MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

Meeting: Operations and Programs Committee
Meeting date: 8/10/2023
Agenda Item #: 4.1
Item type: Discussion

Title:	Project Planning Update: East Auburn, County Road 6, Cedar Lake Trail Connection and Minneapolis Parkway
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Purpose:
At the August 10, 2023, Minnehaha Creek Watershed District (MCWD) Operations and Programs Committee (OPC) meeting, MCWD staff will provide an update on capital project planning, and in particular, project visioning and feasibility of four MCWD projects that are moving toward design.

Summary:
On July 13, 2023, the Board of Managers authorized distribution of the 2024 Capital Improvement Plan (CIP), which included the detailed five-year look into MCWD's project planning cycle (Multi-year CIP). As a mission-driven organization that centers its work on the delivery of high-impact capital projects that integrate water and natural resources with the built environment, MCWD has progressively improved its approach to capital project planning through cycles of implementation. This improvement is best captured in the development of the Multi-year CIP initiative, which was developed to better predict and communicate time, staff allocation and resources needed to deliver projects during each phase of implementation – planning, design, construction, and warranty.

Four capital projects are presently in the planning phase of development, which includes opportunity screening, project visioning, and project feasibility studies. These projects – East Auburn Wetland Restoration, County Road 6 Pond Retrofit, Greenway to Cedar Trail Connection and Streambank Restoration, and Minnehaha Parkway Stormwater Management – are described in more detail below. The project one-page summaries for each initiative are also included (Attachment 1), and provide additional context in the form of scope, schedule, budget, and location.

<u>East Auburn Wetland Restoration</u>
This planned wetland restoration project will target phosphorus export from a degraded wetland on Six Mile Creek just downstream of Wassermann Lake. In 2020, MCWD research and monitoring staff identified a particular cell of the wetland as the main source of phosphorus being exported downstream to East Auburn Lake and developed a request for proposals (RFP) to conduct a cursory feasibility analysis of wetland restoration that would reduce the amount of nutrients leaving the system. In February 2023, MCWD contracted with Moore Engineering to complete this feasibility effort based on more robust data collected in 2022 to inform potential project options. A variety of alternatives have been analyzed, and staff will present the preliminary report (Attachment 2) as part of the OPC discussion.

<u>County Road 6 Pond Retrofit</u>
This planned retrofit of an existing MCWD pond in the Long Lake Creek subwatershed will target nutrient and total suspended solids (TSS) loading to downstream Long Lake. MCWD research and monitoring staff identified concentrations of phosphorus in the pond to be higher than previously understood, presenting an opportunity to make significant progress towards the watershed load reduction goal for Long Lake by using existing facilities. As such, staff developed a RFP to conduct a feasibility analysis of pond retrofit options that would reduce nutrient concentrations. In April 2023, MCWD contracted with Stantec to complete a feasibility analysis of pond retrofit options. Alternatives have been analyzed, and staff will present the preliminary report (Attachment 3) as part of the OPC discussion.

Greenway to Cedar Trail Connection and Streambank Restoration

This planned streambank stabilization, riparian restoration, and construction of a trail connection along Minnehaha Creek from the Minnehaha Creek Preserve to the Cedar Lake LRT Regional Trail, has completed the feasibility phase and is moving towards development of a design RFP. The Board received a feasibility report on this project at its June 23, 2023 meeting, including a copy of the draft feasibility report (Attachment 4). This critical link connecting upstream and downstream projects in the Minnehaha Creek Greenway is being planned in partnership with the City of St. Louis Park and Metropolitan Council. Staff will provide an update on outside funding opportunities and recent discussions with adjacent landowners as part of its OPC discussion.

Minnehaha Parkway Stormwater Management

This effort builds on the partnership of the MCWD, the City of Minneapolis and the Minneapolis Park and Recreation Board (MPRB) to create a shared implementation framework for the Minnehaha Parkway Regional Trail Master Plan. Approved by MPRB in 2020, the Master Plan created a 30-year vision to enhance recreation, improve ecological function of the creek corridor, improve public safety, address flooding, and improve water quality in the Minneapolis segment of the Minnehaha Creek corridor. MCWD staff, on behalf of the partnership technical team, are developing a RFP for feasibility analysis of three initial projects in the Parkway. As that RFP is being developed, staff are also working with legal counsel to develop a memorandum of understanding (MOU) and cooperative agreement that further defines the partnership goals, roles, responsibilities, and timeline. An update on each of these efforts will be provided as part of the OPC discussion.

Attachments:

1. Multi-year Capital Improvement Plan project summary pages
2. Draft: East Auburn Wetland Restoration Feasibility Study
3. Draft: County Road 6 Pond Retrofit Feasibility Study
4. Draft: Cedar to Greenway Trail Connection Memo

Attachment 1

MINNEHAHA CREEK WATERSHED DISTRICT

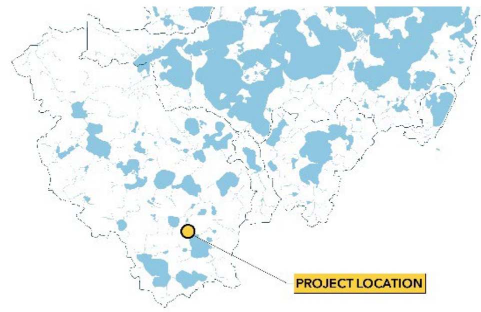
MULTI-YEAR CAPITAL IMPROVEMENT PLAN 2024-2028

OVERVIEW

PROJECT NAME
East Auburn Wetland Restoration

LOCATION
Victoria (Six Mile Creek-Halsted Bay)

TARGET WATERBODY
East Auburn Lake



DESCRIPTION

SCOPE

This project will target phosphorus export from a degraded wetland at the outlet of Wassermann Lake. MCWD will conduct monitoring and feasibility to develop a project approach that will likely include an innovative solution, depending on observed wetland conditions.

GOALS

The project will target a phosphorus reduction of 135 lbs/yr. Secondary benefits including habitat restoration and increased water storage will be explored through feasibility.

JUSTIFICATION

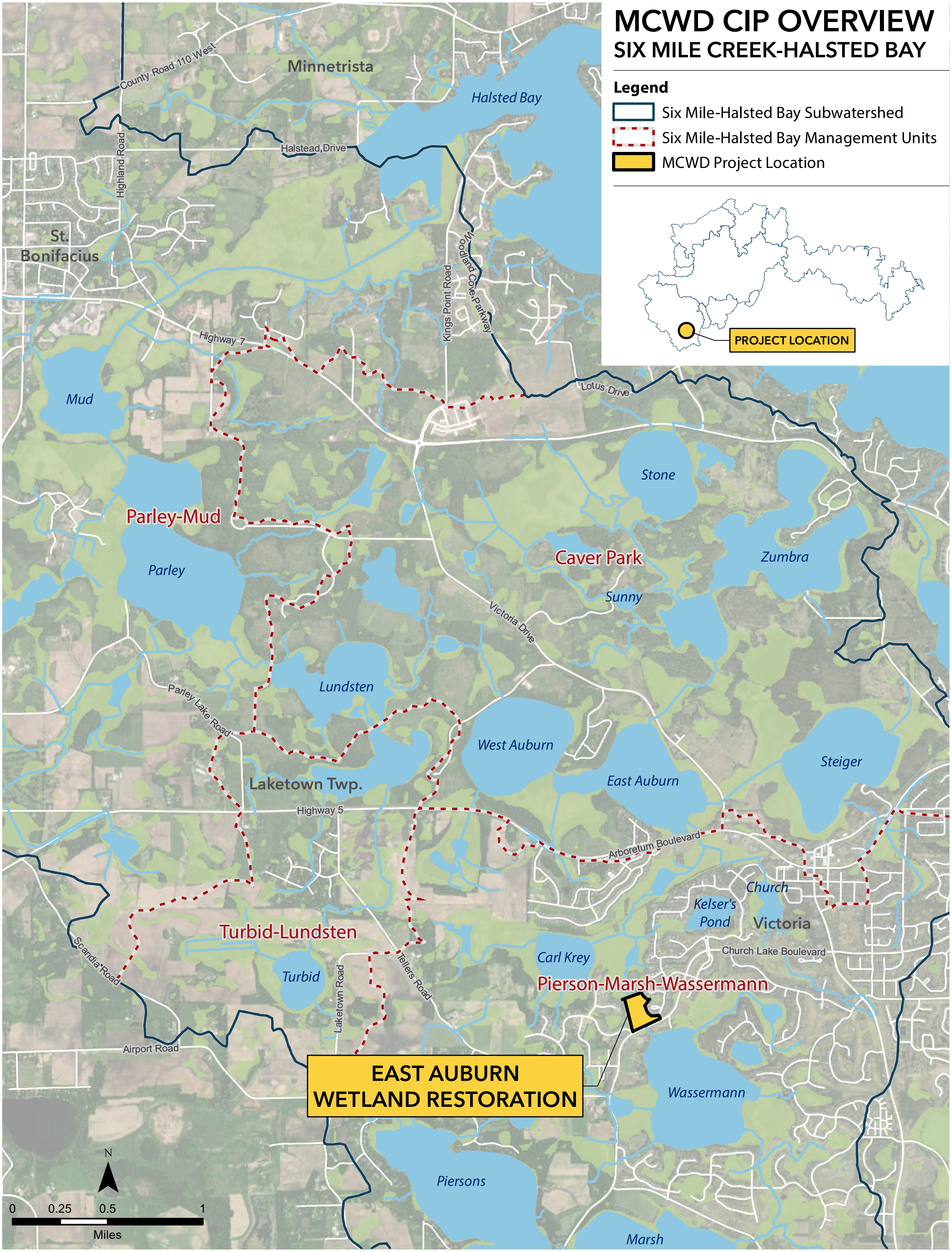
East Auburn is an impaired waterbody requiring a total nutrient reduction of 626 lbs/yr, with 410 lbs/yr designated from the upstream watershed. This project will target a specific wetland segment at the outlet of Wassermann Lake that represents the highest identified concentration of nutrient export to East Auburn Lake. Management methods for reducing nutrient output from degraded wetlands are not well established, and successful implementation may support the implementation of projects in similar wetland systems in the future.

WORKPLAN SUMMARY

In 2023, MCWD will seek to complete a feasibility assessment to identify the project scope to address nutrient export from the subject wetland. 2023 anticipated work includes refining the project approach, developing partnership agreements, and commencing project design, pending Board consideration.

SCHEDULE + BUDGET

PLANNING	DESIGN	CONSTRUCTION
2023 – 2024	2024	2025
$50,000	$68,000	$482,000


MCWD CIP OVERVIEW
SIX MILE CREEK-HALSTED BAY
Legend
Six Mile-Halsted Bay Subwatershed
Six Mile-Halsted Bay Management Units
MCWD Project Location
PROJECT LOCATION
EAST AUBURN
WETLAND RESTORATION
Minnetrista
St. Bonifacius
Laketown Twp.
Victoria
Halsted Bay
Mud
Parley
Lundsten
Stone
Zumbra
Sunny
West Auburn
East Auburn
Steiger
Church
Kelser's Pond
Carl Krey
Turbid
Wassermann
Piersons
Marsh
Parley-Mud
Caver Park
Turbid-Lundsten
Pierson-Marsh-Wassermann
County Road 110 West
Halstead Drive
Highland Road
Highway 7
Kings Point Road
Woodland Cove Parkway
Lotus Drive
Victoria Drive
Parley Lake Road
Highway 5
Arboretum Boulevard
Church Lake Boulevard
Scandia Road
Laketown Road
Tellers Road
Airport Road
N
0
0.25
0.5
1
Miles

MINNEHAHA CREEK WATERSHED DISTRICT

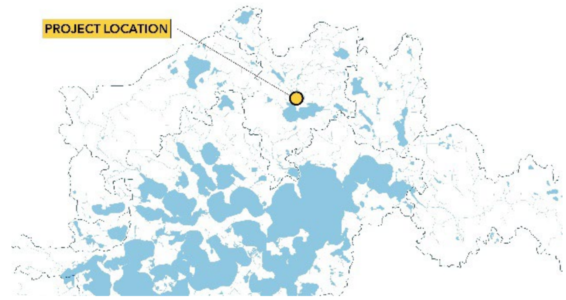
MULTI-YEAR CAPITAL IMPROVEMENT PLAN 2024-2028

OVERVIEW

PROJECT NAME
County Road 6 Pond Retrofit

LOCATION
Orono (Long Lake Creek)

TARGET WATERBODY
Long Lake



DESCRIPTION

SCOPE
Proposed retrofit of an existing MCWD pond providing downstream treatment of both the Wolsfeld and Holy Name management units through the addition of a sand filtration bench to improve water quality treatment capacity.

GOALS
Reduce nutrient loading to Long Lake by approximately 150 lbs/yr and reduce TSS loading by approximately 85%.

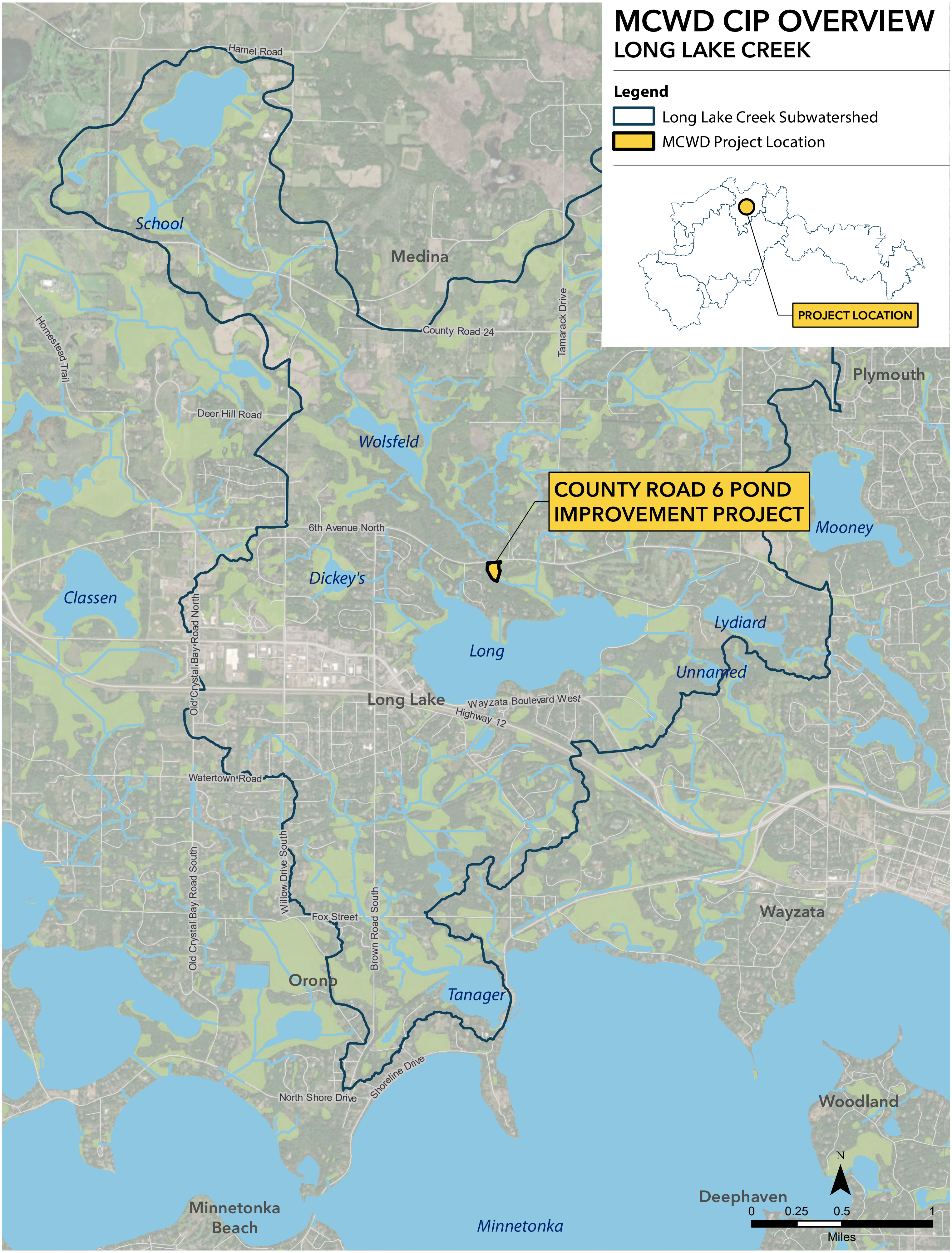
JUSTIFICATION
Long Lake is impaired for nutrients and requires a 62% (411 lbs) reduction to meet state water quality standards, including 195 lbs/yr from watershed sources. Monitoring of the County Road 6 pond in 2021 identified concentrations of phosphorus in the pond to be higher than previously understood, presenting an opportunity to make significant progress towards the watershed load reduction goal. With other projects in the subwatershed reliant on land use change, this presents a short term implementation opportunity.

WORKPLAN SUMMARY
In 2023, MCWD intends to build on the collected monitoring data and concept development to complete project feasibility. Pending the completion of project feasibility, Board consideration, and project ordering, MCWD anticipates 2023 project design and 2024 construction.

SCHEDULE + BUDGET

PLANNING	DESIGN	CONSTRUCTION
2022	2023-2024	2024-2025
$25,000	$110,000	$415,000

MCWD CIP OVERVIEW
LONG LAKE CREEK



MINNEHAHA CREEK WATERSHED DISTRICT

MULTI-YEAR CAPITAL IMPROVEMENT PLAN 2024-2028

OVERVIEW

PROJECT NAME

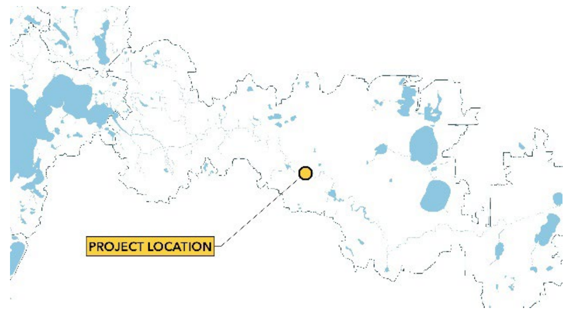
Greenway to Cedar Trail Connection and Streambank Restoration

LOCATION

St. Louis Park (Minnehaha Creek)

TARGET WATERBODY

Minnehaha Creek



DESCRIPTION

SCOPE

Planned streambank stabilization, riparian restoration, and construction of a trail connection along Minnehaha Creek from the Minnehaha Creek Preserve to the Cedar Lake LRT Regional Trail. This link in the Minnehaha Creek Greenway will be planned in partnership with the City of St. Louis Park and Metropolitan Council and timed to coinicide with Southwest LRT (SWLRT) construction completion.

GOALS

Provide a key connection between existing and future MCWD projects upstream and downstream of the rail corridor, increasing pedestrian and bicyclist safety and improving recreation and transportation access to the Cedar Lake LRT Regional Trail and future SWLRT stations at Blake Road and Louisiana Avenue. The overall ecological integrity of the stream corridor will be improved through approximately 1,500 lineal feet of streambank stabilization and riparian restoration.

JUSTIFICATION

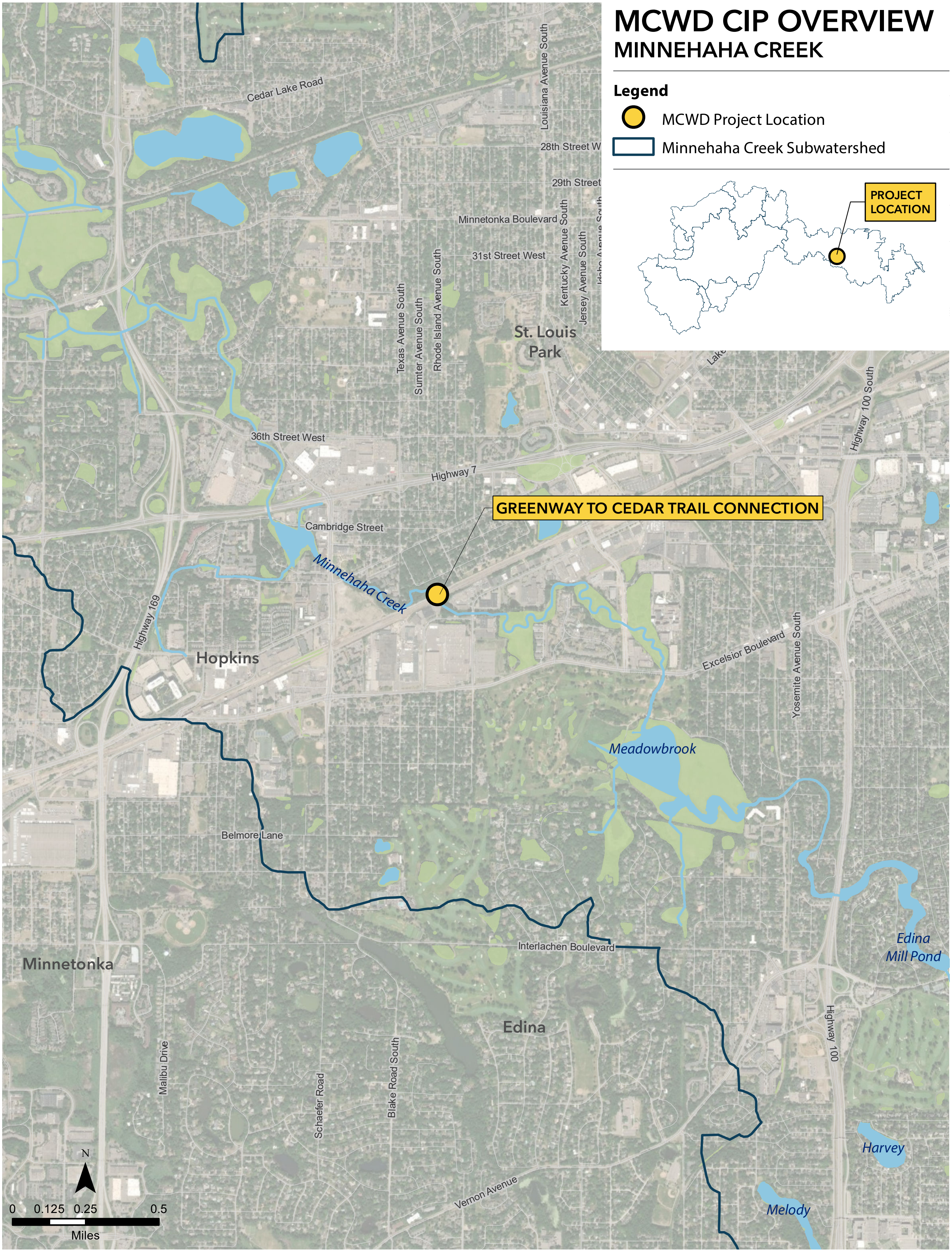
Upstream and downstream Minnehaha Creek Greenway projects are currently separated by freight rail and the future Southwest LRT line, and there is no direct pedestrian or bicycle connection between these investments or the Cedar Lake LRT Regional Trail. The bridge crossing at Minnehaha Creek is the site of past creek manipulation, and Minnehaha Creek is currently impaired for fecal coliform bacteria, chloride, low dissolved oxygen, and fish and macroinvertebrate communities. Lake Hiawatha, Minnehaha Creek's receiving waterbody, is impaired for nutrients due to sediment and nutrient loads transported by Minnehaha Creek and both waterbodies have TMDLs.

WORKPLAN SUMMARY

In 2023, MCWD will compile existing and newly collected data to complete a feasibility assessment and develop a scope for project design. MCWD will pursue partnership agreements, including a design and construction agreement with St. Louis Park, and target 2024 to iniate design. Construction will be coordinated between MCWD and the other agencies who own or operate the SWLRT right-of-way.

SCHEDULE + BUDGET

PLANNING	DESIGN	CONSTRUCTION
2023	2024 – 2025	2025 – 2026
$25,000	$65,000	$445,000


MCWD CIP OVERVIEW
MINNEHAHA CREEK
Legend
MCWD Project Location
Minnehaha Creek Subwatershed
PROJECT LOCATION
GREENWAY TO CEDAR TRAIL CONNECTION
Cedar Lake Road
Louisiana Avenue South
28th Street W
29th Street
Minnetonka Boulevard
31st Street West
Kentucky Avenue South
Jersey Avenue South
Texas Avenue South
Sumter Avenue South
Rhode Island Avenue South
St. Louis Park
36th Street West
Highway 7
Cambridge Street
Minnehaha Creek
Highway 169
Hopkins
Excelsior Boulevard
Yosemite Avenue South
Highway 100 South
Meadowbrook
Belmore Lane
Interlachen Boulevard
Edina Mill Pond
Minnetonka
Edina
Highway 100
Malibu Drive
Schaefer Road
Blake Road South
Harvey
Vernon Avenue
Melody
N
0 0.125 0.25 0.5
Miles

MINNEHAHA CREEK WATERSHED DISTRICT

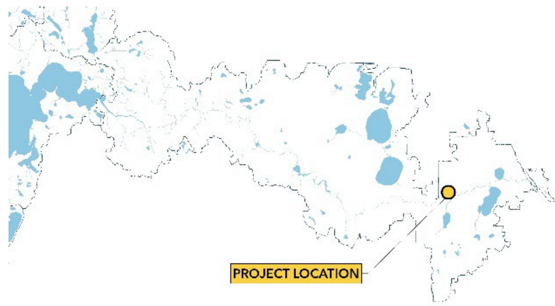
MULTI-YEAR CAPITAL IMPROVEMENT PLAN 2024-2028

OVERVIEW

PROJECT NAME
Minnehaha Parkway Stormwater Management

LOCATION
Minneapolis (Minnehaha Creek)

TARGET WATERBODY
Minnehaha Creek, Lake Hiawatha



DESCRIPTION

SCOPE
Proposed partnership with the City of Minneapolis and Minneapolis Park and Recreation Board (MPRB) to create a shared implementation framework for the Minnehaha Parkway Regional Trail Master Plan, a 30 year vision to enhance recreation, improve ecological function of the creek corridor, improve public safety, address flooding, and improve water quality in the Minneapolis segment of the Minnehaha Creek corridor.

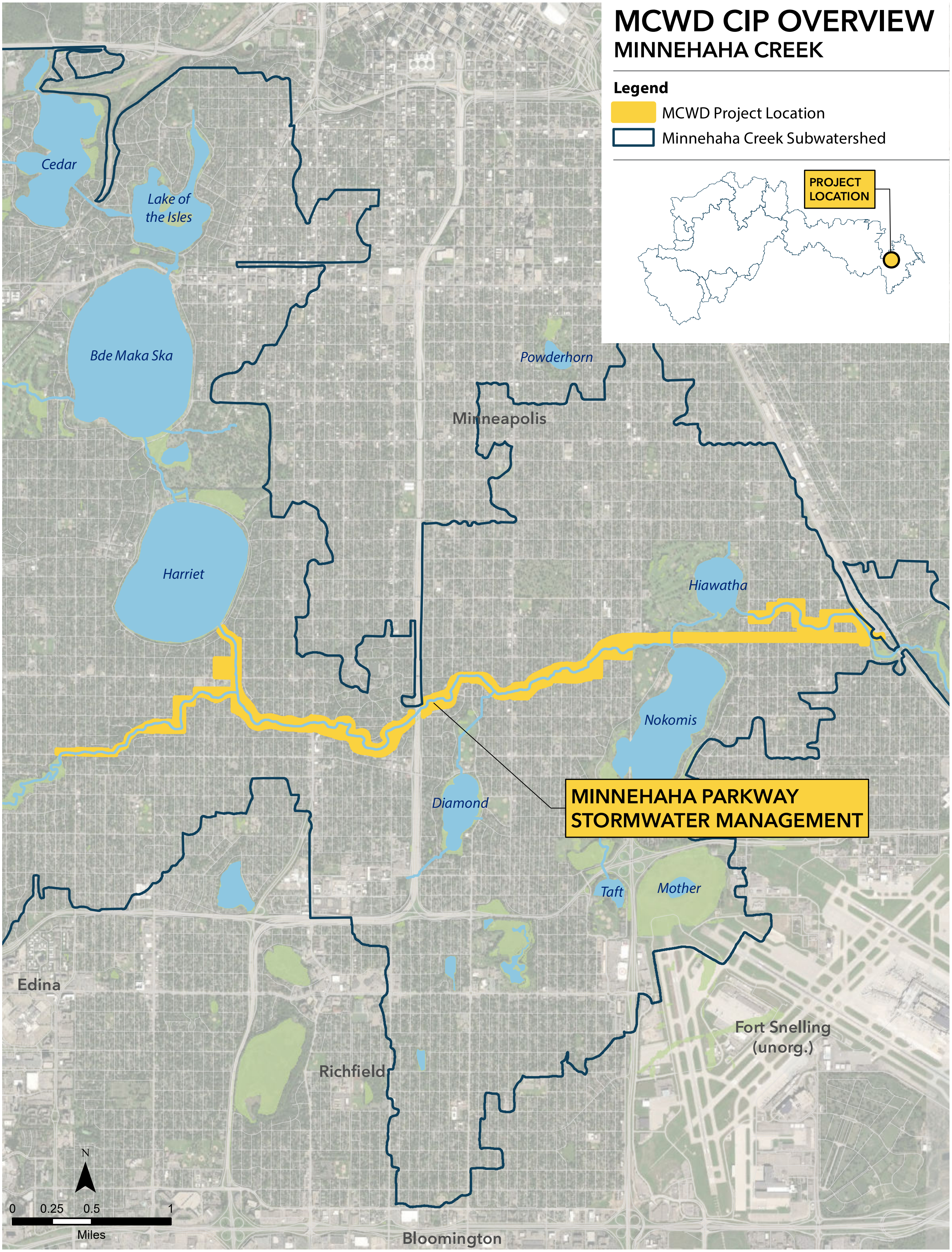
GOALS
The Minnehaha Parkway Regional Trail Master Plan includes 35 water resource projects, which together would remeandor 2.65 miles of creek, restore 51.8 acres of upland landscape, reduce annual phsophorus loading to lake Hiawatha by 434 lbs/year; increase floodplain storage by 56 acre-feet; and create six new creek access points.

JUSTIFICATION
Minnehaha Creek is an iconic regional and cultural natural resource. It is an impaired water body for multiple parameters, including fecal coliform bacteria, chloride, low dissolved oxygen, and fish and macroinvertebrate communities. Further, the MPCA has listed downstream receiving water body Lake Hiawatha as impaired for excess nutrients. Minnehaha Creek is further impacted by rapidly fluctuating water flows that contribute to bank erosion and impair the biotic integrity of the stream.

WORKPLAN SUMMARY
The focus for 2023-2024 will be on developing a shared implementation framework between MCWD, MPRB, and Minneapolis to identify and implement priority capital improvements in the Minnehaha Parkway. Successful partnership development will lead to future advancement of specific capital projects through the planning, design, and construction cycle. The below timeline is illustrative of a potential first phase project for implementation.

SCHEDULE + BUDGET

PLANNING	DESIGN	CONSTRUCTION
2023– 2024	2024 – 2025	2026 – 2028
$100,000	$250,000	$1.25 million


MCWD CIP OVERVIEW
MINNEHAHA CREEK
Legend
MCWD Project Location
Minnehaha Creek Subwatershed
PROJECT LOCATION
Cedar
Lake of the Isles
Bde Maka Ska
Harriet
Powderhorn
Minneapolis
Hiawatha
Nokomis
Diamond
Taft
Mother
MINNEHAHA PARKWAY STORMWATER MANAGEMENT
Edina
Richfield
Fort Snelling (unorg.)
Bloomington
N
0 0.25 0.5 1
Miles

Attachment 2

East Auburn Wetland Restoration Feasibility Study

June 2023

Moore Project No. 22924

moore engineering, inc.

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Appendix C .... Sediment Sampling Data
Appendix D .... Groundwater Sampling Statistics

1. Introduction

Minnehaha Creek Watershed District (MCWD) in their 2017 Water Resources Management Plan (WRMP) identified a goal to address nutrient export to East Auburn Lake. Based on internal research and monitoring, MCWD identified Cell 1 in the wetland complex that feeds East Auburn Lake (referred to as the East Auburn Wetland) as the primary contributor of phosphorus to the lake. MCWD selected the Moore Engineering Team (Moore Engineering, Inc. [Moore], Wetland Solutions, Inc. [WSI], and Dr. Nathan Johnson to develop a feasibility assessment for the Cell 1 Wetland to evaluate and recommend alternative strategies to manage phosphorus export from the wetland to East Auburn Lake.

1.1. Project Location

The Cell 1 Wetland site is in the City of Victoria, in Carver County, along Six Mile Creek between Wasserman Lake upstream and Lake Auburn downstream. Six Mile Creek is either an excavated or artificially incised creek that flows through a series of four wetlands between the two lakes. Six Mile Creek flows into the Cell 1 Wetland at the outlet from Wasserman Lake where it passes through a 24-inch pipe under Church Lake Boulevard (County Road 43). The Cell 1 Wetland extends from below this culvert to a narrow cross-section where there is a pedestrian footpath at its north end. Below this footpath the creek continues through a series of additional wetland cells. The location of the Cell 1 Wetland and surrounding features is shown in Figure 1-1.

Figure 1-1. Cell 1 Wetland Location

1.2. Cell 1 Wetland History

The Cell 1 Wetland is not shown on the 1853 surveys of the area. Wasserman Lake and Auburn Lake are shown, however Six Mile Creek is shown largely bypassing Auburn Lake to the west (Figure 1-2). In the 1905 United States Geological Survey (USGS) topographic map Six Mile Creek is shown connecting to the southeast corner of Auburn Lake as it exists today. This map also shows a road in place near the existing location of Church Lake Boulevard at the southern end of Cell 1, indicating that a culvert was already in place at the outlet of Wasserman Lake by 1905 (Figure 1-3). Review of more recent aerial photographs dating back to the 1940s demonstrates that the channel through the Cell 1 Wetland has been manipulated from its natural condition and straightened to improve drainage.

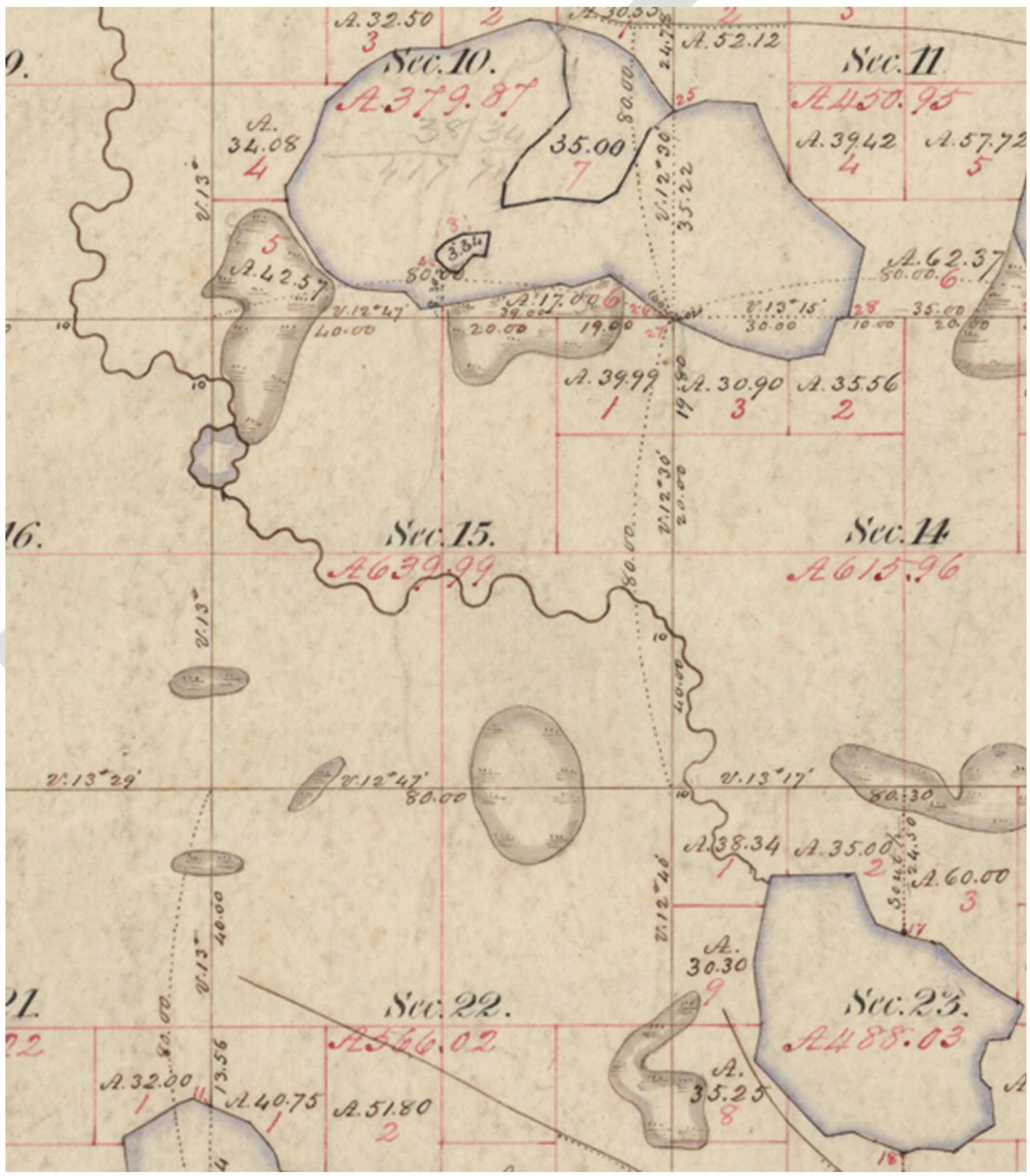


Figure 1-2. 1853 Survey of Wasserman Lake (Bottom Right) and Auburn Lake (Top Center)

Figure 1-3. 1905 USGS Survey

1.3. Cell 1 Wetland Description

The Cell 1 Wetland is one of four wetland cells in the East Auburn Wetland between Wasserman Lake and Auburn Lake along Six Mile Creek. The Cell 1 Wetland is the most upstream wetland cell and is an emergent marsh with a channel that meanders through the cell and under the bridge at the downstream (northern) extent of the wetland. In this location the wetland narrows and the channel flows under the bridge before expanding into the next marsh (Cell 2) located to the north of the walkway. The Cell 2 downstream boundary is considered the trail where the wetland flows through a 36-inch culvert. After going under the trail, the wetland continues in Cell 3 before narrowing and entering Cell 4. Cell 4 continues until the wetland flows under Arboretum Boulevard (MN Highway 5) and into East Auburn Lake.

In addition to these sites there has been additional data collection within Cell 1 and within Cells 3 and 4 as part of other, detailed studies.

1.3.1. Wetland Vegetation Community

The wetland community in the East Auburn Wetland is dominated by emergent vegetation with a channel that meanders through all the wetland cells from Wasserman Lake to East Auburn Lake. In addition, there are some areas of shallow open water in the wetlands and Carl Krey Lake located west of the wetland. Based on an evaluation by Wenck (2019) of Cells 3 and 4, the dominant plant communities in the marsh were invasives including narrow leaf cattail (*Typha angustifolia*), common reed (*Phragmites australis*), and reed canary grass (*Phalaris arundinacea*). In addition to these communities there were some native species observed at lower densities.

1.3.2. Wetland Topography

Survey elevations were collected in select locations in the Cell 1 Wetland as part of a recent study by Stantec in 2021 and 2022. This topographic detail showed that the light detection and ranging (LiDAR) data previously collected for the site was not particularly accurate in the marsh, likely due to vegetation density and potentially standing water. The field topographic survey showed that the wetland bottom in the marsh was approximately 943.5 to 945 feet (NAVD88). The elevations within the channel were about one foot lower and between 942.5 and 943.5 feet. The wetland survey points are shown in Figure 1-4. These survey points and the aerial photograph were used to develop estimated contours for the marsh that are shown in Figure 1-5.

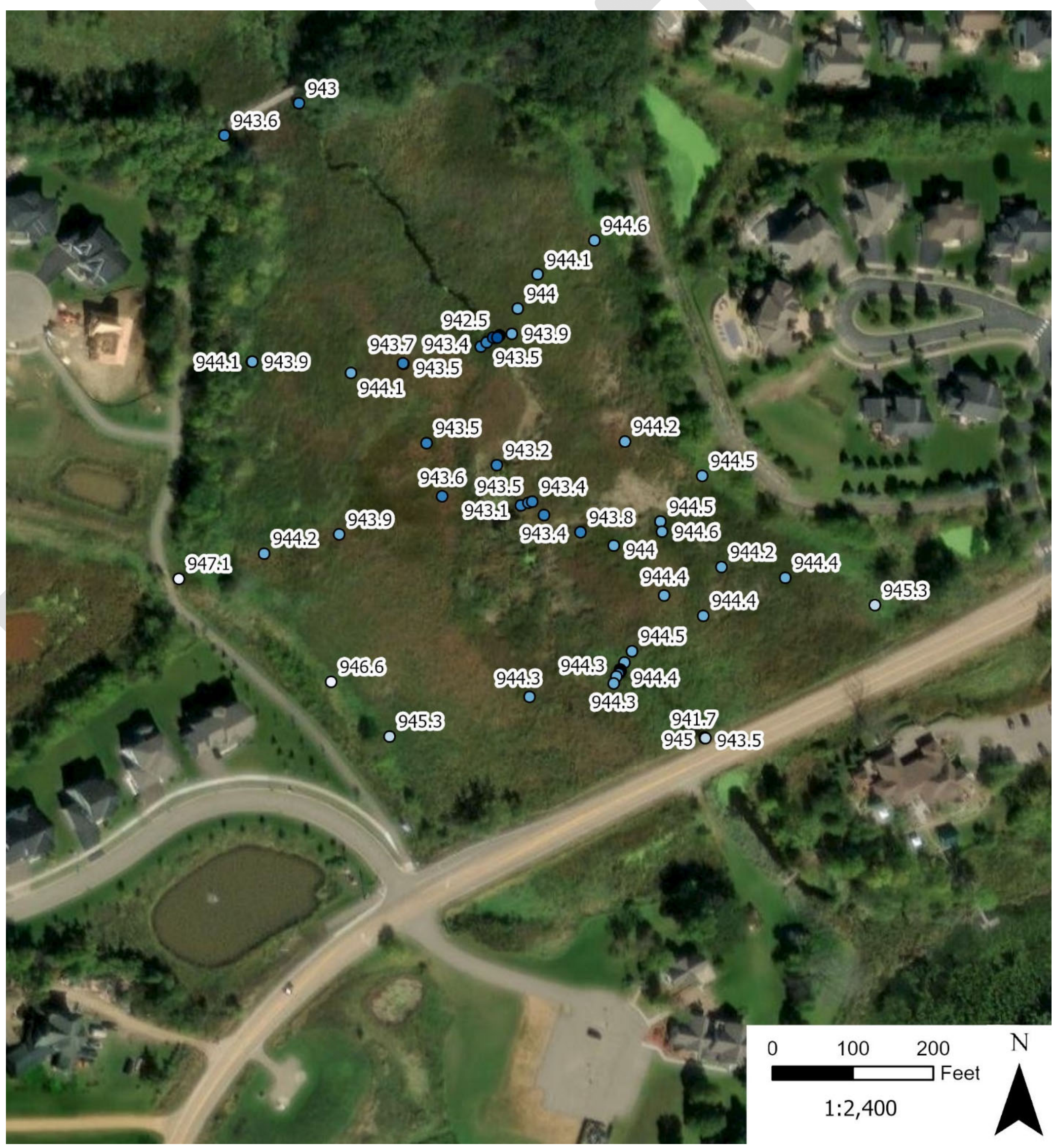


Figure 1-4. Cell 1 Wetland Survey (ft NAVD88)

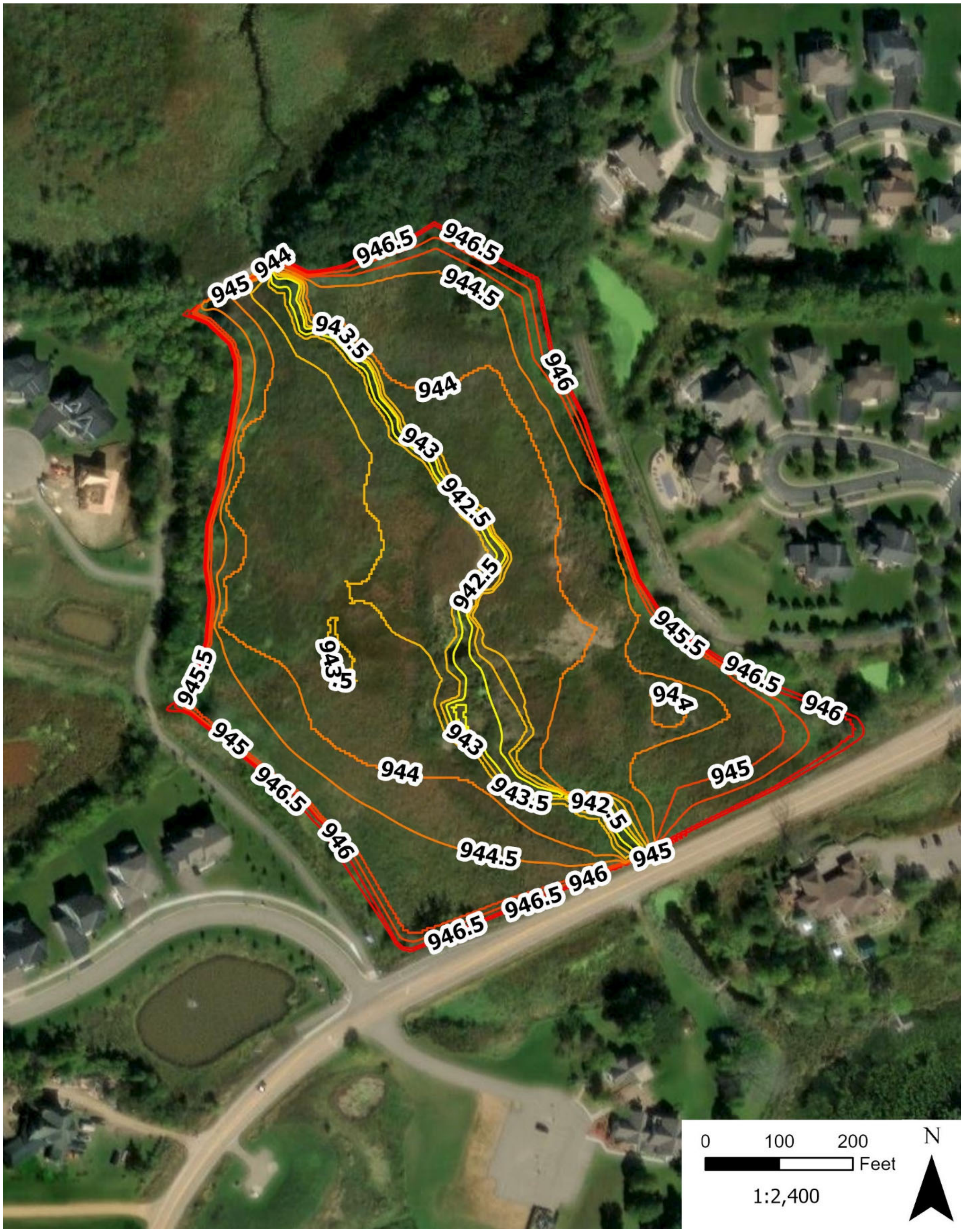


Figure 1-5. Cell 1 Wetland Elevation Contours (ft NAVD88)

2. Data Analysis

This feasibility assessment relied on data collected by others during other studies. These data included surface water and groundwater quality, flows, sediment samples, water levels, and vegetation data. The collected data were used to evaluate the wetland and develop alternatives to reduce nutrient exports from the wetland. The following sections discuss the data that were evaluated and observations from this analysis.

2.1. Sampling Locations

The wetland complex has been sampled for water quality and hydrology at several stations during different time periods. The longest-term dataset is available for the wetland complex inlet and outlet with station CSI12 (upstream station) located at Church Lake Boulevard downstream of Wasserman Lake and CSI05 (downstream station) located upstream of East Auburn Lake at Arboretum Boulevard. In addition to these stations, data collection has occurred at the wetland midpoint, between Cell 2 and Cell 3, at CSI19. Finally, data collection also occurred between Cell 1 and Cell 2 at CSI22. These sampling locations are shown in Figure 2-1. The statistics and periods-of-record (PORs) for these stations are provided in the Appendices.

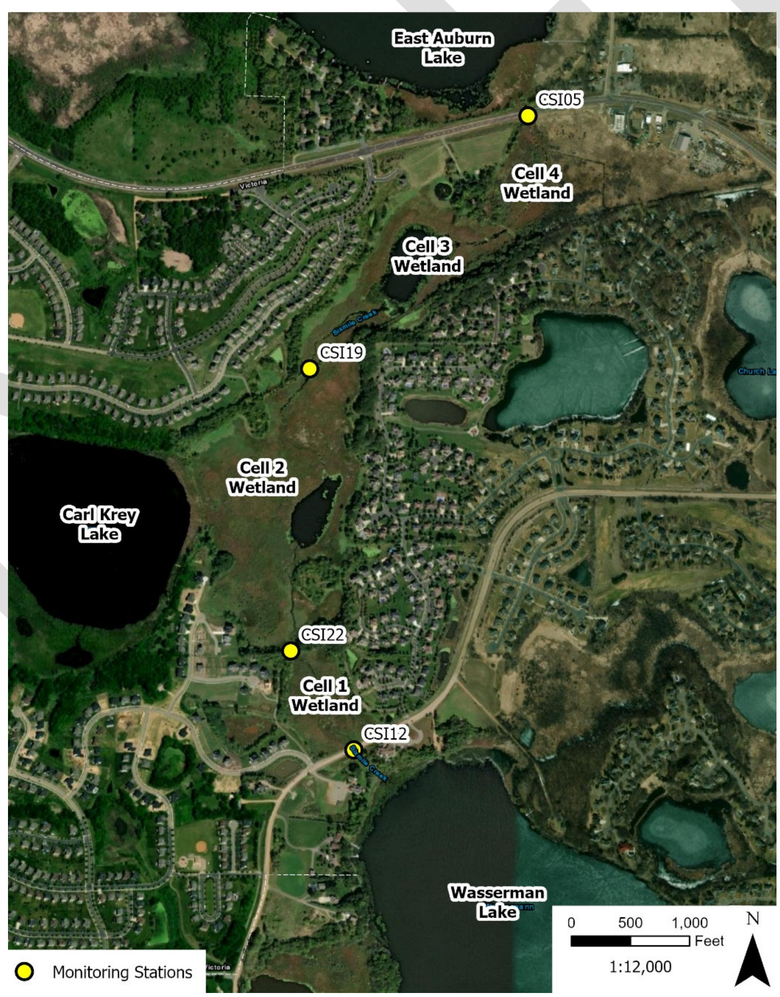


Figure 2-1. Sampling Stations on Six Mile Creek

In addition to these longer-term data, detailed data have been collected within the Cell 1 Wetland. This included data collection by Stantec in 2022 for water quality, water levels, and sediment characteristics. These data were collected at a series of locations within the channel, marsh, fringe, and adjacent uplands. All of these data were collected between May and September of 2022. These Cell 1 sampling stations are shown in Figure 2-2.

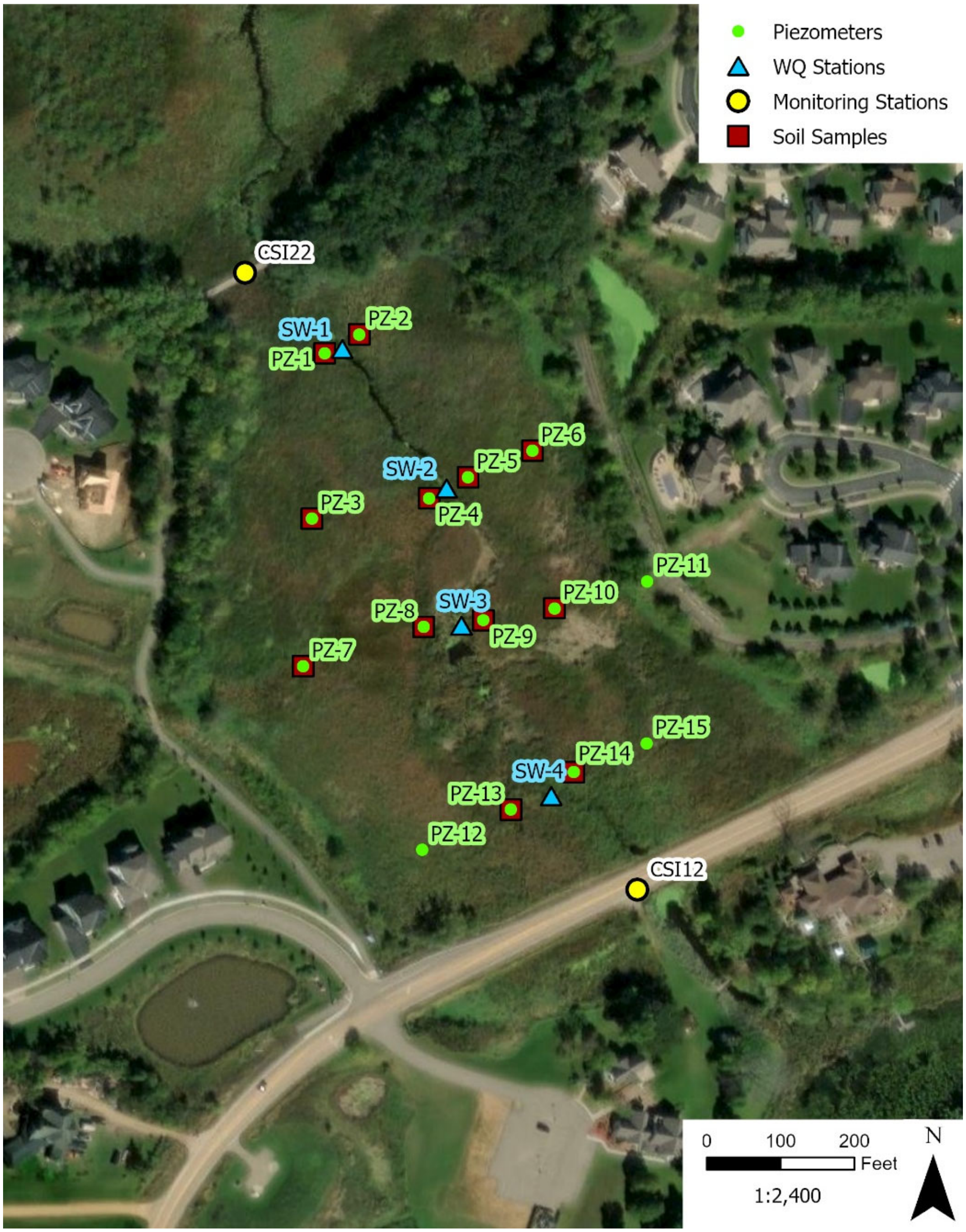


Figure 2-2. Cell 1 Wetland Sampling Stations

2.1. Flow Measurements

Flow measurements were collected at the inlet and outlet of the wetland complex beginning in 2009. These measurements showed a slight increase in flows through the wetland (Figure 2-3). This increase is expected due to direct rainfall on the wetland and runoff from the areas adjacent to the wetland that contribute stormwater. Median flows at the inlet and outlet were 2.30 cfs and 2.72 cfs, respectively with peak measured flows of 42.5 cfs at the inlet and 28.1 cfs at the outlet. This generally indicates that the existing culverts that control wetland inflows and outflows are sized appropriately to pass low storm events and baseflow without causing extensive ponding but do restrict discharge for higher events (as indicated between a minimal difference in median and low flows, and a significant difference in peak flows).

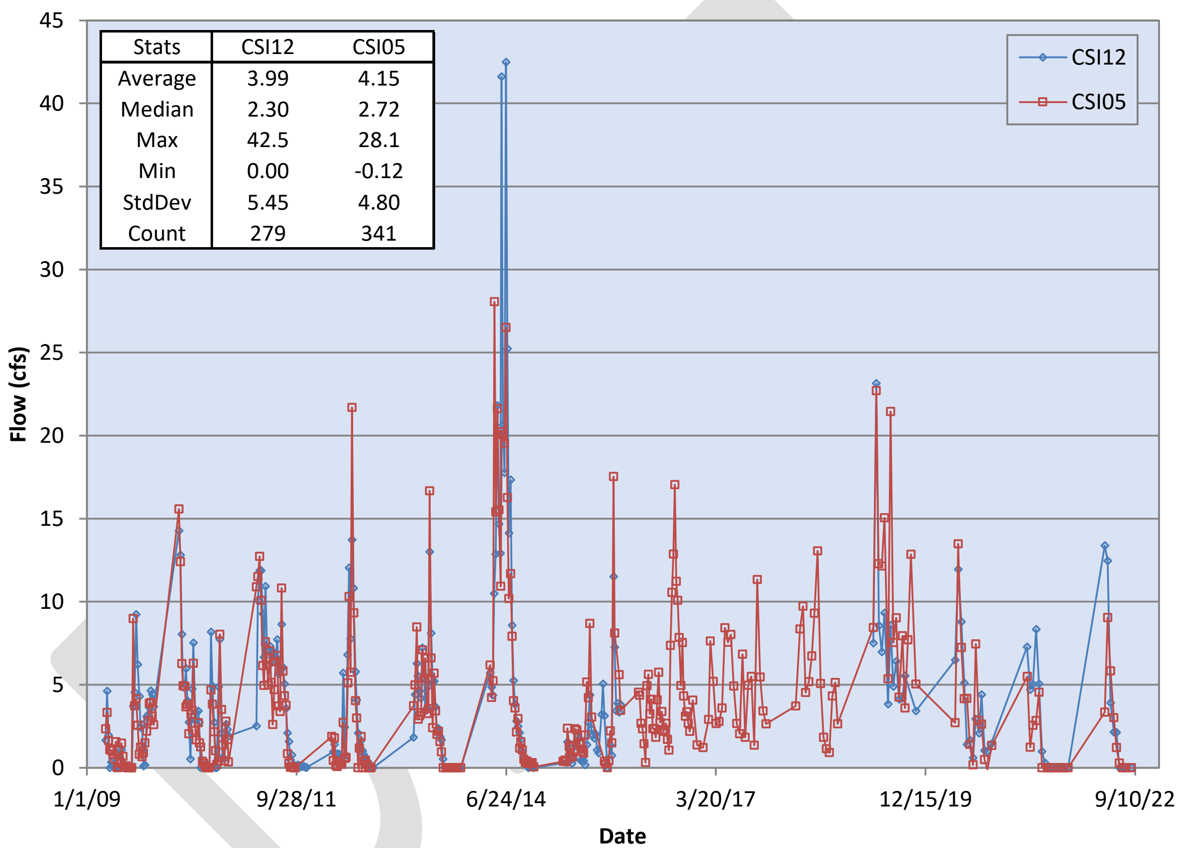


Figure 2-3. Flow Measurements at the Inlet and Outlet of the Wetland Complex

In addition to evaluating the time series, the annual pattern of flows was also considered to examine the magnitude of flows during different months. These data show that flows were highest in spring and early summer before flows began to taper off in the late summer before increasing slightly in the fall in years with wetter than normal precipitation as shown in Figure 2-4. These seasonal changes in flow were particularly pronounced in the upstream areas of the wetland at CSI12.

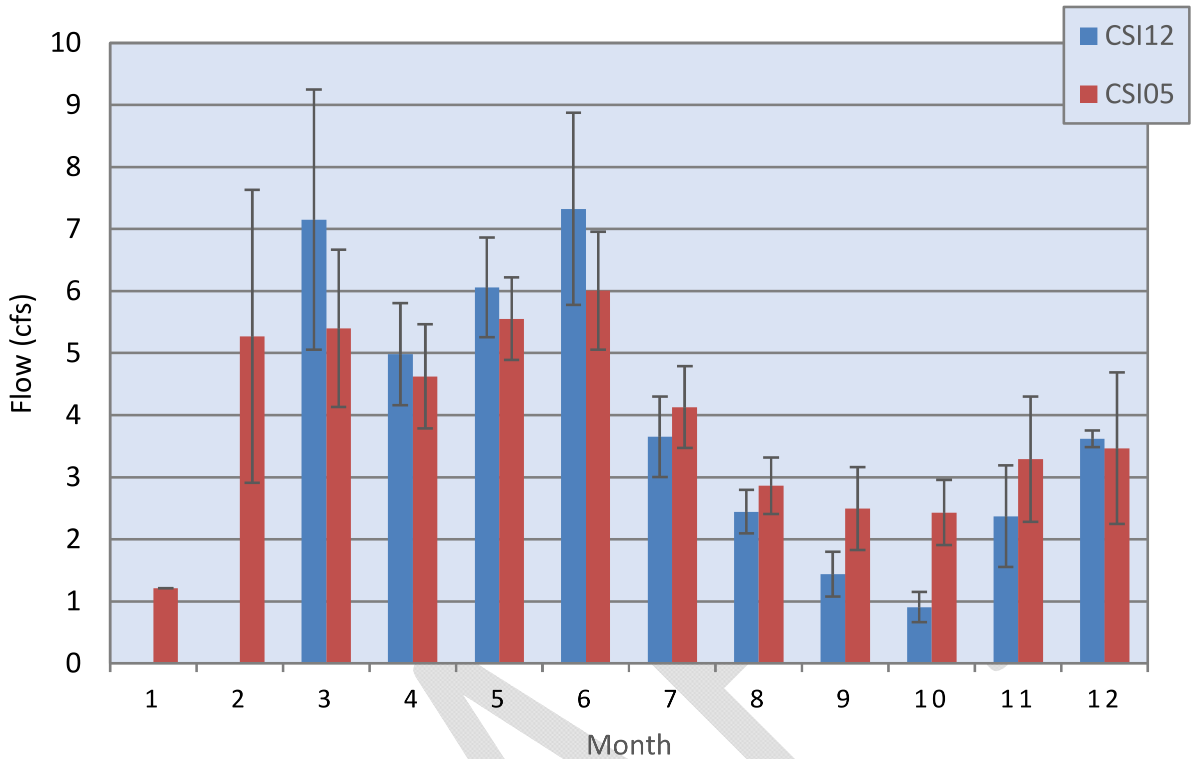
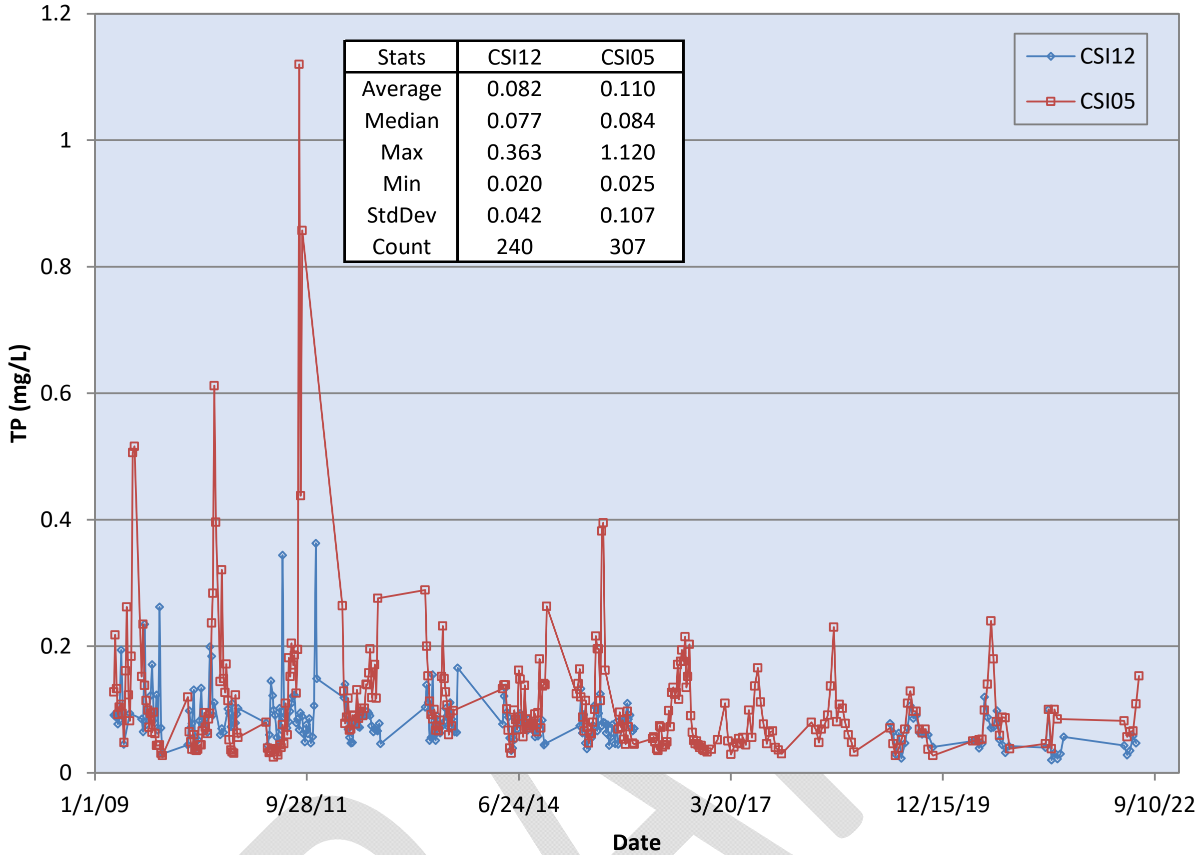


Figure 2-4. Average Monthly Flows at the Inlet and Outlet of the Wetland Complex

2.2. Water Quality

Water quality data have been collected from the previously described stations at varying frequencies and over variable PORs. The stations with the longest PORs are located immediately upstream of the Cell 1 Wetland (CSI12) and at the outlet of the wetland complex (CSI05). These stations have data extending back to 2009. At these stations the total phosphorus (TP) increased between the wetland inlet and outlet with higher average and median values at the downstream station. Additionally, the data showed a consistent seasonal trend with higher concentrations being released in the summer from the wetland complex (Figure 2-5).



Stats	CSI12	CSI05
Average	0.082	0.110
Median	0.077	0.084
Max	0.363	1.120
Min	0.020	0.025
StdDev	0.042	0.107
Count	240	307

Figure 2-5. Total Phosphorus at the Inlet and Outlet of the Wetland Complex

Ortho-phosphorus (OP) at these same stations showed a more significant increase between the wetland inlet and outlet (Figure 2-6). OP discharged increased in both total mass and the ratio of OP to TP; at the wetland inlet approximately 10-percent of the TP was in the OP form while at the wetland outlet approximately 40-percent of the TP was in the OP form. These data also showed a seasonal pattern with increasing concentrations later in the year at the downstream station. Stormwater sampling statistics for all sampled stations are provided in Appendix A.

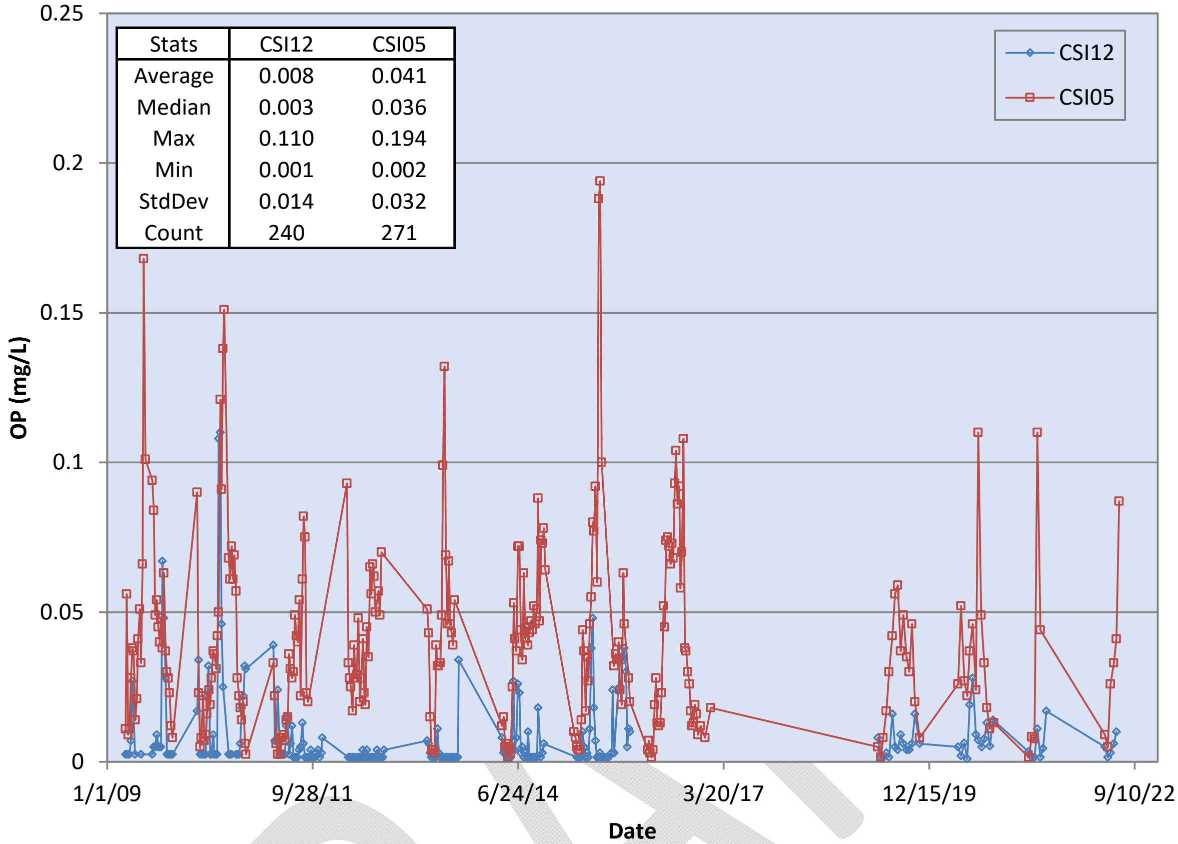


Figure 2-6. Ortho-Phosphorus at the Inlet and Outlet of the Wetland Complex

Concentrations of TP and OP were also evaluated monthly to examine trends in concentration during different months. For TP, this examination showed average outflow concentrations exceeding average inflow concentrations from March through September. (Figure 2-7). Increases in concentration were particularly apparent from June to September. OP showed the same increases in concentration through the wetland with a consistent release of OP in all months (Figure 2-8). This release was particularly pronounced from June through September.

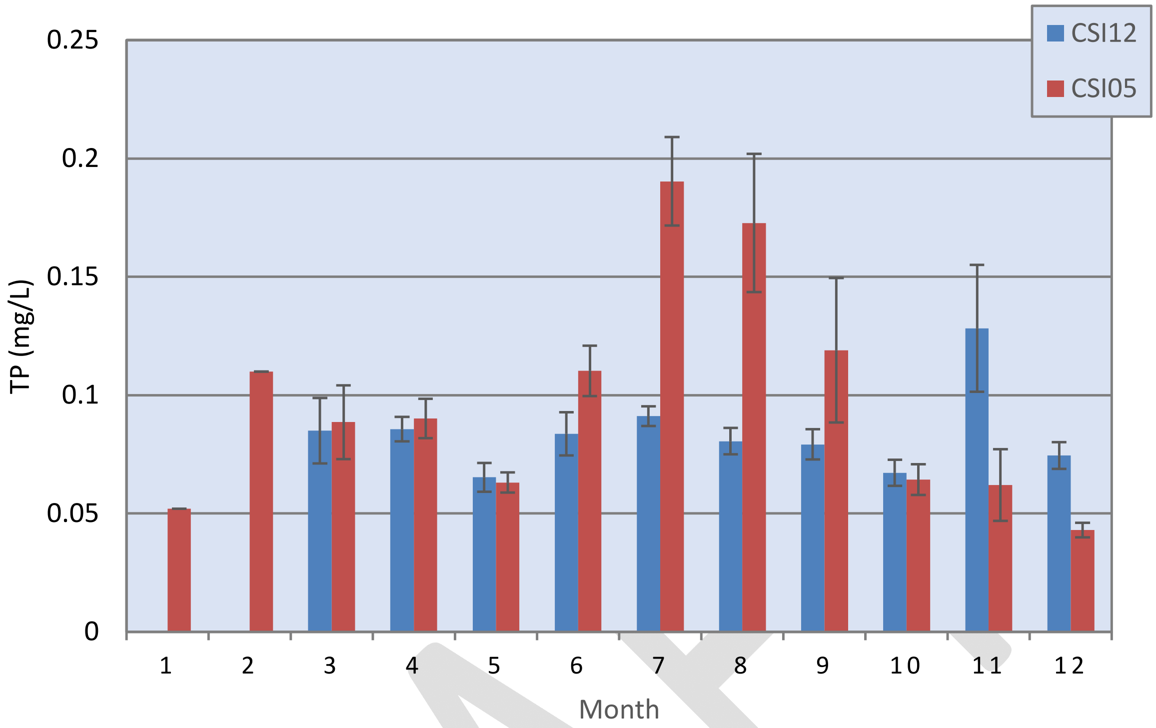


Figure 2-7. Average Monthly Total Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

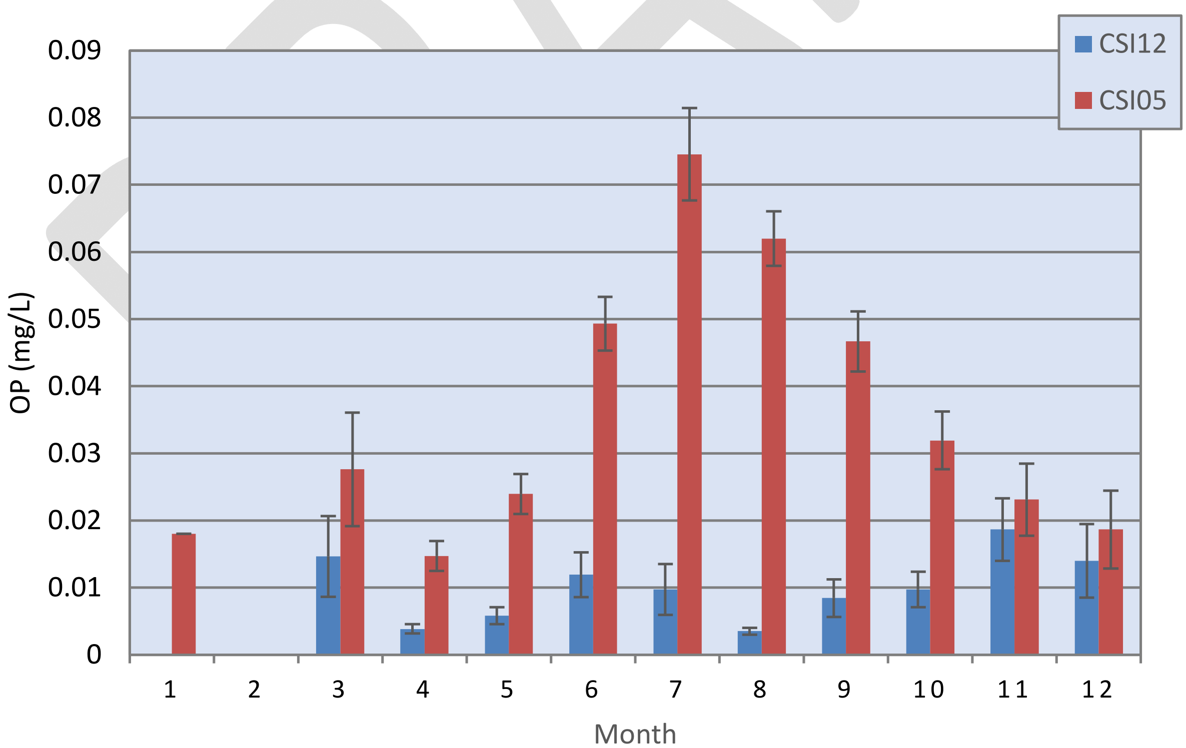


Figure 2-8. Average Monthly Ortho-Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

Concentrations of TP and OP were paired with flows to evaluate the mass of phosphorus entering and leaving the wetland. These data showed a consistent export of TP except during infrequent occasions when the load entering exceeded the load leaving the wetland (Figure 2-9). OP showed a similar relationship with the load leaving the wetland significantly exceeding the load entering the wetland (Figure 2-10).

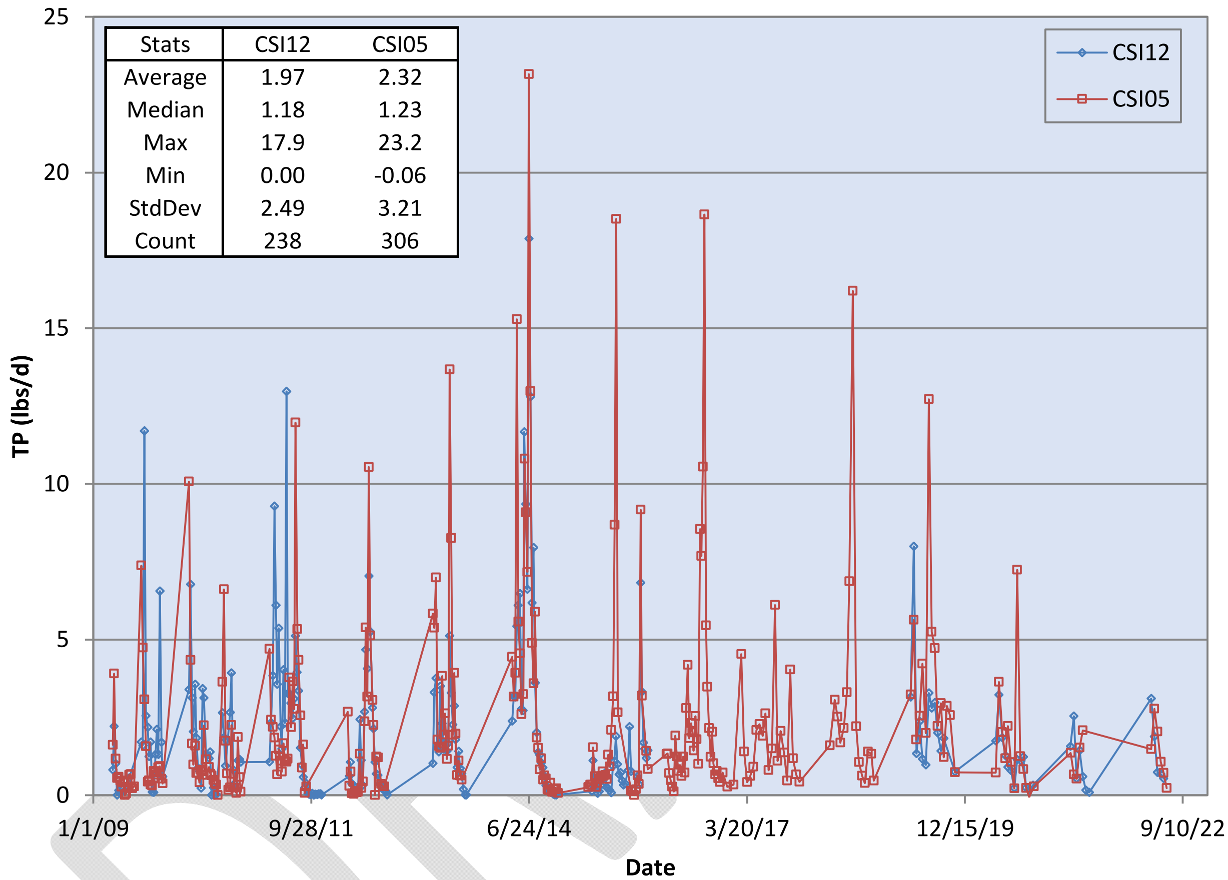


Figure 2-9. Total Phosphorus Load Entering and Leaving the Wetland Complex

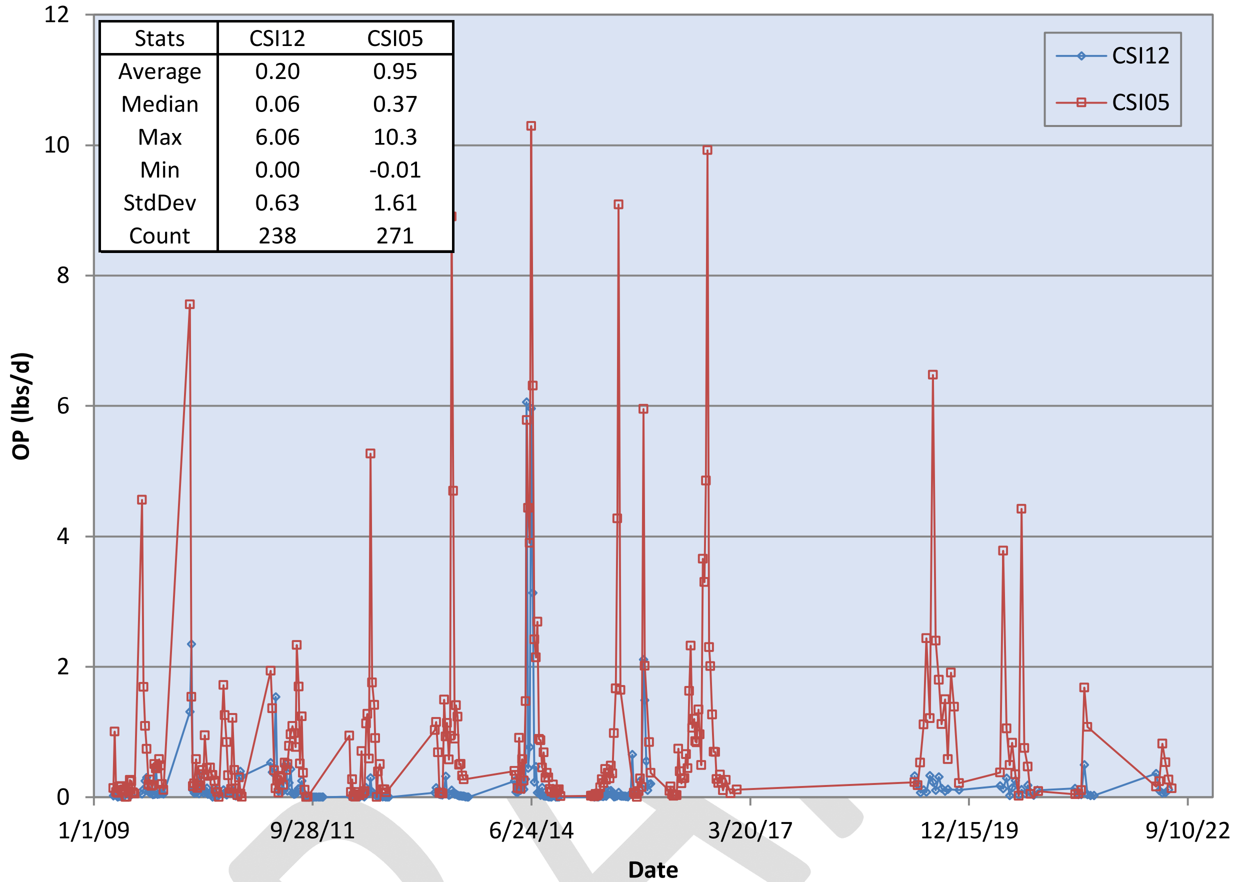


Figure 2-10. Ortho-Phosphorus Load Entering and Leaving the Wetland Complex

Monthly loading was also evaluated for TP and OP. These data show that, excluding January and February which had single samples, the months with consistent export were July through October, with October only having a minor export as shown in Figure 2-11. A similar loading pattern existed for OP except that export occurred in most months, and June through September had the largest increases in OP loading (Figure 2-12).

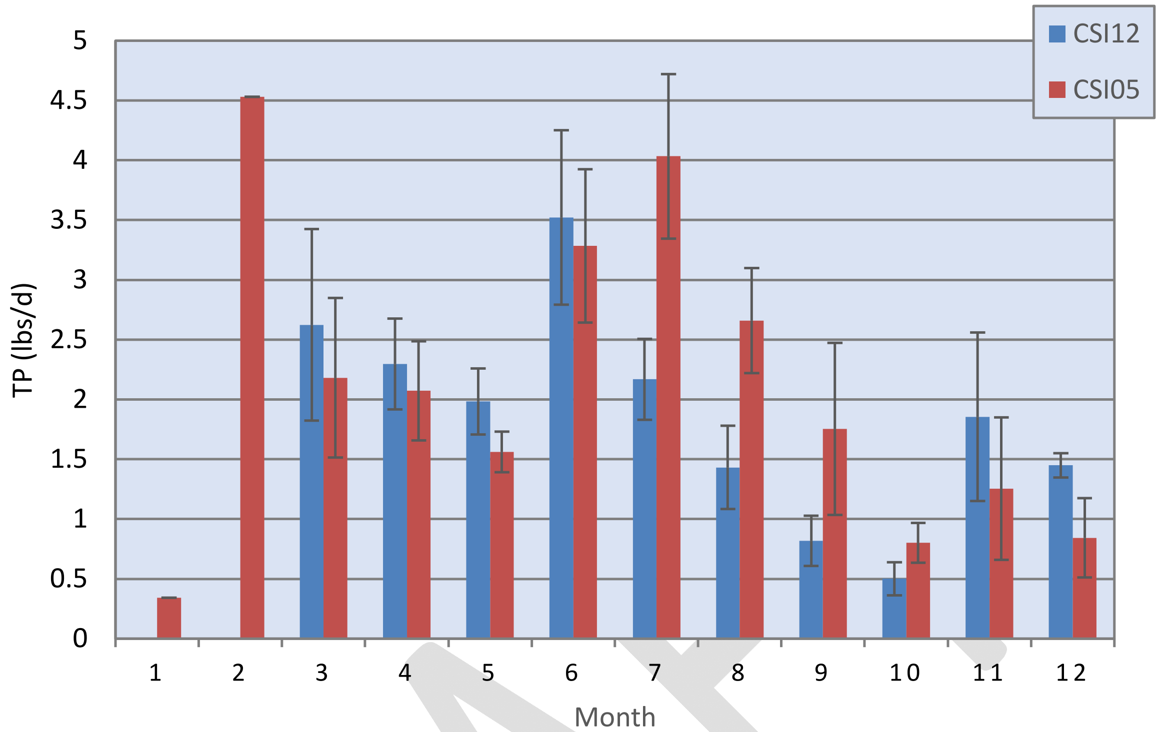


Figure 2-11. Average Monthly Total Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

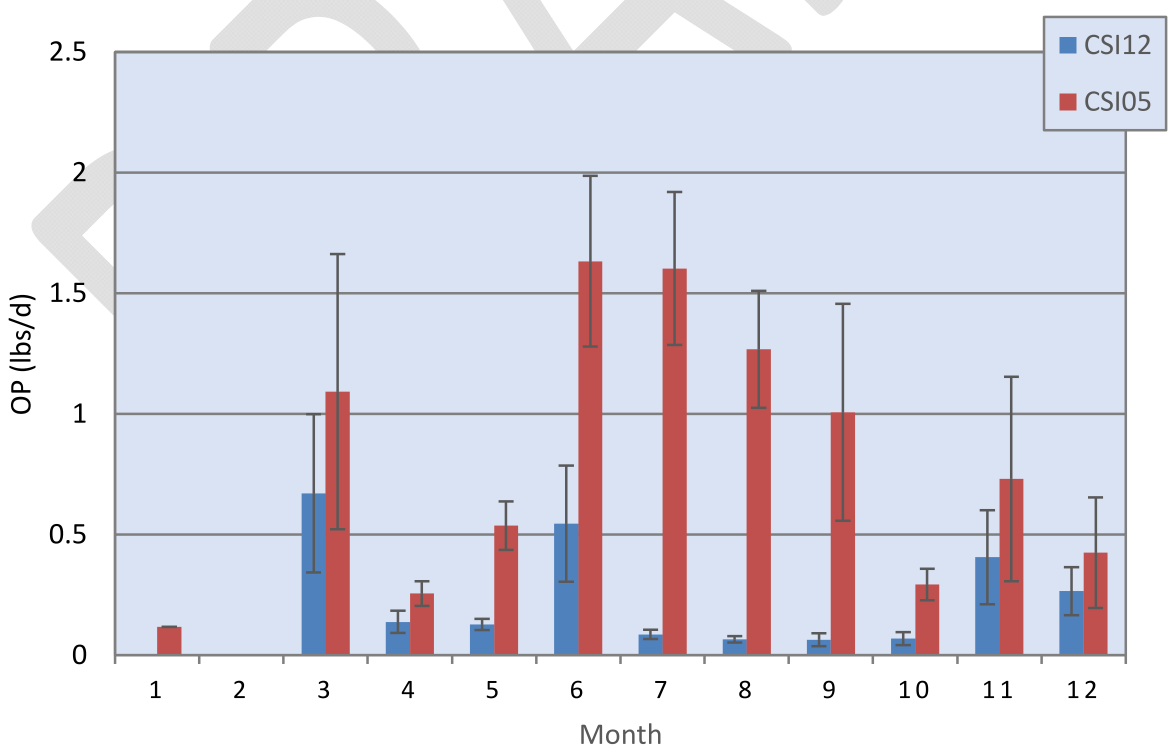


Figure 2-12. Average Monthly Ortho-Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

2.2.1. Cell 1 Wetland Surface Water Quality Sampling

Limited surface water quality samples have been collected at station CSI22 at the outlet from Cell 1 to Cell 2. These data were collected between mid-2020 through mid-2022. At CSI22, TP concentrations were elevated when compared to samples collected at CSI12, the inflow from Wasserman Lake to Cell 1 (Figure 2-13). Similar but more pronounced increases were observed for OP in the Cell 1 Wetland as shown in Figure 2-14.

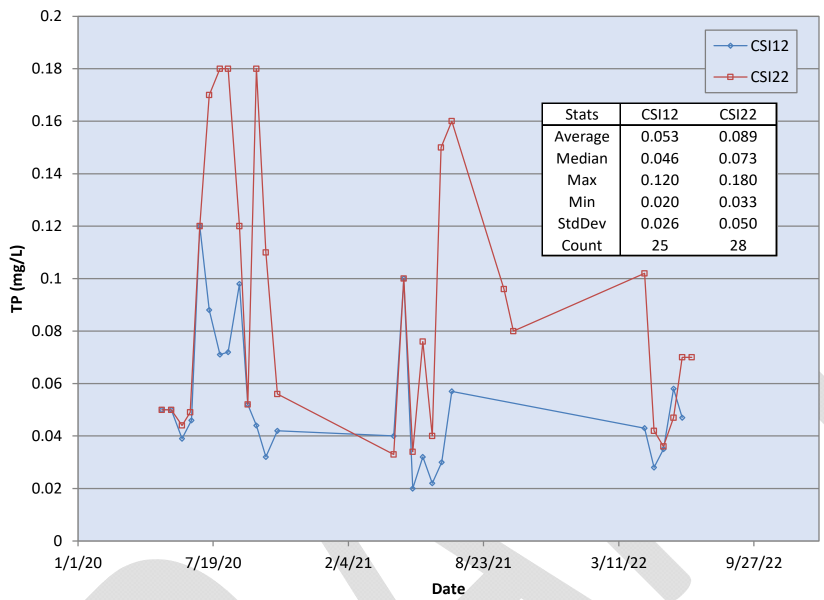


Figure 2-13. Total Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

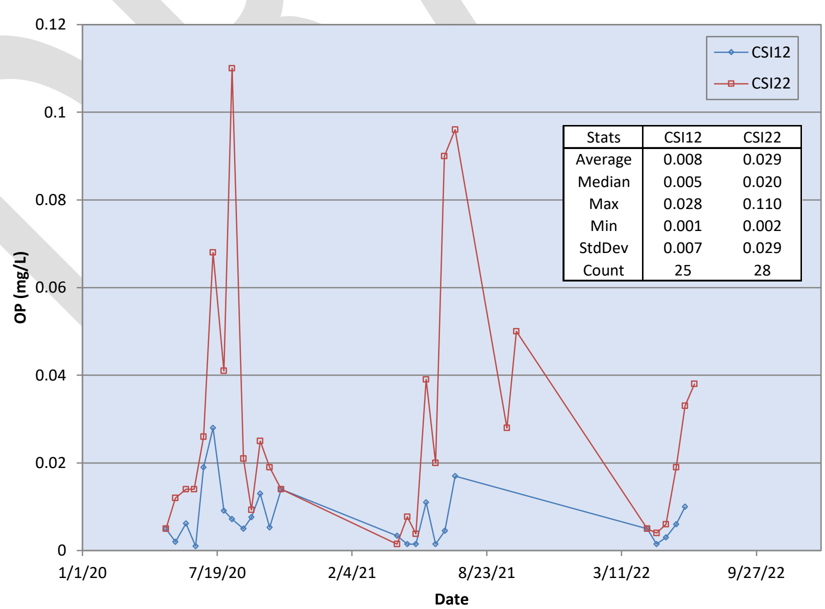


Figure 2-14. Ortho-Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

2.3. Water Levels

Water level data were collected at shallow monitoring wells installed in the Cell 1 Wetland as part of the detailed study completed by Stantec in 2022 (Stantec, 2022). Within Cell 1, water levels were collected at five locations (1 channel, 3 in the wetland, and 1 upland), shown in Figure 2-2. At the wetland monitoring well locations, water levels were collected at three depths, surface, shallow, and deep. The water levels were plotted and are shown in Figure 2-15. These data show that most of the marsh dried out by mid-June and that water was primarily contained in the channel (elevations less than 943.5 feet) by early-July. Review of water levels demonstrates the sub-surface drainage of water to the channel with a gradual drop in levels during the summer months before re-hydration of the entire marsh during August and early-September following precipitation events. The complete details for each sampling location including all three collected water levels are shown in Appendix B.

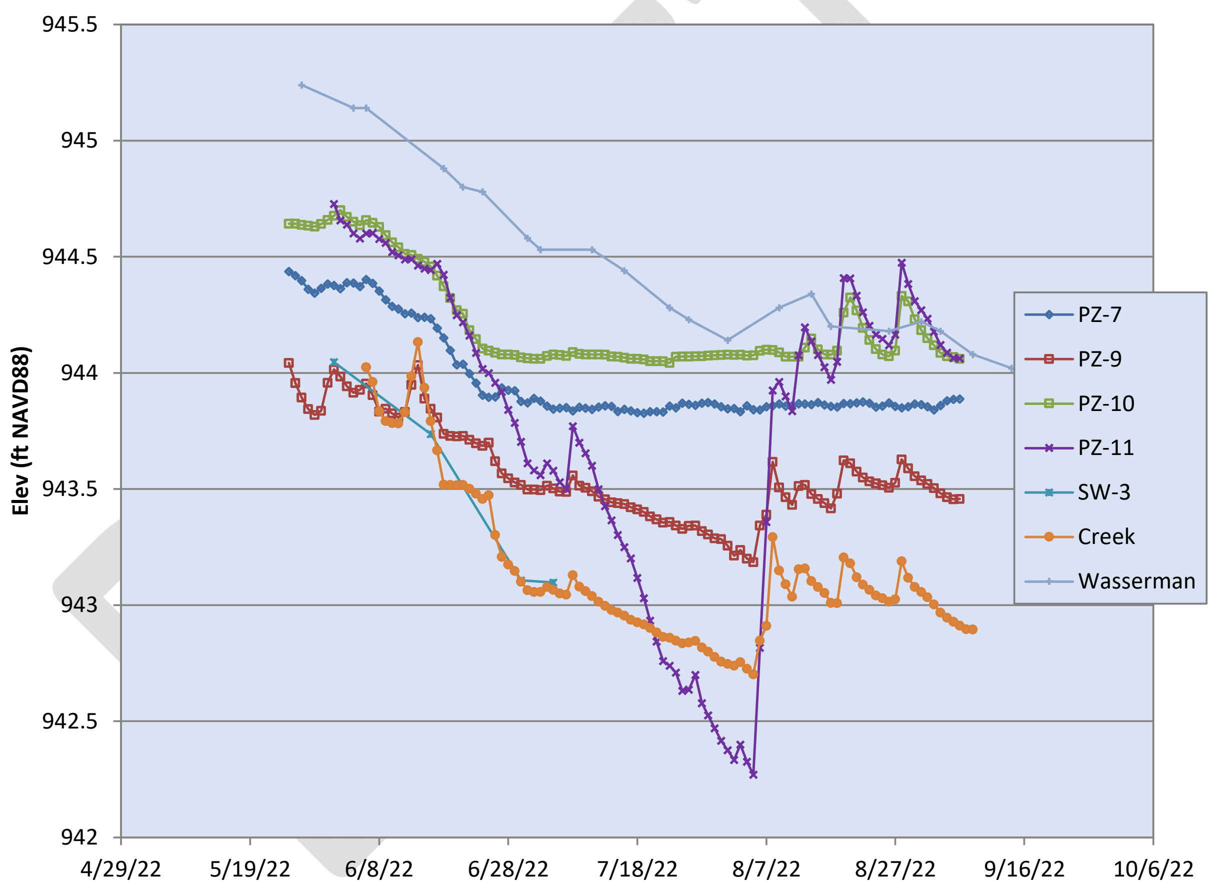


Figure 2-15. Cell 1 Wetland Water Levels

2.4. Soil Sampling

Soil sampling was completed as part of the detailed study of the Cell 1 Wetland by Stantec (Stantec, 2022). This included collection of samples at each of the piezometer locations at three depths: surface (0-1 feet), shallow (1-2 feet), and deep (4-5 feet) and in the stream. At each of these depths/locations the soil TP fractionation was measured and reported. Forms of soil phosphorus (P) that were measured and reported included: loosely-bound P, iron-bound P, labile organic P, aluminum-bound P, calcium-bound P, and refractory organic P. This order also generally corresponds to the bioavailability of these sources with the loosely-bound P, iron-bound P, and labile organic P being mobile and the aluminum-bound P, calcium-bound P, and refractory organic P being non-mobile under normal conditions. The average soil fractionation for the depths/locations are shown in Figure 2-16. These samples show that there is more mobile P in the stream and surface stations than in the shallow and deep samples. For these same samples average non-mobile P was similar amongst the depths/locations. The collected sediment data sampling results for all of the locations and depths are provided in Appendix C.

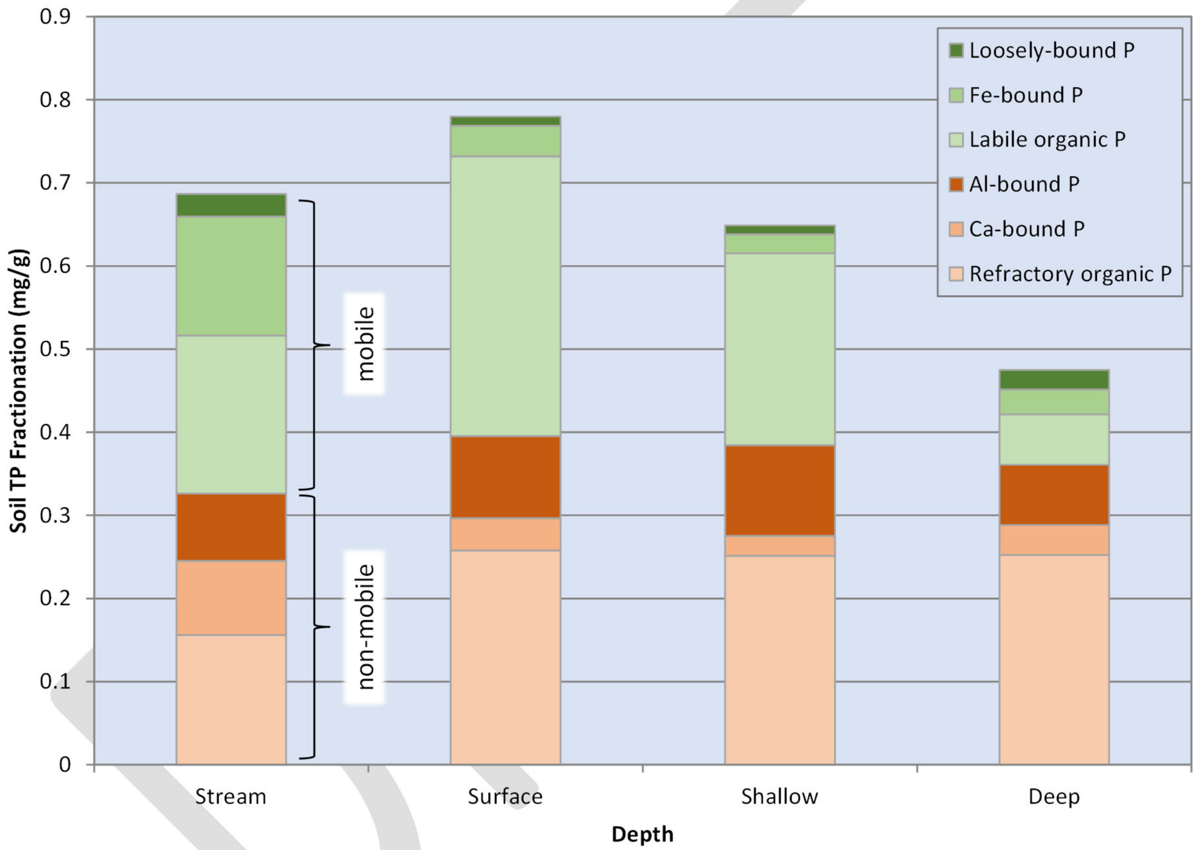


Figure 2-16. Sediment Total Phosphorus Fractionation Averages by Depth/Location

Concentrations of these components are shown for the surface samples in Figure 2-17. In the surface samples, TP varied between 0.55 and 1.23 mg/g. Some variability in concentrations were observed across the wetland with PZ-10 having approximately 50-percent more TP than any of the other samples.

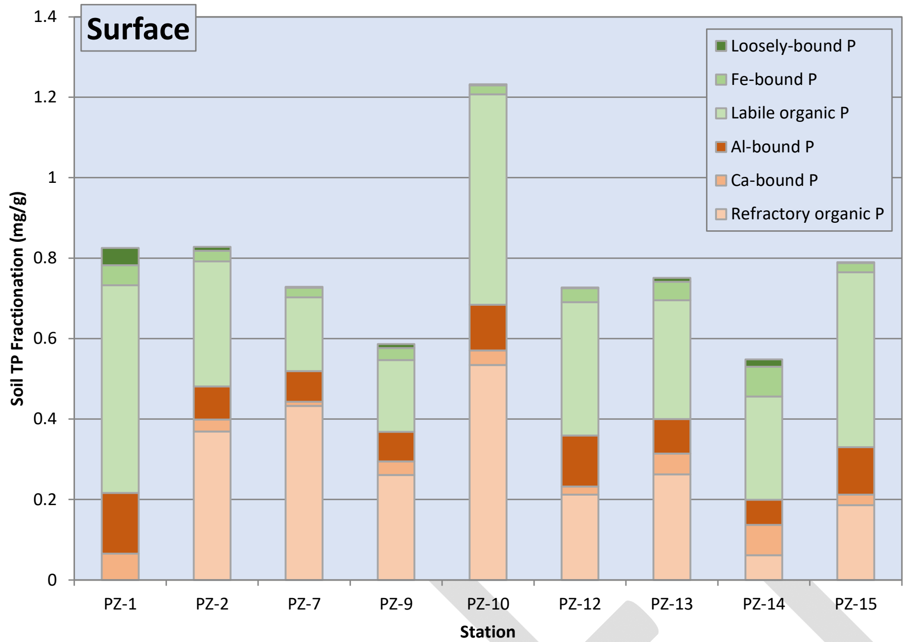


Figure 2-17. Sediment Total Phosphorus Fractionation for Surface Samples

The shallow sediment samples showed a range of TP concentrations from 0.44 to 1.00 mg/g. As with the surface samples some variability was observed between sampling stations with PZ-1 having the highest concentrations of TP. The TP fractionation for all of the shallow samples is shown in Figure 2-18.

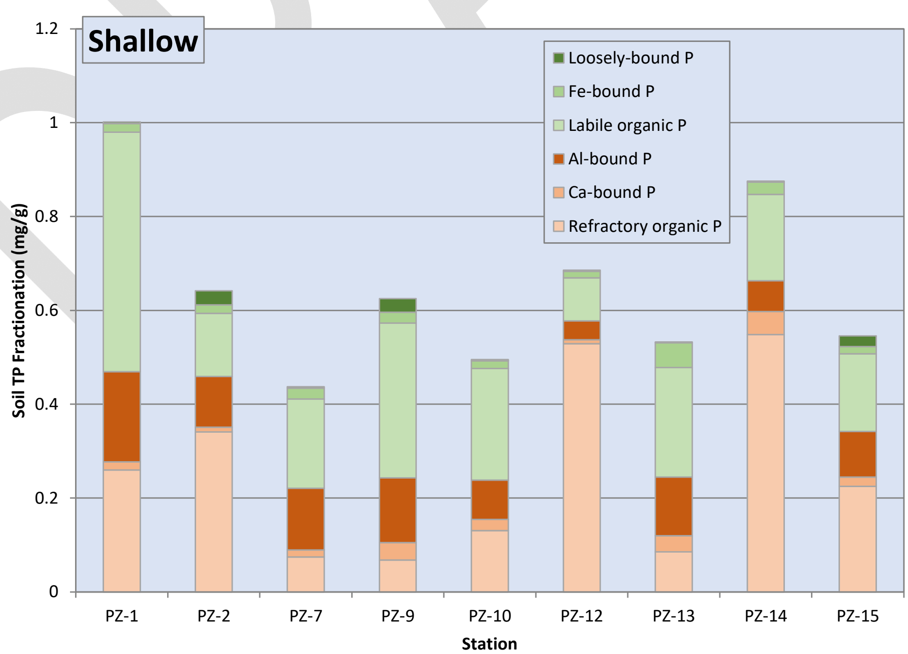


Figure 2-18. Sediment Total Phosphorus Fractionation for Shallow Samples

The deep sediment samples had the lowest TP concentrations on average of all of the collected samples. The range of concentrations were from 0.30 to 0.64 mg/g. These samples also showed the most consistent concentrations and the lowest mobile P fraction. The TP fractionation for the deep samples is shown in Figure 2-19.

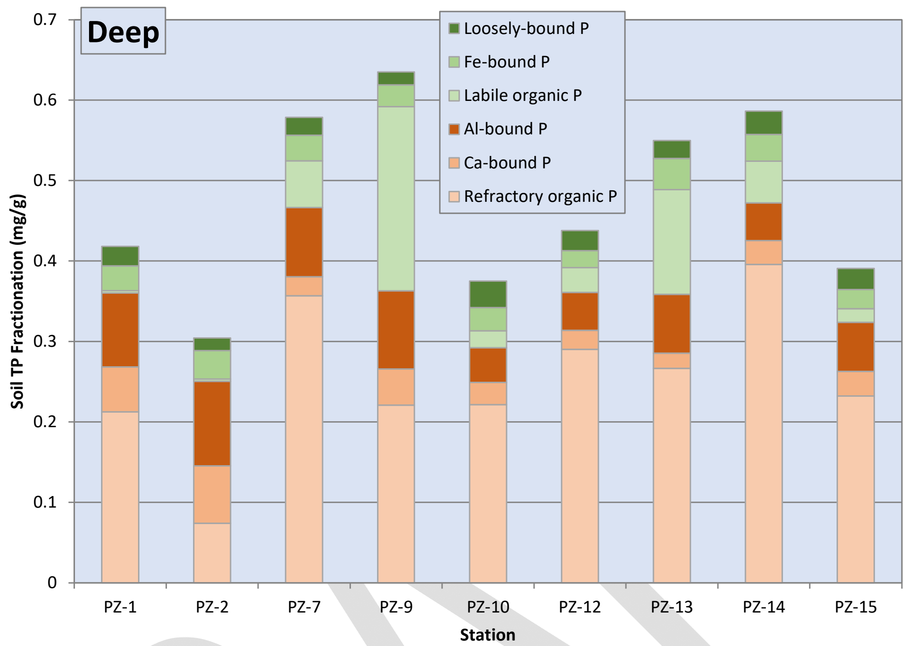


Figure 2-19. Sediment Total Phosphorus Fractionation for Deep Samples

2.5. Groundwater Sampling

Groundwater quality samples were collected in conjunction with installation of the piezometers and sediment sampling described in Sections 2.3 and 2.4. Samples were collected from the same subsurface depth zones as the sediments (0-1 feet, 1-2 feet, and 4-5 feet below surface) and the results represent pore water quality. Samples were collected at varying frequencies between May and August 2022 (Stantec, 2022). Surface pore water TP averaged 0.417 mg/L and ranged from 0.064 to 0.886 mg/L across the site. Surface OP concentrations were generally lower averaging 0.172 mg/L and ranging from 0.023 to 0.379 mg/L. Figure 2-20 shows the spatial variability in near-surface pore water average TP and OP concentrations. Figure 2-21 shows the groundwater TP and OP concentrations for the shallow pore water interval and Figure 2-22 for the deep pore water interval. Pore water TP and OP concentrations generally increased with depth below the wetland surface. TP averaged 0.244 mg/L for the shallow samples and 0.372 mg/L for the deep samples. OP averaged 0.124 mg/L for the shallow samples and 0.178 mg/L for the deep samples. Detailed results are provided in Appendix D.

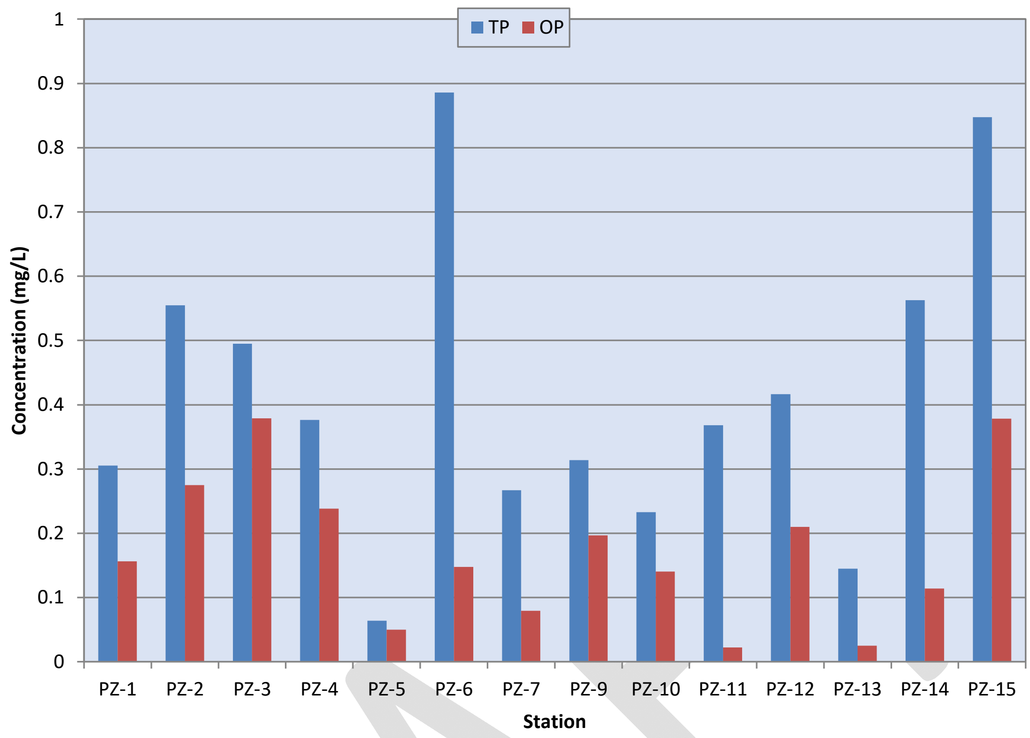


Figure 2-20. Surface (0-1 feet) Groundwater Phosphorus Concentrations

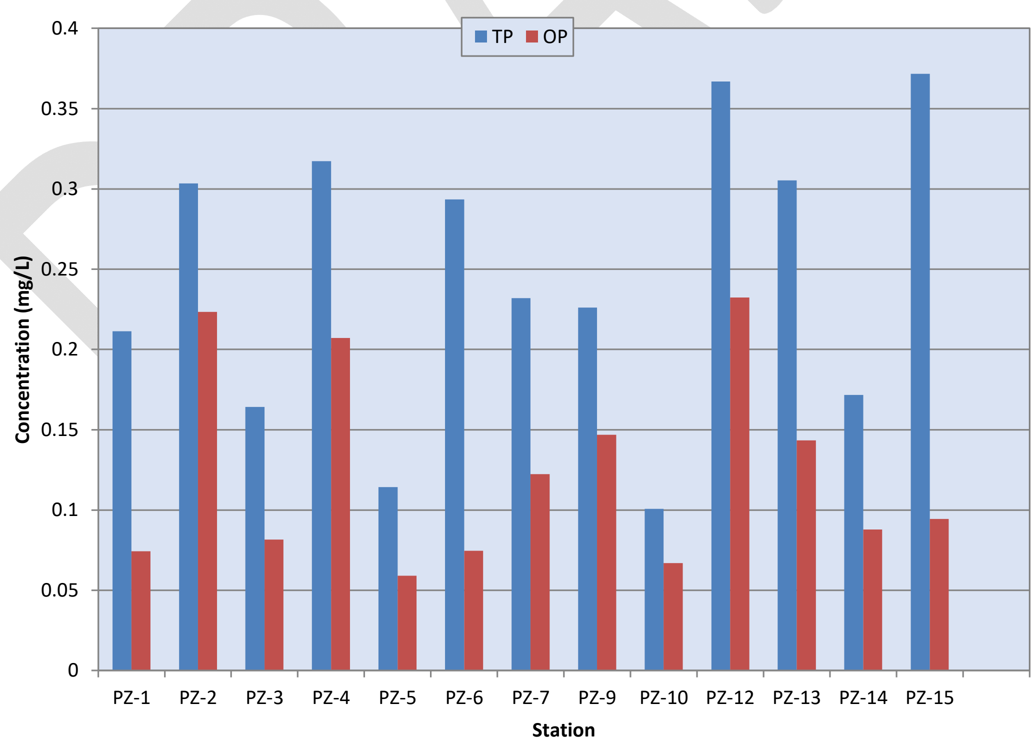


Figure 2-21. Shallow (1-2 feet) Groundwater Phosphorus Concentrations

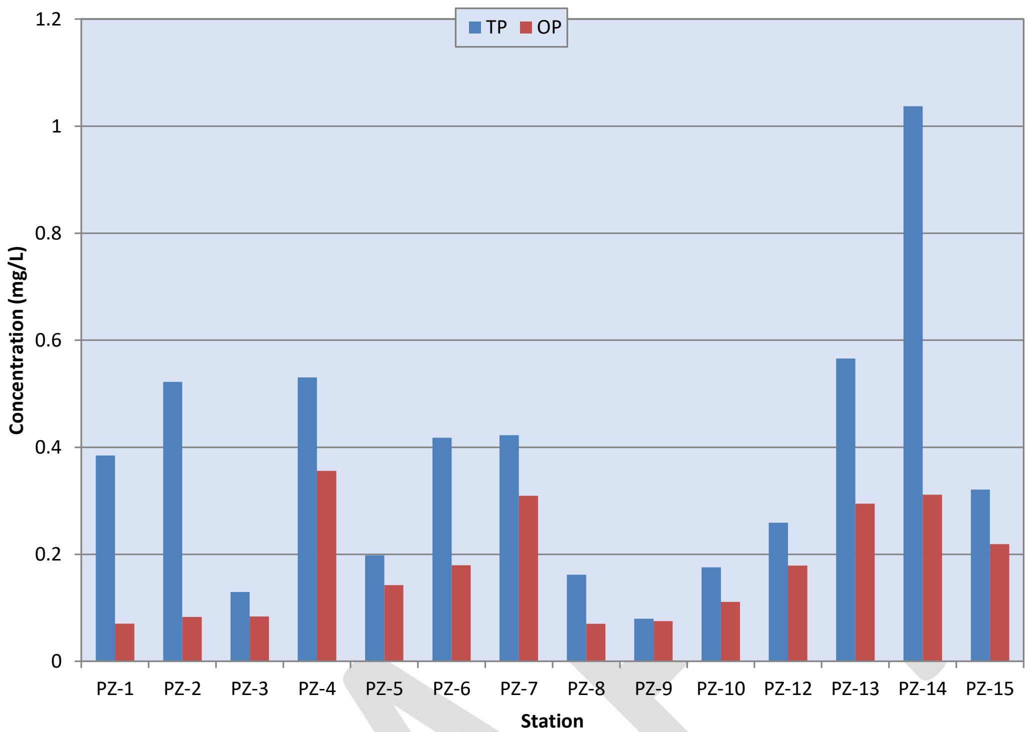


Figure 2-22. Deep (4-5 feet) Groundwater Phosphorus Concentrations

3. Alternatives Development

Both the impairments and potential alternative solutions to reduce loading were evaluated based on the data available for the Cell 1 Wetland. This section first discusses reported and observed impairments and then proposed alternatives that might be implemented to reduce nutrient export.

3.1. Cell 1 Wetland Impairments

The East Auburn Wetland has been identified as a source of phosphorus loading to East Auburn Lake. This finding was documented in the *East Auburn Phosphorus Analysis* (MCWD 2019). In this analysis MCWD evaluated phosphorus concentrations into and out of the East Auburn Wetland. The analysis found that TP was higher at the outlet than at the inlet. It also showed that TP was relatively constant through the wetland while OP increased, and that these changes were most pronounced during summer (warmer months). This analysis also considered mass loading and found that the Auburn Wetland exported 135 pounds per year of OP on average.

To further isolate where changes in water quality took place, samples were collected at the wetland midpoint, downstream of Cell 2. These supplemental data showed that the first half of the wetland had higher phosphorus release than the second half, which showed very little additional increase. The increase in phosphorus was attributed to historic phosphorus loading from Wasserman Lake due to historically poor water quality in the lake. Cell 1 was implicated as the most likely source of phosphorus release because of the higher loading that would have occurred from the lake to this wetland cell. The analysis of sediment samples discussed in Section 2.4

support this theory with elevated TP concentrations observed in the stream and surface sediments, with lower concentrations of TP in the shallow and deep sediment samples.

This study used available data to further examine the phosphorus dynamics of the system and found that, as shown in the MCWD study, phosphorus increased through the Cell 1 Wetland and that the most significant mass loads occurred during the June through August timeframe. This study further considered the potential root causes of the phosphorus releases and developed a hypothesis based on the following data:

- Sediment phosphorus data indicate that the labile organic fraction is the dominant mobile TP fraction.
- The increase in TP through the wetland is dominated by exports in June, July, and August (Figure 2-9).
- Water levels in the wetland collected in 2022 show the system drying out in mid-June with water only present in the channel and levels slowly dropping as the channel drains the marsh.

Based on these observations in the data, it is hypothesized that phosphorus increases in the Cell 1 Wetland are being driven by a wet-dry cycling and release of TP primarily from the labile organic P fraction in the wetland sediments. This labile organic P, the most prevalent mobile fraction in the wetland, is potentially related to the export and settling of particulate phosphorus from Wasserman Lake during periods of poorer lake water quality and increased algae. In the current hydrologic condition, the wet-dry cycling is occurring because of the channel that cuts through the wetland that allows the marsh to completely dry out during the summer months when snowmelt has ended and runoff and rainfall is less frequent and driven by larger events.

This hydrologic regime allows the wetland to dry out, which both releases TP during oxidation of organic matter and allows subsurface flow from the marsh through the organic soils, transporting TP in the pore water to the channel where it flows downstream. Subsequently, during the next rainfall event, flows and levels increase, flushing the water with higher concentrations of TP out of the wetland and downstream before the cycle repeats.

3.2. Evaluated Alternatives

This study focused on identifying existing issues in the Cell 1 Wetland that are contributing to the release and export of phosphorus to the downstream wetlands and East Auburn Lake. After identifying the existing issues, the range of potential alternatives that might be used to address these releases were developed.

The alternatives developed for this project fell into one or more of three general categories: hydrologic modification, topographic modification, and chemical treatment. A total of seven alternatives were identified that might be implemented to address the release of phosphorus to varying extents. The estimated effectiveness of these alternatives was considered based on the assumption that the hypothesized cause of the phosphorus release was correct. These estimates of effectiveness were developed based on professional judgment and the mechanisms of release and export that were being addressed by the alternative.

Costs were estimated for each alternative based on the rough concepts the project developed. These cost estimates included a design and construction engineering estimate of 15-percent of the construction cost and a 30-percent construction contingency assuming potential work in wet conditions. Costs were prepared at the Class 4 level (Concept Study) as defined by the Association for the Advancement of Cost Engineering International (AACEI) for *Engineering, Procurement, and Construction for the Building and General Construction Industries* with a lower bound of -20 percent and an upper bound of +30 percent.

3.2.1. Hydrologic Manipulation

This alternative involves the installation of a water level control structure at the downstream end of the Cell 1 Wetland. This control structure would be designed to allow water to be held in the marsh at or above the wetland bottom. The anticipated structure for this alternative is a sheet pile weir installed at the bridge between the Cell 1 and Cell 2 Wetlands. The rationale for this alternative is to prevent the complete dehydration of the marsh with associated oxidation of organic material and phosphorus release during re-hydration. This alternative would also keep water within the channelized portion of the wetland which would reduce the subsurface drainage of water through the marsh bottom to the channel. This is expected to reduce the transport of pore-water phosphorus to the channel that then flows downstream between events when the marsh is flooded. Depending on the level of inundation, this alternative may also increase the residence time of water which may increase phosphorus removal in the marsh. Potential disadvantages of this alternative include making the marsh more anaerobic which could release iron-bound phosphorus and result in potential stage increases during storms.

Estimated costs for this alternative were $299,000 for the installation of a sheet pile weir across the marsh between Cell 1 and Cell 2 of the East Auburn Wetland. The conceptual cost estimate for Alternative 1 is shown in Table 3-1.

Table 3-1. Alternative 1 – Sheet Pile Weir Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 15,000	$ 15,000
2	CLEARING AND GRUBBING	AC	0.5	$ 15,000	$ 7,500
3	SHEETPILE (70'Lx15'D AND 50'Lx10'D)	SF	1,550	$ 75	$ 116,250
4	COMMON EXCAVATION	CY	40	$ 20	$ 800
5	RIPRAP	CY	40	$ 150	$ 6,000
6	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
7	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
8	VEGETATION ESTABLISHMENT	LS	1	$ 5,000	$ 5,000
				CONSTRUCTION SUBTOTAL	$ 170,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 34,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 26,000
				CONTINGENCY (30% ASSUMED)	$ 69,000
				TOTAL	**$ 299,000**
				LOW ESTIMATE (-20%)	$ 240,000
				HIGH ESTIMATE (+30%)	$ 390,000

3.2.2. Channel Elimination

This alternative involves backfilling the channel through the marsh to increase levels in the marsh, provide additional residence time, and reduce the pore-water flow subsurface through the marsh bottom into and downstream in the channel. This alternative is expected to reduce phosphorus by increasing residence time by spreading flow throughout the wetland rather than it being concentrated in the ditch and increases effective use of the marsh area for treatment and reducing pore-water phosphorus transport in the channel between inundation events. Potential disadvantages include stage increases due to reduced conveyance capacity through the marsh and complexity with permitting that would be required to get approval to place fill in the wetland.

Estimated costs for this alternative were $211,000 and dominated by the cost to fill, assuming material would need to be brought in from offsite. This alternative also assumed the installation of three rip-rap ditch blocks to reduce the potential for water to erode the placed fill. The cost estimate is shown in Table 3-2.

Table 3-2. Alternative 2 – Backfilling Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 11,000	$ 11,000
2	COMMON EXCAVATION (1200'Lx10'Wx3'D)	CY	1,500	$ 40	$ 60,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	IMPORT TOPSOIL	CY	300	$ 50	$ 15,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 120,000
	DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)				$ 24,000
	PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)				$ 18,000
				CONTINGENCY (30% ASSUMED)	$ 49,000
				TOTAL	$ 211,000
				LOW ESTIMATE (-20%)	$ 170,000
				HIGH ESTIMATE (+30%)	$ 280,000

3.2.3. Channel Elimination with In-Channel Treatment

This alternative is a modification of the previous alternative that would have the channel backfilled with an adsorptive material (*e.g.,* water treatment plant residuals). This alternative is expected to have the same benefits as the previous alternative, but with additional removal associated with adsorption on the channel fill. This also reduces the risk of continued pore-water drainage and preferential flow of water through the channel fill. Potential disadvantages are the same as those described for the previous alternative.

Estimated costs for this alternative were $370,000 with costs dominated by the cost to import fill with adsorptive capacity (e.g., water treatment plant residuals). The cost estimate is provided in

Table 3-3.

Table 3-3. Alternative 3 – Backfilling Channel with Adsorptive Media Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 19,000	$ 19,000
2	MEDIA	CY	1,500	$ 100	$ 150,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
5	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
6	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 210,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 42,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 32,000
				CONTINGENCY (30% ASSUMED)	$ 86,000
				TOTAL	**$ 370,000**
				LOW ESTIMATE (-20%)	$ 300,000
				HIGH ESTIMATE (+30%)	$ 490,000

3.2.4. Wetland Regrading

This alternative involves the re-grading of the entire Cell 1 Wetland. This would allow for improved hydraulics through the wetland, increased residence time, and an expected increase in removal efficiency. This would also have the added benefit of allowing for a more desirable wetland plant community to be established. The primary removal associated with this alternative is increased treatment due to residence time and hydraulic efficiency and the reduction of pore-water phosphorus release by removal of the channel. Primary disadvantages of this alternative are anticipated capital cost, challenges of working in unstable soils in wet conditions, wetland disturbance, and permitting complexity required for altering the wetland.

The estimated cost for this alternative was $1,226,000. The primary driver of this cost was the estimated cost to re-contour the wetland as shown in Table 3-4.

Table 3-4. Alternative 4 – Wetland Regrading Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	DEWATERING	LS	1	$ 150,000	$ 150,000
3	CLEARING AND GRUBBING	AC	11.5	$ 10,000	$ 115,000
4	COMMON EXCAVATION (1.5'Dx11.5AC)	CY	27,830	$ 15	$ 417,450
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	WETLAND PLANTING	SY	55,660	$ 1	$ 55,660
				CONSTRUCTION SUBTOTAL	$ 820,000
				DESIGN AND CONSTRUCTION ENGINEERING (10% OF CONSTRUCTION COSTS ASSUMED)	$ 82,000
				PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)	$ 41,000
				CONTINGENCY (30% ASSUMED)	$ 283,000
				TOTAL	**$ 1,226,000**
				LOW ESTIMATE (-20%)	$ 990,000
				HIGH ESTIMATE (+30%)	$ 1,600,000

3.2.5. Wetland Modification with Deep Zones

This alternative has similar goals to the previous alternative and involves back-filling the channel and excavating deep zones in the marsh. This would increase residence time and hydraulic efficiency which is expected to increase treatment and reduce pore-water phosphorus release. Primary disadvantages include permitting complexity, capital cost, and degree of wetland disturbance.

The estimated costs for this alternative were $683,000. The cost estimate is provided in Table 3-5.

Table 3-5. Alternative 5 – Wetland Deep Zones Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 38,000	$ 38,000
2	DEWATERING	LS	1	$ 100,000	$ 100,000
3	CLEARING AND GRUBBING	AC	1.5	$ 15,000	$ 22,500
4	COMMON EXCAVATION	CY	5,000	$ 40	$ 200,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 20,000	$ 20,000
CONSTRUCTION SUBTOTAL					$ 420,000
DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)					$ 63,000
PERMITTING (10% OF CONSTRUCTION COSTS ASSUMED)					$ 42,000
CONTINGENCY (30% ASSUMED)					$ 158,000
TOTAL					**$ 683,000**
LOW ESTIMATE (-20%)					$ 550,000
HIGH ESTIMATE (+30%)					$ 890,000

3.2.6. Sediment Treatment

This alternative involves the treatment of the wetland area with an adsorptive amendment such as EutroSORB® G. This alternative could include treatment across the entire marsh, or just within and adjacent to the channel. This alternative would provide treatment by binding phosphorus that is released from sediments and to a lesser degree binding phosphorus in water that flows through the marsh near the sediment interface. The primary challenge of this alternative is an application method that would ensure that the amendment reached the sediment given the density of the vegetation in the marsh. Disadvantages of this alternative are potential impacts to the benthic community and capital cost depending on application rate and wetland preparation for treatment (burning, mowing, etc.).

Two cost estimates were developed for this alternative. The first assumed wetland wide sediment treatment with mowing of the wetland in advance of application. This cost was estimated to be $1,996,000 as shown in

Table 3-6.

Table 3-6. Alternative 6a – Sediment Treatment Whole Wetland Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 71,000	$ 71,000
2	WETLAND MOWING	AC	11.5	$ 5,000	$ 57,500
3	PHOSLOCK TREATMENT	TN	87	$ 15,000	$ 1,305,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 25,000	$ 25,000
CONSTRUCTION SUBTOTAL					$ 1,490,000
DESIGN AND CONSTRUCTION ENGINEERING (2% OF CONSTRUCTION COSTS ASSUMED)					$ 30,000
PERMITTING (1% OF CONSTRUCTION COSTS ASSUMED)					$ 15,000
CONTINGENCY (30% ASSUMED)					$ 461,000
TOTAL					**$ 1,996,000**
LOW ESTIMATE (-20%)					$ 1,600,000
HIGH ESTIMATE (+30%)					$ 2,600,000

The second scenario was treatment of just the channel. The estimated cost for this scenario was $159,000. The cost estimate for this scenario is provided in Table 3-7.

Table 3-7. Alternative 6b – Sediment Treatment Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 8,000	$ 8,000
2	PHOSLOCK TREATMENT	TN	4	$ 15,000	$ 60,000
3	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
4	VEGETATION ESTABLISHMENT	LS	1	$ 10,000	$ 10,000
CONSTRUCTION SUBTOTAL					$ 90,000
DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)					$ 18,000
PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)					$ 14,000
CONTINGENCY (30% ASSUMED)					$ 37,000
TOTAL					**$ 159,000**
LOW ESTIMATE (-20%)					$ 130,000
HIGH ESTIMATE (+30%)					$ 210,000

3.2.7. Inflow or Outflow Alum Treatment

This alternative would use an alum feed system to provide treatment of flows coming into or out of the wetland. This would reduce concentrations of phosphorus in the water column. This would provide treatment for both phosphorus in the water and potential sediment release. The primary disadvantage of this alternative is a feed system that adequately mixes the alum in the water to be treated and the operation and maintenance associated with an alum feed system. There is also the potential for generation of floc that may accumulate downstream in the wetland and require maintenance.

The estimated cost for this alternative was $ 1,016,000. Costs evaluated for the alum treatment system were based on the average cost for alum treatment systems (Harper & Herr, 1998) with price escalated from 1998 to 2023 using the Consumer Price Index. These systems are highly site dependent and can have significant variations in price based on the level of infrastructure needed to measure flows, supply power, inject the alum, ensure adequate mixing, and capture floc for removal. The estimated costs are shown in Table 3-8.

Table 3-8. Alternative 7 – Alum Treatment System Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	CIVIL SITE IMPROVEMENTS	LS	1	$ 50,000	$ 50,000
3	ALUM TREATMENT SYSTEM	LS	1	$ 500,000	$ 500,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 650,000
				DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 98,000
				PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)	$ 33,000
				CONTINGENCY (30% ASSUMED)	$ 235,000
				TOTAL	**$ 1,016,000**
				LOW ESTIMATE (-20%)	$ 820,000
				HIGH ESTIMATE (+30%)	$ 1,330,000

4. Alternatives Analysis

4.1. Ranking Criteria

Following development of the available alternatives, each alternative was scored for each of 10 criteria that address the project and permitting complexity, project impacts, expected degree of success, costs, and risk. Each of the evaluated criteria is briefly discussed in the following sections. Regardless of specific criterion evaluation methodology, a higher quantitative score corresponds to a qualitatively better outcome, or easier practice to implement.

4.1.1. Wetland Impacts

Each of these alternatives is expected to have some degree of impact on the existing Cell 1 wetland. This criterion considered a smaller degree of impact more favorable with a higher score equating to less impact. Alternatives that were expected to have substantial impacts on vegetation and modification of the wetland surface from excavation or fill were scored a one, while those with impacts affecting only a small area (<0.1 acres) or no area scored a three, and alternatives between these scored a two.

4.1.2. Permitting Complexity

Since the proposed project is in a wetland that is designated as a Minnesota Department of Natural Resources Public Water and regulated by multiple local, state, and federal agencies, it is expected that the alternatives that were developed will require some level of permitting approval to implement. It is also assumed that alternatives would generally need to maintain or improve the function of the wetland in order to not be determined as an impact to wetland that could potentially require mitigation. This criterion evaluates the expected degree of permitting that will be required and the anticipated difficulty of the associated permitting with a higher score equating to easier permitting. Alternatives that were expected to have challenging permitting were scored a one, alternatives with little expected permitting were scored a three, and others were scored a two.

4.1.3. Engineering Complexity

This criterion considers the expected degree of engineering complexity associated with project implementation. A high score for this criterion is associated with projects that are expected to be less complex to develop. As with permitting, alternatives that required significant engineering complexity were scored a one, those with little required engineering were scored a three, and others scored a two.

4.1.4. Phosphorus Export Reduction

The developed alternatives are expected to have a range of effectiveness for phosphorus retention and/or removal. Based on the data analysis completed it appears that a majority of the phosphorus being exported from this system is internally generated and released during periods when the wetland experiences intermittent inundation. This criterion considers the expected degree of phosphorus export reduction with high reductions having a high score. Alternatives that were estimated to reduce export by 50-percent or more were scored a three, those with expected reductions of 20-50-percent were scored a two, and others were scored a one.

4.1.5. Capital Costs

Each of the presented alternatives will have a capital cost associated with its development. This criterion considers the expected cost associated with construction of the proposed alternative with a high score equating to a lower capital cost. Alternatives with an estimated cost greater than $800,000 received a one, between $400,000-$800,000 received a two, and less than $400,000 received a three.

4.1.6. Operations and Maintenance Costs

Once constructed, each of the proposed alternatives is expected to have varying degrees of operations and maintenance costs. This criterion considers the expected degree of ongoing costs associated with the project with a higher score for projects with expected lower costs.

4.1.7. Reduction Time Scale

Not all of the evaluated alternatives will provide a reduction on the same time scale. This criterion evaluates the expected duration before phosphorus reductions would be expected with a higher score equating to a quicker expected reduction. Alternatives with an expected two year or greater lag received a one, one to two years received a two, and a less than one year lag received a three.

4.1.8. Risk

There are unknowns associated with the alternatives that could result in different than expected outcomes. This criterion describes the expected risk associated with the alternatives. Alternatives with a high degree of uncertainty received a one, those with a moderate degree of uncertainty received a two, and those that would be expected to perform well regardless of the cause of the export received a three.

4.1.9. Ability to Mitigate Risk

Some of the evaluated alternatives have the potential to mitigate risks associated with their implementation (e.g. making weir plates removable so levels in the marsh can be adjusted if too high or too low). This criterion considers the ability to modify the alternative once implemented to reduce potential adverse outcomes. Alternatives with limited potential for mitigation received a one, those with some degree of ability to mitigate received a two, and those with one or more options for mitigation received a three.

4.2. Alternatives Matrix

For each of the considered alternatives the evaluated criteria were ranked on the three point scale with a higher score signifying the desirable outcome (i.e. lower risk, lower complexity, lower cost, etc.). Scores on each criteria were then summed to yield a total score for each alternative. These scores were then used to rank the projects from best to worst with the highest scoring project receiving the highest score. The alternatives matrix is shown in Table 4-1, ranked in order of score from high to low. In addition to the alternatives matrix, estimated TP export reductions were developed for each alternative. These values were estimated based on professional judgement and the mechanisms of export being addressed by each alternative. The estimated export reductions for each alternative are shown in Table 4-2. Estimated reductions ranged from 20- to 80-percent for the evaluated alternatives.

Based on the scoring criteria and ranking, manipulating hydrology through installation of sheet pile was the highest-ranked option. The next highest-ranked alternatives which tied for second were backfilling the channel with adsorptive media and sediment treatment. The highest estimated export reduction was for alum treatment, followed by sediment treatment, with manipulating hydrology in third.

Though this methodology provides an absolute ranking, it should be considered that the differences in the first ranked option (sheet pile weir) and the fourth ranked option (alum treatment system) is only three ranking points. However, the difference between the first ranked option and the seventh ranked option (regrading entire wetland) is 12 ranking points. Based on this method and detail of analysis, it can be said with high confidence that the sheet pile alternative is a better alternative than regrading the entire wetland. However, it is less clear whether the sheet pile is absolutely the better alternative than filling the channel or entire wetland with adsorptive media (second ranked alternatives). Rather, it can be concluded that the top four alternatives likely would be better than the bottom three alternatives.

MCWD can use this ranking matrix to consider which alternative to pursue, based on MCWD specific parameters. The current ranking methodology weights each criterion equally. For example, if the initial capital costs are not a concern, and the highest degree of TP treatment is desired, this could move the second ranked alternatives (filling channel with adsorptive media or adsorptive treatment of sediments) ahead of the sheet pile control structure. Finally, combinations of alternatives were not considered.

Table 4-1. Alternatives Ranking Matrix

No.	Alternative	Description	Wetland Impacts	Permitting Complexity	Engineering Complexity	TP Export Reduction	Capital Costs	O&M Costs	Reduction Time Scale	Risk	Ability to Mitigate Risk	Total Score	Rank
1	Manipulate Hydrology	Outlet water level control structure	3	2	3	2	3	3	2	2	3	23	1
3	Channel Treatment	Fill channel with adsorptive media	2	1	3	2	3	3	3	3	1	21	2
6	Sediment Treatment	Adsorptive treatment of sediments	2	2	3	3	1	3	3	2	2	21	2
7	Inflow/Outflow Alum Treatment	Alum treatment of water	3	2	1	3	1	1	3	3	3	20	4
2	Channel Elimination	Fill channel	2	1	3	1	3	3	2	2	1	18	5
5	Topographic Modification	Deep zones and fill channel	1	1	2	1	2	3	1	2	1	14	6
4	Topographic Modification	Regrade wetland	1	1	1	1	1	3	1	1	1	11	7

Table 4-2. Estimated Export Reduction for Evaluated Alternatives

No.	Alternative	Description	Est. Export Reduction
1	Manipulate Hydrology	Outlet water level control structure	50%
2	Channel Elimination	Fill channel	20%
3	Channel Treatment	Fill channel with adsorptive media	35%
4	Topographic Modification	Regrade wetland	30%
5	Topographic Modification	Deep zones and fill channel	25%
6	Sediment Treatment	Adsorptive treatment of sediments	70%
7	Inflow/Outflow Alum Treatment	Alum treatment of water	80%

5. Hydraulic Evaluation

To evaluate the potential implications of manipulating hydrology the project team acquired a copy of the District's XPSWMM stormwater model to better understand the wetland's hydraulic behavior under existing and proposed conditions. The project team truncated the District's model, updated it based on previously collected survey information, and subdivided the wetland into its four cells, as the provided model considered the wetland complex as a single cell. New, cell-specific storage curves were developed using a combination of previously collected survey data and LiDAR. Hydraulic connections from one cell to another were input based on survey information. Overflows between the cells were modeled based on LiDAR, where survey information was unavailable. Hydrologic inputs were updated to reflect the smaller, cell-specific drainage area. However, area was the only input parameter that was changed for the hydrologic components; watershed percent impervious, widths, and soils information were not altered.

The model was executed for the 100-year event to understand high water levels in the wetland, and adjacent water bodies. The project team then developed a series of conceptual proposed conditions to determine what effect manipulating the runout elevation of the wetland would have on the wetland and adjacent water bodies, assuming a sheet pile weir structure would be constructed to modify the wetland's runout elevation. Sheet pile widths varied from 10-feet wide to 500-feet wide, and elevations varied from 943.0 to 944.5. The intent of developing a series of models across this range of values is not to suggest that a 500-foot-wide sheet pile weir should be constructed. Rather, this is to provide a data point beyond what is a reasonable project, such that it can be understood how the system functions, and direct discussions such as: "if the objective is to raise the wetland's normal water level as high as possible, how wide of a weir is necessary such that the floodplain is unaltered?".

The extent of the area evaluated included Wasserman Lake to the south, Carl Krey Lake to the west, and Auburn Lake to the north. Table 5-1 summarizes existing high-water levels, and the assumed design constraints for the points of analysis.

Table 5-1: Assumed High Water Level Constraints

Comment	Existing 100-yr HWL	Assumed Maximum Elevation	Constraint Comment
Wasserman Lake	946.60	946.60	No-rise is required; in Zone A
Carl Krey Lake	945.99	945.99	No-rise is required; in Zone A
Auburn Lake	942.51	942.51	No-rise is required; in Zone A
Cell 1	945.23	950.00	No floodplain; cannot flood residents
Cell 2	945.23	946.00	No floodplain; cannot flood residents
Cell 3	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise
Cell 4	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise

Under existing conditions, the wetland (Cell 1) overflows at an elevation of 942.25. Based on the conceptual sheet pile model runs, this runout elevation could be raised to approximately 944.0 and still achieve the design criteria listed above. To achieve no-rise conditions on Wasserman Lake and maintain a runout elevation of 944.0, a sheet pile weir of between 25- to 50-feet would be required. A shorter length of sheet pile would be feasible if the proposed runout elevation is less than 944.0. These finer details would be addressed depending on the exact elevation and configuration desired, as part of a final design.

6. Conclusions and Recommendations

The Cell 1 Wetland located at the upstream end of the East Auburn Wetland Complex has been identified as the likely source of elevated total phosphorus (TP) loads to East Auburn Lake. This study collected and evaluated available water quality, flow, level, and sediment data for the Cell 1 Wetland and wetland complex with the goal of identifying the likely source of this TP loading.

Based on that evaluation, the dominant mechanisms that appear to contribute to the export of TP are decreased water levels in early summer that result in the wetland drying out. These dry outs result in subsurface drainage of the marsh to the channel which transports TP, primarily as ortho-phosphorus (OP), to the channel where it flows out or is flushed out during summer storm events. This dehydration of the wetland also results in mobilization of labile organic phosphorus in the sediments which is flushed out during these same rainfall and flow events.

To develop recommendations, this study considered seven potential alternative management strategies. These alternatives were ranked based on nine criteria and estimated TP export reductions were developed. Each of these alternatives had estimated capital costs developed to implement the projects. From the alternatives ranking and reduction estimates the recommended alternative is manipulation of hydrology through installation of a sheet pile weir between the Cell 1 and Cell 2 Wetlands.

This weir would be constructed to reduce the short-circuiting and drainage of phosphorus laden water through the channel in the marsh during the summer months when this system dries out. It is recommended that this weir include weir plates that can be removed in the event that elevated phosphorus concentrations occur due to the release of iron-bound phosphorus and anaerobic conditions.

To further reduce the potential for release, a second alternative could be applied in concert with hydrologic manipulation. This recommended alternative is application of sediment treatment within the channel. This would reduce the export of phosphorus from subsurface drainage to the channel and would reduce the likelihood of sediment release associated with increasing the wetland hydroperiod and anaerobic conditions.

To provide additional information that can be used to advance a final design this study would recommend continued collection of flow and level data within the Cell 1 Wetland and continued collection of water quality samples at CSI12, CSI05, and CSI22. Additionally, it is recommended that drone-based LiDAR topography be collected to improve the understanding of the wetland bathymetry to guide design of a sheet pile weir. The optimal timing of this data collection would be during mid- to late-summer when the wetland water levels are very low. This LiDAR survey could be paired with traditional survey in areas with standing water and within the channel.

7. References

Harper, H. H., & Herr, J. L. (1998). *Alum Treatment of Stormwater: The First Ten Years*. Stormwater and Urban Water Systems Modeling Conference, Toronto, Canada.

Stantec. (2022). *Auburn Wetland Monitoring Project—Technical Memo* (No. 227704313).

Appendix A

Stormwater Sampling Statistics

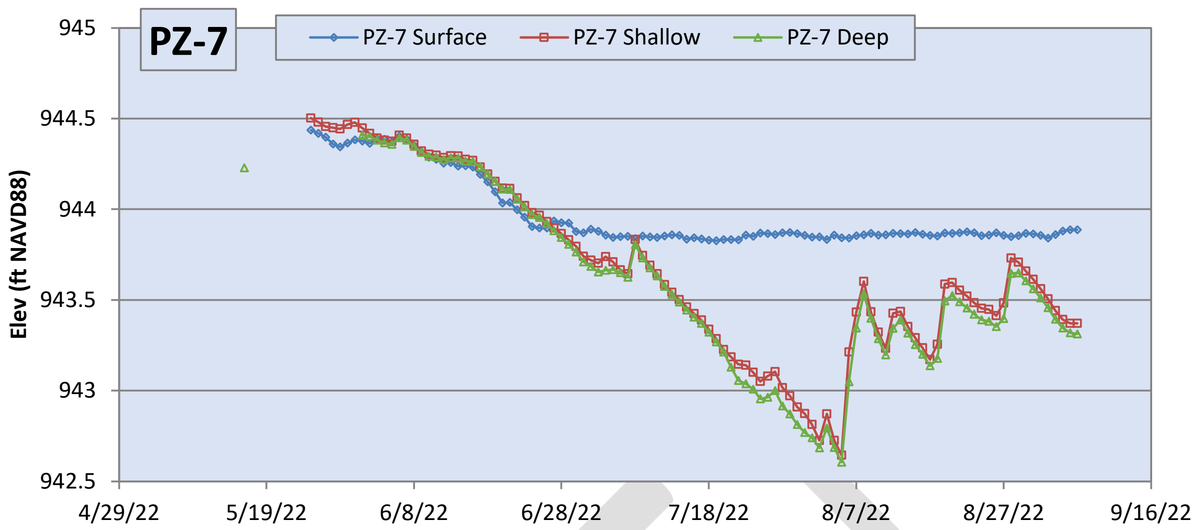
Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
Temp	C	CSI05	15.2	-0.06	28.8	7.60	508	Apr-09	Jun-22
		CSI12	16.9	0.00	30.2	7.81	451	Apr-09	Jun-22
		CSI19	15.7	0.00	27.2	8.86	27	May-20	Oct-21
		CSI22	14.4	0.00	27.1	8.82	33	May-20	Jun-22
		SW-1	23.4	21.9	25.5	1.51	4	Jun-22	Jul-22
		SW-2	23.4	22.1	24.5	1.08	4	Jun-22	Jul-22
		SW-3	20.4	19.0	20.9	0.93	4	Jun-22	Jul-22
		SW-4	21.1	20.3	22.2	0.84	4	Jun-22	Jul-22
DO	%	SW-1	4.16	0.14	8.52	3.93	4	Jun-22	Jul-22
		SW-2	4.39	0.16	8.51	4.15	4	Jun-22	Jul-22
		SW-3	4.03	0.33	8.60	4.09	4	Jun-22	Jul-22
		SW-4	3.71	0.52	8.33	3.69	4	Jun-22	Jul-22
	mg/L	CSI05	4.00	0.00	20.9	3.39	508	Apr-09	Jun-22
		CSI12	6.83	0.00	27.3	4.55	451	Apr-09	Jun-22
		CSI19	3.72	0.00	10.8	3.20	34	Jul-19	Oct-21
		CSI22	5.66	0.00	49.4	8.74	33	May-20	Jun-22
pH	SU	CSI05	7.34	4.25	9.10	0.42	487	Apr-09	Jun-22
		CSI12	7.98	6.68	17.1	0.79	435	Apr-09	Jun-22
		CSI19	7.54	7.28	7.99	0.21	23	May-20	Oct-21
		CSI22	7.56	6.92	8.49	0.43	27	May-20	Jun-22
		SW-1	7.39	6.76	7.98	0.65	4	Jun-22	Jul-22
		SW-2	7.43	6.68	8.18	0.83	4	Jun-22	Jul-22
		SW-3	6.61	6.44	6.76	0.16	3	Jun-22	Jul-22
		SW-4	7.54	7.15	8.25	0.61	3	Jun-22	Jul-22
Cond	uS/cm	CSI05	404	244	745	57.3	500	Apr-09	Jun-22
		CSI12	356	233	621	35.2	444	Apr-09	Jun-22
		CSI19	392	314	487	45.6	23	May-20	Oct-21
		CSI22	420	292	755	98.0	28	May-20	Jun-22
		SW-1	461	352	610	129	4	Jun-22	Jul-22
		SW-2	445	338	557	119	4	Jun-22	Jul-22
		SW-3	495	352	598	111	4	Jun-22	Jul-22
		SW-4	488	345	705	174	4	Jun-22	Jul-22
ORP	mV	SW-1	-38.3	-136	34.7	75.3	4	Jun-22	Jul-22
		SW-2	-4.83	-37.6	13.3	22.6	4	Jun-22	Jul-22
		SW-3	-30.8	-132	86.3	110	3	Jun-22	Jul-22
		SW-4	-39.4	-78.0	-6.50	36.1	3	Jun-22	Jul-22
TSS	mg/L	CSI05	7.31	0.50	268	27.6	100	Apr-09	Dec-15
		CSI12	8.80	0.50	104	11.7	100	Apr-09	Dec-15
Chloride	mg/L	CSI05	36.1	19.8	104	14.8	50	Apr-09	Nov-15
		CSI12	26.9	21.0	39.3	2.99	52	Apr-09	Dec-15

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
TFE	mg/L	SW-1	1.35	0.11	3.42	1.56	4	Jun-22	Jul-22
		SW-2	2.92	0.09	7.15	3.43	4	Jun-22	Jul-22
		SW-3	2.74	0.11	7.44	3.46	4	Jun-22	Jul-22
		SW-4	1.41	0.08	2.97	1.51	4	Jun-22	Jul-22
TP	mg/L	CSI05	0.12	0.03	1.12	0.12	500	Apr-09	Jun-22
		CSI12	0.08	0.02	0.36	0.04	440	Apr-09	Jun-22
		CSI19	0.10	0.03	0.51	0.09	31	Jul-19	Oct-21
		CSI22	0.09	0.03	0.18	0.05	28	May-20	Jun-22
		SW-1	0.11	0.05	0.26	0.10	4	Jun-22	Jul-22
		SW-2	0.43	0.04	1.08	0.49	4	Jun-22	Jul-22
		SW-3	0.59	0.04	1.76	0.81	4	Jun-22	Jul-22
		SW-4	0.22	0.01	0.44	0.23	4	Jun-22	Jul-22
OP	mg/L	CSI05	0.04	0.00	0.19	0.03	460	Apr-09	Jun-22
		CSI12	0.01	0.00	0.11	0.01	440	Apr-09	Jun-22
		CSI19	0.04	0.00	0.23	0.04	31	Jul-19	Oct-21
		CSI22	0.03	0.00	0.11	0.03	28	May-20	Jun-22
		SW-1	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-2	0.03	0.02	0.03	0.00	4	Jun-22	Jul-22
		SW-3	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-4	0.03	0.01	0.05	0.02	4	Jun-22	Jul-22
TN	mg/L	CSI05	1.21	0.30	4.49	0.58	151	Apr-09	Jun-22
		CSI12	1.63	0.50	5.13	0.65	142	Apr-09	Jun-22
		CSI19	1.22	0.50	2.50	0.43	28	Aug-19	Oct-21
		CSI22	1.38	0.60	3.60	0.65	28	May-20	Jun-22
		SW-1	2.76	0.88	6.64	2.71	4	Jun-22	Jul-22
		SW-2	2.61	0.85	5.30	2.13	4	Jun-22	Jul-22
		SW-3	2.33	0.78	4.43	1.83	4	Jun-22	Jul-22
		SW-4	2.36	0.76	4.57	1.89	4	Jun-22	Jul-22
TKN	mg/L	CSI05	1.29	0.73	2.54	0.40	43	Apr-09	Nov-15
		CSI12	1.70	0.82	2.43	0.37	42	Apr-09	Dec-15
NO3-N	mg/L	CSI05	0.07	0.02	0.41	0.12	43	Apr-09	Nov-15
		CSI12	0.19	0.02	3.69	0.57	42	Apr-09	Dec-15
Flow	cfs	CSI05	4.11	-0.12	28.1	4.91	542	Apr-09	Aug-22
		CSI12	4.09	0.00	42.5	5.57	492	Apr-09	Aug-22
Elevation	ft NAVD88	Wasserman	944.8	938.0	947.2	0.72	790	Aug-64	Nov-22
		Creek	943.1	942.7	944.2	0.33	9,005	Jun-22	Sep-22
		CSI05	941.8	941.1	944.2	0.43	78	Mar-16	Jul-22
		SW-1	943.4	943.0	943.9	0.46	4	Jun-22	Jul-22
		SW-2	943.5	943.1	944.0	0.45	4	Jun-22	Jul-22
		SW-3	943.5	943.1	944.0	0.47	4	Jun-22	Jul-22

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
		SW-4	943.7	943.2	944.4	0.59	4	Jun-22	Jul-22

Appendix B

Detailed Water Level Data


PZ-7
PZ-7 Surface
PZ-7 Shallow
PZ-7 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
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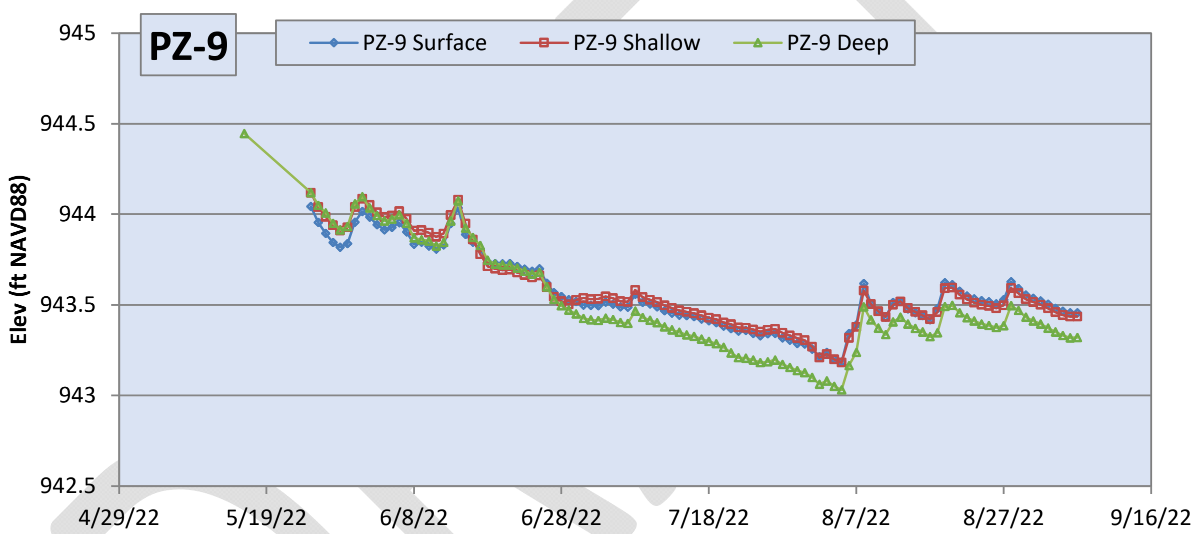
5/19/22
6/8/22
6/28/22
7/18/22
8/7/22
8/27/22
9/16/22


PZ-9
PZ-9 Surface
PZ-9 Shallow
PZ-9 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
4/29/22
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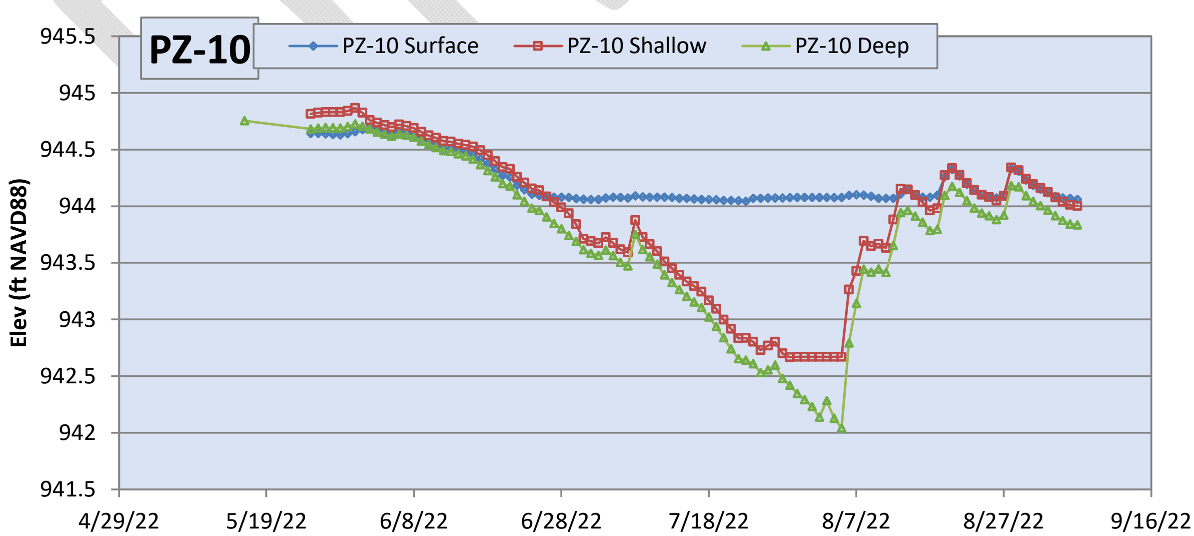
PZ-10
PZ-10 Surface
PZ-10 Shallow
PZ-10 Deep
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Appendix C

Sediment Sampling Data

		Phosphorus												
STN	Depth	Loosely-bound mg/g	Fe-bound mg/g	Labile organic mg/g	Mobile Pool mg/g	Al-bound mg/g	Ca-bound mg/g	Refractory Organic mg/g	Permanent Pool mg/g	Total mg/g	Organic Content %	Moisture Content %	Dry Density g/cm^3	Wet Density g/cm^3
PZ-1	Surface	0.043	0.050	0.516	0.609	0.151	0.065	0.00	0.216	0.813	53.5	75.1	0.285	1.08
	Shallow	0.003	0.019	0.510	0.532	0.192	0.018	0.260	0.469	1.00	69.1	76.4	0.266	1.05
	Deep	0.024	0.031	0.003	0.058	0.092	0.056	0.212	0.360	0.418	75.4	84.1	0.171	1.02
PZ-2	Surface	0.010	0.026	0.311	0.347	0.082	0.030	0.369	0.481	0.828	42.1	70.1	0.357	1.12
	Shallow	0.030	0.018	0.135	0.183	0.108	0.010	0.341	0.459	0.642	80.3	80.1	0.218	1.02
	Deep	0.016	0.035	0.003	0.054	0.105	0.071	0.074	0.250	0.304	43.9	77.9	0.251	1.08
PZ-7	Surface	0.002	0.024	0.183	0.209	0.077	0.010	0.433	0.520	0.729	11.8	41.4	0.907	1.47
	Shallow	0.003	0.023	0.190	0.216	0.132	0.015	0.074	0.221	0.437	81.1	83.6	0.177	1.02
	Deep	0.022	0.032	0.058	0.112	0.086	0.024	0.357	0.466	0.578	76.9	86.9	0.139	1.02
PZ-9	Surface	0.010	0.030	0.178	0.218	0.074	0.034	0.261	0.369	0.587	55.6	81.9	0.200	1.05
	Shallow	0.029	0.023	0.330	0.382	0.138	0.037	0.068	0.243	0.625	75.3	88.9	0.117	1.02
	Deep	0.016	0.027	0.229	0.272	0.097	0.045	0.221	0.363	0.635	56.6	92.6	0.077	1.02
PZ-10	Surface	0.003	0.022	0.523	0.548	0.114	0.036	0.535	0.684	1.23	64.8	75.6	0.277	1.06
	Shallow	0.003	0.016	0.238	0.257	0.084	0.024	0.131	0.238	0.495	85.6	80.4	0.214	1.02
	Deep	0.033	0.029	0.021	0.083	0.043	0.028	0.221	0.292	0.375	84.5	90.4	0.100	1.01
PZ-12	Surface	0.002	0.035	0.331	0.368	0.127	0.020	0.212	0.359	0.727	48.4	74.0	0.302	1.09
	Shallow	0.002	0.014	0.092	0.108	0.040	0.009	0.529	0.577	0.685	33.4	62.4	0.477	1.18
	Deep	0.025	0.021	0.031	0.077	0.047	0.024	0.290	0.361	0.438	86.9	87.3	0.134	1.01
PZ-13	Surface	0.010	0.046	0.295	0.351	0.086	0.052	0.263	0.400	0.751	60.3	76.6	0.265	1.06
	Shallow	0.002	0.053	0.233	0.288	0.125	0.034	0.086	0.245	0.533	32.5	66.8	0.408	1.16
	Deep	0.022	0.039	0.130	0.191	0.073	0.019	0.267	0.359	0.550	81.3	86.2	0.147	1.02
PZ-14	Surface	0.018	0.074	0.257	0.349	0.062	0.075	0.062	0.199	0.548	31.4	64.2	0.450	1.18
	Shallow	0.002	0.026	0.184	0.212	0.066	0.049	0.549	0.663	0.875	36.5	68.0	0.389	1.14
	Deep	0.029	0.033	0.052	0.114	0.047	0.030	0.396	0.472	0.586	90.4	88.2	0.124	1.01
PZ-15	Surface	0.002	0.023	0.435	0.460	0.118	0.026	0.186	0.330	0.790	39.4	68.2	0.385	1.13

		Phosphorus												
		Loosely-bound	**Fe-bound**	**Labile organic**	**Mobile Pool**	**Al-bound**	**Ca-bound**	**Refractory Organic**	**Permanent Pool**	**Total**	**Organic Content**	**Moisture Content**	**Dry Density**	**Wet Density**
STN	Depth	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	%	%	g/cm^3	g/cm^3
	Shallow	0.023	0.015	0.166	0.204	0.097	0.020	0.225	0.342	0.546	85.8	84.1	0.171	1.01
	Deep	0.026	0.024	0.017	0.067	0.061	0.031	0.232	0.324	0.391	91.1	87.4	0.133	1.01
SW-1	Stream	0.039	0.305	0.262	0.606	0.104	0.062	0.000	0.166	0.700	28.4	71.6	0.340	1.14
SW-2	Stream	0.021	0.104	0.192	0.317	0.078	0.078	0.230	0.386	0.703	43.2	90.0	0.106	1.04
SW-3	Stream	0.024	0.072	0.216	0.312	0.098	0.090	0.301	0.490	0.802	38.9	83.2	0.185	1.07
SW-4	Stream	0.024	0.091	0.091	0.206	0.045	0.126	0.093	0.264	0.470	15.2	53.4	0.646	1.32

Appendix D

Groundwater Sampling Statistics

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
Temp	C	PZ-1	Surface	21.8	17.1	26.6	6.74	2	Jun-22	Jun-22
			Shallow	17.5	13.9	22.4	3.16	6	Jun-22	Aug-22
			Deep	10.8	7.80	13.1	2.20	7	May-22	Aug-22
		PZ-2	Surface	19.0	17.8	20.2	1.70	2	Jun-22	Jun-22
			Shallow	13.7	9.30	17.5	3.19	5	Jun-22	Jul-22
			Deep	9.23	5.30	13.0	2.69	8	May-22	Aug-22
		PZ-3	Surface	20.4	17.4	23.5	4.36	2	Jun-22	Jun-22
			Shallow	16.8	11.1	21.5	3.31	7	Jun-22	Aug-22
			Deep	8.99	4.72	12.0	2.72	8	May-22	Aug-22
		PZ-4	Surface	20.7	17.6	23.8	4.40	2	Jun-22	Jun-22
			Shallow	16.5	9.83	21.3	3.53	7	Jun-22	Aug-22
			Deep	9.71	5.53	13.4	2.97	8	May-22	Aug-22
		PZ-5	Surface	18.5	16.1	20.9	3.39	2	Jun-22	Jun-22
			Shallow	15.7	11.2	18.2	3.09	5	Jun-22	Jul-22
			Deep	8.42	5.07	12.3	2.39	8	May-22	Aug-22
		PZ-6	Surface	21.8	21.8	21.8	---	1	Jun-22	Jun-22
			Shallow	18.0	15.7	20.5	1.77	5	Jun-22	Aug-22
			Deep	11.8	8.36	15.5	2.31	7	May-22	Aug-22
		PZ-7	Surface	18.5	17.7	19.3	1.14	2	Jun-22	Jun-22
			Shallow	15.9	9.07	18.9	3.75	7	Jun-22	Aug-22
			Deep	9.57	4.86	13.5	3.15	8	May-22	Aug-22
		PZ-8	Deep	6.52	6.52	6.52	---	1	May-22	May-22
		PZ-9	Surface	21.2	18.7	25.6	2.47	7	Jun-22	Aug-22
			Shallow	16.0	13.3	17.3	1.41	6	Jun-22	Aug-22
			Deep	9.03	6.07	11.8	2.03	8	May-22	Aug-22
		PZ-10	Surface	20.2	19.8	20.6	0.57	2	Jun-22	Jun-22
			Shallow	16.7	12.4	18.9	2.44	6	Jun-22	Aug-22
			Deep	10.1	5.25	13.8	3.11	8	May-22	Aug-22
		PZ-11	Surface	12.5	10.4	14.0	1.87	3	Jun-22	Aug-22
		PZ-12	Surface	19.2	18.0	20.0	0.94	4	Jun-22	Aug-22
			Shallow	17.0	11.3	19.8	3.08	7	Jun-22	Aug-22
			Deep	9.39	5.26	14.3	3.15	9	May-22	Aug-22
		PZ-13	Surface	17.9	12.8	23.4	4.61	4	Jun-22	Aug-22
			Shallow	16.8	12.0	20.7	3.42	6	Jun-22	Aug-22
			Deep	10.0	4.83	15.8	3.47	8	May-22	Aug-22
		PZ-14	Surface	16.5	16.5	16.5	---	1	Jun-22	Jun-22
			Shallow	16.7	13.1	19.5	2.74	5	Jun-22	Aug-22
			Deep	8.90	5.53	12.1	2.37	8	May-22	Aug-22
		PZ-15	Surface	19.3	18.6	20.5	1.07	3	Jun-22	Aug-22
			Shallow	16.5	11.2	19.2	3.11	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	8.65	4.91	12.7	2.75	8	May-22	Aug-22
DO	mg/L	PZ-1	Surface	3.98	0.85	7.11	4.43	2	Jun-22	Jun-22
			Shallow	0.98	0.41	2.04	0.60	6	Jun-22	Aug-22
			Deep	0.37	0.16	0.59	0.16	7	May-22	Aug-22
		PZ-2	Surface	0.63	0.56	0.70	0.10	2	Jun-22	Jun-22
			Shallow	0.26	0.16	0.37	0.10	5	Jun-22	Jul-22
			Deep	0.17	-0.10	0.70	0.25	8	May-22	Aug-22
		PZ-3	Surface	2.42	1.93	2.91	0.69	2	Jun-22	Jun-22
			Shallow	1.44	0.37	6.17	2.10	7	Jun-22	Aug-22
			Deep	0.41	0.11	1.05	0.35	8	May-22	Aug-22
		PZ-4	Surface	0.44	0.33	0.54	0.15	2	Jun-22	Jun-22
			Shallow	0.59	0.16	0.98	0.32	7	Jun-22	Aug-22
			Deep	0.23	0.09	0.39	0.11	8	May-22	Aug-22
		PZ-5	Surface	2.00	1.17	2.82	1.17	2	Jun-22	Jun-22
			Shallow	0.37	0.20	0.60	0.15	5	Jun-22	Jul-22
			Deep	0.16	0.00	0.50	0.18	8	May-22	Aug-22
		PZ-6	Surface	0.26	0.26	0.26	---	1	Jun-22	Jun-22
			Shallow	0.79	0.23	1.87	0.67	5	Jun-22	Aug-22
			Deep	0.34	0.01	0.61	0.20	7	May-22	Aug-22
		PZ-7	Surface	0.23	0.20	0.26	0.04	2	Jun-22	Jun-22
			Shallow	0.83	0.30	1.24	0.29	7	Jun-22	Aug-22
			Deep	0.46	0.12	0.83	0.30	8	May-22	Aug-22
		PZ-8	Deep	0.12	0.12	0.12	---	1	May-22	May-22
		PZ-9	Surface	1.68	0.51	4.38	1.35	7	Jun-22	Aug-22
			Shallow	0.29	0.07	0.55	0.17	7	Jun-22	Aug-22
			Deep	0.06	-0.02	0.30	0.11	8	May-22	Aug-22
		PZ-10	Surface	1.09	0.45	1.73	0.91	2	Jun-22	Jun-22
			Shallow	1.31	0.18	4.28	1.75	6	Jun-22	Aug-22
			Deep	0.41	-0.05	1.20	0.45	8	May-22	Aug-22
		PZ-11	Surface	0.34	0.11	0.69	0.31	3	Jun-22	Aug-22
		PZ-12	Surface	0.52	0.23	0.72	0.23	4	Jun-22	Aug-22
			Shallow	0.60	0.14	1.01	0.37	7	Jun-22	Aug-22
			Deep	0.24	0.03	0.59	0.17	9	May-22	Aug-22
		PZ-13	Surface	2.76	0.65	7.84	3.41	4	Jun-22	Aug-22
			Shallow	3.68	0.38	18.9	7.45	6	Jun-22	Aug-22
			Deep	0.23	0.03	0.46	0.14	8	May-22	Aug-22
		PZ-14	Surface	4.65	4.65	4.65	---	1	Jun-22	Jun-22
			Shallow	1.30	0.53	3.96	1.49	5	Jun-22	Aug-22
			Deep	0.14	0.00	0.34	0.12	8	May-22	Aug-22
		PZ-15	Surface	0.48	0.42	0.54	0.06	3	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	0.90	0.35	3.00	1.04	6	Jun-22	Aug-22
			Deep	0.07	-0.06	0.28	0.11	8	May-22	Aug-22
pH	SU	PZ-1	Surface	6.74	6.64	6.83	0.13	2	Jun-22	Jun-22
			Shallow	6.45	6.20	6.68	0.16	6	Jun-22	Aug-22
			Deep	6.65	6.36	6.93	0.22	7	May-22	Aug-22
		PZ-2	Surface	6.83	6.83	6.83	---	1	Jun-22	Jun-22
			Shallow	6.35	6.31	6.39	0.04	4	Jun-22	Jul-22
			Deep	6.49	6.38	6.64	0.08	7	May-22	Aug-22
		PZ-3	Surface	6.37	6.32	6.41	0.06	2	Jun-22	Jun-22
			Shallow	6.15	5.77	6.32	0.18	7	Jun-22	Aug-22
			Deep	6.10	5.67	6.54	0.31	8	May-22	Aug-22
		PZ-4	Surface	6.32	6.20	6.44	0.17	2	Jun-22	Jun-22
			Shallow	6.20	6.01	6.42	0.15	7	Jun-22	Aug-22
			Deep	6.25	5.95	6.69	0.24	8	May-22	Aug-22
		PZ-5	Surface	6.85	6.85	6.85	---	1	Jun-22	Jun-22
			Shallow	6.27	6.17	6.37	0.08	4	Jun-22	Jul-22
			Deep	6.06	5.93	6.54	0.22	7	May-22	Aug-22
		PZ-6	Surface	6.49	6.49	6.49	---	1	Jun-22	Jun-22
			Shallow	6.29	5.98	6.42	0.18	5	Jun-22	Aug-22
			Deep	6.20	6.03	6.43	0.13	7	May-22	Aug-22
		PZ-7	Surface	6.71	6.70	6.72	0.01	2	Jun-22	Jun-22
			Shallow	6.10	5.69	6.30	0.21	7	Jun-22	Aug-22
			Deep	5.85	5.50	6.10	0.19	8	May-22	Aug-22
		PZ-8	Deep	6.44	6.44	6.44	---	1	May-22	May-22
		PZ-9	Surface	6.29	6.19	6.41	0.09	6	Jun-22	Aug-22
			Shallow	6.24	6.15	6.33	0.08	6	Jun-22	Aug-22
			Deep	6.15	5.96	6.31	0.13	7	May-22	Aug-22
		PZ-10	Surface	6.53	6.53	6.53	---	1	Jun-22	Jun-22
			Shallow	6.17	6.12	6.29	0.07	5	Jun-22	Aug-22
			Deep	6.21	5.97	6.49	0.17	7	May-22	Aug-22
		PZ-11	Surface	6.47	6.39	6.57	0.09	3	Jun-22	Aug-22
		PZ-12	Surface	6.51	6.36	6.73	0.16	4	Jun-22	Aug-22
			Shallow	6.36	5.89	6.61	0.23	7	Jun-22	Aug-22
			Deep	6.22	5.76	6.33	0.18	9	May-22	Aug-22
		PZ-13	Surface	6.93	6.83	7.02	0.08	4	Jun-22	Aug-22
			Shallow	6.69	6.56	6.93	0.14	6	Jun-22	Aug-22
			Deep	6.07	5.61	6.31	0.20	8	May-22	Aug-22
		PZ-14	Shallow	6.22	6.01	6.51	0.23	4	Jun-22	Aug-22
			Deep	6.16	6.02	6.35	0.10	7	May-22	Aug-22
		PZ-15	Surface	6.37	6.29	6.44	0.11	2	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	6.19	6.10	6.32	0.09	5	Jun-22	Aug-22
			Deep	6.08	5.97	6.21	0.08	7	May-22	Aug-22
Cond	uS/cm	PZ-1	Surface	575	543	607	44.7	2	Jun-22	Jun-22
			Shallow	476	407	551	46.3	6	Jun-22	Aug-22
			Deep	626	464	940	149	7	May-22	Aug-22
		PZ-2	Surface	634	584	684	70.7	2	Jun-22	Jun-22
			Shallow	522	483	538	23.1	5	Jun-22	Jul-22
			Deep	723	644	1,026	124	8	May-22	Aug-22
		PZ-3	Surface	663	634	692	41.5	2	Jun-22	Jun-22
			Shallow	336	210	566	116	7	Jun-22	Aug-22
			Deep	299	197	447	81.2	8	May-22	Aug-22
		PZ-4	Surface	532	458	606	104	2	Jun-22	Jun-22
			Shallow	423	284	638	109	7	Jun-22	Aug-22
			Deep	394	251	614	119	8	May-22	Aug-22
		PZ-5	Surface	806	748	863	81.3	2	Jun-22	Jun-22
			Shallow	566	554	588	13.5	5	Jun-22	Jul-22
			Deep	493	429	715	104	8	May-22	Aug-22
		PZ-6	Surface	1,137	1,137	1,137	---	1	Jun-22	Jun-22
			Shallow	989	713	1,162	199	5	Jun-22	Aug-22
			Deep	862	723	1,277	189	7	May-22	Aug-22
		PZ-7	Surface	624	537	711	123	2	Jun-22	Jun-22
			Shallow	424	253	676	130	7	Jun-22	Aug-22
			Deep	326	176	676	167	8	May-22	Aug-22
		PZ-8	Deep	651	651	651	---	1	May-22	May-22
		PZ-9	Surface	495	419	552	51.7	7	Jun-22	Aug-22
			Shallow	430	393	492	40.4	7	Jun-22	Aug-22
			Deep	429	384	636	84.2	8	May-22	Aug-22
		PZ-10	Surface	875	862	888	18.4	2	Jun-22	Jun-22
			Shallow	708	588	817	98.2	6	Jun-22	Aug-22
			Deep	658	576	917	107	8	May-22	Aug-22
		PZ-11	Surface	1,228	1,163	1,261	56.0	3	Jun-22	Aug-22
		PZ-12	Surface	759	606	901	124	4	Jun-22	Aug-22
			Shallow	816	622	1,255	208	7	Jun-22	Aug-22
			Deep	745	517	1,102	210	9	May-22	Aug-22
		PZ-13	Surface	740	664	897	108	4	Jun-22	Aug-22
			Shallow	845	703	918	73.9	6	Jun-22	Aug-22
			Deep	677	552	993	139	8	May-22	Aug-22
		PZ-14	Surface	726	726	726	---	1	Jun-22	Jun-22
			Shallow	686	620	744	50.3	5	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	625	557	954	134	8	May-22	Aug-22
		PZ-15	Surface	910	793	990	103	3	Jun-22	Aug-22
			Shallow	897	815	941	46.8	6	Jun-22	Aug-22
			Deep	821	745	1,211	158	8	May-22	Aug-22
ORP	mV	PZ-1	Surface	-104	-151	-57.2	66.1	2	Jun-22	Jun-22
			Shallow	-110	-194	-80.2	43.8	6	Jun-22	Aug-22
			Deep	-145	-189	-104	33.5	7	May-22	Aug-22
		PZ-2	Surface	-135	-135	-135	---	1	Jun-22	Jun-22
			Shallow	-1.18	-83.4	123	87.9	4	Jun-22	Jul-22
			Deep	-99.1	-196	-42.4	51.9	7	May-22	Aug-22
		PZ-3	Surface	-68.2	-84.0	-52.3	22.4	2	Jun-22	Jun-22
			Shallow	-124	-158	-70.0	27.4	7	Jun-22	Aug-22
			Deep	-159	-198	-106	31.1	8	May-22	Aug-22
		PZ-4	Surface	-104	-131	-77.5	38.1	2	Jun-22	Jun-22
			Shallow	-141	-201	-81.6	45.2	7	Jun-22	Aug-22
			Deep	-163	-204	-108	31.6	8	May-22	Aug-22
		PZ-5	Surface	-136	-136	-136	---	1	Jun-22	Jun-22
			Shallow	-82.0	-126	-42.2	45.7	4	Jun-22	Jul-22
			Deep	-66.9	-196	6.00	68.0	7	May-22	Aug-22
		PZ-6	Surface	-165	-165	-165	---	1	Jun-22	Jun-22
			Shallow	-68.5	-131	-29.2	38.8	5	Jun-22	Aug-22
			Deep	-87.5	-168	-29.3	47.9	7	May-22	Aug-22
		PZ-7	Surface	-151	-159	-143	11.7	2	Jun-22	Jun-22
			Shallow	-108	-174	-70.0	35.9	7	Jun-22	Aug-22
			Deep	-108	-193	106	93.4	8	May-22	Aug-22
		PZ-8	Deep	-230	-230	-230	---	1	May-22	May-22
		PZ-9	Surface	-53.7	-141	34.7	64.8	6	Jun-22	Aug-22
			Shallow	-88.9	-144	-26.6	51.1	6	Jun-22	Aug-22
			Deep	-26.9	-189	403	198	7	May-22	Aug-22
		PZ-10	Surface	-112	-112	-112	---	1	Jun-22	Jun-22
			Shallow	-60.7	-111	-10.0	41.5	4	Jun-22	Aug-22
			Deep	-92.4	-193	-6.20	64.1	7	May-22	Aug-22
		PZ-11	Surface	-56.3	-79.8	-26.4	27.3	3	Jun-22	Aug-22
		PZ-12	Surface	-118	-149	-102	21.1	4	Jun-22	Aug-22
			Shallow	-148	-227	-65.9	62.9	7	Jun-22	Aug-22
			Deep	-123	-195	124	98.9	9	May-22	Aug-22
		PZ-13	Surface	-40.2	-101	39.1	58.2	4	Jun-22	Aug-22
			Shallow	-91.4	-193	136	116	6	Jun-22	Aug-22
			Deep	-123	-202	-24.0	62.2	8	May-22	Aug-22
		PZ-14	Shallow	-27.1	-152	43.1	85.5	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	-92.5	-188	-3.50	65.7	7	May-22	Aug-22
		PZ-15	Surface	-106	-128	-84.5	30.5	2	Jun-22	Aug-22
			Shallow	-58.2	-115	-8.80	44.9	5	Jun-22	Aug-22
			Deep	-89.0	-192	-1.10	65.4	7	May-22	Aug-22
TFE	mg/L	PZ-1	Surface	2.68	2.22	3.14	0.65	2	Jun-22	Jun-22
			Shallow	5.36	2.33	7.77	2.12	6	Jun-22	Aug-22
			Deep	6.80	4.86	8.94	1.44	8	May-22	Aug-22
		PZ-2	Surface	2.12	1.70	2.54	0.59	2	Jun-22	Jun-22
			Shallow	5.14	3.40	6.26	1.19	5	Jun-22	Jul-22
			Deep	6.41	5.66	7.28	0.68	8	May-22	Aug-22
		PZ-3	Surface	4.50	4.19	4.81	0.44	2	Jun-22	Jun-22
			Shallow	4.17	2.43	5.65	1.21	7	Jun-22	Aug-22
			Deep	3.57	3.13	3.83	0.26	8	May-22	Aug-22
		PZ-4	Surface	3.91	3.84	3.97	0.09	2	Jun-22	Jun-22
			Shallow	2.91	2.24	4.20	0.64	7	Jun-22	Aug-22
			Deep	2.91	2.45	3.46	0.40	8	May-22	Aug-22
		PZ-5	Surface	3.23	2.43	4.03	1.13	2	Jun-22	Jun-22
			Shallow	5.82	3.32	6.72	1.45	5	Jun-22	Jul-22
			Deep	2.38	1.71	3.08	0.38	8	May-22	Aug-22
		PZ-6	Surface	17.4	10.7	24.0	9.40	2	Jun-22	Jun-22
			Shallow	11.1	2.45	15.7	4.91	6	Jun-22	Aug-22
			Deep	3.22	1.72	4.21	0.74	8	May-22	Aug-22
		PZ-7	Surface	8.11	6.01	10.2	2.96	2	Jun-22	Jun-22
			Shallow	7.44	3.33	12.2	2.81	7	Jun-22	Aug-22
			Deep	4.09	2.76	6.91	1.34	8	May-22	Aug-22
		PZ-8	Deep	1.58	1.58	1.58	---	1	May-22	May-22
		PZ-9	Surface	4.60	1.11	7.03	1.82	7	Jun-22	Aug-22
			Shallow	2.13	1.40	3.72	0.77	7	Jun-22	Aug-22
			Deep	1.47	1.36	1.56	0.08	8	May-22	Aug-22
		PZ-10	Surface	4.37	3.66	5.08	1.00	2	Jun-22	Jun-22
			Shallow	4.34	0.78	6.21	1.92	6	Jun-22	Aug-22
			Deep	4.07	3.49	5.00	0.51	8	May-22	Aug-22
		PZ-11	Surface	4.96	3.73	7.41	1.67	4	Jun-22	Aug-22
		PZ-12	Surface	4.31	1.84	6.89	2.29	4	Jun-22	Aug-22
			Shallow	7.47	2.66	11.4	3.34	7	Jun-22	Aug-22
			Deep	7.69	5.87	9.02	0.99	9	May-22	Aug-22
		PZ-13	Surface	1.74	0.78	2.68	0.83	4	Jun-22	Aug-22
			Shallow	5.19	3.10	8.57	1.85	6	Jun-22	Aug-22
			Deep	5.62	5.35	5.82	0.16	8	May-22	Aug-22
		PZ-14	Surface	7.78	7.78	7.78	---	1	Jun-22	Jun-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	7.15	1.56	10.4	3.47	5	Jun-22	Aug-22
			Deep	4.50	3.96	5.38	0.43	8	May-22	Aug-22
		PZ-15	Surface	6.32	2.79	8.58	3.09	3	Jun-22	Aug-22
			Shallow	8.08	3.25	13.8	4.58	6	Jun-22	Aug-22
			Deep	8.25	5.78	14.2	2.59	8	May-22	Aug-22
TP	mg/L	PZ-1	Surface	0.31	0.25	0.37	0.09	2	Jun-22	Jun-22
			Shallow	0.21	0.11	0.33	0.08	6	Jun-22	Aug-22
			Deep	0.38	0.22	0.70	0.16	8	May-22	Aug-22
		PZ-2	Surface	0.56	0.55	0.56	0.01	2	Jun-22	Jun-22
			Shallow	0.30	0.25	0.35	0.04	5	Jun-22	Jul-22
			Deep	0.52	0.42	0.63	0.08	8	May-22	Aug-22
		PZ-3	Surface	0.50	0.22	0.77	0.39	2	Jun-22	Jun-22
			Shallow	0.16	0.12	0.19	0.02	7	Jun-22	Aug-22
			Deep	0.13	0.09	0.22	0.04	8	May-22	Aug-22
		PZ-4	Surface	0.38	0.28	0.47	0.13	2	Jun-22	Jun-22
			Shallow	0.32	0.14	0.42	0.09	7	Jun-22	Aug-22
			Deep	0.53	0.40	0.65	0.09	8	May-22	Aug-22
		PZ-5	Surface	0.06	0.03	0.10	0.05	2	Jun-22	Jun-22
			Shallow	0.11	0.08	0.15	0.03	5	Jun-22	Jul-22
			Deep	0.20	0.07	0.38	0.10	8	May-22	Aug-22
		PZ-6	Surface	0.89	0.88	0.89	0.01	2	Jun-22	Jun-22
			Shallow	0.29	0.05	0.37	0.12	6	Jun-22	Aug-22
			Deep	0.42	0.38	0.47	0.04	8	May-22	Aug-22
		PZ-7	Surface	0.27	0.18	0.36	0.13	2	Jun-22	Jun-22
			Shallow	0.23	0.14	0.37	0.07	7	Jun-22	Aug-22
			Deep	0.42	0.29	0.55	0.08	8	May-22	Aug-22
		PZ-8	Deep	0.16	0.16	0.16	---	1	May-22	May-22
		PZ-9	Surface	0.31	0.06	0.71	0.21	7	Jun-22	Aug-22
			Shallow	0.23	0.16	0.36	0.08	7	Jun-22	Aug-22
			Deep	0.08	0.02	0.10	0.03	8	May-22	Aug-22
		PZ-10	Surface	0.23	0.07	0.40	0.23	2	Jun-22	Jun-22
			Shallow	0.10	0.03	0.19	0.06	6	Jun-22	Aug-22
			Deep	0.18	0.06	0.25	0.05	8	May-22	Aug-22
		PZ-11	Surface	0.37	0.08	0.68	0.25	4	Jun-22	Aug-22
		PZ-12	Surface	0.42	0.20	0.79	0.26	4	Jun-22	Aug-22
			Shallow	0.37	0.24	0.56	0.11	7	Jun-22	Aug-22
			Deep	0.26	0.21	0.31	0.04	9	May-22	Aug-22
		PZ-13	Surface	0.14	0.08	0.32	0.12	4	Jun-22	Aug-22
			Shallow	0.31	0.15	0.47	0.12	6	Jun-22	Aug-22
			Deep	0.57	0.50	0.64	0.05	8	May-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
		PZ-14	Surface	0.56	0.56	0.56	---	1	Jun-22	Jun-22
			Shallow	0.17	0.03	0.25	0.09	5	Jun-22	Aug-22
			Deep	1.04	0.87	1.20	0.14	8	May-22	Aug-22
		PZ-15	Surface	0.85	0.11	1.67	0.79	3	Jun-22	Aug-22
			Shallow	0.37	0.09	1.02	0.33	6	Jun-22	Aug-22
			Deep	0.32	0.24	0.43	0.06	8	May-22	Aug-22
OP	mg/L	PZ-1	Surface	0.16	0.15	0.16	0.01	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.12	0.03	6	Jun-22	Aug-22
			Deep	0.07	0.01	0.17	0.06	8	May-22	Aug-22
		PZ-2	Surface	0.28	0.21	0.34	0.09	2	Jun-22	Jun-22
			Shallow	0.22	0.17	0.26	0.04	5	Jun-22	Jul-22
			Deep	0.08	0.01	0.36	0.12	8	May-22	Aug-22
		PZ-3	Surface	0.38	0.13	0.63	0.35	2	Jun-22	Jun-22
			Shallow	0.08	0.04	0.14	0.03	7	Jun-22	Aug-22
			Deep	0.08	0.04	0.14	0.03	8	May-22	Aug-22
		PZ-4	Surface	0.24	0.20	0.27	0.05	2	Jun-22	Jun-22
			Shallow	0.21	0.09	0.26	0.06	7	Jun-22	Aug-22
			Deep	0.36	0.20	0.47	0.08	8	May-22	Aug-22
		PZ-5	Surface	0.05	0.04	0.06	0.01	2	Jun-22	Jun-22
			Shallow	0.06	0.03	0.08	0.02	5	Jun-22	Jul-22
			Deep	0.14	0.03	0.22	0.06	8	May-22	Aug-22
		PZ-6	Surface	0.15	0.03	0.27	0.17	2	Jun-22	Jun-22
			Shallow	0.07	0.01	0.17	0.07	6	Jun-22	Aug-22
			Deep	0.18	0.12	0.30	0.05	8	May-22	Aug-22
		PZ-7	Surface	0.08	0.05	0.11	0.04	2	Jun-22	Jun-22
			Shallow	0.12	0.05	0.19	0.05	7	Jun-22	Aug-22
			Deep	0.31	0.17	0.54	0.10	8	May-22	Aug-22
		PZ-8	Deep	0.07	0.07	0.07	---	1	May-22	May-22
		PZ-9	Surface	0.20	0.06	0.61	0.19	7	Jun-22	Aug-22
			Shallow	0.15	0.10	0.25	0.05	7	Jun-22	Aug-22
			Deep	0.08	0.05	0.09	0.01	8	May-22	Aug-22
		PZ-10	Surface	0.14	0.04	0.24	0.14	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.14	0.04	6	Jun-22	Aug-22
			Deep	0.11	0.04	0.13	0.03	8	May-22	Aug-22
		PZ-11	Surface	0.02	0.02	0.03	0.00	4	Jun-22	Aug-22
		PZ-12	Surface	0.21	0.06	0.46	0.17	4	Jun-22	Aug-22
			Shallow	0.23	0.07	0.38	0.10	7	Jun-22	Aug-22
			Deep	0.18	0.13	0.21	0.03	9	May-22	Aug-22
		PZ-13	Surface	0.03	0.01	0.04	0.01	4	Jun-22	Aug-22
			Shallow	0.14	0.08	0.22	0.06	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	0.29	0.16	0.40	0.09	8	May-22	Aug-22
		PZ-14	Surface	0.11	0.11	0.11	---	1	Jun-22	Jun-22
			Shallow	0.09	0.02	0.17	0.06	5	Jun-22	Aug-22
			Deep	0.31	0.14	0.48	0.10	8	May-22	Aug-22
		PZ-15	Surface	0.38	0.06	0.83	0.40	3	Jun-22	Aug-22
			Shallow	0.09	0.04	0.16	0.05	6	Jun-22	Aug-22
			Deep	0.22	0.08	0.29	0.06	8	May-22	Aug-22
TN	mg/L	PZ-1	Surface	2.46	1.94	2.97	0.73	2	Jun-22	Jun-22
			Shallow	3.76	2.26	5.24	1.22	6	Jun-22	Aug-22
			Deep	5.28	2.55	7.45	1.66	8	May-22	Aug-22
		PZ-2	Surface	2.85	2.75	2.94	0.13	2	Jun-22	Jun-22
			Shallow	2.95	2.51	3.85	0.55	5	Jun-22	Jul-22
			Deep	4.69	1.01	6.36	1.61	8	May-22	Aug-22
		PZ-3	Surface	2.30	2.15	2.45	0.21	2	Jun-22	Jun-22
			Shallow	1.90	1.58	2.24	0.29	7	Jun-22	Aug-22
			Deep	2.71	1.39	4.71	1.08	8	May-22	Aug-22
		PZ-4	Surface	1.84	1.75	1.93	0.13	2	Jun-22	Jun-22
			Shallow	3.71	1.52	7.77	1.96	7	Jun-22	Aug-22
			Deep	8.68	6.54	11.0	1.32	8	May-22	Aug-22
		PZ-5	Surface	1.38	1.15	1.60	0.32	2	Jun-22	Jun-22
			Shallow	1.64	1.32	2.13	0.38	5	Jun-22	Jul-22
			Deep	3.31	1.44	5.80	1.37	8	May-22	Aug-22
		PZ-6	Surface	2.50	1.90	3.10	0.85	2	Jun-22	Jun-22
			Shallow	2.16	1.42	3.08	0.53	6	Jun-22	Aug-22
			Deep	5.66	5.00	6.35	0.49	8	May-22	Aug-22
		PZ-7	Surface	1.25	1.10	1.39	0.21	2	Jun-22	Jun-22
			Shallow	1.95	1.36	3.03	0.58	7	Jun-22	Aug-22
			Deep	5.57	4.37	6.41	0.70	8	May-22	Aug-22
		PZ-8	Deep	2.67	2.67	2.67	---	1	May-22	May-22
		PZ-9	Surface	2.03	1.21	3.11	0.76	7	Jun-22	Aug-22
			Shallow	1.33	0.91	2.33	0.49	7	Jun-22	Aug-22
			Deep	1.73	1.33	2.85	0.53	8	May-22	Aug-22
		PZ-10	Surface	1.56	1.31	1.80	0.35	2	Jun-22	Jun-22
			Shallow	1.65	1.44	2.10	0.24	6	Jun-22	Aug-22
			Deep	2.44	1.14	3.59	0.75	8	May-22	Aug-22
		PZ-11	Surface	1.45	0.85	2.19	0.60	4	Jun-22	Aug-22
		PZ-12	Surface	1.47	0.82	2.03	0.50	4	Jun-22	Aug-22
			Shallow	2.83	2.01	5.70	1.35	7	Jun-22	Aug-22
			Deep	4.67	3.95	5.33	0.46	9	May-22	Aug-22
		PZ-13	Surface	1.19	0.81	1.75	0.45	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	1.59	1.12	3.17	0.79	6	Jun-22	Aug-22
			Deep	5.69	4.66	6.95	0.93	8	May-22	Aug-22
		PZ-14	Surface	2.81	2.81	2.81	---	1	Jun-22	Jun-22
			Shallow	2.11	1.08	2.54	0.59	5	Jun-22	Aug-22
			Deep	8.38	7.48	9.06	0.53	8	May-22	Aug-22
		PZ-15	Surface	2.96	1.83	3.79	1.02	3	Jun-22	Aug-22
			Shallow	3.18	1.73	7.99	2.39	6	Jun-22	Aug-22
			Deep	3.93	2.11	5.73	1.02	8	May-22	Aug-22
Elevation	ft NAVD 88	PZ-1	Surface	943.6	943.4	943.9	0.25	4	Jun-22	Aug-22
			Shallow	943.0	941.9	943.9	0.70	7	Jun-22	Aug-22
			Deep	943.1	941.7	944.1	0.81	8	May-22	Aug-22
		PZ-2	Surface	943.8	943.8	943.9	0.08	2	Jun-22	Jun-22
			Shallow	943.2	942.4	943.9	0.59	6	Jun-22	Aug-22
			Deep	943.1	941.7	944.2	0.83	8	May-22	Aug-22
		PZ-3	Surface	943.9	943.7	944.3	0.29	5	Jun-22	Jul-22
			Shallow	943.7	942.7	944.5	0.61	7	Jun-22	Aug-22
			Deep	943.6	942.7	944.3	0.63	8	May-22	Aug-22
		PZ-4	Surface	943.6	943.4	943.9	0.25	6	Jun-22	Aug-22
			Shallow	943.6	943.2	944.1	0.31	7	Jun-22	Aug-22
			Deep	944.1	943.0	948.3	1.73	8	May-22	Aug-22
		PZ-5	Surface	944.1	944.0	944.2	0.13	2	Jun-22	Jun-22
			Shallow	943.5	942.8	944.3	0.53	6	Jun-22	Aug-22
			Deep	943.5	942.7	944.4	0.60	8	May-22	Aug-22
		PZ-6	Surface	944.4	944.4	944.4	---	1	Jun-22	Jun-22
			Shallow	943.3	942.3	944.4	0.73	6	Jun-22	Aug-22
			Deep	943.4	942.0	944.7	0.93	7	May-22	Aug-22
		PZ-7	Surface	944.0	943.5	944.5	0.20	10,038	May-22	Sep-22
			Shallow	943.7	942.6	944.5	0.49	10,040	May-22	Sep-22
			Deep	943.6	942.5	944.5	0.48	9,320	May-22	Sep-22
		PZ-9	Surface	943.6	943.2	944.1	0.21	10,034	May-22	Sep-22
			Shallow	943.6	943.2	944.1	0.23	10,039	May-22	Sep-22
			Deep	943.5	943.0	944.4	0.29	10,039	May-22	Sep-22
		PZ-10	Surface	944.2	944.0	944.7	0.22	10,028	May-22	Sep-22
			Shallow	943.9	942.6	944.9	0.66	10,029	May-22	Sep-22
			Deep	943.7	942.0	944.8	0.73	10,032	May-22	Sep-22
		PZ-11	Up	943.8	942.2	944.8	0.69	9,281	Jun-22	Sep-22
		PZ-12	Surface	944.6	944.0	944.9	0.38	5	Jun-22	Aug-22
			Shallow	944.3	943.5	944.9	0.49	7	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	850.2	95.9	945.1	283	9	May-22	Aug-22
		PZ-13	Surface	944.2	943.8	944.6	0.30	6	Jun-22	Aug-22
			Shallow	944.0	943.0	944.6	0.57	7	Jun-22	Aug-22
			Deep	944.1	943.0	945.6	0.78	8	May-22	Aug-22
		PZ-14	Surface	944.2	943.9	944.4	0.26	3	Jun-22	Jun-22
			Shallow	943.8	942.9	944.5	0.55	6	Jun-22	Aug-22
			Deep	943.8	942.6	944.7	0.71	8	May-22	Aug-22
		PZ-15	Surface	944.4	944.1	944.7	0.28	4	Jun-22	Aug-22
			Shallow	944.2	943.5	944.7	0.45	6	Jun-22	Aug-22
			Deep	944.0	942.9	944.7	0.65	8	May-22	Aug-22

Stantec **Memo**

To:	Josh Wolf, Project and Land Program Manager (MCWD)	From:	Chris Meehan (PE), Tom Beneke, Sylvia Doerr, Nick Wyers (PE), Rena Weis Stantec
Project/File:	227706022	Date:	July 31, 2023

Reference: County Road 6 Pond Retrofit Feasibility Study

1 Introduction

Minnehaha Creek Watershed (MCWD) identified the Long Lake Creek – County Road 6 Pond (CR6 Pond) in Orono, MN as a candidate for performance improvements via engineered retrofits, based on nutrient and sedimentation monitoring. The CR 6 Pond is downstream from Holy Name and Wolsfeld Lakes, and upstream from Long Lake. All three lakes are impaired by excess nutrients. The CR6 Pond is strategically located in the subwatershed, with recent monitoring and analysis of the pond and subwatershed indicating opportunities for further improvements in the pond's effectiveness in total phosphorus load reduction. MCWD Research & Monitoring has shown that Long Lake requires a 62% reduction in phosphorus (742 lbs.) to meet state water quality standards, which includes 411 lbs/yr from watershed sources. Due to the significant load reductions required to progress towards Long Lake's goal, this study sought to consider retrofit practices and sizes that would maximize TP removals.

This study seeks to identify and evaluate retrofit opportunities at the CR6 pond, with a primary focus on total phosphorus (TP) removal potential. The study evaluates opportunities based on water quality benefits, water quantity benefits, ecological integrity, project costs, regulatory hurdles, site constraints, and project complexity.

2 Water Quality (P8) Modeling Updates

2.1 Streamflow Calibration

The combined P8 model detailed in Stantec's March 27, 2023, Memo to Brian Beck (MCWD) was first re-calibrated for streamflow after updating live storage volume values in upstream ponds. Updates to streamflow calibration parameters focused on better matching the following aspects of observed and simulated streamflow:

- Storm event magnitude
- Storm event timing
- Baseflow magnitude

Figure 1 below demonstrates the P8 model fit described in the March 27, 2023, Memo. While this model meets general performance criteria for total flow volume percent bias (PBIAS) during the growing season (0.2%), the timing and magnitude of simulated events does not accurately describe the observations.

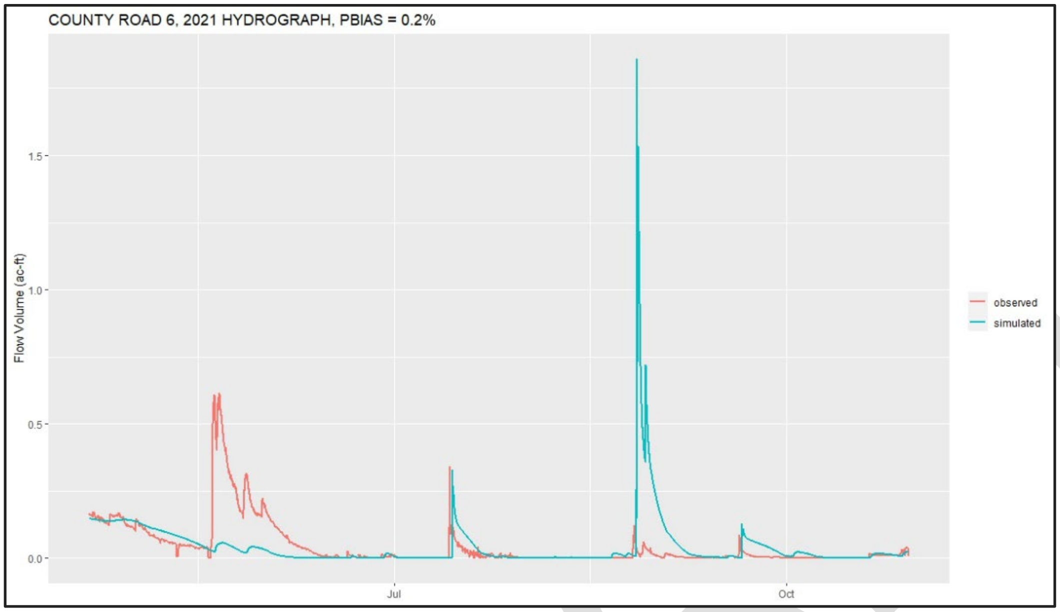


Figure 1. Streamflow hydrograph results from the March 2023 P8 model. Hydrograph demonstrates hourly observed and simulated flow volume at the County Road 6 pond inlet for the 2021 growing season.

Figure 2 below demonstrates the P8 model fit after updating the previous model in Figure 1 with more accurate upstream live storage volumes, but prior to re-calibration (i.e., the March 2023 version plus updated live storage). This hydrograph, again illustrating the same 2021 growing season, demonstrates a poor model fit for storm event magnitude, storm event timing, and baseflow magnitude. As shown, the most notable change is a large increase in baseflow.

Reference: County Road 6 Pond Retrofit Feasibility Study

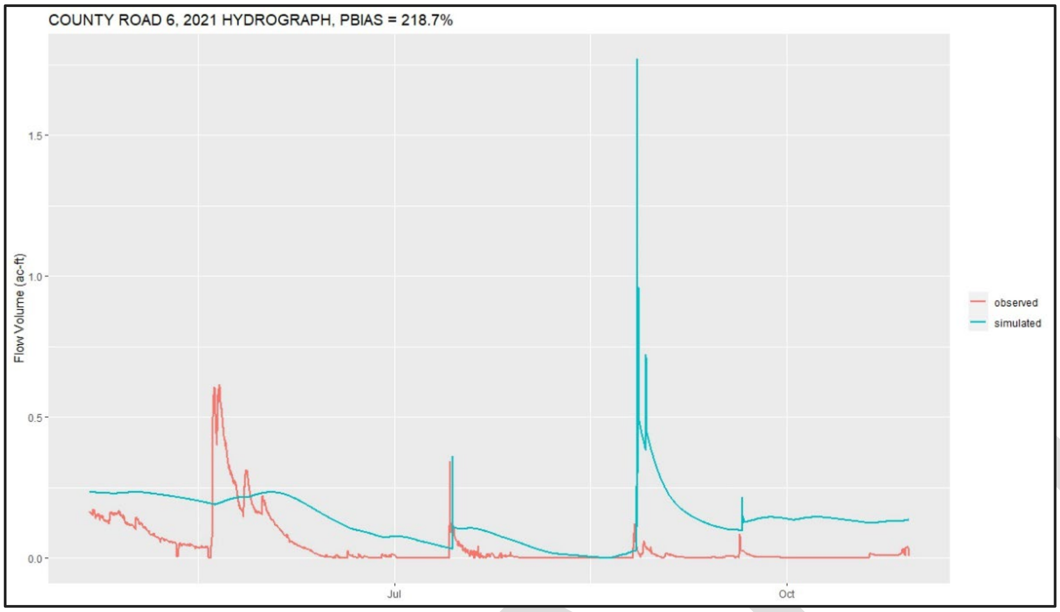


Figure 2. Streamflow hydrograph results from the March 2023 P8 model with updated live storage pond volumes (prior to re-calibration). Hydrograph demonstrates hourly observed and simulated flow volume at the County Road 6 pond inlet for the 2021 growing season.

To address these issues, P8 model parameters for antecedent moisture condition, connected impervious extent, evapotranspiration, and aquifer device time of concentration. Table 1 below summarizes parameters adjusted in the re-calibrated P8 model.

Table 1. P8 streamflow parameter adjustments made to re-calibrated model.

Parameter Name	**Value**	**Unit**
Growing Season Month (start)	6	Month Index
Growing Season Month (end)	10	Month Index
Antecedent Moisture Condition II (growing season)	4	Inches
Antecedent Moisture Condition III (growing season)	4.5	Inches
Antecedent Moisture Condition II (non-growing season)	0.02	Inches
Antecedent Moisture Condition III (non-growing season)	0.11	Inches
Connected Impervious Fraction	0	Percent
Evapo-Transpiration Calibration Factor	1.4	Unitless
Time of Concentration (aquifers)	Increased by a factor of 4 for all aquifer devices	Unitless

The results of the re-calibrated P8 model are illustrated in Figure 3. Storm event timing, storm event magnitude, and baseflow magnitude are an improvement from the prior iteration of the model, while also meeting low percent bias model performance criteria for total flow volume. The re-calibrated P8 model under simulates total flow volume for the 2021 growing season by approximately 5%.

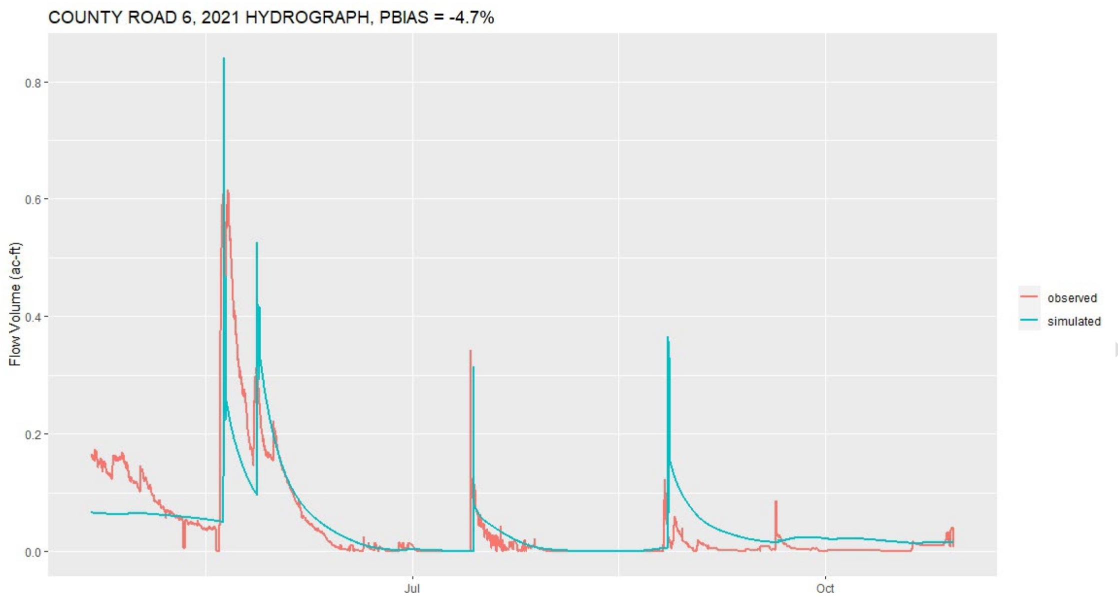


Figure 3. Streamflow hydrograph results from the re-calibrated model. Hydrograph demonstrates hourly observed and simulated flow volume at the County Road 6 pond inlet for the 2021 growing season.

2.2 Pollutant Calibration

The P8 model that was re-calibrated for streamflow was then calibrated for total suspended solids (TSS) and total phosphorus (TP). Initial attempts at calibration demonstrated that sediment and particulate phosphorus at the County Road 6 pond inlet were low. Particulate phosphorus loads were so low that this configuration of the model could not be adjusted to accurately describe observed conditions.

Based on model sensitivity analysis, it is Stantec's view that the upstream ponds in the P8 model are overestimating pollutant removals, resulting in a very small particulate pollutant load at the County Road 6 inlet. Stantec developed an additional version of the P8 model with zero pond or pipe devices upstream of the County Road 6 inlet, where all watersheds were combined to a single upstream basin using the same streamflow calibration parameters from the full model version (Figure 3). This was done to calibrate the pollutant load entering the County Road 6 pond more accurately and facilitate more realistic estimates of the various engineered pollutant removal scenarios.

Table 2 summarizes load estimates at the County Road 6 inlet and outlet. These loads were estimated using the USGS LOADEST regression software, from observed streamflow and TP concentration data for the 2021 and 2022 growing seasons. Based on this analysis, the County Road 6 ponds remove approximately 28% of the TP on an annual basis.

Table 2. Annual TP loads at the Country Road 6 Inlet and Outlet.

Year	Annual TP Load (lbs)		% Removal
	Inlet	Outlet	
2021	235.5	198.7	15.6%
2022	301.1	189.1	37.2%
Average	268.4	193.9	27.8%

In practice, applying these observed reductions under the current (baseline) condition meant adjusting the "Scale Factor" for TSS and TP until the incoming pollutant concentrations closely matched the observed pollutant concentrations at the inlet. For the 2021 growing season the observed and simulated TSS concentrations at the County Road 6 inlet were 91.6 mg/L and 91.8 mg/L, respectively. The observed and simulated TP concentrations were 0.365 mg/L and 0.363 mg/L, respectively.

Once pollutant loads at the inlet were accurately simulated the "Particle Removal Scale Factor" was adjusted globally for both pond segments/devices. This value was adjusted to 0.1 for both devices, resulting in a TP removal of 34% from inlet to outlet (compared with the estimated average of ~28% in Table 2).

3 Existing Pond Conditions

The existing pond is a 2-acre, dual-celled system, with a submerged berm separating the cells. The existing pond outlet is comprised of a sheet pile weir with five 1x2 ft rectangular orifices that control the normal water level.

Survey was completed to inform critical elevations at the pond, as well as to document utility locations.

MCWD's Research & Monitoring (R&M) Program has monitored influent and effluent phosphorus concentrations at the CR6 pond. Results have indicated that particulate phosphorus dominates the effluent TP. Therefore, the primary goal of the retrofit feasibility study it to identify solutions to improve removal of particulate phosphorus, while providing enhanced dissolved phosphorus removal.

4 Opportunity Identification

A comprehensive list of wet pond retrofit types was developed and reviewed in collaboration with MCWD staff to select preferred project types. Each of the retrofit types is listed below, with justification for either continuing or discontinuing evaluation of each retrofit type.

4.1 Retrofit Types Selected for Further Analysis

The following five alternatives were selected by Stantec and MCWD staff for evaluation within this study.

4.1.1 GRAVITY SAND FILTER BENCH

Gravity sand filter benches utilize vertical depth capacity (head) available in ponds between the normal water level and the overflow outlet (live storage) to filter water through a filter media along a portion of a pond's perimeter, before discharging filtered water downgradient. Filter benches can be active or passive, utilizing pumps or gravity, which drives cost and the quantity of water that can be treated. Gravity systems rely on rainfall events to pass water through filters, while active systems regularly direct water through filters regardless of precipitation patterns. The CR6 pond has sufficient head difference available to make a gravity filter bench a feasible option. Additionally, the existing access corridor along the east side of the pond would provide for less intrusive construction and operations & maintenance of a filter bench located on the eastern perimeter of the southern cell. Water quality treatment capacity is driven by the surface area of a filter; therefore, encroachment of the conceptual filter bench footprint into the existing water surface area of the pond was considered, to maximize treatment potential within existing land access rights agreements.

4.1.2 WEIR ACROSS EXISTING BERM

The CR6 pond is a two-celled system, with the cells separated by a submerged earthen berm. Physical separation between cells has the potential to concentrate sedimentation within the first cell, while continuing to utilize the full residence time that the second cell provides to maximize fine particulate sedimentation. Since the CR6 pond is already configured as a two-celled system, modifications to reinforce functionality as a multi-celled system were considered. Modifications to raise the elevation of the separation between cells has the potential to maximize settling capability in the upgradient cell, before water flows into the downgradient cell. This would also maximize ponding within the existing easement area. Two types of weirs were considered: (1) sheet pile weir and (2) earthen berm with riprap reinforced overflow. The material selected will drive the cost associated with the this retrofit alternative.

4.1.3 PUMPED SAND FILTER BENCH W/ FLOAT SWITCH

Pumped sand filters provide the same benefits as gravity filter benches, except they are able to overcome limitations that gravity filters experience. Pumped sand filters can be located at higher elevations than the water storage system that is used as source water and pumped filters do not need to rely on natural storm events to route water through the filter. This alternative considers the use of a float switch, which would activate pumping between specific, programmed water levels. This allows periodic treatment of pond water via filtration, as the pond fills with stormwater runoff and/or baseflow. The existing access corridor along the east side of the pond would provide for less intrusive construction and operations & maintenance of a filter bench located on the eastern perimeter of the southern cell. Water quality treatment capacity is driven by the surface area of a filter; therefore, encroachment of the conceptual filter bench footprint into the existing water surface area of the pond was considered, to maximize treatment potential within existing land access rights agreements.

4.1.4 PUMPED SAND FILTER BENCH W/ REAL TIME SENSOR

Pumped sand filters provide the same benefits as gravity filter benches, except they are able to overcome limitations that gravity filters experience. Pumped sand filters can be located at higher elevations than the water storage system that is used as source water and pumped filters do not need to rely on natural storm events to route water through the filter. This alternative considers the use of a real time sensor, which would activate pumping between specific, programmed water levels and in advance of rainfall events forecasted by the National Weather Service. This allows periodic treatment of pond water via filtration, as the pond fills with stormwater runoff and/or baseflow. The predictive nature of the real time sensor allows further system manipulation, such as drawing down water levels in a pond prior to a runoff event, to maximize available storage capacity in the pond and maximize capacity for settling and sedimentation of storm runoff within the pond. The existing access corridor along the east side of the pond would provide for less intrusive construction and operations & maintenance of a filter bench located on the eastern perimeter of the southern cell. Water quality treatment capacity is driven by the surface area of a filter; therefore, encroachment of the conceptual filter bench footprint into the existing water surface area of the pond was considered, to maximize treatment potential within existing land access rights agreements. Real time sensors for stormwater management are an emerging technology, which allow water resource managers to leverage facilities at a system scale to maximize water quality and quantity benefits.

4.1.5 ALUM DOSING STATION WITH INTERCEPTION OF GOLF COURSE RUNOFF

Alum is a coagulant which binds to dissolved phosphorus. Its most common use in surface water resource management is to apply alum to waterbodies that are experiencing high dissolved phosphorus load from sediment (internal load). The dissolved phosphorus load is then bound to the alum in a layer at the bottom of the waterbody. The internal load in CR6 pond is unknown, so the applicability of alum dosing the sediment is not well defined at this time.

Another method of using alum to bind and settle dissolved phosphorus is to construct a dosing station that pumps water out of an upstream storage reservoir, injects the water with alum, and allows the floc of alum-bound-phosphorus to settle in a second storage / settling reservoir. The alum injection is ongoing, as water is routinely or continuously pumped out of the first reservoir as the it fills with stormwater runoff and/or baseflow.

The CR6 pond is a candidate for an alum dosing station due to its existing physical configuration as a two-celled system. Modifications to the pond's existing submerged berm would be required, to create a more distinct separation between pond cells. Once floc settles in the downgradient cell, clean water would discharge from the pond's outlet.

MCWD Research & Monitoring (R&M) data indicates that there is significant phosphorus load from the Spring Hill Golf Club east of the CR6 pond and north of County Road 6. The golf course does not naturally drain to the CR6 pond, and instead directly drains to Long Lake without water quality treatment. Assessment of this alternative considered the additional load generated from the golf course and project components that would be required to convey water from the golf course to the CR6 pond.

4.2 Retrofit Types Not Selected for Further Analysis

4.2.1 DEAD POOL VOLUME MODIFICATIONS TO ALTER RESIDENCE TIME

Dead pool volume of ponds impacts the residence time of ponds and subsequently, the settling of particulates within the water column. Significant changes to the grading and bathymetry of CR6 pond were deemed infeasible due to land rights restrictions and the existing easement footprint. Dead pool volume modifications were instead considered within the retrofit type of weir modifications.

4.2.2 OUTLET MODIFICATIONS TO ALTER RESIDENCE TIME

The outlet control structure of a pond controls the normal water level and spillway elevations of the basin. It was decided that outlet modifications would not be considered as an alternative for this study, but would instead be considered as a component of other evaluated options including the sand filter benches and weir modifications.

4.2.3 ADDITION OF PRE-TREATMENT

CR 6 pond sits just downstream of the confluence of two streams, which convey discharge from Wolsfeld Lake and Holy Name Lake. Depending on the condition of the streams upstream of CR6 pond, runoff may experience sediment and phosphorus loading from the erosion of the streams. Relatively low sediment accumulation rates observed in CR6 pond during routine pond sedimentation surveys indicates that this is likely not a primary issue. However, the incorporation of pre-treatment practices at the influent of stormwater management facilities, such as ponds, is a strategy that is shown to reduce nutrient and sediment accumulation within the ponds themselves. Pre-treatment can include construction of wet forebays, manhole sumps with or without energy dissipation or floatable material capture devices, etc. Due to the lack of space on site to construct a pre-treatment forebay, and lack of storm sewer infrastructure to retrofit a manhole sump, the addition or pre-treatment devices was not pursued further at CR6 ponds.

4.2.4 ALUM APPLICATION TO POND SEDIMENTS

The application of alum is an established practice within lakes, to chemically bind dissolved phosphorus that is released by lake sediments, to stop internal loading. Alum application to pond sediments is a potentially emerging technology that is being considered by practitioners in the state of Minnesota. Alum applications rely on site access to facilitate access of alum application equipment, which is problematic at many ponds. CR6 pond has existing access via the easement to the east of the pond. However, data does not exist to indicate whether the CR6 pond experiences internal loading significant enough to warrant alum applications. Furthermore, alum applications essentially “lock” phosphorus from being released from sediments within the sediment surface layer. Since ponds are designed to experience sediment loading and settle those loads, the longevity of alum applications within ponds is dependent on the rate of sediment accumulation within ponds. For these reasons, alum application to the sediments of the CR6 pond were not further explored.

4.2.5 IRON FILINGS APPLICATION TO POND SEDIMENTS

The application of iron filings to lake sediments is an emerging technology that is being explored by researchers, to chemically bind dissolved phosphorus that is released by lake sediments, to stop internal loading. Alum application to pond sediments is a potentially emerging technology that is being considered by practitioners in the state of Minnesota. Alum applications rely on site access to facilitate access of alum application equipment, which is problematic at many ponds. CR6 pond has existing access via the easement to the east of the pond. However, data does not exist to indicate whether the CR6 pond experiences internal loading significant enough to warrant alum applications. Furthermore, alum applications essentially "lock" phosphorus from being released from sediments within the sediment surface layer. Since ponds are designed to experience sediment loading and settle those loads, the longevity of alum applications within ponds is dependent on the rate of sediment accumulation within ponds. For these reasons, alum application to the sediments of the CR6 pond were not further explored.

4.2.6 AERATION

Aeration is most commonly employed in stormwater ponds for aesthetic purposes, which are not a priority at the CR6 Pond. However, the stormwater management industry has recently posed the question of whether mechanical aeration (i.e. fountain or bubbler) can limit or prevent ponds from experiencing dissolved oxygen (DO) stratification, and in turn, reduce sediment P loads. The impacts of aeration on controlling sediment P loads in ponds are not well understood by the industry, and MCWD has a lack of information about the significance of internal sediment loading of P within the CR6 Pond, therefore, aeration was not further evaluated within this study.

4.2.7 PROPRIETARY CARTRIDGE FILTER SYSTEM; PUMPED

Proprietary cartridge filters, such as Jellyfish, StormFilter, etc.; are a relatively new technology that are being implemented more widely within the landscape. With regular maintenance, data shows that they are capable of removing 50% of TP from the water that is directed to them. These systems can be either gravity fed or receive water pumped from a storage area. A proprietary cartridge filter system could be leveraged at CR6 Pond, paired with a pump to overcome pressure head. Due to the watershed size draining to the CR6 pond, a significant quantity of cartridge filters would be required to collect a majority of discharge from the pond during water quality events and/or to maximize TP removal. The cost of cartridge filter systems is primarily driven by the quantity of filters and cartridge filters require regular (typically 1-2 times per year) maintenance or replacement of cartridges. Due to the significant costs and maintenance required support proprietary cartridge filter systems, this retrofit type was not selected for further analysis.

5 Alternatives Assessment

Concept design, water quality modeling, and planning level opinion of probable cost was completed for each alternative. This information is used to evaluate cost efficiency of TP removal associated with each alternative, as well as to provide insight into the physical configuration and operations & maintenance requirements of each alternative. Itemized opinion of probable cost and concept design schematics for each alternative are included in the appendix.

5.1.1 CONCEPT DESIGN

Concept design and sizing was completed for each alternative, utilizing understanding of physical space constraints, informed by survey data. Concept design was used to inform key parameters for water quality modeling, preparation of opinion of probable cost, and to provide a visual understanding of retrofit size and extent.

5.1.1.1 Gravity Sand Filter Bench

The following assumptions and design choices were made for the concept design of a gravity sand filter bench:

- Bench would be located on the eastern portion of the southern cell, with access for construction & maintenance via the existing access corridor within the easement.
- Bench would be graded into the pond, to ensure it is contained within the limits of the existing easement. Therefore, some wet detention area will be lost within the pond.
- Clean sand (not iron enhanced) was assumed, to target particulate phosphorus.
- Outlet modifications to change normal water level (NWL) from 949.3 ft to 951.5 ft.
- Top of filter bench at elevation 951.5 ft.
- 14,000 sf filter bench area.

5.1.1.2 Weir (Sheet Pile or Earthen)

The following assumptions and design choices were made for the concept design of a weir:

- Top of weir at 952 ft, with overflow notch at 951.5 ft.
- Outlet modifications to change normal water level (NWL) from 949.3 ft to 951.5 ft.

5.1.1.3 Pumped Sand Filter Bench w/ Float Switch

The following assumptions and design choices were made for the concept design of a pumped sand filter bench with float switch:

- Bench would be located on the eastern portion of the southern cell, with access for construction & maintenance via the existing access corridor within the easement.
- Bench would be graded into the pond, to ensure it is contained within the limits of the existing easement. Therefore, some wet detention area will be lost within the pond.
- Clean sand (not iron enhanced) was assumed, to target particulate phosphorus.
- Outlet modifications to change normal water level (NWL) from 949.3 ft to 951.5 ft.

- Top of filter bench at elevation 951.5 ft.
- 14,000 sf filter bench area.
- Electrical service to tie-in at County Road 6, to run along existing access corridor.

5.1.1.4 Pumped Sand Filter Bench w/ Real Time Sensor

The following assumptions and design choices were made for the concept design of a pumped sand filter bench with float switch:

- Bench would be located on the eastern portion of the southern cell, with access for construction & maintenance via the existing access corridor within the easement.
- Bench would be graded into the pond, to ensure it is contained within the limits of the existing easement. Therefore, some wet detention area will be lost within the pond.
- Clean sand (not iron enhanced) was assumed, to target particulate phosphorus.
- Outlet modifications to change normal water level (NWL) from 949.3 ft to 951.5 ft.
- Top of filter bench at elevation 951.5 ft.
- 14,000 sf filter bench area.
- Electrical service to tie-in at County Road 6, to run along existing access corridor.

5.1.1.5 Alum Dosing w/ Golf Course Interception

- Construction of lift station south of County Road 6 at existing culvert, with new directionally drilled 6-inch HDPE forcemain to convey water west to CR6 Pond.
- First cell of CR6 pond used as reservoir for water prior to treatment.
- Weir construction to better define distinction between pond cells.
- Alum dosing building located on east side of CR6 pond, between cells.
- Second cell of CR6 pond used as settling basin for alum-bound P floc.
- Electrical service to tie-in at County Road 6, to run along existing access corridor.

5.1.2 WATER QUALITY MODELING

TP removals were estimated in the pollutant calibrated P8 for the following scenarios:

- The current/baseline scenario

- Weir improvement at the outlet of the north cell
- Gravity filter bench addition to the south cell
- Pumped filter bench addition to the south cell

Generally, these scenarios were simulated by applying the hydraulically-relevant design specifications to the simulated devices in P8. These elements can include pond elevation, permanent pool area and volume, flood pool area and volume, infiltration rate, outlet type, and weir length/discharge coefficient. Table 3 summarizes how each scenario was simulated in P8.

A fifth scenario, automated alum dosing, was estimated outside of P8, using an assumed annual TP removal of 75% based on research outlined in Wagner (2017). Under this scenario, runoff originating from the 61-acre Spring Hill Golf Course drainage (north of County Road 6) would be piped to the inlet of the north cell of the ponds for treatment. This additional TP load was estimated from the 2018 monitoring record (12 samples). For each grab sample, a daily TP load was calculated from measured streamflow and TP concentration. Then, the median daily load across all samples was multiplied by 365, yielding an estimated annual load delivered to the north cell of the pond. It is estimated that 22.7 pounds of TP would be added to the County Road 6 pond under this scenario.

Table 3. Summary of P8 device conceptualization for pollutant removal scenario analysis.

Option ID	Scenario	Device Type		Description
		North Cell	South Cell	
--	Baseline	Pond	Pond	Pond dimensions reflect current pond design specs.
1	Gravity Filter Bench	Pond	General	P8 infiltration rate set to filter bench estimated infiltration rate (1.6-3.0 in/hr), upon activation. Normal spillway outflow set to HydroCAD simulated outflows.
2A & 2B	Weir	Pond	Pond	Adjusted weir dimensions based on engineering spec.
3 & 4	Pumped Filter Bench	Pond	General	P8 infiltration rate set to filter bench estimated infiltration rate (1.6-3.0 in/hr), pumping continuously. Normal spillway outflow set to HydroCAD simulated outflows.

The removal estimates for these scenarios are summarized below in Table 4. Note the tables distinguishes between the annual TP removal (total removal) and the annual TP removal gained from each scenario (total removal – baseline removal).

Table 4. TP removal scenarios.

Option ID	Scenario	TP (lbs/year)		Annual TP Removal	Annual TP Removal (Gained)	
		Inlet (north cell)	Outlet (south cell)	%	lbs/yr	%
--	Baseline	273	180	34%	0	0%
1	Gravity Filter Bench (1.6 - 3.0 in/hr)	273	113-132	52-59%	48-67	27-37%
2A & 2B	Weir (sheet pile or earthen)	273	174-176	36%	4-6	2-4%
3	Pumped Filter Bench w/ Float Switch (1.6 - 3.0 in/hr)	273	96-122	55-65%	58-84	32-47%
4	Pumped Filter Bench w/ Real Time Sensor (1.6 - 3.0 in/hr)	273	90-122	55-67%	58-90	32-50%
5	Alum Dosing Station*	296	51-102	66-83%	102-152	50-75%

*Total inlet load calculated as [273 lbs (current condition) + 23 lbs (golf course drainage)]

5.1.3 CONCEPT-LEVEL OPINION OF PROBABLE COST

Concept-level opinion of probable cost was prepared for each evaluated alternative. Itemized opinion of probable cost is included in the appendix, for reference and understanding of drivers of cost within each alternative. General and alternative specific assumptions made for each alternative are also detailed in the appendix.

5.1.3.1 Capital Costs

Capital costs were estimated for each alternative, including 30% contingency and 30% for engineering, legal, admin, and finance. Results are tabulated below.

Option ID	Alternative	Capital Cost *(construction, contingency, legal, admin, finance)*
1	Gravity Sand Filter Bench	$664,000
2A	Weir – Sheet Pile	$956,000
2B	Weir – Earthen	$206,000
3	Pumped Sand Filter Bench w/ Float Switch	$1,011,000
4	Pumped Sand Filter Bench w/ Real Time Sensor	$1,349,000
5	Alum Dosing	$3,628,000

5.1.3.2 Operations & Maintenance Costs

Operations & maintenance (O&M) costs were estimated for each evaluated alternative, considering key activities required to ensure functionality over an assumed 30-year project lifecycle. The cost of regular inspections was not included. Itemized estimates are included in Table 5 below, which show components and frequency of maintenance activities. Assumptions are also included in the Appendix.

Table 5. O&M OPC

(1) GRAVITY FILTER BENCH OPERATIONS AND MAINTENANCE COST SCHEDULE

NO.	ITEM DESCRIPTION	FREQUENCY		UNIT PRICE	30 YEAR COST
O&M COST SCHEDULE					
1	FILTER MEDIA REPLACEMENT	10	YEARS	$ 200,000	$ 600,000
	30 YEAR MAINTENACE COST TOTAL				$ 600,000

(2A and 2B) WEIR/BERM OPERATIONS AND MAINTENANCE COST SCHEDULE

ASSUME NO OPERATIONS AND MAINTENACE COSTS

(3) PUMPED FILTER BENCH W/ FLOAT SWITCH OPERATIONS AND MAINTENANCE COST SCHEDULE

NO.	ITEM DESCRIPTION	FREQUENCY		UNIT PRICE	30 YEAR COST
O&M COST SCHEDULE					
1	FILTER MEDIA REPLACEMENT	10	YEARS	$ 200,000	$ 600,000
2	PUMP REPLACEMENT	10	YEARS	$ 100,000	$ 300,000
	30 YEAR MAINTENACE COST TOTAL				$ 900,000

(4) PUMPED FILTER BENCH W/ REAL TIME SENSOR OPERATIONS AND MAINTENANCE COST SCHEDULE

NO.	ITEM DESCRIPTION	FREQUENCY		UNIT PRICE	30 YEAR COST
O&M COST SCHEDULE					
1	FILTER MEDIA REPLACEMENT	10	YEARS	$ 200,000	$ 600,000
2	PUMP REPLACEMENT	10	YEARS	$ 100,000	$ 300,000
3	OPTI-RTC SYSTEM MAINTENANCE	10	YEARS	$ 30,000	$ 90,000
	30 YEAR MAINTENACE COST TOTAL				$ 990,000

(5) ALUM DOSING FACILITY OPERATIONS AND MAINTENANCE COST SCHEDULE

NO.	ITEM DESCRIPTION	FREQUENCY		UNIT PRICE	30 YEAR COST
O&M COST SCHEDULE					
1	ALUM FACILITY MAINTENANCE	1	YEAR	$ 30,000	$ 900,000
	30 YEAR MAINTENACE COST TOTAL				$ 900,000

5.1.3.3 Lifecycle Costs

Lifecycle costs were estimated by summing estimated project capital costs and O&M costs and are shown in Table 6. Inflation and discount rates were not considered. A 30-year lifecycle was assumed for all retrofit types.

Table 6. Lifecycle Costs

Option ID	Alternative	Capital Cost	Maintenance Cost (30-year)	Lifecycle Cost
1	Gravity Sand Filter Bench	$ 664,000	$ 600,000	$ 1,264,000
2A	Weir - Sheet Pile	$ 956,000	$ -	$ 956,000
2B	Weir - Earthen	$ 206,000	$ -	$ 206,000
3	Pumped Sand Filter Bench w/ Float Switch	$ 1,011,000	$ 900,000	$ 1,911,000
4	Pumped Sand Filter Bench w/ Real Time Sensor	$ 1,349,000	$ 990,000	$ 2,339,000
5	Alum Dosing Station w/ Golf Course Drainage	$ 3,628,000	$ 900,000	$ 4,528,000

6 Evaluation of Alternatives

Qualitative and quantitative evaluation criteria were considered to compare the alternatives and inform recommendations.

6.1 Evaluation Criteria

Criteria were discussed and prioritized, in collaboration with MCWD staff. Potential project options were evaluated against criteria including: the ability of the project to achieve MCWD goals, estimated project capital and operation & maintenance costs, permitting needs and hurdles, site constraints, data needs for final design, and engineering complexity. Criteria are outlined in more detail below.

6.1.1 TOTAL PHOSPHORUS REMOVALS

The ability of alternatives to remove total phosphorus and reduce the effluent load from the CR6 Pond was identified as the primary goal of the feasibility study, and a overarching goal of MCWD. To address this goal, concept design of alternatives sought to maximize TP removal capacity of each evaluated option. Evaluation of TP removal capacity was completed via P8 water quality modeling, using a refined version of the District's P8 model for the CR6 Pond.

6.1.2 DISCHARGE RATE AND FLOOD CONTROL

To address MCWD's goals for water quantity management, this study looked at the potential to manage and maintain discharge rates, and the estimated impact on upstream and downstream flood elevations. Potential project alternatives were evaluated qualitatively for impact on discharge rate and flooding.

6.1.3 ECOLOGICAL INTEGRITY

The ability of project alternatives to support MCWD's goal to maintain and build ecological integrity through habitat restoration and preservation was evaluated qualitatively.

6.1.4 PROMOTING THRIVING COMMUNITIES

Promoting thriving communities is one of MCWD's goals. MCWD staff indicated that this goal is not a priority or applicable at the CR6 site. The pond exists on private property, with an easement that grants MCWD the ability to own and operate the pond; promoting public access at the site is not feasible under the current agreement. Furthermore, the site does not have space for safe public access or incorporation of amenities, and public access to the pond itself is not desired due to the risk of damage to engineered infrastructure and safety risks to the public due to the pond not being intended for swimming or boating. Implementing projects that will reduce TP loads to Long Lake are anticipated to have a cascade effect and improve the quality of water for the users of Long Lake.

6.1.5 CAPITAL COSTS

The capital cost to build each project alternative is a key factor in determining which project option to install so that District funds are targeted effectively to projects with the highest impact for the cost. Capital costs for each alternative were estimated based on recent bids Stantec has reviewed from similar projects in nearby geographies and further supported by engineering judgement and/or discussions with local contractors. Capital costs assumed constant percentages for Contingency (30%) and Legal, Engineering, Admin & Finance (30%). The appendix includes a summary of assumptions made to estimate costs for each project alternative.

6.1.6 OPERATION & MAINTENANCE COSTS

The operation and maintenance costs are another key factor in determining which project option to install as operation and maintenance costs can vary widely across different types of projects. Operation and maintenance costs for each alternative were estimated based on filtration media replacement costs and schedules. The appendix includes a summary of assumptions made to estimate costs for each project alternative.

6.1.7 LIFE CYCLE COSTS

The life cycle cost of a project totals expenditures over the life of the project to reflect the total cost of a project. Project lifecycles were assumed to be 30 years.

6.1.8 PERMITTING NEEDS AND HURDLES

Permitting needs and hurdles for each project were estimated based on the project site location on a public waterway and based on the proposed activity or potential impact for each alternative.

6.1.9 SITE CONSTRAINTS

Project site constraints include land rights, site access, and utilities. These site factors were evaluated for each project option.

6.1.10 ENGINEERING COMPLEXITY & DATA NEEDS

Engineering complexity and challenges as well as the level of additional data needed to move a project to final design were evaluated for each project alternative.

6.2 Evaluation Matrix

Option ID	Retrofit	Water quality benefit (TP lbs/yr)	Rate & Flood Control	Capital Costs ($)	O&M Costs ($/lifespan)	Lifecycle Cost ($/lifespan)	Cost Efficiency ($/lb TP)	O&M Requirements	Potential Regulatory Considerations	Site Constraints	Design complexity & Data needs
1	Gravity sand filter bench	48-64	Decreased pond storage & outlet modifications could impact rates and flood elevations	$664,000	$600,000	$1,264,000	$600-900	• Raking & replacement of media	- Public Waters Work Permit - May require No-Rise Certification	- Expands basin area	Low
2A	Weir (sheet pile)	4-6	Weir could impact rates and flood elevations	$956,000	$0	$956,000	$5,300-8,000	• Inspections & general maintenance	- Public Waters Work Permit - Floodplain No-Rise Certification	- Ponding area limited to existing easement	Medium
2B	Weir (earthen)	4-6	Weir could impact rates and flood elevations	$206,000	$0	$206,000	$1,100-1,700	• Inspections & general maintenance	- Public Waters Work Permit - Floodplain No-Rise Certification	- Ponding area limited to existing easement	Medium
3	Pumped sand filter bench w/ float switch	60-80	Decreased pond storage & outlet modifications could impact rates and flood elevations	$1,011,000	$900,000	$1,911,000	$800-1,100	• Raking & replacement of media • Maintenance of pump	- Public Waters Work Permit - Floodplain No-Rise Certification	- Expands basin area - Electrical service to pump	Medium
4	Pumped sand filter bench w/ real time sensor	60-94	Decreased pond storage & outlet modifications could impact rates and flood elevations	$1,349,000	$990,000	$2,339,000	$900-1,300	• Raking & replacement of media • Maintenance of pump • Setup and programming of sensor • Maintenance of sensor	- Public Waters Work Permit - Floodplain No-Rise Certification	- Expands basin area - Electrical service to pump	High
5	Alum dosing station	115-155	No impact	$3,628,000	$900,000	$4,528,000	$1,000-1,500	• Operation of station • Removal of settled floc	- Public Waters Work Permit - NPDES/SDS permit with renewals required every 5 years - Road authority permit	- Coordination with Road Authority and Golf Course - Electrical service to dosing station	High

7 Recommendations

The goal of this study was to define retrofit options for implementation at the County Road 6 Pond, to maximize TP removal prior to discharge to Long Lake. Construction of a gravity sand filter bench would be the most cost effective in terms of $/lb TP, but the gravity bench has lower TP removal potential than either of the two pumped filter bench options and the alum dosing station. The pumped filter bench provides a median option in terms of cost and removal potential, compared to the gravity filter bench and the alum dosing station. The alum dosing station provides the highest TP removal potential but requires extensive operations & maintenance efforts.

To ensure thoughtful selection of a retrofit for the CR6 Pond, additional scenarios could be investigated. For purposes of this study, it was assumed that the filter media was clean washed sand, rather than iron enhanced sand, which has the ability to remove dissolved phosphorus but may require additional maintenance. Additional scenarios could be pursued, such as evaluation of filter benches in tandem with intercepting golf course TP loads.

Depending on the alternative that is selected for advancement, additional feasibility work may need to be completed. For example, pursuit of design of an alum dosing station would require additional feasibility work, whereas work to-date is sufficient to advance design of a gravity or pumped filter bench.

Stantec

Memo

To:	Gabe Sherman, MCWD Michael Hayman, MCWD	From:	Nick Wyers, PE Rena Weis, EIT Chris Meehan, PE
Project/File:	227703704	Date:	February 10, 2023 Revised May 19, 2023

Reference: Cedar to Greenway Trail Connection

Introduction

This memo documents the updated feasibility study that was completed to progress design for the proposed trail between the Cedar Lake Trail and Meadowbrook Road in St. Louis Park. This work described within this document builds off the concept design that was completed in 2015/2016 and accounts for construction progress and changes to the original design at the SWLRT site. Two potential trail configurations were evaluated and are further described below. Streambank stabilization practices and habitat improvement opportunities between the 325 Blake Road North site and Meadowbrook Road were also identified by Inter-Fluve and are described in the attached memo.

Data Collection

Topographic and tree survey were completed on site to inform the feasibility study. Land surface, notable features, utilities, rail bridges, and key features of Minnehaha Creek were surveyed along the corridor of interest. A benchmark was established just north of Powell Road, in the boulevard, and permanent benchmarks were surveyed as well (i.e. fire hydrant top nuts, etc.). The tree survey noted tree species, condition, location, and diameter at breast height (DBH) of all trees greater than 6-inches within the proposed trail corridor and construction access routes. All trees with diameters greater than 6-inches were tagged. Survey data is provided as an attachment to this memo (CAD format). A spreadsheet containing tree survey data is also provided.

Alignment Design Considerations

Two trail alignments were evaluated. Key design criteria include maintainability, user experience, user accessibility, and natural resource impacts. Features of the two proposed alignments are relatively interchangeable with each other.

Option 1 accommodates a maximum speed of 16 mph, and Option 2 accommodates a maximum speed of 12 mph. Each option is split into two exhibits on the provided drawings. Maximum speeds are per MnDOT Bicycle Facility Design Manual guidelines and are directly related to minimum allowable turn radii.

The proposed trail would ultimately be maintained by the City of St Louis Park, and as such, it is important to ensure the trail will be maintainable with the City's standard equipment; particularly for snow clearing in the winter months. The City uses standard F150 pickup trucks with 8 ft wide plows for snow clearing, which require 10 ft wide trails and 10 ft vertical clearance. Both trail alignments considered meet these dimensional criteria. The radii associated with the 16 mph trail design will most easily accommodate pickup trucks, while the 12 mph trail design may require use of skid-steers.

The current MnDOT ADA standards are utilized in the preliminary grading layout. Some of these standards include a maximum 2% cross slope, a maximum 5% running slope, and current curb ramp standards for widths and slopes. The maximum running slope shown on the feasibility drawings is 4.30% and 4.89% for Option 1 and Option 2, respectively, which satisfies ADA requirements. The cross slope of the trail in both Option 1 and Option 2 is no greater than 2%, satisfying ADA requirements.

During the site visit, we observed large boulders / riprap beneath the rail bridges, which was placed as part of the SWLRT project. This rock will need to be moved prior to construction of a trail. The rock has little salvage value, since it is limestone based and is not suitable for use on water resources projects due to high erodibility. We estimate the quantity of rock to be 150 cubic yards.

Both trail alignments are expected to result in floodplain impacts, due to the work's proximity to Minnehaha Creek. Estimated floodplain impacts are 700 CY and 220 CY for Option 1 (16 mph) and Option 2 (12 mph), respectively.

As the trail design is further refined, utility conflicts will need to be evaluated. Most notably, there is a City watermain crossing over the creek, which intersects the proposed trail alignment, as well as a 48-inch CMP storm sewer outfall into the creek in the location of the proposed trail. Other smaller storm sewer outfalls are also present into the creek along the trail alignment. The Option 2 (12 mph) alignment cuts into the pipe cover of the watermain alignment. These impacts may require insulation of the watermain if route is selected. The 48-inch CMP outfall could possibly be downsized, as regional diversions in the area have likely reduced the required capacity the pipe, but an assessment of the contributing drainage area would be required to further inform the recommended solution. Smaller existing outfalls to the creek may be able to be consolidated into fewer pipes, reducing the number of instances when pipes cross beneath the trail. Other private utilities may be in the way adjacent to the road or the bike trail, these should be deep enough to avoid impact, but will be coordinated on final design.

Alignment Tradeoff Considerations

Both alignments were reviewed with MCWD staff, and the following tradeoffs were identified.

Option 1 (16 mph)

- Faster speed limit
- Shorter length, fewer curves, nicer overall user experience through trees south of rail bridges (see Exhibit 2)
- More tree removals (see Exhibit 2)
- More floodplain fill & bank stabilization south of rail bridges (see Exhibit 2)
- Larger trail radii north of rail bridges, resulting in easier winter maintenance & snow clearing (see Exhibit 6)

Reference: Cedar to Greenway Trail Connection

- More floodplain fill north of rail bridges (see Exhibit 3)
- Requires encroachment on private property (see Exhibit 3)
- Approximately $780,000 project cost

Option 2 (12 mph)

- Avoids impacts to trees south of rail bridge, resulting in more winding trail closer to the street, which may not be desirable to users (see Exhibit 4)
- Avoids creek impacts and minimizes floodplain fill south of rail bridges (see Exhibit 4)
- Tight trail radii north of rail bridges will result in reduced navigability during winter snow clearing (see Exhibit 7)
- Minimizes floodplain fill north of rail bridges (see Exhibit 5)
- Contained to public property (see Exhibit 5)
- Approximately $640,000 project cost

Opinion of Probable Cost

An opinion of probable cost (OPC) was prepared for each alignment option. The OPCs include items required for both civil (Stantec) and ecological / streambank (Inter-Fluve) portions of construction. Costs associated with a base bid of critical work to construct the trail connection and a bid alternate of supplemental streambank stabilization work were estimated for each alignment option. The OPCs assume 30 percent contingency of estimated construction subtotal costs. The OPCs assume legal, engineering, admin, and finance costs as 30 percent of construction cost including contingency.

The base bid for Option 1 is estimated to cost approximately $780,000, while the base bid for Option 2 is estimated to cost approximately $640,000. Major differences in cost between the two alignments are primarily driven by tree removals and earthwork. Additional costs could be incurred if retaining walls or other structural measures are deemed necessary as design progresses. Note that if the bid alternate items are completed separately from the trail construction at a later time, the cost of that alternate work will be higher due to reduced efficiencies. See attached Opinion of Probable Costs for further detail.

Permitting Discussion

Both alignment options involve natural resource impacts that will require permits from MCWD and other regulatory agencies. We anticipate that the other regulatory agencies with jurisdiction are the MnDNR; USACE; and City of St Louis Park, serving in the capacity of Local Floodplain Administrator. Key activities triggering regulatory authority are work in public waterbodies associated with floodplain fill and streambank stabilization. We anticipate that a Work in Public Waters Permit and USACE 404 permit will need to be obtained, as well as a no-rise certificate approved by the City. Required MCWD permits will include Floodplain Alteration; Streambank & Shoreline Stabilization; Erosion Control; and possibly Waterbody Crossings & Structures, depending on the scope of work associated with altering outfalls to the creek.

Reference: Cedar to Greenway Trail Connection

Note that the provided alignments depict the following three different estimated 100-year floodplain extents along the trail corridor:

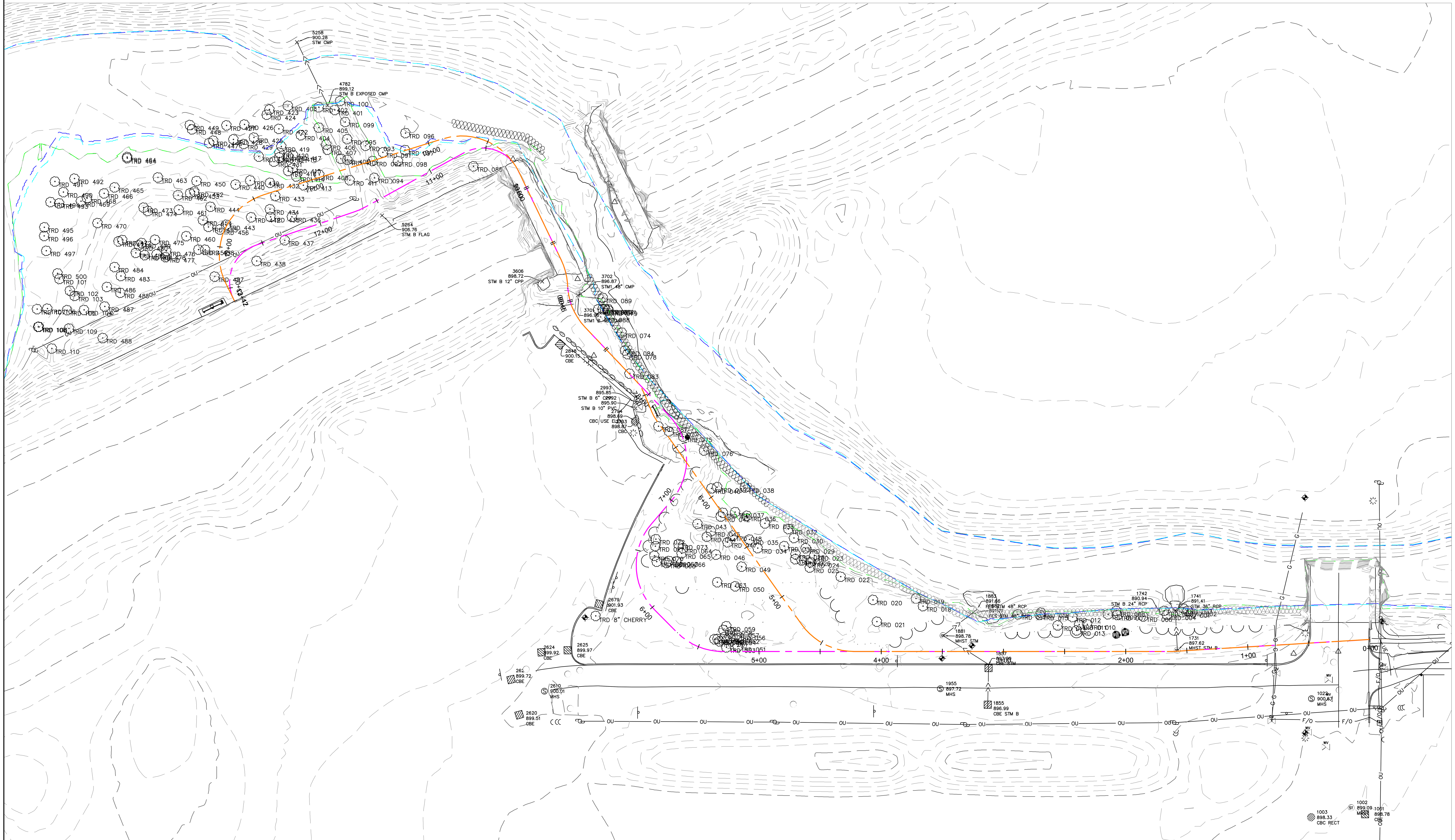
1. XP-SWMM floodplain - taken from MCWD XP-SWMM model, drawn based on LiDAR
2. HEC-RAS floodplain - taken from Inter-Fluve's reach-specific HEC-RAS model, drawn based on LiDAR
3. Interpolated survey floodplain - XP-SWMM floodplain elevation, drawn based on surveyed topography, rather than LiDAR

The interpolated survey floodplain extent is the most conservative, though floodplain modeling can and should be refined as design progresses.

Recommendations & Next Steps

Based on discussions with MCWD staff, it is recommended that the alignment shown by Option 1 be carried forward into design, based on Option 1's higher speed limit, better anticipated user experience, and larger radii to accommodate winter maintenance. However, Option 1 results in more significant natural resource impacts than Option 2, requiring more tree removal and more floodplain fill. Therefore, before design is advanced, it is recommended that floodplain modeling be completed to better evaluate the potential impacts and mitigation options for the anticipated floodplain fill. Furthermore, conversations should be facilitated with impacted property owners, as Option 1 does require the use of private property.

PROPOSED TRAIL ALIGNMENTS



	OPTION 1 (16 MPH)
	OPTION 2 (12 MPH)
	FLOODPLAIN (SWMM)
	FLOODPLAIN (HEC-RAS)
	FLOODPLAIN (INTERPOLATED SURVEY)
	BANK RESTORATION AREA
	BANK RESTORATION AREA (ALTERNATE #1)

0 40 80 Feet

N

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CLIENT:

MINNEHAHA CREEK WATERSHED DISTRICT

PROJECT TITLE:

MCWD CEDAR-GREENWAY TRAIL CONNECTION

CITY OF HOPKINS
DAKOTA COUNTY, MINNESOTA

ISSUE NO.:	DESCRIPTION:	DATE:
0	FEASIBILITY STUDY	11/04/2022

CERTIFICATION:

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

NOT FOR CONSTRUCTION

LICENSE NO.: ____________

DATE: ____________

PROJECT NO.: 227703704

DWN BY:	CHK'D BY:	APP'D BY:
JRP	RW	CM

ISSUE DATE: 11/04/2022

ISSUE NO.: 0

SHEET TITLE:

OVERALL ALIGNMNENT PLAN

SHEET NO.:

EXHIBIT 1

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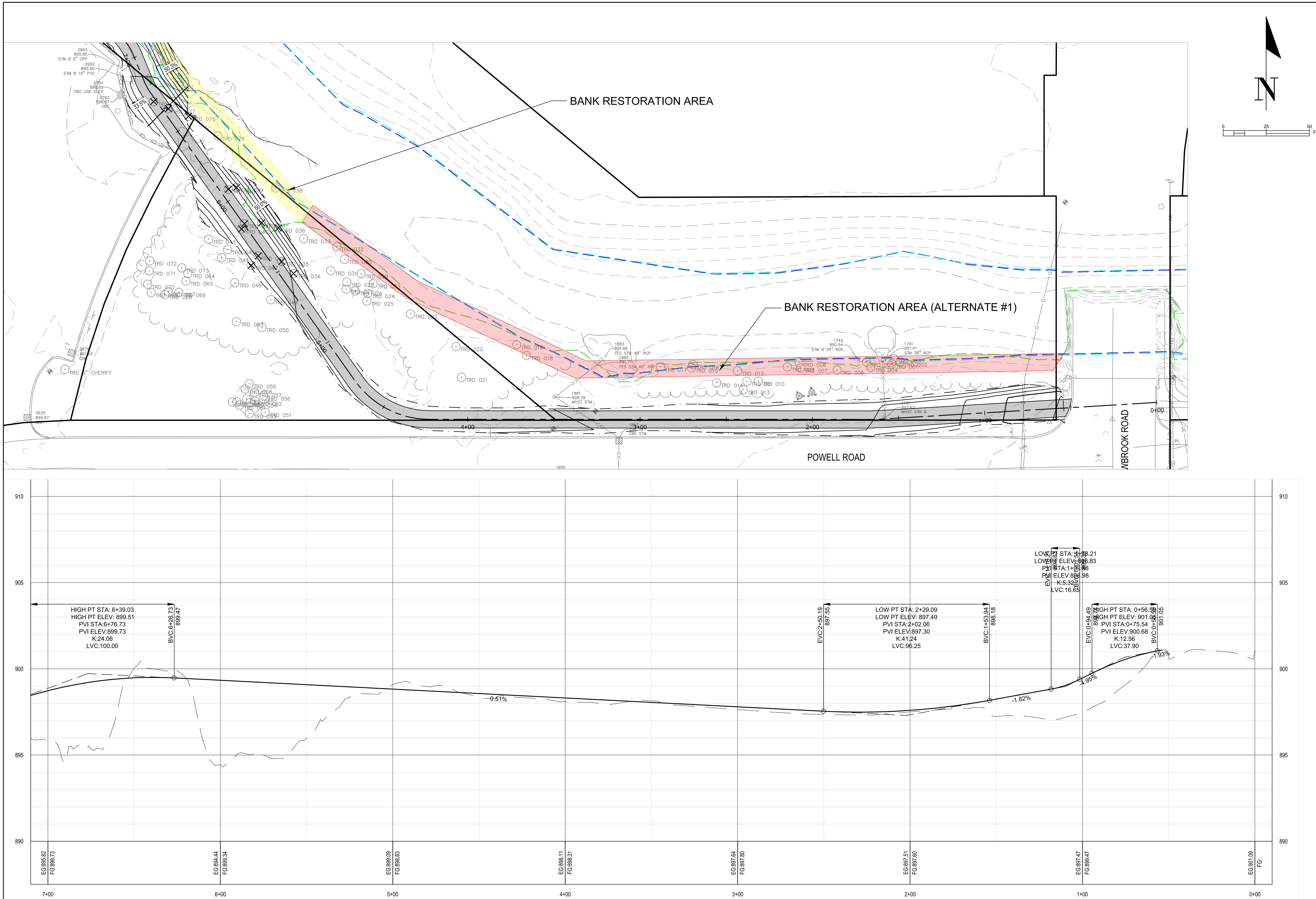

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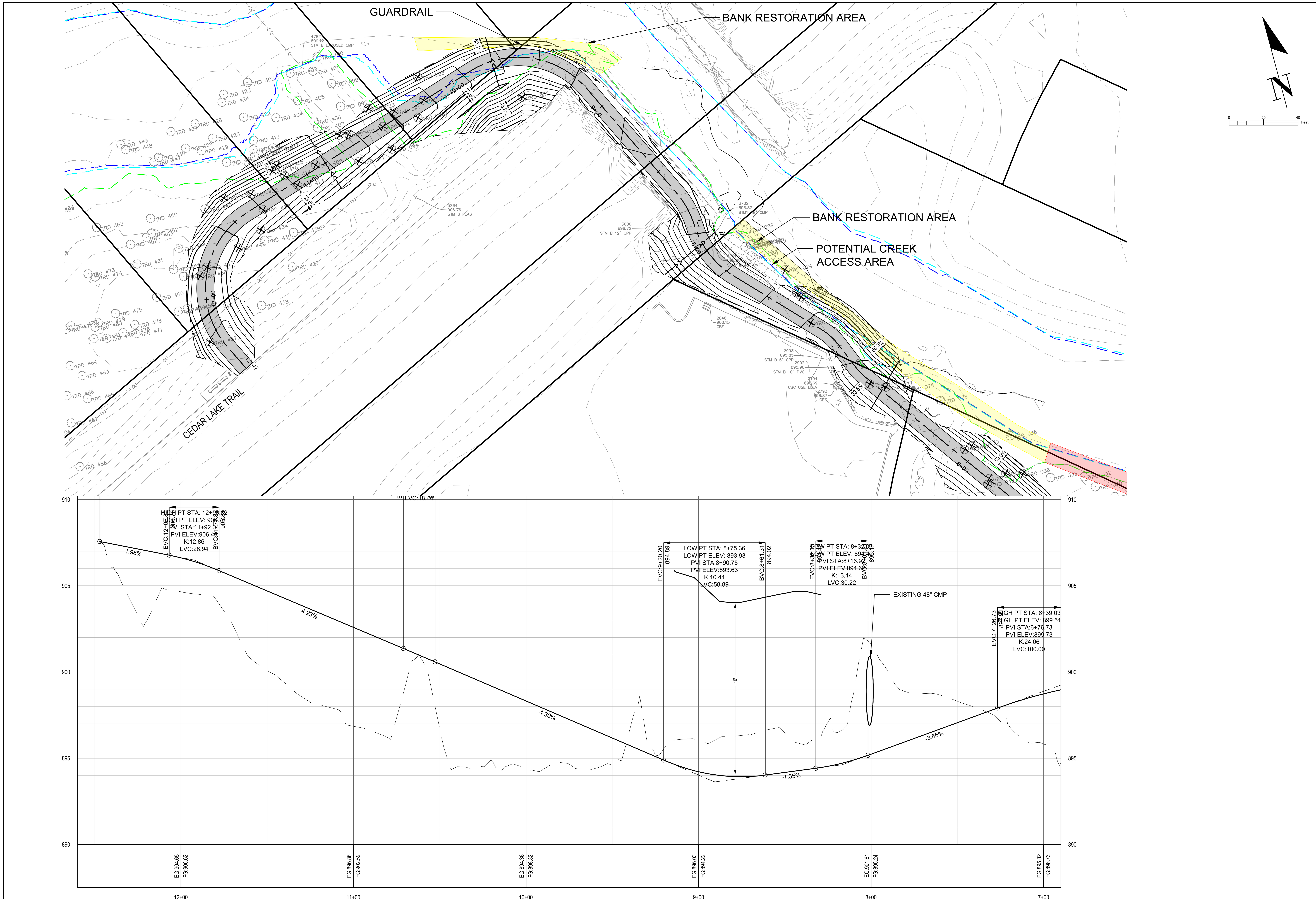
ISSUE DATE: 11/04/2022
ISSUE NO.: 0

SHEET TITLE:
OPTION 1 - 16 MPH

SHEET NO.:
EXHIBIT 2



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CITY OF HOPKINS
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ISSUE DATE: 11/04/2022
ISSUE NO.: 0
SHEET TITLE: OPTION 1 - 16 MPH
SHEET NO.: EXHIBIT 3

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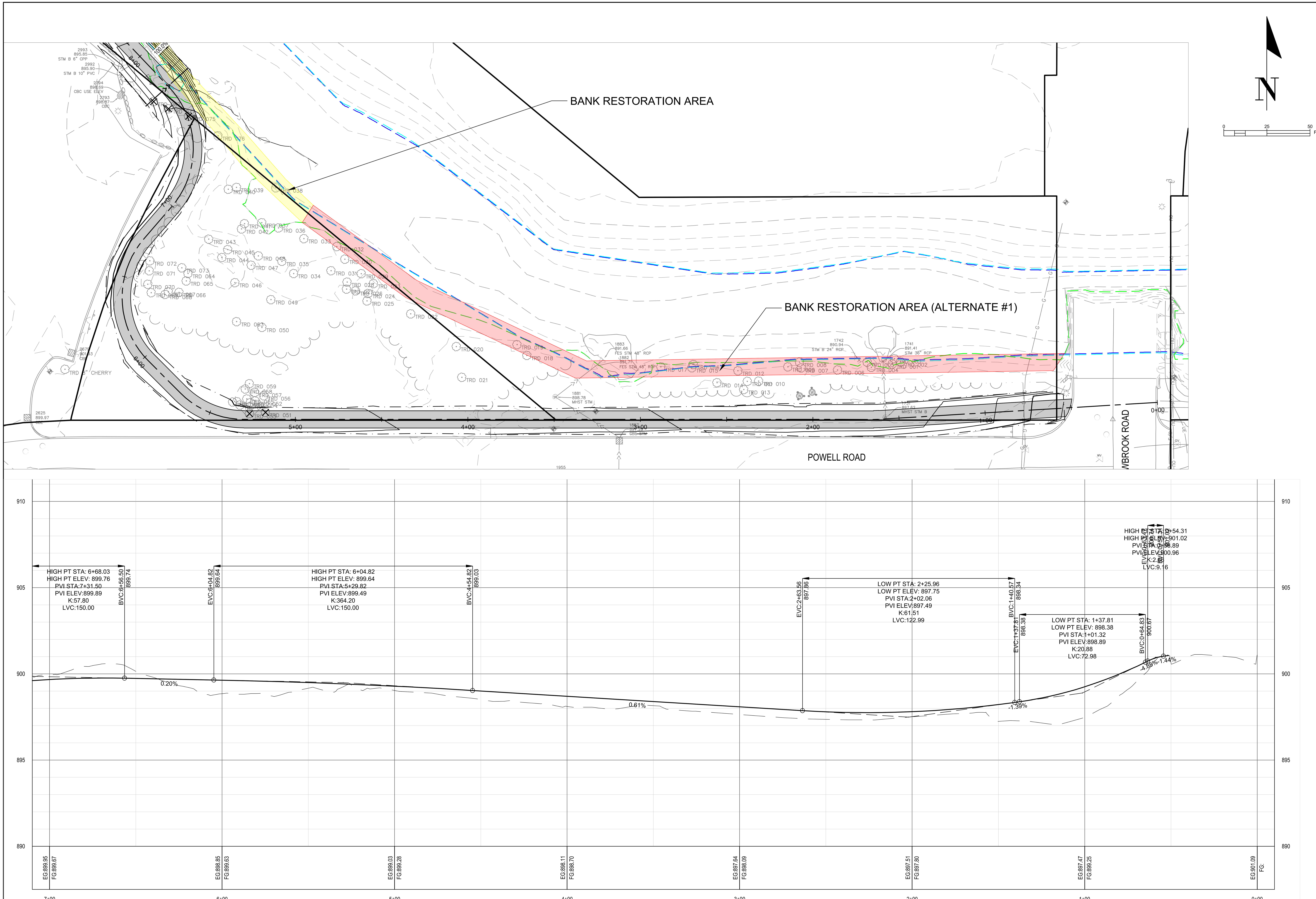

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MINNEHAHA CREEK WATERSHED DISTRICT

PROJECT TITLE:

MCWD CEDAR-GREENWAY TRAIL CONNECTION

CITY OF HOPKINS
DAKOTA COUNTY, MINNESOTA

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JRP	RW	CM

ISSUE DATE: 11/04/2022

ISSUE NO.: 0

SHEET TITLE:

OPTION 2 - 12 MPH

SHEET NO.:

EXHIBIT 4

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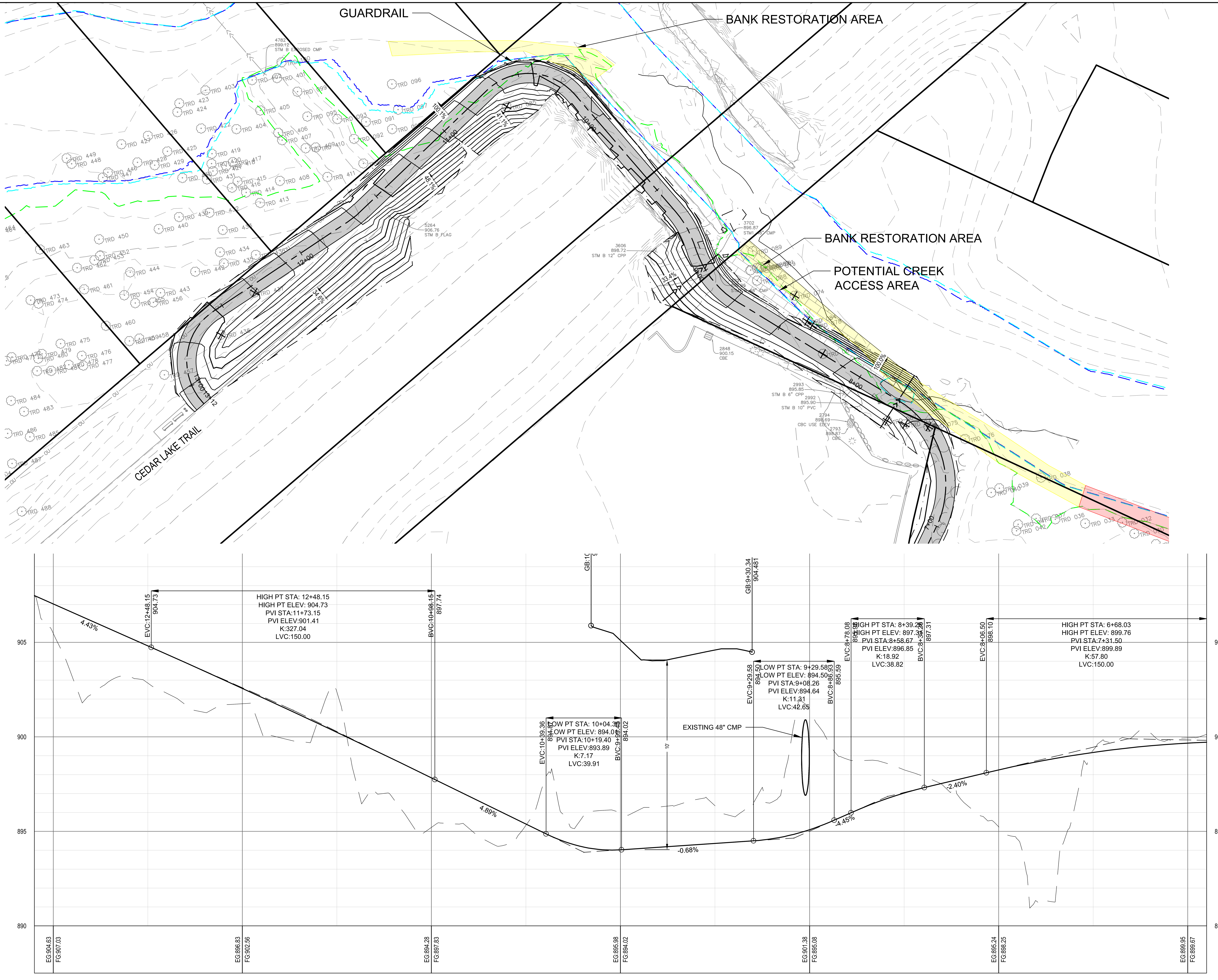

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CLIENT:

MINNEHAHA CREEK WATERSHED DISTRICT

PROJECT TITLE:

MCWD CEDAR-GREENWAY TRAIL CONNECTION

CITY OF HOPKINS
DAKOTA COUNTY, MINNESOTA

ISSUE NO.	DESCRIPTION	DATE
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JRP	RW	CM

ISSUE DATE: 11/04/2022

ISSUE NO.: 0

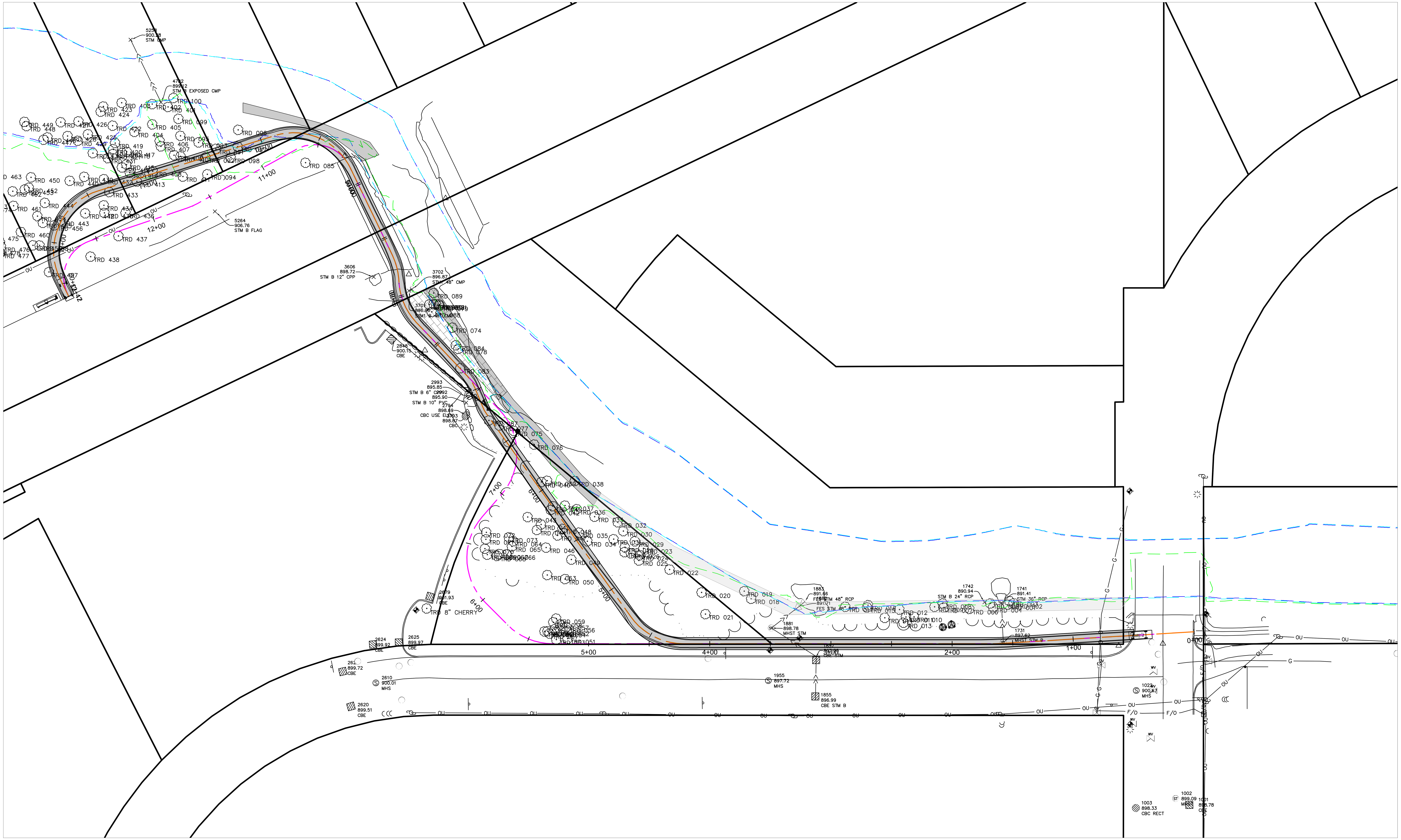
SHEET TITLE:

OPTION 2 - 12 MPH

SHEET NO.:

EXHIBIT 5

\\us0242-ppfss01\shared_projects\227703704\drafting\5_DESIGN\1_CAD\2 EXHIBITS\227703704-Exhibit 2 - Option 1.dwg



OPTION 1 (16 MPH)
OPTION 2 (12 MPH)
FLOODPLAIN (SWMM)
FLOODPLAIN (HEC-RAS)
FLOODPLAIN (INTERPOLATED SURVEY)

0 40 80 Feet

N

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CLIENT: MINNEHAHA CREEK WATERSHED DISTRICT

PROJECT TITLE:

MCWD CEDAR-GREENWAY TRAIL CONNECTION

CITY OF HOPKINS
DAKOTA COUNTY, MINNESOTA

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LICENSE NO.: ____

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PROJECT NO.: 227703704

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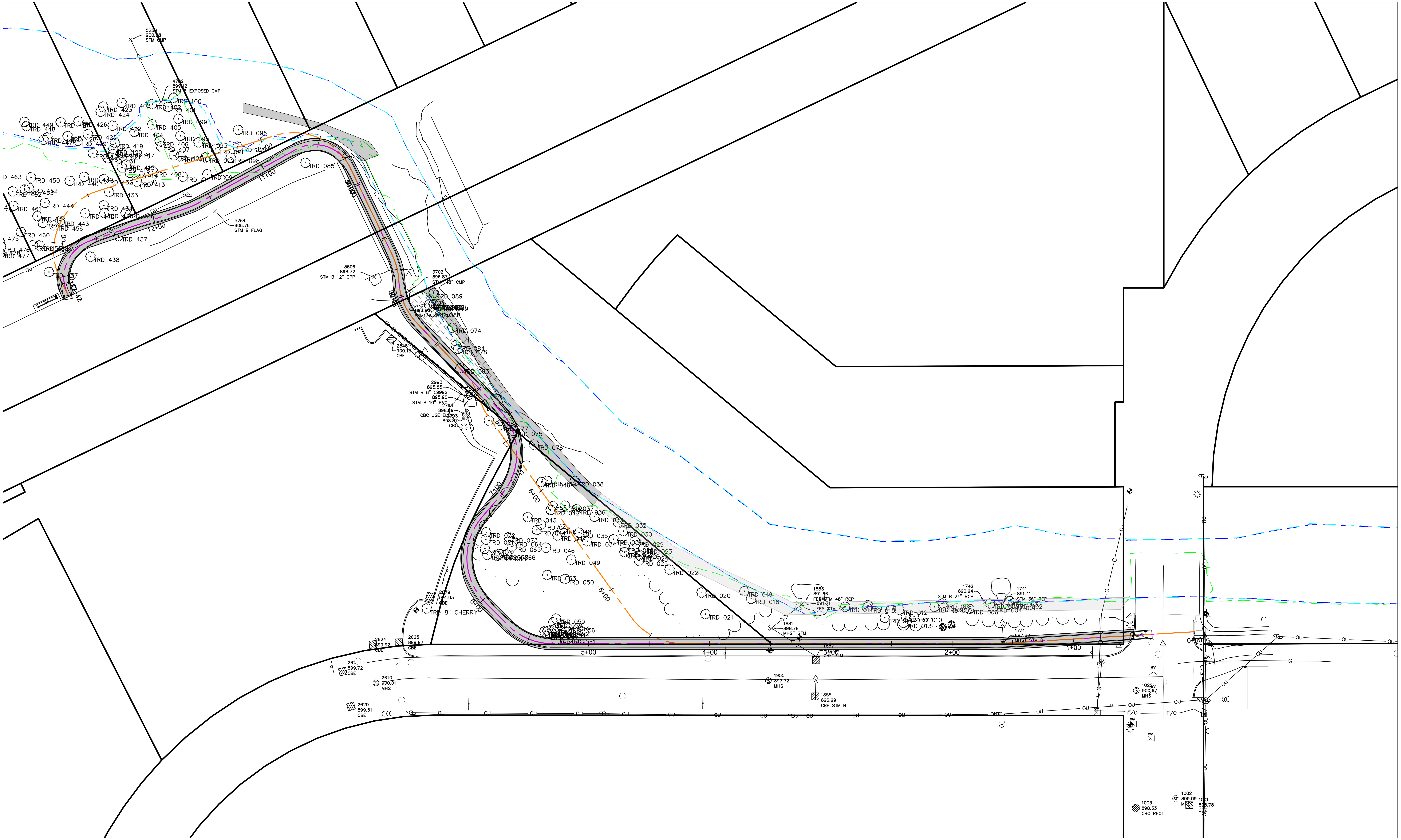
JRP	RW	CM

ISSUE DATE: 11/04/2022

ISSUE NO.: 0

SHEET TITLE: 16 MPH VEHICLE TRACKING

SHEET NO.: EXHIBIT 6



OPTION 1 (16 MPH)
OPTION 2 (12 MPH)
FLOODPLAIN (SWMM)
FLOODPLAIN (HEC-RAS)
FLOODPLAIN (INTERPOLATED SURVEY)

0 40 80 Feet

N

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CLIENT:
MINNEHAHA CREEK WATERSHED DISTRICT

PROJECT TITLE:
MCWD CEDAR-GREENWAY TRAIL CONNECTION
CITY OF HOPKINS
DAKOTA COUNTY, MINNESOTA

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0	FEASIBILITY STUDY	11/04/2022

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NOT FOR CONSTRUCTION

LICENSE NO.: ____

DATE: ____

PROJECT NO.: 227703704

DWN BY:	CHK'D BY:	APP'D BY:
JRP	RW	CM

ISSUE DATE: 11/04/2022

ISSUE NO.: 0

SHEET TITLE:
12 MPH VEHICLE TRACKING

SHEET NO.:
EXHIBIT 7

OPINION OF PROBABLE COST

OPINION OF PROBABLE COST
MINNEHAHA CREEK WATERSHED DISTRICT
CEDAR TRAIL GREENWAY
227703704
FEASIBILITY STUDY
3/3/2023

NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
16 MPH DESIGN					
1	MOBILIZATION	LS	1	$ 56,000.00	$ 56,000.00
2	DEWATERINGS & EROSION/SEDIMENT CONTROL	LS	1	$ 37,000.00	$ 37,000.00
3	CLEAR & GRUB TREE	EA	41	$ 1,000.00	$ 41,000.00
4	COMMON EXCAVATION - ONSITE	CU YD	1000	$ 20.00	$ 20,000.00
5	COMMON EXCAVATION (FLOODPLAIN) - ONSITE	CU YD	1500	$ 20.00	$ 30,000.00
6	COMMON EXCAVATION - OFFSITE	CU YD	500	$ 25.00	$ 12,500.00
7	COMMON BORROW	CU YD	820	$ 30.00	$ 24,600.00
8	REMOVE RIPRAP	LS	1	$ 15,000.00	$ 15,000.00
9	AGGREGATE BASE CLASS 5	TON	800	$ 22.00	$ 17,600.00
10	3" BITUMINOUS WALK	SQ FT	12000	$ 3.50	$ 42,000.00
11	PEDESTRIAN CURP RAMP	EA	1	$ 2,000.00	$ 2,000.00
12	GUARD RAIL	LIN FT	85	$ 100.00	$ 8,500.00
13	CM PIPE SEWER	LIN FT	140	$ 100.00	$ 14,000.00
14	TRAFFIC CONTROL	LS	1	$ 2,000.00	$ 2,000.00
15	STONE TOE	CU YD	308.00	$ 180.00	$ 55,440.00
16	FES LIFTS	LIN FT	1050.00	$ 50.00	$ 52,500.00
17	IMPORTED FES LIFT BACKFILL (TOPSOIL)	CU YD	147.00	$ 30.00	$ 4,410.00
18	SITE ACCESS AND RESTORATION	LS	1	$ 18,000.00	$ 18,000.00
19	WETLAND IMPACTS	SQ YD	630	$ 15.00	$ 9,450.00
	SUBTOTAL				$ 462,000.00
	[30%] CONTINGENCY				$ 138,600.00
	TOTAL CONSTRUCTION COST				$ 600,600.00
	30% LEGAL, ENGINEERING, ADMIN, FINANCE				$ 180,180.00
	TOTAL PROJECT COSTS				$ 780,780.00

NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
ALTERNATE #1: ADDITIONAL BANK RESTORATION					
A.1	MOBILIZATION	LS	1	$ 8,000.00	$ 8,000.00
A.2	STONE TOE	CU YD	132.00	$ 180.00	$ 23,760.00
A.3	FES LIFTS	LIN FT	450.00	$ 50.00	$ 22,500.00
A.4	IMPORTED FES LIFT BACKFILL (TOPSOIL)	CU YD	63.00	$ 30.00	$ 1,890.00
A.5	SITE ACCESS AND RESTORATION	LS	1	$ 5,000.00	$ 5,000.00
	SUBTOTAL				$ 61,150.00
	[30%] CONTINGENCY				$ 18,345.00
	TOTAL CONSTRUCTION COST				$ 79,495.00
	30% LEGAL, ENGINEERING, ADMIN, FINANCE				$ 23,848.50
	TOTAL ALTERNATE COSTS				$ 103,343.50

	TOTAL BASE + ALTERNATE BID	$ 884,123.50

OPINION OF PROBABLE COST
MINNEHAHA CREEK WATERSHED DISTRICT
CEDAR TRAIL GREENWAY
227703704
FEASIBILITY STUDY
3/3/2023

NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
12 MPH DESIGN					
1	MOBILIZATION	LS	1	$ 46,000.00	$ 46,000.00
2	DEWATERINGS & EROSION/SEDIMENT CONTROL	LS	1	$ 31,000.00	$ 31,000.00
3	CLEAR & GRUB TREE	EA	10	$ 1,000.00	$ 10,000.00
4	COMMON EXCAVATION - ONSITE	CU YD	800	$ 20.00	$ 16,000.00
5	COMMON EXCAVATION (FLOODPLAIN) - ONSITE	CU YD	1500	$ 20.00	$ 30,000.00
6	COMMON EXCAVATION - OFFSITE	CU YD	500	$ 25.00	$ 12,500.00
7	COMMON BORROW	CU YD	50	$ 30.00	$ 1,500.00
8	REMOVE RIPRAP	LS	1	$ 15,000.00	$ 15,000.00
9	AGGREGATE BASE CLASS 5	TON	850	$ 22.00	$ 18,700.00
10	3" BITUMINOUS WALK	SQ FT	12700	$ 3.50	$ 44,450.00
11	PEDESTRIAN CURP RAMP	EA	1	$ 2,000.00	$ 2,000.00
12	GUARD RAIL	LIN FT	65	$ 100.00	$ 6,500.00
13	CM PIPE SEWER	LIN FT	110	$ 100.00	$ 11,000.00
14	TRAFFIC CONTROL	LS	1	$ 2,000.00	$ 2,000.00
15	STONE TOE	CU YD	308.00	$ 180.00	$ 55,440.00
16	FES LIFTS	LIN FT	1050.00	$ 50.00	$ 52,500.00
17	IMPORTED FES LIFT BACKFILL (TOPSOIL)	CU YD	147.00	$ 30.00	$ 4,410.00
18	SITE ACCESS AND RESTORATION	LS	1	$ 18,000.00	$ 18,000.00
19	WETLAND IMPACTS	SQ YD	180	$ 15.00	$ 2,700.00
	SUBTOTAL				$ 379,700.00
	[30%] CONTINGENCY				$ 113,910.00
	TOTAL CONSTRUCTION COST				$ 493,610.00
	30% LEGAL, ENGINEERING, ADMIN, FINANCE				$ 148,083.00
	TOTAL PROJECT COSTS				$ 641,693.00

NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
ALTERNATE #1: ADDITIONAL BANK RESTORATION					
A.1	MOBILIZATION	LS	1	$ 8,000.00	$ 8,000.00
A.2	STONE TOE	CU YD	132.00	$ 180.00	$ 23,760.00
A.3	FES LIFTS	LIN FT	450.00	$ 50.00	$ 22,500.00
A.4	IMPORTED FES LIFT BACKFILL (TOPSOIL)	CU YD	63.00	$ 30.00	$ 1,890.00
A.5	SITE ACCESS AND RESTORATION	LS	1	$ 5,000.00	$ 5,000.00
	SUBTOTAL				$ 61,150.00
	[30%] CONTINGENCY				$ 18,345.00
	TOTAL CONSTRUCTION COST				$ 79,495.00
	30% LEGAL, ENGINEERING, ADMIN, FINANCE				$ 23,848.50
	TOTAL ALTERNATE COSTS				$ 103,343.50

	TOTAL BASE + ALTERNATE BID	$ 745,036.50

TREE REMOVAL TABULATION

Tree Removal Tabulation

tag_id	condition	dbh	comment	common_name	16 MPH Removal	12 MPH Removal
34		22, 24	2 stems	Cottonwood	1	0
35		7		Boxelder	1	0
36		8, 5	two stems	Boxelder	1	0
37	Dead	7			1	0
39	Dying	14 (dead), 14		Boxelder	1	0
40	Dying	18		Boxelder	1	0
41		9		Boxelder	1	0
42		11		Boxelder	1	0
47		9		Boxelder	1	0
48	Dead	6		Boxelder	1	0
51		14		Boxelder	0	1
53		24, 28, 25, 24	quad stem	Cottonwood	0	1
74		6		American Elm	1	1
75		20		Boxelder	1	1
77		10		Boxelder	1	1
78		11, 10, 13		Boxelder	1	1
83		13, 12, 8		White Mulberry	1	1
84		6		White Mulberry	1	1
85		9		Black Cherry	1	1
87		7		White Mulberry	1	1
91		6		Boxelder	1	0
92		9		White Mulberry	1	0
93	Dead	14, 12 (both dead)	very dead		1	0
94		6		White Mulberry	1	0
96		9		Green Ash	1	0
97		7		White Mulberry	1	0
98		7		Boxelder	1	0
408		8		Boxelder	1	0
409		20		Boxelder	1	0
410		7		Boxelder	1	0
411		7, 6		Common Buckthorn	1	0
413		36		Cottonwood	1	0
414		7		Bur Oak	1	0
415		15		Green Ash	1	0
416		8		Green Ash	1	0
432		10		Boxelder	1	0
433		6		Boxelder	1	0
434		27		Bur Oak	1	0
437		12		Bur Oak	0	1
438		11		Bur Oak	0	1
439		20, 11		Green Ash	1	0
442		6		Common Buckthorn	1	0
443		28, 28		Cottonwood	1	0
456		7		Cottonwood	1	0
457		11		Bur Oak	1	0

*In each design alternate column, "1" indicates anticipated tree removal

INTER-FLUVE MEMO: STREAMBANK EVALUATION

MEMORANDUM

To: Rena Weis and Chris Meehan, PE; Stantec

From: Sean Morrison, Maren Hancock, PE, and Jonathon Kusa, PE; Inter-Fluve, Inc.

Date: March 1, 2023 Project: Greenway to Cedar Trail Connection Project

Re: Preliminary Reach Assessment Findings

Inter-Fluve staff completed a preliminary reach assessment of Minnehaha Creek between the downstream reach of the 325 Blake Road site and Meadowbrook Road, adjacent to the location of the planned Cedar Lake Trail connection project. The reach appeared vertically stable with some lateral erosion along the outside of meander bends, and infrastructure induced erosion as a result of hardened streambanks and stream crossings.

Due to the proximity of the proposed alternative trail alignments to the Creek, a structural and hydraulic analysis of bank treatment and stabilization alternatives will be necessary as a next step for the project to limit the risk of future erosion impacts to the proposed trail. Hydraulic modeling of this reach will be needed to identify the appropriate bank treatment type and any additional modifications necessary to avoid impacts to the floodplain and 100-year water surface elevation, if feasible.

Though we understand that due to funding limitations additional habitat and creek improvement projects will likely not be included in this phase, Inter-Fluve identified a "Future Opportunities Area" in which there are a number of projects that could be implemented to improve habitat availability, complexity, and stream function, as funding becomes available.

EXISTING CONDITIONS ASSESSMENT

A preliminary reach assessment was completed of the subject reach of the Minnehaha Creek in order to identify feasibility constraints associated with the proposed Cedar Trail connection and to identify stream restoration opportunities within the project area. The proposed trail project will connect the Cedar Lake Regional Trail from its crossing of the Minnehaha Creek parallel to the Southwest Light Rail Transit (SWLRT) bridge to Meadowbrook Road via a new trail segment on the south side of the creek extending underneath the series of bridges at the SWLRT crossing and along the creek bank and shoulder of Powell Road.

Inter-Fluve staff walked the reach starting from the downstream limit of the Blake Road development project to Meadowbrook Road on September 26, 2022. At the time of the assessment, discharge from the Grey's Bay Dam was 0 cubic feet per second (cfs.) There was some flow in the assessment reach, which was likely a result of stormwater discharge from recent rains.

Overall, the reach was found to be vertically stable with a pool-riffle morphology. In general, streambank erosion was limited to areas where infrastructure impacts were noted (as shown in Figure 1 below), and floodplain connectivity was minimal. A representative cross-section measured for this reach had a 51-foot bankfull width, and 1-foot bankfull depth (Figure 1). The cross-section also showed an inset floodplain bench approximately 2 feet below an elevated terraced located between the Cedar Lake Regional Trail and the creek. The terrace was dominated by a buckthorn (*Rhamnus cathartica*) understory. This two-stage cross-section characteristic has previously been noted by Inter-Fluve throughout the Minnehaha Creek corridor and is understood to be a function of the regulated hydraulic regime of the Creek.

Riffle material throughout the reach was dominated by rounded gravels and cobbles. There was a deep pool at Station 20+00, which was un-wadable at the time of the survey. This pool provided a refuge for aquatic species in the otherwise mostly dewatered creek. A canoe/kayak dock in disrepair was located on the river left margin of the pool (Figure 2).

At Station 17+00, a water main pipe extended over the creek. Based on topography, the pipe was buried, but not below the floodplain/floodplain terrace, resulting in a lateral mound bisecting the floodplain (Figure 1). The utility crossing appeared undersized (at approximately 35-feet-wide) and constricts the channel based on bank erosion noted downstream of the crossing. Downstream of the utility crossing, a privately owned cinder block wall replaced the natural bank on river left (Figure 3).

Bank erosion was present on either side of the creek upstream of the Cedar Trail/SWLRT/BNSF crossing, and downstream of the crossing on river right (Figure 4). Downstream of the crossing, several floodplain bars were present and colonized with reed canary grass. Granite slabs and wood piles were located on the right bank and in the channel at the location of an assumed previous crossing. Immediately upstream of the Meadowbrook Road crossing, concrete slabs were found on the right bank

Large and small debris (e.g., bikes, pieces of construction debris, road signs, trash, etc.) was noted throughout the corridor.

IMPROVEMENT OPURTUNITIES

Inter-Fluve identified several creek improvement opportunities along this reach. These include improvements along the connection corridor that will be required for the Cedar Trail connection project to be implemented, as well as several improvements identified in a Future Opportunities Area that could be implemented to improve habitat availability and complexity, and stream function, if additional funding becomes available.

Creek Improvements Necessary for Cedar Trail Connection Project

Inter-Fluve noted bank erosion in the creek along the proposed trail connection corridor, specifically in the segment where the proposed trail alignments are nearest the creek immediately upstream and downstream of the Cedar Trail/SWLRT/BNSF bridge crossings. Due to the close proximity of the proposed connection-trail to the creek, bank stabilization will be necessary to prevent hydraulically-induced bank erosion impacting the trail. Two trail alignments were provided by Stantec (Figure 6). The bank stabilization treatment type will be a function of the proposed trail design and grades, and results of hydraulic modeling. Due to the close proximity of the trail and creek, there is the potential that the bank stabilization work may encroach on the creek's channel, potentially necessitating bank shaping work on the opposite side of the creek (if feasible) to match existing regulatory flood elevations. It is anticipated that bank stabilization will be needed to support trail implementation both upstream and downstream of the Cedar Trail/SWLRT/BNSF crossing. Additional areas may be in need of bank stabilization and restoration depending on the proximity of the proposed trail to the creek and the desire to mediate existing stormwater outfalls.

Next steps for the design of this project include hydraulic modeling to assess the impact on the creek, the type of stabilization treatment needed, and potential impacts requiring treatment on adjacent areas.

A budgetary Engineers Opinion of Probable Construction Costs (EOPCC) is included in Table 1. The EOPCC includes an estimate for a bioengineering bank stabilization treatment that is assumed to be sufficient to support the project needs. However, additional design analysis and hydraulic modeling will be needed to determine if the assumed treatment will be appropriate for this creek segment. Additionally, hydraulic modeling will be necessary to review flood flow impacts resulting from the work and assess if any potential impacts can be mitigated through adjustment on the opposite bank. The EOPCC assumes a volume of earthwork needed for this purpose, but that volume is only a high-level estimate at this time. Additional design and modeling for the trail construction may determine that geotechnical or structural solutions are needed for the bank to support the trail which are not included in the EOPCC. Additional potential improvement opportunities including aquatic and riparian habitat improvements, resetting of the stormwater outlet riprap with a focus on the outlet shown in Figure 5, and invasive species removal are not included in the EOPCC. Proposed items mentioned in the Future Opportunities Area section (below) are also not included in the EOPCC.

Future Opportunities Area

Inter-Fluve identified the portion of the reach including the utility crossing and buckthorn dominated terrace as a "Future Opportunities Area" (Figure 6) with a number of projects that could be implemented as funding allows. Potential projects in this area include:

- Address undersized utility crossing to restore creek function and minimize creek impacts. This could include replacing the crossing with wider crossing (potentially with a bridge and trail connection to Edgebrook Dr.), or burring the utility line below the floodplain and creek. Also address impacts to bisected floodplain.
- Create backwater wetland in floodplain terrace to improve floodplain connection and backwater habitat availability adjacent to refuge pool. This could include buckthorn removal and revegetation with native species.
- Remove man-made debris (including canoe/kayak dock)
- Invasive species removal
- Meet with the landowner to discuss acceptability/feasibility of coordinating on a project to replace the cinderblock wall and restore creek bank and floodplain connection

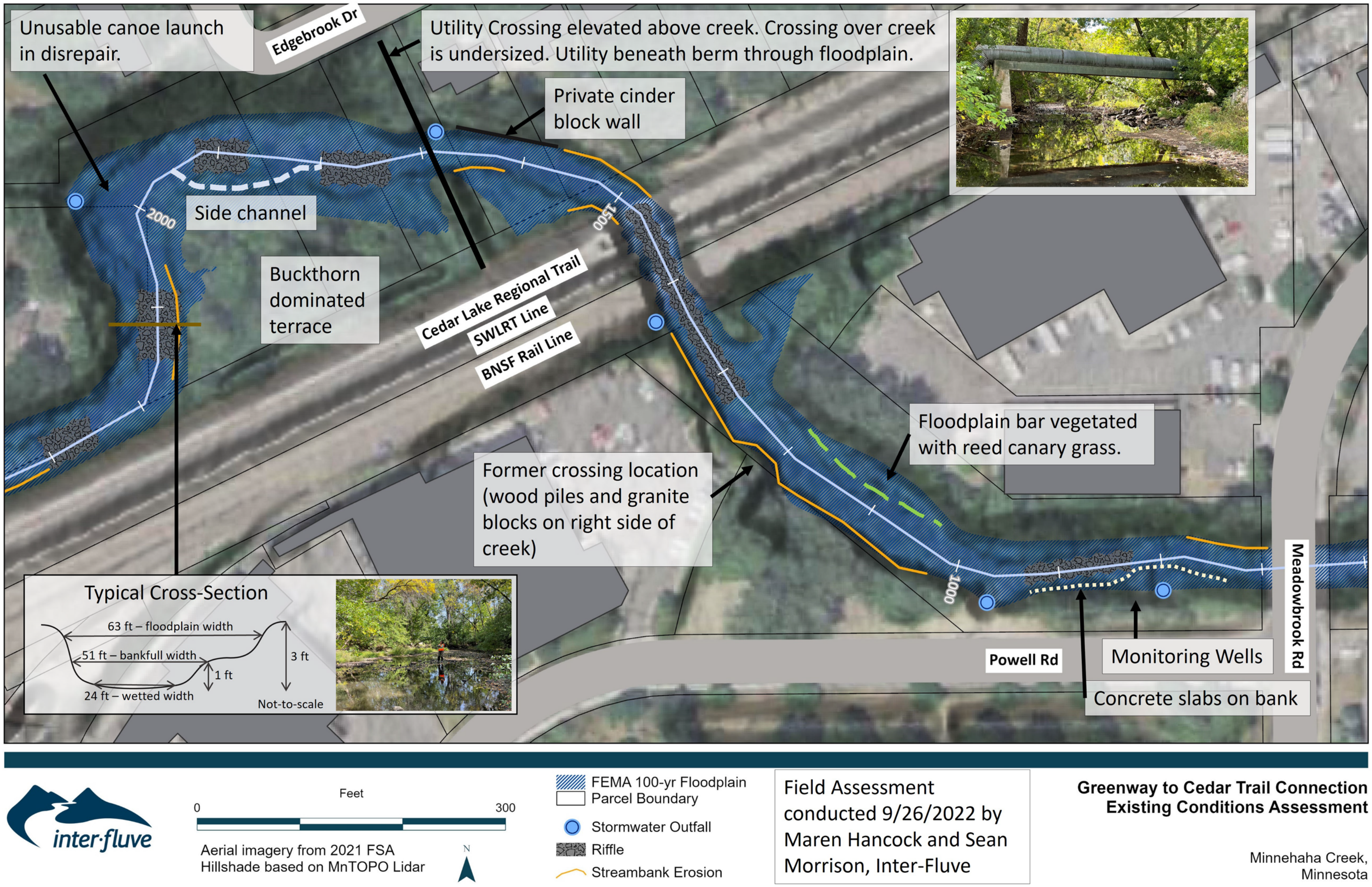

Figure 1: Existing conditions of the assessed reach.

Figure 2: Pool and unusable canoe/kayak dock.

Figure 3: Cinderblock wall downstream of utility crossing.

Figure 4: Bank erosion downstream of Cedar Lake Trail crossing.

Figure 5: Outfall along connection corridor.

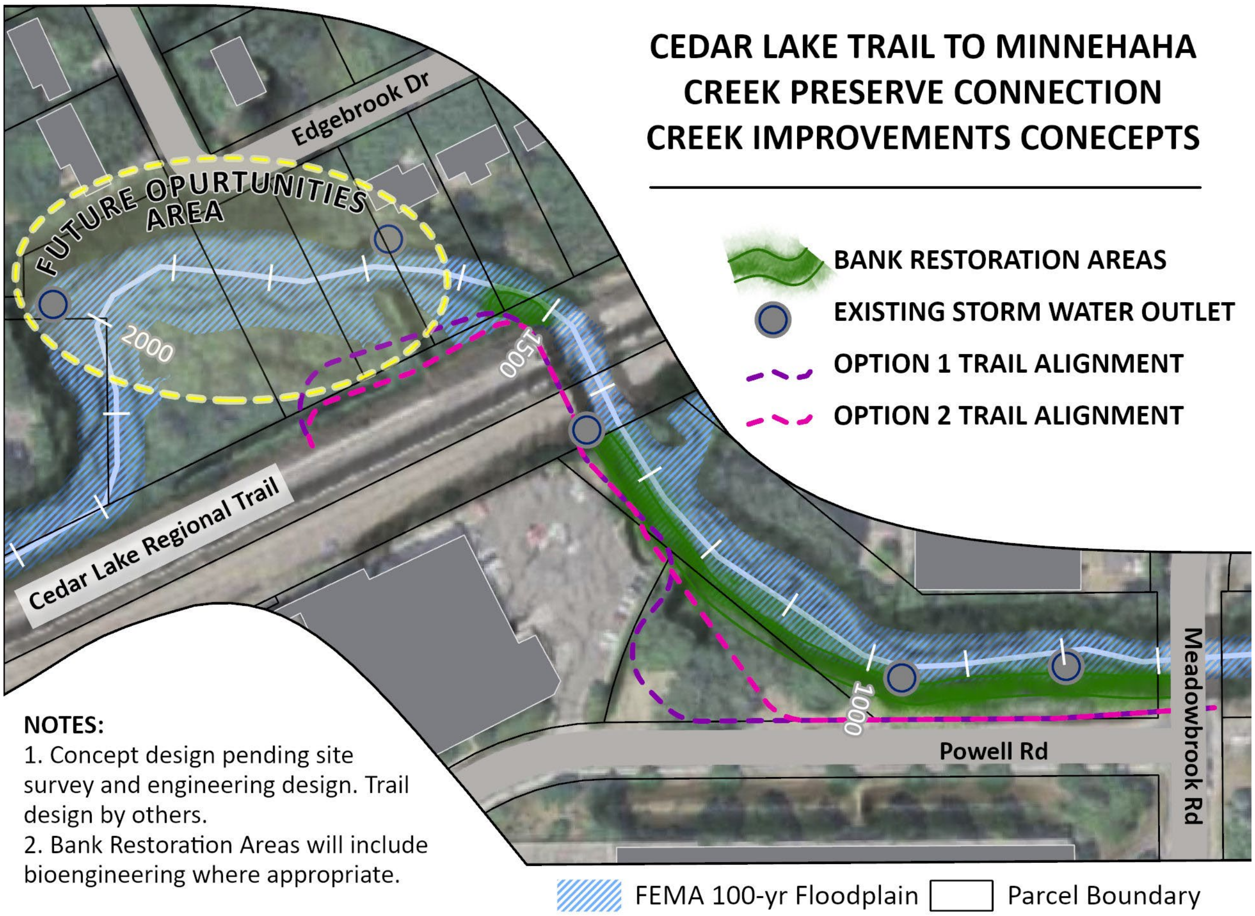

Figure 6: Concept design for bank stabilization along Connection corridor.

Table 1: EOPCC for Cedar Trail to Minnehaha Preserve bank stabilization.

Cedar Trail to Minnehaha Preserve Trail Connection - Bank Toe Stabilization Budgetary Engineer's Opinion of Probable Construction Cost December 2022						
Item #	**Item**	**Unit**	**Quantity**	**Unit Cost**	**Sub Total**	**Notes**
1	MOBILIZATION AND DEMOBILIZATION	LUMP SUM	1	$31,000	$31,000	Assumes 15% of overall cost
2	DEWATERING & EROSION/SEDIMENT CONTROL	LUMP SUM	1	$21,000	$21,000	Assumes 10% of overall cost
3	STONE TOE	CY	440	$180	$79,200	Assumes subgrade excavation and filter gravel are incidental
4	FES LIFTS	FACE FT	1,500	$50	$75,000	Assumes three FES lift layers over stone toe
5	IMPORTED FES LIFT BACKFILL (Topsoil)	CY	210	$30	$6,300	
6	FLOODPLAIN BENCH CUT/EARTHWORK	CY	1,500	$10	$15,000	Assumes estimated volume for cut on opposite bank; 67% cut material reused onsite for fill
7	EXPORT CLEAN FILL	CY	500	$20	$10,000	Assumes 33% cut material exported, assumes clean fill
8	REVEGETATION AND RESTORATION	LUMP SUM	1	$20,000	$20,000	Assumes seeding and shrub planting in restored areas.
		Rounded Subtotal			$258,000	
		Contingency		40%	$103,000	
		ESTIMATED TOTAL			**$361,000**	
		AACE Class 4 Low Range (-30%)			$253,000	
		AACE Class 4 High Range (+50%)			$542,000	
		Engineering, Design, and Permitting			**$110,000**	

Additional Assumptions - (1) Stone toe and FES lift bank design will be used (no structural bank solutions, walls, reinforcement, etc.) (2) A permittable design is achievable through floodplain bench cutting on opposite bank to achieve no-rise conditions. (3) No resetting of stormwater outlet riprap is included. (4) Structural and civil work for bank stabilization and trail are separate items not included in this EOPCC.