WENCK File #1507-0003
July 2018

0

Rush Creek Headwaters Subwatershed Assessment Report

Jubert Lake
Photo Credit: Sharon Meister

elm creek
Watershed Management Commission

Prepared for:
Elm Creek Watershed Management Commission

Prepared by:

WENCK Associates, Inc.
7500 Olson Memorial Highway
Suite 300
Golden Valley, MN 55427
Phone: 763-252-6800

Table of Contents

Table of Contents (Cont.)

TABLES

FIGURES

APPENDICES

List of Acronyms

ACPF	Agricultural Conservation Planning Framework
AIS	Aquatic Invasive Species
BMP	Best Management Practice
Commission	Elm Creek Watershed Management Commission
ECWMC	Elm Creek Watershed Management Commission
GIS	Geographic Information System
LiDAR	Light Detection and Ranging
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MU	Management Unit
NASS	National Agricultural Statistics Service
NCHF	North Central Hardwood Forest
NRCS	National Resource Conservation Service
NURP	Nationwide Urban Runoff Program
P8	Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds
SCS	Soil Conservation Service
SWA	Subwatershed Assessment
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
WRAPS	Watershed Restoration and Protection Strategies

Executive Summary

The purpose of the Rush Creek Headwaters Subwatershed Assessment (SWA) is to evaluate conditions in that part of the Elm Creek watershed that is tributary to the upper part of the North Fork Rush Creek and to the upper part of the South Fork Rush Creek as well as the area draining to Henry Lake. Both the North Fork and South Fork of Rush Creek have impaired fish and macroinvertebrate biotic communities which have been stressed by excessive nutrient concentrations in streamflow. In addition, the North Fork suffers from excessive E. coli concentrations and low dissolved oxygen, which further stresses aquatic organisms. Lake Henry has been designated an Impaired Water for excess nutrient concentrations, and Jubert Lake in the study area is not formally listed as Impaired but also exhibits high nutrients in the summer.

The 23.8 square mile Study Area is primarily in the City of Corcoran, Minnesota, with a sizable percent in the City of Rogers, and a small sliver within the City of Greenfield. The Study Area was subdivided into six Management Units (MUs) based on topography and drainage. The hydrology of each MU was modeled to estimate precipitation runoff and sediment and nutrient pollutant loading to the lakes and streams. In addition, a considerable amount of other data was collected for each MU to better understand the potential sources of sediment, nutrients, and bacteria. These data include topography, soil type and characteristics, land cover and land use, feedlot and other animal locations, potential septic system locations, stream conditions, and known flooding areas. Watershed and city staff and residents in the area also contributed information about conditions and problem areas.

Several methods and tools were used to help identify the most feasible and cost effective practices to address the several impairments in this Study Area, including both structural and nonstructural practices. These range from agricultural best management practices (BMPs) such as grassed waterways, alternative tile intakes, and manure management practices to streambank stabilization, septic system inspection and repair, and education and outreach. These were prioritized based on a number of factors, and the most technically feasible were then evaluated for estimated cost and pollutant load reductions. The top ten practices by cost effectiveness and pollutant load removals were identified for each MU. In addition, each MU-scale assessment also identified fields that had the greatest sediment delivery potential, fields that were likely tile-drained, and animal locations that were in close proximity to stream or ditch conveyances. These are areas where outreach to property owners about additional practices they could consider would have the most potential impact on water quality improvement.

The top 10, most effective practices across the Study Area are shown in Table E.1 and Figure E.1.

Table E.1. Summary of identified priority practices in the Study Area.

Rank	BMP ID	Management Unit	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Delivery Potential
				Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			
	Top practices in terms of load reduction (TP)								
1	WR-3	South Tributary	Wetland Rest.	126.8	156.9	202.8	$713,900	$867,300	High
2	WR-5	Lower Rush Creek	Wetland Rest.	33.1	117.4	97.1	$167,900	$197,900	High
3	GW-15	South Tributary	G. Waterway	0.0	47.4	84.1	$17,700	$66,200	Med
4	WR-1	South Tributary	Wetland Rest.	17.8	62.4	80.7	$70,000	$74,700	High
5	DP-26	South Tributary	Wetland Rest.	9.7	579.3	77.3	$101,700	$110,000	High
6	DP-81	Lower Rush Creek	Wetland Rest.	5.3	219.8	60.9	$97,000	$104,800	High
7	DP-61	Upper Rush Creek	Wetland Rest.	4.4	229.5	54.3	$81,600	$88,000	Med
8	WR-4	Upper Rush Creek	Wetland Rest.	20.0	46.8	48.5	$119,800	$140,200	High
9	DP-58	Upper Rush Creek	Wetland Rest.	6.5	248.6	39.6	$118,000	$127,800	Med
10	GW-2	South Tributary	G. Waterway	0.0	20.6	36.6	$11,100	$36,800	Low

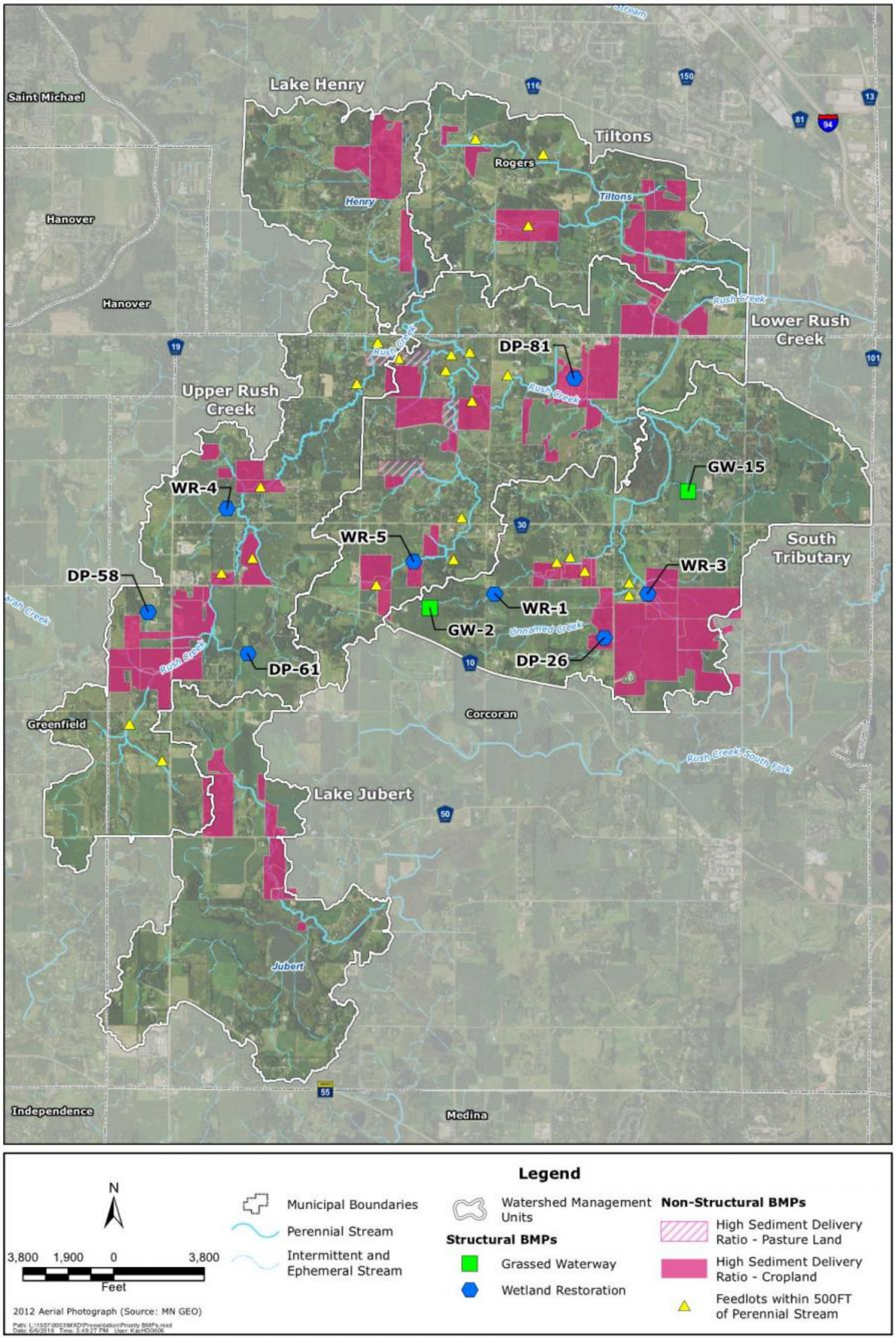


Figure E.1. Priority projects and practices in the Study Area.

1.0 Introduction and Purpose

1.1 PURPOSE

The 2016 Elm Creek Watershed Total Maximum Daily Load (TMDL) study (MPCA 2016a) established pollutant load reductions for numerous impaired lakes and streams in the Elm Creek watershed in Hennepin County, Minnesota. Among the implementation actions identified in the TMDL and the subsequent Watershed Restoration and Protection Strategy (WRAPS) report (MPCA 2016b) was the systematic completion of Subwatershed Assessments (SWA). A SWA is a more intense, finer-scaled look at a small area of land to identify potential pollutant load-reducing Best Management Practices (BMPs) down to the field or lot level. A SWA provides the framework for targeting BMPs to where they will be most effective at improving and protecting downstream water resources, and where they make the most sense based on soils and topography.

The purpose of the Rush Creek Headwaters SWA is to evaluate conditions in that part of the Elm Creek watershed that is tributary to the upper part of the North Fork Rush Creek and to the upper part of the South Fork Rush Creek as well as the area draining to Henry Lake. The outcome of this SWA will be a prioritized list of the most feasible and cost effective practices to address the requirements of the several impairments in this study area. Watershed, Hennepin County, and City staff and other partners can then work with willing landowners to implement these practices.

1.2 STUDY AREA

The Study Area is 15,230 acres (23.8 square miles) (Table 1.1), primarily in the City of Corcoran, Minnesota, with a sizable percent in the City of Rogers, and a small sliver within the City of Greenfield. The Study Area is comprised of that area that is tributary to North Fork Rush Creek upstream of the CR 116 (Fletcher Lane) crossing as well as the drainage area to Lake Jubert, which is the headwaters of the South Fork Rush Creek.

Table 1.1. Study area by city.

City	Acres	% of Total
Corcoran	11,050	72.6
Greenfield	359	2.4
Rogers	3,821	25.1
Total	15,230	

The Study Area was subdivided into six Management Units (MUs) to provide a finer scale of assessment (Table 1.2 and Figure 1.2). Two of the six MUs represent the direct drainage area to the two lakes in Study Area, Lake Jubert and Lake Henry. Two other MUs, Tilton's and South Tributary, are the drainage areas to tributaries to North Fork Rush Creek. The final two MUs are Upper and Lower North Fork Rush Creek. The boundary between Upper and Lower is the hydrologic boundary near CR 117 (109^{th} Avenue North) which is also near the corporate boundary between Corcoran and Rogers.

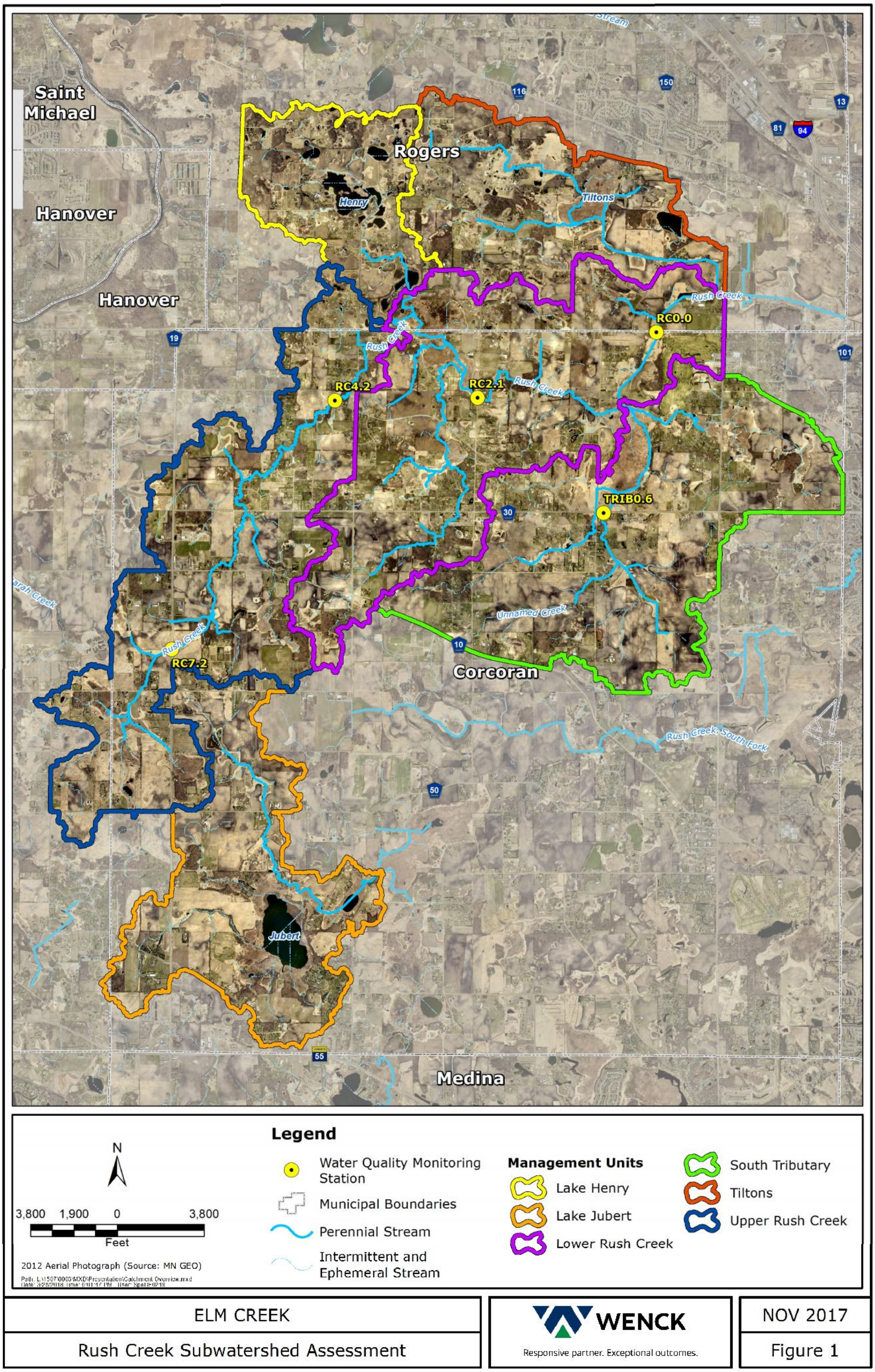


Figure 1.1. Study Area and Management Units.

Table 1.2. Management Unit areas.

Management Unit	Acres	% of Total
Lake Henry	1,162	7.6%
Lake Jubert	2,193	14.4%
Lower North Fork Rush Creek	3,445	22.6%
Upper North Fork Rush Creek	3,338	21.9%
South Tributary	3,297	21.6%
Tilton's	1,795	11.8%
Total	15,230	

1.3 IMPAIRMENTS

Both forks of Rush Creek do not meet several state water quality standards, and have been designated as Impaired Waters (Table 1.3.) Lake Henry does not meet state water quality standards for nutrients, and has also been designated an Impaired Water. Not enough monitoring data was available on Lake Jubert in the study area to determine whether it should be designated an Impaired Water, but the limited data that is available suggest that it could be in the future.

The catalyst for the completion of this Subwatershed Assessment was to help the Commission and cities better understand and identify the E. coli impairment drivers in this area of the watershed. This assessment will also help the cities within the drainage areas to these Impaired Waters take steps to meet their requirements to reduce the amount of pollutants discharged to them. A Total Maximum Daily Load (TMDL) study was completed and approved by the USEPA in 2017 (MPCA 2016). That TMDL established total phosphorus (TP) load reduction requirements for Lake Henry and bacteria load reduction requirements for both forks of Rush Creek. A Stressor Analysis (Lehr 2015) was performed for the TMDL to evaluate the potential causes of the impairments to the fish and macroinvertebrate communities. In addition to altered habitat and hydrology, the Stressor ID identified excess nutrients as a likely cause of the low dissolved oxygen conditions, and established TP load reduction requirements for both forks.

Table 1.3. Draft 2018 303(d) List impaired waters in the Study Area.

Lake or Stream	DNR Lake # or Stream AUID	Affected Use	Pollutant
Lake Henry	27-0175-00	Aquatic recreation	Nutrients (Total Phosphorus)
South Fork Rush Creek (upper portion)	07010206-760	Aquatic life	M-IBI[1], F-IBI
North Fork Rush Creek	07010206-528	Aquatic life/ recreation	E. coli, Dissolved Oxygen, M-IBI, F-IBI

[1] Index of Biotic Integrity. A measure of the quantity and quality of aquatic life. M-IBI denotes macroinvertebrate impairment and F-IBI denotes fish impairment.
Source: MPCA.

1.4 WATER QUALITY MONITORING DATA

The Commission periodically monitors one water quality and flow monitoring station (RC2.1) in the Study Area, and had collected data at other stations in preparation for the completion of the TMDL. Additional monitoring was completed in 2017 at five stations, four on North Fork Rush and one on the South Tributary (see Figure 1.1). This data was analyzed both for current water quality at the stations as well as longitudinally to determine how water quality changes moving from upstream to downstream. Figures detailing that water quality data can be found in Appendix A. Table 1.4 provides a general summary of the 2017 monitoring results and how water quality parameters changed longitudinally between monitoring stations. Interpretation of these results will be discussed in more detailed in the individual Management Unit sections of this report.

Table 1.4. Summary of 2017 water quality monitoring results.

Monitoring Station(s)	Management Unit(s)	Summary of Results Between Monitoring Stations
RC7.2 to RC4.2	Upper Rush Creek	- DO increases - TSS and TP increase during storms, similar during baseflow - E. coli steady - TN is low
RC4.2 to RC2.1	Lower Rush Creek Lake Henry	- DO decreases - TSS, TP, SRP, and E. coli decrease during storms, similar during baseflow - TN is low
TRIB 0.6	South Tributary	- DO moderate and similar to RC2.1 - TSS high during storm events, low during baseflow - TP and SRP higher than RC2.1 and RC4.2 - E. coli similar to other stations - TN is low
RC2.1 to RC0.0	Lower Rush Creek	- DO increases slightly - TSS, TP and SRP similar - E. coli increases slightly - TN is low

DO: dissolved oxygen; TSS: total suspended solids; TP: total phosphorus; TN: total nitrate; SRP: soluble reactive phosphorus

1.5 LOCAL WATER PLANS AND STUDIES

Elm Watershed-Wide TMDL and Restoration and Protection Strategy Report. The Elm Creek Watershed TMDL (MPCA 2016a) addresses 22 impairments in the Elm Creek hydrologic watershed and two impairments in the Crow River watershed. These include nutrient impairments on seven lakes, and E. coli, dissolved oxygen (DO), and fish and macroinvertebrate community biological impairments on Elm, Rush, South Fork Rush, and Diamond Creeks. That TMDL established load required load reductions for those impaired waters and general strategies for improvement. The Watershed Restoration and Protection Strategy (WRAPS) report (MPCA 2016b) included more detailed recommended actions to improve the impaired waters as well as protect the water bodies that currently meet state standards or for which there is little information known on current water quality.

Within the Study Area, the following load reductions must be achieved to improve water quality.

North Fork Rush Creek E. coli. The stream is impaired by excess bacteria - E. coli - and requires significant reductions. A source assessment completed for the TMDL suggests that fecal matter from livestock is the primary potential source of bacteria loading. Fecal matter sources include wash-off from pastures, runoff from feedlots and livestock operations, and domestic animals, application of manure to fields as fertilizer, direct access of livestock to streams, wildlife, and sewage treatment systems. Based on monitoring data, the violations primarily occur in July and August. The load reductions were established for five flow categories: very high, high, mid-range, low and dry flow conditions. The necessary bacteria reductions range from a 40% reduction to a 98% reduction during certain flow regimes to meet E. coli concentration standards.

Implementation activities for the E. coli-impaired subwatersheds should focus on manure and pasture management initiatives, limiting livestock access to streams, septic system upgrades or hook-ups to regional sanitary collection and treatment facilities, and pet waste control measures.

Table 1.5. North Fork Rush Creek TMDL required E. coli load reductions.

Flow Regime	Very High	High	Mid	Low	Dry
% Reduction	66	40	59	75	98

North Fork Rush Creek TP. The Stressor Identification Study completed for the biotic impairments (Lehr 2015) concluded that the likely cause of low DO in these streams is excess nutrients, which increases productivity and results in increased carbonaceous biochemical oxygen demand from breakdown of organic matter. Total phosphorus load reductions to meet the standard vary by flow regime, and range from a 54 percent reduction to an 81 percent reduction. The numerous flow-through and riparian wetlands also affect DO dynamics in the stream.

Table 1.6. North Fork Rush Creek TMDL required TP load reductions.

Flow Regime	Very High	High	Mid	Low	Dry
% Reduction	64	71	65	66	81

North Fork Rush Creek Biotic Integrity. The Stressor Identification Study found other stressors in addition to excess nutrients. Altered hydrology is a primary stressor affecting both the fish and macroinvertebrate communities. Altered hydrology can result from flashy flows resulting from increased imperviousness in the watershed or from drain tiling or ditching that delivers runoff faster to the stream. It can also result in periods of low or no flow if surficial groundwater to the stream is reduced. Excess sediment deposited on the streambed is also a primary stressor. This sediment may be delivered in runoff from the watershed, or it may be contributed from streambank erosion. Altered physical habitat, low dissolved oxygen, and excess nutrients are secondary stressors.

Henry Lake TP. Henry Lake is about 47 acres in area with a maximum depth of 8.2 feet, and is classified as a shallow lake. The watershed area draining to the lake is approximately 812 acres. The primary land use within the watershed is agricultural. The summer average TP concentrations indicate the lake is hyper-eutrophic and exceeds the shallow lake standard. The TMDL noted that the shallow lake seems to alternate between the algal and plant dominated conditions. Aquatic vegetation surveys indicated the lake has nuisance levels of CLPW. The lake also has a diverse native plant community in some years.

The TMDL requires watershed load reductions of 82.4% (568 pounds), and Internal load reductions of 82.1% (221 pounds). Implementation actions aimed at reducing curlyleaf pondweed growth to non-nuisance conditions and reducing sediment phosphorus release.

Elm Creek Watershed Third Generation Watershed Management Plan. The Elm Creek Watershed Management Commission adopted its Third Generation Watershed Management Plan in 2015 (Wenck 2015). That Plan established goals, policies, and implementation actions to manage water resources in the watershed for the period 2015-2024.

The Plan sets forth several priority actions to be pursued by the Commission and its member cities. These are:

1. Begin implementing priority projects and actions in 2015, providing cost-share to member cities to undertake projects to help achieve WRAPS lake and stream goals.
2. Use the results of the WRAPS study to establish priority areas, and complete subwatershed assessments to identify specific Best Management Practices that feasibly and cost-effectively reduce nutrient and sediment loading to impaired water resources. Convene a TAC of agencies specializing in ag outreach to help guide assessments in agricultural subwatersheds.
3. Develop a model manure management ordinance to regulate the placement of new small non-food animal operations using the City of Medina ordinance as a guide, and require member cities to adopt that ordinance or other ordinances and practices to accomplish its objectives.
4. Partner with other organizations to complete a pilot project for targeted fertilizer application and to increase and focus outreach to agricultural operators.
5. Continue participating in joint education and outreach activities with WMWA and other partners.

The Rush Creek Headwaters Subwatershed Assessment (SWA) is consistent with Priority 2. The results of this SWA will be used to locate and undertake the other priority actions to work towards meeting TMDL and WRAPS requirements and achieving the Commission’s water resources goals.

2.0 Methods

2.1 GIS DATA/LAYERS

One of the primary objectives of this assessment is to compile all available GIS data for the Study Area into one central location/database. Appendix B provides a complete list of the GIS data/layers that were compiled and/or created for this assessment. Once these layers were compiled, a series of maps ("map books") were generated for each management using some of the GIS layers listed in Appendix B (link to map book files). The GIS layers included in the map books were selected based on their ability to show potential priority concern "hot spot" areas within each Management Unit. Below is a list of GIS layers used to create the map books:

- Land Cover, National Wetlands Inventory (NWI) wetlands, slope, soil erodibility, and hydrologic soil group
- Potential septic locations
- MPCA registered feedlots and Three Rivers Park District (TRPD) livestock animal inventory
- Estimated soil loss (Revised Universal Soil Loss Equation(RUSLE))
- Potentially drained (tiled) areas
- Restorable wetland areas (RWI)

These map books provided a "first cut" in identifying issues of concern potential problem areas within each Management Unit. In general, areas that demonstrate high potential risk across multiple map book layers were identified as potential focus areas for the structural and non-structural BMP analysis described below.

2.2 PUBLIC AND AGENCY INPUT

The Study process was collaborative. A Core Team of the Commission's technical advisors from Hennepin County Energy and Environment department; representatives from the cities of Corcoran and Rogers; and the Commission's consultant met four times to provide input, review data, and discuss strategies. The Commission's regular Technical Advisory Committee (TAC), comprised of city staff and representatives from all nine member cities, also met four times to receive status reports and an overview of the Core Team's work. The City of Corcoran invited all property owners in the Study Area within Corcoran to an Open House to share information and obtain public input, which was attended by about 50 persons. Information was also gleaned from two past stream assessments performed on Rush Creek (and other streams in the watershed). Input from these meetings is discussed in each of the Management Units sections below.

2.3 STRUCTURAL BMP SITING AND ANALYSIS

Structural BMPs were sited and evaluated using a combination of modeling tools, GIS desktop analysis, aerial photo interpretation, and input from public city and staff. Below is a description of the structural BMP siting process and methods used to assess cost/benefit of potential practices.

2.3.1 Agricultural Conservation Planning Framework

The Agricultural Conservation Planning Framework (ACPF) is a LiDAR-based toolbox designed to identify pollutant hotspots and potential field-scale sites for specific agricultural BMPs. Most of the GIS layers and data inputs required to run the ACPF toolbox are available for download through the North Central Region Water Network website (link to website). One key input that is required to run the ACPF toolbox but is not available through the ACPF website is a high-resolution hydrologically conditioned digital elevation model (DEM). A hydro-conditioned DEM is a digital elevation model that has been corrected to reflect the natural flow of water on the landscape through "digital dam" highpoints such as roads, field crossings, bridges and low points such as lakes, wetlands and other shallow depressions. ACPF contains a subset of tools to help users take a raw/unconditioned DEM through the hydro-conditioning process.

Using the hydro-conditioned DEM, the next steps in the ACPF toolbox include the development of the flow network, stream reaches, and subwatershed catchment areas for the project study area. Once these steps are complete, the user may begin analyzing contiguous fields within the project study area using ACPF's field boundary database. This database is unique to ACPF and contains site-specific data for individual fields (typically 40-200 acres) such as field slope, distance to stream, cropping rotation, hydrologic soil group, hydric soil conditions, etc. This database is used by ACPF to further characterize field conditions (i.e. sediment delivery ratio, tile-drained/not tile-drained) and identify fields that have higher potential for sediment and nutrient loading to the stream network. This database is also used by the individual BMP tools within ACPF to site specific locations for conservation practices.

2.3.2 Types of BMPs Considered

This study sited and evaluated six different structural BMP options using the ACPF toolbox. Below is a brief description of these BMPs and the methods used by ACPF to site each practice.

<u>Water and Sediment Control Basin (WASCOBS)</u>

Source: www.nrcs.usda.gov

Water and sediment control basins (WASCOBs) are small earthen ridge-and-channel embankments built across the slope of field or minor waterway to temporarily detain and release water through a piped outlet or through infiltration. They are constructed perpendicular to the flow direction and parallel to each other. Potential benefits include volume/rate control and reduction of TSS and particulate phosphorus through settling and/or infiltration. The "WASCOBS Tool" within ACPF was used to site potential locations for WASCOB berms and the area of inundation upslope of the berm. This tool utilizes calculated slopes, flow accumulation grids, and embankment height of flow pathways to determine suitable locations for these practices.

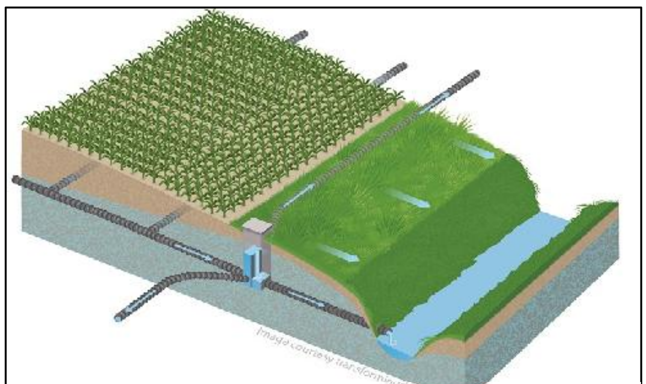
<u>Grassed Waterway</u>

Grassed waterways are broad, shallow constructed channels that are seeded to grass and drain water from areas of concentrated flow. The vegetative cover in the waterway helps slow the water flow and protects the channel surface from rill and gully erosion. Water quality benefits for grass waterways include reduction of sediment and particulate phosphorus. The "Grassed Waterways Tool" within ACPF was used to site potential locations for grassed waterways in the Elm Creek Headwaters study area. This tool utilizes a user-defined stream power index (SPI) threshold to site potential locations for these practices. It should be pointed out that in many cases, grass waterways and WASCOBs can be used inter-changably depending on field/site conditions.


Source: www.nrcs.usda.gov

Saturated Buffer

Saturated buffers employ a lateral distribution line within a riparian buffer and a diversion gate that intercepts a tile above its outlet to a stream. The diversion gate comprises a control structure that diverts outflow portion of the tile flow to the distribution line, raises the water table within the buffer, which enhances the buffer's ability to naturally remove nutrients conveyed by tile drainage. Thus, the main water quality benefits of saturated buffers are nitrate and dissolved phosphorus uptake and removal, although the buffers should also be efficient at removing sediment and particulate phosphorus if present. The "Riparian Denitrifying Practices Tool" within ACPF was used to site potential locations for saturated buffers. This tool utilizes field boundary characteristics, streambank height, soil organic carbon content, and slopes within the riparian zone to identify riparian areas that may be suitable for saturated buffers.


Source: transformingdrainage.org

Denitrifying Bioreactor

Denitrifying bioreactors are a buried bed/wall of woodchips that receive a portion of tile drainage flows from an adjoining field. The woodchips provide a carbon source, which combined with the reducing conditions in the saturated subsurface environment, encourage naturally occurring bacteria to reduce nitrate through denitrification processes. Thus, the primary water quality benefit of these BMPs are nitrate removal, however these systems have are also efficient in removing TSS and TP. The "Edge of Field Bioreactors Tool" within ACPF was used to


Source: web.extension.illinois.edu

site potential locations for bioreactors. The tool utilizes field boundary characteristics, flow accumulation, and an unfilled DEM to identify edge of field locations suitable for these practices.

Wetland Restoration


Source: www.nrcs.usda.gov

Wetland restorations re-establish and/or repair the hydrology, plant communities and soils of a former or degraded wetland that has been drained, farmed or otherwise modified since European settlement. Restoring wetland hydrology typically involves breaking drainage tile lines, building a dike or embankment to retain water and/or installing adjustable outlets to regulate water levels. The primary benefits of wetland restorations include water storage, volume/rate control, groundwater recharge, nitrate removal, and TSS and particulate phosphorus reduction via settling. Potential sites for wetland restorations were identified using two separate tools within the ACPF toolbox – the "Nutrient Removal Wetlands Tool" and the "Depression Identification Tool." The nutrient removal wetlands tool sites potential wetland restoration sites along collective flow pathways that are downstream of tile drained fields. The depression identification tool identifies depressions on the landscape that have poorly drained/hydric soils and are currently in agricultural production.

Alternative Tile Intake (ATI)


Source: www.nrcs.usda.gov

Open intakes that are flush with the surface of the ground can provide a direct conduit for sediment and nutrients to enter the tile system, which lead to ditches, streams, and rivers. Alternative tile intakes (ATIs) increase sediment trapping efficiency through increased settling time and/or filtering. They can also reduce the velocity of flow into the tile inlet. Alternative tile intakes include: 1) Perforated risers, such as the Hickenbottom riser; 2) Dense pattern tile within the isolated surface depression with a capacity equal to the open tile inlet it replaces; 3) Other variations include a slotted riser and addition of a vegetated buffer surrounding the inlet. The primary benefits of ATIs include volume/rate control and TSS and particulate phosphorus reduction via settling. Potential locations for ATIs were identified using the "Depression Identification Tool" within the ACPF toolbox. This tool identifies depressions on the landscape that have poorly drained/hydric soils and are currently in agricultural production. For the purposes of this assessment, ATIs are presented as an alternative option to wetland restorations for depression areas where landowners would like to continue farming and not remove from production.

2.3.3 Structural BMP Prioritization

Once the hydro-conditioned DEM and field boundary database were established in ACPF, the six individual BMP siting tools described in Section 2.3.2 were run to provide a first cut of potential BMP locations. The initial model runs provided several hundred BMP options and it was apparent this list would need to be refined. The TAC devised a prioritization scheme to refine the initial list of BMPs based on visual inspection of multiple years of air photos in Google Earth and/or ArcGIS. Below is a list of criteria used for prioritization:

- Removed BMPs that already exist on the landscape.
- Removed BMPs sited in non-agricultural areas.
- Removed BMPs that were sited within or have the potential to impact existing infrastructure (i.e. roads, houses, barns, buildings).
- Removed soil erosion/stabilization BMPs (i.e. grassed waterways and WASCOBs) that were sited in areas showing no evidence of soil erosion and/or areas that are likely tile drained.
- Removed BMPs that were very small and would provide minimal benefit.
- Removed BMPs that had very large impacted areas that would make feasibility extremely difficult.
- Made sure to keep, and in some cases add, BMPs in specific locations that were identified as problem areas during the public Open House.

2.3.4 Sizing, Design and Reduction Estimates for Structural BMPs

BMP sizing, design, and pollutant reduction estimates were evaluated using methodology and research from various sources, including: the ACPF ArGIS Toolbox User's Manual (link to manual), Natural Resources Conservation Service (NRCS) practice guides/standards (link to website), MPCA's Minnesota Stormwater Manual, subwatershed assessment studies in neighboring watersheds, local experience, and recently published research. In general, BMPs were sized according to design standards if site conditions would allow based on desktop review.

BMP load reduction benefits were calculated based on each BMP's drainage area, annual water volume, annual pollutant load, and the recommended removal efficiency of the practice. Removal efficiencies were applied in full if BMP footprints and variable storage volumes meet minimum design standards and/or literature criteria. Annual flow and pollutant loads to each BMP were estimated using the Elm Creek Watershed Soil and Water Assessment Tool (SWAT) model that was developed for the Elm Creek Watershed TMDL Study (link to TMDL). This model was set up for the entire Elm Creek watershed and was calibrated at a relatively large scale using monitoring data at four long-term monitoring sites throughout the watershed.

The SWAT-predicted loads used in this report should be considered planning level estimates since the model was not calibrated, validated, or compared to any field or site-specific data within the Rush Creek Headwaters study area. Thus, all BMP pollutant load reduction estimates should be considered “edge of field” estimates with the assumption that BMPs with higher delivery potential (i.e. located near perennial streams/waterways) may present better opportunities to reduce monitored pollutant loads/concentrations in downstream waterbodies. Table 2.1 and Appendix C provide more detailed summaries of the methods and assumptions used to determine structural BMP sizing, design and benefits.

2.3.5 Planning Level Cost Estimates for Structural BMPs

Planning level cost estimates were developed for each BMP based on guidance from various groups and agencies (NRCS, BWSR, SWCDs, etc.) as well as past experience in other watersheds. The planning level cost estimates include the following components:

- Construction costs for the proposed BMP, such as: mobilization, site preparation, filter media, drain tile, outlet control structures and/or modifications, minor structural work, seeding, and erosion control
- Easement, land acquisition and/or lost production costs
- Engineering cost and contingency (typically 30% of construction cost)
- Annual maintenance cost (typically 5% of construction cost) which includes general site inspection and minor housekeeping

Cost estimate methodology for each BMP type are summarized in Table 2.1. Appendix C provides itemized cost breakdown (per unit) assumptions used for each BMP option. It is important to note that all the proposed projects have potential design challenges and cost considerations that need to be fully investigated prior to their implementation. During final design and monitoring, a proposed project may not meet estimated pollutant removal efficiency and/or the cost estimates presented in this report due to design challenges that may be identified during the design process. BMP performance can also vary from year to year based on climatic conditions and other environmental factors. In addition, ongoing and consistent maintenance activities are required to maintain performance. This includes sediment removal, vegetation maintenance, filter maintenance and monitoring.

Table 2.1. Structural BMP sizing, pollutant reduction, and cost estimate assumptions.

BMP	BMP Sizing Methods	BMP Pollutant Reduction Estimates and Benefits	BMP Cost Estimates
Grassed Waterways (GW)	GW length determined in ACPF according to the user-defined SPI threshold value. 15-foot bottom width assumed for all GWs according to NRCS design standards (USDA NRCS Engineering Field Handbook Chapter 7) for GWs with drainage areas less than 30 acres	GW benefits estimated using median literature values presented in (Fiener and Aurswald, 2003) and (Mekonnen et. al., 2014) - TSS = 70% - TP = 50% - TN = 30%	Planning level construction cost estimates include design, contingency, mobilization/demobilization, minor grading and excavation, seeding, outlet riprap, and site restoration. Other cost considerations include lost production cost and annual maintenance. See Appendix C for detailed cost assumptions.
Water & Sediment Control Basin (WB)	Standard berm length of 100 meters (328 feet) and a 1-meter embankment height assumed for all WB berms sited in this study. WB ponded area and depth behind the berm is estimated in ACPF based on berm dimensions and analysis of the upslope contributing area using a filled DEM.	WB benefits were estimated using Minnesota Stormwater Manual pollutant removal efficiencies for constructed basins (link). - TSS = 85% - TP = 50% - TN = 30% - Storage = WASCOB ponded volume	Planning level construction cost estimates include design, contingency mobilization/demobilization, surface inlet, berm construction, tile installation, grading, seeding and site restoration. Other cost considerations include annual maintenance. See Appendix C for detailed cost assumptions.
Denitrifying Bioreactor (BR)	BR sized at 5% of the field drainage area to account for construction disturbance and the possibility to allow retention times >4 hours. Note: ACPF limits the area of upstream field drainage for a single bioreactor to 20 to 100 acres.	BR benefits estimated using median literature values presented in (Rambags et al., 2016) and (Driel et al., 2006) - TSS = 90% - TP = 30% - TN = 40%	Planning level construction cost estimates include design, contingency, mobilization/demobilization, outlet control structure, excavation, woodchip filter media, drain tile, liner, seeding and site restoration. Other cost considerations annual maintenance. See Appendix C for detailed cost assumptions.
Saturated Buffer (SB)	SB length assumed to be 300 feet (max size) per 20 acres of drainage area. Note: ACPF only sites potential locations for SBs, therefore each location was visually inspected through desktop review to determine site suitability and upstream contributing drainage area.	SB benefits were estimated using Minnesota Stormwater Manual pollutant removal efficiencies for biofiltration BMPs (link). - TSS = 85% - TP = 44% - TN = 50%	Planning level construction cost estimates include design, contingency, mobilization/demobilization, control structure, anti-seep collar, additional drain tile, outlet riprap, seeding and site restoration. Other cost considerations include maintenance. See Appendix C for detailed cost assumptions.

BMP	BMP Sizing Methods	BMP Pollutant Reduction Estimates and Benefits	BMP Cost Estimates
Nutrient Removal Wetlands (NRW)	For each sited NRW, ACPF estimates the following design parameters: - Height/elevation of the outlet control structure - Upstream contributing watershed area - Dead pool depth and surface area - Flood pool depth and surface area	Benefits estimated using Minnesota Stormwater Manual pollutant removal efficiencies for constructed wetlands (link). - TSS = 73% - TP = 38% - TN = 30% - Storage = variable storage volume (flood pool) of wetland	Planning level construction cost estimates include design, contingency, permitting, land easements, mobilization/ demobilization, outlet control structure and buffer seeding. Other cost considerations include annual maintenance. Since easement acquisition will be a major cost for these practices, it is included in the construction costs for each practice. See Appendix C for detailed cost assumptions
Wetland Restorations in Depression Areas (WRD)	For each sited depression area, ACPF calculates the following parameters: - Surface area of depression area - Maximum depth of depression - Upstream contributing watershed area	Benefits estimated using Minnesota Stormwater Manual pollutant removal efficiencies for constructed wetlands (link). - TSS = 73% - TP = 38% - TN = 30% - Storage = variable storage volume (flood pool) of wetland	Planning level construction cost estimates include design, contingency, permitting, land easements, mobilization/ demobilization, removal of existing tile lines, outlet control structure and buffer seeding. Other cost considerations include annual maintenance. Since easement acquisition will be a major cost for these practices, it is included in the construction costs for each practice. See Appendix C for detailed cost assumptions
Alternative Tile Intakes (ATI)	Within each depression area identified by ACPF, it is assumed that a minimum of one tile intake is required for every 4 acres of depression area.	Pollutant reduction benefits are summarized below and were estimated using median literature values presented in The Agricultural BMP Handbook for Minnesota (link) - TSS = 50% - TP = 35% (assumes DP is 30% of TP)	Planning level construction cost estimates include design, contingency mobilization/demobilization and installation of ATIs. Other cost considerations include annual maintenance.

2.4 NON-STRUCTURAL BMPS

Several non-structural BMPs were identified throughout this study's planning process as being as important, if not more important, to meeting water quality goals and targets as the structural practices discussed in Section 2.3. Siting specific locations for non-structural BMPs and evaluating their potential cost/benefit would require a significant data collection effort and/or a comprehensive review/audit of the cropping and land management practices of each landowner throughout the project study area. These efforts are outside the scope of this assessment, however this report does identify general areas and fields in each Management Unit that could be targeted for non-structural BMPs using existing data, modeling tools (ACPF), and input from the public and city/county staff. Below is a description of the non-structural BMPs that were considered for this assessment.

<u>Pasture and Feedlot Management</u>


Source: www.nrcs.usda.gov

MN Rule 7020 governs the permitting, standards for discharge, design, construction, operation and closure of feedlots throughout Minnesota. Hennepin County is a non-delegated feedlot county, meaning the MPCA manages the feedlot program for the County and the cities. Most feedlots in the state must register with the MPCA. The registration minimums are as follows: feedlots located in shoreland with 10 animal units, areas outside shoreland 50 animal units. Pasture areas are defined as where grass or other growing plants are used for grazing and where the concentration of animals is such that vegetation is maintained. Feedlot registration enables the PCA to communicate directly with feedlot owners regarding all aspects of feedlot management including technical requirements, permitting, inspections and corrective action.

BMP options to protect surface water are typically either full containment systems or discharge runoff systems. Typically, feedlot control systems are integrated structures and practices for collecting, storing and treating livestock manure and feed wastes to reduce runoff and subsequent pollution. Examples include: lagoons, vaults or other lined impoundments, but can also include covers such as roofs, or walls and berms to prevent precipitation from entering the feedlot and subsequent run-off of mixed precipitation and manure. Typically, dairy farms have additional treatment for milkhouse waste water in addition to standard feedlot controls due to high biological oxygen demand (BOD). Other feedlot and pasture management BMPs include, but are not limited to:

- clean water diversions = a temporary ridge or excavated channel to divert concentrated and sheet surface water, and possibly subsurface water, from or around feedlot areas with high pollutants
- roof runoff controls = management of downspouts so that rainwater and/or other runoff water is directed away from their manure storage facilities and confined animal feeding areas.
- settling basins = basins within or adjacent to feedlots to store and treat stormwater runoff
- resource exclusion (animal fencing) = implementing barriers to limit/prevent animal access to stream channels. While a variety of natural materials can be used for livestock exclusion, including boulders, logs and woody vegetation, fencing is the

preferred method. Options for fencing include wood slats or boards, barbed wire, high tensile wire or electrical fencing.

- vegetative buffers/filter strips = areas of grassy vegetation engineered to receive and treat feedlot wastewater before it has a chance to enter nearby waters
- rotational grazing = a management-intensive system of raising livestock on subdivided pastures called paddocks. Livestock are regularly rotated to fresh paddocks at the right time to prevent overgrazing and optimize grass growth. A rotational grazing system is an alternative to continuous grazing in which a one-pasture system is used that allows livestock unrestricted access to the entire pasture throughout the grazing season.

On a larger community scale, other BMPs can include more restrictive land use and zoning controls which may prohibit new or expansion of existing feedlots. Further, animal operations that fall below animal unit registration thresholds may still pose a potential source of pollution. Therefore, geographically targeted site visits of both permitted feedlots and non-permitted livestock operations may be encouraged.

Two different datasets were used to estimate the amount of livestock animals throughout the project Study Area. The MPCA feedlot database contains information regarding the number and type of registered livestock throughout the state of Minnesota. This database only includes registered feedlots and therefore typically does not include smaller operations with less than 100 animal units. Based on past experience and local input, the MPCA tends to underestimate the amount of livestock animals on the landscape. As part of the Elm Creek Watershed TMDL and WRAPS study, TRPD conducted a livestock animal inventory using several years (2006, 2008, and 2011) of high resolution air photos and window surveys. This analysis identified the presence, number, and general type of livestock animals throughout the entire Elm Creek watershed. Results of the TRPD analysis suggest that a majority of the livestock animals throughout the Elm Creek watershed are unregistered and the MPCA database significantly underestimates the amount animals in the watershed.

<u>Manure Management</u>


Source: www.nrcs.usda.gov

The Minnesota Feedlot rules also include regulations regarding the requirements for manure management plans and land application of manure. The MCPA has developed templates, guides and standards for the development and implementation of manure management plans, manure nutrient management and application rates.

While the MPCA is responsible for all state feedlot regulations in Hennepin County, the Elm Creek Watershed Management Commission has required that all cities must update their Local Stormwater Management Plans to include the development, administration and enforcement of a Manure Management ordinance for new non-production animal agriculture.

BMP options pertaining to manure management include the development and implementation of site specific manure management plans. Manure management plans pertain to both animal husbandry BMPs and site/facilities BMPs. Animal husbandry BMPs include diet modification, vaccination protocols, biosecurity, and adequate space, ventilation, and temperature that may have an impact on manure contents and movement across a site. Site/facility BMPs are similar to those mentioned in feedlot management section above but also include the proper land application of manure to recommended rates for crop nutrient removal, (in method, amount and time of year). Adequate separation distance between location of applied manure on the landscape and surface waters and areas of groundwater sensitivity are imperative.

Soil Health and Management


Source: www.cornandsoybeandigest.com

Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as its own ecosystem (i.e. minimal management required) to retain water and nutrients, stabilize soil, and help sustain bacteria and other microorganisms to support plant/crop growth. BMPs to improve soil health include crop rotation, no-till or conservation till, cover crops, crop residue management, and critical area planting. Implementing these types of practices help reduce soil erosion and retain water thus reducing TSS, TP, and E. coli loading to surface waters.

SSTS Inspection and Repair/Replace


Source: www.pca.state.mn.us

MN Rules 7080 through 7083 pertains to the design, installation, inspection, local program requirements, and licensing and certification program for septic systems throughout the state.

Hennepin County administers the septic program including permitting, inspection and enforcement for the cities of Corcoran, Greenfield and Rogers.

Program elements that can help protect surface and groundwater resources include: an active pump maintenance program, a robust permitting, inspection and record keeping program, system compliance inspection triggers during building permits or land use applications for existing systems, and compliance inspections upon property transfer.

Education and Outreach

Education and outreach can be an effective BMP in that property owners are often willing to undertake practices but are unsure what they should do or how to do them. These practices can range from simple fliers or brochures and web links to workshops, site inspections, and technical assistance. Demonstration projects allow unsure property owners to see a BMP in the field and to visualize and understand how it would work in their own situation.


Source: Rush Creek Headwaters Subwatershed Assessment Public Meeting

2.5 BMPS NOT SPECFICALLY SITED OR ADDRESSED IN THIS REPORT

Data collected in previous studies as well as input for this SWA identified other BMPs that might be effective in managing the water resources in this area. These were not specifically analyzed and sited for this report, but are presented for information purposes and for future analysis.

Stream Assessments and Restoration

The Commission has at least twice reviewed streambank conditions in Elm, Diamond, North Fork Rush, and South Fork Rush Creeks. The 2001 Physical and Ecological Classifications of Elm Creek and its tributaries was performed by the Hennepin Conservation District. The project purpose was to assess condition of the streams, identify natural areas, identify potential areas for greenways and buffers, provide recommendations for restoration, preservation and land use management within the watershed. The study found that very few segments of natural stream corridor remain but that those extant were worthy of preservation. Several stream stabilization and restoration projects recommended from the study have been completed. That stream assessment was updated in 2007 and additional projects identified, some of which are on the Commission's current Capital Improvement Program (CIP). These locations are shown on figures in the Upper Rush Creek and Lower Rush Creek Management Units.

Stream restoration projects provide multiple benefits aside from simply stabilizing streambanks to prevent erosion. They are an opportunity to enhance habitat, restore more natural structure and function, enhance buffers, and improve water quality. A targeted stream stabilization program that undertakes small projects with the cooperation of willing landowners can over time achieve the same benefits as more costly restorations of longer segments.

Ditch Maintenance and Repairs

There are two kinds of ditches present in the study area: county ditches and private ditches. Input at the public Open House indicated that a number of property owners are experiencing sedimentation in and washouts on their private ditches. This may lead to conveyance of excess sediment and nutrients downstream to county ditches and public streams. Locations of potential ditch maintenance needs identified at the Open House are included on figures in the respective Management Unit discussion below.

Hennepin County is the Ditch Authority under Minnesota Statutes Chapter 103E for the designated County Ditches in the Elm Creek watershed. The County performs maintenance in emergency situations, but most of the ditch maintenance is locally completed by permit and is driven by complaints or by the need to correct roadway flooding issues.

Urban/Residential BMPs

While much of the Study Area is in agriculture, there are numerous small developments, commercial nodes, and scattered large-lot residential development. Some of the residential developments have incorporated BMPs to treat stormwater to reduce nutrients in and sediment in runoff, and to moderate the rates and volumes of runoff. Individual sites can be evaluated to find suitable locations for lot-level urban/ residential BMPs such as rain gardens, bioinfiltration swales, and pervious pavements. An often under-utilized nonstructural BMP is street sweeping. Enhanced, more frequent street sweeping in priority areas can be very effective in reducing nutrient and sediment loads.

3.0 Upper Rush Creek Management Unit

The Upper Rush Creek Management Unit (MU) begins at the headwaters of North Fork Rush Creek south of Salem Lane and west of County Road 19 (see Figure 1.1 and link to mapbook). The headwaters of this Management Unit consists of a series of wetlands on the western edge of the City of Corcoran and the eastern edge of the City of Greenfield. From here, the Creek flows northeast past County Roads 19, 10, and 30. The Rush Creek crossing at County Road 117 marks the downstream end of the Management Unit. This point also represents the boundary of the City of Corcoran and City of Rogers. A majority of this MU is located within the City of Corcoran with small portions in the Cities of Greenfield and Rogers. RC7.2 (County Road 19) and RC4.2 (Oakdale Drive) are the two monitoring stations located in this MU. This section is intended to provide an overview of the Upper Rush Creek Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

3.1 LAND USE

Corn/soybean rotations (36%), grassland and pasture (32%) are the primary land uses from the National Agricultural Statistics Service (NASS) 2015 assessment of land use/land cover (Table 3.1). Even though it is the third highest land use, wetland coverage (18%) in the Upper Rush Creek Management Unit is the lowest among the six Management Units in the Study Area. Most of the larger wetlands are located upstream of County Road 10 near the headwaters of this MU. Urban/ developed, forest/shrubland, and open water all account for less than 10% of the land use.

Table 3.1. Upper Rush Creek land use.

	Upper Rush Creek	
Land Use Type	Acres	Percent
Corn/Soybeans	1,185	36%
Pasture/Grass Land	1,081	32%
Wetlands	611	18%
Urban/Developed	224	7%
Forest/Shrubland	207	6%
Open Water	26	<1%
Barren	2	<1%
Other Cropland	2	<1%
Total	3,338	100%

Source: 2015 NASS.

3.2 SOILS

Hydrologic soil group classifications are based on Natural Resources Conservation Service (NRCS) Web Soil Survey. Group A soils are comprised of sandy soils that promote infiltration and reduce the risk for runoff. Group B soils are silty loams or loam soils that tend to have a well-drained profile. Group C soils are sandy clay loams with an increase in runoff potential and smaller grain size. Group D soils are heavy clay soils with limited infiltration potential and have the highest risk of runoff. Hydrologic soil conditions for the

Upper Rush Creek Management Unit is predominantly groups B and C soils (Table 3.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 3.2. Upper Rush Creek hydrologic soil groups

Hydrologic Soil Type	Upper Rush Creek	
	Acres	Percent
A	--	--
A/D	47	1%
B	984	30%
B/D	465	14%
C	516	15%
C/D	1,323	40%
D	--	--
Unclassified/ Open Water	3	<1%
Total	3,338	100%

Source: SSURGO.

3.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Upper Rush Creek MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes throughout are moderate compared to the other Management Units in the Study Area (Table 3.3). Most of the high sloped areas are located along the main stream channel and near the headwaters (upstream of RC7.2) and downstream end (near RC4.2) of the MU.

The Tile Drainage Determination Tool in ACPF was used to estimate altered hydrology. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicate that approximately 70% of the agricultural fields in the MU are likely tile drained. These results suggest that there are approximately 850 acres of drained cropland in the Upper Rush Creek MU, which is second most among the six Management Units.

Table 3.3. Upper Rush Creek slope and drainage summary

Parameter	Percent of Management Unit
Percent of subwatershed >5% slope	41%
Percent of subwatershed >10% slope	13%
Percent of subwatershed >18% slope	3%
Percent of subwatershed in cropland production	36%
Percent of cropland likely tile drained (source: ACPF)	70%

3.4 ANIMAL AGRICULTURE

Table 3.4 provides a summary of MPCA registered feedlots and the TRPD livestock inventory for the Upper Rush Creek MU. These results indicate a majority of livestock operations throughout the MU are small operations and are therefore unregistered. The Upper Rush Creek MU has the second highest concentration of animals per acre and the third most animals within 500 feet of the stream compared to the other the six Management Units in the Study Area.

Table 3.4. Upper Rush Creek livestock inventory.

Parameter	Upper Rush Creek	
	MPCA Registered Feedlots	TRPD Animal Inventory
Total Sites	1	33
Total Animal Units	60	652
Primary Animal Type	Cows	Cows
CAFOs	None	None
Sites within 500 feet of perennial stream	1	7
Animal units within 500 feet of perennial stream	60	37

3.5 SEPTIC ANALYSIS

A significant change to state administrative rules occurred in 1994 requiring septic systems to be inspected for condition and compliance at the time of sale or when building permits are issued as well as revising standards for new construction. A GIS analysis was completed in each MU to estimate the number of homes with septic systems that would be priorities for review. County property records were analyzed to determine those that were constructed or sold prior to 1990, and thus may be less likely to conform to the new rules. It is important to note that these pre-1990 systems are not out of compliance. They simply likely have not been inspected for compliance. That same analysis also pin-pointed those that were located within 500 feet of a stream, where a noncompliant system may be at higher risk of exporting nutrients and bacteria to the stream.

Results of the Upper Rush Creek septic analysis (Table 3.5) suggest that at least 87 homes were constructed and/or sold prior to 1990, which is the second most among the six Management Units. This analysis also suggests that the Upper Rush Creek MU has the second highest number of homes located within 500 feet of perennial streams. There are 114 systems within 500 feet of the stream, 43 of which were constructed or sold prior to 1990.

Table 3.5. Upper Rush Creek septic estimates.

Septic Analysis	Total Homes in Watershed		Homes within 500 Feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Homes constructed or sold prior to 1990	87	28%	43	14%
Homes constructed or sold after 1990	224	72%	71	23%
Totals	311	100%	114	37%

3.6 UPPER RUSH CREEK KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the Upper Rush Creek Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality monitoring results indicate the following:
    - o TSS and TP increase from upstream to downstream through the MU
    - o E. coli is high and above the standard at both monitoring stations
    - o Total nitrogen is generally low at both monitoring stations
- Land use is dominated by cropland and grass/pasture
- Slopes are moderate compared to the other Management Units with most of the high sloped areas concentrated along the main stream channel and near the headwaters and downstream ends of the Management Unit.
- Altered hydrology: analysis indicates 70% (850 acres) of the agricultural fields in this MU are likely tile drained - second most among the six Management Units.
- Livestock animal concentrations are the second highest among the six Management Units and there are several operations located within 500 feet of streams. A majority of the sites are small, unregistered operations.
- Septic analysis indicates 130 homes were constructed and/or sold prior to 1990, 43 of which are located within 500 feet of the stream – second most among the six Management Units.
- Public input and local knowledge: 16 homeowners in the Upper Rush Creek Management attended the Rush Creek Headwaters SWA Open House in early December 2017. Feedback from these landowners was that sedimentation in the ditch and near culverts is causing drainage/flooding issues in several locations throughout the MU.

3.7 UPPER RUSH CREEK STRUCTURAL BMP SITING

Structural BMPs for the Upper Rush Creek Management Unit were sited using the ACPF Toolbox as described in Section 2.3. These tools identified 61 potential BMP options throughout the Upper Rush Creek Management Unit (Figure 3.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: Four potential locations were identified. TSS and TP load reductions for these practices ranged from 6-8 tons/yr and 4-6 lbs/yr, respectively. Cost benefit for ranged from $200-$240/pound of TP removed
- Saturated Buffers: Ten potential locations were identified. TSS and TP load reductions ranged from 2-7 tons/yr and 2-7 lbs/yr, respectively. Cost benefit for these practices ranged from $110-$310/pound of TP removed.
- Grassed Waterways: Twelve potential sites were identified. TSS and TP load reductions ranged from 2-12 tons/yr and 3-17 lbs/yr, respectively. Cost benefit ranged from $80-$220/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this Management Unit, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: seventeen potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <1-14 tons/yr and <1-14 lbs/yr, respectively. Cost benefit ranged from $40-$360/pound of TP removed.
- Wetland Restorations: eighteen potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from <1-20 acre-ft while TSS and TP load reductions ranged from <1-249 tons/yr and 1-54 lbs/yr, respectively. Cost benefit ranged from $80-$1,390/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 55 acre-ft and TSS and TP loading would decrease by approximately 1,100 tons/yr and 450 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions. Table 3.6 provides a summary of the top 10 BMP options for the Upper Rush Creek Management Unit in terms of annual TP load reduction and TP cost-benefit. Appendix D contains a complete summary of all 61 BMP options and their estimated load reduction and cost-benefit.

3.8 UPPER RUSH CREEK NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD livestock inventory and the Field Characterization Tool in ACPF as described in Section 2.4. Figure 3.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the Upper Rush Creek MU. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education, outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit “High” delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are 18 agricultural fields with “High” delivery potential and 7 livestock sites (37 animal units) located within 500 feet of perennial streams.

Table 3.6. Summary of top ranked structural BMP options in the Upper Rush Creek MU.

Rank	BMP ID	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit			Delivery Potential
			Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)	
Top practices in terms of load reduction (TP)											
1	DP-61	Wetland Rest.	4.4	229.5	54.3	$81,600	$88,000	$1,000	$20	$80	Med
2	WR-4	Wetland Rest.	20.0	46.8	48.5	$119,800	$140,200	$400	$150	$140	High
3	DP-58	Wetland Rest.	6.5	248.6	39.6	$118,000	$127,800	$1,000	$30	$160	Med
4	DP-65	Wetland Rest.	2.7	92.9	35.6	$79,100	$85,200	$1,600	$50	$120	Med
5	DP-64	Wetland Rest.	6.6	225.5	35.5	$105,500	$114,100	$900	$30	$160	Low
6	GW-29	G. Waterway	--	11.9	16.9	$12,500	$43,300	--	$180	$130	High
7	GW-35	G. Waterway	--	11.1	15.8	$14,900	$53,900	--	$240	$170	Med
8	GW-24	G. Waterway	--	10.7	15.2	$11,200	$37,600	--	$180	$120	Med
9	DP-58	ATIs	--	13.8	14.3	$9,300	$18,600	--	$70	$60	Med
10	DP-67	Wetland Rest.	1.3	17.6	13.7	$50,700	$54,100	$2,000	$150	$200	Low
Top practices in terms of cost-benefit (TP)											
1	DP-58	ATIs	--	13.8	14.3	$9,300	$18,600	--	$70	$60	Med
2	DP-64	ATIs	--	11.8	12.2	$8,100	$16,200	--	$70	$70	Low
3	DP-65	ATIs	--	8.5	8.8	$6,300	$12,600	--	$70	$70	Med
4	DP-61	ATIs	--	8.4	8.7	$6,300	$12,600	--	$80	$70	Med
5	DP-67	ATIs	--	6.6	6.9	$5,100	$10,200	--	$80	$70	Low
6	DP-61	Wetland Rest.	4.4	229.5	54.3	$81,600	$88,000	$1,000	$20	$80	Med
7	GW-34	G. Waterway	--	6.8	9.6	$6,200	$15,400	--	$110	$80	Med
8	DP-52	ATIs	--	6.3	6.5	$5,100	$10,200	--	$80	$80	Low
9	DP-66	ATIs	--	3.1	3.2	$3,300	$6,600	--	$110	$100	High
10	DP-59	ATIs	--	2.5	2.6	$2,700	$5,400	--	$110	$100	High

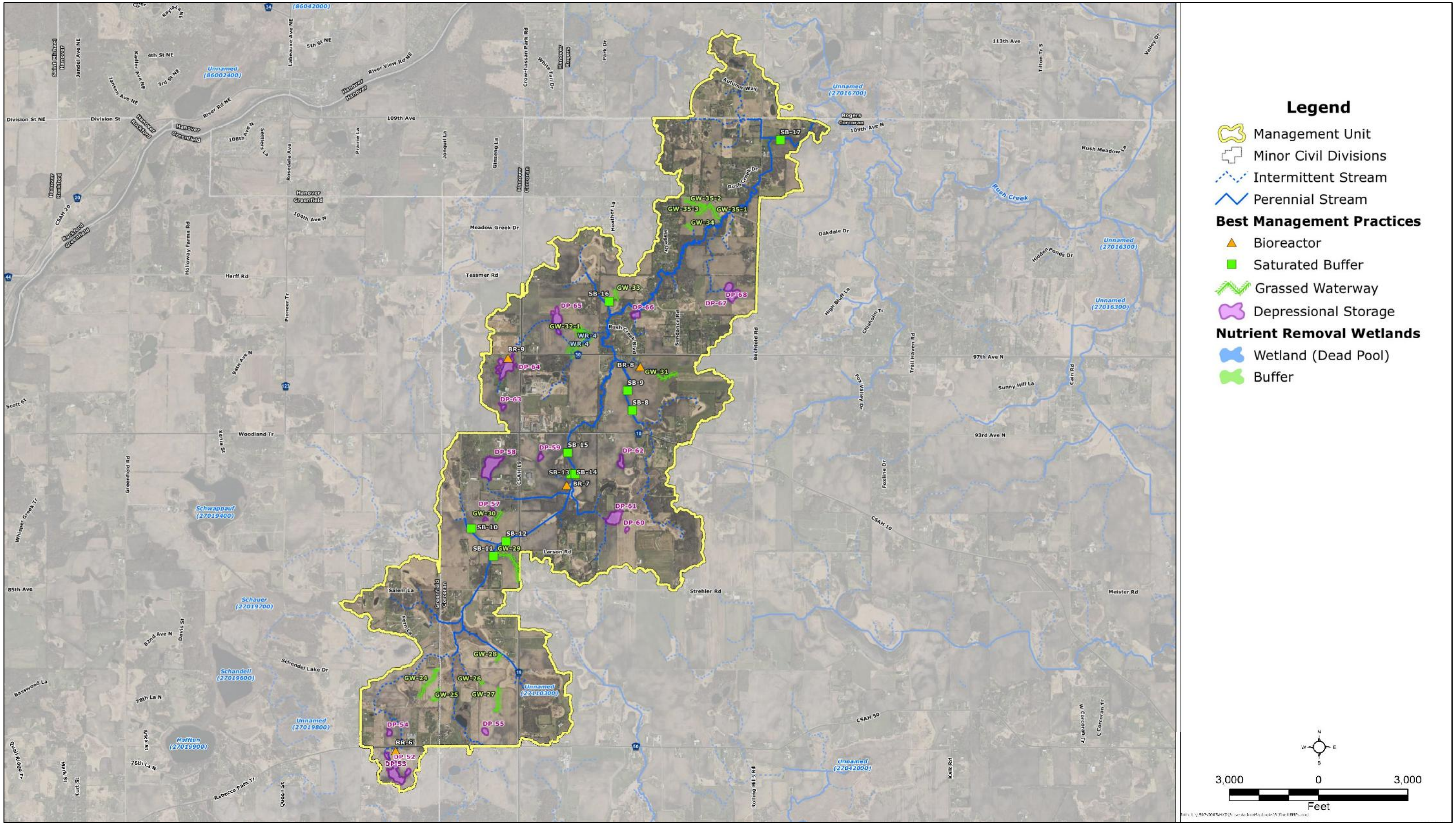


Figure 3.1. Upper Rush Creek MU structural BMPs.

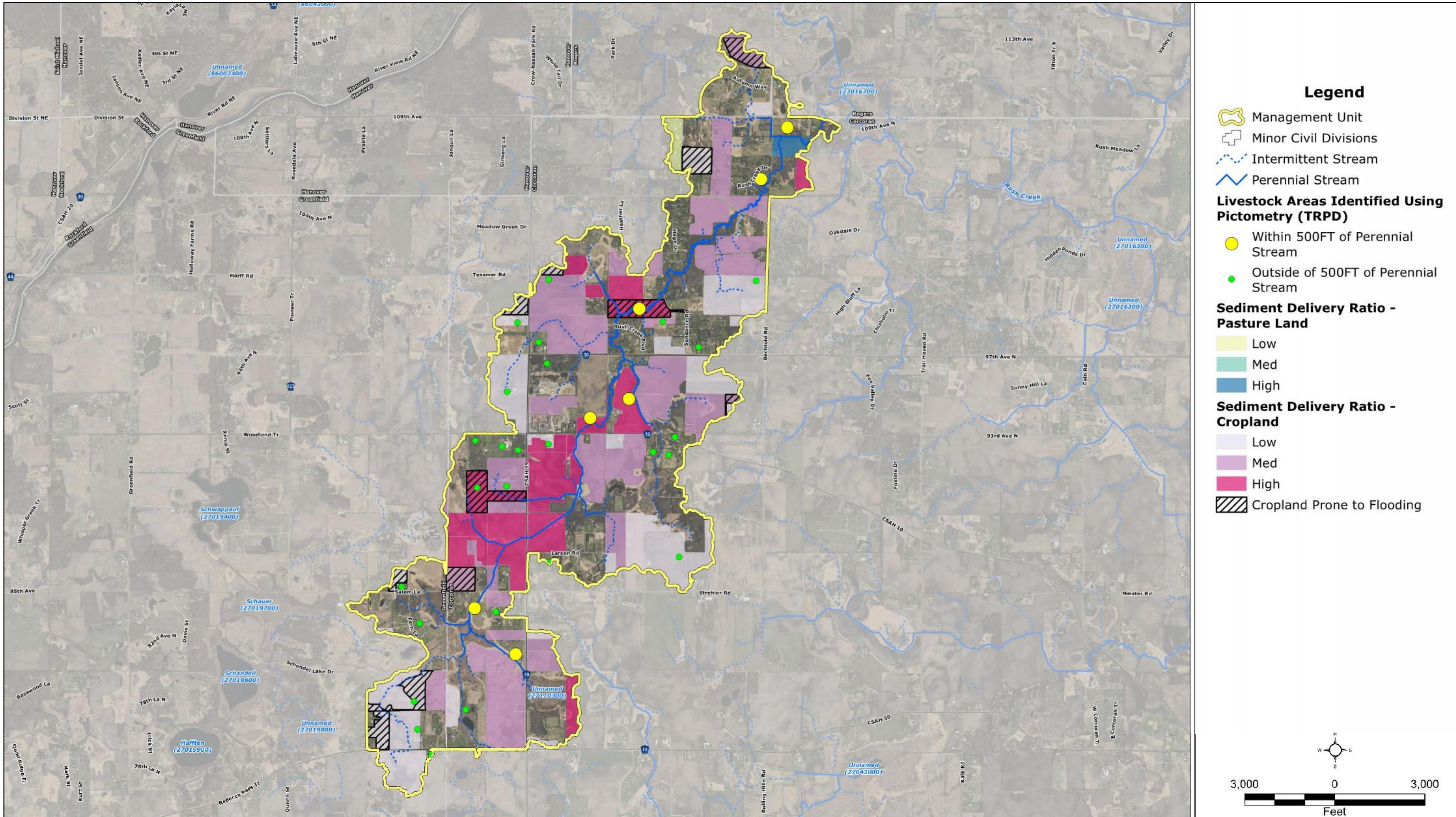


Figure 3.2. Upper Rush Creek MU fields and livestock operations for non-structural BMPs.

3.9 UPPER RUSH CREEK SUMMARY AND RECOMMENDATIONS

The primary objectives of this section were to identify the issues of concern in the Upper Rush Creek Management Unit and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations for the Upper Rush Creek Management Unit.

- Explore potential wetland restorations with willing landowners. The top five potential BMPs in terms of TP load reduction were all wetland restoration projects (DP-61, WR-4, DP-58, DP-65, and DP-64). One potential site, DP-61, also ranked in the top 10 in terms of cost-benefit (Table 3.6). Implementing wetland restorations will help address many of the issues/concerns within this MU, including TSS and TP loading and flooding/altered hydrology.

- Implement Alternative Tile Intakes where wetland restorations are not feasible. One of the top ten load reduction practices and eight of the top ten cost-benefit practices in the Upper Rush Creek MU are installation of ATIs in depression areas (Table 3.6). ATIs are a cost-effective approach to reducing TSS and TP and temporarily slowing the flow of water on the landscape.

- Implement grassed waterways and/or other stabilization practices in high sloped areas. 17 grassed waterways were identified in areas along concentrated flow paths with high slopes throughout the Upper Rush Creek MU. Three potential sites (GW-29, GW-35, GW-24) ranked in the top 10 in terms of TP load reduction, while another site, GW-34, ranked in the top 10 in terms of cost-benefit. Implementing grassed waterways or other stabilization practices will help reduce TSS, TP loading concerns in this MU.

- Identify and implement animal husbandry and pasture management BMPs. The TRPD animal inventory identified seven potential sites located within 500 feet of the stream. These sites should be targeted first for landowner outreach and BMP implementation such as runoff controls, improvements to manure storage systems, rotational grazing, and resource exclusion. Implementing these types of BMPs will help reduce TP loading and E. coli concentrations throughout the MU and the Elm Creek watershed.

- Identify and implement manure management and soil health BMPs. The field characterization tool identified 18 agricultural fields with “High” delivery potential in the Upper Rush Creek MU. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Implementing these types of practices and controls will help address many of the issues/concerns within this MU, including soil erosion, TSS/TP/E. coli loading, and water retention.

- Septic system inspections and upgrades. The septic system analysis suggest 130 systems are likely located within 500 feet of perennial streams, 43 of which were sold and/or built prior to 1990. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP and E. coli loading to surface and groundwater throughout this MU.

4.0 Lake Jubert Management Unit

The Lake Jubert Management Unit represents the headwaters of the South Fork Rush and therefore does not flow to any of the other MUs in the Study Area. This MU is the subwatershed to Lake Jubert, which is a 93 acre lake that is not designated as impaired at this time. The major stream channel in this MU flows from north to south around Lake Jubert along the northeast corner of the lake and then east through Scott Lake. Flow to Lake Jubert consists of several intermittent channels that enter the lake on the south, east and northeast side. This MU is located completely within the City of Corcoran and there are the no stream monitoring stations. This chapter is intended to provide an overview of the Lake Jubert Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

4.1 LAND USE

Corn/soybean rotations (33%), grassland and pasture (28%) are the primary land uses in the Lake Jubert MU (Table 4.1). Even though it accounts for 18% of the MU, wetland coverage is moderate compared to the other MUs. Forest/shrubland, urban/developed, and open water all account for less than 10% of the land use.

Table 4.1. Lake Jubert land use.

Land Use Type	Lake Jubert	
	Acres	Percent
Corn/Soybeans	717	33%
Pasture/Grass Land	605	28%
Wetlands	462	21%
Forest/Shrubland	187	9%
Urban/Developed	111	5%
Open Water	109	5%
Barren	2	<1%
Other Cropland	--	--
Total	2,193	100%

Source: 2015 NASS.

4.2 SOILS

Hydrologic soil conditions for the Lake Jubert Management Unit is predominantly groups B and C soils (Table 4.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 4.2. Lake Jubert hydrologic soil groups

Hydrologic Soil Type	Lake Jubert	
	Acres	Percent
A	--	--
A/D	50	2%

Hydrologic Soil Type	Lake Jubert	
	Acres	Percent
B	917	42%
B/D	351	16%
C	116	5%
C/D	659	30%
D	--	--
Unclassified/ Open Water	100	5%
Total	2,193	100%

4.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Lake Jubert MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes are high compared to the other MUs (Table 4.3). The highest sloped areas are located to the west and northwest of Lake Jubert.

The Tile Drainage Determination Tool in ACPF were used to estimate altered hydrology throughout the Lake Jubert MU. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicates that approximately 46% of the agricultural fields in the Lake Jubert MU are likely tile drained. These results suggest that there are approximately 325 acres of drained cropland in this MU, which is the second lowest among the six MUs.

Table 4.3. Lake Jubert slope and drainage summary

Parameter	Percent
Percent of subwatershed >5% slope	52%
Percent of subwatershed >10% slope	22%
Percent of subwatershed >18% slope	6%
Percent of subwatershed in cropland production	33%
Percent of cropland likely tile drained (source: ACPF)	46%

4.4 ANIMAL AGRICULTURE

Table 4.4 provides a summary of MPCA registered feedlots and the TRPD livestock inventory for the Lake Jubert MU. There are currently no MPCA registered feedlots in this MU, therefore it is assumed that all of the livestock operations identified through the TRPD analysis are small and unregistered. The Lake Jubert MU has a moderate concentration of animals per acre compared to the other MUs and no animals within 500 feet of the stream.

Table 4.4. Lake Jubert livestock inventory.

Parameter	Lake Jubert	
	MPCA Registered Feedlots	TRPD Animal Inventory
Total Sites	0	9
Total Animal Units	--	282

Parameter	Lake Jubert	
	MPCA Registered Feedlots	TRPD Animal Inventory
Primary Animal Type	--	cows
CAFOs	--	0
Sites within 500 feet of perennial stream	--	0
Animal units within 500 feet of perennial stream	--	0

4.5 SEPTIC ANALYSIS

Results of the Lake Jubert septic analysis (Table 4.5) suggest that at least 41 homes were constructed and/or sold prior to 1990, which is the third lowest among the six MUs. This analysis also suggests that the Lake Jubert MU has the second lowest number of homes located within 500 feet of perennial streams. There are 22 systems within 500 feet of the stream, 4 of which were constructed or sold prior to 1990.

Table 4.5. Lake Jubert septic estimates.

Septic Analysis	Total Homes in Watershed		Homes within 500 feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Constructed or sold prior to 1990	41	33%	4	3%
Constructed or sold after 1990	113	67%	22	14%
Totals	154	100%	26	17%

4.6 LAKE JUBERT KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the Lake Jubert Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality monitoring on streams within the Lake Jubert MU has not been conducted. Limited lake water quality data is available.
- Land use in this Management Unit is dominated by cropland and grass/pasture
- Slopes are high compared to the other Management Units with most of the high sloped areas located to the west and northwest of Lake Jubert.
- Altered hydrology: analysis indicates 46% (325 acres) of the agricultural fields in this MU are likely tile drained – second lowest in the Study Area.
- Livestock animal concentrations are moderate compared to the other MUs and there are no operations located within 500 feet of streams.
- Septic analysis indicates 45 homes were constructed and/or sold prior to 1990, 4 of which are located within 500 feet of the stream – second lowest in the Study Area.
- Public input and local knowledge: 9 homeowners in the Lake Jubert MU attended the Rush Creek Headwaters SWA Public meeting in early December, 2017. Feedback from these landowners was that areas north of the lake are prone to seasonal flooding and there are heavy tree downfalls and vegetation debris along the main stream channel north of Lake Jubert.

4.7 LAKE JUBERT STRUCTURAL BMP SITING

Structural BMPs for the Lake Jubert MU were sited using the ACPF Toolbox and methods described in Section 2.3. These tools identified 30 potential BMP options throughout the Lake Jubert MU (Figure 4.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: Two potential locations were identified. TSS and TP load reductions for these practices ranged from 7-9 tons/yr and 4-5 lbs/yr, respectively. Cost benefit for ranged from $190-$210/pound of TP removed
- Saturated Buffers: One potential location (SB-7) was identified. TSS and TP load reductions for this practice are 4 tons/yr and 3 lbs/yr, respectively. Cost benefit for this practice is $220/pound of TP removed.
- Grassed Waterways: five potential sites were identified. TSS and TP load reductions ranged from 2-27 tons/yr and 2-33 lbs/yr, respectively. Cost benefit ranged from $110-$290/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this Management Unit, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: eleven potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <1-19 tons/yr and <1-17 lbs/yr, respectively. Cost benefit ranged from $50-$300/pound of TP removed.
- Wetland Restorations: eleven potential locations were identified for wetland restoration using the depression identification tool. Storage benefit for these restorations range from <1-15 acre-ft while TSS and TP load reductions ranged from <1-375 tons/yr and 1-34 lbs/yr, respectively. Cost benefit ranged from $150-$3,740/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 45 acre-ft and TSS and TP loading would decrease by approximately 860 tons/yr and 175 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions. Table 3.6 provides a summary of the top 10 BMP options for the Lake Jubert MU in terms of annual TP load reduction and TP cost-benefit. Appendix D contains a complete summary of all 30 BMP options and their estimated load reduction and cost-benefit.

4.8 LAKE JUBERT NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD livestock inventory and the Field Characterization Tool in ACPF as described in Section 2.4. Figure 4.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the Lake Jubert Management Unit. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education and outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit “High” delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are 9 agricultural fields with “High” delivery potential and no livestock operations located within 500 feet of perennial streams.

Table 4.6. Summary of top ranked structural BMP options in the Lake Jubert MU.

Rank	BMP ID	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit			Delivery Potential
			Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)	
Top practices in terms of load reduction (TP)											
1	DP-45	Wetland Rest.	10.0	375.3	34.0	$123,400	$133,700	$700	$20	$200	$123,400
2	GW-19	G. Waterway	--	26.8	33.2	$19,600	$74,400	--	$140	$110	$19,600
3	DP-46	Wetland Rest.	11.6	283.1	25.3	$152,800	$165,900	$700	$30	$330	$152,800
4	DP-42	Wetland Rest.	1.8	40.3	20.4	$56,700	$60,600	$1,700	$80	$150	$56,700
5	DP-45	ATIs	--	18.8	17.0	$9,300	$18,600	--	$50	$50	$9,300
6	DP-46	ATIs	--	12.2	12.7	$8,700	$17,400	--	$70	$70	$8,700
7	GW-21	G. Waterway	--	9.0	11.2	$9,300	$29,000	--	$160	$130	$9,300
8	DP-42	ATIs	--	11.3	10.2	$6,300	$12,600	--	$60	$60	$6,300
9	GW-22	G. Waterway	--	7.9	9.8	$8,400	$25,100	--	$160	$130	$8,400
10	DP-48	ATIs	--	6.2	5.6	$3,900	$7,800	--	$60	$70	$3,900
Top practices in terms of cost-benefit (TP)											
1	DP-45	ATIs	--	18.8	17.0	$9,300	$18,600	--	$50	$50	Low
2	DP-42	ATIs	--	11.3	10.2	$6,300	$12,600	--	$60	$60	Low
3	DP-46	ATIs	--	12.2	12.7	$8,700	$17,400	--	$70	$70	Low
4	DP-48	ATIs	--	6.2	5.6	$3,900	$7,800	--	$60	$70	Med
5	DP-41	ATIs	--	5.0	4.5	$3,300	$6,600	--	$70	$70	Low
6	DP-50	ATIs	--	3.6	3.2	$2,700	$5,400	--	$80	$80	Med
7	GW-19	G. Waterway	--	26.8	33.2	$19,600	$74,400	--	$140	$110	Low
8	DP-51	ATIs	--	2.8	2.5	$2,700	$5,400	--	$100	$110	Med
9	DP-47	ATIs	--	2.4	2.2	$2,700	$5,400	--	$110	$120	Med
10	GW-21	G. Waterway	--	9.0	11.2	$9,300	$29,000	--	$160	$130	Low

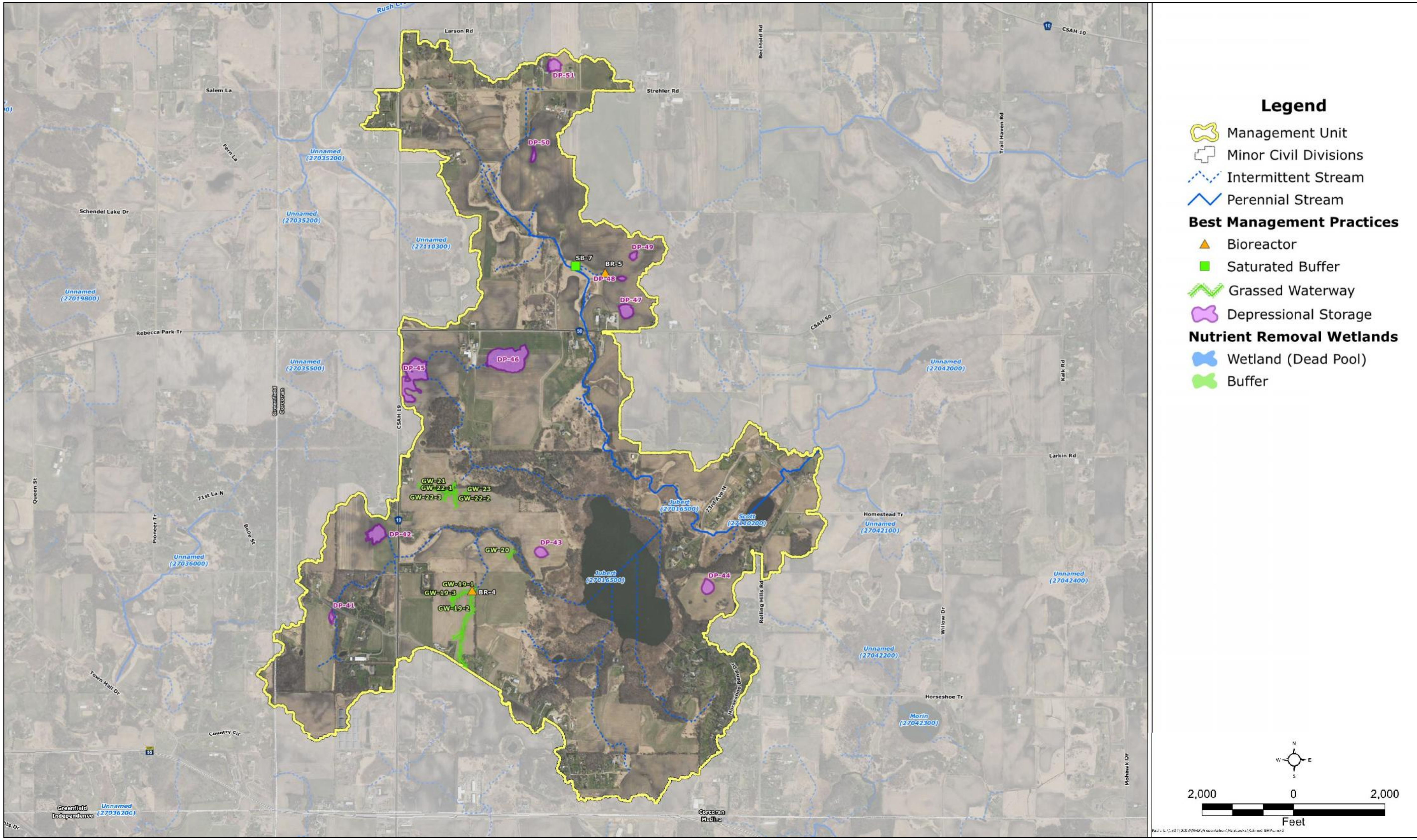


Figure 4.1. Lake Jubert MU structural BMPs.

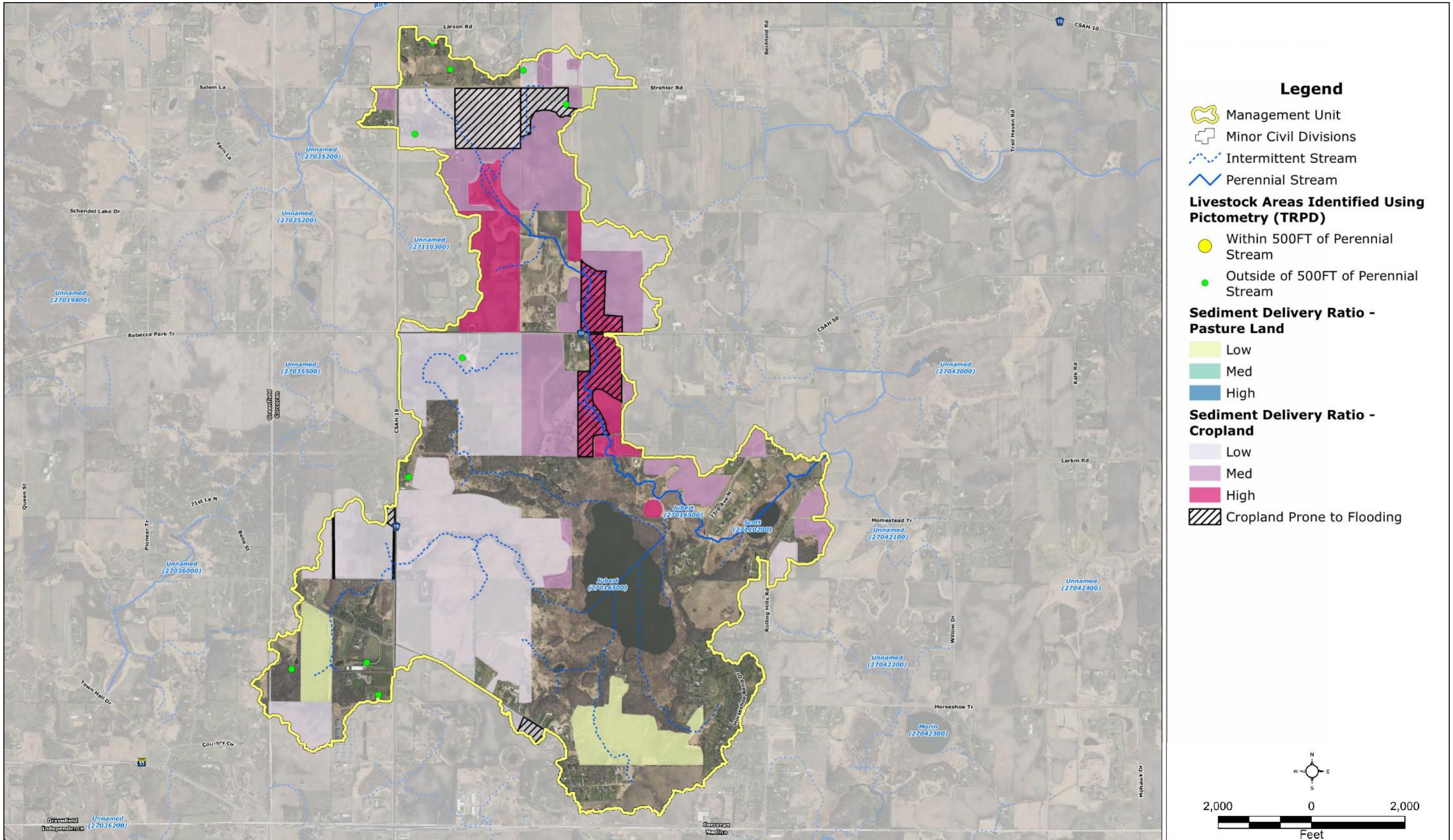


Figure 4.2. Lake Jubert MU fields and livestock operations for non-structural BMPs.

4.9 LAKE JUBERT SUMMARY AND RECOMMENDATIONS

The primary objectives of this section were to identify the issues of concern in the Lake Jubert Management Unit and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations for the Lake Jubert MU.

- Explore potential wetland restorations with willing landowners. Three of the top BMPs in terms of TP load reduction were wetland restoration projects (DP-45, DP-46, DP-42) (Table 4.6). Implementing wetland restorations will help address many of the issues/concerns within this MU, including TSS and TP loading and flooding/altered hydrology.

- Implement Alternative Tile Intakes where wetland restorations are not feasible. Eight of the top ten practices in terms of cost-benefit are installation of ATIs in depression areas (Table 4.6). ATIs are a relatively cost-effective approach to reducing TSS and TP loads and temporarily slowing the flow of water on the landscape.

- Implement grassed waterways and/or other stabilization practices in high sloped areas. Five grassed waterways were identified in areas along concentrated flow paths in the high sloped areas east of Lake Jubert. Three potential sites (GW-19, GW-21, and GW-22) ranked in the top 10 in terms of TP load reduction. Implementing grassed waterways or other stabilization practices will help reduce TSS and TP loading to Lake Jubert.

- Identify and implement manure management and soil health BMPs. The field characterization tool identified 9 agricultural fields with “High” delivery potential in the Lake Jubert MU. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Implementing these types of practices and controls will help address many of the issues/concerns within this MU, including soil loss/erosion, TSS/TP loading, and water retention.

- Septic system inspections and upgrades. The septic system analysis suggest 26 systems are likely located within 500 feet of perennial streams, 4 of which were sold and/or built prior to 1990. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP and E. coli loading to surface and groundwater throughout this MU.

5.0 Lower Rush Creek Management Unit

The Lower Rush Creek Management Unit begins at the outlet of the Upper Rush Creek MU. The upstream end of this MU consists of a large, channelized wetland complex situated along County Road 117, the Corcoran/Rogers border. North Rush Creek leaves this wetland complex and flows to the south/southwest and then east/northeast through the northern part of the City of Corcoran. Two major tributaries enter North Rush Creek in this MU – one unnamed tributary that discharges to the creek upstream of Trail Haven Road, and South Tributary that discharges downstream of Cain Road. A majority of this MU is located within the City of Corcoran, however there is a small portion within the City of Rogers. RC2.1 (Trail Haven Road – long-term monitoring station) and RC4.2 (County Road 117) are the two monitoring stations located in this MU. This section is intended to provide an overview of the Lower Rush Creek Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

5.1 LAND USE

Corn/soybean rotations (33%), grassland and pasture (26%) are the primary land uses in the Upper Rush Creek MU (Table 5.1). Wetland coverage (23%) is the third highest among the six Management Units in the Study Area. This MU has one large wetland complex near the its headwaters and several other smaller wetlands along the main-stem and tributary stream channels. Urban/developed, forest/shrubland, and open water account for less than 10% of the land use.

Table 5.1. Lower Rush Creek land use.

Land Use Type	Lower Rush Creek	
	Acres	Percent
Corn/Soybeans	1,148	33%
Pasture/Grass Land	903	26%
Wetlands	790	23%
Urban/Developed	312	9%
Forest/Shrubland	261	8%
Open Water	25	<1%
Barren	6	<1%
Other Cropland	<1	<1%
Total	3,445	100%

Source: 2015 NASS.

5.2 SOILS

Hydrologic soil conditions are predominantly groups B and C soils (Table 5.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 5.2. Lower Rush Creek hydrologic soil groups.

Hydrologic Soil Type	Lower Rush Creek	
	Acres	Percent
A	--	--
A/D	15	<1%
B	1,239	36%
B/D	323	9%
C	412	12%
C/D	1,456	42%
D	--	--
Unclassified/ Open Water	--	--
Total	3,445	100%

Source: SSURGO.

5.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Lower Rush Creek MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes are the second highest among the six Management Units (Table 5.3). Most of the high sloped areas are located throughout the central portion of the MU and along the main stream and tributary channels.

The Tile Drainage Determination Tool in ACPF was used to estimate altered hydrology throughout the Lower Rush Creek Management Unit. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicates that approximately 65% of the agricultural fields in the Lower Rush Creek MU are likely tile drained. These results suggest that there are approximately 750 acres of drained cropland in the Lower Rush Creek MU, which is the third most among the six Management Units.

Table 5.3. Lower Rush Creek slope and drainage summary.

Parameter	Percent
Percent of subwatershed >5% slope	47%
Percent of subwatershed >10% slope	16%
Percent of subwatershed >18% slope	4%
Percent of subwatershed in cropland production	33%
Percent of cropland likely tile drained (source: ACPF)	65%

5.4 ANIMAL AGRICULTURE

Table 5.4 provides a summary of MPCA registered feedlots and the TRPD animal inventory for the Lower Rush Creek Management Unit. These results indicate a majority of livestock operations throughout the Management Unit are small and unregistered. This MU has the second lowest concentration of animals per acre of the six Management Units, however it does have the most animals within 500 feet of the stream.

Table 5.4. Lower Rush Creek livestock inventory.

Parameter	Lower Rush Creek	
	MPCA Registered Feedlots	TRPD Animal Inventory
Total Sites	2	31
Total Animal Units	171	372
Primary Animal Type	Cows	Cows
CAFOs	None	None
Sites within 500 feet of perennial stream	None	9
Animal units within 500 feet of perennial stream	None	56

5.5 SEPTIC ANALYSIS

Results of the Lower Rush Creek septic analysis (Table 5.5) suggest that at least 89 homes were constructed and/or sold prior to 1990, which is the third most among the six Management Units. This analysis also suggests that this MU has the highest number of homes located within 500 feet of perennial streams. There are 119 systems within 500 feet of the stream, 43 of which were constructed or sold prior to 1990.

Table 5.5. Lower Rush Creek septic estimates

Septic Analysis	Total Homes in Watershed		Homes within 500 feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Constructed or sold prior to 1990	89	32%	46	17%
Constructed or sold after 1990	187	68%	73	26%
Totals	276	100%	119	43%

5.6 LOWER RUSH CREEK KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the Lower Rush Creek Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality monitoring results indicate the following:
  - TSS, TP and SRP generally decreases downstream of the large wetland complex near the upstream end of MU.
  - TSS TP and SRP remain similar through the MU downstream of the wetland complex.
  - E. coli decreases in the large wetland complex and then increases slightly through the MU downstream of the wetland complex
  - Total nitrogen is generally low at both monitoring stations.
- Land use in this MU is dominated by cropland and grass/pasture.
- Slopes are high compared to the other Management Units, with most of the high sloped areas located throughout the central portion of the MU and along the main stream and tributary channels.
- Altered hydrology: analysis indicates 65% (750 acres) of the agricultural fields in this MU are likely tile drained - third most among the six Management Units.

- Livestock animal concentrations are the second lowest highest among the six Management Units but it has the highest number of animals within 500 feet of the stream. A majority of the animal operations are small and unregistered.
- Septic analysis indicates 89 homes were constructed and/or sold prior to 1990, 46 of which are located within 500 feet of the stream – this is the highest number among the six Management Units.
- Public input and local knowledge: five homeowners in the Lower Rush Creek Management attended the Rush Creek Headwaters SWA Open House in early December, 2017. Feedback from these landowners was that flooding, culvert and drainage issues caused by runoff and sediment accumulation in the stream channels are common throughout this MU.

5.7 LOWER RUSH CREEK STRUCTURAL BMP SITING

Structural BMPs for the Lower Rush Creek Management Unit were sited using the ACPF Toolbox as described in Section 2.3. These tools identified 52 potential BMP options throughout the Lower Rush Creek Management Unit (Figure 5.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: Three potential locations were identified. TSS and TP load reductions for these practices ranged from 1-3 tons/yr and 2-3 lbs/yr, respectively. Cost benefit for ranged from $280-$430/pound of TP removed
- Saturated Buffers: Seven potential locations were identified. TSS and TP load reductions ranged from <1-7 tons/yr and 1-6 lbs/yr, respectively. Cost benefit for these practices ranged from $120-$570/pound of TP removed.
- Grassed Waterways: Eleven potential sites were identified. TSS and TP load reductions ranged from <1-8 tons/yr and <1-9 lbs/yr, respectively. Cost benefit ranged from $110-$980/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this MU, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: fifteen potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <1-10 tons/yr and <1-13 lbs/yr, respectively. Cost benefit ranged from $60-$760/pound of TP removed.
- Wetland Restorations: sixteen potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from <1-33 acre-ft while TSS and TP load reductions ranged from <1-220 tons/yr and <1-97 lbs/yr, respectively. Cost benefit ranged from $90-$3,560/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 71 acre-ft and TSS and TP loading would decrease by approximately 570 tons/yr and 327 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions. Table 5.6 provides a summary of the top 10 BMP options for the Lower Rush Creek Management Unit in terms of annual TP load reduction and TP cost-benefit. Appendix D contains a complete summary of all 52 BMP options and their estimated load reduction and cost-benefit.

5.8 LOWER RUSH CREEK NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD livestock inventory and the Field Characterization Tool in ACPF as described in Section 2.4.

Figure 5.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the Lower Rush Creek Management Unit. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education and outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit “High” delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are 26 agricultural fields with “High” delivery potential and 9 livestock operations (56 animal units) located within 500 feet of perennial streams.

Table 5.6. Summary of top ranked structural BMP options in the Lower Rush Creek MU.

Rank	BMP ID	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit			Delivery Potential
			Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)	
Top practices in terms of load reduction (TP)											
1	WR-5	Wetland Rest.	33.1	117.4	97.1	$167,900	$197,900	$300	$80	$100	High
2	DP-81	Wetland Rest.	5.3	219.8	60.9	$97,000	$104,800	$1,000	$20	$90	High
3	DP-82	Wetland Rest.	1.6	26.7	24.1	$44,000	$46,800	$1,400	$90	$100	High
4	DP-81	ATIs	--	8.6	12.7	$7,500	$15,000	--	$90	$60	High
5	DP-71	Wetland Rest.	6.3	88.1	11.6	$76,700	$82,600	$700	$50	$360	Low
6	DP-78	Wetland Rest.	1.7	21.3	10.3	$39,000	$41,200	$1,200	$100	$200	Med
7	GW-46	G. Waterway	--	4.3	8.8	$7,400	$20,700	--	$240	$120	High
8	GW-40	G. Waterway	--	7.7	8.7	$7,100	$19,100	--	$120	$110	Med
9	GW-42	G. Waterway	--	1.9	8.2	$8,400	$25,300	--	$660	$150	High
10	DP-72	ATIs	--	9.6	7.9	$6,300	$12,600	--	$70	$80	Med
Top practices in terms of cost-benefit (TP)											
1	DP-81	ATIs	--	8.6	12.7	$7,500	$15,000	--	$90	$60	High
2	DP-72	ATIs	--	9.6	7.9	$6,300	$12,600	--	$70	$80	Med
3	DP-73	ATIs	--	8.4	7.0	$5,700	$11,400	--	$70	$80	High
4	DP-82	ATIs	--	3.3	4.8	$3,900	$7,800	--	$120	$80	High
5	DP-81	Wetland Rest.	5.3	219.8	60.9	$97,000	$104,800	$1,000	$20	$90	High
6	DP-71	ATIs	--	7.0	5.8	$5,100	$10,200	--	$70	$90	Low
7	DP-78	ATIs	--	6.2	5.1	$4,500	$9,000	--	$70	$90	Med
8	DP-75	ATIs	--	4.3	3.6	$3,300	$6,600	--	$80	$90	Low
9	WR-5	Wetland Rest.	33.1	117.4	97.1	$167,900	$197,900	$300	$80	$100	High
10	DP-82	Wetland Rest.	1.6	26.7	24.1	$44,000	$46,800	$1,400	$90	$100	High

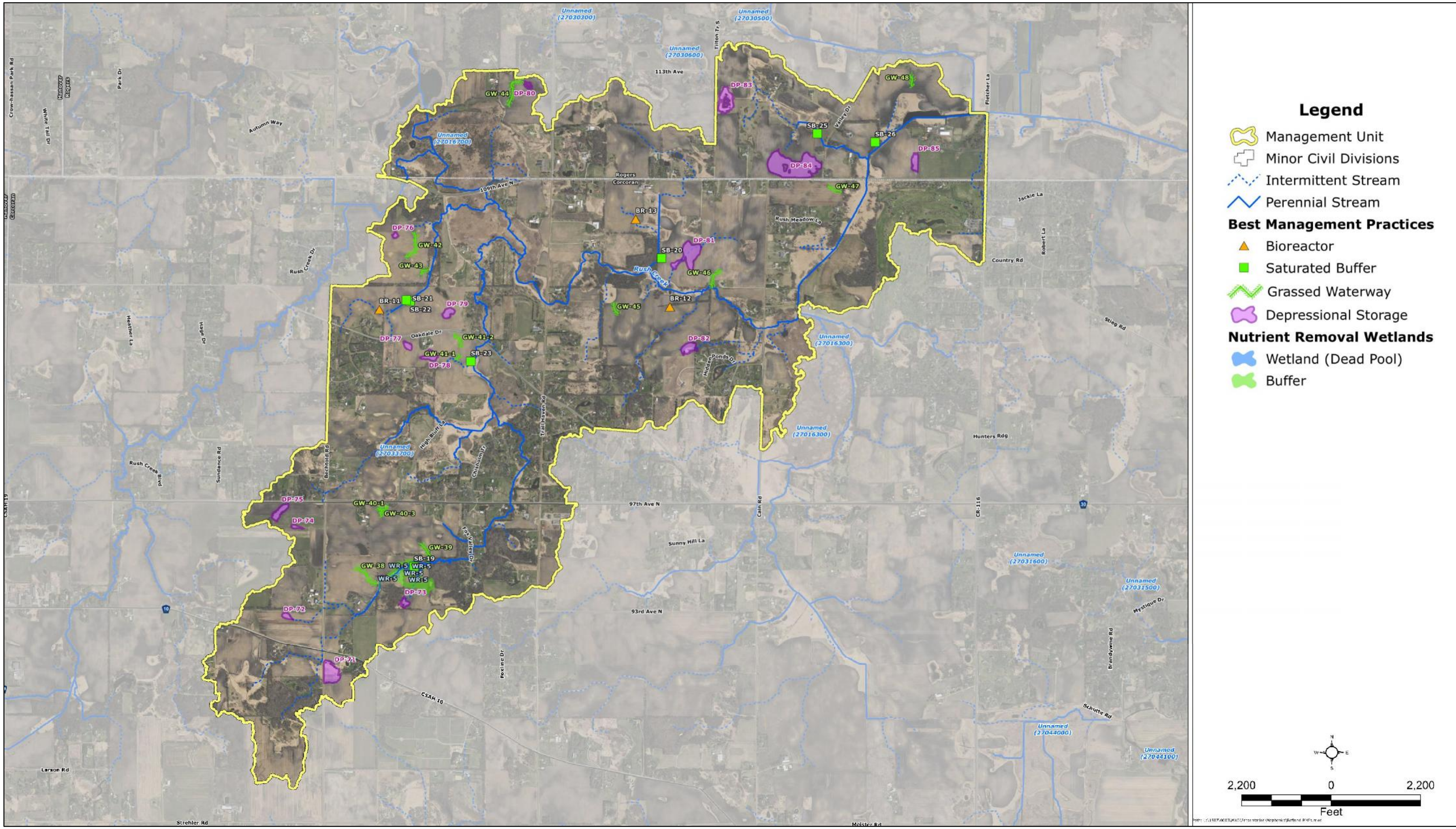


Figure 5.1. Lower Rush Creek MU structural BMPs.

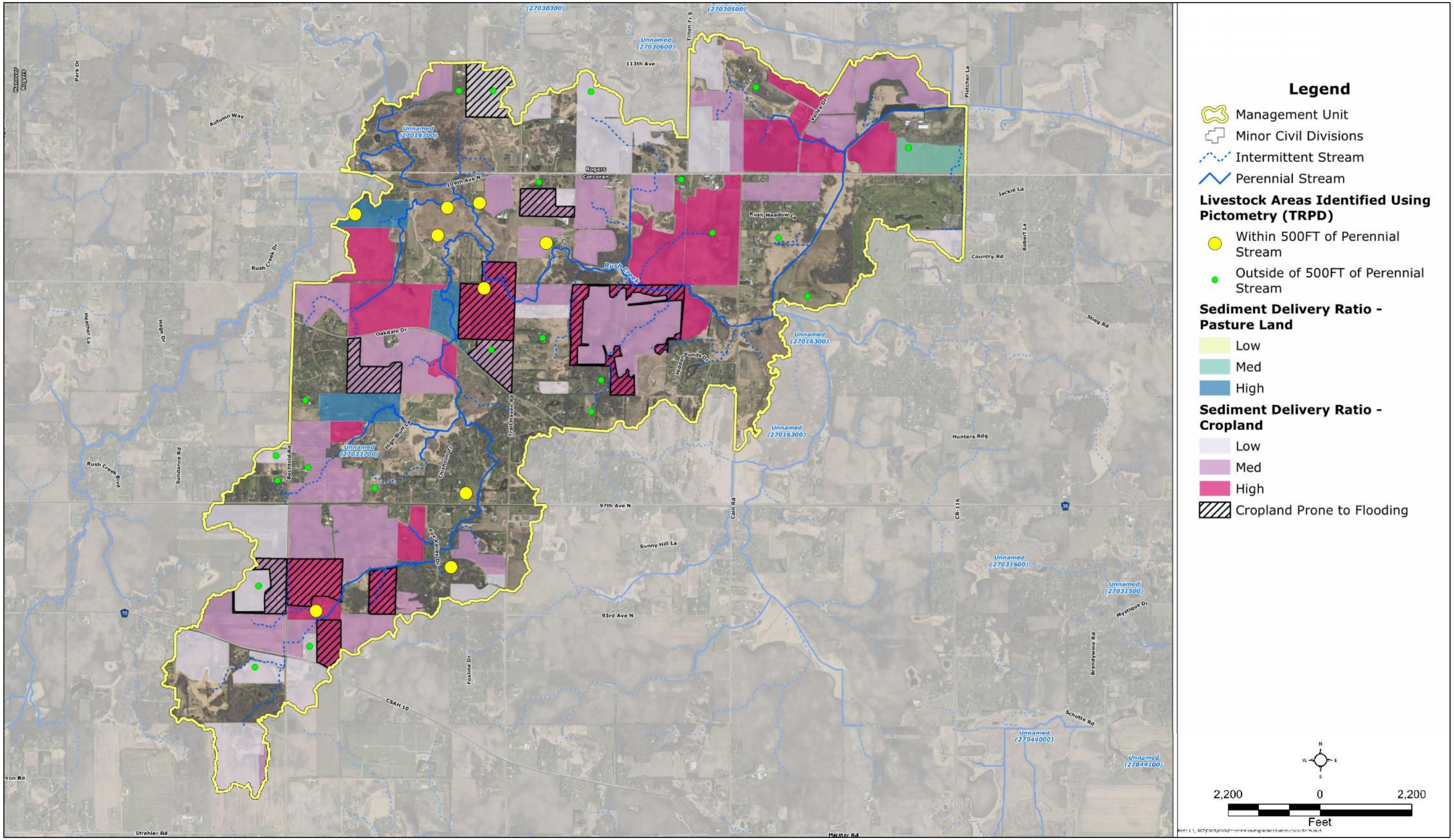


Figure 5.2. Lower Rush Creek MU fields and livestock operations for non-structural BMPs.

5.9 LOWER RUSH CREEK SUMMARY AND RECOMMENDATIONS

The primary objectives of this section were to identify the issues of concern in the Upper Rush Creek Management Unit and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations for the Upper Rush Creek MU.

- **Explore potential wetland restorations with willing landowners.** Five of the top BMPs in terms of TP load reduction were wetland restoration projects (WR-5, DP-81, DP-82, DP-71, and DP-78). Three potential sites (DP-81, WR-5 and DP-82) also rank in the top 10 in terms of cost-benefit (Table 5.6). Implementing wetland restorations will help address many of the issues/concerns within this MU, including TSS and TP loading and flooding/altered hydrology.

- **Implement Alternative Tile Intakes where wetland restorations are not feasible.** Two of the top load reduction practices and seven of the top cost-benefit practices are installation of ATIs in depression areas (Table 5.6). ATIs represent a relatively cost-effective approach to reducing TSS and TP loads and temporarily slowing the flow of water on the landscape.

- **Implement grassed waterways and/or other stabilization practices in high sloped areas.** 11 grassed waterways were identified in areas along concentrated flow paths with high slopes. Three potential sites (GW-46, GW-40, and GW-42) ranked in the top 10 in terms of TP load reduction. Implementing grassed waterways or other stabilization practices will help reduce TSS and TP loading concerns in this MU.

- **Identify and implement animal husbandry and pasture management BMPs.** The TRPD animal inventory identified nine livestock operations located within 500 feet of the stream. These sites should be targeted first for landowner outreach and BMP implementation such as runoff controls, improvements to manure storage systems, rotational grazing, and resource exclusion. Implementing these types of BMPs will help reduce TP loading and E. coli concentrations throughout the MU and the Elm Creek watershed.

- **Identify and implement manure management and soil health BMPs.** The field characterization tool identified 26 agricultural fields with “High” delivery potential. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Implementing these types of practices and controls will help address many of the issues/concerns within this MU, including soil erosion, TSS/TP/E. coli loading, and water retention.

- **Septic system inspections and upgrades.** The septic system analysis suggest 119 systems are likely located within 500 feet of perennial streams, 46 of which were sold and/or built prior to 1990. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP, E. coli and loading of other pollutants to surface and groundwater throughout this MU.

6.0 South Tributary Management Unit

The South Tributary Management Unit represents the largest tributary to North Rush Creek in the project study area. There are three main branches of this tributary and they all flow and meet at a large, ditched wetland complex located at the outlet of the MU (see Figure 1.1 and link to mapbook). This MU is located completely within the City of Corcoran. There is one monitoring station, TRIB0.6, located upstream of the large wetland complex. This section is intended to provide an overview of the South Tributary MU, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

6.1 LAND USE

The South Tributary Management Unit has the highest percentage of cultivated land in the Study Area. Corn/soybean rotations (42%), grassland and pasture (24%) are the primary land uses (Table 6.1). Even though it is the third highest land use, wetland coverage (18%) is the second lowest in the Study Area. There are a few larger wetland complexes within this MU that comprise most of the wetland area. Urban/developed, forest/shrubland, open water, and other land uses all account for less than 10% of the land use in this MU.

Table 6.1. South Tributary land use.

Land Use Type	South Tributary	
	Acres	Percent
Corn/Soybeans	1,391	42%
Pasture/Grass Land	782	24%
Wetlands	606	18%
Urban/Developed	303	9%
Forest/Shrubland	190	6%
Open Water	13	<1%
Other Cropland	9	<1%
Barren	3	<1%
Total	3,297	100%

Source: 2015 NASS.

6.2 SOILS

Hydrologic soil conditions for the South Tributary MU are predominantly groups B and C soils (Table 6.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 6.2. South Tributary hydrologic soil groups

Hydrologic Soil Type	South Tributary	
	Acres	Percent
A	--	--
A/D	6	<1%

Hydrologic Soil Type	South Tributary	
	Acres	Percent
B	1,333	40%
B/D	481	15%
C	164	5%
C/D	1,313	40%
D	--	--
Unclassified/ Open Water	--	--
Total	3,297	100%

Source: SSURGO.

6.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the South Tributary MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes are moderate compared to the other Management Units in the Study Area (Table 6.3). Most of the high sloped areas are located throughout the central portion of the MU, near the headwaters in the southwest part of the MU, and along the main tributary channels.

The Tile Drainage Determination Tool in ACPF was used to estimate altered hydrology throughout the Lower Rush Creek MU. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicate that approximately 76% of the agricultural fields in the MU are likely tile drained. These results suggest that there are approximately 1,050 acres of drained cropland in the South Tributary MU, which by far is the most among the six Management Units.

Table 6.3. South Tributary slope and drainage summary.

Parameter	Percent
Percent of subwatershed >5% slope	47%
Percent of subwatershed >10% slope	16%
Percent of subwatershed >18% slope	3%
Percent of subwatershed in cropland production	42%
Percent of cropland likely tile drained (source: ACPF)	76%

6.4 ANIMAL AGRICULTURE

Table 6.4 provides a summary of MPCA registered feedlots and the TRPD animal inventory for the South Tributary MU. These results indicate a majority of animal operations are small and unregistered. The South Tributary MU has the lowest concentration of animals per acre and the third lowest amount of livestock animals within 500 feet of the stream compared to the other Management Units in the Study Area.

Table 6.4. South Tributary livestock inventory.

Parameter	South Tributary	
	MPCA Registered Feedlots	TRPD Animal Inventory
Total Sites	3	23
Total Animal Units	53	334
Primary Animal Type	Cows	Cows
CAFOs	None	None
Sites within 500 feet of perennial stream	1	5
Animal units within 500 feet of perennial stream	37	32

6.5 SEPTIC ANALYSIS

Results of the South Tributary septic analysis (Table 6.5) suggest that at least 94 homes were constructed and/or sold prior to 1990, which is the most among the six Management Units. This analysis also suggests that the South Tributary MU has the third highest number of homes located within 500 feet of perennial streams. There are 81 homes within 500 feet of the stream, 32 of which were constructed or sold prior to 1990.

Table 6.5. South Tributary septic estimates.

Septic Analysis	Total Homes in Watershed		Homes within 500 feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Constructed or sold prior to 1990	94	33%	32	11%
Constructed or sold after 1990	190	67%	49	17%
Totals	284	100%	81	29%

6.6 SOUTH TRIBUTARY KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the South Tributary Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality monitoring results indicate the following:
  - TSS is high during storm events
  - TP and SRP generally higher than the other monitoring station in Study Area
  - E. coli is high and above the standard
  - Total nitrogen is generally low
- Land use is dominated by cropland and grass/pasture. This MU has the highest percent of cultivated land in the Study Area.
- Slopes are moderate compared to the other Management Units with most of the high sloped areas located throughout the central portion, near the headwaters in the southwest part of the MU, and along the main tributary channels.
- Altered hydrology: analysis indicates 76% (1,050 acres) of the agricultural fields in this Management Unit are likely tile drained - highest among the six MUs.
- Livestock animal concentrations are the lowest among the six Management Units and third fewest animals located within 500 feet of streams. A majority of the operations are small and unregistered.

- Septic analysis indicates 94 homes were constructed and/or sold prior to 1990, 32 of which are located within 500 feet of the stream – third most among the six Management Units.
- Public input and local knowledge: eight homeowners in the South Tributary MU attended the Rush Creek Headwaters SWA Open House in early December, 2017. Feedback from these landowners was that flooding and poor drainage in some of the stream/ditch channels are the primary issues/concerns throughout the Management Unit.

6.7 SOUTH TRIBUTARY STRUCTURAL BMP SITING

Structural BMPs for the South Tributary Management Unit were sited using the ACPF Toolbox as described in Section 2.3. These tools identified 110 potential BMP options (Figure 6.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: Three potential locations were identified. TSS and TP load reductions for these practices ranged from <1-7 tons/yr and 1-6 lbs/yr, respectively. Cost benefit for ranged from $180-$880/pound of TP removed
- Saturated Buffers: Six potential locations were identified. TSS and TP load reductions ranged from 1-3 tons/yr and 2-4 lbs/yr, respectively. Cost benefit for these practices ranged from $200-$390/pound of TP removed.
- Grassed Waterways: Eighteen potential sites were identified. TSS and TP load reductions ranged from <1-47 tons/yr and 1-84 lbs/yr, respectively. Cost benefit ranged from $40-$840/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this Management Unit, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: Forty potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <1-14 tons/yr and <1-18 lbs/yr, respectively. Cost benefit ranged from $60-$2,010/pound of TP removed.
- Wetland Restorations: forty-three potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from <1-127 acre-ft while TSS and TP load reductions ranged from <1-707 tons/yr and <1-203 lbs/yr, respectively. Cost benefit ranged from $50-$7,670/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 293 acre-ft and TSS and TP loading would decrease by approximately 3,000 tons/yr and 950 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions, however BMPs with higher delivery potential (i.e. located near perennial streams/ waterways) may present better opportunities to reduce pollutant loads and concentrations in downstream waterbodies. Table 6.6 provides a summary of the top 10 BMP options for the Upper South Tributary Management Unit in terms of annual TP load reduction and TP cost-benefit. Appendix D contains a complete summary of all 110 BMP options and their estimated load reduction and cost-benefit.

6.8 SOUTH TRIBUTARY NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD livestock inventory and the Field Characterization Tool in ACPF as described in Section 2.4. Figure 6.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the South Tributary MU. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education and outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit “High” delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are 19 agricultural fields with “High” delivery potential and 5 sites (32 animal units) located within 500 feet of perennial streams.

Table 6.6. Summary of top ranked structural BMP options in the South Tributary MU.

Rank	BMP ID	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit			Delivery Potential
			Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)	
Top practices in terms of load reduction (TP)											
1	WR-3	Wetland Rest.	126.8	156.9	202.8	$713,900	$867,300	$300	$280	$210	High
2	GW-15	G. Waterway	--	47.4	84.1	$17,700	$66,200	--	$70	$40	Med
3	WR-1	Wetland Rest.	17.8	62.4	80.7	$70,000	$74,700	$200	$60	$50	High
4	DP-26	Wetland Rest.	9.7	579.3	77.3	$101,700	$110,000	$600	$10	$70	High
5	GW-2	G. Waterway	--	20.6	36.6	$11,100	$36,800	--	$90	$50	Low
6	DP-23	Wetland Rest.	13.3	363.6	35.2	$169,100	$183,800	$700	$30	$260	Med
7	WR-2	Wetland Rest.	9.8	25.3	32.7	$64,100	$70,600	$400	$140	$110	High
8	DP-15	Wetland Rest.	18.9	458.2	31.4	$193,600	$210,600	$600	$20	$340	Low
9	DP-5	Wetland Rest.	5.6	129.7	29.8	$108,300	$117,200	$1,000	$50	$200	Med
10	DP-40	Wetland Rest.	34.9	706.9	26.2	$320,700	$349,800	$500	$20	$670	High
Top practices in terms of cost-benefit (TP)											
1	GW-15	G. Waterway	--	47.4	84.1	$17,700	$66,200	--	$70	$40	Med
2	WR-1	Wetland Rest.	17.8	62.4	80.7	$70,000	$74,700	$200	$60	$50	High
3	GW-2	G. Waterway	--	20.6	36.6	$11,100	$36,800	--	$90	$50	Low
4	DP-23	ATIs	--	13.6	17.6	$10,500	$21,000	--	$80	$60	Med
5	DP-15	ATIs	--	12.2	15.7	$9,300	$18,600	--	$80	$60	Low
6	DP-5	ATIs	--	11.5	14.9	$8,700	$17,400	--	$80	$60	Med
7	DP-26	ATIs	--	10.3	13.3	$8,100	$16,200	--	$80	$60	High
8	DP-40	ATIs	--	10.1	13.1	$8,100	$16,200	--	$80	$60	High
9	DP-28	ATIs	--	7.7	10.0	$6,300	$12,600	--	$80	$60	High
10	DP-26	Wetland Rest.	9.7	579.3	77.3	$101,700	$110,000	$600	$10	$70	High

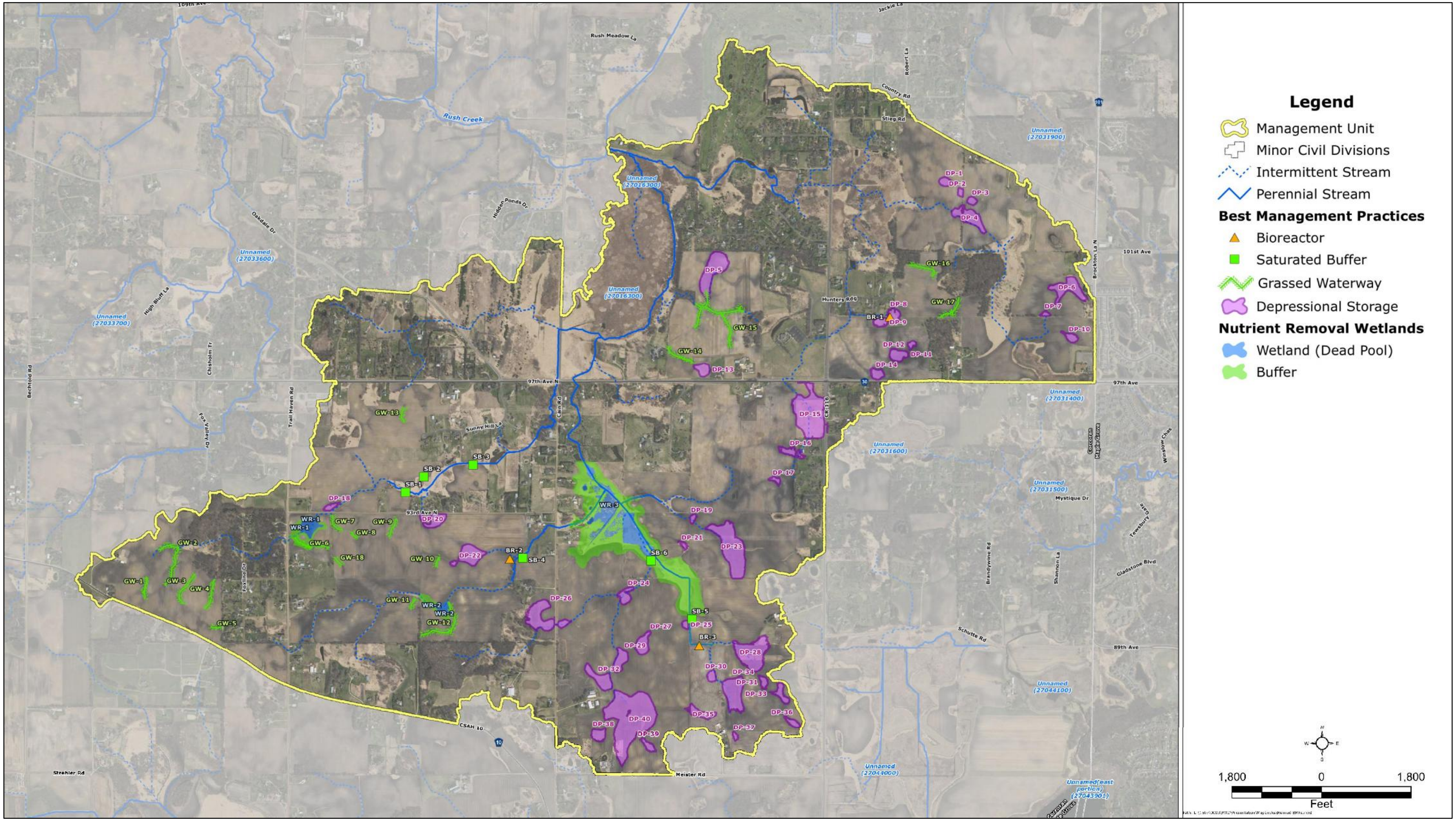


Figure 6.1. South Tributary MU Structural BMPs.

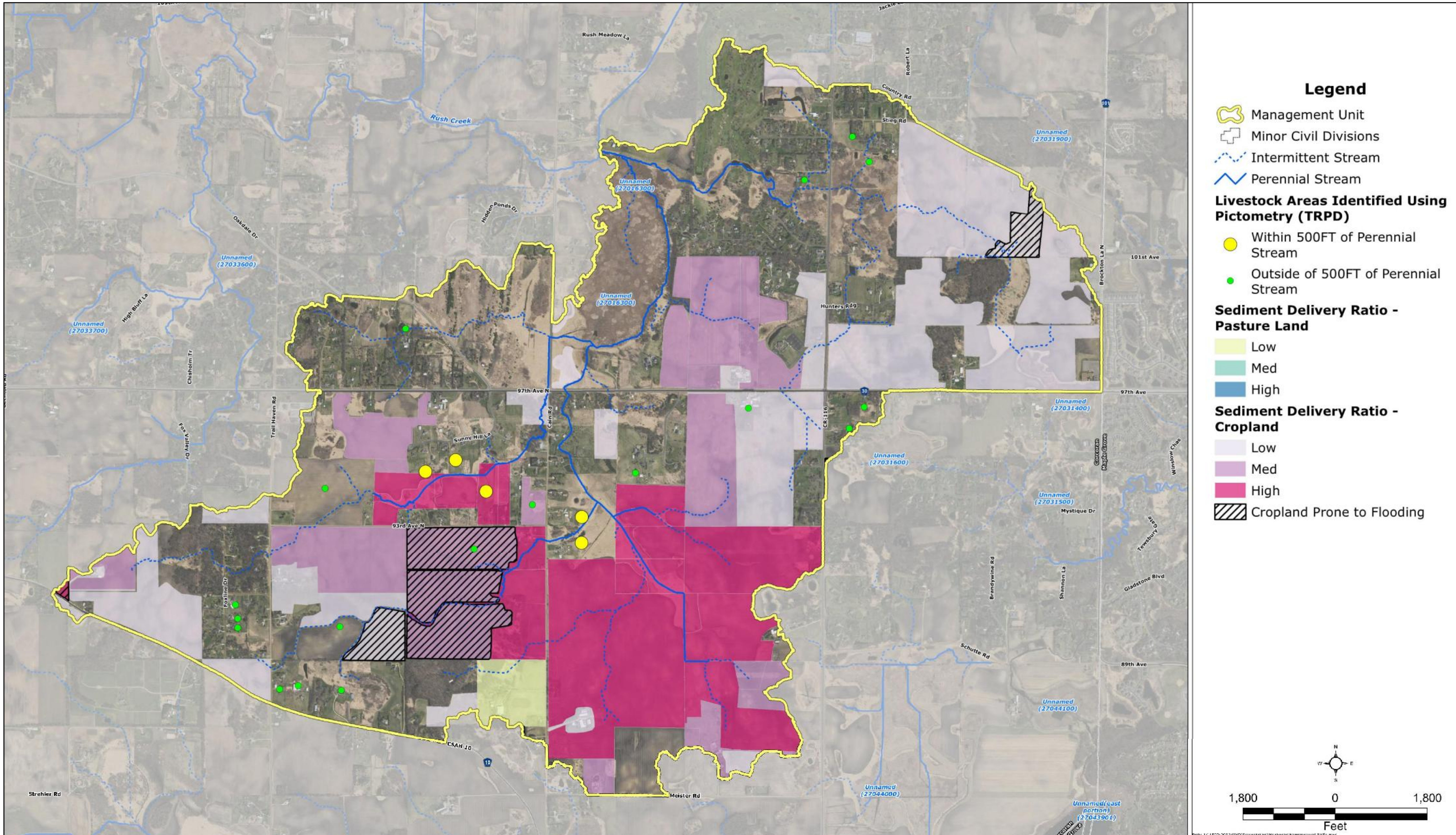


Figure 6.2. South Tributary MU fields and livestock operations for non-structural BMPs.

6.9 SOUTH TRIBUTARY SUMMARY AND RECOMMENDATIONS

The primary objectives of this section were to identify the issues of concern in the South Tributary Management Unit and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations.

- Explore potential wetland restorations with willing landowners. The South Tributary MU has the highest amount of drained agricultural land and the most drained depressions in the Study Area. Eight of the top potential BMPs in terms of TP load reduction were wetland restoration projects. Two potential sites, WR-1 and DP-26, also ranked in the top 10 in terms of cost-benefit (Table 6.6). Implementing wetland restorations will help address many of the issues/concerns within this MU, including TSS and TP loading and flooding/altered hydrology.

- Implement Alternative Tile Intakes where wetland restorations are not feasible. Six of the top ten cost-benefit practices are installation of ATIs in depression areas (Table 6.6). ATIs are a relatively cost-effective approach to reducing TSS and TP loads and temporarily slowing the flow of water on the landscape.

- Implement grassed waterways and/or other stabilization practices in high sloped areas. Eighteen grassed waterways were identified in areas along concentrated flow paths with high slopes. Two potential sites, GW-15 and GW-2, ranked in the top 10 in terms of both TP load reduction and cost benefit. Grassed waterways or other stabilization practices will help reduce TSS and TP loading concerns in this MU.

- Identify and implement animal husbandry and pasture management BMPs. The TRPD animal inventory identified five potential sites located within 500 feet of the stream. These sites should be targeted first for landowner outreach and BMP implementation such as runoff controls, improvements to manure storage systems, rotational grazing, and resource exclusion. Implementing these types of BMPs will help reduce TP loading and E. coli concentrations.

- Identify and implement manure management and soil health BMPs. The field characterization tool identified 19 agricultural fields with “High” delivery potential. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Implementing these types of practices and controls will help address many of the issues/concerns within this Management Unit, including soil erosion, TSS/TP/E. coli loading, and water retention.

- Septic system inspections and upgrades. The septic system analysis suggest 81 systems are likely located within 500 feet of perennial streams, 32 of which were sold and/or built prior to 1990. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP and E. coli loading to surface and groundwater throughout this Management Unit.

7.0 Lake Henry Management Unit

The Lake Henry Management Unit is a headwater tributary to North Fork Rush Creek. This MU includes the subwatershed to Lake Henry, which is a 47 acre impaired shallow lake. The major perennial stream channel in this MU begins downstream of Lake Henry and generally flows from north to south before discharging to the large wetland complex that represents the upstream point of the Lower Rush Creek MU. Flow to Lake Henry consists of several intermittent channels that enter the lake on the southwest, west, northwest and northeast sides. This MU is located completely within the City of Rogers. There are no stream monitoring stations located in this Management Unit. This chapter is intended to provide an overview of the Lake Henry Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

7.1 LAND USE

Wetlands (33%) and grassland/pasture (29%) are the primary land uses in the Lake Henry MU (Table 7.1). There are several large wetland complexes located both upstream of Lake Henry and downstream along the main stream channel. Corn/soybeans (18%) and other cropland is the lowest among the six Management Units in the Study Area. Forest/ shrubland, open water, and urban/developed all account for less than 10% of the land use.

Table 7.1. Lake Henry land use.

Land Use Type	Henry Lake	
	Acres	Percent
Wetlands	383	33%
Pasture/Grass Land	339	29%
Corn/Soybeans	213	18%
Forest/Shrubland	108	9%
Open Water	81	7%
Urban/Developed	37	3%
Barren	1	<1%
Other Cropland	--	--
Total	1,162	100%

Source: 2015 NASS.

7.2 SOILS

Hydrologic soil conditions for the Lake Henry Management Unit is predominantly groups B and C soils (Table 7.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 7.2. Lake Henry hydrologic soil groups.

Hydrologic Soil Type	Henry Lake	
	Acres	Percent
A	--	--
A/D	--	--
B	312	27%
B/D	218	19%
C	155	13%
C/D	415	36%
D	--	--
Unclassified/ Open Water	62	5%
Total	1,162	100%

Source: SSURGO.

7.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Lake Henry MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes throughout are moderate compared to the other Management Units in the Study Area (Table 7.3). Most of the high sloped areas are located north of Henry Lake and along the main stream channel downstream of Lake Henry.

The Tile Drainage Determination Tool in ACPF was used to estimate altered hydrology throughout the MU. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicate that approximately 88% of the agricultural fields in the MU are likely tile drained. These results suggest that there are approximately 180 acres of drained cropland in the MU, which is the lowest most among the six Management Units.

Table 7.3. Lake Henry slope and drainage summary.

Parameter	Percent
Percent of subwatershed >5% slope	47%
Percent of subwatershed >10% slope	16%
Percent of subwatershed >18% slope	3%
Percent of subwatershed in cropland production	18%
Percent of cropland likely tile drained (source: ACPF)	88%

7.4 ANIMAL AGRICULTURE

Table 7.4 provides a summary of MPCA registered feedlots and the TRPD animal inventory for the Lake Henry Management Unit. These results indicate a majority of animal operations throughout the management are moderately sized registered operations. The MU has the highest concentration of animals per acre but the fewest number of animals within 500 feet of perennial streams. However, it should be pointed out that a majority of the sites are located upstream of Lake Henry.

Table 7.4. Lake Henry livestock inventory.

Parameter	Henry Lake MPCA Registered Feedlots	Henry Lake TRPD Animal Inventory
Total Sites	2	10
Total Animal Units	232	252
Primary Animal Type	Cows	Cows
CAFOs	None	None
Sites within 500 feet of perennial stream	1	0
Animal units within 500 feet of perennial stream	183	0

7.5 SEPTIC ANALYSIS

Results of the Lake Henry septic analysis (Table 7.5) suggest that at least 21 homes were constructed and/or sold prior to 1990, which is the lowest among the six Management Units. This analysis also suggests that the Lake Henry MU has the fewest homes located within 500 feet of perennial streams. There are 11 homes within 500 feet of the stream, 3 of which were constructed or sold prior to 1990.

Table 7.5. Lake Henry septic estimates.

Septic Analysis	Total Homes in Watershed		Homes within 500 feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Constructed or sold prior to 1990	21	26%	3	4%
Constructed or sold after 1990	60	74%	8	10%
Totals	81	100%	11	14%

7.6 LAKE HENRY KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the Lake Henry Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality there is no stream monitoring data in the Lake Henry MU. Some lake water quality data is available.
- Land use is dominated by wetlands and grass/pasture
- Slopes are moderate compared to the other Management Units, with most of the high sloped areas located north of Lake Henry and along the stream channels downstream of Lake Henry
- Altered hydrology: analysis indicates 88% (180 acres) of the agricultural fields are likely tile drained - lowest among the six Management Units.
- Livestock animal concentrations are highest in the Study Area and a majority of the livestock operations are located upstream of Lake Henry. There are no animal operations located within 500 feet of perennial streams downstream of Lake Henry.
- Septic analysis indicates 21 homes were constructed and/or sold prior to 1990, 3 of which are located within 500 feet of the stream – lowest among the six Management Units.
- Public input and local knowledge: no homeowners in the Lake Henry MU attended the Rush Creek Headwaters SWA Public meeting in early December, 2017.

7.7 LAKE HENRY STRUCTURAL BMP SITING

Structural BMPs for the Lake Henry Management Unit were sited using the ACPF Toolbox as described in Section 2.3. These tools identified seven potential BMP options (Figure 7.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: No bioreactors were sited in this MU.
- Saturated Buffers: One potential location was identified. TSS reductions for this practice would be 2 tons/yr and TP reductions would be 5 lbs/yr. Cost benefit for this practice is $140/pound of TP removed.
- Grassed Waterways: Two potential sites were identified. TSS and TP load reductions ranged from 4-17 tons/yr and 14-27 lbs/yr, respectively. Cost benefit ranged from $40-$80/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this Management Unit, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: Two potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from 1-11 tons/yr and 3-17 lbs/yr, respectively. Cost benefit ranged from $20-$70/pound of TP removed.
- Wetland Restorations: Two potential locations were identified for wetland restoration using the depression identification tool. Storage benefit for these restorations range from 1-6 acre-ft while TSS and TP load reductions ranged from 16-32 tons/yr and 6-34 lbs/yr, respectively. Cost benefit ranged from $50-$560/pound of TP removed.

The model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 7 acre-ft and TSS and TP loading would decrease by approximately 70 tons/yr and 85 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions, however BMPs with higher delivery potential (i.e. located near perennial streams/waterways) may present better opportunities to reduce pollutant loads and concentrations in downstream waterbodies. Table 7.6 provides a summary all BMP options for the Lake Henry Tributary Management Unit ranked in terms of annual TP load reduction and TP cost-benefit.

7.8 LAKE HENRY NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD livestock inventory and the Field Characterization Tool in ACPF as described in Section 2.4. Figure 7.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the South Tributary MU. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education and outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit “High” delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are four agricultural fields with “High” delivery potential and no sites located within 500 feet of perennial streams. Again, while there are no animal operations located near perennial streams, there are several located upstream of Lake Henry.

Table 7.6. Summary of top ranked structural BMP options in the Lake Henry MU.

Rank	BMP ID	BMP Type	Estimated Benefits			Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit			Delivery Potential
			Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)			Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)	
Top practices in terms of load reduction (TP)											
1	DP-69	Wetland Rest.	1.1	32.0	34.1	$35,500	$37,400	$1,700	$60	$50	Low
2	GW-37	G. Waterway	--	16.5	27.0	$7,500	$21,000	--	$60	$40	Low
3	DP-69	ATIs	--	10.5	16.9	$7,400	$14,800	--	$70	$40	Low
4	GW-36	G. Waterway	--	4.1	13.5	$7,300	$20,400	--	$200	$80	Low
5	DP-70	Wetland Rest.	5.6	15.6	6.4	$66,900	$71,900	$600	$230	$560	Med
6	SB-18	Sat. Buffer	--	2.3	5.2	$8,400	$14,300	--	$320	$140	High
7	DP-70	ATIs	--	1.4	3.2	$3,300	$6,600	--	$240	$100	Med
Top practices in terms of cost-benefit (TP)											
1	GW-37	G. Waterway	--	16.5	27.0	$7,500	$21,000	--	$60	$40	Low
2	DP-69	ATIs	--	10.5	16.9	$7,400	$14,800	--	$70	$40	Low
3	DP-69	Wetland Rest.	1.1	32.0	34.1	$35,500	$37,400	$1,700	$60	$50	Low
4	GW-36	G. Waterway	--	4.1	13.5	$7,300	$20,400	--	$200	$80	Low
5	DP-70	ATIs	--	1.4	3.2	$3,300	$6,600	--	$240	$100	Med
6	SB-18	Sat. Buffer	--	2.3	5.2	$8,400	$14,300	--	$320	$140	High
7	DP-70	Wetland Rest.	5.6	15.6	6.4	$66,900	$71,900	$600	$230	$560	Med

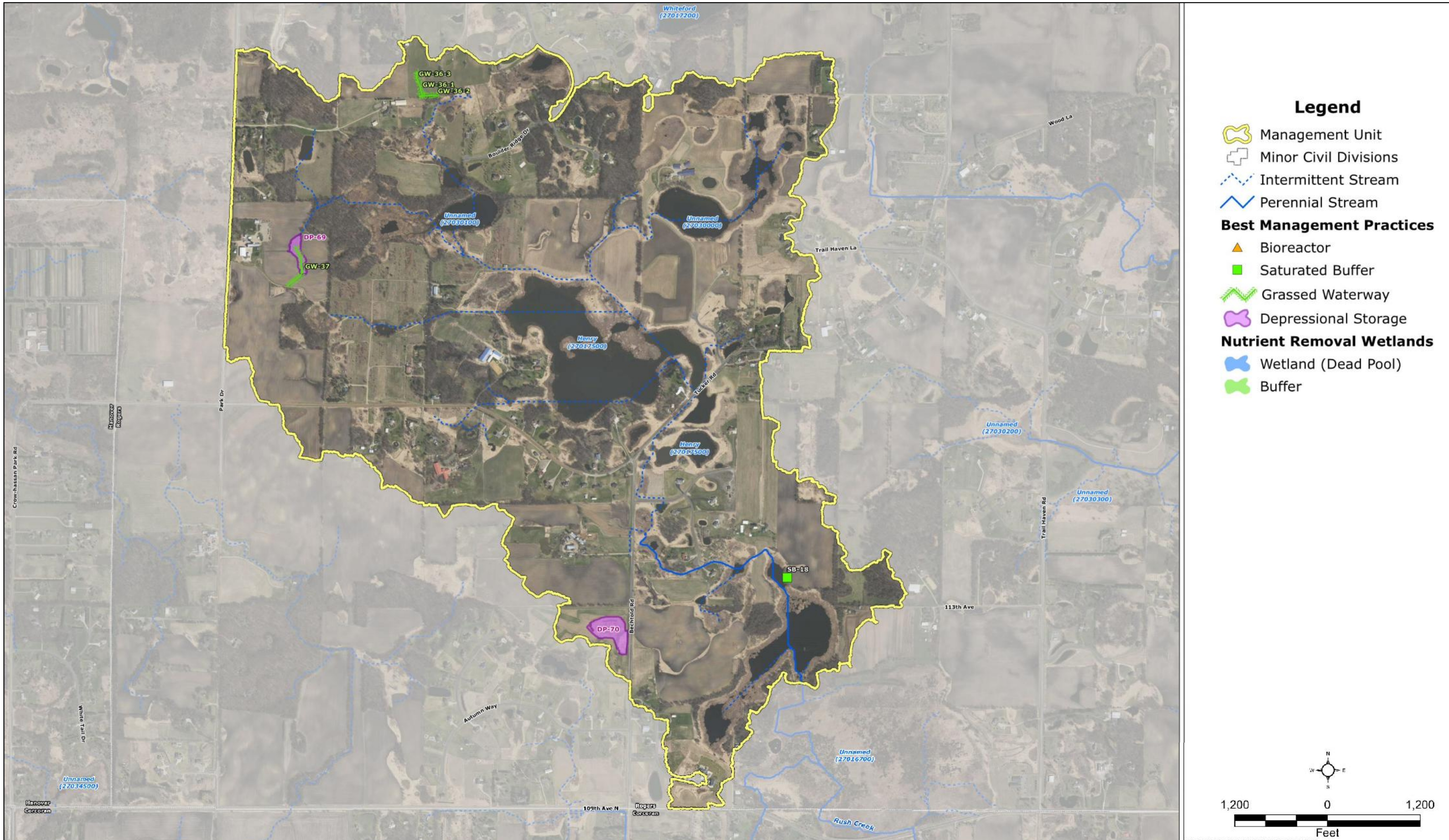


Figure 7.1. Lake Henry MU structural BMPs.

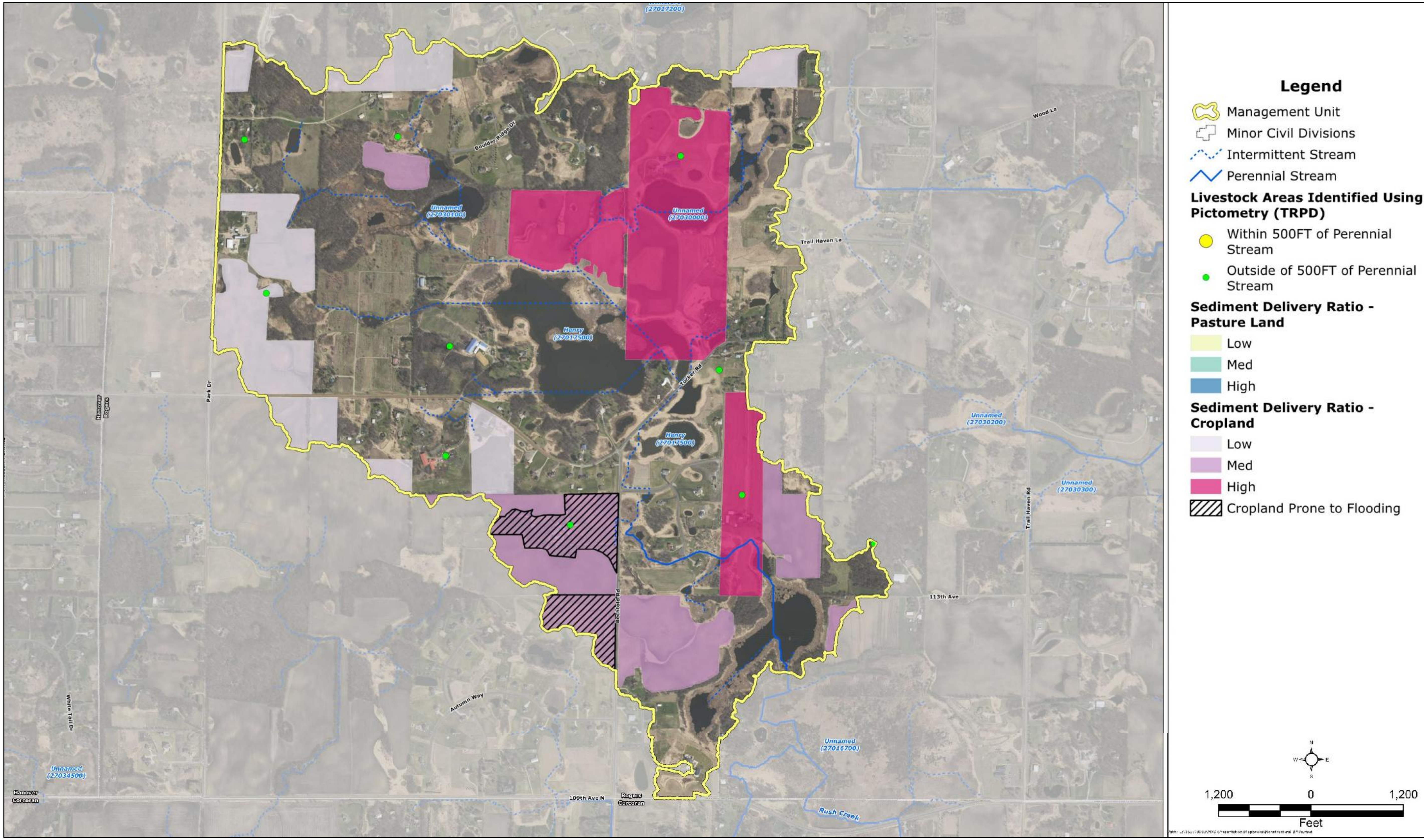


Figure 7.2. Lake Henry MU fields and livestock operations for non-structural BMPs.

7.9 LAKE HENRY SUMMARY AND RECOMMENDATIONS

The primary objectives of this chapter were to identify the issues of concern in the Lake Henry Management Unit and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations for the Lake Henry MU.

- Explore potential wetland restorations with willing landowners. One of the top three potential BMPs in terms of TP load reduction and cost benefit was wetland restoration project DP-69 (Table 7.6). One other location, DP-70, was also sited for potential wetland restoration. Implementing wetland restorations will help address many of the issues/concerns within this MU, including TSS and TP loading and altered hydrology.

- Implement Alternative Tile Intakes where wetland restorations are not feasible. One of the top practice in terms of cost benefit (DP-69) is installation of ATIs in depression areas (Table 7.6). ATIs represent a cost-effective approach to reducing TSS and TP loads and temporarily slowing the flow of water on the landscape.

- Implement grassed waterways and/or other stabilization practices in high sloped areas. Two grassed waterways were identified in areas along concentrated flow paths with high slopes. One potential site, GW-37 ranked in the top three in terms of both TP load reduction and cost-benefit. Implementing grassed waterways or other stabilization practices will help reduce TSS and TP loading concerns in this MU.

- Identify and implement animal husbandry and pasture management BMPs. The TRPD animal inventory did not identify any animal operations within 500 feet of perennial stream, however there are several small operations located upstream of Lake Henry. These sites should be targeted first for landowner outreach and BMP implementation such as runoff controls, improvements to manure storage systems, rotational grazing, and resource exclusion. Implementing these types of BMPs will help reduce TP loading and E. coli concentrations to Lake Henry.

- Identify and implement manure management and soil health BMPs. The field characterization tool identified four agricultural fields with “High” delivery potential. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Similarly, agricultural fields in close proximity to Lake Henry should also be targeted for these types of practices. Implementing these controls will help decrease soil erosion, TSS/TP/E. coli loading, and improve water retention.

- Septic system inspections and upgrades. The septic system analysis suggest 11 homes are located within 500 feet of perennial streams, 3 of which were sold and/or built prior to 1990. There are also several homes located directly around Lake Henry with older construction and/or point of sale. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP and E. coli loading to surface and groundwater throughout this MU.

- Evaluate Internal Loading in Lake Henry. The Lake Henry TMDL calls for a watershed load reduction of 568 lbs/yr and an internal load reduction of 221 lbs/yr. Internal loading (i.e. sediment cores and common carp population assessment) was not measured or assessed as part of this study. Based on the size of the Lake Henry watershed and the watershed BMP siting presented in this study, it may be difficult to meet the lake's TMDL watershed load reductions requirements. Thus, it is recommended that sediment cores be collected and a common carp population assessment be performed for Lake Henry to better estimate internal load. Once collected, results of these assessment should be used to reassess watershed and internal load reduction goals/targets for the lake.

8.0 Tilton's Management Unit

The Tilton's Management Unit is another tributary subwatershed to North Rush Creek in the project study area. This MU is comprised of a main tributary at the downstream end that is fed by two separate branches draining the headwater portion of the MU (see Figure 1.1 and link to mapbook). This MU is located completely within the City of Rogers. There are no monitoring stations. This section is intended to provide an overview of the Tilton's Management Unit, identify issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

8.1 LAND USE

Wetlands (33%), corn/soybeans (28%), and grassland/pasture (29%) are the primary land uses (Table 8.1). There is one large wetland complex in the center portion of the MU and several other smaller wetlands near the headwaters. Forest/shrubland, urban/ developed, open water and other land uses account for less than 10% of the land use in this MU.

Table 8.1. Tilton's land use.

Land Use Type	Tilton's	
	Acres	Percent
Wetlands	592	33%
Corn/Soybeans	500	28%
Pasture/Grass Land	400	22%
Forest/Shrubland	166	9%
Urban/Developed	101	6%
Open Water	36	2%
Barren	<1	<1%
Other Cropland	<1	<1%
Total	1,795	100%

Source: 2015 NASS.

8.2 SOILS

Hydrologic soil conditions are predominantly groups B and C soils (Table 8.2). Some soils within the study area are dual hydrologic soil groups; this designation is given when the soils can be reclassified from D soils to an A, B, or C with drainage modifications. Such modifications include engineered soil or installing a tile drainage network.

Table 8.2. Tilton's hydrologic soil groups.

Hydrologic Soil Type	Tilton's	
	Acres	Percent
A	2	<1%
A/D	108	6%
B	390	22%
B/D	373	21%
C	280	15%

Hydrologic Soil Type	Tilton's	
	Acres	Percent
C/D	642	36%
D	--	--
Unclassified/ Open Water	--	--
Total	1,795	100%

Source: SSURGO.

8.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Tilton's MU were characterized using the Rush Creek Headwaters hydro-conditioned DEM. Slopes throughout are the lowest among the six Management Units in the Study Area (Table 8.3). There are a few high sloped areas around the periphery of the boundary, however much of this subwatershed is characterized by low-lying wetlands.

The Tile Drainage Determination Tool in ACPF was used to estimate altered hydrology throughout the Tilton's MU. This tool uses NASS land use, hydrologic soil conditions, and field slope to determine which agricultural fields are likely drained with subsurface drain tile. Output of this tool indicate that approximately 70% of the agricultural fields in the Tilton's MU are likely tile drained. These results suggest that there are approximately 350 acres of drained cropland in the MU which is third lowest among the six Management Units.

Table 8.3. Tilton's slope and drainage summary.

Parameter	Percent
Percent of subwatershed >5% slope	39%
Percent of subwatershed >10% slope	12%
Percent of subwatershed >18% slope	3%
Percent of subwatershed in cropland production	28%
Percent of cropland likely tile drained (source: ACPF)	70%

8.4 ANIMAL AGRICULTURE

Table 8.4 provides a summary of MPCA registered feedlots and the TRPD animal inventory for the Lake Jubert MU. There are currently no MPCA registered feedlots in this MU therefore it can be assumed that all of the animal operations identified through the TRPD analysis are small and unregistered. The MU has a moderate concentration of animals per acre compared to the other Management Units and the second highest number of animals (51) within 500 feet of the stream.

Table 8.4. Tilton's livestock inventory.

Parameter	Tilton's	
	MPCA Registered Feedlots	TRPD Animal Inventory
Total Sites	None	16
Total Animal Units	None	261
Primary Animal Type	--	Cows

Parameter	Tilton's	
	MPCA Registered Feedlots	TRPD Animal Inventory
CAFOs	None	None
Sites within 500 feet of perennial stream	None	3
Animal units within 500 feet of perennial stream	None	51

8.5 SEPTIC ANALYSIS

Results of the Tilton's septic analysis (Table 8.5) suggest that at least 25 homes were constructed and/or sold prior to 1990, which is the second lowest among the six Management Units. This analysis also suggests that the Tilton's MU has the third fewest homes located within 500 feet of perennial streams. There are 59 systems within 500 feet of the stream, 14 of which were constructed or sold prior to 1990.

Table 8.5. Tilton's septic estimates.

Septic Analysis	Total Homes in Watershed		Homes within 500 feet of Stream	
	Number	Percent of Total	Number	Percent of Total
Constructed or sold prior to 1990	25	21%	14	12%
Constructed or sold after 1990	92	79%	45	38%
Totals	117	100%	59	50%

8.6 TILTON'S KEY ISSUES/CONCERNS

Below is a summary of the characterization efforts for the Tilton's Management Unit and the key factors that may be contributing to increased runoff and pollutant loading.

- Water quality there is no stream monitoring data.
- Land use in this MU is dominated by wetlands, grass/pasture, and cropland.
- Slopes are low compared to the other Management Units, as this subwatershed is characterized by low-lying wetlands
- Altered hydrology: analysis indicates 70% (350 acres) of the agricultural fields are likely tile drained – third lowest among the six Management Units.
- Livestock animal concentrations are moderate in this Management Unit and there are three animal operations (51 animal units) located within 500 feet of perennial streams.
- Septic analysis indicates 25 homes were constructed and/or sold prior to 1990, 14 of which are located within 500 feet of the stream – third lowest among the six Management Units.
- Public input and local knowledge: no homeowners in the Tilton's MU attended the Rush Creek Headwaters SWA Open House in early December, 2017.

8.7 TILTON'S STRUCTURAL BMP SITING

Structural BMPs for the Tilton's Management Unit were sited using the ACPF Toolbox as described in Section 2.3. These tools identified 18 potential BMP options throughout the

Tilton's Management Unit (Figure 8.1). Below is a brief overview of the different BMPs identified through this analysis.

- Bioreactors: One potential location was identified. TSS reductions for this practice would be 2 tons/yr and TP reductions would be 2 lbs/yr. Cost benefit for this practice is $560/pound of TP removed.
- Saturated Buffers: Four potential location were identified. TSS and TP load reductions ranged from <1-1 tons/yr and 1-2 lbs/yr, respectively. Cost benefit ranged from $300-$520/pound of TP removed.
- Grassed Waterways: Three potential sites were identified. TSS and TP load reductions ranged from 1-2 tons/yr and 3-5 lbs/yr, respectively. Cost benefit ranged from $250-$390/pound of TP removed.
- Water and Sediment Control Basins: The ACPF toolbox did not site any WASCOBs in this Management Unit, however WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- Alternative Tile Intakes: Five potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <1-1 tons/yr and <1-2 lbs/yr, respectively. Cost benefit ranged from $140-$690/pound of TP removed.
- Wetland Restorations: Five potential locations were identified for wetland restoration using the depression identification tool. Storage benefit for these restorations range from <1-2 acre-ft while TSS and TP load reductions ranged from <1-4 tons/yr and <1-3 lbs/yr, respectively. Cost benefit ranged from $560-$2,740/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 5 acre-ft and TSS and TP loading would decrease by approximately 17 tons/yr and 30 lbs/yr, respectively. As discussed in Section 2.3, all BMP pollutant load reduction estimates should be viewed as edge of field reductions, however BMPs with higher delivery potential (i.e. located near perennial streams/waterways) may present better opportunities to reduce pollutant loads and concentrations in downstream waterbodies. Table 8.6 provides a summary of the top 10 BMP options for the Tilton's Management Unit ranked in terms of annual TP load reduction and TP cost-benefit.

8.8 TILTON'S NON-STRUCTURAL BMPS

Potential locations for non-structural BMPs were identified using a combination of the TRPD animal inventory and the Field Characterization Tool in ACPF as described in Section 2.4. Figure 8.2 depicts locations of livestock operations (and proximity to streams) and delivery potential for the agricultural fields (cropland and pasture) throughout the Tilton's MU. This map is intended to provide a starting point for resource managers to begin planning and targeting landowner education and outreach for non-structural BMP implementation. In general, livestock operations within 500 feet of the stream and agricultural fields that exhibit "High" delivery potential should be prioritized first for outreach and the livestock management, manure management and soil health BMPs described in Section 2.4. Results of this analysis suggest there are 13 agricultural fields with "High" delivery potential and no sites located within 500 feet of perennial streams.

Table 8.6. Summary of top ranked structural BMP options in the Tilton's MU.

Rank	BMP ID	BMP Type	Estimated Benefits Storage (acre-ft)	Estimated Benefits TSS (tons/yr)	Estimated Benefits TP (lbs/yr)	Construction Cost	20-Year Life Cycle Cost	Life Cycle Cost Benefit Storage ($/acre-ft)	Life Cycle Cost Benefit TSS ($/ton)	Life Cycle Cost Benefit TP ($/lb)	Delivery Potential
Top practices in terms of load reduction (TP)											
1	GW-50	G. Waterway	--	2.3	5.4	$6,900	$27,600	--	$590	$250	Low
2	GW-49	G. Waterway	--	1.7	3.9	$7,300	$30,100	--	$910	$390	Low
3	GW-51	G. Waterway	--	1.5	3.4	$5,000	$16,900	--	$580	$250	Low
4	DP-88	Wetland Rest.	0.6	1.2	3.4	$7,100	$38,100	$3,100	$1,570	$560	High
5	DP-90	Wetland Rest.	2.1	3.6	3.0	$7,600	$54,300	$1,300	$750	$910	Med
6	SB-29	Sat. Buffer	--	1.4	2.4	$6,000	$14,400	--	$510	$300	High
7	DP-88	ATIs	--	1.3	2.2	$4,500	$6,100	--	$230	$140	High
8	BR-14	Bioreactor	--	1.5	1.7	$8,400	$19,400	--	$650	$560	Med
9	DP-89	Wetland Rest.	0.8	0.8	1.7	$6,800	$27,300	$1,600	$1,620	$790	Med
10	DP-90	ATIs	0.0	0.9	1.5	$3,300	$4,500	--	$250	$150	Med
Top practices in terms of cost-benefit (TP)											
1	DP-88	ATIs	--	1.3	2.2	$4,500	$9,000	--	$350	$200	High
2	DP-90	ATIs	--	0.9	1.5	$3,300	$6,600	--	$380	$220	Med
3	GW-50	G. Waterway	--	2.3	5.4	$9,000	$27,600	--	$590	$250	Low
4	GW-51	G. Waterway	--	1.5	3.4	$6,600	$16,900	--	$580	$250	Low
5	SB-29	Sat. Buffer	--	1.4	2.4	$8,400	$14,400	--	$510	$300	High
6	DP-89	ATIs	--	0.5	0.9	$2,700	$5,400	--	$540	$310	Med
7	GW-49	G. Waterway	--	1.7	3.9	$9,500	$30,100	--	$910	$390	Low
8	SB-27	Sat. Buffer	--	0.8	1.3	$8,100	$13,900	--	$890	$520	High
9	SB-28	Sat. Buffer	--	0.8	1.3	$8,100	$13,900	--	$890	$520	High
10	SB-30	Sat. Buffer	--	0.8	1.3	$8,100	$13,900	--	$890	$520	High

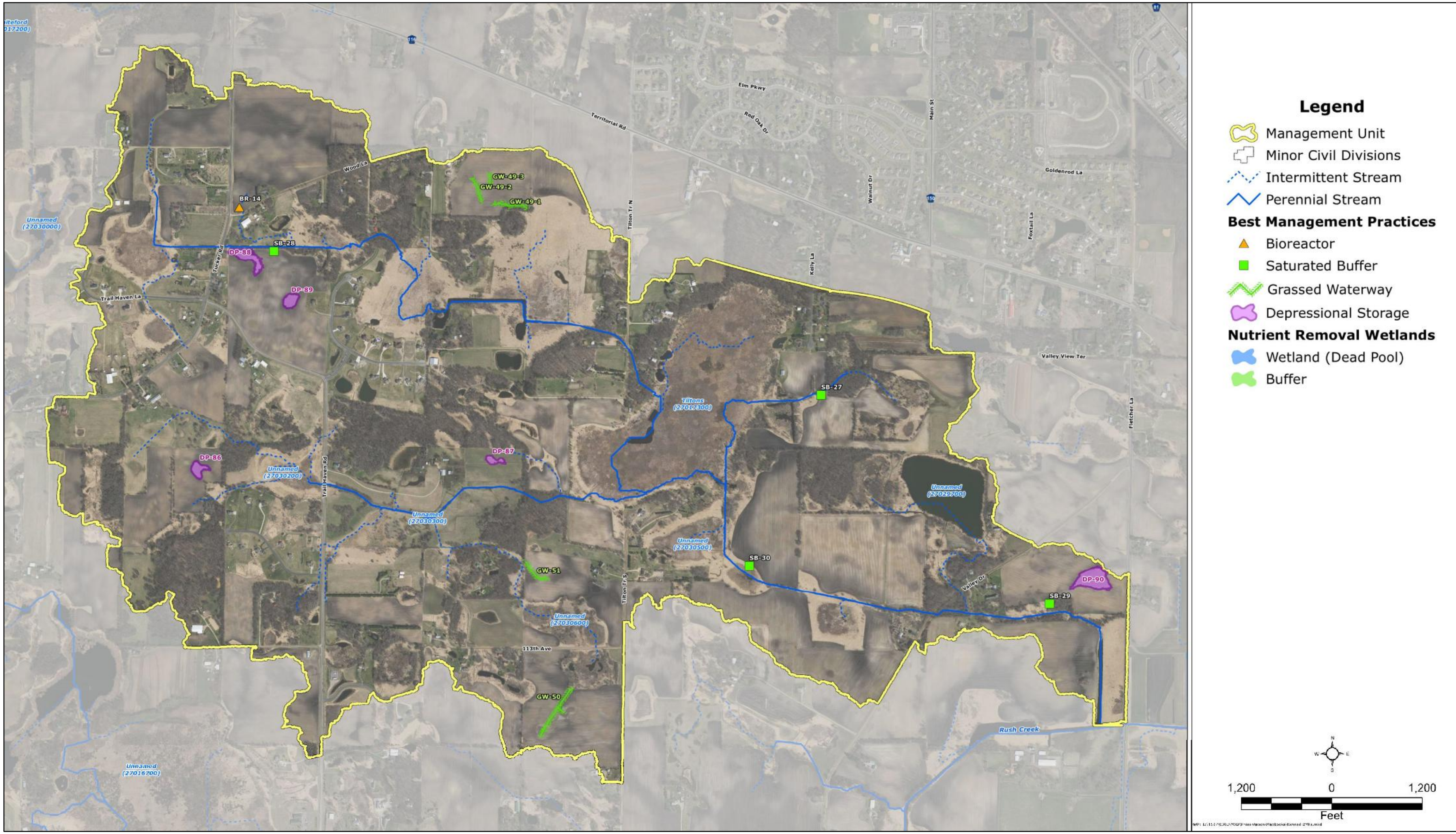


Figure 8.1. Tilton's MU structural BMPs.

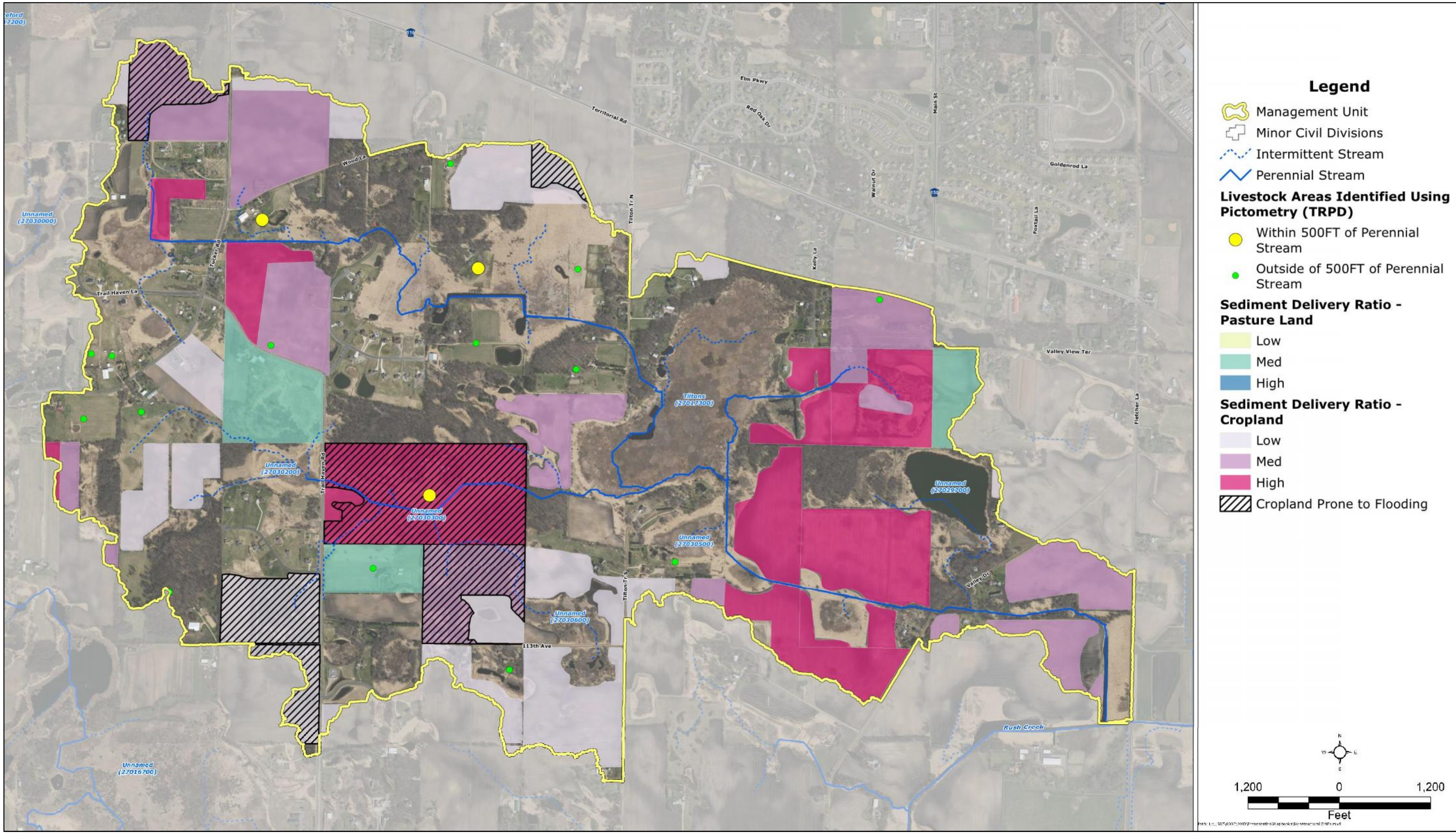


Figure 8.2. Tilton's MU fields and livestock operations for non-structural BMPs.

8.9 TILTON'S SUMMARY AND RECOMMENDATIONS

The primary objectives of this section were to identify the issues of concern in the Tilton's MU and watershed management strategies to address these concerns. These objectives were accomplished through review of existing/historic water quality data, GIS data/analyses, public input/local knowledge, and finally, identification of structural and non-structural practices to address issues of concern. Below is a summary of the final results and recommendations for the Tilton's Management Unit.

- **Explore potential wetland restorations with willing landowners.** Three of the top BMPs in terms of TP load reduction were wetland restoration projects (DP-88, DP-90, DP-89). Implementing wetland restorations will help address TSS and TP loading and flooding/altered hydrology.

- **Implement Alternative Tile Intakes where wetland restorations are not feasible.** Two of the top load reduction practices and three of the top cost-benefit practices are installation of ATIs in depression areas (Table 8.6). ATIs represent a cost-effective approach to reducing TSS and TP loads and temporarily slowing the flow of water on the landscape.

- **Implement grassed waterways and/or other stabilization practices in high sloped areas.** Three grassed waterways were identified in areas along concentrated flow paths with high slopes. All three of these practices ranked in the top 10 in terms of TP load reduction and cost-benefit. Although this MU is characterized by low slopes, implementing these practices in priority areas will help reduce TSS and TP loading to downstream resources.

- **Identify and implement animal husbandry and pasture management BMPs.** The TRPD animal inventory identified three potential livestock operations located within 500 feet of the stream. These sites should be targeted first for landowner outreach and BMP implementation such as runoff controls, improvements to manure storage systems, rotational grazing, and resource exclusion. Implementing these types of BMPs will help reduce TP loading and E. coli concentrations throughout the Management Unit and the Elm Creek watershed.

- **Identify and implement manure management and soil health BMPs.** The field characterization tool identified 13 agricultural fields with "High" delivery potential. These fields should be targeted first for landowner education, outreach, and BMP implementation such as cover crops, no-till or conservation till, and development of site specific manure management plans. Implementing these types of practices and controls will help address many of the issues/concerns within this Management Unit, including soil erosion, TSS/TP/E. coli loading, and water retention.

- **Septic system inspections and upgrades.** The septic system analysis suggest 59 systems are likely located within 500 feet of perennial streams, 14 of which were sold and/or built prior to 1990. These systems should be targeted first for landowner outreach and septic inspection to determine current status and condition. Any system that is an imminent threat to public health and safety and/or are failing to protect groundwater should be upgraded to meet current rules and standards. Addressing failing septic will help reduce TP and E. coli loading to surface and groundwater throughout this Management Unit.

9.0 Summary and Recommendations

9.1 STRUCTURAL PRACTICES

The previous report sections and figures and tables in Appendix D detail the identified structural practices. Table 9.1 summarizes structural practices by type and Management Unit. Table 9.2 summarizes the top ten practices in terms of load reduction within the overall Study Area.

Table 9.1. Summary of identified priority practices by Management Unit.

Practice	Parameter	Management Unit					
		Upper Rush Creek	Lake Jubert	Lower Rush Creek	South Tributary	Lake Henry	Tilton's
Alternative Tile Intakes	Count	17	11	15	40	2	5
	Total Const. Cost	$66,300	$45,900	$59,100	$159,000	$10,700	$14,700
	Total P removed	73 lbs/yr	61 lbs/yr	56 lbs/yr	172 lbs/yr	20 lbs/yr	5 lbs/yr
Bioreactors	Count	4	2	3	3	0	1
	Total Const. Cost	$46,300	$21,700	$27,100	$32,900	--	$11,000
	Total P removed	19 lbs/yr	10 lbs/yr	7 lbs/yr	10 lbs/yr	--	2 lbs/yr
Grassed Waterways	Count	12	5	11	18	2	3
	Total Const. Cost	$102,300	$48,200	$79,000	$142,800	$14,800	$25,100
	Total P removed	112 lbs/yr	60 lbs/yr	63 lbs/yr	206 lbs/yr	41 lbs/yr	13 lbs/yr
Saturated Buffers	Count	10	1	7	6	1	4
	Total Const. Cost	$81,900	$8,000	$57,800	$48,200	$8,400	$32,700
	Total P removed	40 lbs/yr	3 lbs/yr	22 lbs/yr	17 lbs/yr	5 lbs/yr	6 lbs/yr
Wetland Restorations	Count	18	11	16	43	2	5
	Total Const. Cost	$962,000	$828,000	$974,000	$3,140,000	$102,400	$161,000
	Total P removed	271 lbs/yr	104 lbs/yr	236 lbs/yr	720 lbs/yr	41 lbs/yr	9 lbs/yr

Table 9.2. Summary of identified priority practices in the Study Area.

Rank	BMP ID	Management Unit	BMP Type	Estimated Benefits Storage (acre-ft)	Estimated Benefits TSS (tons/yr)	Estimated Benefits TP (lbs/yr)	Construction Cost	20-Year Life Cycle Cost	$/lb/yr TP Removed	Delivery Potential
Top practices in terms of load reduction (TP)										
1	WR-3	South Tributary	Wetland Rest.	126.8	156.9	202.8	$713,900	$867,300	$210	High
2	WR-5	Lower Rush Creek	Wetland Rest.	33.1	117.4	97.1	$167,900	$197,900	$100	High
3	GW-15	South Tributary	G. Waterway	0.0	47.4	84.1	$17,700	$66,200	$40	Med
4	WR-1	South Tributary	Wetland Rest.	17.8	62.4	80.7	$70,000	$74,700	$50	High
5	DP-26	South Tributary	Wetland Rest.	9.7	579.3	77.3	$101,700	$110,000	$70	High
6	DP-81	Lower Rush Creek	Wetland Rest.	5.3	219.8	60.9	$97,000	$104,800	$90	High
7	DP-61	Upper Rush Creek	Wetland Rest.	4.4	229.5	54.3	$81,600	$88,000	$80	Med
8	WR-4	Upper Rush Creek	Wetland Rest.	20.0	46.8	48.5	$119,800	$140,200	$140	High
9	DP-58	Upper Rush Creek	Wetland Rest.	6.5	248.6	39.6	$118,000	$127,800	$160	Med
10	GW-2	South Tributary	G. Waterway	0.0	20.6	36.6	$11,100	$36,800	$50	Low

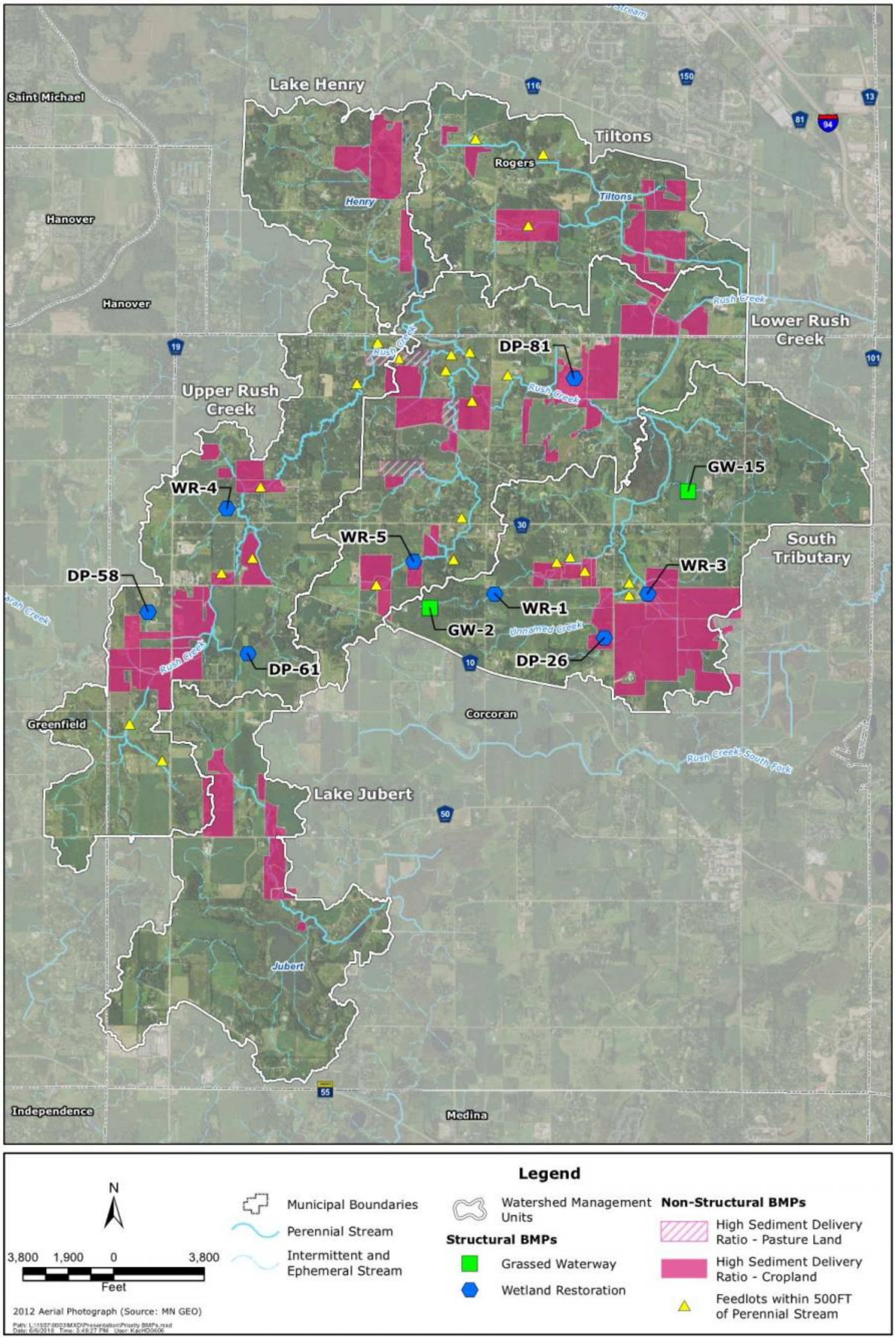


Figure 9.1. Priority projects and practices in the Study Area.

9.2 NONSTRUCTURAL PRACTICES

9.2.1 Nonstructural Practice Focal Areas

Table 9.3 summarizes nonstructural practice focal areas identified through modeling and the GIS analysis as well as comments from staff and the public. The frequency of comments reporting sediment accumulating in streams, ditches, and culverts indicates a need to focus on preventing erosion and soil loss. Fields with high sediment delivery potential are priorities not only for practices such as buffers and grassed waterways, as well as pasture and feedlot/livestock management, manure application management, and soil health management.

In Table 9.3 for the Lake Henry MU, the top figure in each cell are the focal areas tributary to Lake Henry, while the bottom figures in each cell are the focal areas downstream of the lake, tributary to the outlet channel.

Table 9.3. Summary of priority nonstructural practice focal areas by MU.

Management Unit	Fields with High Sediment Delivery Potential	Within 500 feet of Stream		Other
		Animal Operations (animal units)	SSTS Likely Pre-1990	
Upper Rush	18	7 (37)	43	Sediment accumulation in ditches and culverts
Lake Jubert	9	0 (0)	4	Seasonal flooding north of lake and downfalls in channel; monitoring data needed
Lower Rush	26	9 (56)	46	Localized flooding, sediment in ditches and culverts
South Tributary	19	5 (32)	32	Localized flooding, sediment in ditches and culverts
Lake Henry	2 (to lake) 4 (to stream)	7 (104) 0 (0)	15 3	Internal load and carp study needed
Tilton's	13	0 (0)	14	-
Totals	89	28 (229)	142	

9.2.2 Other Nonstructural Practices

Stream Restoration and Stabilization. As noted in section 2.5 above, a condition assessment has been completed at least twice on the primary streams in the Elm Creek watershed, and several locations on Upper Rush Creek had been identified as in need of repair and restoration. In addition, aerial photo inspection of the stream shows numerous locations where the stream meanders through a narrow band of buffer, typically either wetland or dense woodland, with erosion and deposition on inner and outer bends. This may be contributing to sediment accumulation in the stream and at culverts and to excess nutrient concentrations. In many cases, the restoration action may be as simple as thinning the tree canopy to allow more sunlight to penetrate to the streambank and allow for the growth of a stabilizing understory.

Stream restoration projects provide multiple benefits aside from simply stabilizing streambanks to prevent erosion. They are an opportunity to enhance habitat, restore more natural structure and function, enhance buffers, and improve water quality. A targeted stream stabilization program that undertakes small projects with the cooperation of willing landowners can over time achieve the same benefits as more costly restorations of longer segments.

Education and Outreach. Property owners may be willing to undertake BMPs but are unsure of what to do. A program of education and outreach that targets useful information to the different stakeholders may increase the number of property winners willing to undertake voluntary actions. Demonstration projects may also be helpful to help those stakeholders understand and visualize how that BMP may fit into their own properties and operations.

SSTS Outreach. Education and outreach specifically targeted to homeowners with SSTS focused on proper maintenance and the benefits of SSTS upgrades, can link those actions to protecting downstream resources.

10.0 References

Fiener, P., Auerswald, K. 2002. Effectiveness of Grassed Waterways in Reducing Runoff and Sediment Delivery from Agricultural Watersheds. Journal of Environmental Quality. Vol. 32 No. 3, p. 927-936.

Lehr, R. 2015. Elm Creek Watershed Stressor Identification Report. pca.state.mn.us/sites/default/files/wq-iw11-04w.pdf

Mekonnen, M., Keesstra, S.D., Stroosnijder, L., Baartman, J.E.M., Maroulis, J. 2015. Soil Conservation Through Sediment Trapping: A Review. Land Degrad. Develop. 26: 544-556.

Minnesota Geospatial Commons. 2015. gisdata.mn.gov/

Minnesota Pollution Control Agency. 2016a. Elm Creek Watershed Management Commission Watershed Total Maximum Daily Load. pca.state.mn.us/sites/default/files/wq-iw11-04e.pdf

Minnesota Pollution Control Agency. 2016b. Elm Creek Watershed (Upper Mississippi River Basin) Watershed Restoration and Protection Strategy. pca.state.mn.us/sites/default/files/wq-ws4-27a.pdf

USDA NRCS. 2014. Soil Survey Geographic (SSURGO) Data Base. lib.ncsu.edu/gis/nrcs.html

Wenck Associates. 2015. Elm Creek Watershed Management Commission Third Generation Watershed Management Plan. elmcreekwatershed.org/management-plan.html