Diamond Creek Subwatershed Assessment Report

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Executive Summary

The purpose of the Diamond Creek Subwatershed Assessment (SWA) is to evaluate conditions in the Diamond Creek Hydrologic Unit Code (HUC) 12 Subwatershed portion of the Elm Creek Watershed. Impairments in SWA Study Area include Diamond Lake (nutrients) and Diamond Creek (*E. coli*, dissolved oxygen, and macroinvertebrate and fish communities). French Lake in the study area is not formally listed as impaired due to its status as a wetland, however it also exhibits high nutrients in the summer.

The 15.67 square mile Study Area is primarily in the City of Dayton, Minnesota, with a sizable area in the City of Rogers, and a small portion within the City of Champlin. The Study Area was subdivided into five 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, wetlands, 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, septic system locations, water quality and stream conditions. City of Dayton, City of Rogers, City of Champlin, Hennepin County, Three Rivers Park District (TRPD), Elm Creek Watershed Management Commission (ECWMC), Diamond Lake Association, and residents in the Study Area also contributed information about conditions and problem areas.

Several methods and tools were used to help identify the most feasible, cost-effective, and beneficial locations for improvements to address the several impairments in this Study Area, including both structural and nonstructural (i.e., land management) 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. Where possible, practices were prioritized based on several factors, and the most technically feasible were then evaluated for estimated cost and pollutant load reductions. The top structural practices by cost effectiveness and pollutant load removals were identified for each MU. In addition, each MU-scale assessment also identified areas for potential non-structural practices, such as livestock management and septic outreach, where outreach to property owners would have the most potential impact on water quality improvement.

Abbreviations

ACPF	Agricultural Conservation Planning Framework
ATI	Alternative Tile Intake
BMP	Best Management Practice
BWSR	Board of Water and Science Resources
CFS	Cubic Feet per Second
CLP	Curly leaf pondweed
DEM	Digital Elevation Model
DO	Dissolved Oxygen
ECWMC	Elm Creek Watershed Management Commission
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LiDAR	Light Detection and Ranging
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MU	Management Unit
NRCS	National Resource Conservation Service
SSTS	Subsurface Sewage Treatment System
SWA	Subwatershed Assessment
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus

TRPD	Three Rivers Park District
TSS	Total Suspended Solids
WASCOB	Water and Sediment Control Basin
WMWA	West Metro Water Alliance
WRAPS	Watershed Restoration and Protection Strategies

1.0 INTRODUCTION

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). Compared to the previous studies, 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 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 Diamond Creek SWA is to evaluate conditions in that part of the Elm Creek watershed that drains Diamond Lake and Diamond Creek. The outcome of this SWA will be a list of the most feasible and cost-effective practices to address the requirements of the several impairments in this study area. City, Hennepin County, TRPD, and ECWMC members/staff and other partners can then work with willing landowners to implement these practices.

1.1 STUDY AREA

The Study Area is 10,031 acres (15.67 square miles) (Table 1.1), primarily in the City of Dayton, Minnesota, with a sizable percent in the City of Rogers, and a small portion within the City of Champlin. The Study Area includes areas that drain to Elm Creek upstream of Hayden Lake.

Table 1.1. Study Area by City.

City	Acres	Percent of Total Study Area
Dayton	8,760	87%
Rogers	1,230	12%
Champlin	41	<1%
Total	10,031	

The Study Area was subdivided into five Management Units (MUs) to provide a finer scale of assessment (Table 1.2 and Figure 1.1). Two of the four MUs represent the direct drainage area to the two lakes in Study Area, Diamond Lake and French Lake, which also represent the headwaters of Diamond Creek. One MU, Hayden Lake North and South, are drainage areas that bypass Diamond Creek and flow directly to Hayden Lake. The final MU, Diamond Creek, is the drainage area downstream of Diamond and French Lakes that flows directly to Diamond Creek.

Table 1.2. Management Unit areas.

Management Unit	Acres	Percent of Total Study Area
Diamond Lake	2,524	25%
French Lake	901	9%
Diamond Creek	2,709	27%
Hayden Lake South	2,323	23%
Hayden Lake North	1,081	11%
Not Contributing Area	493	5%
Total	**10,031**	**100%**

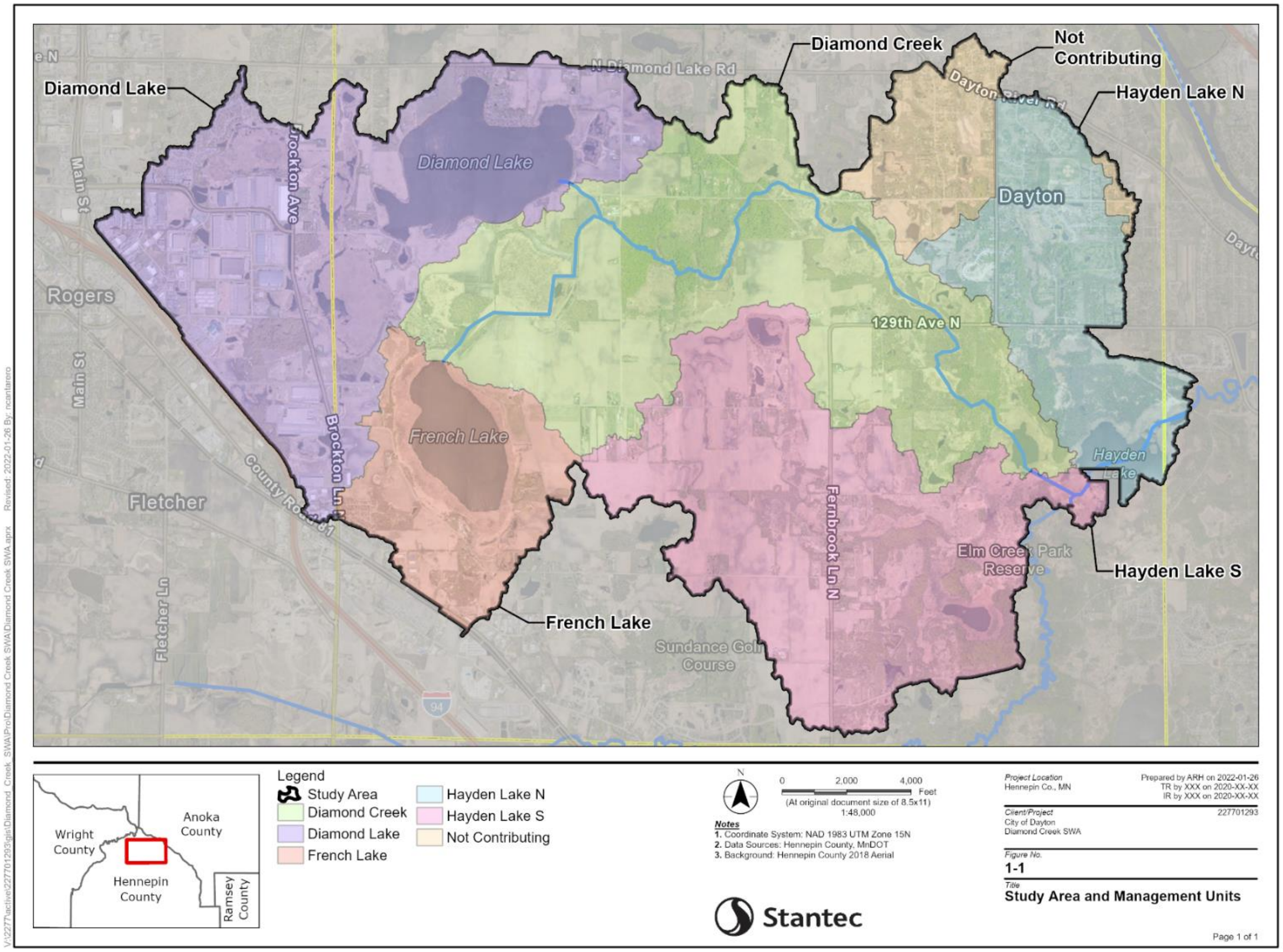

Figure 1.1. Study Area and Management Units.

1.2 IMPAIRMENTS

Diamond Creek does not meet state water quality standards for several parameters, and it has been designated as an impaired water (Table 1.3). Diamond Lake does not meet state water quality standards for nutrients and has also been designated an Impaired Water. French Lake is very shallow (max depth four feet or less) and is therefore considered a wetland and not subject to the State's lake water quality standards. However, monitoring data collected by TRPD for French Lake indicate the wetland has very high phosphorus concentrations and is hypereutrophic (see Appendix A). Improvements to French Lake will be needed to meet TMDL goals for Diamond Creek. Appendix A of this report establishes a lake response model and potential phosphorus reduction goals to help improve French Lake and downstream waterbodies (i.e., Diamond Creek) to help meet TMDL goals.

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
Diamond Lake	27-0125	Aquatic recreation	Nutrients (Total Phosphorus)
Diamond Creek	07010206-525	Aquatic life/ recreation	*E. coli*, Dissolved Oxygen, M-IBI[1], F-IBI[1]

[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*.

2.0 METHODS

2.1 REVIEW OF LOCAL WATER PLANS AND STUDIES

Table 2.1 summarizes the data, studies and models that were compiled and reviewed for the Diamond Creek Subwatershed Assessment study. All information in Table 2.1 was supplied by the City of Dayton, the City of Rogers, Elm Creek Watershed Management Commission (ECWMC), Hennepin County Energy and Environment Department, Three Rivers Park District (TRPD), or is available online. Appendix B provides more detailed reviews of each plan/study summarized in Table 2.1.

Table 2.1. Summary of data, studies, and models reviewed.

Data/Study	Description	Source
Diamond and French Lake Fish Assessments (2019)	General fisheries assessment for Diamond and French Lake, and common carp population assessment (Diamond Lake only) conducted in the summer of 2019	Wenck/ Stantec
Diamond Lake water quality data (1975-2020)	Water quality data collected by various parties including Secchi depth, surface TP, Chl-a, temperature and DO profiles	MPCA (link)
French Lake water quality data (2001-2013)	Water quality data collected by TRPD including Secchi depth, surface TP, Chl-a	MPCA (link)
Grass Lake (wetland) water quality data (2015)	Water quality data collected by TRPD in 2015 at the outlet of Grass Lake to Diamond Lake which includes water level, TP, SRP, TN, and TSS	TRPD
Diamond and French Lake Bathymetry	Water quality data collected by TRPD including Secchi depth, surface TP, Chl-a, temperature and DO profiles	TRPD
Diamond Lake Sediment Analysis (from TMDL)	Internal Phosphorus Loading and Sediment Phosphorus Fractionation Analysis for Diamond Lake	UW – Stout & TRPD
Diamond Lake Aquatic Vegetation Report (2020)	Report summarizing results of historic and 2020 vegetation survey results for Diamond Lake	DNR (link)
City of Dayton Local Water Management Plan (2018)	City of Dayton water plan to guide projects, provide effective allocation of resources, and a funding plan for projects and programs for 2018- 2027.	City of Dayton
City of Rogers Stormwater GIS Files	GIS files provided by City of Rogers including subwatersheds, stormsewers, outfalls, catch basins, and existing BMPs	City of Rogers
Physical and Ecological Classification of Elm Creek and its Tributaries (2000)	Elm Creek channel survey, inventory, and recommendations conducted in the fall of 1999 and spring of 2000 using Rosgen Level I and II classifications, Wisconsin Stream Classification Guidelines, Schumm Channel Evolution Model, and the Henshaw Stability Rating	Dindorf-Miesbaur/ ECWMC
Elm Creek Channel Study (2007)	Report quantifying current conditions of the stream channels within Elm Creek and recommended management practices	Bonestroo/ ECWMC

Data/Study	Description	Source
Diamond Creek Channel Assessment (2012)	Channel assessment conducted by TRPD in 2012 to document channel dimensions, bank stability, vegetation, and overall condition within the Three Rivers Park portion of Diamond Creek	TRPD
ECWMC Watershed TMDL (2016)	TMDL for all impaired waterbodies in Elm Creek Watershed, including Diamond Lake and Diamond Creek	TRPD/ ECWMC/ MPCA (link)
Elm Creek WRAPS Report (2016)	Watershed Restoration and Protection report detailing restoration and protection strategies for all impaired and non-impaired waterbodies in Elm Creek Watershed	TRPD/ ECWMC/ MPCA (link)

2.2 REVIEW OF MONITORING DATA

ECWMC periodically monitors water quality and flow at five stations within the Study Area and had collected data at other stations to support development of the TMDL. Appendices B and C provide detailed reviews of the historic lake and stream monitoring data that have been collected in the SWA Study Area. In general, nutrients, sediment and other water quality parameters are poor in the upstream headwater lakes within the Study Area (i.e., Diamond and French Lakes) and remain poor downstream throughout Diamond Creek.

2.3 PUBLIC AND AGENCY INPUT

The Study process was collaborative and included a Stakeholder Team of the ECWMC technical advisors from Hennepin County Energy and Environment Department; representatives from the cities of Dayton and Rogers; representatives from Diamond Lake Association; and the City's consultant met two times to provide input, review data, and discuss strategies.

2.4 BMP SITING AND ANALYSIS

Best management practices (BMPs) were sited and evaluated using a combination of modeling tools, GIS desktop analysis, aerial photo interpretation, site visits, and input from City, County, TRPD, and ECWMC commissioners and staff. Below is a brief description of the BMP siting process and methods used to assess cost/benefit of various practice types.

2.4.1 Rural/Agricultural BMPs

The Agricultural Conservation Planning Framework (ACPF) was the primary tool used to identify potential locations in the Study Area for rural/agricultural BMPs. 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 (https://acpf4watersheds.org). ACPF was used to evaluate the applicability of the following agricultural BMP types in the Study Area:

- Grassed Waterways

- Water and Sediment Control Basins (WASCOBs)
- Wetland Restorations
- Alternative Tile Intakes (ATIs)

Appendix C provides a detailed description of how the ACPF tool was setup for the Study Area and the process used to estimate planning level costs and benefits for each BMP type. 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. These activities include sediment removal, vegetation maintenance, filter maintenance and monitoring.

2.4.2 Urban/Residential BMPs

A majority of the Study area is undeveloped agricultural land, however there are several areas that have been developed and/or are currently undergoing development. Some of the residential developments have incorporated BMPs to treat stormwater to reduce nutrients and sediment, and to moderate the rates and volumes of runoff. Appendix D provides a detailed review of some of the developed and developing areas within the Study Area, including lot-level urban/residential BMP options such as regional treatment ponds, sump manholes, rain gardens, and swales.

2.4.3 Non-Structural BMPs

Several non-structural BMPs were identified throughout this study's planning process as being as important to meeting water quality goals and targets as the structural practices discussed above. 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 Study Area. These efforts are outside the scope of this assessment; however, this report does identify general areas and MUs that could be targeted for non-structural BMPs using existing data, modeling tools (ACPF), and input from the public and city/county staff. Non-structural BMPs that were considered for this assessment include:

- Pasture and Feedlot Management
- Manure Management
- Soil Health and Management
- SSTS Inspection and Repairs/Replacements
- Education and Outreach

Appendix E provides a detailed discussion of the non-structural BMPs considered for this report.

2.4.4 Stream Restoration and Channel Improvements

The Elm Creek TMDL report, WRAPS report, and local water plans all identified stream restoration and channel improvements as priority strategies to meet TMDL goals within the Study Area. 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.

The ECWMC has at least twice reviewed streambank conditions in Diamond Creek. The 2000 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, and 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. See Appendix B for a detailed review of this study. This report provided the following in-stream/channel recommendations for Diamond Creek:

- Stabilize Channels Through Natural Channel Design
- Improve In-stream Habitat Conditions
- Restore Natural Hydrology
- Increase Sinuosity in Specific Target Areas

Additionally, Appendix F highlights a specific location that was recently identified for in-stream restorations/improvements.

2.4.5 In-Lake Management

The Diamond Lake TMDL calls for an average annual TP reduction of approximately 2,000 lbs/yr for Diamond Lake to meet State water quality standards. Of this reduction, it was estimated that approximately 30% (~640 lbs/yr) comes from internal sources within Diamond Lake. Based on the French Lake water quality modeling analyses presented in Appendix G of this report, approximately 73% (1,483 lbs/year) of the total annual P load to French Lake is likely from internal loading.

To meet water quality goals, internal loading will need to be reduced by approximately 80% for Diamond Lake and 61% for French Lake. The TMDL and WRAPS Studies indicate internal load in these lakes is likely a combination of phosphorus release from the sediment, rough fish activity, wind/wave action, and breakdown of submerged aquatic vegetation (SAV). Appendix G presents two potential strategies, alum treatment and lake drawdown, to improve biotic conditions and address internal nutrient loading in Diamond Lake and French Lake.

3.0 DIAMOND LAKE MANAGEMENT UNIT

The Diamond Lake management unit (MU) is situated just east of Rogers, Minnesota. It is located to the northwest of the French and Hayden lakes management units, and to the west of the Diamond Creek MU. The southern boundary of the MU runs along Highway 94, with the rest of the MU stretching to the northeast until it reaches N Diamond Lake Road (Figure 3.1). Urban and developed areas dominate the western portion of the MU, with agricultural land and open water comprising the eastern area. Diamond Lake, located in the northeastern corner of the MU, is surrounded by largely agricultural practices, and fails to meet the state water quality standards for several metrics. The 405-acre lake, with a max depth of eight feet, has an outlet to Diamond Creek on the eastern shoreline, which offers a high potential for nutrient exchange to the surrounding watershed area. This section is intended to provide an overview of the Diamond Lake Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

3.1 LAND USE

Urban/developed (33%) is the primary land use in this MU, closely followed by corn/soybean rotations (20%) and grassland/pasture (9%) from the Metropolitan Council's Generalized Land Use (2020) assessment of land use/land cover (Table 3.1). Land within this MU is likely to be developed in the near future, so an increase in urban/developed land is expected in contrast with a decrease in cropland.

Table 3.1. Diamond Lake land use.

Land Use Type	Diamond Lake	
	Acres	Percent
Crops	506	20%
Pasture/Hay	231	9%
Wetlands	364	14%
Urban/Developed	844	33%
Forest/Shrubland	145	6%
Open Water	429	17%
Barren	2	<1%
Other Cropland	2	<1%
Total	2,523	100%

Source: 2020 Generalized Land Use (Met Council).

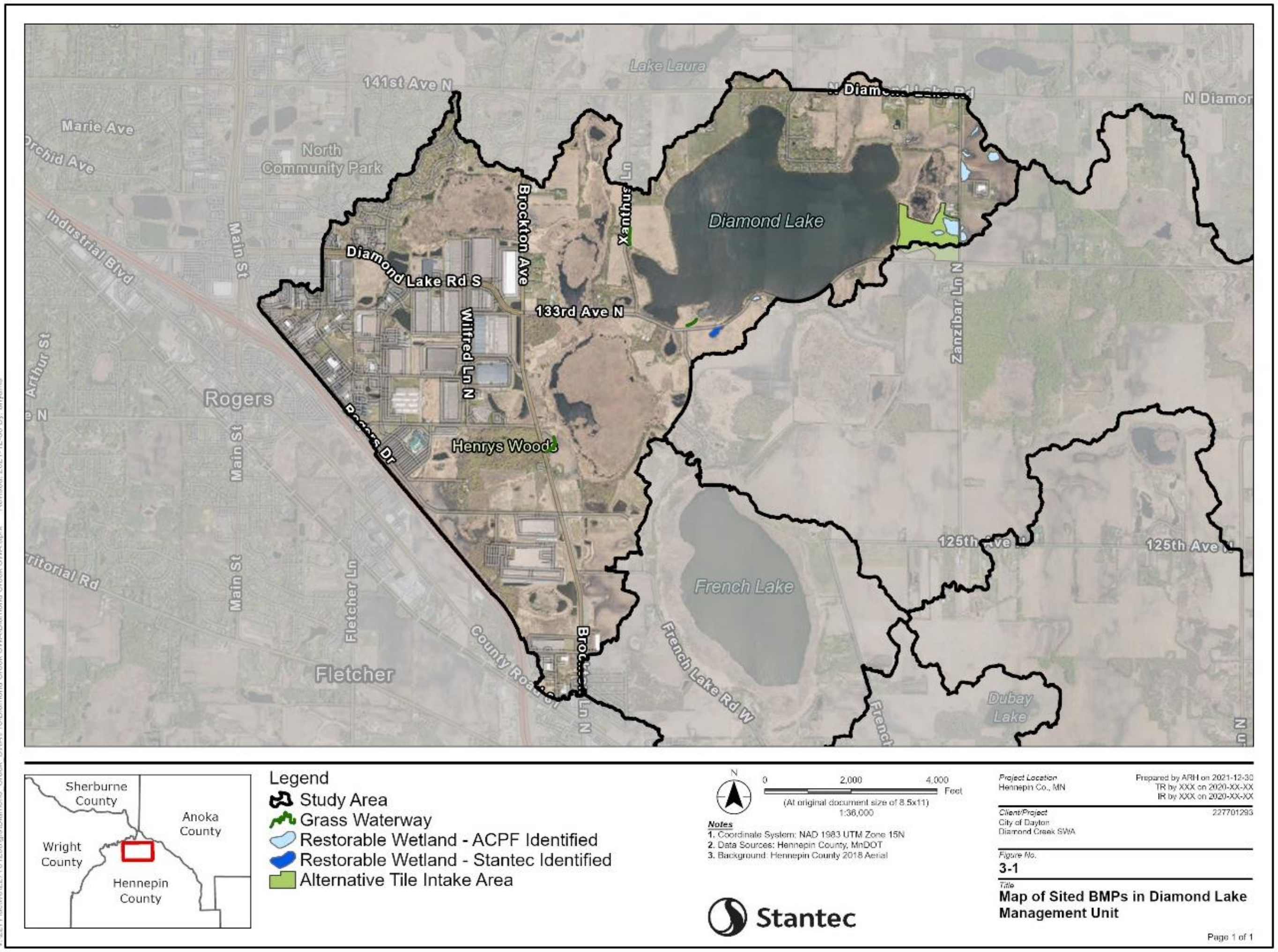

Figure 3.1. Map of sited BMPs in Diamond Lake MU

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 Diamond Lake MU are predominantly groups C and C/D 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. Diamond Lake hydrologic soil groups

Hydrologic Soil Type	Diamond Lake	
	Acres	Percent of MU
A	--	--
A/D	--	--
B	15	<1%
B/D	337	14%
C	967	38%
C/D	795	32%
D	--	--
Unclassified/ Open Water	409	16%
Total	2523	100%

Source: SSURGO.

3.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Diamond Lake MU were characterized using the Diamond Creek hydro-conditioned DEM. Slopes throughout are low compared to the other MUs in the Study Area (Table 3.3). This MU also has the lowest amount of cropland in production compared to the other MUs.

Table 3.3. Diamond Lake slope and drainage summary

Parameter	Percent of MU
Percent of subwatershed >5% slope	20%
Percent of subwatershed >10% slope	9%
Percent of subwatershed >18% slope	6%

Percent of subwatershed in cropland production	20%

3.4 ANIMAL AGRICULTURE

Table 3.4 provides a summary of MPCA registered feedlots, TRPD livestock inventory, and the City of Dayton's animal activities inventory for the Diamond Lake MU. These results indicate most livestock operations throughout the MU are small operations and are therefore unregistered. The Diamond Lake MU has the fewest overall livestock sites of all the MUs. Only feedlots with 10 animal units in shoreland areas, and 50 animal units outside shoreland areas, are required to register with the MPCA.

Table 3.4. Diamond Lake livestock inventory.

Parameter	Diamond Lake		
	MPCA Registered Feedlots	TRPD Animal Inventory	Dayton Animal Inventory
Total Sites	0	6	0
Primary Animal Type	--	Cows	--
Sites within 500 feet of perennial stream	0	0	0

3.5 SEPTIC ANALYSIS

A significant change to state administrative rules occurred in 1995 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. Thus, systems constructed prior to 1995 have not likely been inspected for compliance and may be less likely to conform to the new rules. 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 1995, and thus may be less likely to conform to the new rules. That same analysis also pin-pointed those systems that are potentially 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 Diamond Lake septic analysis (Table 3.5) suggest that at least 18 homes were constructed prior to 1995.

Table 3.5. Diamond Lake septic estimates.

Septic Systems Constructed	Total Systems in MU		Systems where parcel is within 500 ft of Stream	
	Number	Percent of MU	Number	Percent of MU
Prior to 1995	18	78%	0	--
1995 and after	5	22%	0	--

Totals	23	100%	0	--

3.6 KEY ISSUES AND CONCERNS

To establish critical opportunities for management, information and data included in the appendices and references was reviewed. Listed below is and overview of the most pressing issues within the Diamond Lake MU.

- ***Water Quality*** monitoring shows that Diamond Lake fails to meet water quality standards (Table 3.6) for both TP and chlorophyll-a (see Appendix A Figures A-3 and A-5).
  - Large presence of curlyleaf pondweed (CLP) in the lake.
  - High TP and chlorophyll-a are likely driven by nutrient loading from surrounding agricultural practices and Grass Lake, shown in Appendix H.
  - Diamond Lake requires an estimated TP reduction of approximately 2,000 lbs/yr to meet state water quality standards.
    - Of this reduction, approximately 30% (~640 lbs/yr) comes from internal sources.
- ***Land use*** is primarily urban/developed, with the least amount of cropland when compared to the other MUs. However, increased development of cropland is expected in the near future.
- ***Slopes*** are low in comparison to other management units, with only 20% of the MU having a slope greater than 5%.
- ***Livestock animal*** operations least prevalent in this MU. Livestock inventories suggest that most livestock operations within the MU are small, and therefore unregistered.
- ***Septic*** analysis indicates that 18 systems in the MU were constructed before 1995, none of which are within 500 feet of a stream.

Table 3.6 Water quality standards for shallow lakes in the North Central Hardwood Forest Ecoregion

Parameter	Shallow Lake Standard
TP	60 µg/L
Chl-a	20 µg/L
Secchi depth	>1 m

3.7 BMP SITING AND OPTIONS

Structural BMPs for the Diamond Lake MU were sited using the methods as described in Section 2.4. These tools identified 21 potential BMP options throughout the Diamond Lake MU (Figure 3.1). Below is a brief overview of the different BMPs identified through this analysis, which is also summarized in Table 3.6.

- **Grassed Waterways:** Three potential sites were identified. TSS and TP load reductions ranged from 0.1-0.8 tons/yr. and 2.6-3.9 lbs/yr, respectively. Cost benefit ranged from $320-$410/lbs of TP removed.
- **Water and Sediment Control Basins:** The ACPF toolbox did not cite 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 (ATI):** Nine potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from 0.3-1.9 tons/yr. and 0.5-2.1 lbs/yr, respectively. Cost benefit ranged from $210-$1,610/pound of TP removed.
- **Wetland Restorations:** Nine potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from 0.2-3.3 acre-ft while TSS and TP load reductions ranged from 0.1-17.7 tons/yr. and 0.7-5.5 lbs/yr, respectively. Cost benefit ranged from $610-$2,830/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 7.5 acre-ft and TSS and TP loading would decrease by approximately 36.2 tons/yr. and 44.85 lbs/yr, respectively. As discussed in Section 2.4, all BMP pollutant load reduction estimates should be viewed as edge of field reductions.

Table 3.7 provides a summary of the top 10 BMP options for the Diamond Lake MU in terms of annual TP load reduction. Appendix C contains a complete summary of all 21 BMP options and their estimated load reduction and cost-benefit.

Table 3.7 Top 10 sited BMPs in Diamond Lake MU

BMP Type	BMP ID	Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)	20-Year Life Cycle Cost	Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)
Wetland	119380	1.1	3.5	5.5	$67,700	$3,000	$980	$610
Wetland	153968	3.3	17.7	5.5	$103,500	$1,600	$290	$950
Grassed Waterways	162	--	0.8	3.9	$24,500	--	$1,600	$320
Wetland	117	0.8	1.7	3.7	$53,400	$3,200	$1,550	$710
Wetland	108410	1	2	3.6	$56,800	$2,900	$1,440	$780
Grassed Waterways	60	--	0.1	3.5	$25,600	--	$11,100	$370
Grassed Waterways	119	--	0.5	2.6	$21,500	--	$2,000	$410
ATIs	106052	--	1.5	2.1	$9,200	--	$300	$210
ATIs	119380	--	1.5	2.1	$21,600	--	$710	$500
Wetland	150442	0.3	0.5	1.8	$43,500	$7,800	$4,340	$1,200

4.0 FRENCH LAKE MANAGEMENT UNIT

The French Lake management unit (MU) is located just east of Rogers, Minnesota. The MU shares its northwestern boundary with the Diamond Lake MU, its northeastern boundary with the Diamond Creek MU, and its eastern boundary with the Hayden Lakes MU (Figure 4.1). The MU is comprised largely of open water and agricultural land, with some developed areas near the western boundary. French Lake is situated in the north central area of the MU and has an outflow to Diamond Creek on its northern shoreline. However, the roughly 320-acre lake is not subject to the State's water quality standards due to its shallow nature (max depth ~4 feet), which considers it a wetland by state definition. For the purposes of this report, French Lake water quality were compared to the State water quality standards for shallow lakes in the North Central Hardwood Forest Ecoregion (see Table 3.6). These standards are a reasonable goal/benchmark for improving water quality in French Lake. This section is intended to provide an overview of the French Lake Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

4.1 LAND USE

Crops consisting of corn/soybean rotations (30%) is the primary land use in this MU from the Metropolitan Council's Generalized Land Use (2020) assessment of land use/land cover (Table 4.1). The French Lake MU also has the most open water (23%) compared to the other MUs. Like the Diamond Lake MU, this MU is also expected to see a conversion of agricultural land in the near future.

Table 4.1. French Lake land use.

Land Use Type	French Lake	
	Acres	Percent of MU
Crops	272	30%
Pasture/Hay	107	14%
Wetlands	149	16%
Urban/Developed	116	13%
Forest/Shrubland	38	4%
Open Water	215	23%
Barren	<1	<1%
Other Cropland	4	<1%
Total	901	100%

Source: 2020 Generalized Land Use (Met Council).

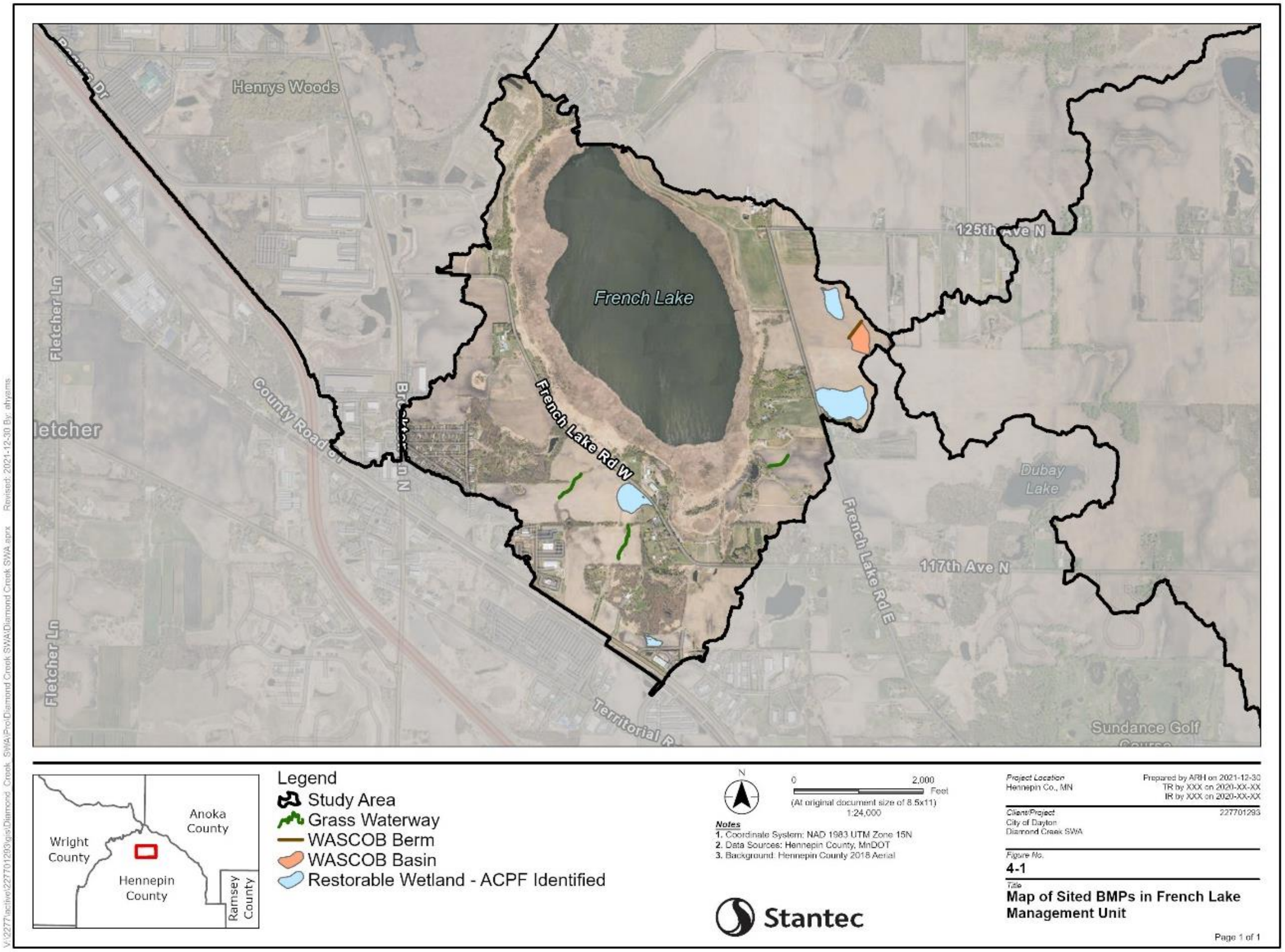

Figure 4.1. Map of sited BMPs in French Lake MU

4.2 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 Diamond Lake MU are predominantly groups C and C/D 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. French Lake hydrologic soil groups

Hydrologic Soil Type	French Lake	
	Acres	Percent
A	--	--
A/D	--	--
B	--	--
B/D	145	16%
C	278	31%
C/D	268	30%
D	--	--
Unclassified/ Open Water	210	23%
Total	901	100%

Source: SSURGO.

4.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the French Lake MU were characterized using the Diamond Creek hydro-conditioned DEM. Slopes throughout are moderate compared to the other MUs in the Study Area (Table 4.3).

Table 4.3. French Lake slope and drainage summary

Parameter	Percent of MU
Percent of subwatershed >5% slope	22%
Percent of subwatershed >10% slope	10%
Percent of subwatershed >18% slope	4%
Percent of subwatershed in cropland production	30%

4.4 ANIMAL AGRICULTURE

Table 4.4 provides a summary of MPCA registered feedlots, TRPD livestock inventory, and the City of Dayton's animal activities inventory for the French Lake MU. These results indicate most livestock operations throughout the MU are small operations and are therefore unregistered. The French Lake MU has the second fewest number of livestock operations compared to the other MUs. This MU is also one of only two that has an active MPCA registered feedlot.

Table 4.4. French Lake livestock inventory.

Parameter	French Lake		
	MPCA Registered Feedlots	TRPD Animal Inventory	Dayton Animal Inventory
Total Sites	1	5	2
Primary Animal Type	Cows	Cows	N/A
Sites within 500 feet of perennial stream	0	0	0

4.5 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. Thus, systems constructed prior to 1995 have not likely been inspected for compliance and may be less likely to conform to the new rules. 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 1995, and thus may be less likely to conform to the new rules. That same analysis also pin-pointed those systems that are potentially 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 French Lake septic analysis (Table 4.5) suggest that at least 15 systems were constructed prior to 1995.

Table 4.5. French Lake septic estimates.

Septic Systems Constructed	Total Systems in MU		Systems where parcel is within 500 ft of Stream	
	Number	Percent of MU	Number	Percent of MU
Prior to 1995	15	71%	0	--
1995 and after	6	29%	0	--
Totals	21	100%	0	--

4.6 KEY ISSUES AND CONCERNS

To establish critical opportunities for management, information and data included in the appendices and references was reviewed. Listed below is and overview of the most pressing issues within the French Lake MU.

- **Water quality** Due to French Lake's shallow (max depth ~4 feet) nature, it is considered a wetland and not regulated by the state's water quality standards.
  - Very high mean summer TP and chlorophyll-a concentrations
  - Approximately 73% (1,483 lbs/year) of the total annual P load is likely from internal loading.
- **Land use** is primarily cropland consisting of corn/ soybean rotations (30%) and has the most open water (23%) of all the MUs. This MU is also expected to see a growth in the development of agricultural lands in the near future.
- **Slopes** are low in most of the MU, with 22% having a slope greater than 5%.
- **Livestock animal** concentrations are the second fewest in this MU, with most livestock operations being small and therefore unregistered. One feedlot is present in this MU, however, none of the livestock operations with the MU fall within 500 feet of a perennial stream
- **Septic** analysis indicates at least 15 systems were built prior to 1995. None of these occur within 500 feet of a stream.

4.7 BMP SITING AND OPTIONS

Structural BMPs for the French Lake MU were sited using the ACPF Toolbox as described in Section 2.4. These tools identified 12 potential BMP options throughout the French Lake MU (Figure 4.1). Below is a brief overview of the different BMPs identified through this analysis.

- **Grassed Waterways:** Three potential sites were identified. TSS and TP load reductions ranged from 0.2-0.3 tons/yr. and 3.4-5.3 lbs/yr, respectively. Cost benefit ranged from $270-$410/pound of TP removed.
- **Water and Sediment Control Basins:** One potential site was identified. TSS and TP load reductions are 0.7 tons/yr. and 17.9 lbs/yr, respectively. Cost benefit was $70/pound of TP removed.
- **Alternative Tile Intakes:** Four potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from 0.2-0.4 tons/yr. and 0.8-2.1 lbs/yr, respectively. Cost benefit ranged from $350-$5,810/pound of TP removed.
- **Wetland Restorations:** Four potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from 0.5-20.4 acre-ft while TSS and TP load reductions ranged from 0.2-13.6 tons/yr. and 2.5-14 lbs/yr, respectively. Cost benefit ranged from $390-$2,980/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 30.7 acre-ft and TSS and TP loading would decrease by approximately 28.3 tons/yr. and

63.3 lbs/yr, respectively. As discussed in Section 2.4, all BMP pollutant load reduction estimates should be viewed as edge of field reductions.

Table 4.6 provides a summary of the top 10 BMP options for the French Lake MU in terms of annual TP load reduction. Appendix C contains a complete summary of all 12 BMP options and their estimated load reduction and cost-benefit.

Table 4.6 Top 10 sited BMPs in French Lake MU

BMP Type	BMP ID	Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)	20-Year Life Cycle Cost	Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)
WASCOBs	BMP-5	--	0.7	17.9	$25,900	--	$1,990	$70
Wetland	682785	7	13.6	14	$108,100	$800	$400	$390
Wetland	546117	2.8	3.1	8	$83,200	$1,500	$1,340	$520
Grassed Waterways	100	--	0.3	5.3	$28,700	--	$5,400	$270
Grassed Waterways	72	--	0.2	3.5	$24,000	--	$6,800	$350
Grassed Waterways	51	--	0.2	3.4	$27,500	--	$8,100	$410
Wetland	611406	20.4	9	3.1	$187,000	$500	$1,040	$2,980
Wetland	767557	0.5	0.2	2.5	$48,200	$4,400	$12,830	$970
ATIs	546117	--	0.4	2.1	$34,000	--	$4,440	$810
ATIs	682785	--	0.2	1.4	$46,400	--	$9,400	$1,710

5.0 DIAMOND CREEK MANAGEMENT UNIT

The Diamond Creek Management unit is located centrally within the other three management units, with Diamond and French Lakes MUs to the west and the Hayden Lakes MU acting as the southern boundary (Figure 5.1). This MU is located around Diamond Creek, which serves as the major connecting tributary of the four management units. The creek starts on the western border, receiving water from both French and Diamond Lakes, as well as their surrounding wetlands. The creek then meanders east, and eventually turns south where it meets Hayden Lake and its surrounding wetland area. This section is intended to provide an overview of the Diamond Creek Management Unit, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

5.1 LAND USE

Crops in the form of corn/soybean rotations (35%) and grassland/pasture (15%) are the primary land use for this MU from the Metropolitan Council's Generalized Land Use (2020) assessment of land use/land cover (Table 5.1). Wetlands (23%) represent the second highest land use type within this MU, which is also the second most among the other MUs. Urban/developed (4%) and open water (1%) are the lowest land use types for the Diamond Creek MU, and the lowest among the other MUs.

Table 5.1. Diamond Creek land use.

Land Use Type	Diamond Creek	
	Acres	Percent
Crops	942	35%
Pasture/Hay	415	15%
Wetlands	612	23%
Urban/Developed	109	4%
Forest/Shrubland	553	20%
Open Water	32	1%
Barren	1	<1%
Other Cropland	45	2%
Total	2,709	100%

Source: 2020 Generalized Land Use (Met Council).

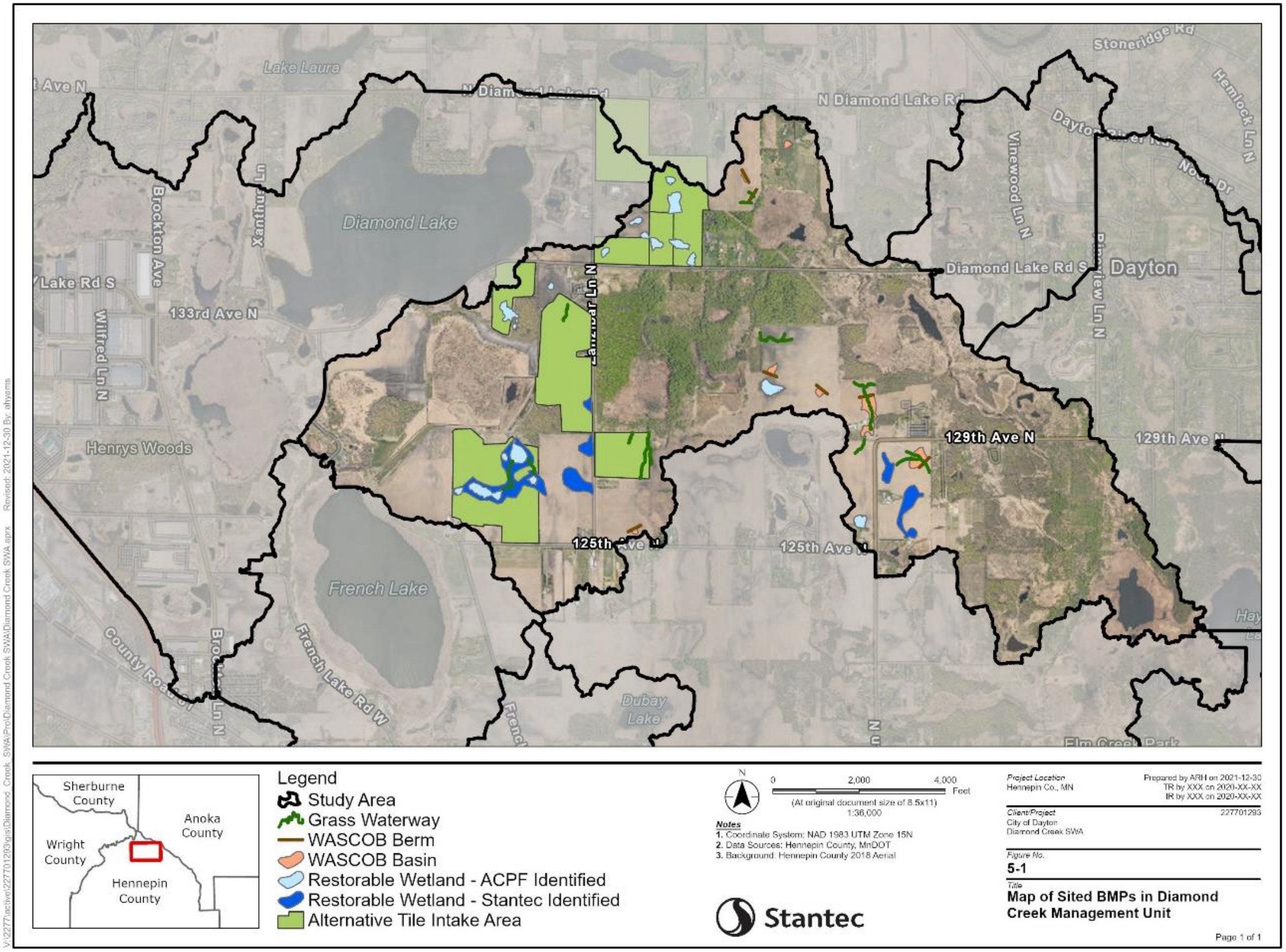

Figure 5.1. Map of sited BMPs in Diamond Creek MU

5.2 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 Diamond Lake MU are predominantly groups C and C/D 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. Diamond Creek hydrologic soil groups

Hydrologic Soil Type	Diamond Creek	
	Acres	Percent
A	<1	<1%
A/D	103	4%
B	23	<1%
B/D	235	9%
C	1435	53%
C/D	894	33%
D	--	--
Unclassified/ Open Water	19	<1%
Total	2709	100%

Source: SSURGO

5.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Diamond Creek MU were characterized using the Diamond Creek hydro-conditioned DEM. Slopes throughout are low compared to the other MUs in the Study Area (Table 5.3). The Diamond Creek MU also has the lowest percentage (3%) of high sloped areas (slopes over 18%).

Table 5.3. Diamond Creek slope and drainage summary

Parameter	Percent of MU
Percent of subwatershed >5% slope	30%
Percent of subwatershed >10% slope	11%
Percent of subwatershed >18% slope	3%

Percent of subwatershed in cropland production	35%

5.4 ANIMAL AGRICULTURE

Table 5.4 provides a summary of MPCA registered feedlots, TRPD livestock inventory, and the City of Dayton's animal activities inventory for the Diamond Creek MU. These results indicate most livestock operations throughout the MU are small operations and are therefore unregistered. The Diamond Creek MU has the most MPCA registered feedlots compared to the other MUs and has one MPCA registered feedlot within 500 feet of a stream.

Table 5.4. Diamond Creek livestock inventory.

Parameter	Diamond Creek		
	MPCA Registered Feedlots	TRPD Animal Inventory	Dayton Animal Inventory
Total Sites	2	14	1
Primary Animal Type	Elk/Horses	Horses	N/A
Sites within 500 feet of perennial stream	1	0	0

5.5 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. Thus, systems constructed prior to 1995 have not likely been inspected for compliance and may be less likely to conform to the new rules. 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 1995, and thus may be less likely to conform to the new rules. That same analysis also pin-pointed those systems that are potentially 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 Diamond Creek septic analysis (Table 5.5) suggest that at least 37 systems were constructed prior to 1995. This analysis also suggests that the Diamond Creek MU has the highest number of systems located within 500 feet of perennial streams. There are 11 systems within 500 feet of the stream, all of which were constructed prior to 1995.

Table 5.5. Diamond Creek septic estimates.

Septic Systems Constructed	Total Systems in MU		Systems where parcel is within 500 ft of Stream	
	Number	Percent of MU	Number	Percent of MU
Prior to 1995	37	84%	11	25%
1995 and after	7	16%	0	-
Totals	44	100%	11	25%

5.6 KEY ISSUES AND CONCERNS

To establish critical opportunities for management, information and data included in the appendices and references was reviewed. Listed below is and overview of the most pressing issues within the Diamond Creek MU.

- **Water Quality** Diamond Creek is listed as an impaired waterway for aquatic life and recreation.
  - High phosphorus and TSS concentrations
  - Low dissolved oxygen concentrations
  - *E. coli* is high and above the standard
- **Land use** consists primarily of corn/ soybean rotation (35%), wetlands (23%), and grasslands/ pasture (15%). Urban/developed land is the lowest in this MU at only 4%.
- **Slopes** throughout are low with only 3% of the MU having a slope greater than 18%, which is the lowest of all the MUs.
- **Altered Hydrology:** Several straightened, ditched, and channelized sections of the creek facilitate poor water quality and degraded habitat for aquatic species.
- **Livestock animal** concentrations are higher in this MU, with two MPCA registered feedlots, the most of any MU. Of these registered feedlots, one is within 500 feet of a stream.
- **Septic** analysis indicates 37 systems were constructed prior to 1995. 11 systems are potentially within 500 feet of a stream which is the highest among the MUs.

5.7 BMP SITING AND OPTIONS

Structural BMPs for the Diamond Creek MU were sited using the ACPF Toolbox as described in Section 2.4. These tools identified 72 potential BMP options throughout the Diamond Creek MU (Figure 5.1). Below is a brief overview of the different BMPs identified through this analysis.

- **Grassed Waterways:** 16 potential sites were identified. TSS and TP load reductions ranged from 0.1-1 tons/yr and 1.2-12.7 lbs/yr, respectively. Cost benefit ranged from $230-$780/pound of TP removed.
- **Water and Sediment Control Basins:** Eight potential sites were identified. TSS and TP load reductions ranged from 0.1-0.8 tons/yr and 2.0-14.7 lbs/yr, respectively. Cost benefit ranged from $90-$660/lbs of TP removed.

- **Alternative Tile Intakes:** 24 potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from 0.1-2.7 tons/yr and 0.2-6.8 lbs/yr, respectively. Cost benefit ranged from $220-$5,130/lbs of TP removed.
- **Wetland Restorations:** 24 potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from 0.2-23.1 acre-ft while TSS and TP load reductions ranged from <0.1-99.2 tons/yr and 0.7-25.8 lbs/yr, respectively. Cost benefit ranged from $470-$3,090/lbs of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 76.6 acre-ft and TSS and TP loading would decrease by approximately 178.5 tons/yr and 269.9 lbs/yr, respectively. As discussed in Section 2.4, 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 Diamond Creek MU in terms of annual TP load reduction. Appendix C contains a complete summary of all 72 BMP options and their estimated load reduction and cost-benefit.

Table 5.6 Top 10 BMPs in Diamond Creek MU

BMP Type	BMP ID	Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)	20-Year Life Cycle Cost	Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)
Wetland	9	23.1	99.2	25.8	$585,100	$1,300	$290	$1,140
WASCOBs	BMP-10	--	0.8	14.7	$25,900	--	$1,650	$90
Wetland	65	5.5	14.7	13	$164,900	$1,500	$560	$640
Grassed Waterways	38	--	1	12.7	$57,300	--	$3,000	$230
Wetland	377446	3	5.2	10.4	$100,400	$1,700	$960	$480
WASCOBs	BMP-8	--	0.5	10.1	$25,900	--	$2,410	$130
Grassed Waterways	36	--	0.6	8.8	$45,000	--	$3,600	$250
WASCOBs	BMP-15	--	0.4	8	$25,900	--	$3,040	$160
Wetland	457807	0.9	3.7	7.2	$67,300	$3,700	$910	$470
Wetland	422661	2.1	2.5	7.2	$104,800	$2,500	$2,090	$730

6.0 HAYDEN LAKE NORTH AND SOUTH MANAGEMENT UNITS

The Hayden Lake North and South management units (MU) are situated just south of the city of Dayton, Minnesota. It is located to the east of the French and Diamond Lakes MU's, and directly to the south of the Diamond Creek MU (Figure 6.1). This largely agricultural MU is comprised of crop and pastureland on the western half, and forested and wetland areas on the eastern half. Hayden Lake and its surrounding wetland act as the confluence for Diamond and Elm Creeks. This is a critical area for management as it is a high nutrient accumulation zone. This section is intended to provide an overview of the Hayden Lake North and South Management Units, identify primary issues/concerns, and present potential BMP options to reduce pollutant loading and improve water quality.

6.1 LAND USE

Crops in the form of corn/soybean (30%) rotations is the primary land use in this MU, closely followed by wetlands (24%) from the Metropolitan Council's Generalized Land Use (2020) assessment of land use/land cover (Table 6.1). The Hayden Lake North & South MUs has the most even distribution of land use types compared to the other MUs.

Table 6.1. Hayden Lake North & South land use.

Land Use Type	Hayden Lake N & S	
	Acres	Percent
Crops	1,021	30%
Pasture/Hay	450	13%
Wetlands	803	24%
Urban/Developed	477	14%
Forest/Shrubland	510	15%
Open Water	95	3%
Barren	<1	<1%
Other Cropland	49	1%
Total	3,405	100%

Source: 2020 Generalized Land Use (Met Council).

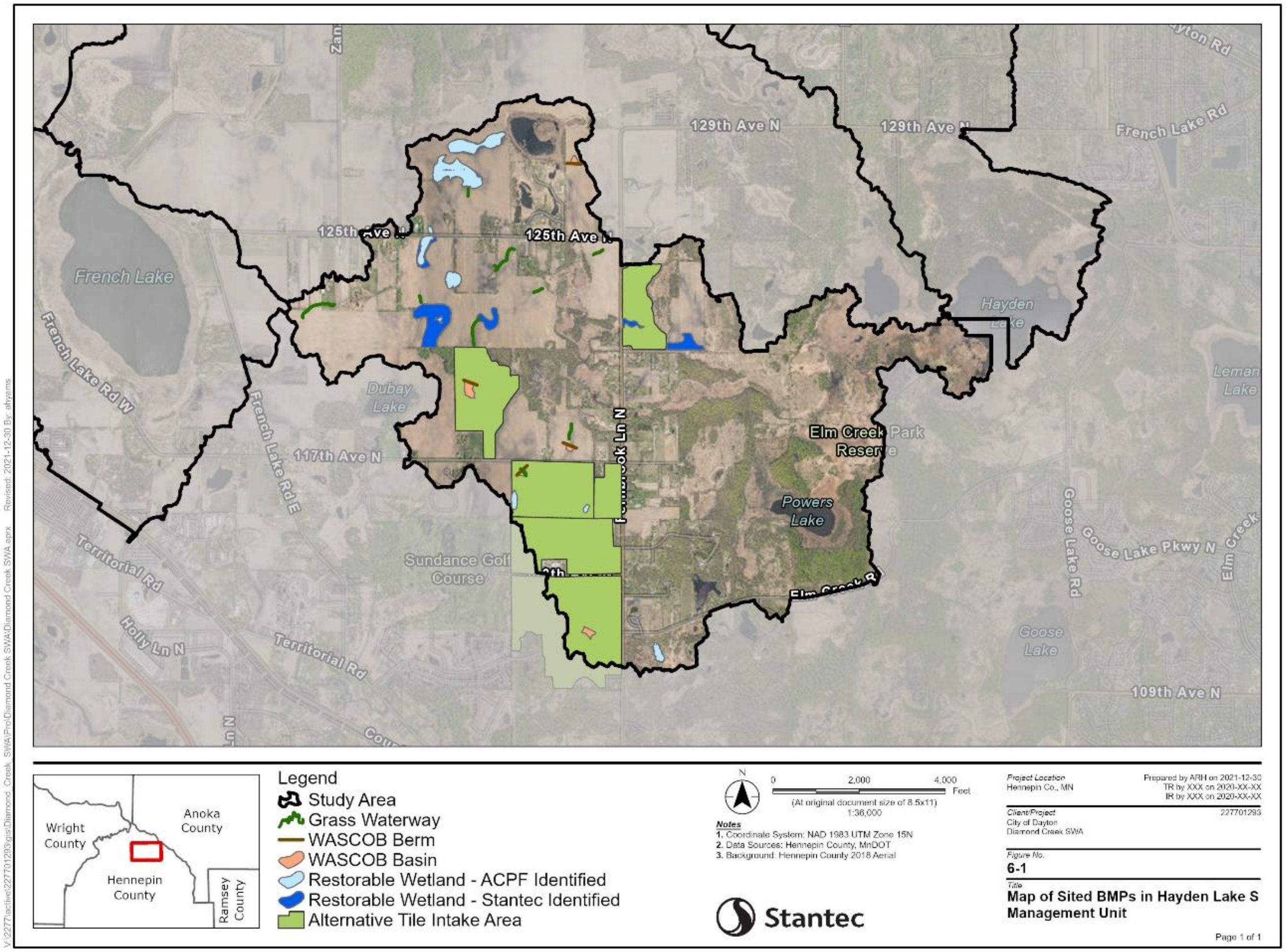

Figure 6.1. Map of sited BMPs in Hayden Lake MU

6.2 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 Hayden Lake MU are predominantly groups C and C/D 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. Hayden Lake North & South hydrologic soil groups

Hydrologic Soil Type	Hayden Lake N & S	
	Acres	Percent
A	310	9%
A/D	545	17%
B	53	1%
B/D	79	2%
C	1,327	39%
C/D	985	29%
D	--	--
Unclassified/ Open Water	106	3%
Total	3405	100%

Source: SSURGO.

6.3 SLOPE AND DRAINAGE MANAGEMENT

Topography and slope throughout the Hayden Lake North & South MU were characterized using the Diamond Creek hydro-conditioned DEM. Slopes throughout are moderate compared to the other MUs in the Study Area (Table 6.3).

Table 6.3. Hayden Lake North & South slope and drainage summary

Parameter	Percent of MU
Percent of subwatershed >5% slope	25%
Percent of subwatershed >10% slope	11%
Percent of subwatershed >18% slope	4%
Percent of subwatershed in cropland production	30%

6.4 ANIMAL AGRICULTURE

Table 6.4 provides a summary of MPCA registered feedlots, TRPD livestock inventory, and the City of Dayton's animal activities inventory for the Hayden Lake North & South MU. These results indicate most livestock operations throughout the MU are small operations and are therefore unregistered. The Hayden Lake North & South MU has the highest number of animal activities compared to the other MUs.

Table 6.4. Hayden Lake North & South livestock inventory.

Parameter	Hayden Lake N & S		
	MPCA Registered Feedlots	TRPD Animal Inventory	Dayton Animal Inventory
Total Sites	1 (Inactive)	19	1
Primary Animal Type	--	Cows/Horses	N/A
Sites within 500 feet of perennial stream	0	0	0

6.5 SEPTIC ANALYSIS

A significant change to state administrative rules occurred in 1995 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. Thus, systems constructed prior to 1995 have not likely been inspected for compliance and may be less likely to conform to the new rules. 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 systems that were constructed or sold prior to 1995. That same analysis also pin-pointed those that are potentially 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 Hayden Lake North & South septic analysis (Table 6.5) suggest that at least 185 systems were constructed prior to 1995, which is the most among the MUs.

Table 6.5. Hayden Lake North & South septic estimates.

Septic System Constructed	Total Systems in MU		Systems where parcel is within 500 ft of Stream	
	Number	Percent of MU	Number	Percent of MU
Prior to 1995	185	84%	1	0.5%
1995 and after	36	16%	0	-
Totals	221	100%	1	0.5%

6.6 KEY ISSUES AND CONCERNS

To establish critical opportunities for management, information and data included in the appendices and references was reviewed. Listed below is and overview of the most pressing issues within the Hayden Lake MU.

- **Land use** is primarily agriculture in the form of corn/ soybean rotation (30%), followed by wetlands (24%). The land use types are most evenly distributed in this MU.
- **Slopes** are moderate, with 25% of slopes being greater than 5% and only 4% of slopes greater than 18%.
- **Livestock animal** operations are the highest in this MU, however, most livestock operations throughout the MU are small and therefore unregistered. None of the currently registered operations occur within 500 feet of a stream.
- **Septic** analysis shows 185 systems were constructed prior to 1995, which is the highest among the MUs. However, only one system is potentially located within 500 feet of a stream.

6.7 BMP SITING AND OPTIONS

Structural BMPs for the Hayden Lake MU were sited using the ACPF Toolbox as described in Section 2.4. These tools identified 49 potential BMP options throughout the Hayden Lake MU (Figure 6.1). Below is a brief overview of the different BMPs identified through this analysis.

- **Grassed Waterways:** 10 potential sites were identified. TSS and TP load reductions ranged from 0.1-2.8 tons/yr and 1.3-13.8 lbs/yr, respectively. Cost benefit ranged from $130-$760/pound of TP removed.
- **Water and Sediment Control Basins:** Five potential sites were identified. TSS and TP load reductions ranged from 0.8-2.2 tons/yr and 5.5-15.1 lbs/yr, respectively. Cost benefit ranged from $90-$240/lb of TP removed.
- **Alternative Tile Intakes:** 17 potential locations were identified for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from 0.3-11.2 tons/yr and 0.6-15.4 lbs/yr, respectively. Cost benefit ranged from $30-$3,840/pound of TP removed.
- **Wetland Restorations:** 17 potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from 0.1-18.9 acre-ft while TSS and TP load reductions ranged from <0.1-353.1 tons/yr and 0.4-58.5 lbs/yr, respectively. Cost benefit ranged from $210-$4,790/lb of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 75.7 acre-ft and TSS and TP loading would decrease by approximately 1,112.1 tons/yr and 392.5 lbs/yr, respectively. As discussed in Section 2.4, all BMP pollutant load reduction estimates should be viewed as edge of field reductions.

Table 6.6 provides a summary of the top 10 BMP options for the Hayden Lake MU in terms of annual TP load reduction. Appendix C contains a complete summary of all 49 BMP options and their estimated load reduction and cost-benefit.

Table 6.6 Top 10 sited BMPs in Hayden Lake MU

BMP Type	BMP ID	Storage (acre-ft)	TSS (tons/yr)	TP (lbs/yr)	20-Year Life Cycle Cost	Storage ($/acre-ft)	TSS ($/ton)	TP ($/lb)
Wetland	192	10.8	353.1	58.5	$291,500	$1,300	$40	$250
Wetland	380705	8.8	213.2	43.3	$184,700	$1,000	$40	$210
Wetland	422326	18.9	345.5	32.7	$250,000	$700	$40	$380
Wetland	47	3.6	58.2	28.6	$120,400	$1,700	$100	$210
Wetland	11	8.8	33	19.4	$244,100	$1,400	$370	$630
ATIs	192	--	11.2	15.4	$158,000	--	$710	$510
WASCOBs	BMP-4	--	2.2	15.1	$25,900	--	$590	$90
Grassed Waterways	16	--	2.8	13.8	$36,000	--	$600	$130
ATIs	576045	--	9.9	13.7	$9,200	--	$50	$30
Grassed Waterways	26	--	2.1	10.2	$30,500	--	$700	$150

7.0 RECOMMENDATIONS

The Primary objectives of this study were to evaluate current conditions, identify water quality impairments, and develop cost-effective solutions in the Diamond Creek HUC 12 subwatershed portions of the Elm Creek Watershed. Five management units were identified within the study area containing lakes, streams, and wetlands, and each was evaluated in depth. The primary objectives for each MU were achieved through review of existing/ historic water quality data including biologic assessments, WRAPS, TMDL studies, and other relevant documents provided by stakeholders. Structural and non-structural BMPs were identified for the MUs including stream, in-lake, and larger watershed level actions aimed at reducing the concentration of TP and other critical pollutants. Below is a summary of the results and recommendations for the individual MU's and the greater watershed in general.

- Explore potential wetland restorations with willing landowners
- Partner with Hennepin County for opportunities to identify and implement
  - alternative tile intakes where wetland restorations are not feasible
  - grassed waterways and/or other stabilization practices in high sloped areas
  - animal husbandry and pasture management BMPs
  - manure management and soil health BMPs
- Incorporate sited urban BMPs into City Development Review or City infrastructure improvement project process to identify implementation opportunities
- Update ACPF mapping results as needed based on projects and development
- Septic system inspections and upgrades. The septic system analysis suggests 11 systems within the Diamond Creek MU and one system within the Hayden Lake N MU that are potentially located within 500 feet of perennial streams, all of which were sold and/or built prior to 1995. These systems should be targeted for landowner outreach and septic inspection to determine the 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 the Diamond Creek MU.
- Grass Lake could be a significant source of phosphorus to Diamond Lake based on the data collected by TRPD in 2015. However, only one year of water quality data was collected and other data on Grass Lake (e.g., upstream loading, wetland depth and volume, accumulated sediment) is lacking. Since this is such a large and complicated wetland system, further monitoring is required to evaluate the true extent of phosphorus loading from Grass Lake to Diamond Lake; Appendix H outlines a sampling plan and associated costs. It is recommended that this data be collected for 2-3 years to establish baseline conditions and phosphorus loads from Grass Lake to Diamond Lake.
- Pursue funding opportunities for potential projects through
  - Elm Creek Watershed Commission
  - Board of Water and Soil Resources
  - Minnesota Clean Water, Land and Legacy Amendment funds
  - Hennepin County Energy and Environment

- Minnesota Pollution Control Agency
- Minnesota Department of Agriculture

8.0 REFERENCES

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APPENDIX A

Stream and Lake Monitoring Data Review Technical Appendix

1.0 DIAMOND CREEK SUBWATERSHED STREAM MONITORING DATA

The Commission, in partnership with TRPD, monitored water quality and flow at three stations along Diamond Creek from 2007 through 2012 in preparation for the TMDL study. No stream water quality data has been collected since 2012. The 2007-2012 water quality data was analyzed extensively for the TMDL/WRAPS studies and again for this SWA. Figures A1 through A7 contain box plots showing the sampling results of several key water quality parameters. Water quality data from TRPD monitoring of French and Diamond Lakes were also included in the box plots for certain parameters (TP, ortho-P, chlorophyll-a, and transparency) to evaluate how the lakes may be impacting water quality in Diamond Creek. Table A1 provides a general summary of the monitoring data and how specific parameters change between the three Diamond Creek monitoring stations. Interpretation of these results are discussed in more detailed in the individual subwatershed sections of the report.

Table A-1 Summary of the 2007-2012 water quality monitoring results for Diamond Creek.

Monitoring Station(s)	Management Unit(s)	Summary of Results Between Monitoring Stations
French Lake	French Lake	• TP is high (mean = 191 µg/L), however lower than Diamond Creek stations • Ortho-P is low (mean = 36 µg/L) • Chlorophyll-a is very high (mean = 121 µg/L) • Transparency is moderate (mean = 58 cm) compared to Diamond Creek stations • Surface DO (summer) is high compared to Diamond Creek stations and indicative of eutrophic summer conditions
Diamond Lake	Diamond Lake	• TP is high (mean = 177 µg/L), however lower than Diamond Creek stations • Ortho-P is low (mean = 39 µg/L) • Chlorophyll-a is high (mean = 63 µg/L) • Transparency is generally better (mean = 105 cm) than Diamond Creek stations • Surface DO (summer) is high compared to Diamond Creek stations and indicative of eutrophic summer conditions
S004-536 (Zanzibar Lane N)	Diamond Creek	• TP is very high (mean = 430 µg/L), higher than upstream lakes • Ortho-P is high (mean = 133 µg/L), higher than upstream lakes • Chlorophyll-a is moderate (mean = 17 µg/L); however, it is significantly lower than upstream lakes • TSS is high (mean = 40 mg/L), higher than downstream stations • Transparency is generally poor (mean = 21 cm), worse than upstream lakes • DO (summer) is low (mean = 4 mg/L), significantly lower than upstream lakes • *E. coli* is high, similar to other stream stations
S004-537 (Diamond Lake Rd S)	Diamond Creek	• TP is very high (mean = 447 µg/L), higher than upstream lakes and slightly higher than S004-536 • Ortho-P is high (mean = 212 µg/L), higher than upstream lakes and higher than S004-536 • Chlorophyll-a is low (mean = 8 µg/L), lower than S004-536 • TSS is relatively low (mean = 10 mg/L), lower than S004-536 • Transparency is generally good (mean = 68 cm), significantly better than S004-536 • DO (summer) is low (mean = 4 mg/L), similar to S004-536 and significantly lower than upstream lakes • *E. coli* is high and similar to other stream stations
S004-538 (TRPD trails upstream of Hayden Lake)	Diamond Creek	• TP is high (mean = 264 µg/L), however, lower than upstream stations (S004-536 and S004-537) • Ortho-P is high (mean = 125 µg/L), however, lower than S004-537

Monitoring Station(s)	Management Unit(s)	Summary of Results Between Monitoring Stations
		• Chlorophyll-a is low (mean = 8 µg/L), similar to S004-537 • TSS is relatively low (mean = 16 mg/L), lower than S004-536 and similar to S004-537 • Transparency is good (mean = 89 cm), slightly better than S004-537 • DO (summer) is low (mean = 5 mg/L), similar to S004-536 and S004-537 and significantly lower than upstream lakes • *E. coli* is high and similar to other stream stations

DO: dissolved oxygen; TSS: total suspended solids; TP: total phosphorus; ortho-P: ortho-phosphorus

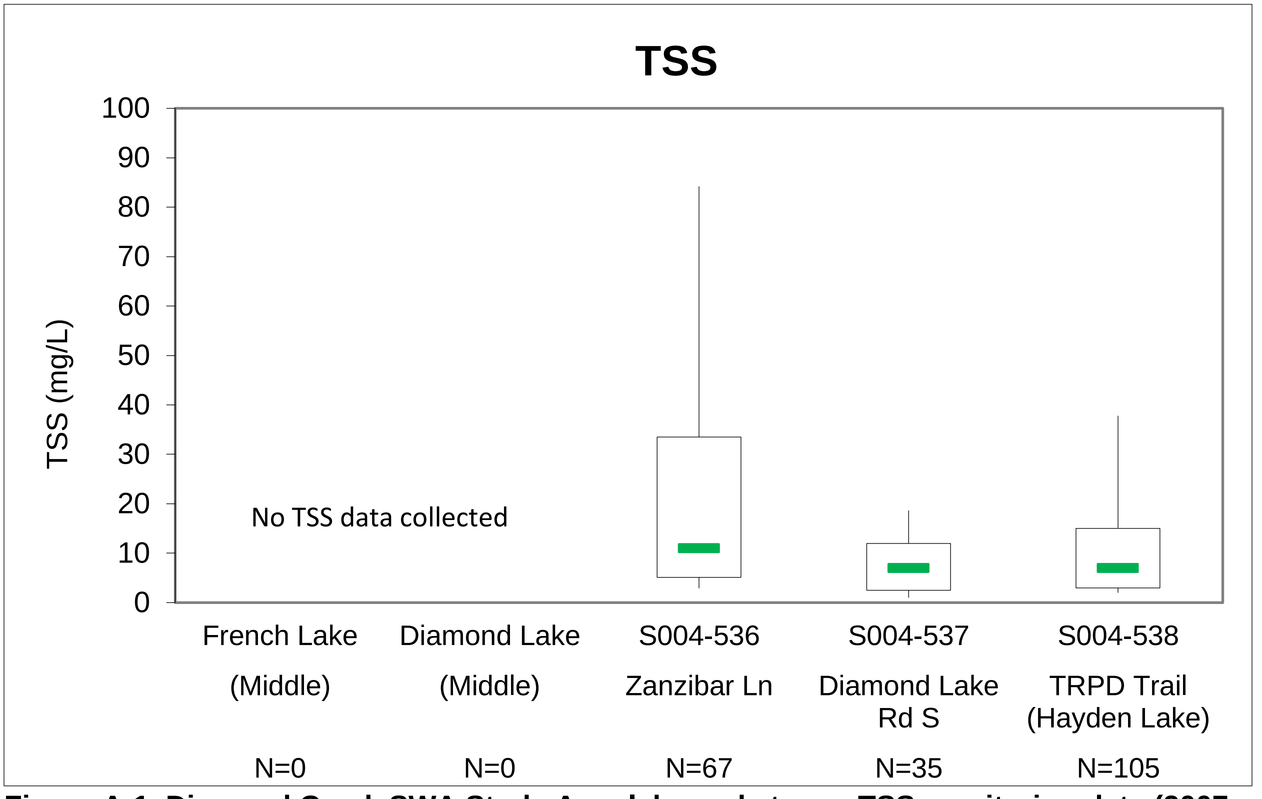


Figure A-1. Diamond Creek SWA Study Area lake and stream TSS monitoring data (2007-2012). Boxplots for the in-pool TSS (Total Suspended Solids) concentration of each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset.

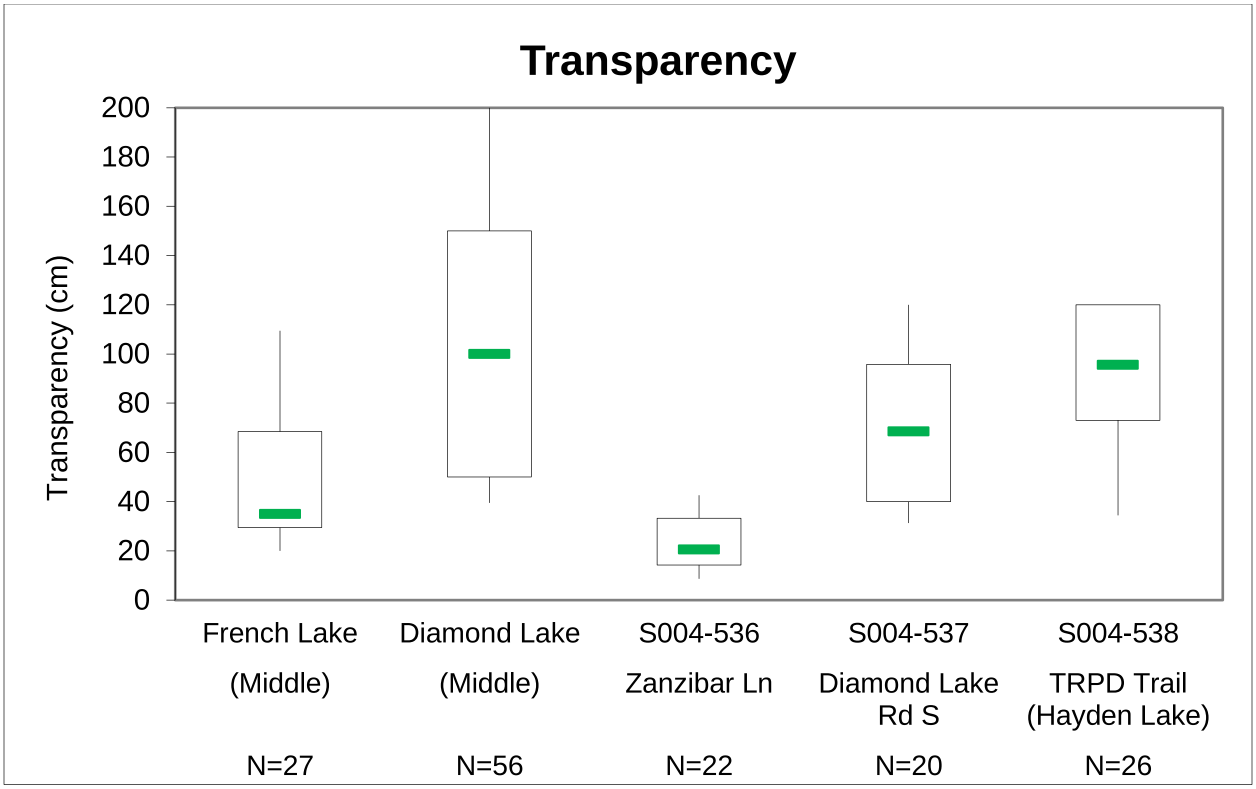


Figure A-2. Diamond Creek SWA Study Area lake and stream transparency monitoring data (2007-2012). Boxplots for the in-pool transparency (cm) of each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the median concentration of all data collected.

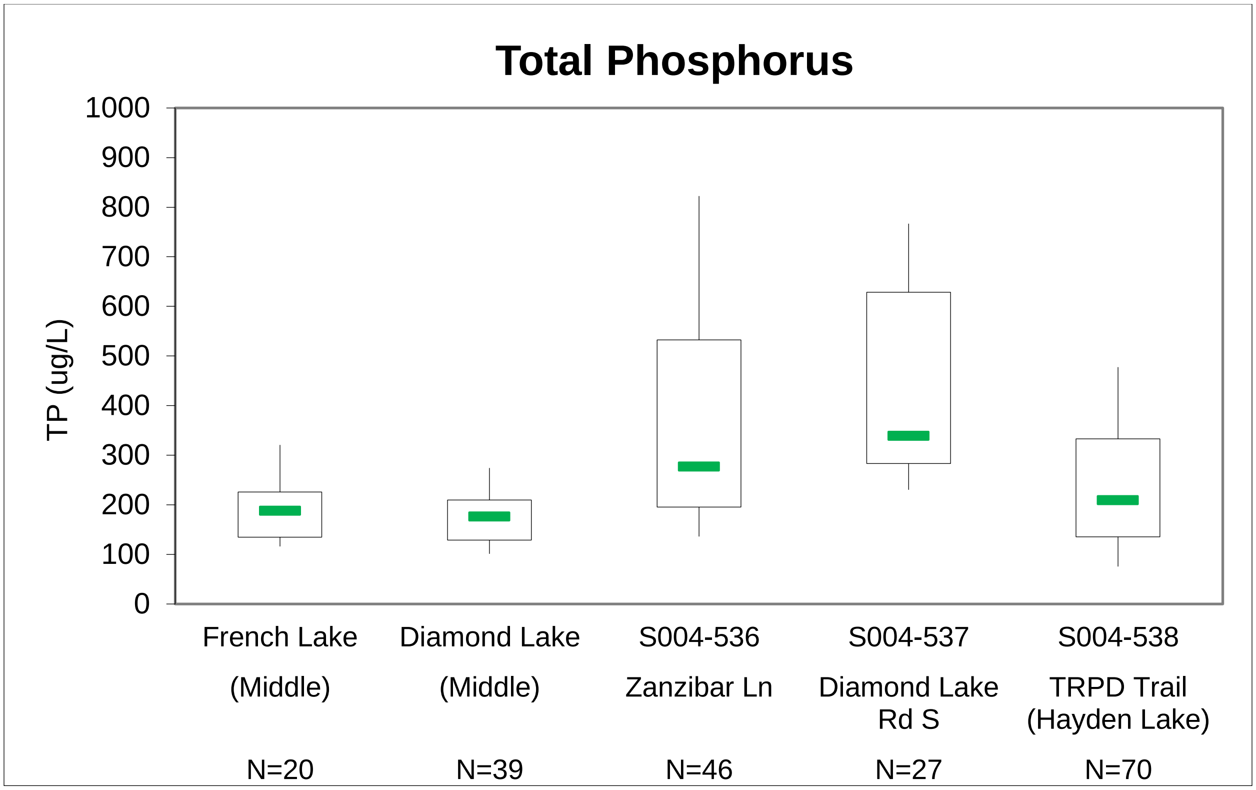


Figure A-3. Diamond Creek SWA Study Area lake and stream summer TP monitoring data (2007-2012). Boxplots for the in-pool Total Phosphorus (TP) concentration of each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the median concentration of all data collected.

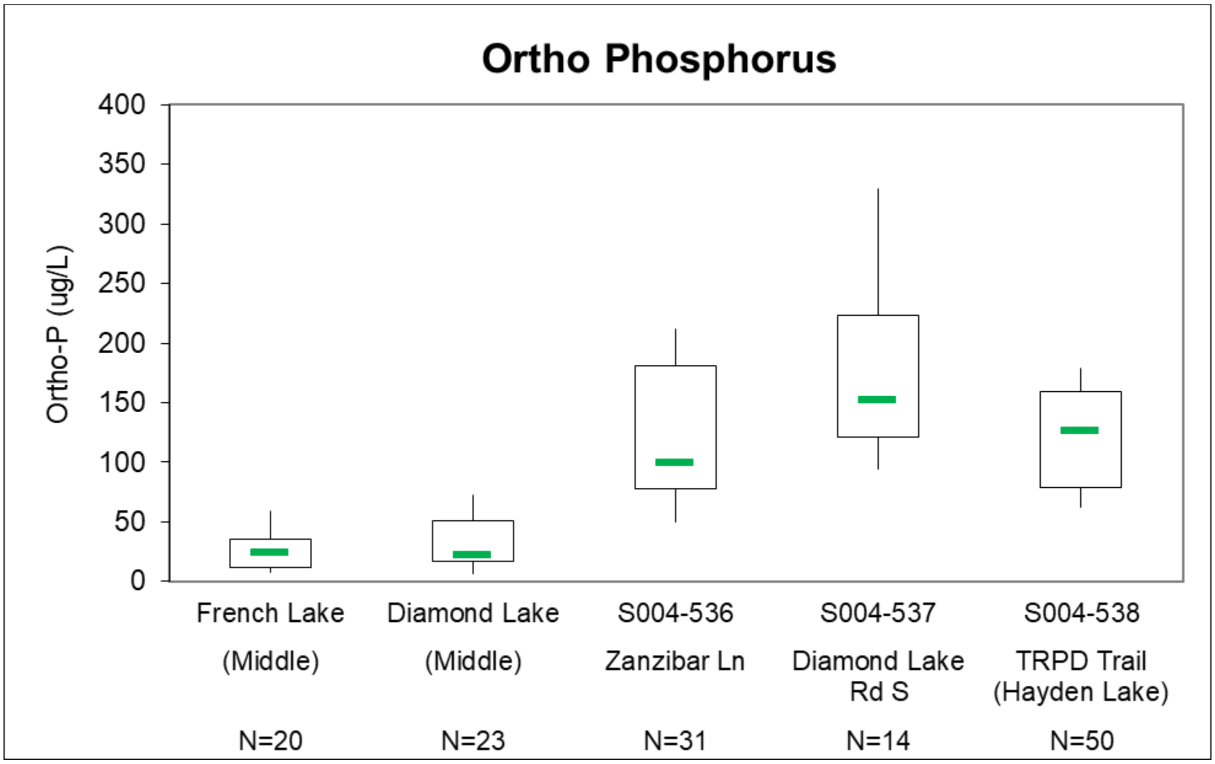


Figure A-4. Diamond Creek SWA Study Area lake and stream summer orthophosphate monitoring data (2007-2012). Boxplots for the in-pool Ortho-Phosphorus (Ortho-P) concentrations in each of the study lakes. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the median concentration of all data collected.

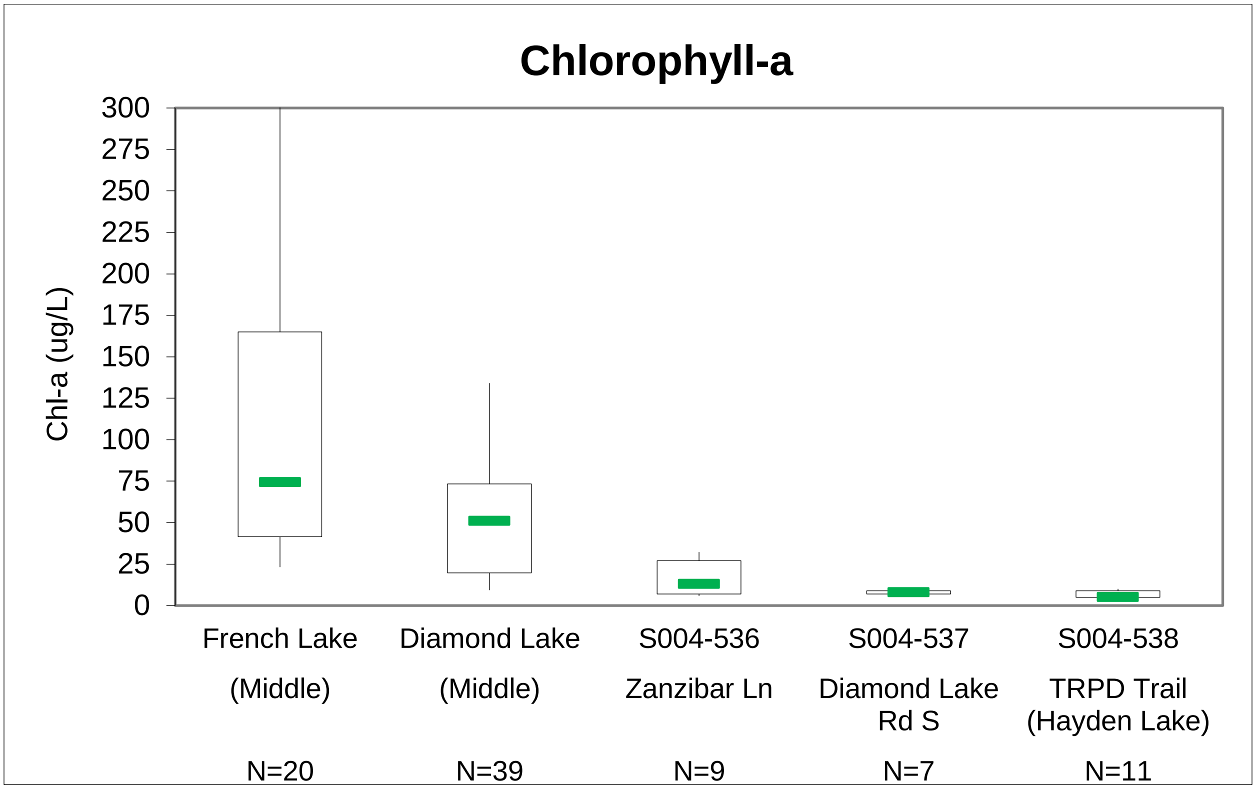


Figure A-5. Diamond Creek SWA Study Area lake and stream summer chlorophyll-a monitoring data (2007-2012). Boxplots for the in-pool Chlorophyll-a (Chl-a) concentrations for each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the average concentration of all data collected.

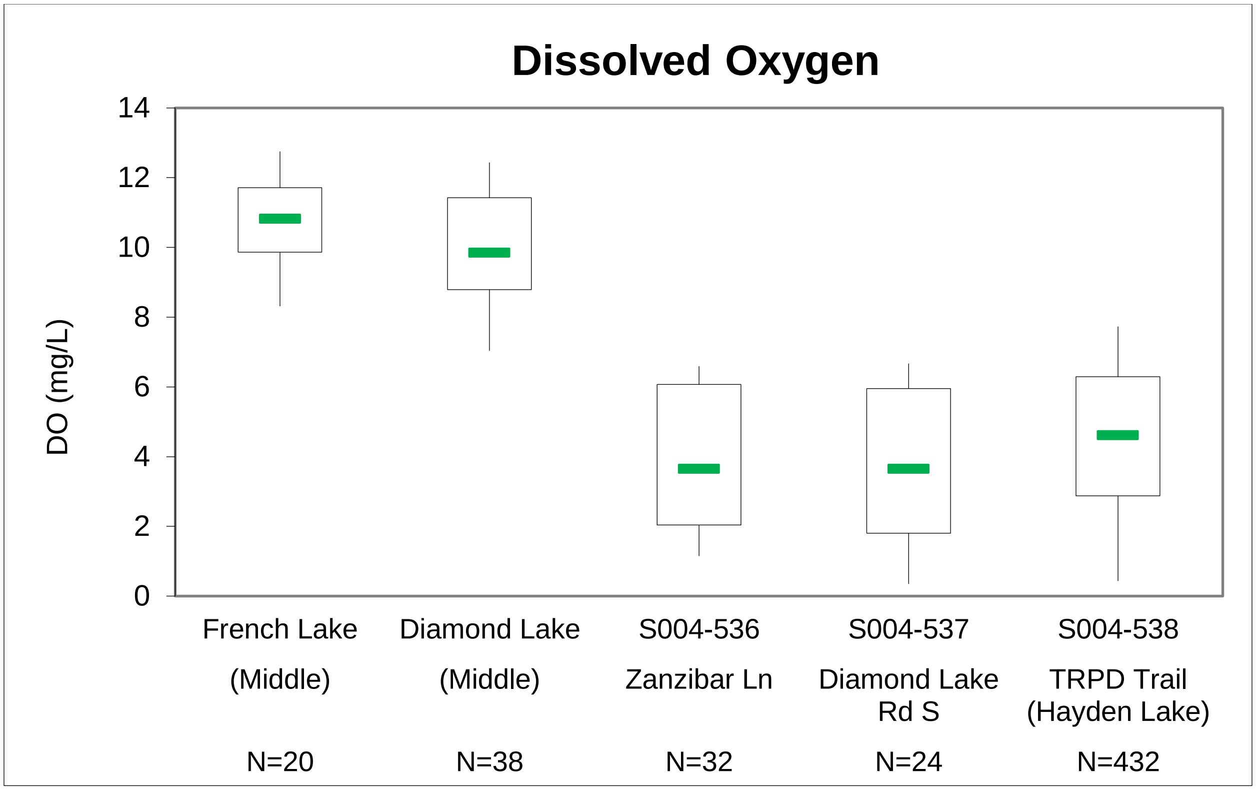


Figure A-6. Diamond Creek SWA Study Area lake and stream summer dissolved oxygen monitoring data (2007-2012). Boxplots for the in-pool Dissolved Oxygens (DO) concentrations for each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the average concentration of all data collected.

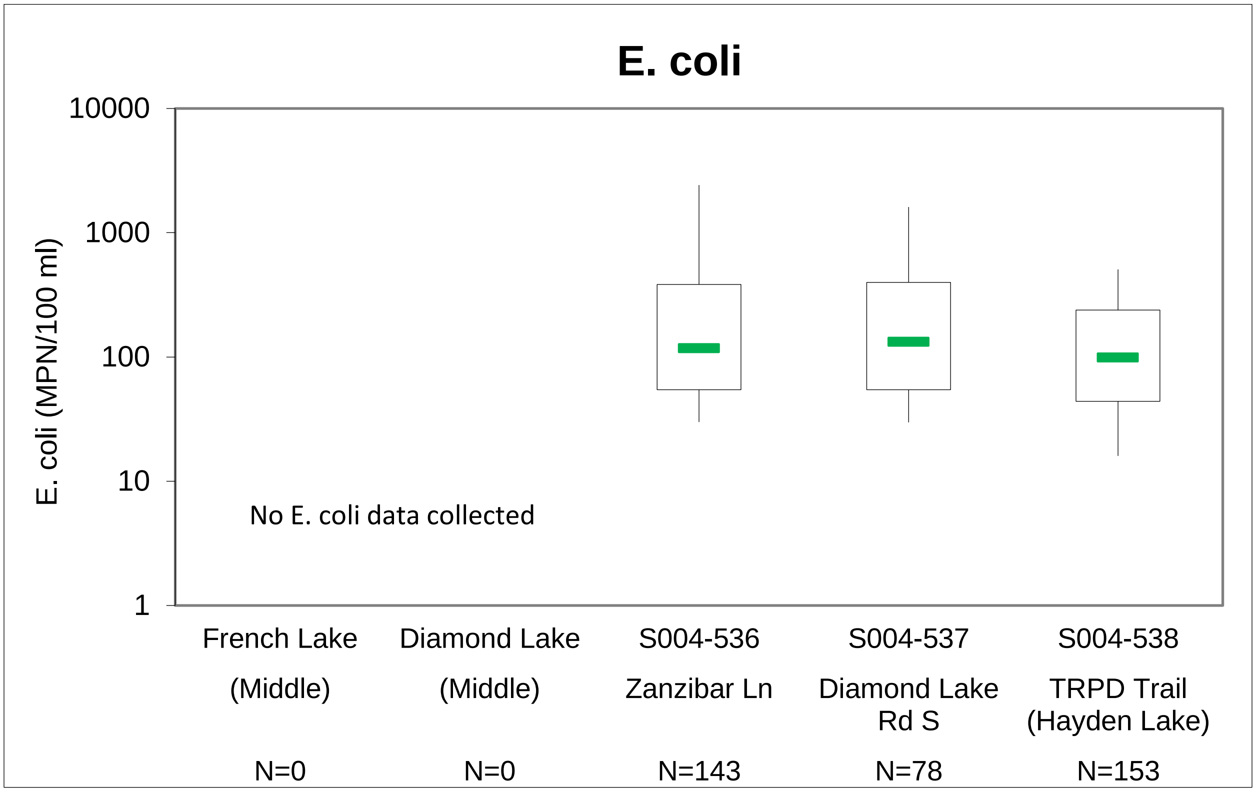


Figure A-7. Diamond Creek SWA Study Area lake and stream *E. coli* monitoring data (2007-2012). Boxplots for the in-pool E. coli concentrations for each study lake. The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the average concentration of all data collected.

2.0 DIAMOND CREEK SUBWATERSHED LAKE MONITORING AND ASSESSMENTS

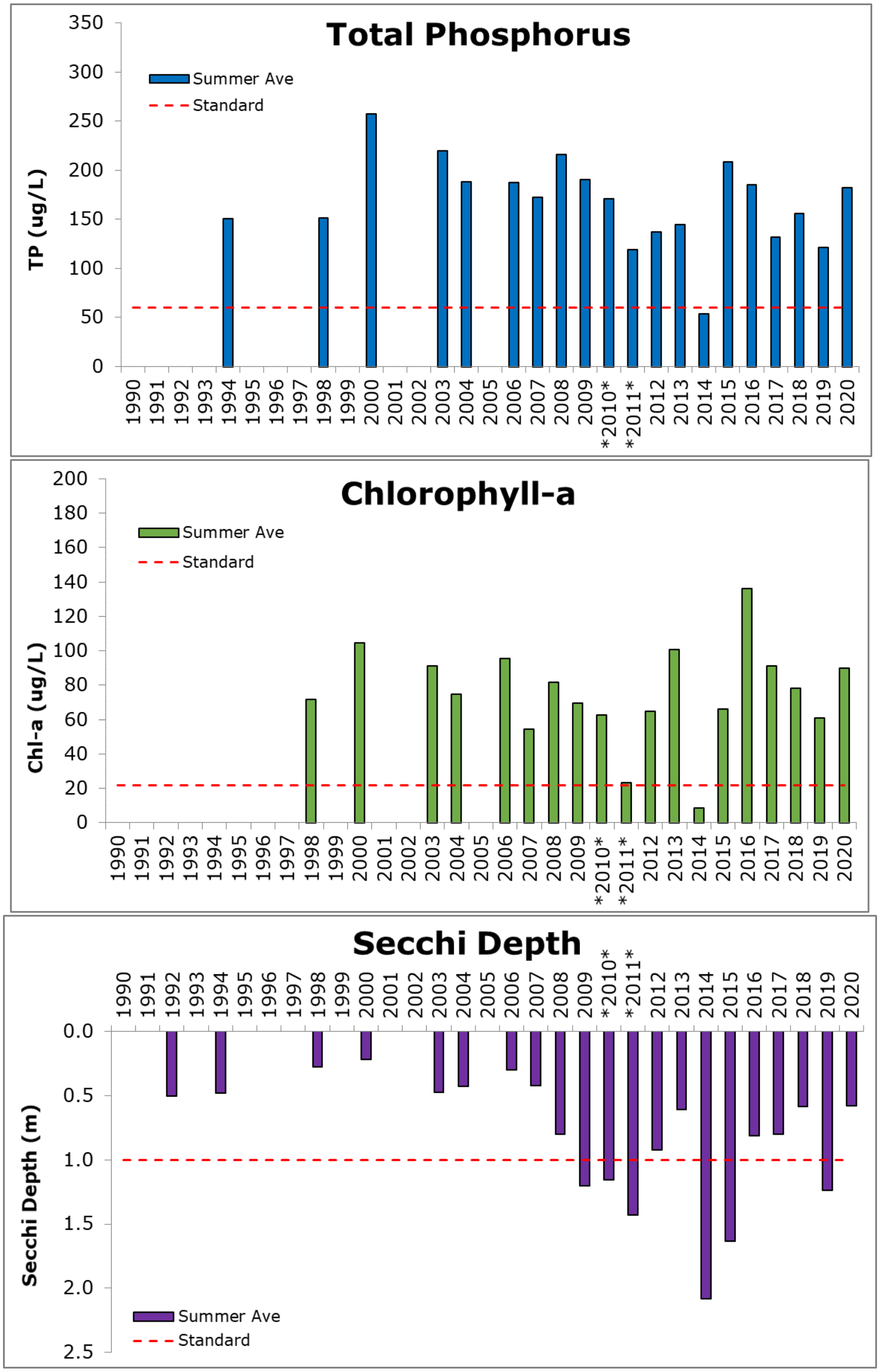
A significant amount of data/information has been collected on Diamond Lake since the completion of the TMDL study in 2011, including in-lake water quality monitoring, vegetation management and surveys, and a fisheries survey. Minimal water quality data has been collected recently on French Lake: however, a fisheries survey for the lake was completed by the City of Dayton in 2019 (Wenck 2019). Data on Both Diamond and French Lake were compiled and reviewed for this SWA and are summarized below.

2.1 LAKE WATER QUALITY DATA

Water quality monitoring has been conducted on Diamond Lake every year since the completion of the TMDL study in 2011. Water quality was monitored in French Lake from 2001-2013 but has not been monitored in recent years. Much of the water quality data for Diamond and French Lakes were collected by Three Rivers Park District (TRPD) and funded by the Elm Creek Watershed Management Commission (ECWMC, the Commission). Results of the Commission's lake monitoring efforts are presented in annual report cards (link to report cards). Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth for both lakes over the past 20 years is shown in Figures C1 and C2.

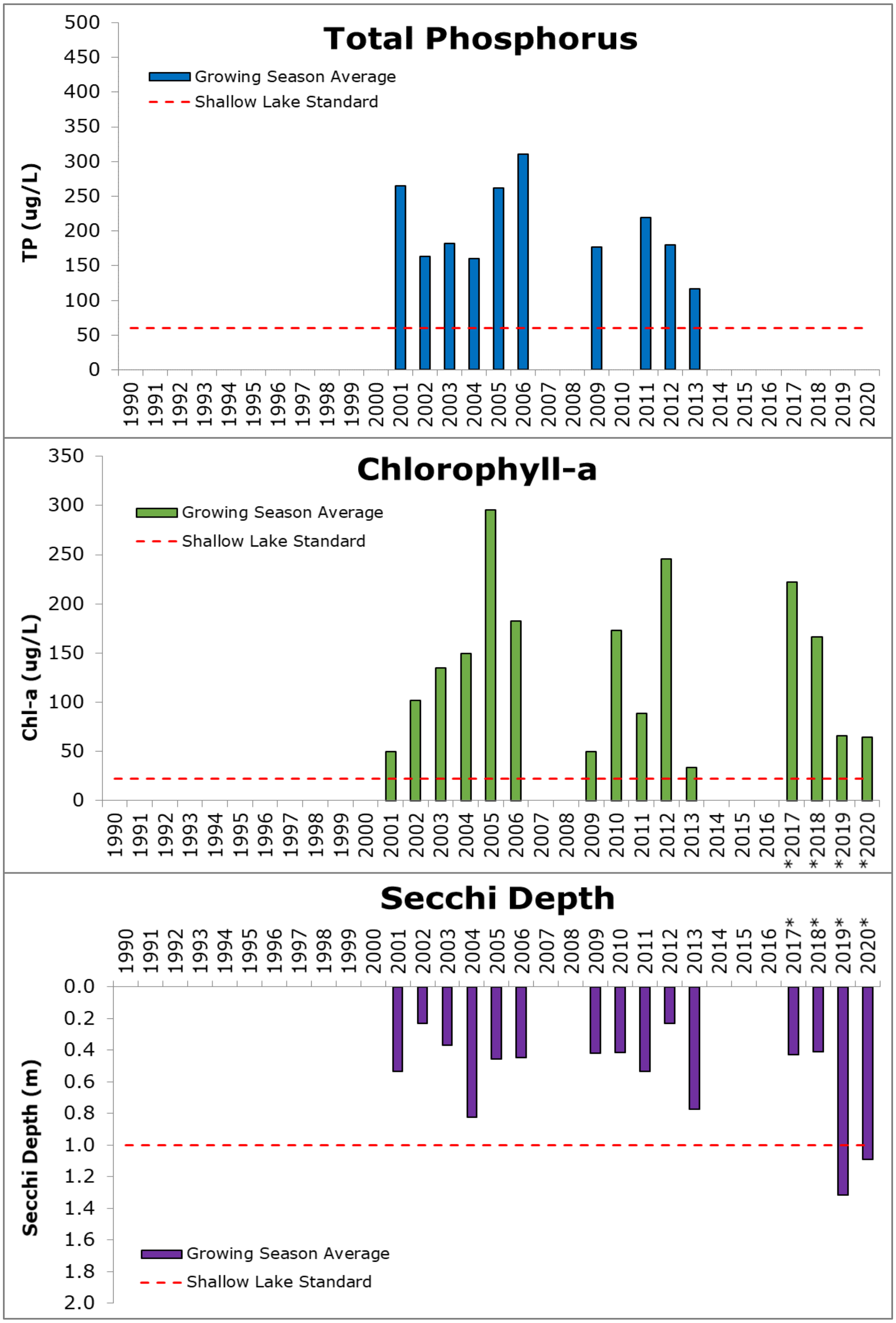
In general, water quality has not improved in Diamond Lake since the TMDL study was completed. Diamond Lake water quality monitoring data from 2010 and 2011 was used to develop the lake response model applied in the TMDL study. Average summer TP, chlorophyll-a, and Secchi depth for these years were 145 µg/L, 43 µg/L, and 1.29 meters, respectively. Since 2011 (2012 through 2020), TP, chlorophyll-a, and Secchi depth have averaged 147 µg/L, 77 µg/L, and 1.03 meters, respectively. Although the average TP has remained similar, chlorophyll-a has increased substantially, and both parameters still fail to meet water quality standards by large margins. Secchi depth in Diamond Lake currently meets State water quality standards; however, the summer average Secchi depth was lower from 2012 through 2020 (1.03 meters) compared to 2010 and 2011 (1.29 meters).

Due to its shallow nature (max depth ~4 feet), French Lake is considered a wetland by state definition and is therefore not subject to the State's lake water quality standards. However, improving and maintaining good water quality in French Lake is critical to the greater Diamond Creek Subwatershed given the size of French Lake (~320 acres), connectivity to Diamond Creek and Diamond Lake, and its contribution to downstream impairments. For the purposes of this report, French Lake water quality were compared to the State water quality standards for shallow lakes in the North Central Hardwood Forest Ecoregion. These standards are a reasonable goal/benchmark for improving water quality in French Lake. Water quality monitoring conducted by TRPD from 2001 through 2013 indicate that the average summer TP concentration (204 µg/L) is more than three times the shallow lake TP standard (60 µg/L) while the average chlorophyll-a concentrations (137 µg/L) is over six times the shallow lake standard (20 µg/L). These concentrations were slightly higher than Diamond Lake and would suggest French Lake displayed hypereutrophic conditions and was in a predominately turbid water state from 2001 through 2013. Although no in-lake water quality measurements have been collected since 2013, French Lake is included in the University of Minnesota's Lake Browser database which uses remote sensing imagery to model water quality conditions (i.e. clarity, chlorophyll-a, and colored dissolved organic matter (CDOM) for thousands of lakes throughout the state of Minnesota (link to Minnesota Lake Browser website). The University of Minnesota modeled clarity and chlorophyll-a data for French Lake were downloaded and included in Figure 9 to see if conditions have changed since 2013. Interestingly, French chlorophyll-a and clarity (i.e., Secchi depth) showed considerable improvements in 2019 and 2020 compared to previous years. Chlorophyll-a still exceeds the shallow lake standard; however, clarity has met the shallow lake standard the past two years.



Asterix (*) denotes years used to develop the Diamond Lake TMDL.

Figure C-1. Diamond Lake summer average TP (top), chlorophyll-a (middle), and Secchi depth (bottom).



Asterix (*) denotes years in which University of Minnesota Remote Sensing data were used to estimate water quality.

Figure C-2. French Lake summer average TP (top), chlorophyll-a (middle), and Secchi depth (bottom).

2.2 VEGETATION MANAGEMENT (2013-PRESENT)

The Diamond Lake TMDL calls for an average annual TP reduction of approximately 2,000 pound per year for Diamond Lake to meet State water quality standards. Of this reduction, it was estimated that approximately 30% (~640 pounds per year) comes from internal sources within Diamond Lake. The TMDL study suggests internal load is likely a combination of internal sources including phosphorus release from the sediment, rough fish activity, wind/wave action, and breakdown of submerged aquatic vegetation (SAV). Based on SAV surveys conducted by TRPD around the time of TMDL study, it was estimated that curly-leaf pondweed (CLP), an invasive plant that typically dies and decomposes in late June/early July, covered approximately 90% of the lake during the early summer growing season. TRPD estimated that the early summer CLP plant biomass in Diamond Lake contributes a minimum of 640 pounds of TP per year (~80% of the internal load) to Diamond Lake after the CLP dies off by mid-summer. Thus, the TMDL report suggested that controlling Diamond Lake CLP biomass would be key to meeting the lake's TMDL reduction goals.

Curly-leaf pondweed herbicide treatments were initiated by the Diamond Lake Improvement Association in 2013 (Table 1). The herbicide treatments are documented and summarized in the DNR's 2020 Aquatic Vegetation Report for Diamond Lake (link to report). From 2013 through 2018, Endothall herbicide was used to treat CLP at 15% of the lake's littoral area (60.5 acres). A variance to treat more than 15% of the littoral area was granted in 2019 and 2020 to allow for whole lake control of CLP using Fluridone. Low dose Fluridone was applied to approximately 405 acres shortly after ice-out. Fluridone for CLP control is generally applied early in the growing season and subsequent bump treatments are necessary to maintain concentrations and exposures (4-5 parts per billion for up to 30 days).

Table C-1. Diamond Lake CLP management summary (from DNR report)

Date	Treatment [W,P,N]	Target Species	Total Acres Treated	Herbicide	Licensed Commercial Applicator
2013	P	CLP	60.5	Endothall	Clarke Aquatic Services
2014	P	CLP	60.5	Endothall	Lake Restoration Inc.
2015	P	CLP	60.5	Endothall	Lake Restoration Inc.
2016	P	CLP	60.5	Endothall	Lake Restoration Inc.
May 2017	P	CLP	60.5	Endothall	Lake Restoration Inc.
May 2018	P	CLP	60	Endothall & Diquat	Lake Restoration Inc.
May 2019*	W	CLP	405	Fluridone (Sonar AS)	PLM Lake and Land Mgmt Corp
APR 2020*	W	CLP	405	Fluridone (Sonar AS)	PLM Lake and Land Mgmt Corp

Treatment: W (whole lake), P (partial lake), N (no treatment)

CLP is an abbreviation for curly-leaf pondweed

* LVMP year

The DNR and local partners are currently evaluating the effects of the 2019, 2020, and 2021 Fluridone treatments to determine the efficacy on CLP management and potential effects to the native plant community. In early spring 2019, CLP was found throughout the lake and observed at 74% frequency of occurrence (FOO) but the 2020 survey showed significant declines (3% FOO) as a result of the Fluridone treatment applied before the survey. Historically, CLP has been observed as high as 92% FOO in 2011. Impacts to native plants were noted post Fluridone treatments, including coontail showing signs of degradation during the first year of treatment. Although declines in species richness occurred since the Fluridone treatments the percent of points with submersed native taxa has stayed consistent within the last three years. The most abundant native plants included coontail, sago pondweed and most recently horned pondweed and chara. The first observation of horned pondweed was documented during the 2019 survey. Sago pondweed and chara were found at their highest densities in the most recent survey while coontail and Canadian waterweed declined most likely due to 2019 and 2020 Fluridone treatments. Survey efforts will continue in 2021 and will include spring and summer point intercept surveys, herbicide concentration monitoring and post-treatment delineations for CLP.

Although CLP FOO decreased significantly in 2019 and 2020 as a result of the Fluridone treatments, water quality parameters did not show a significant response. Figure 3 contains a series of box plots showing monitored TP, chlorophyll-a, and Secchi depth for three different time periods before and during CLP treatments: 1) six years prior to endothall treatments (2007 through 2012); 2) six years of endothall treatments (2013 through 2018); and 3) two years of Fluridone treatments (2019 and 2020). These data suggest TP concentrations and Secchi depth have remained relatively consistent across each period of CLP management. Chlorophyll-a, on the other hand, has shown a slight increase and a higher incidence of nuisance algae blooms (i.e., chl-a levels that exceed 50 µg/L) since treatments began in 2013.

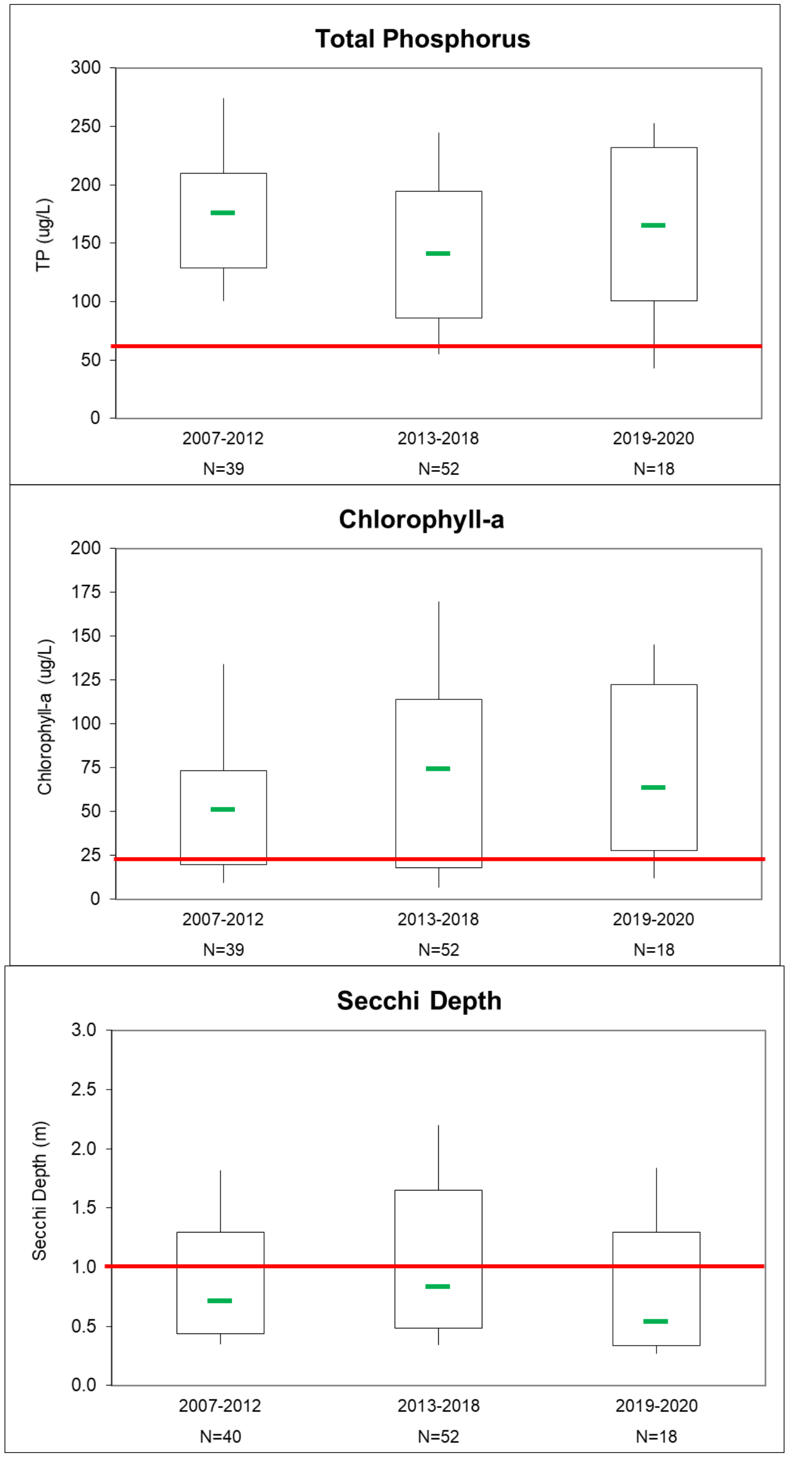


Figure C-3. Diamond Lake water quality monitoring before CLP management (2007-2012), during Endothall treatments (2013-2018), and during Fluridone treatments (2019 and 2020). The upper and lower edge of each box represent the 75th and 25th percentile of the data range for each site. Error bars above and below each box represent the 95th and 5th percentile of the dataset. The green dash is the average concentration of all data collected. The red line represents the shallow lake water quality standards.

2.3 DIAMOND AND FRENCH LAKE FISHERIES SURVEYS (2019)

The City of Dayton contracted with Wenck Associates, Inc. in 2019 to assess the fish populations in French and Diamond Lakes (Wenck Associates, 2019). These assessments, which took place between July 19 and July 25, included trap net surveys in both lakes and a biomass density estimate of the common carp population within Diamond Lake. The purpose of these surveys was to provide information to complement the Diamond Creek Subwatershed Assessment (SWA) project which was currently underway at the time.

The fish community sampled in French lake in 2019 was indicative of marginal dissolved oxygen (DO) levels and frequent winterkill. Generally, fish abundance was very low during the survey. The most abundant species sampled was central mudminnow, which alongside the green sunfish is adapted to habitats that frequently exhibit low DO levels. Only two fathead minnows were sampled despite the lake being known to have strong populations of this zooplanktivorous fish at times. One mature female and one mature male fathead minnow were sampled, suggesting a near-complete 2018-2019 winterkill and the persistence of a low density yet reproductively viable population that could rebound when conditions are favorable.

Relative to French lake, the sampled fish community within Diamond Lake is indicative of more stable ecosystem with less frequent winterkill. An abundant assemblage of sunfish was sampled, but sizes were small. Hybrid sunfish were prevalent. While no adult northern pike were sampled, the presence of young of year northern pike suggests that a viable reproducing population of adults is present within the lake/watershed. Abundance of young of year black bullhead was extremely high and outside normal range as was noted in the 1992 MN DNR standard survey, however average weight was very low and outside normal range for lakes of this type. These young of year black bullhead could be spotted with the naked eye in dense shoals along the shorelines of the lake at the time of sampling. Young of year common carp were sampled with mini-fyke nets which is strongly indicative of the presence of a reproducing population of common carp within Diamond Lake (or within the watershed). The electrofishing survey revealed a relatively low density of adult common carp (57lbs/acre) in Diamond Lake itself; implying that they are not significantly affecting water quality at this time. However, the presence of adult common carp suggests the potential for that density to increase exponentially if efficient reproduction (strong year class of young fish) occurs.

Fish abundance within lakes can be inversely related to water quality through a top-down ecological effect known as trophic cascade (Carpenter and Kitchell 1999). These top-down effects are complex and over time, they have the potential to drive poor water quality conditions in lakes, particularly shallow systems. Based on the results of these survey efforts, French and Diamond Lakes are likely experiencing middle-out and top-down effects by benthivorous (substrate feeding) and zooplanktivorous (plankton feeding) fish species respectively in certain years (Kaemink et al 2016). Black Bullhead are benthivorous and currently hyperabundant in Diamond Lake; thus, are very likely contributing to currently observed water quality impairments (Hanson and Butler 1994; Braig and Johnson 2003).

Common carp are a prolific benthivorous omnivore that is associated with degraded water and habitat quality at biomass densities above 89 lbs./acre through constant bioturbation of sediments while feeding

(Bajer et al 2009; Bajer et al 2016; Bajer et al 2009; Bajer and Sorensen 2015; Huser et al 2016). Common carp biomass density in Diamond Lake is currently below that threshold (57 lbs/acre), however the occurrence of large adults and young of year individuals within the population signals successful reproduction and over-wintering within the system that could lead to a strong year class of common carp at any time. A single successful year class of common carp in the subwatershed could quickly elevate the biomass density well above 89 lbs./acre in Diamond Lake in the subsequent 1-3 years if survival rate is high through their first and second year. In this region common carp have the highest relative reproductive success in shallow peripheral habitats where egg and larval predator populations are limited by frequent winterkill or other disturbances (Bajer and Sorensen 2010; Bajer et al 2012).

Partial migrations of common carp commonly occur between deeper lakes and these peripheral spawning habitats to facilitate over-winter survival (carp move to spawning sites in the spring and early summer and back to deeper lakes for the rest of the year. The outlets of Diamond (overwintering) and French (spawning) lakes and the stream channels between appear to be passable by large fish such as common carp, thus spawning migrations may be happening between these lakes and/or the greater watershed. Management of these migrations via fish barriers is recommended as an efficient way to minimize reproductive success of common carp.

The presence of a relatively diverse community of known predators of common carp eggs and larvae within the subwatershed is likely acting as efficient biocontrol, limiting their reproductive success (Bajer et al 2012). Positive management of these carp limiting species is recommended via habitat improvement, which will also benefit recreational fishing opportunities. Suppressive management of the common carp population through removal via seining or other methods is not recommended at this time, however we suggest that a single electrofishing survey event be completed annually in August to monitor their reproductive success through time. If significant year classes of common carp are observed surviving past the predation bottleneck (1-2 years), removals via the judas fish method, baited box trapping, and/or ecological trapping may be required to manage water quality impairment as biomass density increases exponentially (Bajer et al 2011).

Based on the survey results and review of available historic fisheries information/data for French and Diamond Lakes, the following recommendations were made:

- Monitor future fish relative abundance in Diamond and French lakes using fisheries lake survey methods (biennial/triennial August). Relate to water quality data analyzed during the TMDL and Diamond Creek SWA projects.
- Monitor common carp abundance and biomass density in Diamond Lake via electrofishing methods (annual August). If significant year classes appear in these surveys, pursue Common Carp removals.
- Implement semi-permanent fish barriers at outlets of Diamond and French lakes to suppress potential production of strong year classes of common carp within subwatershed/watershed.
- Pursue active management of gamefish populations in Diamond Lake via habitat improvements.

2.4 FRENCH LAKE WATER QUALITY MODEL AND REDUCTION GOALS

French Lake is considered a wetland by State definition and is therefore not subject to State lake water quality standards, nor has a TMDL been developed for the lake. However, the lake is hypereutrophic and displays poor water quality (i.e., TP, chlorophyll-a, clarity) which directly affects downstream resources and impaired waterbodies. As part of this SWA study, we developed a nutrient budget (i.e., total phosphorus) for French Lake to assess potential drivers of poor water quality conditions. This process is described below in more detail.

French Lake's TP budget was estimated by developing a response model for years that have in-lake TP monitoring data (2001-2012). The lake response model selected for this exercise was the Canfield-Bachman Lake equation (Canfield and Bachman, 1981). This equation estimates the lake phosphorus sedimentation rate, which is needed to predict the relationship between in-lake phosphorus concentrations and phosphorus load inputs. The phosphorus sedimentation rate is an estimate of net phosphorus loss from the water column through sedimentation to the lake bottom and is used in concert with user supplied lake-specific characteristics such as annual phosphorus loading, mean depth, and hydraulic flushing rate to predict in-lake phosphorus concentrations. Model predictions are then compared to measured data to evaluate how well the model describes the lake system. If necessary, the model parameters are adjusted appropriately to achieve an approximate match to monitored data.

To setup the lake response model for French Lake, we used methods similar to the lake TMDLs in the Elm Creek Watershed TMDL Study (MPCA, 2016) and other TMDL studies throughout the State. The four major phosphorus sources defined in the French Lake response model were: watershed load, internal load, loading from point source dischargers (i.e., Dayton Park Properties), and atmospheric load.

Watershed TP loading was estimated using the Elm Creek SWAT mode that was developed as part of the Elm Creek Watershed TMDL Study. Model output files were obtained from TRPD and the modeled subwatershed draining to French Lake was used as inputs into the lake model.

Internal phosphorus loading from lake sediments, vegetation die-off/decay, and rough fish activity can be a major component of a lake's phosphorus budget. None of these internal sources have ever been measured or evaluated for French Lake. Therefore, a relatively low internal loading rate of 1 mg/m2/day was used as a starting point and adjusted upward as needed after the other phosphorus sources were added to the model.

Phosphorus loading from the Dayton Park Properties wastewater treatment facility was estimated using the Discharge Monitoring Reports obtained from the MPCA's Wastewater Data Browser (link to website). This facility no longer discharges to French Lake as operations ceased in 2012 when Dayton Park connected to the City's sanitary sewer system.

Atmospheric phosphorus loading to French Lake was estimated using literature rates for dry (<25 inches of rainfall), average (25-38 inches), and wet (>38 inches) precipitation years (Barr Engineering, 2004). Atmospheric loading to lakes is typically small compared to watershed and internal sources in most lakes and reservoirs.

With the watershed, internal, point source, and atmospheric phosphorus loads defined, the lake response model predicted average annual TP concentrations from 2001–2012 were compared to available monitored in-lake TP concentrations. The model predicted the in-lake TP concentrations for French Lake were lower than monitored values, and therefore adjustments were made to increase the internal phosphorus loading rate (increased from 1.0 mg/m2/day to 4.7 mg/m2/day) to better match the monitored TP data. The final lake response model results suggest internal loading is likely the largest source (73%) of TP loading to the lake (Figure 4). Watershed loading is the second largest contributor and accounts for approximately 23% of the lake's annual TP budget. Atmospheric deposition (4%) and inputs from the Dayton Park Property facility (<1%) account for relatively small portions of the overall budget.

To meet the 60 µg/L shallow lake target/goal, TP loading to French Lake will need to be reduced by approximately 1,300 pounds per year based on the 2001-2012 model inputs. A majority of this load reduction, about 900 pounds per year, will need to come through managing the lake's internal load since it was estimated that a majority of the lake's TP load comes from internal sources. However, a significant load reduction (~400 pounds per year) will also need to come from reducing watershed loading sources to the lake.

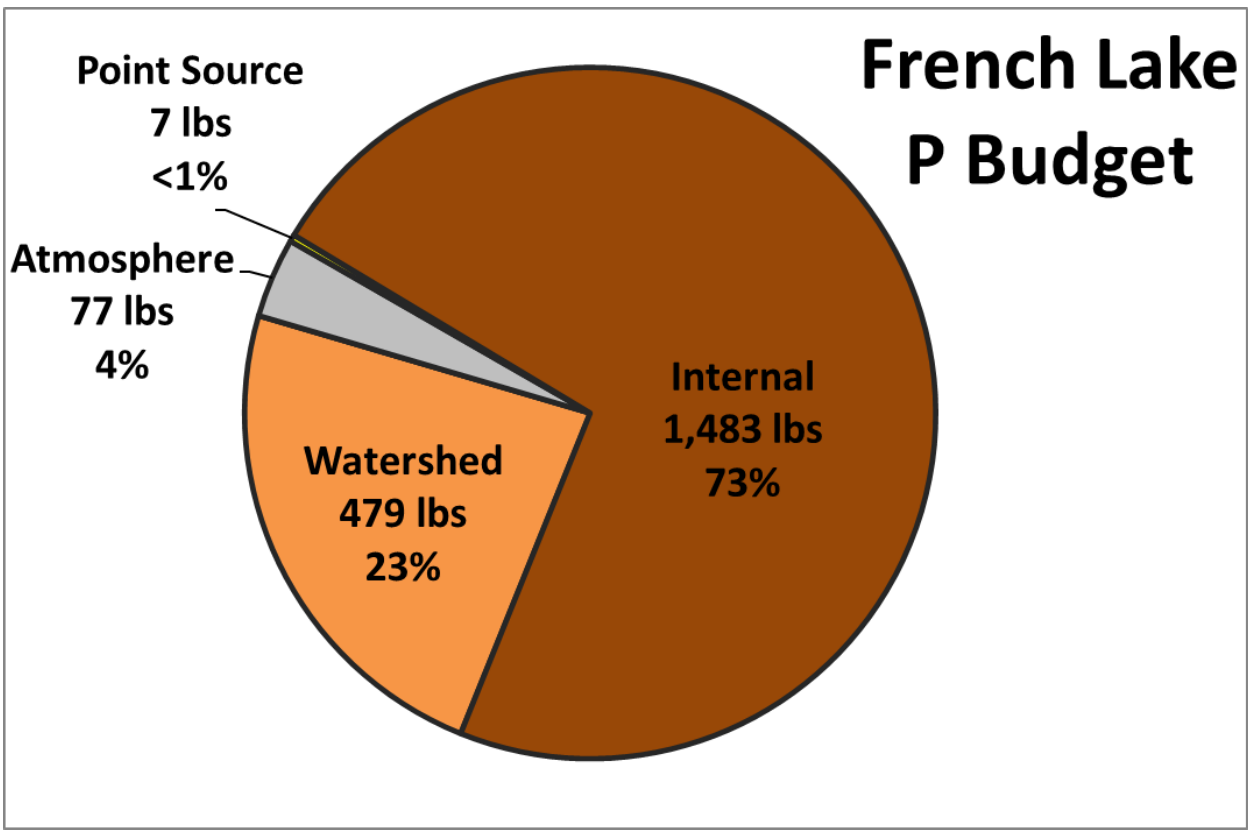


Figure C-4. French Lake annual TP budget (2001-2012)

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APPENDIX B

Background Report and Plan Review Technical Appendix

1.0 DIAMOND CREEK SUBWATERSHED REVIEW OF BACKGROUND STUDIES/REPORTS, TMDLS, AND LOCAL WATER PLANS

1.1 PHYSICAL AND ECOLOGICAL CLASSIFICATION OF ELM CREEK AND ITS TRIBUTARIES (2002)

A physical and ecological stream classification project was completed by Hennepin County Conservation District in the Fall of 1999 and Spring of 2000 for the Elm Creek Watershed Management Commission (ECWMC). Summarized in 2002 in the report, Physical and Ecological Classification of Elm Creek and its Tributaries", also known as the "Elm Creek Habitat Study", the study assessed stream habitat conditions throughout Elm, Rush, and Diamond Creeks.

The project inspected, inventoried, and documented the condition and types of stream channels and riparian corridors within Elm Creek, Rush Creek, and Diamond Creek. The project identified natural areas and potential greenways and buffers, and provided recommendations for restoration, preservation, and land use management within the watershed.

A summary of the Diamond Creek stream reaches that were included in the report is shown in Figure B1. A summary of each reach and recommended actions from the report are included below. The full report is available from Hennepin County upon request.

- Reach A
  - Reach A starts at French Lake and flows North. The area was ditched in the 1940's and in 1972 and was re-ditched and "cleaned" out in 1999. The area directly upstream of the ditched portion was deeply incised and full of sediment.
  - Recommendations:
    - Add buffer on east side of Reach A, adjacent to Ag fields
    - Restore stream meander
    - Preservation of corridor to connect Diamond and French Lakes within Elm Creek Park Reserve
    - Grading within the stream to prevent migration of the headcut
- Reach B
  - Ditched wetland downstream of French Lake, which could be restored to a natural wetland.
  - Recommendations
    - Add or increase buffers along reach B and ditched branches.
    - Potential restoration of ditched wetland
    - Preservation of corridor to connect Diamond and French Lakes with Elm Creek Park Reserve
- Reach C
  - Site was not surveyed but assessed from aerial photographs (1997). This section is made of multiple ditched areas.
  - Recommendations
    - Add buffers to the ditched sections of the creek to protect from overland flow
- Reach D:
    - An old growth forest surrounds reach D on the edge of Hennepin Parks east of Zanzibar Lane in Dayton. This is an intermittent stream, so water only flows in this portion certain times of the year. Ultimately flows into a large wetland.
    - Recommendations

        - Remove debris that may cause erosive crosscurrents
- Reach E
    - This stream is located within a wetland area in Hennepin Parks. This section was ditched sometime in the past when more agriculture was being practiced around the stream.
    - Recommendations
        - Remove debris to prevent culvert obstruction and bank erosion
        - Portion of stream may be restored to its historical channel

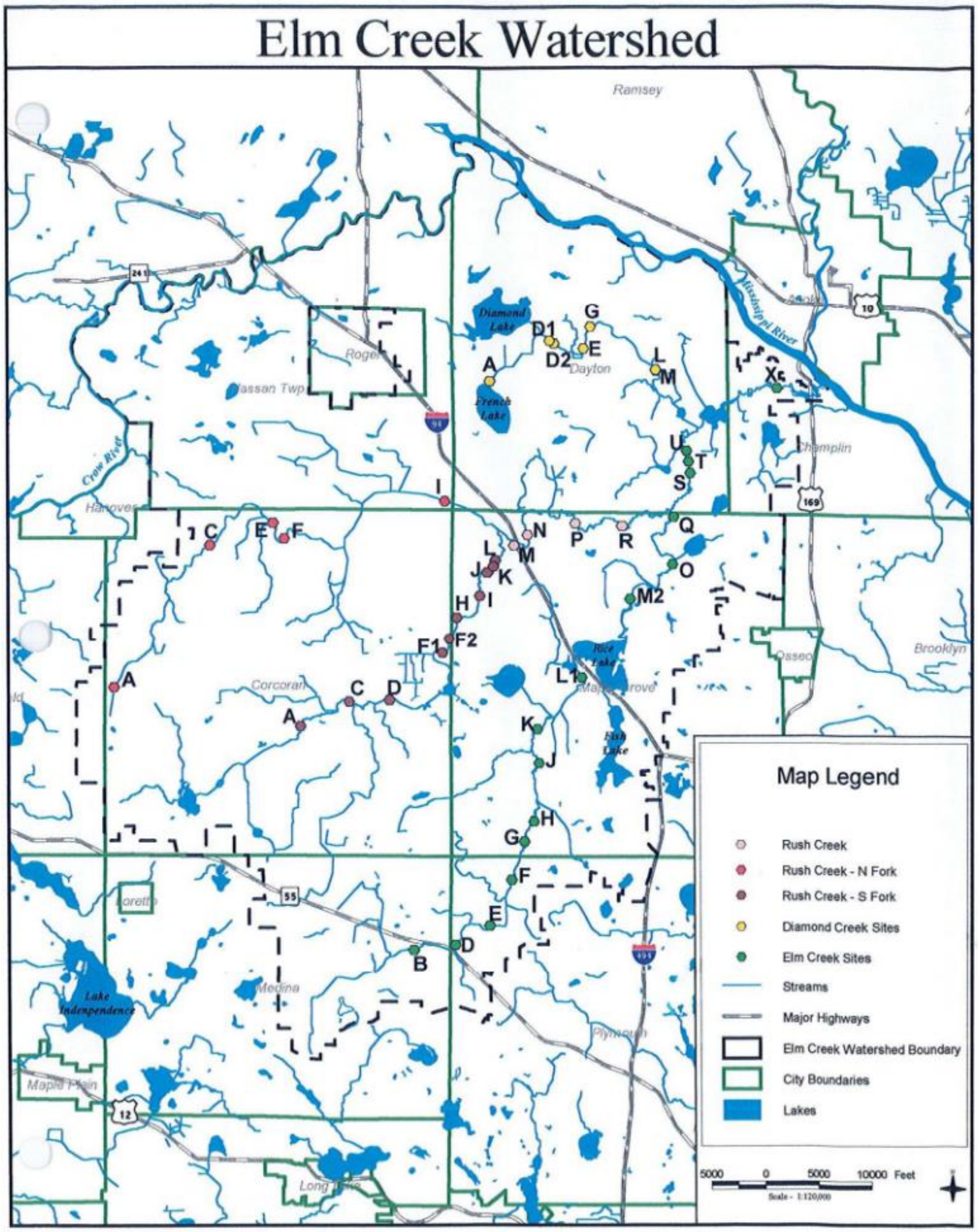

Figure B-1. Reaches assessed as part of the Elm Creek Habitat Study (2002).

1.2 ELM CREEK CHANNEL STUDY (2007)

The ECWMC commissioned an Elm Creek Channel Study to quantify the current conditions and identify management practices to address concerns of the impacts of land development to natural stream channels within the Elm Creek Watershed. Communities within the watershed are faced with a growing number of expensive stream repair projects and a loss of natural resources. The Study was conducted by Bonestroo in 2007.

The study conducted field survey of existing stream channels, analyzed stream channel capacity, estimated stormwater runoff from the watershed, did conceptual stabilization planning for five priority stream channel locations, and made watershed management recommendations.

The report was reviewed to identify if any of the five priority stream channel locations are within the Diamond Lake SWA study area, but none are.

1.3 ELM CREEK TMDL REPORT (2016)

Diamond Creek does not meet state water quality standards for several parameters, and it has been designated as an impaired water (Table B-1). Diamond Lake does not meet state water quality standards for nutrients and has also been designated an Impaired Water. French Lake is very shallow (max depth 4 feet or less) and is therefore considered a wetland and not subject to the State's lake water quality standards. However, monitoring data collected by TRPD for French Lake indicate the wetland has very high phosphorus concentrations and is hypereutrophic (see Appendix A). Improvements to French Lake will be needed to meet TMDL goals for Diamond Creek. Appendix A of this report establishes a lake response model and potential phosphorus reduction goals to help improve French Lake and downstream waterbodies (i.e., Diamond Creek) to help meet TMDL goals.

Table B-1. Impaired waterbodies in the Diamond Creek SWA Study Area.

Lake or Stream	DNR Lake # or Stream AUID	Affected Use	Pollutant
Diamond Lake	27-0125	Aquatic recreation	Nutrients (Total Phosphorus)
Diamond Creek	07010206-525	Aquatic life/ recreation	*E. coli*, Dissolved Oxygen, M-IBI[1], F-IBI[1]

[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.*

The catalyst for the completion of this Subwatershed Assessment was to help the City of Dayton, Hennepin County, ECWMC, and other partners better understand and identify the drivers of poor water quality 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 number of pollutants discharged to them.

A Total Maximum Daily Load (TMDL) study for the entire Elm Creek Watershed was completed and approved by the USEPA in 2017 (MPCA 2016). That TMDL established total phosphorus (TP) load reduction requirements for Diamond Lake and bacteria reduction requirements for Diamond Creek. A Stressor ID Analysis (Lehr 2015) was performed for the TMDL to evaluate the potential causes of the impairments to the fish and macroinvertebrate communities in Diamond Creek. The Stressor ID study identified altered hydrology, altered physical habitat, excess sediment (TSS), and low dissolved oxygen as the primary stressors to the fish community. The study identified excess TP as the primary stressor to macroinvertebrates and the main driver of low dissolved oxygen levels. Based on these findings, the Elm Creek TMDL study developed TP and TSS TMDLs and load reduction requirements for Diamond Creek to address all these pollutants. Tables B-2 and B-3 summarize the TMDL load reductions needed for all impairments in the Diamond Creek Subwatershed Study Area.

Table B-2. Diamond Creek load reduction goals from the Elm Creek TMDL study.

	E. coli	TSS		TP	
Flow Condition/ Source	**Percent**	**Percent**	**(tons/yr)**	**Percent**	**(lbs/yr)**
Very High	0%	0%	--	64%	880
High	0%	30%	32.9	71%	1,257
Mid	0%	0%	--	65%	242
Low	23%	0%	--	66%	137
Very Low	0%	47%	0.7	81%	21
Total: All Sources	2%	11%	33.6	68%	2,537
Total: Dayton MS4	2%	11%	13.6	68%	648
Total: Rogers MS4	NA	11%	7.5	68%	466
Total: Hennepin County MS4	NA	11%	0.1	68%	5
Total: MnDOT MS4	NA	11%	0.1	68%	NA
Total: Non-MS4 Runoff	2%	11%	10.0	68%	1,250

Table B-3. Diamond Lake TP load reduction goals from the Elm Creek TMDL study.

Diamond Lake TMDL Summary (AUID 27-0125)		**Existing TP Load[1]**	**TP Allocations**		**Load Reduction**	
		lbs/yr	lbs/yr	lbs/day	lbs/yr	%
TOTAL LOAD/LOADING CAPACITY		2898.0	835.8	2.290	2062.2	71.2%
5% EXPLICIT MOS		0.0	41.8	0.114	41.8	1.4%
TOTAL REDUCTION					**2104.0**	**72.6%**
WLAs	Construction/Industrial Stormwater	8.4	8.4	0.023	0.0	0.0%
	Dayton MS4	258.4	68.4	0.187	190.0	73.5%
	Rogers MS4	1209.5	320.3	0.877	889.2	73.5%
	Hennepin County MS4	16.2	4.3	0.012	11.9	73.5%
	MnDOT MS4	15.4	4.1	0.011	11.3	73.5%
LAs	Non-MS4 Runoff	489.8	129.7	0.355	360.1	73.5%
	Atmospheric Deposition	103.8	103.8	0.284	0.0	0.0%
	Internal Load	796.5	155.1	0.425	641.4	80.5%

[1] Existing TP load is the average for the years 2010 and 2011.

1.4 ELM CREEK WRAPS REPORT (2016)

The Elm Creek Watershed-Wide TMDL and Restoration and Protection Strategy (WRAPS) Report identified several strategies and activities to achieve the pollutant reduction goals noted in Tables 3-6 and 3-7. These strategies include, but are not limited to:

- Implement manure and pasture management BMPs
- Limit livestock access to streams
- Septic system upgrades or hook-ups to regional sanitary collection and treatment facilities
- Pet waste control measures
- Perform urban and rural BMP subwatershed assessment studies
- Increase riparian buffers and enforce DNR buffer rules on all streams
- Perform stream channel walking survey to identify and implement in-channel BMPs and/or stream corridor baseflow enhancement projects
- Monitor fish populations in Diamond Lake to determine impacts to water quality
- Develop vegetation management plan for Diamond Lake to manage curly-leaf pondweed
- Conduct drawdown and/or internal load treatment feasibility study for Diamond Lake

1.5 ELM CREEK WATERSHED THIRD GENERATION WATERSHED MANAGEMENT PLAN (2015).

The Elm Creek Watershed Management Commission adopted its Third Generation Watershed Management Plan (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:

- Priority 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.
- Priority 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 technical advisory committee (TAC) of agencies specializing in agricultural outreach to help guide assessments in agricultural subwatersheds.
- Priority 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.
- Priority 4:
  - Partner with other organizations to complete a pilot project for targeted fertilizer application and to increase and focus outreach to agricultural operators.
- Priority 5:
  - Continue participating in joint education and outreach activities with WMWA and other partners.

The Diamond Creek 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 Commission's water resources goals.

1.6 DAYTON LOCAL WATER PLAN (2018)

The City of Dayton updated its Local Water Plan in October 2018. The Plan updated the City's goals and related policies to address the problems and issues that were evaluated as part of the Plan update. Those goals are as follows:

- Goal 1. Identify and plan for means to effectively protect and improve water quality.
- Goal 2. Protect, preserve, and manage natural surface and constructed retention systems to control excessive volumes and rates of runoff and prevent flooding.
- Goal 3. Enhance groundwater recharge.
- Goal 4. Protect and preserve wetlands through administration of the Wetland Conservation Act.
- Goal 5. Control or manage sediment discharge into surface waters and drainageways.
- Goal 6. Protect and enhance fish and wildlife habitat and water related recreational amenities.
- Goal 7. Manage the City's surface water consistent with best practices and the City's NPDES MS4 Permit's SWPPP.
- Goal 8. Manage the City's surface waters consistent with other state and federal requirements.
- Goal 9. Inform the public about urban stormwater management and potential pollutants according to the requirements of the City's NPDES MS4 permit.

The Plan identifies the following solutions/projects within the Diamond Creek subwatershed.

- Develop a vegetation management plan to manage curly-leaf pondweed in Diamond Lake to comply with the Elm Creek WMC's TMDL and WRAPS reports.
- Conduct an Internal Load Management Plan to evaluate internal load reduction options, feasibility, and costs for Diamond Lake to comply with the Elm Creek WMC's TMDL and WRAPS reports.
- Develop management options for Diamond Lake from the Internal Load Management Plan: Alum treatment, common carp/fish management, lake-wide curly-leaf pondweed treatments, full/partial lake drawdown.
- Conduct early morning longitudinal DO surveys along Diamond Creek to determine specific reaches that may be causing low DO and being strategies for improvement.

APPENDIX C

Rural Structural BMP Technical Appendix

1.0 STRUCTURAL AGRICULTURAL BMPS SITING

Structural agricultural BMPs were sited and evaluated using a combination of modeling tools, GIS desktop analysis, aerial photo interpretation, site visits, and input from Hennepin County staff, Three Rivers Park District (TRPD) staff, City staff, and Commission staff.

The Agricultural Conservation Planning Framework (ACPF) was used as the starting point to identify and site potential locations for structural BMPs within the rural and agricultural portions of the Diamond Creek SWA study area. ACPF is a LiDAR-based toolbox designed to identify potential field-scale sites for 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 different individual BMP tools within ACPF to site specific locations for conservation practices.

Once the hydro-conditioned DEM and field boundary database were established in ACPF, four individual BMP siting tools were run to provide a first cut of potential BMP locations. Below is a brief description of these BMPs and the methods used by ACPF to site each practice.

- **Water and Sediment Control Basins.** 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 and 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.
- **Grassed Waterways.** 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

Diamond Creek SWA study area. This tool utilizes a user-defined stream power index (SPI) threshold to site potential locations for these practices. In many cases, grass waterways and WASCOBs can be used inter-changeably depending on site conditions.

- **Wetland Restoration.** 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, or installing adjustable outlets to regulate water levels. The primary benefits of wetland restorations include water storage, volume and 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 or hydric soils that are currently in agricultural production.
- **Alternative Tile Intakes.** 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 filtering. They can also reduce the velocity of flow into the tile inlet. ATIs 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 and 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 or hydric soils that 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 the area from production.

The initial model runs provided several hundred BMP options and it was apparent this list would need to be refined. A prioritization scheme was developed to refine the initial list of BMPs based on visual inspection of multiple years of air photos in Google Earth and ArcGIS. The draft BMP GIS layers were then provided to Hennepin County Environment and Energy Department staff (Kris Guentzel and Paul Stewart) who visited many of the potential BMP sites in the field to assess feasibility. Below is a list of criteria used for prioritization and BMP field review:

- 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 and stabilization BMPs (i.e., grassed waterways and WASCOBs) that were sited in areas showing no evidence of soil erosion, are not row cropped, and 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 several cases add, BMPs in specific locations that were identified as potential locations by Hennepin County staff during their field assessment.

2.0 STRUCTURAL AGRICULTURAL BMP SIZING, DESIGN, COST AND POLLUTANT REDUCTION METHODS

Agricultural BMP sizing, design, and pollutant reduction estimates were evaluated using methodology and research from various sources, including: the ACPF ArcGIS Toolbox User's Manual (link to manual), Natural Resources Conservation Service (NRCS) practice guides and 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 as site conditions would allow based on a desktop review.

BMP load reduction benefits were calculated based on each BMP's drainage area, annual water volume, annual pollutant loads, and the recommended removal efficiency of the practice. Removal efficiencies were applied in full if the BMP footprints and variable storage volumes meet minimum design standards and 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. 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 Diamond Creek SWA 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 and waterways) may present better opportunities to reduce monitored pollutant loads in downstream waterbodies.

Planning level cost estimates were developed for each BMP based on guidance from various groups and agencies (Hennepin County, NRCS, BWSR, SWCDs, etc.) as well as 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 lost production costs
- Engineering costs and contingency (typically 30% of construction costs)
- Annual maintenance costs, (typically 5% of construction costs) which includes general site inspection and minor housekeeping

Cost estimate methodology for each BMP type is summarized in Table C1. Detailed cost estimate assumptions for each BMP are presented in Tables C2-C5. 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 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 for BMPs to maintain performance. This includes sediment removal, vegetation maintenance, filter maintenance, and monitoring.

Table C-1. Summary of BMP sizing methods, pollutant reduction assumptions, 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 and demobilization, minor grading and excavation, seeding, outlet riprap, and site restoration. Other cost considerations include lost production cost and annual maintenance. See tables below for detailed cost assumptions.
Water & Sediment Control Basin (WASCOB)	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 and demobilization, surface inlet, berm construction, tile installation, grading, seeding and site restoration. Other cost considerations include annual maintenance. See tables below for detailed cost assumptions.
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 and 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 tables below 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 and 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

BMP	BMP Sizing Methods	BMP Pollutant Reduction Estimates and Benefits	BMP Cost Estimates
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 = 20%	Planning level construction cost estimates include design, contingency, mobilization and demobilization, and installation of ATIs. Other cost considerations include annual maintenance.

2.1 GRASSED WATERWAY COST ASSUMPTIONS:

- The length of the grassed waterway was generated by the model
- The outlet structure for each waterway was assumed to require 10 cubic yards of riprap ($150/CY) and clearing and grubbing
- Mobilization and demobilization and grading were assumed to be lump sums ($1,500 LS; $3,000 LS)

Table C-2. Grassed waterway cost assumptions

Item	Unit	Unit Cost
Mobilization	LS	$1,500
Grading	LS	$3,000
Seeding & Erosion Control	AC	$15,000
Outlet Riprap	LS	$1,500
Clearing and Grubbing (outlet area)	LS	$500
Annual Lost Production	AC	$800
Design, Contingency		30% of construction cost
Annual Maintenance		5% of construction cost

2.2 WASCOB COST ASSUMPTIONS:

- The berm of each WASCOB sited by ACPF have a generic size of 330 ft (length) by 3 ft (top width) by 3.5 ft (height) ($10/CY)
- Side slopes of the berm is 10:1
- Basin surface areas were generated by the ACPF
- A surface inlet installation for each WASCOB ($500 LS)
- Assumed ~200 feet of tiling will be needed for each WASCOB ($20/LF; $4,000 LS)
- Area for seeding was the entire berm surface area ($15,000/AC; $350 LS)
- Mobilization/demobilization, grading & berm construction, and clearing and grubbing were lump sums given berm size assumptions described above ($1,500 LS; $4,300 LS; $500 LS)

Table C-3. WASCOB waterway cost assumptions

Item	Unit	Unit Cost
Mobilization	LS	$1,500
Grading	LS	$3,000
Berm Construction	LS	$1,300
Surface Inlet	EA	$500
Additional Tile	LS	$4,000
Seeding (berm)	LS	$350
Clearing and Grubbing (outlet area)	LS	$500
Annual Lost Production (berm)	AC	$800
Design, Contingency		30% of construction cost
Annual Maintenance		5% of construction cost

2.3 DEPRESSION/WETLAND RESTORATION COST ASSUMPTIONS:

- Depressions are wetland restoration opportunities identified by ACPF and/or Stantec during previous wetland restoration investigation efforts
- A lump sum of $5,000 for the outlet control structure (e.g., berm, ditch plug, weir) for each wetland restoration ($5,000 LS)
- Area for seeding is the entire flood pool surface area ($1000/AC)
- Mobilization/demobilization, grading, wetland delineation, and permitting are lump sum estimates ($7,500 LS; $6,000 LS; $3,000 LS; $3,500)
- Easement cost ($10000/AC) were assumed for the entire depression and buffer area and accounts for a significant amount of the cost for this practice

Table C-4. Grassed waterway cost assumptions

Item	Unit	Unit Cost
Mobilization	LS	$7,500
Grading	LS	$6,000
Seeding	AC	$1,000
Wetland Delineation	EA	$3,000
Permitting	EA	$3,500
Easement	AC	$10,000
Design, Contingency		50% of construction cost
Annual Maintenance	LS	$500

2.4 ALTERNATIVE TILE INTAKES (ATIS) IN DEPRESSIONAL AREAS COST ASSUMPTIONS:

- ATI installation can be targeted in depressional areas as an alternative to wetland restoration
- Minor grading is assumed to be necessary in the cost analysis to be conservative

- Mobilization/demobilization, grading, and erosion control were lump sums ($1,500 LS; $1,000 LS; $500 LS)
- Assumed one ATI is needed per 0.5 acre of depressional area
- 100 feet of tiling needed for each ATI to connect to existing tile line ($20/LF)

Table C-5. Grassed waterway cost assumptions

Item	Unit	Unit Cost
Mobilization (per depressional area site)	LS	$1,500
Grading (per ATI)	EA	$500
ATI Installation (per ATI)	EA	$600
Tile Installation (per ATI)	EA	$2,000
Erosion Control (per ATI)	EA	$500
Design, Contingency		30% of construction cost
Annual Maintenance		5% of construction cost

3.0 STRUCTURAL AGRICULTURAL BMPS RESULTS

As described above, structural BMPs for the Diamond Creek SWA Study were sited using the ACPF Toolbox and further refined by field assessment by Hennepin County staff. Through this process, 154 potential BMP options were identified throughout the Study Area (Tables C6-C9 and Figure C1). Below is a brief overview of the different BMPs identified through this analysis.

- **Grassed Waterways**: 32 potential sites were identified. TSS and TP load reductions ranged from 0.1-2.8 tons/yr and 1.2-13.8 lbs/yr, respectively. Cost benefit ranged from $130-$780/pound of TP removed.
- **Water and Sediment Control Basins**: 14 potential sites were identified. TSS and TP load reductions ranged from 0.1-2.2 tons/yr and 2-17.9 bs/yr, respectively. Cost benefit ranged from $70-$660/pound of TP removed. Additionally, WASCOBs could likely be constructed at many of the grassed waterway locations depending on site conditions and landowner preference.
- **Wetland Restorations**: 54 potential locations were identified for wetland restoration using the depression identification and nutrient removal wetland tools. Storage benefit for these restorations range from <1-23.1 acre-ft while TSS and TP load reductions ranged from <0.1-351.1 tons/yr and 0.4-58.5 lbs/yr, respectively. Cost benefit ranged from $210-$4790/pound of TP removed.
- **Alternative Tile Intakes**: 54 potential locations were identified on 14 parcels for ATIs using the depression identification tool. TSS and TP load reductions for these practices ranged from <0.1-11.2 tons/yr and 0.2-15.4 lbs/yr, respectively. Cost benefit ranged from $30-$5810/pound of TP removed.

Model estimates suggest that if all these BMPs were implemented, storage would be increased by approximately 190.5 acre-ft and TSS and TP loading would decrease by approximately 285 tons/yr and 1640 lbs/yr, respectively. As discussed above, all BMP pollutant load reduction estimates should be viewed as edge of field reductions.

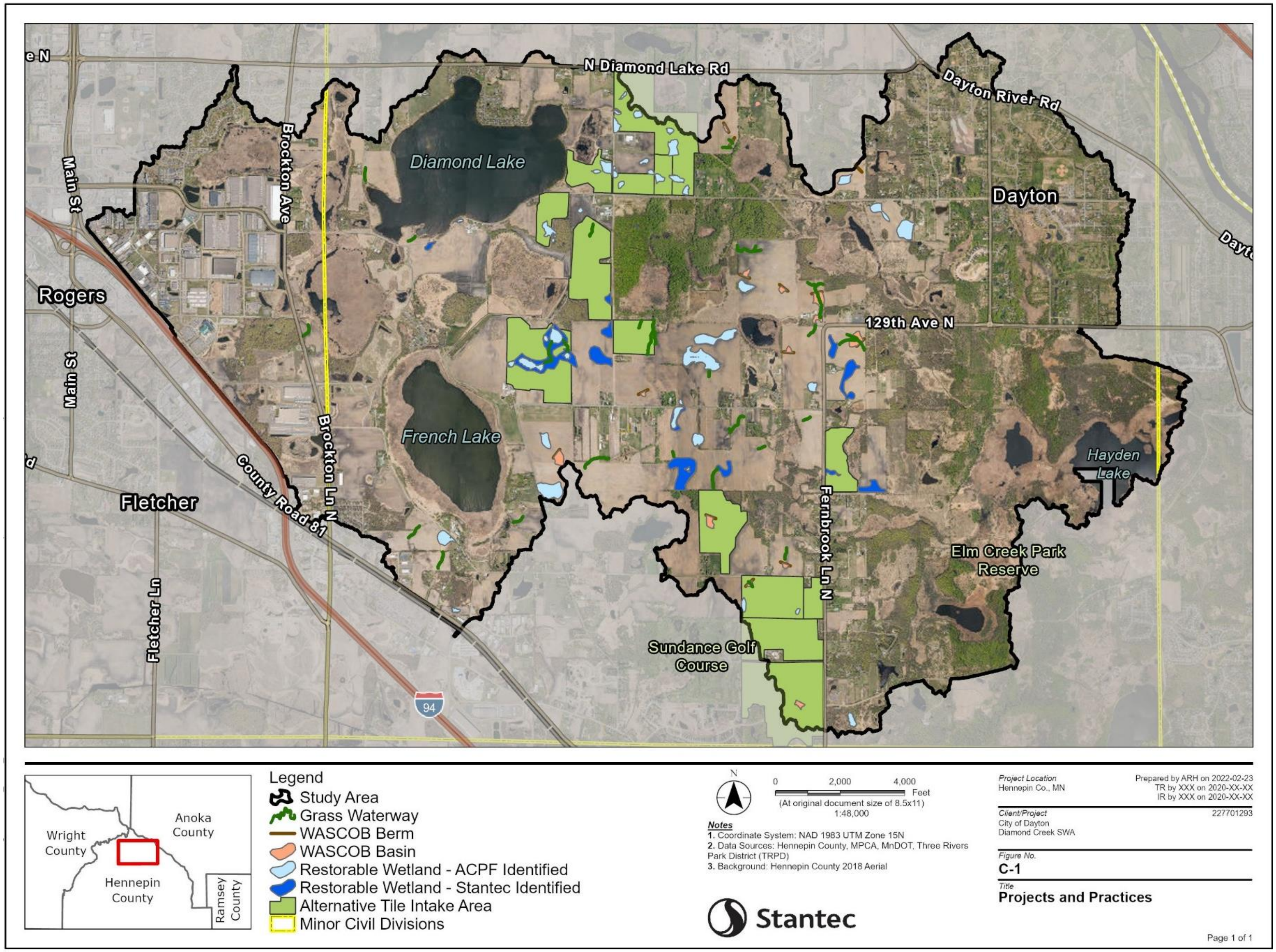

Figure C-2. Rural Structural BMPs sited for Diamond Creek SWA Study Area

Table C-6. Grassed waterways sited in the Diamond Creek SWA Study Area

MU	BMP ID	Estimated Benefit - Storage (acre-ft)	Estimated Benefit - 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)
Diamond Creek	38	--	1.0	12.7	$20,300	$57,300	--	$3,000	$230
	36	--	0.6	8.8	$16,800	$45,000	--	$3,600	$250
	9	--	0.4	6.6	$14,800	$37,800	--	$4,700	$280
	65	--	0.3	4.0	$12,100	$28,200	--	$4,700	$360
	39	--	0.3	4.3	$14,000	$34,600	--	$5,800	$410
	37	--	0.2	3.0	$11,200	$24,900	--	$5,500	$420
	109	--	0.2	2.9	$11,300	$25,000	--	$7,000	$430
	39	--	0.2	2.9	$11,200	$24,800	--	$6,100	$430
	9	--	0.2	2.8	$11,200	$24,700	--	$7,200	$440
	92	--	0.1	1.9	$10,300	$21,400	--	$7,400	$550
	36	--	0.1	2.0	$10,300	$21,700	--	$7,800	$550
	65	--	0.2	2.7	$12,400	$29,200	--	$7,300	$550
	65	--	0.1	1.8	$10,100	$21,000	--	$7,800	$580
	11	--	0.1	1.7	$10,100	$20,800	--	$8,500	$600
	11	--	0.1	1.3	$9,700	$19,200	--	$10,800	$760
	92	--	0.1	1.2	$9,600	$19,000	--	$10,400	$780
Diamond Lake	162	--	0.8	3.9	$11,100	$24,500	--	$1,600	$320
	60	--	0.1	3.5	$11,400	$25,600	--	$11,100	$370
	119	--	0.5	2.6	$10,300	$21,500	--	$2,000	$410
French Lake	100	--	0.3	5.3	$12,300	$28,700	--	$5,400	$270
	72	--	0.2	3.5	$11,000	$24,000	--	$6,800	$350
	51	--	0.2	3.4	$12,000	$27,500	--	$8,100	$410
Hayden Lake N & S	156	--	1.0	5.1	$10,600	$22,700	--	$1,100	$220
	16	--	2.8	13.8	$14,300	$36,000	--	$600	$130
	26	--	2.1	10.2	$12,800	$30,500	--	$700	$150

MU	BMP ID	Estimated Benefit - Storage (acre-ft)	Estimated Benefit - 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)
	16	--	1.5	7.5	$13,200	$31,900	--	$1,000	$210
	46	--	0.8	4.0	$10,100	$21,000	--	$1,300	$260
	17	--	0.7	3.5	$10,000	$20,300	--	$1,400	$290
	53	--	0.7	3.4	$9,900	$20,100	--	$1,500	$300
	16	--	0.5	2.6	$9,600	$18,900	--	$1,800	$360
	54	--	0.7	3.2	$10,900	$23,700	--	$1,800	$370
	11	--	0.1	1.3	$9,600	$19,200	--	$10,900	$760

Table C-7. WASCOBs sited in the Diamond Creek SWA Study Area

MU	BMP ID	Estimated Benefit - Storage (acre-ft)	Estimated Benefit - 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)
Diamond Creek	BMP-10	--	0.8	14.7	$11,100	$25,900	--	$1,650	$90
	BMP-8	--	0.5	10.1	$11,100	$25,900	--	$2,410	$130
	BMP-15	--	0.4	8.0	$11,100	$25,900	--	$3,040	$160
	BMP-9	--	0.3	6.0	$11,100	$25,900	--	$4,050	$220
	BMP-11	--	0.3	5.5	$11,100	$25,900	--	$4,730	$240
	BMP-14	--	0.2	3.0	$11,100	$25,900	--	$8,020	$430
	BMP-13	--	0.1	2.3	$11,100	$25,900	--	$10,320	$550
	BMP-6	--	0.1	2.0	$11,100	$25,900	--	$13,230	$660
French Lake	BMP-5	--	0.7	17.9	$11,100	$25,900	--	$1,990	$70
Hayden Lake N & S	BMP-4	--	2.2	15.1	$11,100	$25,900	--	$590	$90
	BMP-2	--	1.3	9.0	$11,100	$25,900	--	$1,000	$140
	BMP-7	--	1.2	8.4	$11,100	$25,900	--	$1,060	$150
	BMP-1	--	1.3	7.5	$11,100	$25,900	--	$990	$170

MU	BMP ID	Estimated Benefit - Storage (acre-ft)	Estimated Benefit - 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)
	BMP-3	--	0.8	5.5	$11,100	$25,900	--	$1,640	$240

Table C-8. Wetland restorations sited in the Diamond Creek SWA Study Area

MU	BMP ID	Size (acres)	Estimated Benefit – Storage (acre-ft)	Estimated Benefit – TSS (tons/yr)	Estimated Benefit – 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)
Diamond Creek	457807	2.43	0.9	3.7	7.2	$59,200	$67,300	$3,700	$910	$470
	377446	4.79	3.0	5.2	10.4	$84,400	$100,400	$1,700	$960	$480
	65	9.39	5.5	14.7	13.0	$133,600	$164,900	$1,500	$560	$640
	65	2.95	1.7	1.9	5.2	$64,800	$74,600	$2,200	$2,000	$710
	169809	1.49	1.1	0.7	3.7	$49,100	$54,100	$2,600	$3,620	$730
	422661	5.10	2.1	2.5	7.2	$87,800	$104,800	$2,500	$2,090	$730
	109	1.55	0.9	0.6	3.2	$49,800	$54,900	$3,000	$4,940	$860
	68	3.65	2.1	1.9	4.6	$72,200	$84,400	$2,000	$2,200	$910
	158297	2.32	0.9	0.6	3.3	$58,000	$65,800	$3,500	$5,420	$990
	163656	0.97	0.4	0.8	2.3	$43,600	$46,800	$6,500	$2,780	$1,000
	294871	4.09	1.2	0.9	4.1	$76,900	$90,600	$3,900	$4,950	$1,110
	9	39.36	23.1	99.2	25.8	$453,900	$585,100	$1,300	$290	$1,140
	158778	1.90	0.7	0.4	2.6	$53,500	$59,800	$4,100	$8,240	$1,160
	143563	1.17	0.5	0.2	1.7	$45,700	$49,600	$5,100	$15,540	$1,450
	68	8.94	5.2	4.0	4.6	$128,800	$158,600	$1,500	$1,980	$1,730
	224732	4.16	2.9	1.2	2.4	$77,700	$91,600	$1,600	$3,970	$1,910
	151390	0.79	0.3	0.1	1.1	$41,700	$44,400	$7,100	$33,570	$2,020
	403647	1.13	0.3	<0.1	1.0	$45,300	$49,100	$8,800	$54,210	$2,530
	145649	14.84	20.5	18.6	4.7	$191,800	$241,300	$600	$650	$2,560
	65	4.01	2.4	0.8	1.7	$76,100	$89,500	$1,900	$5,530	$2,670
	416075	0.95	0.2	<0.1	0.8	$43,400	$46,600	$9,900	$72,590	$2,850

MU	BMP ID	Size (acres)	Estimated Benefit – Storage (acre-ft)	Estimated Benefit – TSS (tons/yr)	Estimated Benefit – 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)
	189067	0.68	0.2	<0.1	0.7	$40,500	$42,700	$10,300	$86,060	$2,980
	120384	1.01	0.3	<0.1	0.8	$44,000	$47,400	$7,500	$49,990	$3,050
	374725	0.71	0.2	<0.1	0.7	$40,800	$43,200	$10,700	$92,060	$3,090
Diamond Lake	119380	2.45	1.1	3.5	5.5	$59,500	$67,700	$3,000	$980	$610
	117	1.44	0.8	1.7	3.7	$48,600	$53,400	$3,200	$1,550	$710
	108410	1.68	1.0	2.0	3.6	$51,200	$56,800	$2,900	$1,440	$780
	153968	5.01	3.3	17.7	5.5	$86,800	$103,500	$1,600	$290	$950
	150442	0.73	0.3	0.5	1.8	$41,100	$43,500	$7,800	$4,340	$1,200
	98718	0.52	0.3	0.2	1.4	$38,800	$40,500	$7,000	$9,260	$1,460
	106052	0.83	0.3	0.2	1.3	$42,100	$44,800	$8,300	$11,520	$1,710
	95333	0.66	0.2	0.1	0.8	$40,300	$42,500	$13,400	$31,800	$2,770
	199770	0.58	0.2	0.1	0.7	$39,400	$41,300	$13,700	$34,220	$2,830
French Lake	682785	5.34	7.0	13.6	14.0	$90,300	$108,100	$800	$400	$390
	546117	3.56	2.8	3.1	8.0	$71,300	$83,200	$1,500	$1,340	$520
	767557	1.06	0.5	0.2	2.5	$44,600	$48,200	$4,400	$12,830	$970
	611406	10.97	20.4	9.0	3.1	$150,400	$187,000	$500	$1,040	$2,980
Hayden Lake N & S	380705	10.80	8.8	213.2	43.3	$148,700	$184,700	$1,000	$40	$210
	47	6.21	3.6	58.2	28.6	$99,700	$120,400	$1,700	$100	$210
	192	18.42	10.8	353.1	58.5	$230,100	$291,500	$1,300	$40	$250
	422326	15.46	18.9	345.5	32.7	$198,400	$250,000	$700	$40	$380
	874646	2.50	3.0	13.3	6.6	$59,900	$68,200	$1,100	$260	$520
	11	15.04	8.8	33.0	19.4	$193,900	$244,100	$1,400	$370	$630
	44	1.72	1.0	2.5	4.4	$51,600	$57,300	$2,800	$1,170	$660
	16	4.46	2.6	8.4	5.7	$80,900	$95,800	$1,800	$570	$840
	767467	1.68	0.6	1.1	3.3	$51,200	$56,800	$4,700	$2,530	$850
	517879	3.86	1.6	1.4	4.4	$74,500	$87,300	$2,700	$3,170	$1,000
	543145	3.81	3.0	6.2	3.7	$73,900	$86,600	$1,400	$700	$1,170

MU	BMP ID	Size (acres)	Estimated Benefit – Storage (acre-ft)	Estimated Benefit – TSS (tons/yr)	Estimated Benefit – 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)
	16	4.00	2.3	4.8	3.7	$76,000	$89,300	$1,900	$920	$1,210
	16	6.34	3.7	3.1	4.4	$101,000	$122,100	$1,600	$1,950	$1,400
	770004	0.59	0.2	0.1	1.2	$39,600	$41,600	$13,700	$20,640	$1,750
	11	11.33	6.6	6.1	4.8	$154,400	$192,200	$1,400	$1,580	$2,020
	576045	0.42	0.1	0.1	0.9	$37,800	$39,200	$16,700	$32,320	$2,130
	479758	0.52	0.1	<0.1	0.4	$38,800	$40,500	$16,800	$206,600	$4,790

Table C-9. Alternative Tile Intake sited in depressional areas in the Diamond Creek SWA Study Area

MU	BMP ID	# of ATIs	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)
Diamond Creek	169809	2	--	0.9	3.5	$7,700	$15,400	--	$890	$220
	457807	3	--	2.7	3.7	$10,800	$21,600	--	$400	$290
	109	2	--	0.7	2.6	$7,700	$15,400	--	$1,160	$290
	377446	6	--	1.5	6.8	$20,100	$40,200	--	$1,370	$300
	158297	3	--	0.9	3.5	$10,800	$21,600	--	$1,250	$310
	163656	1	--	1.3	1.0	$4,600	$9,200	--	$350	$450
	422661	7	--	0.6	2.9	$23,200	$46,400	--	$3,640	$790
	189067	1	--	0.1	0.5	$4,600	$9,200	--	$4,270	$930
	151390	1	--	0.1	0.5	$4,600	$9,200	--	$3,880	$970
	65	4	--	0.4	1.4	$13,900	$27,800	--	$3,770	$1,010
	158778	3	--	0.2	0.9	$10,800	$21,600	--	$4,740	$1,190
	65	13	--	0.9	3.4	$41,800	$83,600	--	$4,580	$1,220
	416075	1	--	0.1	0.4	$4,600	$9,200	--	$5,840	$1,270
	68	5	--	0.3	1.2	$17,000	$34,000	--	$5,550	$1,390
	294871	5	--	0.3	1.2	$17,000	$34,000	--	$5,610	$1,410
	143563	2	--	0.1	0.5	$7,700	$15,400	--	$6,490	$1,630

MU	BMP ID	# of ATIs	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)
	374725	1	--	0.0	0.2	$4,600	$9,200	--	$9,230	$2,000
	120384	1	--	0.1	0.2	$4,600	$9,200	--	$8,960	$2,250
	9	52	--	1.5	6.8	$162,700	$325,400	--	$11,060	$2,400
	403647	2	--	0.1	0.3	$7,700	$15,400	--	$12,030	$2,610
	224732	6	--	0.1	0.6	$20,100	$40,200	--	$14,670	$3,190
	68	12	--	0.3	1.2	$38,700	$77,400	--	$14,790	$3,210
	65	5	--	0.1	0.4	$17,000	$34,000	--	$14,430	$3,860
	145649	20	--	0.3	1.2	$63,500	$127,000	--	$20,440	$5,130
Diamond Lake	106052	1	--	1.5	2.1	$4,600	$9,200	--	$300	$210
	119380	3	--	1.5	2.1	$10,800	$21,600	--	$710	$500
	98718	1	--	0.6	0.9	$4,600	$9,200	--	$730	$520
	150442	1	--	1.1	0.9	$4,600	$9,200	--	$410	$540
	199770	1	--	0.5	0.6	$4,600	$9,200	--	$1,020	$720
	117	2	--	0.7	1.0	$7,700	$15,400	--	$1,100	$780
	108410	2	--	0.7	1.0	$7,700	$15,400	--	$1,130	$810
	95333	1	--	0.3	0.5	$4,600	$9,200	--	$1,330	$950
	153968	7	--	1.9	1.4	$23,200	$46,400	--	$1,240	$1,610
French Lake	767557	1	--	0.2	1.3	$4,600	$9,200	--	$1,920	$350
	546117	5	--	0.4	2.1	$17,000	$34,000	--	$4,440	$810
	682785	7	--	0.2	1.4	$23,200	$46,400	--	$9,400	$1,710
	611406	15	--	0.2	0.8	$48,000	$96,000	--	$31,920	$5,810
Hayden Lake N & S	576045	1	--	9.9	13.7	$4,600	$9,200	--	$50	$30
	479758	1	--	0.5	1.8	$4,600	$9,200	--	$1,000	$250
	47	8	--	5.7	7.8	$26,300	$52,600	--	$460	$340
	192	25	--	11.2	15.4	$79,000	$158,000	--	$710	$510
	874646	3	--	1.5	1.7	$10,800	$21,600	--	$720	$630
	422326	21	--	6.2	8.6	$66,600	$133,200	--	$1,070	$770

MU	BMP ID	# of ATIs	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)
	770004	1	--	0.4	0.6	$4,600	$9,200	--	$1,050	$770
	767467	2	--	0.6	0.9	$7,700	$15,400	--	$1,200	$880
	380705	14	--	3.5	4.8	$44,900	$89,800	--	$1,280	$930
	44	2	--	0.6	0.8	$7,700	$15,400	--	$1,380	$1,000
	16	6	--	1.1	1.5	$20,100	$40,200	--	$1,840	$1,340
	517879	5	--	0.3	1.2	$17,000	$34,000	--	$5,890	$1,480
	543145	5	--	0.7	1.0	$17,000	$34,000	--	$2,400	$1,750
	16	5	--	0.7	1.0	$17,000	$34,000	--	$2,400	$1,750
	11	20	--	0.8	3.1	$63,500	$127,000	--	$8,180	$2,050
	16	8	--	0.3	1.2	$26,300	$52,600	--	$9,110	$2,280
	11	15	--	0.3	1.3	$48,000	$96,000	--	$15,290	$3,840

APPENDIX D

Urban BMP Technical Appendix

1.0 URBAN BMPS

1.1 BACKGROUND

Much of the Diamond SWA Study area is undeveloped agricultural land, however there are several areas that have been developed or are in the process of developing. BMPs for the undeveloped agricultural portions of the SWA Study area are presented in Appendices C and E. This technical appendix presents BMP options to treat runoff and stormwater for several developed and developing portions of the SWA Study Area. Much of the City of Rogers portion of the SWA Study area west of Diamond Lake was developed under stormwater rules in the last 20 years and therefore has stormwater treatment BMPs in-place. As a result, the City of Rogers portion of the SWA Study area was reviewed for this study, however no additional BMPs were identified or sited at this time. However, several developed and developing areas within the City of Dayton were identified within the Study Area for BMPs or future regional BMP opportunities as development occurs. These areas and BMP options are described in more detail below.

1.2 METHODS

Stantec reviewed existing LiDAR and storm sewer information provided by the City of Dayton to identify potential locations for stormwater BMPs within developed areas, as well as potential regional BMP opportunities in areas that will likely be developed soon (e.g., French Lake Management Unit).

It is important to note that all the proposed projects in this report have potential design challenges and cost considerations that need to be fully investigated prior to their implementation. Therefore, BMPs proposed here as options for consideration may encounter challenges during the design process that may result in pollutant removal estimates that differ from the BMPs proposed in this report. In addition, BMP performance can vary from year to year based on climatic conditions, ongoing maintenance regimes, and other environmental factors.

1.3 PROPOSED PROJECTS AND BMPS

Four BMPs were identified throughout the Diamond Creek Study Area (See Figure D-1). In siting and developing the list of proposed BMPs, we focused primarily on public owned property such as easements, parks, and City/County right of way, as they are usually easier to implement, maintain, and manage over the life of the practice. Where possible, BMP cost estimates were developed, and pollutant reduction benefits were estimated. Below is a detailed description of each proposed stormwater BMP.

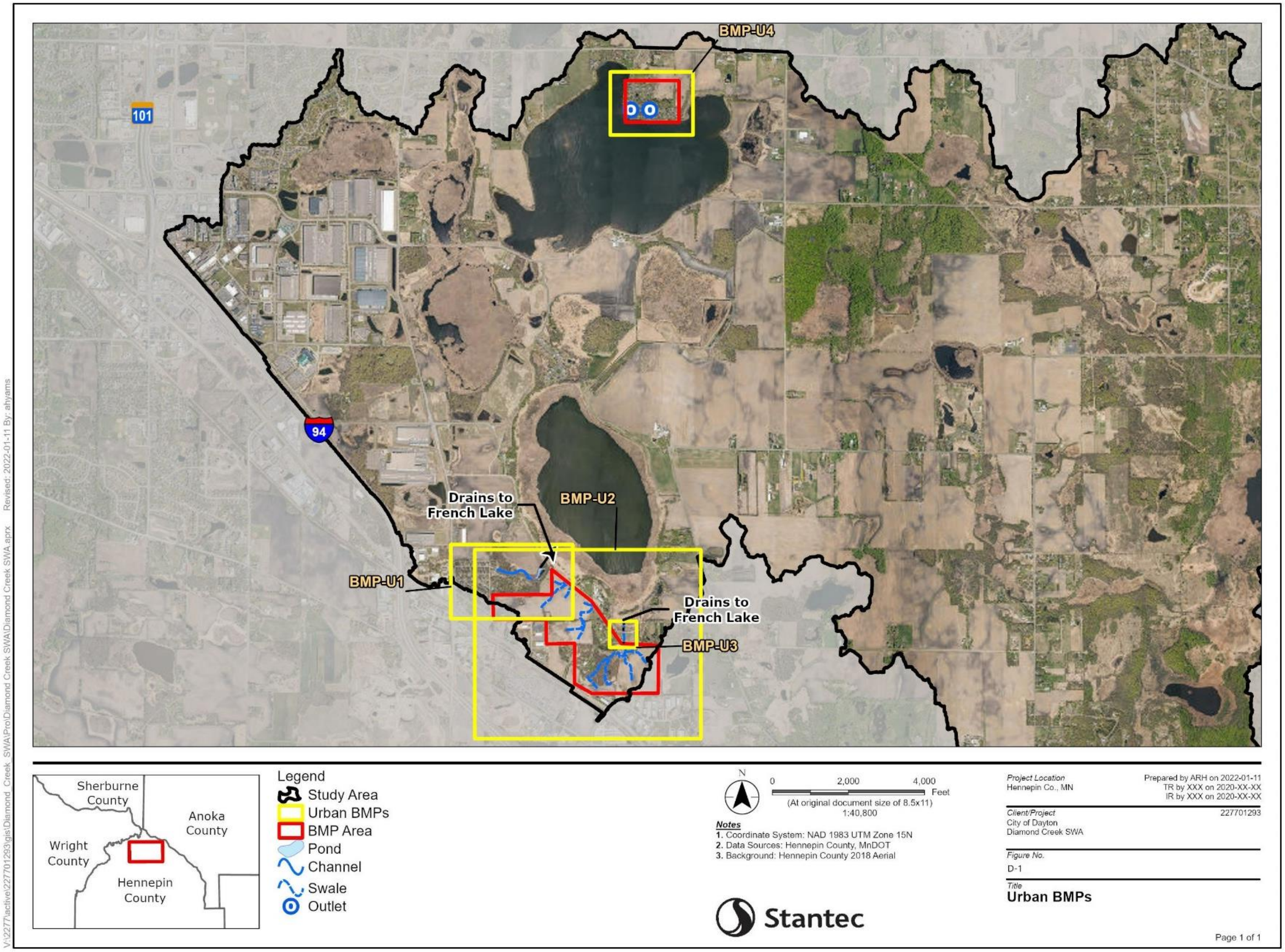

Figure D-1. Proposed urban BMP locations within the Dayton SWA Study Area

1.3.1 BMP-U1 (French Lake Management Unit)

BMP-U1 is a pond/basin located just west of French Lake in Dayton along a natural channel that flows to French Lake. This channel and basin collect runoff from a combination of farmland, trailer park and natural, undisturbed woodlands. Based on review of air photos and a site visit conducted by Stantec staff, there are two channels that flow into the basin and there is a large sediment delta that has formed on upstream side of the basin. Based on the large size of this basin's drainage area, multiple parcels/landowners, and development pressures, we propose that a separate feasibility study be conducted for this site to perform a more detailed evaluation of stormwater treatment options and potential costs. The feasibility study would include the following activities:

- Conduct a survey of the area surrounding the basin, inlet channels, and discharge culvert
- Conduct a bathymetry survey of the basin
- Update the stormwater models based on the surveys completed
- Estimate sediment depths within the basin and map the sediment delta and accumulation
- Collect sediment samples for laboratory analysis of phosphorus
- Collect water samples from the basin and at the inlets and outlet for laboratory analysis of nutrients
- Measure flow at the inlets and outlets to calculate nutrient loads
- Evaluate the collected data
- Assess 2-3 potential BMP options to provide a benefit in nutrient reduction
- Prepare a memorandum of the BMP options that includes the following elements:
  - Calculated benefits in terms of nutrient load reduction
  - Estimated costs
  - Estimated implementation schedule and comparison to the TMDL goals for the benefit provided

Estimated cost of the feasibility study for BMP-U1 are presented below in Table D1.

Table D-1. BMP-U1 feasibility study cost estimate

Task	Description	Estimated Cost
1	Survey	$1,700
2	Bathymetry	$1,200
3	Modeling	$1,300
4	Sediment and water sampling	$2,300
5	Review Alternatives	$1,500
6	Cost Estimates	$1,000
7	Memorandum	$1,900
8	Meeting(s)	$700
PROJECT TOTAL		**$11,600**

Figure D-2. Proposed BMP-U1 location

1.3.2 BMP-U2 (French Lake Management Unit)

The next area (location BMP-U2 on Figure D1) is a series of swales and concentrated flow paths on the south and southwest side French Lake adjacent to West French Lake Road. These swales and flow paths currently collect surface runoff from large adjacent agricultural fields, and discharge through a culvert under West French Lake Road prior to entering French Lake. This area is currently being developed and transitioning from agricultural dominated land use to urban/commercial land use and therefore will be required to implement stormwater treatment BMPs to treat runoff from these sites. The City is currently working with the developers to identify regional stormwater treatment options and has some preliminary concept plans and design options. The City and developers should continue to explore options to maximize treatment of TSS and TP to French Lake.

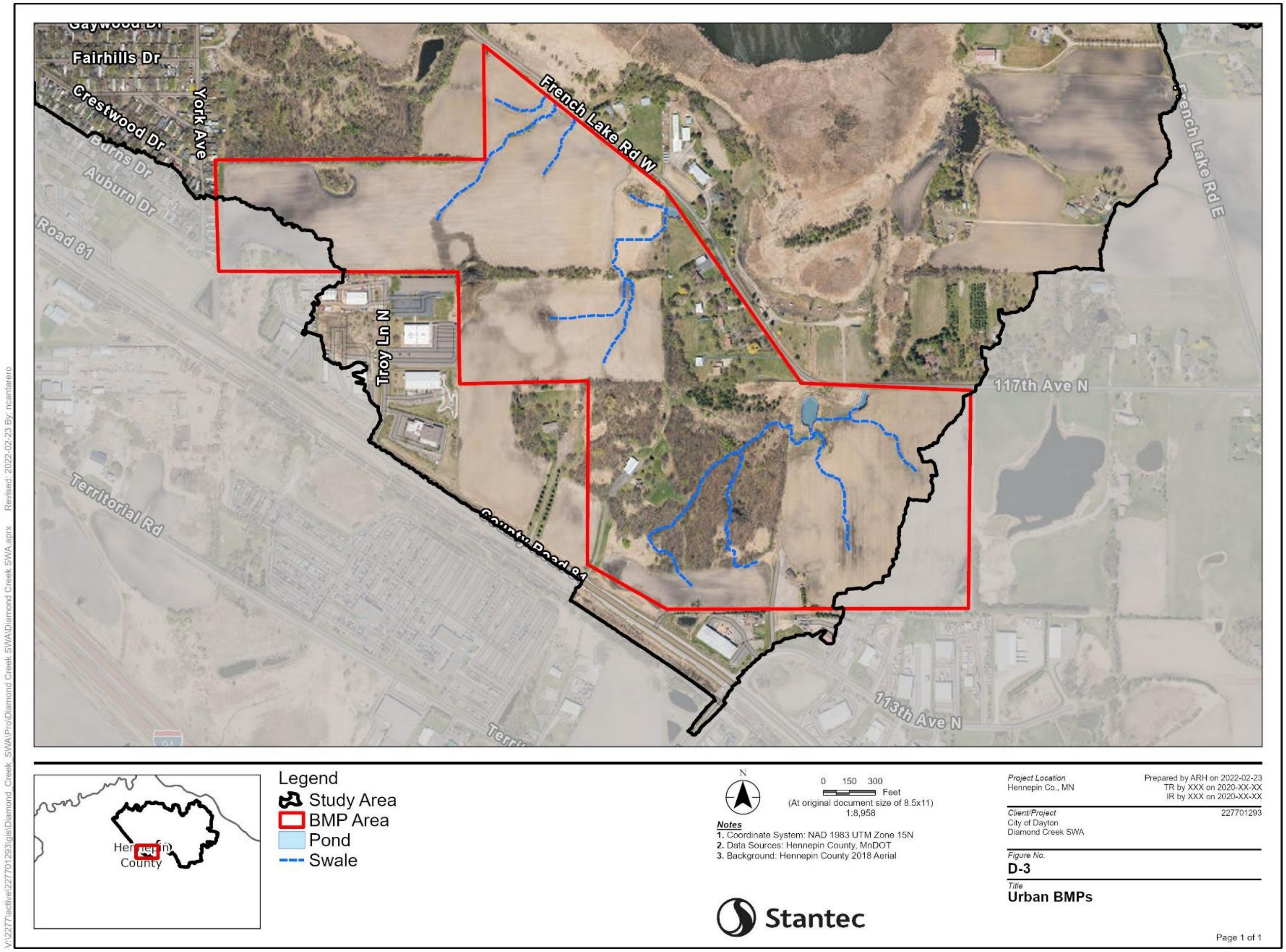

Figure D-3. Proposed BMP-U2 location

1.3.3 BMP-U3 (Diamond Lake Management Unit)

BMP-U3 is a roadside swale on the south side of French Lake Road. The swale collects surface runoff from a large adjacent agricultural field, and discharges through a culvert under French Lake Road to French Lake. This site will also need some more investigation and a feasibility study to identify potential engineering options. The feasibility would likely include the following activities:

- Model the drainage area and discharge to estimate water quality and quantity characteristics
- Assess 2-3 potential BMPs in the watershed and swale
- Estimate water quality benefits provided by the BMPs
- Prepare a feasibility memorandum to evaluate selected BMPs for the basin and watershed
- Provide a summary and comparison of cost and benefit for each potential BMP

Estimated cost of the feasibility study for BMP-U3 are presented below in Table D2 below

Table D-2. BMP-U3 feasibility study cost estimate

Task	Description	Estimated Cost
1	Survey	$600
2	Modeling	$950
3	Concept development	$1,000
4	Cost Estimates	$800
5	Memorandum	$1,700
6	QA/QC	$500
7	Meeting	$700
PROJECT TOTAL		**$6,250**

Figure D-4. Proposed BMP-U3 location

1.3.4 BMP-U4 (Diamond Lake Management Unit)

BMP-U4 is a residential neighborhood north of Diamond Lake on 138th Avenue North. Runoff from the homes and streets in this neighborhood is collected in storm sewers. There are two outfalls to Diamond Lake from these storm sewers – one at the intersection of Lawndale Lane North and 138th Avenue North, and the other near the mid-point of 138th Avenue. The discharge at Lawndale Lane is a flared end section that discharges into a swale that flows to Diamond Lake. The other discharge is a culvert from a catch basin in 138th Avenue that flows south to Diamond Lake. The following potential BMPs were sited to treat stormwater runoff in this neighborhood:

- Install sump manholes with Preserver Baffles
- Work with willing landowners to install curb-cut rain gardens
- Stabilize the swale at Lawndale Lane to provide additional stormwater treatment

Planning level cost estimates for each BMP option are presented in Tables D3, D4, and D5.

Table D-3. Cost estimate for sump manholes with Preserver Baffles (per manhole)

Item	Description	Quantity	Units	Unit Cost	Extended Cost
1	Mobilization	1	LS	$1,000.00	$1,000.00
2	Sawcut and Remove Bituminous	100	SF	$5.00	$500.00
3	Remove Curb and Gutter	30	LF	$10.00	$300.00
4	Remove Existing Structure	1	EA	$1,500.00	$1,500.00
5	New Structure with Sump and Baffle	1	EA	$8,000.00	$8,000.00
6	Hand Form Curb and Gutter	30	LF	$35.00	$1,050.00
7	Pavement Patching	100	SF	$10.00	$1,000.00
8	Sod	50	SF	$5.00	$250.00
TOTAL ESTIMATED COST					**$13,600.00**

Table D-4. Cost estimate for curb cuts with rain gardens (per rain garden)

Item	Description	Quantity	Units	Unit Cost	Extended Cost
1	Mobilization	1	LS	$1,000.00	$1,000.00
2	Remove Curb and Gutter	30	LF	$10.00	$300.00
3	Place New Curb with Curb Cuts	30	LF	$35.00	$1,050.00
4	Rain Guardian	2	EA	$1,800.00	$3,600.00
5	Excavate Rain Garden/Haul off Soil	40	CY	$18.00	$720.00
6	Planting	1000	SF	$2.50	$2,500.00
7	Sod	50	SF	$5.00	$250.00
TOTAL ESTIMATED COST					**$9,420.00**

Table D-5. Cost estimate for swale stabilization

Item	Description	Quantity	Units	Unit Cost	Extended Cost
1	Mobilization	1	LS	$1,000.00	$1,000.00
2	Tree Clearing and Grubbing	1	LS	$2,500.00	$2,500.00
3	Class 1 Rip Rap	12	CY	$100.00	$1,200.00
4	Native Seed with erosion control blanket	2000	SF	$1.00	$2,000.00
5	Live Plants	50	EA	$40.00	$2,000.00
TOTAL ESTIMATED COST					**$8,700.00**

Figure D-5. Proposed BMP-U4 location

APPENDIX E

Non-Structural BMP Technical Appendix

1.0 DIAMOND CREEK SUBWATERSHED NON-STRUCTURAL RURAL/AGRICULTURAL 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 throughout this report. 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, city, and county staff. Below is a description of the non-structural BMPs that were considered for this assessment.

1.1 PASTURE AND FEEDLOT MANAGEMENT


Source: www.nrcs.usda.gov

MN Rule 7020 governs the permitting, standards for discharge, design, construction, operation, and closure of animal feedlots throughout Minnesota. Hennepin County is a non-delegated feedlot county, meaning the MPCA manages the feedlot program for the County and 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 with 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 MPCA 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 from feedlots 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 to downstream or adjacent waterbodies. Examples of control systems include lagoons, vaults, or other lined impoundments, but can also include covers such as roofs, 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 milk house wastewater 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.

Three different datasets were used to estimate the number of livestock animals throughout the Diamond Creek Subwatershed Study Area:

1. The MPCA feedlot database;
2. Three Rivers Park District (TRPD) animal feedlot inventory; and
3. City of Dayton 2018 Inventory.

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.

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 field 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 most of the livestock animals throughout the Elm Creek watershed are unregistered and the MPCA database significantly underestimates the number of animals in the watershed.

The Elm Creek Watershed Management Commission (ECWMC) requirement is that member cities must have in place ordinances codifying the ECWMC's rules and standards. The ECWMC's 3rd Generation Watershed Management Plan created a strategy to adopt new standards governing siting and management of non-productive livestock operations. In November 2018 the City of Dayton adopted such standards (Resolution 11-18 Livestock Management). As part of the research regarding ECWMC's requirement for the City to adopt such standards, the City conducted an inventory through aerial photography of the number of both production and non-production livestock operations as well as a review of the existing City code to access compliance with the ECWMC's Livestock Management Policy. The following are the results of that City-wide research. There are 61 animal enclosure sites which are defined as identifiable pens, fenced in areas or paddocks with evidence of current or past large animal husbandry. Of the 61 sites, 12 are located within DNR designated shoreland areas. According to available MPCA records, there are six registered feedlots within the City of Dayton (one of which is not active).

Based on review of the three livestock datasets described above, it is estimated that there are 50-60 livestock animal operations within the Diamond Creek SWA Study area (Table E-1, Figure E-1). These operations likely house anywhere from 2-350 animals each, most of which are cattle. However, most livestock operations identified throughout the study area are small operations and are therefore unregistered.

Table E-1. Diamond Creek SWA study area livestock inventory summary.

Parameter	**Diamond Creek SWA Study Area**		
	MPCA Registered Feedlots	**TRPD Livestock Inventory**	***City of Dayton Livestock Inventory***
Total Sites	4	44	9
Primary Animal Type	*Cattle*	*Cattle*	*Horse*

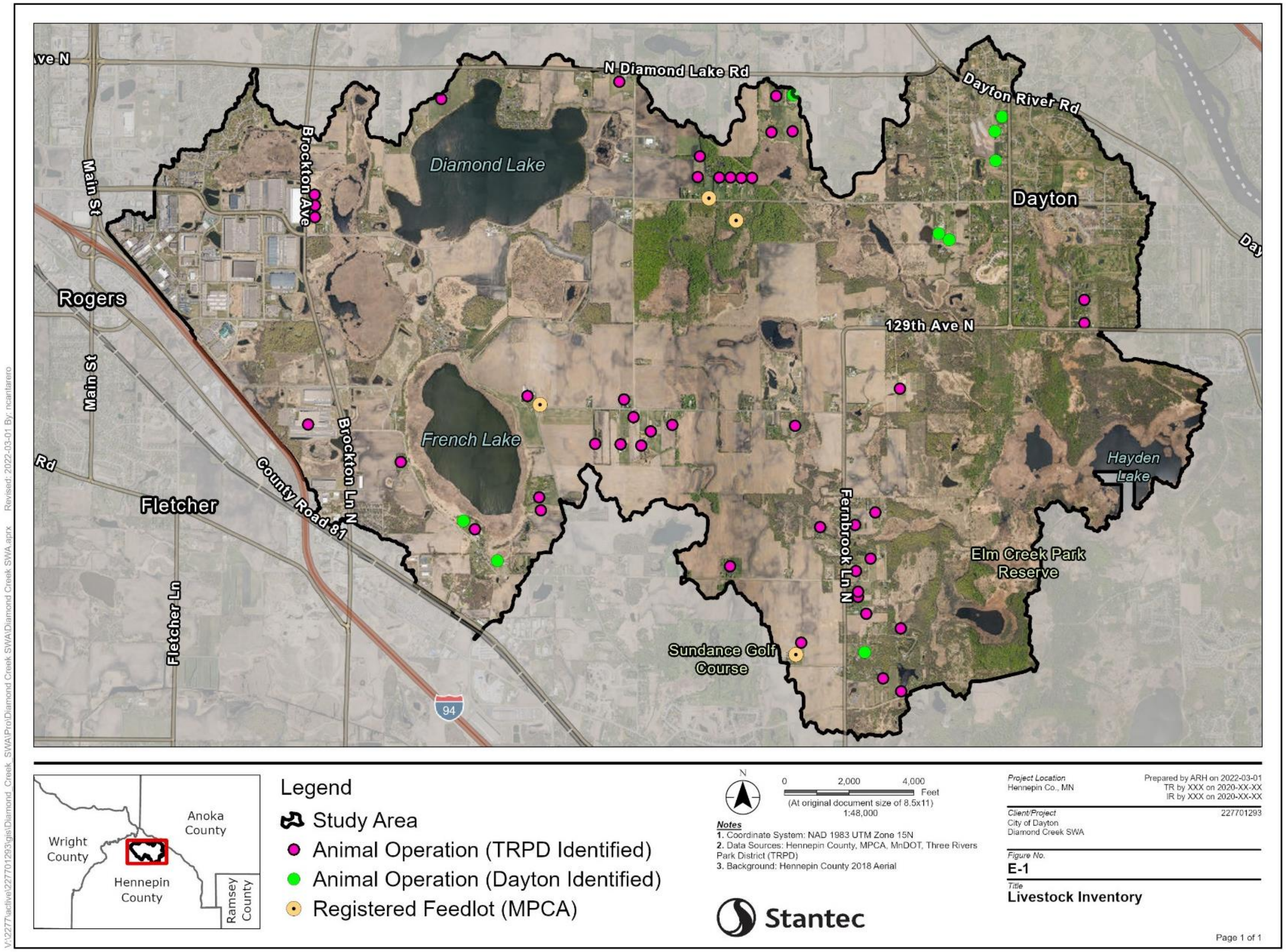

Figure E-1. Diamond Creek SWA study area livestock inventory summary.

1.2 MANURE MANAGEMENT

The Minnesota Feedlot rules also include regulations for manure management plans and the land application of manure. The MPCA has developed templates, guides and standards for the development and implementation of manure management plans, manure nutrient management, and land 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, 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 the 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. As stated above, according to available MPCA records, there are six registered feedlots within the City of Dayton (one of which is not active).

1.3 SOIL HEALTH AND MANAGEMENT

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.

1.4 SUB SURFACE TREATMENT SYSTEM (SSTS) INSPECTION, MAINTENANCE, AND REPAIR

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

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.

In 2019, the City of Dayton was awarded a BWSR Clean Water Fund Grant titled Septic Risk Assessment Model and Program Enhancement. The purpose of the grant was to systematically retrieve, review, scan, and evaluate all existing SSTS permit materials in possession of the City. Once evaluated, the information was further refined and entered into an electronic database which was then uploaded to a GIS web-based application. The existing septic system pump maintenance program has been enhanced and recommendations for further code enhancements are forthcoming from the City.

Preliminary results of the City of Dayton Septic Risk Assessment indicate that there are approximately 406 parcels with septic systems within the Diamond Creek SWA Study Area (see Table E-2). Of the 406 systems, approximately 329 were constructed prior to 1995 or the date of installation is unknown. 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. Thus, it can be assumed that any system installed prior to 1995, or in which there is no record of installation, was likely not designed to current septic system standards and rules. It is important to note that the pre-1995 systems are not necessarily out of compliance, rather, they most likely have not been inspected for compliance. Table E-2 also summarizes parcels with systems 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.

Table E-2. Diamond Creek SWA Study Area septic system estimates.

Septic Systems Constructed	**Total systems in study area**	**Percent of total systems**	**Systems where parcel is within 500 ft of stream**	***Percent of total systems***
Prior to 1995	329	81%	13	*3%*
1995 and after	77	19%	0	-
Totals	*406*	*100%*	*13*	*3%*

APPENDIX F

Stream Channel Improvement Technical Appendix

1.0 STREAM CHANNEL IMPROVEMENTS

1.1 BACKGROUND

The Diamond Creek Channel Study, TMDL report, WRAPS report, and local water plans all identified stream restoration and channel improvements as a strategy to improve hydrology, water quality, and habitat conditions in Diamond Creek. In some cases, these studies identified specific locations along Diamond Creek and its tributaries that exhibited bank erosion, altered hydrology, and/or degraded habitat conditions. This appendix highlights specific locations that could be targeted for in-stream improvements.

1.2 DIAMOND LAKE OUTLET TRIBUTARY CHANNEL RESTORATION (DIAMOND CREEK MANAGEMENT UNIT)

Diamond Lake outlets to the southeast to a small tributary channel which flows a relatively short distance to its confluence with Diamond Creek (Figure F-1). This channel is approximately 2,050 linear feet and runs through a combination of woods and wetlands. The channel is adjacent to agricultural fields and has been heavily ditched and straightened. Thus, this channel has been identified by local stakeholders as a potential location to restore natural hydrology and improve in-stream habitat conditions. A desktop analysis and cost estimate to stabilize the channel using Natural Channel Design is presented in Table F-1. The probable cost of this project is estimated to be $400,000 or about $195 per linear foot stabilized. In addition to the stabilizing the channel, length could be added to the channel by re- meandering (see Table F-1). Historical aerial photos show much greater sinuosity to the channel than currently exists. The planning level cost analysis presented in Table F-1 does not include estimated land purchase. The current value of the property is ~$520,000 (based on Hennepin County GIS 2021 mapping values) and is classified as residential.

Figure F-1. Diamond Lake outlet tributary channel restoration.

Table F-1. Planning-level cost estimate for Diamond Lake outlet tributary channel restoration.

Bid Item	Description	Units	Quantity	Unit Cost	Extension
1	MOBILIZATION & DEMOBILIZATION (5% of total cost)	LS	1	$15,500.00	$15,500.00
2	TEMPORARY CONSTRUCTION ENTRANCE - MAINTAINED	EA	1	$2,000.00	$2,000.00
3	FLOTATION SILT CURTAIN, TYPE MOVING WATER - MAINTAINED	LF	60	$35.00	$2,100.00
4	SILT FENCE, TYPE MS - MAINTAINED	LF	400	$5.00	$2,000.00
5	SEDIMENT CONTROL LOG, TYPE STRAW	LF	2100	$5.00	$10,500.00
6	CONSTRUCT, MAINTAIN, & RESTORE SITE ACCESS AND STAGING AREAS	LS	1	$5,000.00	$5,000.00
7	TREE CLEARING & PROCESSING	EA	100	$350.00	$35,000.00
8	STREET SWEEPING	HOUR	10	$110.00	$1,100.00
9	GRADED BANK	LF	2,050	$20.00	$41,000.00
10	COARSE WOOD TOE w/ FABRIC ENCAPSULATED SOIL LIFTS (FES)	LF	2,050	$60.00	$123,000.00
11	WOVEN ECB, ROLANKA BIOD-MAT 40	SY	5000	$5.00	$25,000.00
12	NON-WOVEN ECB CAT 3 TYPE STRAW 2S (NO POLY NETTING)	SY	5000	$3.00	$15,000.00
13	NATIVE SEEDING	AC	5.0	$2,500.00	$12,500.00
14	NATIVE SEED MIX	LB (PLS)	150	$20.00	$3,000.00
15	COMMON EXCAVATION ONSITE (EV)	CY	2000	$15.00	$30,000.00
SUBTOTAL					$322,700.00
20% CONTINGENCY					$64,500.00
TOTAL					$387,200.00
If re-meandered to add additional length (500 LF)					$461,700.00

APPENDIX G

In Lake Management Technical Appendix

1.0 DIAMOND AND FRENCH LAKE IN-LAKE MANAGEMENT FEASIBILITY AND COST ESTIMATES

1.1 BACKGROUND

In-lake water quality and internal loading in shallow lakes is unique in that it can be closely linked to many different processes. Internal loading in shallow lakes can occur when legacy phosphorus has accumulated in the sediment of shallow lakes and is released through various mechanisms. These mechanisms predominantly include diffusion from sediments under anoxic condition, sediment disturbance by benthic-dwelling fish such as common carp or bullheads, wind-driven sediment resuspension and release of dissolved phosphorus from decaying aquatic plants. These mechanisms can result in phosphorus mobilization from the sediments into the overlying water column where it becomes available for uptake by algae and can negatively impact water quality (Sondergaard et al. 2003).

The Diamond Lake TMDL calls for an average annual TP reduction of approximately 2,000 pound per year for Diamond Lake to meet State water quality standards. Of this reduction, it was estimated that approximately 30% (~640 pounds per year) comes from internal sources within Diamond Lake. The TMDL study suggests internal load is likely a combination of internal sources including phosphorus release from the sediment, rough fish activity, wind/wave action, and breakdown of submerged aquatic vegetation (SAV). In the TMDL, TRPD estimated that the early summer curly leaf pondweed (CLP) plant biomass in Diamond Lake likely contributes a minimum of 640 pounds of TP per year (~80% of the internal load) to Diamond Lake after the CLP dies off by mid-summer. Thus, the TMDL report suggested that controlling Diamond Lake CLP biomass is key to meeting the lake's TMDL reduction goals. As discussed in Appendix A, herbicide treatments to control CLP have been carried out by the Diamond Lake Improvement Association starting around 2013. The herbicide treatments have included smaller-scale Endothall treatments (2013 through 2018), and more recently lake-wide Fluridone treatments (2019 through 2021). Although the recent Fluridone treatments have been successful in reducing CLP occurrence and biomass, lake water quality parameters (i.e., TP, chlorophyll-a, and Secchi depth) have not shown a favorable response. This suggests that further watershed load reductions combined with other in-lake management to control the internal P load will be needed for Diamond Lake.

Based on the French Lake water quality modeling analyses presented in Appendix A of this report, approximately 73% (1,483 lbs/year) of the total annual P load to French Lake is likely from internal loading. This analysis suggest that internal load will need to be reduced by approximately 900 lbs/year for French Lake to achieve the shallow standard reduction goal/target. Sediment cores have never been collected from French Lake for phosphorus analysis, and little is known about the lake's vegetation community. However, recent water quality based on satellite imagery and a fisheries survey conducted in 2019 (see Appendix A) indicated that French Lake has very few fish and may have recently shifted to a clear water state compared to historic conditions. More water quality and biotic information will need to be collected on French Lake to assess current conditions and update the water quality analysis in Appendix A.

Here we present two potential strategies, alum treatment and lake drawdown, to improve biotic conditions and address internal nutrient loading in Diamond Lake and French Lake. The feasibility of these strategies (and others) will need to be assessed in more detail and discussed with the Lake Association, Minnesota DNR, and other stakeholders to further assess the pros/cons/outcomes of each option (e.g., TMDL reduction benefit, plant response, fish response), review funding sources, educate stakeholders, build local buy-in, and identify other in-lake strategies that may not presented here (e.g., fisheries management).

1.2 DIAMOND LAKE ALUM TREATMENT

As described above, phosphorus accumulates in lake sediments and can be released back into the water column under certain environmental conditions. Sediment release of dissolved phosphorus is typically highest under anoxic conditions (devoid of oxygen). Preliminary sediment cores were taken by TRPD to assess phosphorus release from the sediment for the development of the Diamond Lake TMDL.

Three factors are considered when determining whether to treat a lake with alum:

1. the rate at which phosphorus is releasing from the sediment under anoxic conditions;
2. the depth and area of lake experiencing anoxia; and
3. concentration of the mobile sediment phosphorus pool (redox-P) in the lake's sediments.

The redox-P and anoxic release rates measured from the preliminary sediment cores collected during the TMDL study indicate Diamond Lake has the potential for internal loading control by sediment inactivation.

Aluminum sulfate (alum) is one of the most common chemicals used for sediment-phosphorus inactivation. The adsorption of phosphorus to aluminum is very stable under most environmental conditions and provides a long-term sink of phosphorus in the lake. Alum is applied to lakes by injection of liquid alum just below the lake water surface. The alum quickly forms a solid precipitate (floc) and settles to the bottom of the lake, which converts redox-P to an immobile phosphorus fraction (aluminum bound-P). This process reduces sediment phosphorus release rates, and ultimately reduces the phosphorus concentration in lakes when internal load is a significant portion of the total phosphorus load to a lake. The mass of aluminum needed to convert redox-P to aluminum bound-P in each treatment zone was calculated using an empirically derived relationship between redox-P concentration and the ratio needed to inactivate 90% of the elevated redox-P (Al: P90%) (James et al. 2015).

We used the following considerations to provide a planning-level alum dose for Diamond Lake:

- **Application Depth and Area**. The minimum depth of anoxia was primarily observed at 6.5 ft. The bathymetry collected by the TRPD had a 1 ft resolution, so we chose a conservative application area of 63 acres which represents the anoxic area below 6 ft water depth. This application area captures the shallowest anoxic depth observed from 1998-2018.
- **Dosing Calculation**. The physical characteristics and mass of redox-P for the two preliminary sediment cores were used to prescribe the alum dose (Table G-1). The preliminary cores collected during the TMDL study were a composite of the top 10 cm. We assumed an alum dose to treat the top 6 cm of sediment which is more conservative and cost effective than dosing the top 10 cm. Additional cores would need to be collected and partitioned for a more refined sediment phosphorus profile and dose prescription.
- **Cost Estimate Assumptions** (see Tables G-2 and G-3)

- Unit cost estimates of $2.38/gallon for alum, and $5.10/gallon for sodium aluminate (buffer, if needed). Note that these unit prices are subject to market fluctuations.
- $15k per treatment for mobilization cost and assumed two mobilizations for (one for each half-dose).
- 10% engineering design cost with a minimum of $20K
- $15K for sediment monitoring needed for follow up monitoring and adaptive management of 2nd dose (based on experience with other projects)
- 20% contingency
- Costs estimates were evaulated in 2020

- Phosphorus Load Reduction Estimates and Assumptions.
  - Anoxic release rate of 3.2 mg/m^2/d that was used in the TMDL
  - Anoxia occurs up to 6-6.5 ft and for approximately 120 days/year
  - Current sediment release is 215 lbs/yr for areas 6 ft and deeper
  - Alum treatments can reduce sediment P release by up to 90% (194 lbs/yr) based on previous experience. The longevity of an alum treatment to control sediment diffusion of phosphorus is typically 5-20 years depending on the dose applied and the extent of continued loading from the watershed.

Table G-1. Diamond Lake Sediment Chemistry used for Alum Dosing

Depth (cm)	Redox P (mg/g)	Wet Bulk Density (g/cm^3)	Solids (%)	Redox P (mg/cm^3)	Redox P (mg/m^2/cm)	Redox P (g/m^2/cm)	Redox P (g/m^2)	Al: $P_{90\%}$
6	0.15	1.04	0.099	0.0151	151	0.2	0.9	104.4

Table G-2. Diamond Lake alum dose and cost estimate assumptions

Aluminum Dose				Alum Only Volume & Cost		Buffered Alum Volume & Cost		
Al Dose - per section (g/m2)	Al Dose - integrated (g/m2)	Al mass (kg)	Al mass (lb.)	Aluminum Sulfate (gal)	Alum Only Cost ($)	Aluminum Sulfate (gal)	Sodium Aluminate (gal)	Buffered Alum Cost ($)
95	95	24,137	53,213	108,953	$259,308	47,359	23,680	$233,481

Table G-3. Diamond Lake alum treatment planning-level cost estimate summary

Material Cost	Sediment Monitoring	Mobilization ($15,000x2)	Engineering Cost	Contingency	Total Estimated Cost
$233,481	$15,000.00	$30,000.00	$23,348.10	$57,365.82	$359,195

1.3 DIAMOND LAKE DRAWDOWN

Full and partial lake drawdowns have the potential to reduce internal loading and manage CLP and other invasive species by allowing sediment to consolidate and the CLP turions (i.e. vegetative propagules) to freeze and become inactive. Drawdowns can also help re-set the fish community when a lake lacks sufficient density of top predators and is dominated by high percentage of rough fish and/or undesirable species. There are several factors to consider when determining the feasibility of a full lake drawdown, including pumping duration and operation/maintenance, pump size, downstream capacity and impact, cost, and permitting activities.

Diamond Lake drawdown planning-level feasibility and probable cost estimates were developed for two scenarios:

Scenario 1: Full (~7 foot) drawdown
Scenario 2: Partial (~ 3 foot) drawdown

The drawdown scenarios included the following assumptions:

- Drawdown Duration for Both Scenarios
  - The drawdown pumping would begin in late August and run for approximately 3 months
  - The pumps for both scenarios 1 and 2 were sized to achieve the desired drawdown in 3 months (90 days)
  - The drawdown volumes were calculated based on Bathymetry data provided by TRPD
  - The estimated drawdown volumes were multiplied by 1.25 as a conservative measure to account for saturated side slopes and any groundwater seep that is expected; and
  - The estimates include an additional month of operation to continue drawdown in case large precipitation events occur, or, to make sure we can keep the Lake drawn down until we hit freezing conditions in late November.
- Base Flow (1.3 cfs) Assumptions for Both Scenarios
  - An estimated1.3 cfs of base flow is expected during this time. This flow has been subtracted from the operating flow rates.
  - Diamond Lake averages 1.3 cfs of inflow between September and February. This was calculated from SWAT model estimates from 2000-2012.
- Pumping Capacity for Scenario 1 (Full drawdown)
  - A 16” Diesel dewatering pump (~10,000 GPM/20 cfs) will be used with dual 12” intake hoses and a single 16” discharge pipe.
  - This will be achieved by running approx. 2,500 LF of Dual 12” Intake hose to get to the deepest part of the lake and discharging about 1,100 LF downstream.
- Pumping Capacity for Scenario 2 (Partial drawdown)
  - A 12” Diesel dewatering pump (~5,000 GPM/10 cfs) will be used with dual 8” intake hoses and a single 12” discharge pipe.

- This will be achieved by running approx. 1000 LF of Dual 8” Intake hose to get to the 4’ depth of the lake and discharging about 1,100 LF downstream.

- Operation for Both Scenarios (See Figure G-1)
  - A pump structure/platform will be hauled to the southeast end of Diamond Lake via the existing public access road.
  - Intake Piping (dual 12” or dual 8”) will be used to pump water from the desired depth of Diamond Lake to a location downstream of the outlet.
  - Sandbagging or sheet piling will be placed upstream of the discharge point to permit backflow.
  - A sedimentation/discharge basin (or alternative pretreatment if required) will be created to disperse the energy at the discharge and direct the flow.
  - Overall, it is difficult to predict the exact rates and volume needed to be drawn dawn and the duration the pumps will need to be running. To balance the expected pump run times with the actual volume needed to be pump, the following assumptions were made:
    - The pumps will be running 24 hours a day and will be running at near capacity (~80%).
    - A 1.5 cfs constant inflow was subtracted from the pumping rates.
    - The drawdown volumes were multiplied by 1.25 to account for saturated lake side-slopes and groundwater,
    - With these pumping rates and volumes, the drawdowns will be achieved in 2 months. An extra month has been added to the estimate to account for lower pump efficiencies, pump downtime, and any additional, unexpected delays or large precipitation events.

- Refill Estimates
  - For Scenario 1 (full drawdown), the average time to refill the lake is 357 days. So, if the refill was started on January 1, the Lake is expected to reach its normal water level about 11.5 months later (December).
  - For the Partial (3 ft) drawdown, the average time to refill the lake is 191 days. So, if the refill was started on January 1, the Lake is expected to reach its normal water level about 6.5 months later (June).

Tables G-4 and G-5 below summarize the planning-level probable cost estimates for Diamond Lake drawdown Scenarios 1 and 2. These costs do not include any wetland mitigation, major structural work, and/or land or easement acquisition. All costs were rounded to reflect planning-level probable cost estimates.

Table G-4. Diamond Lake drawdown Scenario 1 (full drawdown) planning-level cost estimate

NO	ITEM	UNITS	QUANTITY	UNIT PRICE	TOTAL
1	MOBILIZATION/DEMOBILIZATION (5%)	LUMP SUM	1	$ 15,000	$15,000
2	SANDBAGGING AT OUTLET	LUMP SUM	1	$ 2,500	$ 2,500
3	16" DIESEL PUMP EQUIPMENT RENTAL	MONTHLY	3	$ 15,750	$ 47,250
4	DUAL 12" LAYFLAT INTAKE HOSE FOR 3 MONTHS	LF	2,500	$ 25	$ 62,500
5	16" PE DISCHARGE PIPE FOR 3 MONTHS	LF	1,100	$ 30	$ 33,000
6	PUMPING STRUCTURE/PLATFORM	LUMP SUM	1	$ 10,000	$ 10,000
7	PUMP OPERATION & MAINTENANCE	MONTHLY	3	$ 2,500	$ 7,500
8	PUMP FUEL FOR 3 MONTHS	GAL	43,200	$ 3	$ 129,600
10	SED BASIN & STABILIZATION FOR DISCHARGE	LUMP SUM	1	$ 7,500	$ 7,500
11	RESTORATION	LUMP SUM	1	$ 10,000	$ 10,000
Subtotal					$ 324,850
Engineering, Design, and Const. Mgmt. (10%)					$ 32,500
Legal (5%)					$ 16,250
Permitting (10%)					$ 32,500
Contingency (30%)					$ 97,500
Total					$ 503,600

Table G-5. Diamond Lake drawdown Scenario 2 (partial drawdown) planning-level cost estimate

NO	ITEM	UNITS	QUANTITY	UNIT PRICE	TOTAL
1	MOBILIZATION/DEMOBILIZATION (5%)	LUMP SUM	1	$ 7,500	$ 7,500
2	SANDBAGGING AT OUTLET	LUMP SUM	1	$ 2,500	$ 2,500
3	12" DIESEL PUMP EQUIPMENT RENTAL	MONTHLY	3	$ 9,000	$ 27,000
4	DUAL 8" LAYFLAT INTAKE HOSE FOR 3 MONTHS	LF	1,000	$ 15	$ 15,000
5	12" PE DISCHARGE PIPE FOR 3 MONTHS	LF	1,100	$ 15	$ 16,500
6	PUMPING STRUCTURE/PLATFORM	LUMP SUM	1	$ 10,000	$ 10,000
7	PUMP OPERATION & MAINTENANCE	MONTHLY	3	$ 2,500	$ 7,500
8	PUMP FUEL FOR 3 MONTHS	GAL/MO	15,120	$ 3	$ 45,360
9	SED BASIN & STABILIZATION FOR DISCHARGE	LUMP SUM	1	$ 5,000	$ 5,000
10	RESTORATION	LUMP SUM	1	$ 10,000	$ 10,000
Subtotal					$ 142,580
Engineering, Design, and Const. Mgmt. (10%)					$ 14,300
Legal (5%)					$ 7,200
Permitting (10%)					$ 14,250
Contingency (30%)					$ 42,800
Total					$ 221,130

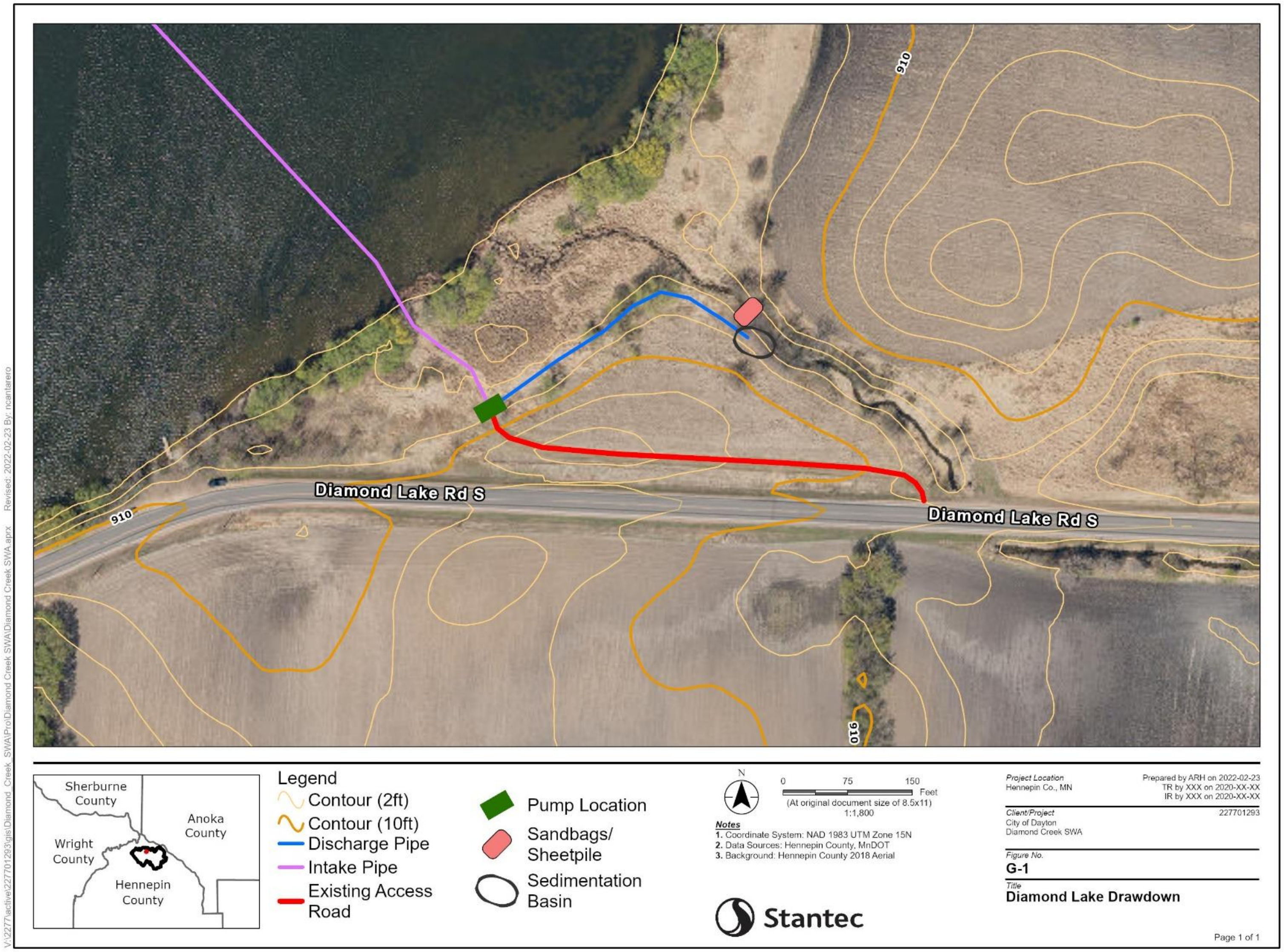

Figure G-1. Diamond Lake drawdown planning-level sketch of pumping operation

1.4 FRENCH LAKE DRAWDOWN

The phosphorus diagnostic modeling presented in Appendix C suggest that French Lake will likely require significant internal load reductions to meet water quality goals/targets (~900 pounds per year). Here we present planning-level feasibility and probable cost estimates for one French Lake drawdown scenario (i.e., full drawdown) to help achieve the internal load reduction goal. Since French Lake is very shallow (maximum depth of ~4 feet), a partial drawdown scenario was not assessed. The engineering feasibility assumptions, and cost estimate assumptions for French Lake are similar to the Diamond Lake drawdown assessment described above. Note that sediment phosphorus chemistry data is not available for French Lake so we have not estimated an alum treatment dose, but this strategy should also be considered for French Lake.

The full drawdown for French Lake includes the following assumptions:

- Drawdown Duration
  - The drawdown pumping would begin in late August and run for approximately 3 months to achieve an approximate full drawdown of the lake
  - The pump was sized to achieve the desired drawdown in 3 months (90 days)
  - The drawdown volumes were calculated based on Bathymetry data provided by TRPD
  - The estimated drawdown volumes were multiplied by 1.25 as a conservative measure to account for saturated side slopes and any groundwater seep that is expected; and
  - The estimates include an additional month of operation to continue drawdown in case large precipitation events occur, or, to make sure we can keep the Lake drawn down until we hit freezing conditions in late November.
- Base Flow (1.0 cfs) Assumptions
  - An estimated 1.0 cfs of base flow is expected during this time. This flow has been subtracted from the operating flow rates.
  - French Lake averages 1.0 cfs of inflow between September and February. This was calculated from SWAT model estimates we have from 2000-2012.
- Pumping Capacity
  - A 12” Diesel dewatering pump (~5,000 GPM/11.2 cfs) will be used with dual 8” intake hoses and a single 12” discharge pipe.
  - This will be achieved by running approx. 1,500 LF of Dual 8” intake hose to get to the 3.5’ depth of the lake and discharging directly downstream of the farm road/outlet culvert for the lake.
- Operation (See Figure G-2)
  - A pump structure/platform will be hauled to the northeast end of French Lake via the existing farm/access road
  - Intake Piping (dual 12” or dual 8”) will be used to pump water from the lowest depth of French Lake to the downstream end of the culvert/outlet, underneath the farm road
  - Sandbagging or sheet piling will be placed upstream on the downstream end of the culvert underneath the farm road to permit backflow
  - A sedimentation/discharge basin (or alternative pretreatment if required) will be created to disperse the energy at the discharge and direct the flow
  - Overall, it’s difficult to predict the exact rates and volume needed to be drawn dawn and the duration the pumps will need to be running. To balance the expected pump run times with the actual volume needed to be pump, the following assumptions were made:

- The pumps will be running 12 hours a day and will be running at near capacity (~80%).
- A 1.0 cfs constant inflow was subtracted from the pumping rates.
- The drawdown volumes were multiplied by 1.25 to account for saturated lake side-slopes and groundwater,
- With these pumping rates and volumes, the drawdowns will be achieved in 2 months. An extra 15 days has been added to the estimate to account for lower pump efficiencies, pump downtime, and any additional, unexpected delays or large precipitation events.

- Refill Estimates
  - The average/mean time to refill the lake is 377 days. So, if the refill was started on January 1, the Lake is expected to reach its normal water level by approximately January 15 the following year.

Table G-6 below summarizes the planning-level probable cost estimates for a full drawdown of French Lake. These costs do not include any wetland mitigation, major structural work, and/or land/easement acquisition. All costs were rounded to reflect planning level probably cost estimates.

Table G-6. French Lake drawdown planning-level cost estimate

NO	ITEM	UNITS	QUANTITY	UNIT PRICE	TOTAL
1	MOBILIZATION/DEMOBILIZATION (5%)	LUMP SUM	1	$ 6,000	$ 6,000
2	SANDBAGGING AT OUTLET	LUMP SUM	1	$ 750	$ 750
3	12" DIESEL PUMP EQUIPMENT RENTAL (5k-7k gpm)	MONTHLY	3	$ 6,000	$ 18,000
4	DUAL 8" LAYFLAT INTAKE HOSE FOR 3 MONTHS	LF	1,500	$ 25	$ 37,500
5	12" PE DISCHARGE PIPE FOR 3 MONTHS	LF	10	$ 30	$ 300
6	PUMPING STRUCTURE/PLATFORM	LUMP SUM	1	$ 10,000	$ 10,000
7	PUMP MAINTENANCE	MONTHLY	3	$ 1,000	$ 3,000
8	PUMP FUEL FOR 3 MONTHS	GAL	8,000	$ 3	$ 24,000
10	SED BASIN & STABILIZATION FOR DISCHARGE	LUMP SUM	1	$ 5,000	$ 5,000
11	RESTORATION	LUMP SUM	1	$ 7,500	$ 7,500
Subtotal					$ 112,050
Engineering, Design, and Const. Mgmt. (10%)					$ 11,200
Legal (5%)					$ 6,000
Permitting (10%)					$ 11,200
Contingency (30%)					$ 33,600
Total					$ 174,050

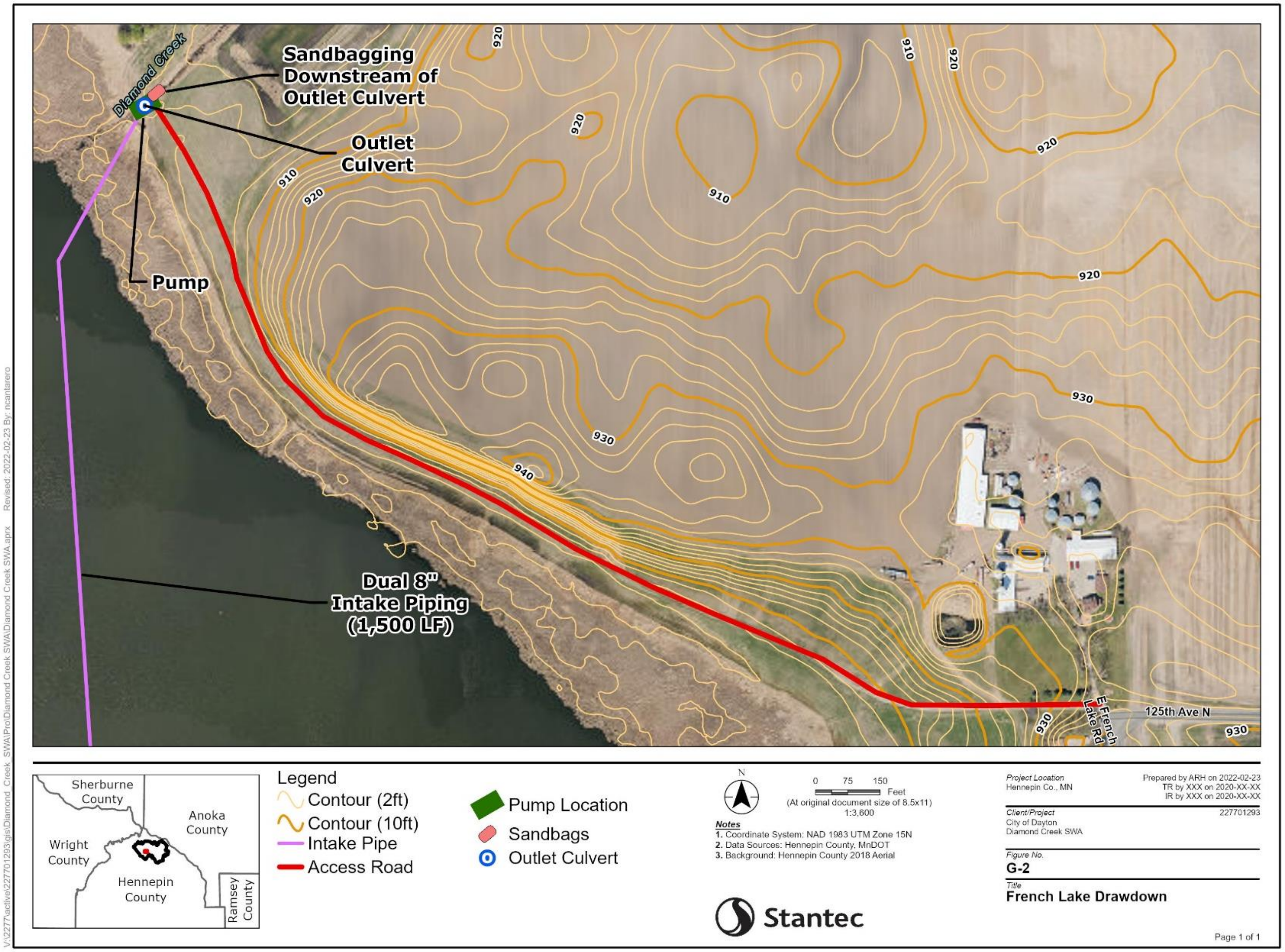

Figure G-2. French Lake drawdown planning-level sketch of pumping operation

APPENDIX H

Grass Lake Technical Appendix

1.0 GRASS LAKE MONITORING AND FEASIBILITY STUDY

1.1 BACKGROUND

Grass Lake is a large (320 acre) wetland complex located west of Diamond Lake in Dayton and Rogers (Figure H-1). The wetland discharges through a channel to the west, which flows through a smaller wetland basin before discharging into Diamond Lake. It is estimated that approximately 64% (~1,600 acres) of Diamond Lake's 2,500-acre drainage area flows to Grass Lake before it enters Diamond Lake. The outlet of Grass Lake is located just north of South Diamond Lake Road approximately 1,500 feet west of Diamond Lake. Drainage to Grass Lake includes approximately 1,200 acres of developed area in Rogers and 400 acres of developed and undeveloped land in Dayton. Nearly all the area in Rogers were developed in the last ~20 years and therefore have some level of stormwater treatment prior to discharging to Grass Lake, primarily wet ponds.

1.2 GRASS LAKE HISTORIC MONITORING DATA

Due to its size, large drainage area, and proximity to Diamond Lake, TRPD monitored sediment and nutrients concentrations in 2015 to determine if this wetland may be contributing high levels of pollutants to Diamond Lake. Fourteen water grab samples were collected between April and October 2015 and analyzed for total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), and total suspended solids (TSS). No flow data were collected in 2014, so loading of each parameter cannot be estimated. Results of the 2015 sampling are presented below in Table H-1. These results suggest that TSS and TN levels are generally low coming out of Grass Lake, which is typical for large wetland treatment complexes. TP and SRP concentrations, on the other hand, are relatively high, which suggest the wetland may not be assimilating and removing phosphorus as efficiently as sediment and nitrogen. Phosphorus concentrations peaked from July through September when temperatures are warmer and more biological activity occurs. More monitoring will be needed to evaluate Grass Lake's phosphorus contribution to Diamond Lake and whether management of the wetland complex to reduce phosphorus export is feasible and cost effective.

Table H-1. 2015 water quality sample results for Grass Lake provided by TRPD

Date	TP (ug/L)	SRP (ug/L)	TN (mg/L)	TSS (mg/L)
4/13/15	109	46	0.94	3.8
4/27/15	74	30	0.77	1.0
5/11/15	97	67	0.88	1.0
5/26/15	85	54	0.69	1.0
6/8/15	96	89	0.56	1.0
6/22/15	155	96	1.10	2.4
7/20/15	250	119	1.30	4.8
8/3/15	261	119	1.35	2.6
8/17/15	418	124	2.06	7.4
8/31/15	294	129	1.58	3.6
9/14/15	252	127	1.35	5.4
9/28/15	512	107	1.61	3.6
10/12/15	158	55	1.14	1.8
10/26/15	121	62	0.94	2.0
Min	74	30	0.56	1.0
Max	512	129	2.06	7.4
Average	206	87	1.16	3.0

1.3 PROPOSED MONITORING FOR GRASS LAKE

As discussed above, Grass Lake could be a significant source of phosphorus to Diamond Lake based on the data collected by TRPD in 2015. However, only one year of water quality data was collected and other data on Grass Lake (e.g., upstream loading, wetland depth and volume, accumulated sediment) is lacking. Since this is such a large and complicated wetland system, further monitoring and assessment is required to evaluate the true extent of phosphorus loading from Grass Lake to Diamond Lake. Additional evaluations could include phosphorus loading hot spot(s) within the wetland complex and upstream drainage area, and what engineering solutions may improve phosphorus retention. Table H-2 outlines a sampling plan and associated costs to help answer these questions and fill necessary data gaps to evaluate potential engineering options. This plan includes the following components:

- Water quality sampling of three sites within the wetland complex from April through September (~12 samples)
- Continuous flow monitoring at the outlet of Grass Lake
- Continuous water level monitoring at three locations within the wetland complex

It is recommended that this data be collected for 2-3 years to establish baseline conditions and phosphorus loads from Grass Lake to Diamond Lake. The estimated costs presented in Table H-2 assume TRPD would conduct the sample collection, flow and water level monitoring, and laboratory analytical analysis.

Table H-2. Proposed sampling plan for Grass Lake and estimated costs

Task	Site(s)	Equipment/ Parameters	Estimated Cost
Routine samples (12 per site)	1) Grass Lake Outlet (Xanthus Ln N) 2) South Cell at S. Diamond Lake Rd 3) Northwest Cell at Brockton Ln N	Temp/DO/Conductivity/pH	$3,000
		TSS (36)	
		TP (36)	
		TN (36)	
		Ortho-P (36)	
		Total Iron (36)	
		Gauged flow (Grass Lake Outlet only)	
		Staff time and equipment (12 events)	$7,000
Continuous Flow Monitoring (1 site)	Grass Lake Outlet Only	Area/Velocity Meter	$3,000
		Staff time	
Water Level recorders (2 sites)	1) South Cell at S. Diamond Lake Rd 2) Northwest Cell at Brockton Ln N	Transducers	$2,000
		Staff Time	
PROJECT TOTAL			$15,000

1.4 FEASIBILITY STUDY FOR GRASS LAKE

As water quality and flow data are collected for Grass Lake, it is recommended that the Cities of Dayton and Roger, TRPD, and other local partners review the results to determine if an engineering feasibility study of the wetland complex is warranted. Table H-3 below outlines potential tasks and costs of an engineering feasibility study for managing phosphorus loading from Grass Lake. Primary tasks will likely include:

- Background data review and surveying
- Hydrologic and hydraulic analysis to determine surface water and groundwater flow through the site which will be paired with nutrient concentration to evaluate the magnitude of potential loads and sources of nutrients
- Review of engineering options (e.g., sediment dredging, sediment inactivation, alum injection, water level management, channel restoration, wetland bypass, etc.)
- Reporting

The tasks and cost estimates presented in Table H-3 should be revisited and reassessed after additional monitoring data has been collected and reviewed.

Table H-3. Grass Lake engineering feasibility study potential tasks and cost estimates

Task	Description	Estimated Cost
1	Background Data Gathering & Survey	$7,000
2	Hydrologic Analysis	$4,250
3	Hydraulic Analysis	$4,000
4	Evaluate Engineering Options	$9,000
5	Reporting	$5,800
6	QA/QC & Project Management	$2,800
Project TOTAL		$32,850

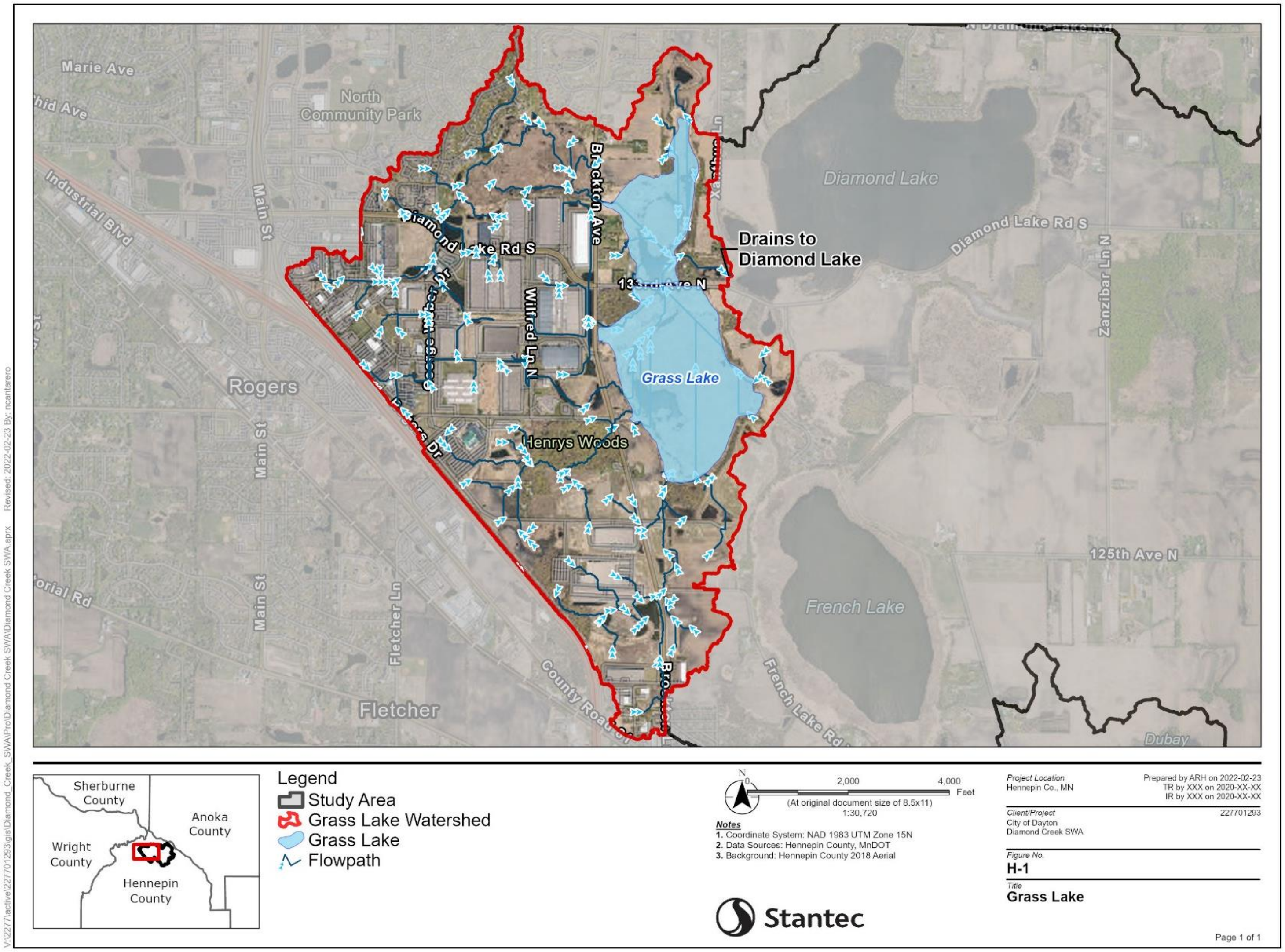

Figure H-1. Map of Grass Lake