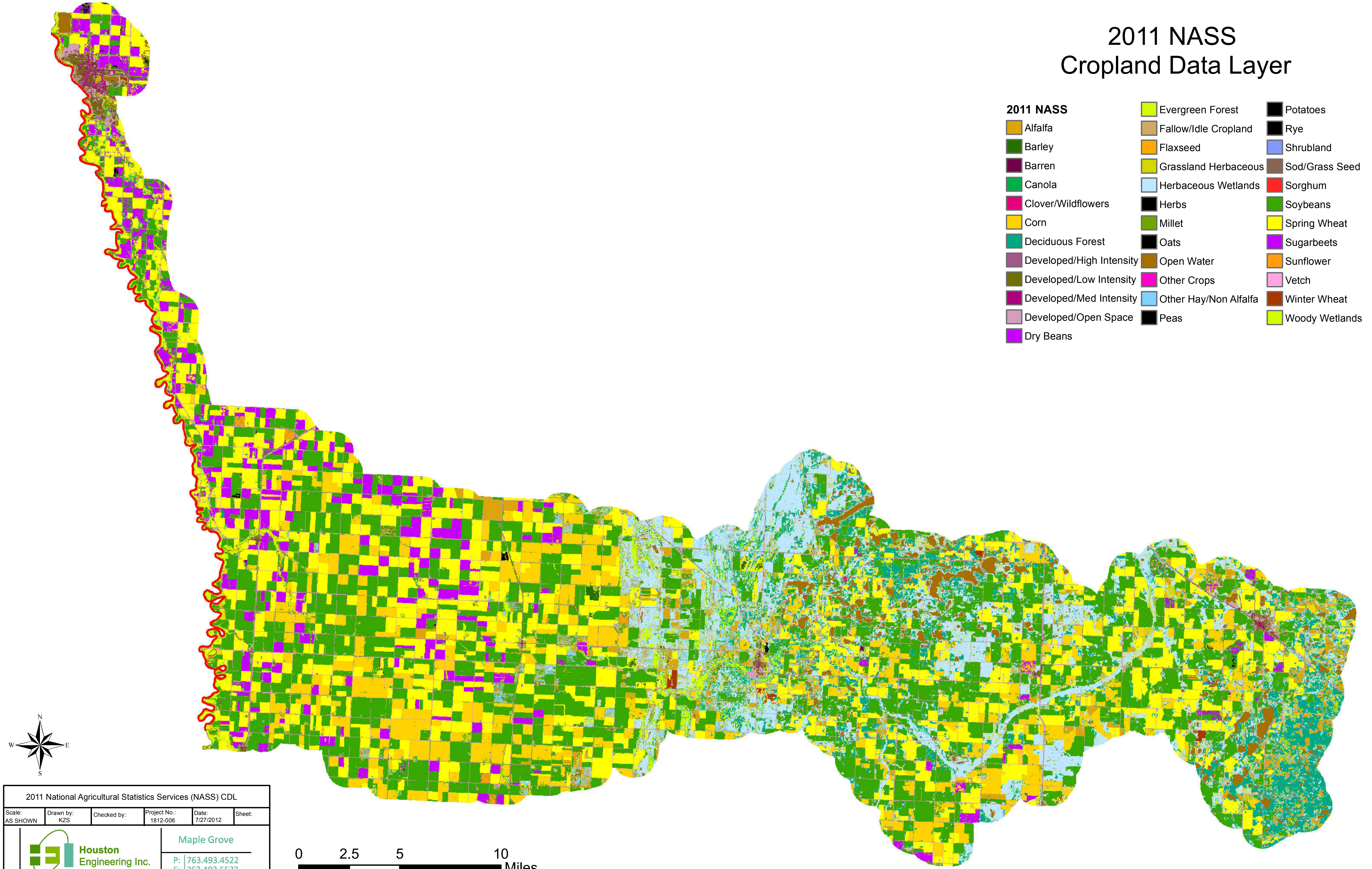
# 2011 NASS Cropland Data Layer




| 2011 National Agricultural Statistics Services (NASS) CDL | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 7/27/2012 | Sheet: |

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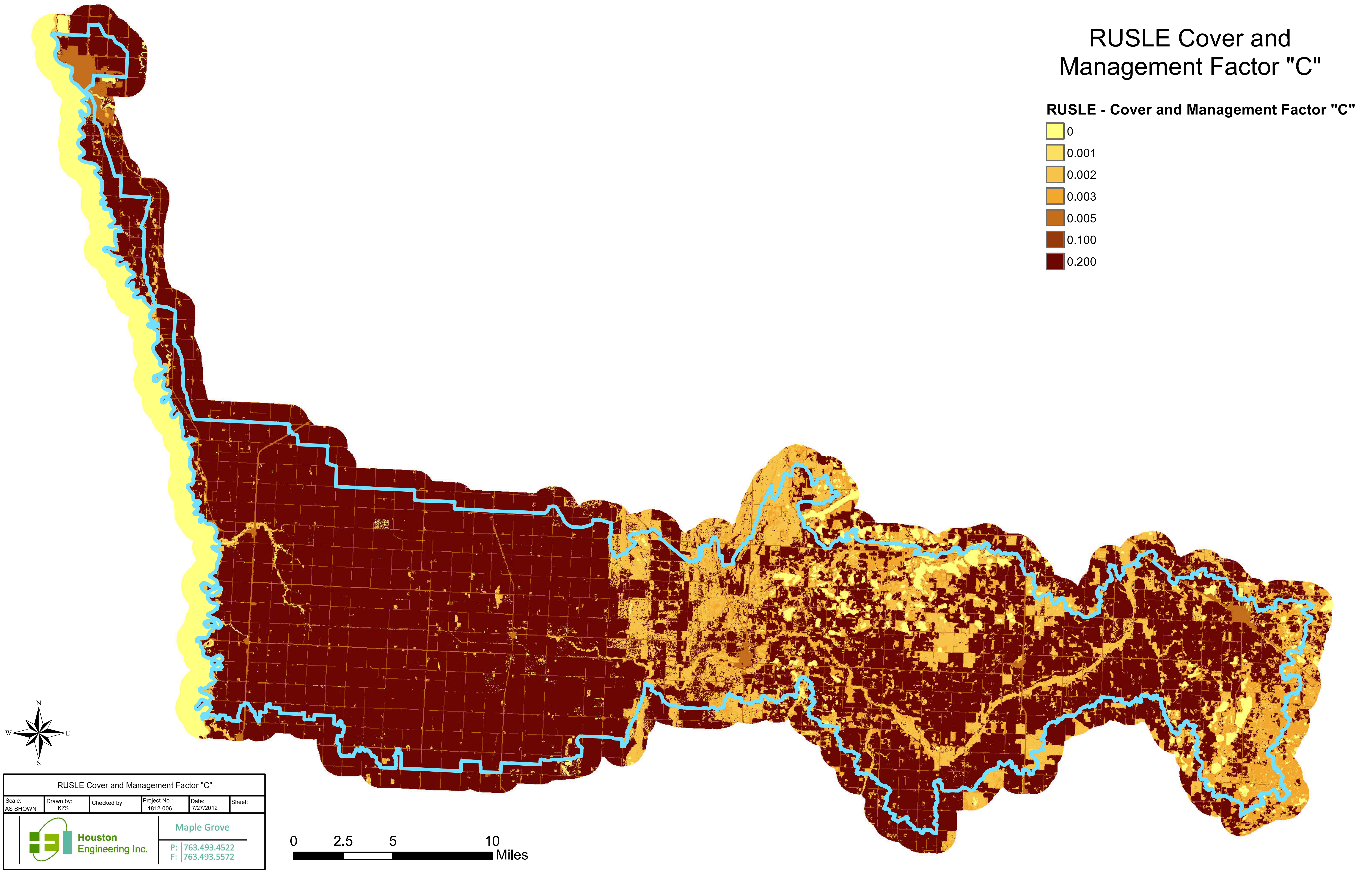
# RUSLE Cover and Management Factor "C"




| RUSLE Cover and Management Factor "C" | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 7/27/2012 | Sheet: |

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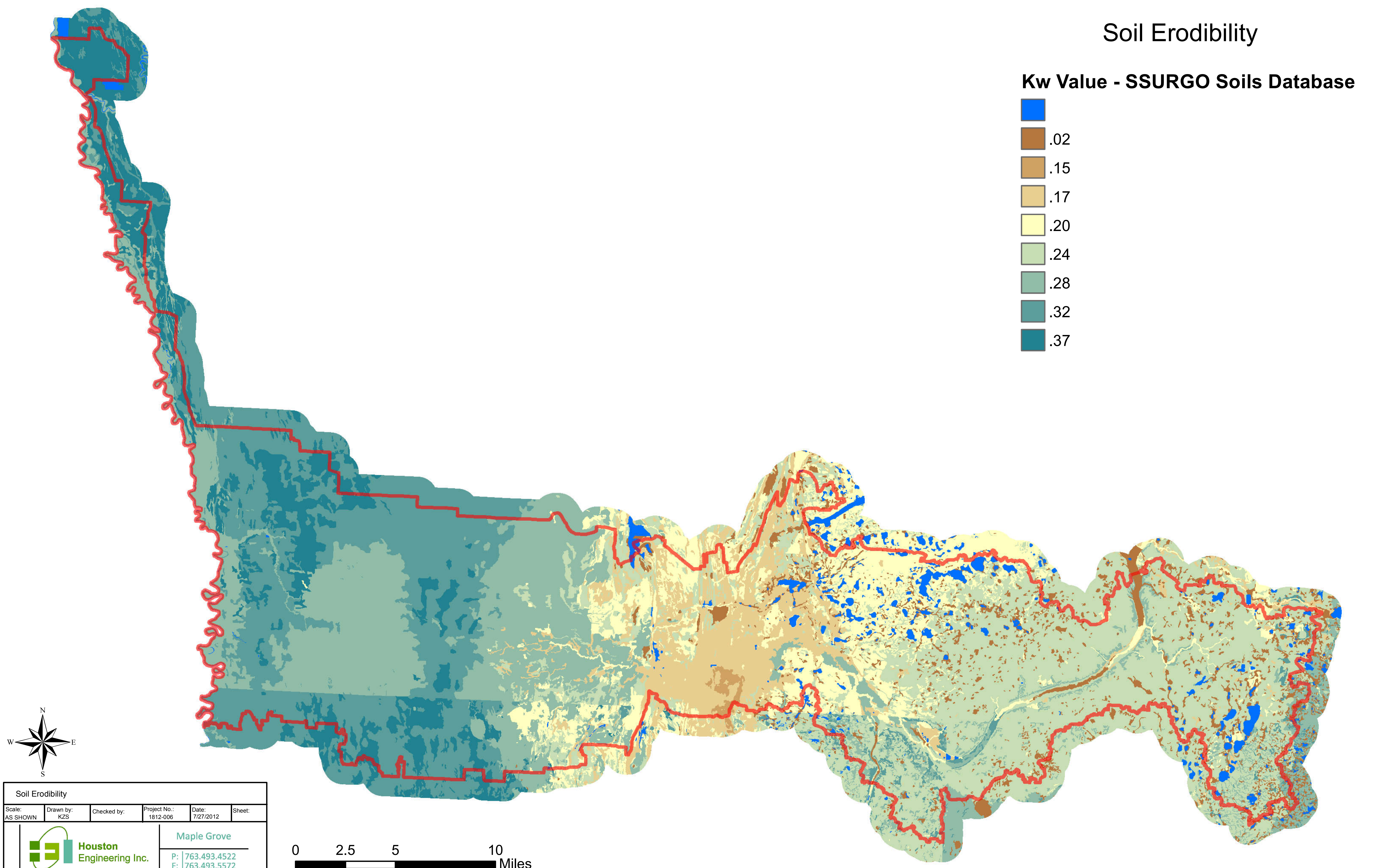


| Soil Erodibility | | | | | |
|---|---|---|---|---|---|
| Scale: AS SHOWN | Drawn by: KZS | Checked by: | Project No.: 1812-006 | Date: 7/27/2012 | Sheet: |

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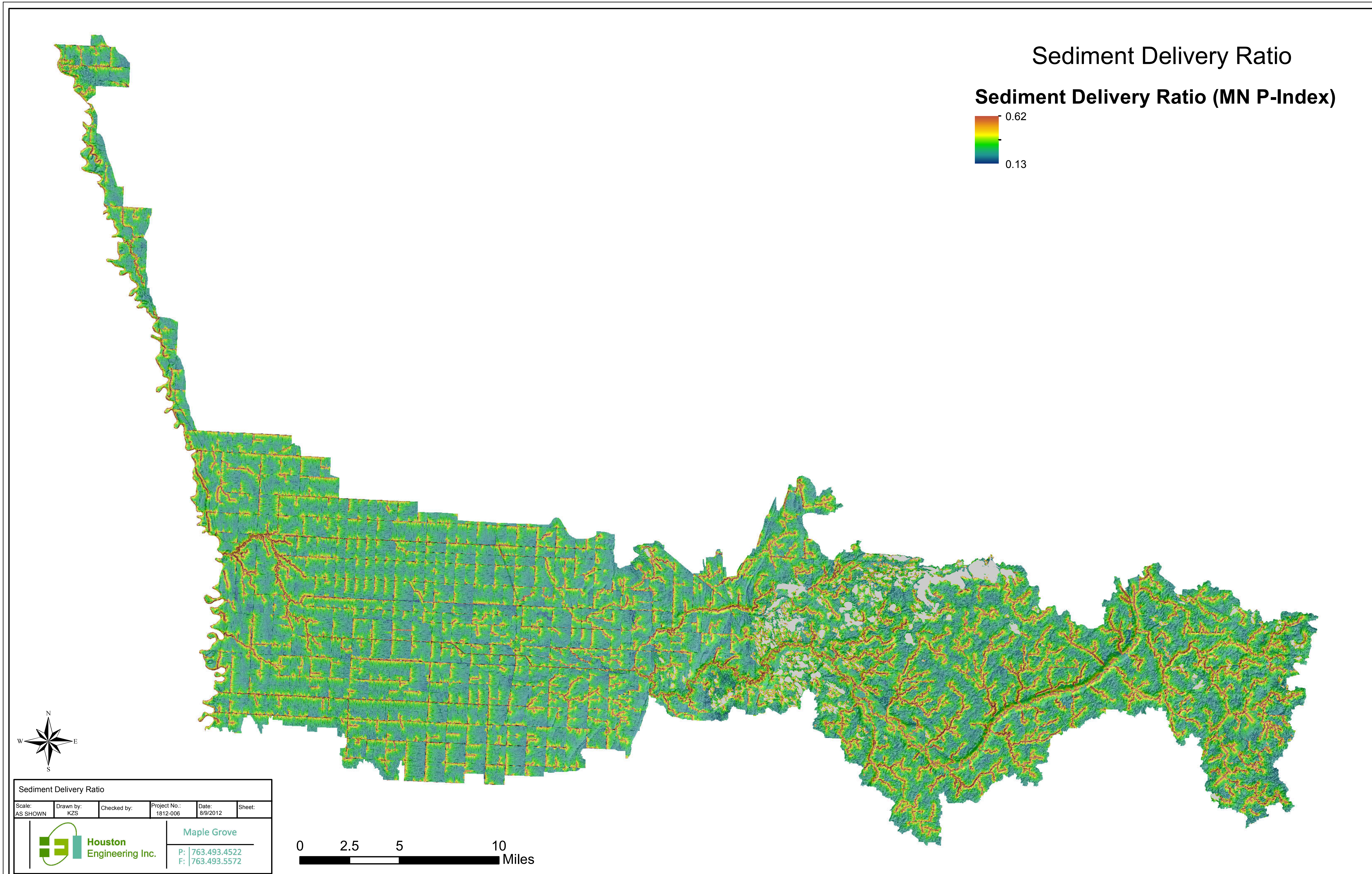
Sediment Delivery Ratio
Sediment Delivery Ratio (MN P-Index)
0.62
0.13
N
W
E
S
Sediment Delivery Ratio
Scale: AS SHOWN
Drawn by: KZS
Checked by:
Project No.: 1812-006
Date: 8/9/2012
Sheet:
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0
2.5
5
10
Miles

# APPENDIX B

GIS Data Summary

1. **Raw_DEM**
    a. *Data type:* Raster
    b. *Summary:* Raw LiDAR derived DEM. 3 meter by 3 meter resolution. Elevation units are in feet (NAVD 88).
2. **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.
3. **LS_Factor**
    a. *Data type:* Raster
    b. *Summary:* Length/Slope factor used in RUSLE. It is created from the hydrologically conditioned DEM and methodology from USDA Agricultural Handbook No. 703.
4. **SDR**
    a. *Data type:* Raster
    b. *Summary:* Ratio used to multiply the total potential sediment load to obtain the effective sediment load. The ration is derived from the downstream flow length to the point of interest (overland catchment pour point).
5. **total_load**
    a. *Data type:* Raster
    b. *Summary:* The total potential sediment yield from RUSLE for each individual raster cell. The values are in tons/acre.
6. **eff_load**
    a. *Data type:* Raster
    b. *Summary:* The effective sediment load for each raster cell from RUSLE. The values have been multiplied by the Sediment Delivery Ratio to the overland catchment pour point. The values are in tons/acre.
7. **acc_eff_load**
    a. *Data type:* Raster
    b. *Summary:* The eff_load raster accumulated in the downstream direction to create a total effective sediment loading from the upstream area from RUSLE.
8. **RUSLE_ranks**
    a. *Data type:* Raster
    b. *Summary:* Ranking of the acc_eff_load raster 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.
9. **SPI_raster**
    a. *Data type:* Raster
    b. *Summary:* Raster cell values represent the result of the SPI equation.

10. **SPI_ranks**
    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.
11. **Flowpaths.shp**
    a. *Data type:* Polyline Shapefile
    b. *Summary:* LiDAR derived flowpaths for areas with > 5 acres of drainage area.
    c. *Attributes:*
        i. Type:
            1. Overland (greater than 5 acres of drainage area but less than 0.5 sq. km.)
            2. In-channel (greater than 0.5 sq. km. drainage area)
12. **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. *Terrain Analysis Attributes*
        i. *GRIDCODE* – Common ID corresponding to Overland_Pourpoint.shp
        ii. *Max_eff* – Value from acc_eff_load at overland catchment pour point.
        iii. *Mean_SPI* - Mean value of the SPI_ranks raster dataset for the overland catchment area.
        iv. *Mean_RSL* – Mean value of the RUSLE_ranks raster dataset for the overland catchment area.
        v. *Score* – Mean value of the score raster dataset for the overland catchment area.
13. **Overland_Pourpoint.shp**
    a. *Data type:* Point Shapefile
    b. *Summary:* Outlet locations of overland flow into in-channel flow using the thresholds of drainage areas greater than 5 acres and less than 0.5 sq. km.
    c. *Attributes:*
        i. *GRIDCODE* – Common ID corresponding to Overland_Catchment.shp.
14. **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 baisns
            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)

**15. 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 downstream area during a 10-year, 24-hour rainfall event (TP-40).
    i. *Area_SqMi:* Total area in square miles.
    ii. *Acres:* Total area in acres

**16. NonContribAreas_10yr24hr_rainfall.shp**

a. *Data type:* Polygon Shapefile
b. *Summary:* Non-contributing areas as defined by areas that would not contribute runoff to downstream areas during a 10-year, 24-hour rainfall event (TP-40).
    i. *Area_SqMi:* Total area in square miles.
    ii. *Acres:* Total area in acres

**17. Project_Watershed.shp**

a. *Data type:* Polygon Shapefile
b. *Summary:* Total project area including contributing and non-contributing areas.
c. *Attributes:*
    i. *Area_SqMi:* Total area in square miles.
    ii. *Acres:* Total area in acres

**18. 10yr_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: Commin ID with GridID field from the 10yr_DepressionDA.shp
    ii. *FillElev:* Elevation in feet of the spill out elevation.
    iii. *FillArea:* Surface area of depression and spill out elevation.
    iv. *DrainArea:* Drainage area to depression.

**19. 10yr_DepressionDA.shp**

a. *Data type:* Polygon Shapefile
b. *Summary:* Corresponding contributing area of 10yr_Depressions.shp
c. *Attributes:*
    i. *GridID:* Common ID with GridID field from the 10yr_Depressions.shp
    ii. *DrainArea:* Drainage area in acres.

# Appendix C: Lake Characteristics Table

| *Identication and Location* | | | | | | | *Impairment Status* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Name** | **Lake ID** | **County** | **Part of State** | **Ecoregion** | **Drainage Basin** | **Major Watershed** | **Special Desig.** | **Impaired Use(s)** | **TMDL Pollutant** | **First listing yr** | **TMDL Schedule** | **Depth class** |
| Ketchum | 44-0152-00 | Mahnomen | Northwest | NCHF | Red River | Sand Hill | None | Aquatic recreation | Phosphorus (Nutrients) | 2014 | 2015 | Shallow |
| Uff | 60-0119-00 | Polk | Northwest | LA (NCHF) | Red River | Sand Hill | None | Aquatic recreation | Phosphorus (Nutrients) | 2014 | 2015 | Shallow |
| Unnamed | 60-0236-00 | Polk | Northwest | LA (NCHF) | Red River | Sand Hill | None | Aquatic recreation | Phosphorus (Nutrients) | 2014 | 2015 | Shallow |
| Kittleson | 60-0327-00 | Polk | Northwest | LA (NCHF) | Red River | Sand Hill | None | Aquatic recreation | Phosphorus (Nutrients) | 2014 | 2015 | Shallow |

| *Identification* | | *Total Phosphorus Standard* | | *Existing Water Quality* | | | *Existing-Conditions Period-Lake* | | *Existing-Conditions Period-WS* | | *Lake Morphometry* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **TP WQS (ug/L)** | **Alt. TP Goal (ug/L)** | **TP (ug/L)** | **Chl-a (ug/L)** | **Secchi Disk (m)** | **Lake End Year** | **Lake # of Years** | **WS End Year** | **WS # of Years** | **Lake Area (ac)** | **Lake Vol (ac-ft)** |
| Ketchum | 44-0152-00 | 60 | -- | 87.0 | 67.0 | 0.43 | 2012 | 2 | 2009 | 14 | 156 | 768 |
| Uff | 60-0119-00 | 60 | -- | 130.6 | 69.7 | 0.27 | 2012 | 2 | 2009 | 14 | 129 | 423 |
| Unnamed | 60-0236-00 | 60 | -- | 68.7 | 45.0 | 0.50 | 2012 | 2 | 2009 | 14 | 118 | 387 |
| Kittleson | 60-0327-00 | 60 | -- | 86.8 | 35.1 | 0.43 | 2012 | 2 | 2009 | 14 | 297.5 | 976 |

| *Identification* | | *Lake Morphometry - [cont.]* | | | | *Atmospheric data* | | | *Existing Watershed Land Use/Land Cover* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **Mean Depth (ft)** | **Max Depth (ft)** | **Littoral Area (ac)** | **Littoral Area (%)** | **Precip (in/yr)** | **Evap (in/yr)** | **Atm P (lb/ac/yr)** | **Total Area (ac)** | **Urban (ac)** | **Agric. (ac)** | **Natural (ac)** |
| Ketchum | 44-0152-00 | 10.7 | 17 | 156 | 100 | 24 | 43.2 | 0.27 | 1,550 | 55.2 | 611.6 | 730.7 |
| Uff | 60-0119-00 | 3.3 | 8 | 129 | 100 | 24 | 43.2 | 0.27 | 699 | 142.8 | 374.2 | 179.1 |
| Unnamed | 60-0236-00 | 3.3 | 12 | 118 | 100 | 24 | 43.2 | 0.27 | 2,125 | 105.1 | 1221.1 | 799.6 |
| Kittleson | 60-0327-00 | 3.3 | 7.9 | 297.5 | 100 | 25.4 | 43.2 | 0.27 | 13,440 | 646.0 | 5959.5 | 6529.5 |

| *Identification* | | *Existing Watershed Areal Water and P Loads* | | | *Existing Water Budget- (acre-feet per year)* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **Runoff (in/yr)** | **P export (lbs/ac/yr)** | **Runoff TP (ug/L)** | **WS Runoff** | **Precipitation** | **Wastewater** | **Total Inflows** | **Evaporation** | **Withdrawals** | **Outflow** |
| Ketchum | 44-0152-00 | 2.52 | 0.077 | 134 | 399 | 315 | 0 | 714 | 511 | 0 | 204 |
| Uff | 60-0119-00 | 4.48 | 0.101 | 99 | 261 | 219 | 0 | 480 | 404 | 0 | 76 |
| Unnamed | 60-0236-00 | 3.95 | 0.057 | 64 | 700 | 259 | 0 | 959 | 418 | 0 | 541 |
| Kittleson | 60-0327-00 | 3.28 | 0.044 | 60 | 3,833 | 649 | 0 | 4,482 | 1,059 | 0 | 3,423 |

| Identification | | Existing Phosphorus Budget - (pounds per year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **WS Runoff** | **Precipitation** | **Wastewater** | **Internal Loading** | **Total Inputs** | **Retained Load** | **Withdrawn Load** | **Outflow Load** |
| Ketchum | 44-0152-00 | 146 | 42 | 0 | 0 | 187 | 139 | 0 | 49 |
| Uff | 60-0119-00 | 71 | 35 | 0 | 0 | 106 | 97 | 0 | 9 |
| Unnamed | 60-0236-00 | 121 | 31 | 0 | 134 | 289 | 174 | 0 | 115 |
| Kittleson | 60-0327-00 | 624 | 79 | 0 | 1,166 | 1,870 | 1,076 | 0 | 675 |

| Identification | | Existing Lake Model Data | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **Lake Model Used** | **Internal Loading Estimate Method** | **Other Calibration Parameter** | **Calibration Parameter Value** | **Lk-Areal P Load (lbs/ac/yr)** | **Lk-Vol. P Load (ug/L/yr)** | **Overflow Rate (ft/yr)** | **Res. Time (yr)** | **Flushing Rate ($yr^{-1}$)** | **Sed. Coeff. ($yr^{-1}$)** | **Retent. Coeff. (--)** |
| Ketchum | 44-0152-00 | First-order Settling | Nurnberg 2009 | P settling rate | 0.86 | 1.20 | 96.5 | 0.96 | 4.9 | 0.20 | 0.286 | 0.738 |
| Uff | 60-0119-00 | First-order Settling | Nurnberg 2009 | P settling rate | 0.405 | 0.82 | 81.1 | 0.12 | 26.9 | 0.04 | 0.084 | 0.916 |
| Unnamed | 60-0236-00 | Canfield & Bachman Lk | Nurnberg 2009 | P decay rate | 1.01 | 2.45 | 110.7 | 4.59 | 0.7 | 1.43 | 0.395 | 0.605 |
| Kittleson | 60-0327-00 | Canfield & Bachman Lk | Nurnberg 2009 | P decay rate | 1.00 | 6.28 | 153.4 | 11.42 | 0.3 | 3.33 | 0.424 | 0.576 |

| Identification | | Lake Modeling Results-Existing | | | | TMDL Water & P Totals | | | TMDL Lake Model Data | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | **Modeled Lk TP (ug/L)** | **Observed Lk TP (ug/L)** | **Lake TP Error (ug/L)** | **Lake TP Error (%)** | **Total Inflow (ac-ft/yr)** | **Outflow (ac-ft/yr)** | **TMDL (lbs/yr)** | Lk-Areal P Load (lbs/ac/yr) | Lk-Vol. P Load (ug/L/yr) | Overflow Rate (ft/yr) | Res. Time (yr) |
| Ketchum | 44-0152-00 | 87.1 | 87.0 | 0.1 | 0.11% | 714 | 204 | 92.6 | 0.59 | 47.7 | 0.96 | 4.9 |
| Uff | 60-0119-00 | 130.8 | 130.5 | 0.3 | 0.23% | 480 | 76 | 36.6 | 0.28 | 28.0 | 0.12 | 26.9 |
| Unnamed | 60-0236-00 | 68.7 | 68.7 | 0.0 | 0.00% | 959 | 541 | 204.8 | 1.74 | 78.5 | 4.59 | 0.7 |
| Kittleson | 60-0327-00 | 86.5 | 86.8 | 0.3 | 0.35% | 4,482 | 3,423 | 1,118 | 3.76 | 91.7 | 11.42 | 0.3 |

| Identification | | TMDL Lake Model Data [cont.] | | | Lake Model Results-TMDL | | | |
|---|---|---|---|---|---|---|---|---|
| **Lake name** | **Lake ID** | Flushing Rate ($yr^{-1}$) | Sed. Coeff. ($yr^{-1}$) | Retent. Coeff. (--) | TMDL Model TP (ug/L) | TP WQS (ug/L) | TMDL Lake TP Error (ug/L) | TMDL Lake TP Error (%) |
| Ketchum | 44-0152-00 | 0.20 | 0.286 | 0.738 | 60.0 | 60 | 0.0 | 0.00% |
| Uff | 60-0119-00 | 0.04 | 0.084 | 0.916 | 59.9 | 60 | 0.1 | 0.16% |
| Unnamed | 60-0236-00 | 1.43 | 0.395 | 0.605 | 60.2 | 60 | 0.2 | 0.33% |
| Kittleson | 60-0327-00 | 3.33 | 0.424 | 0.576 | 59.7 | 60 | 0.3 | 0.50% |