STREAM MITIGATION DESIGN REPORT

I-95 ETL NORTHBOUND EXTENSION PHASE II – LILLY RUN STREAM RESTORATION

Harford County, MD

Submitted to:
Maryland Transportation Authority
U.S. Army Corps of Engineers
Maryland Department of the Environment
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Table of Contents

Appendices

A. **Hydrology Mapping and Computations**
  - Drainage Area Maps (Existing Conditions)
  - WinTR-20 Output

B. **Site Assessment Mapping**

C. **Existing Channel Geomorphic Data**
  - Lilly Run Section and Profiles
  - Existing Conditions Pebble Count

D. **Ecological Uplift Data**
  - Pfankuch Channel Stability Forms
  - BEHI / NBS Geomorphic Data
  - Habitat Assessment Field Data Sheets

E. **Design Computations**
  - Proposed Floodplain Computations
  - Proposed Channel Computations
  - Sediment Analysis Data
  - Scour Hole Computations

F. **Design Plans (under separate cover)**

1. INTRODUCTION

The Maryland Transportation Authority (MDTA) is proposing to construct mitigation along Lilly Run Phases 2 through 4 as mitigation for the I-95 Express Toll Lanes (ETL) Northbound Extension Phase II Project. On behalf of the Maryland Transportation Authority (MDTA), Johnson, Mirmiran & Thompson (JMT) has completed this Design Report to discuss the design of Lilly Run that is to be used as compensatory mitigation for the-above mentioned projects. MDTA proposed that a mitigation credit ratio of 1:1 be utilized for the stream site, as the impacted first and zero order streams match closely in function and value with those proposed to be restored. See Table 1 below for calculation of proposed stream mitigation credits:

Table 1: Proposed Stream Mitigation Credit Calculation

Mitigation Sites	Proposed Restored Stream Length	Proposed Mitigation Credit Ratio	Proposed Stream Mitigation Credits
Lilly Run	2067 LF Perennial	1:1	2067 LF Perennial
Totals	**2067 LF**	**-**	**2067 LF**

*Values shown above approximate for Reaches 1-6. Finalized values will be provided in future submittals.

This report has been prepared in accordance with the *Maryland Compensatory Mitigation Guidance* (Interagency Mitigation Task Force (IMTF), 1994) and the *Compensatory Mitigation for Losses of Aquatic Resources; Final Rule* date April 10, 2008. This report will document and address the twelve elements required for mitigation plans per the Final Rule which include the following:

- Objectives
- Site Selection Criteria
- Site Protection Instruments
- Baseline Information
- Credit Determination Methodology
- Mitigation Work Plan
- Maintenance Plan
- Ecological Performance Standards
- Monitoring Requirements
- Long-Term Management Plan
- Adaptive Management Plan
- Financial Assurances

The following sections of the report will address all these elements as well as expand upon the existing conditions of the sites and proposed designs.

2. SITE DESCRIPTION

The following sections provide a brief site description for the location of Lilly Run. **Figure 1** below shows the location of the site.

Lilly Run is a perennial stream located southeast of I-95, within the Lower Susquehanna River watershed. The watershed is highly urbanized with a combination of impervious roadways, a railway, residential areas and industrial areas draining directly to the site.

The project site is divided into 4 reaches along Lilly Run and its unnamed tributaries. All reaches will be restored as a part of the Phase II mitigation package. Reach 1 is the most upstream reach of the project site and starts at the downstream end of the culvert that flows beneath Revolution St. Reach 2 is just downstream of Fountain St where Lilly Run is currently piped. Reach 3 is an unnamed tributary that starts at an outfall adjacent to S Juniata St. Reach 4 is the downstream most portion of Lilly Run for the project site and ends just upstream of the Amtrak train tracks. In general, the site is highly urbanized with straightened channels, erosive banks and a disconnected floodplain causing extreme flooding. More detailed information of the conditions of the site can be seen in the *Existing Channel Conditions Visual Assessment* Section.

Figure 1: Lilly Run mitigation reach map

3. SITE SELECTION CRITERIA

A mitigation search was originally conducted for the Section 200 ultimate build-out using GIS, aerial imagery and field reviews. MDTA also coordinated with multiple agencies for aid in identification of existing opportunities, field reconnaissance, and assessment of sites; those agencies include USACE, MDE, the Environmental Protection Agency (EPA), the US Department of Agriculture and the Harford County Department of Planning and Public Works. USACE identified the Lilly Run stream restoration site during the I-95 ETL Phase I mitigation site search; the first phase of the four-phase mitigation project initially planned by the City of Havre de Grace will be completed as part of the I-95 ETL Northbound Extension Phase I mitigation. All our phases of Lilly Run are high priority for the City of Havre de Grace, due to ongoing flooding concerns; therefore, the remaining phases of Lilly Run were selected to be part of the Phase II mitigation package.

4. SITE PROTECTION INSTRUMENTS

The proposed mitigation site will be protected through a Memorandum of Agreement between MDTA and the City of Havre de Grace. The draft Memorandum of Agreement will be provided when available, with the final document provided no later than one year after completion of construction.

5. PHYSIOGRAPHIC REGION, SURFACE GEOLOGY AND WATERSHED CHARACTERISTICS

Lilly Run is a tributary to the Susquehanna River and is located within the Lower Susquehanna River watershed (02-12-02-01) and is classified as a Use I waterway. The drainage area to the downstream end of the project site is approximately 939.61 acres. Lilly Run is not listed on the Maryland 303(d) lists of impaired waters. However, the downstream receiving waters of the Susquehanna River are listed on the 303(d) list of impaired waters. In addition, the downstream receiving waters of the tributary to Susquehanna River are listed for various impairments including Nitrogen and Phosphorus (Total). The downstream Susquehanna River is listed for additional impairments including Cadmium, Mercury, PCBs, and TSS.

Lilly Run is located within the Aberdeen Estuaries and Lowlands District of the Atlantic Coastal Plain Province. The landform description associated with this area is characterized as a relatively featureless lowland. As for the geologic structure of the project site, this region is essentially flat-lying sedimentary beds. The drainage pattern is dendritic (estuarine).

The surface soils within the stream restoration corridors mainly include Hatboro-Codorus complex, 0 to 3 percent slopes, frequently flooded (HcA) and Othello Silt Loams, 0 to 2 percent slopes, northern coastal plain (Ot). These soils are classified as very deep and poorly drained soils. The Hatboro-Codorus complex was formed in alluvium derived from greenstone and/or phyllite and/or quartzite and/or schist rock located in floodplain. The Othello Silt Loams was formed in silty eolian deposits over fluviomarine deposits. These are considered to be hydric soils that, according to the definition created by The National Technical Committee for Hydric Soils (NTCHS), are soils formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Lilly Run is located within an urbanized watershed where a significant amount of the waterways upstream of the project site have been piped. These impacts result in flashy and intense discharges through the open stream channel within the project site. In addition, the urbanized areas can negatively impact the water quality and habitat of the project stream reach.

The stream flow within the project site is perennial and driven by rainfall and occasionally by snowmelt. Bankfull flows may occur as a result of a variety of rain events including rain, snow, frontal storm events and tropical storms.

6. EXISTING CHANNEL CONDITIONS VISUAL ASSESSMENT

A visual assessment of Lilly Run's existing channel conditions was performed on April 10, 2019. This visual assessment identified areas most in need of bed and bank improvements, pattern and profile improvements, habitat enhancements, sediment and debris sources, degradation / aggradation areas, and localized impacts throughout the stream corridor that may influence long-term stability of design options.

The visual assessment of the project site has been separated into four stream reaches. These areas can be seen in the site assessment map located in **Figure 1** above and **Appendix B**:

- ***Reach 1:*** Main Stem from Revolution Street to Fountain Street.
- ***Reach 2:*** Main Stem piped section under soccer fields to be daylighted.
- ***Reach 3:*** Unnamed tributary from Juniata Street to Main Stem.
- ***Reach 4:*** Main Stem from pedestrian bridge to Amtrak train tracks.

6.1 REACH 1

Reach 1 begins at Revolution St culvert and flows approximately 880-feet downstream to Fountain St culvert (**Figure 2**). Reach 1 is confined within an approximately 75-foot-wide grassed area with development on either side. This area of the project site includes existing conditions survey of one cross section, one pebble count, and one longitudinal profile. This section of the main stem is straightened with little to no sinuosity and nearly vertical stream banks reaching 4-feet in height. Reach 1 is confined between 14-foot-wide old railroad tie walls which serve as the stream banks on various stretches of the reach. There is soil stabilization netting found in the channel bottom suggesting the stream has been improved before. Some fish were found in this reach however they were frequently stuck in the existing matting. There was no in-channel habitat for them either. The vegetation of the reach consists of grasses along the stream banks with moderate to high bank erosion and no overhead cover. Aggradation of sediment was found throughout the reach, ultimately leading to the sediment buildup at the Fountain St culvert. The outfall location and inverts of existing outfalls will need to be incorporated in concurrence with the stream restoration design. See **Photos 1-3** for visual of Reach 1.

Figure 2: Reach 1 map. Channel is fairly straight and confined between parallel 14-foot-wide railroad tie walls.

Photo 1: Looking upstream at Revolution Street Culvert. Note vertical railroad tie walls on left and right side.

Photo 2: Middle section of reach. Note straight channel with no cover or in-channel habitat.

Photo 3: Looking downstream at Fountain Street culvert

6.2 REACH 2

Reach 2 starts at Fountain Street culvert and is piped through a 42” x 72” CMP and ties into the main stem approximately 355-feet downstream (**Figure 3**). The opening of the CMP is approximately halfway filled with sediment (see **Photos 4** and **5**) greatly reducing its conveyance. The pipe runs below existing sports fields and daylighting the stream to an open channel is of great interest. The invert and outfall locations of the CMP will need to be incorporated in concurrence with the stream restoration design.

Figure 3: Map of Reach 2. Note system is within enclosed 42" x 72" CMP under sports field.

Photo 4: Looking upstream at Fountain Street from 42" x 72" Reach 2 CMP

Photo 5: Looking downstream at 42" x 72" Reach 2 CMP. Note CMP is halfway filled with deposits.

6.3 REACH 3

Reach 3 begins is from the N Juniata Street 24” x 42” CMP outfall to its confluence with the main stem (**Figure 4**). The N Juniata Street CMP outfalls into a 2-foot-wide channel in an open grass area (**Photo 6**). It flows through a constriction between the existing basketball and tennis courts and then opens back up. The unnamed tributary flows under a pedestrian bridge and ties into the main stem of Lilly Run about 450 feet downstream from the culvert outfall.

Existing conditions survey by JMT included one cross section, one pebble count, and one longitudinal profile within this reach. Reach 3 is a straight channel with little to no sinuosity. Bank erosion and channel degradation are not prevalent though the upstream portion. The stream banks are approximately 1-foot high with minor vegetation including grasses and trees located adjacent to the channel (**Photo 7**). Downstream of the pedestrian bridge the stream banks become approximately 3-feet high with more dense vegetation, less grasses and moderate bank erosion (**Photo 8**).

Figure 4: Map of Reach 3.

Photo 6: Unnamed tributary south of existing parking lot between existing tennis and basketball courts adjacent to S Juniata St. Note pipe outfalls into 2' wide channel in open grassy area.

Photo 7: Unnamed tributary middle section with 1' high banks and minor vegetation including grasses and trees.

Photo 8: Unnamed tributary downstream of pedestrian bridge. Stream banks are 3' high with more dense vegetation and moderate bank erosion.

6.4 REACH 4

Reach 4 begins downstream of the limits of Reach 3 at a pedestrian bridge and continues 860 feet downstream to an existing culvert that runs under the Amtrak railway (**Figure 5**). Existing conditions survey by JMT included one cross section, one pebble count, and one longitudinal profile. This reach is constricted on its right bank due to the stadium structures and sports fields on the left bank. The available floodplain varies from 55' to 65' within Reach 4. The stream channel is straightened with very minor sinuosity. The stream banks range from 2 to 6-feet with moderate bank erosion. The vegetative cover is primarily grasses and shrubs which line the stream and dominates most of the left bank. There are very few trees located along the reach. The stream lined shrubs are at risk for creating undercut banks or falling into the stream as streambanks continue to erode. The outfall location and inverts of said outfalls will need to be incorporated in concurrence with the stream restoration design. See **Photos 9-12** for more details.

Figure 5: Map of Reach 4 confined next to stadium

Photo 9: Looking downstream at most downstream section of reach at Amtrak rail.

Photo 10: Looking upstream. Note stadium's foundation limiting right bank floodplain.

Photo 11: Looking upstream at middle section of reach. Stream is fairly straight, banks are vertical.

Photo 12: Looking downstream from upper portion of reach.

7. WATERSHED HYDROLOGY STUDY

In order to determine peak discharge rates for this project, a hydrologic analysis was performed using GISHydro2000. Due to the highly developed nature of the project site, the existing and ultimate conditions were assumed to have the same land use boundaries; Therefore, the drainage area values that were generated from GISHydro2000, such as curve number and time of concentration, were used for computing discharge values.

The overall peak discharge rate was determined for the key Points of Investigations (POIs) throughout the project site. GISHydro2000 provided an output of discharges using the TR20 method and the Fixed Region equation. The Fixed Region equation discharges were chosen to represent the drainage area of Lilly run because the TR-20 output has not been calibrated for this submission; This makes the Fixed Region discharges the most conservative values to use for our proposed design. The TR-20 output should be calibrated in future submittals to meet the requirements of the discharge value expectations per the *Introduction to GISHydro2000 Training Manual, November 2007.* This expectation, per the training manual is as follows: “Calibration of TR-20 is expected for the [Fixed Region Regression Equation] between the best estimate and the best estimate plus one standard deviation,” (Moglen, 24). In future submittals, the TR-20 calibration in GISHydro2000 will allow for determining acceptable discharge values computed using WinTR-20. The GISHydro2000 output of discharges using the TR20 method and the Fixed Region equation can be found in Appendix A. The location of the three (3) POIs, which are discussed in further detail below, along with soil type, time of concentration (Tc) paths and land use boundaries, are shown on the Drainage Area Map provided in Appendix A.

Three (3) POIs were used to analyze the drainage areas to the ultimate project outfall of Lilly Run. POI-1 is located at the downstream end of Reach 1 at the Fountain St. culvert. POI-2 is located at the upstream end of Reach 3 at the 24" x 42" CMP outfall that flows underneath N Juniata St. POI-3 is located at the downstream end of Reach 4 at the ultimate outfall for our project which is the culvert that flows under the Amtrak Train Tracks. Please see **Table 2** below for the overall drainage area and discharge of the above-mentioned POIs using the Fix Region Equation.

Table 2: Lilly Run Drainage Area and Discharge Table

Drainage Area (acres)	Q2 (cfs)	Q10 (cfs)	Q100 (cfs)
939.61	299	809	2,420

8. BASELINE INFORMATION AND EXISTING CONDITIONS GEOMORPHOLOGY DATA

Geomorphology data was collected at the project site to determine the existing conditions of the site. Exact locations of cross sections, longitudinal profiles, Wolman pebble counts and additional data collected in the field can be seen on the Site Assessment Map located in **Appendix B**. All field data has also been entered into Rivermorph 5.2.0 and data plots can be seen in **Appendix C**.

During our geomorphic field assessment of Lilly Run, three (3) cross sections and three (3) longitudinal profiles were surveyed using laser level equipment to characterize existing channel conditions throughout the project site. The cross sections surveyed (**Photos 13–15**) will serve to represent average existing channel conditions for each respective reach found through the project site. Reach 2, the piped portion of Lilly Run, will be represented by the field assessment data collected at Reach 1. Assumptions and design approaches for Reach 2 can be found in Section 10 of this report.

Photo 13: XS 1 Looking downstream

Photo 14: XS 3 Looking downstream

Photo 15: XS 4 Looking downstream

Pebble counts were conducted on all riffle sections. The representative D30, D50 and D84 sediment sizes are based on the average grain sizes from the three pebble counts conducted. The results of the pebble counts show that the majority of the particles are gravels along with coarse to very coarse sand.
The pebble counts are summarized in **Table 3** below:

Table 3: Lilly Run Pebble Count Summary Table

Size Fraction	XS 1 Pebble Count (100 Particles)	XS 3 Pebble Count (101 Particles)	XS 3 Pebble Count (100 Particles)	Combined Pebble Count
D16	0.25	0.58	1	0.5
D35	1.70	2.56	3.67	2.69
D50	6.85	5.82	8.55	6.91
D84	24.95	28.99	40	29.98

9. RESTORATION AND UPLIFT OPPORTUNITY

This section will describe the strategies of proposed design elements to be utilized in the proposed restoration of Lilly Run as outlined in the *Final Draft Function-Based Rapid Stream Assessment Methodology* developed by the U.S. Fish and Wildlife Service (Starr et al. 2015) and the ecological benefits or functional uplift they may provide. The assessment methodology is largely based on the Stream Functions Pyramid as described in *A Function-Based Framework for Stream Assessment and Restoration*

Projects (Harman et al. 2012) (**Figure 6**). The pyramid consists of a hierarchal relationship of five (5) critical categories that evaluate the health and function of a stream.

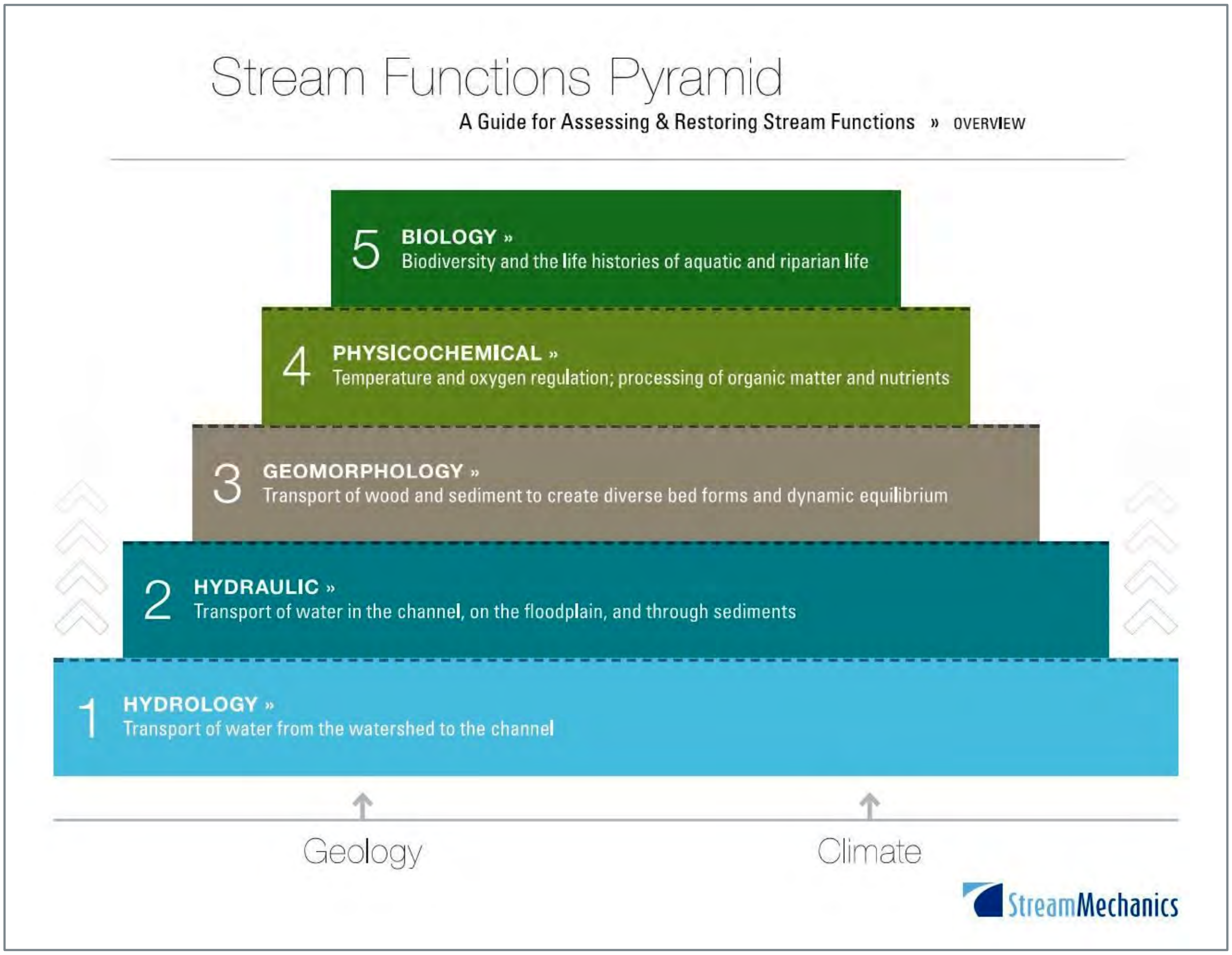

Figure 6: Stream Functions Pyramid (Harman et al., 2012)

The foundation of the proposed design for the Restoration of Lilly Run is based on the supporting premise of the Stream Functions Pyramid, that lower functions of the Pyramid support and form the foundation for higher level functions. If a proposed restoration project cannot or can only partially improve the hydrology, hydraulics and geomorphology, higher chemical and biological functions may only be supported for a brief period or may never become established at all. It is imperative that a successful design first focus on the establishment of the lower functions, before trying to force higher level functions.

The primary objective of the restoration design of Lilly Run, is to first focus on the correct hydrologic, hydraulic and geomorphic functions to establish a self-sustaining valley bottom ecosystem. Streams, wetlands, water, vegetation and wildlife are all critical components of a connected system. Each supports the sustainability of the other and serve as indicators of ecological health. The proposed restoration strategy is well founded upon the watershed assessment, an understanding to causes of current channel instability, and the sediment and geomorphic analyses performed. These studies have been utilized to limit potential design flaws and provide guidance to the proper channel and floodplain dimensions which will serve to maintain sediment equilibrium of the bedload, enhance the deposition of very fine suspended load materials and maintain long-term stability of a connected ecosystem. The design strategy closely resembles a Rosgen Priority 2 Restoration with the conversion of a F stream type to a less entrenched C channel that aids in moving the channel forward in the evolutionary process.

The design for Reach 1 includes the removal of existing railroad ties along the banks of the existing stream and modifying the existing stream geometry to construct a C-type stream. Due to the lack of available floodplain width, the proposed C-type stream is located along the existing stream channel. The design for Reach 2 includes removing the existing 42” x 72” CMP pipe and constructing a proposed C-type stream to direct the flow. The design for Reach 3 includes a proposed forebay and an adjacent wetland feature to remove pollutants and enhance water quality. The design for Reach 4 includes constructing a proposed C-type stream channel and filling in the existing channel to the same grade as the newly constructed floodplain.

The proposed design focuses on providing water quality improvements, bed load equilibrium, groundwater recharge, hyporheic exchange and improved hydraulic efficiency and function. All of which work together to form the foundation for improved in-channel and riparian ecological and biological functions. The five major categories of the Stream Functions Pyramid are discussed below. Multiple site assessment data sheets can be seen in **Appendix D**.

9.1 HYDROLOGY

Hydrology is primarily driven by land use within the upstream and adjacent watershed to the project site. During large storm or run-off events land use and soil types dictate the amount of water delivered to the project site. Land use also dictates the quality of that water delivered. While little can be done within the project site itself to change upstream watershed conditions, a properly restored valley bottom can greatly improve hydrologic functions during base flow conditions.

Existing Conditions

Upstream of Lilly Run is a highly urbanized watershed that is exposed to large amounts of flow for brief periods of time causing extreme flooding. Like many other urban streams, Lilly Run has become hydrologically disconnected due to excessive alluviation and vertical channel incision. The reaches have been straightened causing a high energy, unstable flow regime.

Proposed Conditions

In the proposed conditions, restoring Lilly Run will create an extensive hyporheic zone throughout the project site valley bottom. This reestablished connection will form the foundation for vital nutrient processing and physiochemical processes. The connection of surface and groundwater will support a diverse native wetland community and robust riparian vegetation. A more sustained groundwater hydrology throughout the valley bottom which includes greater water retention and saturation of soils will help sustain base flow of the channel during dry periods and regulate water temperature year-round.

Reestablishing or creating a dense riparian root system highly connected to groundwater promotes greatly increased sediment and nutrient processing and the protection of both channel banks and the floodplain surface from erosive flows. The reconnection to the water table also allows for the creation of varied hydrologic conditions by manipulating floodplain topography to support diverse wetland communities. Floodplain depressions, old channel bends or oxbows, wet and dry areas, all serve to create a mosaic of flora and fauna. The highly connected and varied floodplain surface will also serve to increase the surface and sub-surface storage of water promoting a rise in the elevation of the local water table or hydraulic head gradients and more sustained base flow of the channel.

9.2 HYDRAULICS

Existing Conditions

Lilly Run is incised in several locations and capable of mobilizing sediments much larger in size than is sustainable within the system. This disruption of the sediment regime creates hydraulic instabilities within the channel which drives both streambank and streambed erosion. Entrenchment ratios are an average of 3.7 for the three reaches, indicating entrenchment. Channelization of Lilly Run through the piping of flows and straightening of the stream have highly altered a stable flood flow regime. Also, as discussed in the Hydrology section above, Lilly Run has become largely hydrologically disconnected due to excessive alluviation and vertical channel incision. The site also has extensive flooding issues due to urbanization, with potential for impacts to infrastructure and the environment by these flood flows.

Proposed Conditions

Hydraulic function of the proposed valley bottom is likely to be improved through the creation of a lower and well-connected floodplain which will serve to reduce channel depth and create a frequent hydraulic connection of bankfull and higher flow events. The lower elevation floodplain will provide a significantly improved interaction between base and flood flows during most routine storm events and remain stable throughout the entire hydrograph with a surface treatment of native vegetation. During much higher storms, flood flows will access the entire existing valley bottom and be oriented in a uniform, down-valley direction. The reduction in bank height and bankfull depth of the proposed channel will result in significant decreases in channel velocities, shear stress and stream power. Introducing a more sinuous system coupled with the creation of a lower floodplain will also aid in decreasing channel velocity. The removal of impermeable soils will promote increased infiltration within the lower floodplain surface. The lower floodplain elevation will greatly increase surface water, groundwater and base flow interaction. Increased floodplain connectivity will result in a design which promotes increased groundwater recharge and increased flood flow attenuation which may result in decreased downstream flood elevations. Despite this improved floodplain connectivity for smaller discharges, it is likely large scale flood event impacts will be relatively unaffected by the design implementation, as urbanization, confinement, and urban structures control the 100-year and larger magnitude flood conditions.

9.3 GEOMORPHOLOGY

Existing Conditions

Lilly Run is capable of mobilizing gravel and even small cobble sized sediments. The source of these sediments is from bed scour and should not be considered part of the sustainable sediment supply. The geomorphic instability has been documented in Section 7. The excessive tractive forces within the incised channel are causing local bed scour and instances of lateral plan form migration as a result. The larger sediments can only be mobilized a short distance and deposit. Once these materials build to an elevation which they can no longer be mobilized by water in the channel, this process forces lateral erosion into the opposing streambanks. The impaired sediment regime has also impaired bed form diversity. In the existing conditions facet sequences primarily consist of pools due to channel straightening and very few riffle sections within the project site area. Several streambanks are vertical and exposed with little to no vegetative protection which creates an unstable scenario.

Proposed Conditions

The proposed design will include the same principals for each reach to promote bed form diversity and creation of a floodplain feature.

Reaches 1 and 4 will replace the existing entrenched F-type channel with a C-type channel of correct form and profile. Reach 4 will also include the creation/restoration of two wetland features adjacent to either side of the proposed channel. Reach 2 will remove the piped stream system to create a C-type channel to connect to the upstream and downstream portions of Lilly Run. Bed form diversity will be restored from a system that includes degrading and aggrading sections of streams, over straightened channels, piped systems or other flow obstructions to an appropriate riffle-pool morphology with integrated stability and habitat features. Proposed riffles will be orientated in a cross-valley direction to shield the channel from valley flood flows. Reach 3 will include the creation/restoration of a wetland feature adjacent to the existing stream channel and improvements at the outfall.

The newly created lower floodplain feature will serve to relieve the excessive tractive forces that have contributed to the lateral and vertical degradation of the existing system. The lower floodplain surface will serve to create a native riparian wetland buffer aggressively planted to create a dense root system. The appropriate composition of the native plantings to a wet hydrologic regime will promote long-term vegetative resistance to maintain the proposed geomorphic form and function of the proposed design.

In order to transport and provide vegetative treatment of finer sediments which may be delivered to the project reach from upstream streambank erosion and maintain a stable equilibrium underlayment within the valley bottom, the proposed channel dimensions must be sized to provide a frequent hydraulic connection to the surrounding floodplain and maintain a low transport condition during bankfull flow events.

The dimensions of the channel are based upon providing stability of the proposed channel bed by importing furnished underlayment. This underlayment will provide an armoring layer or protection of the smaller fine-grained sediments located in the channel and those delivered to the project reach from upstream sources.

Geomorphic functions of the valley bottom through the project site will serve to promote long-term stability through appropriate channel sizing, bed form diversity (riffle/pool features), and sediment transport equilibrium. Grade control structures (both in the channel and in the floodplain) will serve to protect the integrity of the design and provide protection to the level of the 100-year storm. The sediment equilibrium created in the proposed design will promote both long-term vertical and lateral stability.

9.4 PHYSICOCHEMICAL

Physicochemical functions include the interaction of physical and chemical processes to create basic water quality of the stream, as well as facility nutrient and organic carbon processes. Please note that no actual measurements of water quality (i.e. temperature, pH, turbidity, etc.) were taken for this project.

Existing Conditions

Based on observed site conditions, the water quality of Lilly Run through the project reaches appears to be fair to poor. A visual observation of the surrounding land use, riparian cover and detritus in the channel are all observable indicators of fair to poor water quality. The existing channel is highly disturbed by past and recent land use practices and is not geomorphically or hydraulically stable to support indicators of high water quality. An additional concern for water quality within the project site is the fact that most of the runoff entering the project site comes from adjacent impervious areas such as residential and commercial properties that discharge at the upstream end of the site. The runoff has the potential to carry contaminants which could impact the quality of the water. It is recommended that further characterization of the thermal condition of the stream be conducted for the next design phase, to verify restoration potential of these reaches.

Proposed Conditions

In the proposed conditions the channel and floodplain will be hydrologically connected to both surface and groundwater, creating an extensive hyporheic exchange zone which is critical to nutrient processing and microbial processes. This zone forms the foundation for life cycles of both aquatic and riparian life and regulates year-round surface water temperature through groundwater interaction. The frequent connection and expanse of the proposed floodplain area will greatly increase hydrologic residence time and promote nutrient processing. The proposed design will introduce canopy cover to the stream, reducing solar gain and thereby further enhancing water temperature regulation. Riparian tree and wetland herbaceous plantings are a key component of the restoration. Lower summertime water temperatures typically are related to improved dissolved oxygen conditions through reduced aerobic metabolic rates at higher water temperatures. Other indicators of water quality may be improved. pH levels can be balanced, and turbidity reduced through the removal of the overburden of alluvial soils present within the site. These soils typically have a low pH value and their high input into the stream from bank erosion decreases water clarity. Dissolved oxygen levels can also be improved through improved riffle-pool morphology.

The proposed floodplain area will be seeded and planted with numerous native grasses, herbaceous plants, shrub and tree plant species. In the proposed conditions, the channel and floodplain vegetation will be highly connected to groundwater, providing year-round thermal stability. In addition, due to the small size of the proposed channel, the proposed herbaceous and grass community along the channel will help provide shading. The combination of a restored hyporheic connection and shading of the proposed channel will enhance year-round temperature regulation.

A recent study conducted by Newcomer Johnson et al. 2016, found that more positive results from stream restoration typologies which lower the floodplain, increase sinuosity, and provide both in-stream and oxbow wetlands, increase nutrient retention and decrease nutrient concentrations compared to a pre-restoration or reference condition. Stream and floodplain restoration which provides a significant increase in wetlands with root zones connected to both surface and groundwater may promote increased nitrification and denitrification.

9.5 BIOLOGY

Healthy biological function is result of improvements made in all other functions, but no information could be found on previous biological studies performed in this area and one was not performed as a part of this project. However, the proposed design will connect the longitudinal profile to a surrounding floodplain which should increase stream bottom habitat quality for both macroinvertebrate and finfish communities. Reduction in sediment transport will also be a positive step toward improved benthic habitats which are routinely subjected to excessive fine sediment deposition in the channel from eroding banks within the project reach. Macroinvertebrates, for example, require a temporal stability of stream facet features (specifically, riffles) through the year and for some sensitive species, over several years of their in-stream life stages. More specifically, herpetological habitats are greatly uplifted as compared with an upland condition. Multiple species, including wood turtles, painted turtles, and a variety of salamanders and newts, rely on a symbiosis between the stream and floodplain areas to deposit sediments suitable for nesting, provide hydrology for specific inundation periods for reproduction, and require hydrology throughout the year to provide essential cover and foraging habitats.

The proposed restoration design will create velocities slow enough to deposit significant leaf and woody material into the floodplain, providing substrate for herpetological function. Potential oxbow and slow channel features will provide open water and emergent habitats critical for reproduction and foraging. Isolated oxbows may experience periodic drying in summer months, effectively creating isolated habitats removed from fish predation. Pools will provide potential hibernacula which may remain relatively frost-free due to their connection to groundwater. Sedges, rough grading and other vegetated hummocks will provide basking locations.

Further in-stream habitat improvements are proposed through the extensive use of facet feature variability and imported vegetation. The inclusion of live stakes, live fascines, and vegetation along the banks will likely increase the capture of leaf litter and course organic material for macroinvertebrate processing. These habitat and substrate enhancements will positively benefit fish communities by increasing habitat refugia and food sources for fish and are expected to have significant benefits to young fish. Riparian tree and wetland herbaceous plantings are a key component of the restoration.

Within the proposed floodplain, the reemergence of wetlands is highly anticipated. Frequent saturation of the floodplain surface will greatly deter upland and invasive species from recolonizing the site. The proposed design may create diverse floodplain topography with lower depressed areas to support several hydrologic zones for nutrient processing and plant diversity. Although the floodplain surface on the proposed design may look flat on paper, a mosaic of micro topography will be created by construction activities, abandoned channel filling and groundwater seepage. The creation of highly variable micro topography throughout the floodplain will support diverse hydrologic conditions. A mosaic of dry, moist and shallow water areas will support a greater diversity of flora and fauna. A dense vegetation root system connected to groundwater greatly increases sediment and nutrient processing (denitrification), evapotranspiration and infiltration.

9.6 STREAM STABILITY AND HABITAT ASSESSMENT SHEETS

The Pfankuch channel stability forms, BEHI / NBS geomorphic data forms and habitat assessment field data sheets have been filled out for all reaches to better assess their impairments and propose an appropriate restoration practice. The BEHI / NBS geomorphic data results represent those of all the reaches combined whereas the Pfankuch channel stability forms and habitat assessment field data sheets have been broken down by reach. Reach 2 was not included in the stream stability and habitat assessment sheets. The forms can be found in **Appendix D** and the results have been summarized below.

The BEHI / NBS geomorphic data forms were completed to estimate the sediment loss from streambank erosion on a yearly basis based on Protocol 1 of *Recommendations of the Expert Panel to Define Removal Rates for individual Stream Restoration Projects* prepared by Tom Schueler and Bill Stack. An assumed bulk density of 2,600 lbs/cy was used for computations as it is a similar value to soils of other sites in the area and no soil data was collected for the site. The computations show that the predicted erosion amount through the project site is 273.1 tons/year. The eroded soils would carry nutrients and suspended sediment with it causing further contamination downstream of this channel. The proposed design will remove the eroded banks and provide a more stable channel that would significantly reduce bank erosion within the project limits.

The Pfankuch channel stability form was used to determine an overall stability rating for the channel’s potential stream type. The habitat assessment field data sheets consider ten (10) habitat parameters to help determine an overall score to be used in determining the habitat conditions of the site. The results for each reach can be found below:

Reach 1

The existing stream type of Reach 1 has been determined to be an F4 with the potential to become a C4 when given a proper floodplain to meander through and decreasing bank erosion. As a result of an analysis of the upper banks, lower banks and stream bottom, the grand total of the form was 67. This computes to a good (stable) stability rating. This rating is in line with what was observed in the field since there were both stable and impaired sections of the channel.

The habitat assessment field data analysis showed that only one parameter was labeled as an optimal condition (bank stability) and another as a suboptimal condition (sediment deposition). All other parameters showed either marginal or poor conditions which is in line with what was observed during the visual assessment of the site.

Reach 3

The existing stream type of Reach 3 has been determined to be an F4 with the potential to become a C4 when given a proper floodplain to meander through and decreasing bank erosion. As a result of an analysis of the upper banks, lower banks and stream bottom, the grand total of the form was 67. This computes to a good (stable) stability rating. This rating is in line with what was observed in the field since there were both stable and impaired sections of the channel.

The habitat assessment field data analysis showed that only one parameter was labeled as an optimal condition (sediment deposition) and two were labeled as suboptimal conditions (substrate diversity and bank stability). All other parameters showed either marginal or poor conditions which is in line with what was observed during the visual assessment of the site.

Reach 4

The existing stream type of Reach 4 has been determined to be an F4 with the potential to become a C4 when given a proper floodplain to meander through and decreasing bank erosion. As a result of an analysis of the upper banks, lower banks and stream bottom, the grand total of the form was 69. This computes to a good (stable) stability rating. This rating is in line with what was observed in the field since there were both stable and impaired sections of the channel.

The habitat assessment field data analysis showed that only one parameter was labeled as an optimal condition (sediment deposition) and three others were labeled as suboptimal conditions (substrate diversity, bank stability and bank vegetative protection). All other parameters showed either marginal or poor conditions. The results are in line with what was observed during the visual assessment of the site.

10. HYDRAULIC COMPUTATIONS AND ANALYSIS

JMT is proposing to create 2,067 feet of proposed channel within the project site. The basis for the design is to develop the most stable channel dimension, pattern, and profile parameters feasible within the existing constraints of the Lilly Run Stream Restoration area. The proposed design will be split into four (4) reaches to better characterize anticipated flooding conditions within each stream segment. The main stem of Lilly Run is separated into three (3) separate reaches (Reaches 1, 2 and 4), along with one (1) additional tributary (Reach 3). Design computations for the proposed restoration of Reaches 1-4 can be found in **Appendix E** and hydrology information can be found in **Appendix A.** A full hydraulic model analysis is to be performed in future submittals and all computations included in this submittal will need to be confirmed to ensure the feasibility of the proposed design.

The proposed channel design for Reaches 1, 2 and 4 will replace the existing eroding stream banks and will include an easily accessible floodplain. This will provide the reaches with an increased cross-sectional flow area and low elevation energy dissipation during large storm events. The proposed channel and adjacent floodplain are designed to convey the computed discharges up to and including the 100-yr storm event in a stable manner through the project site. Andrew's Methodology was used to determine the particle sizes required to provide a stable streambed during large storm events. A table summarizing the results discussed below can be seen at the end of this section (**Table 4**).

Reach 1

JMT is proposing a performed scour hole at the existing Revolution St culvert at the upstream end of Reach 1. The scour hole was sized based off the Fountain St culvert at the downstream end of the reach since pipe information for the Revolution St culvert is currently unknown. The scour hole will need to be sized accordingly for future submittals.

A minimum of 1-foot class ‘0’ furnished underlayment along with gravel and smaller substrates is proposed throughout the entire stream profile. Additional riffle grade control is proposed at the downstream end of Reach 1 before the Fountain St culvert. The underlayment has been sized as Class ‘0’ to provide material that can withstand the shear stresses of the 100-year storm discharge. The proposed slope of the valley throughout Reach 1 is 0.437%; this was determined using the elevations of the longitudinal profile collected during the geomorphic survey. The minimum width of the floodplain surface and proposed cut to maintain shear stress levels at 2.0 psf for the 100-year storm event discharge has been calculated as 65-feet. This is being maintained throughout the entirety of the project reach. JMT is proposing to use the maximum amount of floodplain available to reduce shear stress values and promote vegetative growth.

The proposed channel dimensions for this reach includes a total riffle width of 13-feet, an average depth of 1.5-feet, 3:1 side slopes and 2:1 cut slopes at the edges of the floodplain. These dimensions are based on the bankfull characteristics observed and measured in the field at the representative riffle cross section for this Reach.

Reach 2

A Class ‘0’ preformed scour hole is being proposed at the upstream end of Reach 2 at the Fountain St culvert outfall to dissipate energy into the downstream floodplain. JMT is proposing that the currently piped segments of Reach 2 under various sports fields be daylighted in this area and the proposed design tie into the Lilly Run at the current outfall of the existing pipe. The scour hole is proposed to start at the elevation of the existing culvert and extend for a length of 31.5-feet and a width of 28-feet based on the existing size of the culvert. A 2-foot wide cutoff wall is proposed at the end of the scour hole to prevent head cuts / scour from occurring at the start of the channel.

A minimum of 1-foot class ‘0’ furnished underlayment along with gravel and smaller substrates is proposed throughout the entire stream profile. Additional riffle grade control is proposed at the downstream end of Reach 2 before the tie in point to the existing reach downstream. A geomorphic survey was not conducted for Reach 2 as it is currently being piped underground therefore particle size data collected during Reach 1 survey was used for underlayment sizing. The underlayment has been sized as Class ‘0’ to provide material that can withstand the shear stresses of the Reach 1 100-year storm discharge. The proposed slope of the valley throughout Reach 2 is assumed to be 0.50%; due to lack of geomorphic survey data this was determined to be a comparable slope to Reach 1 while tying into the necessary downstream elevation. The minimum width of the floodplain surface and proposed cut to maintain shear stress levels at 2.0 psf for the 100-year storm event discharge has been calculated as 65-feet. This is being maintained throughout the entirety of the project reach. JMT is proposing to use the maximum amount of floodplain available to reduce shear stress values and promote vegetative growth.

The proposed channel dimensions for this reach includes a total riffle width of 10-feet, an average depth of 1-foot, 3:1 side slopes and 2:1 cut slopes at the edges of the floodplain. These dimensions are based on the bankfull characteristics observed and measured in the field at the representative riffle cross section for Reach 1.

Reach 3

A forebay is proposed at the Juniata St culvert outfall at Reach 3 to dissipate energy and improve water quality coming from the upstream urban watershed by trapping sediment and debris. The forebay was sized using the same methodology as the scour hole at Reach 2, based on the size of the culvert outfall. Starting at the invert of the culvert, the forebay will be comprised of Class ‘0’ material, extending 18-feet long and 16-feet wide. A wetland feature has been proposed to the left of the existing stream channel in order to capture excess runoff and promote water quality. The wetland feature will capture a small amount of runoff including the adjacent basketball courts. It will also capture overflow from the stream channel during large storm events. The wetland feature will not be accounted for wetland creation/restoration credit but will enhance the water quality of the receiving wetland area created at Reach 4. No stream channel improvements are proposed for Reach 3.

Reach 4

A minimum of 1-foot class ‘0’ furnished underlayment along with gravel and smaller substrates is proposed throughout the entire stream profile. Additional riffle grade control is proposed at the upstream and downstream tie in points for Reach 4. The upstream tie-in is located 40-feet downstream of the pedestrian bridge-and the downstream point is just before the Amtrak train tracks. The underlayment has been sized as Class ‘0’ to provide material that can withstand the shear stresses of the 100-year storm discharge. The proposed slope of the valley throughout Reach 4 is 0.75%; this was determined using the elevations of the longitudinal profile collected during the geomorphic survey. The minimum width of the floodplain surface and proposed cut to maintain shear stress levels at 2.0 psf for the 100-year storm event discharge has been calculated as 50-feet. This is being maintained throughout the entirety of the project reach. JMT is proposing to use the maximum amount of floodplain available to reduce shear stress values and promote vegetative growth. The proposed design will be located to the west of the existing stream location as to avoid impacts to the stadium structures.

The proposed channel dimensions for this reach includes a total riffle width of 11-feet, an average depth of 1-foot, 3:1 side slopes and 2:1 cut slopes at the edges of the floodplain. These dimensions are based on the bankfull characteristics observed and measured in the field at the representative riffle cross section for this Reach.

Two (2) wetland features have been proposed to the left and right of the proposed stream channel in order to capture excess runoff and promote water quality.

Table 4: Hydraulic Computations Summary Table

	Reach 1	Reach 2	Reach 4
Design Discharge (cfs)*	2,420	2,420	2,420
Slope	0.437%	0.50%	0.75%
Proposed Floodplain Width (ft)**	65	65	50
SEDIMENT MOBILITY ANALYSIS			
Boundary Shear Stress (psf)**	0.24	0.19	0.30
D_{50} = Existing Mean Riffle Bed Material Size based on measured data (mm)	6.85	6.85	8.55
D_{50} = Required Mean Riffle Bed Material Size based on Boundary Shear Stress (mm)***	19	19	24
D_{50} = Proposed Mean Riffle Bed Material Size (mm)***	152	152	152

*100-year discharge (see **Appendix A**)
Computed using Rivermorph (see **Appendix E)
***Based on Andrew's Methodology (see **Appendix E**)

11. CREDIT DETERMINATION METHODOLOGY

USACE and MDE confirmed that 1 LF credit is required per 1 LF of stream impacted (1:1) due to the low-quality nature of the streams to be impacted. Lilly Run is one of the sites being used to fulfill mitigation requirements and any mitigation provided above and beyond what is required for this project will be reserved for the ultimate Section 200 build out. As shown in Table 1 of Section 1, Lilly Run is approximately providing approximately 2,067 LF of perennial stream credit.

12. RESTORATION DESIGN DISCUSSION AND MITIGATION WORK PLAN

The basis for the design is to develop a stable channel dimension, pattern, and profile that will transport the fine sediment load from the upper watershed over time while maintaining a stable channel dynamic equilibrium, where channel dimension and facet sequence vary only within the stable natural variability of the site. Channel dimension should persist without significant aggregation or degradation; however, floodplains would serve as sinks for the deposition of fine sediments. To understand the long-term dynamic equilibrium of the proposed design, one needs to understand the condition of the proposed streambed substrate. The foundation of the design of Lilly Run include the following:

- Improve water quality by creating a low-elevation riparian floodplain and dense riparian root zone that is highly attached to the active channel, eliminating erosion and downstream sedimentation and providing increased storage to capture and treat nutrients originating from the highly urbanized upper watershed.
- Provide additional sinuosity to the channel and a more appropriate riffle-pool facet sequence.
- Streambed substrate will be comprised of imported furnished underlayment sized to withstand the maximum shear stress of the channel.
- Developing a floodplain that can withstand shear stresses not to exceed 2.0 lbs./sq.ft., the threshold for vegetative stability.
- Lowering of the 100-year floodplain elevation and in hand decreasing the footprint of the 100-year floodplain. The reduced floodplain elevation should reduce the extent of flooding of adjacent areas that have a history of flooding events.

The proposed restoration technique to be utilized is floodplain restoration, which focuses on replacing existing eroding stream banks and connecting the stream channel to an easily accessible floodplain. This technique is based upon the research of Walters and Merits (Walter & Merritts, 2008). This technique maximizes ecological uplift through the following functions and values:

- Increasing floodplain and channel connectivity
- Diversifying wetland hydrology through incorporating surface, groundwater, and flood flow hydrology into floodplain wetlands
- Encouraging greater hyporheic exchange
- Augmenting stream channel base flow through contact and connectivity with the floodplain surface and groundwater table
- Increasing the physical quantity of wetlands at the site
- Increasing frequency of flood flow contact with floodplain surfaces and dense proposed hydrophytic vegetation, which increases opportunity for nutrient processing and suspended sediment deposition during flood flows as well as base flow.

The restoration of Lilly Run will aim towards establishing a natural riparian corridor using native materials found on-site and attempt to reduce the use of imported materials or hard armoring structures. Major design elements and/or improvements to existing natural features to be utilized in the proposed restoration include:

Woody Materials:

Trees and other woody materials removed during excavation of the proposed lower floodplain as well as those imported from other incidental clearing and grubbing activities will not be repurposed and used on this site due to the high energy flows from the highly urbanized upstream watershed, as well as the poor quality of the on-site materials for re-use. Although not preferred, some hard-armoring structures will be implemented in order for grade control and habitat features throughout the proposed channel and floodplain to be able to withstand peak discharges.

Wood structures to be potentially imported within the Lilly Run project site include:

- **Live Fascines and Live Stakes.** Live fascines and live stakes may be utilized primarily on the outside of channel meander bends to either form or provide immediate stabilization and support to the streambanks. These materials serve as structural support to earth and soil stabilization matting, trapping fine sediment and binding it to the floodplain surface. A variety of species may be utilized adapted to permanently saturated conditions and providing critical near bank habitat, food sources and streambank stability.

Other Stability Measures:

Throughout Lilly Run, there are constraints that may require the proposed design to include additional stability measures. It is anticipated based on field observations that a portion or all the following structures or practices may be utilized to make the necessary improvements to these areas:

- **In-Stream Rock Structures.** In-Stream Rock Structures may consist of rock cross vanes, rock j-hook vanes, or random boulder placements for providing additional grade control and offsetting higher shear stresses and velocities in steeper reaches or where grade may be necessary to transition flows at confluence points. The use of rock structures may also provide deeper pool areas, varying flow dynamics and oxygenation of the water for improved habitat and water chemistry.

- **Preformed Scour Holes.** Preformed Scour Holes may be utilized at the outfall of the existing pipes at reaches 1, 2 and 3 to prevent bed scour and allow for the vertical and lateral expansion of excessive energy exiting the structure. The use of Preformed Scour Holes is an effective method of quickly transitioning high energy flows to a low energy condition and preserving the integrity of restoration efforts immediately downstream.

- **Imported Gravel Underlayment.** A coarser gravel underlayment may be necessary in portions of steeper reaches to offset higher shear stresses and velocities on the bed of the channel. The underlayment will be sized to resist the peak discharges anticipated through the full hydrograph and will likely be choked-in with native substrate found at the project site.

Conceptual design plans have been included in **Appendix E** to show preliminary floodplain width, bankfull dimensions, structure locations, landscaping and site access. The preliminary floodplain width was determined through simplistic shear stress computations to provide a floodplain that reduces the proposed 100-year shear stresses to 2.0 lbs/sf or less and avoids impacts to adjacent trees and other existing resources. The typical section was determined from the bankfull channel dimensions collected in the field to create a proposed condition that promotes frequent flooding of the surrounding floodplain. It is anticipated that both the floodplain and channel dimensions will be modified for future submissions.

The proposed design will improve upon existing conditions by providing additional sinuosity to the channel and a more appropriate riffle-pool facet sequence. Design computations will be provided with future submittals.

13. MAINTENANCE PLAN

All maintenance requirements for this site shall follow the standards set forth in the Compensatory Mitigation Plan and 2008 Final Mitigation Rule.

14. MONITORING REQUIREMENTS AND PERFORMANCE STANDARDS

All monitoring requirements and performance standards for this site shall follow the standards set forth in the Compensatory Mitigation Plan and 2008 Final Mitigation Rule.

15. LONG-TERM MANAGEMENT PLAN

All long-term management for this site shall follow the standards set forth in the Compensatory Mitigation Plan and 2008 Final Mitigation Rule.

16. FINANCIAL ASSURANCES

The MDTA, as a state agency, operates on a 5-year Transportation Improvement Program (TIP) cycle and has allocated $1.1 billion as a specific line item in its TIP budget to construct Phases I and II of the I-95 ETL Northbound Extension Project (see **Appendix F**). The funding allocated for the project is inclusive of any compensatory mitigation, including required construction, monitoring, and long-term maintenance activities, for unavoidable impacts associated with the proposed improvements.

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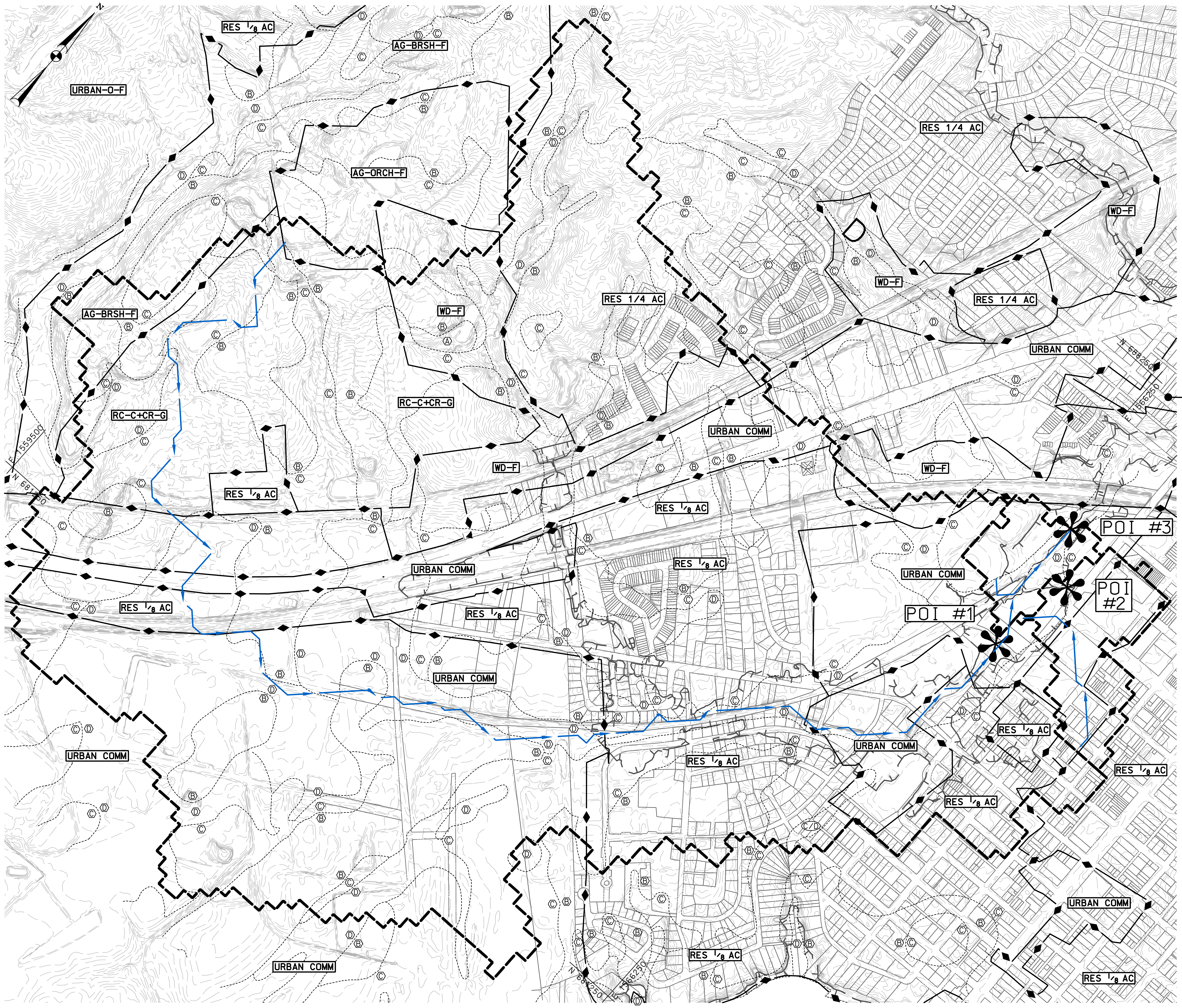
Appendix A

Hydrology Mapping and Computations



500′ 0 500′ 1000′

SCALE: 1"=500′

DISCHARGE SUMMARY TABLE

POI	Q_2	Q_{10}	Q_{100}
3*	299	809	2420

*DISCHARGE AT DOWNSTREAM MOST POINT OF PROJECT SITE.

DRAINAGE AREA SUMMARY TABLE

POI	D.A. (AC.)	TcPATH	RCN
1	897.92	1.126	86
2	31.45	0.300	91
3	939.61	2.418	85

LEGEND

— 310 —	EXISTING CONTOUR
········	SOIL BOUNDARY
Ⓓ	SOIL TYPE
✻	POINT OF INVESTIGATION (POI)
——➝——	TcPATH (TIME OF CONCENTRATION)
— — — —	DRAINAGE AREA BOUNDARY
——◆——	LAND USE BOUNDARY
RES 1/4 AC	RESIDENTIAL 1/4 ACRE
RES 1/8 AC	RESIDENTIAL 1/8 ACRE
URBAN COMM	URBAN COMMERCIAL
URBAN-O-F	URBAN OPEN SPACE-FAIR
AG-ORCH-F	AGRICULTURAL ORCHARD-FAIR
AG-BRSH-F	AGRICULTURAL BRUSH-FAIR
RC-C+CR-G	ROW CROP CONTOURED W/ COVER-GOOD
WD-F	WOODS-FAIR

HORIZONTAL DATUM NAD 83/91
VERTICAL DATUM NAVD 88

WWW.JMT.COM 410-329-3100

PRELIMINARY NOT FOR CONSTRUCTION

Maryland Transportation Authority
Engineering Division

ADDENDUMS & REVISIONS

NO.	DESCRIPTION	BY	DATE

JOHN F. KENNEDY MEMORIAL HIGHWAY
I-95 ETL NORTHBOUND EXTENSION

LILLY RUN DRAINAGE AREA MAP

DESIGNED BY KNH
DRAWN BY KNH
CHECKED BY JM
CONST. REVIEW BY
DATE JUNE 2019
SCALE 1"=500′

CONTRACT NO. KH-3009
DRAWING NO. DA-01
SHEET NO. 1 OF 1

FILE: \\jmt.corp.local\jmtdfs\SMD\130770_048_I95_ETL_N_Tran\CADD\Lilly Run\pDA-E000-KH3009_Lilly Run Mitigation.dgn
DATE: Wednesday, June 05, 2019 AT 11:24 AM

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1



 *****************80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY******************

 JOB TR-20                                                   NOPLOTS
 TITLE     I-95 ETL
 TITLE     Lilly Run
  2 XSECTN   003                  1.0       42.20
  8                             41.06        0.00        0.00
  8                             41.34        0.76        0.69
  8                             41.63        4.68        2.46
  8                             41.91       12.57        4.95
  8                             42.20       24.91        8.06
  9 ENDTBL
  5 RAINFL 1              .1
  8          0.0000      0.0011      0.0021      0.0032      0.0042
  8          0.0053      0.0063      0.0074      0.0085      0.0095
  8          0.0106      0.0116      0.0127      0.0138      0.0148
  8          0.0159      0.0169      0.0180      0.0190      0.0201
  8          0.0212      0.0222      0.0233      0.0243      0.0254
  8          0.0264      0.0275      0.0286      0.0296      0.0307
  8          0.0317      0.0328      0.0338      0.0349      0.0360
  8          0.0370      0.0381      0.0391      0.0402      0.0413
  8          0.0423      0.0434      0.0444      0.0455      0.0465
  8          0.0476      0.0487      0.0497      0.0508      0.0518
  8          0.0529      0.0539      0.0550      0.0561      0.0571
  8          0.0582      0.0592      0.0603      0.0613      0.0624
  8          0.0635      0.0661      0.0688      0.0715      0.0742
  8          0.0769      0.0795      0.0822      0.0849      0.0876
  8          0.0902      0.0929      0.0956      0.0983      0.1009
  8          0.1036      0.1063      0.1090      0.1117      0.1143
  8          0.1170      0.1197      0.1224      0.1250      0.1277
  8          0.1304      0.1331      0.1358      0.1384      0.1411
  8          0.1438      0.1484      0.1530      0.1576      0.1622
  8          0.1668      0.1714      0.1760      0.1806      0.1852
  8          0.1898      0.1943      0.1989      0.2035      0.2081
  8          0.2127      0.2169      0.2210      0.2252      0.2293
  8          0.2334      0.2428      0.2521      0.2615      0.2708
  8          0.2802      0.2976      0.3150      0.3428      0.3869
  8          0.5000      0.6131      0.6572      0.6850      0.7024
  8          0.7198      0.7292      0.7385      0.7479      0.7572
  8          0.7666      0.7707      0.7748      0.7790      0.7831
  8          0.7873      0.7919      0.7965      0.8011      0.8057
  8          0.8102      0.8148      0.8194      0.8240      0.8286
  8          0.8332      0.8378      0.8424      0.8470      0.8516
  8          0.8562      0.8589      0.8616      0.8642      0.8669
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  8          0.8696      0.8723      0.8750      0.8776      0.8803
  8          0.8830      0.8857      0.8883      0.8910      0.8937
  8          0.8964      0.8991      0.9017      0.9044      0.9071
  8          0.9098      0.9124      0.9151      0.9178      0.9205
  8          0.9231      0.9258      0.9285      0.9312      0.9339
  8          0.9365      0.9376      0.9387      0.9397      0.9408
  8          0.9418      0.9429      0.9439      0.9450      0.9461
  8          0.9471      0.9482      0.9492      0.9503      0.9513
1



 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.9524      0.9535      0.9545      0.9556      0.9566
  8          0.9577      0.9587      0.9598      0.9609      0.9619
  8          0.9630      0.9640      0.9651      0.9662      0.9672
  8          0.9683      0.9693      0.9704      0.9714      0.9725
  8          0.9736      0.9746      0.9757      0.9767      0.9778
  8          0.9788      0.9799      0.9810      0.9820      0.9831
  8          0.9841      0.9852      0.9862      0.9873      0.9884
  8          0.9894      0.9905      0.9915      0.9926      0.9937
  8          0.9947      0.9958      0.9968      0.9979      0.9989
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  5 RAINFL 2            .1
  8          0.0000      0.0011      0.0021      0.0032      0.0042
  8          0.0053      0.0064      0.0074      0.0085      0.0096
  8          0.0106      0.0117      0.0127      0.0138      0.0149
  8          0.0159      0.0170      0.0181      0.0191      0.0202
  8          0.0212      0.0223      0.0234      0.0244      0.0255
  8          0.0265      0.0276      0.0287      0.0297      0.0308
  8          0.0319      0.0329      0.0340      0.0350      0.0361
  8          0.0372      0.0382      0.0393      0.0404      0.0414
  8          0.0425      0.0435      0.0446      0.0457      0.0467
  8          0.0478      0.0488      0.0499      0.0510      0.0520
  8          0.0531      0.0542      0.0552      0.0563      0.0573
  8          0.0584      0.0595      0.0605      0.0616      0.0627
  8          0.0637      0.0664      0.0691      0.0717      0.0744
  8          0.0771      0.0798      0.0824      0.0851      0.0878
  8          0.0905      0.0931      0.0958      0.0985      0.1012
  8          0.1038      0.1065      0.1092      0.1119      0.1146
  8          0.1172      0.1199      0.1226      0.1253      0.1279
  8          0.1306      0.1333      0.1360      0.1386      0.1413
  8          0.1440      0.1484      0.1529      0.1573      0.1618
  8          0.1662      0.1707      0.1752      0.1796      0.1841
  8          0.1885      0.1930      0.1974      0.2019      0.2063
  8          0.2108      0.2150      0.2193      0.2235      0.2278
```

```
  8          0.2321      0.2413      0.2506      0.2599      0.2692
  8          0.2785      0.2965      0.3145      0.3430      0.3879
  8          0.5000      0.6121      0.6570      0.6855      0.7035
  8          0.7215      0.7308      0.7401      0.7494      0.7587
  8          0.7679      0.7722      0.7765      0.7807      0.7850
  8          0.7892      0.7937      0.7981      0.8026      0.8070
  8          0.8115      0.8159      0.8204      0.8248      0.8293
  8          0.8338      0.8382      0.8427      0.8471      0.8516
  8          0.8560      0.8587      0.8614      0.8640      0.8667
  8          0.8694      0.8721      0.8747      0.8774      0.8801
  8          0.8828      0.8854      0.8881      0.8908      0.8935
  8          0.8962      0.8988      0.9015      0.9042      0.9069
  8          0.9095      0.9122      0.9149      0.9176      0.9202
  8          0.9229      0.9256      0.9283      0.9309      0.9336
  8          0.9363      0.9373      0.9384      0.9395      0.9405
  8          0.9416      0.9427      0.9437      0.9448      0.9458
1



 *********************80-80 LIST OF INPUT DATA (CONTINUED)**********************

  8          0.9469      0.9480      0.9490      0.9501      0.9512
  8          0.9522      0.9533      0.9543      0.9554      0.9565
  8          0.9575      0.9586      0.9596      0.9607      0.9618
  8          0.9628      0.9639      0.9650      0.9660      0.9671
  8          0.9681      0.9692      0.9703      0.9713      0.9724
  8          0.9735      0.9745      0.9756      0.9766      0.9777
  8          0.9788      0.9798      0.9809      0.9819      0.9830
  8          0.9841      0.9851      0.9862      0.9873      0.9883
  8          0.9894      0.9904      0.9915      0.9926      0.9936
  8          0.9947      0.9958      0.9968      0.9979      0.9989
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  5 RAINFL 3              .1
  8          0.0000      0.0011      0.0023      0.0034      0.0046
  8          0.0057      0.0069      0.0080      0.0092      0.0103
  8          0.0115      0.0126      0.0137      0.0149      0.0160
  8          0.0172      0.0183      0.0195      0.0206      0.0218
  8          0.0229      0.0241      0.0252      0.0263      0.0275
  8          0.0286      0.0298      0.0309      0.0321      0.0332
  8          0.0344      0.0355      0.0366      0.0378      0.0389
  8          0.0401      0.0412      0.0424      0.0435      0.0447
  8          0.0458      0.0470      0.0481      0.0492      0.0504
  8          0.0515      0.0527      0.0538      0.0550      0.0561
  8          0.0573      0.0584      0.0596      0.0607      0.0618
  8          0.0630      0.0641      0.0653      0.0664      0.0676
  8          0.0687      0.0714      0.0742      0.0769      0.0796
```

```
  8          0.0824     0.0851     0.0878     0.0905     0.0933
  8          0.0960     0.0987     0.1014     0.1042     0.1069
  8          0.1096     0.1124     0.1151     0.1178     0.1205
  8          0.1233     0.1260     0.1287     0.1315     0.1342
  8          0.1369     0.1396     0.1424     0.1451     0.1478
  8          0.1505     0.1549     0.1592     0.1636     0.1679
  8          0.1722     0.1766     0.1809     0.1853     0.1896
  8          0.1939     0.1983     0.2026     0.2070     0.2113
  8          0.2156     0.2199     0.2242     0.2284     0.2327
  8          0.2370     0.2462     0.2555     0.2647     0.2740
  8          0.2832     0.3023     0.3213     0.3509     0.3959
  8          0.5000     0.6041     0.6491     0.6787     0.6977
  8          0.7168     0.7260     0.7353     0.7445     0.7538
  8          0.7630     0.7673     0.7716     0.7758     0.7801
  8          0.7844     0.7887     0.7930     0.7974     0.8017
  8          0.8061     0.8104     0.8147     0.8191     0.8234
  8          0.8278     0.8321     0.8364     0.8408     0.8451
  8          0.8495     0.8522     0.8549     0.8576     0.8604
  8          0.8631     0.8658     0.8685     0.8713     0.8740
  8          0.8767     0.8795     0.8822     0.8849     0.8876
  8          0.8904     0.8931     0.8958     0.8986     0.9013
  8          0.9040     0.9067     0.9095     0.9122     0.9149
  8          0.9176     0.9204     0.9231     0.9258     0.9286
  8          0.9313     0.9324     0.9336     0.9347     0.9359
1


 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.9370     0.9382     0.9393     0.9404     0.9416
  8          0.9427     0.9439     0.9450     0.9462     0.9473
  8          0.9485     0.9496     0.9508     0.9519     0.9530
  8          0.9542     0.9553     0.9565     0.9576     0.9588
  8          0.9599     0.9611     0.9622     0.9634     0.9645
  8          0.9656     0.9668     0.9679     0.9691     0.9702
  8          0.9714     0.9725     0.9737     0.9748     0.9759
  8          0.9771     0.9782     0.9794     0.9805     0.9817
  8          0.9828     0.9840     0.9851     0.9863     0.9874
  8          0.9885     0.9897     0.9908     0.9920     0.9931
  8          0.9943     0.9954     0.9966     0.9977     0.9989
  8          1.0000     1.0000     1.0000     1.0000     1.0000
  9 ENDTBL
  5 RAINFL 4              .1
  8          0.0000     0.0012     0.0024     0.0036     0.0049
  8          0.0061     0.0073     0.0085     0.0097     0.0109
  8          0.0121     0.0134     0.0146     0.0158     0.0170
  8          0.0182     0.0194     0.0206     0.0219     0.0231
```

```
  8          0.0243      0.0255      0.0267      0.0279      0.0292
  8          0.0304      0.0316      0.0328      0.0340      0.0352
  8          0.0364      0.0377      0.0389      0.0401      0.0413
  8          0.0425      0.0437      0.0449      0.0462      0.0474
  8          0.0486      0.0498      0.0510      0.0522      0.0534
  8          0.0547      0.0559      0.0571      0.0583      0.0595
  8          0.0607      0.0619      0.0632      0.0644      0.0656
  8          0.0668      0.0680      0.0692      0.0705      0.0717
  8          0.0729      0.0757      0.0785      0.0813      0.0841
  8          0.0869      0.0897      0.0925      0.0954      0.0982
  8          0.1010      0.1038      0.1066      0.1094      0.1122
  8          0.1150      0.1178      0.1206      0.1234      0.1262
  8          0.1291      0.1319      0.1347      0.1375      0.1403
  8          0.1431      0.1459      0.1487      0.1515      0.1543
  8          0.1571      0.1615      0.1659      0.1703      0.1747
  8          0.1791      0.1835      0.1878      0.1922      0.1966
  8          0.2010      0.2054      0.2098      0.2141      0.2185
  8          0.2229      0.2272      0.2315      0.2359      0.2402
  8          0.2445      0.2539      0.2632      0.2726      0.2820
  8          0.2913      0.3107      0.3301      0.3596      0.4033
  8          0.5000      0.5967      0.6404      0.6699      0.6893
  8          0.7087      0.7180      0.7274      0.7368      0.7461
  8          0.7555      0.7598      0.7641      0.7685      0.7728
  8          0.7771      0.7815      0.7859      0.7902      0.7946
  8          0.7990      0.8034      0.8078      0.8122      0.8165
  8          0.8209      0.8253      0.8297      0.8341      0.8385
  8          0.8429      0.8457      0.8485      0.8513      0.8541
  8          0.8569      0.8597      0.8625      0.8653      0.8681
  8          0.8709      0.8738      0.8766      0.8794      0.8822
  8          0.8850      0.8878      0.8906      0.8934      0.8962
  8          0.8990      0.9018      0.9046      0.9075      0.9103
  8          0.9131      0.9159      0.9187      0.9215      0.9243
1



 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.9271      0.9283      0.9295      0.9308      0.9320
  8          0.9332      0.9344      0.9356      0.9368      0.9381
  8          0.9393      0.9405      0.9417      0.9429      0.9441
  8          0.9453      0.9466      0.9478      0.9490      0.9502
  8          0.9514      0.9526      0.9538      0.9551      0.9563
  8          0.9575      0.9587      0.9599      0.9611      0.9623
  8          0.9636      0.9648      0.9660      0.9672      0.9684
  8          0.9696      0.9708      0.9721      0.9733      0.9745
  8          0.9757      0.9769      0.9781      0.9794      0.9806
  8          0.9818      0.9830      0.9842      0.9854      0.9866
```

```
  8          0.9879      0.9891      0.9903      0.9915      0.9927
  8          0.9939      0.9951      0.9964      0.9976      0.9988
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  5 RAINFL 5             .1
  8          0.0000      0.0013      0.0026      0.0039      0.0052
  8          0.0065      0.0078      0.0091      0.0103      0.0116
  8          0.0129      0.0142      0.0155      0.0168      0.0181
  8          0.0194      0.0207      0.0220      0.0233      0.0246
  8          0.0259      0.0272      0.0285      0.0298      0.0310
  8          0.0323      0.0336      0.0349      0.0362      0.0375
  8          0.0388      0.0401      0.0414      0.0427      0.0440
  8          0.0453      0.0466      0.0479      0.0492      0.0505
  8          0.0517      0.0530      0.0543      0.0556      0.0569
  8          0.0582      0.0595      0.0608      0.0621      0.0634
  8          0.0647      0.0660      0.0673      0.0686      0.0699
  8          0.0712      0.0724      0.0737      0.0750      0.0763
  8          0.0776      0.0806      0.0836      0.0865      0.0895
  8          0.0925      0.0955      0.0985      0.1014      0.1044
  8          0.1074      0.1104      0.1133      0.1163      0.1193
  8          0.1223      0.1252      0.1282      0.1312      0.1342
  8          0.1371      0.1401      0.1431      0.1461      0.1490
  8          0.1520      0.1550      0.1580      0.1609      0.1639
  8          0.1669      0.1714      0.1759      0.1804      0.1849
  8          0.1894      0.1939      0.1984      0.2029      0.2074
  8          0.2120      0.2165      0.2210      0.2255      0.2300
  8          0.2345      0.2388      0.2431      0.2474      0.2517
  8          0.2560      0.2655      0.2750      0.2845      0.2940
  8          0.3035      0.3231      0.3426      0.3716      0.4130
  8          0.5000      0.5870      0.6284      0.6574      0.6769
  8          0.6965      0.7060      0.7155      0.7250      0.7345
  8          0.7440      0.7483      0.7526      0.7569      0.7612
  8          0.7655      0.7700      0.7745      0.7790      0.7835
  8          0.7880      0.7926      0.7971      0.8016      0.8061
  8          0.8106      0.8151      0.8196      0.8241      0.8286
  8          0.8331      0.8361      0.8391      0.8420      0.8450
  8          0.8480      0.8510      0.8539      0.8569      0.8599
  8          0.8629      0.8658      0.8688      0.8718      0.8748
  8          0.8777      0.8807      0.8837      0.8867      0.8896
  8          0.8926      0.8956      0.8986      0.9015      0.9045
1



 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.9075      0.9105      0.9135      0.9164      0.9194
  8          0.9224      0.9237      0.9250      0.9263      0.9276
```

```
8          0.9288      0.9301      0.9314      0.9327      0.9340
8          0.9353      0.9366      0.9379      0.9392      0.9405
8          0.9418      0.9431      0.9444      0.9457      0.9470
8          0.9483      0.9495      0.9508      0.9521      0.9534
8          0.9547      0.9560      0.9573      0.9586      0.9599
8          0.9612      0.9625      0.9638      0.9651      0.9664
8          0.9677      0.9690      0.9702      0.9715      0.9728
8          0.9741      0.9754      0.9767      0.9780      0.9793
8          0.9806      0.9819      0.9832      0.9845      0.9858
8          0.9871      0.9884      0.9897      0.9909      0.9922
8          0.9935      0.9948      0.9961      0.9974      0.9987
8          1.0000      1.0000      1.0000      1.0000      1.0000
9 ENDTBL
5 RAINFL 6              .1
8          0.0000      0.0014      0.0027      0.0041      0.0054
8          0.0068      0.0082      0.0095      0.0109      0.0122
8          0.0136      0.0150      0.0163      0.0177      0.0190
8          0.0204      0.0217      0.0231      0.0245      0.0258
8          0.0272      0.0285      0.0299      0.0313      0.0326
8          0.0340      0.0353      0.0367      0.0381      0.0394
8          0.0408      0.0421      0.0435      0.0449      0.0462
8          0.0476      0.0489      0.0503      0.0516      0.0530
8          0.0544      0.0557      0.0571      0.0584      0.0598
8          0.0612      0.0625      0.0639      0.0652      0.0666
8          0.0680      0.0693      0.0707      0.0720      0.0734
8          0.0748      0.0761      0.0775      0.0788      0.0802
8          0.0816      0.0846      0.0877      0.0908      0.0939
8          0.0970      0.1001      0.1032      0.1063      0.1094
8          0.1125      0.1156      0.1187      0.1218      0.1249
8          0.1280      0.1311      0.1342      0.1373      0.1404
8          0.1435      0.1466      0.1497      0.1528      0.1559
8          0.1590      0.1621      0.1652      0.1683      0.1714
8          0.1745      0.1791      0.1837      0.1883      0.1929
8          0.1975      0.2021      0.2068      0.2114      0.2160
8          0.2206      0.2252      0.2298      0.2344      0.2390
8          0.2437      0.2481      0.2525      0.2569      0.2613
8          0.2657      0.2753      0.2849      0.2945      0.3041
8          0.3137      0.3332      0.3527      0.3810      0.4202
8          0.5000      0.5798      0.6190      0.6473      0.6668
8          0.6863      0.6959      0.7055      0.7151      0.7247
8          0.7343      0.7387      0.7431      0.7475      0.7519
8          0.7563      0.7610      0.7656      0.7702      0.7748
8          0.7794      0.7840      0.7886      0.7932      0.7979
8          0.8025      0.8071      0.8117      0.8163      0.8209
8          0.8255      0.8286      0.8317      0.8348      0.8379
8          0.8410      0.8441      0.8472      0.8503      0.8534
8          0.8565      0.8596      0.8627      0.8658      0.8689
8          0.8720      0.8751      0.8782      0.8813      0.8844
```

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1


 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.8875      0.8906      0.8937      0.8968      0.8999
  8          0.9030      0.9061      0.9092      0.9123      0.9154
  8          0.9184      0.9198      0.9212      0.9225      0.9239
  8          0.9252      0.9266      0.9280      0.9293      0.9307
  8          0.9320      0.9334      0.9348      0.9361      0.9375
  8          0.9388      0.9402      0.9416      0.9429      0.9443
  8          0.9456      0.9470      0.9484      0.9497      0.9511
  8          0.9524      0.9538      0.9551      0.9565      0.9579
  8          0.9592      0.9606      0.9619      0.9633      0.9647
  8          0.9660      0.9674      0.9687      0.9701      0.9715
  8          0.9728      0.9742      0.9755      0.9769      0.9783
  8          0.9796      0.9810      0.9823      0.9837      0.9850
  8          0.9864      0.9878      0.9891      0.9905      0.9918
  8          0.9932      0.9946      0.9959      0.9973      0.9986
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  5 RAINFL 7              .1
  8          0.0000      0.0014      0.0028      0.0043      0.0057
  8          0.0071      0.0085      0.0100      0.0114      0.0128
  8          0.0142      0.0156      0.0171      0.0185      0.0199
  8          0.0213      0.0227      0.0242      0.0256      0.0270
  8          0.0284      0.0299      0.0313      0.0327      0.0341
  8          0.0355      0.0370      0.0384      0.0398      0.0412
  8          0.0426      0.0441      0.0455      0.0469      0.0483
  8          0.0498      0.0512      0.0526      0.0540      0.0554
  8          0.0569      0.0583      0.0597      0.0611      0.0625
  8          0.0640      0.0654      0.0668      0.0682      0.0697
  8          0.0711      0.0725      0.0739      0.0753      0.0768
  8          0.0782      0.0796      0.0810      0.0825      0.0839
  8          0.0853      0.0885      0.0918      0.0950      0.0983
  8          0.1015      0.1048      0.1080      0.1113      0.1145
  8          0.1177      0.1210      0.1242      0.1275      0.1307
  8          0.1340      0.1372      0.1405      0.1437      0.1470
  8          0.1502      0.1534      0.1567      0.1599      0.1632
  8          0.1664      0.1697      0.1729      0.1762      0.1794
  8          0.1827      0.1874      0.1921      0.1968      0.2015
  8          0.2062      0.2109      0.2156      0.2203      0.2251
  8          0.2298      0.2345      0.2392      0.2439      0.2486
  8          0.2533      0.2577      0.2622      0.2666      0.2710
  8          0.2754      0.2851      0.2948      0.3044      0.3141
  8          0.3238      0.3431      0.3624      0.3898      0.4269
  8          0.5000      0.5731      0.6102      0.6376      0.6569
```

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  8          0.6762      0.6859      0.6956      0.7052      0.7149
  8          0.7246      0.7290      0.7334      0.7378      0.7423
  8          0.7467      0.7514      0.7561      0.7608      0.7655
  8          0.7702      0.7749      0.7797      0.7844      0.7891
  8          0.7938      0.7985      0.8032      0.8079      0.8126
  8          0.8173      0.8206      0.8238      0.8271      0.8303
  8          0.8336      0.8368      0.8401      0.8433      0.8466
  8          0.8498      0.8530      0.8563      0.8595      0.8628
1



 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.8660      0.8693      0.8725      0.8758      0.8790
  8          0.8823      0.8855      0.8887      0.8920      0.8952
  8          0.8985      0.9017      0.9050      0.9082      0.9115
  8          0.9147      0.9161      0.9175      0.9190      0.9204
  8          0.9218      0.9232      0.9247      0.9261      0.9275
  8          0.9289      0.9303      0.9318      0.9332      0.9346
  8          0.9360      0.9375      0.9389      0.9403      0.9417
  8          0.9431      0.9446      0.9460      0.9474      0.9488
  8          0.9502      0.9517      0.9531      0.9545      0.9559
  8          0.9574      0.9588      0.9602      0.9616      0.9630
  8          0.9645      0.9659      0.9673      0.9687      0.9701
  8          0.9716      0.9730      0.9744      0.9758      0.9773
  8          0.9787      0.9801      0.9815      0.9829      0.9844
  8          0.9858      0.9872      0.9886      0.9900      0.9915
  8          0.9929      0.9943      0.9957      0.9972      0.9986
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  5 RAINFL 8              .1
  8          0.0000      0.0016      0.0031      0.0047      0.0063
  8          0.0079      0.0094      0.0110      0.0126      0.0141
  8          0.0157      0.0173      0.0188      0.0204      0.0220
  8          0.0236      0.0251      0.0267      0.0283      0.0298
  8          0.0314      0.0330      0.0345      0.0361      0.0377
  8          0.0393      0.0408      0.0424      0.0440      0.0455
  8          0.0471      0.0487      0.0502      0.0518      0.0534
  8          0.0550      0.0565      0.0581      0.0597      0.0612
  8          0.0628      0.0644      0.0659      0.0675      0.0691
  8          0.0707      0.0722      0.0738      0.0754      0.0769
  8          0.0785      0.0801      0.0816      0.0832      0.0848
  8          0.0864      0.0879      0.0895      0.0911      0.0926
  8          0.0942      0.0978      0.1014      0.1050      0.1086
  8          0.1122      0.1158      0.1193      0.1229      0.1265
  8          0.1301      0.1337      0.1373      0.1409      0.1445
  8          0.1481      0.1516      0.1552      0.1588      0.1624
```

```
  8          0.1660      0.1696      0.1732      0.1768      0.1804
  8          0.1840      0.1875      0.1911      0.1947      0.1983
  8          0.2019      0.2069      0.2118      0.2168      0.2217
  8          0.2266      0.2316      0.2365      0.2415      0.2464
  8          0.2514      0.2563      0.2613      0.2662      0.2712
  8          0.2761      0.2806      0.2851      0.2896      0.2941
  8          0.2985      0.3083      0.3181      0.3279      0.3377
  8          0.3475      0.3660      0.3845      0.4095      0.4414
  8          0.5000      0.5586      0.5905      0.6155      0.6340
  8          0.6525      0.6623      0.6721      0.6819      0.6917
  8          0.7015      0.7059      0.7104      0.7149      0.7194
  8          0.7239      0.7288      0.7338      0.7387      0.7437
  8          0.7486      0.7536      0.7585      0.7635      0.7684
  8          0.7734      0.7783      0.7832      0.7882      0.7931
  8          0.7981      0.8017      0.8053      0.8089      0.8125
  8          0.8160      0.8196      0.8232      0.8268      0.8304
1



 ********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

  8          0.8340      0.8376      0.8412      0.8448      0.8484
  8          0.8519      0.8555      0.8591      0.8627      0.8663
  8          0.8699      0.8735      0.8771      0.8807      0.8842
  8          0.8878      0.8914      0.8950      0.8986      0.9022
  8          0.9058      0.9074      0.9089      0.9105      0.9121
  8          0.9136      0.9152      0.9168      0.9184      0.9199
  8          0.9215      0.9231      0.9246      0.9262      0.9278
  8          0.9293      0.9309      0.9325      0.9341      0.9356
  8          0.9372      0.9388      0.9403      0.9419      0.9435
  8          0.9450      0.9466      0.9482      0.9498      0.9513
  8          0.9529      0.9545      0.9560      0.9576      0.9592
  8          0.9607      0.9623      0.9639      0.9655      0.9670
  8          0.9686      0.9702      0.9717      0.9733      0.9749
  8          0.9764      0.9780      0.9796      0.9812      0.9827
  8          0.9843      0.9859      0.9874      0.9890      0.9906
  8          0.9921      0.9937      0.9953      0.9969      0.9984
  8          1.0000      1.0000      1.0000      1.0000      1.0000
  9 ENDTBL
  6 RUNOFF 1   5       1       0.0410      91.311       0.300
  6 RUNOFF 1   6       2       1.4030      84.309       2.418
  6 ADDHYD 4   1   1 2 3
  6 REACH  3   3   3   1       1016.6
  6 RUNOFF 1   4       2       0.0240      85.536       1.126
  6 ADDHYD 4   2   1 2 3                                    1         1
  4 DIMHYD                0.02
  8          0.000       0.111       0.356       0.655       0.896
```

```
  8          1.000       0.929       0.828       0.737       0.656
  8          0.584       0.521       0.465       0.415       0.371
  8          0.331       0.296       0.265       0.237       0.212
  8          0.190       0.170       0.153       0.138       0.123
  8          0.109       0.097       0.086       0.076       0.066
  8          0.057       0.049       0.041       0.033       0.027
  8          0.024       0.021       0.018       0.015       0.013
  8          0.012       0.011       0.009       0.008       0.008
  8          0.006       0.006       0.005       0.005       0.000
  9 ENDTBL

    ENDATA
  7 INCREM 6                      0.1
  7 COMPUT 7   5     2            0.0        2.65         1.01 2  1   1
    ENDCMP 1
  7 COMPUT 7   5     2            0.0        3.20         1.02 2  1   2
    ENDCMP 1
  7 COMPUT 7   5     2            0.0        4.12         1.03 2  1   3
    ENDCMP 1
  7 COMPUT 7   5     2            0.0        4.92         1.04 2  1   4
    ENDCMP 1
  7 COMPUT 7   5     2            0.0        6.14         1.05 2  1   5
    ENDCMP 1
  7 COMPUT 7   5     2            0.0        7.23         1.06 2  1   6
    ENDCMP 1
1



 *********************80-80 LIST OF INPUT DATA (CONTINUED)**********************

  7 COMPUT 7   5     2            0.0        8.47         1.07 2  1   7
    ENDCMP 1
  7 COMPUT 7   5     2            0.0       11.99         1.08 2  1   8
    ENDCMP 1
    ENDJOB 2

 *******************************END OF 80-80 LIST*******************************
1
 TR20 -------------------------------------------------------------------- SCS -
                                   I-95 ETL                             VERSION
 04/12/**                         Lilly Run                            2.04TEST
 14:22:56                    PASS   1   JOB NO.   1                    PAGE   1


            COMPUTED DIMHYD PEAK RATE FACTOR =  282.026
```

```
 EXECUTIVE CONTROL INCREM    MAIN TIME INCREMENT =   .100 HOURS


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  2.65       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 1            RAIN TABLE NO. = 1


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.62                         194.6                        (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                  1.27 WATERSHED INCHES;    1203 CFS-HRS;      99.4 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   1


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  3.20       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 2            RAIN TABLE NO. = 2


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.60                         270.4                        (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                  1.72 WATERSHED INCHES;    1632 CFS-HRS;     134.9 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   2
1
 TR20 -------------------------------------------------------------------- SCS -
                                   I-95 ETL                                VERSION
 04/12/**                         Lilly Run                              2.04TEST
 14:22:56                    PASS   3   JOB NO.   1                      PAGE   2



 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  4.12       RAIN DURATION =  1.00
```

```
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 3            RAIN TABLE NO. = 3


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.58                         396.2                       (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                  2.52 WATERSHED INCHES;    2391 CFS-HRS;     197.6 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   3


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  4.92       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 4            RAIN TABLE NO. = 4


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.58                         500.8                       (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                  3.25 WATERSHED INCHES;    3078 CFS-HRS;     254.4 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   4


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  6.14       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 5            RAIN TABLE NO. = 5


 OPERATION ADDHYD   XSECTION   2
1
 TR20 -------------------------------------------------------------------- SCS -
                                   I-95 ETL                             VERSION
 04/12/**                         Lilly Run                            2.04TEST
 14:22:56                    PASS   5   JOB NO.   1                    PAGE   3
```

```
    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.57                         652.7                       (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                   4.38 WATERSHED INCHES;    4153 CFS-HRS;     343.2 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   5


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  7.23       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 6            RAIN TABLE NO. = 6


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.57                         780.6                       (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                   5.42 WATERSHED INCHES;    5133 CFS-HRS;     424.2 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   6


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH =  8.47       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 7            RAIN TABLE NO. = 7


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)             PEAK DISCHARGE(CFS)          PEAK ELEVATION(FEET)
       13.56                         918.3                       (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                   6.61 WATERSHED INCHES;    6262 CFS-HRS;     517.5 ACRE-FEET.
1
 TR20 -------------------------------------------------------------------- SCS -
                                    I-95 ETL                              VERSION
 04/12/**                          Lilly Run                             2.04TEST
 14:22:56                    PASS   8   JOB NO.   1                      PAGE   4
```

```
 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   7


 EXECUTIVE CONTROL COMPUT    FROM XSECTION   5  TO XSECTION   2
    STARTING TIME =   .00       RAIN DEPTH = 11.99       RAIN DURATION =  1.00
    ANT. RUNOFF COND. = 2       MAIN TIME INCREMENT =   .100 HOURS
    ALTERNATE NO. = 1           STORM NO. = 8            RAIN TABLE NO. = 8


 OPERATION ADDHYD   XSECTION   2

    PEAK TIME(HRS)            PEAK DISCHARGE(CFS)         PEAK ELEVATION(FEET)
       13.57                       1267.3                      (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                  10.04 WATERSHED INCHES;    9513 CFS-HRS;     786.1 ACRE-FEET.


 EXECUTIVE CONTROL ENDCMP    COMPUTATIONS COMPLETED FOR PASS   8
1
 TR20 -------------------------------------------------------------------- SCS -
                              I-95 ETL                                  VERSION
 04/12/**                    Lilly Run                                 2.04TEST
 14:22:56                SUMMARY, JOB NO.   1                          PAGE   5


                             SUMMARY TABLE 1
                             ---------------
    SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL IN ORDER PERFORMED.
    A CHARACTER FOLLOWING THE PEAK DISCHARGE TIME AND RATE (CFS) INDICATES:
 F-FLAT TOP HYDROGRAPH   T-TRUNCATED HYDROGRAPH   R-RISING TRUNCATED HYDROGRAPH

 XSECTION/  STANDARD                                   PEAK DISCHARGE
 STRUCTURE   CONTROL    DRAINAGE   RUNOFF   ------------------------------------
    ID      OPERATION     AREA     AMOUNT   ELEVATION   TIME     RATE    RATE
                        (SQ MI)    (IN)       (FT)      (HR)     (CFS)   (CSM)

 RAINFALL OF   2.65 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  1,    ARC 2
 MAIN TIME INCREMENT   .100 HOURS

    ALTERNATE    1   STORM    1
    ---------------------------
 XSECTION   2  ADDHYD     1.47     1.27        ---     13.62      195    132.7

 RAINFALL OF   3.20 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  2,    ARC 2
```

```
    ALTERNATE    1   STORM    2
    ---------------------------
 XSECTION   2  ADDHYD     1.47     1.72        ---     13.60      270    183.7

 RAINFALL OF   4.12 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  3,    ARC 2

    ALTERNATE    1   STORM    3
    ---------------------------
 XSECTION   2  ADDHYD     1.47     2.52        ---     13.58      396    269.4

 RAINFALL OF   4.92 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  4,    ARC 2

    ALTERNATE    1   STORM    4
    ---------------------------
 XSECTION   2  ADDHYD     1.47     3.25        ---     13.58      501    340.8

 RAINFALL OF   6.14 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  5,    ARC 2

    ALTERNATE    1   STORM    5
    ---------------------------
 XSECTION   2  ADDHYD     1.47     4.38        ---     13.57      653    444.2
1
 TR20 ------------------------------------------------------------------- SCS -
                                 I-95 ETL                              VERSION
 04/12/**                       Lilly Run                             2.04TEST
 14:22:56                  SUMMARY, JOB NO.   1                       PAGE   6


                            SUMMARY TABLE 1
                            ---------------
    SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL IN ORDER PERFORMED.
    A CHARACTER FOLLOWING THE PEAK DISCHARGE TIME AND RATE (CFS) INDICATES:
 F-FLAT TOP HYDROGRAPH   T-TRUNCATED HYDROGRAPH   R-RISING TRUNCATED HYDROGRAPH

 XSECTION/  STANDARD                                   PEAK DISCHARGE
 STRUCTURE   CONTROL    DRAINAGE   RUNOFF   ------------------------------------
    ID      OPERATION     AREA     AMOUNT   ELEVATION   TIME      RATE    RATE
                         (SQ MI)    (IN)       (FT)     (HR)      (CFS)   (CSM)


 RAINFALL OF   7.23 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
 RAINTABLE NUMBER  6,    ARC 2

    ALTERNATE    1   STORM    6
```

```
   ---------------------------
XSECTION   2  ADDHYD     1.47     5.42        ---     13.57      781    531.3

RAINFALL OF   8.47 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
RAINTABLE NUMBER  7,    ARC 2

   ALTERNATE    1   STORM    7
   ---------------------------
XSECTION   2  ADDHYD     1.47     6.61        ---     13.56      918    624.5

RAINFALL OF  11.99 inches AND  24.00 hr DURATION, BEGINS AT    .0 hrs.
RAINTABLE NUMBER  8,    ARC 2

   ALTERNATE    1   STORM    8
   ---------------------------
XSECTION   2  ADDHYD     1.47    10.04        ---     13.57     1267    861.9
1
 TR20 ------------------------------------------------------------------ SCS -
                               I-95 ETL                               VERSION
 04/12/**                      Lilly Run                             2.04TEST
 14:22:56                 SUMMARY, JOB NO.   1                       PAGE   7


                             SUMMARY TABLE 2
                             ---------------
           MODIFIED ATT-KIN REACH ROUTING IN ORDER PERFORMED.
   QUESTION MARK (?) AFTER: OUTFLOW PEAK - MAX. NUMBER ROUTING ITERATIONS USED;
                            LENGTH FACTOR - VALUE K* GREATER THAN  1.0;
                            ATT-KIN COEFF - VALUE C GREATER THAN 0.667.

                     HYDROGRAPH INFORMATION         ROUTING PARAMETERS
                    ------------------------    -------------------------------
            FLOOD    INFLOW        OUTFLOW       Q-A EQ.           PEAK  ATT-
 XSEC REACH  PLAIN  -----------   -----------   ----------- LENGTH  RATIO  KIN
  ID  LENGTH LENGTH PEAK   TIME   PEAK   TIME   COEFF POWER FACTOR   Q/I  COEFF
       (FT)   (FT) (CFS)  (HR)   (CFS)  (HR)    (X)   (M)   (k*)   (Q*)  (C)


 BASEFLOW IS    .0 CFS

   ALTERNATE    1   STORM    1
   ---------------------------
   3   1017           190  13.6     190  13.6   1.41   1.39   .001  1.000  1.00?

   ALTERNATE    1   STORM    2
   ---------------------------
   3   1017           264  13.6     264  13.6   1.43   1.38   .001  1.000  1.00?
```

```
    ALTERNATE    1   STORM    3
    ---------------------------
   3   1017           388  13.6     388  13.6   1.47   1.38   .001  1.000  1.00?

    ALTERNATE    1   STORM    4
    ---------------------------
   3   1017           490  13.6     490  13.6   1.49   1.38   .001  1.000  1.00?

    ALTERNATE    1   STORM    5
    ---------------------------
   3   1017           639  13.6     639  13.6   1.52   1.37   .001  1.000  1.00?

    ALTERNATE    1   STORM    6
    ---------------------------
   3   1017           764  13.6     764  13.6   1.54   1.37   .001  1.000  1.00?

    ALTERNATE    1   STORM    7
    ---------------------------
   3   1017           899  13.6     899  13.6   1.56   1.37   .001  1.000  1.00?

    ALTERNATE    1   STORM    8
    ---------------------------
   3   1017          1242  13.6    1242  13.6   1.60   1.37   .001  1.000  1.00?
1
 TR20 ------------------------------------------------------------------- SCS -
                             I-95 ETL                                 VERSION
 04/12/**                   Lilly Run                                2.04TEST
 14:22:56                SUMMARY, JOB NO.   1                        PAGE   8


                          SUMMARY TABLE 3
                          ---------------
      STORM DISCHARGES (CFS) AT XSECTIONS AND STRUCTURES FOR ALL ALTERNATES
      QUESTION MARK (?) AFTER: OUTFLOW PEAK - RISING TRUNCATED HYDROGRAPH.

 XSECTION/          DRAINAGE
 STRUCTURE            AREA      STORM NUMBERS..........
   ID                (SQ MI)        1         2         3         4         5


 XSECTION    2         1.47
 ---------------------------
    ALTERNATE    1                 195       270       396       501       653

                          SUMMARY TABLE 3
                          ---------------
      STORM DISCHARGES (CFS) AT XSECTIONS AND STRUCTURES FOR ALL ALTERNATES
      QUESTION MARK (?) AFTER: OUTFLOW PEAK - RISING TRUNCATED HYDROGRAPH.
```

```
 XSECTION/          DRAINAGE
 STRUCTURE            AREA      STORM NUMBERS..........
   ID               (SQ MI)          6          7          8


 XSECTION    2         1.47
 ---------------------------
    ALTERNATE    1                 781       918      1267
1
 TR20 ------------------------------------------------------------------- SCS -
                                   I-95 ETL                                VERSION
 04/12/**                         Lilly Run                              2.04TEST




 END OF  1 JOBS IN THIS RUN
```

```
                    SCS  TR-20,  VERSION 2.04TEST
                                   FILES

     INPUT  = tr20in.dat                               , GIVEN DATA FILE
     OUTPUT = tr20out.dat                              , DATED 04/12/**,14:22:56

              FILES GENERATED - DATED 04/12/**,14:22:56

    FILE trlog.TMG CONTAINS MESSAGE + WARNING INFORMATION



          TOTAL NUMBER OF WARNINGS =  16,  MESSAGES =   0

                    *** TR-20 RUN COMPLETED ***
```

```
Fixed Region Peak Flow Estimates for: Lilly Run I-95 ETL
GISHydro Release Version Date: January 8, 2011
Hydro Extension Version Date:  January 8, 2011
Analysis Date:                 April 12, 2019

Geographic Province(s):
   -Western Coastal Plain (100.0% of area)

Q(1.25):  171 cfs
Q(1.50):  228 cfs
Q(2):     299 cfs
Q(5):     550 cfs
Q(10):    809 cfs
Q(25):    1290 cfs
Q(50):    1780 cfs
Q(100):   2420 cfs
Q(200):   3240 cfs
Q(500):   4690 cfs

Area Weighted Prediction Intervals (from Tasker)
 Return     50 PERCENT        67 PERCENT        90 PERCENT        95 PERCENT
 Period  lower    upper    lower    upper    lower    upper    lower    upper
  1.25    126       231     109       268      82       357      71       413
   1.5    172       302     149       347     114       455     100       520
     2    231       387     203       440     159       564     140       638
     5    410       740     354       856     267      1130     232      1310
    10    583      1120     496      1320     363      1800     310      2110
    25    894      1860     747      2220     527      3150     442      3750
    50   1190      2670     973      3260     661      4800     545      5820
   100   1540      3800    1230      4740     801      7300     645      9060
   200   1960      5360    1530      6870     946     11100     744     14100
   500   2630      8350    1980     11100    1140     19300     867     25400


Individual Province Tasker Analyses Follow: 2016 Maryland Fixed Region Equations
v2.1 (10/30/2017)

 Flood frequency estimates for
 Lilly Run I-95 ETL
 REGION: Western Coastal Plain
 area=      1.50:impervious area =  45.60:C&D-soils =  66.79 :skew=   0.51

 Return    Discharge    Standard       Equivalent      Standard
 Period      (cfs)      Error of        Years of       Error of
                       Prediction       Record         Prediction
                        (percent)                       (logs)
    1.25        171.        47.3            2.50           0.1953
    1.50        228.        44.1            2.54           0.1830
```

```
   2.00         299.         40.1              3.26           0.1678
   5.00         550.         46.4              4.69           0.1916
  10.00         809.         51.9              5.78           0.2121
  25.00        1290.         58.8              7.11           0.2368
  50.00        1780.         66.4              7.50           0.2624
 100.00        2420.         75.8              7.51           0.2927
 200.00        3240.         87.0              7.33           0.3261
 500.00        4690.        104.9              6.95           0.3741

          P R E D I C T I O N   I N T E R V A L S
Return     50 PERCENT        67 PERCENT        90 PERCENT        95 PERCENT
Period  lower    upper    lower    upper    lower    upper    lower    upper
   1.25    126.       231.    109.       268.     82.       357.     71.       413.
   1.50    172.       302.    149.       347.    114.       455.    100.       520.
   2.00    231.       387.    203.       440.    159.       564.    140.       638.
   5.00    410.       740.    354.       856.    267.      1130.    232.      1310.
  10.00    583.      1120.    496.      1320.    363.      1800.    310.      2110.
  25.00    894.      1860.    747.      2220.    527.      3150.    442.      3750.
  50.00   1190.      2670.    973.      3260.    661.      4800.    545.      5820.
 100.00   1540.      3800.   1230.      4740.    801.      7300.    645.      9060.
 200.00   1960.      5360.   1530.      6870.    946.     11100.    744.     14100.
 500.00   2630.      8350.   1980.     11100.   1140.     19300.    867.     25400.


WARNING -- Prediction beyond observed data
WARNING - Impervious area out of range of observed data
```

Worksheet for Reach 2 - 3.5' pipe

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.024	
Channel Slope	0.00500	ft/ft
Normal Depth	3.50	ft
Diameter	3.50	ft
Discharge	38.53	ft³/s

Results

Discharge	38.53	ft³/s
Normal Depth	3.50	ft
Flow Area	9.62	ft²
Wetted Perimeter	11.00	ft
Hydraulic Radius	0.88	ft
Top Width	0.00	ft
Critical Depth	1.93	ft
Percent Full	100.0	%
Critical Slope	0.01447	ft/ft
Velocity	4.01	ft/s
Velocity Head	0.25	ft
Specific Energy	3.75	ft
Froude Number	0.00	
Maximum Discharge	41.45	ft³/s
Discharge Full	38.53	ft³/s
Slope Full	0.00500	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Worksheet for Reach 2 - 3.5' pipe

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	3.50	ft
Critical Depth	1.93	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.01447	ft/ft

Worksheet for Reach 3 - 2' pipe

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.024	
Channel Slope	0.00488	ft/ft
Normal Depth	2.00	ft
Diameter	2.00	ft
Discharge	8.56	ft³/s

Results

Discharge	8.56	ft³/s
Normal Depth	2.00	ft
Flow Area	3.14	ft²
Wetted Perimeter	6.28	ft
Hydraulic Radius	0.50	ft
Top Width	0.00	ft
Critical Depth	1.04	ft
Percent Full	100.0	%
Critical Slope	0.01693	ft/ft
Velocity	2.72	ft/s
Velocity Head	0.12	ft
Specific Energy	2.12	ft
Froude Number	0.00	
Maximum Discharge	9.21	ft³/s
Discharge Full	8.56	ft³/s
Slope Full	0.00488	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Worksheet for Reach 3 - 2' pipe

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.00	ft
Critical Depth	1.04	ft
Channel Slope	0.00488	ft/ft
Critical Slope	0.01693	ft/ft

Appendix B

Site Assessment

100' 0 100' 200'

SCALE: 1" = 100'

HORIZONTAL DATUM NAD 83/91

VERTICAL DATUM NAVD 88

WWW.JMT.COM 410-329-3100

PRELIMINARY
NOT FOR
CONSTRUCTION

Maryland Transportation Authority
Engineering Division

ADDENDUMS & REVISIONS

NO.	DESCRIPTION	BY	DATE

JOHN F. KENNEDY MEMORIAL HIGHWAY
I-95 ETL NORTHBOUND EXTENSION

SITE ASSESSMENT MAP

CONTRACT NO. KH-3009

DRAWING NO. **SAM-01**

DESIGNED BY KNH

DRAWN BY KNH

CHECKED BY JM

CONST. REVIEW BY

DATE JUNE 2019

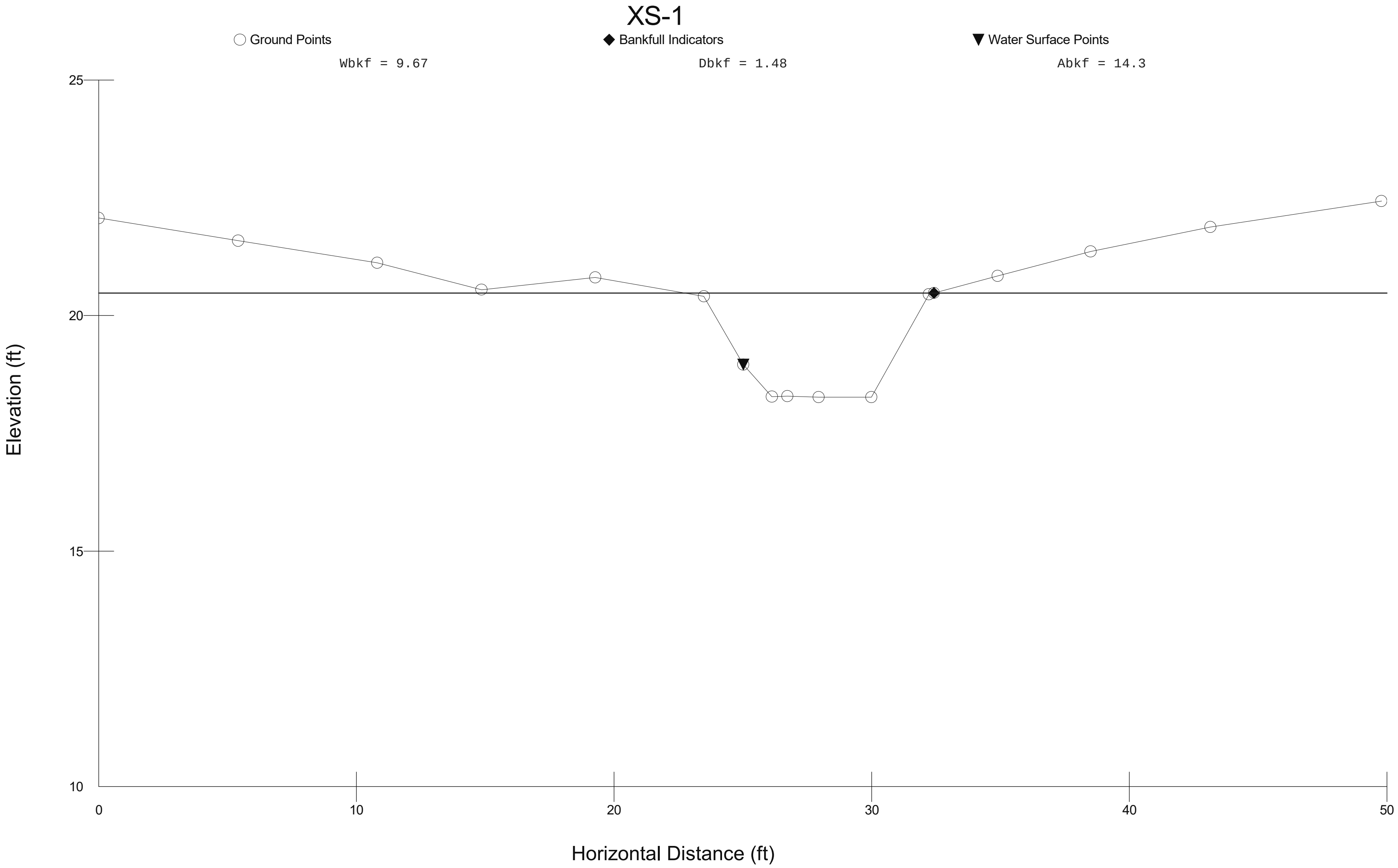
SCALE 1"=100'

SHEET NO. 1 OF 1

FILE: \\jmt.corp.local\jmtdfs\SMD\130770_048_195_ETL_N_Tran\CADD\Lilly Run\pSAM-E001-KH3009_Lily Run Mitigation.dgn
DATE: Wednesday, June 19, 2019 AT 12:50 PM

Appendix C

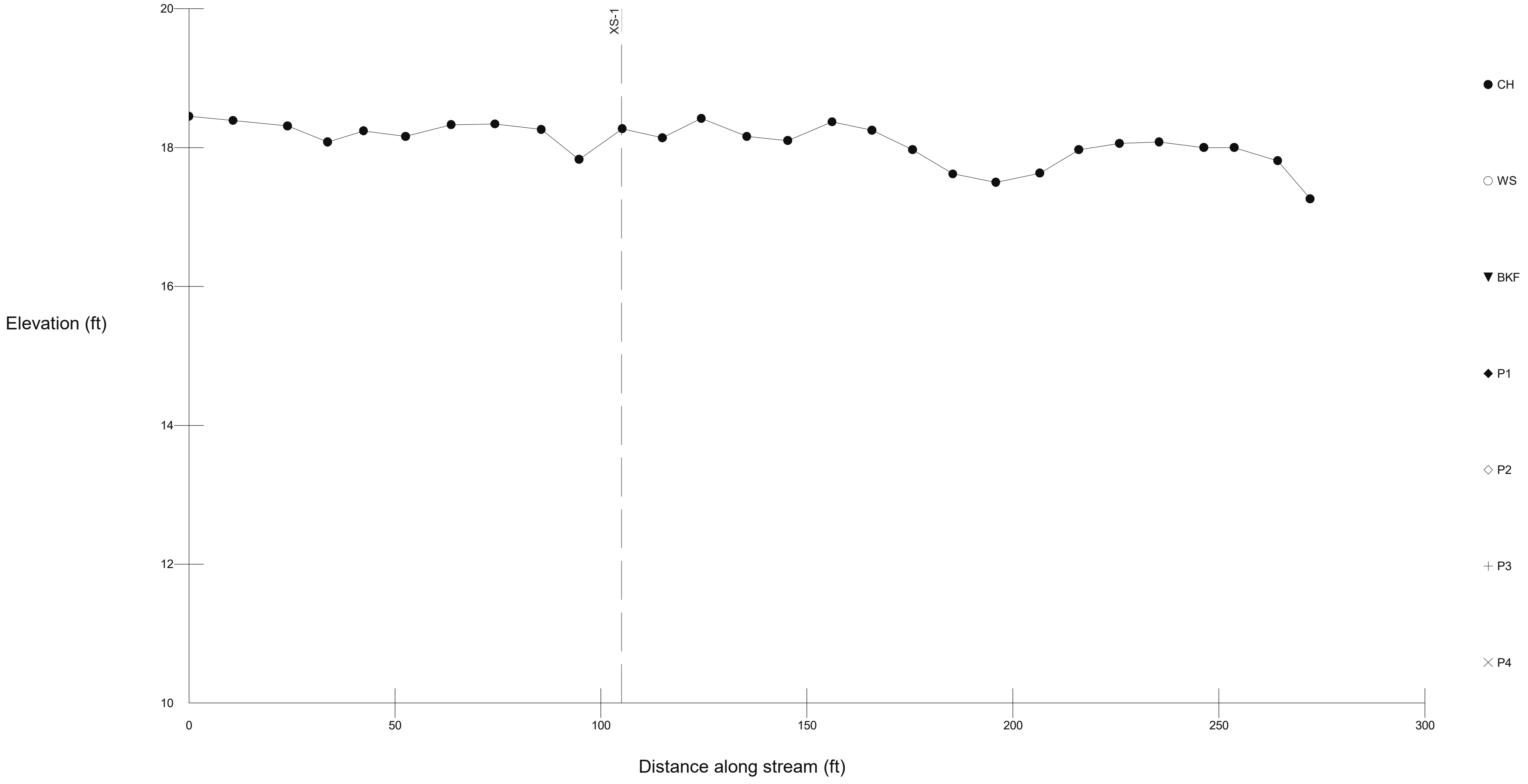
Existing Channel Geomorphic Data



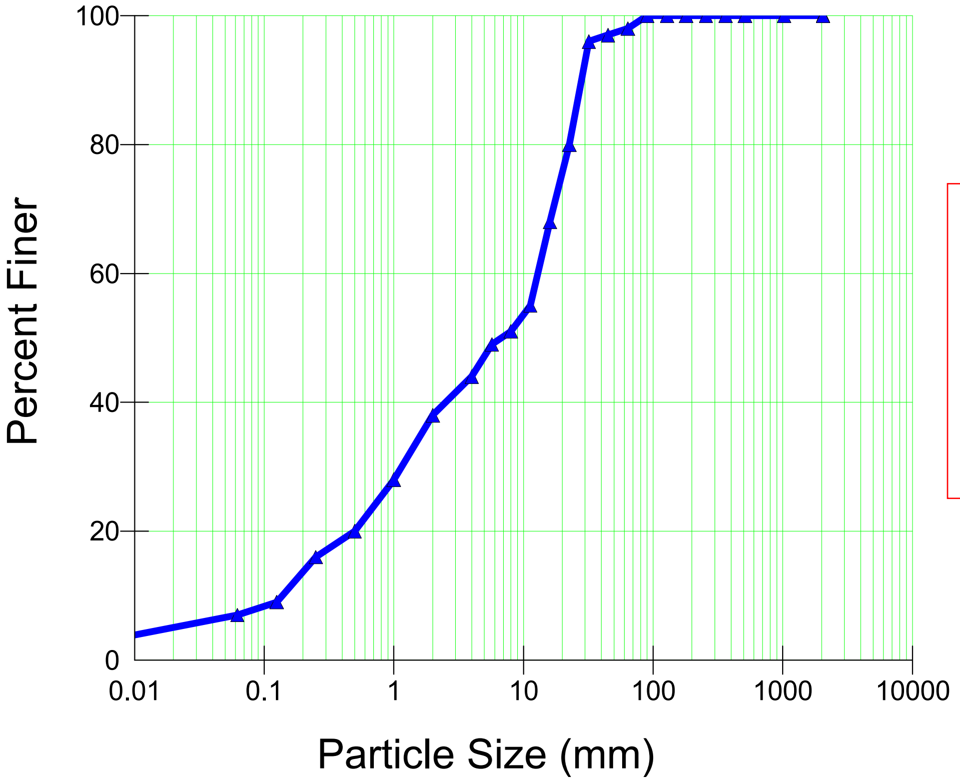
XS-1

○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 9.67
Dbkf = 1.48
Abkf = 14.3
Elevation (ft)
25
20
15
10
0
10
20
30
40
50
Horizontal Distance (ft)

Longitudinal Profile 1

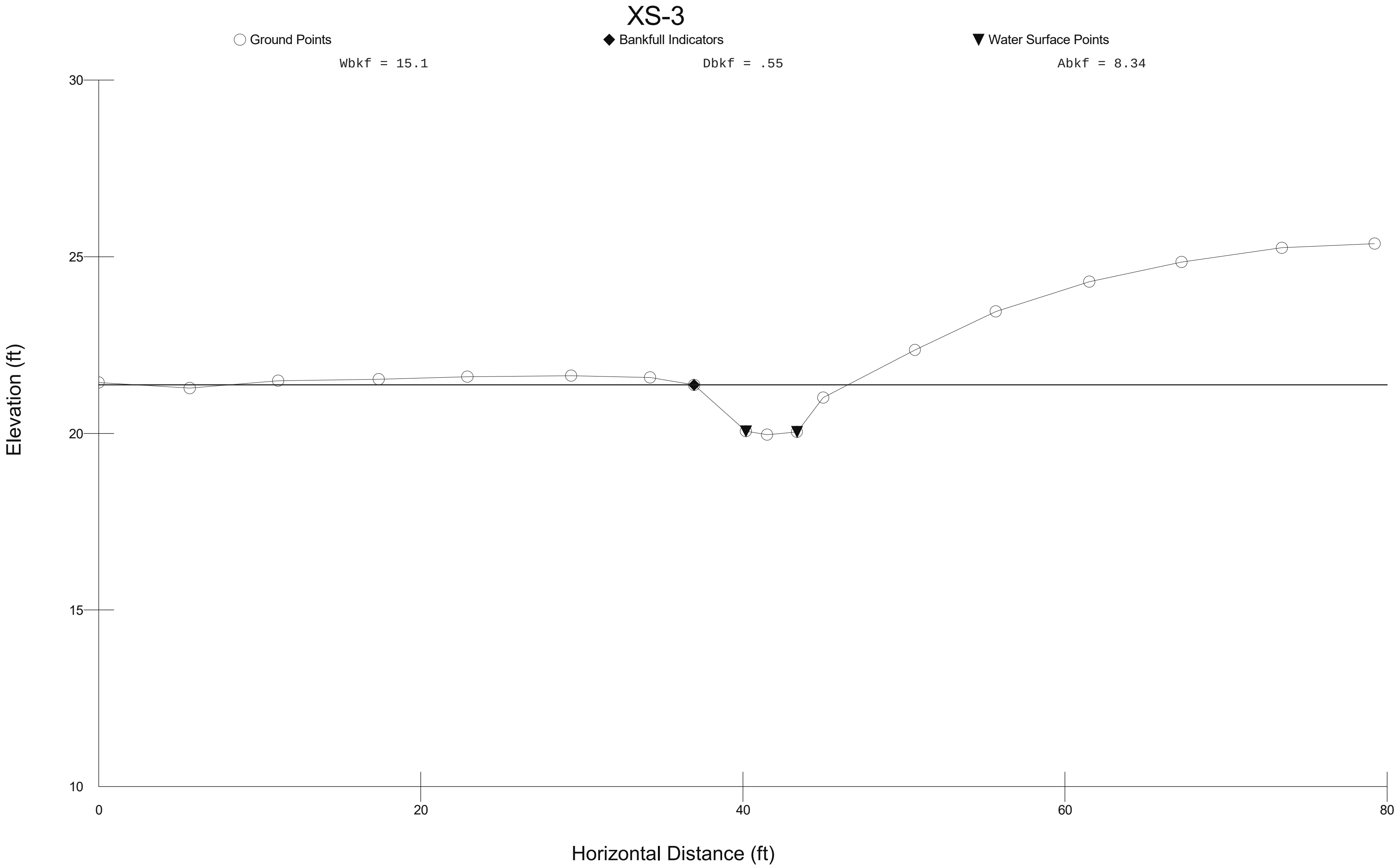


XS-1 Pebble Count

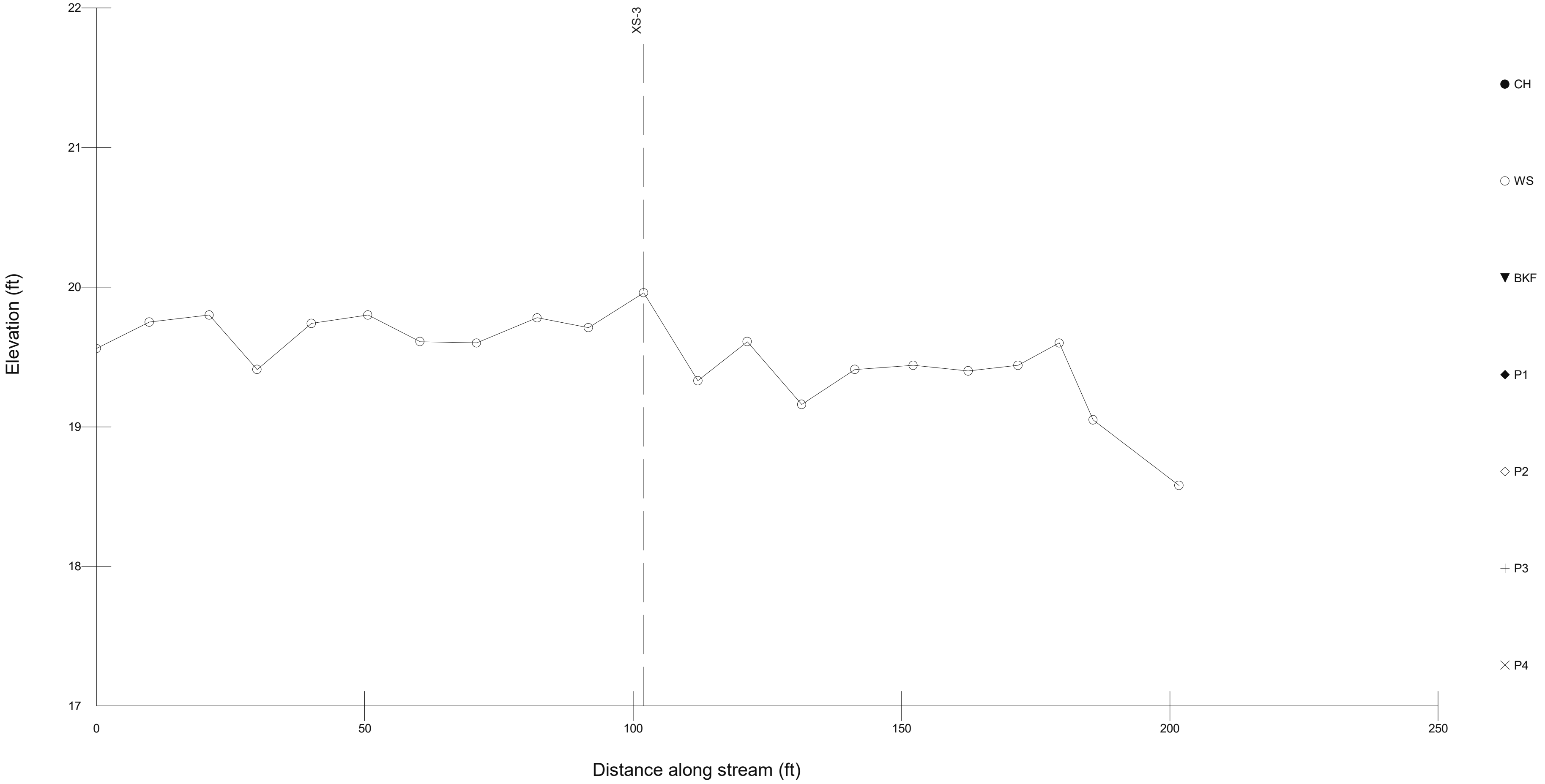


Particle Size Analysis

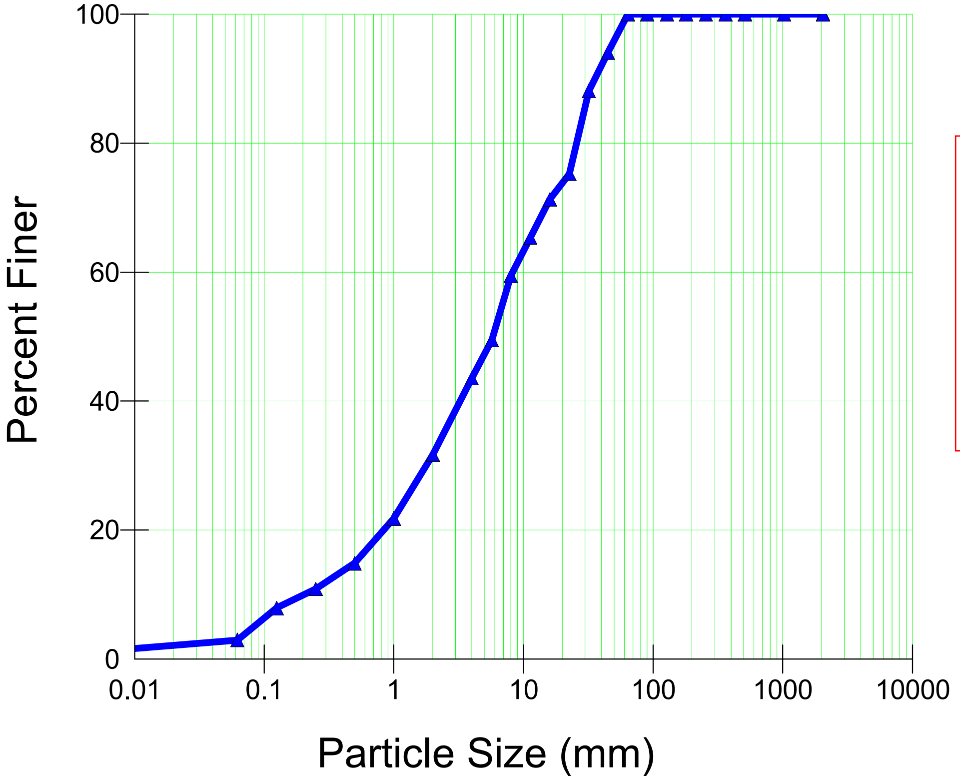
D16 (mm) = 0.25
D35 (mm) = 1.7
D50 (mm) = 6.85
D84 (mm) = 24.95
D95 (mm) = 31.41
D100 (mm) = 90


XS-3
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 15.1
Dbkf = .55
Abkf = 8.34
Elevation (ft)
30
25
20
15
10
0
20
40
60
80
Horizontal Distance (ft)

Longitudinal Profile 3

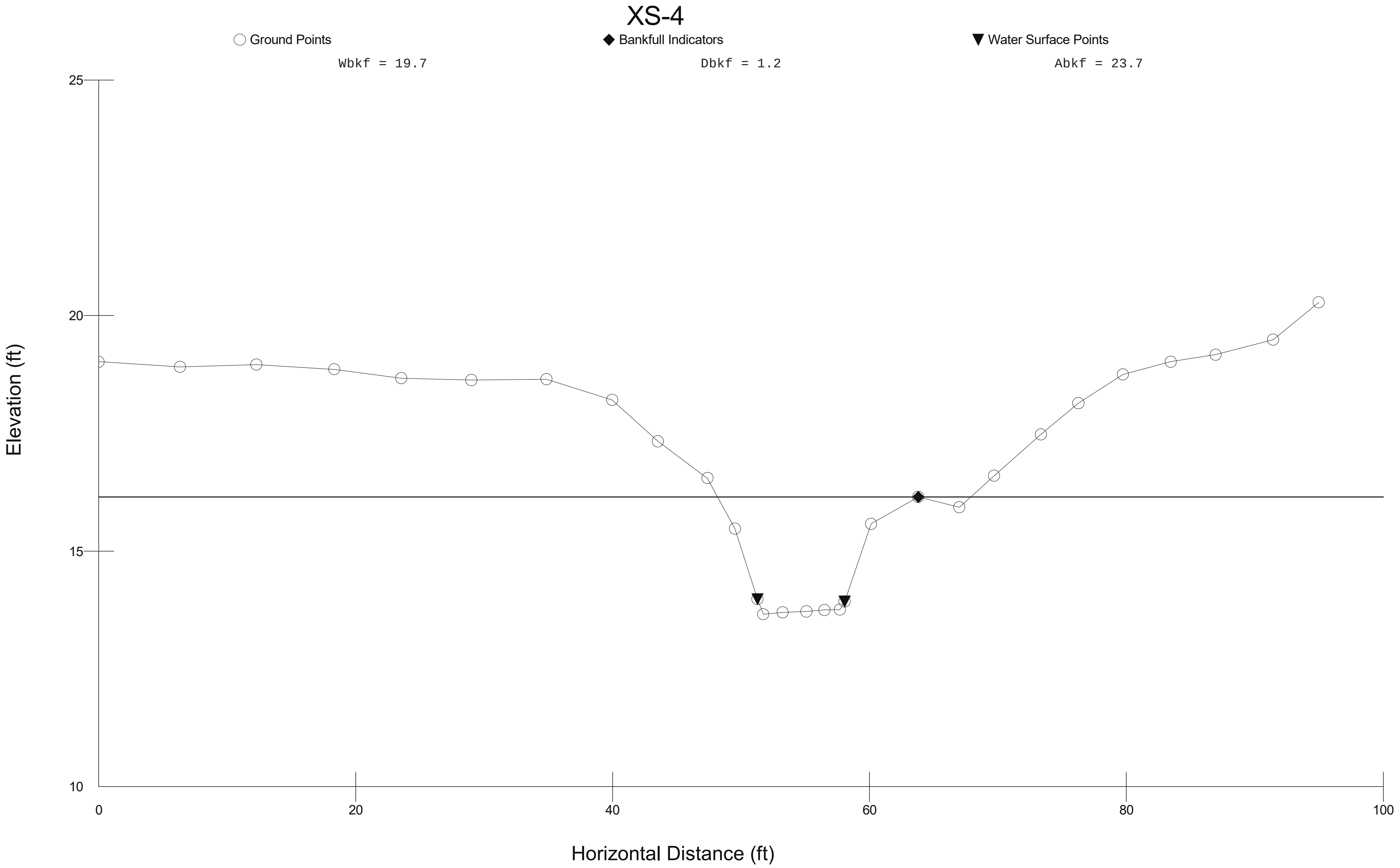


XS-3 Pebble Count

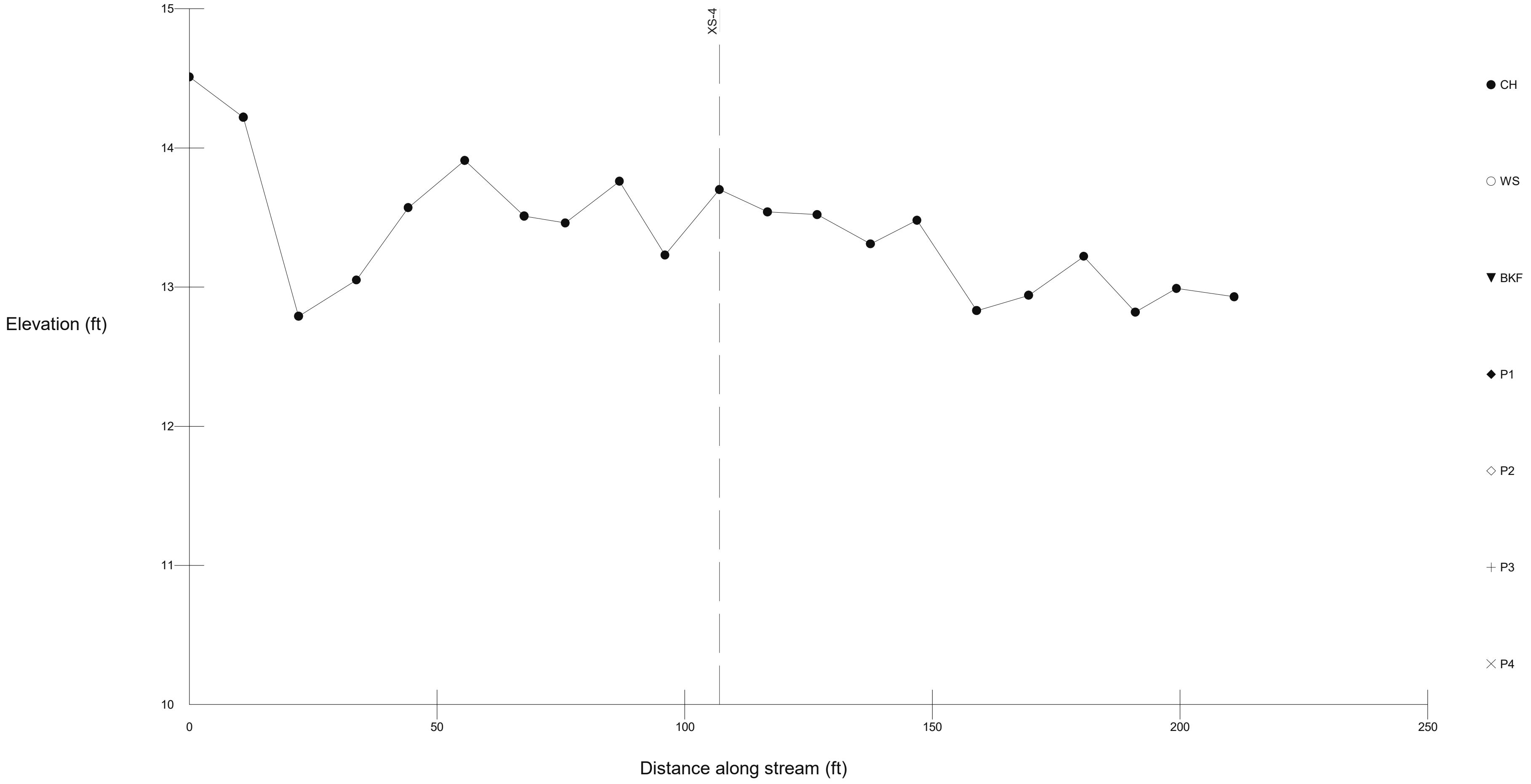


Particle Size Analysis

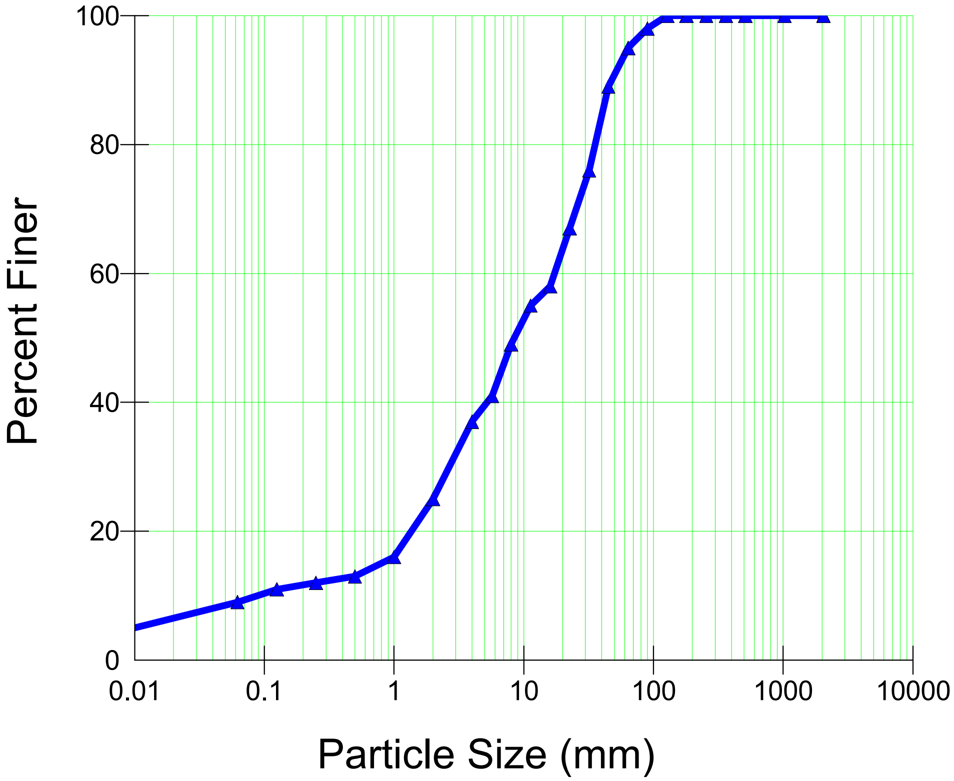
D16 (mm) = 0.58
D35 (mm) = 2.56
D50 (mm) = 5.82
D84 (mm) = 28.99
D95 (mm) = 48.01
D100 (mm) = 64


XS-4
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 19.7
Dbkf = 1.2
Abkf = 23.7
Elevation (ft)
25
20
15
10
0
20
40
60
80
100
Horizontal Distance (ft)

Longitudinal Profile 4

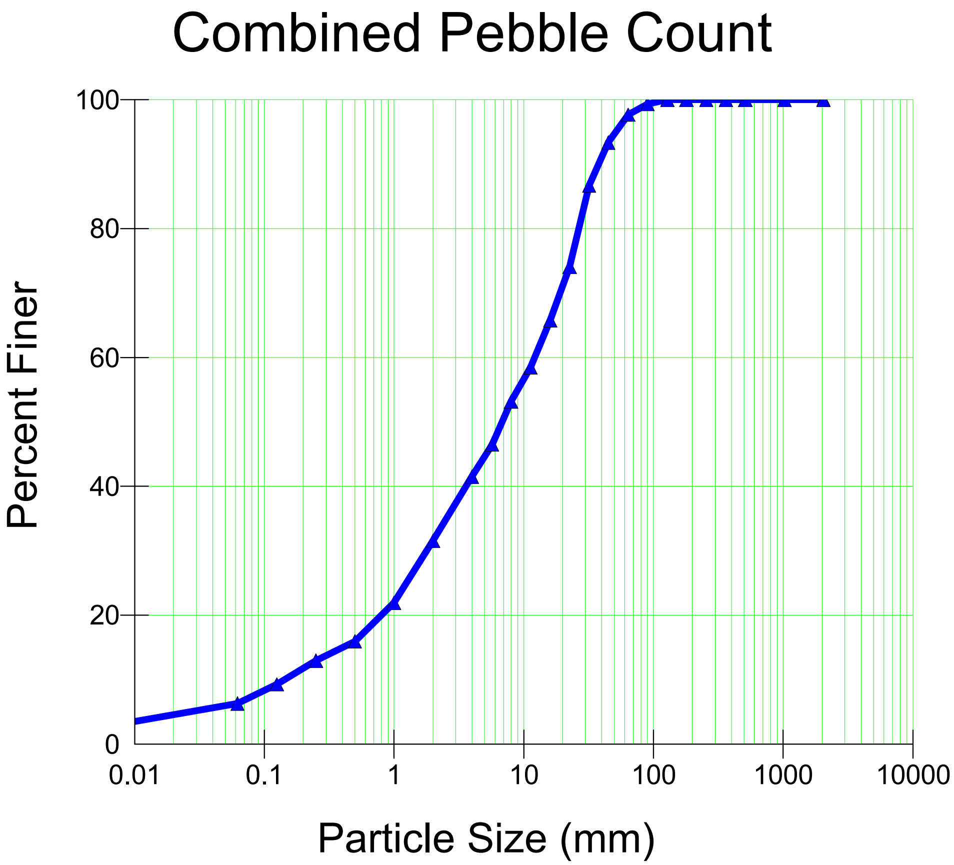


XS-4 Pebble Count



Particle Size Analysis

D16 (mm) = 1
D35 (mm) = 3.67
D50 (mm) = 8.55
D84 (mm) = 40
D95 (mm) = 64
D100 (mm) = 128



Particle Size Analysis

D16 (mm) = 0.5
D35 (mm) = 2.69
D50 (mm) = 6.91
D84 (mm) = 29.98
D95 (mm) = 52.23
D100 (mm) = 127.99

Appendix D

Ecological Uplift Data

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: LILLY RUN **Location:** REACH 1 **Valley Type:** **Observers:** PVC & KNH **Date:** 4/10/2019

Loca-tion	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	[✓ 2]	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	[✓ 3]	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	[✓ 2]	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	[✓ 3]	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	[✓ 4]
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	[✓ 8]
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	[✓ 2]	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	[✓ 12]	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	[✓ 4]	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	[✓ 1]	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	[✓ 2]	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	[✓ 6]	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	[✓ 8]	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	[✓ 6]	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	[✓ 4]
			Excellent total =	23	**Good total =**	10	**Fair total =**	18	**Poor total =**	16

Stream type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+
Stream type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**		
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107		
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120		
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+		

Grand total = 67

Existing stream type = F4

***Potential stream type =** C4

Modified channel stability rating = Good (Stable)

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: LILLY RUN **Location:** REACH 3 **Valley Type:** **Observers:** PVC & KNH **Date:** 4/10/2019

Loca-tion	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	[✓ 2]	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	[✓ 3]	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	[✓ 2]	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	[✓ 3]	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	[✓ 4]
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	[✓ 8]
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	[✓ 2]	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	[✓ 6]	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	[✓ 4]	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	[✓ 4]
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	[✓ 1]	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	[✓ 6]	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	[✓ 8]	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	[✓ 12]	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	[✓ 4]
			Excellent total =	17	**Good total =**	30	**Fair total =**	0	**Poor total =**	20

Stream type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	67
Existing stream type =	F4
***Potential stream type =**	C4
Modified channel stability rating =	Good (Stable)

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: LILLY RUN **Location:** REACH 4 **Valley Type:** **Observers:** PVC & KNH **Date:** 4/10/2019

Location	**Key**	**Category**	**Excellent**		**Good**		**Fair**		**Poor**	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	[✓ 2]	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	[✓ 3]	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	[✓ 2]	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	[✓ 6]	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	[✓ 4]
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	[✓ 8]
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	[✓ 2]	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	[✓ 6]	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	[✓ 4]	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	[✓ 4]
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	[✓ 2]	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	[✓ 6]	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	[✓ 8]	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools. [✓ 8]	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	[✓ 4]
			Excellent total =	13	**Good total =**	30	**Fair total =**	6	**Poor total =**	20

Stream type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+
Stream type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**		
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107		
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120		
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+		

Grand total = 69

Existing stream type = F4

***Potential stream type =** C4

Modified channel stability rating = Good (Stable)

*Rating is adjusted to potential stream type, not existing.

Only enter data in the green cells. All other cells are either linked to other worksheets or have equations.

Project Name Lilly Run Stream Mitigation

Feature	Lat/Long		Length, ft (Bank or deposition)	Height, ft (Bank or Headcut)	BEHI Rating	NBS Rating	Predicted Rate of Bank Erosion (ft/year)	Predicted Erosion Amount (ft^3/year)	Predicted Erosion Amount (tons/year)	Predicted Erosion Rate (tons/year/ft)	Comments
Feature I.D. (Bank., Headcut or Deposition I.D.)	Start	End									
	Headcut Location or Start of Bank/Deposition	For Banks or Deposition only									
Left Bank, LB1	Reach 4		264	2.60	Moderate	High	0.80	548.29	26.40	0.100	
Right Bank, RB1	Reach 4		264	2.60	Moderate	High	0.80	548.29	26.40	0.100	
Left Bank, LB2	Reach 4		238	2.00	Moderate	High	0.80	380.96	18.34	0.077	
Right Bank, RB2	Reach 4		238	1.70	Moderate	High	0.80	323.82	15.59	0.065	
Left Bank, LB3	Reach 4		346	6.00	High	High	1.00	2078.40	100.07	0.289	
Right Bank, RB3	Reach 4		346	2.40	Moderate	High	0.80	665.09	32.02	0.092	
Left Bank, LB4	Reach 3		87	0.33	Low	Low	0.02	0.57	0.03	0.000	
Right Bank, RB4	Reach 3		87	0.33	Low	Low	0.02	0.57	0.03	0.000	
Left Bank, LB5	Reach 3		186	1.00	Moderate	Low	0.13	23.20	1.12	0.006	
Right Bank, RB5	Reach 3		186	1.00	Moderate	Low	0.13	23.20	1.12	0.006	
Right Bank, RB6	Reach 3		340	2.80	High	Low	0.40	380.91	18.34	0.054	
Left Bank, LB6	Reach 3		340	2.80	High	Low	0.40	380.91	18.34	0.054	
Right Bank, RB7	Reach 1		94	2.70	High	Low	0.40	101.63	4.89	0.052	
Left Bank, LB7	Reach 1		491	3.70	Low	Low	0.02	36.30	1.75	0.004	
Left Bank, LB8	Reach 1		134	2.00	Moderate	Low	0.13	33.38	1.61	0.012	
Left Bank, LB9	Reach 1		256	2.00	Moderate	Low	0.13	64.03	3.08	0.012	
Left Bank, LB10	Reach 1		256	2.60	Moderate	Low	0.13	83.23	4.01	0.016	
TOTAL OF ALL GRIDS			**4152.1**	**N/A**	**N/A**	**N/A**	**6.9**	**5672.8**	**273.1**	**0.9**	

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

RAPID HABITAT ASSESSMENT: LOW GRADIENT Ephemeral/Intermittent >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Station ID/ Stream Name	LILLY RUN - REACH 1		**LAT (DD)**	
Reach Length (m)	Date	4/10/19	**LONG (DD)**	

HABITAT PARAMETER	**CATEGORY**			
	Optimal	**Sub-optimal**	**Marginal**	**Poor**
1. SUBSTRATE/ DIVERSITY **AVAILBLE COVER FOR AMPHIBIANS CRAYFISH** **SCORE:** 4	*Greater than 50% of substrate consisting of mix of snags, tree roots or other stable habitat providing cover for amphibians and aquatic or terrestrial invertebrates. LWD in moderate to advanced stage of decay and within- active channel; Substrate roughness capable of trapping lots of organic matter. If moss covered, rate high.*	*30 to 50% cover and mix of diverse stable habitat; well suited for full cover potential; adequate habitat for maintenance of populations; presence of additional LWD in the form of new fall. Substrate roughness still capable of trapping organic matter.*	*10 to 30% mix of stable cover; habitat availability less than desirable; substrate frequently disturbed or removed. LWD low in density and/or may be new fall or in early decay stage. Some areas suitable for trapping organic matter. If lg. wood is absent, score low.*	*Less than 10% stable cover; lack of habitat is obvious; substrate unstable or lacking. Few areas suitable for trapping organic matter.*
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 [✓ 4] 3 2 1 0
2. POOL SUBSTRATE CHARACTER-IZATION **In dry channels, pool areas should still be observable** **SCORE:** 10	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged (or remnant) aquatic vegetation are common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged (or remnant) vegetation are present.	All mud or clay or sand bottom; little or no root mat; no submerged (or remnant) vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1 0
3. CHANNEL ALTERATION **SCORE:** 1	Channelization or dredging absent of minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (>than past 20 years) may be present, but no evidence of recent channelization.	Channelization may be extensive; embankments or shoring structures present on both banks; 40 to 80% of the stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 [✓ 1] 0
4. SEDIMENT DEPOSITION **SCORE:** 15	Little or no enlargement of “islands” or point bars and less than 20% of the bottom affected by fine sediment deposition. Leaf packs and woody debris with minimal silt covering.	Some new increase in bar formation, mostly from sand, or fine sediment; 20 to 50% of the bottom is affected; slight deposition in pools. Leaf packs with moderate silt covering.	Moderate deposition of new sand, or fine sediment on old and new bars; 50 to 80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent. Leaf packs with heavier silt covering.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. CHANNEL SINUOSITY **SCORE:** 5	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	the bends in the stream increase the stream length up to 2 times longer than if it was in a straight line.	Channel is straight; waterway has been channelized for a long distance.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0

Rate in Channel and Toe of Banks

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

***RAPID HABITAT ASSESSMENT**: LOW GRADIENT >>>>>>>>>>>>>>>>>>>>>>>>>>>*	**Reviewers Initials**	

	Optimal	**Sub-optimal**	**Marginal**	**Poor**
6. BANK STABILITY (score each bank) *determine left/ right by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems (<5% of bank affected).	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
LEFT: 9	**10 [✓ 9]**	**8 7 6**	**5 4 3**	**2 1 0**
RIGHT: 9	**10 [✓ 9]**	**8 7 6**	**5 4 3**	**2 1 0**
7. BANK VEGETATIVE PROTECTION **SCORE:**	More than 90% of the streambank surfaces and immediate riparian zones covered by vegetation including trees, understory shrubs, and non-woody plants (herbs, grasses, ferns, mosses); vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces are covered by vegetation, but one class of plants is not well represented; disruption evident, but not affecting plant growth potential to extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces are covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less that one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces are covered by vegetation; disruption of streambank vegetation very high; vegetation has been removed to 2 inches or less in average stubble height.
		If assessed in winter or early spring look for remnants of herbs, and saplings.		
LEFT: 4	**10 9**	**8 7 6**	**5 [✓ 4] 3**	**2 1 0**
RIGHT: 4	**10 9**	**8 7 6**	**5 [✓ 4] 3**	**2 1 0**
8. WIDTH OF UNDISTURBED VEG. ZONE (undisturbed veg. Is trees, shrubs, and non-woody macro-phytes)	Width of undisturbed vegetative zone is >18 meters; human activities (parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted this zone.	Zone width is between 12 and 18 meters; human activities have only minimally impacted this zone.	Zone width is between 6 and 12 meters; human activities have impacted the zone a great deal.	Width of zone is less than 6 meters; little or no undisturbed vegetation due to man-induced activities.
LEFT: 0	**10 9**	**8 7 6**	**5 4 3**	**2 1 [✓ 0]**
RIGHT: 0	**10 9**	**8 7 6**	**5 4 3**	**2 1 [✓ 0]**

TOTAL:

(max=160)

Max Pool Depth (if water is present; otherwise "NA") ______cm

Average Channel Width (Toe of Banks) _________m

Total from front 35 **+ Total from back** 26 **=** 61

Score Percentage= Total Score /160 X 100 33.9 **%**

Average Width Intact Rip Vegetative Zone (m) **Left** <1 **m** **Right** <1 **m**

→ What is the dominant vegetation type in the reach?
☐ **Deciduous** ☐ **Coniferous (pine/cypress)** ☐ **Mixed (>10%)**

Estimated age of forest: ____*>50 yrs* ____*25-50 yrs* ____*5-25 yrs* _X_*<5 yrs*

Number of strata *(e.g, canopy, subcanopy, shrub, herb (4 max))*________

Stream Surface Shading (%) (average of lower, middle, upper reach)	**Indicate % based on cloudless day in <u>summer</u> at noon. Fill in square that applies.**		
☒ **Fully exposed (0-25%)**	☐ **Partly shaded (25-50%)**	☐ **Partly exposed (50-75%)**	☐ **Fully shaded (75-100%)**

-or- % Canopy (Densiometer)		**Compass Bearing (facing downstream) (0-360°)**	

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

RAPID HABITAT ASSESSMENT: LOW GRADIENT Ephemeral/Intermittent >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Station ID/ Stream Name	LILLY RUN - REACH 3			**LAT (DD)**	
Reach Length (m)		Date	4/10/19	**LONG (DD)**	

HABITAT PARAMETER	**CATEGORY**			
	Optimal	**Sub-optimal**	**Marginal**	**Poor**
1. SUBSTRATE/ DIVERSITY **AVAILBLE COVER FOR AMPHIBIANS CRAYFISH** **SCORE:** 11	*Greater than 50% of substrate consisting of mix of snags, tree roots or other stable habitat providing cover for amphibians and aquatic or terrestrial invertebrates. LWD in moderate to advanced stage of decay and within- active channel; Substrate roughness capable of trapping lots of organic matter. If moss covered, rate high.*	*30 to 50% cover and mix of diverse stable habitat; well suited for full cover potential; adequate habitat for maintenance of populations; presence of additional LWD in the form of new fall. Substrate roughness still capable of trapping organic matter.*	*10 to 30% mix of stable cover; habitat availability less than desirable; substrate frequently disturbed or removed. LWD low in density and/or may be new fall or in early decay stage. Some areas suitable for trapping organic matter. If lg. wood is absent, score low.*	*Less than 10% stable cover; lack of habitat is obvious; substrate unstable or lacking. Few areas suitable for trapping organic matter.*
	Rate in Channel and Toe of Banks			
	20 19 18 17 16	**15 14 13 12 [✓ 11]**	**10 9 8 7 6**	**5 4 3 2 1 0**
2. POOL SUBSTRATE CHARACTERIZATION **In dry channels, pool areas should still be observable** **SCORE:** 10	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged (or remnant) aquatic vegetation are common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged (or remnant) vegetation are present.	All mud or clay or sand bottom; little or no root mat; no submerged (or remnant) vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	20 19 18 17 16	**15 14 13 12 11**	**[✓ 10] 9 8 7 6**	**5 4 3 2 1 0**
3. CHANNEL ALTERATION **SCORE:** 8	Channelization or dredging absent of minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (>than past 20 years) may be present, but no evidence of recent channelization.	Channelization may be extensive; embankments or shoring structures present on both banks; 40 to 80% of the stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	20 19 18 17 16	**15 14 13 12 11**	**10 9 [✓ 8] 7 6**	**5 4 3 2 1 0**
4. SEDIMENT DEPOSITION **SCORE:** 18	Little or no enlargement of "islands" or point bars and less than 20% of the bottom affected by fine sediment deposition. Leaf packs and woody debris with minimal silt covering.	Some new increase in bar formation, mostly from sand, or fine sediment; 20 to 50% of the bottom is affected; slight deposition in pools. Leaf packs with moderate silt covering.	Moderate deposition of new sand, or fine sediment on old and new bars; 50 to 80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent. Leaf packs with heavier silt covering.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	20 19 [✓ 18] 17 16	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
5. CHANNEL SINUOSITY **SCORE:** 3	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	the bends in the stream increase the stream length up to 2 times longer than if it was in a straight line.	Channel is straight; waterway has been channelized for a long distance.
	20 19 18 17 16	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 [✓ 3] 2 1 0**

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

RAPID HABITAT ASSESSMENT: LOW GRADIENT >>>>>>>>>>>>>>>>>>>>>>>>>>>> **Reviewers Initials**

	Optimal	**Sub-optimal**	**Marginal**	**Poor**
6. BANK STABILITY (score each bank) *determine left/ right by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems (<5% of bank affected).	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
LEFT: 6	10 9	8 7 [✓ 6]	5 4 3	2 1 0
RIGHT: 6	10 9	8 7 [✓ 6]	5 4 3	2 1 0
7. BANK VEGETATIVE PROTECTION **SCORE:**	More than 90% of the streambank surfaces and immediate riparian zones covered by vegetation including trees, understory shrubs, and non-woody plants (herbs, grasses, ferns, mosses); vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces are covered by vegetation, but one class of plants is not well represented; disruption evident, but not affecting plant growth potential to extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces are covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less that one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces are covered by vegetation; disruption of streambank vegetation very high; vegetation has been removed to 2 inches or less in average stubble height.
		If assessed in winter or early spring look for remnants of herbs, and saplings.		
LEFT: 5	10 9	8 7 6	[✓ 5] 4 3	2 1 0
RIGHT: 5	10 9	8 7 6	[✓ 5] 4 3	2 1 0
8. WIDTH OF UNDISTURBED VEG. ZONE (undisturbed veg. Is trees, shrubs, and non-woody macro-phytes)	Width of undisturbed vegetative zone is >18 meters; human activities (parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted this zone.	Zone width is between 12 and 18 meters; human activities have only minimally impacted this zone.	Zone width is between 6 and 12 meters; human activities have impacted the zone a great deal.	Width of zone is less than 6 meters; little or no undisturbed vegetation due to man-induced activities.
LEFT: 1	10 9	8 7 6	5 4 3	2 [✓ 1] 0
RIGHT: 1	10 9	8 7 6	5 4 3	2 [✓ 1] 0

TOTAL:

(max=160)

Max Pool Depth (if water is present; otherwise "NA") ______cm

Average Channel Width (Toe of Banks) _________m

Total from front 50 **+ Total from back** 24 **=** 74

Score Percentage= Total Score /160 X 100 46.2 **%**

Average Width Intact Rip Vegetative Zone (m)	**Left** 1 **m**	**Right** 1 **m**

→ What is the dominant vegetation type in the reach?

☐ Deciduous ☐ Coniferous (pine/cypress) ☐ Mixed (>10%)

Estimated age of forest: ____***>50 yrs*** ____***25-50 yrs*** X ***5-25 yrs*** ____***<5 yrs***

Number of strata *(e.g, canopy, subcanopy, shrub, herb (4 max))*________

Stream Surface Shading (%) (average of lower, middle, upper reach)	**Indicate % based on cloudless day in <u>summer</u> at noon. Fill in square that applies.**		
☐ Fully exposed (0-25%)	**☒ Partly shaded (25-50%)**	**☐ Partly exposed (50-75%)**	**☐ Fully shaded (75-100%)**

-or- % Canopy (Densiometer)		**Compass Bearing (facing downstream) (0-360°)**	

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

RAPID HABITAT ASSESSMENT: LOW GRADIENT Ephemeral/Intermittent >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Station ID/ Stream Name	LILLY RUN - REACH 4		**LAT (DD)**	
Reach Length (m)		Date 4/10/19	**LONG (DD)**	

HABITAT PARAMETER	**CATEGORY**			
	Optimal	**Sub-optimal**	**Marginal**	**Poor**
1. SUBSTRATE/ DIVERSITY **AVAILBLE COVER FOR AMPHIBIANS CRAYFISH** **SCORE:** 15	*Greater than 50% of substrate consisting of mix of snags, tree roots or other stable habitat providing cover for amphibians and aquatic or terrestrial invertebrates. LWD in moderate to advanced stage of decay and within- active channel; Substrate roughness capable of trapping lots of organic matter. If moss covered, rate high.* **Rate in Channel and Toe of Banks**	*30 to 50% cover and mix of diverse stable habitat; well suited for full cover potential; adequate habitat for maintenance of populations; presence of additional LWD in the form of new fall. Substrate roughness still capable of trapping organic matter.*	*10 to 30% mix of stable cover; habitat availability less than desirable; substrate frequently disturbed or removed. LWD low in density and/or may be new fall or in early decay stage. Some areas suitable for trapping organic matter. If lg. wood is absent, score low.*	*Less than 10% stable cover; lack of habitat is obvious; substrate unstable or lacking. Few areas suitable for trapping organic matter.*
	20 19 18 17 16	**[✓ 15] 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
2. POOL SUBSTRATE CHARACTER-IZATION **In dry channels, pool areas should still be observable** **SCORE:** 10	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged (or remnant) aquatic vegetation are common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged (or remnant) vegetation are present.	All mud or clay or sand bottom; little or no root mat; no submerged (or remnant) vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	20 19 18 17 16	**15 14 13 12 11**	**[✓ 10] 9 8 7 6**	**5 4 3 2 1 0**
3. CHANNEL ALTERATION **SCORE:** 8	Channelization or dredging absent of minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (>than past 20 years) may be present, but no evidence of recent channelization.	Channelization may be extensive; embankments or shoring structures present on both banks; 40 to 80% of the stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	20 19 18 17 16	**15 14 13 12 11**	**10 9 [✓ 8] 7 6**	**5 4 3 2 1 0**
4. SEDIMENT DEPOSITION **SCORE:** 18	Little or no enlargement of “islands” or point bars and less than 20% of the bottom affected by fine sediment deposition. Leaf packs and woody debris with minimal silt covering.	Some new increase in bar formation, mostly from sand, or fine sediment; 20 to 50% of the bottom is affected; slight deposition in pools. Leaf packs with moderate silt covering.	Moderate deposition of new sand, or fine sediment on old and new bars; 50 to 80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent. Leaf packs with heavier silt covering.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	20 19 [✓ 18] 17 16	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
5. CHANNEL SINUOSITY **SCORE:** 2	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	the bends in the stream increase the stream length up to 2 times longer than if it was in a straight line.	Channel is straight; waterway has been channelized for a long distance.
	20 19 18 17 16	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 [✓ 2] 1 0**

Appendix 1: Modified Environmental Protection Agency Rapid Bioassessment Protocol (EPA RBP)
Habitat Assessment Field Data Sheet (Low Gradient Ephemeral/Intermittent Streams)

***RAPID HABITAT ASSESSMENT**: LOW GRADIENT >>>>>>>>>>>>>>>>>>>>>>>>>>>>*	**Reviewers Initials**	

	Optimal	**Sub-optimal**	**Marginal**	**Poor**
6. BANK STABILITY (score each bank) *determine left/ right by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems (<5% of bank affected).	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
LEFT: 6	**10 9**	**8 7 [✓ 6]**	**5 4 3**	**2 1 0**
RIGHT: 6	**10 9**	**8 7 [✓ 6]**	**5 4 3**	**2 1 0**
7. BANK VEGETATIVE PROTECTION **SCORE:**	More than 90% of the streambank surfaces and immediate riparian zones covered by vegetation including trees, understory shrubs, and non-woody plants (herbs, grasses, ferns, mosses); vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces are covered by vegetation, but one class of plants is not well represented; disruption evident, but not affecting plant growth potential to extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces are covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less that one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces are covered by vegetation; disruption of streambank vegetation very high; vegetation has been removed to 2 inches or less in average stubble height.
LEFT: 7	**10 9**	**8 [✓ 7] 6**	**5 4 3**	**2 1 0**
RIGHT: 7	**10 9**	**8 [✓ 7] 6**	**5 4 3**	**2 1 0**
8. WIDTH OF UNDISTURBED VEG. ZONE (undisturbed veg. Is trees, shrubs, and non-woody macro-phytes)	Width of undisturbed vegetative zone is >18 meters; human activities (parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted this zone.	Zone width is between 12 and 18 meters; human activities have only minimally impacted this zone.	Zone width is between 6 and 12 meters; human activities have impacted the zone a great deal.	Width of zone is less than 6 meters; little or no undisturbed vegetation due to man-induced activities.
LEFT: 1	**10 9**	**8 7 6**	**5 4 3**	**2 [✓ 1] 0**
RIGHT: 1	**10 9**	**8 7 6**	**5 4 3**	**2 [✓ 1] 0**

If assessed in winter or early spring look for remnants of herbs, and saplings.

TOTAL:
(max=160)

Max Pool Depth (if water is present; otherwise "NA") ______cm

Average Channel Width (Toe of Banks) _________m

Total from front 53 **+ Total from back** 28 **=** 81

Score Percentage= Total Score /160 X 100 50.6 **%**

Average Width Intact Rip Vegetative Zone (m) **Left** 1 **m** **Right** 1 **m**

→ **What is the dominant vegetation type in the reach?**
☐ **Deciduous** ☐ **Coniferous (pine/cypress)** ☐ **Mixed (>10%)**

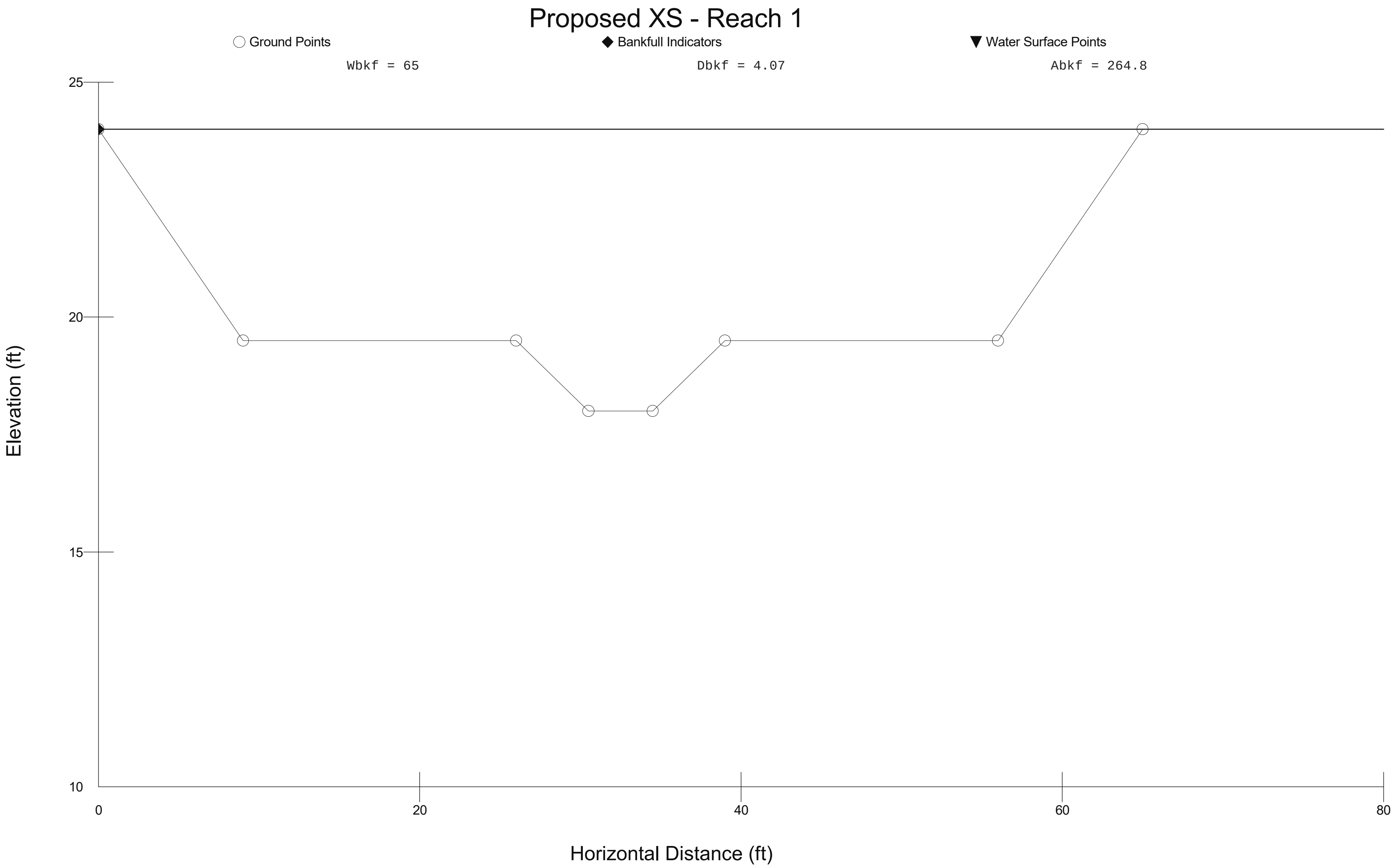
Estimated age of forest: ____*>50 yrs* ____*25-50 yrs* ____*5-25 yrs* X *<5 yrs*

Number of strata *(e.g, canopy, subcanopy, shrub, herb (4 max))*________

Stream Surface Shading (%) (average of lower, middle, upper reach)	**Indicate % based on cloudless day in <u>summer</u> at noon. Fill in square that applies.**		
☒ **Fully exposed (0-25%)**	☐ **Partly shaded (25-50%)**	☐ **Partly exposed (50-75%)**	☐ **Fully shaded (75-100%)**
-or- % Canopy (Densiometer)	**Compass Bearing (facing downstream) (0-360°)**		

Appendix E

Design Computations


Proposed XS - Reach 1
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 65
Dbkf = 4.07
Abkf = 264.8
25
20
15
10
Elevation (ft)
0
20
40
60
80
Horizontal Distance (ft)

REACH 1 - PROPOSED HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
18.1	0.1	0.43	4.63	4.6	0.09	0.09	0.00437	0.0499	1.1	0.4	3.51	0	0.17	0.02	0.05	0.01	0.23	0
18.2	0.2	0.92	5.26	5.2	0.17	0.18	0.00437	0.0384	2.08	0.79	5.08	0.01	0.72	0.05	0.2	0.04	0.33	0
18.3	0.3	1.47	5.9	5.8	0.25	0.25	0.00437	0.03451	3.05	1.13	6.02	0.02	1.66	0.07	0.45	0.08	0.4	0
18.4	0.4	2.08	6.53	6.4	0.32	0.32	0.00437	0.03267	3.91	1.41	6.63	0.03	2.93	0.09	0.8	0.12	0.44	0
18.5	0.5	2.75	7.16	7	0.38	0.39	0.00437	0.03161	4.64	1.63	7.05	0.04	4.49	0.1	1.22	0.17	0.46	0
18.6	0.6	3.48	7.79	7.6	0.45	0.46	0.00437	0.0307	5.5	1.88	7.47	0.05	6.54	0.12	1.78	0.23	0.49	0.15
18.7	0.7	4.27	8.43	8.2	0.51	0.52	0.00437	0.03011	6.23	2.08	7.78	0.07	8.9	0.14	2.43	0.3	0.51	0.34
18.8	0.8	5.12	9.06	8.8	0.57	0.58	0.00437	0.02963	6.96	2.28	8.05	0.08	11.67	0.16	3.18	0.36	0.53	0.64
18.9	0.9	6.03	9.69	9.4	0.62	0.64	0.00437	0.0293	7.57	2.44	8.26	0.09	14.71	0.17	4.01	0.43	0.54	1
19	1	7	10.32	10	0.68	0.7	0.00437	0.02896	8.31	2.62	8.48	0.11	18.37	0.19	5.01	0.5	0.55	1.56
19.1	1.1	8.03	10.96	10.6	0.73	0.76	0.00437	0.02871	8.92	2.77	8.66	0.12	22.28	0.2	6.08	0.57	0.56	2.17
19.2	1.2	9.12	11.59	11.2	0.79	0.81	0.00437	0.02845	9.65	2.95	8.85	0.14	26.92	0.22	7.34	0.66	0.58	3.04
19.3	1.3	10.27	12.22	11.8	0.84	0.87	0.00437	0.02826	10.26	3.1	9	0.15	31.79	0.23	8.67	0.73	0.58	3.94
19.4	1.4	11.48	12.85	12.4	0.89	0.93	0.00437	0.02809	10.87	3.24	9.14	0.16	37.15	0.24	10.13	0.82	0.59	4.98
19.5	1.5	12.75	13.49	13	0.95	0.98	0.00437	0.02791	11.61	3.4	9.31	0.18	43.38	0.26	11.83	0.91	0.61	6.39
19.6	1.6	17.47	47.93	47.4	0.36	0.37	0.00437	0.03192	4.4	1.56	6.92	0.04	27.21	0.1	7.42	0.16	0.45	0
19.7	1.7	22.23	48.38	47.8	0.46	0.47	0.00437	0.03059	5.62	1.91	7.52	0.06	42.55	0.13	11.6	0.24	0.49	1.07
19.8	1.8	27.03	48.83	48.2	0.55	0.56	0.00437	0.02978	6.72	2.22	7.96	0.08	59.87	0.15	16.33	0.34	0.52	2.95
19.9	1.9	31.87	49.28	48.6	0.65	0.66	0.00437	0.02912	7.94	2.53	8.37	0.1	80.7	0.18	22.01	0.45	0.55	6.32
20	2	36.75	49.72	49	0.74	0.75	0.00437	0.02866	9.04	2.8	8.69	0.12	103.07	0.2	28.11	0.57	0.57	10.53
20.1	2.1	41.67	50.17	49.4	0.83	0.84	0.00437	0.0283	10.14	3.07	8.97	0.15	127.79	0.23	34.85	0.71	0.59	15.84
20.2	2.2	46.63	50.62	49.8	0.92	0.94	0.00437	0.028	11.24	3.32	9.23	0.17	154.8	0.25	42.21	0.85	0.6	22.19
20.3	2.3	51.63	51.06	50.2	1.01	1.03	0.00437	0.02775	12.34	3.56	9.46	0.2	184.05	0.28	50.19	1	0.62	29.56
20.4	2.4	56.67	51.51	50.6	1.1	1.12	0.00437	0.02754	13.44	3.8	9.67	0.22	215.5	0.3	58.76	1.16	0.63	37.92
20.5	2.5	61.75	51.96	51	1.19	1.21	0.00437	0.02735	14.54	4.03	9.86	0.25	249.12	0.32	67.93	1.33	0.65	47.23
20.6	2.6	66.87	52.41	51.4	1.28	1.3	0.00437	0.02719	15.64	4.26	10.04	0.28	284.87	0.35	77.68	1.51	0.66	57.46
20.7	2.7	72.03	52.85	51.8	1.36	1.39	0.00437	0.02707	16.61	4.46	10.19	0.31	320.99	0.37	87.53	1.69	0.67	67.38
20.8	2.8	77.23	53.3	52.2	1.45	1.48	0.00437	0.02694	17.71	4.67	10.34	0.34	360.86	0.4	98.4	1.89	0.68	79.31
20.9	2.9	82.47	53.75	52.6	1.53	1.57	0.00437	0.02684	18.69	4.86	10.48	0.37	400.88	0.42	109.32	2.08	0.68	90.73
21	3	87.75	54.2	53	1.62	1.66	0.00437	0.02674	19.79	5.07	10.62	0.4	444.8	0.44	121.29	2.29	0.69	104.3
21.1	3.1	93.07	54.64	53.4	1.7	1.74	0.00437	0.02666	20.77	5.25	10.74	0.43	488.67	0.46	133.25	2.5	0.7	117.18
21.2	3.2	98.43	55.09	53.8	1.79	1.83	0.00437	0.02657	21.87	5.45	10.86	0.46	536.57	0.49	146.32	2.72	0.71	132.35
21.3	3.3	103.83	55.54	54.2	1.87	1.92	0.00437	0.02651	22.84	5.63	10.97	0.49	584.24	0.51	159.32	2.94	0.72	146.65
21.4	3.4	109.27	55.98	54.6	1.95	2	0.00437	0.02644	23.82	5.8	11.07	0.52	633.76	0.53	172.82	3.17	0.72	161.63
21.5	3.5	114.75	56.43	55	2.03	2.09	0.00437	0.02639	24.8	5.97	11.17	0.55	685.12	0.55	186.82	3.4	0.73	177.26
21.6	3.6	120.27	56.88	55.4	2.11	2.17	0.00437	0.02633	25.78	6.14	11.27	0.59	738.31	0.58	201.33	3.63	0.73	193.56
21.7	3.7	125.83	57.33	55.8	2.2	2.26	0.00437	0.02628	26.87	6.33	11.37	0.62	795.93	0.6	217.04	3.89	0.74	212.5
21.8	3.8	131.43	57.77	56.2	2.27	2.34	0.00437	0.02624	27.73	6.47	11.45	0.65	850.19	0.62	231.84	4.13	0.75	228.15
21.9	3.9	137.07	58.22	56.6	2.35	2.42	0.00437	0.0262	28.71	6.63	11.53	0.68	908.87	0.64	247.84	4.38	0.75	246.43
22	4	142.75	58.67	57	2.43	2.5	0.00437	0.02616	29.68	6.79	11.61	0.72	969.38	0.66	264.34	4.64	0.76	265.36
22.1	4.1	148.47	59.11	57.4	2.51	2.59	0.00437	0.02612	30.66	6.95	11.69	0.75	1031.71	0.68	281.33	4.9	0.76	284.95
22.2	4.2	154.23	59.56	57.8	2.59	2.67	0.00437	0.02608	31.64	7.11	11.77	0.78	1095.86	0.71	298.83	5.17	0.77	305.19
22.3	4.3	160.03	60.01	58.2	2.67	2.75	0.00437	0.02605	32.62	7.26	11.84	0.82	1161.83	0.73	316.82	5.44	0.77	326.09
22.4	4.4	165.87	60.46	58.6	2.74	2.83	0.00437	0.02602	33.47	7.39	11.91	0.85	1226.46	0.75	334.44	5.71	0.77	345.21
22.5	4.5	171.75	60.9	59	2.82	2.91	0.00437	0.02599	34.45	7.55	11.98	0.88	1295.99	0.77	353.4	5.99	0.78	367.36
22.6	4.6	177.67	61.35	59.4	2.9	2.99	0.00437	0.02597	35.43	7.7	12.05	0.92	1367.35	0.79	372.86	6.28	0.78	390.16
22.7	4.7	183.63	61.8	59.8	2.97	3.07	0.00437	0.02594	36.28	7.83	12.11	0.95	1437.13	0.81	391.89	6.55	0.79	410.99
22.8	4.8	189.63	62.24	60.2	3.05	3.15	0.00437	0.02592	37.26	7.97	12.17	0.99	1512.05	0.83	412.32	6.85	0.79	435.04
22.9	4.9	195.67	62.69	60.6	3.12	3.23	0.00437	0.0259	38.11	8.1	12.23	1.02	1585.25	0.85	432.28	7.13	0.79	457.01
23	5	201.75	63.14	61	3.2	3.31	0.00437	0.02588	39.09	8.25	12.29	1.06	1663.75	0.87	453.68	7.44	0.8	482.31
23.1	5.1	207.87	63.59	61.4	3.27	3.39	0.00437	0.02586	39.95	8.37	12.34	1.09	1740.36	0.89	474.58	7.73	0.8	505.41
23.2	5.2	214.03	64.03	61.8	3.34	3.46	0.00437	0.02584	40.8	8.5	12.39	1.12	1818.65	0.91	495.92	8.02	0.81	529.05
23.3	5.3	220.23	64.48	62.2	3.42	3.54	0.00437	0.02582	41.78	8.64	12.45	1.16	1902.5	0.93	518.79	8.34	0.81	556.21
23.4	5.4	226.47	64.93	62.6	3.49	3.62	0.00437	0.02581	42.63	8.76	12.5	1.19	1984.22	0.95	541.07	8.64	0.81	580.99
23.5	5.5	232.75	65.38	63	3.56	3.69	0.00437	0.02579	43.49	8.88	12.55	1.23	2067.64	0.97	563.82	8.95	0.81	606.32
23.6	5.6	239.07	65.82	63.4	3.63	3.77	0.00437	0.02578	44.34	9	12.6	1.26	2152.73	0.99	587.02	9.26	0.82	632.19
23.7	5.7	245.43	66.27	63.8	3.7	3.85	0.00437	0.02576	45.2	9.12	12.65	1.29	2239.52	1.01	610.69	9.57	0.82	658.62
23.8	5.8	251.83	66.72	64.2	3.77	3.92	0.00437	0.02575	46.05	9.24	12.69	1.33	2328	1.03	634.82	9.89	0.82	685.59
23.9	5.9	258.27	67.16	64.6	3.85	4	0.00437	0.02573	47.03	**9.38**	12.74	1.37	**2422.54**	**1.05**	660.6	10.23	0.83	716.46

Additional Information:

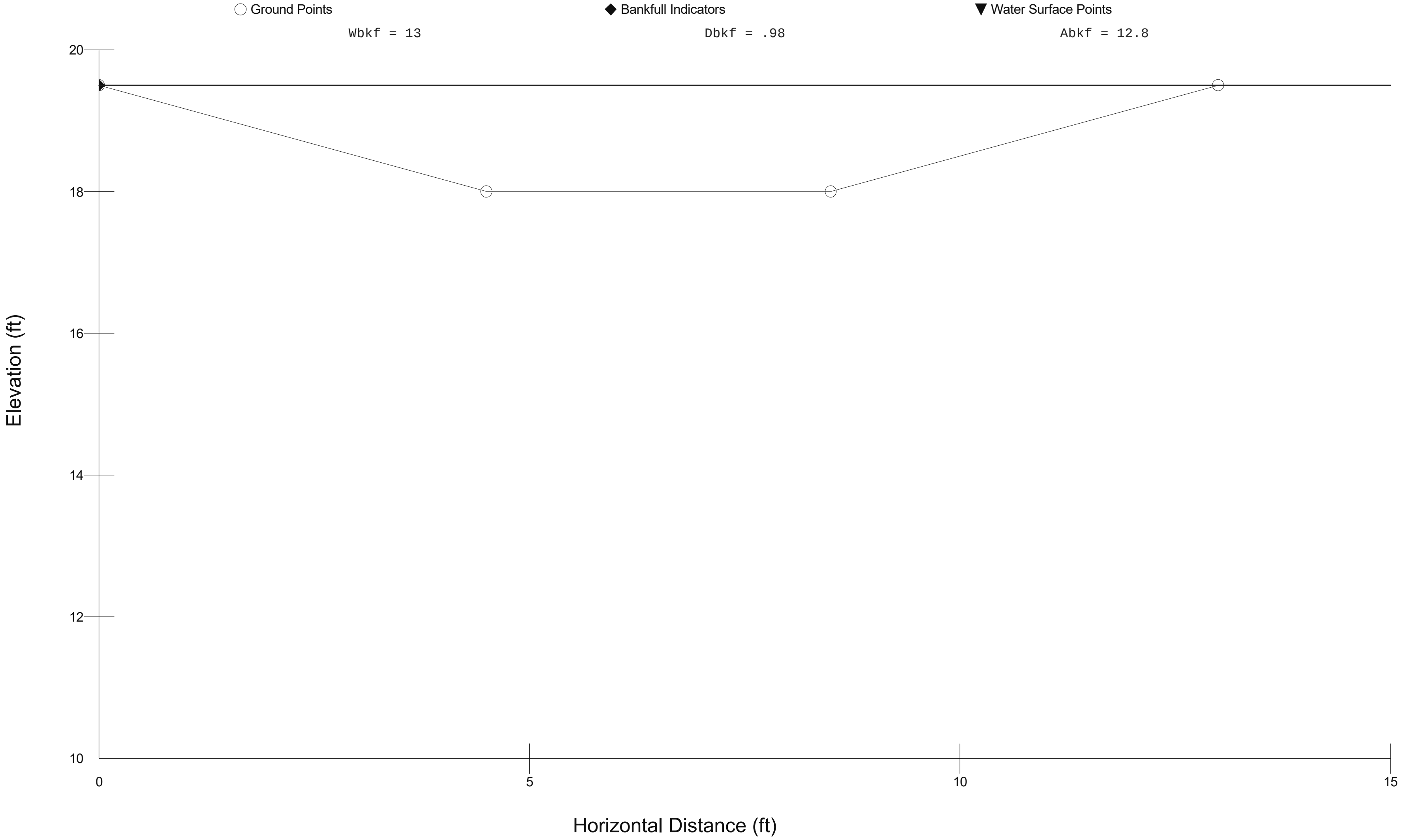
Slope = 0.437%

D50 = 6.85 mm

D84 = 24.95 mm

Q100 = 2400 cfs

Shear Stress = < 2psf

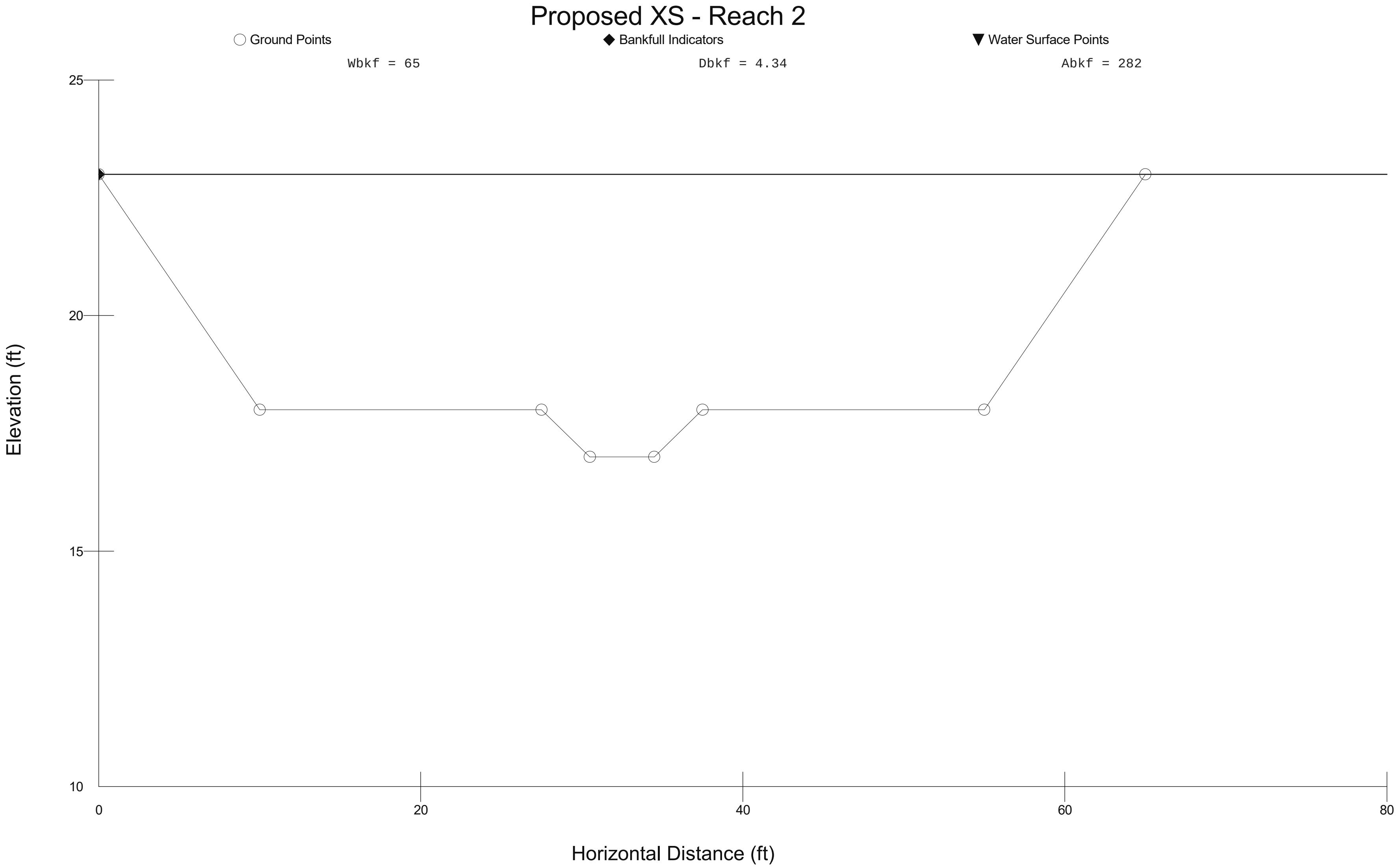


Proposed Channel - Reach 1

REACH 1 - PROPOSED CHANNEL HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
18.1	0.1	0.43	4.63	4.6	0.09	0.09	0.00437	0.0499	1.1	0.4	3.51	0	0.17	0.02	0.05	0.01	0.23	0
18.2	0.2	0.92	5.26	5.2	0.17	0.18	0.00437	0.0384	2.08	0.79	5.08	0.01	0.72	0.05	0.2	0.04	0.33	0
18.3	0.3	1.47	5.9	5.8	0.25	0.25	0.00437	0.03451	3.05	1.13	6.02	0.02	1.66	0.07	0.45	0.08	0.4	0
18.4	0.4	2.08	6.53	6.4	0.32	0.32	0.00437	0.03267	3.91	1.41	6.63	0.03	2.93	0.09	0.8	0.12	0.44	0
18.5	0.5	2.75	7.16	7	0.38	0.39	0.00437	0.03161	4.64	1.63	7.05	0.04	4.49	0.1	1.22	0.17	0.46	0
18.6	0.6	3.48	7.79	7.6	0.45	0.46	0.00437	0.0307	5.5	1.88	7.47	0.05	6.54	0.12	1.78	0.23	0.49	0.15
18.7	0.7	4.27	8.43	8.2	0.51	0.52	0.00437	0.03011	6.23	2.08	7.78	0.07	8.9	0.14	2.43	0.3	0.51	0.34
18.8	0.8	5.12	9.06	8.8	0.57	0.58	0.00437	0.02963	6.96	2.28	8.05	0.08	11.67	0.16	3.18	0.36	0.53	0.64
18.9	0.9	6.03	9.69	9.4	0.62	0.64	0.00437	0.0293	7.57	2.44	8.26	0.09	14.71	0.17	4.01	0.43	0.54	1
19	1	7	10.32	10	0.68	0.7	0.00437	0.02896	8.31	2.62	8.48	0.11	18.37	0.19	5.01	0.5	0.55	1.56
19.1	1.1	8.03	10.96	10.6	0.73	0.76	0.00437	0.02871	8.92	2.77	8.66	0.12	22.28	0.2	6.08	0.57	0.56	2.17
19.2	1.2	9.12	11.59	11.2	0.79	0.81	0.00437	0.02845	9.65	2.95	8.85	0.14	26.92	0.22	7.34	0.66	0.58	3.04
19.3	1.3	10.27	12.22	11.8	0.84	0.87	0.00437	0.02826	10.26	3.1	9	0.15	31.79	0.23	8.67	0.73	0.58	3.94
19.4	1.4	11.48	12.85	12.4	0.89	0.93	0.00437	0.02809	10.87	3.24	9.14	0.16	37.15	**0.24**	10.13	0.82	0.59	4.98

Additional Information:
Slope = 0.437%
D50 = 6.85 mm
D84 = 24.95 mm

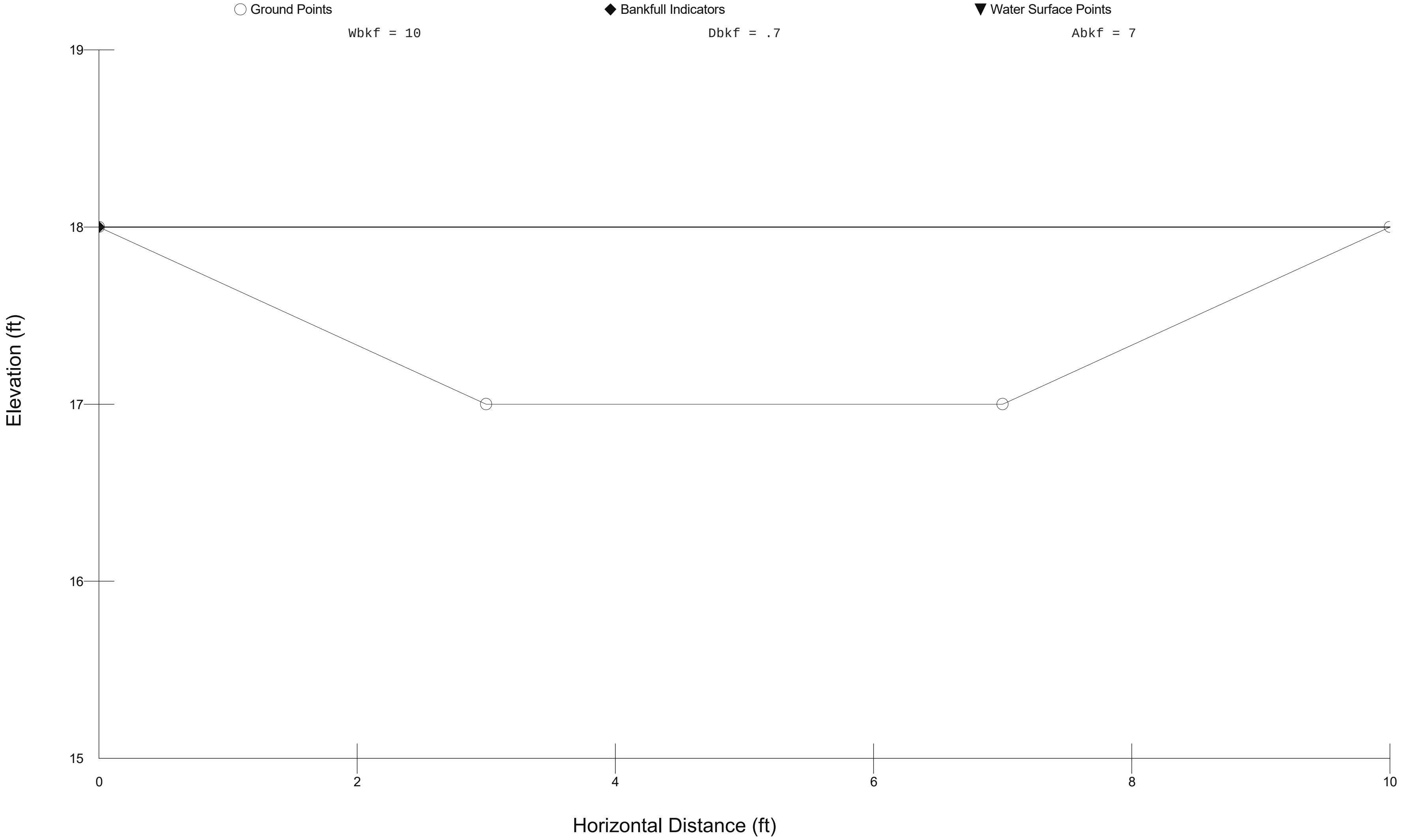

Proposed XS - Reach 2
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 65
Dbkf = 4.34
Abkf = 282
25
20
15
10
Elevation (ft)
0
20
40
60
80
Horizontal Distance (ft)

REACH 2 - PROPOSED HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
17.1	0.1	0.43	4.63	4.6	0.09	0.09	0.005	0.0499	1.1	0.42	3.51	0	0.18	0.03	0.06	0.01	0.25	0
17.2	0.2	0.92	5.26	5.2	0.17	0.18	0.005	0.0384	2.08	0.84	5.08	0.01	0.77	0.05	0.24	0.05	0.35	0
17.3	0.3	1.47	5.9	5.8	0.25	0.25	0.005	0.03451	3.05	1.21	6.02	0.02	1.78	0.08	0.55	0.1	0.43	0.03
17.4	0.4	2.08	6.53	6.4	0.32	0.32	0.005	0.03267	3.91	1.51	6.63	0.04	3.13	0.1	0.98	0.15	0.47	0
17.5	0.5	2.75	7.16	7	0.38	0.39	0.005	0.03161	4.64	1.74	7.05	0.05	4.8	0.12	1.5	0.21	0.49	0
17.6	0.6	3.48	7.79	7.6	0.45	0.46	0.005	0.0307	5.5	2.01	7.47	0.06	7	0.14	2.18	0.29	0.52	0.33
17.7	0.7	4.27	8.43	8.2	0.51	0.52	0.005	0.03011	6.23	2.23	7.78	0.08	9.52	0.16	2.97	0.36	0.54	0.67
17.8	0.8	5.12	9.06	8.8	0.57	0.58	0.005	0.02963	6.96	2.44	8.05	0.09	12.49	0.18	3.9	0.44	0.56	1.16
17.9	0.9	6.03	9.69	9.4	0.62	0.64	0.005	0.0293	7.57	2.61	8.26	0.11	15.73	0.19	4.91	0.52	0.57	1.73
18	1	7	10.32	10	0.68	0.7	0.005	0.02896	8.31	2.81	8.48	0.12	19.65	0.21	6.13	0.61	0.59	2.57
18.1	1.1	11.52	45.77	45.4	0.25	0.25	0.005	0.03451	3.05	1.21	6.02	0.02	13.92	0.08	4.34	0.1	0.43	0.22
18.2	1.2	16.08	46.22	45.8	0.35	0.35	0.005	0.0321	4.28	1.63	6.85	0.04	26.15	0.11	8.16	0.18	0.48	0
18.3	1.3	20.68	46.67	46.2	0.44	0.45	0.005	0.03081	5.37	1.97	7.41	0.06	40.81	0.14	12.73	0.28	0.52	1.77
18.4	1.4	25.32	47.11	46.6	0.54	0.54	0.005	0.02986	6.6	2.33	7.92	0.08	59.11	0.17	18.44	0.4	0.56	4.89
18.5	1.5	30	47.56	47	0.63	0.64	0.005	0.02924	7.7	2.64	8.3	0.11	79.26	0.2	24.73	0.53	0.58	9.17
18.6	1.6	34.72	48.01	47.4	0.72	0.73	0.005	0.02876	8.8	2.94	8.62	0.13	101.95	0.22	31.81	0.67	0.61	14.82
18.7	1.7	39.48	48.46	47.8	0.81	0.83	0.005	0.02837	9.89	3.22	8.91	0.16	127.08	0.25	39.65	0.83	0.62	21.79
18.8	1.8	44.28	48.9	48.2	0.91	0.92	0.005	0.02803	11.12	3.52	9.2	0.19	155.92	0.28	48.65	1.01	0.65	30.98
18.9	1.9	49.12	49.35	48.6	1	1.01	0.005	0.02778	12.22	3.78	9.43	0.22	185.88	0.31	58	1.19	0.66	40.54
19	2	54	49.8	49	1.08	1.1	0.005	0.02758	13.19	4.01	9.62	0.25	216.63	0.34	67.59	1.38	0.67	50.06
19.1	2.1	58.92	50.24	49.4	1.17	1.19	0.005	0.02739	14.29	4.26	9.82	0.28	251.04	0.36	78.33	1.59	0.69	61.79
19.2	2.2	63.88	50.69	49.8	1.26	1.28	0.005	0.02723	15.39	4.5	10	0.31	287.69	0.39	89.76	1.8	0.7	74.63
19.3	2.3	68.88	51.14	50.2	1.35	1.37	0.005	0.02708	16.49	4.74	10.17	0.35	326.54	0.42	101.88	2.03	0.71	88.53
19.4	2.4	73.92	51.59	50.6	1.43	1.46	0.005	0.02697	17.47	4.95	10.31	0.38	365.69	0.45	114.09	2.25	0.72	101.85
19.5	2.5	79	52.03	51	1.52	1.55	0.005	0.02685	18.57	5.17	10.46	0.42	408.79	0.47	127.54	2.5	0.73	117.73
19.6	2.6	84.12	52.48	51.4	1.6	1.64	0.005	0.02676	19.55	5.37	10.59	0.45	451.97	0.5	141.02	2.74	0.74	132.81
19.7	2.7	89.28	52.93	51.8	1.69	1.72	0.005	0.02667	20.64	5.59	10.72	0.49	499.27	0.53	155.77	3.01	0.75	150.61
19.8	2.8	94.48	53.37	52.2	1.77	1.81	0.005	0.02659	21.62	5.78	10.83	0.52	546.44	0.55	170.49	3.27	0.76	167.4
19.9	2.9	99.72	53.82	52.6	1.85	1.9	0.005	0.02652	22.6	5.97	10.94	0.55	595.55	0.58	185.81	3.53	0.76	185
20	3	105	54.27	53	1.93	1.98	0.005	0.02646	23.58	6.16	11.05	0.59	646.58	0.6	201.73	3.81	0.77	203.39
20.1	3.1	110.32	54.72	53.4	2.02	2.07	0.005	0.02639	24.68	6.36	11.16	0.63	702.05	0.63	219.04	4.1	0.78	224.83
20.2	3.2	115.68	55.16	53.8	2.1	2.15	0.005	0.02634	25.65	6.54	11.25	0.67	757.01	0.66	236.19	4.39	0.79	244.89
20.3	3.3	121.08	55.61	54.2	2.18	2.23	0.005	0.02629	26.63	6.72	11.35	0.7	813.89	0.68	253.93	4.69	0.79	265.74
20.4	3.4	126.52	56.06	54.6	2.26	2.32	0.005	0.02624	27.61	6.9	11.43	0.74	872.68	0.71	272.28	4.99	0.8	287.39
20.5	3.5	132	56.5	55	2.34	2.4	0.005	0.0262	28.59	7.07	11.52	0.78	933.38	0.73	291.21	5.29	0.8	309.81
20.6	3.6	137.52	56.95	55.4	2.41	2.48	0.005	0.02617	29.44	7.22	11.59	0.81	993.05	0.75	309.83	5.59	0.81	330.38
20.7	3.7	143.08	57.4	55.8	2.49	2.56	0.005	0.02613	30.42	7.39	11.67	0.85	1057.48	0.78	329.93	5.91	0.81	354.3
20.8	3.8	148.68	57.85	56.2	2.57	2.65	0.005	0.02609	31.39	7.56	11.75	0.89	1123.81	0.8	350.63	6.24	0.82	379.01
20.9	3.9	154.32	58.29	56.6	2.65	2.73	0.005	0.02606	32.37	7.72	11.83	0.93	1192.05	0.83	371.92	6.57	0.82	404.5
21	4	160	58.74	57	2.72	2.81	0.005	0.02603	33.23	7.87	11.89	0.96	1258.93	0.85	392.79	6.89	0.83	427.83
21.1	4.1	165.72	59.19	57.4	2.8	2.89	0.005	0.026	34.2	8.03	11.96	1	1330.9	0.87	415.24	7.23	0.83	454.82
21.2	4.2	171.48	59.64	57.8	2.88	2.97	0.005	0.02597	35.18	8.19	12.03	1.04	1404.77	0.9	438.29	7.58	0.84	482.59
21.3	4.3	177.28	60.08	58.2	2.95	3.05	0.005	0.02595	36.04	8.33	12.09	1.08	1477.04	0.92	460.84	7.92	0.84	507.98
21.4	4.4	183.12	60.53	58.6	3.03	3.12	0.005	0.02592	37.01	8.49	12.16	1.12	1554.66	0.95	485.05	8.28	0.85	537.27
21.5	4.5	189	60.98	59	3.1	3.2	0.005	0.0259	37.87	8.63	12.21	1.16	1630.5	0.97	508.72	8.62	0.85	564.02
21.6	4.6	194.92	61.42	59.4	3.17	3.28	0.005	0.02588	38.72	8.76	12.27	1.19	1708.09	0.99	532.92	8.97	0.85	591.42
21.7	4.7	200.88	61.87	59.8	3.25	3.36	0.005	0.02586	39.7	8.92	12.33	1.23	1791.29	1.01	558.88	9.35	0.86	622.93
21.8	4.8	206.88	62.32	60.2	3.32	3.44	0.005	0.02585	40.56	9.05	12.38	1.27	1872.47	1.04	584.21	9.7	0.86	651.71
21.9	4.9	212.92	62.77	60.6	3.39	3.51	0.005	0.02583	41.41	9.18	12.43	1.31	1955.42	1.06	610.09	10.07	0.86	681.14
22	5	219	63.21	61	3.46	3.59	0.005	0.02581	42.27	9.32	12.48	1.35	2040.12	1.08	636.52	10.43	0.87	711.22
22.1	5.1	225.12	63.66	61.4	3.54	3.67	0.005	0.02579	43.24	9.47	12.54	1.39	2130.79	1.1	664.81	10.83	0.87	745.72
22.2	5.2	231.28	64.11	61.8	3.61	3.74	0.005	0.02578	44.1	9.59	12.59	1.43	2219.11	1.13	692.36	11.2	0.87	777.19
22.3	5.3	237.48	64.55	62.2	3.68	3.82	0.005	0.02577	44.95	9.72	12.63	1.47	2309.21	1.15	720.47	11.58	0.88	809.33
22.4	5.4	243.72	65	62.6	3.75	3.89	0.005	0.02575	45.81	9.85	12.68	1.51	2401.09	1.17	749.14	11.97	0.88	842.14
22.5	5.5	250	65.45	63	3.82	3.97	0.005	0.02574	46.66	**9.98**	12.72	1.55	**2494.75**	**1.19**	778.36	12.36	0.88	875.62
22.6	5.6	256.32	65.9	63.4	3.89	4.04	0.005	0.02573	47.52	10.11	12.77	1.59	2590.2	1.21	808.14	12.75	0.89	909.76
22.7	5.7	262.68	66.34	63.8	3.96	4.12	0.005	0.02572	48.37	10.23	12.81	1.63	2687.44	1.24	838.48	13.14	0.89	944.58
22.8	5.8	269.08	66.79	64.2	4.03	4.19	0.005	0.0257	49.23	10.36	12.86	1.67	2786.47	1.26	869.38	13.54	0.89	980.08
22.9	5.9	275.52	67.24	64.6	4.1	4.27	0.005	0.02569	50.08	10.48	12.9	1.71	2887.31	1.28	900.84	13.94	0.89	1016.26

Additional Information:
Slope = 0.50%
D50 = 6.85 mm
D84 = 24.95 mm
Q100 = 2400 cfs
Shear Stress = < 2psf

Proposed Channel - Reach 2



Wbkf = 10

Dbkf = .7

Abkf = 7

REACH 2 - PROPOSED CHANNEL HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
17.1	0.1	0.43	4.63	4.6	0.09	0.09	0.005	0.0499	1.1	0.42	3.51	0	0.18	0.03	0.06	0.01	0.25	0
17.2	0.2	0.92	5.26	5.2	0.17	0.18	0.005	0.0384	2.08	0.84	5.08	0.01	0.77	0.05	0.24	0.05	0.35	0
17.3	0.3	1.47	5.9	5.8	0.25	0.25	0.005	0.03451	3.05	1.21	6.02	0.02	1.78	0.08	0.55	0.1	0.43	0.03
17.4	0.4	2.08	6.53	6.4	0.32	0.32	0.005	0.03267	3.91	1.51	6.63	0.04	3.13	0.1	0.98	0.15	0.47	0
17.5	0.5	2.75	7.16	7	0.38	0.39	0.005	0.03161	4.64	1.74	7.05	0.05	4.8	0.12	1.5	0.21	0.49	0
17.6	0.6	3.48	7.79	7.6	0.45	0.46	0.005	0.0307	5.5	2.01	7.47	0.06	7	0.14	2.18	0.29	0.52	0.33
17.7	0.7	4.27	8.43	8.2	0.51	0.52	0.005	0.03011	6.23	2.23	7.78	0.08	9.52	0.16	2.97	0.36	0.54	0.67
17.8	0.8	5.12	9.06	8.8	0.57	0.58	0.005	0.02963	6.96	2.44	8.05	0.09	12.49	0.18	3.9	0.44	0.56	1.16
17.9	0.9	6.03	9.69	9.4	0.62	0.64	0.005	0.0293	7.57	2.61	8.26	0.11	15.73	**0.19**	4.91	0.52	0.57	1.73

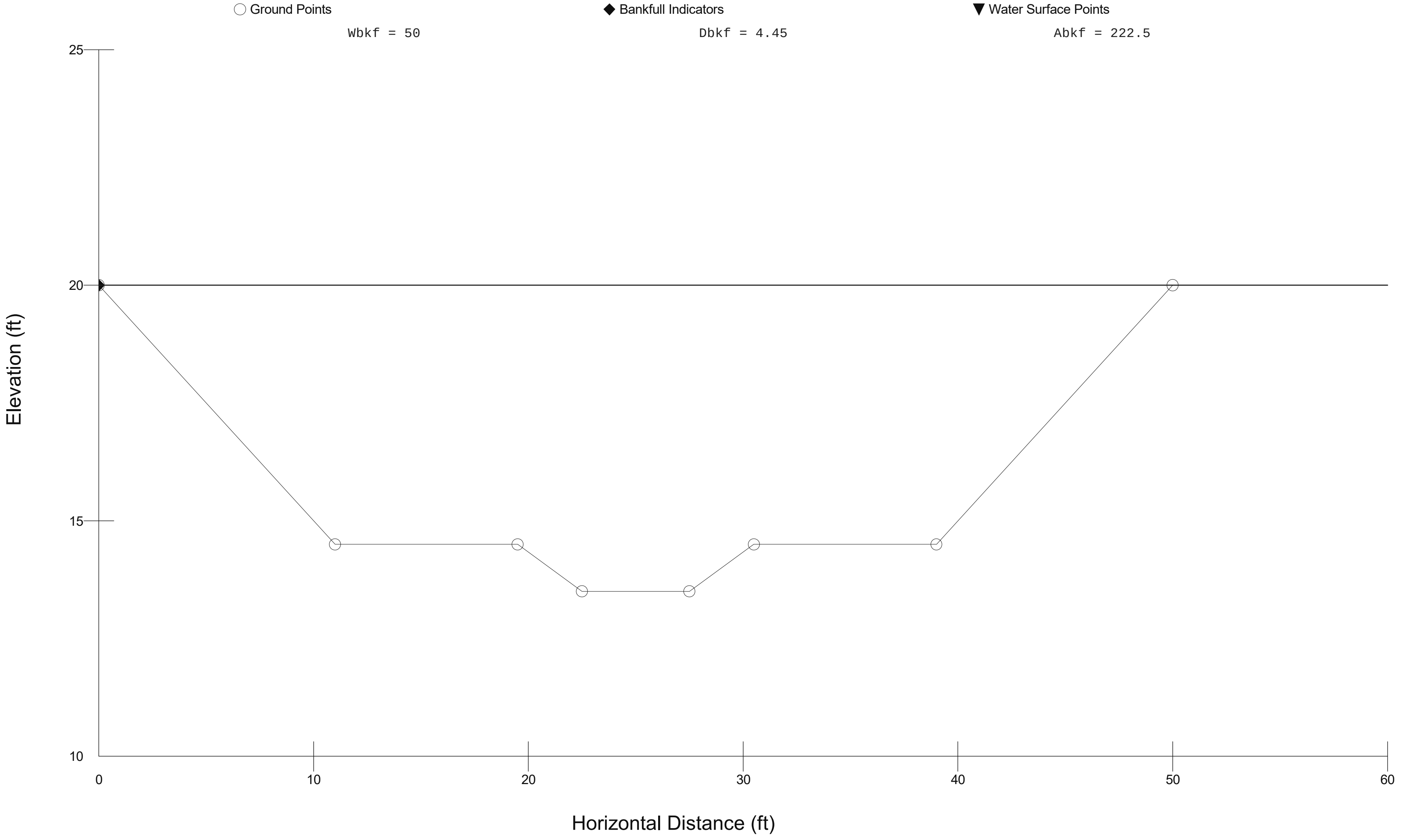
Additional Information:

Slope = 0.50%

D50 = 6.85 mm

D84 = 24.95 mm

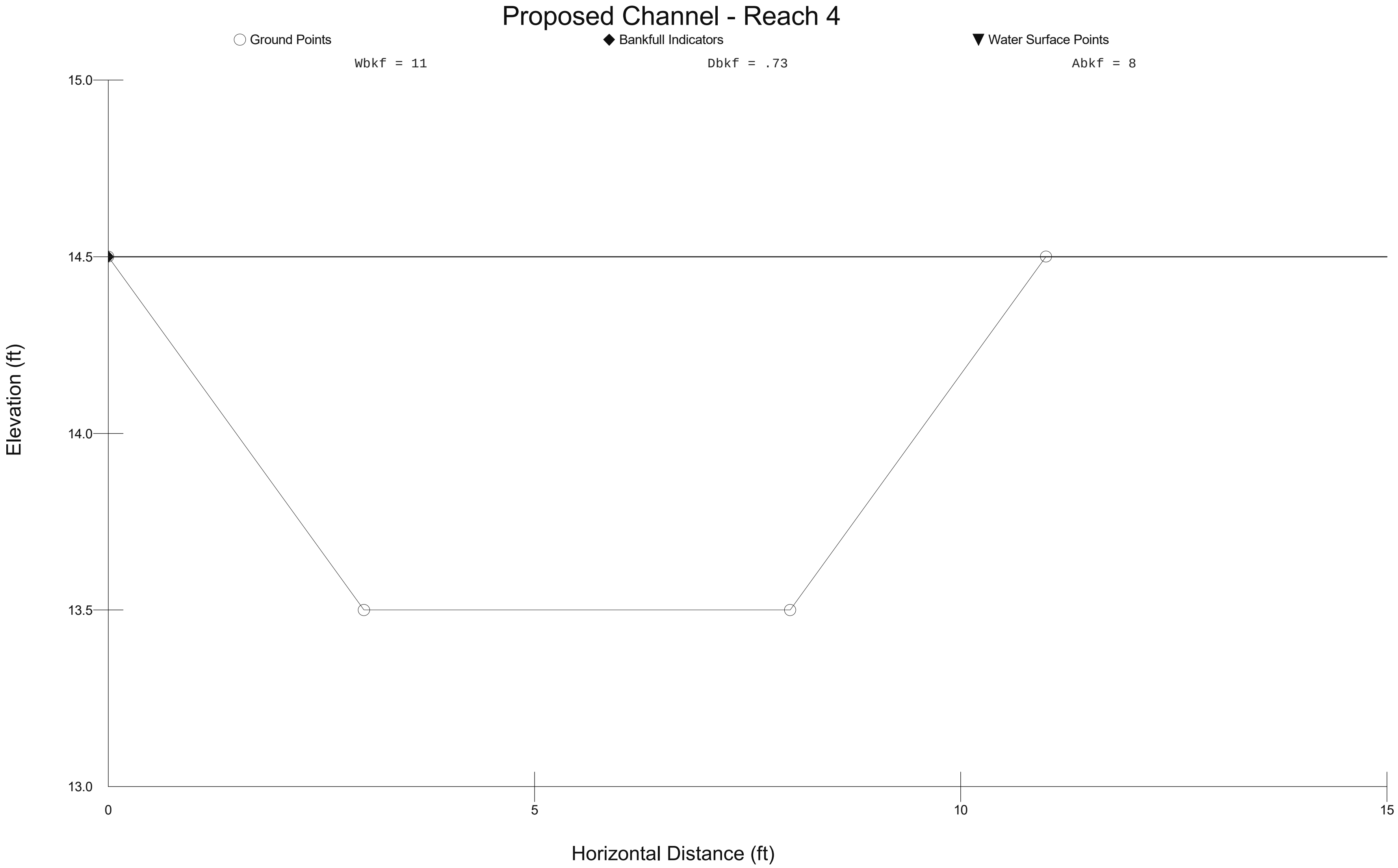
Proposed XS - Reach 4



REACH 4 - PROPOSED HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
13.6	0.1	0.53	5.63	5.6	0.09	0.09	0.0075	0.07448	0.69	0.35	2.35	0	0.18	0.04	0.09	0.02	0.2	0
13.7	0.2	1.12	6.26	6.2	0.18	0.18	0.0075	0.04851	1.37	0.85	4.06	0.01	0.95	0.08	0.44	0.07	0.35	0
13.8	0.3	1.77	6.9	6.8	0.26	0.26	0.0075	0.04218	1.98	1.24	4.96	0.02	2.2	0.12	1.03	0.15	0.43	0
13.9	0.4	2.48	7.53	7.4	0.33	0.34	0.0075	0.03926	2.51	1.57	5.55	0.04	3.88	0.15	1.82	0.25	0.47	0.21
14	0.5	3.25	8.16	8	0.4	0.41	0.0075	0.03735	3.05	1.87	6.02	0.05	6.08	0.19	2.85	0.36	0.51	0.68
14.1	0.6	4.08	8.79	8.6	0.46	0.47	0.0075	0.03617	3.51	2.12	6.36	0.07	8.65	0.22	4.05	0.47	0.55	1.39
14.2	0.7	4.97	9.43	9.2	0.53	0.54	0.0075	0.03511	4.04	2.4	6.71	0.09	11.93	0.25	5.58	0.61	0.58	2.61
14.3	0.8	5.92	10.06	9.8	0.59	0.6	0.0075	0.0344	4.5	2.63	6.97	0.11	15.59	0.28	7.29	0.74	0.6	4.06
14.4	0.9	6.93	10.69	10.4	0.65	0.67	0.0075	0.0338	4.95	2.86	7.21	0.13	19.8	0.3	9.27	0.89	0.62	5.91
14.5	1	8	11.32	11	0.71	0.73	0.0075	0.0333	5.41	3.08	7.43	0.15	24.61	0.33	11.52	1.05	0.63	8.18
14.6	1.1	10.82	28.77	28.4	0.38	0.38	0.0075	0.03783	2.9	1.79	5.89	0.05	19.32	0.18	9.04	0.32	0.51	1.86
14.7	1.2	13.68	29.22	28.8	0.47	0.47	0.0075	0.036	3.58	2.16	6.42	0.07	29.57	0.22	13.84	0.48	0.56	5.1
14.8	1.3	16.58	29.67	29.2	0.56	0.57	0.0075	0.03474	4.27	2.52	6.85	0.1	41.75	0.26	19.54	0.67	0.59	10.09
14.9	1.4	19.52	30.11	29.6	0.65	0.66	0.0075	0.0338	4.95	2.86	7.21	0.13	55.78	0.3	26.11	0.88	0.62	16.81
15	1.5	22.5	30.56	30	0.74	0.75	0.0075	0.03308	5.64	3.18	7.53	0.16	71.64	0.35	33.53	1.12	0.65	25.17
15.1	1.6	25.52	31.01	30.4	0.82	0.84	0.0075	0.03256	6.25	3.46	7.78	0.19	88.4	0.38	41.37	1.36	0.67	33.99
15.2	1.7	28.58	31.46	30.8	0.91	0.93	0.0075	0.03208	6.93	3.77	8.04	0.22	107.72	0.43	50.41	1.64	0.69	45.31
15.3	1.8	31.68	31.9	31.2	0.99	1.02	0.0075	0.03171	7.54	4.03	8.25	0.25	127.75	0.46	59.78	1.92	0.7	56.72
15.4	1.9	34.82	32.35	31.6	1.08	1.1	0.0075	0.03136	8.23	4.32	8.46	0.29	150.45	0.51	70.41	2.23	0.73	70.86
15.5	2	38	32.8	32	1.16	1.19	0.0075	0.03109	8.84	4.57	8.64	0.32	173.7	0.54	81.29	2.54	0.74	84.75
15.6	2.1	41.22	33.24	32.4	1.24	1.27	0.0075	0.03085	9.45	4.82	8.8	0.36	198.5	0.58	92.9	2.87	0.75	99.8
15.7	2.2	44.48	33.69	32.8	1.32	1.36	0.0075	0.03064	10.06	5.06	8.95	0.4	224.86	0.62	105.23	3.21	0.76	115.99
15.8	2.3	47.78	34.14	33.2	1.4	1.44	0.0075	0.03045	10.67	5.29	9.1	0.43	252.77	0.66	118.3	3.56	0.78	133.32
15.9	2.4	51.12	34.59	33.6	1.48	1.52	0.0075	0.03028	11.28	5.52	9.23	0.47	282.23	0.69	132.09	3.93	0.79	151.79
16	2.5	54.5	35.03	34	1.56	1.6	0.0075	0.03013	11.89	5.75	9.36	0.51	313.25	0.73	146.6	4.31	0.8	171.4
16.1	2.6	57.92	35.48	34.4	1.63	1.68	0.0075	0.03	12.42	5.94	9.47	0.55	344.21	0.76	161.09	4.68	0.81	189.76
16.2	2.7	61.38	35.93	34.8	1.71	1.76	0.0075	0.02987	13.03	6.16	9.59	0.59	378.26	0.8	177.03	5.09	0.82	211.51
16.3	2.8	64.88	36.37	35.2	1.78	1.84	0.0075	0.02977	13.56	6.35	9.69	0.63	412.12	0.83	192.87	5.48	0.83	231.8
16.4	2.9	68.42	36.82	35.6	1.86	1.92	0.0075	0.02965	14.17	6.57	9.8	0.67	449.22	0.87	210.24	5.91	0.84	255.72
16.5	3	72	37.27	36	1.93	2	0.0075	0.02956	14.71	6.75	9.89	0.71	486	0.9	227.45	6.32	0.84	277.96
16.6	3.1	75.62	37.72	36.4	2	2.08	0.0075	0.02948	15.24	6.93	9.97	0.75	524.22	0.94	245.33	6.74	0.85	301.13
16.7	3.2	79.28	38.16	36.8	2.08	2.15	0.0075	0.02939	15.85	7.14	10.07	0.79	565.89	0.97	264.83	7.2	0.86	328.25
16.8	3.3	82.98	38.61	37.2	2.15	2.23	0.0075	0.02931	16.38	7.32	10.15	0.83	607.04	1.01	284.1	7.64	0.86	353.4
16.9	3.4	86.72	39.06	37.6	2.22	2.31	0.0075	0.02924	16.92	7.49	10.23	0.87	649.65	1.04	304.03	8.09	0.87	379.5
17	3.5	90.5	39.5	38	2.29	2.38	0.0075	0.02918	17.45	7.67	10.31	0.91	693.7	1.07	324.65	8.54	0.88	406.54
17.1	3.6	94.32	39.95	38.4	2.36	2.46	0.0075	0.02912	17.98	7.84	10.38	0.95	739.22	1.1	345.96	9.01	0.88	434.54
17.2	3.7	98.18	40.4	38.8	2.43	2.53	0.0075	0.02906	18.52	8.01	10.45	1	786.2	1.14	367.94	9.48	0.89	463.5
17.3	3.8	102.08	40.85	39.2	2.5	2.6	0.0075	0.029	19.05	8.18	10.52	1.04	834.66	1.17	390.62	9.96	0.89	493.43
17.4	3.9	106.02	41.29	39.6	2.57	2.68	0.0075	0.02895	19.58	8.34	10.59	1.08	884.59	1.2	413.99	10.45	0.9	524.33
17.5	4	110	41.74	40	2.64	2.75	0.0075	0.0289	20.12	8.51	10.66	1.12	936.02	1.24	438.06	10.95	0.9	556.21
17.6	4.1	114.02	42.19	40.4	2.7	2.82	0.0075	0.02886	20.57	8.65	10.71	1.16	986.27	1.26	461.57	11.43	0.91	585.14
17.7	4.2	118.08	42.64	40.8	2.77	2.89	0.0075	0.02881	21.11	8.81	10.77	1.21	1040.62	1.3	487.01	11.94	0.91	618.89
17.8	4.3	122.18	43.08	41.2	2.84	2.97	0.0075	0.02877	21.64	8.97	10.84	1.25	1096.48	1.33	513.15	12.46	0.92	653.64
17.9	4.4	126.32	43.53	41.6	2.9	3.04	0.0075	0.02873	22.1	9.11	10.89	1.29	1150.97	1.36	538.66	12.95	0.92	685.16
18	4.5	130.5	43.98	42	2.97	3.11	0.0075	0.02869	22.63	9.27	10.95	1.33	1209.8	1.39	566.19	13.48	0.93	721.82
18.1	4.6	134.72	44.42	42.4	3.03	3.18	0.0075	0.02866	23.09	9.41	11	1.37	1267.14	1.42	593.02	13.99	0.93	755.06
18.2	4.7	138.98	44.87	42.8	3.1	3.25	0.0075	0.02862	23.62	9.56	11.05	1.42	1328.97	1.45	621.96	14.53	0.93	793.64
18.3	4.8	143.28	45.32	43.2	3.16	3.32	0.0075	0.02859	24.08	9.7	11.1	1.46	1389.18	1.48	650.14	15.05	0.94	828.63
18.4	4.9	147.62	45.77	43.6	3.23	3.39	0.0075	0.02856	24.61	9.85	11.15	1.51	1454.04	1.51	680.49	15.61	0.94	869.17
18.5	5	152	46.21	44	3.29	3.45	0.0075	0.02853	25.07	9.98	11.2	1.55	1517.16	1.54	710.03	16.14	0.95	905.92
18.6	5.1	156.42	46.66	44.4	3.35	3.52	0.0075	0.0285	25.53	10.11	11.24	1.59	1581.69	1.57	740.23	16.67	0.95	943.51
18.7	5.2	160.88	47.11	44.8	3.42	3.59	0.0075	0.02847	26.06	10.26	11.29	1.64	1651.13	1.6	772.73	17.25	0.95	986.97
18.8	5.3	165.38	47.55	45.2	3.48	3.66	0.0075	0.02845	26.52	10.39	11.34	1.68	1718.62	1.63	804.31	17.79	0.96	1026.37
18.9	5.4	169.92	48	45.6	3.54	3.73	0.0075	0.02842	26.97	10.52	11.38	1.72	1787.55	1.66	836.58	18.35	0.96	1066.62
19	5.5	174.5	48.45	46	3.6	3.79	0.0075	0.0284	27.43	10.65	11.42	1.76	1857.95	1.68	869.52	18.9	0.96	1107.73
19.1	5.6	179.12	48.9	46.4	3.66	3.86	0.0075	0.02838	27.89	10.77	11.46	1.8	1929.8	1.71	903.15	19.46	0.97	1149.71
19.2	5.7	183.78	49.34	46.8	3.72	3.93	0.0075	0.02836	28.35	10.9	11.5	1.84	2003.13	1.74	937.47	20.03	0.97	1192.57
19.3	5.8	188.48	49.79	47.2	3.79	3.99	0.0075	0.02833	28.88	11.05	11.55	1.89	2081.86	1.77	974.31	20.64	0.97	1241.92
19.4	5.9	193.22	50.24	47.6	3.85	4.06	0.0075	0.02831	29.34	11.17	11.58	1.94	2158.23	1.8	1010.05	21.22	0.98	1286.64
19.5	6	198	50.69	48	3.91	4.13	0.0075	0.02829	29.79	11.29	11.62	1.98	2236.1	1.83	1046.5	21.8	0.98	1332.25
19.6	6.1	202.82	51.13	48.4	3.97	4.19	0.0075	0.02827	30.25	11.42	11.66	2.02	2315.48	1.86	1083.64	22.39	0.98	1378.75
19.7	6.2	207.68	51.58	48.8	4.03	4.26	0.0075	0.02825	30.71	11.54	11.7	2.07	2396.36	1.89	1121.5	22.98	0.99	1426.16
19.8	6.3	212.58	52.03	49.2	4.09	4.32	0.0075	0.02824	31.16	**11.66**	11.73	2.11	**2478.77**	**1.91**	1160.06	23.58	0.99	1474.46
19.9	6.4	217.52	52.47	49.6	4.15	4.39	0.0075	0.02822	31.62	11.78	11.77	2.16	2562.7	1.94	1199.34	24.18	0.99	1523.68

Additional Information:
Slope = 0.75%
D50 = 8.55 mm
D84 = 40 mm
Q100 = 2400 cfs
Shear Stress = < 2psf


Proposed Channel - Reach 4
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 11
Dbkf = .73
Abkf = 8
15.0
14.5
14.0
13.5
13.0
Elevation (ft)
0
5
10
15
Horizontal Distance (ft)

REACH 4 - PROPOSED CHANNEL HYDRAULIC ANALYSIS

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER (lb/s)	POWER/W (lb/ft/s)	FROUDE	TRANSPORT (lb/s)
13.6	0.1	0.53	5.63	5.6	0.09	0.09	0.0075	0.07448	0.69	0.35	2.35	0	0.18	0.04	0.09	0.02	0.2	0
13.7	0.2	1.12	6.26	6.2	0.18	0.18	0.0075	0.04851	1.37	0.85	4.06	0.01	0.95	0.08	0.44	0.07	0.35	0
13.8	0.3	1.77	6.9	6.8	0.26	0.26	0.0075	0.04218	1.98	1.24	4.96	0.02	2.2	0.12	1.03	0.15	0.43	0
13.9	0.4	2.48	7.53	7.4	0.33	0.34	0.0075	0.03926	2.51	1.57	5.55	0.04	3.88	0.15	1.82	0.25	0.47	0.21
14	0.5	3.25	8.16	8	0.4	0.41	0.0075	0.03735	3.05	1.87	6.02	0.05	6.08	0.19	2.85	0.36	0.51	0.68
14.1	0.6	4.08	8.79	8.6	0.46	0.47	0.0075	0.03617	3.51	2.12	6.36	0.07	8.65	0.22	4.05	0.47	0.55	1.39
14.2	0.7	4.97	9.43	9.2	0.53	0.54	0.0075	0.03511	4.04	2.4	6.71	0.09	11.93	0.25	5.58	0.61	0.58	2.61
14.3	0.8	5.92	10.06	9.8	0.59	0.6	0.0075	0.0344	4.5	2.63	6.97	0.11	15.59	0.28	7.29	0.74	0.6	4.06
14.4	0.9	6.93	10.69	10.4	0.65	0.67	0.0075	0.0338	4.95	2.86	7.21	0.13	19.8	**0.3**	9.27	0.89	0.62	5.91

Additional Information:
Slope = 0.75%
D50 = 8.55 mm
D84 = 40 mm

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Shear of Reach 1

Project:	**I-95 ETL**		
Reach:	**Lilly Run**		
D(50) Riffle:	6.85	mm	D50 of Reach 1 - Shear Stess is less than the results from the hydraulic analysis (See Appendix E), therefore imported material is needed.
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm	= 0.016 ft.
Slope:	0.00437	ft/ft	

Andrews 1984 Methodology			*Andrews 1995 Methodology*		
Tc* (1984)	**Tc (1984)**		**Tc* (1995)**	**Tc (1995)**	
#VALUE!	#VALUE!	lb/sf	0.05141	0.09	lb/sf
Depth (1984)			**Depth (1995)**		
#VALUE!	ft.		0.32	ft.	

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Shear of Reach 4

Project:	**I-95 ETL**		
Reach:	**Lilly Run**		
D(50) Riffle:	8.55	mm	D50 of Reach 4 - Shear Stess is less than the results from the hydraulic analysis (See Appendix E), therefore imported material is needed.
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm =	0.016 ft.
Slope:	0.0075	ft/ft	

Andrews 1984 Methodology		*Andrews 1995 Methodology*	
Tc* (1984)	**Tc (1984)**	**Tc* (1995)**	**Tc (1995)**
#VALUE!	#VALUE! lb/sf	0.06409	0.11 lb/sf

Depth (1984)	**Depth (1995)**
#VALUE! ft.	0.23 ft.

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872

Tc = Tc* x 1.65 x 62.4 x Di

Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994

Tc = Tc* x 1.65 x 62.4 x Di

Depth = (Tc* x 1.65 x Di) / Slope

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Max Channel Shear (Reach 1)

Project:	**I-95 ETL**		
Reach:	**WUS 18A**		
D(50) Riffle:	19	mm	
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm =	0.016 ft.
***Slope:**	0.00437	ft/ft	

*Slope of the steepest riffle to evaluate the max shear conditions

D50 required to meet the maximum channel shear results from the hydraulic analysis (See Appendix E).

Andrews 1984 Methodology			*Andrews 1995 Methodology*		
Tc* (1984)	**Tc (1984)**		**Tc* (1995)**	**Tc (1995)**	
#VALUE!	#VALUE!	lb/sf	0.14174	0.24	lb/sf

Depth (1984)		**Depth (1995)**	
#VALUE!	ft.	0.88	ft.

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Max Channel Shear (Reach 4)

Project:	**I-95 ETL**		
Reach:	**WUS 18A**		
D(50) Riffle:	24	mm	
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm =	0.016 ft.
***Slope:**	0.0075	ft/ft	

*Slope of the steepest riffle to evaluate the max shear conditions

D50 required to meet the maximum channel shear results from the hydraulic analysis (See Appendix E).

Andrews 1984 Methodology		*Andrews 1995 Methodology*	
Tc* (1984)	**Tc (1984)**	**Tc* (1995)**	**Tc (1995)**
#VALUE!	#VALUE! lb/sf	0.17879	0.30 lb/sf

Depth (1984)	**Depth (1995)**
#VALUE! ft.	0.65 ft.

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Shear of Class '0' Riprap (Reach 1)

Project:	**I-95 ETL**		
Reach:	**WUS 18A**		
D(50) Riffle:	152	mm	
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm =	0.016 ft.
***Slope:**	0.00437	ft/ft	

*Slope of the steepest riffle to evaluate the max shear conditions

Class '0' RipRap with D50 of 6 inches (152 mm) - Shear Stress greater than max channel shear (0.24 psf) using the results from the hydraulic analysis (See Appendix E). Therefore, Class 0 Riprap will be used for riffle protection.

Andrews 1984 Methodology		*Andrews 1995 Methodology*	
Tc* (1984)	**Tc (1984)**	**Tc* (1995)**	**Tc (1995)**
#VALUE!	#VALUE! lb/sf	1.11986	1.89 lb/sf

Depth (1984)	**Depth (1995)**
#VALUE! ft.	6.94 ft.

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994
Tc = Tc* x 1.65 x 62.4 x Di
Depth = (Tc* x 1.65 x Di) / Slope

Lilly Run Bankfull Channel

Sediment Transport Analysis

Andrews Methodology - Shear of Class '0' Riprap (Reach 4)

Project:	**I-95 ETL**		
Reach:	**WUS 18A**		
D(50) Riffle:	152	mm	
D(50) Bar/Sub:	n/a	mm	
Mobile Size (Di):	5	mm =	0.016 ft.
***Slope:**	0.0075	ft/ft	

*Slope of the steepest riffle to evaluate the max shear conditions

Class '0' RipRap with D50 of 6 inches (152 mm) - Shear Stress greater than max channel shear (0.30 psf) using the results from the hydraulic analysis (See Appendix E). Therefore, Class 0 Riprap will be used for riffle protection.

Andrews 1984 Methodology			*Andrews 1995 Methodology*		
Tc* (1984)	**Tc (1984)**		**Tc* (1995)**	**Tc (1995)**	
#VALUE!	#VALUE!	lb/sf	1.11986	1.89	lb/sf
Depth (1984)			**Depth (1995)**		
#VALUE!	ft.		4.04	ft.	

Andrews 1984 Methodology:

Tc* = 0.0834 x [(D50(riffle) / D50(bar)]^-0.872

Tc = Tc* x 1.65 x 62.4 x Di

Depth = (Tc* x 1.65 x Di) / Slope

Andrews 1995 Methodology:

Tc* = 0.0376 x [(Di / D50(riffle)]^-0.994

Tc = Tc* x 1.65 x 62.4 x Di

Depth = (Tc* x 1.65 x Di) / Slope

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future®

Project: I-95 ETL Stream Mitigation Job No. 17-10674-001
Subject: Lilly Run Sheet No. 1 of 1
Computed By: KNH Date: 04-29-19

Plunge Pool Design at Lilly Run - Reach 2

Type I - Preformed Scour Hole (Depressed 1/2 Culvert Rise)

Using Empirical Preformed Scour Hole Equations from MDSHA Highway Drainage Manual, I-3-E-2:

$D_{50} = (0.0125d^2/TW)(Q_{10}/d^{2.5})^{1.333}$ where:

D_{50} =	Median stone diameter (ft)		
d =	Pipe diameter (ft)	=	3.5
TW =	Tailwater depth (ft)	=	3.5
Q =	Design pipe flow (cfs)	=	38.53

D_{50} = 0.09 ft

C =	Basin Length (ft)	=	31.5	
A =	Basin Inlet Width (ft)	=	28	
B =	Basin Outlet Width (ft)	=	28	
D =	Basin Riprap Thickness (ft)	=	1	*
E =	Culvert Span (ft)	=	3.5	
F =	Basin Depression (ft)	=	3.5	
d =	Culvert Diameter or Span (ft)	=	3.5	
D_{50} =	Median Stone Diameter (ft)	=	0.5	Class 0 Riprap

Notes: * Use 12" as nominal placement thickness for Class 0.

Plunge Pool Design at Lilly Run - Reach 3

Type I - Preformed Scour Hole (Depressed 1/2 Culvert Rise)

Using Empirical Preformed Scour Hole Equations from MDSHA Highway Drainage Manual, I-3-E-2:

$D_{50} = (0.0125d^2/TW)(Q_{10}/d^{2.5})^{1.333}$ where:

D_{50} = Median stone diameter (ft)
d = Pipe diameter (ft) = 2
TW = Tailwater depth (ft) = 2
Q = Design pipe flow (cfs) = 8.56

D_{50} = 0.04 ft

C = Basin Length (ft) = 18
A = Basin Inlet Width (ft) = 16
B = Basin Outlet Width (ft) = 16
D = Basin Riprap Thickness (ft) = 1 *

E = Culvert Span (ft) = 2
F = Basin Depression (ft) = 2
d = Culvert Diameter or Span (ft) = 2
D_{50} = Median Stone Diameter (ft) = 0.5 Class 0 Riprap

Notes: * Use 12" as nominal placement thickness for Class 0.

Appendix F

Design Plans (under separate cover)