Prepared by: EOR

For the Nine Mile Creek Watershed District

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DRAFT

South Fork Nine Mile Creek Bank Stabilization Feasibility Report

Cover Images

Bryant Lake Regional Park – Three Rivers Park District (Reach 6)

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INTRODUCTION

Emmons & Olivier Resources, Inc. (EOR) was contracted by the Nine Mile Creek Watershed District (NMCWD) to conduct a baseline stream assessment and identify bank erosion and other degraded riparian conditions along 3.3 miles of the South Fork Nine Mile Creek in Minnetonka, Eden Prairie, Edina, and Bloomington (Figure 1). One of the primary goals of the baseline assessment was to identify restoration opportunities to address the biotic impairments listed by the Minnesota Pollution Control Agency (MPCA) for South Fork Nine Mile Creek (SFNMC), which is impaired for fish and benthic macroinvertebrates from Lake Smetana to Normandale Lake (Figure 2). Several biotic stressors have been identified for SFNMC including excess sediment, inadequate baseflow, dissolved oxygen, and ionic strength (Barr, 2010). Biotic stressors play a major role in biotic impairments by influencing water quality and available instream habitat that can affect the distribution and abundance of biotic organisms in the creek.

The South Fork of Nine Mile Creek has a drainage area of 17.4 square miles and is comprised of urban and suburban development within a mosaic of wetlands, lakes, meadows, and woodlands. The combination of these land uses result in both flashy and attenuated stormwater flow that impacts the flow rate, flow duration, and erosion and depositional processes that exist within the channel. Surface water discharge is the primary source of flow within the creek, but some groundwater discharge is present in the upper reaches. This is an important aspect of the stream that will need to be considered during development of the final project design to address the degraded stream conditions and biotic impairments of the creek.

Restoration objectives for this project include reconnecting the creek with its floodplain, restoring eroding banks to reduce sediment and nutrient loading within the creek, providing pool refugia during periods of low flow, increasing instream habitat for fish and macroinvertebrates, and restoring vegetation diversity through removal of invasive species and planting native herbaceous vegetation. The restoration design proposed in this feasibility report aims to address the known biotic stressors of SFNMC through construction of numerous riffles to increase dissolved oxygen concentrations during periods of sustained flow, create deep pool habitat, restore floodplain connectivity, and reduce channel incision and bank erosion to minimize excess sediment contributions to the creek. It is anticipated that the new riffles will also intercept coarse sediment in the short-term as the creek adjusts to the reconnected floodplain. The restoration design also includes vegetation restoration within the riparian corridor to establish deep-rooted herbaceous vegetation along the stream banks and increase vegetation diversity for non-game habitat.

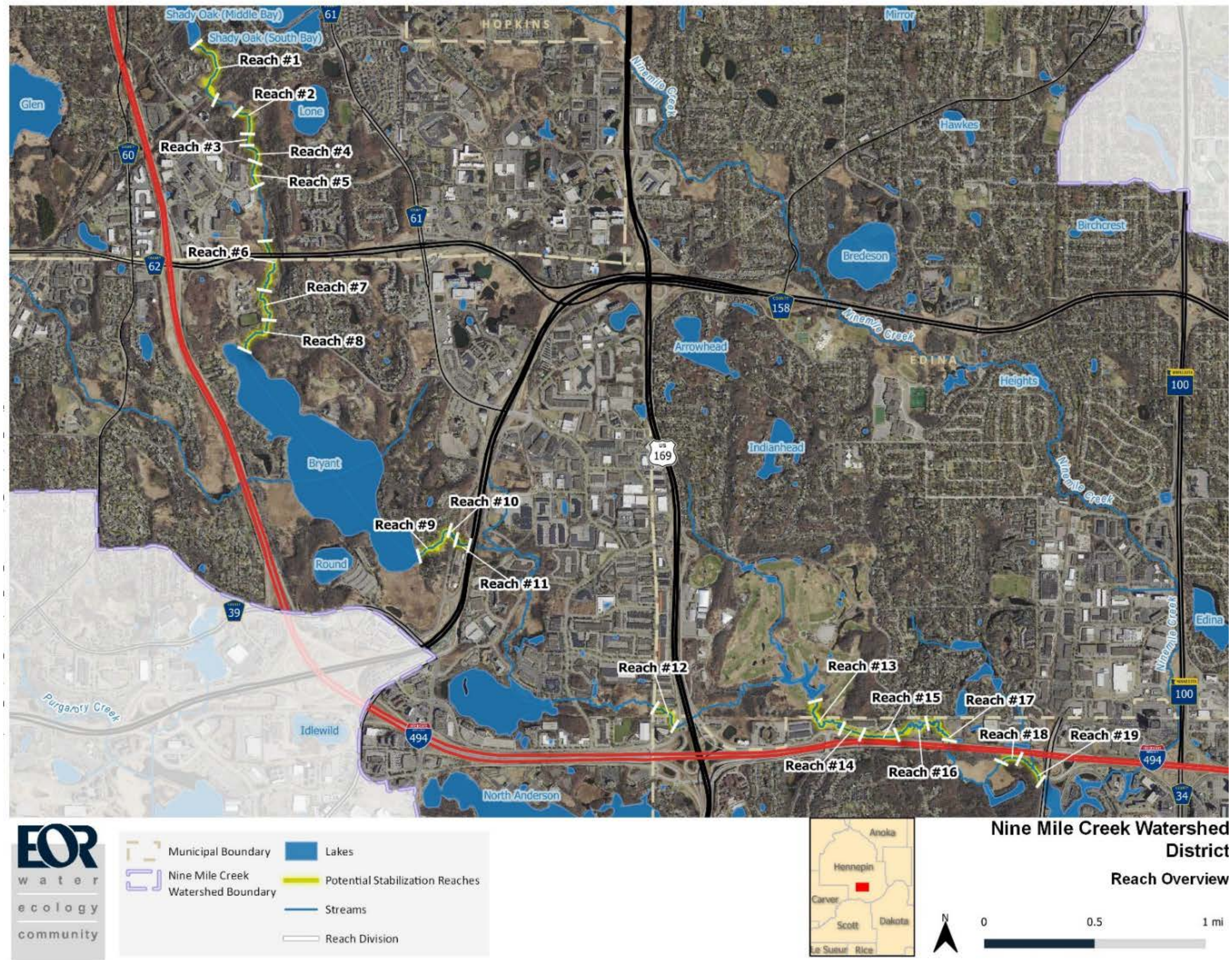


Figure 1. Baseline Assessment Reaches Along the South Fork of Nine Mile Creek

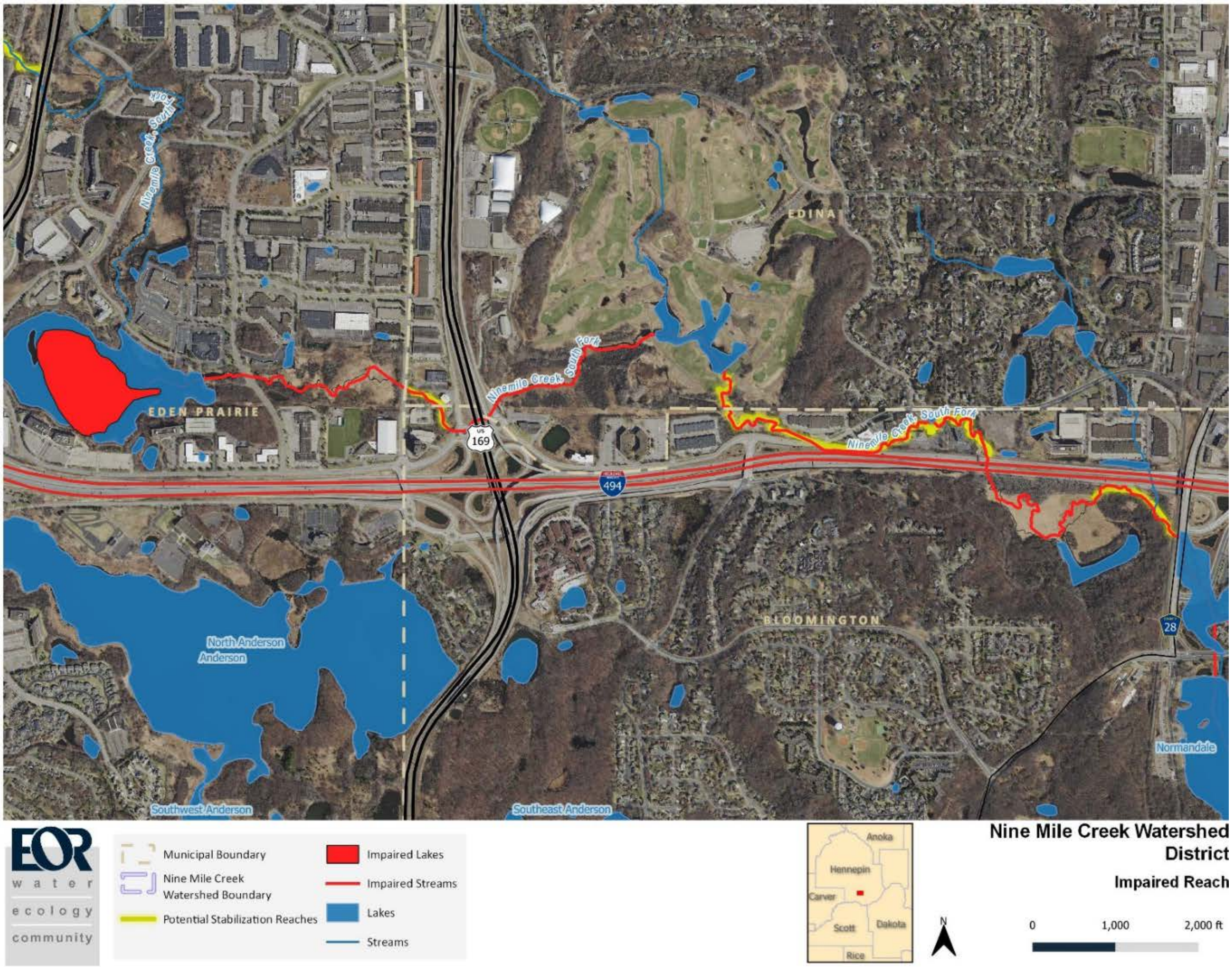


Figure 2. MPCA Impaired Waters Along South Fork Nine Mile Creek

INITIAL EVALUATION

As part of the initial baseline assessment conducted for SFNMC (included for reference in Appendix F), the Pfankuch Stream Stability Index was used to evaluate the existing channel condition along the creek corridor. The Pfankuch Stream Stability Index is a stream channel assessment tool that provides an initial evaluation of the overall condition of wadeable streams and includes an assessment of bank condition, floodplain accessibility, riparian vegetation, bank and channel substrates, and the stage of channel evolution. Refer to Appendix F for project background and detailed results from the baseline stream assessment. Field assessments conducted for the baseline assessment identified several geomorphic issues along the creek including accelerated lateral bank migration and subsequent bank erosion, channel incision, and floodplain abandonment. Following the baseline stream assessment, five reaches were identified and prioritized for restoration including reaches 6-8 (Figure 3) and reaches 16-17 (Figure 4).

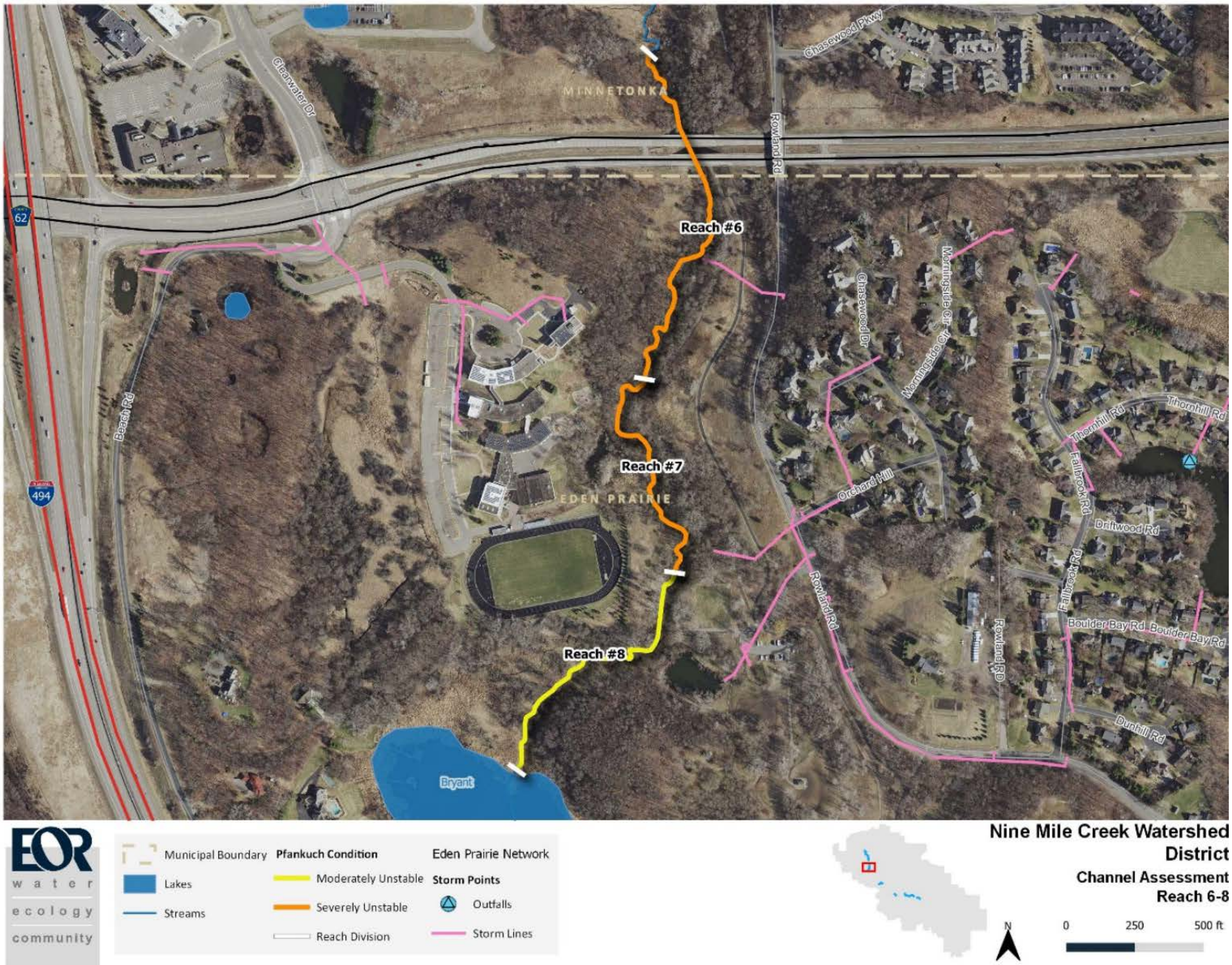


Figure 3. Overview Map of Priority Reaches 6-8

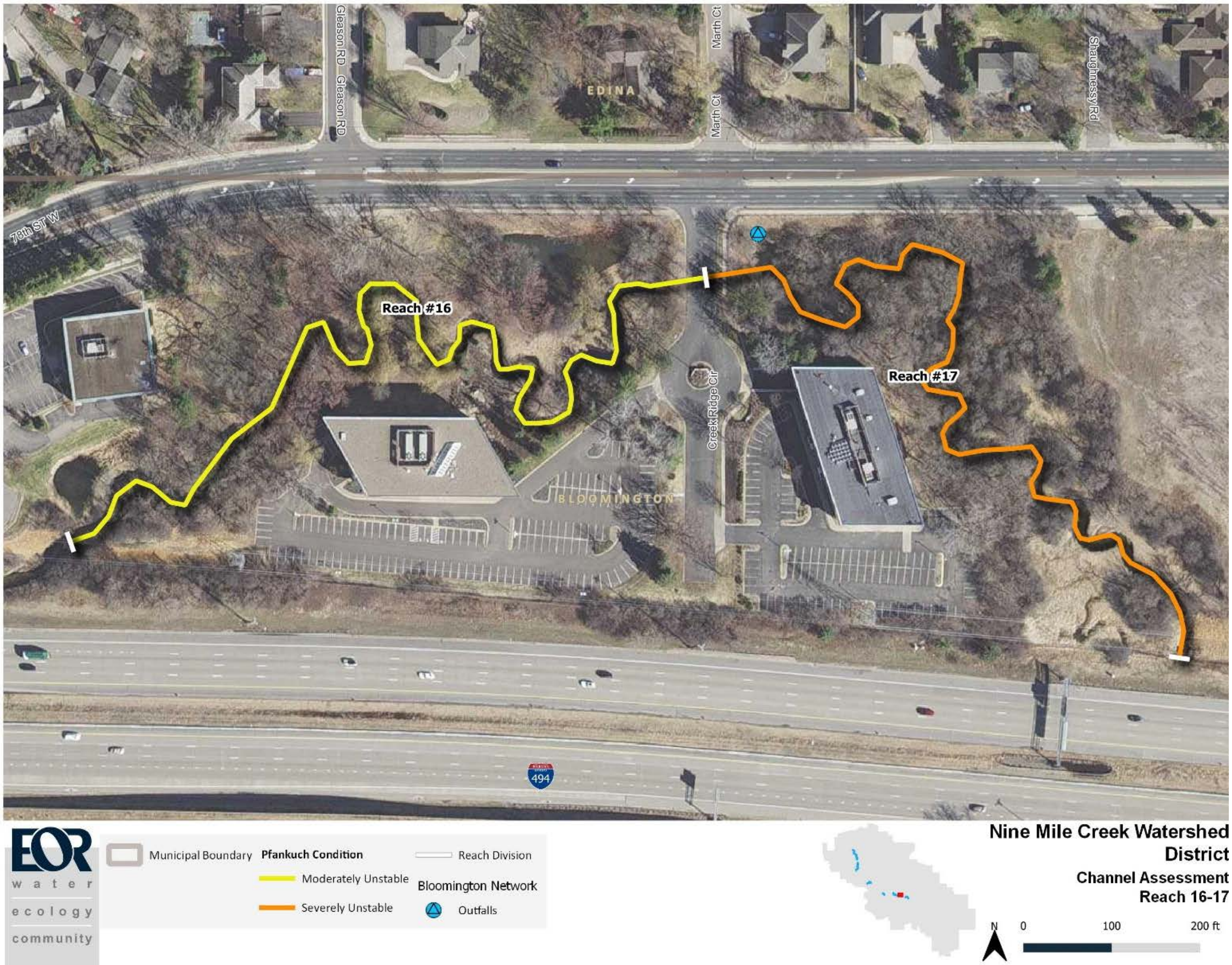


Figure 4. Overview Map of Priority Reaches 16-17

GEOMORPHIC SURVEY & ANALYSIS

A full geomorphic assessment was conducted in reaches 6-8 and reaches 16-17 and included stream bed and water surface elevation profiles, channel cross sections, bankfull measurements, computations of bankfull dimensions, flood dimensions, dimensionless ratios, and a pebble count. The survey was conducted using survey-grade GPS and total station equipment and was analyzed using AutoCAD Civil 3D and the Mecklenburg Stream Reach Spreadsheet. The survey was completed in the Hennepin County coordinate system with elevations calibrated to the North American Vertical Datum of 1988 (NAVD88). Survey points measured in the field included creek bed and surface water elevations, top of bank and toe elevations, ground elevations, culverts, structures, and bankfull elevation indicators. Cross sections were surveyed across riffles, runs, pools, and glides in each reach. One reference reach cross section was surveyed in each project reach where the stream channel was stable and contained a relatively connected floodplain (≤2-year recurrence interval). The reference reach cross sections were used as a guide to inform the project design practices proposed in the 30% construction plan. It should be noted the 30% construction plan for reaches 6-8 begins immediately downstream of Highway 62 since the channel grade upstream of the highway is held in check by existing rock grade control riffles under Highway 62.

Data was compiled in the Mecklenburg Stream Reach Spreadsheet to determine various geomorphic parameters for each surveyed cross section (Tables 1-4). The cross sections measured in each project reach included four different stream features (riffle, run, pool, glide) and were measured in locations that represented average channel conditions along the stream corridor.

For reaches 6-8, floodplain abandonment was documented at many of the cross-section sites, as reflective in the high bank height ratios shown in Tables 1-2. A stream that is connected to its floodplain at bankfull stage would have a bank height ratio of 1.0 and can dissipate flood flow energy over the floodplain. The greater the number above 1.0, the greater the degree of floodplain separation (also known as the degree of channel incision). In general, for incised channels, flows above the bankfull stage seldom access the floodplain and are thus contained within the stream channel. Instead of dissipating flood energy over the floodplain, flows are contained within the stream channel and result in increased shear stress on the channel banks. This increase in shear stress and flow velocity generally leads to increased bank erosion, especially in sandy soils, stratified soils, and along banks with poor root density and vegetative surface protection. The bank erosion documented throughout reaches 6-8 are also reflective of the bankfull width data shown in Tables 1-2. The bankfull widths (the channel width at bankfull stage) of cross sections 3, 5, 6, and 8 are significantly greater than other cross sections and are indicative of lateral channel migration (channel widening) measured at these sites. As bank erosion progresses, the channel width increases as the channel seeks to rebuild a new floodplain within the incised channel. The rate of channel migration varies and is dependent on channel bed substrates, flood frequency, vegetation, bank soils, and other variables. Reaches 6-8 also contain significant shade from the existing tree canopy and invasive shrubs, particularly common buckthorn. The dense shade has resulted in limited herbaceous vegetation along the stream banks with bare soils present in many areas. The combination of channel incision and floodplain abandonment along with poor herbaceous cover has resulted in bank erosion throughout the project reach.

Similar conditions were observed and measured in reaches 16-17. Compared to the reference reach cross section (cross section 1) measured at the upstream end of reach 16, the cross-sectional areas and bankfull widths of comparable stream features increased downstream through the project reach (Table 3, Table 4). The increased cross-sectional areas and bankfull widths correlated to significant lateral bank migration observed in the project reach. In addition, partial floodplain abandonment was measured at all three cross sections in reach 17, as reflective in the high bank height ratios in cross sections 6-8 shown in Table 4. Like reaches 6-8, dense stands of common buckthorn and heavy shade have resulted in limited herbaceous vegetation along the stream banks where the tree canopy is dense. The combination of poor herbaceous cover and a partially disconnected floodplain have resulted in lateral bank migration and subsequent bank erosion throughout the project reach.

Location maps of all surveyed cross sections are included for reference in Appendix A and cross section graphs and associated geomorphic data summaries can be found in Appendix B.

Table 1. Select Geomorphic Data for Reaches 6-8 (Cross Sections 1-5)

	Cross Section 1 Reference	Cross Section 2	Cross Section 3	Cross Section 4	Cross Section 5
Cross Section Location	Pool	Riffle	Riffle	Pool	Run
Cross Sectional Area [ft2]	11.7	14.8	17.2	10.4	16.1
Bankfull Width [ft]	7.6	11.2	18.3	8.8	13.6
Entrenchment Ratio	3.3	2.1	1.1	3.4	2.6
Bank Height Ratio [Incision]	1.2	1.8	2.1	1.1	1.4
Max. Depth [ft.]	2.1	1.6	1.6	2.3	1.6
Width-Depth Ratio	4.9	8.5	19.6	7.5	11.5
Stream Type	C4	C4→G4	F4	C4	C4

→ denotes direction of changing stream type

Table 2. Select Geomorphic Data for Reaches 6-8 (Cross Sections 6-10)

	Cross Section 6	Cross Section 7	Cross Section 8	Cross Section 9	Cross Section 10
Cross Section Location	Pool	Pool	Glide	Run	Glide
Cross Sectional Area [ft2]	12.8	11.7	13.6	11.8	10.6
Bankfull Width [ft]	10.5	9.7	12.4	11.0	8.9
Entrenchment Ratio	1.7	1.6	1.4	2.0	2.8
Bank Height Ratio [Incision]	1.0	2.6	2.3	1.8	1.6
Max. Depth [ft.]	2.1	1.7	1.2	1.7	1.7
Width-Depth Ratio	8.5	8.0	11.3	10.1	7.4
Stream Type	B4c	B4c→G4c	G4c	B4c	C4

→ denotes direction of changing stream type

Table 3. Select Geomorphic Data for Reaches 16-17 (Cross Sections 1-5)

	Cross Section 1 Reference	Cross Section 2	Cross Section 3	Cross Section 4	Cross Section 5
Cross Section Location	Riffle	Pool	Riffle	Run	Pool
Cross Sectional Area [ft2]	25.4	46.6	37.5	28.7	32.5
Bankfull Width [ft]	12.9	21.4	19.3	12.3	16.9
Entrenchment Ratio	3.1	4.2	4.7	5.7	4.1
Bank Height Ratio [Incision]	1.2	1.1	1.2	1.2	1.2
Max. Depth [ft.]	2.4	3.2	3.0	3.3	3.5
Width-Depth Ratio	6.5	9.8	9.9	5.3	8.8
Stream Type	E4	E4→C4	C4→E4	E4	E4

→ denotes direction of changing stream type

Table 4. Select Geomorphic Data for Reaches 16-17 (Cross Sections 6-8)

	Cross Section 6	Cross Section 7	Cross Section 8
Cross Section Location	Run	Glide	Pool
Cross Sectional Area [ft2]	35.2	45.4	28.5
Bankfull Width [ft]	17.3	33.4	16.0
Entrenchment Ratio	5.8	3.0	5.0
Bank Height Ratio [Incision]	1.3	1.3	1.7
Max. Depth [ft.]	2.5	2.0	2.6
Width-Depth Ratio	8.5	24.6	9.0
Stream Type	E4→C4	C4→F4	E4→C4

→ denotes direction of changing stream type

HYDROLOGIC & HYDRAULIC MODELING

Two models were constructed using Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.1.0. One model was constructed as a one-dimensional (1D) model comprising reaches 6-8. Due to high channel sinuosity and multiple flow paths in reaches 16 and 17, the model for this project area was constructed as a two-dimensional (2D) model which allowed for better simulation of varying flow paths at changing water surface elevations. Road crossing data were extracted from an XPSWMM model constructed in 2012 by Barr Engineering. In addition, flow data were taken as the peak flows represented at each location in the XPSWMM model. The Highway 62 crossing was not included in the model, but the bridge deck is well above the 100-year flow elevation. Elevation data were derived from Lidar data published by the State of Minnesota and collected in 2011.

HEC-RAS requires 2D models to be run in unsteady mode; therefore, rather than running a complete hydrograph through the reach 16-17 model, a quasi-steady hydrograph was used representing the peak flows in an equilibrium state. This approach did not account for storage routing effects; however, the storage within the model domain is limited and is not likely to contribute significantly to flow routing in this reach. The 1D model of reaches 6-8 was run in steady flow mode with outputs for the 2-year, 10-year, and 100-year recurrence intervals (Table 1). Table 2 shows the 2D modeled flows for reaches 16-17. The flow in reaches 6-8 is characterized by higher peak flows with a shorter duration due to minimal attenuation of flashy stormwater flow from the surrounding drainage area. In contrast, the flow in reaches 16-17 is characterized by significantly lower peak flows with a longer duration that is influenced by wetland and lake storage upstream of the project area.

Table 5. Recurrence Interval Flows in Reaches 6-8

Recurrence Interval (years)	Peak flow (CFS)
2	187
10	305.5
100	536.9

Table 6. Recurrence Interval Flows in Reaches 16-17

Recurrence Interval (years)	Peak flow (CFS)
2	112.9
10	172.1
100	228

Figures 5-7 show the velocity patterns for the 2-year, 10-year, and 100-year recurrence intervals for reaches 6-8 and Figures 8-10 show the velocity patterns for the 2-year, 10-year, and 100-year recurrence intervals for reaches 16-17. The highest modeled flow velocities occur along channel constrictions and downstream of existing road culverts. The high velocities shown at the inlet to Bryant Lake in Reach 8 are the result of downstream boundary conditions that were set at normal depth in the model. This neglects the possible backwater effects that could be caused by high water levels in Bryant Lake. Since lake levels are largely

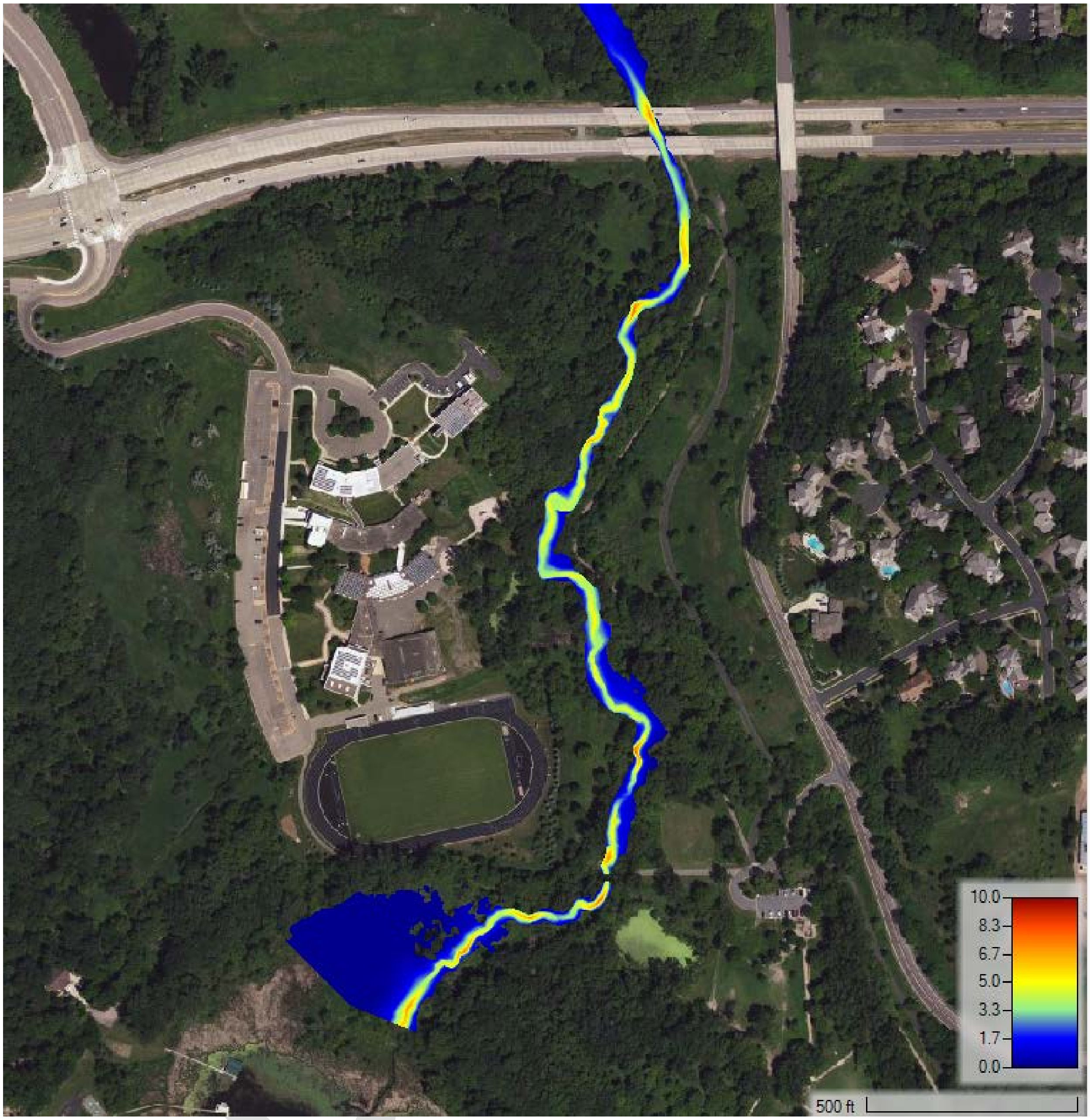


Figure 5. 2-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 6-8

independent of stream flow, it is difficult to predict what the downstream lake elevation would be during an actual flood event. The normal depth assumption gives a conservatively high estimate of velocities in this portion of the reach; however, under conditions with higher lake levels these velocities would be considerably lower.

The velocity pattern data highlight the need for improved floodplain connectivity to reduce flood energy within the channel and sufficient bank toe protection to reduce shear stress to minimize bank erosion. The proposed 30% construction design includes several bioengineering techniques to address the high shear stresses depicted in the velocity maps and include installation of woody debris and rootwads to deflect

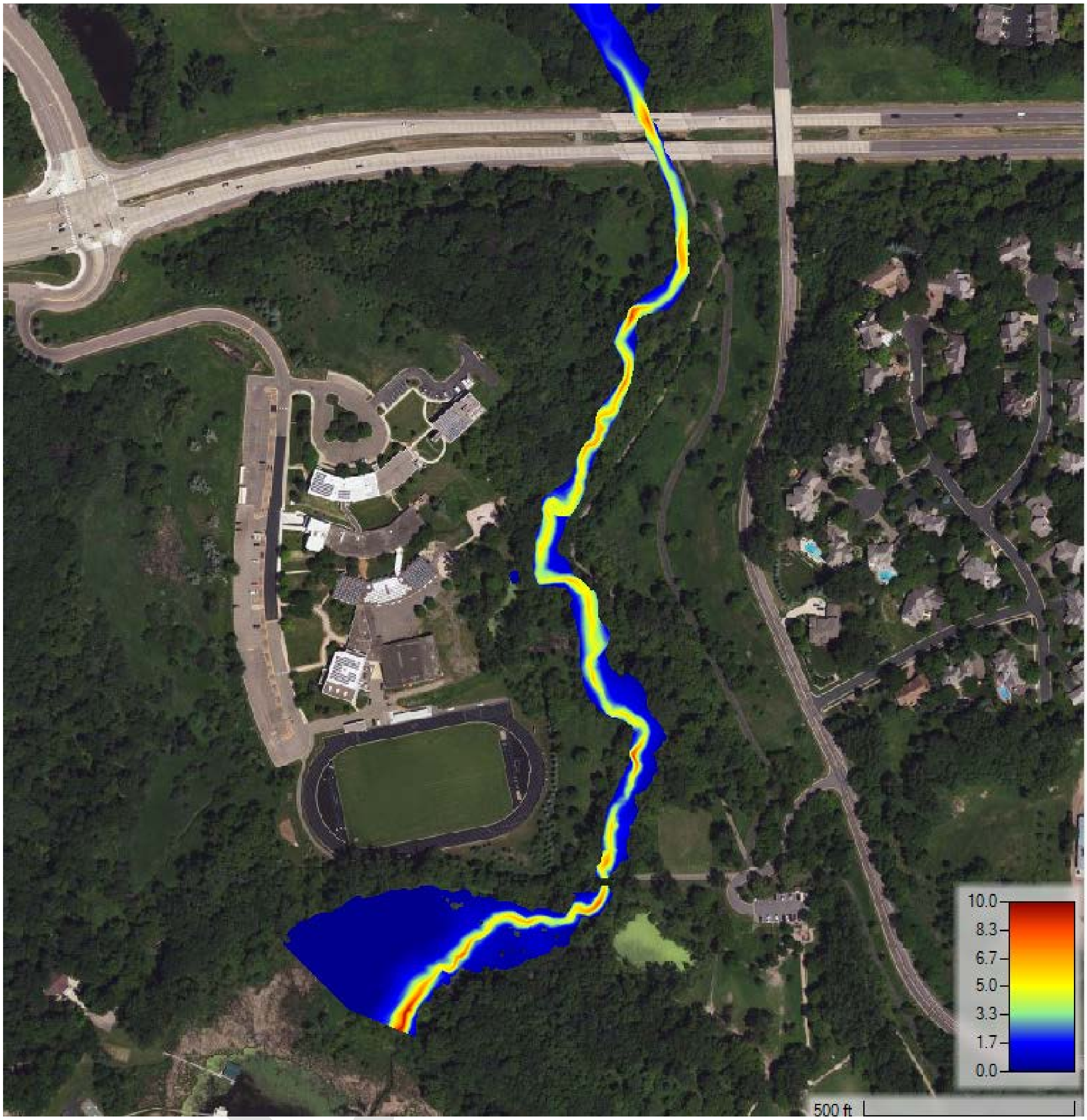


Figure 6. 10-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 6-8

flows toward the center of the channel. In addition, the design includes construction of riffle grade control structures to raise the elevation of the creek bed to reconnect the floodplain during bankfull events and distribute flood energy onto the floodplain.

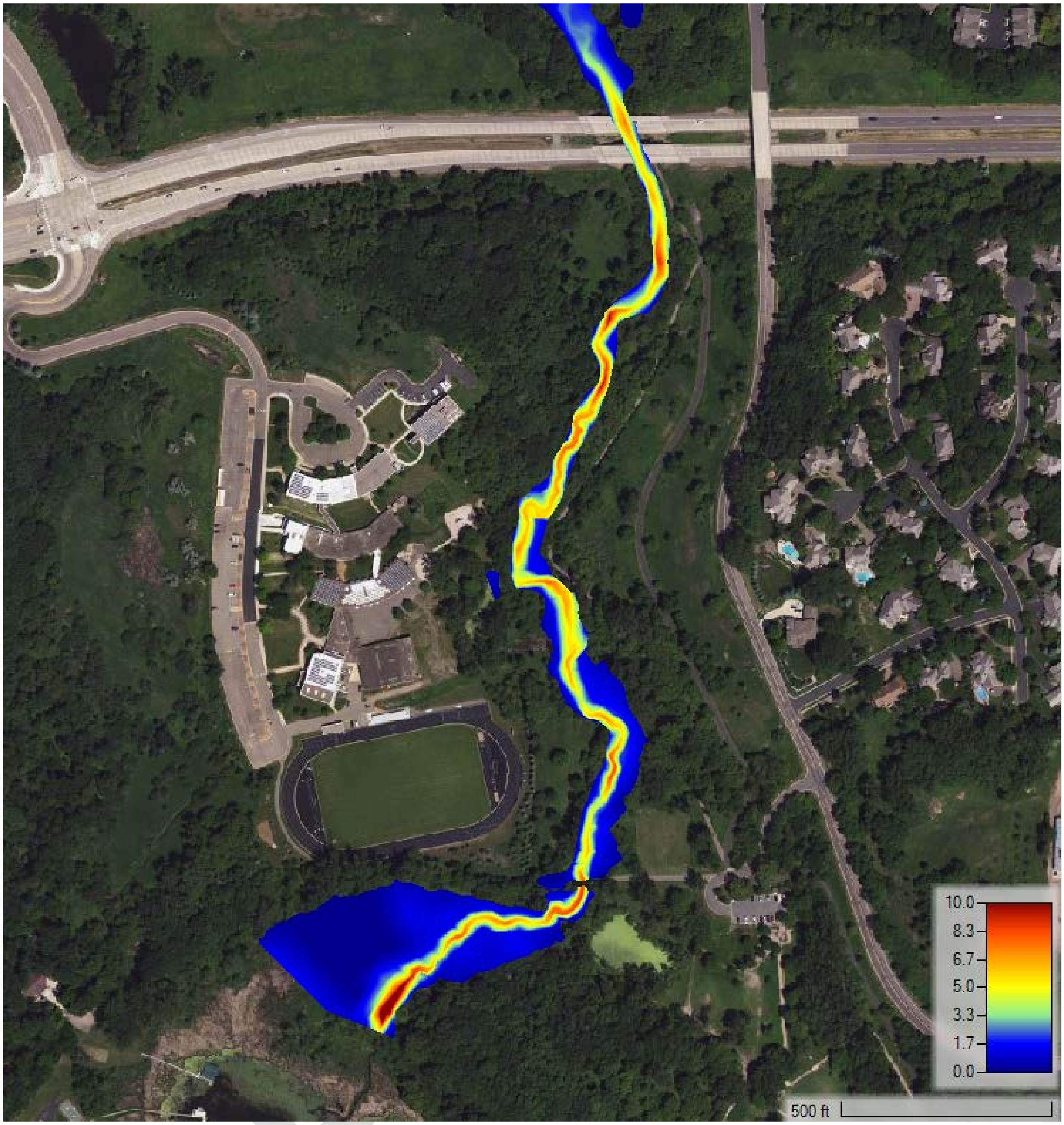


Figure 7. 100-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 6-8

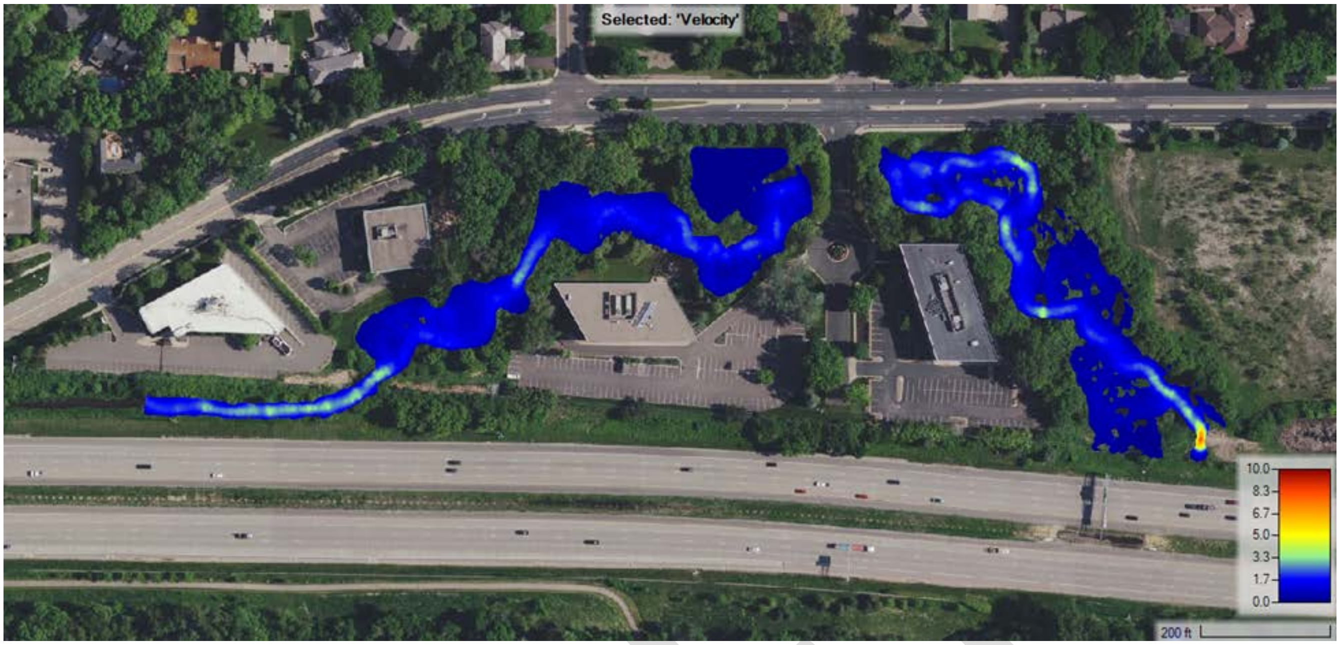


Figure 8. 2-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 16-17

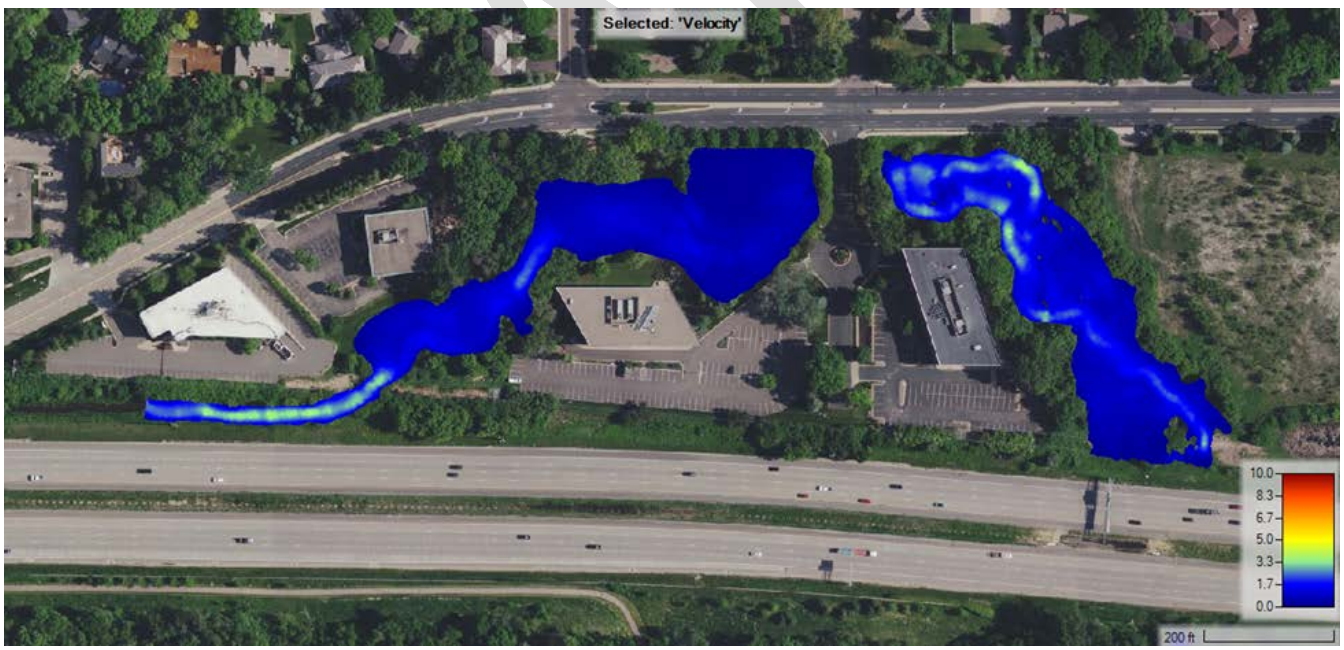


Figure 9. 10-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 16-17

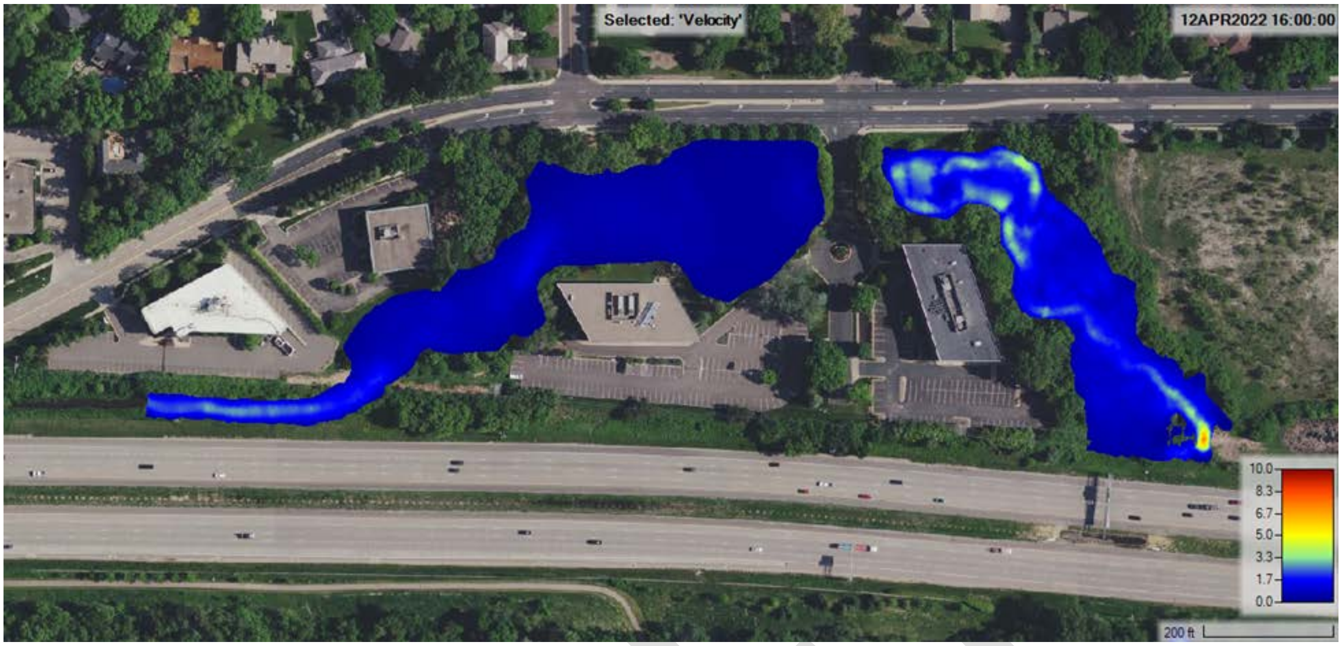


Figure 10. 100-Year Recurrence Interval Flow Velocities (ft/s) for Reaches 16-17

ANALYSIS OF AFFECTED PROPERTIES

An analysis of affected properties will be completed in the next scope of work for all parcels within each project reach. This will be accomplished by advancing the HEC-RAS modeling to include the final design channel dimensions and elevations of the grade control riffles which will be compared to the existing conditions model to verify if modeled flood extents will increase, decrease, or remain the same. This exercise will also provide the necessary information to complete a no-net rise certification for the project, which will be required by both the city of Bloomington and Eden Prairie.

RESTORATION OBJECTIVES & PRACTICES

Restoration objectives for this project include reconnecting the creek with its floodplain, restoring eroding banks to reduce sediment and nutrient loading within the creek, increasing instream habitat for fish and macroinvertebrates, and restoring vegetation diversity in the riparian corridor through removal of invasive species and planting native herbaceous vegetation. Based on the results of the geomorphic assessment and analysis of flow modeling data, several bioengineering practices were developed to meet the restoration objectives for the project while also restoring natural stream processes to improve fine sediment transport, maintain pool depths, and provide suitable substrates for macroinvertebrates and fish spawning to address the biotic impairments of the creek. The primary practice for supporting creek hydrology will be the installation of rock grade control riffles that will be designed to increase the creek bed elevation, provide deep pool habitat, and re-establish floodplain connectivity that had been affected by channel incision.

Toew

ood

The toewood practice utilizes natural materials (primarily large tree trunks, rootwads, and branches) to reconstruct a stable stream bank (Figure 11). Native soil is used as fill between the logs and branches with topsoil salvaged for use in a soil lift above the toewood structure. The rootwads and large tree trunks can be used to build-out the stream bank, thereby reestablishing a stream bank formerly lost to erosion. Building out the stream bank will also improve fine sediment transport and maintain deep pool habitat by creating a narrower stream channel. Based on the existing size and number of trees within the project reaches, it appears there is ample woody material that could be harvested on-site for many of the bank erosion sites. Harvesting wood onsite offers a dual benefit for the project by reducing import of materials and providing selective thinning of the tree canopy to allow more sunlight to reach the ground surface, thereby allowing for the establishment of deep-rooted grasses and forbs to further stabilize the stream banks and increase the diversity of riparian vegetation.

Figure 11. Example of Toewood Installed Post-Construction

Brush Bundles with Rootwads

This practice uses smaller trees and branches installed in a layered fashion along the bank toe to protect the stream bank (Figure 12). Small bundles of branches and brush will be installed parallel to the bank toe with rootwads used to anchor the brush bundles in place. Small trenches will need to be excavated into the bank for proper placement and anchoring of the rootwads to hold the brush bundles against the bank toe. Excess soil from rootwad trenching will be used as fill within the brush bundles for added ballast and substrate for vegetation establishment above the bundles. This practice is proposed in areas where minor channel adjustments are needed to create a narrower creek channel.

Figure 12. Example of Brush & Rootwads Installed Post Construction

Bank Shaping & Riffle Grade Control

This practice incorporates a combination of bank grading, grade control, and strategic placement of woody material to reconnect the floodplain and provide deep pool habitat (Figure 13). A gradation of boulders, cobbles, and gravels will be used to create grade control riffles to increase and stabilize the bed elevation, thereby restoring channel slope and floodplain connectivity while also increasing pool depths and concentrated flow over riffles. Minor bank grading may be required based on the new bed elevation and established bankfull elevation. Logs and rootwads will be installed in pools to provide additional instream habitat. As with the approaches above, this practice will require harvest of woody material that will allow for selective tree thinning and establishment of herbaceous riparian vegetation near the stream channel.

Figure 13. Example of Riffle Grade Control and Deep Pool Habitat with Rootwads

Bank Shaping & Vegetated Boulder Toe

Boulder toe stabilization will be installed in areas immediately downstream of culvert crossings where flood energy and channel gradient are highest including the downstream end of the box culvert in Reach 7 and downstream of the road culvert under Creekridge Circle in Reach 17. Boulder toe rock will be installed along the bank toe and at a shallow slope (minimum 4:1) to allow for incorporation of native fill for establishment of vegetation within the boulder toe rock (Figure 14). The vegetated boulder toe will extend up to the bankfull elevation, and a bankfull bench will be graded at the top of the boulder toe.

Figure 14. Example of Vegetated Boulder Toe 1-Year Post Construction

All practices presented above will achieve project goals to stabilize the stream banks, reduce sediment and nutrient loading, and improve instream fish and macroinvertebrate habitat. In addition, the practices will also allow for narrowing of the stream channel to increase baseflow water depth and velocity, restore instream coarse substrates suitable for a variety of aquatic biota, and build-out from key infrastructure while also increasing floodplain connectivity along the creek corridor.

PROPOSED IMPROVEMENTS

See Appendix C for preliminary 30% Construction Plans and the locations of specific practices that are recommended within each reach of the proposed project. The recommended improvements for each reach are summarized below:

Reach 6 Existing Conditions

Reach 6 begins immediately downstream of Highway 62 and extends downstream approximately 800 feet. Channel downcutting (incision) begins in this reach and increases downstream. Bank heights range from 1.5-3 feet with some banks over 6 feet in height, resulting in a floodplain that is mostly disconnected from the creek except during high flow events. A dense tree canopy occurs throughout the reach with common buckthorn dominating the shrub layer. Dense shading has resulted in poor streambank vegetation with raw banks common throughout the corridor. Bank erosion has resulted in fine sediment accumulation in the channel, but exposed gravel and cobble substrates occur within the stream. Perennial flow from groundwater supports a small assemblage of minnows and macroinvertebrates that were observed during the assessment. Stream type: C transitioning to F, Pfankuch Condition: Severely Unstable.

Considerations and Options

- Bank shaping & riffle grade control, toewood, brush bundles with rootwads

Recommendations

Recommendations include selective tree thinning and removal of invasive species and reincorporating the woody material into toewood, brush bundles, and rootwads. These practices will help protect the stream banks by reducing shear stress and flood energy along the banks while providing instream habitat. Riffle grade control will also be installed to reconnect the creek with the floodplain and help maintain deep pool habitat during periods of low flow and increase dissolved oxygen levels. Minimal grading is proposed due to the narrow stream corridor and steep topography near the creek.

Reach 7 Existing Conditions

Reach 7 begins at the downstream terminus of Reach 6 and extends downstream to a paved walking path west of Bryant Lake Dog Park. Similar to Reach 6, channel incision has resulted in bank heights that range from 1.5-4 feet, resulting in a floodplain that is mostly disconnected from the creek except during high flow events. A dense tree canopy occurs throughout the reach with buckthorn dominating the shrub layer. Dense shading has resulted in poor streambank vegetation with raw banks common along the corridor. Bank erosion is substantial in this reach, yet exposed gravel and cobble substrates occur within the stream including numerous large fieldstone boulders scattered within the channel. Perennial flow from groundwater discharge supports a small assemblage of minnows and macroinvertebrates that were observed during the assessment. Pools are limited by sediment aggradation with depths that range from 0.8-1.25 feet. Stream type: F, Pfankuch Condition: Severely Unstable.

Considerations and Options

- Bank shaping & riffle grade control, toewood, brush bundles with rootwads

Recommendations

Recommendations include selective tree thinning and removal of invasive species and reincorporating the woody material into toewood, brush bundles, and rootwads. These practices will help protect the stream banks by reducing shear stress and flood energy along the banks while providing instream habitat. Riffle grade control will also be installed to reconnect the creek with the floodplain and help maintain deep pool habitat during periods of low flow and increase dissolved oxygen levels. Bank shaping is proposed in strategic areas to increase the floodplain width and reduce flood energy along the steep valley walls.

Reach 8 Existing Conditions

Reach 8 begins at the paved trail crossing west of Bryant Lake Dog Park and extends downstream to the inlet to Bryant Lake. Reach 8 has a lower stream gradient compared to reaches 6-7 and is kept in check by the water elevation of Bryant Lake. The stream channel becomes narrower in areas with a reduced tree canopy, but bank erosion is still significant throughout the reach. A large sediment delta occurs at the inlet to Bryant Lake that has been enlarging due to bank erosion and channel incision that has occurred upstream. Stream substrates are predominantly sand with some gravel exposed in riffles and at channel constrictions. Pool depths are greatly diminished by the high sediment load and are on average less than one foot in depth. Stream type: F transitioning to a C, Pfankuch Condition: Moderately Unstable.

Considerations and Options

- Bank shaping & riffle grade control, toewood, rootwads, vegetated boulder toe

Recommendations

Design components include selective tree thinning and removal of invasive species and reincorporating the woody material into toewood and rootwads. These practices will help protect the stream banks by reducing shear stress and flood energy along the banks while providing instream habitat. Riffle grade control will be installed to reconnect the creek with the floodplain and help maintain deep pool habitat during periods of low flow and increase dissolved oxygen levels. Riffle grade control is also proposed to increase the water depth through the existing culvert at the beginning of the reach to improve aquatic connectivity and allow for fish passage during periods of low flow. Bank shaping is proposed along much of the reach to reconnect the floodplain and allow for flood energy to dissipate onto the floodplain.

Reach 16 Existing Conditions

Reach 16 starts approximately 1,200 feet upstream of Creekridge Circle and extends downstream to the culvert under Creekridge Circle. The stream channel courses through a dense forested corridor dominated by boxelder, cottonwood, and common buckthorn. The dense tree and shrub canopy limits available sunlight, thereby reducing herbaceous ground cover. Lateral bank migration is exacerbated by a combination of high channel sinuosity, poor streambank vegetation, and numerous channel obstructions comprised of down trees, branches, and debris jams. Bank erosion has resulted in the formation of several mid-channel bars and side bars which has caused further bank erosion through deflection of high flow velocities into the adjacent stream banks. In areas with a reduced tree canopy, the stream channel is narrower with densely vegetated stream banks and limited bank erosion compared to the wooded areas. Pool depths in this reach range from 1-2 feet and provide habitat for a few species of fish including minnows and dace. The open canopy areas also allow for the growth of aquatic macrophytes in the creek. Stream type: C, Pfankuch Condition: Moderately Unstable.

Considerations and Options

- Bank shaping & riffle grade control, toewood, brush bundles with rootwads

Recommendations

Recommendations in this reach include selective tree thinning and removal of invasive species and reincorporating the woody material into toewood, brush bundles, and rootwads. These practices will help protect the stream banks by reducing shear stress and flood energy along the banks while providing instream habitat. Riffle grade control will also be installed to reconnect the creek with the floodplain and help maintain deep pool habitat during periods of low flow and increase dissolved oxygen levels. Bank shaping is proposed at strategic locations to increase the floodplain width and reduce flood energy in areas with high topographic relief.

Reach 17 Existing Conditions

Reach 17 is located between Creekridge Circle and I-494. Similar to Reach 16, the stream channel courses through a dense forested corridor dominated by common buckthorn and boxelder. Herbaceous ground cover is limited due to the dense tree and shrub canopy. Bank erosion and sediment issues abound in this reach and are the result of lateral bank migration that is exacerbated by a combination of high channel sinuosity, poor streambank vegetation, and numerous log jams and down trees. The stream channel has migrated near significant infrastructure including the road embankment of 78th Street and a commercial building; therefore, this reach is considered a top priority bank stabilization. Bank heights range from 2-6 feet with a few banks over 15 feet in height. Pool depths in this reach range from 1-2 feet and provide habitat for a few species of fish including minnows and dace. Stream type: C transitioning to F, Pfankuch Condition: Severely Unstable.

Considerations and Options

- Bank shaping & riffle grade control, toewood, brush bundles with rootwads, vegetated boulder toe

Recommendations

Design components include selective tree thinning and removal of invasive species and reincorporating the woody material into brush bundles, toewood, and rootwads. These practices will help protect the stream banks by reducing shear stress and flood energy along the banks while providing instream habitat. Riffle grade control will be installed to reconnect the creek with the floodplain and help maintain deep pool habitat during periods of low flow and increase dissolved oxygen levels. Riffle grade control is also proposed to increase the water depth through the existing culvert at Creekridge Circle to improve aquatic connectivity and allow for fish passage during periods of low flow. Bank shaping is proposed along much of the reach to reconnect the floodplain and allow for flood energy to dissipate onto the floodplain.

CONSTRUCTION SEASON FEASIBILITY

The Minnesota Department of Natural Resources (MNDNR) has established work exclusion dates for work in public waters to protect fish spawning and migration (MNDNR, 2014). The South Fork of Nine Mile Creek is classified as a non-trout stream with work exclusion dates from March 15- June 15. No work can occur within the stream during these dates unless documentation is provided to the local MNDNR fisheries office indicating the proposed work will have a minimal impact on fish habitat. Approval of submitted documentation by the MNDNR Area Fisheries Manager is required before any work can occur in the stream.

It is recommended construction of the SFNMC project occur after the work exclusion dates expire, ideally between June 15 and September 15. Work during this construction window would allow for proper grading and materials installation and provide a sufficient growing season for establishment of vegetative cover. To limit impacts to wildlife, tree harvest is recommended in late fall or early winter when most terrestrial species have migrated or are in hibernation.

ASSUMPTIONS

It is assumed a sufficient number of shrubs and trees can be harvested along the project reaches for the various bioengineering practices proposed. However, slight adjustments in the quantity and/or location of the proposed inputs may be required based on the actual quantities of woody material derived from the project sites. It is also assumed the MNDNR and the United States Army Corps of Engineers will approve permits for raising the creek bed to reconnect the floodplain as proposed in the 30% construction plan. Completion of a no-net rise document is anticipated to advance the permit review process and will be included in a separate scope of work to complete the final construction documents.

PERMITTING & LOCAL/NON-GOVERNMENTAL LAND USE REQUIREMENTS/NEEDS

A mandatory Environmental Assessment Worksheet (EAW), which included an archeological assessment and a phase 1 environmental site assessment, was prepared for the proposed project and was out for public comment from June 28, 2022 to July 28, 2022. In addition, NMCWD held a public hearing to receive comments on the EAW on August 4, 2022. The EAW and received comments and NMCWD responses are included for reference in Appendix D.

The proposed project will require several permits from local, state, and federal agencies. Permit applications will be submitted upon completion of final project construction plans which will be advanced in conjunction with a wetland delineation as a separate scope of work. Permits anticipated for this project include the following:

- Minnesota Public Waters Work Permit: Required for projects constructed below the Ordinary High-Water Level (OHWL) that will alter the course, current, or cross-section of public waters.
- U.S. Army Corps of Engineers Permit: Required for work in navigable waters of the United States and discharges of dredged or fill material into waters of the United States.
- National Pollution Discharge Elimination System (NPDES) Permit: Required for projects that will disturb over 1.0 acres of land.
- Nine Mile Creek Watershed District: Watershed permit required for projects within watershed district boundaries.
    - Rule 2.0 - Floodplain and Drainage Alterations: Any alteration or filling of land and/or redirection of flow below the District's 100-year floodplain.
    - Rule 5.0 - Erosion and Sediment Control: The excavation of 50 cubic yards or more of earth, or alteration or removal of 5,000 square feet or more of surface area or vegetation.
    - Rule 6.0 - Watercourse and Basin Crossing: Any construction, improvement, repair, or removal of a crossing or structure in contact with or under the bed or bank of any waterbody.
    - Rule 7.0 - Shoreline and Streambank Improvements: Any installation of a shoreline or streambank improvement, including but not limited to riprap, a bioengineered installation, or a retaining wall on a public water.

- Wetland Conservation Act Wetland Review: Includes a wetland delineation and Local Government Unit / Technical Evaluation Panel approval of the boundary as well as approval of impacts if work occurs above the OHWL.
    - Rule 3.0 - Wetlands Management: Any activity that results in the draining, excavation, or filling of a wetland regulated through the Wetland Conservation Act (WCA), where the District is the WCA local government unit (LGU) (the cities of Eden Prairie, Edina, Hopkins, and Richfield). Bloomington LGU is the City of Bloomington.
    - Projects requiring *any* District permits are required to meet the wetland buffer and stormwater-treatment provisions of this rule, unless determined exempt through WCA.
- Local Permits
    - City of Eden Prairie - Land Alteration Permit: Required for any land disturbing activity of 100 cubic yards or more, including: excavating, grading, scraping, clearing and grinding of tree stumps, filling, or other changes or movement of earth which may result in diversion of a man-made or natural water course or erosion of sediments.
    - City of Eden Prairie - Water Resources Land Alteration Permit - Shoreland: Required for projects grading and filling within any part of shoreland area along on public waterway.
    - City of Eden Prairie - Floodplain Permit/No-Rise Certificate: Required for projects that the placement of fill, excavation of materials, or the storage of materials or equipment occurs within the floodplain.
    - City of Bloomington - Grading Permit: Required prior to any land disturbing activity if the combined volume of excavation, filling, and other movement of earth material on a site is equal to or greater than 50 cubic yards or the area disturbed is greater than or equal to 5,000 square feet.
    - City of Bloomington - Floodplain Permit/No-Rise Certificate: Required for projects that the placement of fill, excavation of materials, or the storage of materials or equipment occurs within the floodplain.
    - Three Rivers Park District - Special Use Permit: Required for all groups conducting organized events when using a park or trail facility.
- There are nine parcels within the five creek reaches where creek stabilization work is proposed (four publicly owned and five privately owned). For this reason, temporary and/or permanent access and maintenance agreements and easements will need to be acquired for the work to be completed.

No long-term adverse impacts to natural resources are expected to result from implementation of the recommended improvements. Some temporary construction-related impacts will occur to riparian wetlands and mitigation may be required, but impacts are generally expected to be minor. There are no new impervious created by the project.

ENGINEER'S OPINION OF PROBABLE COST

EOR has reviewed recent contractor bid tabulations from similar projects that utilized the practices above to develop the 30% design construction costs. Primary construction costs include mobilization, tree harvest and site clearing, soil excavation and grading, import of rock for riffle grade control structures, and installation of toewood, brush bundles, and rootwads. Table 7 summarizes the project reach lengths, proposed construction activities, and estimated construction costs for the 30% design. The costs provided in the table will be refined based on additional data and design analyses to develop the final construction plan. Factors that will impact final project costs include site access, extent of tree and shrub removal, and the type and quantity of each proposed stabilization practice.

The cost estimates provided in Table 7 assume completion of each project reach individually; economy of scale would be realized if both project reaches are implemented during the same construction timeframe.

Detailed costed estimates are included for reference in Appendix E.

Table 7. Engineer's Opinion of Probable Cost (30% Design) for the SFNMC Bank Stabilization Project

Project Reach	Project Length (LF)	Proposed Bank Stabilization Practices	Engineer's Opinion of Probable Cost
6-8	3,020	Toewood, Brush Bundles with Rootwads, Bank Shaping & Riffle Grade Control	$344,535
16-17	2,300	Toewood, Brush Bundles with Rootwads, Bank Shaping & Riffle Grade Control, Vegetated Boulder Toe	$262,342
CONSTRUCTION SUB-TOTAL	5,320		$606,877
CONSTRUCTION CONTINGENCY (30%)			$182,063
ESTIMATED CONSTRUCTION COST			**$788,940**
ENGINEERING, LEGAL, ADMINISTRATIVE (30%)			$236,682
ESTIMATED PROJECT TOTAL			**$1,025,622**

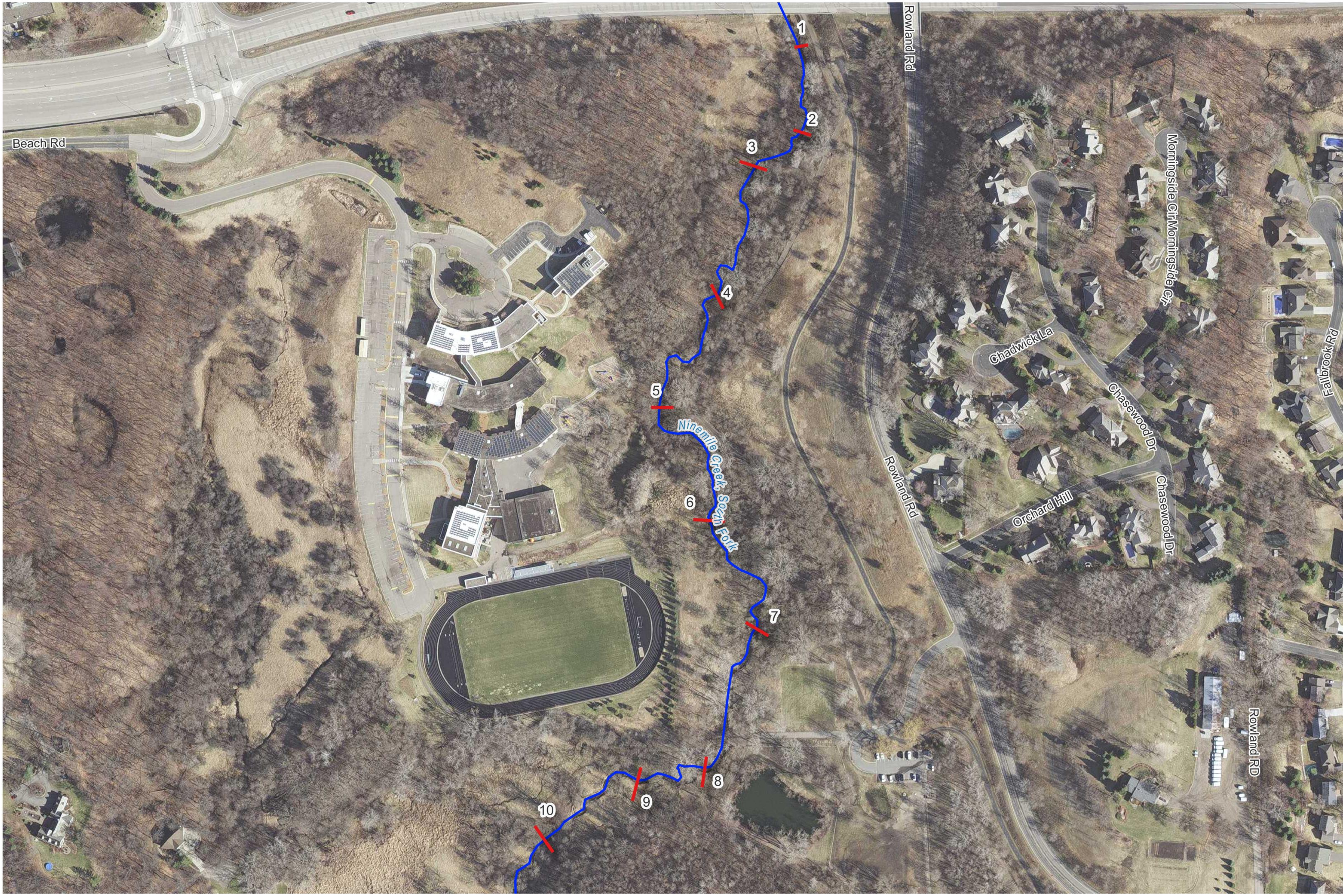
REFERENCES

Barr Engineering Company. 2010. Nine Mile Creek Biological Stressor Identification. Prepared for the Minnesota Pollution Control Agency https://www.pca.state.mn.us/sites/default/files/wq-ws5-07020012a.pdf

Minnesota Department of Natural Resources. Best Practices for Meeting General Public Waters Work Permit GP 2004-0001 (reference for work exclusion dates) https://files.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_chapter1.pdf

Minnesota Lidar elevation data: https://www.mngeo.state.mn.us/chouse/elevation/lidar.html

APPENDIX A. LOCATION MAPS OF SURVEYED CROSS SECTIONS



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EOR
water
ecology
community

Cross Sections
Streams

N

0 200 400 ft

Nine Mile Creek Watershed District

Cross Sections
Reaches 6-8

Date: 2022-07-21T10:47:23.020 Author: Sarah Grandstrand Layout: RM_CrossSection_Reaches16to17
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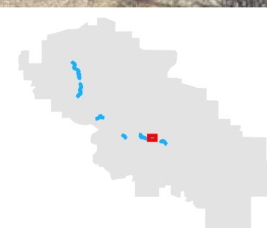
EOR water ecology community

Cross Sections

Streams



Nine Mile Creek Watershed District

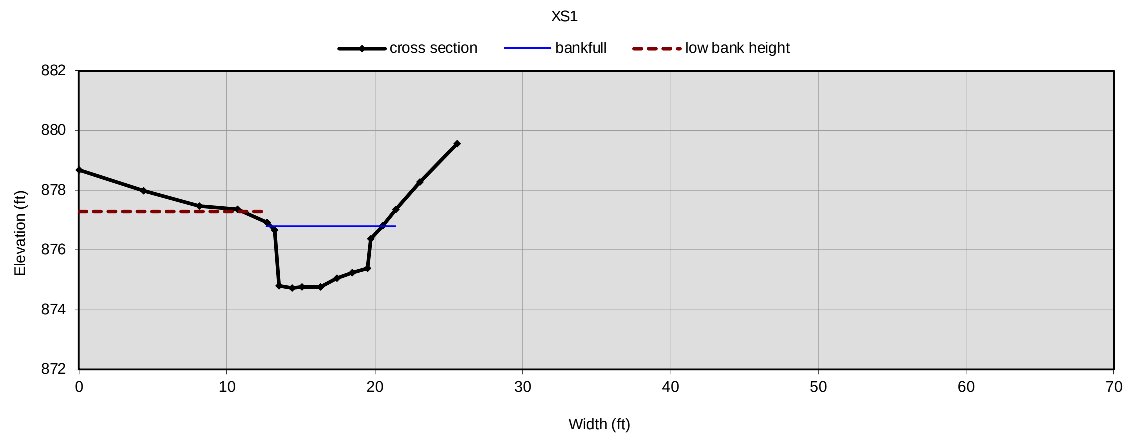
Cross Sections Reaches 16-17

N

0 100 200 ft

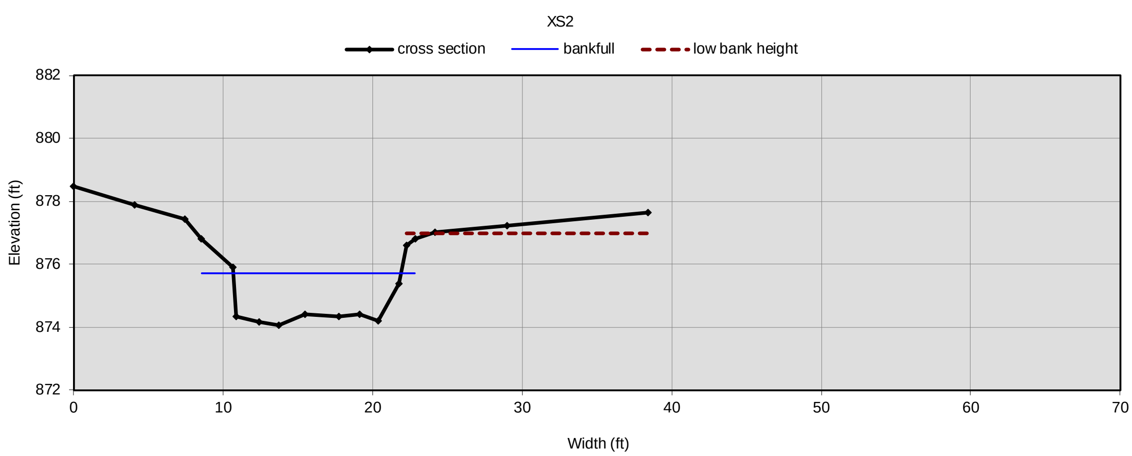
APPENDIX B. CROSS SECTION GRAPHS & GEOMORPHIC DATA

Reaches 6-8 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions		Flood Dimensions		Materials	
11.7	x-section area (ft.sq.)	25.0	W flood prone area (ft)	15	D50 Riffle (mm)
7.6	width (ft)	3.3	entrenchment ratio	25	D84 Riffle (mm)
1.6	mean depth (ft)	2.6	low bank height (ft)	29	threshold grain size (mm):
2.1	max depth (ft)	1.2	low bank height ratio		
10.1	wetted parimeter (ft)				
1.2	hyd radi (ft)				
4.9	width-depth ratio				

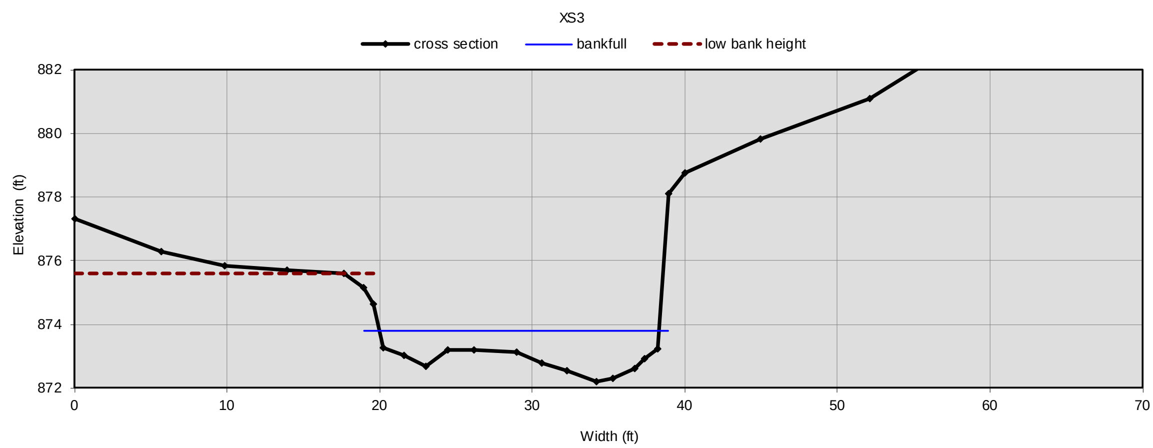
Bankfull Flow		Flow Resistance		Forces & Power	
5.5	velocity (ft/s)	0.027	Manning's roughness	0.82	channel slope (%)
64.8	discharge rate (cfs)	0.08	D'Arcy-Weisbach fric.	0.60	shear stress (lb/sq.ft.)
0.90	Froude number	10.0	resistance factor u/u*	0.55	shear velocity (ft/s)
		18.9	relative roughness	4.4	unit strm power (lb/ft/s)



Bankfull Dimensions		Flood Dimensions		Materials	
14.8	x-section area (ft.sq.)	23.6	W flood prone area (ft)	15	D50 Riffle (mm)
11.2	width (ft)	2.1	entrenchment ratio	25	D84 Riffle (mm)
1.3	mean depth (ft)	2.9	low bank height (ft)	28	threshold grain size (mm):
1.6	max depth (ft)	1.8	low bank height ratio		
13.1	wetted parimeter (ft)				
1.1	hyd radi (ft)				
8.5	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
5.3	velocity (ft/s)	0.028	Manning's roughness	0.82	channel slope (%)
78.7	discharge rate (cfs)	0.08	D'Arcy-Weisbach fric.	0.58	shear stress (lb/sq.ft.)
0.88	Froude number	9.7	resistance factor u/u*	0.55	shear velocity (ft/s)
		16.1	relative roughness	3.6	unit strm power (lb/ft/s)

Reaches 6-8 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions

17.2	x-section area (ft.sq.)
18.3	width (ft)
0.9	mean depth (ft)
1.6	max depth (ft)
19.5	wetted parimeter (ft)
0.9	hyd radi (ft)
19.6	width-depth ratio

Flood Dimensions

20.3	W flood prone area (ft)
1.1	entrenchment ratio
3.4	low bank height (ft)
2.1	low bank height ratio

Materials

15	D50 Riffle (mm)
25	D84 Riffle (mm)
22	threshold grain size (mm):

Bankfull Flow

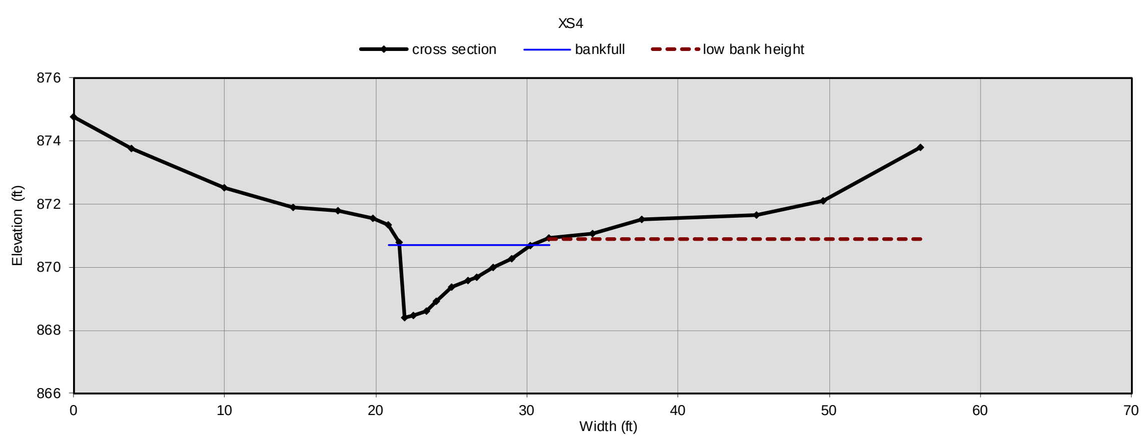
4.5	velocity (ft/s)
76.7	discharge rate (cfs)
0.84	Froude number

Flow Resistance

0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.3	resistance factor u/u*
11.4	relative roughness

Forces & Power

0.82	channel slope (%)
0.45	shear stress (lb/sq.ft.)
0.48	shear velocity (ft/s)
2.1	unit strm power (lb/ft/s)



Bankfull Dimensions

10.4	x-section area (ft.sq.)
8.8	width (ft)
1.2	mean depth (ft)
2.3	max depth (ft)
11.1	wetted parimeter (ft)
0.9	hyd radi (ft)
7.5	width-depth ratio

Flood Dimensions

30.0	W flood prone area (ft)
3.4	entrenchment ratio
2.5	low bank height (ft)
1.1	low bank height ratio

Materials

15	D50 Riffle (mm)
25	D84 Riffle (mm)
23	threshold grain size (mm):

Bankfull Flow

4.8	velocity (ft/s)
49.6	discharge rate (cfs)
0.87	Froude number

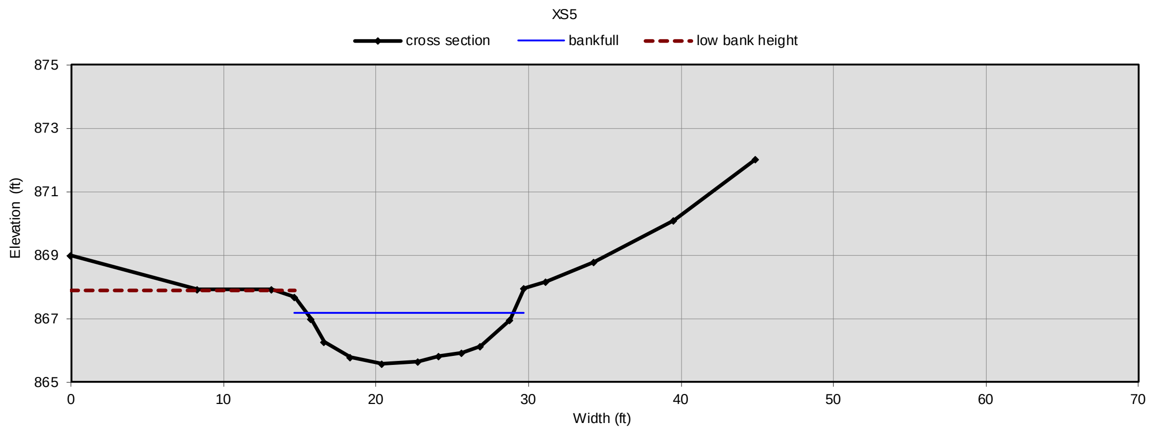
Flow Resistance

0.027	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.7	resistance factor u/u*
14.4	relative roughness

Forces & Power

0.82	channel slope (%)
0.48	shear stress (lb/sq.ft.)
0.50	shear velocity (ft/s)
2.9	unit strm power (lb/ft/s)

Reaches 6-8 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions	
16.1	x-section area (ft.sq.)
13.6	width (ft)
1.2	mean depth (ft)
1.6	max depth (ft)
14.3	wetted parimeter (ft)
1.1	hyd radi (ft)
11.5	width-depth ratio

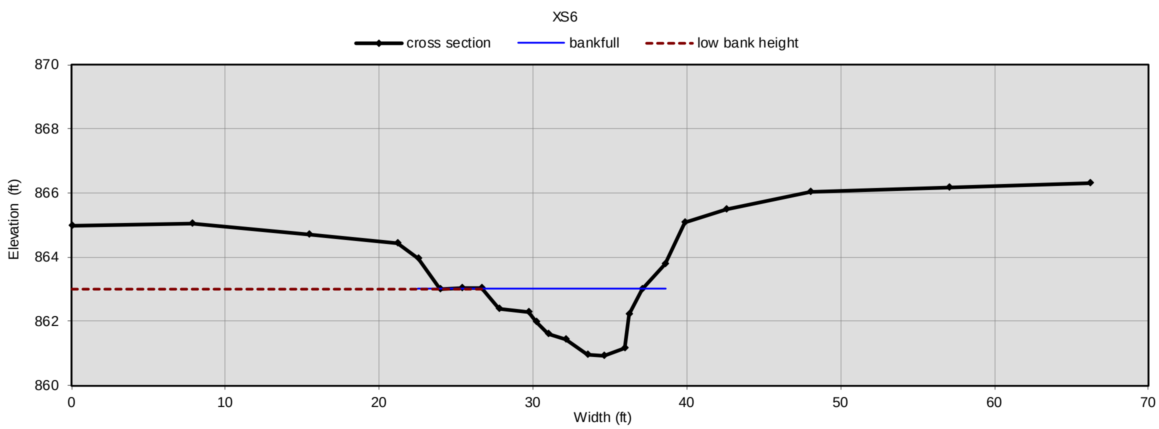
Flood Dimensions	
35.0	W flood prone area (ft)
2.6	entrenchment ratio
2.3	low bank height (ft)
1.4	low bank height ratio

Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
28	threshold grain size (mm):

Bankfull Flow	
5.3	velocity (ft/s)
85.3	discharge rate (cfs)
0.88	Froude number

Flow Resistance	
0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.7	resistance factor u/u*
14.4	relative roughness

Forces & Power	
0.82	channel slope (%)
0.58	shear stress (lb/sq.ft.)
0.55	shear velocity (ft/s)
3.2	unit strm power (lb/ft/s)



Bankfull Dimensions	
12.8	x-section area (ft.sq.)
10.5	width (ft)
1.2	mean depth (ft)
2.1	max depth (ft)
12.0	wetted parimeter (ft)
1.1	hyd radi (ft)
8.5	width-depth ratio

Flood Dimensions	
18.0	W flood prone area (ft)
1.7	entrenchment ratio
2.1	low bank height (ft)
1.0	low bank height ratio

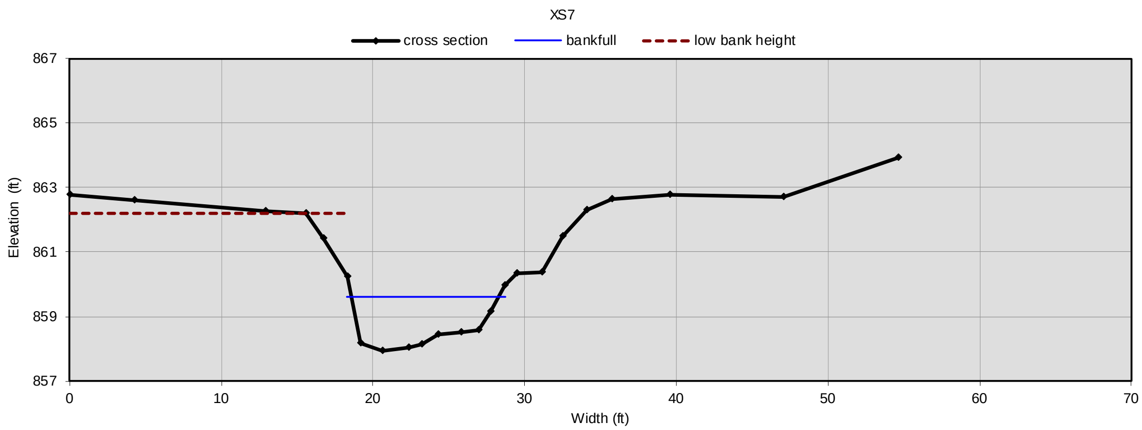
Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
27	threshold grain size (mm):

Bankfull Flow	
5.2	velocity (ft/s)
66.9	discharge rate (cfs)
0.89	Froude number

Flow Resistance	
0.027	Manning's roughness
0.08	D'Arcy-Weisbach fric.
9.8	resistance factor u/u*
15.0	relative roughness

Forces & Power	
0.82	channel slope (%)
0.55	shear stress (lb/sq.ft.)
0.53	shear velocity (ft/s)
3.3	unit strm power (lb/ft/s)

Reaches 6-8 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions	
11.7	x-section area (ft.sq.)
9.7	width (ft)
1.2	mean depth (ft)
1.7	max depth (ft)
11.0	wetted parimeter (ft)
1.1	hyd radi (ft)
8.0	width-depth ratio

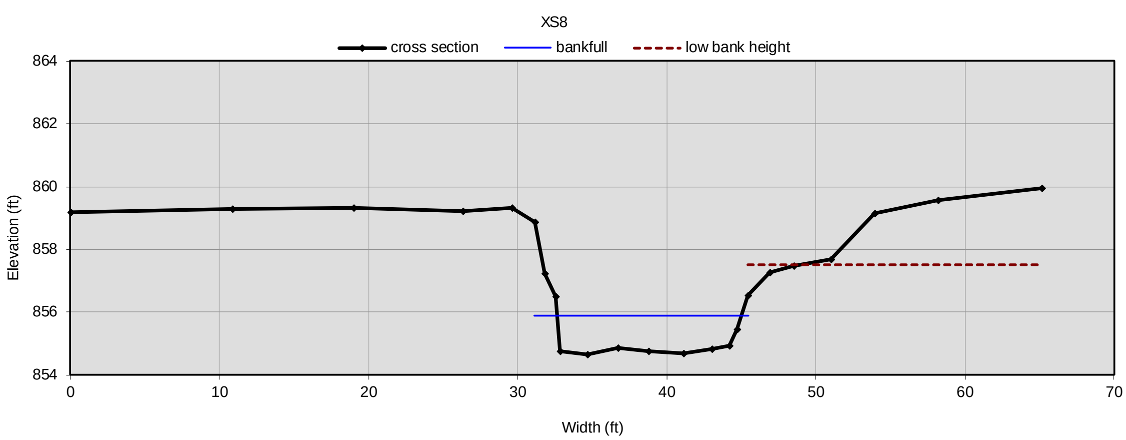
Flood Dimensions	
15.0	W flood prone area (ft)
1.6	entrenchment ratio
4.3	low bank height (ft)
2.6	low bank height ratio

Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
27	threshold grain size (mm):

Bankfull Flow	
5.1	velocity (ft/s)
59.6	discharge rate (cfs)
0.87	Froude number

Flow Resistance	
0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.6	resistance factor u/u*
14.7	relative roughness

Forces & Power	
0.82	channel slope (%)
0.54	shear stress (lb/sq.ft.)
0.53	shear velocity (ft/s)
3.2	unit strm power (lb/ft/s)



Bankfull Dimensions	
13.6	x-section area (ft.sq.)
12.4	width (ft)
1.1	mean depth (ft)
1.2	max depth (ft)
13.9	wetted parimeter (ft)
1.0	hyd radi (ft)
11.3	width-depth ratio

Flood Dimensions	
17.4	W flood prone area (ft)
1.4	entrenchment ratio
2.8	low bank height (ft)
2.3	low bank height ratio

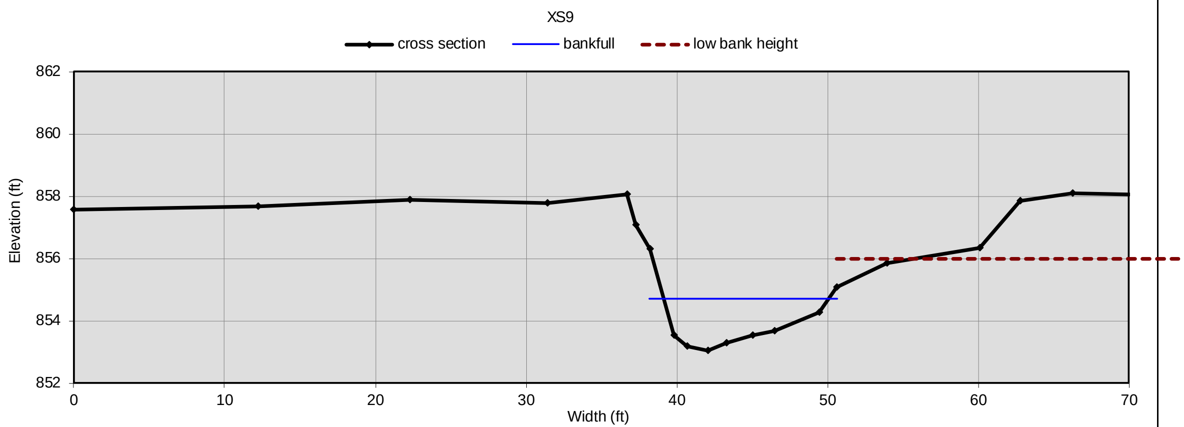
Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
25	threshold grain size (mm):

Bankfull Flow	
4.7	velocity (ft/s)
63.8	discharge rate (cfs)
0.84	Froude number

Flow Resistance	
0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.3	resistance factor u/u*
13.3	relative roughness

Forces & Power	
0.82	channel slope (%)
0.50	shear stress (lb/sq.ft.)
0.51	shear velocity (ft/s)
2.6	unit strm power (lb/ft/s)

Reaches 6-8 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions

11.8	x-section area (ft.sq.)
11.0	width (ft)
1.1	mean depth (ft)
1.7	max depth (ft)
11.9	wetted parimeter (ft)
1.0	hyd radi (ft)
10.1	width-depth ratio

Flood Dimensions

22.1	W flood prone area (ft)
2.0	entrenchment ratio
3.0	low bank height (ft)
1.8	low bank height ratio

Materials

15	D50 Riffle (mm)
25	D84 Riffle (mm)
25	threshold grain size (mm):

Bankfull Flow

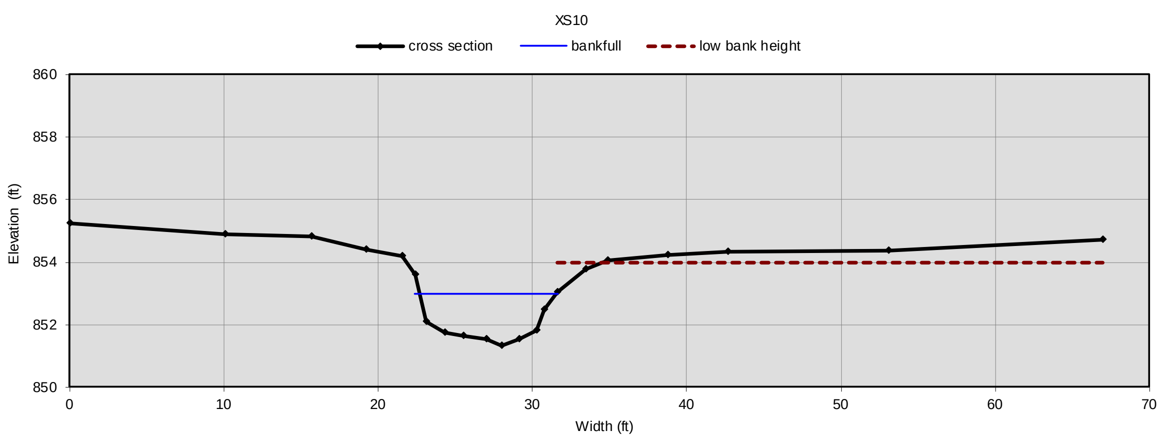
4.9	velocity (ft/s)
57.6	discharge rate (cfs)
0.86	Froude number

Flow Resistance

0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.5	resistance factor u/u*
13.2	relative roughness

Forces & Power

0.82	channel slope (%)
0.51	shear stress (lb/sq.ft.)
0.51	shear velocity (ft/s)
2.7	unit strm power (lb/ft/s)



Bankfull Dimensions

10.6	x-section area (ft.sq.)
8.9	width (ft)
1.2	mean depth (ft)
1.7	max depth (ft)
10.1	wetted parimeter (ft)
1.1	hyd radi (ft)
7.4	width-depth ratio

Flood Dimensions

25.0	W flood prone area (ft)
2.8	entrenchment ratio
2.7	low bank height (ft)
1.6	low bank height ratio

Materials

15	D50 Riffle (mm)
25	D84 Riffle (mm)
26	threshold grain size (mm):

Bankfull Flow

5.1	velocity (ft/s)
53.7	discharge rate (cfs)
0.87	Froude number

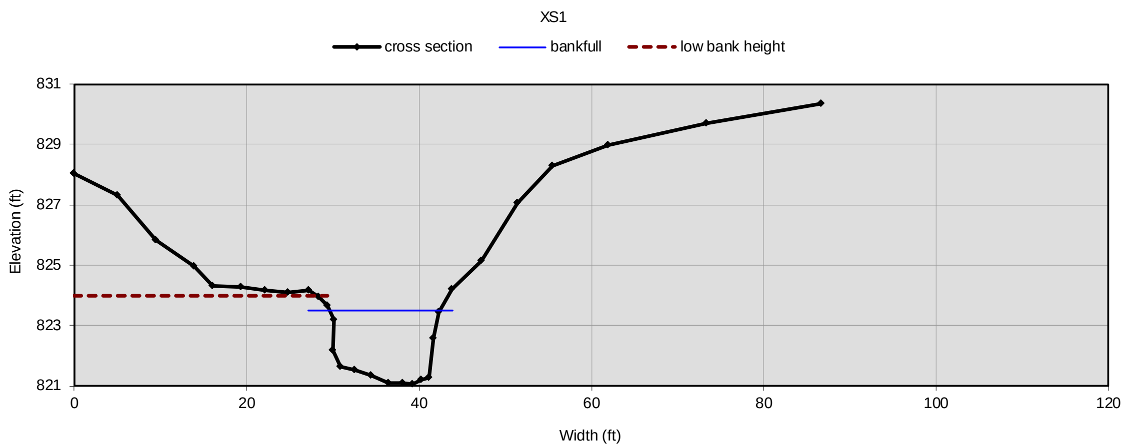
Flow Resistance

0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.6	resistance factor u/u*
14.6	relative roughness

Forces & Power

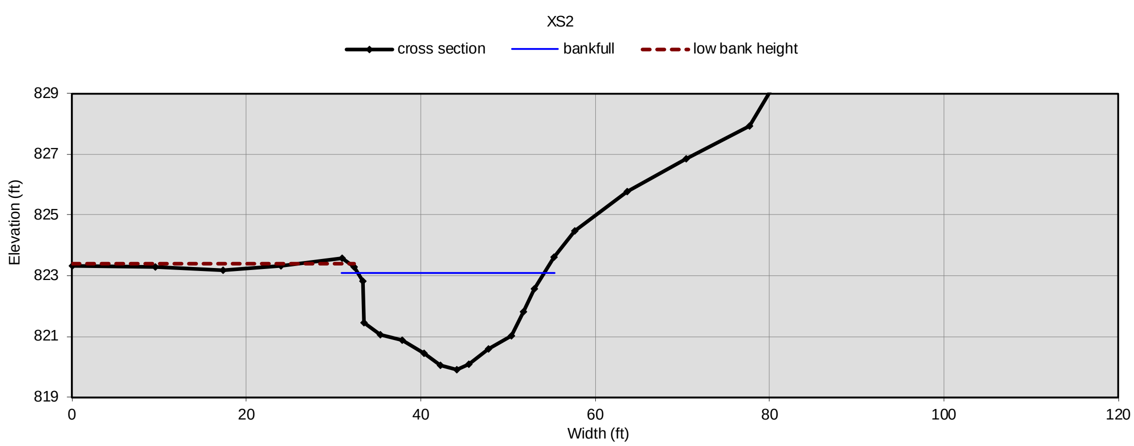
0.82	channel slope (%)
0.54	shear stress (lb/sq.ft.)
0.53	shear velocity (ft/s)
3.1	unit strm power (lb/ft/s)

Reaches 16-17 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions		Flood Dimensions		Materials	
25.4	x-section area (ft.sq.)	39.8	W flood prone area (ft)	15	D50 Riffle (mm)
12.9	width (ft)	3.1	entrenchment ratio	25	D84 Riffle (mm)
2.0	mean depth (ft)	2.9	low bank height (ft)	18	threshold grain size (mm):
2.4	max depth (ft)	1.2	low bank height ratio		
15.5	wetted parimeter (ft)				
1.6	hyd radi (ft)				
6.5	width-depth ratio				

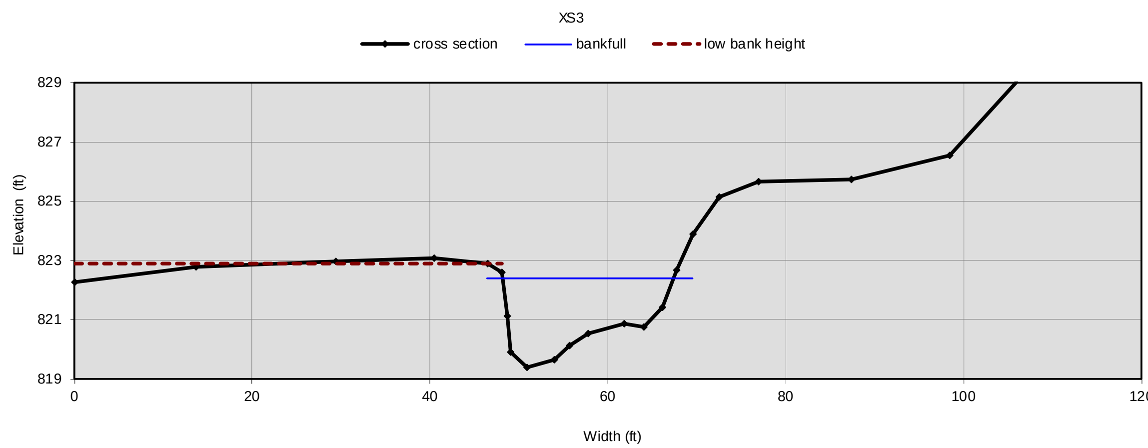
Bankfull Flow		Flow Resistance		Forces & Power	
4.6	velocity (ft/s)	0.027	Manning's roughness	0.35	channel slope (%)
116.2	discharge rate (cfs)	0.07	D'Arcy-Weisbach fric.	0.36	shear stress (lb/sq.ft.)
0.63	Froude number	10.7	resistance factor u/u*	0.43	shear velocity (ft/s)
		24.1	relative roughness	1.97	unit strm power (lb/ft/s)



Bankfull Dimensions		Flood Dimensions		Materials	
46.6	x-section area (ft.sq.)	90.0	W flood prone area (ft)	15	D50 Riffle (mm)
21.4	width (ft)	4.2	entrenchment ratio	25	D84 Riffle (mm)
2.2	mean depth (ft)	3.5	low bank height (ft)	21	threshold grain size (mm):
3.2	max depth (ft)	1.1	low bank height ratio		
23.4	wetted parimeter (ft)				
2.0	hyd radi (ft)				
9.8	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
5.3	velocity (ft/s)	0.026	Manning's roughness	0.35	channel slope (%)
247.4	discharge rate (cfs)	0.06	D'Arcy-Weisbach fric.	0.43	shear stress (lb/sq.ft.)
0.66	Froude number	11.2	resistance factor u/u*	0.47	shear velocity (ft/s)
		26.6	relative roughness	2.5	unit strm power (lb/ft/s)

Reaches 16-17 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions	
37.5	x-section area (ft.sq.)
19.3	width (ft)
1.9	mean depth (ft)
3.0	max depth (ft)
21.6	wetted parimeter (ft)
1.7	hyd radi (ft)
9.9	width-depth ratio

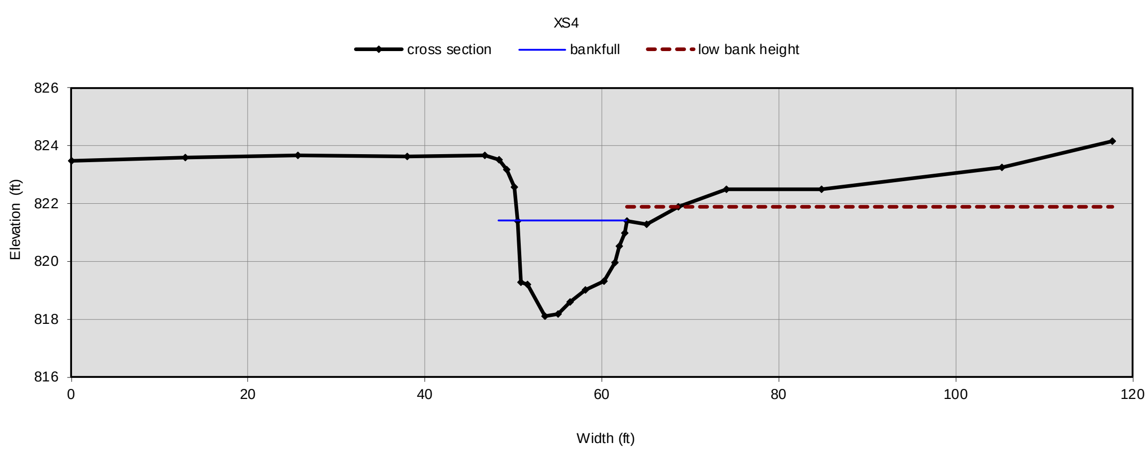
Flood Dimensions	
90.0	W flood prone area (ft)
4.7	entrenchment ratio
3.5	low bank height (ft)
1.2	low bank height ratio

Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
19	threshold grain size (mm):

Bankfull Flow	
4.8	velocity (ft/s)
181.7	discharge rate (cfs)
0.65	Froude number

Flow Resistance	
0.026	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.9	resistance factor u/u*
23.8	relative roughness

Forces & Power	
0.35	channel slope (%)
0.38	shear stress (lb/sq.ft.)
0.44	shear velocity (ft/s)
2.1	unit strm power (lb/ft/s)



Bankfull Dimensions	
28.7	x-section area (ft.sq.)
12.3	width (ft)
2.3	mean depth (ft)
3.3	max depth (ft)
15.3	wetted parimeter (ft)
1.9	hyd radi (ft)
5.3	width-depth ratio

Flood Dimensions	
70.0	W flood prone area (ft)
5.7	entrenchment ratio
3.8	low bank height (ft)
1.2	low bank height ratio

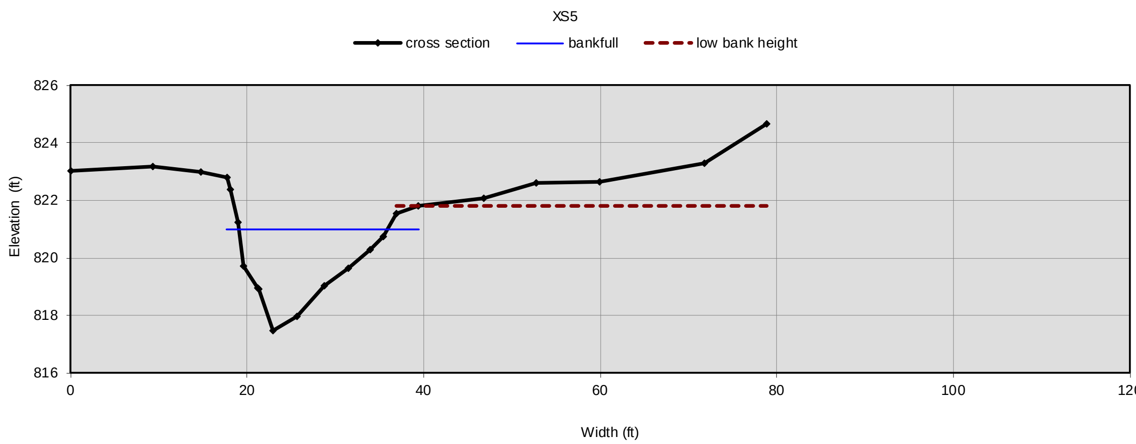
Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
20	threshold grain size (mm):

Bankfull Flow	
5.1	velocity (ft/s)
147.1	discharge rate (cfs)
0.66	Froude number

Flow Resistance	
0.026	Manning's roughness
0.06	D'Arcy-Weisbach fric.
11.1	resistance factor u/u*
28.4	relative roughness

Forces & Power	
0.35	channel slope (%)
0.41	shear stress (lb/sq.ft.)
0.46	shear velocity (ft/s)
2.6	unit strm power (lb/ft/s)

Reaches 16-17 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions	
32.5	x-section area (ft.sq.)
16.9	width (ft)
1.9	mean depth (ft)
3.5	max depth (ft)
19.0	wetted parimeter (ft)
1.7	hyd radi (ft)
8.8	width-depth ratio

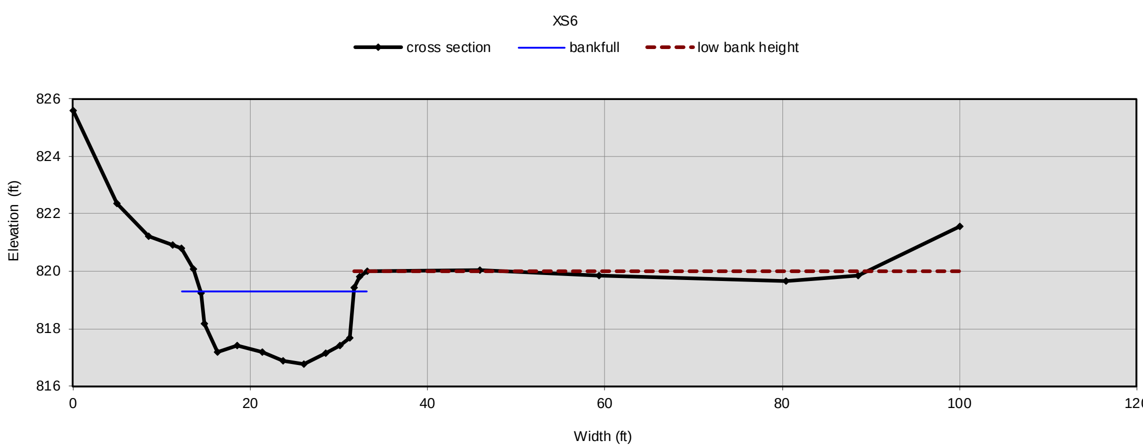
Flood Dimensions	
70.0	W flood prone area (ft)
4.1	entrenchment ratio
4.3	low bank height (ft)
1.2	low bank height ratio

Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
18	threshold grain size (mm):

Bankfull Flow	
4.8	velocity (ft/s)
157.5	discharge rate (cfs)
0.65	Froude number

Flow Resistance	
0.026	Manning's roughness
0.07	D'Arcy-Weisbach fric.
11.0	resistance factor u/u*
23.5	relative roughness

Forces & Power	
0.35	channel slope (%)
0.37	shear stress (lb/sq.ft.)
0.44	shear velocity (ft/s)
2	unit strm power (lb/ft/s)



Bankfull Dimensions	
35.2	x-section area (ft.sq.)
17.3	width (ft)
2.0	mean depth (ft)
2.5	max depth (ft)
19.7	wetted parimeter (ft)
1.8	hyd radi (ft)
8.5	width-depth ratio

Flood Dimensions	
100.0	W flood prone area (ft)
5.8	entrenchment ratio
3.2	low bank height (ft)
1.3	low bank height ratio

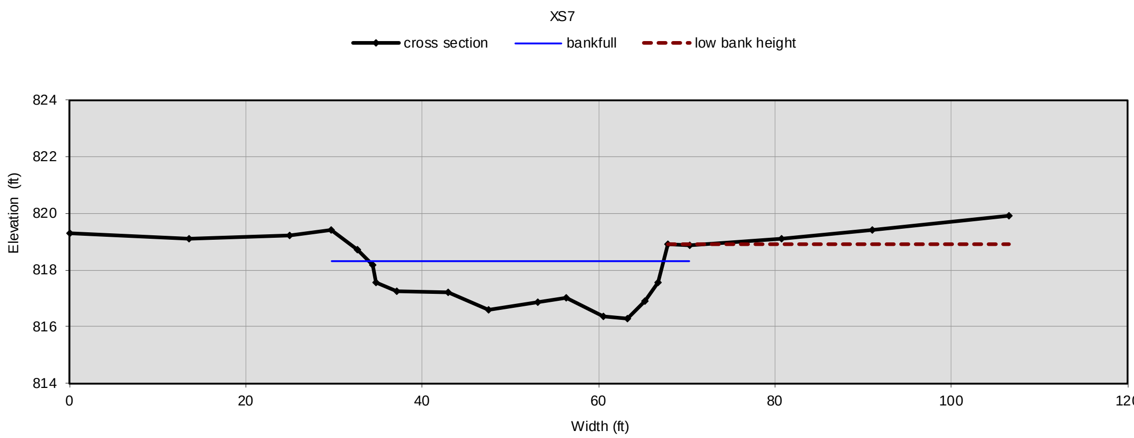
Materials	
15	D50 Riffle (mm)
25	D84 Riffle (mm)
19	threshold grain size (mm):

Bankfull Flow	
4.9	velocity (ft/s)
171.3	discharge rate (cfs)
0.64	Froude number

Flow Resistance	
0.027	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.9	resistance factor u/u*
24.9	relative roughness

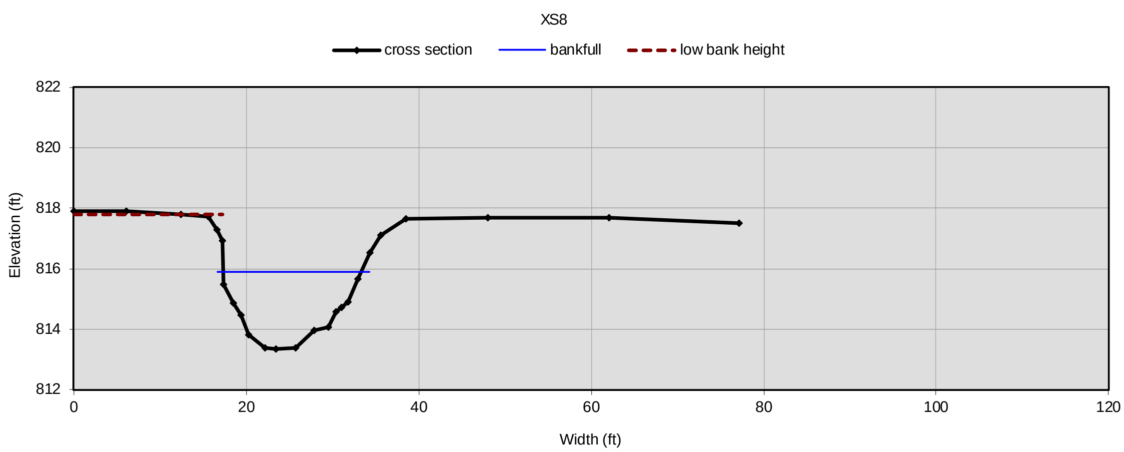
Forces & Power	
0.35	channel slope (%)
0.39	shear stress (lb/sq.ft.)
0.45	shear velocity (ft/s)
2.2	unit strm power (lb/ft/s)

Reaches 16-17 Cross Section Graphs & Geomorphic Data



Bankfull Dimensions		Flood Dimensions		Materials	
45.4	x-section area (ft.sq.)	100.0	W flood prone area (ft)	15	D50 Riffle (mm)
33.4	width (ft)	3.0	entrenchment ratio	25	D84 Riffle (mm)
1.4	mean depth (ft)	2.6	low bank height (ft)	14	threshold grain size (mm):
2.0	max depth (ft)	1.3	low bank height ratio		
34.4	wetted parimeter (ft)				
1.3	hyd radi (ft)				
24.6	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
3.9	velocity (ft/s)	0.027	Manning's roughness	0.35	channel slope (%)
177.3	discharge rate (cfs)	0.08	D'Arcy-Weisbach fric.	0.29	shear stress (lb/sq.ft.)
0.60	Froude number	10.1	resistance factor u/u*	0.39	shear velocity (ft/s)
		16.6	relative roughness	1.16	unit strm power (lb/ft/s)



Bankfull Dimensions		Flood Dimensions		Materials	
28.5	x-section area (ft.sq.)	80.0	W flood prone area (ft)	15	D50 Riffle (mm)
16.0	width (ft)	5.0	entrenchment ratio	25	D84 Riffle (mm)
1.8	mean depth (ft)	4.5	low bank height (ft)	17	threshold grain size (mm):
2.6	max depth (ft)	1.7	low bank height ratio		
17.5	wetted parimeter (ft)				
1.6	hyd radi (ft)				
9.0	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
4.6	velocity (ft/s)	0.027	Manning's roughness	0.35	channel slope (%)
130.5	discharge rate (cfs)	0.07	D'Arcy-Weisbach fric.	0.36	shear stress (lb/sq.ft.)
0.63	Froude number	10.7	resistance factor u/u*	0.43	shear velocity (ft/s)
		21.7	relative roughness	1.78	unit strm power (lb/ft/s)

APPENDIX C. PRELIMINARY 30% CONSTRUCTION PLANS

APPENDIX D. ENVIRONMENTAL ASSESSMENT WORKSHEET

APPENDIX E. DETAILED PRELIMINARY COST ESTIMATE

Reaches 6-8						Engineers Estimate
Line No.	**MNDOT Reference**	**Base Bid Item**	**Units**	**Quantity**	**Estimated Unit Price**	**Estimated Price**
1	2021.501	MOBILIZATION	LUMP	1.0	$31,321.35	$31,321.35
2	2573.501	STABILIZED CONSTRUCTION EXIT	EA	2.0	$3,200.00	$6,400.00
3	2101.505	CLEARING FOR WOODY INVASIVE & SELECTIVE TREE REMOVAL	ACRE	4.5	$4,000.00	$18,000.00
4	2563.601	TRAFFIC CONTROL	LUMP	1.0	$2,000.00	$2,000.00
5	2105.507	COMMON EXCAVATION - ONSITE DISPOSAL	CY	2000.0	$15.00	$30,000.00
6	2511.509	RIPRAP, CLASS III FIELDSTONE	TON	980.1	$110.00	$107,811.00
7	2512.509	1"-4" CRUSHED RIVER ROCK OR APPROVED EQUAL	TON	163.4	$150.00	$24,502.50
8	SP	TOEWOOD - INSTALLATION	LF	540.0	$80.00	$43,200.00
9	SP	ROOT WAD - INSTALLATION	EA	24.0	$600.00	$14,400.00
10	SP	BRUSH BUNDLES WITH ROOTWADS	LF	240.0	$65.00	$15,600.00
11	2575.505	SEEDING FOR CLEARED AREAS / ACCESS ROADS/ STAGING AREAS	AC	5.5	$900.00	$4,950.00
12	2575.508	SEED, STATE MIX 34-261	LBS	220.0	$50.00	$11,000.00
13	2575.508	HYDRAULIC SOIL STABILIZER (MAT INC SOILGUARD OR APPROVED EQUAL)	LBS	5625.0	$2.00	$11,250.00
14	2575.511	MULCH TYPE 1 (WEED-FREE STRAW OR APPROVED EQUAL)	AC	5.5	$1,200.00	$6,600.00
15	SP	TEMPORARY EROSION & SEDIMENT CONTROL	LUMP	1.0	$2,500.00	$2,500.00
16	SP	2-YEAR EXTENDED MAINTENANCE	YR	2.0	$7,500.00	$15,000.00
					Subtotal	**$344,534.85**

Reaches 16-17						Engineers Estimate
Line No.	MNDOT Reference	Base Bid Item	Units	Quantity	Estimated Unit Price	Estimated Price
1	2021.501	MOBILIZATION	LUMP	1.0	$23,849.25	$23,849.25
2	2573.501	STABILIZED CONSTRUCTION EXIT	EA	2.0	$3,200.00	$6,400.00
3	2101.505	CLEARING FOR WOODY INVASIVE & SELECTIVE TREE REMOVAL	ACRE	3.0	$4,000.00	$12,000.00
4	2563.601	TRAFFIC CONTROL	LUMP	1.0	$2,000.00	$2,000.00
5	2105.507	COMMON EXCAVATION - ONSITE DISPOSAL	CY	1500.0	$15.00	$22,500.00
6	2511.509	RIPRAP, CLASS III FIELDSTONE	TON	445.5	$110.00	$49,005.00
7	2512.509	1"-4" CRUSHED RIVER ROCK OR APPROVED EQUAL	TON	74.3	$150.00	$11,137.50
8	SP	TOEWOOD - INSTALLATION	LF	610.0	$80.00	$48,800.00
9	SP	ROOT WAD - INSTALLATION	EA	14.0	$600.00	$8,400.00
10	SP	BRUSH BUNDLES WITH ROOTWADS	LF	630.0	$65.00	$40,950.00
11	2575.505	SEEDING FOR CLEARED AREAS / ACCESS ROADS/ STAGING AREAS	AC	3.0	$900.00	$2,700.00
12	2575.508	SEED, STATE MIX 34-261	LBS	120.0	$50.00	$6,000.00
13	2575.508	HYDRAULIC SOIL STABILIZER (MAT INC SOILGUARD OR APPROVED EQUAL)	LBS	3750.0	$2.00	$7,500.00
14	2575.511	MULCH TYPE 1 (WEED-FREE STRAW OR APPROVED EQUAL)	AC	3.0	$1,200.00	$3,600.00
15	SP	TEMPORARY EROSION & SEDIMENT CONTROL	LUMP	1.0	$2,500.00	$2,500.00
16	SP	2-YEAR EXTENDED MAINTENANCE	YR	2.0	$7,500.00	$15,000.00
					Subtotal	**$262,341.75**

APPENDIX F. BASELINE ASSESSMENT REPORT