Feasibility Report

Middle Riley Creek Stabilization

Prepared for
Riley Purgatory Bluff Creek Watershed District

March, 2020

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Riley Purgatory Bluff Creek Watershed District and the City of Eden Prairie

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Certifications

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.

March 3, 2020

Scott Sobiech PE #: 41338

Date

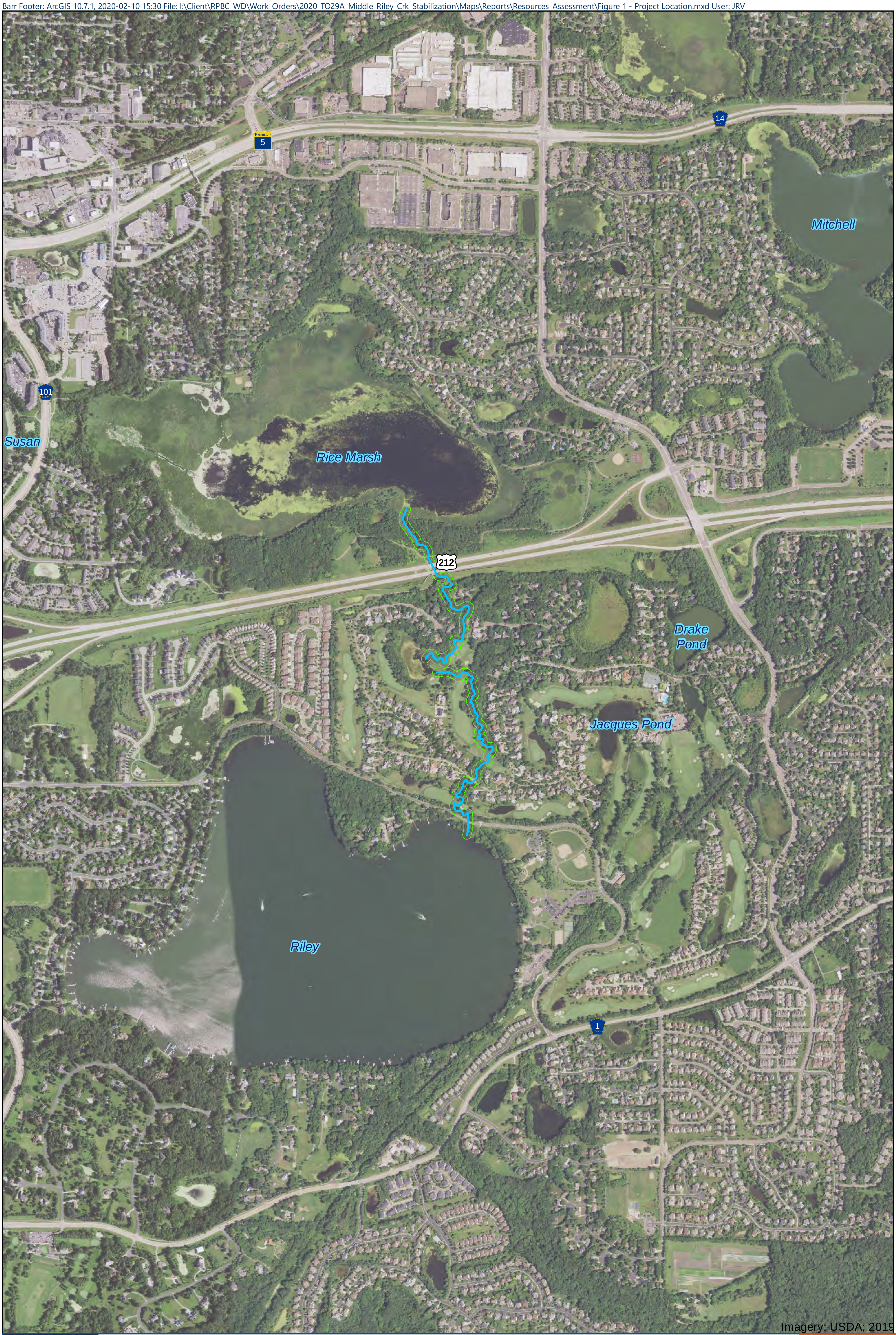
1.0 Context and Goals for this Feasibility Study

This document was written to guide stream stabilization and ecological and habitat enhancement efforts within Riley Creek immediately upstream of Lake Riley (i.e. the Middle Riley Creek Stabilization Project, or Project) as shown in Figure 2-1. The project partners include the Riley Purgatory Bluff Creek Watershed District (RPBCWD) and Bearpath Golf and Country Club (Bearpath). This partnership was created when Bearpath approached the RPBCWD requesting coordination to restore a section of the stream that has resulted in erosion of golf course features. Bearpath will be a funding partner with RPBCWD for the Project. This Feasibility Study documents the goals of the partnership for the Middle Riley Creek Stabilization Project, outlines the proposed restoration conceptual designs, reviews project impacts and permitting requirements, and recommends a restoration approach.

2.0 Vision, Goals, and Project Approach

The vision for this Project is to provide an ecologically diverse stream reach that significantly reduces streambank erosion and provides diverse habitat layers. Presently, this reach has a primarily sandy channel bed with limited riffle/pool variability and poor riparian habitat. The Project will provide greater stream depth variability, more channel bed substructure types, and varied channel velocities. The proposed Project will reduce erosion and improve water quality while also improving natural stream habitat for aquatic organisms. By establishing a stable stream corridor, the Project will also address the Minnesota Pollution Control Agency's (MPCA's) identified nutrient impairment in Lake Riley and aid in protecting the district investment in the Lake Riley alum treatment.

As part of the Project partners planning processes, each have established goals intended to protect, restore, and enhance water resources while also providing a natural stream corridor through the golf course that meets the aesthetic and use goals for Bearpath Golf and Country Club. Table 2-1 provides a summary of how the Project aligns with these goals.



RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Riley Creek Centerline

Project Area

0 500 1,000

Feet

PROJECT LOCATION
Middle Riley Creek Stabilization

Figure 2-1

Table 2-1 Summary of Partner Goals and Project

Partner	Goals	How Project Aligns with Goal
RPBCWD	Design, maintain, and implement Education and Outreach programs to educate the community and engage them in the work of protecting, managing, and restoring water resources. (EO 1)	The project will educate the Bearpath community that is near and recreational users on the project itself but also stewardship ideas that they can implement.
	Include sustainability and the impacts of climate change in District projects, programs, and planning.	The District is going to utilize sustainable materials as part of the project.
	Protect, manage, and restore water quality of District lakes and creeks to maintain designated uses. (WQual 1)	The project is restoring an eroding portion of Reach R3 of Riley Creek.
	Preserve and enhance habitat important to fish, waterfowl, and other wildlife.(WQual 3)	The project will enhance the creek corridor which includes both terrestrial and aquatic habitats. The project will enhance the aquatic habitats by stabilizing eroding streambanks. Furthermore, the project will reduce habitat fragmentation by reconnecting the creek with the terrestrial uplands.
	Protect and enhance the ecological function of District floodplains to minimize adverse impacts. (WQuan 1)	The project will reconnect the creek to the floodplain which will also help increase of pollutant removal, promote infiltration and enhancing the ecological habitat.
	Limit the impact of stormwater runoff on receiving waterbodies. (WQuan 2)	The project will dissipate the energy of stormwater runoff entering the creek at stormwater sewer discharge at location.
Bearpath	Erosion and Sediment Control – To manage erosion and slope failure along the Hole 16 green and the Hole 13 tee box	The project will stabilize the streambanks and reconnect the stream to the floodplain which will dissipate the energy of the runoff, enhance pollutant removal, minimize streambank erosion, and reduce sediment discharge downstream.
	Maintain the aesthetics of the original Jack Nicklaus designed golf course	The project will work with Bearpath to develop plantings, orient project features, and use landscape options (i.e. boulder rock walls) to meet the original design intent for the golf course
	Provide native plant habitat buffer along the stream that can be easily managed by golf course staff	The project will use native plantings that will provide an ecologically diverse ecosystem in the stream buffers and limit the need for active management

This plan intends to adopt an adaptive management approach to restoring Middle Riley Creek. An adaptive management approach evaluates the project performance following implementation and then determine if further actions are necessary to maintain the restoration.

This project looks to mitigate and prevent additional erosion of streambanks and foster the use of natural materials and bioengineering principals for the restoration and maintenance of stream reaches whenever feasible. Technical stakeholders, including the USACE and MNDNR, have expressed a preference for bioengineering over hard armoring for stream stabilization where possible. Bioengineering techniques maintain more of a stream's natural function and provide better habitat and a more natural appearance than hard armoring.

3.0 Location

Reach R3 (Figure 4-1) is approximately 6,000 feet long and located in the middle portion of Riley Creek as it flows to the Minnesota River. Most of the reach is located in Bearpath Golf and Country Club, within the City of Eden Prairie, and has a watershed area of approximately 6 square miles.

4.0 Land Use History

Prior to European settlement, the entire Riley Creek watershed was located in an ecoregion known as the Big Woods, where oak woodland and maple-basswood forests were the dominant vegetation types. As settlement occurred, much of the landscape was initially converted to farmland. As urban development spread outwards from the Minneapolis core, areas of farmland then became converted to urban and suburban landscapes. This conversion is ongoing in some of the undeveloped areas of Riley Creek watershed.

In 1996 plans were developed for the creation of the Bearpath Golf and Country Club and its surrounding residential development within Eden Prairie. The land was converted from agricultural to residential with large green space for the golf course. A primarily natural stream corridor was maintained along the Middle Riley Creek. Three different zoning classifications are found in the vicinity, including public, residential, and rural. Adjacent land use is primarily residential.

RILEY CREEK

Figure 4-1

Riley Creek Reach R3 Centerline

Imagery: Hennepin Co., 2019

0 175 350

Feet

1 inch = 350 feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

5.0 Existing Conditions

5.1 Vegetation

A stream corridor assessment was completed in November 2017 (Appendix A) for the Reach R3B section (HWY 212 to Lake Riley) by RPBCWD staff. Figure 5-1 through Figure 5-4, illustrate the various vegetation in Reach R3B. The landscape starting at Highway 212 and working downstream includes forest and residential land-use types. Large oaks and a few smaller trees made up most of the forest canopy. Groundcover is sparse; with leaf litter covering much of the forest floor at the time of the assessment.

Continuing downstream of the existing wetland, the stream consists of primarily wetland vegetation, with tall sedges and cattails surrounding the immediate banks then transitions back to mostly deciduous forest with moderate shrub cover. Ground cover within the deciduous forest is patchy; some areas are bare, while others have a considerable amount of cover.

The third subreach, which starts upstream of Bearpath Trail and ends near Lake Riley Road, is surrounded primarily by the golf course and wetland grasses and sedges before it crosses Riley Lake Road.

The riparian width along this corridor is generally 90-ft but can be narrower (5-15ft) in areas where golf course features are located close to the stream channel.

Figure 5-1 Deciduous forest downstream of Highway 212

Figure 5-2 Stream entering wetland within the reach

Figure 5-3 Stream along golf course near Hole 16 green (between Bearpath Trail and Riley Lake Road)

Figure 5-4 Erosion upstream of crossing with Lake Riley Road

5.2 Soils and Hydrology

Several different soil types are found in the Project area, as described in Table 5-1**Error! Reference source not found.**. These soil types have moderate susceptibility to erosion and are generally considered hydric.

Table 5-1 Summary of Soils Conditions within the Project Area

Soil Type	Typical Soil Slopes	Erosion Susceptibility	Hydric Status
Angus Loam	2-6 percent slopes	Moderate	Hydric
Hamel, Overwash-Hamel complex	0-3 percent slopes	Slight	Hydric
Lester-Kilkenny complex	6-10 percent slopes	Severe	Hydric
Lester-Metea complex	6-12 percent slopes	Severe	Hydric
Lester Loam	6-10 percent slopes	Severe	Hydric
Lester Loam	10-16 percent slopes	Severe	Not Hydric
Lester Loam	10-22 percent slopes	Severe	Not Hydric
Muskego, Blue Earth, and Houghton complex	0-1 percent slopes	Slight	Hydric
Tadkee-Tadkee, depressional, complex	0-2 percent slopes	Slight	Hydric

Riley Creek and several wetlands are the primary hydrologic resources in the Project area. Downstream of the project reach, Riley Creek enters Lake Riley before traveling through a steep valley, where it is known as Lower Riley Creek, then flowing to the Minnesota River. The project reach includes sections of wetland hydrology, where the stream has relatively low velocity and a wide, shallow channel (primarily upstream portion of the reach) then transitions to a narrower, meandering channel downstream of Bearpath Trail. Table 5-2Table 5-2 summarizes the flow rates in Reach R3 for design storm event of various sizes.

Table 5-2 Summary of Design Flows within the Project Area

Design Event	Upstream Project Location (cfs)	Downstream Project Location (cfs)
1 year	2.6	13
2 year	3.8	21
10 year	12	50
100 year	50	125

5.3 Hydraulics

Hydraulic models at the project location indicate moderate water velocity throughout the reach. The velocities found at the north (Hole 13 Tee Box) and south (Hole 16 Green) project locations are shown below in Table 5-3.

Table 5-3 Summary of Design Velocities and Shear Stress in the Project Area

Design Event	Upstream Project Location		Downstream Project Location	
	Velocity (fps)	Shear Stress (lbs/ft^2)	Velocity (fps)	Shear Stress (lbs/ft^2)
1 year	0.74	0.17	0.58	0.19
2 year	0.91	0.21	0.66	0.22
10 year	1.39	0.35	0.72	0.37
100 year	1.93	0.59	0.7	0.81

Specific stabilization measures should be selected and designed based on expected velocities and shear stresses within the channel for all sites and reaches. Published threshold values for stabilization measures can be used to make final selection of stabilization criteria. Examples of published threshold criteria are presented in **Error! Reference source not found.**.

Table 5-4 Published threshold values for selected stabilization techniques

Stabilization Technique	Allowable Velocity (fps)	Allowable Shear Stress (lbs/ft^2)
Sandy loam soil[a]	1.75-2.25	0.045-0.05
Stiff clay[a]	3-4	0.26
Riprap (12-in D_{50})[a,b] Including rock riffles	10-13	5.1
Riprap (24-in D_{50})[a,c] Including rock vanes	14-18	10.1
Rootwads[d]	N/A	N/A
VRSS and Toewood[d]	N/A	N/A

a – from Reference (2)
b – for use in constructed riffles and grade control
c – for use in rock vanes
d – design and installation guidelines in References (3) and (4)

Based on the design velocity and shear stress values rootwads and other bio-engineering practices or riprap appear sufficient for bank stabilization at both upstream and downstream project locations.

5.4 Water Quality Impairments

The MPCA maintains a list of impaired waters for the state of Minnesota. In general, a creek is considered impaired if it fails to meet one or more of the state's water quality standards presented in Table 5-5. Waters that are not able to meet their designated uses due to exceeding water quality standards are considered impaired. Riley Lake and Lower Riley Creek, from Lake Riley to Grass Lake, both located downstream of the project reach, are included on the MPCA's 2018 Inventory of Impaired Waters (Reference (4)) for several impairments as summarized Table 5-6.

States must develop a list of impaired waters that require total maximum daily load (TMDL) studies and routinely coordinate with the U.S. Environmental Protection Agency (EPA) for study approval. A TMDL study identifies the maximum amount of a certain pollutant that a body of water can receive without violating water quality standards and allocates that amount to the pollutant's sources. The MPCA completed a Watershed Restoration and Protection Strategy (WRAPS) study for the Lower Minnesota River in 2019, including a TMDL study for Lake Riley.

Table 5-5 MPCA Water Quality Standards

Water Quality Parameter	MPCA Water Quality Standard
Total Phosphorus (summer average, µg/L)	100
Chlorophyll *a* (summer average, µg/L)	18
Secchi Disc Transparency (summer average, m)	NA
Total Suspended Solids (mg/L)	30
Daily Dissolved Oxygen Flux (mg/L)	3.5
Biological Oxygen Demand (5 day) (mg/L)	2
Escherichia coli (# per 100 mL)	126 [3]
Chloride (mg/L)	230

Table 5-6 Riley Creek and Minnesota River Impairments

Waterbody	Impaired Use	Pollutant or Stressor	Year Listed	TMDL Study Target Start	TMDL Study Target Completion	TMDL Study Approved
Lake Riley	Aquatic Consumption[1]	Mercury in Fish Tissue[3]	2002		2020	--
	Aquatic Life[1]	Fishes Bioassessments	2018		2029	
	Aquatic Recreation[1]	Nutrient/eutrophication biological indicators	2002		2019	
Riley Creek	Aquatic Life	Turbidity	2002	2014	2019	--
	Aquatic Life[1]	Aquatic Macroinvertebrate Bioassessments	2018		2019	
	Aquatic Life[1]	Fishes Bioassessments	2018		2019	
	Aquatic Recreation[1]	Escherichia coli	2018		2019	
	Aquatic Consumption	Mercury in Fish Tissue[3]	1998	1998	2025	--
Minnesota River	Aquatic Life	Nutrients/Eutrophication	2016	2014	2019	--
	Aquatic Life	Turbidity	1996	2014	2019	--
	Aquatic Consumption	PCB in Fish Tissue	1998	1998	2025	--
	Aquatic Consumption	Mercury in Water Column	1998	--	--	2008[2]
	Aquatic Consumption	Mercury in Fish Tissue	1998	--	--	2008[2]

[1] Included on the MPCA's 2018 impaired waters list.
[2] Covered under the statewide mercury TMDL, approved in 2007.
[3] Mercury impairments for Lake Riley and Staring Lake are not covered by the statewide mercury TMDL due to mercury in fish tissue exceeding a threshold value of 0.57 mg/kg.

5.5 Wetlands

The USFWS National Wetlands Inventory (NWI) located a wetland at the center of the proposed Project area. This wetland is classified as a freshwater emergent wetland surrounding a freshwater pond and is approximately 4.3 acres in size. The proposed Project area extends approximately 0.77 acres into the wetland. North of Highway 212, the NWI identified approximately 0.22 acres of freshwater emergent wetland and freshwater forested/shrub wetland in the proposed Project area extending into Rice Marsh Lake. The NWI also identified approximately 0.01 acres of a lake (Lake Riley) within the proposed Project area south of Riley Lake Road.

5.6 Stream Geomorphic Assessment

The Riley Creek channel through this reach varies from a shallow, low gradient channel with wetland vegetation in the upstream half to a narrow, moderate gradient channel in the downstream reach. The channel bed material consists of primarily sandy mixtures with a few areas including silt.

The upstream reach (from HWY 212 to Bearpath Trail) is generally the wider, shallow section with wetland vegetation characteristics. This section has established vegetation along the banks with limited channel development (riffle/run/pool sequences). The exception to this is in the area within the vicinity of the Hole 13 Tee on Bearpath Golf Course that is narrower and experiencing bank erosion. Bankfull conditions from the November 2017 stream walk indicate this reach is approximately 22-ft wide by 1.8-ft deep.

Downstream of Bearpath Trail, the stream becomes more narrow and sinuous. Bankfull indicators were at approximately 1.5-feet deep and 8 to 10-ft wide during the January 2020 site walk. This section has fair channel development (riffle/run/pool) due to the presence of well-defined pools in the bends, however riffle sequences were not observed.

Additional geomorphological data should be collected during the design phase, including a check of the bankfull indicators, topographic survey, and identification of a reference reach.

5.7 Streambank Erosion

Riley Creek near the project location shows moderate erosion that contributes to the stream's sediment loading. While not extremely severe, erosion has led to an incised channel with reduced floodplain connectivity and a lack of natural habitat in some areas along the reach.

Streambanks at bends within this reach are 4 to 6 feet tall, with vertical side slopes that are predominantly non-vegetated. The vegetation surrounding the riparian area is a mix of natural woods and grasses, along with landscaped features located in the Bearpath Golf Course. Due to the channel depth at the bends, the creek has limited access to the floodplain in these locations. Based on MDNR regional curves and USGS regression equations, Riley Creek should have a mean bankfull depth of 1.5 to 2.5 feet, instead of the current approximate depth of 4 feet in many locations.

The instability within Reach R3 could be caused by a gradual increase in runoff volume and increased peak flow rates, which occur as the result of development in the watershed. Development in the watershed is shown below in **Error! Reference source not found.** and Figure 5-7, which compare the aerial imagery at the project site from 1991 and 2018.

Instability could also result from the meander patterns of the stream, with higher shear stress along the outside of sharp bends increasing erosion along those bends. Several sharp bends are present both at the north and south site locations. While meanders are important for stream health, inadequate protection or bank vegetation, combined with high flows, could cause an increase in erosion at these locations, increasing sediment loading.

5.8 Wildlife

The Riley Creek corridor includes an upland deciduous forest providing potential habitat for a diversity of organisms, such as fish, including green sunfish, fathead minnow, and bluntnose minnow; amphibians, such as frogs, toads, and salamanders; birds such as bald eagles, hawks, heron, wood ducks, and perching birds; and mammals, such as fox, deer, squirrels, beaver, and muskrats. Wildlife found in the Project area are primarily expected to be habitat generalists due to the present lack of high-quality habitat through a majority of this Riley Creek reach.

The proposed Project area north of Highway 212 is located within a Central Region Regionally Significant Ecological Area (RSEA; Reference (5)). In general, RSEAs include places where intact native plant communities and/or native animal habitat are still found in the region and continue to provide important ecological functions. The Project's location within these designated areas enhances the importance of improving local habitat quality and diversity.

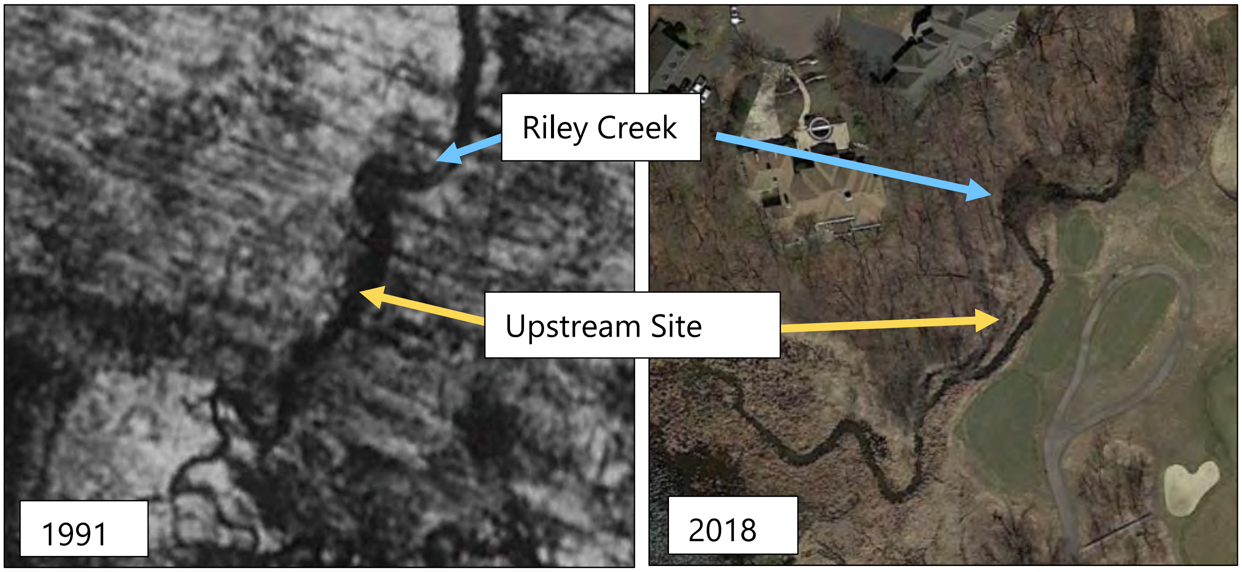


Figure 5-5 Aerial images of upstream project location from 1991 and 2018

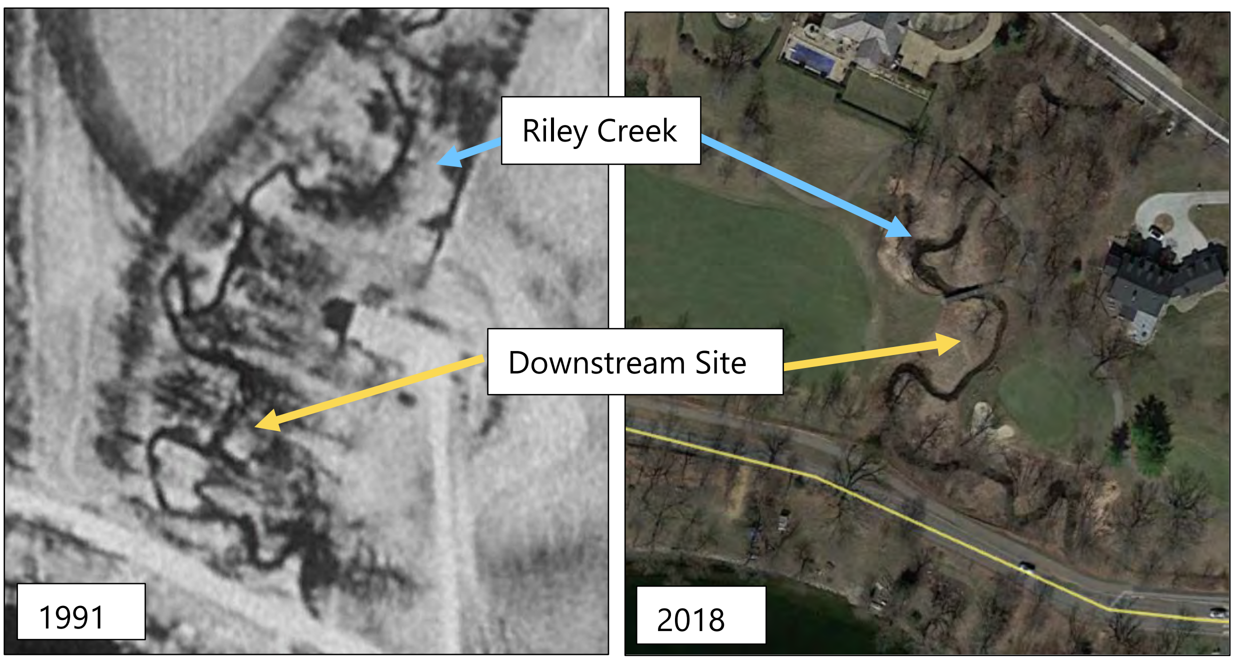


Figure 5-6 Aerial images of downstream project location from 1991 and 2018

5.9 Geotechnical Assessment Hole 16 Green

Barr completed a desktop geotechnical stability assessment of existing conditions at the Hole 16 green in January 2020. The purpose of the assessment was to obtain an initial understanding of the stability of the site, as well as provide a feasibility assessment for potential stabilization options. The stability assessment was performed using Slope/W software developed by Geoslope of Calgary, Alberta.

A review of nearby well logs (MWI) and Web Soil Survey (USDA) data was used to determine a soil profile and engineering parameters for the stability assessment. This data suggests that the site generally consists of lean clay soils. Based on typical engineering values for this soil type, a moist unit weight of 14.5 kN/m^3 was used. A soil friction angle of 28 degrees and a soil cohesion of zero were assumed for the evaluation of drained conditions (long term). For the evaluation of undrained conditions (short term), an assumed soil friction angle of zero was used, with an assumed undrained shear strength of 12 kPa. A creek depth of about 2 feet was used at the toe of the slope.

Based on the existing conditions analyses, the risk of a deep-seated failure at this site appears to be low. However, the drained conditions model suggests that the factor of safety against a shallow surface slide is less than 1.0. This result corresponds with field observations of surface erosion/sloughing along the face of the Hole 16 green slope. Stabilization options that focus on protecting surface soils at the site from shallow surface erosion and water flow should be used. Discussion of potential stabilization options is presented in Sections 8.2.1 and 8.2.2.

5.10 Environmental Desktop Review

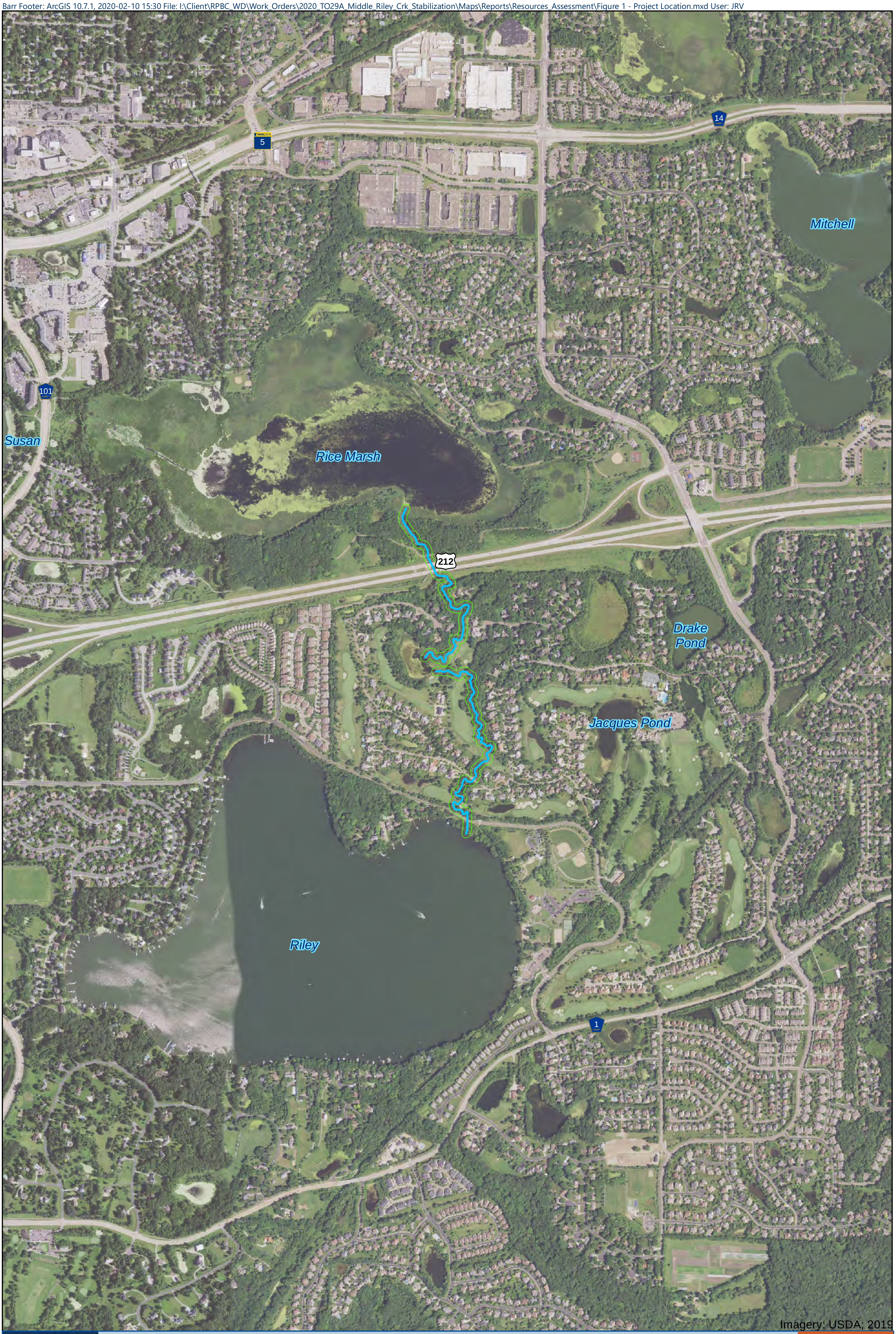
Barr completed a desktop natural resources review of the proposed Project area in February 2020. The proposed Project area is defined as the length of the Middle Riley Creek stabilization project plus a 50-foot construction corridor on either side of the creek (Figure 5-7). Desktop reviewed resources included historic resources, site contamination, water resources, and threatened and endangered species.

5.10.1 Historic Resources Data Request

The Minnesota State Historic Preservation Office (SHPO) was contacted on January 31, 2020 to request a summary of known archeological sites and historic structures located within one mile of the proposed Project. SHPO records identify three historic sites and five archaeological sites within one mile of the proposed Project area (Figure 5-8), although none are directly in the proposed Project area. The nearest archaeological site is located approximately 120 feet northwest of the proposed Project area, and the nearest historical site is approximately 760 feet southeast of the proposed Project area. Impacts to previously recorded historical sites are not anticipated as a result of the proposed Project; however, the potential for undocumented historic resources may need to be evaluated as the project progresses.

5.10.2 Potential Contamination

The Minnesota Pollution Control Agency's (MPCA) What's in my Neighborhood data does not identify any contamination sites within the proposed Project area (Reference (6)). The nearest areas of potential contamination mapped by the MPCA are two construction stormwater structures located more than 700 feet west of the proposed Project area and one construction stormwater structure located more than 700 feet to the east (Figure 5-9). Impacts on known sites of potential contamination are not anticipated as a result of the proposed Project.



RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Riley Creek Centerline

Project Area

0 500 1,000

Feet

PROJECT LOCATION
Middle Riley Creek Stabilization

Figure 5-7

Site Number	Description
Archaeological Sites	
21HE0197	Rice Marsh Lake East
21HE0198	Riley Creek I
21HE0199	Rice Marsh Lake SE
21HE0201	Kahnke
21HE0220	Westminster Heights
Historic Sites	
HE-EPC-007	Riley-Jacques Farmstead
HE-EPC-008	Mirock Cabin
HE-EPC-071	Duane Jacques Farmstead

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Riley Creek Centerline

Project Area

0 250 500

Feet

SHPO REVIEW
Middle Riley Creek Stabilization

Figure 5-8

POTENTIAL CONTAMINATION SITES
Middle Riley Creek Stabilization

Figure 5-9

5.10.3 Threatened and Endangered Species

Barr completed a desktop review for federal and state-listed species and associated habitats that may be found in the proposed Project area in order to determine potential direct impact to listed species. Federally listed species are protected by the federal government under the Endangered Species Act and require consideration for projects involving federal permits. State listed species are only protected under Minnesota's Endangered and Threatened Species Law and must be considered for state level permitting requirements. This desktop review was completed using a combination of data available from the USFWS and the MNDNR, as further described below.

5.10.3.1 Federally Listed Species

The USFWS Information, Planning, and Conservation System (IPaC) website (Reference (7)) lists the northern long-eared bat (*Myotis septentrionalis*) as potentially being present in the proposed Project area. No federally designated critical habitat for any federally listed species is located within the proposed Project area.

The northern long-eared bat inhabits caves and mines during hibernation, and uses forested habitats for roosting and foraging. According to the MNDNR, the nearest hibernacula is over 8 miles southwest of the proposed Project area, and no maternity roost trees have been identified within the vicinity of the proposed Project area. Therefore, it is unlikely development of the proposed Project area would have a significant impact on federally listed species. If the proposed Project requires tree removal, it may need to be times to avoid the northern long-eared bat's roosting season.

5.10.3.2 State-listed Species

Barr has a license agreement (LA-898) with the MNDNR for access to the Natural Heritage Information System (NHIS) database, which was queried in February 2020 to determine if any rare species could potentially be affected by the proposed Project. The NHIS database identified three state-endangered, threatened, special concern, or watchlist species documented within one mile of the proposed Project area. However, no state-listed species have been previously recorded within the proposed Project area (Figure 5-10).

THREATENED AND ENDANGERED SPECIES
Middle Riley Creek Stabilization

Figure 5-10

6.0 Desired Future Outcomes

The proposed stabilization measures will result in reduced stream bank erosion and, therefore, reduced sediment and phosphorus loading to Riley Creek and all downstream water bodies, including Lake Riley, Grass Lake, the Minnesota River, the Mississippi River, and Lake Pepin. The existing stream bank erosion rate (in units of feet per year) for each stabilization site was estimated based on a field assessment method known as the Bank Assessment for Non-Point Source Consequences of Sediment (BANCS) model. The BANCS model uses two erosion-estimation tools to develop risk ratings for the Bank Erosion Hazard Index (BEHI) and the Near-Bank Stress (NBS) (Reference (8)).

The portions of Reach R3 analyzed are generally rated “high” for BEHI due to the high, steep eroding banks. For NBS, the sub-reaches are designated “low” or “very low”. The total reduction in pollutant loading as a result of stabilizing the Reach E and Site D3 project reaches is estimated as **16,640** pounds per year **TSS** and **8.3** pounds per year **TP**. These values are representative of an erosion rate of approximately 0.07 to 0.1 feet per year for the stream banks.

The proposed Project has been designed to provide streambank stability while improving degraded habitat conditions of Reach R3. Presently, Reach R3 has a primarily sandy channel bed with limited riffle/pool variability. The proposed Project would provide greater stream depth variability, more channel bed substructure types, and varied channel velocities. Each of these variabilities enhances in-stream habitat features, potentially allowing more opportunities for macroinvertebrates and fish to use this reach of Riley Creek.

In addition to the expected water quality improvement expect from restoring the stream, the Project will provide other benefits as summarized in Table 6-1.

Table 6-1 Project Benefit Summary

Benefits	Qualitative Discussion	Metric
Habitat (acres)	Create in-channel habitat for fish and macroinvertebrates providing pools, riffle and refuge area for aquatic life. Improve riparian habitat conditions through invasive species removal and better connection of riparian corridor to stream channel.	0.2 acres of in-channel habitat improvements; 0.5 acres of riparian habitat improvements
Pollutants (e.g., TP, TSS, etc; lbs)	Restore stable streambanks and improve riparian buffer to reduce movement of eroded soil and nutrients to Riley Creek	Reduce TSS by 16,640 lbs/yr[1]; Reduce TP by 8.3 lbs/yr[1]
Abstraction (cubic ft)	Re-connecting Riley Creek channel to floodplain allows for greater infiltration due to sandy soils found in the floodplain. Vegetation found within the floodplain also improves infiltration.	Metric cannot be measured in the context of this Project.
Streambank Restored (feet)	Restore stable streambanks and improve riparian buffer is significant driver of the other benefits presented in this table.	815 feet of Reach R3
Groundwater Conserved (gal)	Benefit is not applicable.	
Community Reach	Location in the golf course allows for accessibility of country club members; public hearing held prior to RPBCWD Board ordering project; will hold neighborhood meetings prior to construction	
Wetland Management Class	Benefit is not applicable.	

[1] These values are representative of an erosion rate of approximately 0.07 to 0.1 feet per year for the stream banks.

7.0 Permitting

7.1 USACE Letter of Permission

Impacts to waters of the U.S., such as Riley Creek, must be permitted by the USACE. It is expected that Reach R3 would impact less than three acres and would be authorized under a Letter of Permission (LOP-05-MN).

Review of the Letter of Permission request by USACE for similar projects has taken up to six months. As such, the authorization request and wetland delineation report should be submitted at least six months prior to the start of construction and may be submitted prior to finalization of construction documents. Because the proposed activities involve stabilizing existing streambanks, this type of work is generally considered self-mitigating and/or an enhancement to the aquatic system. As such, USACE-required mitigation is not expected.

7.2 MnDNR Work in Public Waters Permit

Because Riley Creek is considered a public water by the MnDNR, a Work in Public Waters Permit from the agency would be required for all stabilization activities on Riley Creek. Work in Public Waters Permits are reviewed by the MnDNR Area Hydrologist and are typically issued in two to four months. The permit application may be submitted prior to finalization of construction documents. Because the proposed activities involve stabilizing existing streambanks and creating better floodplain connectivity, this type of work is generally considered self-mitigating and/or an enhancement to the aquatic system. As such, MnDNR-required mitigation is not expected.

7.3 MPCA Construction Stormwater General Permit

Construction of the proposed project would require a National Pollutant Discharge Elimination System/State Disposal System Construction Stormwater (CSW) General Permit issued by the MPCA. The CSW permit requires preparation of a stormwater pollution prevention plan explaining how stormwater would be controlled within a project area during construction.

Based on the findings of the environmental desktop study it is not anticipated that contaminated soil and debris would be encountered during stream stabilization activities; therefore it is not anticipated that the project would require additional permits for disposing of contaminated soil. In the unlikely event that environmental contaminants are encountered during the earthwork, contaminated materials would need to be handled and managed appropriately. The response to discovery of contamination typically includes entering the MPCA's voluntary program. In accordance with MPCA guidance, a construction contingency plan could be prepared for this project. This would include specifying initial procedures for handling potentially impacted materials, collecting analytical samples, and working with the MPCA to determine a method for managing impacted materials.

7.4 Environmental Assessment Worksheet

The Minnesota administrative rules (MN Rules 4410.4300) require the preparation of an Environmental Assessment Worksheet (EAW) for any project that would "change or diminish the course, current, or cross-section of one acre or more of any public water or public waters wetland." Depending on the preferred alternative and associated construction footprint of each project, an EAW may be required. At this time, it is expected that an EAW will not be required for the Reach R3 project.

7.5 City of Eden Prairie Land Alteration Permit

The city of Eden Prairie requires a Land Alteration Permit for grading activities in excess of 100 cubic yards of material. A stormwater management plan is also required as part of this permit.

7.6 City of Eden Prairie Vegetation Alteration Permit

The city of Eden Prairie requires a Vegetation Alteration Permit for vegetation to be cleared as part of project activities. A detailed re-vegetation plan is also required as part of this permit.

7.7 RPBCWD Permit

The RPBCWD has developed district-wide rules for floodplain management and drainage alterations, erosion and sediment control, wetland and creek buffers, dredging and sediment removal, shoreline and streambank stabilization, waterbody crossings and structures, appropriation of public surface waters, appropriation of groundwater, and stormwater management. The RPBCWD requires a District Permit for construction of Reach R3 to ensure the project is developed in compliance with district rules.

8.0 Strategies for Ecological Enhancement and Management

The RPBCWD is proposing to enhance 815 feet of Riley Creek (Reach R3), as summarized on Figure 2-1 and Figure 4-1. All restoration projects require ongoing management to ensure their long-term success. This section describes the initial restoration techniques and outlines a management program.

8.1 Restoration Alternatives

Improvements to Reach R3 will be provided through several methods. Rock riffles, log cross vanes, or boulder cross vanes will be used to stabilize the channel bed and introduce flow variability and an improved riffle/pool sequence. The use of grading, root wads, and installation of live stakes on eroding banks will stabilize these areas from further sediment loss and improve habitat within the pools that have become over shallow. The deeper pools will improve habitat, especially during winter months. Vegetation establishment in the overbanks will include enhanced buffers with native vegetation that have deeper roots for improved sediment loss reduction and new riparian habitat. The proposed Project is planned to be cut/fill neutral, meaning there will be no net gain or loss of soil materials from the Project site.

The proposed Project will require modification or replacement of one storm sewer outfall within project reach, which will reduce erosion at this outfall. The stream may also be re-aligned to avoid tight bends and/or steep slopes that have a propensity for erosion. At the Hole 16 green a combination VRSS/fieldstone boulder wall is proposed to stabilize the channel toe and the steep slope that has experienced surface sloughing. A summary of project restoration techniques is provided in Table 8-1.

Table 8-1 Project Design Elements

Design Element	Purpose	Ecological Benefit
Rock Riffles 	Gravel or cobble-sized material installed in the stream bed to create natural flow patterns and to control stream bed elevations.	The variety in flow and channel substrate size provides habitat diversity for aquatic species.
Cross Vanes 	Boulders buried in the stream bed and extending partially (“vanes”) or entirely across the stream (“cross vanes”) to achieve one or more of the following goals: re-direct flows away from banks, encourage sediment deposition in selected areas, and control stream bed elevations.	Scour pools develop over time near the vane, which provide habitat diversity for species that prefer pools to faster flowing in-channel habitat.
Root Wads 	Tree trunks with the root ball attached, installed either singly (root wads) or in conjunction with additional large woody debris and toe wood to Increase bank roughness and resistance to erosion, re-direct flows away from banks, and provide a bench for establishment of riparian vegetation	Creates undercut/overhanging bank habitat features.
VRSS/Toe Wood Bank Stabilization 	Soil lifts created with a combination of root wads and long-lasting, biodegradable fabric and vegetated to stabilize steep slopes and encourage establishment of root systems for further stabilization.	Creates undercut/overhanging bank habitat features.

Design Element	Purpose	Ecological Benefit
Vegetation/Buffer 	Established along a stream bank or overbank area to stabilize bare soils and increase resistance to fluvial erosion.	Using trees, shrubs, and a seed mix of grass and forbs provides a diverse array of vegetation strata and habitat types. Allows for more naturalized aesthetics, with emphasis on native species.

8.2 Anticipated Water Quality and Habitat Improvements

Both conceptual design alternatives are expected to provide improved stream stability and reduce the total suspended solids and total phosphorus loading as discussed in Section 6.0. There are slight differences in the habitat and general ecosystem improvements associated with each alternative.

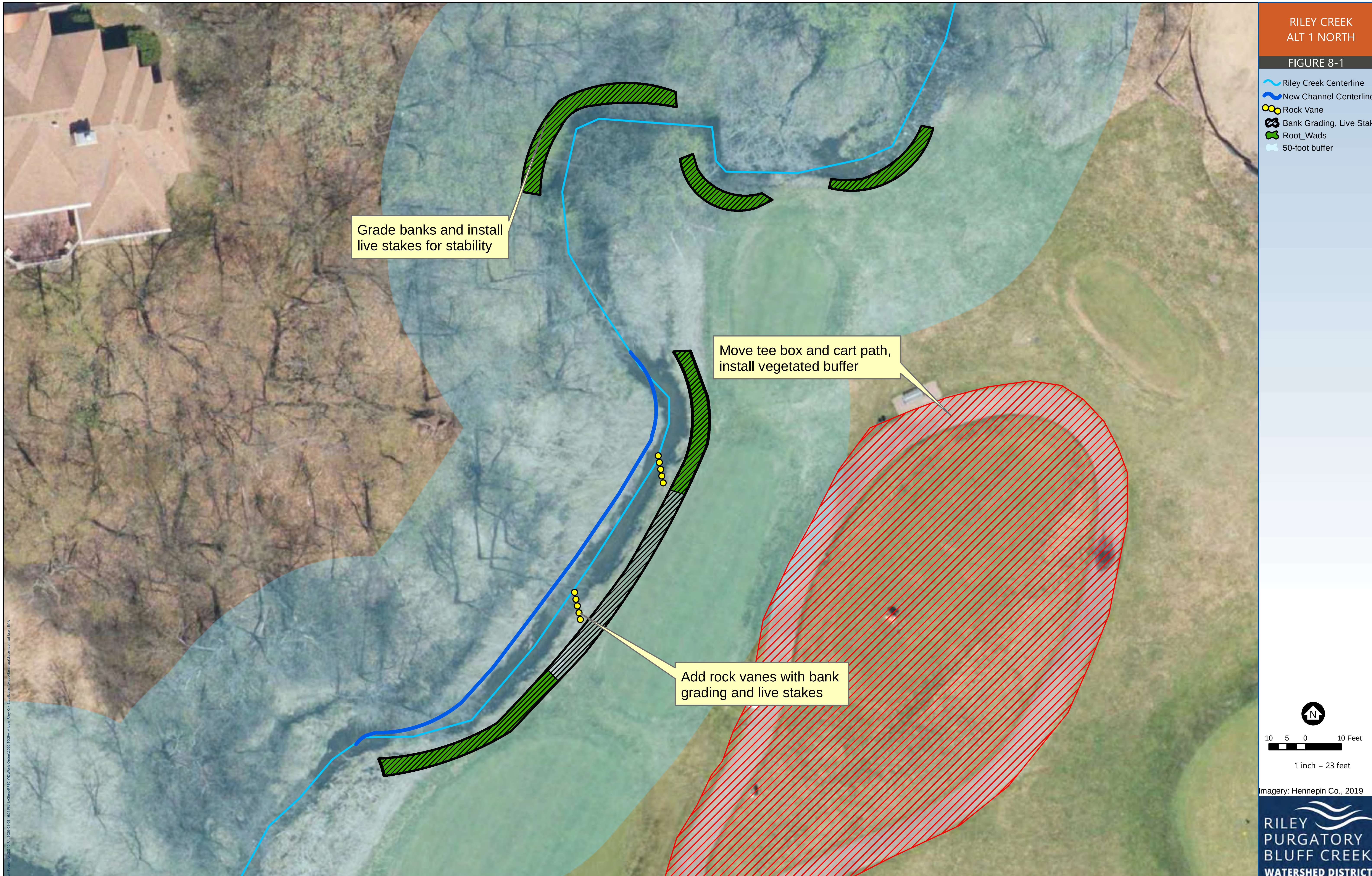
Alternative 1 includes a focus on restoration of bank erosion through stabilization of existing banks largely within their current footprint. In addition to reducing the suspended sediment load originating from the project reach, this option would minimize temporary impacts by ensuring construction only occurs in areas necessary for stabilization. The installation of root wads will increase roughness in channel bends and provide habitat for aquatic organisms. Restoration of the banks with native species will improve the riparian habitat diversity. Rock cross vanes will provide hydraulic diversity and develop deep pools for in-stream habitat.

Alternative 2 involves additional temporary impacts to the wetland and riparian corridor in order to move the stream channel away from actively eroding banks. Tree removals, grading/excavation impacts, and vegetation removal are expected to be higher than Alternative 1. However, the restoration of a meander pattern more representative of the stream type, and located away from steep banks, will promote long term stability for the reach. The improved meander pattern, coupled with more flow and habitat diversity in the stream as compared to Alternative 1, means the benefits will most likely out-weigh impacts.

8.2.1 Conceptual Design 1 – Stabilization in Place

In the first design alternative, in-stream stabilization techniques like toe wood, rock riffles, and rock vanes are used to protect banks without changing the channel alignment. At the north project location, toe wood is installed along the outside bends of the channel to stabilize the banks. Steep banks are graded and vegetated with live stakes. Boulder cross vanes are used to direct flow to the center of the channel, further preventing bank erosion in the straighter portion of the channel. In order to keep the stream in place, the Hole 13 tee box at the upstream project location would need to be shifted away from the stream channel, as shown in Figure 8-1. Bearpath has indicated relocating the tee box would be feasible. Bank grading and live stakes would be used to develop a buffer along the stream to the west of the tee box area, preventing future erosion.

At the southern (downstream) site near the Hole 16 green, the rock wall between the green and Middle Riley Creek is reconstructed to provide adequate stability while remaining aesthetically acceptable to Bearpath. Along the wall, VRSS lifts will be placed for additional stabilization to the channel banks and prevent the channel from migrating to the east, toward the wall and the golf course, as shown in Figure 8-2. Similar to the northern location, toe wood would be installed along outside bends of the channel for stabilization, and rock vanes will be used to direct flow to the center of the channel, preventing future erosion.


RILEY CREEK
ALT 1 NORTH
FIGURE 8-1
Riley Creek Centerline
New Channel Centerline
Rock Vane
Bank Grading, Live Stakes
Root_Wads
50-foot buffer
Grade banks and install live stakes for stability
Move tee box and cart path, install vegetated buffer
Add rock vanes with bank grading and live stakes
N
10 5 0 10 Feet
1 inch = 23 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK
WATERSHED DISTRICT

RILEY CREEK
ALT 1 SOUTH
FIGURE 8-2
Riley Creek Centerline
New Channel Centerline
Rock Vane
Bank Grading, Live Stakes
VRSS Lifts
Rock Wall
Root_Wads
50- foot buffer
Manhole drop structure
Add rock vanes in channel
Establish native wetland vegetation
Fieldstone wall with VRSS lifts to stabilize stream bank
Root wads with bank grading and live stakes
25 12.5 0 25 Feet
1 inch = 43 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

8.2.1.1 Geotechnical Design Hole 16 Green

Barr evaluated the use of a boulder wall to stabilize the Hole 16 Green based on the current alignment of Riley Creek. The assumed soil parameters discussed in Section 5.9 were used to evaluate the feasibility of this stabilization option. Based on a desired minimum factor of safety against sliding of 1.2, it appears that a wall with a minimum above-ground height equal to about two thirds of the height of the slope is necessary (about 2.5 meters) to provide stabilization. A shorter wall may be considered if some regrading and slope shallowing is performed downstream of the wall. The use of a shorter wall will require realignment of the creek channel.

Prior to final design of boulder wall stabilization, Barr recommends that additional subsurface soil information be collected to verify initial assumptions used in the stability analyses. This could include soil borings or hand auger borings to collect samples of subsurface material, combined with laboratory testing to verify soil engineering parameters. Additional wall stability analyses and foundation analyses should also be performed once an initial site layout has been determined.

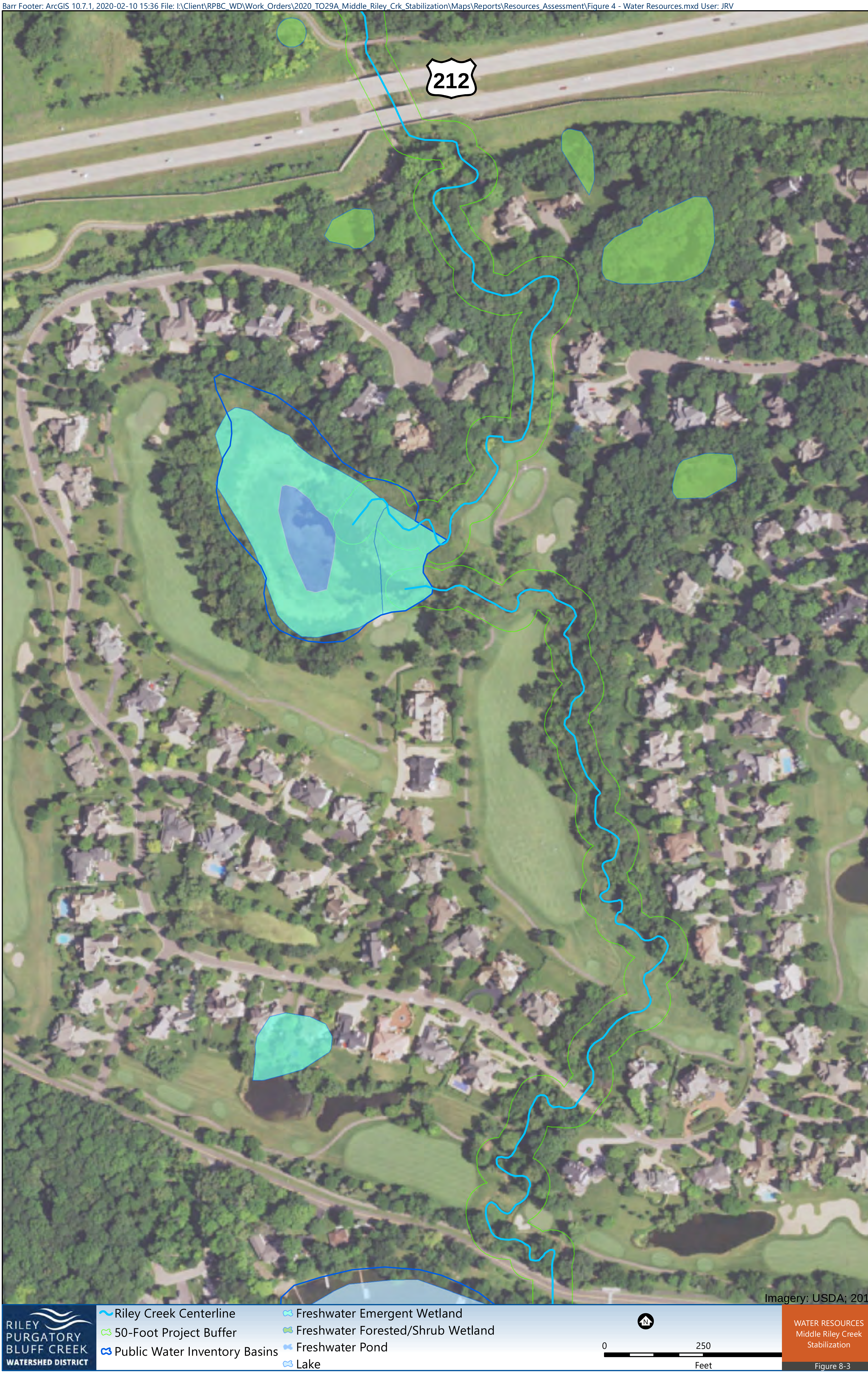
8.2.1.2 Wetland and Upland Impacts

This alternative does not impact any wetlands. The wetlands in the project area are shown in Figure 8-3. Temporary impacts to upland and riparian areas will occur during the course of construction activities. These disturbed areas would stabilized immediately following completion of construction activities. The riparian impacts are a result of grading banks, installing rock vanes, and placing root wads. The temporary upland impacts will be caused by site access routes. Total impacts for both the north and south stabilization locations are shown below in Table 8-2.

Table 8-2 Conceptual Design 1 Approximate Wetland and Upland Impacts

Location	Wetland Impact[1]	Upland Impacts	Riparian Impacts
North (Upstream)	0 acres	0.20 acres	0.03 acres
South (Downstream)	0 acres	0.30 acres	0.09 acres
Total Impacts	0 acres	0.50 acres	0.12 acres

1. Only list potential permanent impacts. Temporary impacts may occur during construction.



WATER RESOURCES
Middle Riley Creek Stabilization

Figure 8-3

8.2.1.3 Tree Removals

Conceptual Design 1 does not include major channel realignment, and instead prioritizes measures that will stabilize the channel in place. Very few tree removals will be necessary for this conceptual design because most of the restoration takes place in the channel or directly adjacent to the bank. Additionally, because the project is located within the Bearpath Golf Course, contractors will likely be able to access most both the North and the South project locations with minimal need to remove trees.

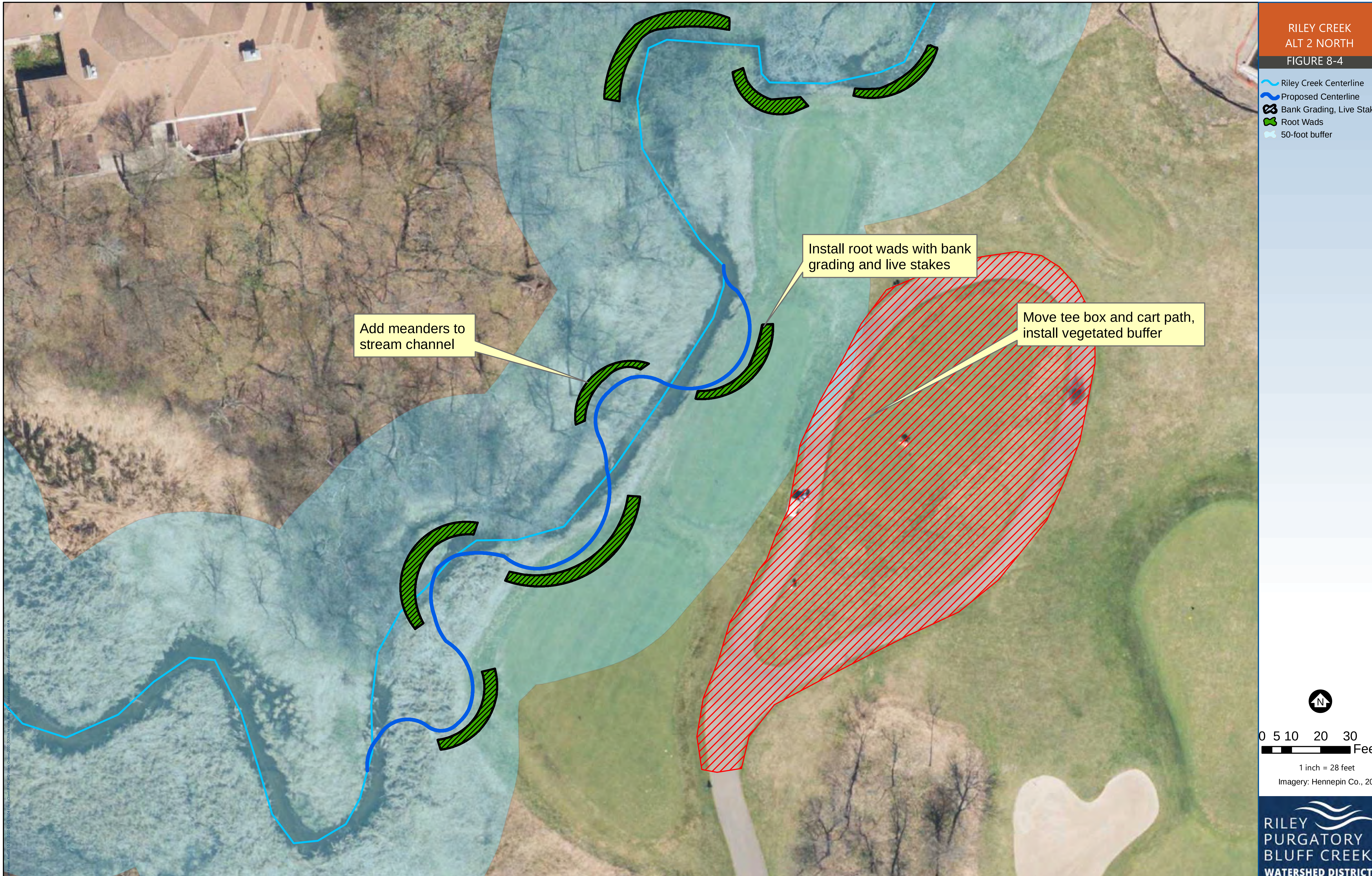
The tree removals that are necessary are mostly caused where bank grading and live stakes are located along the channel banks for stabilization. In addition to making room for grading efforts, removing trees in these locations will allow for better establishment of bank vegetation. Total tree removal amounts at both the North and South stabilization locations are shown below in Table 8-3.

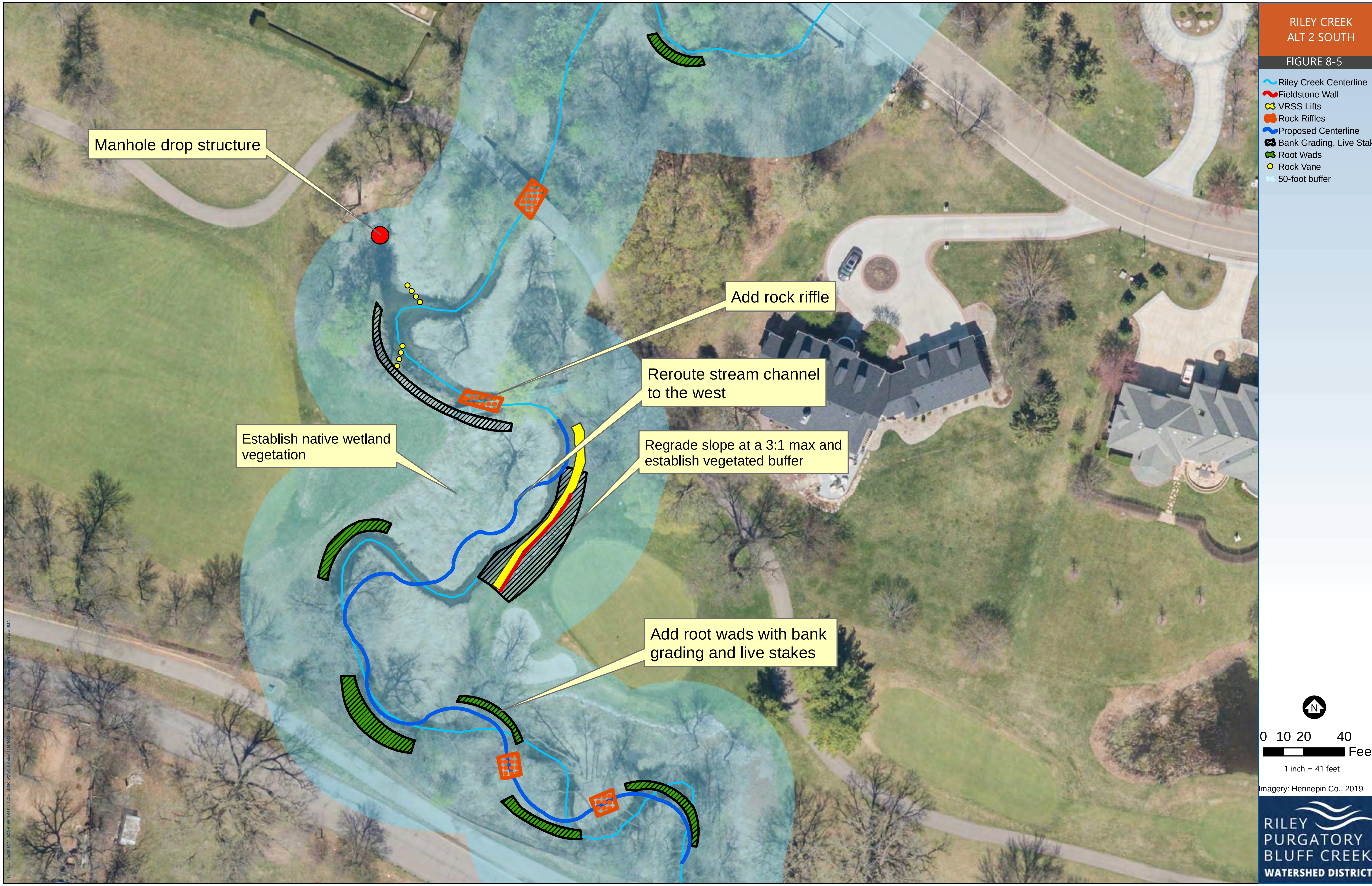
Table 8-3 Conceptual Design 1 Approximate Tree Removals

Location	North (Upstream)	South (Downstream)	Total Tree Removals
Tree Removals	4	6	10

8.2.2 Conceptual Design 2 – Channel Re-alignment

The second alternative involves re-aligning the Middle Riley Creek channel in each project location. At the northern (upstream) project location, additional meanders are added to the channel where it currently runs alongside the adjacent tee box, as shown in Figure 8-4. At the downstream portion of the site, the channel is moved slightly to the west from its current location near the Hole 16 green (Figure 8-5). The re-alignment will prevent erosion adjacent to the Bearpath green, and will allow enough space between the green and the channel for the bank to be graded and adequately vegetated, eliminating the need for VRSS. Just downstream of the Hole 16 green, several actively eroding bends in the stream will be re-aligned to protect against additional erosion and restore a healthier stream pattern. Root wads, bank grading, and live stakes will be used in this design to stabilize the outside bends of the newly-constructed channel. Rock riffles will be used in this reach as well. These structures will help maintain a healthy riffle-pool structure in the channel and direct flow into the center of the channel. Similar to Conceptual Design 1, single rock vanes or log vanes are used near the storm sewer outlet located near the upstream end of the south site for stabilization purposes.


RILEY CREEK
ALT 2 NORTH
FIGURE 8-4
Riley Creek Centerline
Proposed Centerline
Bank Grading, Live Stakes
Root Wads
50-foot buffer
Install root wads with bank grading and live stakes
Add meanders to stream channel
Move tee box and cart path, install vegetated buffer
N
0 5 10 20 30
Feet
1 inch = 28 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK
WATERSHED DISTRICT



RILEY CREEK
ALT 2 SOUTH
FIGURE 8-5
Riley Creek Centerline
Fieldstone Wall
VRSS Lifts
Rock Riffles
Proposed Centerline
Bank Grading, Live Stakes
Root Wads
Rock Vane
50-foot buffer
Manhole drop structure
Add rock riffle
Reroute stream channel to the west
Establish native wetland vegetation
Regrade slope at a 3:1 max and establish vegetated buffer
Add root wads with bank grading and live stakes
N
0 10 20 40
Feet
1 inch = 41 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

8.2.2.1 Geotechnical Design Hole 16 Green

As part of the option for re-alignment of Riley Creek, Barr evaluated a stabilization option for the Hole 16 Green consisting of regrading and shallowing the existing slope. Shallowing the existing slope is a feasible method for increasing stability and reducing future erosion. Based on the results of our initial analysis and a recommended minimum factor of safety against sliding of 1.2, a minimum slope of 3:1 H:V (Horizontal: Vertical) is recommended for this option. Grading at a 2.5:1 slope should be performed from the creek channel to the top of the slope. This will require that the existing channel be moved a minimum of 11.5 feet away from the existing slope. Depending upon the final site layout, this option may require importing fill material to achieve final grade.

Following re-alignment of the stream and regrading of the site, erosion protection should be provided across the re-graded slope and at edge of the creek channel. Some erosion protection options include vegetation and riprap. Hand augers should be performed prior to final design to verify site subsurface material and determine suitability for use as slope fill.

8.2.2.2 Wetland and Upland Impacts

Design Alternative 2 has no wetland impacts. Temporary impacts to upland and riparian areas will occur during the course of construction activities. All disturbed areas would be stabilized immediately following completion of construction activities. The riparian impacts are a result of grading banks, installing rock vanes, and placing root wads. This alternative would require converting some current riparian areas to upland and restoring the stream and riparian features along the new alignment, causing temporary impacts to both riparian and upland areas. Additional temporary upland impacts will be caused by site access routes. Total impacts for both the North and South stabilization locations are shown below in Table 8-4.

Table 8-4 Conceptual Design 2 Approximate Wetland and Upland Impacts

Location	Wetland Impact[1]	Upland Impacts	Riparian Impacts
North (Upstream)	0 acres	0.40 acres	0.20 acres
South (Downstream)	0 acres	0.60 acres	0.3 acres
Total Impacts	0 acres	1.00 acres	0.5 acres

1. Only list potential permanent impacts. Temporary impacts may occur during construction.

8.2.2.3 Tree Removals

Conceptual Design 2 includes major channel realignment, meaning that more tree removals will be necessary for this conceptual design.

Tree removals will be necessary where the stream is realigned. The filling and conversion of the current channel to upland could provide a location to plant replacement trees during the restoration phase of project construction.

Other tree removals will be necessary where bank grading and live stakes are located along the channel banks for stabilization. In addition to making room for grading efforts, removing trees in these locations will allow for better establishment of bank vegetation. Total tree removal amounts at both the North and South stabilization locations are shown below in Table 8-5.

Table 8-5 Conceptual Design 2 Approximate Tree Removals

Location	North (Upstream)	South (Downstream)	Total Tree Removals
Tree Removals	10	10	20

8.3 Regulatory Approval

Preliminary discussions with both the DNR and USACE indicate that both alternatives will be feasible to permit. Alternative 2 includes additional tree impacts and additional temporary impacts to the riparian corridor. These additional impacts could lengthen the review process as compared to Alternative 1, however the long-term benefits associated with the improved stream stability and habitat creation are expected to be sufficient to justify the impacts.

8.4 Cost Considerations

This section presents the general methodology used to develop an engineer's opinion of probable cost (OPC) of the evaluated alternatives. The OPC estimates have been developed for each alternative evaluated. OPC estimates are considered Class 4 feasibility-level estimates as defined by the American Association of Cost Engineers International (AACI International). The Class 4 level OPC estimates typically have an acceptable range of between -10% to -30% on the low range and +20% to +50% on the high range. Based on the development of concepts and initial vetting of the concepts by the RPBCWD and Bearpath a range for the OPC estimate between -10% and +30% of the estimated construction budget was used for budgeting. The cost estimates for each stabilization measure, including the quantities and unit costs, are included in Appendix B. These costs were combined with respective pollutant load reduction (sediment and TP) estimates to estimate the efficiency of each alternative in terms of dollars per pound of pollutant removed.

- The OPC's incorporate a 30% construction contingency.
- Costs associated with design, permitting, and legal services is assumed to be 20% of the estimated construction costs (excluding contingency).
- Costs associated with construction management are assumed to be 10% of the estimated construction costs (excluding contingency).
- Development of the necessary permits and associated documentation is assumed to cost $10,000.
- Construction easements may be necessary to construct the project; however, the cost is expected to be negligible.
- Additional work may be required to determine if cultural and/or historical resources are present at any project site.

Estimated annual loading reductions for TSS and TP are based on the assumption that an alternative is successful in reducing bank erosion at each site to a nominal rate of 0.02 feet per year—representative of a well-vegetated stable bank with very low to low near-bank erosive stress. The annualized pollutant-reduction cost for an alternative is the annual load reduction divided by the annualized cost. Annualized pollutant-reduction costs for all alternatives considered in this study are provided in Table 8-6.

Table 8-6 Summary of Annualized Loading and Costs

Alternative Description	Project Cost Estimate(1)	Annualized Cost(2)	TP Loading		TSS Loading	
			Load Reduction (lb/yr)	**Cost/lb Reduced(3)**	**Load Reduction (lb/yr)**	**Cost/lb Reduced(3)**
Alternative 1. Stabilization in-place with boulder wall (North and South Sites)	$275,000 ($248,000-$358,000)	$19,250 ($18,300- $25,000)	8.3	$2,313 ($2,205-$3,012)	16,645	$1.16 ($1.10-$1.50)
Alternative 2. Re-align stream away from eroding banks (North and South Sites)	$330,000 ($297,000-$429,000)	$23,100 ($22,200 – $29,800)	8.3	$2,776 ($2,675-$3,590)	16,645	$1.39 ($1.33-$1.79)

(1) A Class 4 screening-level opinion of probable cost, as defined by the American Association of Cost Engineers International (AACI International), has been prepared for these alternatives. The opinion of probable construction cost provided in this table is based on Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project. Includes 30% project contingency, 20% for planning, engineering, and design, $10,000 for permitting, and 10% for construction administration. Lower bound assumed at -10% and upper bound assumed at +30%.
(2) Assumed to be 2% of the total project cost for annual maintenance plus the initial project cost distributed evenly over a 20 year project lifespan.
(3) Annualized cost divided by estimated annual pollution load reduction.

9.0 Agreements

Table 9-1 summarizes anticipated agreements required prior to construction of the Lower Riley Creek Restoration Project.

Table 9-1 Summary of Anticipated Agreements

Description	Notes	Period	Lead Organization
Cooperative agreement between RPBCWD and Bearpath	Cooperative agreement between RPBCWD and Bearpath for activities related to construction and maintenance of the restoration project. The agreement would establish procedures for performing specific tasks, and define responsibilities of each organization.	2020	RPBCWD and Bearpath

10.0 Stakeholder Input

A technical stakeholder meeting was held on February 10, 2020 at the RPBCWD office. Technical stakeholders present included representatives from RPBCWD, MDNR (via phone), city of Eden Prairie, USACE (via phone), Bearpath, and Barr.

The meeting provided an opportunity for the stakeholders to see the proposed alternatives and gain a first-hand understanding of the issues present. Stabilization concepts similar to those included in this report were presented to facilitate discussion about the merits of the concepts and potential issues with permitting the project. The technical stakeholders expressed support for the concepts, particularly for addressing erosion along the stream banks and establishing improved stream habitat. The remainder of the discussion focused on permitting as described below.

Initial concepts present options for stream re-alignment to move the stream away from steep slopes. The group generally agreed this approach would be permittable, and most likely preferred because it will improve long-term stability for the reach. This option will cause additional impacts, which may require additional time to review/process the permit.

11.0 Recommendations

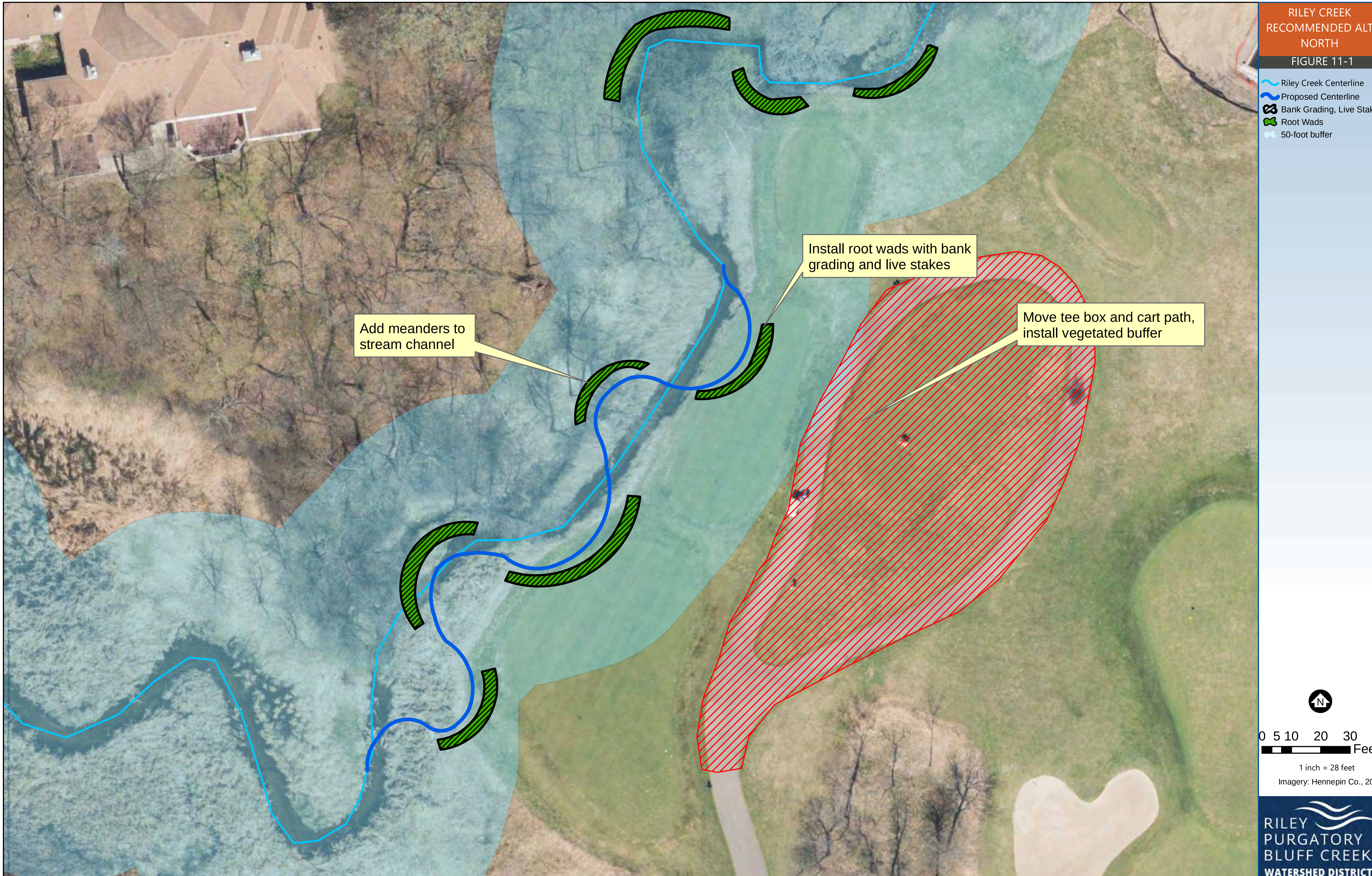
This feasibility report identified two alternatives for the restoration of Riley Creek through Bearpath golf course. The primary goals of this project is to protect, restore, and enhance Riley Creek while also providing a natural stream corridor through the golf course that meets the aesthetic and use goals for Bearpath Golf and Country. Additionally, the project will stabilize the slope failure area on the Hole 16 green and the bank erosion that is exposing golf course infrastructure next to Hole 13 tee box.

The two alternatives included one approach that stabilizes the stream with limited revisions to the stream alignment. The second alternative proposes the re-alignment of the project stream segments to move the stream away from actively eroding banks. The first approach results in less temporary impacts while the second alternative provides additional habitat by increasing the stream length and provides a better long-term solution to the erosion by moving the stream away from the banks.

We recommend implementing a combined approach. This combined approach would include the stream realignment near the Hole 13 tee box and restoration of the downstream segment largely in the existing stream pattern. A slight channel re-alignment away from the Hole 16 green may be necessary to achieve a 3:1 slope. Additionally, this recommended approach would include the boulder wall that aligns with the aesthetical goals of the golf course. This recommendation provides the greatest level of habitat improvements and a resilient solution to the stream erosion. Figures showing this proposed alternative are included as Figure 11-1 and Figure 11-2. A table summarizing the costs is included as Table 11-1 and a summary of each alternative's impacts/benefits is provided as Table 11-2.

The project was also scored using the RPBCWD Prioritization Tool described in the District's plan. Table 11-3 summarizes the score included in the plan and updates based on this feasibility study. The overall score of 33 represents the total project benefit.

After the project is ordered and a cooperative agreement is developed with Bearpath, the project will move into the design phase. The design will take place over spring and summer of 2020, with construction to follow in the fall and early winter of 2020. Table 11-4 contains an estimated project timeline.



RILEY CREEK RECOMMENDED ALT NORTH
FIGURE 11-1
Riley Creek Centerline
Proposed Centerline
Bank Grading, Live Stakes
Root Wads
50-foot buffer
Install root wads with bank grading and live stakes
Add meanders to stream channel
Move tee box and cart path, install vegetated buffer
N
0 5 10 20 30
Feet
1 inch = 28 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

RILEY CREEK RECOMMENDED ALT SOUTH
FIGURE 11-2
Riley Creek Centerline
New Channel Centerline
Rock Vane
Bank Grading, Live Stakes
VRSS Lifts
Rock Wall
Root_Wads
50- foot buffer
Manhole drop structure
Add rock vanes in channel
Establish native wetland vegetation
Fieldstone wall with VRSS lifts to stabilize stream bank
Root wads with bank grading and live stakes
N
25 12.5 0 25 Feet
1 inch = 43 feet
Imagery: Hennepin Co., 2019
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Table 11-1 Summary of Annualized Loading and Costs

Alternative Description	Project Cost Estimate(1)	Annualized Cost(2)	TP Loading		TSS Loading	
			Load Reduction (lb/yr)	Cost/lb Reduced(3)	Load Reduction (lb/yr)	Cost/lb Reduced(3)
Recommended. North Stream Re-alignment, South Stabilization In-Place	$286,000 ($257,000-$372,000)	$20,000 ($19,300- $26,400)	8.3	$2,403 ($2,325-$3,181)	16,645	$1.20 ($1.16-$1.59)

(1)A Class 4 screening-level opinion of probable cost, as defined by the American Association of Cost Engineers International (AACI International), has been prepared for these alternatives. The opinion of probable construction cost provided in this table is based on Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project. Includes 30% project contingency, 20% for planning, engineering, and design, $10,000 for permitting, and 10% for construction administration. Lower bound assumed at -10% and upper bound assumed at +30%.

(2) Assumed to be 2% of the total project cost for annual maintenance plus the initial project cost distributed evenly over a 30 year project lifespan. Includes one major maintenance event at 20 years.

(3) Annualized cost divided by estimated annual pollution load reduction.

Table 11-2 Project Impact/Benefits Summary

	Project Cost Estimate(1)	TP Cost/lb Reduced	TSS Cost/lb Reduced	Length of Stream Restored (ft)	Tree Impacts	Buffer Added, acres
Alternative 1	$275,000	$2,313	$1.16	1,385	10	0.30
Alternative 2	$330,000	$2,776	$1.39	1,400	20	0.37
Recommended Alternative	$286,000	$2,403	$1.20	1,435	15	0.37

(1)A Class 4 screening-level opinion of probable cost, as defined by the American Association of Cost Engineers International (AACI International), has been prepared for these alternatives. The opinion of probable construction cost provided in this table is based on Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project. Includes 30% project contingency, 20% for planning, engineering, and design, $10,000 for permitting, and 10% for construction administration. Lower bound assumed at -10% and upper bound assumed at +30%.

Table 11-3 RPBCWD Prioritization Tool Score

Alternative Description	Goal Index[1]	Sustainability Index[1]	Volume Management Index[1]	Pollutant Management[1]	Stabilization[1]	Habitat Restoration[1]	Partnership[1]	Education[1]	Watershed Benefit[1]	Goal Index[1]
Initial Project Assessment	3	7	1	1	5	5	1	1	3	27
Recommended Alternative	3	7	1	1	5	5	7	1	3	33
(1) See Section 4 of the RPBCWD Watershed Management Plan for prioritization methodology and associated descriptions for the variables used to assess multiple project benefits										

Table 11-4 Estimated Project Timeline

Project Phase	Estimated Dates
Feasibility Study	Complete
Ordering the Project	April 2020
Cooperative Agreement	Spring/Summer 2020
Design/Permitting	Spring/Summer 2020
Construction	Fall/Early Winter 2020
Project Completion	Winter 2020

12.0 References

1. **—.** *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region.* s.l. : Wetlands Regulatory Assistance Program,, August 2010.

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Appendix A

Stream R3 Corridor Assessment

Riley Creek Assessment

Rice Marsh Lake to Lake Riley

Conducted by: RPBCWD staff [Josh Maxwell, Zach Dickhausen] and University of MN volunteers

Summary

Site/Scope

On the 28th of November 2016, and continuing on the 17th of November 2017, Riley Purgatory Bluff Creek Watershed District (RPBCWD) staff conducted a stream corridor assessment of Reach R3 of Riley Creek. On the 28th of November 2016, staff started at Rice Marsh Lake and walked to 85ft downstream of highway 212 (approximately 0.2 stream miles). The walk continued in 2017 on the 17th of November, starting 85ft downstream of highway 212 before ending at Lake Riley (approximately 0.93 stream miles). Staff walked both sides of the creek to assess overall stream conditions and to discover and prioritize possible restoration locations. Staff conducted a Modified Pfankuch Channel Stability Assessment and a Minnesota Pollution Control Agency (MPCA) Stream Habitat Assessment (MSHA) on each subreach to better characterize the stream. A GPS, and a GPS-enabled camera were used to mark points and take photos.

- All pictures were taken <u>Facing Downstream</u> unless noted otherwise.
- <u>Right</u> and <u>Left</u> bank are defined by looking <u>Downstream</u>.
- Erosion was defined as <u>Slight</u>, <u>Moderate</u>, or <u>Severe</u>.
- <u>Stream Bank Erosion</u> was measured from the streambed to the top of the eroding bank.
- Vegetation was defined as <u>Sparse</u>, <u>Patchy</u>, or <u>Dense</u>.
- All measurements were recorded in <u>Feet</u>.
- All major erosion sites were labeled on the GPS by the erosion site number and reach.

Weather Conditions

11/28/2016	11/17/2017
Wind: NA	Wind: 2mph
Temp: NA	Temp: 5.4°C
Cloud Cover: NA	Cloud Cover: 100%

Stream Features

This reach starts in wetlands at the edge of Rice Marsh Lake and then passes through deciduous forest, residential areas, and a golf course before ending at Lake Riley. Riparian widths along both banks averaged about 90ft. The substrate in this reach consisted mainly of sandy mixtures (sand/silt and sand/gravel) with areas of moderate to heavy deposition of silt/silty mixtures. Slope gradients in this reach ranged from less than 10% or flat, to 45%. The first stretch of the reach (R3A) was not very sinuous, but the stream became very sinuous once reaching the wetland area around the golf course (R3B). The channel development (riffle/run/pool), for the most part, was poor-to-fair, except for subreach R3C, in which development was good.

Areas of Concern

There was little-to-moderate erosion along both banks throughout the reach. Subreach R3D exhibited some heavy erosion along both banks, which caused Pfankuch scores to shift to poor/moderately unstable. R3D also had a degraded stormwater culvert along the right bank exhibiting considerable erosion. The R3D riparian zone was less than 16ft, and non-existent in some areas (there were several areas where grass was mowed down to the edge of the stream). MSHA scores were fair for R3A and R3D due to increased siltation, but subreaches R3B and R3C received good scores. No major infrastructure risks or severe mass wasting sites were observed in this reach.

Subreach R3A - Rice Marsh Lake to 85ft Downstream of Highway 212 MSHA: 42.5 (Fair); Pfankuch: 71 (Moderately Stable)

Staff began the creek walk at the south side of Rice Marsh Lake at the outlet of the lake to Riley Creek. The landscape surrounding outlet was full of emergent vegetation, lots of cattails, wetland sedges and grasses, as well as some woody vegetation (small, sparsely growing shrubs). Staff observed submersed aquatic vegetation in the creek as well (broadleaf pondweed, curly leaf pondweed, duckweed), along with filamentous algae. The surrounding landscape was very flat, virtually no grade existed within the first few hundred feet. Staff encountered some woody debris throughout the wetland stretch of the subreach which increased in magnitude as staff moved downstream. The channel was rather wide and shallow for a majority of the subreach. Most of the subreach was a glide with little-to-no channel development (riffle/run/pool). The sediment was very soft, silt/clay mixture. Approximately 70ft upstream of the recreational trail bridge, some relatively minor cutting/erosion occurred along the left bank. Just upstream of the bridge, staff observed a woody debris dam backing up the stream and boulders had been placed under the bridge to prevent erosion. Downstream, staff found some broadleaf pondweed in the stream. At this point, the channel narrowed a bit. The sediment remained very soft, predominantly a silt substrate. Underneath the 212 overpasses, a large amount of riprap was concentrated along both banks to prevent erosion. In addition, multiple artificial rock riffles had been created to add structure within the stream flow. The substrate in areas without the cobble was very mucky/silty and staff easily sunk into it. Staff ended this subreach 85ft downstream of the overpass.

Subreach R3B - 85ft Downstream of the Highway 212 Overpass to the North end Bearpath Golf Course MSHA: 54.75 (Good); Pfankuch: 87 (Moderately Unstable)

This creek walk was a continuation of the creek walk started on the 11th of November 2016. Staff began this creek walk 85ft downstream of the Highway 212 overpass. The landscape within this subreach included forest and residential land-use types. Large oaks and a few smaller trees made up most of the forest canopy. Groundcover was very sparse; leaf litter covered much of the forest floor at the time of the assessment. The slope of the surrounding landscape was moderate, reaching grades up to 50%, but staying mostly around 30%. Houses were set back about 50ft to 100ft from both banks of the stream. Staff observed moss growing along a large proportion of both stream banks within the subreach (IMG_2155), which helped to protect the upper and lower banks from eroding. There was also a fair amount of woody debris within the stream. This subreach was sinuous, but the channel development was poor (riffle/run/pool).

Towards the beginning of the subreach, staff observed some erosion measuring up to 5ft high by 30ft along the right bank (IMG_2157). There were boulders in and along the channel throughout the start of the subreach (IMG_2157). The substrate was primarily composed of gravel and sand, with some silt occurring in the few pooling areas, and some cobble present within the riffles. Just downstream there was another stretch of erosion along the right bank, measuring 4ft high by 20ft (IMG_2158). Staff continued to see woody debris in-stream, including a small woody debris dam (IMG_2159). At this point there was some more erosion along the left bank measuring 3.5ft high (IMG_2159, IMG_2160). Continuing downstream, staff observed a stretch of cutting measuring 0.25ft high which was continuous along the right bank (IMG_2161). However, due to the presence of moss, the right bank was stable, despite the continuous cut bank. The stream then came up to a culvert under a driveway along the outside bend of the left bank as it shifted south (IMG_2162). The culvert was nearly full of sediment and the immediate sediment as seen in IMG_2163 was extremely soft muck/silt. The stream channel then shifted south and there was yet another stretch of erosion along the left bank, 3ft high by 30ft (IMG_2163). A considerable amount of sandy/silt deposition can also be seen in IMG_2163 on the opposing right bank. The stream at this point was 0.94ft deep by 11ft wide. At the start of the Bearpath golf course, staff encountered another woody debris dam (IMG_2165) which was causing some erosion measuring 3ft high by 10ft along the left bank. The golf course was adjacent to the left bank at this point; the grass was mowed to the stream edge (IMG_2165). Staff observed one final patch of erosion on the right bank before entering the next subreach (IMG_2166). The stream at this point measured 1.24ft deep by 6.4ft wide.

	**IMG_2155** General stream picture.		**IMG_2156** General stream picture.
	**IMG_2157** Erosion, 5ft by 30ft, RB.		**IMG_2158** Erosion, 4ft by 20ft, RB.
	**IMG_2159** Woody debris dam; bank erosion, LB.		**IMG_2160** Erosion, 3.5ft high, LB.
	**IMG_2161** General erosion, 0.25ft high, RB; moss on banks.		**IMG_2162** Culvert entrance under driveway on LB.

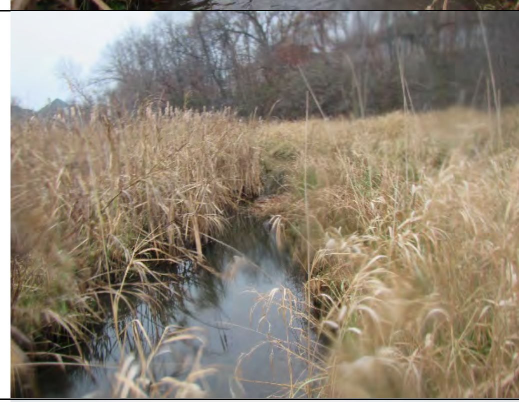
	**IMG_2163** General stream picture; erosion measuring 3ft high by 30ft, LB.		**IMG_2164** General stream picture.
	**IMG_2165** Woody debris dam causing erosion, 3ft by 10ft, LB.		**IMG_2166** Erosion near end of subreach, RB.

Subreach R3C - North End of Bearpath Golf Course to 260ft Upstream of Bearpath Trail MSHA: 50 (Fair); Pfankuch: 73 (Moderately Stable)

This subreach started at the north end of Bearpath Golf Course and had surrounding land slopes with grades less than 5% throughout its entirety. Wetland vegetation, mainly tall sedges and cattails surrounded the immediate banks. The golf course was setback 3ft to 7ft back from the left bank for the first 150ft before the meandering south into a thicker wetland area surrounding a large pond. The golf course was set back 30ft to 45ft along the last 260ft of the subreach. There was limited channel development (riffle/run/pool) in this subreach; it was mostly one continuous glide upstream and downstream of the pond. The channel was typical of a wetland stream as it was deep and narrow throughout the subreach. The channel was also very sinuous and there was little erosion throughout. The vegetation surrounding the channel was made up of primarily wetland and emergent plants, cattails, and wetland sedges and grasses (IMG_2167, IMG_2169, IMG_2170). The substrate within the channel consisted mainly of silt and sand throughout the reach. Staff did encounter mucky sediment in some areas.

About 260ft into the subreach, staff came upon a hairpin turn in the creek which bent right. There was a large deposition zone long the right bank here. Bank-full was measured at this point, approximately 22ft wide by 1.8ft deep. Continuing, the wetland area adjacent to the channel became thicker with tall grasses and the beginning of cattail stands (IMG_2168, IMG_2169). In this area, ponding within the riparian zone was frequent due to the low landscape slopes/floodplain. Bank-full was again measured; it narrowed, measuring approximately 11ft wide by 2.7ft deep. Staff observed some vegetation growing in-stream at this point that appeared to be sago pondweed (IMG_2171). The stream then entered the large ponded wetland area which covered about 2.13 acres (IMG_2172).

Staff walked along the pond to access the stream at the pond's outlet (IMG_2173). About 250ft downstream of the pond was a wooden walking/golf cart bridge crossing the stream (IMG_2174). The channel was deeper and much wider after the ponded wetland area (the surrounding riparian zone was ponded in several areas) but narrowed after the walking bridge. Immediately downstream of the bridge, staff observed a large grass/sedge island in the channel measuring 75ft long by 20ft wide (IMG_2175). Continuing downstream, the surrounding land-type began to shift to from grassy wetland back to mixed grass/forest (IMG_2176). Staff observed a large cement structure (IMG_2176) set back about 15ft from the left bank; its purpose was not identified. At this point, the golf course was set back about 15ft to 45ft from the right bank, and houses were set back about 90ft to 120ft from the left bank. The channel was still very connected to the floodplain at this point with small, isolated ponds being common along the channel. With an increase in canopy cover came an increase in woody debris within the stream with multiple piles of woody debris present (IMG_2178, IMG_2179). Near the second woody debris pile, a smaller riffle was present which was one of the few present in this subreach. The riffle then emptied into a deeper pool which measured 2.3ft in depth. Just downstream of the riffle and pool, erosion was observed on the left bank, measuring 2ft high and stretching for about 100ft (IMG_2181). Staff then found a dumpsite containing organic yard waste on the left bank behind a residence (IMG_2182). The stream then transitioned back to a grassy wetland landscape for about 210ft before the wooden walking/gulf cart bridge at the end of the subreach (IMG_2183). The stream was very connected to the floodplain at the bridge with ambiguous stream/channel edges. The in-stream sediment was very mucky just upstream of the bridge.

	**IMG_2167** General stream picture; golf course in background.		**IMG_2168** General stream picture; narrow, deep channel; cattails starting.
	**IMG_2169** Wetland grasses and sedges, LB.		**IMG_2170** Stream dispersed into wetland.
	**IMG_2171** In-stream vegetation.		**IMG_2172** Stream entering a large, ponded wetland.
	**IMG_2173** Stream DS of pond.		**IMG_2174** Wooden walking/golf cart bridge across stream.

	**IMG_2175** Grass/sedge island, 75ft by 20ft; US.		**IMG_2176** Large cement structure; LB.
	**IMG_2177** General stream picture.		**IMG_2178** Woody debris.
	**IMG_2179** General stream picture; woody debris.		**IMG_2181** Erosion on LB, 2ft high by 100ft.
	**IMG_2182** Yard waste dump site, LB.		**IMG_2183** Walking/cart bridge across stream; mucky sediment; end of subreach.

Subreach R3D - 260ft Upstream of Bearpath Trail to 250ft Downstream of Bearpath Trail MSHA: 66.7 (Good); Pfankuch: 65 (Very Stable)

This subreach started at the walking bridge/cart path just north of Bearpath Trail (IMG_2184). The surrounding landscape contained a higher slope gradient than subreach R3C. At the beginning of the subreach, slope grades were estimated at 20% to 30%; these grades lessened to below 10% in the last quarter of the subreach. The surrounding landscape was mostly deciduous forest with moderate shrub cover. Ground cover was patchy; some areas were bare, while others had a considerable amount of cover. The substrate within the stream was made up predominantly of sand and gravel, with boulders and some cobble in the riffles. This subreach had good channel development (riffle/run/pool), improving from the previous subreach. The subreach also had excellent sinuosity. Houses were set back 30ft to 60ft from both banks.

Staff encountered a fair amount of woody debris immediately following the start of the subreach (IMG_2184). Like the previous subreach, vegetation was observed growing in-stream. Upon construction of the Bearpath Trail bridge, a large amount of riprap was placed for bank stabilization (IMG_2185). Additional boulders were placed for bank protection and used to create an artificial riffle downstream of the bridge as well (IMG_2186, IMG_2187). About 45ft downstream of the bridge, staff observed some exposed erosion blankets on the right bank behind the boulders (IMG_2187). Continuing downstream, a plugged stormwater culvert was found on the right bank which was causing some minor erosion (IMG_2188). Following the District's regular creek sampling site (R3), the surrounding slopes began to flatten out. Staff observed some erosion and undercutting along the left and right banks that measured 1ft high and continued for 50ft as the stream shifted south (IMG_2189). Staff ended this subreach at the walking bridge/cart path seen in IMG_2190. The stream widened for a short stretch here before narrowing again.

	**IMG_2184** General stream picture; woody debris.		**IMG_2185** Bearpath Trail.
	**IMG_2186** Boulder riffle; boulders placed for bank stabilization.		**IMG_2187** Boulder riffle; exposed erosion blanket, RB.
	**IMG_2188** Stormwater culvert causing minor erosion, RB.		**IMG_2189** Erosion along left bank, 1ft by 50ft.

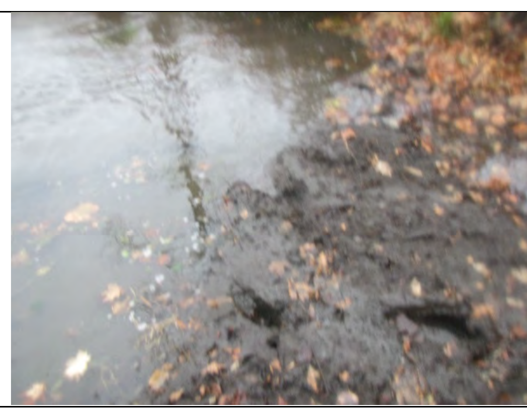
	**IMG_2190** Walking bridge/cart path over stream; end of subreach.		

Subreach R3E - 250ft Downstream of Bearpath Trail to Lake Riley

MSHA: 40.1 (Fair); Pfankuch: 87 (Moderately Unstable)

This subreach started at the cart path just downstream of Bearpath Trail. This subreach was short, and it was surrounded primarily by the golf course and wetland grasses and sedges before it crossed Riley Lake Road. The riparian width was very narrow, about 15ft or less throughout. This subreach exhibited a great deal of erosion along both banks which was affecting stability. The predominant substrate types were sand and silt; the riffles contained some gravel. Although sinuosity was very good, channel development (riffle/run/pool) was graded as fair because of limited riffles present. There were spots where the golf course lawn was mowed to the bank edge which reduced bank stability (IMG_2195, IMG_2198). The slopes of the immediate upper banks were high (entrenched) but flattened out just a few yards beyond the upper bank tops.

Staff observed more instream vegetation growing at the start of this stretch. Immediately downstream of the bridge, staff encountered a heavily clogged stormwater culvert on the right bank (IMG_2191) which was suspended 3ft from the stream bed and was undercut 3.5ft (IMG_2191). Downstream of the culvert, there was considerable silt deposition in the stream and along the right bank as seen in IMG_2192. As the stream turned east, there was a stretch of erosion along the outside bend of the right bank measuring 3ft high by 100ft long (IMG_2193). This erosion reached past the next wooden bridge/cart path (IMG_2194). Downstream of the bridge was another stretch of erosion along the left bank measuring 2ft high by 20ft (IMG_2195). At this point, the riparian zone was non-existent; the top of the bank was sparsely covered by patchy, mowed grass (IMG_2195). The next length of erosion staff observed was on the left bank, measuring 4.5ft high by 40ft as the stream shifted south, heading towards Riley Lake Road (IMG_2196). The right bank was eroding as well, the erosion measuring 2.5ft by 30ft (IMG_2197). There were more silt deposits observed here along the left bank (IMG_2198). Just past the deposition, the outside bend of the left bank was bare and looked unstable (IMG_2198). The stream shifted south, and staff observed the culvert underneath Riley Lake Road (IMG_2199). Staff crossed Riley Lake Road and ended the walk at Lake Riley (IMG_2200, IMG_2201).

	**IMG_2191** Stormwater culvert suspended 3ft and undercut 3.5ft, RB, US.		**IMG_2192** Silt deposition DS of culvert.

	**IMG_2193** Erosion 3ft high by 100ft, RB.		**IMG_2194** Walking bridge/cart path; erosion, RB.
	**IMG_2195** Erosion 2ft high by 20ft, LB; grass mowed to channel.		**IMG_2196** Erosion 4.5ft by 40ft, LB.
	**IMG_2197** Erosion 2.5ft by 30ft, RB.		**IMG_2198** Silt deposition and bare banks, LB.
	**IMG_2199** Culvert under Riley Lake Road.		**IMG_2200** DS side of culvert under Riley Lake Road.

	**IMG_2201** Lake Riley, end of reach.		

Appendix B

Cost Estimate Summary for Alternative Options

Preliminary Cost Estimate for Alternative 1

Item Description	Unit	Estimated Quantity	Unit Price	Extension
Mobilization	LS	1	$14,281	$14,280
Control of Water	LS	1	$10,000	$10,000
Erosion Control	LS	1	$3,795	$3,790
Clearing and Grubbing	ACRE	0.4	$7,000	$2,800
Select Tree Removal (>4") Salvage	Each	10	$710	$7,100
Grading	SY	1515	$6	$9,090
Excavate new channel	CY	140	$12	$1,680
Fill old channel	CY	140	$10	$1,400
Rock Riffles	EACH	0	$10,000	$0
F&I Manhole (48")	Each	1	$6,900	$6,900
F&I Storm (36")	LF	10	$227	$2,270
F&I FES (36")	Each	1	$4,900	$4,900
F&I Casting	Each	1	$1,000	$1,000
Riprap	TON	30	$75	$2,250
Topsoil Import	CY	323	$33	$10,650
Import and Install Root wads	EACH	30	$810	$24,300
Live Stakes	EACH	400	$5	$2,000
Rock Boulder Vane	EACH	5	$2,000	$10,000
Remove Bituminous	SY	624	$8	$4,992
Fieldstone Wall	SF	300	$32	$9,600
VRSS	LF	150	$35	$5,250
Plant Trees	EACH	10	$250	$2,500
Seeding and Mulch	ACRE	1.5	$8,000	$12,000
Erosion Control Blanket	SY	1936	$3	$5,810
One-Year Establishment Maintenance Period	LS	1	$2,530	$2,530
			Construction Total	**$ 157,092**
			Construction Total w/ Contingency (30%)	$ 204,220
			Planning, Engineering & Design (20%)	$ 40,844
			Permitting/Legal	$ 10,000
			Construction Management (10%)	$ 20,422
			Project Total	**$ 275,000**
			Total Construction, Legal, and Engineering Lower Bound (-10%)	**$ 248,000**
			Total Construction, Legal, and Engineering Upper Bound (+30%)	**$ 358,000**

30-yr and Annualized Cost analysis		**Project Total**
Category:		Bioengineering
Estimated life span (years)		20
Number of major maint. Events		1
Annual maintenance % of original project cost		15%
End of life span % of original project cost		25%
Expected annual maintenance		$ 3,350
End of life span maintenance		$ 68,750
Future Capital Cost		$ 667,500
Future annual maintenance		$ 159,380
Future end of life span cost		$ 124,170
Total Future Worth		**$ 951,000**
Annualized Cost		**$ 19,250**
Annual Maintenance Cost		**$ 5,500**

Preliminary Cost Estimate for Alternative 2

Item Description	Unit	Estimated Quantity	Unit Price	Extension
Mobilization	LS	1	$17,774	$17,770
Control of Water	LS	1	$3,159	$3,160
Erosion Control	LS	1	$4,739	$4,740
Clearing and Grubbing	ACRE	0.6	$7,000	$4,200
Select Tree Removal (>4") Salvage	Each	20	$710	$14,200
Grading	SY	1899	$6	$11,390
Excavate new channel	CY	1023	$12	$12,280
Fill old channel	CY	999	$10	$9,990
Rock Riffles	EACH	4	$3,000	$12,000
F&I Manhole (48")	Each	1	$6,900	$6,900
F&I Storm (36")	LF	10	$227	$2,270
F&I FES (36")	Each	1	$4,900	$4,900
F&I Casting	Each	1	$1,000	$1,000
Import and Install Root wads	EACH	30	$810	$24,300
Fieldstone Wall	SF	300	$32	$9,600
VRSS	LF	150	$35	$5,250
Riprap	TON	30	$75	$2,250
Live Stakes	EACH	450	$5	$2,250
Topsoil Import	CY	400	$33	$13,200
Plant Trees	EACH	20	$250	$5,000
Remove Bituminous	SY	624	$8	$4,992
Seeding and Mulch	ACRE	1.5	$8,000	$12,000
Erosion Control Blanket	SY	2904	$3	$8,710
One-Year Establishment Maintenance Period	LS	1	$3,159	$3,160
			Construction Total	**$ 195,512**
			Construction Total w/ Contingency (30%)	$ 254,166
			Planning, Engineering & Design (20%)	$ 50,833
			Permitting/Legal	$ 10,000
			Construction Management (10%)	$ 25,417
			Project Total	**$ 330,000**
			Total Construction, Legal, and Engineering Lower Bound (-10%)	**$ 297,000**
			Total Construction, Legal, and Engineering Upper Bound (+30%)	**$ 429,000**

30-yr and Annualized Cost analysis		**Project Total**
Category:		Bioengineering
Estimated life span (years)		20
Number of major maint. Events		1
Annual maintenance % of original project cost		15%
End of life span % of original project cost		25%
Expected annual maintenance		$ 4,190
End of life span maintenance		$ 82,500
Future Capital Cost		$ 801,000
Future annual maintenance		$ 199,340
Future end of life span cost		$ 149,000
Total Future Worth		**$ 1,149,000**
Annualized Cost		**$ 23,100**
Annual Maintenance Cost		**$ 6,600**

Preliminary Cost Estimate for Recommended Alternative

Item Description	Unit	Estimated Quantity	Unit Price	Extension
Mobilization	LS	1	$15,373	$15,370
Control of Water	LS	1	$2,738	$2,740
Erosion Control	LS	1	$4,106	$4,110
Clearing and Grubbing	ACRE	0.5	$7,000	$3,500
Select Tree Removal (>4") Salvage	Each	15	$710	$10,650
Grading	SY	1515	$6	$9,090
Excavate new channel	CY	521	$12	$6,250
Fill old channel	CY	433	$10	$4,330
Rock Riffles	EACH	0	$3,000	$0
F&I Manhole (48")	Each	1	$6,900	$6,900
F&I Storm (36")	LF	10	$227	$2,270
F&I FES (36")	Each	1	$4,900	$4,900
F&I Casting	Each	1	$1,000	$1,000
Import and Install Root wads	EACH	35	$810	$28,350
Fieldstone Wall	SF	300	$32	$9,600
VRSS	LF	150	$35	$5,250
Riprap	TON	30	$75	$2,250
Live Stakes	EACH	450	$5	$2,250
Rock Boulder Vane	EACH	4	$2,000	$8,000
Topsoil Import	CY	350	$33	$11,550
Plant Trees	EACH	15	$250	$3,750
Remove Bituminous	SY	624	$8	$4,992
Seeding and Mulch	ACRE	1.5	$8,000	$12,000
Erosion Control Blanket	SY	2420	$3	$7,260
One-Year Establishment Maintenance Period	LS	1	$2,738	$2,740
			Construction Total	**$ 169,102**
			Construction Total w/ Contingency (30%)	$ 219,833
			Planning, Engineering & Design (20%)	$ 43,967
			Permitting/Legal	$ 10,000
			Construction Management (10%)	$ 21,983
			Project Total	**$ 286,000**
			Total Construction, Legal, and Engineering Lower Bound (-10%)	**$ 257,000**
			Total Construction, Legal, and Engineering Upper Bound (+30%)	**$ 372,000**

30-yr and Annualized Cost analysis		**Project Total**
Category:		Bioengineering
Estimated life span (years)		20
Number of major maint. Events		1
Annual maintenance % of original project cost		15%
End of life span % of original project cost		25%
Expected annual maintenance		$ 3,790
End of life span maintenance		$ 71,500
Future Capital Cost		$ 694,200
Future annual maintenance		$ 180,310
Future end of life span cost		$ 129,140
Total Future Worth		**$ 1,004,000**
Annualized Cost		**$ 20,000**
Annual Maintenance Cost		**$ 5,700**