Geomorphic and Habitat Assessments of Trout Streams in the Lower Minnesota River Watershed District

August 2019

Prepared By: Christina Berg, Erica Bock, Kirsten Haus, Philip Margarit, Samantha Wheeler, Simone Wilson

Prepared For: The Lower Minnesota River Watershed District

Acknowledgements:

Linda Loomis, Lower Minnesota River Watershed District
Della Schall Young and Shane Soukup, Young Environmental Consulting Group
Joe Magner, Watershed Recovery, LLC
Jeff Weiss, Barr Engineering
Brenda DeZiel, Caddis Fish Consulting, LLC

Executive Summary

In the summer of 2019, the Lower Minnesota River Watershed District (LMRWD) partnered with Young Environmental Consulting Group, Watershed Recovery LLC, Barr Engineering, and Caddis Fish Consulting, LLC to conduct a study on several historical trout streams in the watershed. The study focused on geomorphic assessment to determine the current stability and habitat viability for trout in each stream. This information can then be used to evaluate the extent of restoration work that would be required to establish significant and viable trout habitat. The streams included were Eagle Creek, Assumption Creek, Kennaley's Creek, Ike's Creek, and four Unnamed Creeks within the District (Unnamed 1, 2, 4 and 7) (See Figure 1). Methods used for this study included Rosgen river stability field methods developed by David Rosgen and a habitat assessment (DeZiel, 2019c) for small headwater streams based on the Minnesota Pollution Control Agency (MPCA) Stream Habitat Assessment (MSHA). Surface water temperatures and conditions were measured utilizing a YSI 6820 water quality sonde (WQ sonde) to locate the sections of the streams where groundwater is entering. The field season was heavily impacted by elevated water surface elevations and flooding due to inundation from the Minnesota River. Therefore, portions of each stream were inaccessible and future work is required to investigate those portions of the streams.

Initial Rosgen level I geomorphic reconnaissance was utilized to conduct exploratory assessment of the streams as a whole and to identify key areas for further investigation. This portion was completed in the field with a team of undergraduate interns. The team determined key characteristics of different segments of each stream such as stream type, valley type, stability, and channel-bed substrate. This was accomplished by walking the stream lengths, taking detailed field notes of changes in the streams, and mapping each location on a field map. This work was later used to select certain reaches for level II assessment, including habitat assessment. Pebble counts determined the substrate type and surveys were made of the profiles and cross sections of the channel and adjacent valley walls. This was used to determine the type, shape, and characteristics of the stream and valley.

Habitat assessments conducted on each stream incorporated the modified MSHA worksheet to assess current habitat conditions on cold water streams. This evaluation includes characteristics like depth variability, watershed land use, degree of stream meandering, and degree of bank erosion. Other parameters focused more on specific biological criteria such as aquatic vegetation types and environmental stressors such as aggradation and degradation. Aggradation involves streambed elevation increase caused by sediment deposition, while degradation occurs when the stream bed is lowered by erosion and sediment removal (Brooks et al., 2013). These worksheets were completed by the team at each of the survey locations on the streams and scores were totaled to obtain a representable habitat score for each location. These assessments were utilized to both quantify the current condition of each stream segment's habitat, and to obtain more in-depth observations regarding the overall stability of each stream segment. Surface water temperature measurements were taken to identify the portions of the stream where groundwater enters the stream channel as baseflow, making the creek a gaining stream and creating the cold-water stream environment. Temperature and dissolved oxygen concentrations were measured using a WQ sonde placed at the bottom of the stream channel.

Assumption Creek was found to be a gaining stream throughout the reach until the stream was inundated by the Minnesota River. Assumption Creek was found to have features that improve the stream's trout habitat such as undercut banks. The creek was observed to be undergoing either aggradation or degradation throughout the stream reach. The degradation in

the stream is the responsible process for the creation of undercut banks, as well as the creation of knickpoints throughout the reach. Portions of the Creek were unable to be accessed due to the flooding of the Minnesota River. Due to this, level I and II assessments could be conducted on the portions southeast of Flying Cloud Drive during drier field conditions to expand the study. Eagle Creek was observed to be a gaining stream throughout the entirety of the reach located south of Highway 13. The creek was found to have key attributes needed to support the local trout population, as well as remaining the only stream the team observed multiple trout in. Eagle Creek was discovered to have aggradation issues, which diminishes habitat viability and stream stability. Due to this, Eagle Creek warrants further level III assessment to determine the stability of the stream and the cause behind the aggradation. Ike's Creek was found to be a gaining stream throughout it entire stream length leading into Long Meadow Lake. The creek was found to be unstable throughout its reach, with a high density of knickpoints observed. This stream therefore warrants further level III assessment. Kennaley's Creek was shelved for this field season following initial reconnaissance work and limited surveying at one stream segment. The creek's location within a wetland, and inundation of large swaths of the creek from the Minnesota River caused large portions of the stream to go surveyed due to lack of access. This leaves the potential for level I and II work to be done on the remaining creek during drier field seasons. Unnamed 7 was removed from the study based on a recommendation from the DNR. Unnamed Creeks 1 and 4 were additionally considered a lower priority this summer. Unnamed Creek 1 was found to be a gaining stream throughout its reach, but the baseflow only supported a low water level throughout the creek. Frequent mass wasting, intermittent flow, and extreme erosion were additional negative features observed throughout the stream length. Due to this, Unnamed Creek 1 does not warrant further work. Unnamed Creek 4 was found to be a more viable trout supporting habitat than Unnamed Creek 1. Surface water temperature measurements and historical information both point to Unnamed Creek 4 having a high potential to support trout. Unnamed Creek 4 was mostly inaccessible due to flooding to the north of the railroad, and a dense wetland to the south. During the drier seasons, level I and II assessment should be done to assess the creek's current habitat viability in detail.

Table of Contents

Executive Summary 3
1.0 Introduction 4
2.0 Background Information 6
- 2.1 Assumption Creek
- 2.2 Eagle Creek
- 2.3 Ike's Creek
- 2.4 Kennaley's Creek
- 2.5 Unnamed Creeks 1,2,4 and 7

3.0 Methods 13
- 3.1 Reconnaissance
- 3.2 Habitat Assessment
- 3.3 Pebble Count
- 3.4 Cross Section Survey
- 3.5 Longitudinal Profile Survey
- 3.6 Baseflow Analysis

4.0 Results 18
- 4.1 Assumption Creek
  - 4.1.i Assumption Creek West Reach
  - 4.1.ii Assumption Creek East Reach
  - 4.1.iii Assumption Creek Baseflow Analysis
- 4.2 Eagle Creek
  - 4.2.i Eagle Creek Main Branch
  - 4.2.ii Eagle Creek East Branch
  - 4.2.iii Eagle Creek Reconstructed Reach
  - 4.2.iv Eagle Creek Baseflow Analysis
- 4.3 Ike's Creek
  - 4.3.i Ike's Creek
  - 4.3.ii Ike's Creek Baseflow Analysis
- 4.4 Kennaley's Creek
- 4.5 Unnamed Creek
  - 4.5i Unnamed Creek 1
  - 4.5ii Unnamed Creek 2, 4, and 7
  - 4.5iii Unnamed Creeks Baseflow Analysis

5.0 Error Analysis

6.0 Conclusion and Recommendations for Future Work 45
- 6.1 Assumption Creek
- 6.2 Eagle Creek
- 6.3 Ike's Creek
- 6.4 Kennaley's Creek
- 6.5 Unnamed Creeks 1, 2, 4, and 7
- 6.6 Continuation of Work
- 6.7 Lessons Learned in the Field

7.0 References 52

8.0 Appendix 55
- Appendix A: Background Information Figures
- Appendix B: Habitat Assessment Worksheet
- Appendix C: Diagrams

Appendix D: Assumption Creek Figures and Data
Appendix E: Eagle Creek Figures and Data
Appendix F: Ike's Creek Figures and Data
Appendix G: Kennaley's Creek Figures and Data
Appendix H: Unnamed Creeks 1, 2, and 4 Figures and Data

1.0 Introduction

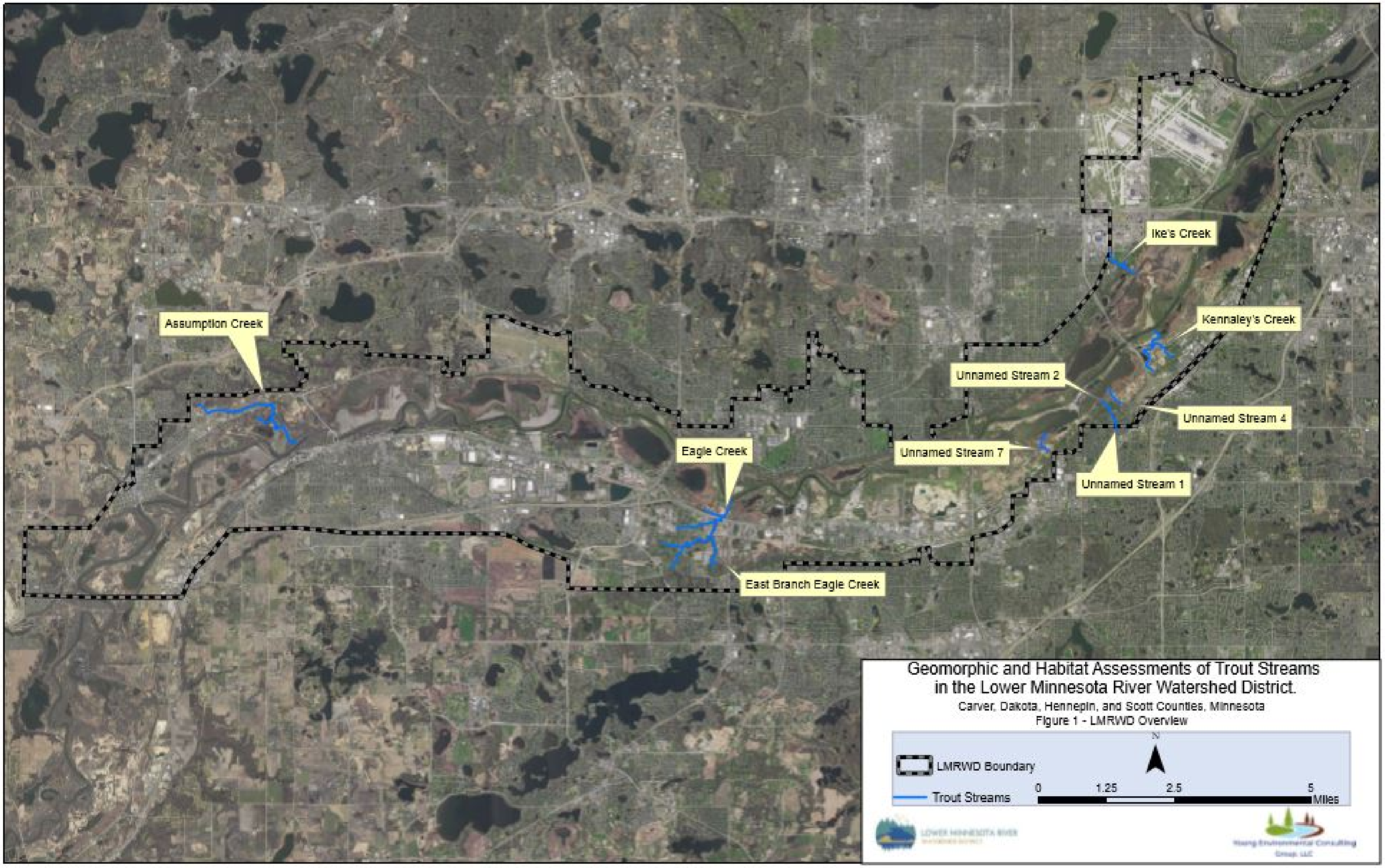
The Lower Minnesota River Watershed District (LMRWD) partnered with Young Environmental Consulting Group, Watershed Recovery, LLC, Barr Engineering, and Caddis Fish Consulting, LLC to complete reconnaissance, surveying, and habitat assessment of historical trout streams throughout the LMRWD. These streams include Eagle Creek, Assumption Creek, Ike's Creek, Kennaley's Creek and three unnamed creeks: 1, 2, 4, and 7. The goal of this study was to complete reconnaissance on the streams for ideal trout habitat and to complete habitat assessment forms, pebble counts, and surveying of cross sections and longitudinal profiles. The data and observations can be used for future restoration projects. The team, made up of undergraduate interns, was expected to complete levels I and II from *River Stability and Field Guide* by Dave Rosgen. Level I includes geomorphic characterization and selection of a representative reach for stability assessment (Rosgen, 2008). This is the first assessment of the quality of the stream based almost solely on observations. It also encompasses broad level stream classification, valley classification, predicting a stream's behavior, and describing stream relationships with biological processes. Level II assessment includes more quantitative analysis of the streams. The characteristics studied are bankfull, entrenchment, slope, width-depth ratio, materials (substrate), and sinuosity. This was studied by completing cross sections and longitudinal profiles in the stream.

Training was an integral part of the study. The team's field season began with four days of training and as-needed training incorporated along the way. The classroom portion of this training included lectures about fish and invertebrate habitat, stream stability, and stream restoration techniques. Two important concepts discussed in training were aggradation and degradation. Aggradation involves streambed elevation increase caused by sediment deposition, while degradation occurs when the stream bed is lowered by erosion and sediment removal (Brooks et al., 2013). Several partners were also involved in the training. The Riley Purgatory Bluff Creek Watershed District provided a safety and field work protocol training. Linda Loomis, administrator of the LMRWD, gave an overview of the watershed district and explained the importance of stream assessment and monitoring. Jeff Weiss, from Barr Engineering Company, taught the team about the Mecklenburg spreadsheet. The spreadsheet is used as a tool for stream and river evaluation. It uses quantitative data to analyze the streams. Using the data that the team collected it describes and shows channel form/shape, bed materials, and pattern. It can be used to prioritize restoration projects when further assessment is completed according to the Rosgen Method. It was used to graph the data from surveys and pebble counts. The training period also included an in-field practice of the reconnaissance methods and habitat overview. The team was taken out to Riley Creek and practiced classifying them using methods learned in the classroom. After field work began, the team also participated in a cross-section survey training on the University of Minnesota St. Paul campus where the students were introduced to the equipment and taught how to use it. Additionally, Brenda DeZiel, Research Scientist at the University of Minnesota, provided an in-stream run-through of habitat assessments with an opportunity to practice and receive feedback. The team was given the habitat assessment sheet and given an in-depth breakdown of it. The team was able to ask questions and clarifications which allowed for all team members to understand how to rate each category. The training for specific methods ensured that those steps of the project were well outlined and that each team member would have the knowledge needed for the procedure.

During the field season of 2019 there was record flooding on the Minnesota River (see figure A.1 in appendix A). This flooding was caused by large snowmelt in the beginning of the season, and then large amounts of precipitation in the later part of the season. Because of this, portions of the streams nearest the Minnesota River were flooded until after July 25th when flood waters receded. This meant that large portions of some of the streams were inaccessible for the majority of the field season, so this report focuses on the unflooded areas.

Trout require cold water because fish are cold blooded and cold water has the ability to hold more oxygen than warm water. Bank vegetation and woody debris are ideal for trout because they offer shade to keep the water at a cool temperature and a place to hide from predators (DeZiel, 2019a). In addition, spawning habitat is a crucial characteristic when looking for suitable trout habitat. Spawning happens in the shallows of the stream where loose gravel is present because trout lay eggs under gravel for protection. Groundwater upwelling is also a benefit for spawning to improve oxygen levels (DeZiel, 2019a). Trout feed on minnows, aquatic insects, worms, etc., so evidence of these in any of these streams is important. For the winter, adult trout need sufficiently deep pools that will not freeze over (DeZiel, 2019a). Water quality is also an important aspect of trout habitat. Trout cannot tolerate high levels of chloride or nitrate, and excessive phosphorus can lead to dangerously low oxygen levels (DeZiel, 2019a).The Department of Natural Resources (DNR) trout stream designation is a critical component when evaluating trout habitat because of the protections it provides. This includes regulation of stormwater runoff temperature, groundwater permitting, riprap stabilization, and water quality (Wendel, 2019). A stream is considered for trout stream classification if trout are observed. If trout are not present in the stream, it can still be designated if it has summer temperatures below 70° F and oxygen levels above 5 ppm (Wendel, 2019). Stakeholder comments also have a large influence on trout stream designation decisions (Wendel, 2019). These designation criteria and protections would play a significant role in a future restoration project and its longevity. The sections below include a comprehensive summary of each stream. Section 3 details significant background and historical information to provide a context for the stream assessments. Section 4 describes the methods used for each component of the assessment such that it could be repeated by a future team. Section 5 includes the detailed results of the data and observations that were possible given the state of the streams. Finally, Section 6 concludes the report with a summary of results, possible sources of error, and recommendations for future work.

Figure 1. Map of the surveyed trout streams.



2.0 Background Information

The purpose of this section is to describe previous work completed on each stream and to give some knowledge about the previous conditions of these streams prior to the team's visit. It is important to note these conditions that have been observed in the past in order to compare with the conditions observed by the team. There are many hypothesized reasons for these differences which will be stated throughout the report and in the conclusion.

It is important to comment on the alternate names that have been used for these streams. This will allow comparison and analysis between this report and similar reports from the DNR, Trout Unlimited, and other invested agencies. The names that are used in this report are specified in Figure 1 on page 12. Naming differences have been discovered for Ike's, Kennaley's, and Unnamed Creeks 1 and 4. Ike's Creek is also referred to as Hust Creek. The stream that this report refers to as Kennaley's also includes Black Dog Creek and Harnack Creek/Unnamed 1. The DNR considers these to each be separate streams but this report analyzes them as a group under the name "Kennaley's Creek" (sometimes spelled Kennealy's in other reports). An alternate name for Unnamed 4 is Naas Creek (Callahan, 2016a). Finally, Trout Unlimited's Dan Callahan uses the name Cedarbridge Creek to describe Unnamed 1, which he believes could include flow from the DNR's Unnamed 7 as well (Callahan, 2016a).

2.1 Assumption Creek

Assumption Creek is in Chaska, MN, north of the Minnesota River (see Figure 1). It is accessible from several access points along Flying Cloud Drive. It is partially surrounded by the Seminary Fen, which provides the creek with groundwater. The fen has its own protective rules as per Minnesota statute 8420.0935, which in turn provide protection to the creek. Aside from the fen, it is also bordered by a corn field. It crosses under Flying Cloud Drive and the watershed land use is residential/urban with significant impervious surface cover. It measures 2.78 miles in length. The riparian width extends greater than 150 feet on the left side and it varies on the right based on proximity to the road.

The 2017 Lower Minnesota River Watershed Monitoring and Assessment Report from the Minnesota Pollution Control Agency (MPCA) listed Assumption Creek as impaired for aquatic life and TSS (MPCA, 2017). Assumption Creek is a designated trout stream, but it is not actively managed for trout by the DNR (MN DNR, 2019). A 2015 newsletter from Minnesota Trout Unlimited did call Assumption Creek "viable and protected" as a trout stream (Callahan, 2015a). The LMRWD Monitoring and Assessment Report mentions a DNR record of a population of reproducing brook trout, which was observed in 2002 (MPCA, 2017). Temperature monitoring in 2014 and 2015 concluded that thermal pollution is not the restricting factor on this coldwater stream ecosystem, as July average maximums hovered around 61° F (MPCA, 2017). Indicator species such as American brook lamprey were recently observed in Assumption Creek (MPCA, 2017). However, a habitat assessment did note overabundant sedimentation and heightened TSS levels. (MPCA, 2017).

2.2 Eagle Creek

Eagle Creek is in Savage, MN, south of the Minnesota River (see Figure 1), and surrounded by forest and prairie. It is accessible from several access points, including a trail in the nearby campground. It has extensive riparian width in some parts of the stream, which extends greater than 150 feet on both sides of the channel. Eagle Creek is designated as a trout stream and the

DNR lists brown trout as the main species present (MN DNR, 2019). Out of the streams mentioned in this report, Eagle Creek receives the most attention for its trout habitat and fishing opportunities. Its proximity to a campground and accessibility from multiple entry points allows for significant fishing opportunities. It has been featured in newsletters by Trout Unlimited, which could be an interested partner if another restoration project was pursued.

In 1945, Eagle Creek received its first stock of trout, and in 1978 it received its last. In those years, there were no notable land use changes or extreme precipitation events, so the stream was better suited to support trout. In the past 10 years, Eagle Creek has experienced higher flow rates due to an increase in annual precipitation and land use changes to the agricultural watershed. These changes in the watershed management, along with climate change, have led to increased flow rates and flooding at Eagle Creek (Metropolitan Council, 2014). A project in 2013 by the LMRWD was conducted to improve the trout habitat because the stream was too wide and shallow, resulting in warmer temperatures during sunny weather. In order to fix this issue, the LMRWD dug out 2,700 feet of the stream to narrow the channel, reduce warming, and repair erosion (Metropolitan Council, 2014).

In 2014, Brenda DeZiel, Research Scientist at the University of Minnesota, visited Eagle Creek and completed a habitat assessment. At that point, she rated channel stability as high and depth variability as excellent. She came back in 2019 to show the team how to properly perform a habitat assessment, and observed that there had been major differences in the stream since 2014. More areas of aggradation are apparent today throughout Eagle Creek, but channel stability and depth variability mostly maintained their 2014 scores (see figure A.2 in Appendix A).

Monitoring of Eagle Creek is included in the 2019 LMRWD Monitoring Plan. This monitoring includes temperature, groundwater elevation, and other parameters, such as Chloride, E.coli, Dissolved Oxygen, and Suspended Solids (Young ECG, 2019).

2.3 Ike's Creek

Ike's Creek is in Bloomington, MN (see Figure 1). The US Fish and Wildlife Service, the City of Bloomington, and a private landowner each own different parts of the stream. There are trails along part of the stream which provide accessibility. It is officially an unnamed stream, but many call it Ike's Creek in honor of its former ownership by the Izaak Walton League, a conservation organization (Meersman, 2012). It is not designated as a trout stream, but there have been past records indicating a presence of trout before 1950 (Niskanen, 2007). The trout stream designation would help protect the vulnerable trout population from increased run-off caused by nearby changes in land use, including proposed commercial developments near the Mall of America (Loomis, 2019). The DNR considered trout stream designation for this creek in 2017, but the City of Bloomington and local stakeholders requested that it not receive the designation because it is already protected by existing ordinances and permitting (Nerbonne, 2017). However, the LMRWD's 2018-2027 Watershed Management Plan highlights Ike's Creek as a high value resource because it is the last remaining trout stream in Hennepin County (LMRWD, 2018, Loomis, 2019). The DNR committed to flow and temperature monitoring at Ike's Creek, along with maintaining an awareness of potential impacts from nearby developments (Nerbonne, 2017).

It has temperatures low enough to support trout because it is fed with groundwater by limestone aquifers (Niskanen, 2007). About 1,450 trout were stocked into Ike's Creek in 2007 by a team of volunteers (Niskanen, 2007). Around 385 trout per mile was estimated in 2007, 28 trout per mile in 2008, 101 trout per mile in 2013, and 385 trout per mile in 2015. As of December 2015, a Trout Unlimited newsletter reported that the population was doing well (Callahan, 2015b). The DNR letter explaining the decision not to designate as a trout stream also mentioned "the presence of a self-sustaining brook trout population." (Nerbonne, 2017). Because of the variable amount of trout in the stream, the Fish and Wildlife Service and the City of Bloomington have implemented signs that prohibit fishing to give time for the trout population to reestablish (Maccaroni, 2015). The stream is currently considered an educational project rather than a fishable resource, but Tony Nelson of Trout Unlimited explained in a 2012 article that even the presence of trout has a positive influence on an urban ecosystem like Ike's Creek (Meersman, 2012).

In 2012, a small dam was removed to restore the connection between the upper and lower reaches of the stream. According to Michelle Sparrow of Twin Cities Trout Unlimited, this created an opportunity for "better fish migration to key spawning and feeding areas." At this time, the stream was also re-meandered to include more sinuosity and pools for fish habitat (Sparrow, 2012). A fish ladder with 6-inch steps was created using red pine logs (see figure A.3 in Appendix A). The "man-made ledges" constructed during this restoration are meant to provide refuge and spawning locations (WCCO, 2012).

2.4 Kennaley's Creek

Kennaley's Creek is located in Eagan, MN, south of the Minnesota River (see Figure 1). It is northeast of Highway 77 and northwest of Highway 13. The accessible part of the stream (near Nichols Road) is surrounded by wetlands until the road and park. The surrounding area to the South is an urban/industrial neighborhood, including apartment buildings and the Black Dog Power Plant owned by Xcel Energy. At the survey site, the land use is a park up to 150 feet on the right bank and urban on the left bank as there is a road within 30 feet. The land is owned by a variety of organizations, including the DNR, other government agencies, and the Union Pacific Railroad. (Nemeth, 2015). Kennaley's Creek is designated as a trout stream and was consistently stocked with trout for fishing from approximately 1947 to 1974 (Johnson, 1978). The aesthetic benefit for this stream is less significant than others because most of it is not visible from a residential area or busy road. However, its western reaches would be accessible for fishing if proper safety measures were taken for walking on marshy ground.

Historical records from the DNR show two events that impacted this stream. The first was the 1977 construction of Cedar Avenue in the nearby area. This construction cut off a western portion of the stream from its headwaters. A thesis by University of Minnesota student Alan Wayne Johnson discusses the disposal of dredge material from the construction near Kennaley's Creek and its potential threat to the ecosystem. Runoff from the sediment piles had the potential to increase suspended sediment in the stream and contaminate the groundwater with leached minerals and salts (Johnson, 1978). A 2006 stream survey mentioned runoff from the road as a source of pollution, including road salt, fertilizers, and other runoff concerns (MN DNR, 2006). Additionally, a 1989 project to expand the Seneca Wastewater Treatment Plant caused significant dewatering of Kennaley's creek (Little, 1993). The expansion required groundwater pumping to dry out the marshy land in preparation for construction. This removed Kennaley's main water source and caused it to dry up. Re-injection was implemented in the early 1990's by the Metropolitan Waste Control Commission (now known as the Metropolitan Council Wastewater Services), but the water was never returned to its original level (Little, 1993). The trout population died off during the dry period. A statement from Minnesota Trout Unlimited in

1994 calls for an investigation of damage and rehabilitation of the creek, including ongoing monitoring (Minnesota Trout Unlimited, 1994). The statement also introduced an alternative option involving a trout fishery donation from the Metropolitan Waste Control Commission to the DNR (Minnesota Trout Unlimited, 1994). Additional research is required to determine whether these options were ever implemented, how long re-injection attempts were continued, and the extent of long-term impacts caused by the dewatering.

A routine DNR monitoring study in the summer of 2015 included temperature monitors placed in two locations on this stream (Nemeth, 2015). The first was on the western branch, just downstream of Nicols Road. At that time, observations recorded included vegetated banks, beaver dams, and a sediment cover of sand and silt. The water level was about 12 inches. The observer also made note of the culvert under Nicols Road as a barrier to trout passage, along with a low-velocity marsh on the downstream side of Nicols Road (which corresponds to similar observations made in 1980). The other monitor was placed slightly upstream (southeast), on the other side of the railroad tracks. Observations near this station include an incised channel and signs of erosion. This area had also been impacted by beaver dams. (Nemeth, 2015).

The western branch of Kennaley's Creek was stocked with 3,900 brook trout in 1980, but sampling in 1982 and beyond showed no evidence of this population's survival (Nemeth, 2015). The 2015 study along with a previous survey from 2006 both concluded that the western branch of Kennaley's Creek would not be viable for future trout stocking due to its short length, minimal baseflow, flood loss potential, beaver dams, and vulnerability to runoff (MN DNR, 2006). However, it is worth noting that the 2015 temperature monitoring found proper temperatures for trout survival at both monitoring sites, with an average summer temperature around 52-55° F. (Nemeth, 2015).

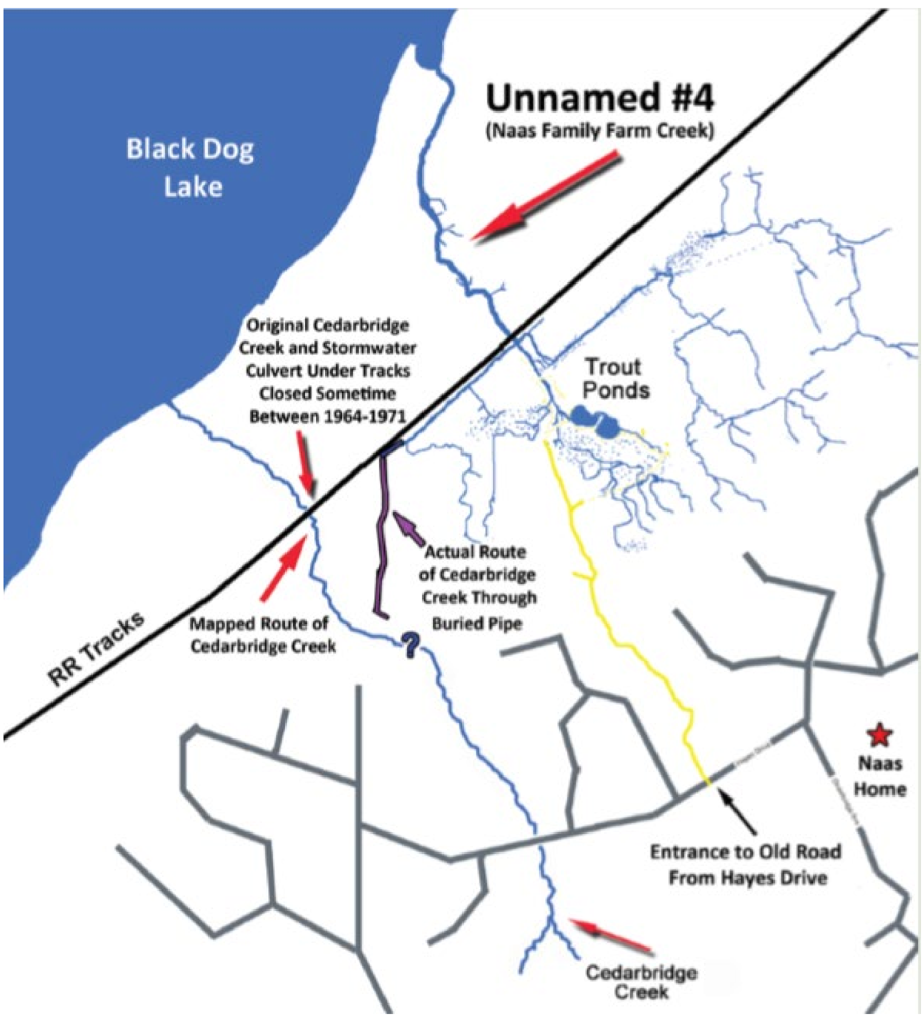
2.5 Unnamed Creeks 1, 2, 4 and 7

Unnamed Creeks 1, 2, 4, and 7 are located in Burnsville, MN, south of the Minnesota River (see Figure 1). Unnamed 7 was ultimately excluded from this study because of a recommendation from the DNR. Because of their close proximity and shared access point, Unnamed Creeks 1, 2, and 4 are combined into the same sections in this report. These creeks can be accessed via the bridge at Hayes Drive or the railroad. Unnamed Creek 1 is surrounded by a residential neighborhood and Cedarbridge Park. Unnamed Creeks 2 and 4 are surrounded by wetland and prairie. The riparian width extends past 150 feet on both sides. Most property is owned by the DNR but there are parts owned privately, by the city, and also by nearby businesses. As the streams proceeds toward the river, they become mostly inaccessible to the public without trespassing on railroad land.

In the 1960s, Unnamed Creek 4 had cold enough water that it supported an abundance of trout (Harper, 2016). As of now, the stream inhabits little to no trout. Decades of stormwater runoff, pollutants, and warmer water steered the trout away (Harper, 2016). In 2015, the DNR performed temperature monitoring to assess if the water was cold enough for trout survival. During the study period of April 16 and October 5, 2015, the stream temperature averaged 52.3 °F, which is a temperature suitable for trout to live in (Nemeth, 2015). A photo of Unnamed Creek 4 from 2015 taken with an underwater camera shows a rocky bottom and good concealment from overhanging vegetation, both positive aspects of potential trout habitat (see figure A.4 in Appendix A). During this same year, the DNR was considering removing Unnamed Creek 4's trout stream designation but ultimately decided to keep it as a trout stream because of trout observed there in the past (Callahan, 2015b). It is unclear whether Unnamed Creeks 1 and 2 are included in this trout stream designation.

The history of the Burnsville unnamed creeks has been investigated by Dan Callahan, Communications Coordinator at Twin Cities Trout Unlimited. A brief summary of his findings are included in this paragraph in order to support the observations recorded in this report. In 1958, the Naas family opened Cedar Hills Trout Farm on Unnamed Creek 4. Unnamed Creek 4 supplied cold water for the fish farm. According to Marianne Naas, one of the two Naas family members still alive today, she remembered Unnamed Creek 1 continuing under the railroad tracks, becoming Unnamed Creek 2, and running into Black Dog Lake. Today, there is no stream flowing under the tracks at the point specified on DNR maps. Callahan discovered the reason why this stream did not continue on its marked path. He found a pond upstream of the tracks that the Naas family created via dam in 1956. The City of Burnsville then installed an underground catch basin because it was causing erosion problems from flash flooding. There are signs of a previous culvert under the tracks that has now been covered up, so all of the stormwater from the surrounding neighborhood heads east until it finds a way to the other side of the tracks. Callahan created a map of the true route of this stream based on his observations (Figure 2).

Figure 2. Map of Unnamed Creeks by Dan Callahan of Trout Unlimited (2016).



Because of the blocked culvert, water from Unnamed Creeks 1 & 2 (which Callahan calls Cedarbridge Creek) flows in a ditch on the south side of the railroad tracks until it eventually joins Unnamed Creek 4 and flows into the river (see Figure 2). This additional flow into Unnamed Creek 4 contributes to its impairment. Pollution and warmer waters have resulted from the stormwater runoff, making the DNR unsure if the stream should be restored for trout. The closed culvert does not affect the stocking of trout, but it can ultimately degrade the trout habitat. Callahan thinks the best way to restore the creek is to reopen the culvert so that Unnamed Creek 2 can get back to its intended course and Unnamed Creek 4 is not polluted by the additional flow.

The Union Pacific Railroad company has a significant amount of autonomy over the railroad land. There are minimal requirements that the company must follow to protect trout habitat and are not obligated to notify the DNR if a culvert is blocked (Callahan, 2016b). In 2015, Callahan alerted the railroad company about water flowing over the tracks due to flooding. The company added more rip rap to the old culvert rather than reopening it. It is important to note the powerful role of the railroad company in any restoration. Their cooperation is a crucial component because most restorations at this site would require some sort of flow under the tracks.

3.0 Methods

The following section describes a summarized standard operating procedure that the team followed for each step of the process.

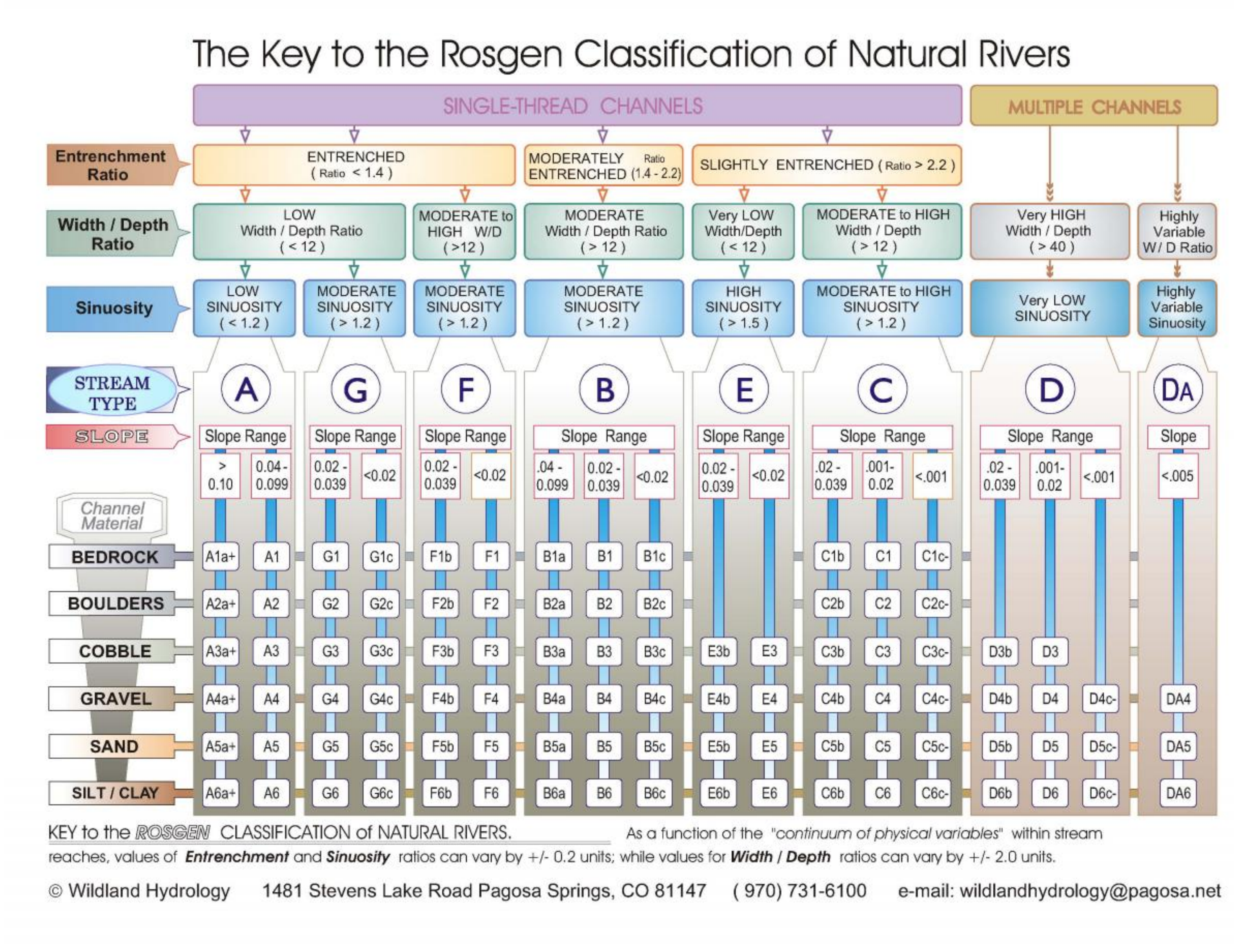


Figure 3. Rosgen stream classification. Use this diagram to reference mentions of stream type in results.

3.1 Reconnaissance

Training

Several streams throughout the LMRWD were selected for observations and completion of a level I geomorphic assessment. The first stage of this study was reconnaissance. Groups of two to three interns parked at the closest parking location to the stream. The appropriate gear allowed the team to get work done more efficiently, it included:

- Lifejackets
- Sunglasses
- Bug Spray/Mosquito Nets
- Boots/Waders
- Long sleeve shirts
- Hats
- Sunscreen
- Wading rods
- Notebooks
- Smartphones (camera & compass)
- Backpacks

The team took in-depth, dated notes while walking along the stream bank or in the stream bed. These notes included information on:

- Classify stream and valley type and note where it changed
- Coordinates
- Shade cover
- Confinement
- Entrenchment
- Vegetation
- Erosion
- Stable/Unstable
- Land use
- Woody/Rocky
- Any other significant observations critical to the stream

Pictures were taken to capture the stream observations more vividly. GPS coordinates were recorded frequently to help with mapping. This data was also used in the habitat assessment worksheet. Team members made observations while moving downstream. This helped the observers familiarize themselves with the streams and riparian zones that would later be surveyed. It also allowed the team to find adequate entry and exit points and to establish an initial opinion of the quality of the streams. This phase also allowed the team to identify areas with access challenges, which were ultimately not selected for further assessment in this study. Pictures were taken to capture the stream observations more vividly. GPS coordinates were recorded frequently to help with mapping.

3.2 Habitat Assessment

The state of trout habitat in the streams was evaluated using the MPCA's Minnesota Stream Habitat Assessment worksheet, modified for small headwater streams by Brenda DeZiel, Caddis Fish Consulting, LLC. A blank copy of the worksheet can be found in Appendix B (see figure B.1 in Appendix B). This section will summarize the methods used to make decisions during the habitat assessment and the sections on the front side of the worksheet (water level, watershed land use, riparian zone, instream zone, cover/refuge, and channel morphology). The back side of the scoresheet does not factor into the score but it was utilized for detailing specific observations such as vegetation type, channel stability factors, and restrictions to flow that could impede trout. A more in-depth description of each metric can be found in the Stream Habitat Assessment for Small Headwater Streams Standard Operating Procedure (DeZiel, 2019c).

The water level was determined based on previous visits to the stream. The team originally performed reconnaissance early in the field work season, during which the streams were observed at near flood water levels. The water levels were especially high because of the flooding of the Minnesota River, described in the introduction of this report. When the team returned to the streams for habitat assessment, the water levels at that time were compared to the previous flood levels earlier in the summer and noted on the sheet. This allowed for an estimate of the water level.

The watershed land use was observed when entering and exiting a stream. The team took note of public parks, roads, highways, residential neighborhoods, businesses, and wetland areas while walking or driving near the stream site. Along with aerial photos, this helped to determine the land use. Many streams are situated within a small piece of public park land or wetland. However, the overall land use outside of the riparian zone was ultimately used to determine the land use score because of the influence that nearby non-park land can have on a stream (ie. runoff).

The Riparian Zone section combines four metrics that relate to the land surrounding the stream. Riparian width was a visual estimate of the riparian buffer width. It measured the distance from the edge of the stream to the edge of the riparian zone on both banks. The visual estimates were coupled with the valley wall measurements taken during cross section surveying. In most cases, the edge of the riparian zone was the start of a heavily human-influenced land-use, such as a residential yard, a park trail, a road, or a crop field. Another indicator of the edge of the riparian zone is a change in vegetation from sedges, grasses, and rushes to larger deciduous and coniferous trees. Riparian Flow Refuge was previously known as “Riparian Connection.” The wording was changed to specify a focus on protected areas where fish could go during high and fast flows. A stream was considered to have wide riparian flow refuge if there were accessible terraces in the stream bed that would become shallows at flood stage. Streams that are incised did not receive high scores for Riparian Flow Refuge because the fish would be confined to the fast flow in or near the thalweg. The level of bank erosion was determined based on the presence of non-cohesive soil, steep-sloping banks, and excessive undercutting. Shade level was visually estimated, taking into account both overhanging vegetation and tree cover.

The substrate types and siltation were scored based on the results of the pebble count (method described below). When gravel was present, embeddedness was scored based on the extent to which the gravel was covered by sand or silt.

The cover types section was evaluated in the context of trout. A feature was marked as present if it was accessible concealment for trout in at least 5% of the reach. Concealment features that were not in the water (such as overhanging woody debris), were not counted in this category. The concealment amount was then evaluated based on the percentage of the stream where trout could take refuge.

The Channel Morphology section scoring was guided by the short descriptions in parentheses next to each option (see figure B.1 in Appendix B). Channel stability was determined based on an overall evaluation of aggradation and degradation.

3.3 Pebble Count

Pebble counts were taken at each cross section to find the main substrate. This was done by selecting a pebble at random while walking in a zig-zag pattern through each reach of the stream from one edge to the other. After each step, the pebble that touched the big toe would be selected for classification. To classify the pebble type, the intermediate axis (see figure C.1 in Appendix C) of the pebble was measured in millimeters using a ruler. The sizes ranged from silt to boulders. This method was repeated at least 100 times at every reach of the stream.

3.4 Cross Section Survey

To capture the valley and channel shape of different points of the streams, cross sections were taken running perpendicular to the channel. Each cross section was taken using a Spectra laser level, laser detector, and a survey rod. This equipment was used to capture accurate elevation data with respect to a known elevation. Locations for cross sections were chosen based on stream geomorphology, channel morphology, and potential characteristics that would signify viable trout habitat. Examples of these characteristics are deep pools, riffles, changing stream types, increased incision, and gravel in the channel substrate. The cross sections were taken using a temporary benchmark (TBM) to represent a known elevation. The TBMs used for the study were constructed by pounding in a piece of rebar into the soil at the highest accessible and unobstructed point available on the valley wall. The TBMs were arbitrarily given an elevation of 100 feet, which was then used as reference for a backsight from the surveying instruments to attain a known instrument height. Back sights were taken with the detector mounted on the survey rod which was placed on top of the rebar, and shot with the laser level on top of a tripod. The detector provided an audible indication when the survey rod height was level with the instrument height. The survey rod height was then recorded as the backsight elevation and represents the true elevation of the instrument height with respect to the TBM.

Once known instrument heights were obtained, a tape measure was pinned into the soil in front of the surveying instrument and ran laterally across the stream channel perpendicular to the flow of the stream. The tape measure was then extended to the highest accessible point on the opposing valley wall parallel to the starting location. The start of the tape measure was given the horizontal distance of 0.00 ft and used as the location for the first elevation measurement or foresight. Foresights were then taken along the transect at varying horizontal distances, with the survey rod on top of the soil or channel bed. The main objective was to capture points of inflection and stream channel morphology, and the measurement intervals changed with respect to those objectives. Foresights along the valley walls and floodplains were spaced out further than foresights in the stream channel, with measurements of 0.5-1 ft intervals taken in the stream channel.

When foresights had been taken along the entire transect, the top of the valley walls were then roughly estimated. This was done to obtain the general shape of the valley as a whole. The estimations were done by having one team member walk with the tape measure to the top of the valley wall near the end point to estimate the horizontal distance of the last point on the transect. Another team member would then walk to the foot of the hillside and slowly raise the survey rod while the team member holding the tape measure watched until the top of the rod was roughly parallel to the top of the valley wall. A height measurement was then directly taken and recorded from the survey rod. This procedure was repeated on the opposite valley wall as well. All data collected from this procedure was subsequently entered into the Mecklenburg spreadsheets for later data analysis and correlation.

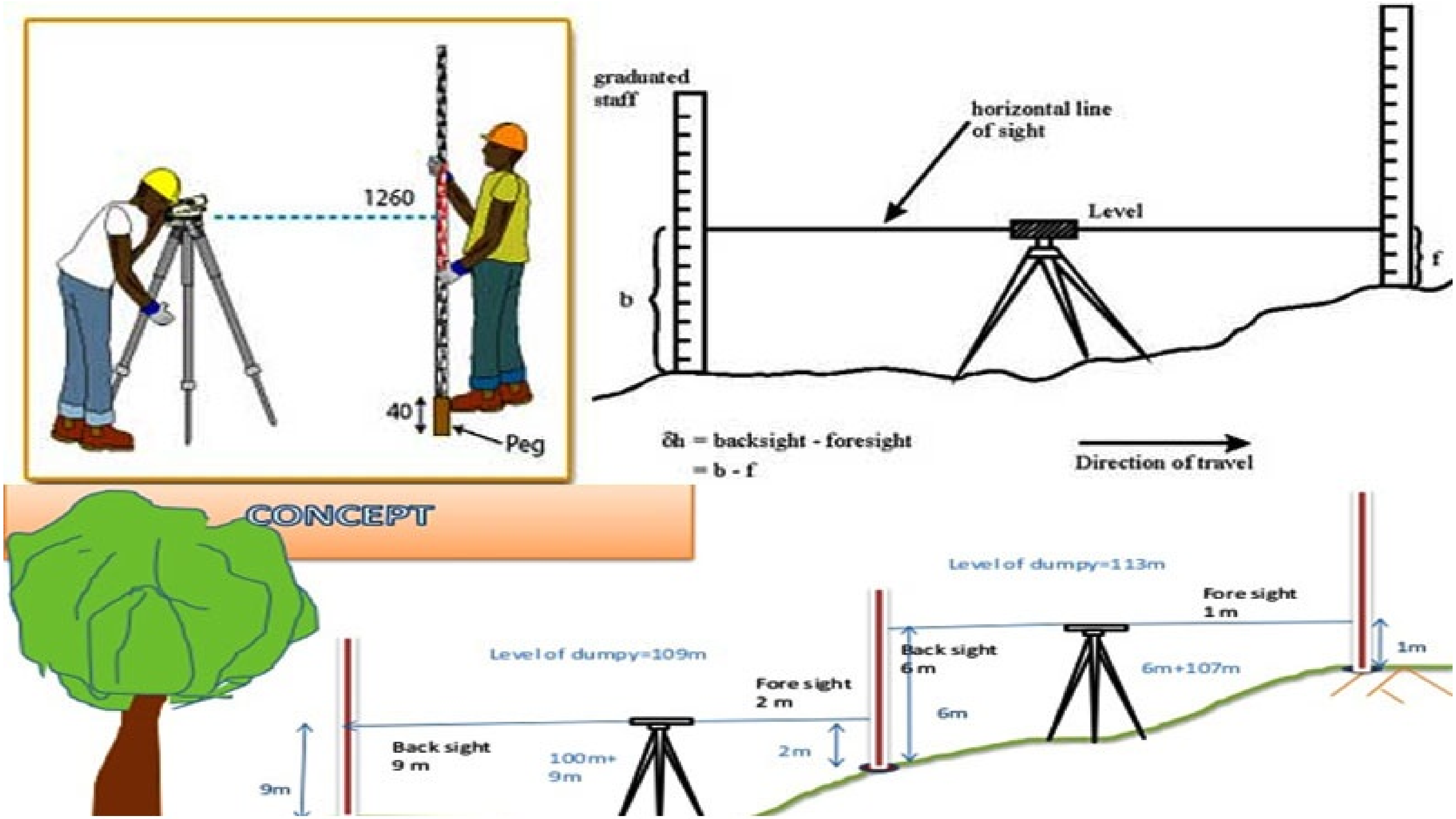


Figure 4. Cross Section Procedure.

3.5 Longitudinal Profile Survey

Longitudinal profiles, or cross sections that run lengthwise through the stream channel, were taken following the cross sectional surveying of each stream. These profiles were taken at the same locations as the previous cross sections, utilizing the pre-placed TBMs to obtain an instrument height. Each longitudinal profile was started further upstream than the original cross section. The starting point's locations were decided based on ease of measurement, distance to the next cross section, and position of key stream channel geomorphic features. The starting point, or the 0.00ft location, was then marked with a piece of rebar placed in the thalweg of the channel and a tape measure attached to the end of the rebar. Foresights were taken at the 0.00 location, with measurements taken in the thalweg. Measurements were also taken for the water level elevation and bankfull elevation. Water level elevations were read off the survey rod in-stream, while bankfull elevations were taken with the detector mounted on the survey rod. These measurements were used to show the trend with respect to the stream channel elevation when graphed in the Mecklenburg spreadsheets. Azimuths were taken in the direction of flow using a compass app on a team member's smartphone. This measurement was taken to show the stream meandering or directional variations when entered into the Mecklenburg spreadsheet.

After taking measurements at the 0.00ft location, the transect was run lengthwise through the stream channel. Wading rods were placed in the hinges of the meanders and the tape measure was run around them to more accurately capture the true distance from the starting location. Foresights, water depth, and bankfull were taken along the transect using the same procedures as the measurements at the starting location. Measurement locations were chosen to capture points of inflection such as the top, middle, and bottom of a pool; or points where the stream changed direction. This measurement interval was decided upon to better capture and show the depth variability of the stream segment, and to better shape the stream channel when graphed in the Mecklenburg spreadsheets. When taking measurements in stretches of the stream where the channel had relatively no elevation change such as a run, larger intervals were left between measurement points.

Due to the landscape, stream meandering, and obstructing brush and riparian vegetation; turning points were utilized to continuously survey the stream channel for greater distances. These turning points were done by taking a foresight at a known distance along the transect. After the foresight was taken, a team member would hold the survey rod in the exact spot of the stream channel that the foresight was taken without moving it. The surveying equipment was then moved further downstream from the foresight. Once the equipment was set-up, a backsight was taken from the survey rod to obtain a new instrument height. This instrument height would be in accordance to the previous elevations obtained with the original instrument height, which allowed for continuous surveying of the transect despite obstructions.

The continuous longitudinal profile should capture multiple cross sections within it. This is done by doing hundreds of feet of longitudinal profile and measuring the heights of the TBM's along the path of the longitudinal profile while surveying in the stream. This allows for calculating the slope and change in elevation along the stream as all the heights will be in relation to each other.

3.6 Baseflow Analysis

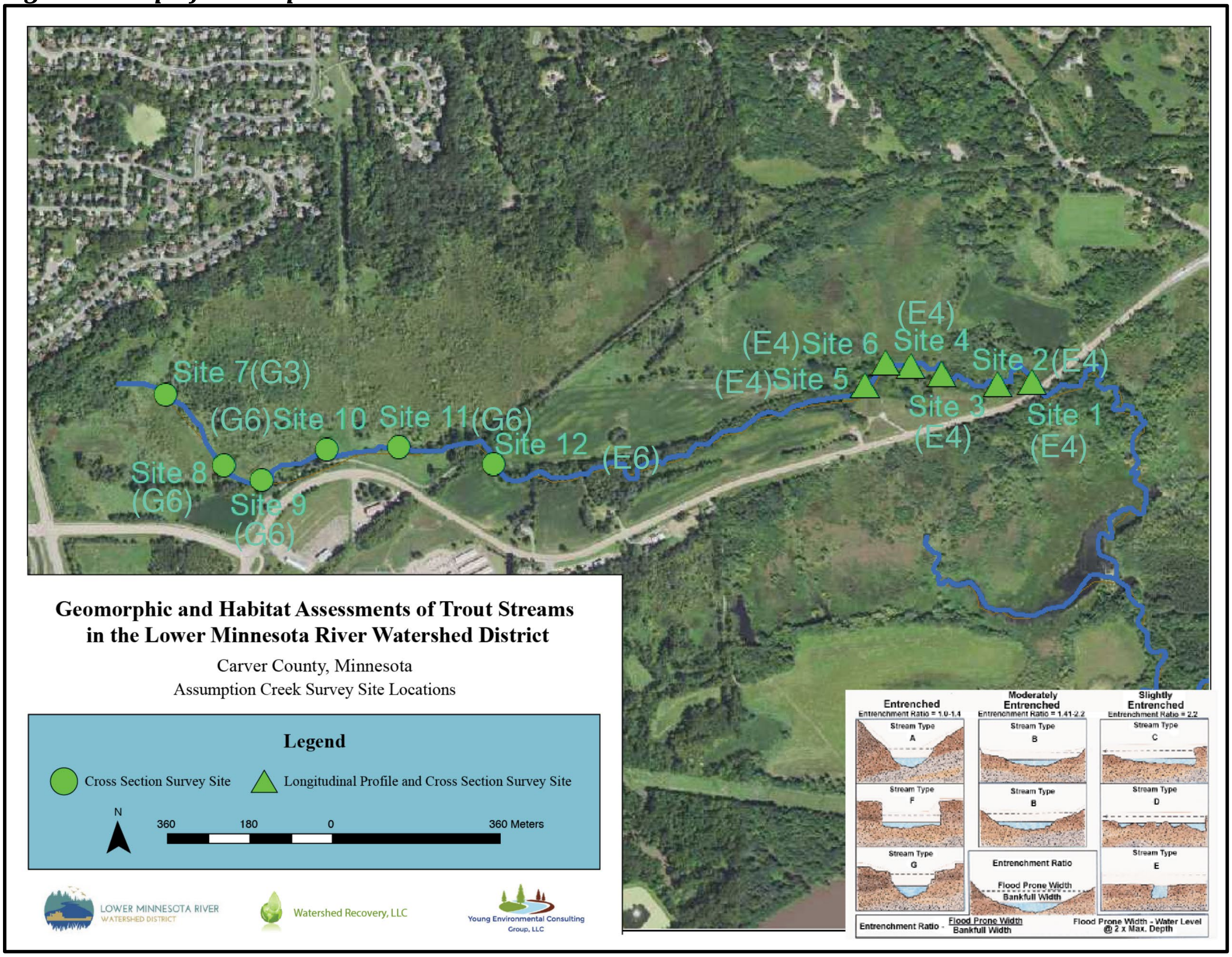
A YSI 6820 water quality sonde (WQ sonde) was used to determine the water temperature and dissolved oxygen (DO) at certain sites in the streams. The WQ sonde was already calibrated for temperature, but the DO sensor needed to be calibrated every time the WQ sonde was started up. In order to calibrate it, the WQ sonde was connected to the handheld controller. The cap was filled with just enough water to cover the port on the DO sensor and screwed on loosely. On the handheld controller, the discrete run menu was accessed through the sonde menu. The dissolved oxygen tab was selected and then the barometric pressure was entered. The true barometric pressure was calculated from the corrected barometric pressure and local altitude retrieved from a weather app. Then the calibration ran until the numbers stabilized and the results were checked in the calibration constants menu. If the DO gain was not within the range of 0.7 to 1.4, the calibration was run again.

To determine where ground water is entering the channel or where the creeks are gaining streams, surface water temperatures and dissolved oxygen concentrations were measured with the WQ sonde placed on the bottom of the channel. Measurements were taken near the headwaters 3 times each to obtain average baseline conditions of the entering groundwater for each of the parameters. Following measurements at the headwaters, measurements were then taken further down the streams going toward the Minnesota River. The purpose of taking these measurements close to the Minnesota River was due to the likelihood of the River's effects on the stream, causing a cessation of baseflow entrance into the channel or making it a losing stream. Measurements were checked for changes in each parameter, and GPS coordinates were taken at each location of change. The procedure used for the baseflow analysis was based on groundwater's cold temperatures, in comparison with surface water. This means that baseflow entering the stream could be tracked by measuring the changes in the surface water temperature of the stream with the WQ sonde. If the water temperature substantially rises from the baseline temperature obtained at the headwaters, one could assume that baseflow is not entering the stream at this location (Brooks et al., 2013).

4.0 Results

4.1 Assumption Creek

Figure 5. Map of Assumption Creek.



4.1.i Assumption Creek West Reach

The western reach of Assumption Creek consists of survey sites 7-12, begins at the headwaters, and runs about halfway through the branch of the stream west of Flying Cloud Drive (see Figure 5). At the headwaters, the stream is only about a foot wide and covered heavily with vegetation. It was easily found during reconnaissance due to the minimal vegetation in early June. In late June, the stream was almost unrecognizable and very difficult to locate as the headwaters had mostly dried up. The headwaters and stream is supported by baseflow. The land use is wetland and prairie, but as the stream moved west, the right bank land use changed to urban/industrial. This reach had an average of an extensive riparian width (>150 feet) and varied much in its riparian flow refuge. Survey sites 7, 8, and 9 had narrow or no riparian flow refuge (0%-20%) while survey sites 10 and 11 had moderate to widely accessible flood plains (50%-100%). This is due to the stream becoming less incised as it moves west. This part of the stream had natural to minor bank erosion issues. While the stream is located in mostly grasslands/prairie/wetland with no major trees for shade, the stream is well-shaded (50%-75%) throughout the reach due to overhanging vegetation. This reach has an average of extensive (>50%) cover/concealment amount. The types of cover include undercut banks, overhanging vegetation, woody debris, root mats, instream vegetation, shallows, and backwaters/side channels. The types of instream vegetation include emergent cattail and reed canary grass. The amount of pools and riffles also almost completely disappears, and the stream becomes a long run. The velocity types of the stream include slow, intermittent, and none. The water level was incredibly shallow throughout. The depth is uniform throughout, making variability poor (<8 inches). The stream begins with almost no degree of stream meandering. This whole part of the western reach has fair channel development, with a pool/riffle/run sequence present, but the thalweg is not distinct throughout. The western reach had an average habitat score of 33.33. The pebble count showed 69% silt/clay/muck, 17% sands, and 14% types of gravel. The pools included majority sand and the riffles and runs consisted of fine gravel and sand. As the stream moved west (points 9, 10, and 11), the substrate was almost completely fine sand, silt, and muck (see figure D.1 in Appendix D).

During reconnaissance in early June it was hypothesized that the stream across survey sites 7, 8, and 9 was an G5/6 type stream due to its incisement and the large amount of silt and sand present. The cross sections from this area supported the hypothesis of an ‘G’ channel. The width-depth ratios are less than 12 and the stream is entrenched. Because the longitudinal profile was not completed, the overall slope and sinuosity could not be analyzed using data but the sinuosity could be analyzed using an aerial map. It seems to be non-sinuous which also matches with the ‘G’ description of the stream (see Figure 4 for stream classifications). During the reconnaissance, survey sites 10, 11, and 12 were thought to be E5 or E6 streams due the observations of being slightly entrenched with a low width-depth ratio. The substrate type was supported with the pebble count mentioned above (see figure D.2 in Appendix D). This was hypothesized due to how low the water levels were during the first outing of reconnaissance in early June when the water levels were at their highest amounts, meaning bankfull could not have been much higher than was observed. The cross sections support the slightly entrenched hypothesis (cross sections 10, 11, and 12 (see figure D.3 in Appendix D) but because longitudinal profiles could not be completed on this portion of Assumption Creek there is no bankfull data to analyze, so the conclusion cannot be fully supported.

Longitudinal profiles were not completed on this reach because in July, when longitudinal profiles were being done, the stream was extremely incised, covered with vegetation, and difficult to access. The buildup of silt and muck also created difficulties in obtaining an accurate longitudinal profile as the survey rod would constantly sink, leading the cross-sections measurements to not correspond with the longitudinal profile depths. The stream was dry in places and is not connected to the eastern reach that crosses Flying Cloud Drive.

4.1.ii Assumption Creek East Reach

Assumption Creek East Reach begins northwest of Flying Cloud Drive and includes sites 1-6 (see Figure 5). It has been accessible for the most part, except for the portion that is southeast of Flying Cloud Drive, which was flooded all summer so limited data were collected in that area. For the portion of the stream not flooded, the water level is still high. This portion is supported by a baseflow and groundwater flow. For survey sites 1-3, the land use is forest, wetlands, prairies, and shrubs on the left bank and urban and industrial on the right bank. From 4-6, it changes to forest, wetlands, prairies, and shrub on both banks. The average riparian use is mostly extensive (>150 ft), but for the sites going south towards Flying Cloud Drive, it narrows. Mid-channel bars are present at sites 5 and 6, indicating aggradation. Erosion ranges from natural to minor adjustments and it does provide undercutting as a concealment type. The amount of shade varies from moderate (25%-30%) to heavy (>75%), this includes shade from trees and other vegetation covering the stream. A variety of concealment types are present throughout the reach including woody debris, deep pools, logs, undercut banks, overhanging vegetation, instream vegetation, and backwaters. Sites 1, 2, and 4 have more concealment cover than sites 3, 5 and 6; the range is between extensive (>50%) and very little (5%-25%). Reed Canary Grass and Duckweed were observed intermittently. Other submergent, floating leaf, and emergent vegetation is also present throughout the whole East Reach. The average habitat assessment score for Assumption Creek Eastern Reach is 54.6.

The stream type of Assumption Creek Eastern Reach is an E stream. The stream is slightly entrenched with a low width-depth ratio. This is shown in the graphs in Appendix D (see figure D.4 in Appendix D). Sites 1-6 vary from E4 to E5 depending on the main substrate. The averages of the main substrates found in this reach are gravel (57%) and sand (31.3%), with some siltation (12%) and very little cobble (2%). Embeddedness varies from moderate (25%-50%) to light (5%-25%). Sites 2, 4, 5 and 6 all have good (12-18in) or excellent depth variability (>18in), fast or moderate velocity, but the channel development, pool width, and riffle-run width ratio varies. Sites 1 and 3 have depths ranging from 8 to 12 inches, no good pool-riffle-run sequences, no obvious thalweg, and the degree of meandering ranges from low to moderate. An example of good depth variability is shown in the longitudinal profile (see figure D.5 in Appendix D). The pools shown at sites 2, 3, and 4 are between 12 and 24 inches deep. At site 4, the elevation goes from around 718 feet to around 716.5 feet. There is excellent depth variability, but the riffle-run sequence for this reach could be improved. There are only a few runs and no defined riffles visible on this graph. An example of poor depth variability is shown after site 4 on the graph. There are not as many deep pools in this section. For this portion of the graph, there are more runs than there are pools, but there still are not any riffles. Knickpoints were observed at site 3.

The portion of Assumption Creek southeast of Flying Cloud drive was mostly inaccessible (about 90%) due to flooding most of the summer. The team, however, did complete reconnaissance on this portion of the stream (first 300 feet or so) that could be accessed in late June. It was observed to have a majority of silt and sand as a substrate and to be a 'B' or 'C' type stream. Due to such high water depths and no quantitative data this reach could not be further analyzed.

4.1iii Assumption Creek Baseflow Analysis

Figure 6. Map of Assumption Creek Baseflow Measurement Sites.

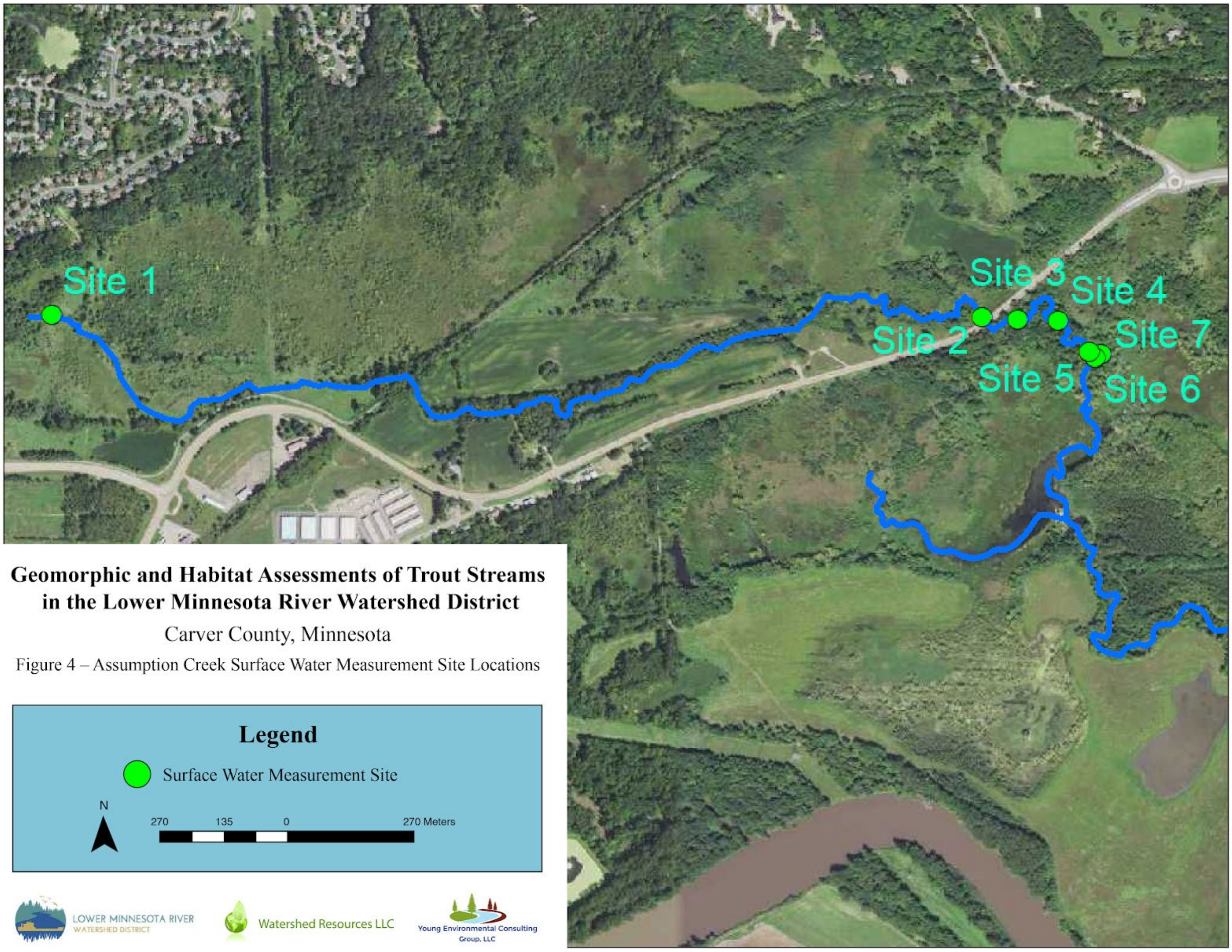


Table 1. Assumption Creek Surface Water Measurements Data.

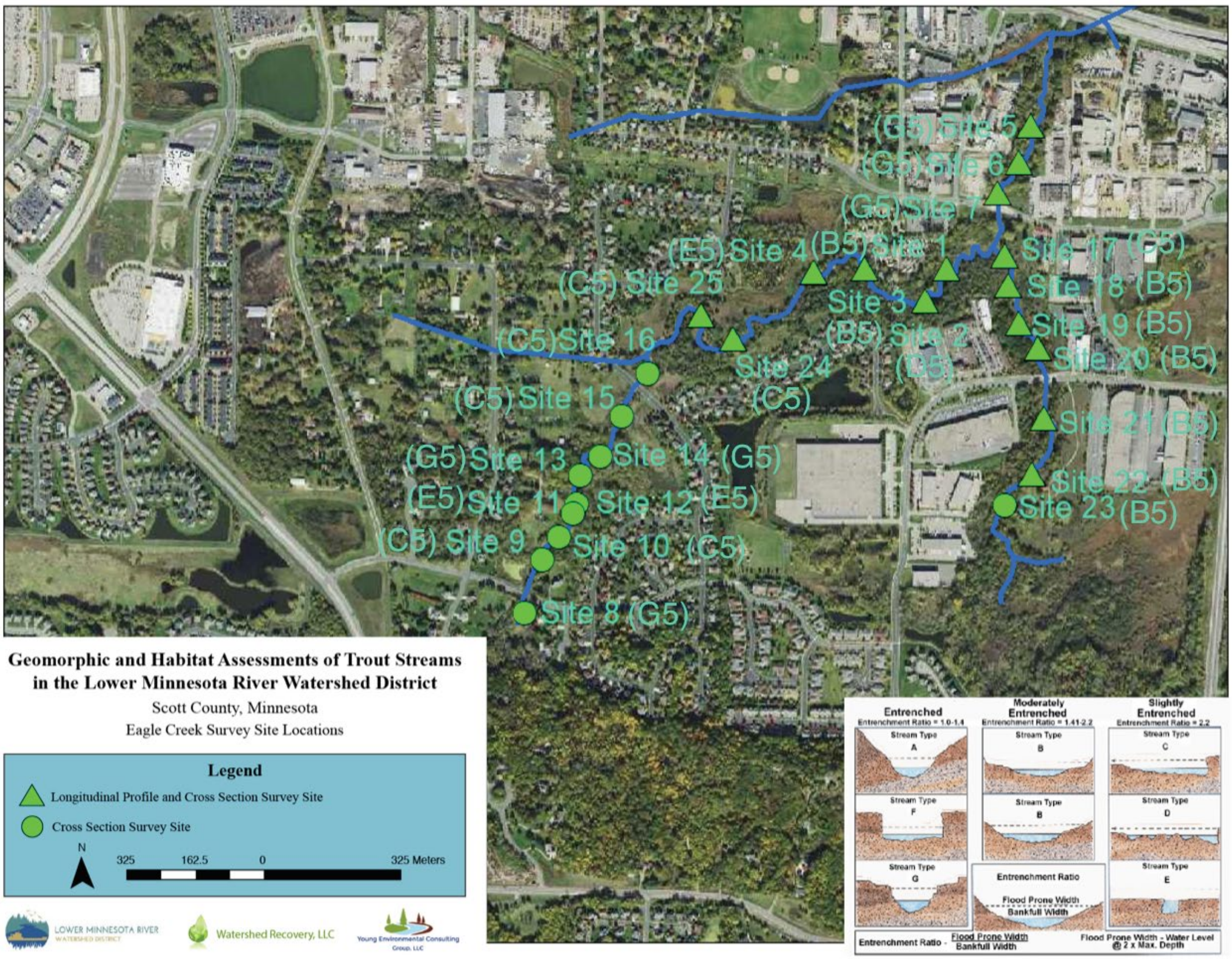
Site Number	Surface Water Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
1_a	17.9	43.3	4.1
1_b	18.2	47.7	4.5
1_c	17.9	39.9	3.8
2	13.7	83.1	8.6
3	14.0	86.5	8.9
4	14.3	90.1	9.2
5	21.8	70.7	6.2
6	22.3	72.0	6.2
7	16.7	93.1	9.1
Subscripts represent multiple measurements at a single location			

Surface water temperature and DO measurements were taken at various points along the stream to verify where groundwater is entering the stream. Assumption Creek was found to be a gaining stream from sites 1-4. A transition zone from a gaining to losing stream was observed at site 7, with surface water conditions at sites 5 and 6 consistent with a cool-warm water environment. This transition zone was observed at the start of the section of the stream that was inundated by the Minnesota River, with flood waters overtaking the land surface near points 5 and 6. Further evidence for this is provided by the sudden increase in aquatic biodiversity observed, with the presence of several fish species including a school of adolescent bullheads. This provided evidence that the stream was transitioning from a cold-water fishery to a cool-warm water fishery.

The surface water temperature at the headwaters compared to those measured further downstream before the transition zone (sites 2-4) was noticeably warmer. The cause of this is theorized to be both the shallowness of the stream near the headwaters, as well as the stream-forming groundwater taking on a shorter flow path. The shorter flow path would in turn allow the water to enter the ground and move through the subsurface into the stream on a shorter temporal scale. This would give it a warmer temperature, as it would have less time to cool to temperatures more concurrent with average groundwater temperatures. The stream's transition away from being a gaining stream is speculated to be caused by the floodwaters putting the water surface elevation over the ground surface elevation of the floodplain. This would in turn cause the hydraulic head of the groundwater to be lower than the stream's water surface elevation, stopping groundwater from entering as baseflow. This was only observed in the flooded portion, so it is speculated that when the stream is not flooded, groundwater would continue to enter the stream past the transition zone observed.

4.2 Eagle Creek

Figure 6. Map of Eagle Creek.



4.2.i Eagle Creek Main Branch

The main branch of Eagle Creek began at the boiling springs south of Preserve Trail, and consisted of survey sites 1-16 (see Figure 6). The reconstructed portion of the stream is between survey sites 4 and 15, and consists of sites 16, 24 and 25. Due to this and the inferred viability for trout habitat based on field reconnaissance observations, the study's scope for Eagle Creek was changed to focus on the northern half of Eagle Creek. This consisted of the portion of the stream that came after the reconstruction, and contained survey sites 1-7. The northern half of the stream's watershed land use transitioned through the course of the stream from forest, to park/residential, to urban/industrial south of Highway 13. The reach's riparian width varied considerably, ranging from moderate 30 to >150 feet. The start of the reach (survey sites 1-4) had wider riparian zones on the right bank, and shorter riparian widths on the left bank. The end portion of the reach (sites 5-7) near the industrial area, saw a deviation of this trend with riparian widths on the left bank equal to or greater than the width on the right bank. The end reach was, in general, moderately shaded (25-50%), with slightly reduced shade at sites 2 and 5.

The creek's substrate mainly consisted of sand and fine gravel. The pebble count showed 4% clay/silt, 86% sand, and 10% gravel. The presence of gravel was observed in variable locations throughout the reach, and had light (5-25%) to moderate (25-50%) embeddedness when present. The average depth variability for the reach was good (12-18 inches). The longitudinal profile at Site 2 shows this depth variability as the bed elevation fluctuates within the range of 716 ft and 713.5 ft (see figure E.4 in Appendix E). The average channel development sequence observed (pool, riffle, run) was fair; with "present, but poor quality sequences in the reach, and no distinct thalweg" (DeZiel, 2019c). One example of this type of sequence is demonstrated in the longitudinal profile from Site 5. This profile shows one distinct pool, but no defined riffle to complete the sequence. The degree of stream meandering for the reach was observed in the field to be moderate, with "at least one good bend with pools of moderate depth for each section observed" (DeZiel, 2019). The reach's water velocity in general was fast, with some moderate flow velocities and eddies (circular flow) observed throughout the reach. The amount of concealment observed was, on average, low throughout the reach, with the main types of cover consisting of overhanging vegetation, deep pools, logs, instream vegetation, and woody debris (see figure E.1 and E.2 in Appendix E). In addition to providing concealment, the in-stream vegetation also provides a feeding area for trout. The amount of siltation seen in the stream channel was generally low, with the silt being mainly confined to the edges of the channel.

Signs of hillslope failure were observed near the campground at the start of the reach, and in the East Branch. This was evident due to slumps in the valley wall, with steep slopes being the contributing factors to the instability of the hillside. Inversely, bank erosion in the reach ranged from natural erosion to a minor degree of erosion. Certain portions of the stream did show signs of incisement (erosion below the rootline) and/or over-widening near sites 3, 5, and 6 (see figure E.3 in Appendix E). Another environmental stressor observed in the stream was filamentous benthic algae, which would indicate excess nutrient loading in the stream. Influenced by all of these factors, the average habitat score for the reach was given a score of 47.31. Three trout were observed on separate occasions, which would suggest that there is a current population of trout residing in the main branch of Eagle Creek.

On Eagle Creek the stream type is B5 for stations 1 and 3 (see Figure 4 for stream classifications). The stream is an E5 for station 4 (Rosgen, 2008) and a D5 type for 2. The main difference between stream types 'B' and 'E' is entrenchment: type 'B' is moderately entrenched while 'E' is only slightly entrenched (Rosgen 2008). At the spot where the stream becomes 'D' type, the stream spreads out into multiple channels. These observations are supported by the cross sections (see Eagle main branch cross sections 1-4 figure E.5 in Appendix E). Past the tributary, the stream becomes more entrenched, therefore switching to an 'G' type at stations 5, 6, and 7 which was later supported by the cross sections (see Eagle main branch cross sections 5-7 figure E.5 in Appendix E).

4.2.ii Eagle Creek East Branch

The East Branch of Eagle Creek consists of survey sites 17-23 (see Figure 6). The riparian width for most of this stream is wide (>100 ft), as is the riparian flow refuge close to the confluence. Farther upstream, the flow refuge decreases (10-50% accessibility). There was only one instance of extreme erosion that was observed on the valley wall in a portion of the stream by cross section 18 (see figure E.5 in Appendix E). The rest of the branch had natural to minor bank erosion issues. The branch transitions from significant shade (>50%-75%) from forest and wooded areas at the headwaters to a less shaded (>5%-25%) channel surrounded by riparian grasses and prairie at the confluence with the main branch. The main sediment types throughout the branch are very fine sand (29.7%), fine sand (43.2%), and medium sand (14.2%). The presence of cobble and gravel increased towards the headwaters. The overabundance of sand and presence of mid-channel bars indicate aggradation in this branch leading to fair channel development. Average depth variability was fair (8-12 inches). This can be seen in the Eagle Creek East Branch longitudinal profiles (see figure E.8 in Appendix E). For example, the sites on the bed elevation in profile 21 generally lie within the range of 710 ft to 711 ft. Very few riffles were observed and most riffles were caused by woody debris rather than rocks. Pools were sufficiently present (approximately 20% of the stream) but not more than 1 foot deep. This is demonstrated by longitudinal profile 18-17 in Appendix E. There are several small variations in the stream bed, but no pools that are significantly deeper than other portions of the profile. Brenda DeZiel speculates that the shallow pools and lack of depth variability is caused by excessive sandy sediment that is not being properly carried away by the flow (DeZiel, 2019b). The stream exhibits some signs of over-widening near the headwaters of the branch through survey sites 20-22. This was evident because the channel became much more shallow and extended all the way to the valley wall with little or no accessible floodplain. The progression from cross sections 18 to 22 demonstrates this over-widening (see figure E.7 in Appendix E). The points that are closer together are part of the channel, while the points more spread apart are on the floodplain and valley wall. The channel in cross sections 18-19 is much skinnier and more confined, whereas the channel in 20-22 has a shallower depth and stretches from valley wall to valley wall. Flow-related channel stability averaged stable or minor adjustment throughout.

This reach received high scores for its variety of concealment types, such as undercut banks (>6 inches), overhanging vegetation, and woody debris, including large logs. Cattails, reed canary grass, sedges, and watercress were the most common types of vegetation. Occasionally there was a presence of floating leaves including duckweed. The average habitat score for this branch is 44.9.

During reconnaissance it was noted that the channel switched back and forth from an E stream type to a G stream type (see Figure 4 for stream classifications). This means that a low width/depth ratio is consistent throughout, but some portions of the stream are entrenched, like cross section 18, while others are not, like cross section 20 (see figure E.7 in Appendix E). It should be noted that none of the cross sections indicate extreme entrenchment, so some of the reconnaissance observations may have underestimated the entrenchment ratio. Further down the branch near the headwaters of the tributary, the stream type changes to B5 because the stream overwidens. The East Branch had a steeper slope than the main branch, which can be seen throughout the longitudinal profiles (see figure E.8 in Appendix E).

4.2.iii Eagle Creek Reconstructed Reach

The reconstructed portion of the stream is between survey sites 4 and 15, and consists of sites 16, 24, and 25 (see Figure 6). There were posts and planks put in place indicating reconstruction had taken place (see figure E.10 in Appendix E). It also scarcely resembled other portions of the stream. The reconstructed portion had an extensive (>150ft) riparian width and the land use was forest/wetland on both banks. The flow refuge accessibility was wide (>80%). There was minimal erosion on the banks. This stretch is moderately shaded (25-50%) with minimal (5-25%) cover/concealment (see figure E.6 in Appendix E). This cover mostly consisted of overhanging vegetation. This stretch also contained abundant instream vegetation, mostly water cress and reed canary grass. The main substrate was sand with a presence of silt along the banks. The longitudinal profiles proved that the stream had good depth variability and an abundance of pools. In many places there was a change in depth of 12-18 inches and there were at least a few pools with depths over 20 inches (see figure E.11 in Appendix E). There was a high degree of stream meandering. The velocity was mainly quick throughout the stretch, most likely due to the high water levels at the time. A major issue was the lack of riffles on this portion, similar to other stretches of the stream.

There was no longitudinal profile completed at site 16 but there were cross sections, longitudinal profiles, pebble counts, and habitat assessments completed at sites 24 and 25. The stream type through the reconstructed portion was estimated to be an E5 during reconnaissance (see Figure 4 for stream classifications). The pebble count supports the observation during the habitat assessment of mostly sand (90%). An 'E' stream type estimation based on the observations proved to be incorrect. While the observation that the stream is not entrenched with a very accessible floodplain was correct, the stream had a width-depth ratio greater than 12, which was not predicted. The cross sections from 24 and 25 prove this (see figure E.12 in Appendix E). This quantitative data makes it a 'C' type stream throughout the reconstruction. The azimuths collected also gave a pattern showing the sinuosity ratio of 2.0 which fits this criteria (see figure E.9 in Appendix E). Because of the large amount of sand, the sediment in this area is not particularly well-suited for trout. However, this portion of Eagle Creek received one of the highest habitat assessments with a score of 56, the lowest category being substrate.

4.2iv Eagle Creek Base Flow Analysis

Figure 7. Map of Eagle Creek Baseflow Measurement Sites.

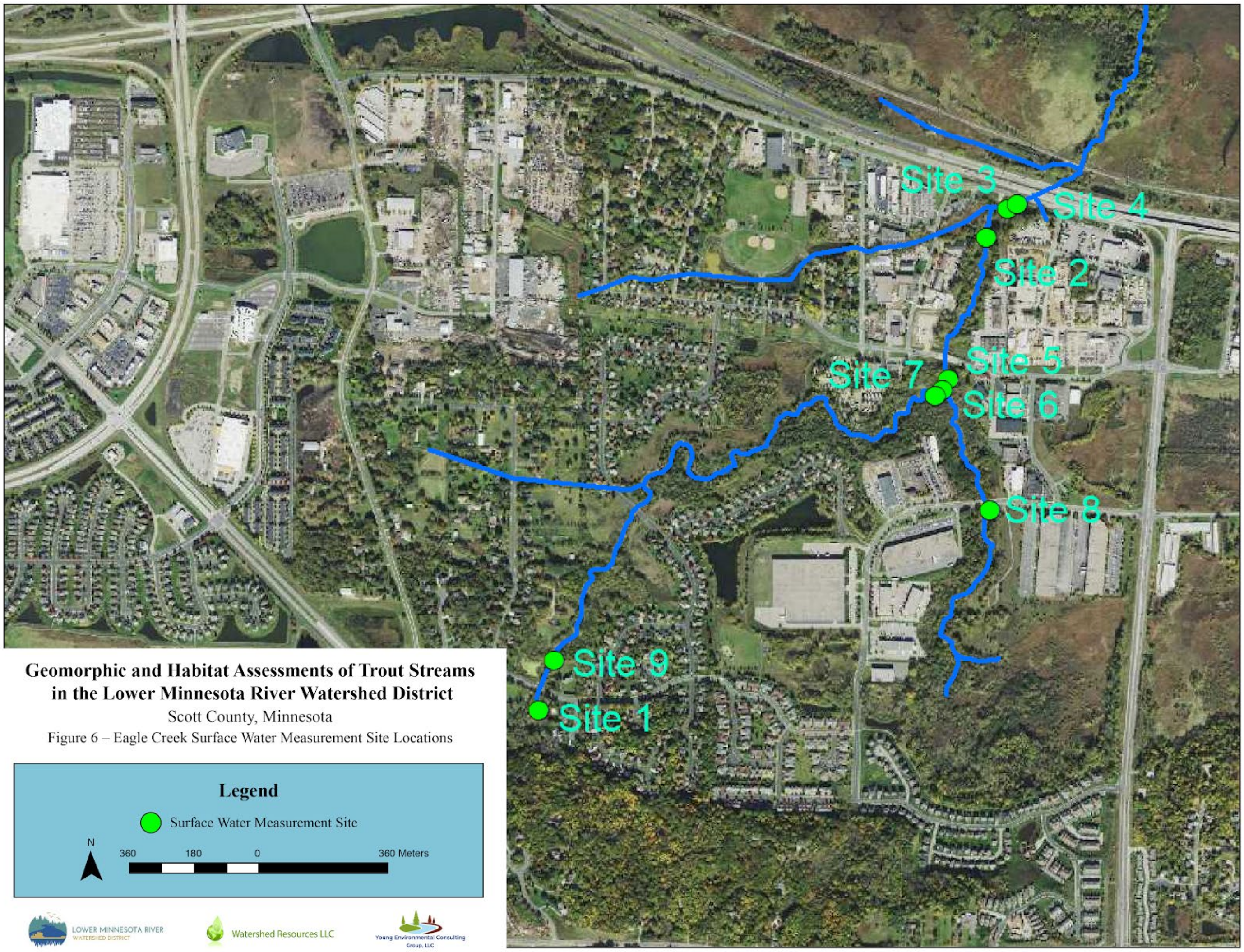


Table 2. Eagle Creek Surface Water Measurements Data.

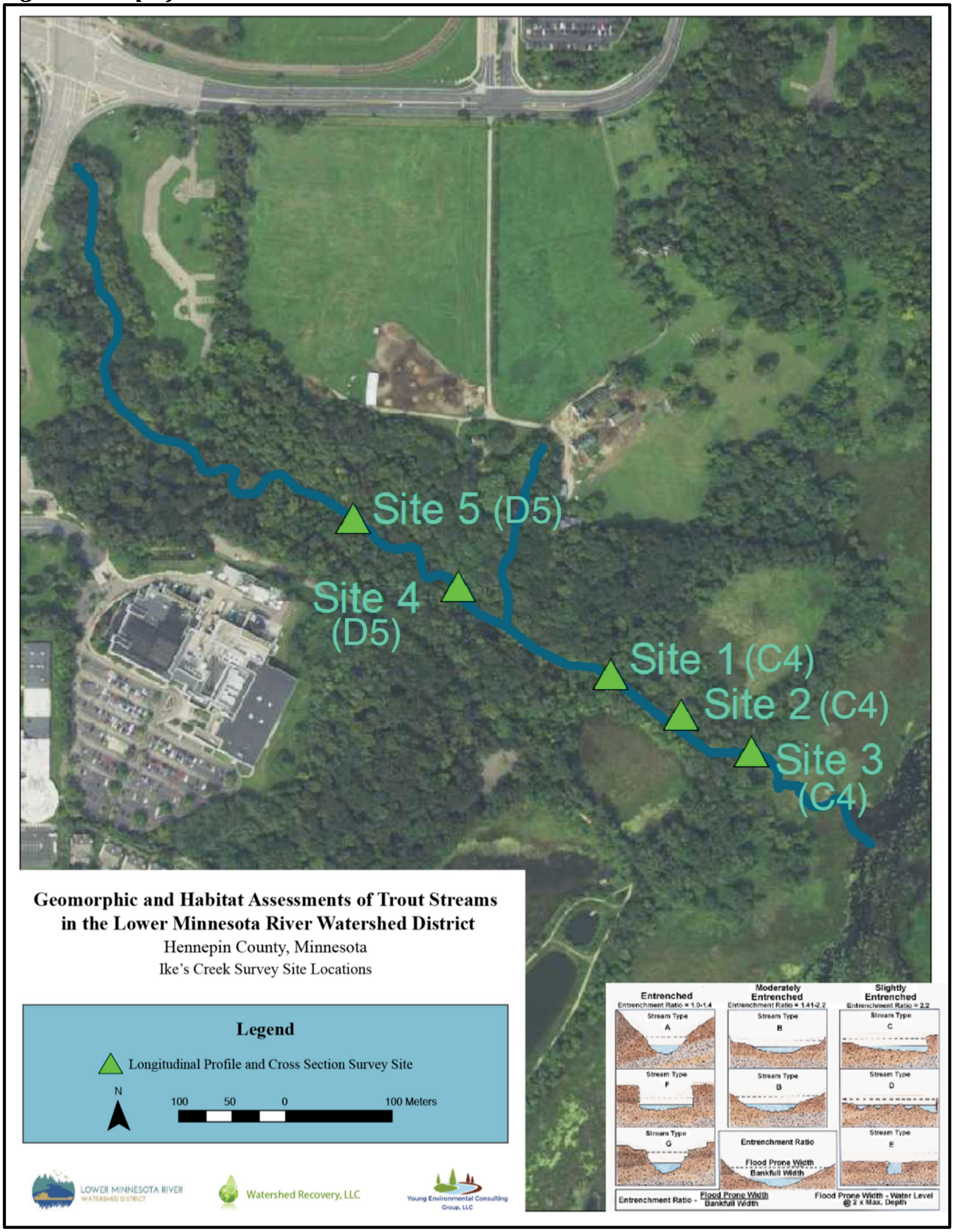
Site Number	Surface Water Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
1_a	11.9	89.9	9.7
1_b	11.9	89.9	9.7
1_c	11.9	90.3	9.7
2	14.6	84.9	8.6
3	14.7	86.3	8.7
4	14.7	86.4	8.8
5	13.7	76.8	7.9
6	13.2	79.5	8.3
7	13.7	77.3	8.0
8	13.1	83.1	8.7
9	12.2	93.2	9.9
Subscripts represent multiple measurements at a single location			

Hydrologically, the baseflow entering into the stream is the dominant component that supports Eagle Creek. Surface water measurements at Eagle Creek showed the stream had consistent groundwater input throughout the portion of the stream observed. Surface water temperatures were observed to slowly increase with increasing distance from the headwaters of the stream. These measurements were taken up until the bridge under Highway 13 (site 4). The conditions measured suggest that Eagle Creek is a gaining stream up until the highway bridge. This is also supported by evidence of groundwater seepage with visible iron bacteria near site 4, which provides evidence showing that groundwater input into the stream is occurring near the end of the stream length before Eagle Creek flows into the Minnesota River

.

4.3 Ike's Creek

Figure 8. Map of Ike's Creek.



The study area of Ike's Creek consists of survey sites 1-5, which were south of the headwaters of the stream (see Figure 8). This encompassed the northern portion of the stream, the constructed wetland section, and the southern section leading into Long Meadow Lake. The watershed land use for the stream consisted of both forest/wetland and park. The riparian width throughout the stream was extensive, with large sections of riparian vegetation on both sides of the bank. The stream's riparian flow refuge was wide (>80% accessible) for most of the stream besides the portions where downcutting in the channel greatly incised the stream, which created a narrow flow refuge (20-50%). The stream's shade cover varied throughout, ranging from light shade cover (5-25%) near its outlet into Long Meadow Lake, to heavy shade cover (>75%) in the heavily forested areas. There was sparse instream vegetation on the lower portion of Ike's Creek, but upstream on sites 4 and 5 there was excessive instream vegetation, with some portions of the stream entirely covered in watercress (see figure F.3 in Appendix F). Neither of these conditions would be ideal for trout. The stream had fair depth variability in the channel, with an average depth variation of 8-12 inches. This was proven by the longitudinal profiles completed (see figure F.6 in Appendix F). The average degree of stream meandering was moderate, with at least "1 good bend in the stream channel and pools with moderate depths" being observed (DeZiel, 2019). This is supported by the profile taken for Ike's Creek, which shows a good bend near the western portion (see figure F.7 in Appendix F). The creek had a fair channel development sequence. The pebble count is on average 37% gravel and 63% sand (see figure F.4 in Appendix F). The gravel was slightly embedded (5-25%).

The amount of concealment available in the stream was lower in the southern portion than the amount seen in the northern portion. At sites 1-3, the amount of cover was very little (5-25%). Farther north, this increased to moderate (25-50%). The main types of cover observed throughout the stream were logs and woody debris; but other types of cover such as overhanging vegetation, backwaters, undercut banks, instream vegetation, deep pools, and root wads were observed (see figure F.1, F.2, F.3 in Appendix F). The velocity of the stream was mostly fast, with some small portions of the stream exhibiting moderate to slow velocities. The degree of siltation observed south of the wetland was moderate on average, with silt being deposited in the pools and runs of the stream. North of the wetland, the stream was silt free, with a negligible amount of silt deposition seen. The stream had moderate bank erosion occurring intermittently throughout its length. Ike's Creek exhibited signs of inherent instability, which was evident by the abundance of knickpoints throughout the entire stream. The stream stability varied throughout, from minor adjustments being observed to major adjustments. Stressors observed are fallen logs acting as flow deflectors, overwidening, and incisement of the stream. North of the wetland portion of the stream, steep banks with non-cohesive soil and steep valley walls were also observed to be stressors. Overall, Ike's creek received an average habitat score of 43.6.

During initial reconnaissance, Stations 4 and 5 were estimated to be a D5 type due to the very large width and shallow depth (see Figure 4 for stream classifications). This is proven in cross section 4 and 5 (see figure F.5 in Appendix F). The stream had a very high width-depth ratio and an abundance of vegetation in this portion of the creek. Station 1, 2, and 3 were estimated to be a C4 stream (Rosgen, 2008). This was also supported by the cross sections (see figure F.5 in Appendix F) with the exception of cross-section 3, which was taken at a deep pool after a knickpoint.

4.3ii Ike's Creek Baseflow Analysis

Figure 9. Map of Ike's Creek Baseflow Measurement Sites.

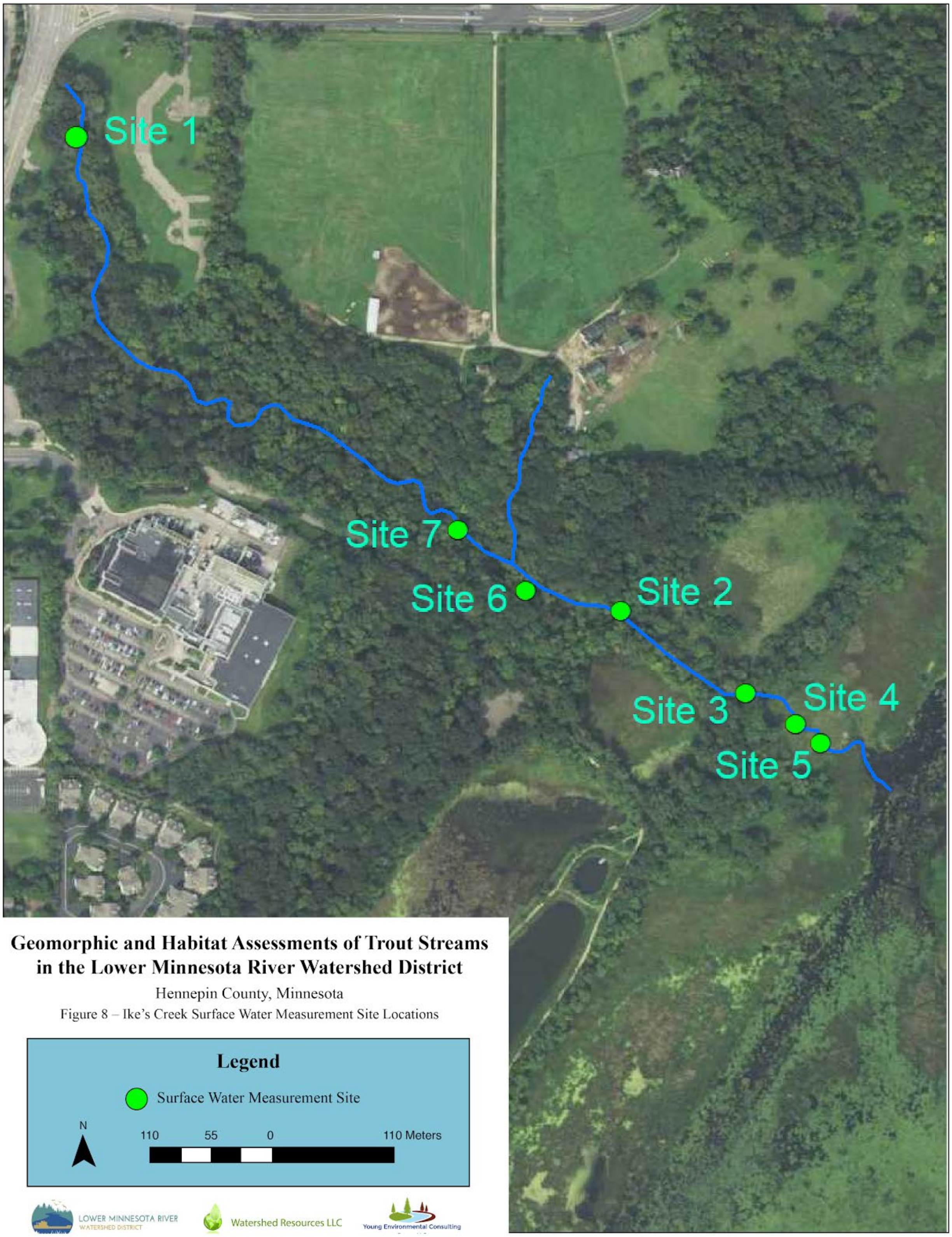


Table 3. Ike’s Creek Surface Water Measurements Data.

Site Number	Surface Water Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
1_a	13.6	34.1	3.5
1_b	13.5	21.7	2.2
1_c	13.6	18.6	1.9
2	13.1	95.4	9.9
3	13.3	97.7	10.6
4	13.5	97.4	10.1
5	13.7	95.1	9.8
6	13.9	91.2	9.4
7	13.9	91.7	9.4
Subscripts represent multiple measurements at a single location			

Surface water conditions were measured at Ike’s Creek throughout its stream length until the creek flows into Long Meadow Lake (Site 5). Surface water temperatures remained relatively consistent throughout the stream’s length and were consistent with groundwater inflow throughout the stream. Due to this, the measurements show that Ike’s Creek is a gaining stream throughout its entire length until it enters Long Meadow Lake.

4.4 Kennaley's Creek

Figure 10. Map of Kennaley's Creek.

Much of Kennaley's Creek was inaccessible due to intense flooding. Reconnaissance includes the southeast branch (south of Nichols Road) up to the headwaters of that branch. The headwaters consisted of boiling springs and were groundwater fed. There were very apparent and large knickpoints. The riparian flow refuge was moderate to wide/accessible, meaning it is unconfined with the stream becoming more incised towards Nichols Road. The stream was excessively covered with overhanging vegetation including grasses and forbs causing the stream to be heavily shaded (>75%) (see figure G.1 in Appendix G). The cover in the stream for trout was extensive (>50%) including undercut banks, overhanging vegetation, woody debris, and root mats. Common types of vegetation included reed canary grass, filamentous algae, cattails, and sedge. There were many different types of substrate, including coarse and fine gravel, sand, and silt and muck, meaning there were greater than four best substrate types. There were about 90% runs and 10% pools. The main substrate in the pools was fine sand, while the main substrate in the run was sand and silt. The embeddedness in the run was very severe (>75%-100%) The silt was moderate to heavy throughout the reach. The stream had poor depth variability and poor channel development with no obvious thalweg. Additionally, it was observed to have a moderate flow speed with aggradation occurring in the stream. There was little to no degree of stream meandering and moderate adjustments are needed for channel stability. There was a narrow culvert where this part of the stream met Nichols Road. The portion of the stream that received the habitat assessment had a score of 30.

Northeast of Nichols Road the portion of the stream that was southeast of the railroad was in an inaccessible portion of wetland. It was almost entirely overgrown and covered in dense cattails. The team tried to access the headwaters of this branch from the most southern point, but it was inaccessible as there was a fence and a privately owned power plant blocking access.

The northwest portion of this branch heading towards the Minnesota River was also inaccessible due to extreme flooding throughout the summer. During recon, the water level was up to the railroad tracks and hardly decreased throughout multiple trips to visit.

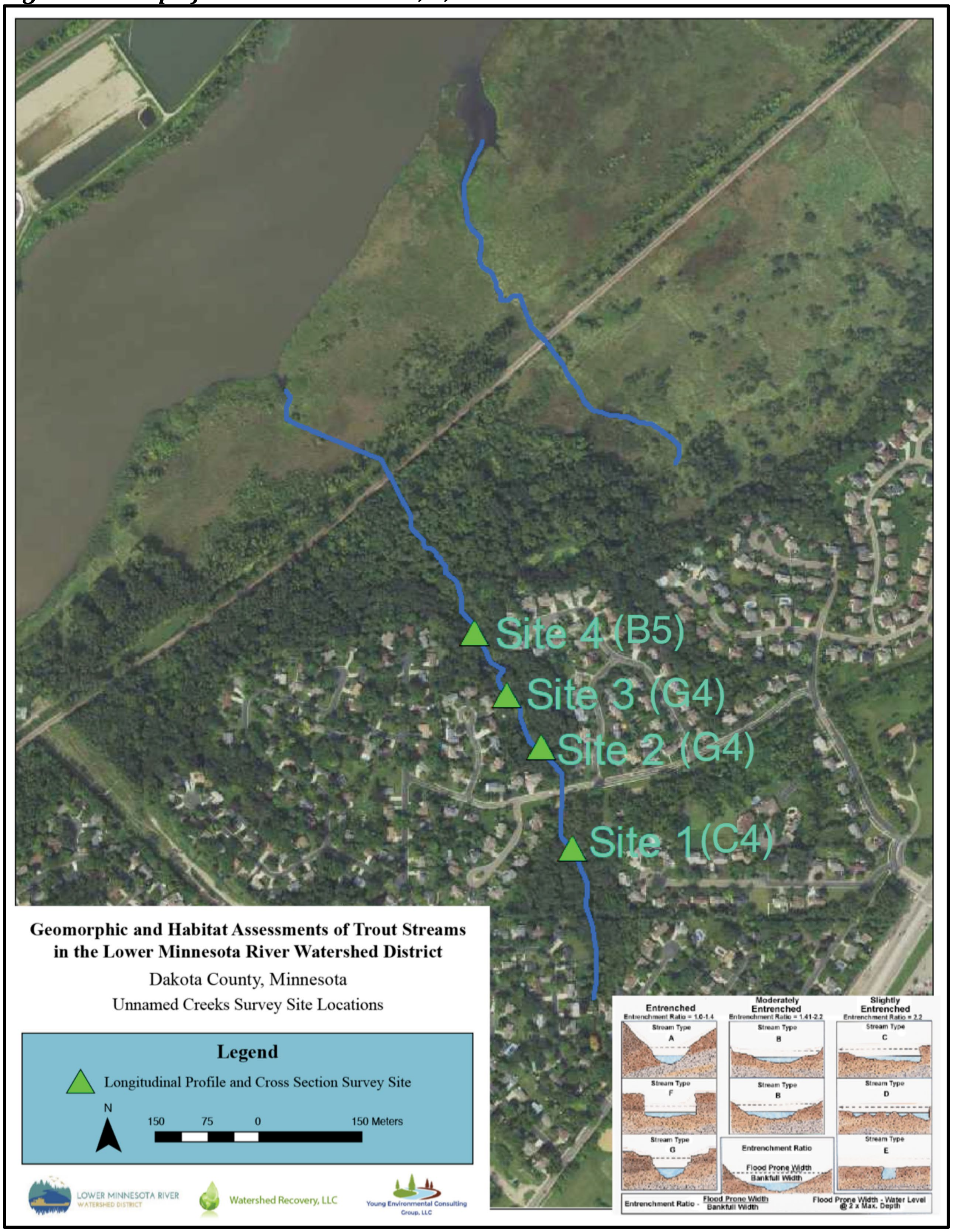
Reconnaissance south of the railroad tracks showed the land was a wetland area with excessive overgrown vegetation, causing the stream to be inaccessible. It often would disappear under vegetation and reappear several feet later. It had excessive muck and siltation built up, especially towards the headwaters. This caused this section of the stream to be impossible to walk through and difficult to survey, as the survey rod would sink in several inches to a foot causing it to be inaccurate. Due to these conditions, no surveys were completed in this branch.

North of the railroad tracks up to Nichols Road, there was one cross section and longitudinal profile that was completed (see Figure 10). The site that was surveyed was estimated to be an A4 stream type (Rosgen, 2008). This branch of the steam was also difficult to survey due to the amount of muck and silt. The stream was becoming more incised as it progressed, showing signs of erosion. The low sinuosity (see figure G.3 in Appendix G) supports the low amount of pools discovered while completing the longitudinal profile.

Because only one survey site was possible on this stream, the survey data is not viable evidence to support or reject the claims made during habitat assessment, as this would require a more comprehensive set of survey data.

4.5 Unnamed Creeks (1, 2, 4, and 7)

Figure 11. Map of Unnamed Creeks 1, 2, 4 and 7.



4.5i Unnamed Creek 1

Unnamed Creek 1 is south of the Minnesota River, and it consists of survey sites 1-4 (see Figure 11). The watershed land use consists of park/residential on the left and right banks. The riparian width remains moderate to wide throughout the stream (30-150 feet). West of Hayes Drive, around survey site 1 the stream is reconstructed (see figure H.1 in Appendix H). Riprap was placed down slope from the road and a wooden box surrounds the culvert that continues the stream under the road (see figure H.1 in Appendix H). Further down on the same side of Hayes Drive, the reconstruction has ended and the stream dries up past this point. Survey sites 2-4 are on the other side of the road, east of Hayes Drive. This branch has significant shade (>75%) from surrounding trees. The averages from the four pebble counts indicate that the main sediment types were fine gravel (27%), fine sand (19%), and medium sand (14%). There was also some larger gravel and cobble observed at survey site 2.

The banks are extremely high, as seen in cross section 3, and contain about 9 feet of erosion (see figure H.2, H.4 in Appendix H). The presence of intense erosion from the steep slopes (see figure H.2 in Appendix H) induced several mid-channel bars, indicating many counts of aggradation which also led to poor depth variability (<8 inches) and fair channel development, lacking a thalweg. The lack of depth variability and pool/riffle sequence is evident in profile 2 (see figure H.5 in Appendix H). The water depth line closely follows the bed elevation, hovering around 2-5 inches of depth in most places (see figure H.5 in Appendix H). The only visible pool is not deeper than 6 inches (see figure H.5 in Appendix H). Cross section 1 provides a visual representation of the missing thalweg, as the bottom of the streambed is mostly the same elevation (see figure H.4 in Appendix H). The erosion and aggradation issues indicated a moderate adjustment for stream stability. Logs, woody debris, shallows, and side channels were all present in the stream as concealment types. No riffles or aquatic vegetation were present in the stream, and minimal bank vegetation was present. The stream's velocity types consisted of slow, stagnant, and intermittent (dry in some areas). At site 4, the high slopes on each side of the bank are farther from the edge of the channel, leaving space for a larger floodplain (see figure H.4 in Appendix H). There is a large riparian zone, with grasses on the terrace and lots of fallen trees (see figure H.3 in Appendix H). After survey site 4 (about 250 feet), there is a catch basin where the stream flows underground to the railroad ditch.

During reconnaissance the stream was classified as a C4/5 near survey site 1, a G4/5 near survey sites 2 and 3, and a B4 near survey site 4 (see Figure 4 for stream classifications). The sediment classifications are consistent with the pebble count data mentioned above. A 'C' stream was hypothesized at survey site 1, with entrenchment ratio greater than 2.2 and the width-depth ratio greater than 12. Cross section 1 is difficult to analyze due to inaccurate water depth and bankfull lines, but the raw data allows for the inference that the bankfull depth was approximately 6 inches, which supports the conclusion that the width-depth ratio is greater than 12 (see figure H.4 in Appendix H) This is because of how shallow the bankfull depth is, and the stream bed width being around 20 ft. Based on this estimate of bankfull, the entrenchment ratio would be around 2, so the stream is slightly more entrenched than originally hypothesized. A 'G' stream was hypothesized in survey sites 2-3. The stream throughout survey sites 2-3 was entrenched and there was no accessible floodplain. Cross section 3 demonstrates this with the steep valley wall on the right side (see figure H.4 in Appendix H). At survey site 4, the stream became a 'B' type because the floodplain was more accessible, increasing the entrenchment ratio. This accessible floodplain is evident in cross section 4. The flat portion on the right before the valley wall slopes up was not part of the channel, but it would allow the channel to expand significantly during a large flood (see figure H.4 in Appendix H). While the valley walls are consistently confined, the streams vary in their entrenchment due to the width of the bankfull channel and the estimated depth at bankfull. The main error during reconnaissance was the estimation of the entrenchment ratio. Cross section analysis shows that the entrenchment was more significant in some locations than originally estimated.

4.5ii Unnamed Creek 2, 4 and 7

Unnamed Creek 2 could not be located because there was a catch basin installed underground after Unnamed Creek 1. Unnamed Creek 7 was removed from the study based on a recommendation by the DNR. No data was collected from these streams.

Unnamed Creek 4 could be located south of the railroad tracks, but because of its wetland nature, no surveying was completed on it. The substrate consisted of muck and silt making it difficult to walk in. The intensity of the overgrown vegetation also made it difficult to traverse on the banks of the streams. Large cattails were present and thick south of the railroad tracks. Unnamed Creek 4 has almost no tree cover, but the stream is shaded due to the large amounts of overgrown bank vegetation. The stream would often disappear under vegetation, making it dangerous to continue to walk forward even with wading rods. It is surrounded by large terraces of canary grass and cattails. and is fairly straight with a few pools but not many run-riffle-pool sequences. What portions of the stream that could have reconnaissance completed on Unnamed Creek 4 were classified as C4 or C5 (see Figure 4 for stream classifications). This substrate classification was due to the observations of gravel and sand being the most common. The 'C' classification is due to the observation that the stream was slightly entrenched, had a moderate to high width depth ratio, and a moderate to high sinuosity. Because there were no longitudinal profiles or cross sections completed, these observations and hypotheses cannot be supported with quantitative data.

4.5iii Unnamed Creeks Baseflow Analysis

Figure 12. Map of Unnamed Creeks 1,2 and 4 Baseflow Measurement Sites.

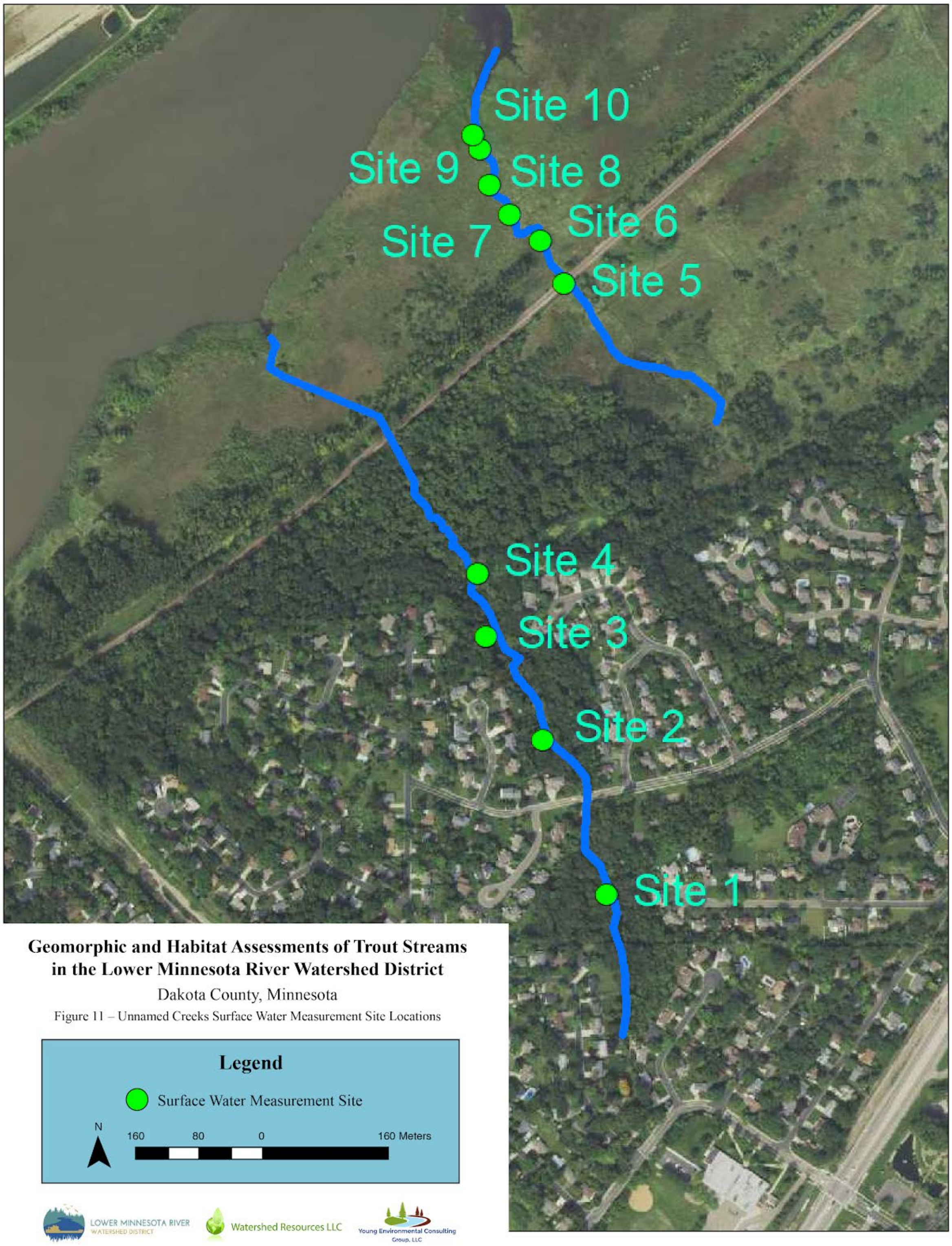


Table 4. Unnamed Creeks 1, 2, and 4 Surface Water Measurements Data.

Site Number	Surface Water Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
1_a	18.3	64.9	6.1
1_b	18.1	63.0	5.9
1_c	17.6	66.6	6.4
2	17.2	80.8	7.8
3	16.9	68.3	6.6
4	17.3	76.5	7.3
5	14.6	75.7	7.7
6	14.8	81.5	8.2
7	15.0	77.3	7.8
8	15.1	78.8	7.9
9	17.3	53.3	5.1
10_a	15.9	73.5	7.3
10_b	22.5	43.4	3.8
Subscripts represent multiple measurements at a single location			

Surface water measurements were taken on Unnamed Creek 1 from the headwaters until it enters the catch basin near site 4. The measurements indicate that the Creek is a gaining stream throughout its length. The focus was then shifted to Unnamed Creek 4. Measurements were taken both south of the railroad bridge, and north of the bridge heading towards the Minnesota River (sites 5-10). Site 10 became the furthest measurement taken as the stream became impassable due to inundation from the Minnesota River. A temperature transition zone was observed at the start of the flooded portion (site 9), with temperatures consistent with groundwater inflow observed south of the zone (sites 5-8). Site 9 was observed to be the start of the transition zone. This was further evident by the increased aquatic biodiversity including the appearance of several fish species observed in the stream, similar to what was seen at Assumption Creek. Following the transition zone, surface water temperatures taken in the flood water along the banks (site 10_a) were measured to be significantly warmer. A second measurement (site 10_b) was taken with the probe placed on the bottom of the stream channel to confirm the loss of groundwater input after this zone. Lower temperatures were observed that remained in concordance with the southern portion of the stream below the transition zone. The different conditions observed are hypothesized to be due to stratification in the water column, with base flow input keeping the bottom of the channel consistent with cold water stream conditions. Inversely, the flood waters are hypothesized to keep the top of the stream at a warmer temperature and keeping the upper portion of the stream at brackish, backwater conditions. The force of the backflow from the Minnesota River is theorized to be nullifying the forward force of the stream, causing the reduction of water cycling throughout the stream, and keeping the stream vertically split into two separate temperature zones. Further work is required to measure surface water conditions and channel sediment temperatures at various points of the stream channel to confirm the current hypothesis on the cause of the condition variations observed.

5.0 Error Analysis

An error analysis is an important component of all scientific studies in order to provide context behind the data presented. The team estimates a 70-75% confidence level in the accuracy of the data collected in this study. Some elements of the data collection were more accurate than others, and they each introduced certain unique forms of error. The most significant error is in the longitudinal profiles and cross sections, which is explained in more detail in this section. Out in the field, the team worked to minimize these errors by adapting to the changing conditions and utilizing group decisions to reduce individual bias.

As with any field work, the data collected in this report was influenced by uncontrolled variables. One significant source of error was the changing conditions in between visits to each stream. As described in the introduction, the flooding of the Minnesota River was significant in 2019. Coupled with multiple large rain events, the water levels at these streams fluctuated greatly during different weeks of the study period. In some cases, this was a positive change; as the flood waters went down, the team was able to access some additional parts of the streams and collect observations and data. However, the fluctuating water levels also made it difficult to determine the “actual” water level that would be present during an average year. Additionally, this introduces error in the comparison aspect of the data analysis. If a storm event occurred between data collection at two streams, the comparison of their water levels may not be completely accurate. One way to reduce this error would be to send out teams to collect data at every stream on the same day. Ideally, this day would be at least three days after a storm event in order to allow water levels to subside. The error due to the extreme flooding could be corrected by repeating similar measurements in 2020 or a future year that would, hopefully, have more average flooding levels.

Another aspect of error that impacted the results is human error associated with each element of data collection. Reconnaissance and habitat assessments involve significant subjective decision-making due to their categorical and estimation-based methods. The team attempted to mitigate this error by engaging in group discussion while recording observations so that no individual team member’s bias would sway the results. Pebble counts are less subjective, but are still impacted by human bias because the measurer has to estimate the intermediate axis of the chosen pebble. Also, when measuring sand smaller than 1 mm, the categorization was a rough visual estimate because it was difficult to measure this size sediment. This error could be reduced by collecting these smaller sediment pieces and measuring them under a microscope. Another option would be to carry samples of each sediment size so that the sediments collected in the stream could be compared to a true “fine sand,” “very fine sand,” etc.

The surveying process utilizes equipment that has the capacity to be more exact than visual distance estimates. However, it is still subject to error. For longitudinal profiles, the surveyor had to estimate bankfull. This can be difficult to determine due to vegetation growth, flooding, and extremely incised banks. At times, there was no sturdy ledge on which to place the survey rod for a bankfull measurement, so the surveyor would have to hold it in place to the best of their ability. Additionally, some of the streams had extremely soft bed material, such that the survey rod sunk into the bed at least an inch. This introduces a larger margin of error because the rod sunk in different amounts at different locations. The tape measure was also a source of error in the surveying procedure because it was not always possible to make it follow the bends of the stream. There were also some points along the stream where significant woody debris or other obstructions forced the tape measure to follow the stream along the bank for a few feet before it returned to the stream bed. To help reduce this tape measure issue, wooden rods were placed at inflection points in order to help the tape measure mimic the stream's meanders. However, this did not allow for the true radii of curvature to be represented. A more accurate length of the stream could be determined by using shorter stretches of tape measure and sturdier rods to hold the tape measure in the thalweg.

When analyzing cross section data, some of the surveying errors became apparent, as the bankfull and water level lines are not in logical positions for some of the cross sections. This could be caused by some of the error in horizontal distance measurement. Some cross sections were not perfectly matched to their location on the longitudinal profiles, so the water level data represented on the graph may not be an accurate representation of the true water level in the cross section location.This incorporates a degree of estimation into cross section analysis because the bankfull elevations and water depths must be inferred based on raw data, photos, and field notes. In order to remedy this data in future work, it would be advisable to complete the cross section surveying at the same time as the longitudinal profiles, without moving the tape measure. This would allow the cross section to be placed within the profile accurately, such that the bankfull and water levels in the longitudinal profile corresponds directly to a cross section.

The longitudinal profile method described earlier in this report was not the original method used for these profiles. The previous method does not diminish the actual data for each section, but it causes difficulties when trying to relate each profile with its adjacent profiles. The original method is described here, so that future studies can streamline the data collection process: Following completion of longitudinal profiles on a stream, the TBMs were resurveyed to get the true elevations with respect to the furthest upstream TBM. This was done by taking a backsight from the furthest most upstream TBM, then taking foresights with the survey rod downstream from the original TBM. Turning points were then made at each foresight with new instrument heights being obtained until a subsequent TBM could be reached downstream from the original benchmark. A foresight was taken at the downstream TBM with the survey rod placed on the top of the rebar. A turning point was then made further downstream of the TBM to continuously survey the other TBMs. This allowed for the elevations of all the TBMs on a stream to be measured with respect to the most upstream TBM, which allowed for a general downward trend to be seen when all longitudinal profiles were connected. Additionally, coordinates were taken at the start and end point of each longitudinal profile, which were later used to connect the profiles.

The water quality measurements taken to track the entrance of baseflow into the streams utilized a YSI 6820 water quality sonde. Due to the need for precision of the instrument in the field, prior calibration of the sonde is required. A potential source of error in these measurements could stem from improper initial calibration of the instrument, degradation of precision due to the length of time between the last calibration and the sonde's usage, and improper recalibration of the DO probe in the field. Other sources of error in the measurements could be random error introduced by the natural heterogeneity of the streams and disturbing the stream bed while traversing the area. A systematic error observed with this process was the placement of the probe in different parts of the channel at areas where backflow from the Minnesota River caused flooding in the stream. Differing temperatures were observed when the sonde was placed near the top of the water column along the banks, and when the sonde was placed on the bottom of the channel at the same point on the stream. The final source of random error observed was temperature increases due to the shallowness of the stream, and exposure to direct sunlight at some of the headwaters of the streams. This source of error found could potentially increase the baseline surface water temperature, and cause higher baseline water temperatures than the temperatures measured further downstream where baseflow still remains the main input into the system. This process could be improved in the future by using the YSI water quality sonde as an exploratory tool to find the general areas where the surface water temperature dramatically changes, and then using a sediment temperature probe to confirm the lack of baseflow entering the stream at those points. This method could reduce systematic error due to probe placement, help reduce random error caused by the natural heterogeneity of the streams, and help attain a more exact baseline temperature of the groundwater.

6.0 Conclusion

6.1 Assumption Creek

Assumption Creek was one of the streams that could not be surveyed in totality due to flooding. The stream possessed varying conditions from aggradation to degradation, but apparent channel adjustments and field observations found that only minor restoration work would be needed. The presence of aquatic vegetation would provide a good food source for trout as it is often inhabited by invertebrates. Also, the excellent depth variability on the east reach provides refuge locations for adult trout while escaping from predators and the hot sun. The east reach does include mid-channel bars, which could be caused by excess sediment entering the system or a lack of sediment transport out of the system. However, the west side is worse trout habitat than the east because of the high siltation. It is hypothesized that the buildup of silt and muck was caused by the shallow water with low flow. Aside from this aggradation, the knickpoints observed are also potential signs of instability and they could indicate the fact that the channel is going through a stream type change. The creek was found to have suitable surface water temperatures and substrate types for the majority of the survey portion of the stream, but future investigations should proceed on Assumption Creek to evaluate the stream in more detail, including the portions not yet surveyed this field season. Surface water temperature measurements at the creek showed the presence of baseflow input throughout the stream until the backflow from the Minnesota River created flooded conditions in the creek. This disruption created cool-warm water fishery conditions in the stream, and reduced the available stream length that supports suitable conditions for trout populations. Due to Assumption Creek's location inside Seminary Fen and the legal protections that accompany this, Assumption Creek was found to be one of the more viable streams for any future restoration work. A level III Rosgen assessment is recommended (explained further in Continuation of Work section), along with levels I and II on the portions that were flooded for this field season.

6.2 Eagle Creek

Eagle Creek was found to have some of the greatest potential for sustainable trout habitat, but current aggradation in the stream warrants further investigation. Suitable substrate for spawning, cold surface water temperatures, and other key features such as good depth variability have been observed, which signify the viability of the stream. The habitat also includes key components for both young trout (D type stream with shallows and slow flow), as well as adult trout (deep pools and overhanging vegetation for shade and feeding). Significant flow refuge accessibility in the reconstructed reach would allow trout to survive flooding events. The key concern the study found for this stream resides in the loss of its sediment transport abilities, causing extensive sand deposition throughout Eagle Creek. The extensive deposition creates diminished available habitat for trout, and provides evidence for instability in the stream. These findings provide the basis for future in-depth investigation into Eagle Creek. Even with these concerns, this stream was the only stream in the study to have several trout observed in it while the team was in the field. The aggradation occurring on Eagle Creek also warrants additional level III assessment to predict the stability of the stream. Future work could include measurements to determine the stability of the channel bed by using scour chains. Bank pins could additionally be used on both the stream banks and valley walls to determine the amount of erosion occurring at the creek. This could be done to identify the sources of sediment in the stream, and locate the areas on the stream that are more susceptible to erosion or mass wasting. Future work could also be done on monitoring Eagle Creek to determine if the aggradation is due to the stream's decreased ability to transport sediment, or if it is due to the backflow of the Minnesota River from extreme flooding. A potential theory for the source of the aggradation is that the force from the backflow is disrupting the flow velocity in the stream by flattening out the slope, causing the deposition of the sand. Future monitoring could be potentially done over a longer temporal scale to observe if the aggradation continues over multiple years, which would determine that the aggradation is occurring due to inherent instability in the stream.

6.3 Ike's Creek

Ike's Creek is one of the other streams that merits priority based off the study's results. The creek was found to be unstable stemming from the density of knickpoints throughout its length. The concentration of knickpoints indicate degradation, due to an increase in discharge and stream power. The large amount of impermeable surface in the surrounding urban area could increase the flow that enters the stream after a storm event, possibly contributing to some of these signs of erosion and degradation. Despite this negative aspect of the stream, Ike's Creek was found to have suitable water temperatures for trout and the substrate type needed for trout spawning to occur. The intense instream vegetation warrants further investigation to determine whether it would be beneficial for trout (as a refuge) or a blockage to flow. Level III assessment is also recommended, along with continued observations of the trout population which was stocked in 2007. Finally, the team recommends close collaboration with the DNR as they monitor for possible changes in the stream caused by runoff or other external factors.

6.4 Kennaley's Creek

Kennaley's Creek was investigated on a limited basis due to large swaths of the creek system remaining flooded throughout the entire field season. The Creek's western branch was subjected to exploratory investigation work and limited surveying. Further work was not commenced on the stream after an internal designation of the stream as a non-priority for this study, due to inaccessibility and diminished trout habitat viability observed. The stream showed signs of instability in the form of large knickpoints, as well as channel incisement signalling degradation occurring. Heavy siltation, heavy embeddedness, and poor channel morphology are all conditions that were found in this limited reach of the stream. Due to the lack of data collected on this stream, no definitive conclusions were able to be made. The creek as a whole could not be analyzed based on one survey point. Further observations and data need to be collected when there is a lower flow and more of the stream is able to be accessed.

6.5 Unnamed Creeks 1, 2, and 4

The Unnamed Creeks were investigated, with the findings showing that Unnamed Creek 4 would be the stream to prioritize out of this stream system. Unnamed Creek 1 was found to have very low water depths and large amounts of mass wasting on the valley walls inputting sediment into the stream. The creek was found to have unsuitable habitat for trout, despite good substrate types and water temperatures. Unnamed Creek 4 was not surveyed during this field season due to flooded waters, but was later observed during hydrologic field measurements on the creek. Suitable substrate, higher water levels, and colder surface water temperatures provided promising preliminary observations of the stream. Historical information supplied by Dan Callahan of Trout Unlimited sheds light on the potential of this stream if Unnamed Creek 1 was routed back towards it's historical stream path (Callahan, 2016b). This stream warrants further investigation, but restoration work may be hindered if the Union Pacific Railroad culvert remains closed. No data was collected on Unnamed Creek 7.

6.6 Continuation of Work

The continuation of the work on this study would include a Level III assessment according the *River Stability Field Guide* by Dave Rosgen. This would include stream stability indices, the BANCS Model to predict the stream bank erosion, sediment competence/entrainment, sediment supply and transport capacity, and stream succession stage shift. There are various worksheets in this level under these categories that would be completed to show a river stability prediction. This assessment would lead to an understanding of what is going on within a river system and would help plan restoration priorities. (Rosgen, 2008). Further hydrogeological investigations could be performed on each of the streams to more accurately pinpoint the locations on the streams where baseflow is entering. Future exploratory work could include using a sediment temperature probe for preliminary investigations. Following this, multiple wells could be installed in key locations to confirm the boundaries between where the streams are gaining groundwater and where the streams are losing surface water into the ground. This could be expanded upon over a longer temporal scale using pressure transducers to monitor the boundary change in-situ to determine the gain or reduction of stream lengths with suitable temperature conditions for trout over an annual period. The observations in the field at the Unnamed Creeks found that the surface water temperatures taken at flooded portions of the stream varied with depth in the stream channel. More work could be done to determine if the upper portions of the water column are acting as cool-warm water fisheries, while the bottom of the channel is remaining a cold water environment. More measurements taken in flood portions of the stream at different depth intervals could be taken to confirm the findings, and determine if the bottom of the stream channels are still able to remain habitable for trout.

Jeff Weiss, project manager from Barr Engineering had some recommendations for future work to be completed on the streams as well, beginning with bankfull identification as it relates to the basis of analysis. Longitudinal profiles with bankfull indicators help, but there are often clear outliers as not every survey site has a good bankfull indicator. Another following step includes slope analysis. If the bankfull slope and the average channel slope match, a stream is not generally degrading or aggrading. If the channel is steeper than bankfull it is likely downcutting, while if the two are getting closer downstream the stream is most likely aggrading. This step could be especially useful on Eagle Creek. Another step would be field observations during bankfull events. This can be difficult because flows are not consistent, and this can also create unsafe conditions of high water depth and high velocity. Observing the high flows allows for understanding whether or not the flows are consistently hitting bankfull indicators. Measuring flows at different water levels can help develop a rating curve. This is helpful when capturing flows near bankfull, and would help calibrate any future efforts to model each stream. It can also be helpful to take flow measurements in order to look at water conditions throughout the year. Completing a watershed assessment is also useful, especially at places like Eagle Creek. Flows are also high because of increased precipitation, which causes degradation initially. As the water levels lower, the sediment is redeposited in the stream. A watershed assessment would help identify where it is coming from. Developing a long-range plan to increase infiltration to help increase groundwater inputs would also be useful. Finally a discussion on habitat limitations is suggested to be completed in greater depth (Weiss, 2019).

A final recommendation for future work is to continue to involve local stakeholders. Upon researching background information for this report, several connections to residents, businesses, and invested partners were uncovered and partnerships were created. These partners include Twin Cities Trout Unlimited, the East and West Metro Fisheries Offices for the Minnesota DNR, the US Fish and Wildlife Service, and local landowners who have expressed interest in potential restorations. Collaboration with these partners was and is crucial to these potential restoration projects. Maintaining this relationship could involve sending out information on this project completed and the results/conclusions.

6.7 Lessons Learned in the Field

This project provides valuable insights which can be used for future work. Longitudinal profiles need to be connected in one long continuous profile connecting all the cross section temporary benchmarks (TBMs) so that the cross sections can be linked in their elevations in the Mecklenburg spreadsheet. Coordinates should be taken at the start and end of each longitudinal profile so that it can be marked on a map and revisited in case of error. Taking pictures at the beginning and end of longitudinal profiles along with cross sections is also beneficial when needing to revisit the survey locations in order for precision. The TBM should be well-marked and in accessible locations. Landmarks near the TBM should also be marked in order for ease of relocation of the sites. TBMs should be placed in the highest part of the valley wall for cross sections but should also be placed in an accessible location when returning for longitudinal profiles (ie: not behind trees or large objects blocking the view from the stream (20 feet up/down stream)).

Keeping a separate stream reach notebook for each stream leads to ideal organization when revisiting notes/data. This makes searching for results much easier to complete and reduces confusion on where data has been written. Taking pictures of the data also creates a backup source of storage in case of lost or damaged notes. Completing the habitat assessment sheets after completing a continuous longitudinal profile is ideal. This ensures that the whole reach of the stream has been observed in order to mark accurate comments on the sheet. It is also crucial to have waterproof notebooks in order to keep written data safe.

In order to complete the work in the most comfortable way during the hot summer months, uninsulated and breathable waders are recommended to prevent wet clothes and mosquito bites. Gloves are also ideal to prevent cuts, rashes, and mosquito bites while surveying as the hands are always on the survey rod, writing, or generally out in the open. Important safety tools needed for this job include wading rods and lifejackets. There were at least 3 deep groundwater springs found at Eagle Creek, so wading rods were useful to see water depths of the stream. These are useful not only at Eagle Creek, but at the other creeks as well, preventing accidents when major changes in depth occurred. First aid kits and eye wash are needed in case of injuries or getting chemicals in eyes. Sunscreen, bugspray, bug nets, and long sleeves are also needed to protect against the sun, and against insects such as ticks and mosquitoes that carry unwanted diseases. This work should ideally be completed in the spring or early summer due to vegetation overgrowth causing safety hazards later in the summer. In some instances, the vegetation completely covered the stream, almost to the point of invisibility. In the case of unstable terrain it is best to keep a distance of 10 feet from the laser leveler once it is level. The instability of the ground causes the laser level to continue to relevel. Keeping an adequate distance away ensures that the ground under the laser level does not move. In situations where there are extreme differences in elevation between the stream and the bank, it is best to complete a turning point as soon as possible so that the survey rod does not need to be raised to an excessive height (15+ feet) for each survey site. While surveying an extremely incised channel, it is best to have two people complete the surveying, one completing bankfull and the other completing stream depth and water depth. This prevents the main surveyor from needing to climb on and off of the bank for each measurement.

7.0 References

Brooks, K.N., Ffolliott, P.F. and Magner, J.A.: (2013). HYDROLOGY AND THE MANAGEMENT OF WATERSHEDS, 4th edition, Wiley-Blackwell, Hoboken, NJ.

Callahan, D. (August 2016a). The Lost Trout Streams of Burnsville. *Trout Unlimited Minnesota, p.16-17.*

Callahan, D. (February 2016b). Twin Cities Lost Trout Streams. *Trout Unlimited Minnesota, p.18-19.*

Callahan, D. (2015a). Twin Cities Lost Trout Streams. *Trout Unlimited Minnesota, p.6-7.*

Callahan, D. (2015b). Hust Creek Update. *Trout Unlimited Minnesota, p.8.*

DeZiel, B. (2019a). *Habitat needs of trout.* Personal communication, email.

DeZiel, B. (2019b). Personal communication, email.

DeZiel, B. (2019c). Stream Habitat Assessment for Small Headwater Streams Standard Operating Procedure. *Caddis Fish Consulting, LLC.*

Harper, J. (2016). Burnsville, Eagan streams that once held trout eyed for restoration.

Harrelson, C. C., Rawlins, C. L., & Potyondy, J. P. (1994). Stream channel reference sites: an illustrated guide to field technique. *Gen. Tech. Rep. RM-245. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.*, *245*.

Johnson, A. W. (1978). *The Effect of Spoil Piles from Highway Construction on a Small Trout Stream* (Thesis). University of Minnesota.

Little, J. (1993). Kennaelly's Creek Update. *Minnesota Trout.*

Loomis, L. (2019). Personal communication, email.

Lower Minnesota River Watershed District. (2018). *Watershed Management Plan for the Lower Minnesota River Watershed District 2018-2027.*

Maccaroni, K. (2015). *River Survey*. Minnesota Department of Natural Resources.

Meersman, T. (6/4/2012). Trout return near MOA. *Star Tribune.*

Metropolitan Council. (2014). Eagle Creek. In Comprehensive water quality assessment of select metropolitan area streams. St. Paul: Metropolitan Council.

Minnesota Department of Natural Resources (2019). Trout Angling Opportunities in Southern and Central Minnesota.

Minnesota Department of Natural Resources (2006). *Stream Survey: Unnamed Stream No. 1, Dakota County.*

Minnesota Pollution Control Agency (MPCA). (2017). *Lower Minnesota River Watershed Monitoring and Assessment Report.* Saint Paul, MN.

Minnesota Trout Unlimited (1994). A Statement of Minnesota Trout Unlimited: Restoration of Kennealy's Creek.

Nemeth, M. (2015). Dakota County Unnamed Streams Temperature Monitoring 2015.

Nerbonne, B. (2019). Personal communication, email.

Nerbonne, B. (2017). Personal communication, letter

Niskanen, C. (6/16/2007). Creek near Mall of America becomes a trout stream again. *Pioneer Press.* Bloomington, MN.

Rosgen, R. (2008). *River Stability Field Guide.* Fort Collins, CO: Wildland Hydrology

Sparrow, M. (9/30/2012). Hust Creek. *Twin Cities Trout Unlimited.*

Standards and Criteria for Identification, Protection, and Management of Calcareous Fens, MN. 8420.0935 (2009).

WCCO News. (6/2/2012). Trout Restoration Project Underway Near MOA. *CBS Local.* Bloomington, MN.

Weiss, Jeff. (2019). Personal communication, email.

Wendel, J. (2019). Personal communication, email.

Young Environmental Consulting Group, LLC. (2019). *Lower Minnesota River Watershed District- Draft Monitoring Plan.*

8.0 Appendix
Appendix A: Background Information Figures

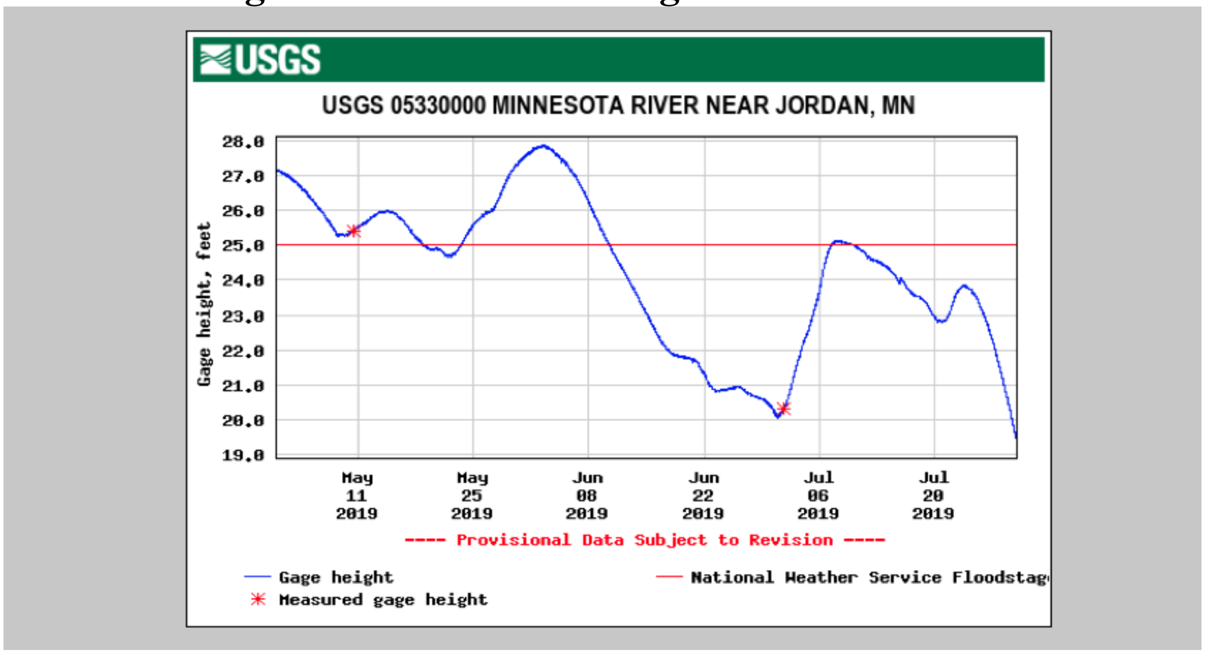


Figure A.1. USGS Hydrograph of the Minnesota River.

Figure A.2. Eagle Creek in 2014 on left and picture of increased aggradation in 2019 on right. Brenda DeZiel (2014). Kirsten Haus (June 2019).

Figure A.3. Ike's Creek restoration (6/2/2012) taken by Tony Nelson of Twin Cities Trout Unlimited.

Figure A.4. Underwater photograph of Unnamed 4. Dan Callahan (2016).

Appendix B: Habitat Assessment Worksheet

SMALLL HEADWATER HABITAT ASSESSMENT (SHHA) (DeZiel, 7/2019)

1. Stream Documentation — **SCORE** ☐ **MAX=100**

Station ID: ________________ Stream Name: ________________________________ Date: ____________________

Rater Name(s): __________________________ Water Level (circle one): Flood / High / Normal / Low / Very Low

2. Watershed Land Use (check the most predominant or check two and average scores) [L=left bank/R =right bank, facing downstream]

L	R			L	R		
☐	☐	Forest, Wetland, Prairie, Shrub	[5]	☐	☐	Diked Wetland	[2]
☐	☐	Old Field/Hay Field	[3]	☐	☐	Urban/Industrial	[0]
☐	☐	Fenced Pasture	[2]	☐	☐	Open Pasture	[0]
☐	☐	Residential/Park	[2]	☐	☐	Mining/Construction	[0]
☐	☐	Conservation Tillage, No Till	[2]	☐	☐	Row Crop	[0]

Comment:

Land Use ☐ **Max=5**

3. Riparian Zone (One check for each column. Circle two if very different conditions exist within reach. +*Note below or on back*).

A. Riparian Width

L	R			
☐	☐	Extensive	>150ft/ 50m	[4]
☐	☐	Wide	100-150ft/30-50m	[3]
☐	☐	Mod.	30-100ft/10-30m	[2]
☐	☐	*Narrow+*	15-30ft/5-10m	[1]
☐	☐	*Very Narrow+*	3-16ft/1-5m	[0]
☐	☐	*None+*	<3ft/ <1m	[-2]

B. Riparian Flow Refuge (at/above annual high flow)

- ☐ Wide, accessible >80% [4]
- ☐ Mod. width, or 50-80% [3]
- ☐ Narrow or 20-50% [2]
- ☐ *Very narrow+ or 10-20%* [1]
- ☐ *None+ or <10%* [-2]
- ☐ Incised ☐ close valley wall

C. Bank Erosion (active erosion)

- ☐ Natural, small areas [2]
- ☐ Minor issues [1]
- ☐ *Mod. issues+* [-1]
- ☐ *Major issues+* [-2]

D. Shade (check predominant) ☐ trees ☐ shrubs ☐ grass/forbs

- ☐ Heavy >75% [4]
- ☐ Well shaded 50-75% [3]
- ☐ Mod. 25-50% [2]
- ☐ *Light+* 5-25% [1]
- ☐ *None+* <5% [0]

Riparian ☐ **Max=14**

4. Instream Zone

A. Substrate (check two for each CT, one if >80%,

	Boulder >100mm [7]	**Lg Cobble** 65-100mm [9]	**Sm Cobble** 35-65mm [9]	**Crs-Gr** 15-35mm [8]	**Fn -Gr** 8-15mm [8]	**Sand** (<8mm) [6]	**Clay** [6]	*Bedrock* [4]	*Woody debris* [4]	*Silt* [-1]	*Muck (anoxic)* [-2]	Channel Type (CT) (%/ ~number)
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	_____/_____
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	_____/_____
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	_____/_____
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	_____/_____
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Present >5%

B. Embeddedness) (avg score when both riffle and run rated)

- ☐ Not rated, sand/silt only [0]

Riffles

- ☐ None (clean) <5% [6]
- ☐ Light 5-25% [3]
- ☐ Mod. 25-50% [1]
- ☐ Severe >50% [-2]

Runs

- ☐ None (clean) <5% [6]
- ☐ Light 5-25% [4]
- ☐ Mod. 25-50% [2]
- ☐ Severe 50-75% [-1]
- ☐ Very Severe >75-100% [-2]

C. Siltation (areas affected)

- ☐ Silt Free (none, very little) [1]
- ☐ Silt Low (edges or little) [0]
- ☐ Silt Mod. (pools/runs effected) [-2]
- ☐ Silt Heavy (all or most of reach -except fast areas) [-3]

D. Substrate Types (best in bold)

- ☐ ≥4 best types [3]
- ☐ 3 best types [2]
- ☐ 2 best types [1]
- ☐ 1 or no best types [0]

Substrate ☐ **Max=28**

5. Cover/Refuge

A. Cover Types/Refuge (check all where >5% and functional; Max score=9)

- ☐ **Undercut Banks** [1]
- ☐ **Overhanging Veg** [1]
- ☐ **Deep Pools** (>20 in, 50 cm) [1]
- ☐ **Logs** [1]
- ☐ **Boulders/ Lg cobbles** [1]
- ☐ **Woody debris (sticks)** [1]
- ☐ **Rootwads** (large tree roots) [1]
- ☐ **Rootmatts** (small feathery roots) [1]
- ☐ *Shallows (slow water 3-6in, 8-15cm* [1]
- ☐ *Backwaters, Side channels* [1]
- ☐ **Leaf Packs** [1]
- ☐ **Instream Veg** (note type on back) [1]

B. Cover/Concealment Amount (in bold)

- ☐ Extensive >50% [9]
- ☐ Mod. 25-50% [6]
- ☐ Very little 5-25-% [3]
- ☐ Sparse <5% [1]
- ☐ *Dense veg+* (no raceway) [-2]

Cover ☐ **Max=18**

6. Channel Morphology (+note/comment on back)

A. Depth Variability (absolute change in depth)

- ☐ Excellent (lots of variation, a few >18in/ >45cm) [6]
- ☐ Good (mod. variation; some 12-18in/ 30-45cm) [4]
- ☐ Fair (minor variation; a few 8-12in/ 20-30cm) [2]
- ☐ *Poor+ (fairly uniform depth, <8in/20 cm)* [0]

B. Channel Stability (flow related)

- ☐ Stable [9]
- ☐ Minor adjustment [6]
- ☐ *Mod. adjustment+* [3]
- ☐ *Major adjustment+* [0]

C. Velocity Types (check all present)

- ☐ Fast (very quick) [1]
- ☐ Mod. (between slow and fast) [1]
- ☐ Slow (barely perceptible) [1]
- ☐ Eddies (circular flow) [1]
- ☐ *None (stagnant)+* [-1]
- ☐ Torrential (could not stand) [-1]
- ☐ Intermittent (dry areas) [-2]
- ☐ Interstitial (flow through rocks) [-1]

D. Degree of Stream Meandering

- ☐ High (at least 2 good bends w/ deep pools) [5]
- ☐ Mod. (at least 1 good bend, pools mod. depth) [3]
- ☐ Low (poor bends, w/ no or sm shallow pools) [2]
- ☐ *None* (poor or no bends, no or few pools) [0]
- ☐ *Channelized* ☐ *B channel* ☐ *Overwidened*

E. Pool Width/ Riffle-Run Width

- ☐ Pool > Riffle-Run [4]
- ☐ Pool = Riffle-Run [2]
- ☐ Pool < Riffle-Run [0]
- ☐ *Run mostly/only+* [-2]
- ☐ *Pool mostly/only+* [-2]

G. Modifications (*check all present*)

- ☐ Straightened [-1] ☐ Dredged [-1]
- ☐ Narrow culvert [-3] ☐ Cemented/Riprap [-2]
- ☐ Channel cut through wetland [-2]
- ☐ Restoration/ bank/bottom armoring [0]
- ☐ *Impounded+* [-3] (note type on back)
- ☐ *Fish Barrier+* [-3] (note type on back)

F. Channel Development (pool/riffle/run, thalweg)

- ☐ Excellent (multiple sequences, clear transitions, thalweg very distinct) [9]
- ☐ Good (a few sequences w/ fair transitions, thalweg distinct) [6]
- ☐ Fair (present, but poor quality, thalweg not distinct [3]
- ☐ *Poor* (lacking, no obvious thalweg) [0] ☐ *low-gradient* ☐ *aggraded channel*

Channel Morph. ☐ **Max=35**

Station ID: _______________	**Stream Name:** ___________________	**Date:**__________	**Person scoring:**__________

Station photos: Field ID: Y / N_________________Middle US: ____________________Middle DS:___________________

Aquatic Vegetation (Instream, in water) Veg Present, not rated ☐ None observed or very sparse See photos ☐

Ratings: Excessive (problem?)=[5]; Abundant=[3]; Moderate=[2]; Sparse=[1]; None=[0]);

Submergent (completely in water)	**Emergent** (standing in water, tall above surface)	**Floating leaf** (in water, leaves flat on water)
____ Water cress	_____Sedge (*triangular*)	____ Duckweed
____ Coontail	_____ Bullrush	____ Floating leaf pond weed
____ Water weed/pond weed	_____ Cattail _____ Reed Canary Grass (Sub/ Em/ Fl)	

____ Algae-on rocks (green mossy) ____ Algae –slimy ____Algae –filamentous (stringy, green) _____ Algae - matts (scum)

Comment: ____

Pool depth ________**ft; DS Riffle/Run depth** _______**ft; Res depth** ________**ft; Pool depth diminished?** Y N M; sand silt WD

Stream Condition/ Stressor Identification (SCSI) Checklist

Present	Photo	Stream Condition
		A. Quality for Spawning/Feeding/Refuge
		+Run/Riffle Substrates Suitable for Spawning
		+Run/Riffle Substrates Suitable for Feeding
		+Logs/WD w/ fast flow (acting like rock riffles)
		+Pool refuge present (one deep pool >20 in)
		- Gravels bright or spongy, moved recently
		- Pool depths mostly/all shallow (<20 in)
		- Algae slimy on rocks
		B. Groundwater/Wetlands
		Springs/ Groundwater Seeps Observed
		Wetland Riparian (sedges, bulrush, cattails)
		Station downstream of wetland
		Station upstream of wetland
		C. Hydrologic Influences
		Backflow from downstream river/stream/lake
		Storm Water Culverts (dump into stream)
		Irrigation Pumps in Stream
		Drain Tiles
		Center Pivot Irrigation Near Stream
		No-flow - Beaver dams
		No flow – road culvert or rock riprap
		D. Blockage to Fish Passage
		Possible Culvert Issue at road crossing
		Artificial Grade Controls/ Check Dams
		Natural Grade Controls/ Waterfall
		Beaver Dams
		Rock Dams
		Carp/ Fish Barrier
		E. Fish/ Invertebrate Presence
		Fish observed
		Inverts observed

Present	Photo	Stressors	Problem
		F. Excess Nutrients	
		Filamentous Algae	
		Blue/Green Algae (surface/column)	
		Dense Macrophytes (instream)	
		Duckweed (small floating leaf)	
		G. Riparian Management	
		Landscaping to Stream Edge	
		Impervious Surfaces	
		Construction -soil disturbed	
		Herbicide Use on Stream Edge	
		Heavily Grazed Pasture/ Feedlot	
		Row-crop to Stream Edge	
		Animal Access to Stream	
		Manure Storage/ Lagoons / WWTP	
		H. Bank Erosion	
		Cutting below rootline (Incised)	
		Groundwater seeps at toe of bank	
		Flow deflectors – logs, tree fall	
		Flow deflector- lateral bar buildup	
		Flow deflector- mid-channel bar	
		Steep banks, non-cohesive soil	
		Trampling (note type):	
		I. Channel Stability	
		Incised–excess scouring (CEM II)	
		Knickpoint observed (CEM II)	
		Diagonal riffle observed (CEM II)	
		Excess Aggradation-sand ripples	
		Overwidened (CEM III)	
		Midchannel bars (CEM III)	
		Stream was overwidened, now point bars & thalweg redeveloping (CEM IV)	

Habitat Assessment/Stream and Riparian Condition/Photos Comments:

____

____

____

Figure B.1. Habitat assessment sheet courtesy of Brenda DeZiel.

Appendix C: Diagrams

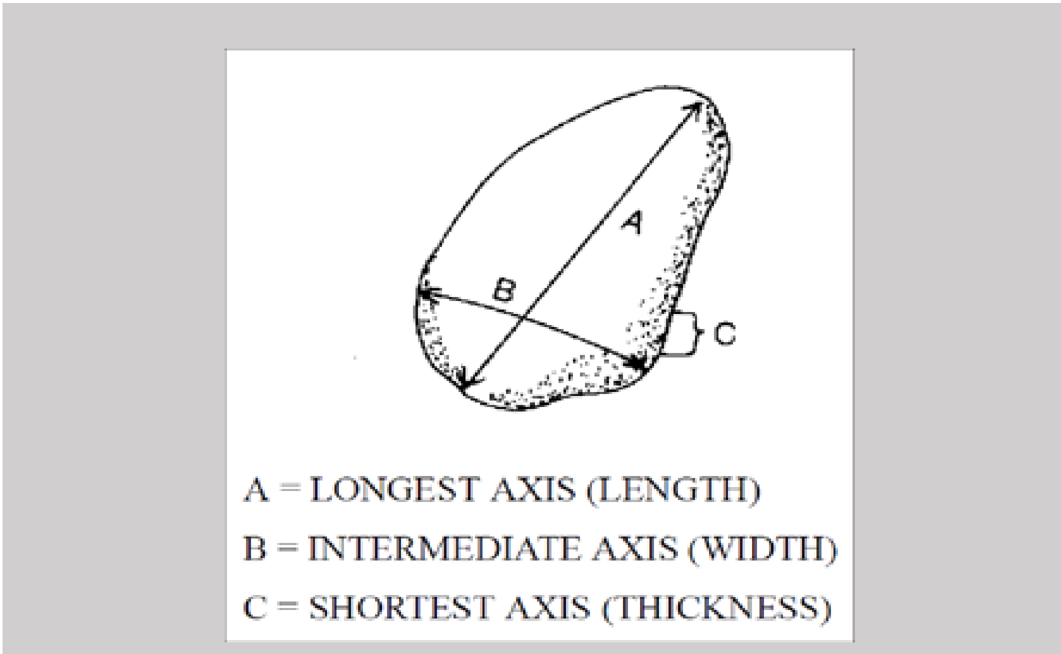


Figure C.1. Pebble Count Intermediate Axis Diagram (Harrelson, 1994).

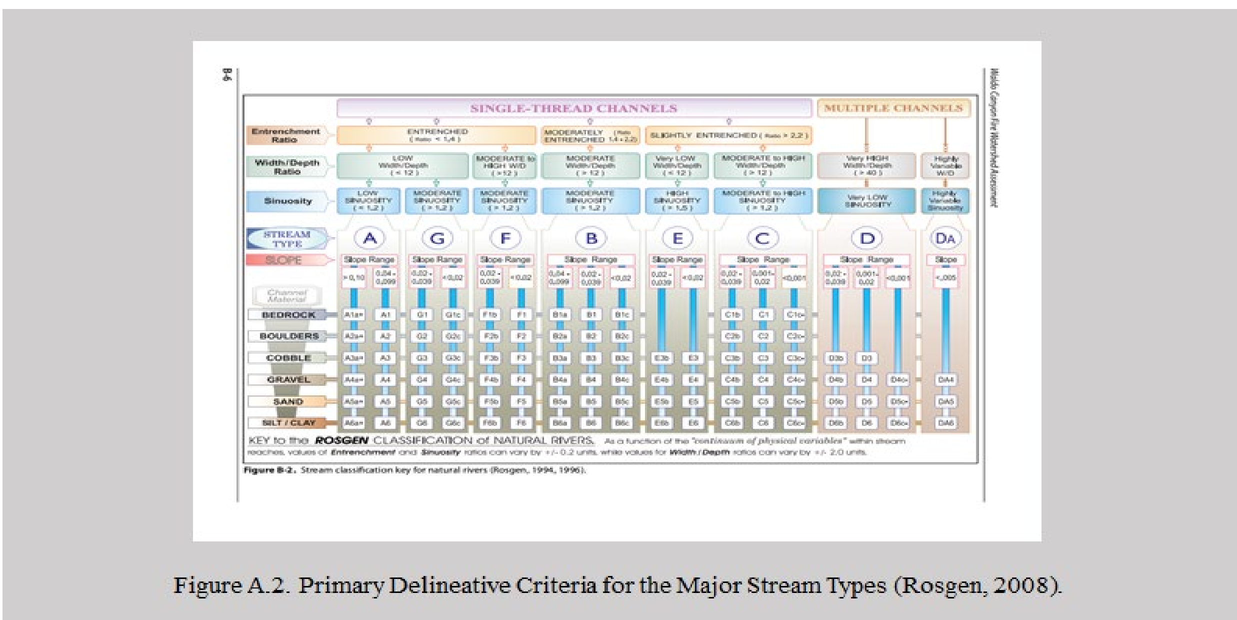


Figure C.2. Primary Delineative Criteria for the Major Stream Types (Rosgen, 2008).

Appendix D: Assumption Creek Figures and Data

<u>Assumption Creek - West Reach</u>

Figure D.1. Muck and silt present at Assumption Creek Western reach. Erica Bock (July 2019).

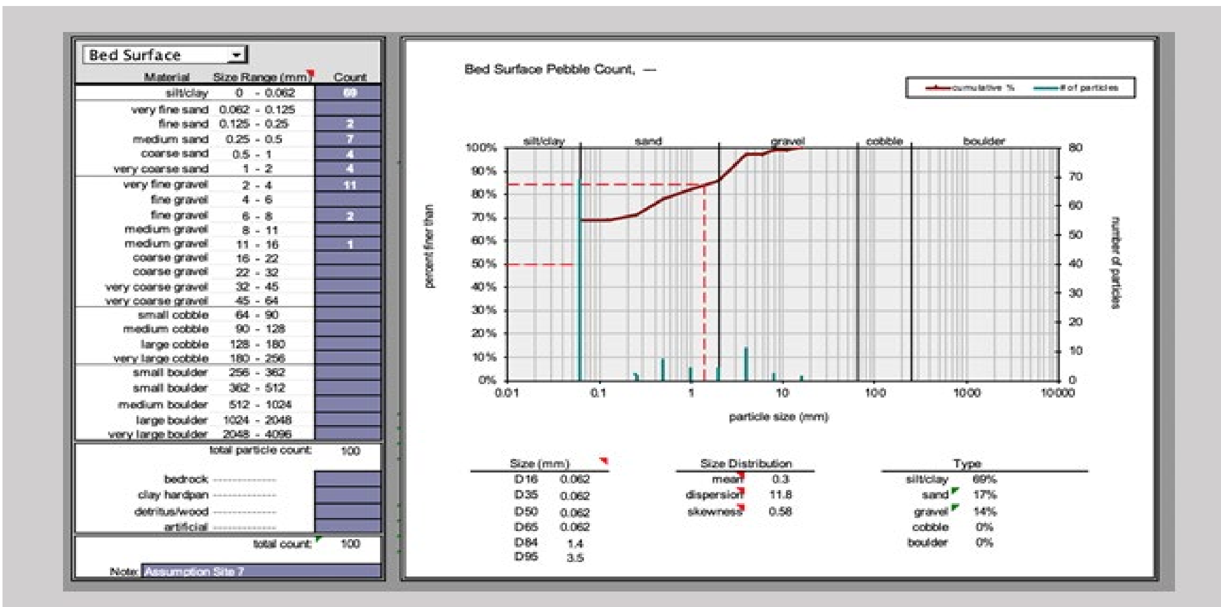
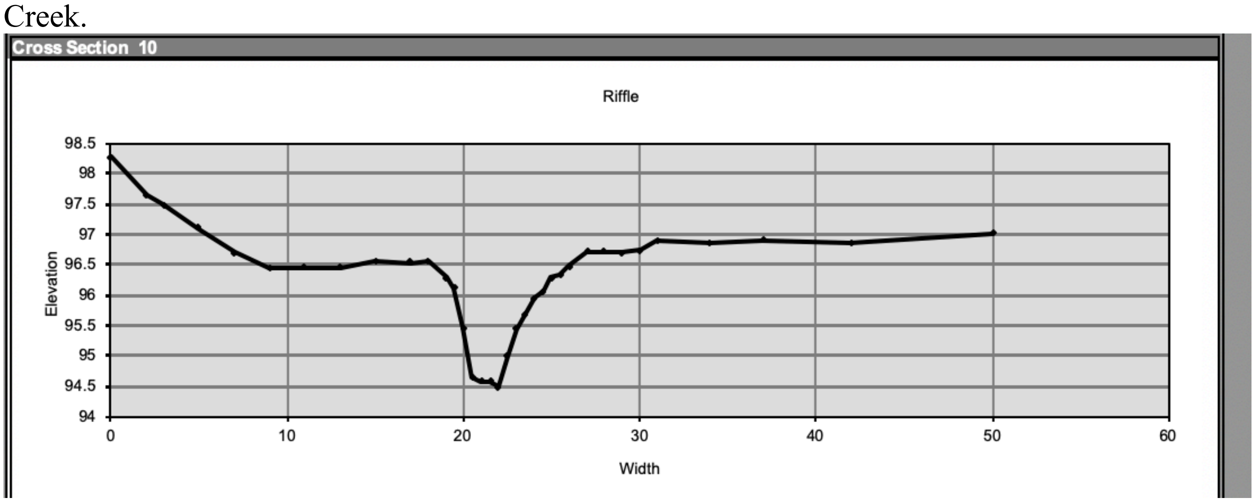
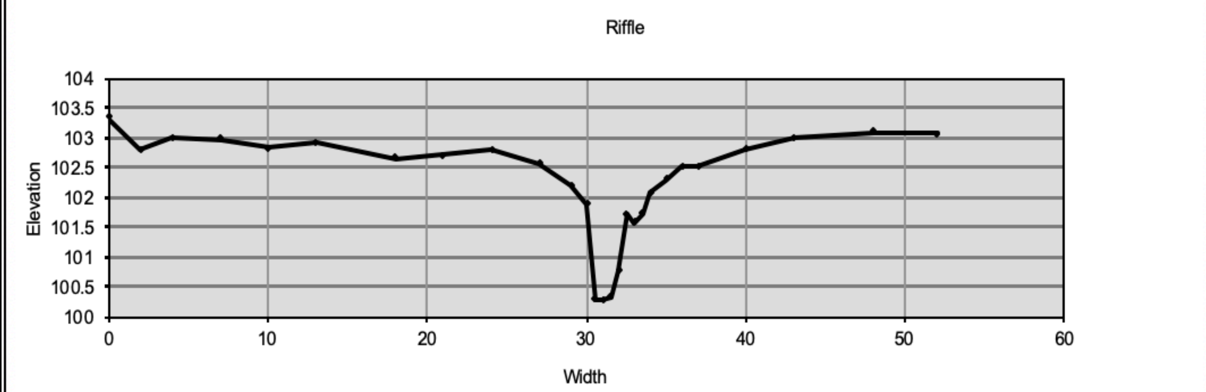


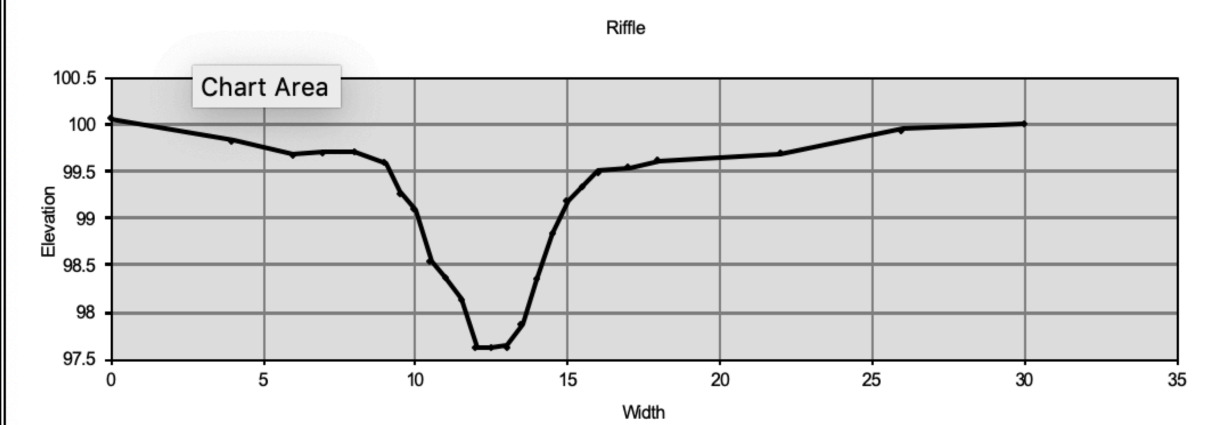
Figure D.2. Pebble Count for the Western reach of Assumption Creek.



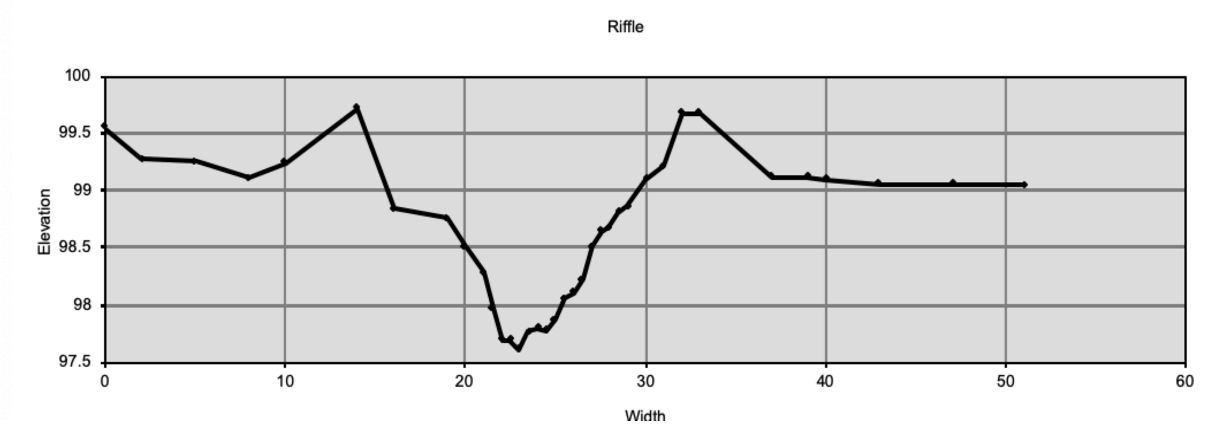
Cross Section 7



Cross Section 8



Cross Section 9



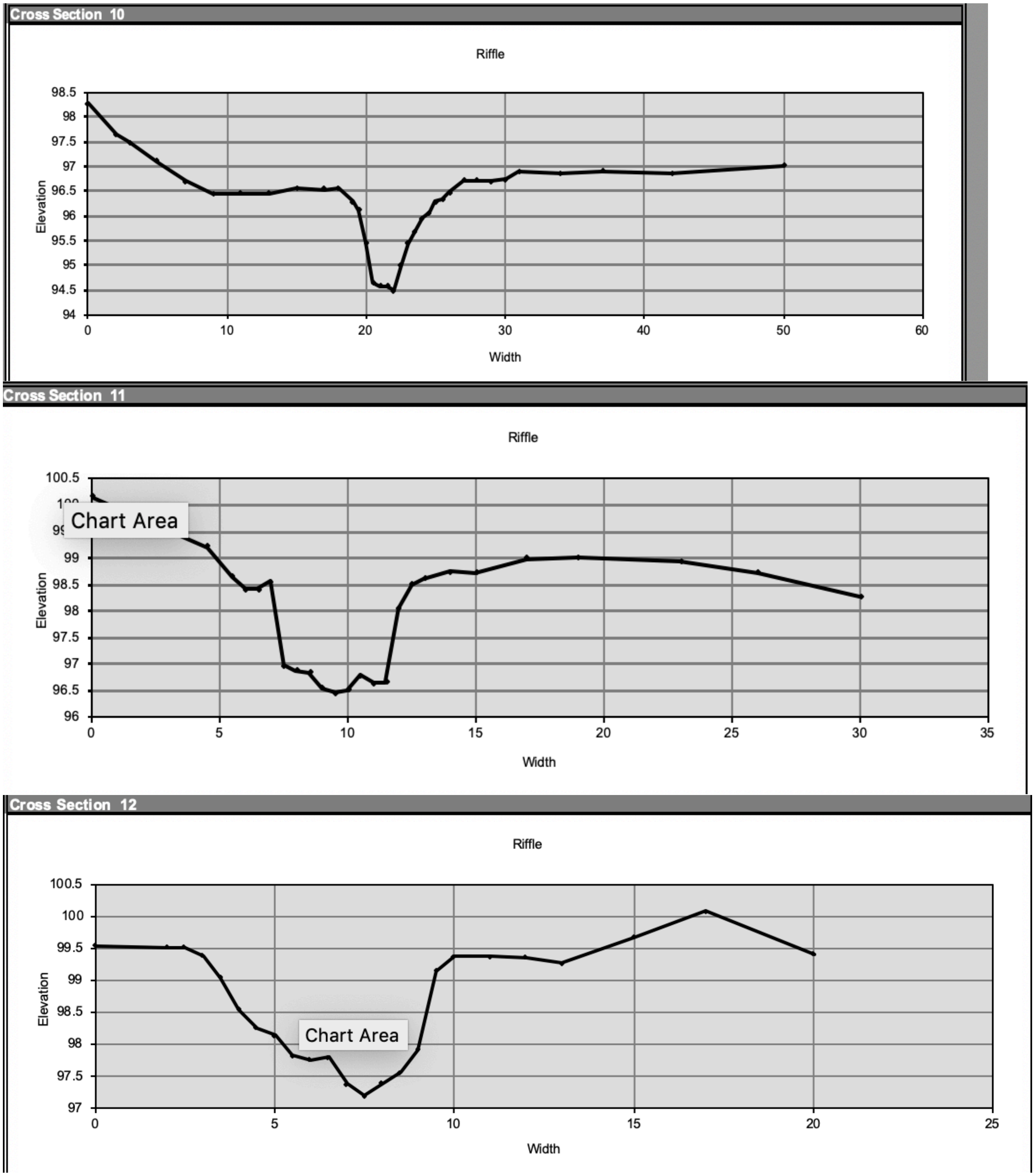
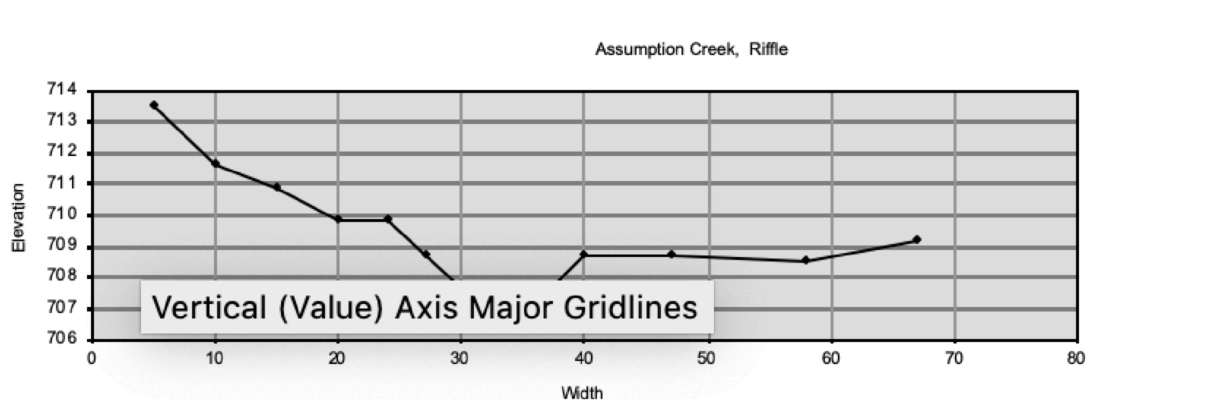


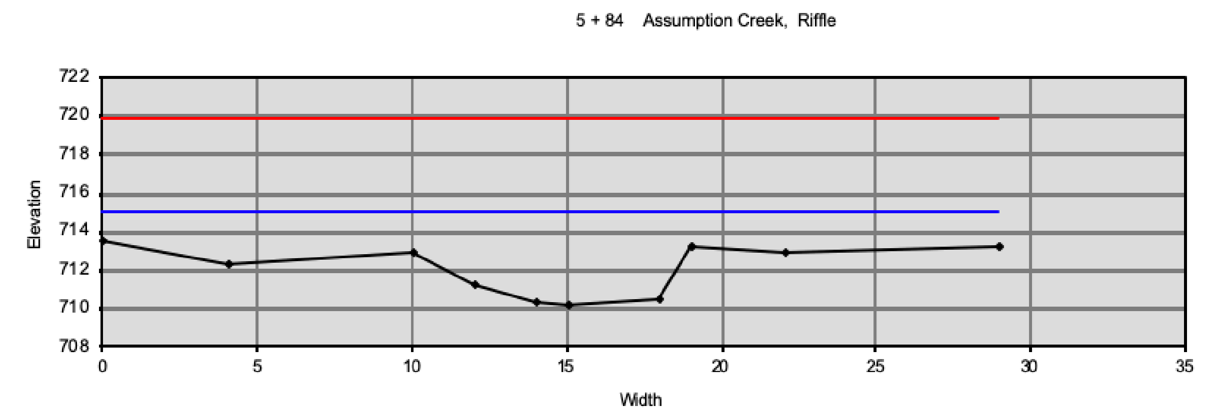
Figure D.3. Assumption Western Reach cross section graphs.

Assumption Creek - East Reach

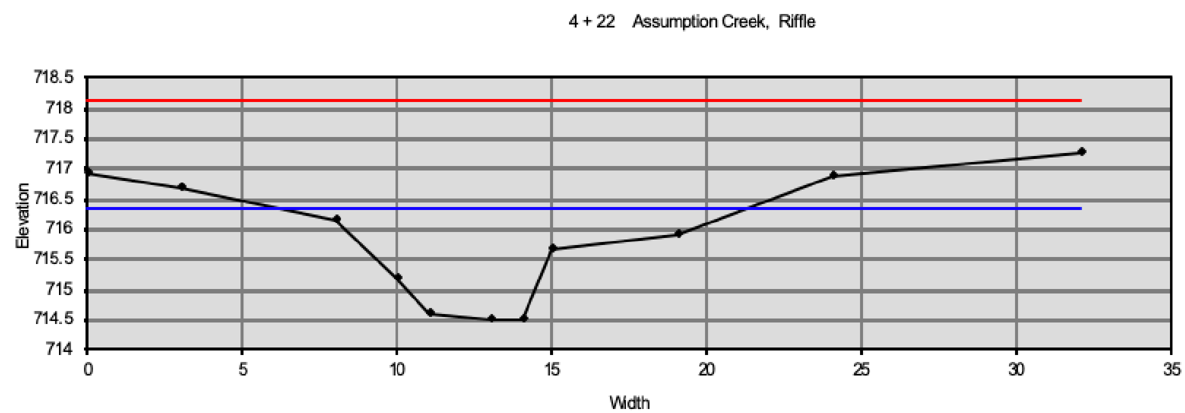
Cross Section 1



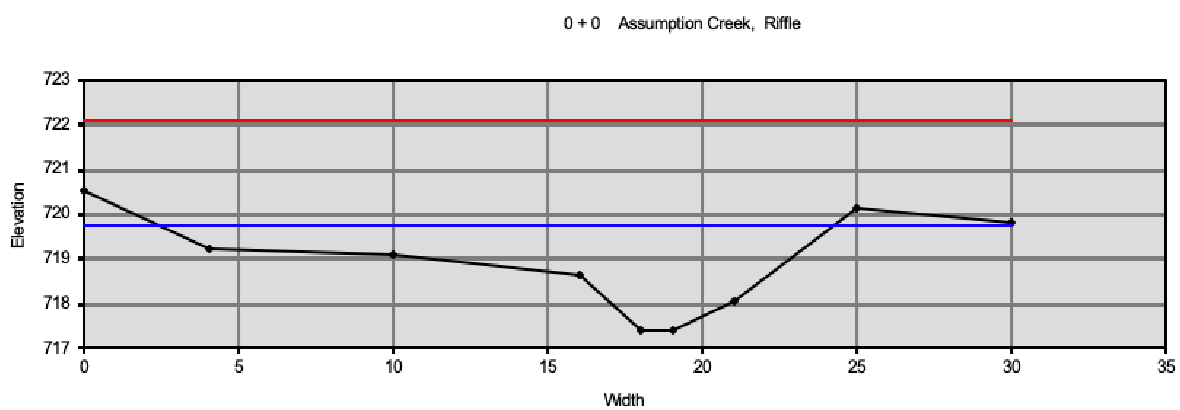
Cross Section 2



Cross Section 3



Cross Section 4



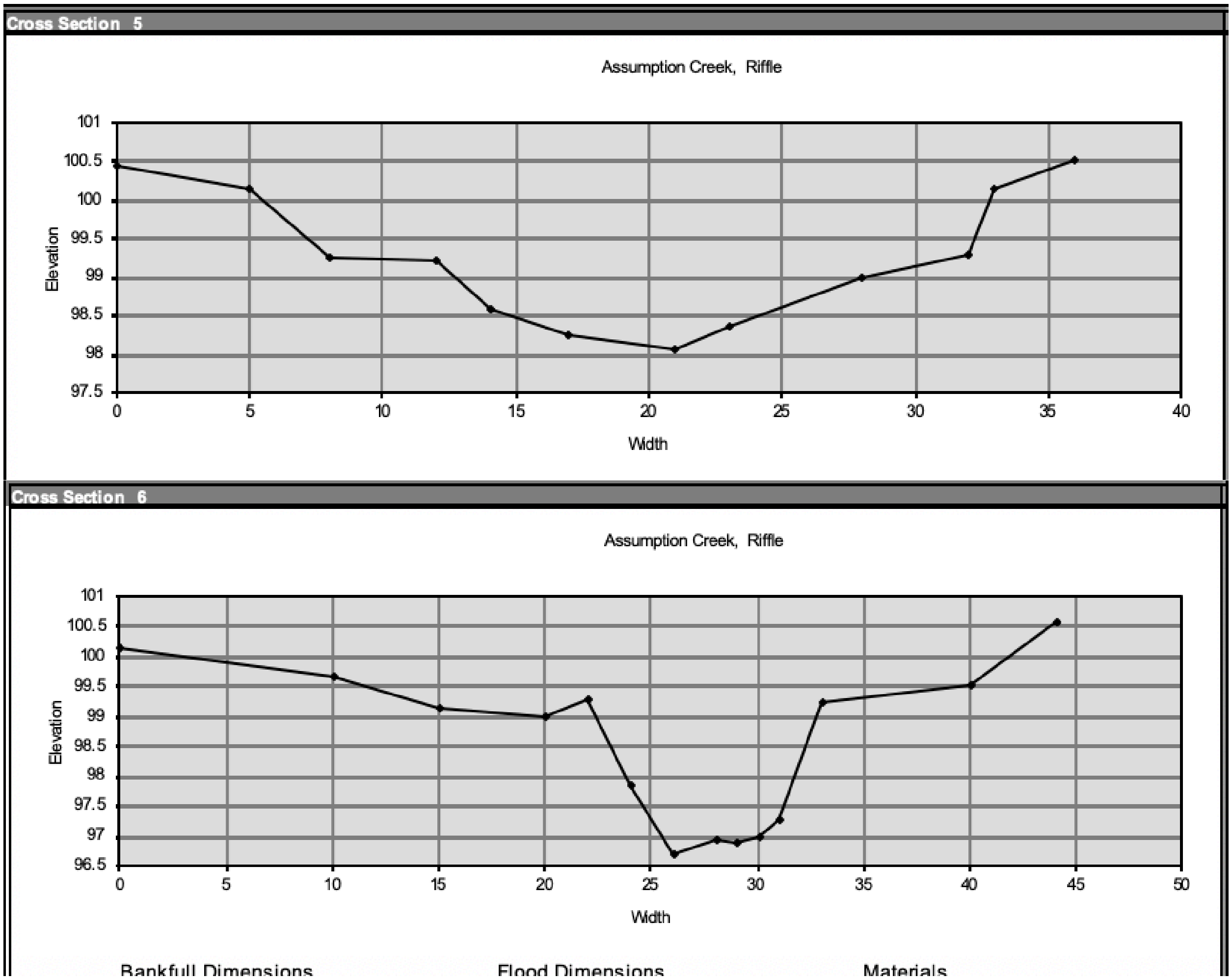
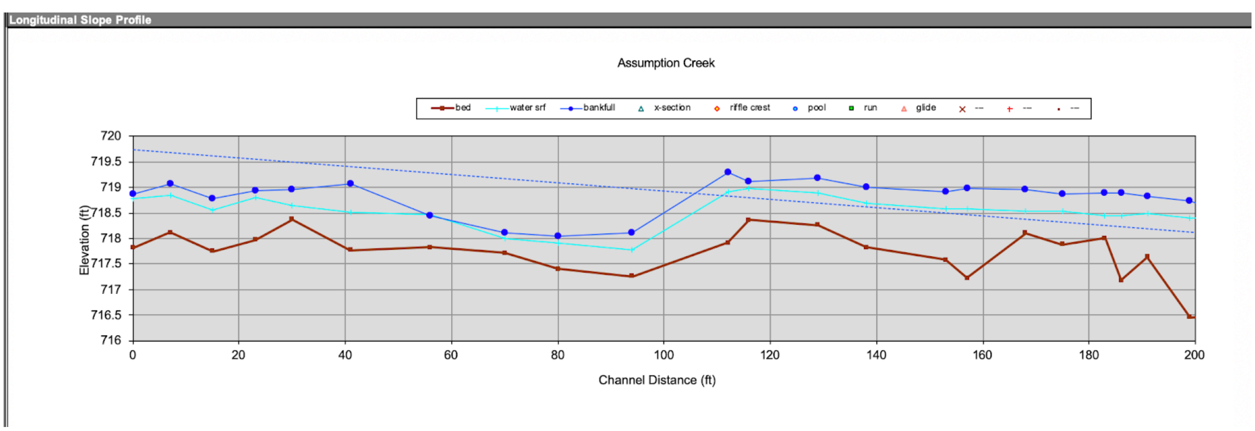
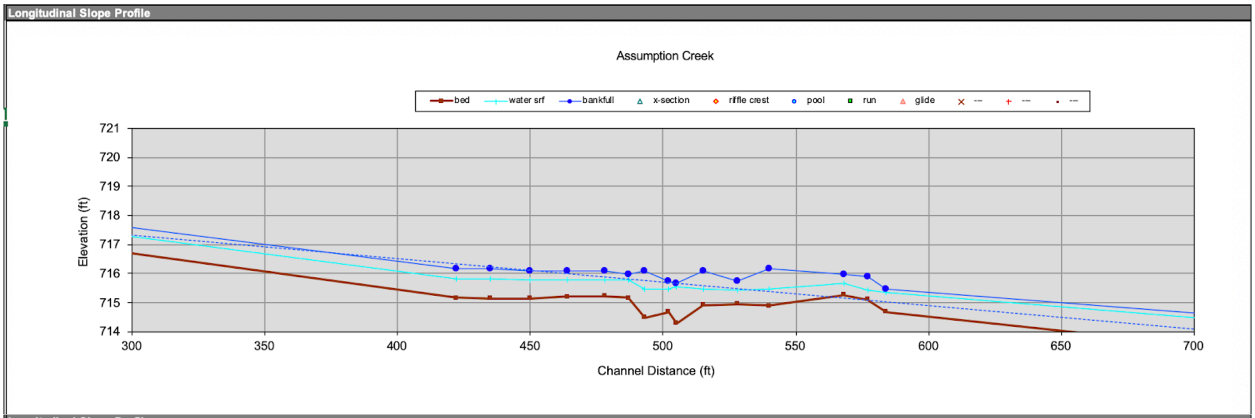
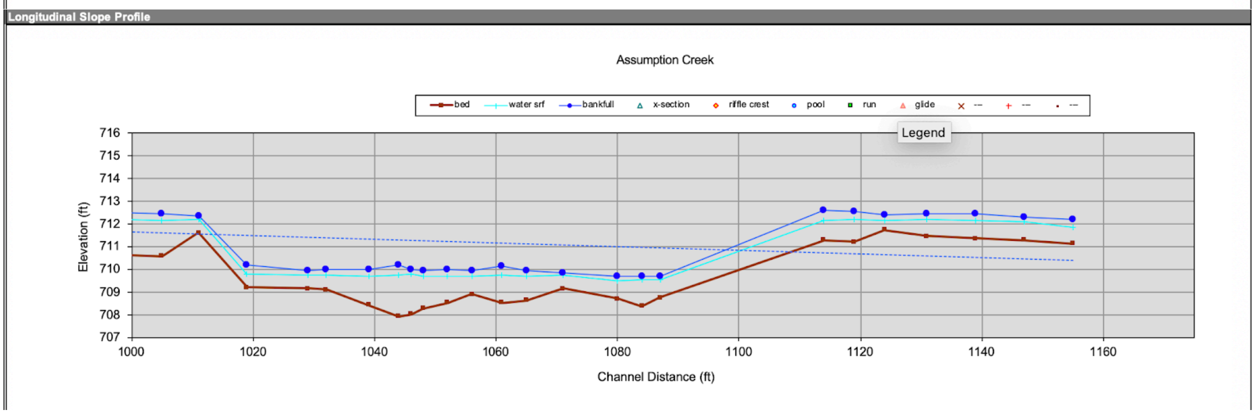


Figure D.4. Assumption Eastern Reach Cross-sections graphs.







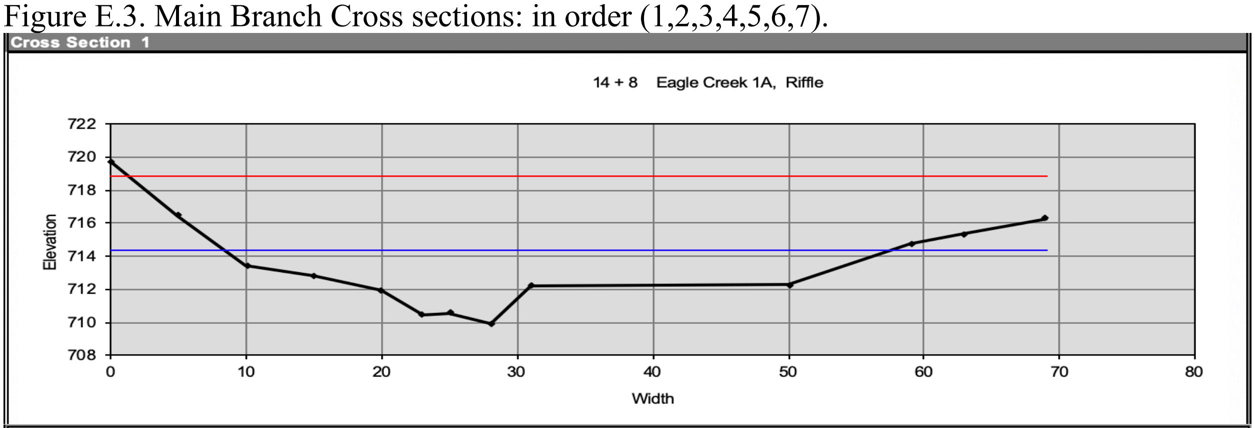
Appendix E: Eagle Creek Figures and Data

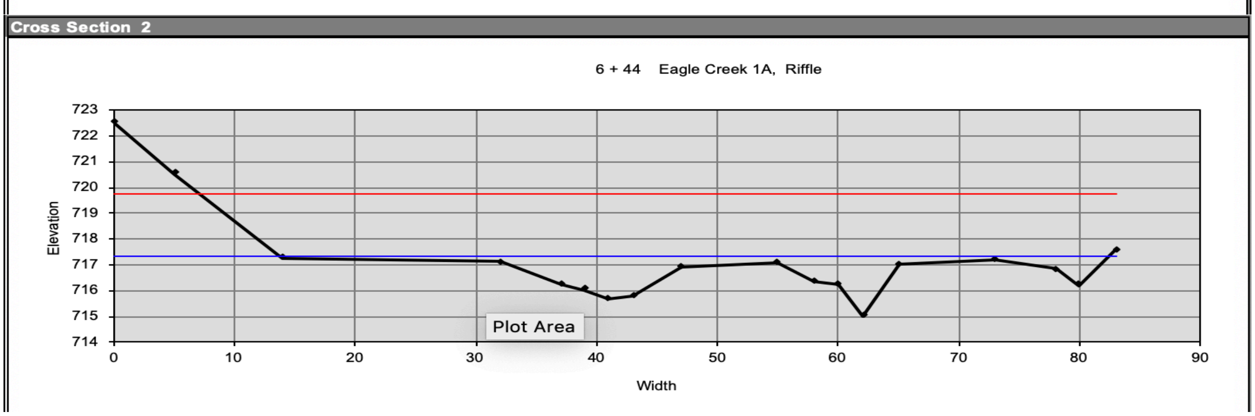
<u>Eagle Creek Main Branch</u>

Figure E.1. Instream vegetation and overhanging vegetation. Erica Bock (June 2019).

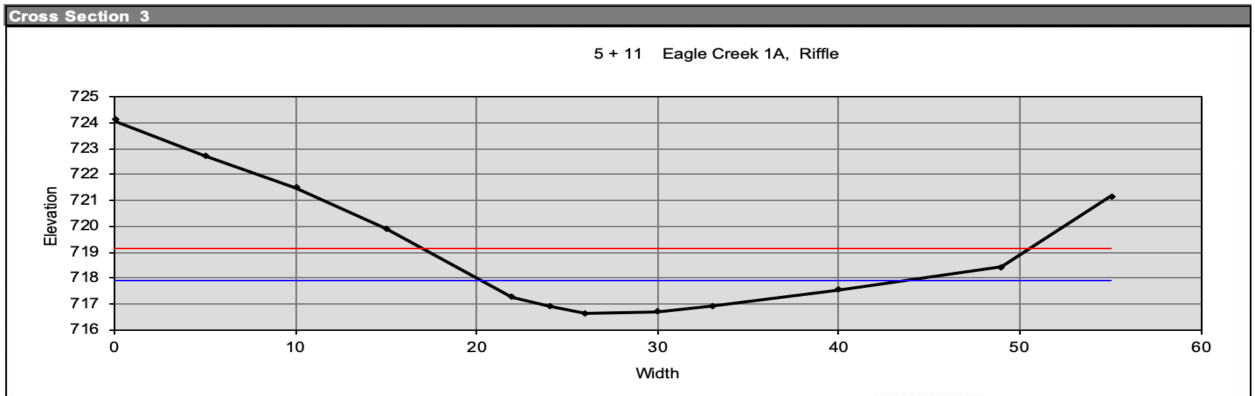
Figure E.2. Undercutting on the bank. Erica (June 2019).

Figure E.3. Main Branch Cross sections: in order (1,2,3,4,5,6,7).

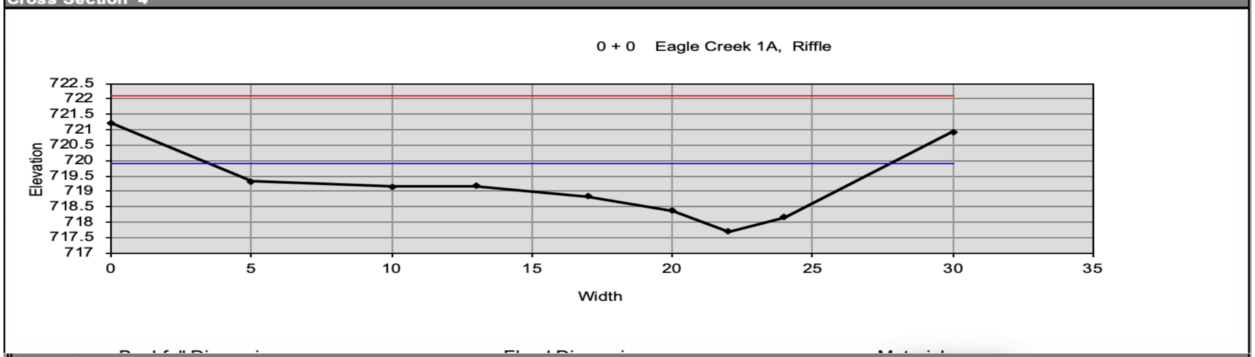




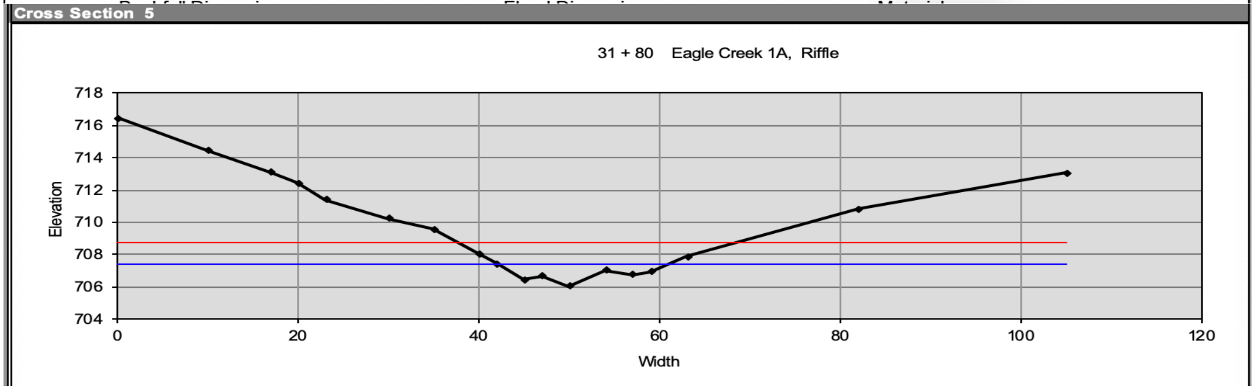
Cross Section 3

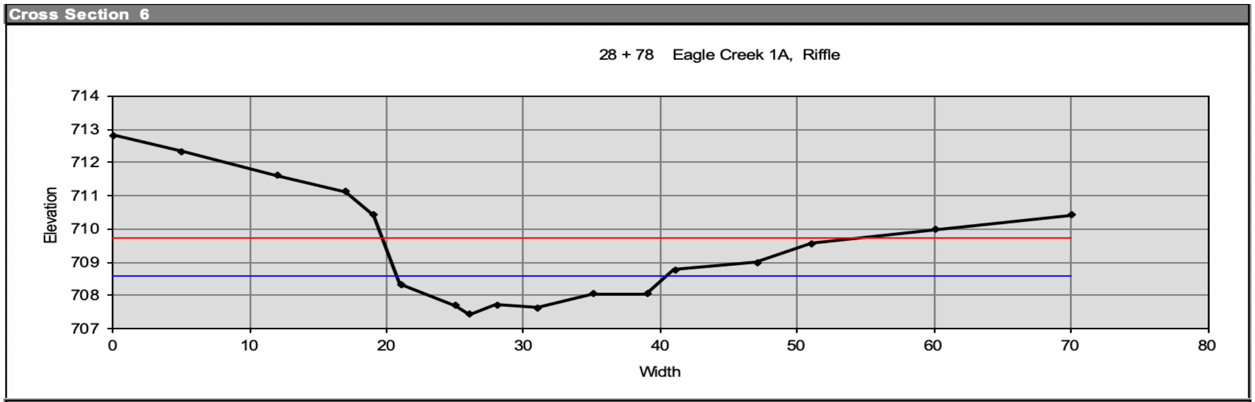


Cross Section 4



Cross Section 5





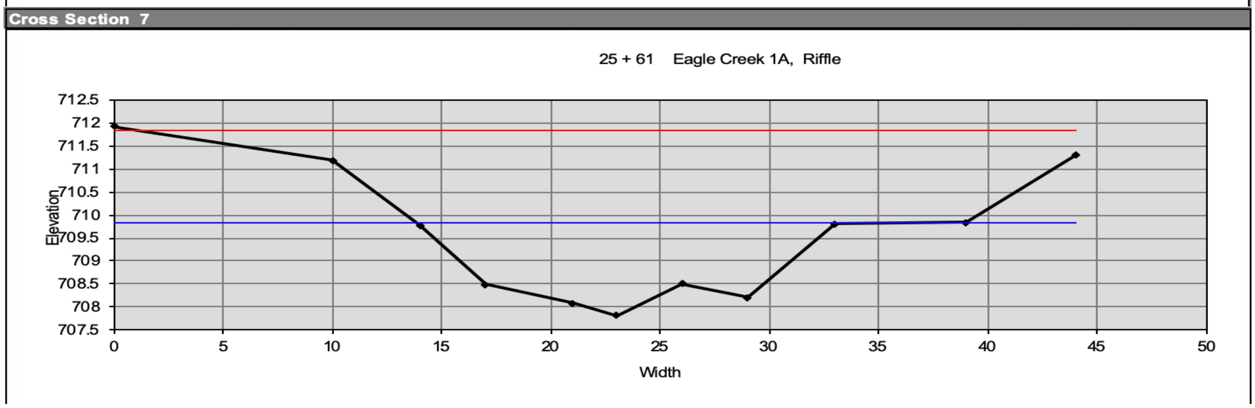
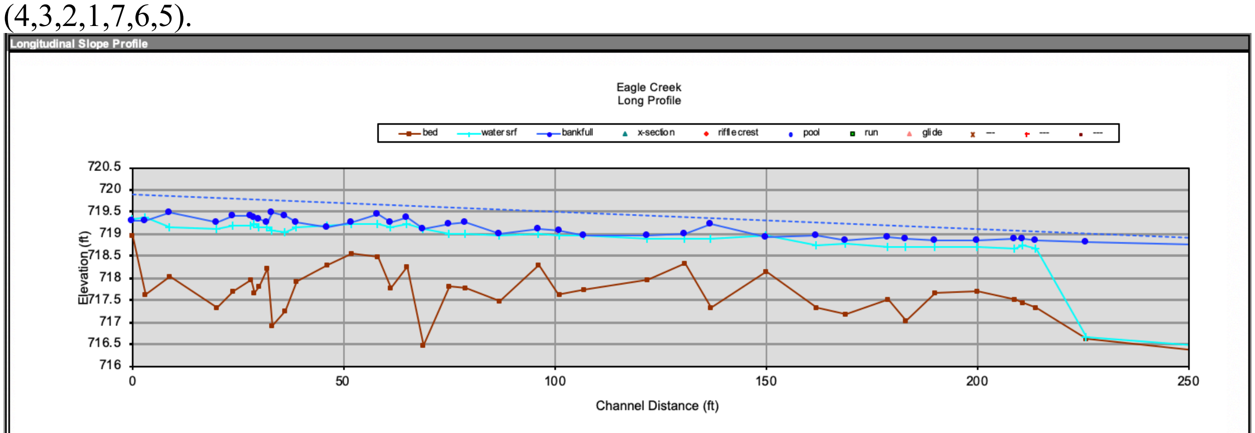
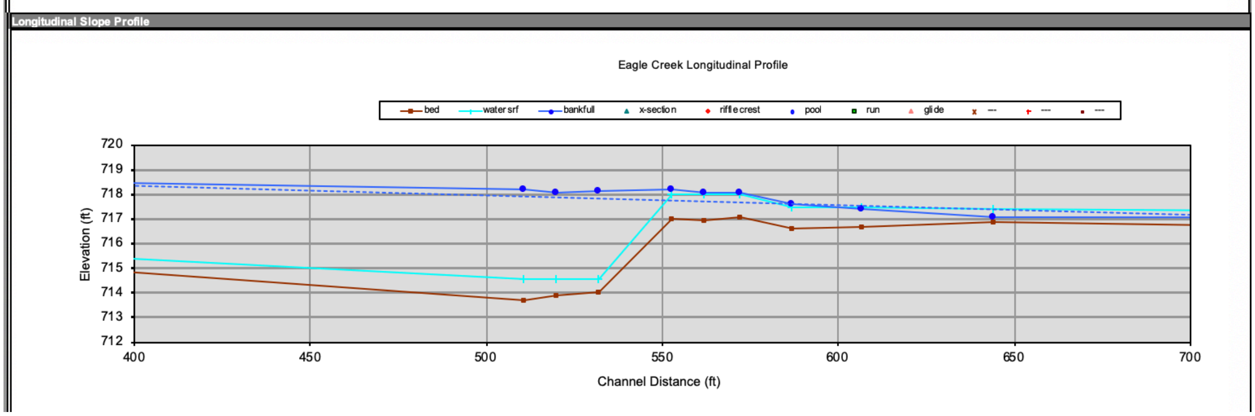
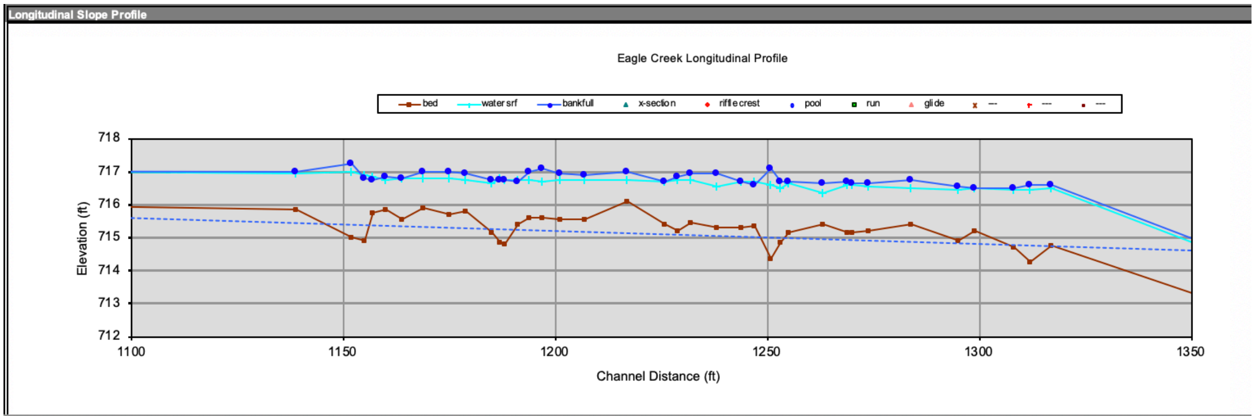
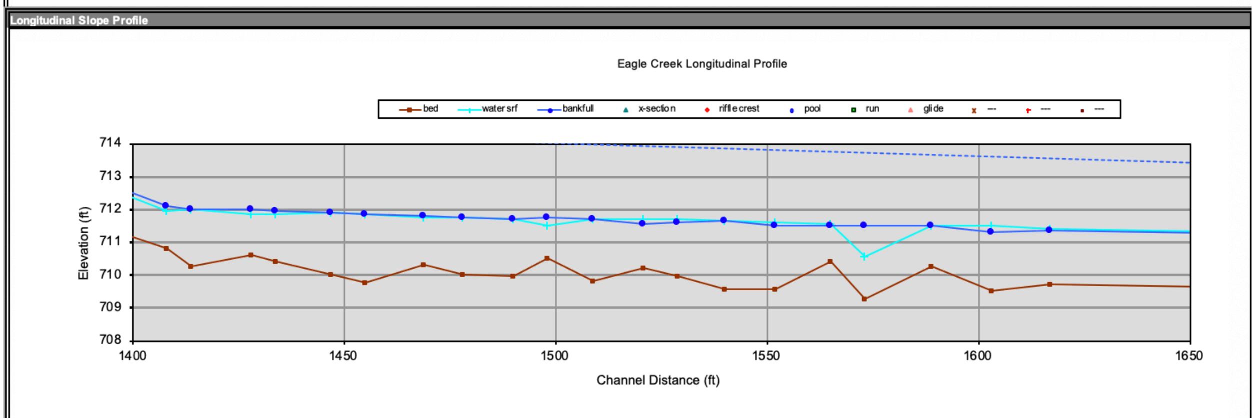


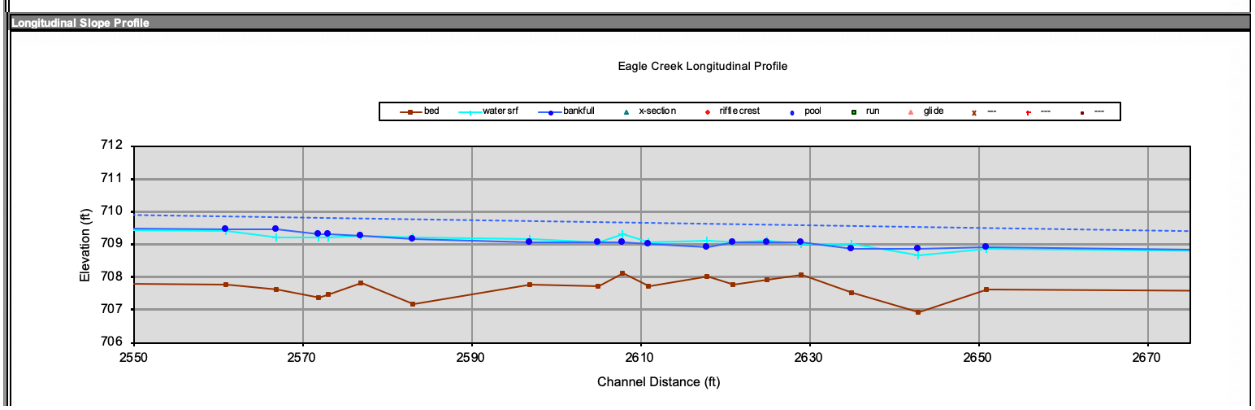
Figure E.4. Main Branch Longitudinal Profiles: in order from upstream to downstream (4,3,2,1,7,6,5).

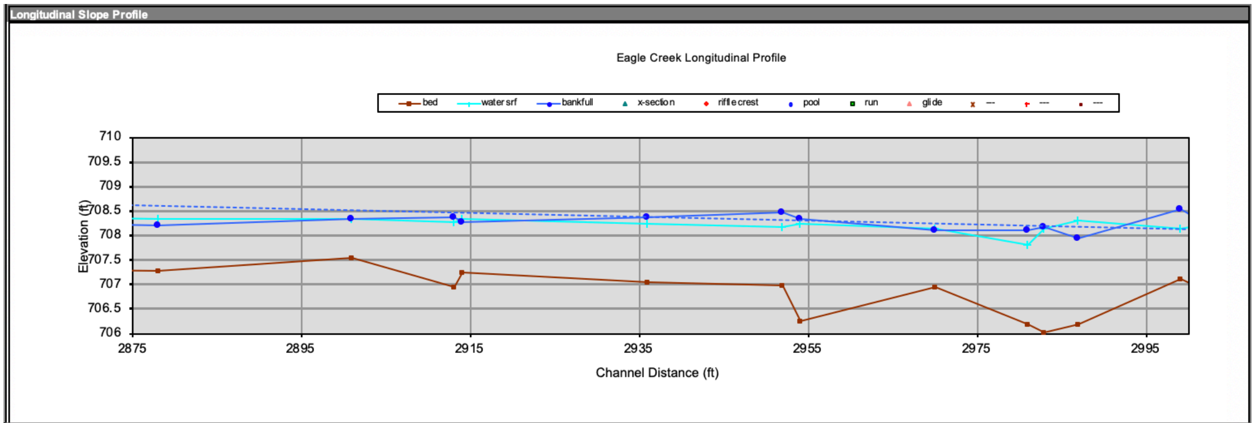


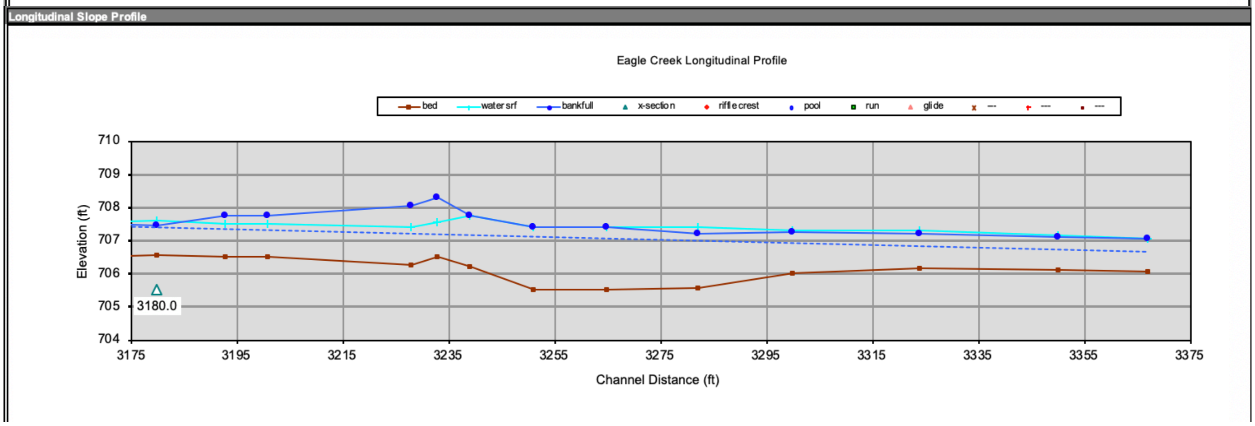



Longitudinal Slope Profile
Eagle Creek Longitudinal Profile
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
Elevation (ft)
718
717
716
715
714
713
712
1100
1150
1200
1250
1300
1350
Channel Distance (ft)


Longitudinal Slope Profile
Eagle Creek Longitudinal Profile
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
Elevation (ft)
714
713
712
711
710
709
708
1400
1450
1500
1550
1600
1650
Channel Distance (ft)


Longitudinal Slope Profile
Eagle Creek Longitudinal Profile
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
Elevation (ft)
712
711
710
709
708
707
706
2550
2570
2590
2610
2630
2650
2670
Channel Distance (ft)



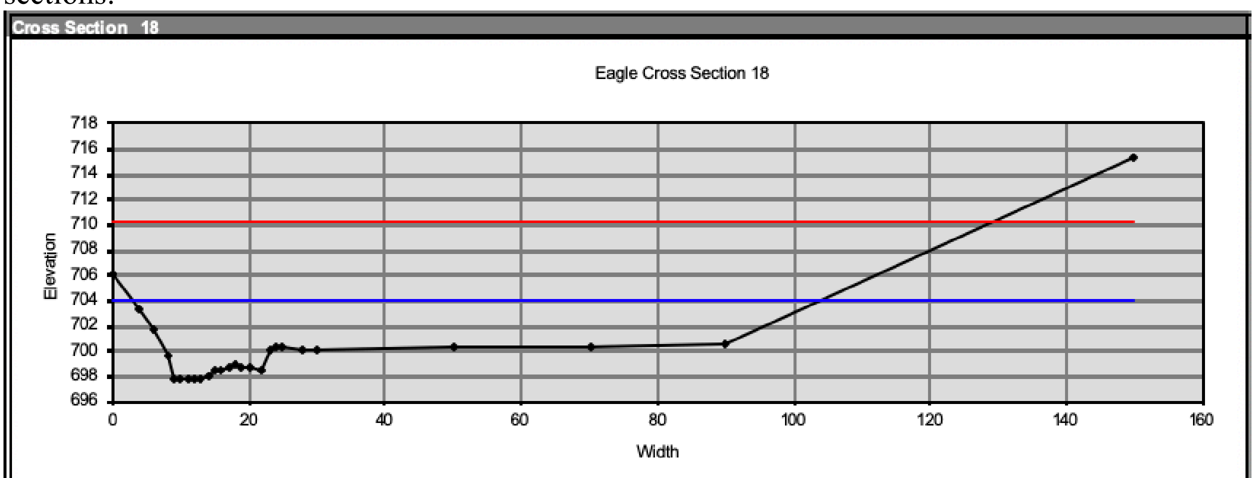


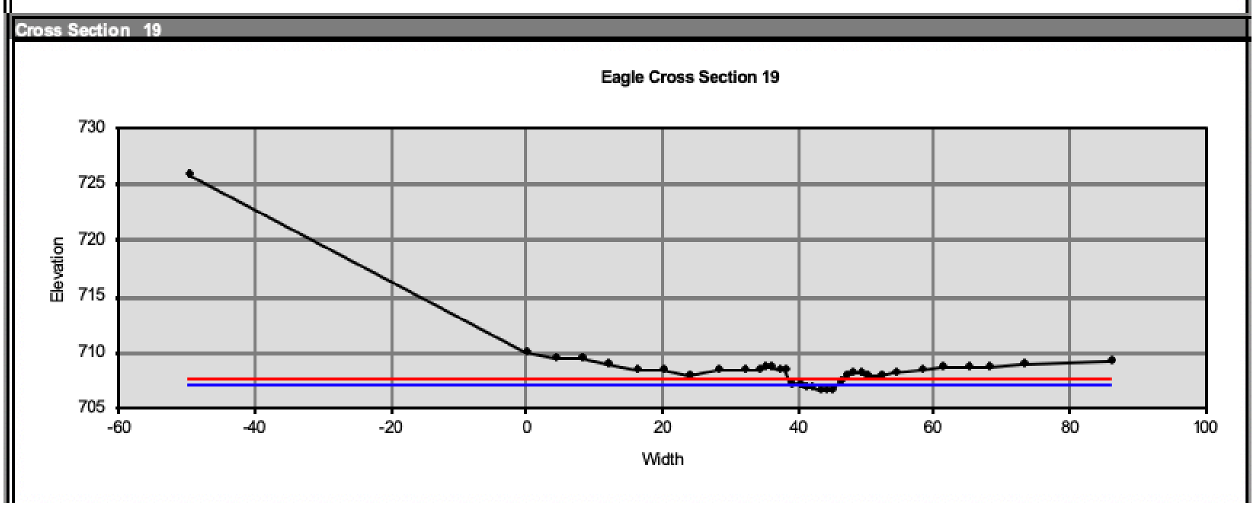
Eagle Creek East Branch

Figure E.5. Bank erosion and scouring at Point 18 on Eagle Creek East Branch. Kirsten Haus (June 2019).

Figure E.6. Concealment in Eagle East Branch. Erica Bock (July 2019).

Figure E.7. East Branch Cross sections:





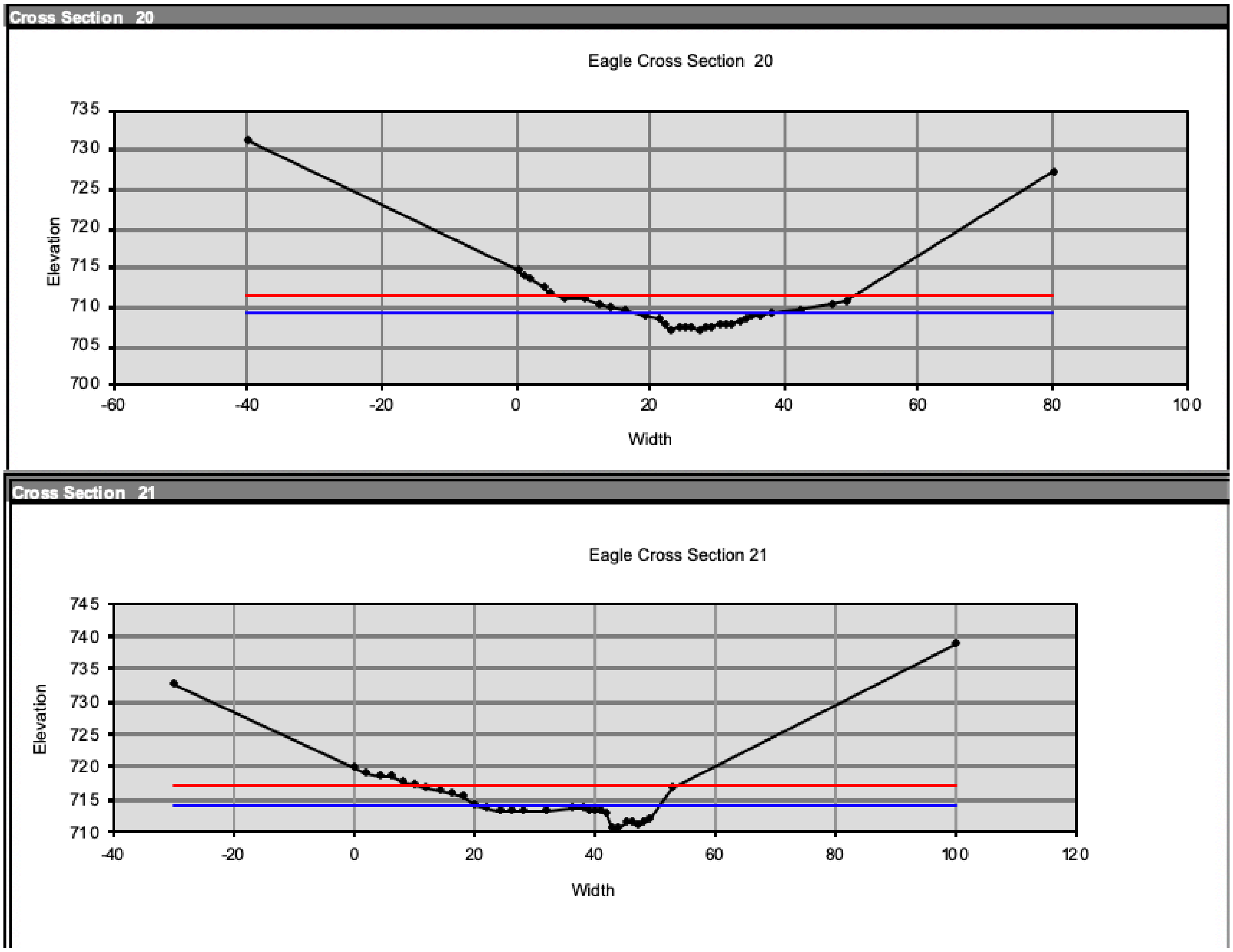
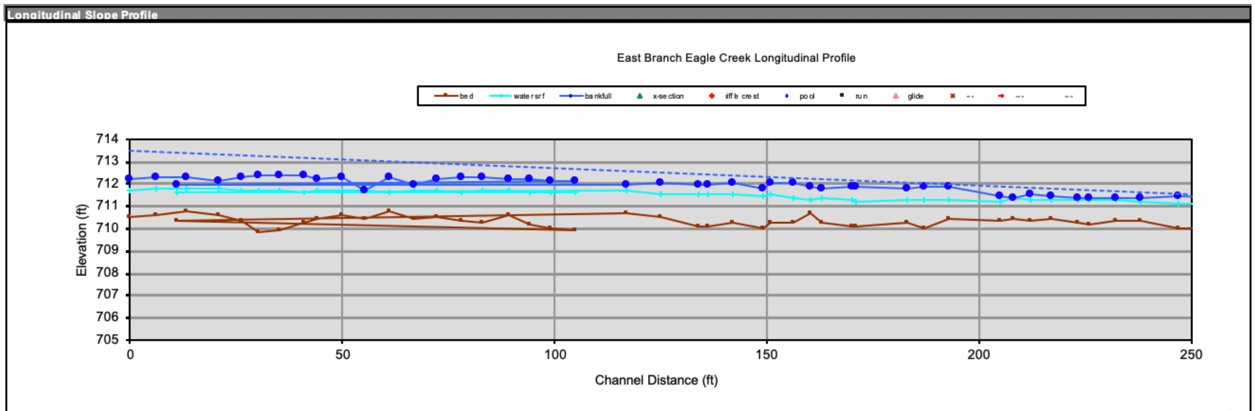
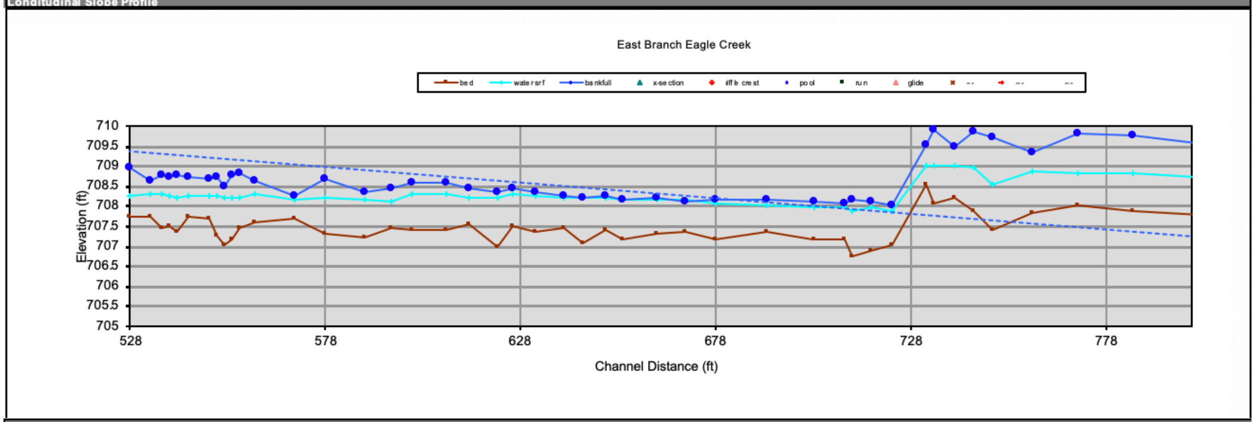


Figure E.8. East Branch Longitudinal Profiles: upstream to downstream (21,20,19,18-17)

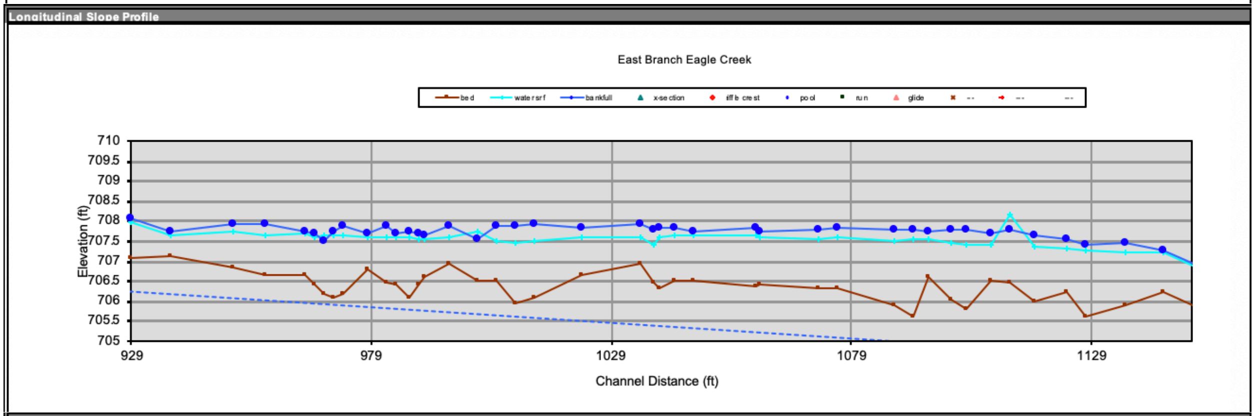
Longitudinal Slope Profile



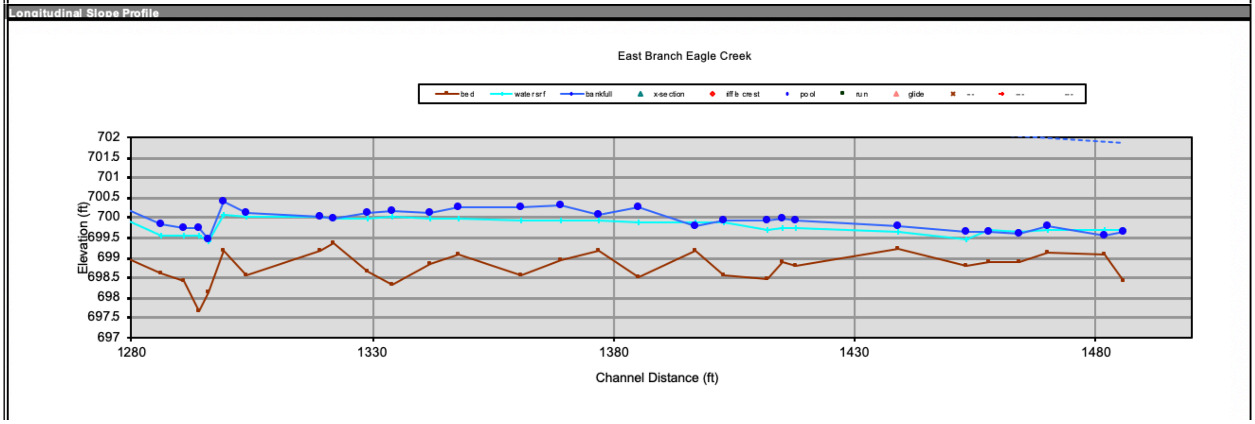
Longitudinal Slope Profile



Longitudinal Slope Profile



Longitudinal Slope Profile



Eagle Creek Reconstructed Reach

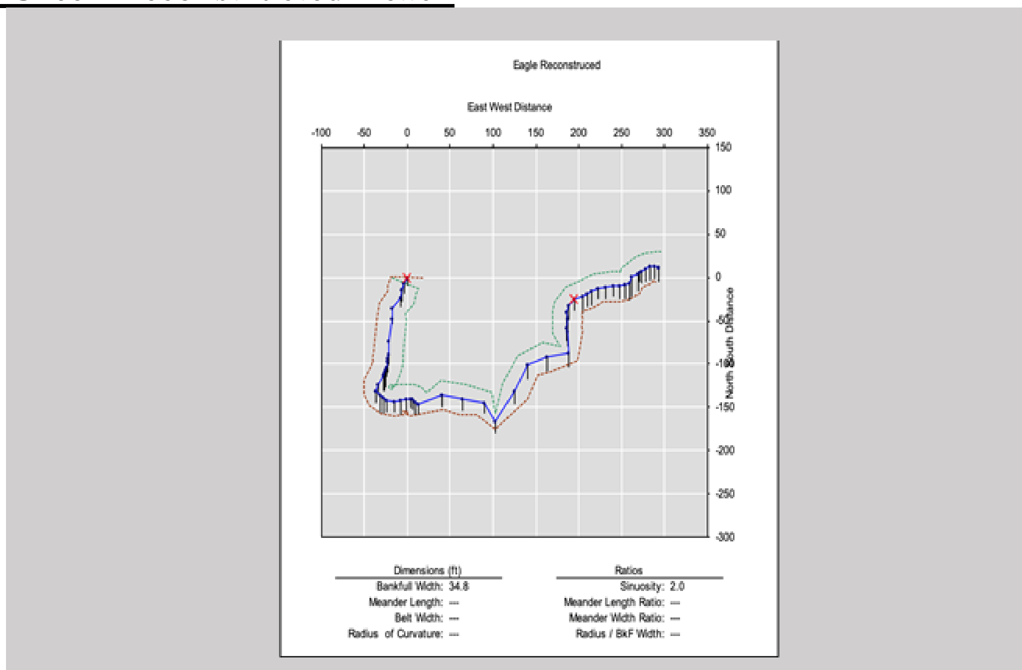


Figure E.9. Pattern given from Azimuth determining sinuosity.

Figure E.10. Eagle reconstruction photos. Top 3 photos Erica Bock. Bottom 3 photos Sam Wheeler (June 2019).

Figure E.11. Eagle Creek Reconstruction Longitudinal Profile:

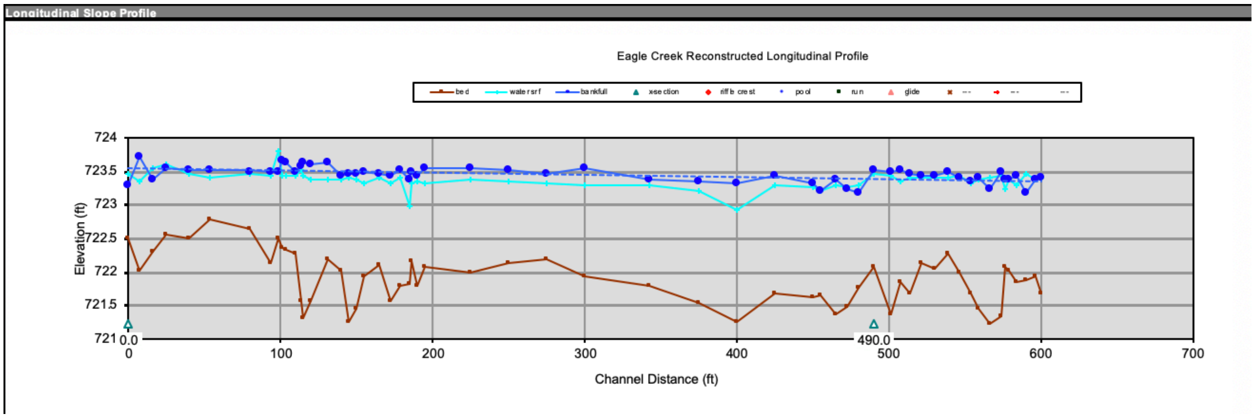
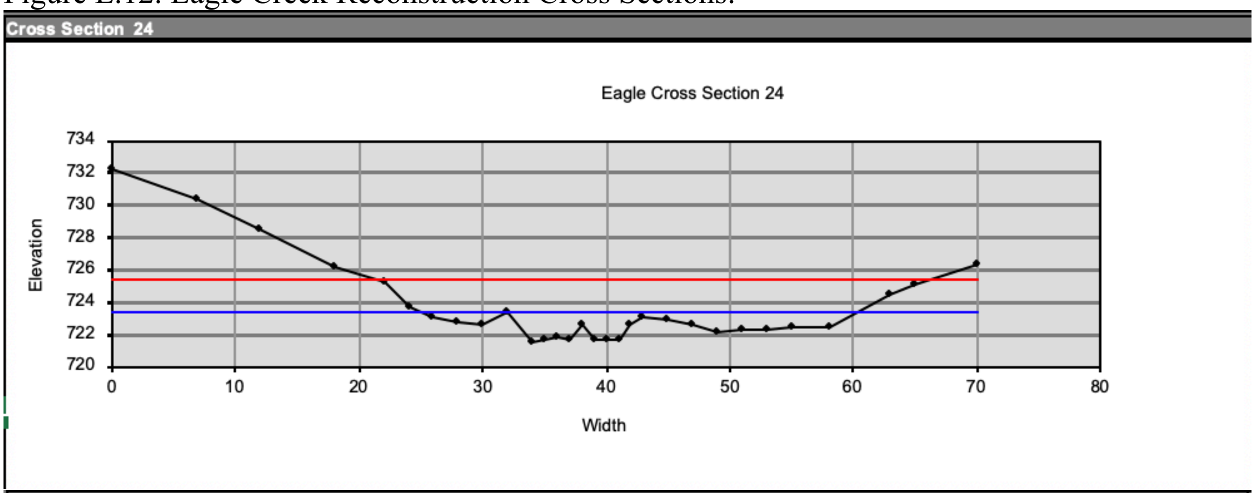
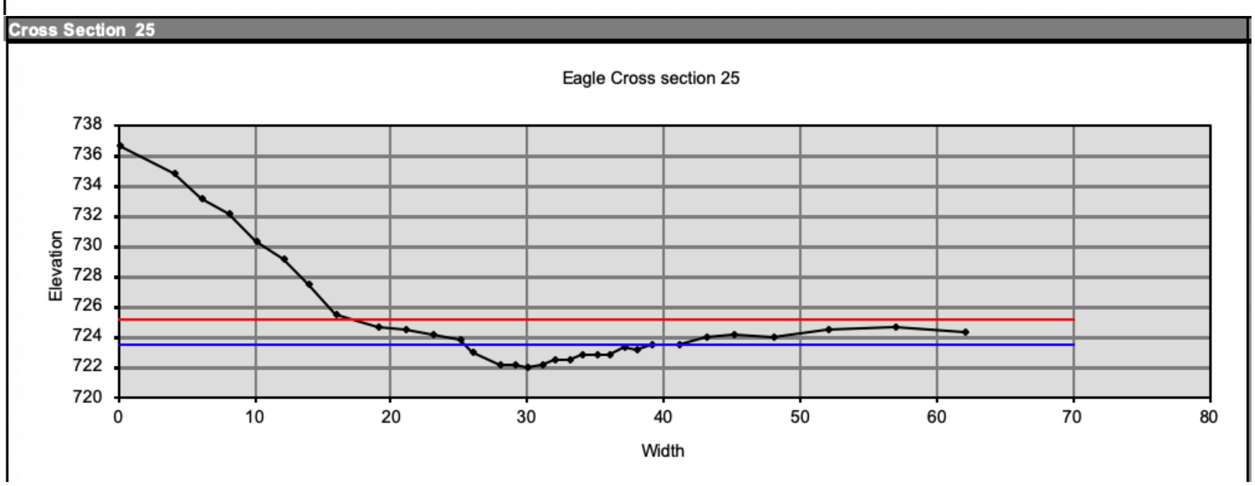


Figure E.12. Eagle Creek Reconstruction Cross Sections:





Appendix F: Ike's Creek Figures and Data

Figure F.1. Woody Debris. Erica Bock (July 2019).

Figure F.2. Knick Points. Erica Bock (July 2019).

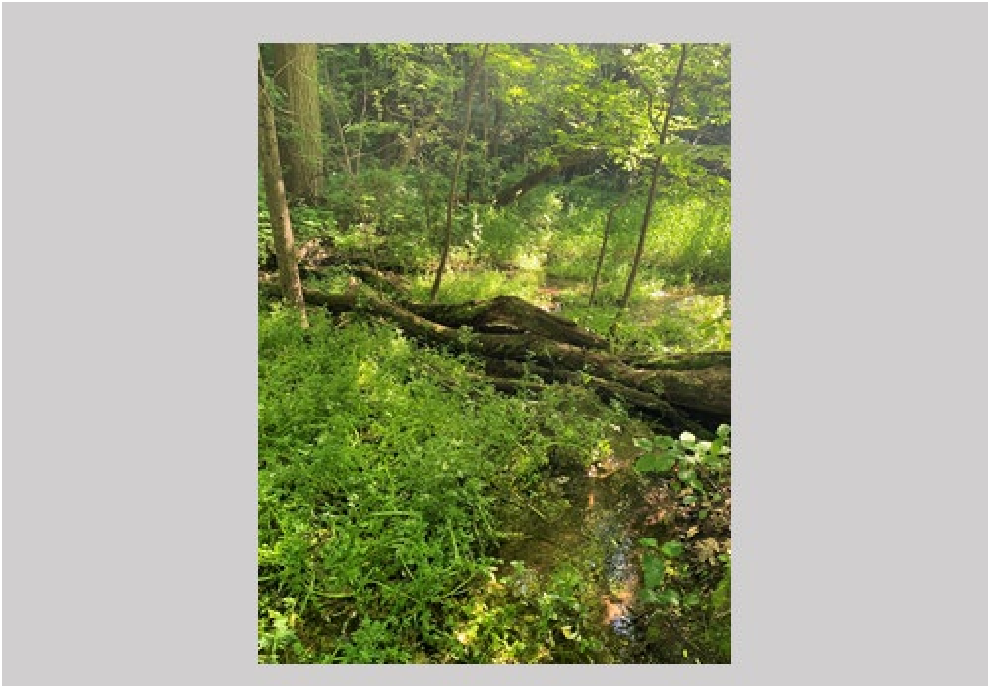


Figure F.3. Excessive Instream vegetation. Erica Bock (July 2019).

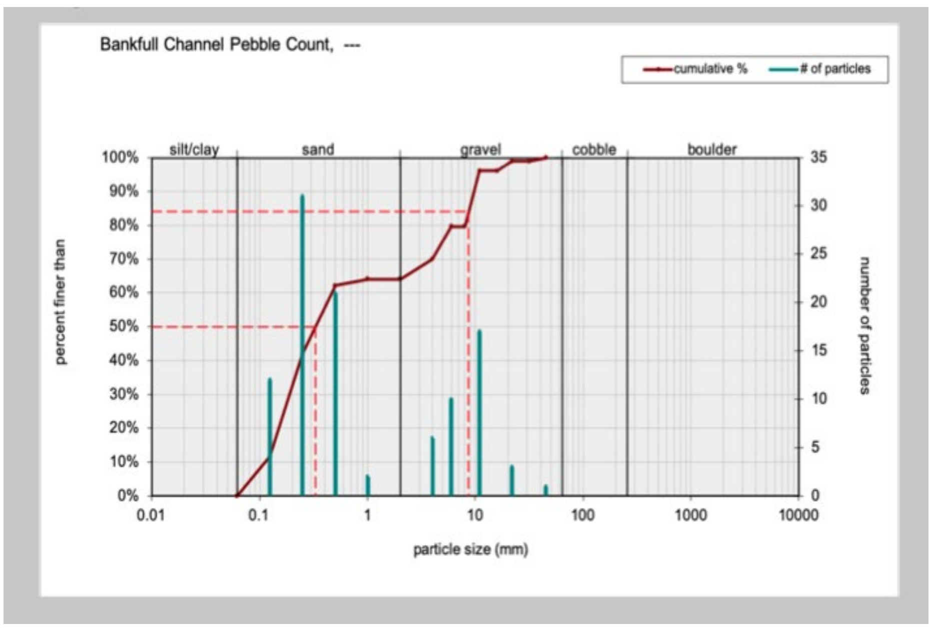
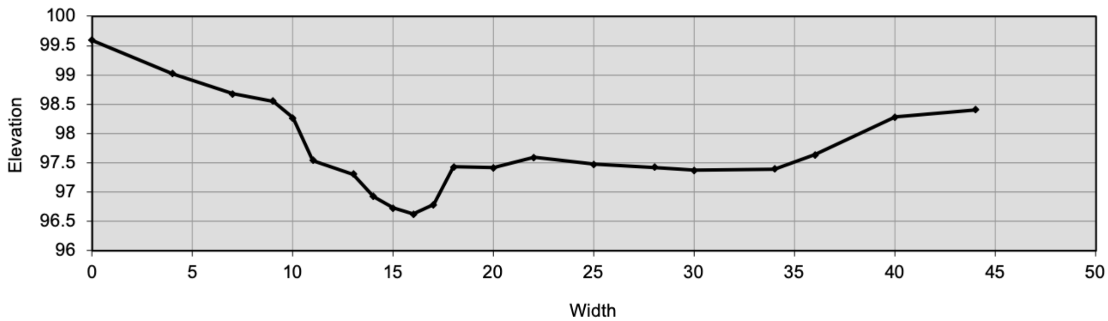


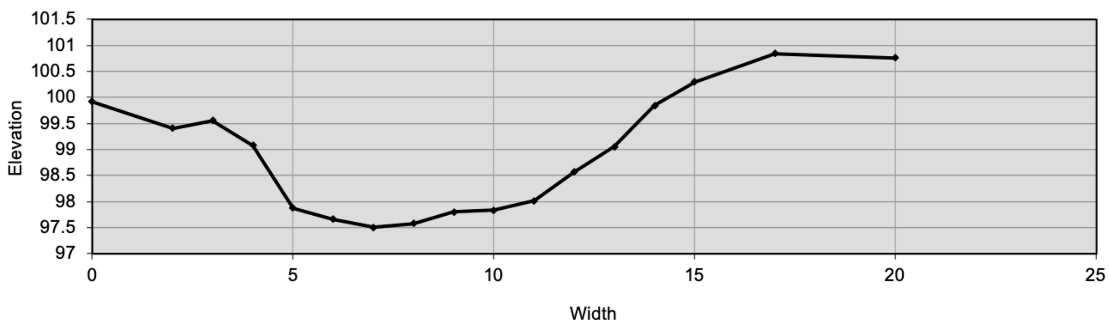
Figure F.4. Ike’s Creek Pebble Count.

Figure F.5. Ike’s Creek Cross sections:

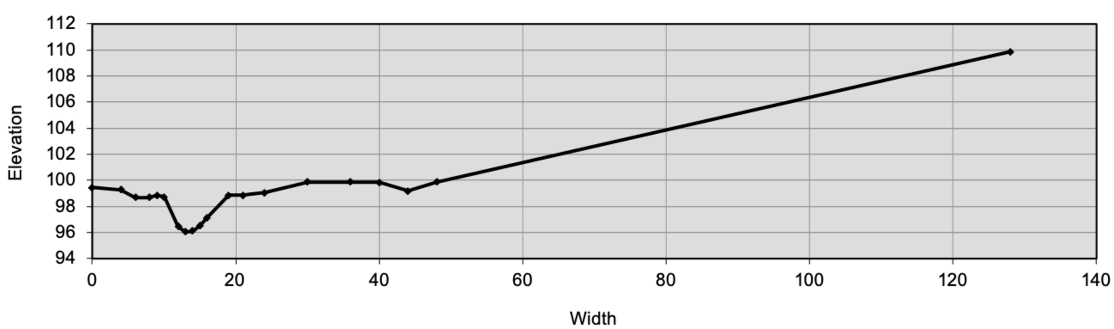
Riffle 1-1

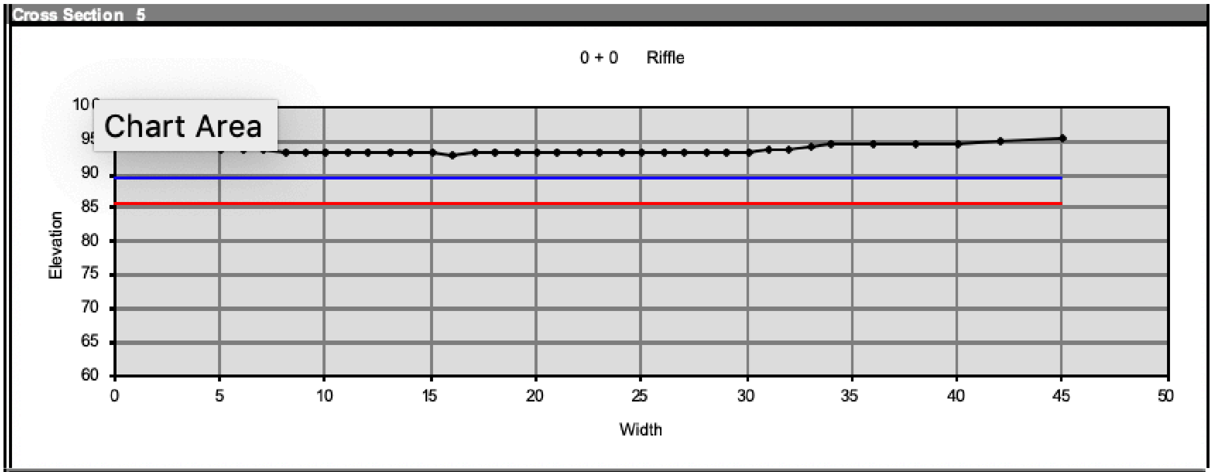


Riffle 1-2



Riffle 1-3





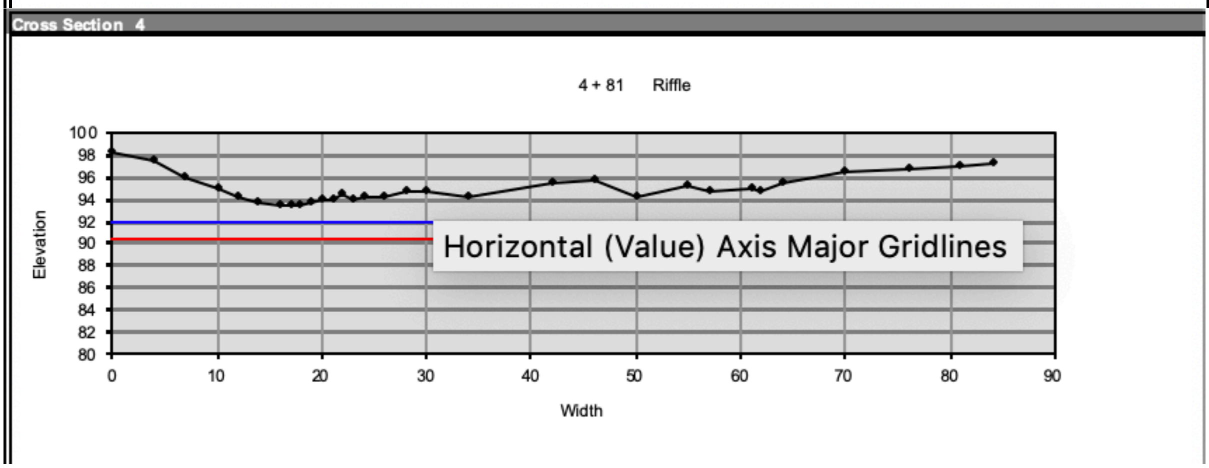


Figure F.6. Ike’s Creek Longitudinal Profiles:

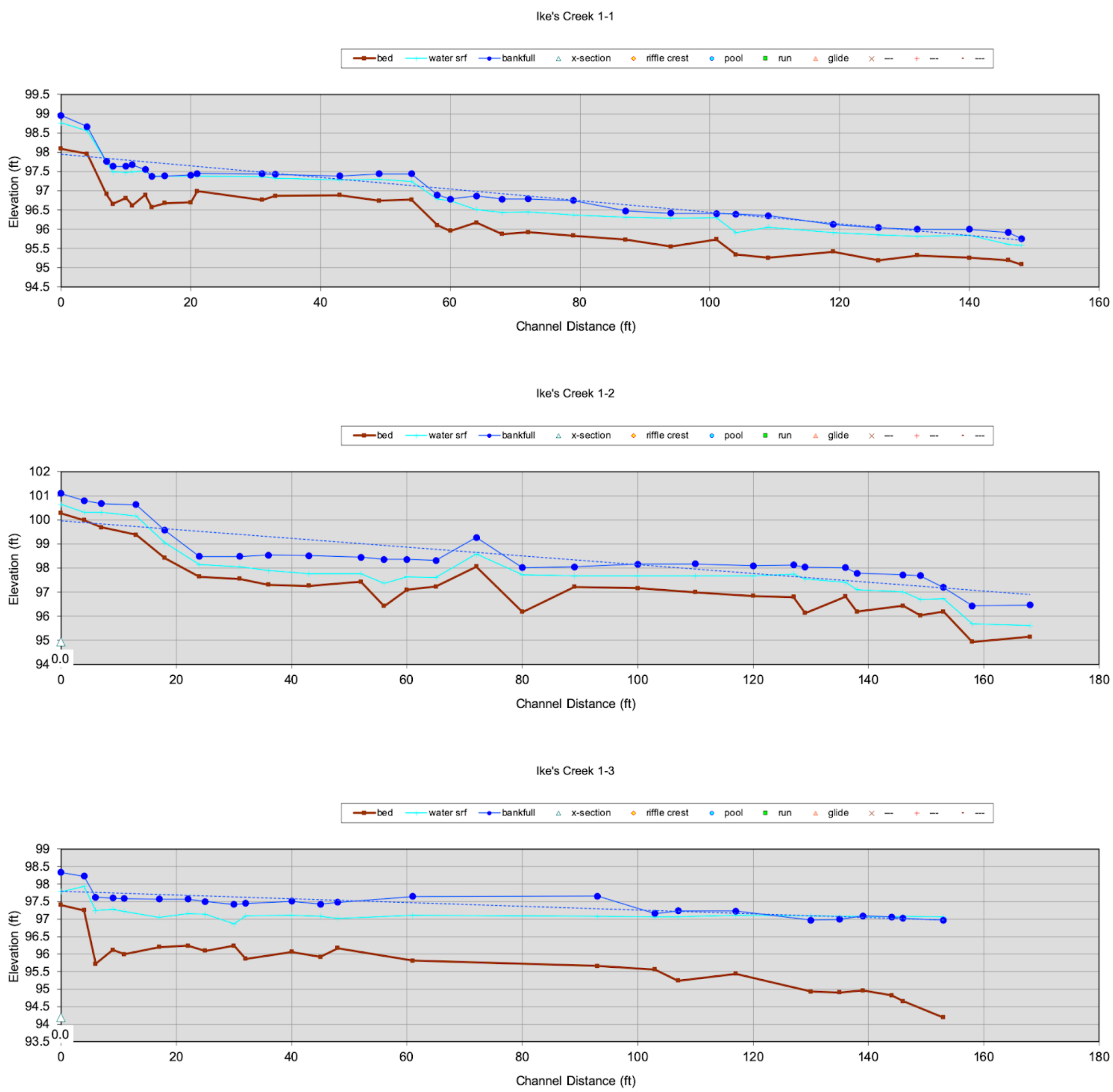
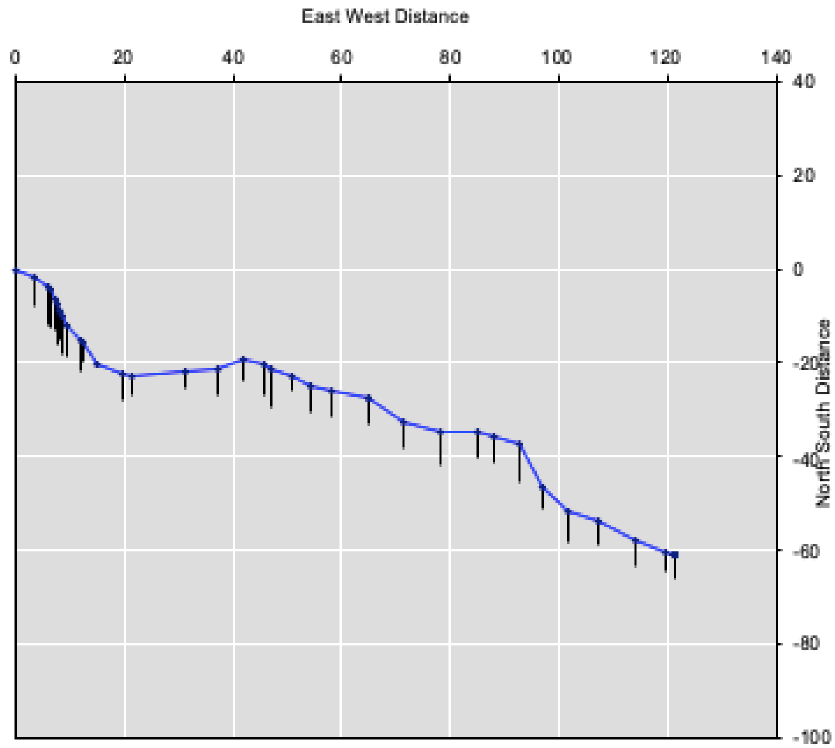


Figure F.7. Patterns given from azimuth determining sinuosity.

Ike's Creek



Dimensions (ft)	
Bankfull Width:	---
Meander Length:	---
Belt Width:	---
Radius of Curvature:	---

Ratios	
Sinuosity:	1.1
Meander Length Ratio:	---
Meander Width Ratio:	---
Radius / BkF Width:	---

Appendix G: Kennaley's Creek Figures and Data

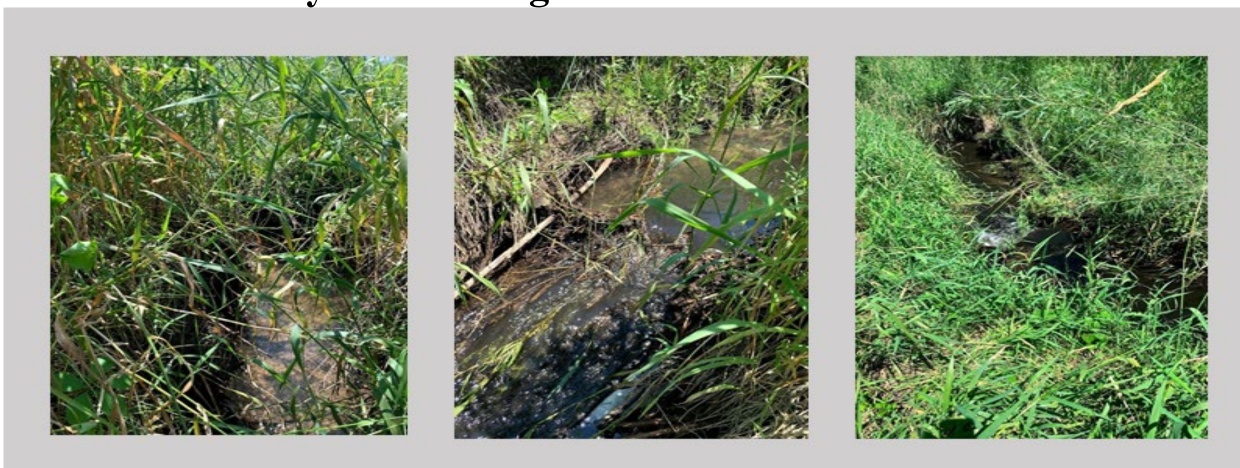


Figure G.1. Vegetation on Kennaley. Sam Wheeler (July 2019).

Figure G.2. Kennaley's Creek Cross Section:

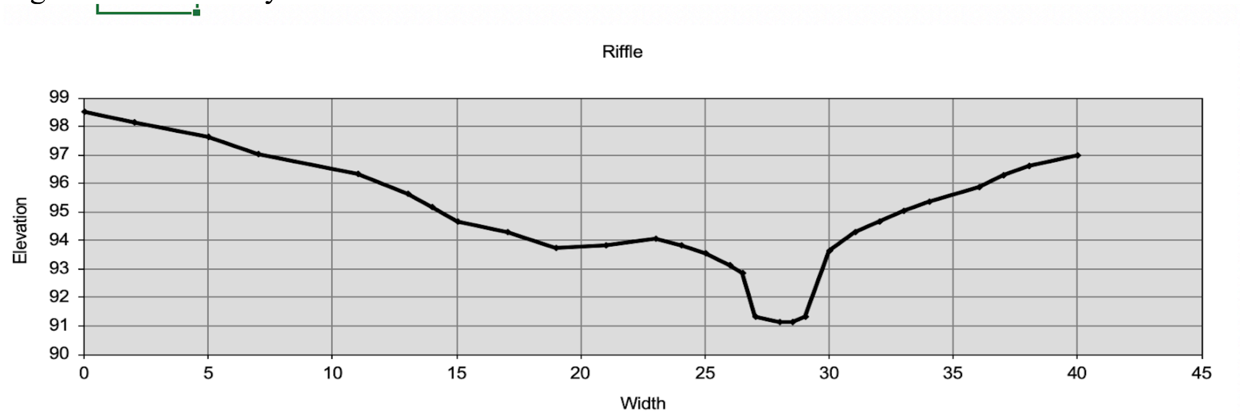
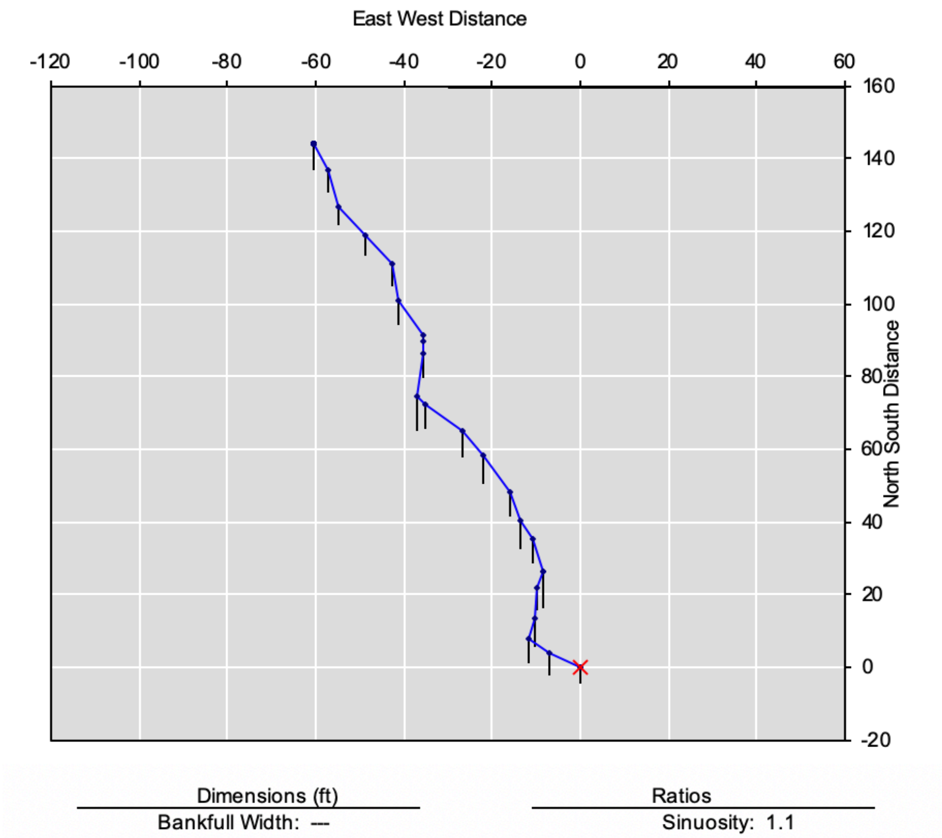


Figure G.3 Kennaley's Creek patterns given from azimuth determining sinuosity.



Appendix H: Unnamed Creeks 1, 2, and 4 Figures and Data

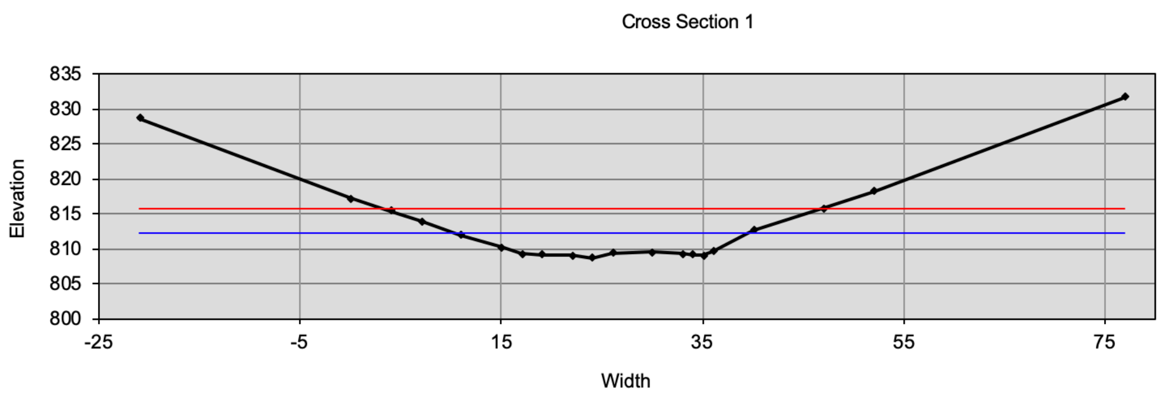
Figure H.1. Construction on the stream. Kirsten Haus (July 2019).

Figure H.2. Erosion. Erica Bock (July 2019).

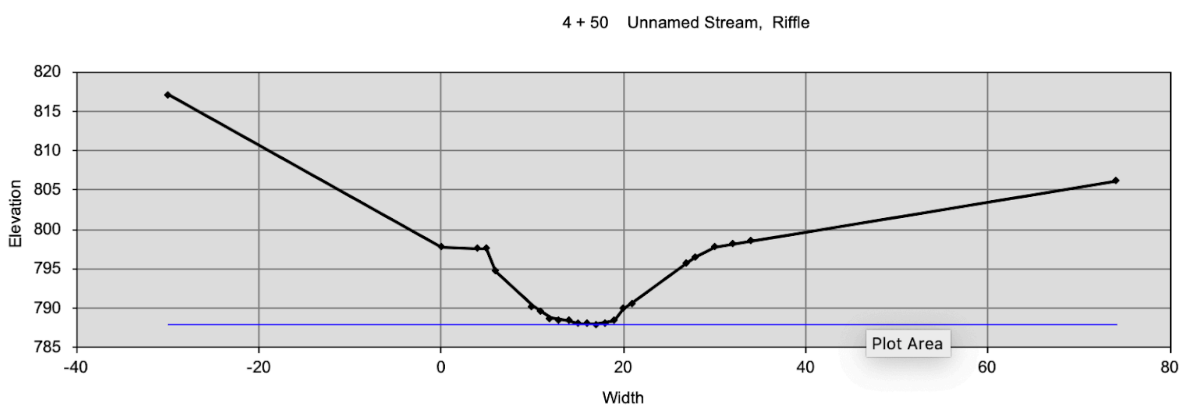
Figure H.3. Land change. Erica Bock (July 2019).

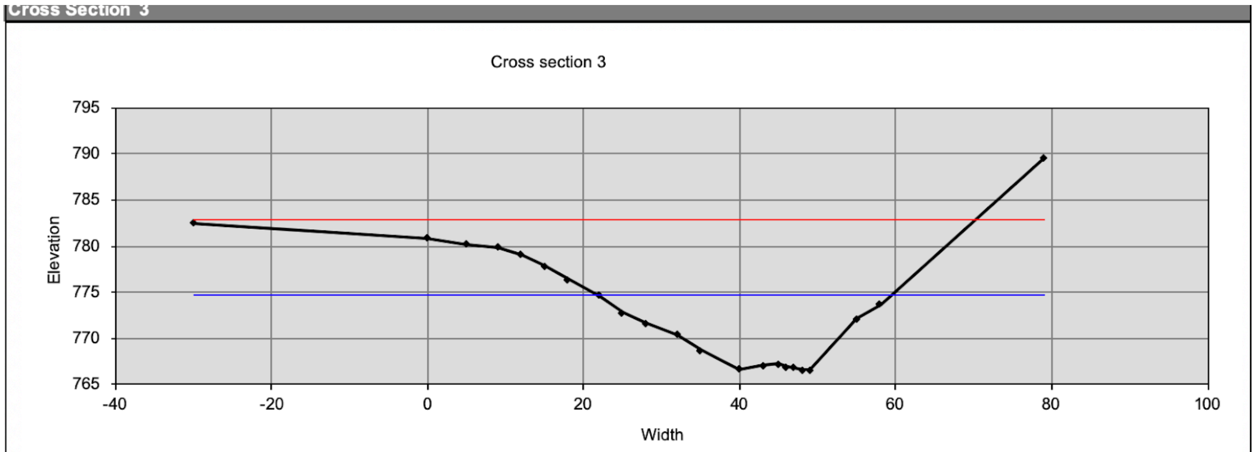
Figure H.4. Unnamed Creek 1 Cross Sections:

Cross Section 1



Cross Section 2





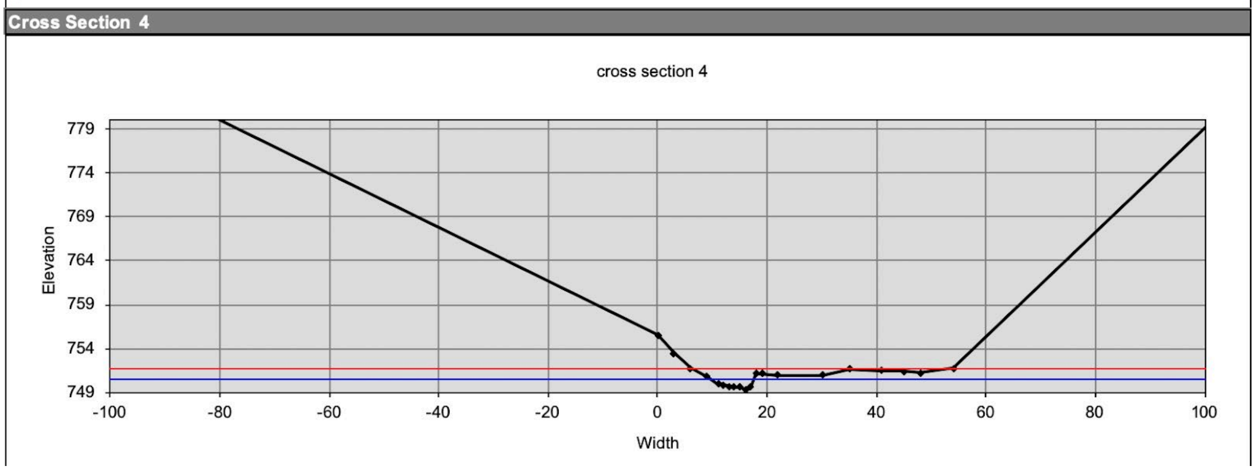
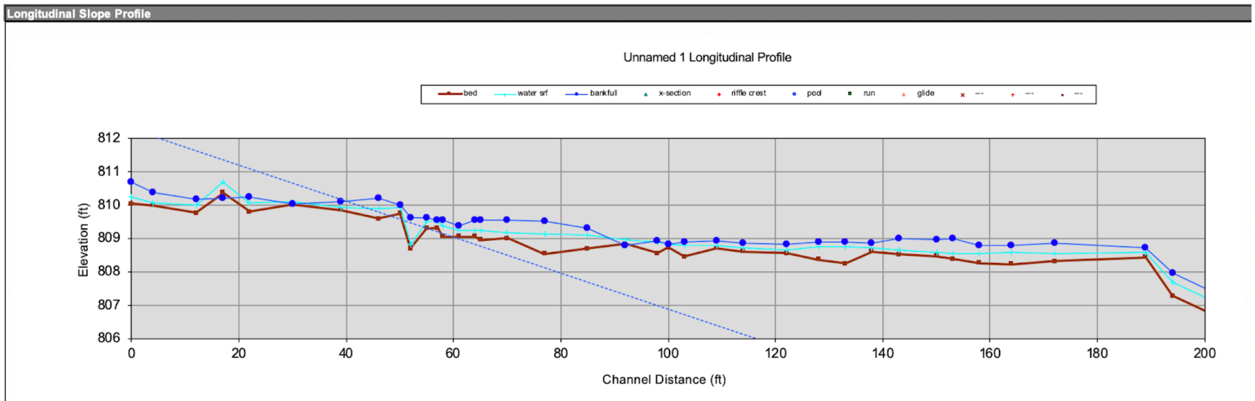
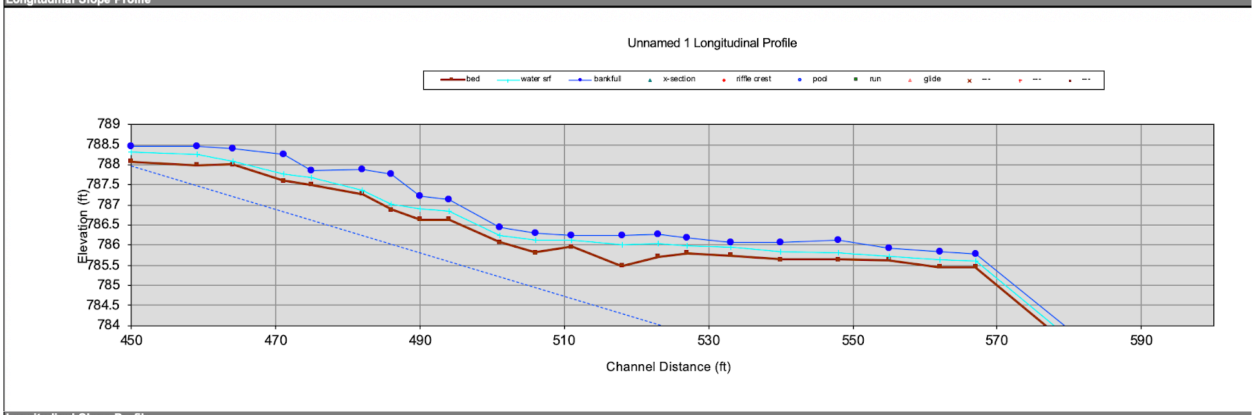


Figure H.5. Unnamed Creek 1 Longitudinal Profiles: upstream to downstream (1,2,3,4).

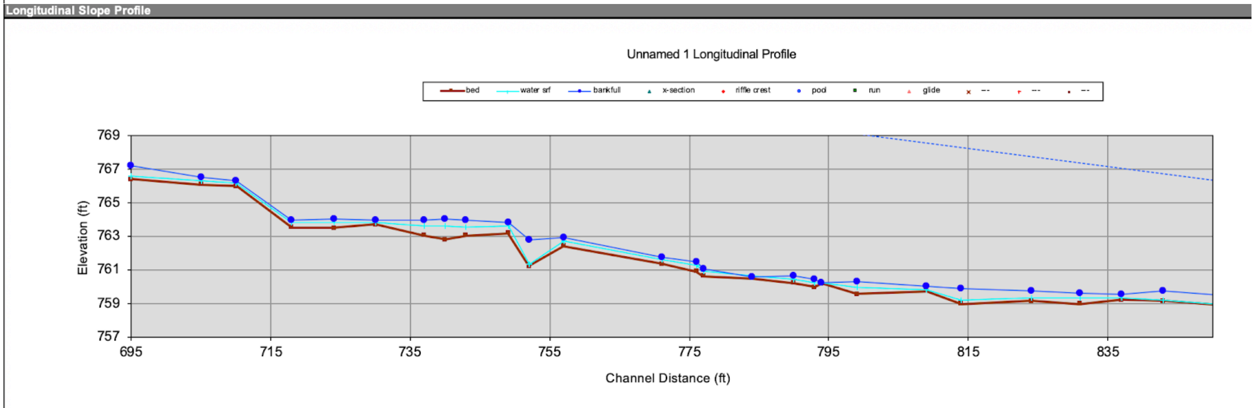
Longitudinal Slope Profile



Longitudinal Slope Profile



Longitudinal Slope Profile



Longitudinal Slope Profile