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Engineer's Report for Lower Riley Creek Stabilization Project

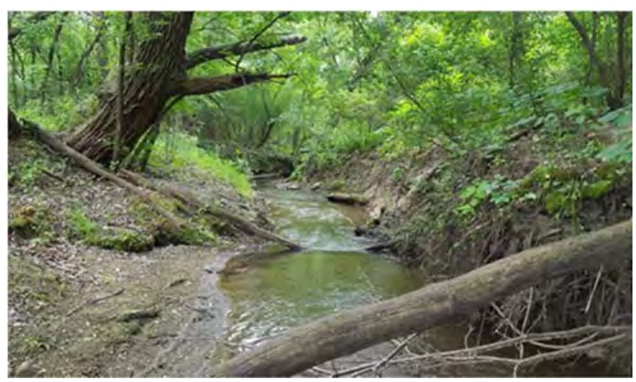
RPBCWD Reach E, Site D3, and LMRWD Reach

Eden Prairie, MN

Prepared for
Riley Purgatory Bluff Creek Watershed District and
Lower Minnesota River Watershed District

October 2016

RPBCWD Reach E



LMRWD Reach

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October 2016

Contents

List of Tables

List of Figures

List of Appendices

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.

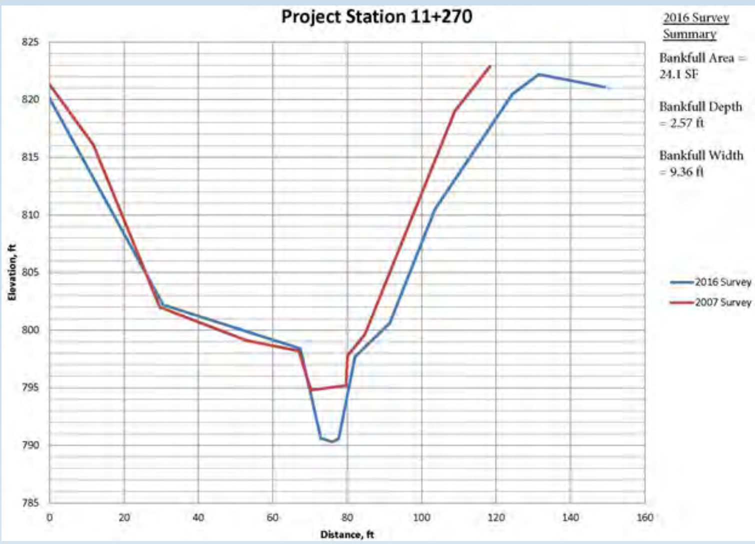
Scott Sobiech PE #: 41338	Date
Jeff Weiss PE #: 48031	Date

ENGINEER'S REPORT FOR LOWER RILEY CREEK STABILIZATION PROJECT

RILEY CREEK REACH E & SITE D3

The Riley Purgatory Bluff Creek Watershed District has identified portions of the Riley Creek Lower Valley as high priority for streambank stabilization. This study evaluates options for stabilizing locations of Riley Creek identified as Reach E and Site D3. The purpose of this study is to assess streambank stabilization measure to begin addressing the MPCA's identified turbidity impairment within this reach of Riley Creek by reducing erosion and improving water quality.

CROSS SECTION COMPARISON



Site D3 is experiencing significant bank erosion that is likely contributing sediment loads to Riley Creek. A comparison of surveyed cross sections shows that the channel has degraded since the 2007 survey as it is currently both deeper and wider. The cause of the initial instability within this reach is likely the gradual increase in runoff volume and increased peak runoff rates generated by a developing watershed.

HYDRAULIC PARAMETERS

Design Condition	Discharge, cfs[a]	Velocity, fps[b]	Flow Depth, ft[c]	Shear Stress, lb/ft^2
Existing Conditions (2-year Event)	110	2	5.9	2.1
Existing Conditions (100-year Event)	869	7	11.0	3.8

(1) 2016 Riley Creek PCSWMM Hydrologic/Hydrailic Model
(2) Approximated from representative cross section, proposed conditions velocity not calculated
(3) Based on 2016 survey for existing conditions and approximate bed raise of 3-ft for proposed conditions
(4) Calculated as T=yDS, where T is shear stress, y is specific weight of water, D is flow depth, S is channel slope

STUDY GOALS AND OBJECTIVES

- Examine the reach and determine the causes of erosion.
- Review the feasibility of implementing streambank stabilization measures along these segments of Riley Creek to reduce erosion and improve water quality.
- Complete assessments for the potential impact to wetlands and determine the impacts to permitting.
- Complete a Phase I Environmental Assessment to determine the likelihood of contamination and the potential need to avoid or treat contaminated sites during construction activities.
- Complete a Phase I Cultural and Historical assessment to determine the likelihood of the presence of cultural or historical sites within the project area and the potential to need to avoid such sites or complete additional investigations prior to the start of construction activities.
- Develop conceptual designs for stabilizing the eroding areas.
- Provide an opinion of costs for conceptual design options to stabilize the streambanks, minimizing erosion.

Reach E has a deeply incised channel. As such, flood flows are concentrated in and near the main channel. This confinement results in faster flows and higher shear stress on the streambanks, increasing erosion potential. Site D3 is ravine feature that conveys intermittent runoff from residential neighborhoods to Riley Creek via a storm sewer outfall near the top of the ravine.

The additional flows conveyed to the ravine through the storm sewer from the residential upstream watershed has resulted in an increase of both the volume and runoff rate. The increased volume and rate is exasperated by the steep channel slope of the ravine. The existing storm sewer outlet includes riprap and geotextile, which has currently failed, resulting in further erosion near the storm sewer outlet. The invert of the ravine is actively eroding because the flows are highly confined by tall banks. This is resulting in the creation of several large scarps.

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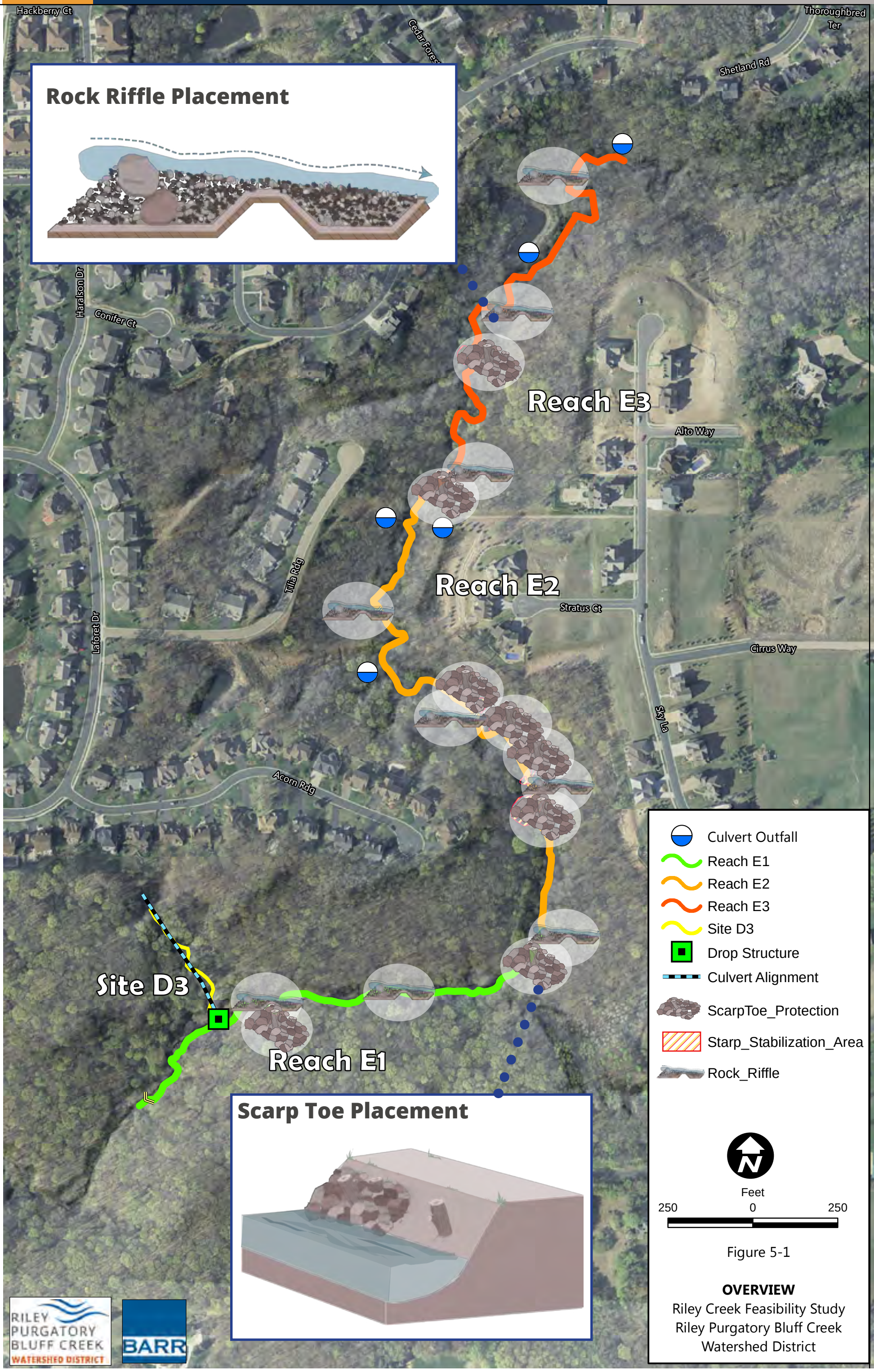
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT



Recommended Stabilization Measures

- Site D3: Alternative A
- Stabilize Site D3 by extending existing culvert to Riley Creek Channel and constructing drop structure for energy dissipation
- Reach E1, E2, and E3: Alternative A2 for all reaches
- Construct 10 rock riffles in channel of Riley Creek Reach E to provide grade control, reconnect stream with floodplain, and recreate pool-riffle sequence in channel;
- Stabilize toe of 11 major scarps using cedar pilings and trees removed within Reach E;
- Install root wads, rock vanes, and log vanes to provide additional toe protection and in-stream habitat;
- Stabilize scarp surface through grading and establishing vegetation;
- Improve existing culvert outfalls where necessary to match newly raised channel bed.

	RPBCWD Reach E and D3
Estimated TSS Reduction (lbs/yr)	2,193,700
Estimated TP Reduction (lbs/yr)	1,261
Cost of Construction (range)[1, 2]	$1,399,000 ($1,189,000 – $1,679,000)
TSS Cost/benefit ($/lb reduced)[3]	$0.05
TP cost/benefit ($/lb reduced)[3]	$78

[1] Range includes costs for: construction; engineering, design, permitting, and construction observation; legal assistance; construction contingency.
[2] Methodology and assumptions used for cost estimates are discussed in Section 4. Detailed cost estimates for all stabilization alternatives considered for this study are provided in Appendix J.
[3] Represents 30-year annualized cost.

Stabilization of site D3, and along Reach E are identified in the Overall Water Management Plan of the Riley-Purgatory-Bluff Creek Watershed District (as amended) and are a necessary and feasible project to reduce the total phosphorus (TP) and total suspended sediment (TSS) loading reductions while limiting impacts to the surrounding environment. Stabilization and restoration of the stream channel, banks, and eroding scarps within the project area would reduce stream bank erosion and, therefore, reduced TSS and TP loading to Riley Creek (which is on the MPCA's impaired waters list) and all downstream water bodies, including Grass Lake, the Minnesota River, the Mississippi River, and Lake Pepin. The recommended alternatives for Reach E (Alternative A2) and Site D3 (Alternative A) have a estimated total annualized pollutant reduction costs are per pound TP and per pound TSS.

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
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Scouring on the downstream side of Flying Cloud Drive is representative of active erosion in Riley Creek

ENGINEER'S REPORT FOR LOWER MINNESOTA REACH STABILIZATION PROJECT

RILEY CREEK REACH

The Lower Minnesota River Watershed District has identified Riley Creek as a high priority for stabilization. This study evaluates options for stabilizing Riley Creek between the jurisdictional boundary and Grass Lake. The purpose of this study is to assess streambank stabilization measure to begin addressing the MPCA's identified turbidity impairment within this reach of Riley Creek by reducing erosion and improving water quality.

HYDRAULIC PARAMETERS

Design Condition	Discharge, cfs[1]	Velocity, fps	Flow Depth, ft[3]	Shear Stress[2], lb/ft[2]
Existing Conditions (2-year Event)	170	3.7	2.8	0.5
Existing Conditions (100-year Event)	991	6.5	5.6	1.2

(1) 2016 Riley Creek PCSWMM Hydrologic/Hydrailic Model
(2) Calculated as T=yDS, where T is shear stress, y is specific weight of water, D is flow depth, S is channel slope

STUDY GOALS AND OBJECTIVES

- Examine the reach and determine the causes of erosion.
- Review the feasibility of implementing streambank stabilization measures along these segments of Riley Creek to reduce erosion and improve water quality.
- Complete assessments for the potential impact to wetlands and determine the impacts to permitting.
- Complete a Phase I Environmental Assessment to determine the likelihood of contamination and the potential need to avoid or treat contaminated sites during construction activities.
- Complete a Phase I Cultural and Historical assessment to determine the likelihood of the presence of cultural or historical sites within the project area and the potential to need to avoid such sites or complete additional investigations prior to the start of construction activities.
- Develop conceptual designs for stabilizing the eroding areas.
- Provide an opinion of costs for conceptual design options to stabilize the streambanks, minimizing erosion.

The Riley Creek channel within this reach gradually transitions from Flying Cloud Drive to Grass Lake. The upper third is moderately incised and moderately entrenched with some eroding banks. The middle third is a primarily stable channel with easy access to a floodplain. The lower third is essentially an alluvial fan with a poorly defined main channel and evidence of the channel frequently migrating across the landscape

Beginning mid-reach, Riley Creek becomes more connected with its floodplain. As flood flows are able to expand into the floodplain, the velocity in the channel drops and the flow in the channel has a reduced sediment carrying capacity. When this happens, the sediment is deposited in the channel and the channel gradually fills up with sediment. The Minnesota River is also a major contributor of sediment to lower Riley Creek as the channel within the portion of the reach is located within the 10-year flood elevation for the Minnesota River. The Minnesota River has a high sediment load and deposits a significant amount of sediment on the floodplain during flood events, so sediment deposition from the Minnesota River may also contribute to channel filling in the LMRWD Reach.

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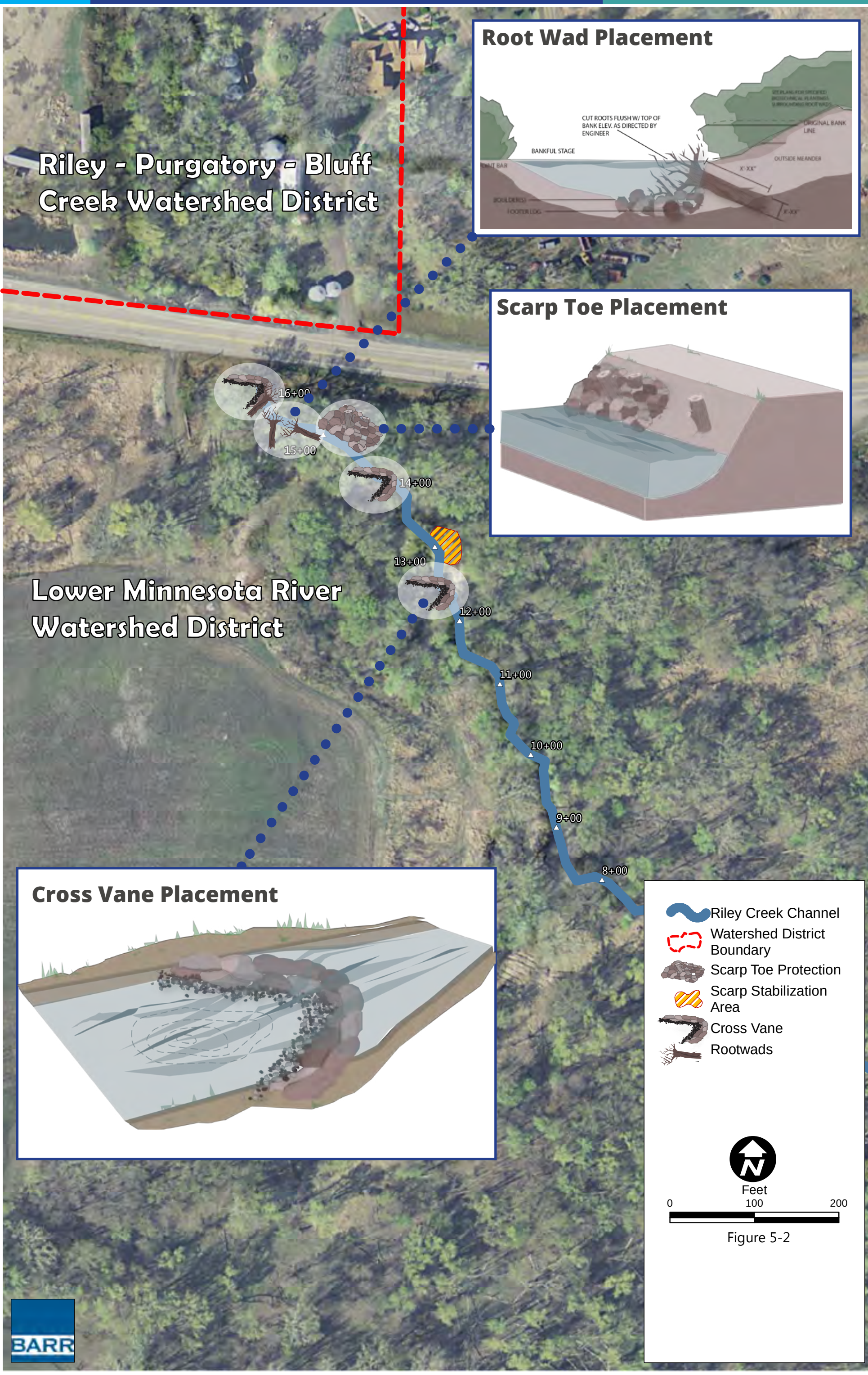


Recommended Stabilization Measures

- Alternative A
- Grade tall, eroding banks immediately downstream of Flying Cloud Drive;
- Install rock vanes and root wads to provide toe protection on the graded banks while providing in-stream habitat.

Estimated TSS Reduction (lbs/yr)	268,000 (228,000-322,000)
Estimated TP Reduction (lbs/yr)	$105
Cost of Construction (range)[1, 2]	$268,000 (228,000-322,000)
TSS cost/benefit ($/lb reduced)[3]	$0.10
TP cost/benefit ($/lb reduced)[3]	$178

[1] Range includes costs for: construction; engineering, design, permitting, and construction observation; legal assistance; construction contingency.

[2] Methodology and assumptions used for cost estimates are discussed in Section 4. Detailed cost estimates for all stabilization alternatives considered for this study are provided in Appendix J.

[3] Represents 30-year annualized cost.

Stabilization of the portion of Riley Creek downstream of Flying Cloud Drive is a necessary and feasible project to reduce the total phosphorus (TP) and total suspended sediment (TSS) loadings to Riley Creek, Grass Lake and the Minnesota River. The stabilization efforts align with the goals listed in the Lower Minnesota River Watershed District Watershed management Plan to protect, preserve and restore surface water quality, to manage erosion and control sediment discharge, and maintain and improve navigation and recreational use of the Lower Minnesota River. Stabilization and restoration of the stream channel and banks within the project area would reduce stream bank erosion and, therefore, reduce TSS and TP loading to Riley Creek (which is on the MPCA's impaired waters list) and all downstream water bodies, including Grass Lake, the Minnesota River, the Mississippi River, and Lake Pepin. The recommended stabilization alternatives the estimated total annualized pollutant reduction costs are per pound TP and per pound TSS.

1.0 Introduction and Objectives

This Engineer's Report summarizes the proposed actions for stabilization of two reaches of Lower Riley Creek in Eden Prairie, Minnesota (Figure 1-1). It is prepared under the direction of the Board of Managers of the Riley Purgatory Bluff Creek Watershed District (RPBCWD) and the Board of Managers of the Lower Minnesota River Watershed District (LMRWD).

The upstream reach, Reach E, is located in the middle of the Riley Creek Lower Valley and is within the Riley Purgatory Bluff Creek Watershed District (RPBCWD) jurisdictional boundary. The downstream reach, Lower Minnesota River Watershed District (LMRWD) Reach, is located just downstream of Flying Cloud Drive (County Road 61) and is within the LMRWD boundary. Both reaches of Riley Creek have been identified as high priority reaches to stabilize by their respective watershed districts, and the Districts agreed to assess the feasibility of stabilization options in a combined effort in order to more effectively and efficiently use resources.

1.1 Assessment Goals and Objectives

The purpose of this report is to assess streambank stabilization and restoration measures to begin addressing the Minnesota Pollution Control Agency's (MPCA's) identified turbidity impairment along the portion of Riley Creek between Dell Road and Grass Lake by reducing erosion and improving water quality. The goals and objectives of this study, across both reaches, are to:

1. Examine the reach and determine the causes of erosion;
2. Review the feasibility of implementing streambank stabilization measures along these segments of Riley Creek to reduce erosion and improve water quality;
3. Complete assessments for the potential impact to wetlands and determine the impacts to permitting;
4. Complete a Phase I Environmental Assessment to determine the likelihood of contamination and the potential need to avoid or treat contaminated sites during construction activities;
5. Complete a Phase I Cultural and Historical assessment to determine the likelihood of the presence of cultural or historical sites within the project area and the potential to need to avoid such sites or complete additional investigations prior to the start of construction activities;
6. Develop conceptual designs for stabilizing the eroding areas;
7. Provide an opinion of costs for conceptual design options to stabilize the streambanks, minimizing erosion.

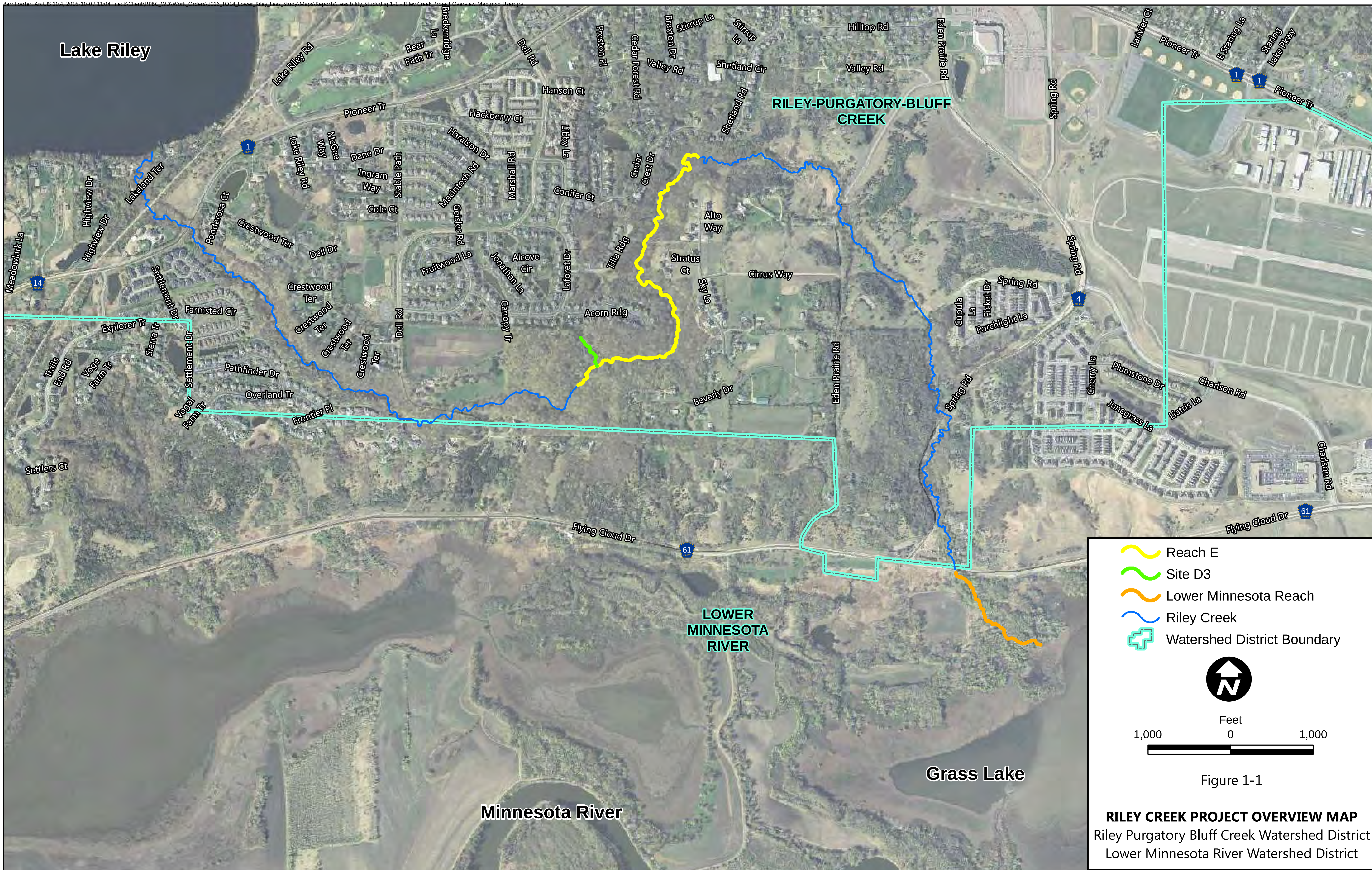


Figure 1-1

RILEY CREEK PROJECT OVERVIEW MAP
Riley Purgatory Bluff Creek Watershed District
Lower Minnesota River Watershed District

1.2 Project Area

The Riley Creek watershed to the WOMP station downstream of Flying Cloud Drive is approximately 10-square miles in Eden Prairie and Chanhassen. It has mild topography in the upper and middle portions of the watershed, and then becomes steep within the Riley Creek Lower Valley. The existing watershed land use is dominated by low density residential zones, and the expected future land use will likely maintain the same land use pattern. Riley Creek originates from Lakes Lucy and Ann in Chanhassen and flows though Lake Susan, Rice Marsh Lake, and Lake Riley before it descends through the Lower Valley. The Riley Creek Lower Valley begins at Lake Riley and extends approximately 25,700 feet before flowing into Grass Lake and then the Minnesota River. Each project reach is further described below and photos of each study reach are provided in Appendix A.

1.2.1 Reach E and Site D3 Characteristics

Reach E (Figure 1-2), which was designated in a 2007 study of the Riley Creek Lower Valley (Reference (1)), has a deeply incised channel with limited floodplain and is dramatically different from the reaches immediately upstream and downstream. The narrow valley limits the ability of flood flows to spread out into a floodplain, thereby keeping flood flows concentrated in and near the main channel.

In this reach, the slope varies from less than 0.25 percent to greater than 1 percent. Channel slopes greater than 1 percent can contribute to higher velocities and increased erosion. In a channel that is in equilibrium with its watershed, bankfull flows (~1.5-year flood events) fill the channel, and flows larger than bankfull begin to spill into the adjacent floodplain. In its current state, the channel can contain flows as great as the 100-year event, thereby concentrating velocities within the channel, which can lead to increased erosion. A comparison of surveyed data from 2007 and 2016 (See Section 3.1.1) indicates that the channel bed has lowered by one to five feet during this period. Continued erosion of the channel bed at similar rates is anticipated, with migration of headcuts upstream, unless the stream is stabilized.

Reach E is located within the Riley Creek Conservation Area (RCCA) in Eden Prairie, Minnesota. The RCCA is entirely on City-owned property covered by a natural landscape with a healthy forest and dense canopy throughout the project area. No houses or other structures are immediately adjacent to the creek within the study area; however, beyond the park extents the landscape is primarily residential developments. Non-native species, such as buckthorn, have started invading portions of the understory.

Reach E of Riley Creek was divided into three sub-reaches based on unique characteristics of the specific sub-reach (Figure 1-2). For each sub-reach, the following discussion includes a brief description of the site characteristics and the issues to be addressed.

- **Sub-reach E1** extends from the upstream limits of the study area (Station 90+00) to where the Riley Creek floodplain significantly constricts (Station 108+00). This reach consists of significant degradation of the channel bed and a knickpoint, or head cut, at approximate Station 4+50.
- **Sub-reach E2** consists of a segment of the stream from Station 108+00 to 120+00 that is confined by tall bluffs. The erosion within this reach has resulted in significant toe erosion of valley slopes and several scarps, one of which is large enough to spot from some satellite images,

and has resulted in the realignment of one of the RCCA's hiking trails. One culvert outfall is located within the project reach.

- **Sub-Reach E3** extends Station 120+00 to 141+00 and consists of significant degradation of the channel bed. The overbanks of this sub-reach have significant buckthorn. Three culvert outfalls are located within Sub-reach E3. A stormwater pond is also present in the left overbank and must maintain its design storage volume.

Site D3 (Figure 1-2) is ravine feature that conveys intermittent runoff from residential neighborhoods to Riley Creek via a storm sewer outfall near the top of the ravine. Site D3 is experiencing significant bank erosion that is likely contributing sediment loads to Riley Creek.

1.2.2 LMRWD Reach Characteristics

The LMRWD Reach (Figure 1-3) has a variety of stream characteristics. The upstream extent of this reach is where the stream begins the transition from the Lower Valley to the Minnesota River floodplain. The stream gradually transitions from a moderately incised reach with moderately tall, eroding banks immediately downstream of Flying Cloud Drive to an actively migrating channel before discharging into Grass Lake within the Minnesota River floodplain. As the creek transitions into the Minnesota River floodplain, flood flows are able to spread out into the floodplain, so flow velocity decreases and suspended sediment in the flow is deposited. This contributes to the alluvial fan upstream of Grass Lake, as well as channel migration with new channels being formed and old channels filling in. Because, this study reach is located entirely within the Minnesota River 100-year floodplain, sediment is also deposited from the Minnesota River, which directly or indirectly impacts on Riley Creek.

The vegetation immediately adjacent to this reach also transitions along the reach. There are trees in the upper third of the reach where the channel is incised, followed by a mix of grasses (mostly reed canary grass) and sparse trees in the middle third, and then dominated by grasses in the lower third that constitutes the alluvial fan. A portion of the adjacent land is agricultural.

1.3 Impairment Status

The MPCA maintains a list of impaired waters for the state of Minnesota. A body of water is considered impaired if it fails to meet one or more of the state's water quality standards. Waters that are not able to meet their designated uses due to exceeding water quality standards are considered impaired. Lower Riley Creek, from Lake Riley to the Grass Lake is included on the MPCA's 2016 Inventory of Impaired Waters (MPCA, 2016). The identified pollutant or stressor for this reach of Riley Creek is turbidity, with aquatic life as the affected designated use.

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 began a TMDL study for this impaired reach of Riley Creek in 2014 and is targeted to complete the study in 2019.

Barr Footer: ArcGIS 10.4, 2016-10-07 11:06 File: I:\Client\RPBC_WD\Work_Orders\2016_TO14_Lower_Riley_Feas_Study\Maps\Reports\Feasibility_Study\Fig 1-2 - Reach E and Site D3 Overview Figure.mxd User: jrv

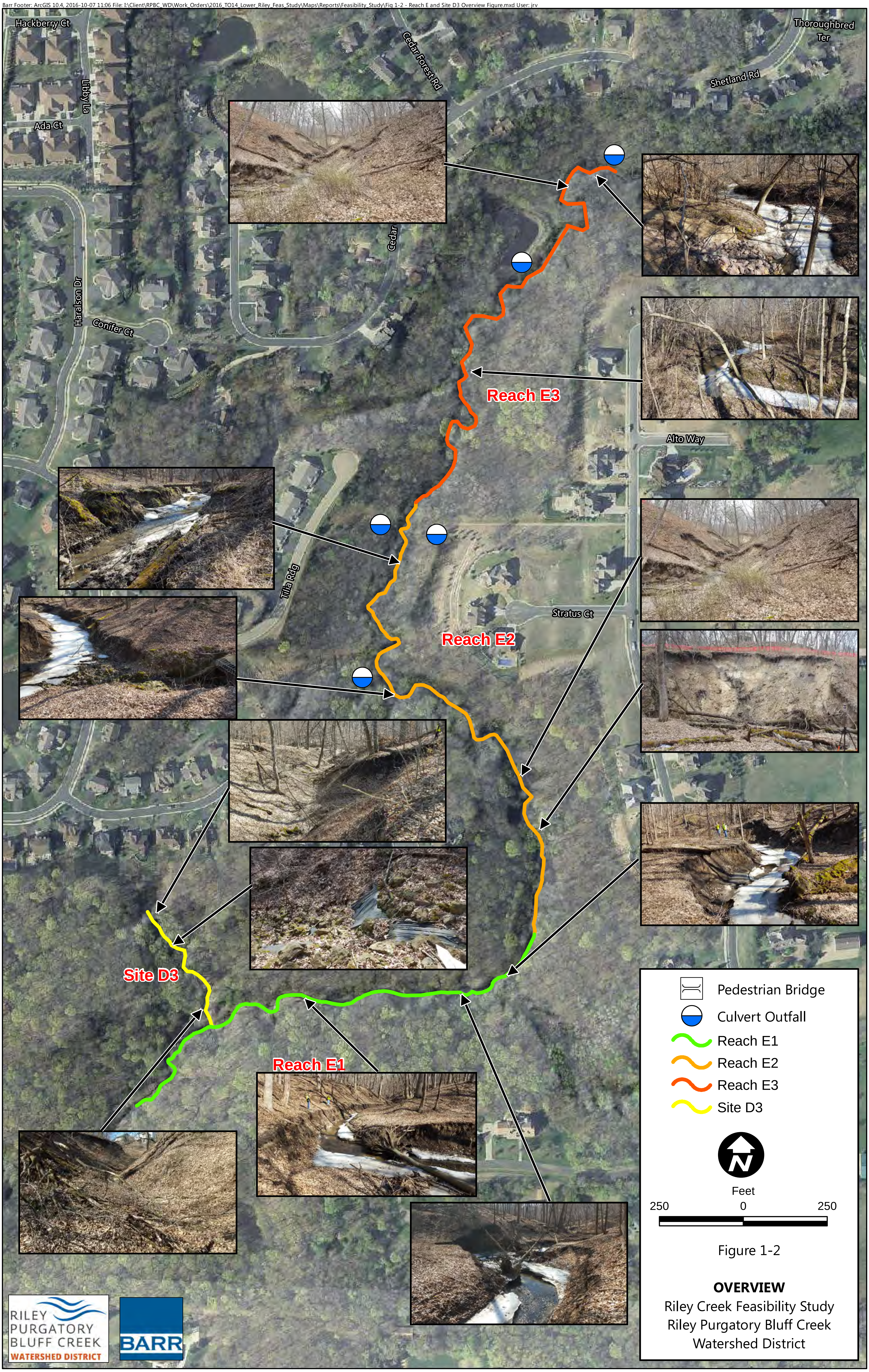


Figure 1-2

OVERVIEW
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

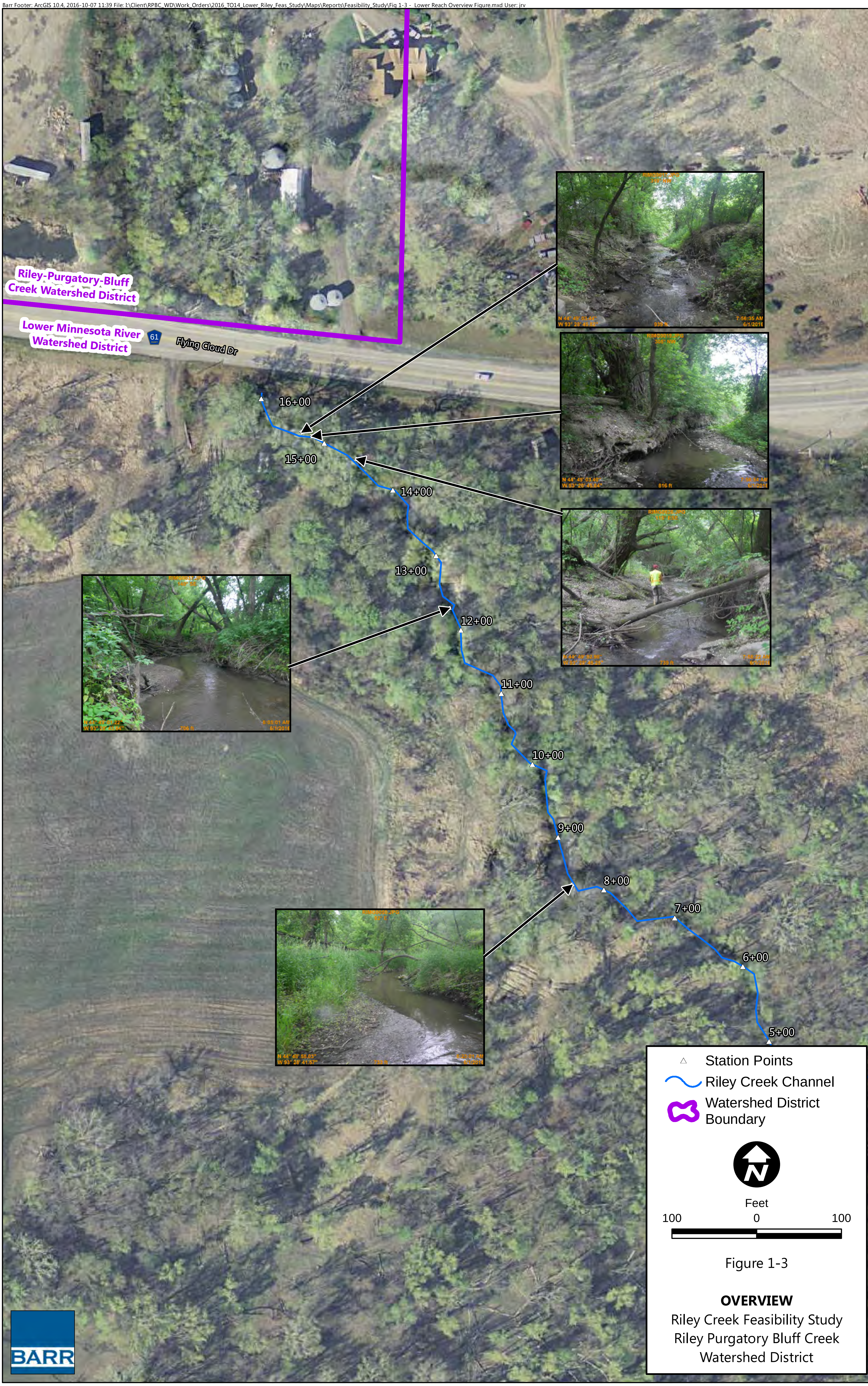


Figure 1-3

OVERVIEW
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

1.4 Past Studies

1.4.1 Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study (2007)

The 2007 Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study (Reference (1)). It examined physical watershed characteristics, hydrologic and hydraulic modeling, watershed slopes, soil types, imperviousness, channel geometry and geomorphology, and erosion processes. The report identified Reach E and Site D3 along the Lower Valley of Riley Creek as high priorities to begin addressing erosion and associated water quality impairments. Specifically, a significant headcut had migrated through the reach, resulting in an incised channel and severely eroding banks. Excerpts from the report relevant to the study reaches is provided in Appendix B.

1.4.2 Creek Restoration Action Strategy (2015)

The RPBCWD completed the Creek Restoration Action Strategy (CRAS) in 2015 (Reference (2)), which created a scoring system to compare restoration potential of all creek reaches within the RPBCWD (i.e. Riley Creek, Purgatory Creek, and Bluff Creek). The creeks were divided into 80 reaches, and the highest scores correspond to the greatest need for stabilization. Reach E of Riley Creek was tied for the highest Tier I CRAS score, which considered the fundamental factors that drive most stream restoration projects including infrastructure risk, stream stability, stream habitat, and water quality. After considering Tier II CRAS categories (public education opportunities, overall watershed benefits, partnerships, and the cost of stabilization per pound of phosphorus "saved"), this reach was tied for the second highest overall score.

As part of the initial scoring of the CRAS, each creek reach was assessed by walking the stream and taking notes and photos. The assessment completed in 2015 by RPBCWD staff noted similar things as was noted in the 2007 Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study (Reference (1)). RPBCWD staff observed a deeply incised and entrenched channel with large, steep eroding valley walls, with one erosion location measured as approximately 50 feet wide and 40 feet tall. RPBCWD staff also noted that the headcuts documented in the 2007 report have migrated upstream such that the upstream reach is also incised and entrenched. The write-up and photos from this assessment can be found in Appendix C.

1.4.3 Strategic Resources Evaluation (2014)

The LMRWD completed a strategic resources evaluation (SRE) in 2014 to assess critical resource areas and recommend management strategies (Reference (3)). The downstream-most portion of Riley Creek, which is within the LMRWD, was included in the SRE. The SRE identified erosion at outside bends where undercut banks and exposed tree roots were observed and also at the downstream end of the box culvert under Flying Cloud Drive, i.e. the upstream portion of this reach. An excerpt from the SRE relevant to the LMRWD reach is presented in Appendix D.

2.0 Problem Identification

In May 2016, site assessments were completed to take measurements and photos to compare current creek conditions to those recorded in the 2007 survey. Potential direct causes of erosion were also considered.

2.1 Geomorphic Assessment

2.1.1 Assessment Methodology

The geomorphic assessment generally followed guidelines and techniques included in the Rosgen classification system (Reference (4)). Rosgen classification uses multiple measurements and ratios to classify a given stream into one of eight different stream types (Figure 2-1). Streams that fall into each stream type typically share many characteristics. One or more measurements that are inconsistent with typical or expected values can help indicate if a stream is stable or unstable.

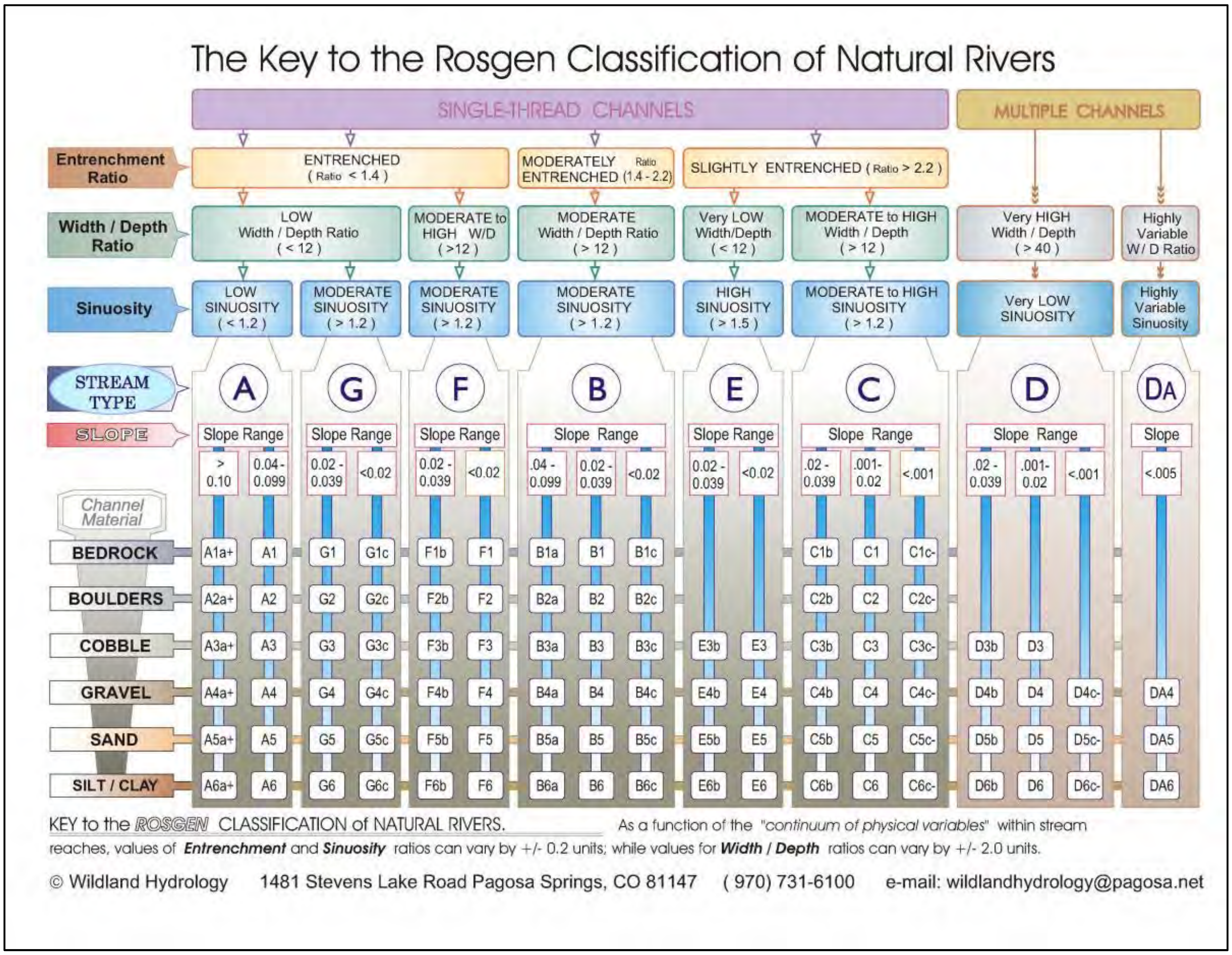


Figure 2-1 Rosgen classification system key (from Reference (4))

As can be seen in Figure 2-1, the Rosgen classification system is dependent on the entrenchment ratio, the width to depth ratio, sinuosity, slope, and bed material. The entrenchment ratio and width-to-depth ratio both use dimensions from the bankfull level for each channel. Bankfull is generally defined as the depth at which flow in the channel just begins to spill into the adjacent floodplain. The flow that results in a bankfull depth is typically between the 1- and 2-year recurring flow, although the exact frequency is dependent on each stream and watershed characteristics. The 1.5-year recurring flow is often used to estimate bankfull flows. The key components of the Rosgen classification system are briefly summarized below:

- *Entrenchment ratio* is the ratio between the bankfull width and the flood prone width. The flood prone width is defined as the width of the floodplain at twice the bankfull depth. This ratio helps described how confined the stream is within its floodplain. A large value indicates a wide floodplain, and a small value indicates a small floodplain.
- The *width-to-depth ratio* is the ratio between the bankfull width and bankfull depth. It provides information about the channel shape.
- *Sinuosity* is the stream length divided by the valley length and provides information about how much the stream meanders through the landscape.
- *Slope* is the average channel slope through the study area.
- *Bed material* characterizes the dominant material and size of material on the channel bottom.

All channel types can be stable in the right site characteristics. In the Twin Cities and central Minnesota, the most common stable channels are Type C and Type E channels. Type C channels are often found in forested areas whereas E channels are often found with grassy riparian areas.

2.1.2 Reach E

Several cross sections were surveyed in 2016. Bankfull indicators found were generally well below the tops of the banks, which typically suggests that the channel is incised. Table 2.1 shows the range of key components of the Rosgen classification system estimated from the field survey.

Table 2.1 Summary of Rosgen classification values for Reach E

Variable	2016 Survey Range
Entrenchment Ratio	1.2 – 6.1
Width-to-Depth Ratio	3.5 – 6.1
Sinuosity	1.2
Slope	0.25% - 1%
Bed Material	Sand

Based on the data in Table 2.1, Reach E is sometimes a Rosgen Type B channel and sometimes a Rosgen Type G channel. Type B channels are primarily found on moderately steep to gently sloping terrain, with the predominant landform seen as a narrow and moderately sloping basin. Type B channels can be stable and are moderately entrenched, display a low channel sinuosity, and often exhibit a streambed that resembles rapids. Type G channels are also known as “gully” stream types found in a variety of landscape settings. G-type channels are entrenched, narrow, and deep with low to moderate sinuosity. Unless containing bedrock and boulder channel materials, G channels have very high bank erosion rates and high sediment supply (Reference (5)). In the 2007 study, multiple cross sections in the reach immediately upstream from this reach of Riley Creek were Rosgen Type C channels, which is the type of channel that would be most expected in this setting. Type C channels have well developed floodplains, can be slightly entrenched, and are relatively sinuous.

Stream survey data was collected in 2016 and compared to similar data collected in 2007 to verify the stream geomorphic changes during this time period. The 2007 survey was conducted during the winter months and included limited data in the upstream portions of the reach below the ice. However, the points available below the ice clearly show that the channel bed has lowered in the upper portions of the reach (approximately the upper 2,500 ft of the reach) while remaining fairly unchanged in the lower section. This survey data correlates with field observations of active erosion and head cutting in the upper section of the study reach. A comparison of cross sections (Figure 2-2) also shows that the channel has lowered since the 2007 survey as it is currently both deeper and wider. Detailed figures showing surveyed locations, longitudinal profile comparison, and all cross section comparisons are included in Appendix E.

Figure 2-2 Reach E Cross Section Comparison Example

Channel dimensions and ratios were not summarized for Site D3 because the Rosgen classification system is not applicable to this stream due to the extremely ephemeral nature of this channel. The cause of erosion at Site D3 is flashy stormwater discharge to a ravine.

2.1.3 LMRWD Reach

The channel within this reach gradually transitions from Flying Cloud Drive to Grass Lake. The upper third is moderately incised and moderately entrenched with some eroding banks. The middle third generally exhibits stable channel dimensions with easy access to a floodplain. The lower third is essentially an alluvial fan with poorly defined channels and evidence of frequent channel migration across the landscape. The channel gradually transitions from a Type B to a Type C and then to an alluvial fan. An alluvial fan is a fan-shaped area of sediment deposition that forms at the downstream end of a stream as the stream transitions from a steep channel slope to flat channel slope. This type of channel transition is expected because there are multiple, major changes to key variables influencing the channel, including floodplain width and influence from backwater from the Minnesota River.

The LMRWD Reach begins at the mouth of the Riley Creek Lower Valley, so the floodplain rapidly expands and flood flows can rapidly expand into the floodplain. As flood flows expand into the floodplain, the velocity in the channel drops and the flow in the channel has a reduced sediment carrying capacity. When this happens, the sediment is deposited in the channel and the channel gradually fills up with sediment.

The Minnesota River is also a major contributor of sediment. The channel within the study reach is located within the 10-year flood elevation for the Minnesota River. The Minnesota River has a high sediment load and deposits a significant amount of sediment on the floodplain during flood events, so sediment deposition from the Minnesota River may also contribute to channel filling in the LMRWD Reach.

Because of the rapid transitions between different channel types, the Rosgen classification dimensions shown in Table 2.2 only show the Rosgen classification values estimated from the 2016 survey data for the upper third of the reach where erosion was evident.

Table 2.2 Summary of Rosgen classification values for LMRWD Reach

Variable	2016 Survey Range
Entrenchment Ratio	1.1-1.3
Width-to-Depth Ratio	5.7-74.4
Sinuosity	1.2
Slope	0.5-1.0%
Bed Material	Sand

2.2 Streambank Erosion

2.2.1 Reach E and Site D3

The initial instability within Reach E was likely caused by the gradual increase in runoff volume and increased peak runoff rates generated by a developing watershed. The bank soils within the Lower Valley are clayey and cohesive, making them somewhat naturally resistant to erosion, particularly if sufficient vegetation is present to provide reinforcement with root masses. Streambanks within this reach are 6 to 10 feet tall, with vertical side slopes that are largely bare of vegetation. A narrow valley concentrates flood flows closer to the channel than in a wide floodplain, thereby generating more erosive pressure on the stream bed and banks, especially during larger storm flows. Due to the channel depth, the creek has limited access to a floodplain. Based on MDNR regional curves (Reference (6)) and USGS regression equations (Reference (7)), Riley Creek should have a mean bankfull depth of 1.5 to 2.5 feet instead of the current 6 to 10 feet. Based on Barr's 2015 PCSWMM model, design flood events up to the 100-yr design storm are largely conveyed within the channel.

At Site D3, two catch basins with beehive grates are installed immediately upstream of separate berms near the head of the ravine. The berms reduce overland flow velocities near the head of the ravine and divert runoff into the storm sewer. However, the storm sewer outlet is still located high enough within the ravine to cause degradation of the ravine bed. The additional flows conveyed to the ravine through the storm sewer from the upstream residential watershed has resulted in an increase of both the volume and runoff rate. The increased volume and rate is exasperated by the steep channel slope of the ravine (11 percent slope). The existing storm sewer outlet includes riprap and geotextile. The riprap has moved; the geotextile fabric is exposed; and there is further erosion near the storm sewer outlet. The invert of the ravine is actively eroding, creating scarps and adding sediment load to Riley Creek.

2.2.2 LMRWD Reach

At the beginning of this study reach, there is evidence of channel downcutting as the culvert until Flying Cloud Drive is perched by approximately two feet. The downcutting is likely caused by the combination of high velocities entering this reach through concentrated flows through the culvert. The channel banks are nearly 6 to 8 feet tall near Flying Cloud Drive with steep side slopes that are largely bare of vegetation. The channel bank heights slowly decline as Riley Creek approaches Grass Lake. Due to the depth of the channel, the creek has limited access to the floodplain especially near Flying Cloud Drive. Based on MNDNR regional curves and USGS regression equations, Riley Creek should have a mean bankfull depth of approximately 2 to 3 feet in this area instead of the current 6 to 8 feet.

3.0 Additional Assessments and Investigations

3.1 Vegetation Assessment

A vegetation assessment was completed during July 2016 to determine the vegetation composition of the riparian areas along the study reaches.

3.1.1 Reach E and Site D3

The plant community surrounding the creek in Reach E and Site D3 is a densely wooded hardwood forest with a nearly continuous canopy cover (90-100%) dominated by sugar maple (Acer saccharum), northern red oak (*Quercus rubra*), and basswood (*Tilia Americana*) tree species. The hardwood forest is indicative of the local southern mesic maple-basswood forests of this region. Other canopy and subcanopy tree species found commonly throughout the upper reach include ironwood (*Ostrya virginiana*), black cherry (*Prunus serotina*), bitternut hickory (*Carya cordiformis*), and hackberry (*Celtis occidentalis*). The ground-layer cover is interrupted to continuous (30-100%) with large bare patches on heavily eroded slopes closer to the stream bank. Wood nettle (*Laportea canadensis*) is the dominant ground cover species covering 80-100% of the ground-layer along large stretches of the reach. Other native plant species found frequently throughout the reach included wild ginger (*Asarum canadense*), Pennsylvania sedge (*Carex pensylvanica*), bloodroot (*Sanguinaria canadensis*), riverbank rye (*Elymus riparius*), and golden glow (*Rudbeckia laciniata*).

Invasive species as listed by the Minnesota Department of Natural Resources (DNR) can be found throughout Reach E but not in large or dense stands. Mature glossy buckthorn (*Rhamnus cathartica*) is found in the subcanopy layer with plants ranging from 3-8' in height. Canada thistle (*Cirsium arvense*) is also found in small openings in the canopy layer.

3.1.2 LMRWD Reach

While Reach E was dominated by hardwood forest plant species the LMRWD Reach is dominated by species indicative of southern floodplain forests. Starting south of Flying Cloud Drive the canopy cover is interrupted to continuous (50-100%) with silver maple (*Acer saccharinum*), cottonwood (*Populus deltoids*), and boxelder (*Acer negundo*) trees. In areas densely shaded by buckthorn, boxelder, and riverbank grapes (*Vitis riparia*) exposed soil with little groundcover is present. Along the creek bank in sunnier locations native species including goldenglow, marestail (*Conyza canadensis*), jewelweed (*Impatiens capensis*), stinging nettle (*Urtica dioica*), and White Grass (*leersia viginica*) form dense cover down to the creek's edge (fig 4). Found near the creek's edge are some small (>200 sf) reed canary grass (*Phalaris arundinacea*) patches. Reed canary grass is a highly aggressive plant listed as an invasive species by the DNR. As the creak approaches Grass Lake the topography flattens out into a floodplain with nearly continuous canopy cover (90-100%) dominated by mature silver maple and black willow (*Salix nigra*) trees. There is no subcanopy or shrub layer near Grass Lake. Ground-layer cover is vegetated by flood-tolerant annual and perennial species dominated by wild rye (*Elymus virginicus*), white grass, false nettle (*Boehmeria cylindrical*), Canada thistle, and plantain (*Plantago major*).

3.2 Geotechnical Assessment

A basic geotechnical assessment was completed in June 2016 to get a preliminary assessment of the scarps located in Reach E and to guide the development of stabilization concepts. The assessment was focused on Reach E due to the tall scarps, steep slopes, and challenging construction access, particularly within Sub-reach E2. The geotechnical concepts for Reach E can be applied to Site D3, although due to shorter slopes and scarps and easier site access, construction at Site D3 is less challenging than Reach E. The height of slopes and scarps within the LMRWD reach are more typical of stream bank heights and do not pose a challenging geotechnical stability issue. Therefore, the geotechnical assessment was not completed in the LMRWD reach.

The assessment was limited to visual surveys of the scarps and did not include hand augers, soil borings or geotechnical modeling. The exposed soil of the existing scarps showed a mix of sand and clay within the soil profile. Recent slumps were observed in some locations. The distances from the tops of the scarps to homes and structures were noted and due to the relatively long distances, scarp erosion does not appear to pose a threat to homes or structures in the area in the foreseeable future. Old scarps that had stabilized enough to be partially revegetated were also observed within the reach. It was also noted that other portions of the reach have steep valley slopes that are not currently eroding; however the right conditions in the future may result in a slope failure, even if the channel has been stabilized. Wet periods, heavy storms, or a combination of the two can create saturated slopes that result in failures. An uprooted tree can also change the dynamics of the slope to make it more susceptible to an isolated failure that could then grow over time.

Due to the scarp dimensions and relatively difficult access for heavy equipment, it was assumed that the design and installation of measures that would result in geotechnical stable slope would be extremely expensive for each scarp and unlikely to be a feasible given the lack of a near-term threat to homes or structures. Alternative measures to slow or significantly reduce scarp erosion were discussed, including options for stabilizing the toes of the scarps and grading some portions of the scarps to create slopes less susceptible to erosion, thereby allowing vegetation to become re-established.

3.3 Phase I Environmental Assessment

3.3.1 Reach E and Site D3

A Phase I Environmental Site Assessment (Phase I) was performed in May 2016 to identify recognized environmental conditions (RECs) associated with the Project area. The Phase I consisted of a records review, site reconnaissance, and local interviews. No RECs were identified in connection with the Project area (Reference (6)). The Phase I report is included as Appendix F.

3.3.2 LMRWD Reach

A Phase I was not completed for the LMRWD Reach of Riley Creek. Some debris from what appears to be old household dumping (bicycles, washing machines, etc.) was observed along portions of the streambank. A Phase I environmental assessment is recommended during the early portion of the design phase to identify potential soil contamination that would require treatment or off-site disposal.

3.4 Historic and Cultural Resources

A Phase I archaeological field survey for Reach E, Site D3, and the LMRWD Reach was completed in June 2016 to determine if these reaches might require further investigation for cultural or historical importance. A records/literature search was completed prior to the field survey using the Minnesota State Archaeological Site Files at the Office of the State Archaeologist, the database files of the State Historic Preservation Office, and several historic maps. The field survey included pedestrian visual surface reconnaissance, followed by 10 shovel tests. No cultural materials other than those that can be reliably associated with present-day use of the area were identified in the surveyed areas (Reference (6)).

Based on the negative results of the field survey, it is unlikely that the proposed project would adversely affect any significant intact cultural features or deposits. The cultural resources report, is included as Appendix G.

3.5 Wetlands

The study reaches were evaluated for wetlands and other waters of the U.S. on June 16-17, 2016. The wetland delineation was completed in accordance with the Routine On-Site Determination Method specified in the U.S. Army Corps of Engineers Wetlands Delineation Manual (1987 Edition) (Reference (8)) and the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region (Reference (9)). The field delineation is necessary to meet requirements of a USACE Section 404 Permit, MnDNR Public Waters permitting, and the Wetland Conservation Act.

One section of Riley Creek and one wetland were identified within the Reach E and Site D3 project area. The creek reach was delineated as a linear waterway and classified as a R2UBH linear waterway according to the Cowardin system (Reference (10)). Riley Creek is also identified as a public watercourse in the MnDNR's Public Water Inventory (PWI).

One wetland was delineated adjacent to Reach E, near the downstream end of the reach. This wetland is an excavated stormwater pond and was classified as a PUBGx shallow open water basin approximately 0.38 acres in size.

One wetland was delineated adjacent to the LMRWD Reach of Riley Creek. This wetland is floodplain of the Minnesota River and was classified as a PFO1A floodplain forest wetland which extends beyond the surveyed area. The full wetland delineation report, including figures and field data sheets, is included as Appendix H.

4.0 Stabilization Options, Evaluation Criteria and Cost Consideration

4.1 Stabilization Options

When selecting alternatives for detailed design and construction, RPBCWD, LMRWD, and the city of Eden Prairie may select differing approaches at each site (even sites with similar characteristics) to best meet the overall project goals. As a result, there are a large number of possible combinations of alternatives that would provide stabilization benefits throughout the entire project area. Furthermore, detailed design efforts may identify and include stabilization techniques or combinations of techniques that are not specifically included in this engineer's report.

4.1.1 Bioengineering and Hard Armoring Stream Stabilization Techniques

Techniques for stream stabilization generally fall into two categories: bioengineering (also known as soft armoring) and hard armoring. Bioengineering techniques employ biological and ecological concepts to control erosion, using vegetation or a combination of vegetation and construction materials, including logs and boulders. Techniques that do not use vegetative material but are intended to achieve stabilization of natural flow patterns and create in-stream habitat, such as boulder or log vanes, are generally included under the umbrella of bioengineering. Hard armoring techniques include the use of engineered materials such as stone (riprap or boulders), gabions, and concrete to stabilize slopes and prevent erosion.

Bioengineering techniques maintain more of a stream's natural function and provide better habitat and a more natural appearance than hard armoring. If vegetation is well-established this approach can also be self-maintaining. Due to biodegradation of construction materials and variable vegetation establishment success, it is typically assumed that bioengineering installations have a shorter life span and may need more frequent (if less expensive) maintenance, particularly as the vegetation is becoming established. Compared to hard armoring, the success of bioengineering techniques is more dependent on the skill of the designer and installer—sometimes making bioengineering construction more expensive. Hard armoring and bioengineering techniques present different challenges, costs, and benefits for stream stabilization design.

Hard armoring methods are viewed as standard and time-tested and typically have a longer life span due to the permanence of the materials used. Hard armoring is usually effective in preventing erosion where it is installed; however, placement must consider downstream impacts, understanding that the armoring may push the erosive stresses downstream. Hard armoring typically requires little maintenance; however, if the armoring fails, maintenance or replacement can be expensive, particularly if the armoring materials need to be removed from the site.

Technical stakeholders, including the USACE and MDNR, have expressed a preference for bioengineering over hard armoring for stream stabilization where possible. The RPBCWD Rules (Rule F) include specific language requiring that a preference be made for natural materials and bioengineering over hard armor.

4.1.2 Stream Vortex Tubes

Some stream stabilization techniques are neither hard armoring nor bioengineering. Stream Vortex Tubes are an example of a stream stabilization technique that does not fit into either category. The Stream Vortex Tube removes sediment from a stream channel and stores it in an off-channel basin. An open-top pipe is placed in the stream so that flow over the top of the opening is forced into a vortices thereby removing sediment from the water. This sediment is conveyed along the pipe into a pond. The sediment could be used as a commercial product for road base, surfacing, and material processing.

4.1.3 Floodplain Reconnection

In addition to reducing sediment loading through streambank stabilization with bioengineering methods, hard armoring or establishment of vegetation/toe protection, alternatives that improve access to the floodplain by raising the stream bed or excavating the floodplain would further improve the conditions by effectively lowering the depth of water in the channel during storm events. Shear stress on the channel bed and banks correlates with the depth of water in the channel, therefore a lower water depth results in reduced channel erosion.

4.1.4 Stream Stabilization Techniques Evaluated

The following stream stabilization techniques were evaluated for stabilizing Riley Creek within the project area. Example figures and additional descriptions for selected techniques are included in Appendix I.

Bioengineering techniques evaluated

- Active floodplain/vegetated bench—modifications made to the stream cross section to increase floodplain connectivity and decrease erosive stress during flood flows; can involve construction of a soil bench, lowering an existing bench, and/or raising the channel bed
- Boulder or log vane—boulders or large logs 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, control stream bed elevations, and create scour pool habitat features
- Constructed riffle—gravel or cobble material installed in the stream bed to create natural flow patterns/varied habitat features and, frequently, to control stream bed elevations
- Vegetated buffer—native vegetation established along a stream bank or overbank area to stabilize bare soils and increase resistance to fluvial erosion
- Vegetated reinforced slope stabilization (VRSS)—soil lifts created with long-lasting, biodegradable fabric and vegetated to stabilize steep slopes and encourage establishment of root systems for further stabilization
- Root wads or toe wood—tree trunks with the root ball attached, installed either singly (root wads) or in conjunction with additional large woody debris and VRSS (toe wood) to achieve one or more of the following goals: increase bank roughness and resistance to erosion, create

undercut/overhanging bank habitat features, re-direct flows away from banks, and provide a bench for establishment of riparian vegetation

- Scarp Toe Stabilization – vertical cedar pilings placed one foot on center along the toe of the actively eroding scarp and extending approximately 2 feet above the channel bed. Salvaged trees are installed longitudinally on the landward side of the cedar pilings. The combined structure would reduce further erosion of the scarp toe and provide a bench for scarp material to deposit, eventually reducing the slope of the scarp and allowing for the scarp revegetation.
- Scarp Stabilization – intended to be constructed in conjunction with Scarp Toe Stabilization, this technique involves grading of the scarp to a stable slope (3:1 or 2:1), installation of erosion control blanket, and establishment of erosion resistant vegetation.

Hard armoring techniques evaluated

- Riprap-lined channel—riprap throughout an entire channel cross section to control stream bed elevations and prevent erosion
- Stone toe protection—riprap or other stones along the lower portion of a stream bank to protect against erosion
- Riprap slope stabilization—riprap along a steep slope to protect against erosion and prevent undercutting and slumping

4.2 Evaluation Criteria

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 Table 4.1.

Table 4.1 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]	10-13	5.1
Riprap (24-in D_{50})[a,c]	14-18	10.1
Rootwads[d]	N/A	N/A

a – from Reference (11)

b – for use in constructed riffles and grade control

c – for use in rock vanes

d – design and installation guidelines in Reference (12)

4.3 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 -15% 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, LMRWD, city of Eden Prairie, and MnDNR, a range for the OPC estimate between -15% and +20% 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 J. 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 15% 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 7% of the estimated construction costs (excluding contingency).
- 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.

4.3.1 Off-site Sediment Disposal

Based on the results of the Phase I assessment (Appendix F) for Reach E and Site D3, it is assumed that a Phase II assessment of bank material would not be necessary and that sediment disposed off-site, if necessary, would not require additional testing or special disposal as hazardous or dredged material. As such, these costs are not included in the estimates.

4.3.2 Wetland Mitigation

Stream banks may meet wetland designation criteria; disturbing the banks as part of a restoration project may be considered a temporary wetland impact. However, because the purpose of stream bank repair and restoration is to create a stable bank that can support a riparian ecosystem, the impacts are typically considered to be self-mitigating and do not usually require additional costs for wetland mitigation. As such, these costs are not included in the estimates.

4.3.3 Tree Replacement and Revegetation

It is assumed that the city of Eden Prairie would determine where tree replacements would be desired (based on estimated tree removals and long-term land use plans) during final design. For the cost estimate, tree replacements are assumed to be equal to tree removals. It may be desirable to open the canopy to assist vegetation reestablishment by providing additional sunlight to the understory. As such, tree replacements along the entire project reach may not be desirable. Because many portions of the project reach have significant shade cover, the costs of shade-tolerant species (shrubs and grasses), appropriate site preparation, seeding, and maintenance to establish the vegetation are included in the cost estimate.

4.3.4 Annualized Pollutant Reduction Costs

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 0.01 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 5.3 and Table 5.4.

4.3.5 Easements

4.3.5.1 Reach E and Site D3 Cost Considerations

Most of the project is located on property owned by the city of Eden Prairie or in areas where the City has access easements. The costs associated with easements on city property are typically negligible; no costs for temporary construction easements are included in this estimate.

4.3.5.2 LMRWD Easements

Much of the LMRWD Reach is surrounded by private land. An existing agreement is in place between the landowner and the Met Council for access to the Riley Creek stream gage station; however, the location of this easement is not conducive to construction of the stabilization measures. Stabilization activities would likely require a new easement with the landowner for construction and maintenance activities.

4.3.6 Miscellaneous Costs

Most site costs include miscellaneous items needed during construction (e.g., a rock construction entrance, a filter dike to control in-stream sediment disturbance, and restoration of access paths). Based on previous project experience, the cost estimates include some overage that could be applied to these miscellaneous items.

5.0 Stabilization Alternatives and Additional Considerations

5.1 Stabilization Alternatives

This section described stabilization alternatives developed for each reach or sub-reach of Riley Creek evaluated in this report, including Site D3, Sub-reach E1, Sub-reach E2, Sub-reach E3, and the LMRWD Reach. Table 5.1 provides a summary of the project alternatives for each reach. Additional descriptions follow in the sections below.

Table 5.1 Summary of Project Alternatives for Reach E and Site D3

Reach	Alternative	Description	Total Project OPC[1] and Range[2]
Site D3	A	Additional culvert Outlet structure	$173,000 ($147,000-$208,000)
	B	Ravine Stabilization	$401,000 ($341,000-$481,000)
E1	A1	4 rock riffles, 2 scarp toe stabilizations	$305,000 ($259,000-$366,000)
	A2	4 rock riffles, 2 scarp toe stabilizations, 2 scarp surface stabilizations	$312,000 ($265,000-$374,000)
	B1	4 cross checks, floodplain excavation, channel fill, 2 scarp toe stabilizations	$635,000 ($540,000-$762,000)
	B2	4 cross checks, floodplain excavation, channel fill, 2 scarp toe stabilizations, 2 scarp surface stabilizations	$641,000 ($545,000-$769,000)
E2	A1	3 rock riffles, 7 scarp toe stabilizations	$499,000 ($424,000-$599,000)
	A2	3 rock riffles, 7 scarp toe stabilizations, 7 scarp surface stabilization	$554,000 ($471,000-$665,000)
	B1	3 cross checks, floodplain excavation, channel fill, 7 scarp toe stabilizations	$656,000 ($558,000-$787,000)
	B2	3 cross checks, floodplain excavation, channel fill, 7 scarp toe stabilizations, 7 scarp surface stabilizations	$711,000 ($604,000-$853,000)
E3	A1	3 rock riffles, 2 scarp toe stabilizations	$349,000 ($297,000-$419,000)
	A2	3 rock riffles, 2 scarp toe stabilizations , 2 scarp surface stabilizations	$360,000 ($306,000-$432,000)
	B1	3 cross checks, floodplain excavation, channel fill, 2 scarp toe stabilizations	$772,000 ($656,000-$926,000)
	B2	3 cross checks, floodplain excavation, channel fill, 2 scarp toe stabilizations, 2 scarp surface stabilizations	$781,000 ($664,000-$937,000)

1 – Includes estimated construction costs, a 15% contingency, 7% of construction costs for construction observation, and 20% of construction costs for engineering, design, permitting, and legal.

2 – 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 15% project contingency, 20% for design, permitting, and legal, and 7% for construction administration. Lower bound assumed at -15% and upper bound assumed at +20%.

5.1.1 Site D3 Alternatives

5.1.1.1 Alternative A – Additional Culvert and Outlet Structure

Alternative A would include constructing an additional culvert and outlet structure to convey runoff originating from the upstream residential area directly to the Riley Creek channel (Figure 5-1). The outlet structure would consist of a manhole designed to dissipate the majority of the runoff's energy before it exits the structure. Some riprap would be necessary to stabilize the stream bed and bank in the vicinity of the new outlet. Runoff originating from the ravine's immediate contributing area would still be allowed to flow down the ravine channel, similar to predevelopment conditions. Natural stabilization of the eroded scarps and stream channel is expected as the flow rate and volume would be reduced by the new culvert.

The additional length of culvert associated with Alternative A would allow stormwater to outlet at the Riley Creek channel than the existing outfall structure. This, in turn, would reduce the volume of water currently conveyed through the surface channel of the ravine. The ravine would continue to convey surface runoff from the immediate contributing area as it did naturally prior to development, and the actively eroding areas would be allowed to naturally stabilize. This work would retain the hydraulic capacity of the ravine without raising water levels. However, culvert installation would require considerable excavation and may be challenging due to the current meandering pattern of the ravine.

Though considerable excavation would be required to properly install the pipe, Alternative A is feasible and would provide a natural surface condition for ravine stabilization. The drop structure/energy dissipation structure could be constructed within a manhole, minimizing the impact to Riley Creek.

The OPC of Alternative A ranges from $147,000 to $208,000.

5.1.1.2 Alternative B – Ravine Stabilization

Alternative B would include stabilizing the ravine through the use of riprap, cross checks, and scarp toe stabilization (Figure 5-2). Within the upper third of the length of Site D3, the ravine bottom and side slopes would be stabilized with riprap up to the 100-year design flow elevation. Eight boulder cross vanes would be installed in the lower two-thirds of Site D3 to provide ravine bottom stability. Alternative B would also include toe stabilization of scarps adjacent to Site D3.

Alternative B provides a less complex, readily feasible solution that design engineers and contractors commonly use in ravine stabilization; however, riprap stabilization is not considered a natural solution and may not be aesthetically pleasing within the natural setting of the RCCA. The use of cross vanes could raise the flood stage in the ravine, requiring additional mitigation measures.

The estimated OPC of Alternative B ranges from $341,000 to $481,000.

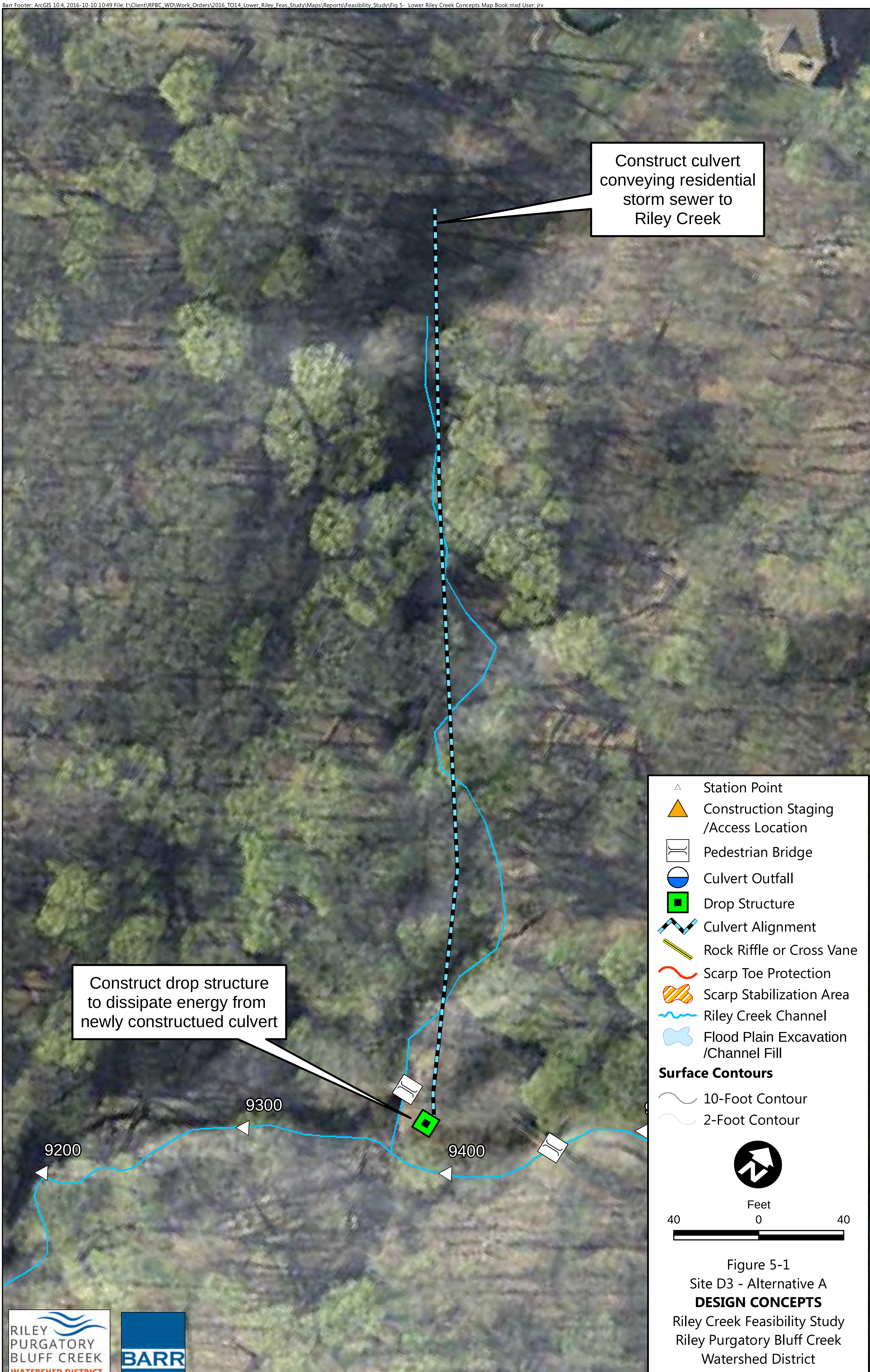


Figure 5-1
Site D3 - Alternative A
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

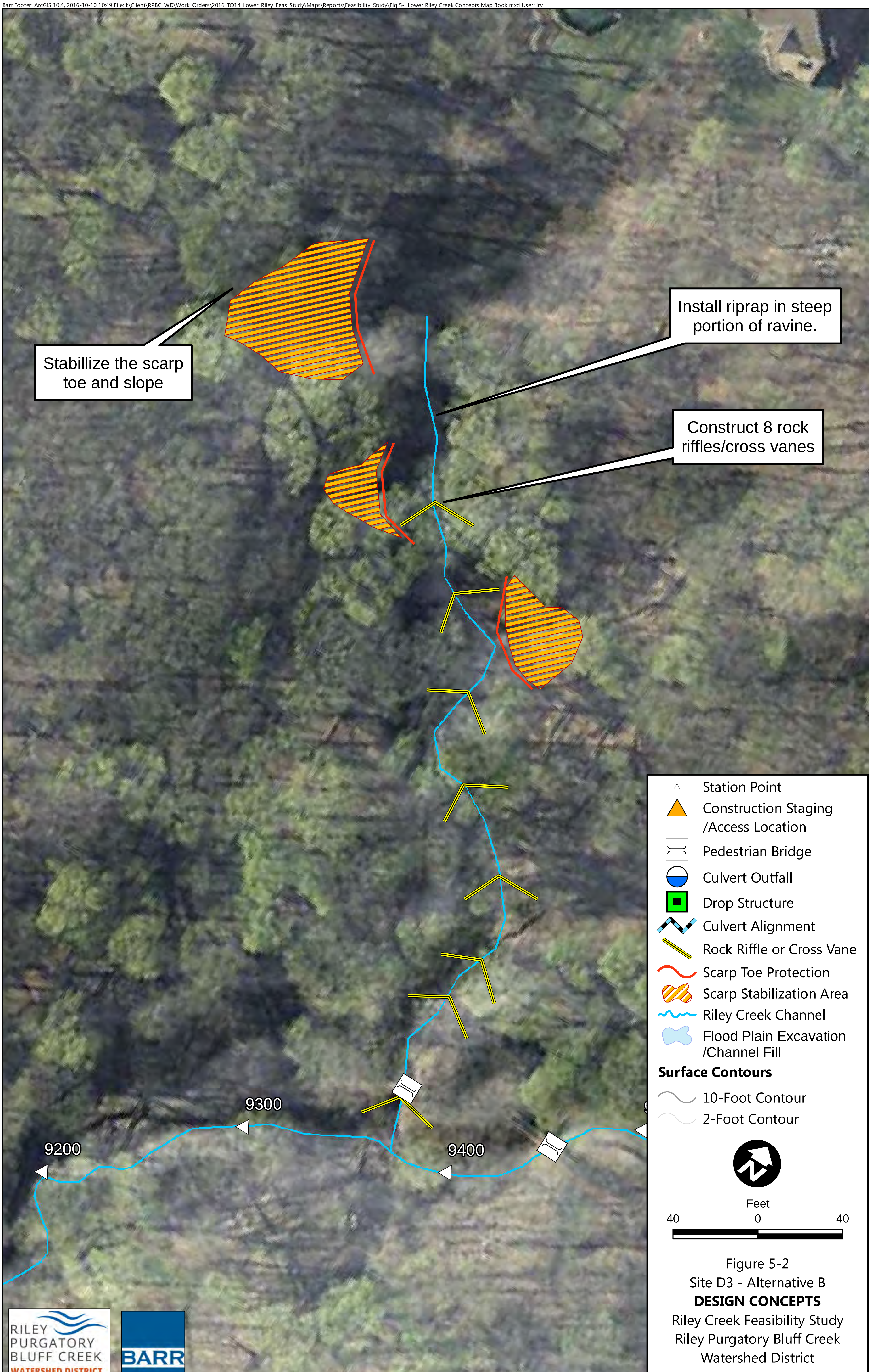


Figure 5-2
Site D3 - Alternative B
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

5.1.2 Sub-reach E1 Alternatives

Two primary alternatives have been developed for Sub-reach E1, each of which contains two variations on the primary stabilization theme.

5.1.2.1 Alternative A1 – Rock Riffles and Scarp Toe Stabilization

Alternative A1 for Sub-reach E1 would include installation of four rock riffles, each approximately three-feet tall. Sedimentation upstream of each rock riffle would naturally raise the channel bed to better match the appropriate bankfull depth and facilitate reconnection of the stream with the floodplain. Alternative A1 would also include stabilizing two active scarp toes to reduce active erosion within the reach (Figure 5-3). Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Sub-reach E1, Alternative A1 would limit the construction footprint and the need for tree removal within the project area. Preliminary hydraulic modeling indicates that raising the bed by three feet would not cause impacts outside of the project reach. Even though design flood impacts are anticipated to be contained within the project reach, raising the design flood level within the project reach could pose permitting challenges. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E1, Alternative A1 ranges from $259,000 to $366,000.

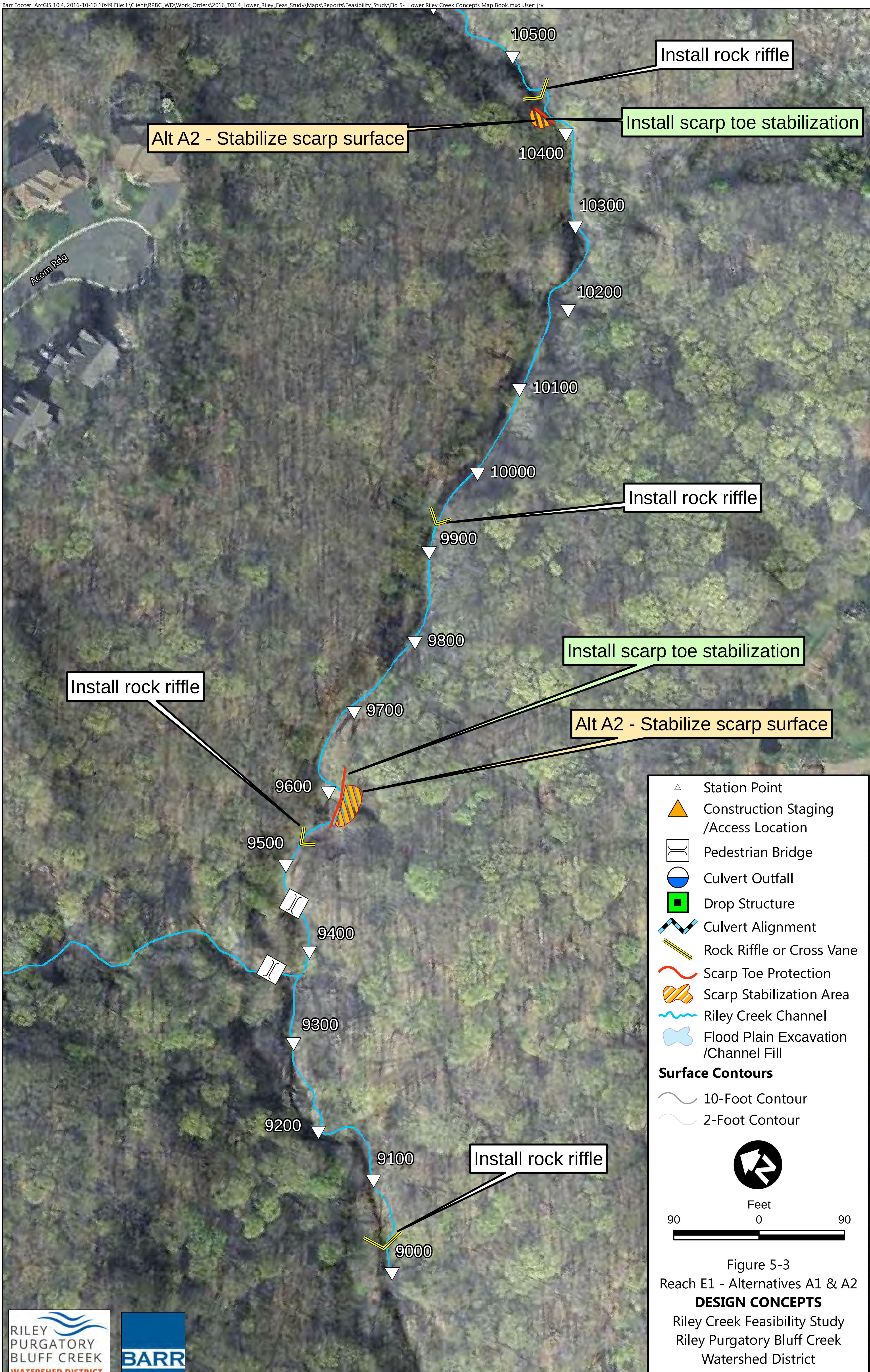
5.1.2.2 Alternative A2 – Rock Riffles, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative A2 for Sub-reach E1 is very similar to Alternative A1 for this reach in that it would include installation of four, three-foot tall rock riffles and would also stabilize two scarp toes. However, Alternative A2 for Sub-reach E1 would also include stabilization of the two scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-3).

Alternative A2 has similar advantages and challenges to those presented with Alternative A1 of Sub-reach E1; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E1, Alternative A2 ranges from $265,000 to $374,000.

Barr Footer: ArcGIS 10.4, 2016-10-10 10:49 File: I:\Client\RPBC_WD\Work_Orders\2016_TO14_Lower_Riley_Feas_Study\Maps\Reports\Feasibility_Study\Fig 5- Lower Riley Creek Concepts Map Book.mxd User: jrv



5.1.2.3 Alternative B1 – Cross Checks, Floodplain Excavation, Channel Fill, and Scarp Toe Stabilization

Alternative B1 for Sub-reach E1 would include clearing and grubbing the floodplain adjacent to the Riley Creek channel, then excavating approximately two-feet of material from the floodplain. The excavated material would be placed in the existing channel to raise the bed approximately two-feet. Four, one-foot tall cross check structures would be installed in Riley Creek (Figure 5-4). Raising the channel bed would facilitate reconnection of the stream with the floodplain and the cross checks would focus the stream energy away from the banks and minimize potential degradation of the stream bottom. Alternative B1 would also include stabilizing two active scarp toes to reduce active erosion within the reach. Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Alternative B1 would approximately balance floodplain excavation and channel fill, simplifying project permitting and mitigates impacts to the design flood elevation. However, excavating the floodplain would require significant removal and disturbance of trees and vegetation along the channel. Such a disturbance in the floodplain would also create a vulnerability to erosion until vegetation is completely re-established. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E1, Alternative B1 ranges from $540,000 to $762,000.

5.1.2.4 Alternative B2 – Cross Checks, Floodplain Excavation, Channel Fill, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative B2 for Sub-reach E1 is very similar to Alternative B1 for this reach in that it would include clearing, grubbing, and excavating the floodplain, and then placing the excavated material in Riley Creek to raise the bed approximately two-feet. Alternative B2 would also include installation of four, one-foot tall cross check structures in Riley Creek and stabilization of two scarp toes. However, Alternative B2 for Sub-reach E1 would also include stabilization of the two scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-4).

Alternative B2 has similar advantages and challenges to those presented with Alternative B1 of Sub-reach E1; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E1, Alternative B2 ranges from $545,000 to $769,000.

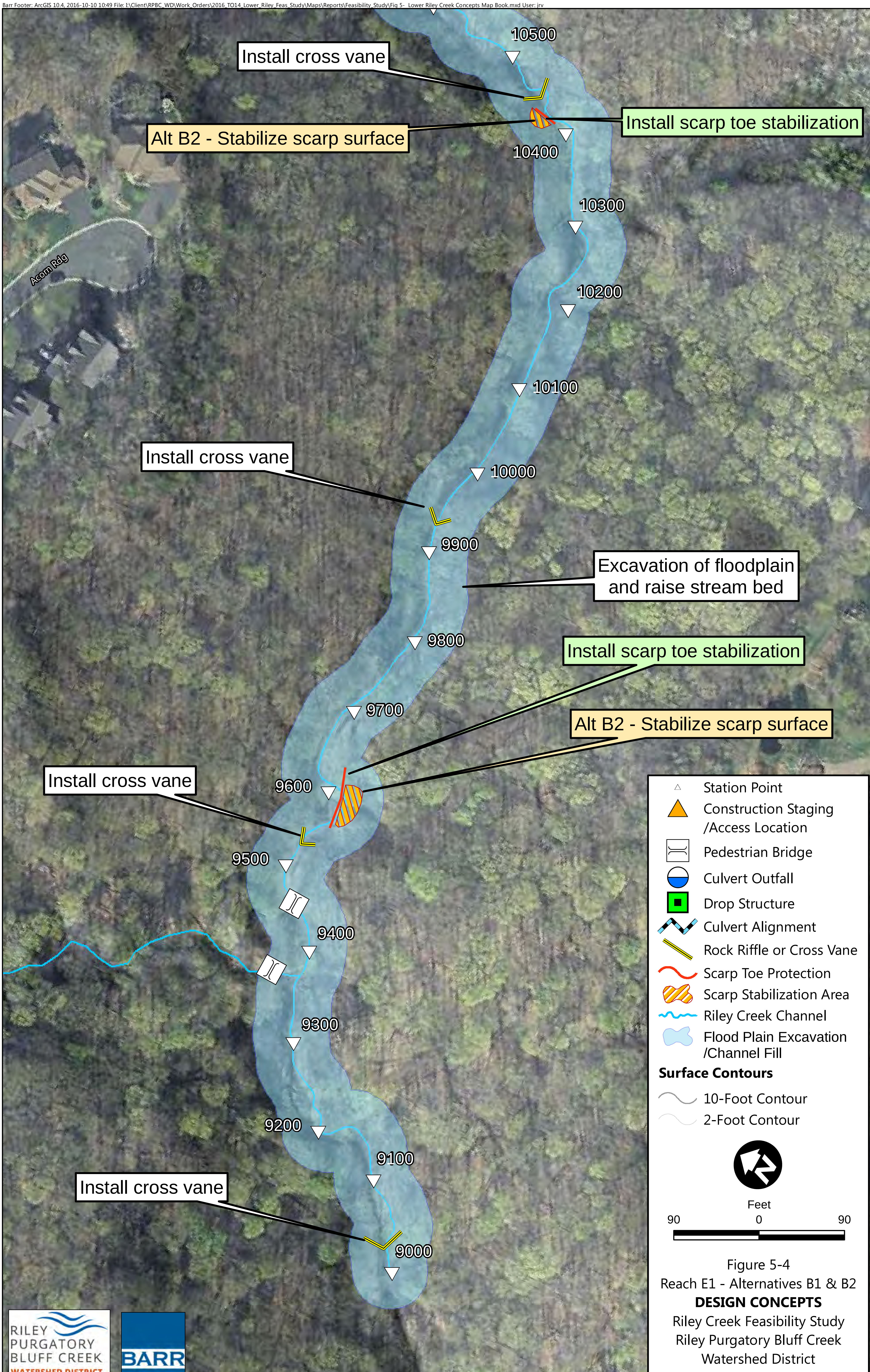


Figure 5-4
Reach E1 - Alternatives B1 & B2
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

BARR

5.1.3 Sub-reach E2 Alternatives

Two primary alternatives have been developed for Sub-reach E2, each of which contains two variations on the primary stabilization theme. All sub-reach E2 alternatives would raise the channel bed. As such, the culvert outfall in this sub-reach may need to be raised and re-stabilized. This culvert modification would need to be evaluated regardless of alternative selected.

5.1.3.1 Alternative A1 – Rock Riffles and Scarp Toe Stabilization

Alternative A1 for Sub-reach E2 would include installation of three rock riffles, each approximately three-feet tall. Sedimentation upstream of each rock riffle would naturally raise the channel bed to better match the appropriate bankfull depth and facilitate reconnection of the stream with the floodplain. Alternative A1 would also include stabilizing seven active scarp toes to reduce active erosion within the reach (Figure 5-5). Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Sub-reach E2, Alternative A1 would limit the construction footprint and the need for tree removal within the project area. Preliminary hydraulic modeling indicates that raising the bed by three feet would not cause impacts outside of the project reach. Even though design flood elevation impacts are anticipated to be contained within the project reach, raising the design flood level within the project reach could pose permitting challenges. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E2, Alternative A1 ranges from $424,000 to $599,000.

5.1.3.2 Alternative A2 – Rock Riffles, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative A2 for Sub-reach E2 is very similar to Alternative A1 for this reach in that it would include installation of three, three-foot tall rock riffles and would also stabilize seven scarp toes. However, Alternative A2 for Sub-reach E1 also includes stabilization of the seven scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-5).

Alternative A2 has similar advantages and challenges to those presented with Alternative A1 of Sub-reach E2; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E2, Alternative A2 ranges from $471,000 to $665,000.

Barr Footer: ArcGIS 10.4, 2016-10-10 10:49 File: I:\Client\RPBC_WD\Work_Orders\2016_TO14_Lower_Riley_Feas_Study\Maps\Reports\Feasibility_Study\Fig 5- Lower Riley Creek Concepts Map Book.mxd User: jrv

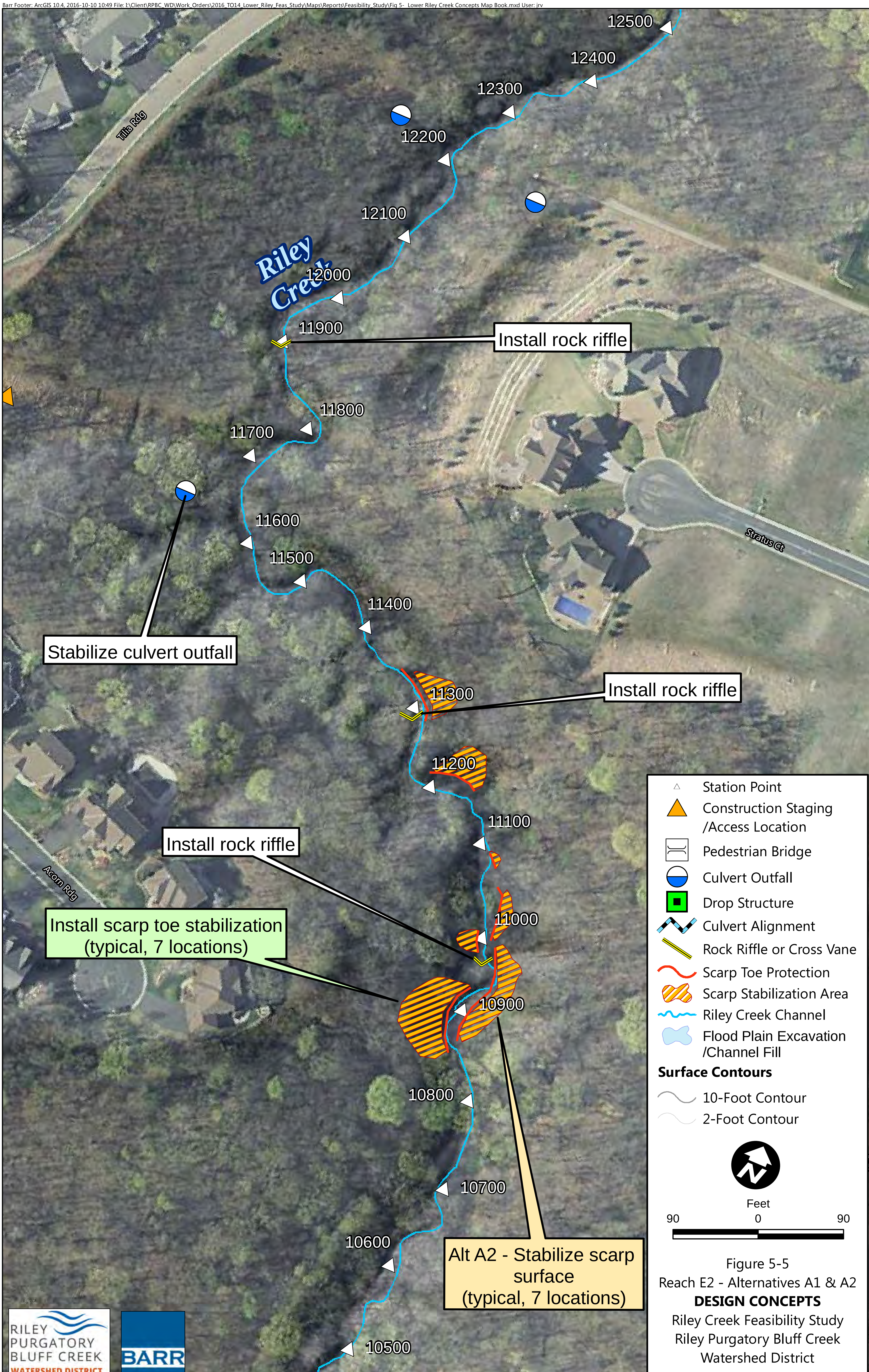


Figure 5-5
Reach E2 - Alternatives A1 & A2
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

5.1.3.3 Alternative B1 – Cross Checks, Floodplain Excavation, Channel Fill, and Scarp Toe Stabilization

Alternative B1 for Sub-reach E2 would include clearing and grubbing the floodplain adjacent to the Riley Creek channel, then excavating approximately two-feet of material from the floodplain. The excavated material would be placed in the existing channel to raise the bed approximately two-feet. Three, one-foot tall cross check structures would be installed in Riley Creek (Figure 5-6). Raising the channel bed would facilitate reconnection of the stream with the floodplain and the cross checks would focus the stream energy away from the banks and minimize potential degradation of the stream bottom. Alternative B1 would also include stabilizing seven scarp toes to reduce active erosion within the reach. Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Alternative B1 would approximately balance floodplain excavation and channel fill, simplifying project permitting and mitigates impacts to the design flood elevations. However, excavating the floodplain would require significant removal and disturbance of trees and vegetation along the channel. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E2, Alternative B1 ranges from $558,000 to $787,000.

5.1.3.4 Alternative B2 – Cross Checks, Floodplain Excavation, Channel Fill, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative B2 for Sub-reach E2 is very similar to Alternative B1 for this reach in that it would include clearing, grubbing, and excavating the floodplain, and then placing the excavated material in Riley Creek to raise the bed approximately two-feet. Alternative B2 would also include installation of three, one-foot tall cross check structures in Riley Creek and stabilization of seven scarp toes. However, Alternative B2 for Sub-reach E2 would also include stabilization of the seven scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-6Figure 5-4).

Alternative B2 has similar advantages and challenges to those presented with Alternative B1 of Sub-reach E2; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E2, Alternative B2 ranges from $604,000 to $853,000.

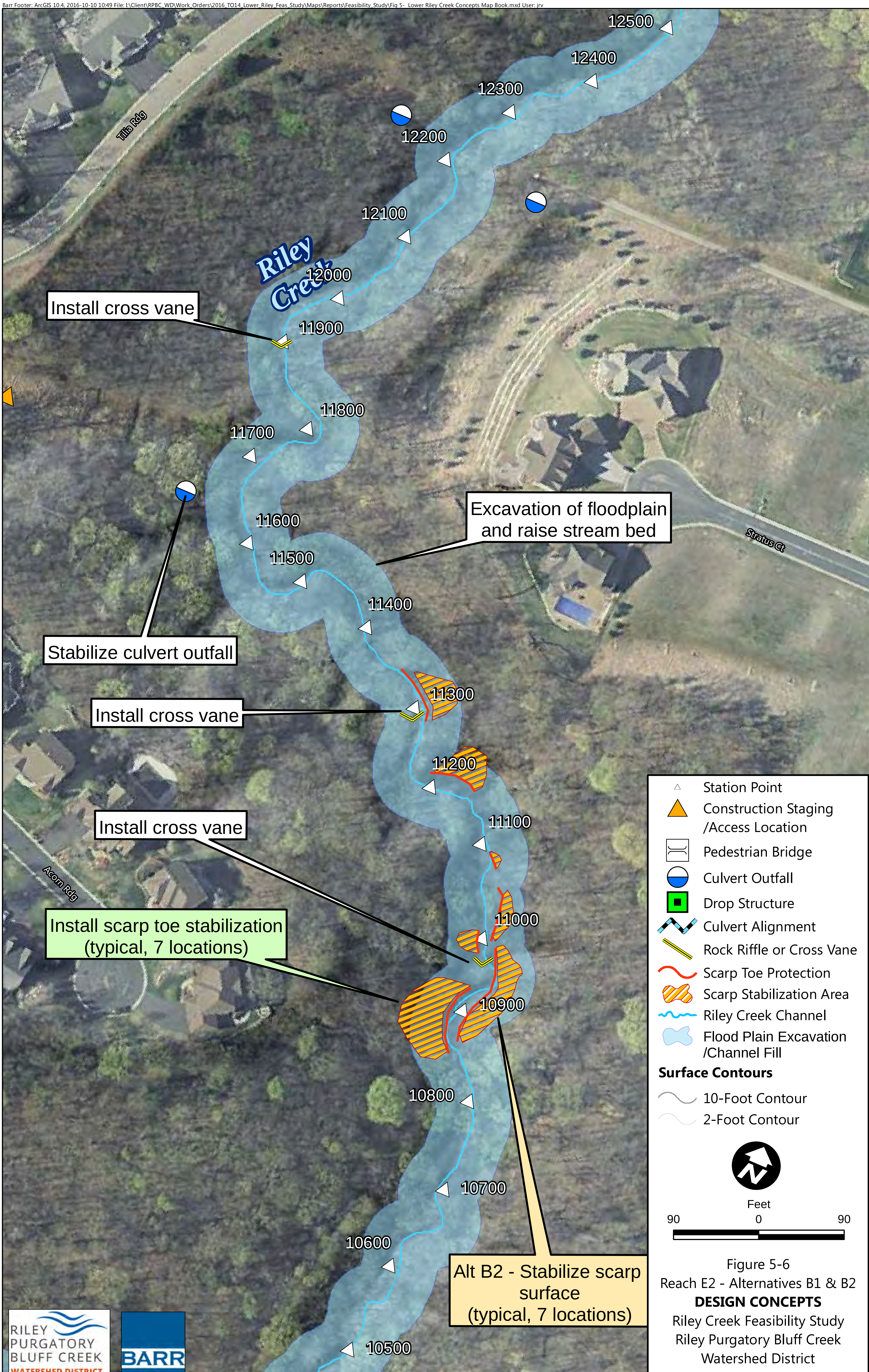


Figure 5-6
Reach E2 - Alternatives B1 & B2
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

5.1.4 Sub-reach E3 Alternatives

Two primary alternatives were developed for Sub-reach E3, each of which contains two variations on the primary stabilization theme. All sub-reach E3 alternatives would raise the channel bed. As such, the three culvert outfalls in this sub-reach may need to be raised and re-stabilized. There is an existing stormwater pond near the downstream end of Sub-reach E3. Similar to the culvert outfalls, the design of this stormwater pond would need to be evaluated during final design to confirm that raising the channel bed would not reduce its storage capacity or function. Culvert and stormwater pond modifications would need to be evaluated regardless of alternative selected.

5.1.4.1 Alternative A1 – Rock Riffles and Scarp Toe Stabilization

Alternative A1 for Sub-reach E3 would include installation of three rock riffles, each approximately three-feet tall. Sedimentation upstream of each rock riffle would naturally raise the channel bed to better match the appropriate bankfull depth and facilitate reconnection of the stream with the floodplain. Alternative A1 would also include stabilizing two active scarp toes to reduce active erosion within the reach (Figure 5-7). Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Sub-reach E3, Alternative A1 would limit the construction footprint and the need for tree removal within the project area. Preliminary hydraulic modeling indicates that raising the bed by three feet would not cause impacts outside of the project reach. Even though design flood elevation impacts are anticipated to be contained within the project reach, raising the design flood level within the project reach could pose permitting challenges. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E3, Alternative A1 ranges from $297,000 to $419,000.

5.1.4.2 Alternative A2 – Rock Riffles, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative A2 for Sub-reach E3 is very similar to Alternative A1 for this reach in that it would include installation of three, three-foot tall rock riffles and would also stabilize two scarp toes. However, Alternative A2 for Sub-reach E3 would also include stabilization of the two scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-7).

Alternative A2 has similar advantages and challenges to those presented with Alternative A1 of Sub-reach E3; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E3, Alternative A2 ranges from $306,000 to $432,000.

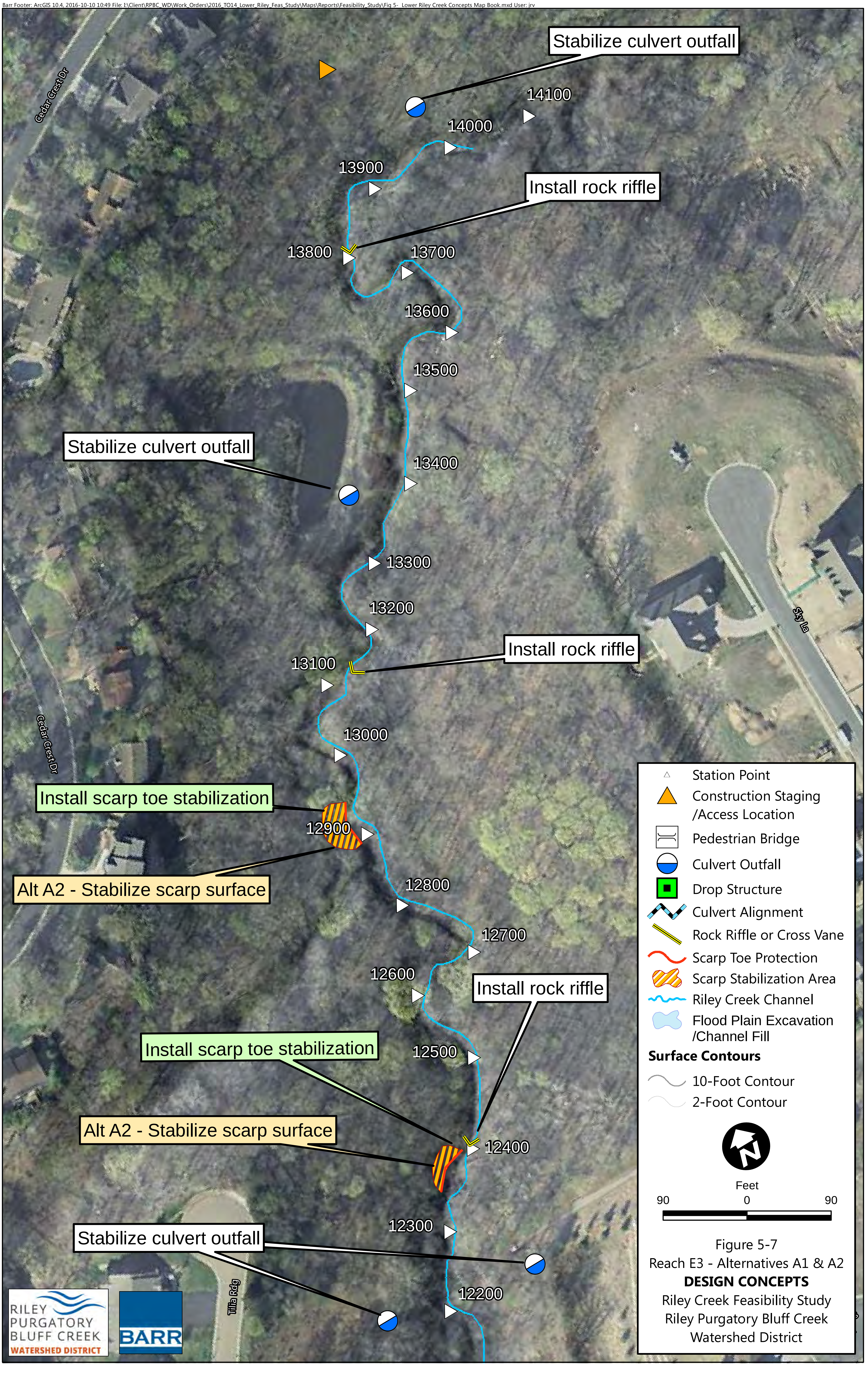


Figure 5-7
Reach E3 - Alternatives A1 & A2
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

5.1.4.3 Alternative B1 – Cross Checks, Floodplain Excavation, Channel Fill, and Scarp Toe Stabilization

Alternative B1 for Sub-reach E3 would include clearing and grubbing the floodplain adjacent to the Riley Creek channel, then excavating approximately two-feet of material from the floodplain. The excavated material would be placed in the existing channel to raise the bed approximately two-feet. Three, one-foot tall cross check structures would be installed in Riley Creek (Figure 5-8). Raising the channel bed would facilitate reconnection of the stream with the floodplain, and the cross checks would focus the stream energy away from the banks and minimize potential degradation of the stream bottom. Alternative B1 would also include stabilizing two scarp toes to reduce active erosion within the reach. Scarp toes would be stabilized with cedar pilings and appropriately sized logs salvaged from within the project area. Once the toes are stabilized, it is expected that the scarps would naturally revegetate over time.

Alternative B1 would approximately balance floodplain excavation and channel fill, simplifying project permitting and mitigates impacts to the design flood elevations. However, excavating the floodplain would require significant removal and disturbance of trees and vegetation along the channel. Relying on natural process for the scarps to re-establish vegetation could take several years and result in additional erosion until these areas become fully vegetated.

The OPC for Sub-reach E3, Alternative B1 ranges from $656,000 to $926,000.

5.1.4.4 Alternative B2 – Cross Checks, Floodplain Excavation, Channel Fill, Scarp Toe Stabilization, and Scarp Surface Stabilization

Alternative B2 for Sub-reach E3 builds upon Alternative B1 by including stabilization of the two scarp surfaces through grading to a stable, 3:1 to 2:1 slope and revegetating with appropriate vegetation (Figure 5-8).

Alternative B2 has similar advantages and challenges to those presented with Alternative B1 of Sub-reach E3; however, the proposed work on the scarp surfaces allows these areas to become stabilized more quickly than relying on natural processes alone, minimizing the potential for continued erosion across these portions of the reach.

The OPC for Sub-reach E3, Alternative B2 ranges from $664,000 to $937,000.

Figure 5-8
Reach E3 - Alternatives B1 & B2
DESIGN CONCEPTS
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

5.1.5 LMRWD Reach Alternatives

Three stabilization alternatives have been developed for the LMRWD reach. Hennepin County is currently planning a roadway reconstruction project on Flying Cloud Drive, immediately adjacent to Riley Creek. It is recommended that a stream stabilization project work in coordination with the Flying Cloud Drive project. Table 5.2 summarizes the project alternatives for this reach, with additional description in the below.

Table 5.2 Summary of Project Alternatives for LMRWD Reach

Reach	Alternative	Description	Total Project OPC[1] and Range[2]
LMRWD Reach	A	3 cross vanes, 3 root wads, bank grading 2 scarp toe stabilizations, 1 scarp surface stabilization	$268,000 ($228,000 – $322,000)
	B	3 cross vanes, 3 root wads, bank grading 2 scarp toe stabilizations, 1 scarp surface stabilization, floodplain excavation	$546,000 ($464,000 – $655,000)
	C	3 cross vanes, 3 root wads, bank grading 2 scarp toe stabilizations, 1 scarp surface stabilization, sediment vortex tube	$512,000 ($435,000 – $614,000)

1 – Includes estimated construction costs, a 15% contingency, 7% of construction costs for construction observation, and 20% of construction costs for engineering, design, permitting, and legal.

2 – 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 15% project contingency, 20% for design, permitting, and legal, and 7% for construction administration. Lower bound assumed at -15% and upper bound assumed at +20%.

5.1.5.1 Alternative A – Cross-Vanes, Root Wads, Bank Grading, Scarp Toe and Surface Stabilization

Alternative A for the LMRWD Reach would include installation of three rock cross-vanes, each approximately three-feet tall (Figure 5-9). Sedimentation upstream of each cross-vane would naturally raise the channel bed to better match the appropriate bankfull depth and facilitate reconnection of the stream with the floodplain. Three root wads would be installed immediately downstream of Flying Cloud Drive to dissipate the stress of flows on the outside bend of Riley Creek in this location. It is anticipated that root wads would be derived from on-site materials. Banks of Riley Creek would be graded back to an approximately 3:1 stable slope. Alternative A would also include stabilizing two active scarp toes to reduce active erosion within the reach. The less severe scarp surface, located near station 15+00, would be allowed to naturally re-vegetate over time. The surface of the more active scarp, located near station 13+00, would be graded to a stable, 3:1 to 2:1 slope and revegetated with appropriate vegetation.

Alternative A would limit the construction footprint and the need to tree removal within the project area. Flood levels for this reach are dictated by the Minnesota River; as such, the bed rise associated with Alternative A would not create flood-related impacts outside of the reach. The biggest challenge associated with Alternative A is that, though bank grading will help stabilize the streambanks, it is not possible to grade back enough of the bank to provide a complete connection of Riley Creek to its floodplain in the uppermost portion of the LMRWD Reach. Though Alternative A would stabilize the LMRWD Reach, it provides no additional considerations for reducing upstream sediment loads.

The OPC for LMRWD Reach, Alternative A ranges from $287,000 to $406,000.

5.1.5.2 Alternative B – Cross-Vanes, Root Wads, Bank Grading, Scarp Toe and Surface Stabilization, and Floodplain Excavation

Alternative B for the LMRWD Reach is very similar to Alternative A in that it would include installation of three, three-foot tall cross vanes, three root wads, bank grading, and stabilization of two scarp toes and one scarp surface. However, Alternative B would also include floodplain excavation on the west bank of Riley Creek, immediately downstream of Flying Cloud Drive (Figure 5-10). The bank in this location is tall, and additional excavation would provide a better connection between Riley Creek and its floodplain.

Alternative B has similar advantages and challenges to those presented with Alternative A of the LMRWD Reach; however, this alternative provides better floodplain connectivity to help address channel down-cutting. Alternative B would require larger construction limits than Alternative A and would, subsequently, require more tree removal. The proposed floodplain excavation area is privately-owned and would require coordination with the affected landowner. Sediment deposited during flooding along the Minnesota River may fill in the floodplain excavation area and require routine maintenance for sediment clean-out. The OPC for LMRWD Reach, Alternative B ranges from $464,000 to $655,000.

5.1.5.3 Alternative C – Cross-Vanes, Root Wads, Bank Grading, Scarp Toe and Surface Stabilization, and Stream Vortex Tube

Alternative C for the LMRWD Reach is also very similar to Alternative A in that it would include installation of three, three-foot tall cross vanes, three root wads, bank grading, and stabilization of two scarp toes and one scarp surface. However, Alternative C would also include installation of a stream vortex tube on the west bank of Riley Creek, immediately downstream of Flying Cloud Drive (Figure 5-11).

A stream vortex tube is essentially a pipe placed in the Riley Creek channel that would connect to an off-channel basin. The vortex created by the pipe, coupled with the off-channel settling basin, would remove sediment from Riley Creek and then return flow to the creek through a small channel. Literature values suggest that a stream vortex tube can reduce sediment loads by one-third to one-half for sediment carrying stream flows (Reference (13)). Though the stream vortex tube would remove sediment, it would primarily remove sediment originating from areas of Riley Creek upstream of the LMRWD Reach.

Alternative C has similar challenges as those presented with Alternative B in that it would require a bigger construction footprint than Alternative A and may be susceptible to Minnesota River sediment deposition, increasing the frequency of routine maintenance for sediment clean-out. The existing design guidelines are vague about the necessary slope needed on the sediment vortex tubes to maximize effectiveness, so it is unclear if they are feasible for this setting. There is too much uncertainty to recommend it as an option; however it could be an option in the future if design guidance is improved. The OPC for LMRWD Reach, Alternative C ranges from $435,000 to $614,000.

Barr Footer: ArcGIS 10.4, 2016-10-07 11:45 File: I:\Client\LowerMinnesotaWD\Work_Orders\Lower Riley Creek Stabilization Feasibility Study\Maps\Feasibility_Study\Figure 5-9 - Alternative A.mxd User: jrv

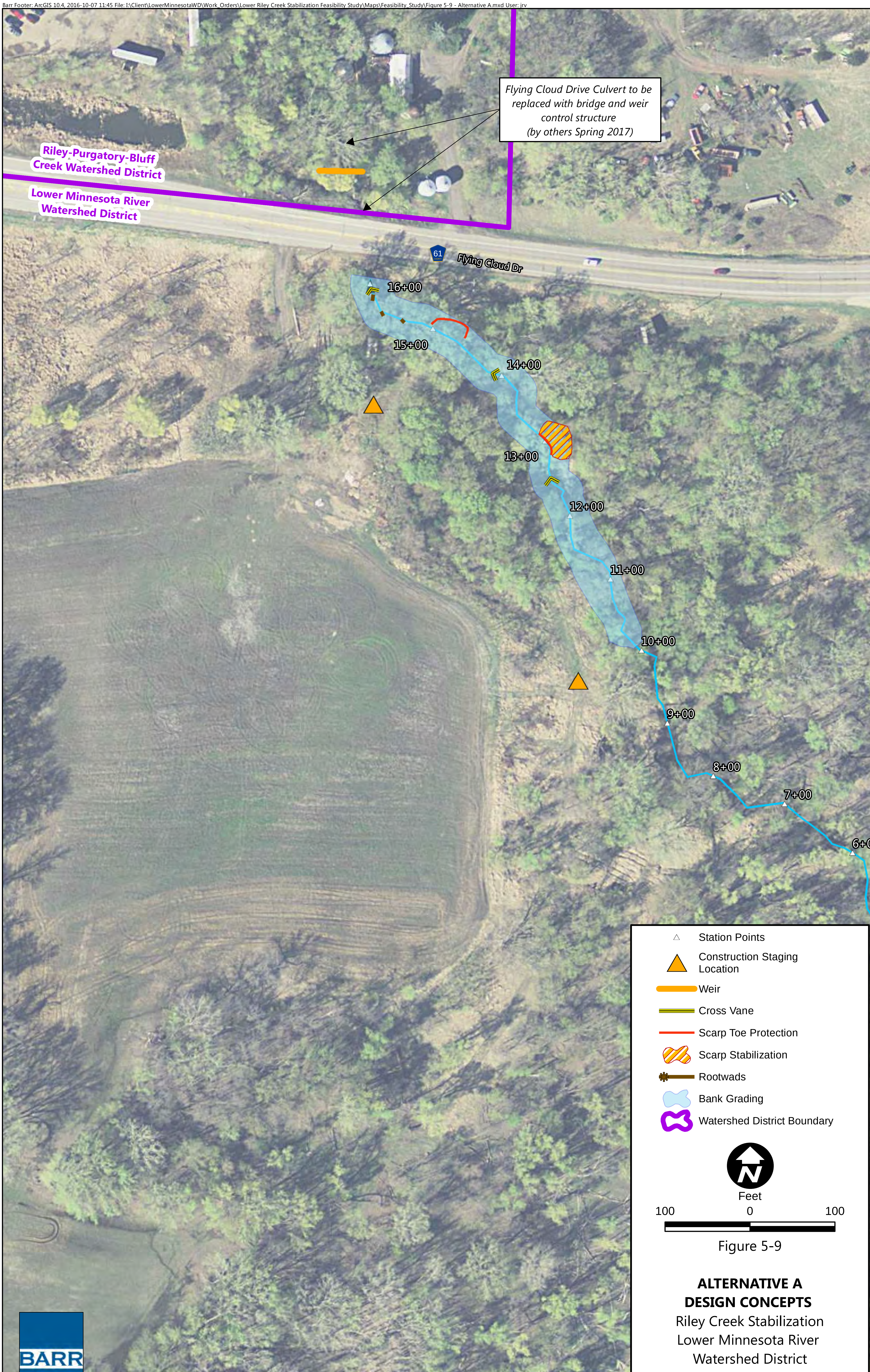


Figure 5-9

ALTERNATIVE A DESIGN CONCEPTS

Riley Creek Stabilization
Lower Minnesota River
Watershed District

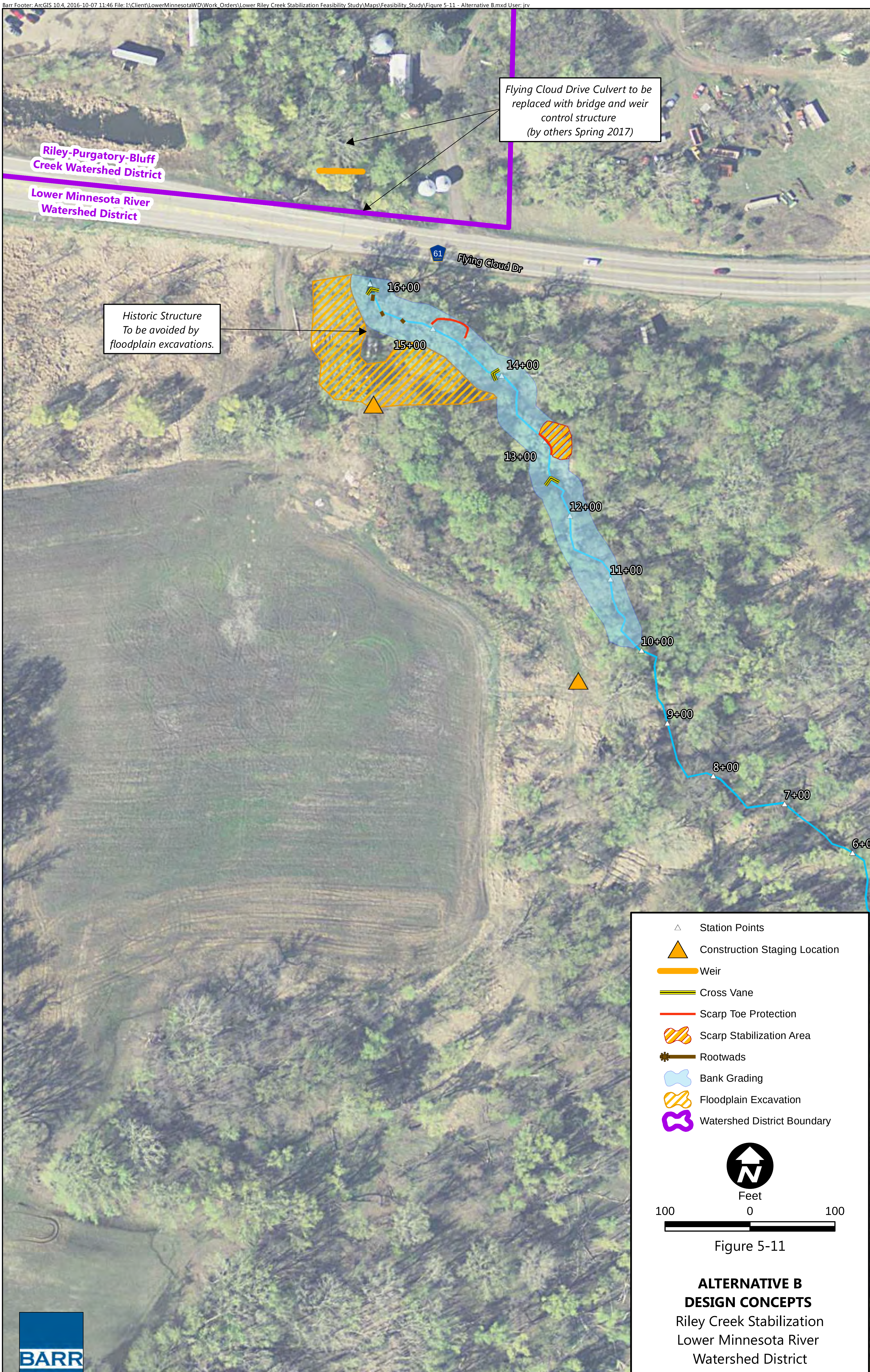


Figure 5-11

ALTERNATIVE B
DESIGN CONCEPTS
Riley Creek Stabilization
Lower Minnesota River
Watershed District

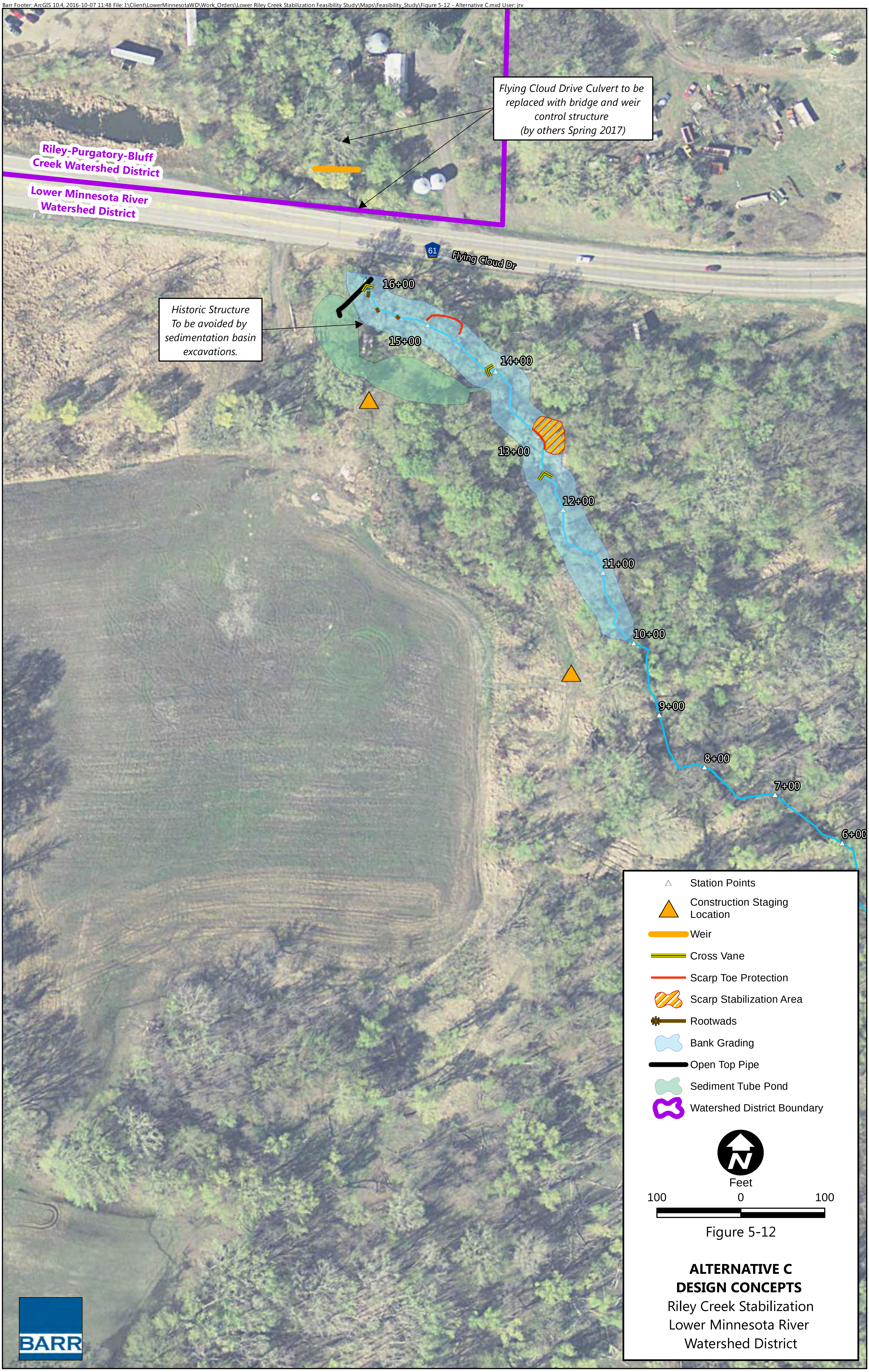


Figure 5-12

ALTERNATIVE C
DESIGN CONCEPTS
Riley Creek Stabilization
Lower Minnesota River
Watershed District

5.2 Water Quality Benefits

The proposed stabilization measures would result in reduced stream bank erosion and, therefore, reduced sediment and phosphorus loading to Riley Creek and all downstream water bodies, including 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 (Reference (1)).

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). The BEHI rating evaluates the susceptibility of a segment of stream bank to erosion as a result of multiple processes: surface erosion, fluvial entrainment, and mass erosion (wasting). The NBS rating characterizes the energy distribution against a segment of stream bank; disproportionate energy distribution in the near-bank region can accelerate bank erosion. The BEHI and NBS estimation tools are applied in a field assessment for each segment of stream bank potentially contributing sediment to the stream channel. BEHI and NBS assessments were completed for Riley Creek during site visits in spring and summer of 2016.

The BEHI and NBS ratings are summarized on a scale of very low to extreme. To convert BEHI and NBS ratings into a stream bank erosion rate estimate, the BANCS model relies on measured bank erosion data to develop relationships applicable to various hydrologic and geologic conditions. No such relationship is currently available for Minnesota; this feasibility study uses relationships developed from data collected in North Carolina (Reference (2)). The estimated total sediment load from bank erosion is calculated using the approximate dimensions of the eroding stream banks at each site.

The pollutant loading and reduction computations for the stream banks were completed using the BANCS model, however this analysis does not quantify erosion from the overbank scarps. Erosion from the scarps includes two processes, 1) erosion from the bare scarp surfaces, and 2) mass wasting from erosion of the scarp toe. Quantification of the combination of these two processes was completed by comparing the 2007 and 2016 survey of the actively eroding scarps. The lateral scarp movement was estimated from the survey data to determine a total sediment loss during the time period and converted to an average annual soil loss for each active scarp.

The portion of scarp erosion associated with the scarp surface was quantified using the RUSLE2 computer model (reference (4)) to predict an average annual loss based on a representative scarp slope. The RUSLE2 model provides this average annual loss estimate as a function of the slope surface area. The scarps within the project reach have similar slopes, lengths, and surface soils, which are the primary inputs for the RUSLE2 model, and allows for the calculated erosion rate to be applied for all of the scarps within the project reach.

The effects of stabilization alternatives on water quality are estimated based on the assumption that each stabilization alternative successfully addresses erosion at the site and brings bank erosion to a low rate, representative of a stable stream in this geologic setting. For this analysis, a stable low erosion rate is assigned a nominal value of 0.02 feet per year for a low NBS and moderate BEHI. Erosion of the scarp due to mass wasting is assumed to be zero if toe protection of the scarp is included in the project. Similarly, if the scarp surface is stabilized, surface erosion is assumed to be zero. The resulting estimated sediment load reduction for stabilization in each reach is calculated and the corresponding reduction of total suspended sediment (TSS) and total phosphorus (TP) load are calculated using an estimation tool developed by BWSR (Reference (3)). The BWSR tool assumes that all eroded sediment becomes TSS, which is conservative because eroded sand and gravel typically is not suspended but is transported as bedload. The BWSR tool also assumes that TP load is equivalent to 1.15 pound TP per pound of eroded sediment.

5.2.1 Reach E and Site D3

The BEHI and NBS ratings for Reach E and Site D3 are summarized in Table 5.3. The portions of Reach E and Site D3 analyzed are generally rated "moderate" or "high" for BEHI due to the high, steep eroding banks. For NBS, the sub-reaches are designated "low" or "high". The total reduction in pollutant loading as a result of stabilizing the Reach E and Site D3 project reaches is estimated as 2,173,930 pounds per year TSS and 1,250 pounds per year TP. These values are representative of an erosion rate of approximately 0.1 to 0.2 feet per year for the stream banks.

Cross section survey data was collected for the project reach in 2007 and 2016. The 2016 survey collected data from cross sections located close to those collected in 2007 with the intention of estimating erosion rates for these cross sections over the 9 year time period. The scarp extents were also surveyed in both 2007 and 2016 for a select number of actively eroding scarps. Based on the collected data, the average erosion cross sectional area was calculated for each sub-reach of the Riley Creek main channel (Reach E). The change in lateral movement for the scarps was also calculated and used to determine an average scarp erosion rate for each sub-reach. Erosion from the surface of the scarps was estimated using the RUSLE2 model (reference (4)) and used to differentiate the effectiveness of the alternatives. Table 5.3 provides a summary of the estimated erosion rates for the scarps and the main channel. The predicted sediment loading based on the surveyed data is 1,184 tons/yr (2,368,000 lb/yr). The predicted sediment loading based on the BANCS model for Reach E and the surveyed scarps is 2,380,400 lb/yr. The results are comparable and indicate the values calculated by the BANCS model are reflective of the stream condition.

Of the total material eroded from the project segment, approximately 459 ton/yr originates from the scarps. Approximately 27 ton/yr of the scarp eroded material originates from the scarp surface. Since the BANCS model does not provide a means to predict the erosion from scarps, the survey data and scarp erosion calculations were added to the BANCS model erosion rates to determine the total reduction in pollutant loading for Reach E and Site D3.

Table 5.3 Riley Creek feasibility study Reach E and Site D3 existing bank erosion and pollutant loading by sub-reach

Reach	Station	Site Description	Alternative Description	Site Length [1][2]	Est. Avg. Bank Height (ft)	BEHI rating[1]	NBS rating[1]	Est. Erosion Rate[2] (ft/yr)	Est. Sed. Load[3] (ton/yr)	"Stable" Sed. Load[4] (ton/yr)	Est. Sed. Load Reduction (ton/yr)	TSS Reduction[5] (lb/yr)	TP Reduction[5] (lb/yr)
Ravine D3	NA	Ephemeral ravine with storm sewer outfalls	Stabilize channel with rock riffles or culvert/drop structure, stabilize scarps with toe protection	524	10	Moderate	Low	0.02	178.1	10.1	158.1	316,200	181.82
			Stabilize channel with rock riffles or culvert/drop structure, stabilize scarps with toe protection, stabilize scarp surface with vegetation/grading								168.0	336,000	193.20
Reach E1	90+00 to 108+00	Upstream reach with significant channel degradation and little floodplain connection	Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection, stabilize scarp surface with vegetation/grading	1800	8	Moderate	High	0.12	190.4	27.7	161.3	322,530	185.46
			Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection, stabilize scarp surface with vegetation/grading								162.7	325,330	187.07
Reach E2	108+00 to 120+00	Middle reach with a highly confined channel and significant erosion scarps	Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection	1200	10	High	High	0.2	450.1	23.1	414.1	828,200	476.2
			Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection, stabilize scarp surface with vegetation/grading								427.0	854,000	491.1
Reach E3	120+00 to 141+00	Downstream reach with moderate channel degradation and moderate connection to the floodplain	Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection	2100	8	High	High	0.2	371.6	32.4	336.4	672,800	386.9
			Stabilize channel with rock riffles or cross vanes, stabilize scarps with toe protection, stabilize scarp surface with vegetation/grading								339.2	678,400	390.1
					Totals Without Scarp Vegetation/Grading				1190.2	93.3	1069.9	2,139,730	1230.3
					Totals With Scarp Vegetation/Grading				1190.2	93.3	1096.9	2,193,730	1261.4

(1) BEHI and NBS ratings for Ravine D3 were estimated from photos and aerial imagery, Reaches 1 through 3 utilized field data and collected photos.

(2) Erosion rates derived from North Carolina BEHI/NBS data

(3) Calculated as length (ft) x height (ft) x erosion rate (ft) / 27 (ft3/cy) x 1.3 (ton/cy). Includes scarp erosion rates estimated from 2007 and 2016 survey data.

(4) Estimated from a representative low BEHI, moderate NBS erosion rate of 0.02 ft/yr

(5) Calculated from equations in Reference (3), TSS reduction of 1.0 lb/lb sediment, TP reduction of 1.15 lb/ton sediment.

5.2.2 LMRWD Reach

The BEHI and NBS ratings for LMRWD Reach are summarized in Table 5.4. The portions of LMRWD Reach analyzed are generally rated "moderate" or "high" for BEHI due the high, steep eroding banks in the upstream portion of the reach. For NBS, the study banks were designated "low" or "very high". The total reduction in pollutant loading as a result of stabilizing the LMRWD reach is estimated as 183,200 pounds per year TSS and 105 pounds per year TP. These values are representative of an erosion rate of approximately 0.02 to 0.28 feet per year for the stream banks.

Table 5.4 Riley Creek feasibility study Lower Minnesota Reach existing bank erosion and pollutant loading by sub-reach

Reach	Station	Site Description	Alternative Description	Site Length (1)(2)	Est. Avg. Bank Height (ft)	BEHI rating(1)	NBS rating(1)	Est. Erosion Rate(2) (ft/yr)	Est. Sed. Load(3) (ton/yr)	"Stable" Sed. Load(4) (ton/yr)	Est. Sed. Load Reduction (ton/yr)	TSS Reduction(5) (lb/yr)	TP Reduction(5) (lb/yr)
Lower Riley	0+00 to 11+00	The bank heights in the lower portion of the reach approach the bank full elevations. The floodplain is flat and water levels are controlled by the Minnesota River.	Alternative A- Grading Banks and stabilize scarps	1100	2	Moderate	Low	0.02	4.2	1.7	2.5	5,080	2.9
			Alternative B- Grading Banks,stabilize scarps, and floodplain excavation								2.5	5,080	2.9
			Alternative C-Grading Banks,stabilize scarps, and sediment vortex tube								111.0	221,930	127.6
Lower Riley	11+00 to 14+00	The bank heights in this reach are higher and the reach is incised although not as significantly incised as further upstream.	Bank Grading	300	6	High	Very High	0.28	48.5	1.4	47.1	94,290	54.2
Lower Riley	14+00 to 16+00	The bank heights in this reach are high and the reach is significantly incised and has large portions of undercutting.	No Construction	200	8	High	Very High	0.28	43.1	1.2	41.9	83,820	48.2
								Total Alt A	95.9	4.3	91.6	183,200	105.3
								Total Alt B	95.9	4.3	91.6	183,200	105.3
								Total Alt C	95.9	4.3	200.0	400,000	230.0

(1) BEHI and NBS ratings were estimated from photos, aerial imagery, field data, and collected photos.
(2) Erosion rates derived from North Carolina BEHI/NBS data
(3) Estimated Sediment Loading for project reach. Calculated as length (ft) x height (ft) x erosion rate (ft) / 27 (ft3/cy) x 1.3 (ton/cy).
(4) Estimated from a representative very low BEHI, very low NBS erosion rate of 0.008 ft/yr
(5) Calculated from equations in Reference (4), TSS reduction of 1.0 lb/lb sediment, TP reduction of 1.15 lb/ton sediment.

5.3 Construction Access

Designating the site access routes is important for determining whether construction access easements are required. In addition, poor access can result in cost increases and project delays. The following sections define the proposed access routes and any additional considerations.

5.3.1 Reach E and Site D3

Reach E and Site D3 are on city of Eden Prairie property that borders public right-of-way and the RPBCWD would need to secure access rights from the city of Eden Prairie prior to initiating construction activities. Within the project area, there are multiple storm sewers from Tilia Ridge and Cedar Crest Drive that discharge into the study reach. The alignment of the storm sewers is generally clear of trees and would likely provide relatively easy access routes. As noted in the vegetation assessment, buckthorn is present in the lower portion of Reach E; therefore, construction traffic should be managed to reduce the spread of buckthorn as much as possible.

The reach between 120+00 and 141+00 consists of dense growth of the invasive species buckthorn. It is recommended that construction traffic be carefully managed to minimize potential spread of buckthorn. For example, construction traffic through an established buckthorn area should not be allowed to proceed into areas where buckthorn is not present. In addition, the RPBCWD Streambank stabilization rule requires that the spread of invasive species be minimized to the extent possible.

Much of the creek is surrounded by steep banks, which can make the movement of construction traffic difficult in some areas. In some cases, construction traffic would be required to use the creek bed to access the proposed project features. This would primarily be true between stations 108+00 to 120+00, where the creek becomes confined between steep, eroding slopes.

5.3.2 LMRWD Reach

Approximately 75 percent of the LMRWD Reach is surrounded by private land. Two stream access locations are proposed, one immediately downstream of Flying Cloud Drive and another near the center of the project reach. Both of these access locations would require construction easements. An existing agreement is in place between the landowner and the Metropolitan Council for access to the Riley Creek stream gage station. Depending on the type of agreement, it may be possible to provide access to the upstream portion of the stream through this existing agreement. The project site is relatively flat and, with the exception of the easement requirement, access to the project features should be relatively simple. A couple locations may require brief longitudinal traverses of the stream due to the presence of steep, eroding banks.

5.4 Construction Easements

All Affected parcel owners will need to agree to a temporary access and construction easements to provide legal access to the property in the interest of completing construction. Permanent easements will also likely be needed to allow for routine maintenance, however the extent of the permanent easements may not be the same as the temporary easements.

5.4.1 Reach E and Site D3

Reach E and Site D3 are surrounded by parkland owned and maintained by the city of Eden Prairie. Access to the project is anticipated to be available through city of Eden Prairie property off of public right-of-way. Therefore, impacts to neighboring properties or the purchase of additional easements are not anticipated. Table 5.5 summarizes which parcels are expected to be impacted by construction of this project.

Table 5.5 Parcels likely to be impacted by construction of Reach E and Site D3

Parcel ID Number	Address	Notes
2911622210051	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622240048	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622210030	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622240019	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622240015	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622310009	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	
2911622320001	City of Eden Prairie, 8080 Mitchell Road, Eden Prairie, MN 55344	

5.4.2 LMRWD Reach

The LMRWD Reach is surrounded by primarily one landowner. The acquisition of temporary construction easements and permanent access and maintenance easements may be necessary for this reach. The surrounding land use is agricultural and impacts to planted fields during the growing season would be avoided to the extent feasible by defining construction easements around planted fields or limiting the construction period to times outside the growing season. Table 5.6 summarizes which parcels are expected to be impacted by construction of this project.

Table 5.6 Parcels likely to be impacted by construction of LMRWD Reach

Parcel ID Number	Address	Notes
3311622220003	15900 Flying Cloud Drive, Eden Prairie, MN 55347	

6.0 Project Impacts

The following sections summarize potential impacts associated with construction of a stabilization project on Site D3, Reach E, and the LMRWD Reach.

6.1 Wetland Impacts

During project design, efforts would be made to avoid wetland impacts to the extent practicable. Unavoidable wetland impacts would be minimized as feasible and may require mitigation.

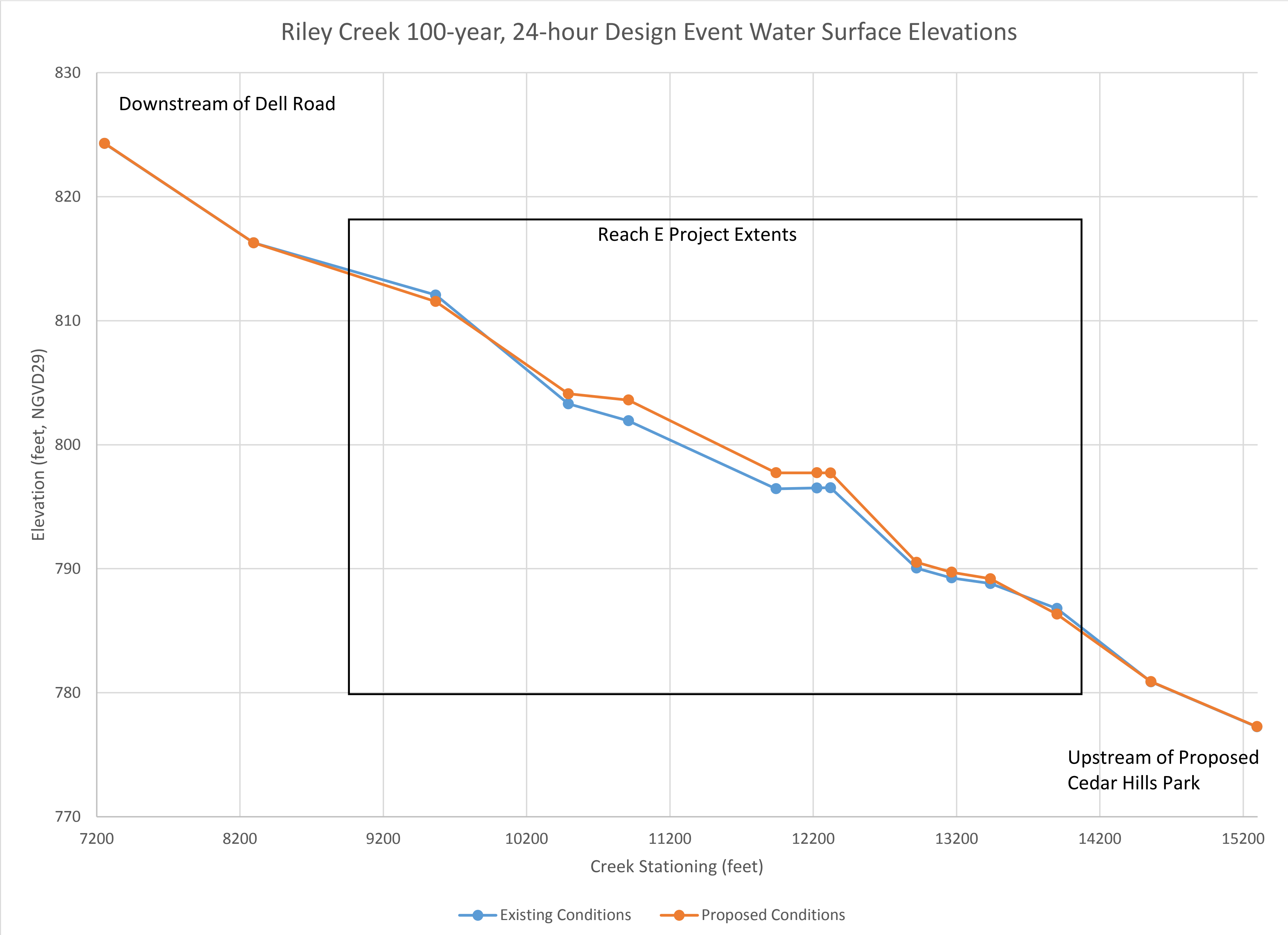
6.2 Floodplain Impacts

6.2.1 Reach E and Site D3

Site D3 receives intermittent flows from a storm sewer outfall however it has a definable bed and banks, is capable of conveying water. The proposed alternative involving the use of cross checks in the ravine would cause a rise in water surface elevation. The majority of Site D3 is not regulated by FEMA or the DNR with regards to floodplain. Impacts to the water surface elevation are not anticipated to require approval or review by these entities. The adjacent homes and properties are situated high enough above the ravine to maintain adequate freeboard, but should be verified during final design.

The proposed alternatives along Reach E involving the use of cross checks in the ravine would cause a rise in water surface elevation. The project site is located within a FEMA Zone A, which is a limited study area without a defined base flood elevation. Impacts within the project area are permitted up to 0.5 feet based on Minnesota state regulations (FEMA allows up to 1-foot of combined rise within a reach). Any rise above these standards would require permitting through the MnDNR and FEMA. The typical process involves the submittal and approval of a Conditional Letter of Map Revision before construction begins then a Letter of Map Revision post construction through FEMA with additional review by the MnDNR. No rise in water surface elevation would be permitted if it resulted in impacts to adjacent structures. However, RPBCWD requires no net rise in flood elevation.

Figure 6-1 shows the existing and projected water surface elevation for the 100-yr design storm based on the District's Hydrology and Hydraulics (H&H) model. The proposed condition simulates raising the bed of the stream by 3-feet without any additional floodplain mitigation, similar to the rock riffle alternatives proposed. The maximum rise within the reach is 1.7 feet and the proposed profile matches the existing profile near the upstream end of the project reach. Based on this preliminary modeling, the rock riffle alternatives could be permitted through the State and FEMA. RPBCWD Rules B and G require no net rise, maintenance of the hydraulic capacity, and compensatory storage within the floodplain for any fill within the channel.



Riley Creek 100-year, 24-hour Design Event Water Surface Elevations
830
820
810
800
790
780
770
Elevation (feet, NGVD29)
7200
8200
9200
10200
11200
12200
13200
14200
15200
Creek Stationing (feet)
Downstream of Dell Road
Reach E Project Extents
Upstream of Proposed Cedar Hills Park
Existing Conditions
Proposed Conditions

The proposed alternatives involving floodplain excavation and channel fill are intended to provide adequate floodplain mitigation to meet the requirements of RPBCWD Rules B and G. In addition, by providing compensatory floodplain storage and maintaining the existing conveyance area, the design is anticipated to produce no rise in the design flood elevation and therefore not require additional consideration from the MDNR or FEMA.

6.2.2 LMRWD Reach

Flood levels for the LMRWD reach are set by the Minnesota River. The proposed alternatives would not alter the flood levels of the Minnesota River.

6.3 Other Project Impacts

6.3.1 Tree Loss

The proposed projects would require some level of tree removal; the final number of significant trees removed would depend on the alternative(s) selected. Trees requiring removal are those located in areas where bank stabilization or site access would be necessary. Per the Eden Prairie City Code, Chapter 11, Section 11.55, Subpart 4 (Tree Replacement Plan Requirements), a tree inventory would be completed during final design to identify significant trees and which of these would be removed or saved. Attempts would be made to target dying/diseased and undercut trees first for removal, followed be less desirable or disease susceptible species such as box elder, cottonwood, or ash. Tree removal would be considered in close coordination with the city of Eden Prairie Forestry Department, and stakeholder input on tree loss would also be considered. A replacement plan for removed trees would be developed in accordance with Eden Prairie City Code.

Many of the trees removed for the projects are proposed to be reused on-site as part of streambank stabilization measures. Trees not used for bank stabilization could be chipped and placed on bare soils on heaver used locations of Riley Creek Conservation Area hiking trails to reduce sediment generation during runoff events.

6.3.2 Protected Species

6.3.2.1 Reach E and Site D3

Based on a review of the MnDNR Natural Resources Heritage System (NHIS), there is one state-listed threatened plant species (kitten tails) located within one-mile of the reach; however, stabilization activities associated with Reach E and Site D3 are not anticipated to affect this species.

There are no federally listed threatened or endangered species and no known bat hibernacula in the vicinity of this reach.

6.3.2.2 LMRWD Reach

Based on a review of the MnDNR NHIS, there is one state-listed threatened plant species (kitten tails), one state-listed threatened fish species (paddlefish), and two state-listed endangered mussels (rock pocketbook and yellow sandshell) located within one-mile of the reach; however, stabilization activities associated with the LMRWD Reach are not anticipated to affect these species.

Two bald eagle nests have previously been documented near the reach. If construction is timed such that it overlaps with the bald eagle nesting season, additional surveys may be required to determine the presence and occupancy status of the nests.

There are no federally listed threatened or endangered species and no known bat hibernacula in the vicinity of this reach.

6.3.3 Utility Conflicts

6.3.3.1 Reach E and Site D3

The project is located within a low lying valley with residential development located on top of the bluffs. Because of the project setting, utilities generally remain on top of the bluffs and would not be a concern for the project features. The primary identified utilities exceptions to this would be the storm sewer outfalls and the Williams Pipeline (liquid petroleum) that runs through the site between station 20+00 and station 21+00. The raising of the channel bed as proposed in all of the alternatives may affect the stormwater outfalls and require them to be raised. Further survey and review of as-built drawings would be necessary during final design to determine the storm sewer impacts and subsequent design considerations.

Final design should include considerations of possible utility crossings of the project area, including sanitary sewer, gas, electric, and communication lines. No additional information regarding these additional utilities is available or has been reviewed for this engineer’s report.

6.3.3.2 LMRWD Reach

The project is located within private land that is mostly agricultural and undeveloped floodplain. Because of the project setting, underground utilities generally would not be a concern for the project features. There is an existing electric line that runs along Flying Cloud Drive. Further survey and review of as-built drawings would be necessary during final design to determine the storm sewer impacts and subsequent design considerations.

Final design should include considerations of possible utility crossings of the project area, including sanitary sewer, gas, electric, and communication lines. No additional information regarding these additional utilities is available or has been reviewed for this engineer’s report.

6.3.4 Use of Riley Creek Conservation Area

Due to the location of Reach E and Site D3 within the RCCA and adjacent to hiking trails, temporary closures of portions of the trails would be necessary for the safety of recreational users. Recreational features (i.e. trails, pedestrian bridges, etc.) disturbed as a result of construction would be restored to original conditions upon construction completion.

7.0 Permitting

Several permits and approvals would be required prior to construction of the proposed stabilization project, as described in the following sections. To facilitate the permit review process, the USACE and MnDNR were invited on a project site visit in order to discuss preliminary stabilization concept plans and answer initial project questions.

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 E and the LMRWD Reach would each 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 and creating better floodplain connectivity, 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

Since 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 each 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 Phase I (Appendix E) it is not anticipated that contaminated soil and debris would be encountered during stream stabilization activities; therefore it is not anticipated that either 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 these projects. 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 may be required for the Reach E project, but that the impact footprint of the LMRWD Reach would be smaller than one acre and an EAW is not required.

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 E and Site D3 to ensure the project is developed in compliance with district rules.

7.8 LMRWD Permit

The LMRWD does not have district-specific rules or permitting processes to govern construction projects. Rather, the LMRWD defers to the city of Eden Prairie for construction project regulation and permitting.

8.0 Stakeholder Input

8.1 Technical Stakeholder Meeting

A technical stakeholder meeting was held on June 22, 2016 at both of the project reaches. Technical stakeholders present included representatives from RPBCWD, LRMWD, MDNR, city of Eden Prairie, and Barr. The USACE was unable to attend; however the project was discussed with USACE at a later date.

The on-site meeting provided an opportunity for the stakeholders to see the reaches 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 raising the bed of the stream to reconnect to the floodplain. The remainder of the discussion focused on permitting as described below.

Preliminary hydrologic and hydraulic modeling indicates that the 100-year flood elevation could be increased in some cases by raising the stream bed to reconnect to the floodplain. Reach E of Riley Creek is a FEMA-designated Zone A with an approximate study to determine the floodplain extents. Raising the flood elevation would not impact any structures; however it would likely still require a variance from both the city of Eden Prairie and RPBCWD.

The technical stakeholders agreed that installing structures within the creek to raise the bed would be considered fill within the floodplain; therefore it may be necessary to create compensatory storage or seek variances from regulations that prohibit floodplain fill.

9.0 Recommendations

This study evaluated a variety of bioengineering and hard-armoring alternatives, as further described in Section 5, for stabilizing Reach E and Site D3, and the LMRWD Reach of Riley Creek. Final projects on each reach would consist of a combination of alternatives discussed in Section 5.1. Where feasible, priority was given to alternatives that were innovative, cost-effective, and used natural materials. The ability of alternatives to improve stream habitat and vegetative surroundings (identified as priorities in stakeholder meetings) was also taken into consideration in choosing the final alternatives. The recommended stabilization measures and range of construction costs for each reach are summarized below.

9.1 Reach E and Site D3 Recommendation

Stabilization of site D3, and along Reach E are identified in the Overall Water Management Plan of the Riley-Purgatory-Bluff Creek Watershed District (as amended) and are a necessary and feasible project to reduce the total phosphorus (TP) and total suspended sediment (TSS) loading reductions while limiting impacts to the surrounding environment.

Stabilization and restoration of the stream channel, banks, and eroding scarps within the project areas would improve water quality by 1) repairing actively eroding sites and 2) preventing erosion at other sites by installing preemptive measures to protect existing stream banks. The proposed projects on all reaches would result in reduced stream bank erosion and, therefore, reduced TSS and TP loading to Riley Creek (which is on the MPCA's impaired waters list) and all downstream water bodies, including Grass Lake, the Minnesota River, the Mississippi River, and Lake Pepin. Table 9.1 also summarizes sediment reductions and associated cost benefits. The recommended alternatives are also shown in Figures 9-1 through 9-4.

The recommended alternatives for Reach E (Alternative A2) and Site D3 (Alternative A) have a combined estimated annual maintenance cost of $28,000. Annualized costs for TP removal associated with the full range of alternatives developed range from $76 per pound TP to $141 per pound TP. The high end of the cost range is representative of the alternatives involving overbank excavation which have a similar impact to the sediment reduction with a much higher cost. For the preferred alternative, the estimated total annualized pollutant reduction costs are $78 per pound TP and $0.05 per pound TSS.

9.2 LMRWD Reach Recommendation

Stabilization of the portion of Riley Creek downstream of Flying Cloud Drive has been identified in the Third Generation Watershed Management Plan (as amended) for the Lower Minnesota River Watershed District and is a necessary and feasible project to reduce the total phosphorus (TP) and total suspended sediment (TSS) loading reductions while limiting impacts to the surrounding environment.

Stabilization and restoration of the stream channel, banks, and eroding scarps within the project area would improve water quality by 1) repairing actively eroding sites and 2) preventing erosion at other sites by installing preemptive measures to protect existing stream banks. The proposed projects on all reaches would result in reduced stream bank erosion and, therefore, reduced TSS and TP loading to Riley Creek (which is on the MPCA's impaired waters list) and all downstream water bodies, including Grass Lake, the

Minnesota River, the Mississippi River, and Lake Pepin. Table 9.1 also summarizes sediment reductions and associated cost benefits. The recommended alternative is also shown in Figure 9-5.

The recommended alternative (Alternative A) has an annualized maintenance cost of $5,400. Annualized costs for TP removal for the full range of alternatives evaluated range from $75 per pound TP to $363 per pound TP. The low end of the cost range is representative of the off-channel treatment pond, which would only reduce pollutant loading from upstream of the project area. Significant flooding in the Minnesota River could wash away the deposited sediments in this basin, thereby reducing the effectiveness. For the preferred alternative, the estimated total annualized pollutant reduction costs are $178 per pound TP and $0.10 per pound TSS.

Table 9.1 Recommended Stabilization Measures and Estimated Costs

	RPBCWD Reach E and D3	LMRWD Reach

Recommended Stabilization Measures	• Site D3: Alternative A
	  • Stabilize Site D3 by extending existing culvert to Riley Creek Channel and constructing drop structure for energy dissipation
	• Reach E1, E2, and E3: Alternative A2 for all reaches
	  • Construct 10 rock riffles in channel of Riley Creek Reach E to provide grade control, reconnect stream with floodplain, and recreate pool-riffle sequence in channel;
	  • Stabilize toe of 11 major scarps using cedar pilings and trees removed within Reach E;
	  • Install root wads, rock vanes, and log vanes to provide additional toe protection and in-stream habitat;
	  • Stabilize scarp surface through grading and establishing vegetation;
	  • Improve existing culvert outfalls where necessary to match newly raised channel bed.
		• Alternative A
		  • Grade tall, eroding banks immediately downstream of Flying Cloud Drive;
		  • Install rock vanes and root wads to provide toe protection on the graded banks while providing in-stream habitat.

Estimated TSS Reduction (lbs/yr)	2,193,700	183,200
Estimated TP Reduction (lbs/yr)	1,261	105
Cost of Construction (range)[1, 2]	$1,399,000 ($1,189,000 – $1,679,000)	$268,000 ($228,000 – $322,000)
TP cost/benefit ($/lb reduced)[3]	$78	$178
TSS cost/benefit ($/lb reduced) [3]	$0.05	$0.10

[1] Range includes costs for: construction; engineering, design, permitting, and construction observation; legal assistance; construction contingency.
2 Methodology and assumptions used for cost estimates are discussed in Section 4. Detailed cost estimates for all stabilization alternatives considered for this study are provided in Appendix J.
[3] Represents 30-year annualized cost.

Barr Footer: ArcGIS 10.4, 2016-10-10 10:44 File: I:\Client\RPBC_WD\Work_Orders\2016_TO14_Lower_Riley_Feas_Study\Maps\Reports\Feasibility_Study\Fig 9- Lower Riley Creek Concepts Map Book.mxd User: jrv

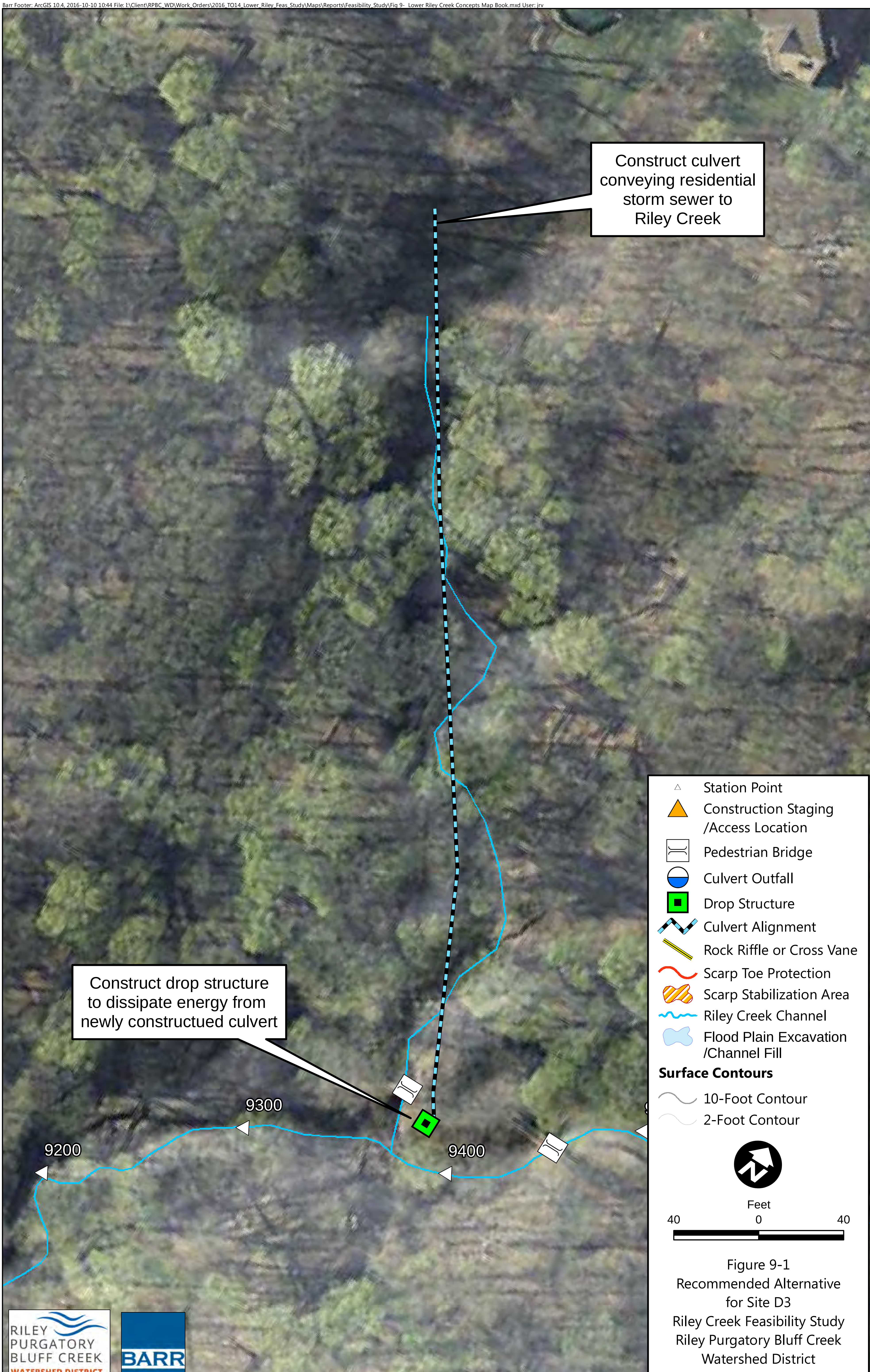


Figure 9-1
Recommended Alternative for Site D3
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek Watershed District

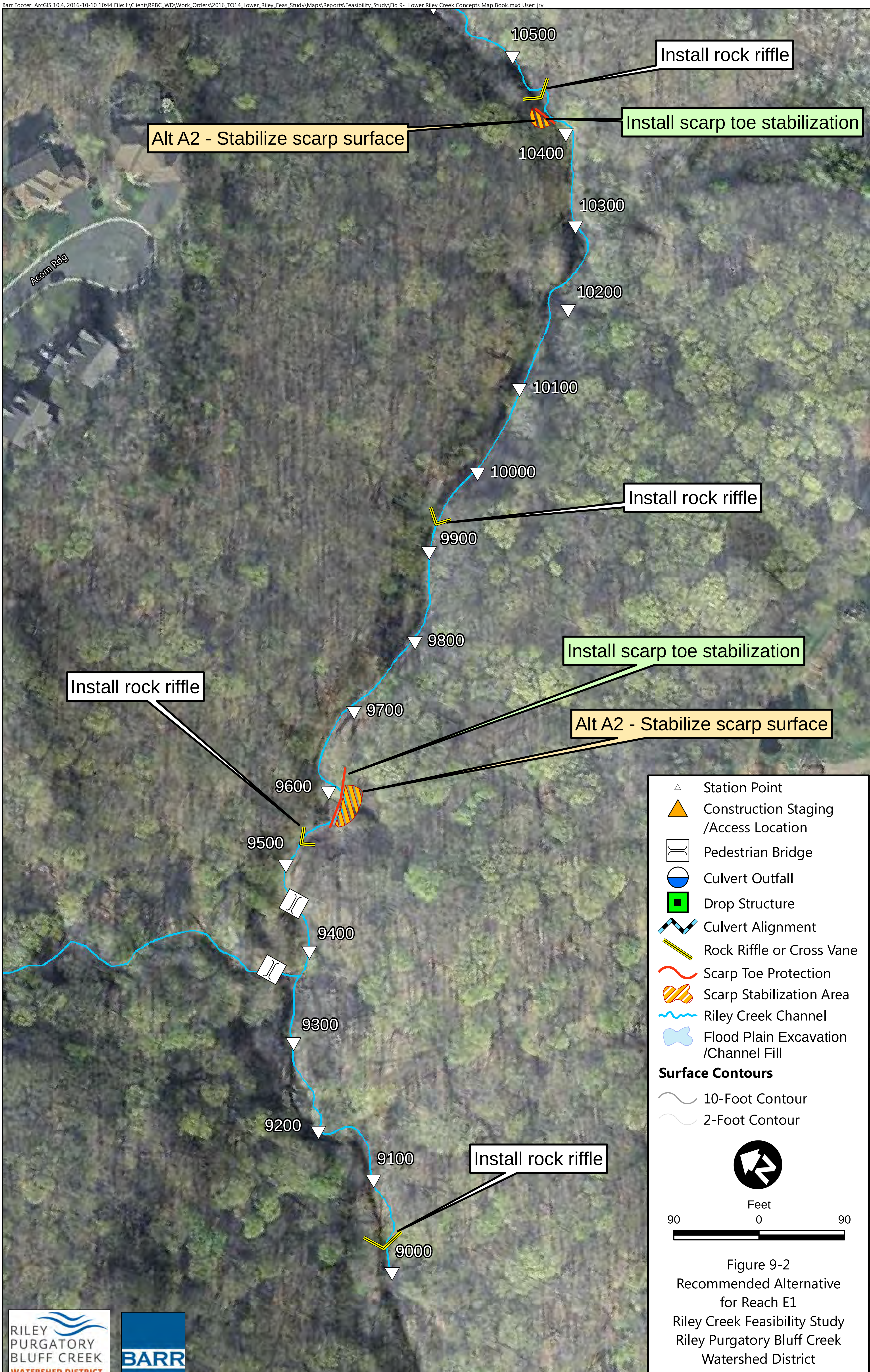


Figure 9-2
Recommended Alternative
for Reach E1
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

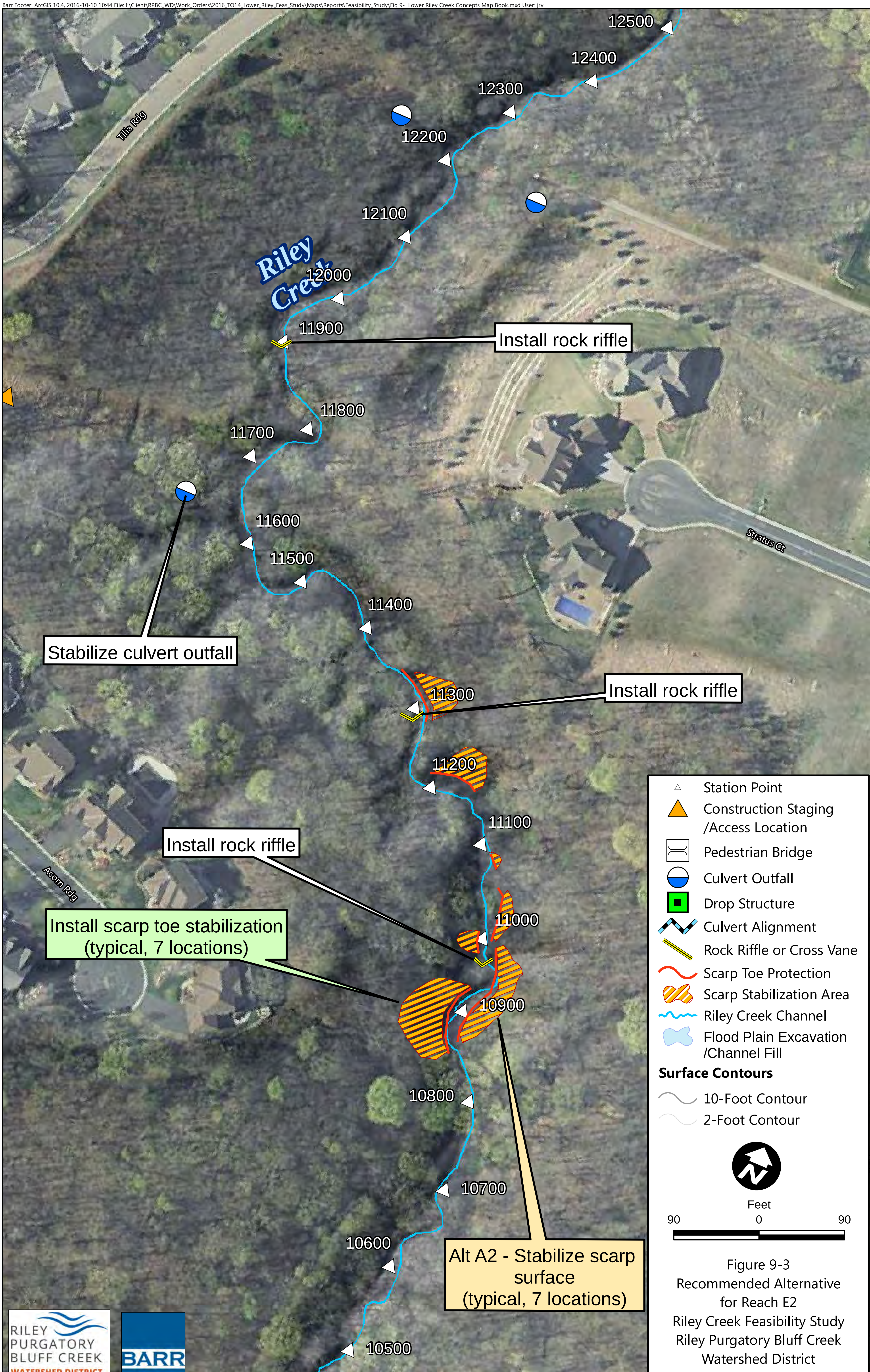


Figure 9-3
Recommended Alternative
for Reach E2
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek
Watershed District

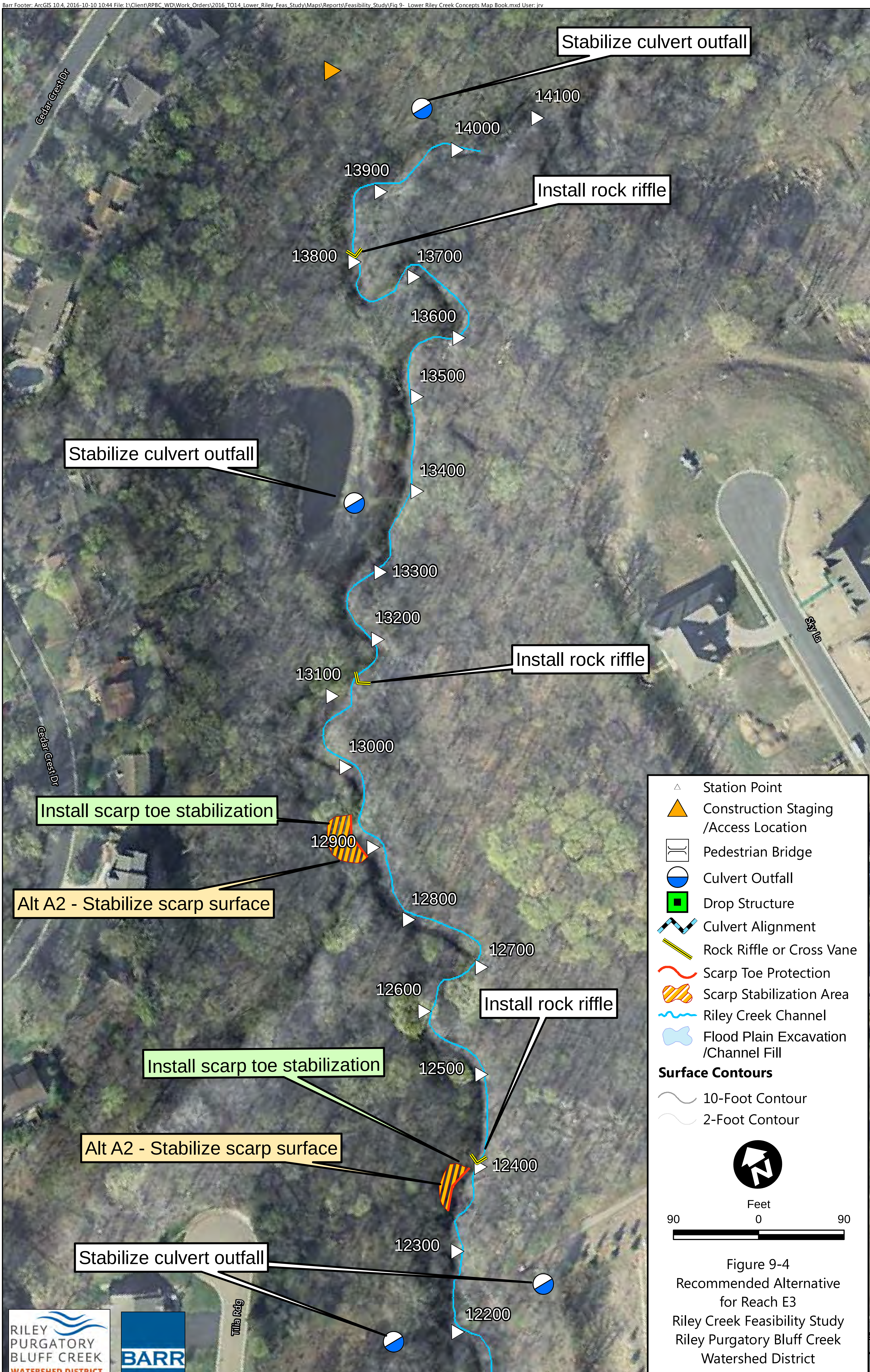
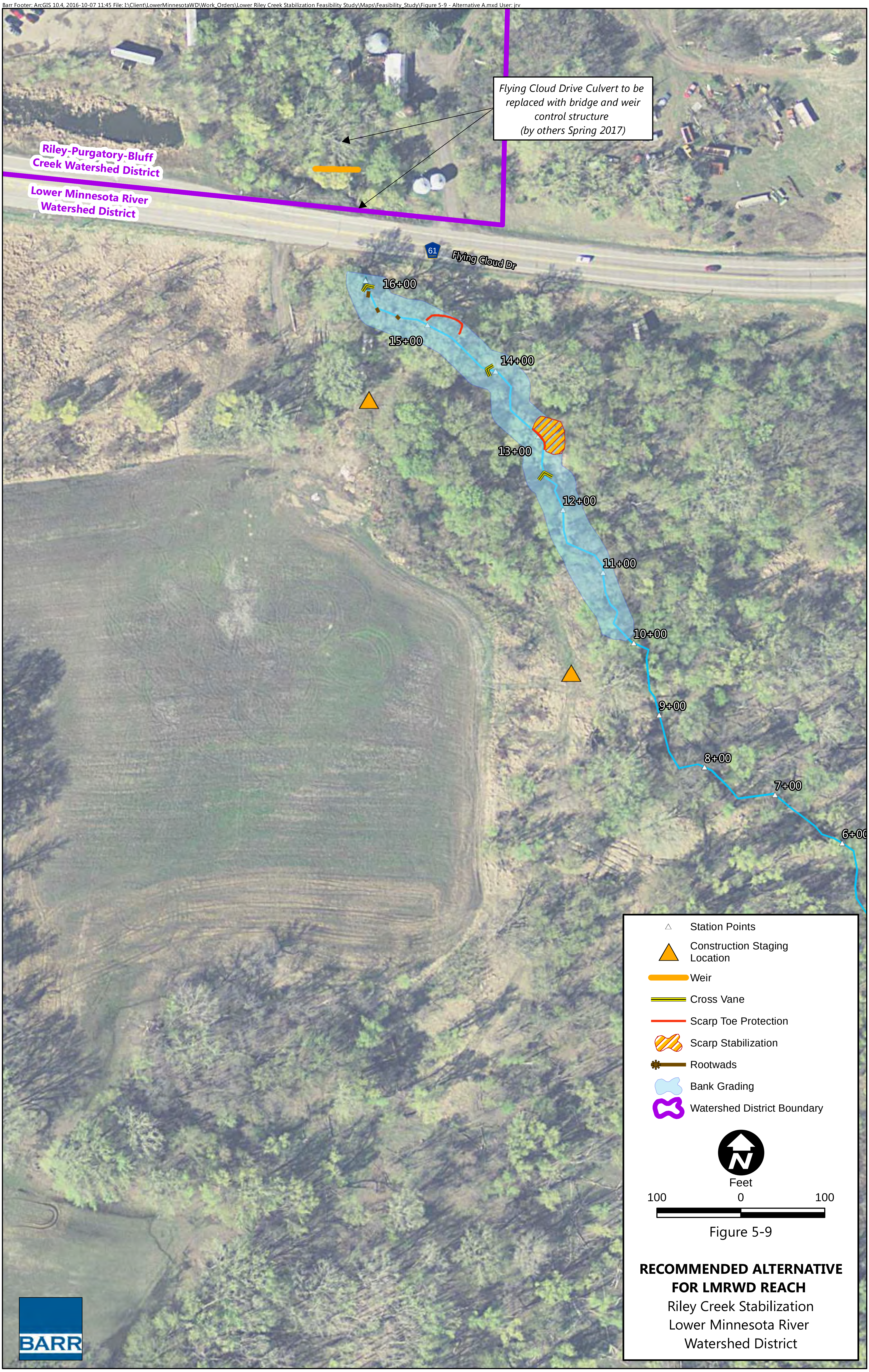


Figure 9-4
Recommended Alternative for Reach E3
Riley Creek Feasibility Study
Riley Purgatory Bluff Creek Watershed District


Flying Cloud Drive Culvert to be replaced with bridge and weir control structure (by others Spring 2017)
Riley-Purgatory-Bluff Creek Watershed District
Lower Minnesota River Watershed District
61
Flying Cloud Dr
16+00
15+00
14+00
13+00
12+00
11+00
10+00
9+00
8+00
7+00
6+00
Station Points
Construction Staging Location
Weir
Cross Vane
Scarp Toe Protection
Scarp Stabilization
Rootwads
Bank Grading
Watershed District Boundary
Feet
100
0
100
Figure 5-9
RECOMMENDED ALTERNATIVE FOR LMRWD REACH
Riley Creek Stabilization
Lower Minnesota River
Watershed District
BARR

10.0 References

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Appendices

Appendix A

2016 Erosion Site Photos

Placeholder for

Appendix A 2016 Erosion Site Photos

Appendix B

Excerpts from Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study

Placeholder for

Appendix B Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study

Appendix C

Excerpts from Creek Restoration Action Strategy

Placeholder for

Appendix C Creek Restoration Action Strategy

Appendix D

Excerpts from Strategic Resources Evaluation

Placeholder for

Appendix D Strategic Resources Evaluation

Appendix E

Survey Comparison

Placeholder for

Appendix E Survey Data Comparison

Appendix F

Phase I Environmental Site Assessment

Placeholder for

Appendix F Phase I Environmental Site Assessment

Appendix G

Phase I Archaeological Survey for Riley Creek Bank Stabilization Feasibility Study

Placeholder for

Appendix G Phase I Archaeological Survey for Riley Creek Bank Stabilization Feasibility Study

Appendix H

Riley Creek 2016 Wetland Delineation Report

Placeholder for

Appendix H Riley Creek 2016 Wetland Delineation Report

Appendix I

Stream Stabilization Examples

Placeholder for

Appendix I Stream Stabilization Examples

Appendix J

Detailed Cost Estimates

Placeholder for

Appendix J Detailed Cost Estimates