# DANIELS RUN STREAM RESTORATION, FAIRFAX, VIRGINIA: 30 PERCENT CONCEPTUAL DESIGN REPORT

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Stream Habitat Assessment and Restoration Program
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office

CBFO-S06-05

Prepared in cooperation with:
Army-Navy Country Club, Fairfax, Virginia

Annapolis, MD
August 2006

## EXECUTIVE SUMMARY

The Army Navy Country Club (ANCC) and the U.S. Fish and Wildlife Service (Service) – Chesapeake Bay Field Office have entered into a partnership agreement (Agreement 51410-1902-5091) to assess and restore the portion of Daniels Run flowing through the ANCC property. Daniels Run is a perennial stream located in the City of Fairfax, Virginia. Daniels Run originates in the central portion of the city and flows in a general northeastern direction until it joins Accotink Creek. Daniels Run enters the ANCC property along the southwestern perimeter of the site, continues on-site for approximately 2,800 feet, and exits along the northeastern perimeter of the site. The Service's stream assessment of Daniels Run (Starr and Eng, 2006) found that there is widespread lateral instability throughout the restoration area, with approximately 60 percent of the banks actively eroding. The downstream reach of the restoration area has a relic headcut that vertically degraded the streambed by an average of 6 to 9 feet. The lateral and vertical instability is mostly likely a result of past channel straightening, removal of the riparian vegetation, and watershed development. It is unlikely that Daniels Run will recovery on its own within the near future. Without restoration, significant amounts of sediment will enter the stream that will adversely affect aquatic species and instream habitat.

The Service and ANCC are developing plans to restore the portion of Daniels Run within the ANCC property using natural channel design methods. An earlier report (Starr and Eng, 2006) presents objectives for the stream restoration and describes the Service's approach to restoring Daniels Run. This report supplements the previous report and presents the geomorphic analysis used to develop the proposed stream cross section, pattern, and profile for the 30 Percent Conceptual Design Plans.

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# I. INTRODUCTION

The Army Navy Country Club (ANCC) and the U.S. Fish and Wildlife Service (Service) – Chesapeake Bay Field Office have entered into a partnership agreement (Agreement 51410-1902-5091) to assess and restore the portion of stream on Daniels Run flowing through the ANCC property. Daniels Run is a perennial stream located in the City of Fairfax, Virginia (Figure 1). Daniels Run originates in the central portion of the city and flows in a general northeastern direction until it joins Accotink Creek. Daniels Run enters the ANCC property along the southwestern perimeter of the site, continues on-site for approximately 2,800 feet, and exits along the northeastern perimeter of the site. Several small tributaries also join Daniels Run on the ANCC property.

The goal of stream restoration is to return the main stem of Daniels Run to a stable, self-maintaining state while meeting the aesthetic goals of the ANCC. Stream stability is not a static state but a dynamic process with a tendency towards equilibrium between stream discharge, sediment transport, and channel dimension, plan form, and longitudinal profile. Restoring a stream to this stable state and restoring its riparian buffer will address a number of aquatic and riparian habitat concerns. A successful stream restoration will also address some water quality issues including reducing sediment and nutrients, which are significant issues for the Chesapeake Bay and its natural resources.

The Service's first task in developing the restoration plans was to collect field data to support preparation of plans. The Service then identified stream restoration objectives and developed and evaluated natural channel design restoration alternatives. The Service presented this work in the Daniels Run Stream Restoration, Arlington, Virginia: Survey and Alternative Analysis Report (Starr and Eng, 2006). The report recommended a combination of soil fabric lifts and instream structures to address the instability problems on Daniels Run.

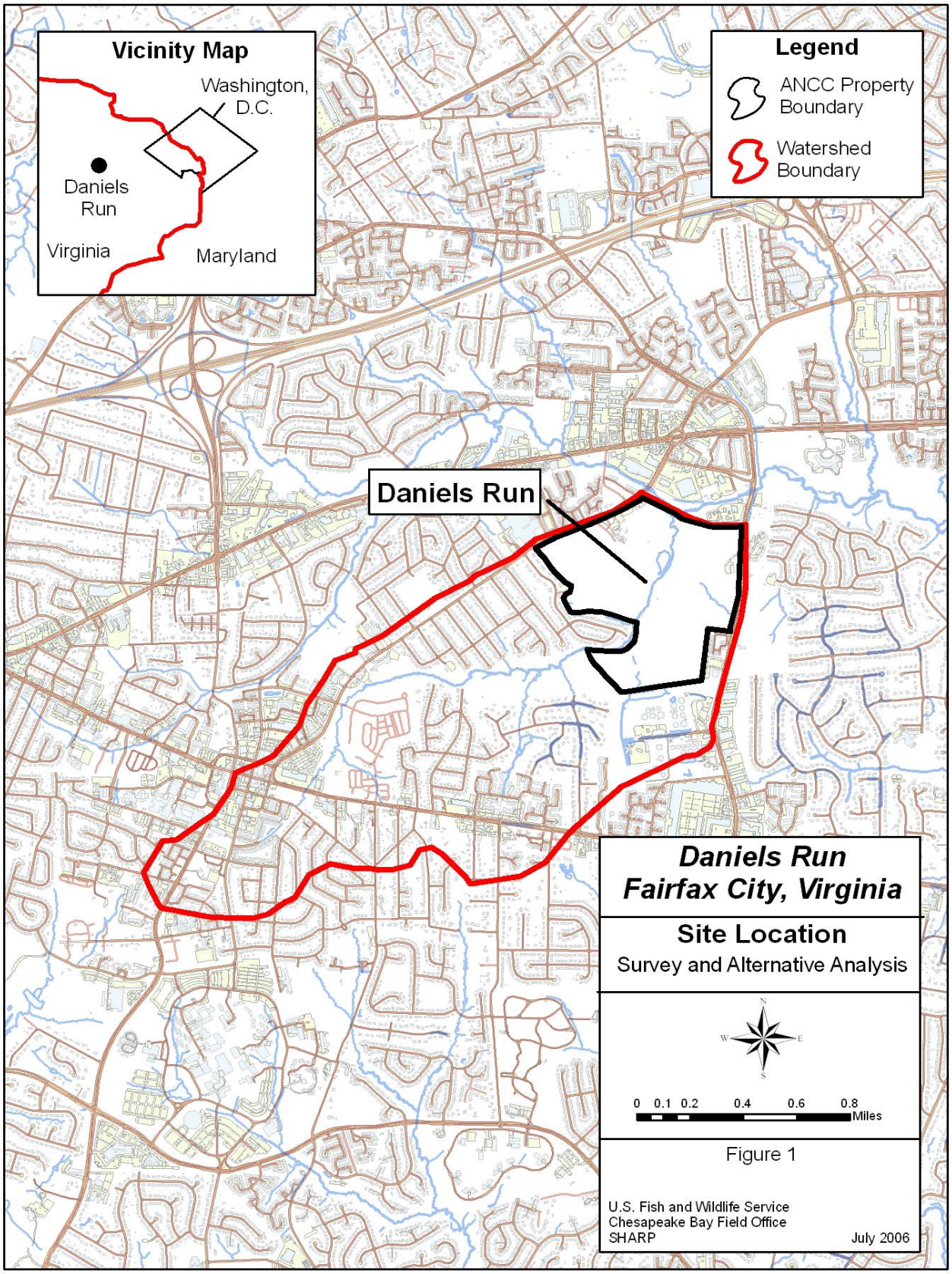
The purpose of this report is to present the geomorphic analysis used to develop the 30 Percent Conceptual Design Plans (30 Percent Plans). The 30 Percent Plans shows proposed stream cross section, pattern, and profile, and the typical details for in-stream restoration structures.

# II. 30 PERCENT DESIGN DEVELOPMENT

This section presents a brief summary of the methods used by the Service to develop the 30 Percent Plans. The Service used a natural channel design approach, which uses stable reference stream characteristics as a template for restoring the impaired stream.

## A. Natural Channel Design Methodology

The Service used natural channel design methodology to design the stream cross sections, planform, and profile for restoring Daniels Run. Natural channel design methodology employs geomorphic measurements from stable streams as a template for designing the restored stream. Measurements from the stable streams are converted to dimensionless ratios by dividing by various bankfull characteristics, which allows the Service to apply characteristics from references streams of difference sizes to the impair stream.


Vicinity Map
Washington, D.C.
Daniels Run
Virginia
Maryland
Legend
ANCC Property Boundary
Watershed Boundary
Daniels Run
Daniels Run
Fairfax City, Virginia
Site Location
Survey and Alternative Analysis
0 0.1 0.2 0.4 0.6 0.8 Miles
Figure 1
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
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July 2006

The objective of natural channel design is to make adjustments in stream cross section, planform, and profile such that the restored stream will accommodate the flow regimes and sediment supply without creating excessive erosion or deposition in the restoration project areas (project areas), or upstream or downstream of the project areas.

## B. Natural Channel Design for Daniels Run

The Service divided the restoration area into two project areas (Figure 2). These project areas should not be confused with the assessment reaches identified in the Survey and Alternative Analysis Report (Starr and Eng, 2006). Project Area 1 includes Reach 1 and 2, with the exception of the farthest downstream portion of Reach 2. Project Area 2 consists of approximately the last 300 feet of Reach 2, where Daniels Run joins Accotink Creek.

### 1. Restoration Stream Type

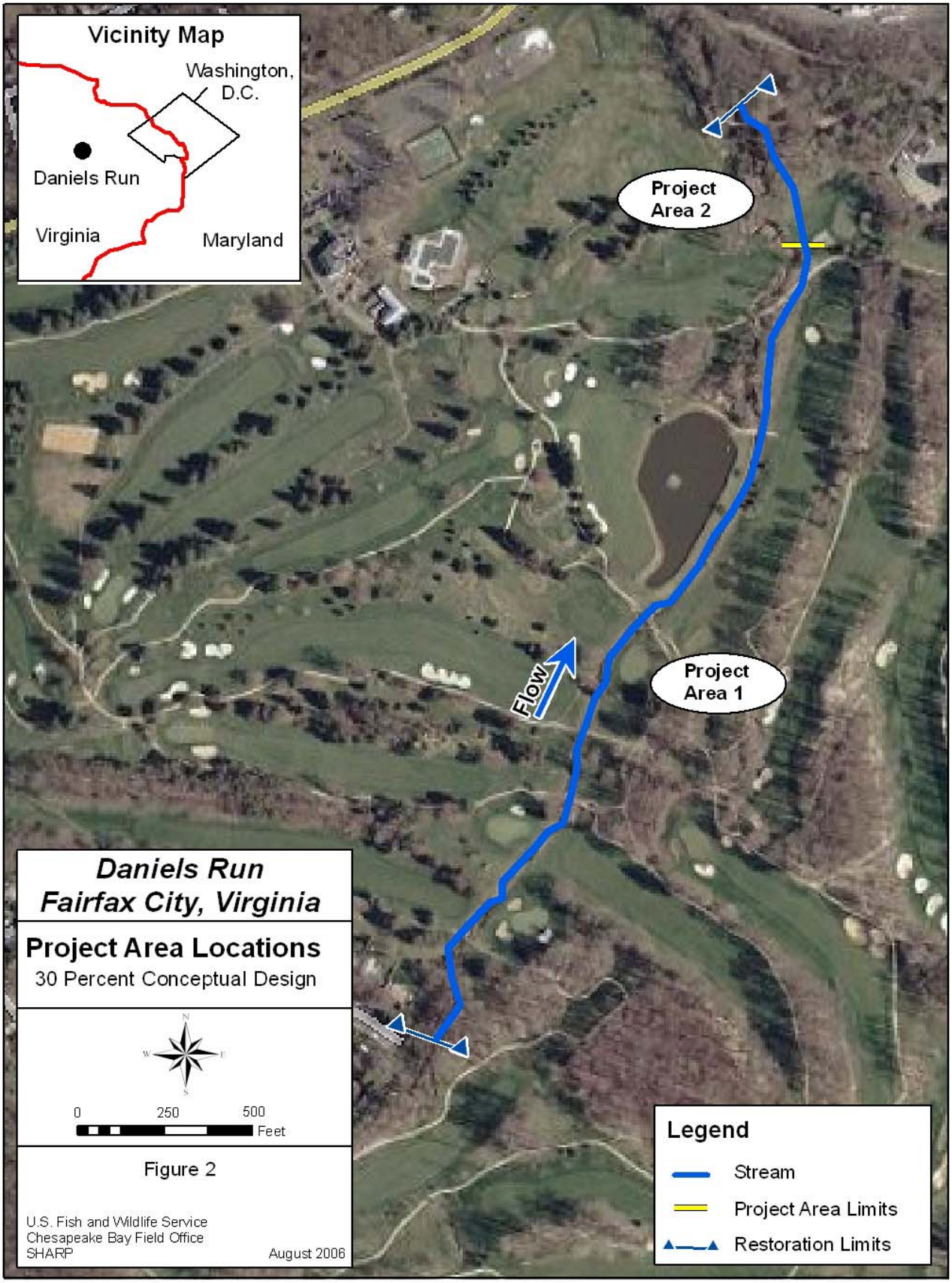
The Service selected two Rosgen stream types (Rosgen 1996) to develop the restoration design criteria for Daniels Run, based on the valley type and site constraints (*e.g.*, channel confinement, control elevations). The Service selected a C4 Rosgen stream type for Project Area 1. Currently, the stream in Project Area 1 is slightly to moderately entrenched and the Service is proposing to reconnect the stream to its original floodplain to obtain a low entrenchment, which is characteristic of a C4 or E4 stream type. However, the Service selected a C4 stream type because of the confinement of the stream and the low sinuosity, which better characterizes a C4 stream type than an E4 stream type.

The Service selected a B4/1[1] Rosgen stream type for Project Area 2. The streambed elevation of Accotink Creek is the downstream control elevation of the restoration effort. Since Accotink Creek is also highly entrenched, a transition stream reach is required to connect the proposed Daniels Run C4 stream type to Accotink Creek. As this transition reach descends to Accotink Creek, the stream will become increasingly entrenched. However, it is feasible to create a floodplain within the proposed channel, although narrower and lower than the original floodplain, which is characteristic of B4/1 stream type.

### 2. Reference Reach

Natural channel design methodology employs the characteristics of stable streams as a template for designing restored streams. Selection of a Rosgen stream type identifies the broad characteristics for the restored stream, but does not provide sufficient design parameters to develop stream restoration plans. Additional geomorphic measurements must be collected from stable streams that fully detail the characteristics of a stable stream's cross section, planform, and profile. A stream possessing stable characteristics is termed a "reference reach." The geomorphic characteristics of the reference reach are used as a template for designing stream restoration projects. The primary requirement of a reference reach is that the stream reach is stable. Reference reaches are not required to be in a natural, undisturbed state.

[1] The B4/1 stream type is similar to the B4 stream type except that bedrock control is present.


Vicinity Map
Washington, D.C.
Daniels Run
Virginia
Maryland
Project Area 2
Project Area 1
Flow
Daniels Run
Fairfax City, Virginia
Project Area Locations
30 Percent Conceptual Design
0
250
500
Feet
Figure 2
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
August 2006
Legend
Stream
Project Area Limits
Restoration Limits

A suitable reference reach should possess similar hydrologic, geologic, and physiographic characteristics to the reach that is to be restored. The shape of a particular stream represents the balance between erosive forces applied to a stream by water flowing down a slope and the resistive forces supplied by native stream substrate and streambanks. Streams formed in differing types of alluvium or rock respond differently to the same hydrology. Likewise, streams of the same lithology and geology exhibit differing forms if subjected to differing hydrologic regimes. For example, compare two streams within the same area, one of which possesses an undeveloped watershed and the other possessing an urbanized watershed. Because urbanization changes the timing and volume of stormflows, the urbanized stream will enlarge its cross section. Because of differences in the response of streams to differences in boundary conditions (*i.e.*, stream flow, vegetation, geology, and lithology), it is important to select a reference reach with similar hydrophysiographic characteristics. Generally, this would be a stream located in the same general area with similar land use, physiography, valley characteristics, and lithology. Finding reference reaches for urban stream restoration is difficult. It is rare to locate a stream that possesses both an urban discharge regime and stable stream characteristics. If a suitable reference reach cannot be located, streams from remote locations may be used for reference reaches if there is close similarity in physiographic conditions (Hey, in press). The Service was unable to locate a reference reach (*i.e.*, a stable stream) near Daniels Run. Therefore, the Service collected data from both C4 and B4/1 reference reaches with physiographic conditions similar to Daniels Run. Table 1 presents selected morphological parameters for three areas. The reference sites include:

- *Silas Creek in Winston-Salem, NC*: Silas Creek is a B4/1c stream type. Reference reach data was collected by Clear Creek Consulting, Inc.
- *Rock Creek above Boulder Bridge, Rock Creek National Park, Washington, DC*: A short section of B4c stream type is located in Rock Creek between a steeper B3/B4 stream type and a C4 stream type. The Service surveyed the reach in 2005. Because the reach was limited in size, the Service was not able to collect a full set of reference reach data. Although the Rock Creek data set is incomplete, it does reflect conditions of a stream subject to urbanized flows.
- *Maryland Characteristic C4 and B4/1c Streams:* Characteristic data from several C4 and B4/1c steam types was obtained from a comprehensive survey of gaged streams in Maryland that the Service collected to develop regional relationships between bankfull discharge, bankfull width, bankfull mean depth, and drainage area (McCandless and Everett, 2002; McCandless, 2003). The Maryland stream survey data contain many of the relationships that are required to develop natural stream designs. The Service only selected streams that are considered stable to develop the reference criteria. For some streams, the Service only used cross section data because the Service does not consider their planforms as reference conditions.
- *Colorado Data:* Characteristic data from several C4 stream types were obtained from stream surveys conducted by Wildland Hydrology, Inc. (Rosgen, 1996).

**Table 1. Summary of Select Dimensionless Ratios**

| Variable | | Reference Data | | | | |
|---|---|---|---|---|---|---|
| | | Colorado[1] | Maryland Piedmont[2] | | Rock Creek, Washington, D.C.[3] | Silas Creek, Winston, NC[4] |
| Stream Type | | C4 | C4 | B4/1c | B4/1c | B4/1c |
| Width/Depth Ratio | Mean | 15.0 | 15.0 | 11.2 | 23.3 | 14.6 |
| Max. Riffle Depth/Mean Riffle Depth | Mean | 1.4 | n/a | 1.2 | 1.5 | 1.5 |
| Mean Pool Depth/Mean Riffle Depth | Mean | n/a | 1.3 | n/a | n/a | 4.5 |
| Pool Width/Riffle Width | Mean | 1.5 | 1.2 | n/a | n/a | 1.0 |
| Pool Area/Riffle Area | Mean | n/a | 1.3 | n/a | n/a | 1.7 |
| Max. Pool Depth/Mean Riffle Depth | Mean | 3.0 | 2.4 | n/a | 2.4 | 2.6 |
| Low Bank Height/Max. Riffle Depth | Mean | n/a | n/a | n/a | n/a | 1.0 |
| Entrenchment Ratio | Mean | n/a | 12.0 | n/a | 1.4 | 1.3 |
| Meander Length Ratio | Mean | 11.5 | 8.4 | n/a | n/a | 7.3 |
| Ratio of Radius of Curvature/ Bankfull Width | Mean | 2.8 | 2.8 | n/a | n/a | 1.5 |
| Meander Width Ratio | Mean | 12.5 | 2.9 | 2.3 | n/a | 1.8 |
| Pool Length/Riffle Width | Mean | 1.5 | n/a | n/a | 1.9 | n/a |
| Pool to Pool Spacing/Bankfull Width | Mean | 6.0 | n/a | n/a | n/a | 3.0 |
| Sinuosity | | n/a | 1.3 | 1.2 | n/a | 1.1 |
| Ratio of Riffle Slope/Average Water Surface Slope | Mean | 2.3 | n/a | n/a | 3.8 | 4.4 |
| Ratio of Run Slope/Average Water Surface Slope | Mean | 0.7 | n/a | n/a | 0.9 | 0.9 |
| Ratio of Pool Slope/Average Water Surface Slope | Mean | 0.3 | n/a | n/a | 0.0 | 0.0 |
| Ratio of Glide Slope/Average Water Surface Slope | Mean | 0.4 | n/a | n/a | 0.0 | 0.9 |
| Ratio of Step Slope/Average Water Surface Slope | Mean | n/a | n/a | n/a | 32.4 | n/a |
| Ratio of Max. Run Depth/Mean Bankfull Depth | Mean | 2.1 | n/a | n/a | 1.6 | 1.9 |
| Ratio of Max. Glide Depth/ Mean Bankfull Depth | Mean | n/a | n/a | n/a | 1.3 | 1.9 |

1. Data collected by Wildland Hydrology, Inc.

2. Data collected by the Service for the *Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region* (McCandless and Everett 2002)

3. Data collected by the Service

4. Data collected by Clear Creeks Consultants, Inc.

## 3. Bankfull Discharge

Bankfull discharge characterizes the range of discharges that are responsible for the shaping and maintaining a stream's cross section, pattern, and profile. Over time, geomorphic processes adjust the stream capacity and shape to accommodate the bankfull discharge within the stream. Bankfull discharge is strongly correlated to many important stream morphological features (*e.g.*, bankfull width, drainage area, etc.) and is the critical parameter used by the Service in assessing

Daniels Run. Bankfull characteristics are also used in the natural channel design approach as a scale factor to convert morphological parameters from a stable reach of one size to a disturbed reach of another size. The Service conducted a bankfull discharge determination as part of the Survey and Alternative Analysis Report and reported the following bankfull discharge characteristics for Daniels Run (Table 2).

Table 2. Summary of Bankfull Characteristics

| Bankfull Characteristics | | Reach 1 Representative Cross Section | Reach 2 Representative Cross Section |
|---|---|---|---|
| Area | $ft^2$ | 29.28 | 33.81 |
| Width | ft | 16.25 | 21.44 |
| Average Depth | ft | 1.80 | 1.58 |
| Manning's n | | 0.04 | 0.04 |
| Velocity | ft/s | 3.74 | 4.26 |
| Discharge | cfs | 104.47 | 125.59 |

## 4. Restoration Strategy

The Service used two restoration strategies for Daniels Run. Project Area 1 is a Priority 1 restoration and Project Area 2 is a Priority 3 restoration (Rosgen 1997). For Project Area 1, the Service will reconnect the stream to the original floodplain. This approach is feasible because the existing stream is either slightly entrenched or the stream will be realigned outside of the existing highly entrenched stream alignment. The Service will create an entrenched stream channel, in Project Area 2, to connect the streambed elevation of Project Area 1 to the streambed elevation of Accotink Creek.

Both restoration strategies will have similar channel cross section conversions that involve narrowing the low flow, active channel, and bankfull channel widths while providing an increase in floodprone width. The difference between the two strategies will be in the floodprone widths. Since the Service will reconnect Project Area 1 to the original floodplain, it will have a much larger floodprone width than Project Area 2. The floodplain area for Project Area 1 will be created by excavating the top of existing stream banks and constructing toe-benches to frame the active channel within the bankfull channel. Toe-benches will be constructed from fill and held in place by rock, woody debris, and riparian shrubs. Figure 3 (modified from Shea *et al*., 2005) illustrates the cross section conversion. The floodplain for Project Area 2 will be narrower and created at a lower elevation than the original abandoned floodplain. The floodplain area and toe-benches for Project Area 2 will be created by excavating a new stream channel in the original floodplain.

In-stream structures, soil fabric lifts, and riparian plantings will be installed to stabilize the stream cross section. In-stream structures will consist of cross vanes, J-hook vanes, and step pools. The instream structures will be designed to steer the flow through tight bends, dissipate energy through turbulence, and prevent high shear stress on streambanks. The soil fabric lifts will be designed to hold the streambanks in place based on the cross section specifications.

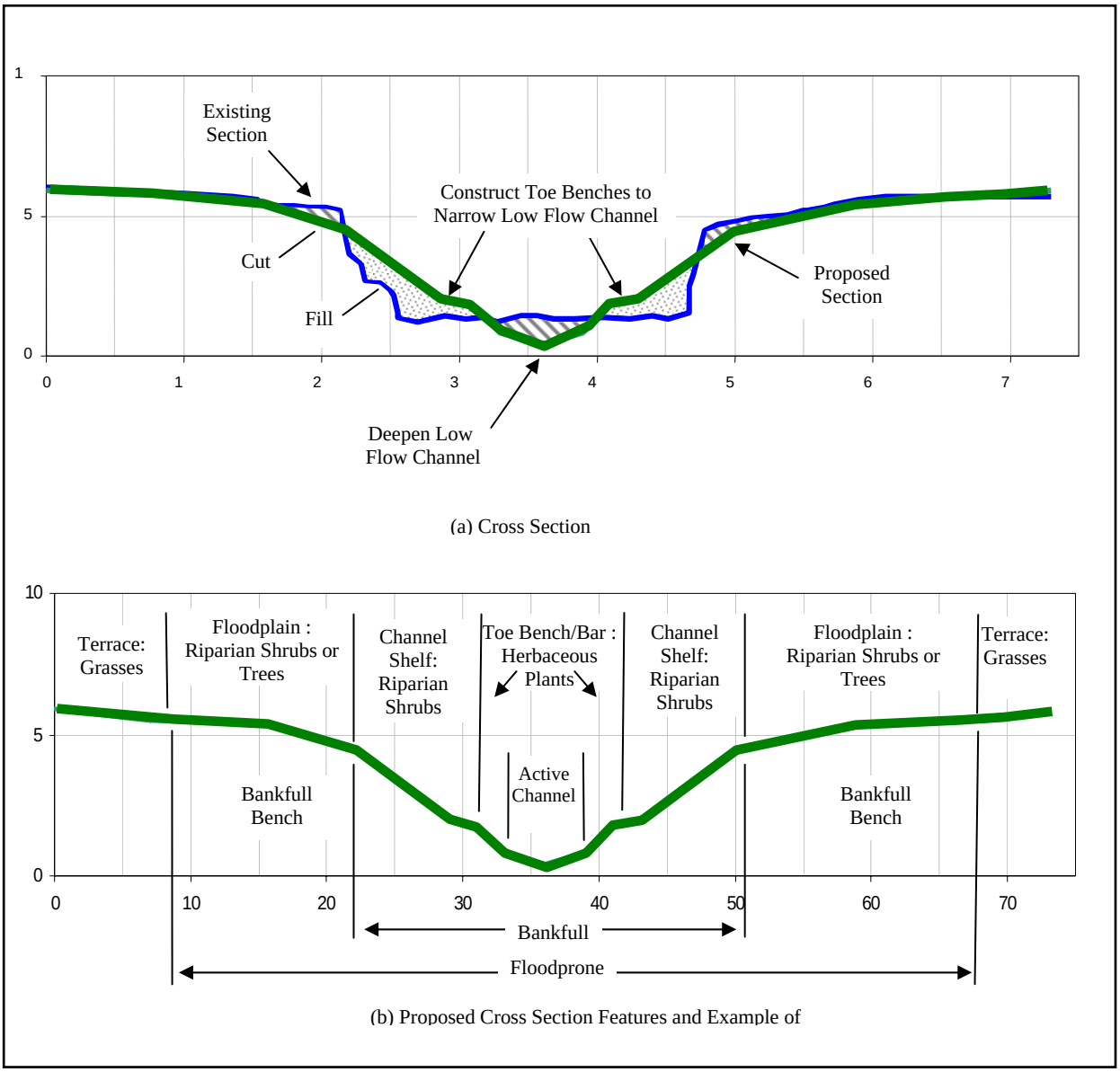



Figure 3. Illustration of Cross Section Conversion for Proposed C4 Rosgen Stream Type

The instream structures and soil fabric lifts provide a skeleton for the stream, but in the long-term, the riparian plantings will maintain the stability of the stream. Riparian plantings will provide rooting to increase the strength of streambanks, riparian habitat, and increase stream roughness that will slow down stream stormflow velocities. No planting occurs within the low flow or active channel. The active channel area is where stream gravel transport occurs. The toe-benches are located between the top of the active channel and bankfull depth. The top of the toe-benches (or channel shelf) is a frequently flooded area located below bankfull elevation. Riparian vegetation that can withstand frequent flooding and provide strong rooting will be planted in this zone. Large woody debris will be placed in the channel shelf during construction to provide some initial channel roughness and for habitat. The floodplain zone starts above bankfull. This area will contain riparian shrubs or trees that can withstand occasional inundation. The bankfull bench is a flat or shallowly sloped zone above bankfull that slows high velocity

flows during flows above bankfull. Flow velocities at the outer edge of the bankfull bench will be too slow to erode the steeper banks connecting the bench to the flood-prone area.

## 5. Cross Section Design

The Service developed a series of typical sections for use in each project area (Table 3). Each series of typical sections consists of a riffle cross section, a glide cross section, and a pool cross section. The sections were developed through an iterative design process. The Service used dimensionless ratios to develop active channel and bankfull channel dimensions. The Service determined target values of bankfull and active channel width/depth ratios, and bankfull and active channel cross section area using regional relationships and the reference reach data. Trial bankfull and active channel depths were used to develop a nested riffle cross section with the appropriate areas and width-depth ratios for the bankfull and active channel. The Service estimated discharge for the cross section using the reach slope. The Service evaluated the shear stress at active channel discharge and made adjustments in the cross section to replicate the existing active channel shear stress. The Service made slight adjustments in the cross section dimensions until the computed discharge matched the target discharge.

Once the riffle cross section was completed, the pool cross sections were constructed in a similar manner. The Service used target values for pool cross sections based on ratios of pool cross section area to riffle cross section area, pool width to riffle width, and maximum pool depth to mean riffle depth.

The glide cross section was constructed to meet several criteria describing the relationship between riffle cross sections and glide cross sections:

- mean depth (riffle < glide)
- width (riffle < glide)
- cross section area (riffle < glide)
- max depth / mean depth ratio (riffle > glide)

Table 3. Summary of Proposed Cross Section Characteristics

| Cross section Characteristics | | | C4 Rosgen Stream Type | | B4/1c Rosgen Stream Type | |
|---|---|---|---|---|---|---|
| | | | Active Channel | Bankfull Channel | Active Channel | Bankfull Channel |
| Riffle | Area | $ft^2$ | 12.2 | 29.4 | 12.0 | 31.0 |
| | Width | ft | 12.5 | 19.0 | 12.0 | 21.0 |
| | Average Depth | ft | 1.0 | 1.6 | 1.0 | 1.5 |
| | Maximum Depth | ft | 1.3 | 2.3 | 1.5 | 2.5 |
| | Width/Depth Ratio | | 12.8 | 12.3 | 12.0 | 14.3 |
| | Entrenchment Ratio[1] | | n/a | 2.3 | n/a | 2.0 |
| Pool | Area | $ft^2$ | 25.1 | 44.3 | 32.9 | 55.3 |
| | Width | ft | 15.5 | 21.0 | 17.0 | 24.0 |
| | Average Depth | ft | 1.6 | 2.1 | 1.9 | 2.3 |
| | Maximum Depth | ft | 2.3 | 3.3 | 2.8 | 3.8 |
| Glide | Area | $ft^2$ | 17.0 | 35.2 | 20.0 | 41.0 |
| | Width | ft | 14.0 | 20.0 | 15.0 | 23.0 |
| | Average Depth | ft | 1.2 | 1.8 | 1.3 | 1.8 |
| | Maximum Depth | ft | 1.5 | 2.5 | 1.8 | 2.8 |

1. Actual entrenchment will vary depending on existing elevations in the field

The Service adjusted glide cross section shape until the evaluation criteria for the active and bankfull channels were satisfied. Summaries of cross section parameters for each set of typical sections are presented in Appendix B.

## C. Development of Restoration Design Plans

### 1. Base Mapping

The Service developed a base map of Daniels Run from a base topographic survey developed by Air Survey and a detailed stream channel survey conducted by Service personnel. The Service merged the two surveys together by tying into benchmarks established by Air Survey. The base mapping was then converted to Terramodel® CADD format.

### 2. Stream Corridor Alignment

The Service evaluated two stream corridor alignments (Figure 4). The first alignment essentially followed the existing stream channel with a 30-foot buffer on either side of the stream. The Service proposed some channel realignment in Study Reach 2 to restore the stream to a proper planform. The ANCC considered this alignment because it preserved an existing golf cart bridge (*i.e.*, Blue 1).

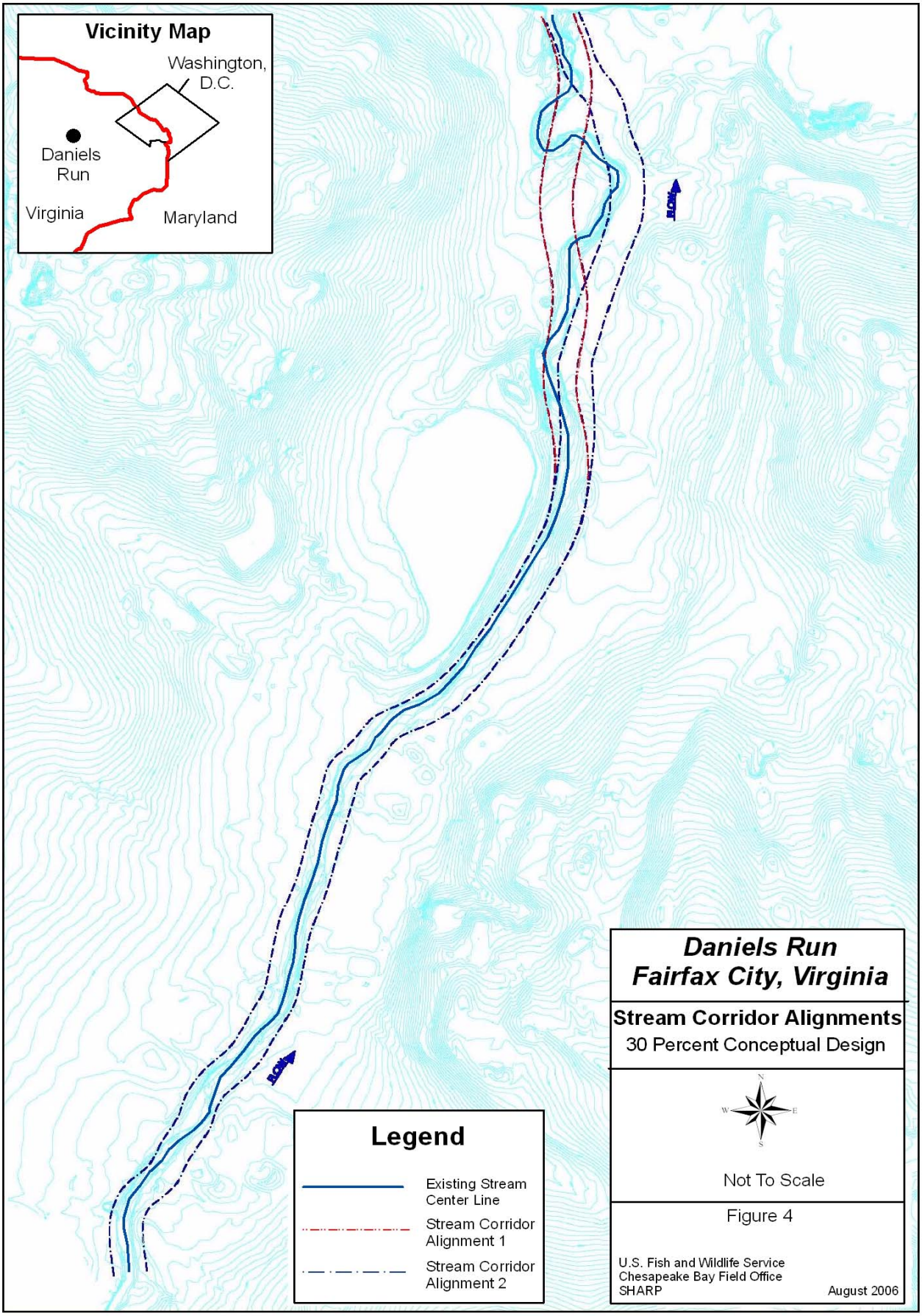
The golf course architect (i.e., Richard Mandell Golf Architecture) proposed a second alignment. The second alignment follows the existing stream channel in Study Reach 1 with a 30-foot buffer on either side of the stream. The proposed alignment diverts from the existing stream channel in Study Reach 2, relocated approximately 60 feet to the right of the stream. The ANCC considered this alignment because it better compliments the golf course features and improves the playability of the course. The ANCC selected this for the proposed stream corridor alignment.

### 3. Planform and Profile

The Service developed a preliminary horizontal alignment and vertical profile for the two stream corridor alignments. However, the Service will only discuss the horizontal alignment and vertical profile for the selected stream corridor alignment.

The Service adjusted the horizontal alignment to produce better agreement with the geomorphic properties developed from reference reach data. The Service also adjusted the alignment to minimize impacts to fixed infrastructure such as golf cart bridges and to reduce grading and vegetation impacts.

The Service developed a preliminary vertical alignment. The Service accomplished this by using a spreadsheet to adjust the depths of the vertical profiles so that the depth of riffles, glides, pools, and runs were in the appropriate range developed from reference reach data.


Vicinity Map
Washington, D.C.
Daniels Run
Virginia
Maryland
FLOW
FLOW
Legend
Existing Stream Center Line
Stream Corridor Alignment 1
Stream Corridor Alignment 2
Daniels Run
Fairfax City, Virginia
Stream Corridor Alignments
30 Percent Conceptual Design
Not To Scale
Figure 4
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August 2006

## 4. Structures

The Service proposes using five types of instream structures in the restoration design: cross vanes, J-hooks, W-weirs, step pools, and soil fabric lifts. Typical details of these structures are provided in the 30 Percent Plans. The extent, configuration, and structure tables for these structures will be added to the 60 Percent Plans.

*Cross Vane Structures*

Cross vane structures are instream structures, made of rocks or a combination of rocks and logs, that provide both lateral and vertical channel stability. They were developed by Wildland Hydrology, Inc. (2001) to reduce shear stress along the outer banks of meander curves, but may be used also to steer and redirect the direction of flow through bends. They consist of a sill used to set grade elevation that is placed in the central third of the bankfull stream; and two vanes that extend from each end of the sill in the downstream direction at an angle of 20-30 degrees from the centerline of the stream, with a vertical pitch of two to seven percent (upward in the downstream direction, and typically tie into the stream banks at the bankfull elevation. The vanes of cross vanes provide bank protection by redirecting flow away from banks. The zone of bank protection created by the vanes extends for approximately one vane length downstream of the end of the vane and about one-half vane length upstream of the sill.

*Step Pool Structures*

Step pool structures are instream structures, made of rocks and logs, that facilitate the transition between rapid streambed elevation changes (e.g., steep stream sections). They occur as natural features that form on steeper streams as a means of dissipating energy. A step pool structure is essentially a series of cross vane structures connected together and with shorter vane arms. The Service may use a step pool structure in the transition reach located on the lower downstream portion of Reach 2 to tie in with Accotink Creek.

*J-hook Structures*

J-hook structures are instream structures, made of rocks and logs, used to divert erosive stream flows away from streambanks until riparian vegetation can establish. They are installed on the outside bank of a meander and provide the same zone of bank protection length as cross vanes. J-hooks are constructed the same as cross vanes except with only one vane arm and there is an arcing hook on the upstream end of the structure where it ties in with the streambed.

*W-weir Structures*

W-weir structures are instream structures, made of rocks and logs, used in rivers or in streams to split flows around instream man-made structures (i.e., bridge piers). They are constructed the same as cross vanes, except instead of being "U-shaped" like a cross vane, they are "W-shaped". The Service will use W-weir structures directly upstream of all bridge crossings to split flows around the bridge piers and reduce streambed erosion potential.

*Soil Fabric Lifts*

Soil fabric lifts are layers of soil held temporally in-place with a bio-degradable fabric until riparian vegetation can establish. The soil lifts are seeded with a grass seed mixture and live cuttings of woody vegetation are placed in between the soil layers. Roots from the grass and live cuttings establish and naturally maintain the soil layers, replacing the degrading fabric. The Service will use soil fabric lifts in areas where streambanks are constructed with loose soils.

# III. NEXT PHASE OF DESIGN DEVELOPMENT

The next step in the design process is to develop 60 Percent Plans. The first step is to undertake hydraulic modeling of existing conditions to prepare preliminary hydraulic modeling of proposed conditions. The 30 Percent Plans will then be modified based on comments received from partners and on results of hydraulic modeling. The Service will prepare grading plans and profiles that will be evaluated for compliance with geomorphic design criteria, sediment transport capabilities, and floodplain hydraulics. Additional design work will include preparation of erosion and sediment control plans, and preparation of construction specifications.

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# Appendix A
# Geomorphic Variables

**Daniels Run**
**Reference Reach Design Criteria**

| No. | Variable | Symbol | Units | | Colorado[1] | Maryland Piedmont[2] | | Rock Creek, Washington, D.C.[3] | Silas Creek, Winston, NC[4] | Proposed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Stream Type | | | | C4 | C4 | B4/1c | B4/1c | B4/1c | C4 | B4/1c |
| 2 | Drainage Area | | $mi^2$ | Mean | n/a | n/a | 27.0 | n/a | 3.3 | 1.9 | 1.9 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 3 | Riffle Bankfull Mean Depth | $d_{bkf}$ | ft | Mean | n/a | n/a | 4.0 | 3.8 | 1.8 | 1.3 | 1.4 |
| | | | | Min | n/a | n/a | n/a | n/a | 1.6 | 2.1 | 1.7 |
| | | | | Max | n/a | n/a | n/a | n/a | 1.9 | 0.7 | 1.2 |
| 4 | Riffle Bankfull Width | $W_{bkf}$ | ft | Mean | n/a | n/a | 44.8 | 89.6 | 25.6 | 19.0 | 21.0 |
| | | | | Min | n/a | n/a | n/a | n/a | 23.1 | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | 28.0 | n/a | n/a |
| 5 | Width/Depth Ratio | $W/d_{bkf}$ | | Mean | 15.0 | 15.0 | 11.2 | 23.3 | 14.6 | 15.0 | 14.6 |
| | | | | Min | 12.0 | 9.0 | n/a | n/a | 12.4 | 9.0 | 12.4 |
| | | | | Max | 18.0 | 27.0 | n/a | n/a | 17.2 | 18.0 | 17.2 |
| 6 | Riffle Bankfull Cross Sectional Area | $A_{bkf}$ | $ft^2$ | Mean | n/a | n/a | 179.3 | 344.0 | 43.7 | 29.3 | 33.8 |
| | | | | Min | n/a | n/a | n/a | n/a | 38.5 | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | 48.9 | n/a | n/a |
| 7 | Riffle Bankfull Maximum Depth | $d_{max}$ | ft | Mean | n/a | n/a | 4.7 | 5.6 | 2.7 | 1.7 | 2.2 |
| | | | | Min | n/a | n/a | n/a | n/a | 2.1 | 1.5 | 1.9 |
| | | | | Max | n/a | n/a | n/a | n/a | 3.2 | 1.9 | 2.5 |
| 8 | Max. Riffle Depth/Mean Riffle Depth | $d_{riff}/d_{bkf}$ | | Mean | 1.4 | n/a | 1.2 | 1.5 | 1.5 | 1.4 | 1.5 |
| | | | | Min | 1.2 | n/a | n/a | n/a | 1.3 | 1.2 | 1.3 |
| | | | | Max | 1.5 | n/a | n/a | n/a | 1.7 | 1.5 | 1.7 |
| 9 | Mean Pool Depth | $d_{bkfp}$ | ft | Mean | n/a | n/a | n/a | n/a | n/a | 1.6 | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | 1.4 | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | 1.9 | n/a |
| 10 | Mean Pool Depth/Mean Riffle Depth | $d_{bkfp}/d_{bkf}$ | | Mean | n/a | 1.3 | n/a | n/a | 4.5 | 1.3 | n/a |
| | | | | Min | n/a | 1.1 | n/a | n/a | 4.0 | 1.1 | n/a |
| | | | | Max | n/a | 1.5 | n/a | n/a | 5.0 | 1.5 | n/a |
| 11 | Pool Width | $W_{bkfp}$ | ft | Mean | n/a | n/a | n/a | n/a | 25.3 | 22.8 | 20.8 |
| | | | | Min | n/a | n/a | n/a | n/a | 22.6 | 19.0 | 20.6 |
| | | | | Max | n/a | n/a | n/a | n/a | 28.0 | 26.6 | 21.0 |
| 12 | Pool Width/Riffle Width | $W_{bkfp}/W_{bkf}$ | | Mean | 1.5 | 1.2 | n/a | n/a | 1.0 | 1.2 | 1.0 |
| | | | | Min | 1.3 | 1.0 | n/a | n/a | 1.0 | 1.0 | 1.0 |
| | | | | Max | 1.7 | 1.4 | n/a | n/a | 1.0 | 1.4 | 1.0 |
| 13 | Pool Bankfull Cross Sectional Area | $A_{pool}$ | $ft^2$ | Mean | n/a | n/a | n/a | n/a | 72.1 | 38.1 | 67.6 |
| | | | | Min | n/a | n/a | n/a | n/a | 53.3 | 32.2 | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | 90.5 | 43.9 | n/a |
| 14 | Pool Area/Riffle Area | $A_{pool}/A_{bkf}$ | | Mean | n/a | 1.3 | n/a | n/a | 1.7 | 1.3 | 2.0 |
| | | | | Min | n/a | 1.1 | n/a | n/a | 1.2 | 1.1 | n/a |
| | | | | Max | n/a | 1.5 | n/a | n/a | 2.1 | 1.5 | n/a |
| 15 | Max. Pool Depth | $d_{mbkfp}$ | ft | Mean | n/a | n/a | n/a | 9.2 | 4.5 | 3.0 | 3.7 |
| | | | | Min | n/a | n/a | n/a | n/a | 4.0 | 2.4 | 3.5 |
| | | | | Max | n/a | n/a | n/a | n/a | 5.0 | 3.9 | 3.9 |
| 16 | Max. Pool Depth/Mean Riffle Depth | $d_{mbkfp}/d_{bkf}$ | | Mean | 3.0 | 2.4 | n/a | 2.4 | 2.6 | 2.4 | 2.6 |
| | | | | Min | 2.5 | 1.9 | n/a | n/a | 2.5 | 1.9 | 2.5 |
| | | | | Max | 3.5 | 3.1 | n/a | n/a | 2.7 | 3.1 | 2.7 |
| 17 | Low Bank Height | LBH | ft | Mean | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 18 | Low Bank Height/Max. Riffle Depth | $LBH/d_{mbkf}$ | | Mean | n/a | n/a | n/a | n/a | 1.0 | 1.0 | 1.0 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 19 | Width of Flood Prone Area | $W_{fpa}$ | ft | Mean | n/a | n/a | n/a | n/a | 33.5 | 228.0 | 29.4 |
| | | | | Min | n/a | n/a | n/a | n/a | 27.7 | 76.0 | 46.2 |
| | | | | Max | n/a | n/a | n/a | n/a | 39.2 | 456.0 | n/a |
| 20 | Entrenchment Ratio | $W_{fpa}/W_{bkf}$ | | Mean | n/a | 12.0 | n/a | 1.4 | 1.3 | 12.0 | 1.4 |
| | | | | Min | n/a | 4.0 | n/a | n/a | 1.2 | 4.0 | 2.2 |
| | | | | Max | n/a | 24.0 | n/a | n/a | 1.4 | 24.0 | n/a |
| 21 | Point Bar Slope | $S_{pt.\ bar}$ | ft/ft | Mean | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 22 | Bankfull Mean Velocity | $u_{bkf}$ | ft/sec | Mean | n/a | n/a | n/a | n/a | 4.6 | 2.8 | 3.7 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 23 | Bankfull Discharge | $Q_{bkf}$ | cfs | Mean | n/a | n/a | n/a | n/a | 199.0 | 109.5 | 125.6 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 24 | Meander Length | $L_m$ | ft | Mean | n/a | n/a | n/a | n/a | 187.0 | 159.6 | 153.7 |
| | | | | Min | n/a | n/a | n/a | n/a | 130.0 | 72.2 | 118.2 |
| | | | | Max | n/a | n/a | n/a | n/a | 245.0 | 254.6 | 183.8 |
| 25 | Meander Length Ratio | $L_m/W_{bkf}$ | | Mean | 11.5 | 8.4 | n/a | n/a | 7.3 | 8.4 | 7.3 |
| | | | | Min | 9.0 | 3.8 | n/a | n/a | 5.6 | 3.8 | 5.6 |
| | | | | Max | 14.0 | 13.4 | n/a | n/a | 8.8 | 13.4 | 8.8 |
| 26 | Radius of Curvature | $R_c$ | ft | Mean | n/a | n/a | n/a | n/a | 38.6 | 53.2 | 31.7 |
| | | | | Min | n/a | n/a | n/a | n/a | 18.5 | 19.0 | 16.8 |
| | | | | Max | n/a | n/a | n/a | n/a | 58.8 | 123.5 | 44.1 |
| 27 | Ratio of Radius of Curvature/Bankfull Width | $R_c/W_{bkf}$ | | Mean | 2.8 | 2.8 | n/a | n/a | 1.5 | 2.8 | 1.5 |
| | | | | Min | 2.5 | 1.0 | n/a | n/a | 0.8 | 1.0 | 0.8 |
| | | | | Max | 3.0 | 6.5 | n/a | n/a | 2.1 | 6.5 | 2.1 |

**Daniels Run**
**Reference Reach Design Criteria**

| No. | Variable | Symbol | Units | | Colorado[1] | Maryland Piedmont[2] | | Rock Creek, Washington, D.C.[3] | Silas Creek, Winston, NC[4] | Proposed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Belt Width | $W_{blt}$ | ft | Mean | n/a | n/a | 102.0 | n/a | 45.5 | 55.1 | 37.4 |
| | | | | Min | n/a | n/a | n/a | n/a | 40.0 | 34.2 | 30.0 |
| | | | | Max | n/a | n/a | n/a | n/a | 51.0 | 114.0 | 38.2 |
| 29 | Meander Width Ratio | $W_{blt}/W_{bkf}$ | | Mean | 12.5 | 2.9 | 2.3 | n/a | 1.8 | 2.9 | 1.8 |
| | | | | Min | 9.0 | 1.8 | n/a | n/a | 1.4 | 1.8 | 1.4 |
| | | | | Max | 16.0 | 6.0 | n/a | n/a | 1.8 | 6.0 | 1.8 |
| 30 | Individual Pool Length | $L_{pool}$ | ft | Mean | n/a | n/a | n/a | 166.0 | n/a | 28.5 | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | 19.0 | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | 38.0 | n/a |
| 31 | Pool Length/Riffle Width | $L_{pool}/W_{bkf}$ | | Mean | 1.5 | n/a | n/a | 1.9 | n/a | 1.5 | n/a |
| | | | | Min | 1.0 | n/a | n/a | n/a | n/a | 1.0 | n/a |
| | | | | Max | 2.0 | n/a | n/a | n/a | n/a | 2.0 | n/a |
| 32 | Pool to Pool Spacing (based on pattern) | p-p | ft | Mean | n/a | n/a | n/a | n/a | 76.6 | 114.0 | 63.0 |
| | | | | Min | n/a | n/a | n/a | n/a | 27.2 | 95.0 | 24.8 |
| | | | | Max | n/a | n/a | n/a | n/a | 126.0 | 133.0 | 94.5 |
| 33 | Pool to Pool Spacing/ Bankfull Width | $p\text{-}p/W_{bkf}$ | | Mean | 6.0 | n/a | n/a | n/a | 3.0 | 6.0 | 3.0 |
| | | | | Min | 5.0 | n/a | n/a | n/a | 1.2 | 5.0 | 1.2 |
| | | | | Max | 7.0 | n/a | n/a | n/a | 4.5 | 7.0 | 4.5 |
| 34 | Stream Length | SL | ft | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 35 | Valley Length | VL | ft | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 36 | Valley Slope | VS | ft/ft | | n/a | n/a | n/a | n/a | 0.0089 | n/a | n/a |
| 37 | Average Water Surface S | S | ft/ft | | n/a | n/a | 0.0022 | 0.0037 | 0.0082 | 0.0047 | 0.0051 |
| 38 | Sinuosity | K | | SL/VL | n/a | 1.3 | 1.2 | n/a | n/a | 1.2 | 1.2 |
| | | | | VS/S | n/a | n/a | n/a | n/a | 1.1 | n/a | n/a |
| 39 | Riffle Slope (water surface facet slope) | $S_{riff}$ | ft/ft | Mean | n/a | n/a | n/a | 0.0141 | 0.0360 | 0.0106 | 0.0194 |
| | | | | Min | n/a | n/a | n/a | 0.0053 | n/a | 0.0071 | 0.0073 |
| | | | | Max | n/a | n/a | n/a | 0.0229 | n/a | 0.0141 | 0.0316 |
| 40 | Ratio of Riffle Slope/ Average Water Surface Slope | $S_{riff}/S$ | | Mean | 2.3 | n/a | n/a | 3.8 | 4.4 | 2.3 | 3.8 |
| | | | | Min | 1.5 | n/a | n/a | 1.4 | n/a | 1.5 | 1.4 |
| | | | | Max | 3.0 | n/a | n/a | 6.2 | n/a | 3.0 | 6.2 |
| 41 | Run Slope (water surface facet slope) | $S_{run}$ | ft/ft | Mean | n/a | n/a | n/a | 0.0033 | 0.0070 | 0.0031 | 0.0045 |
| | | | | Min | n/a | n/a | n/a | 0.0001 | n/a | 0.0024 | 0.0001 |
| | | | | Max | n/a | n/a | n/a | 0.0080 | n/a | 0.0038 | 0.0110 |
| 42 | Ratio of Run Slope/ Average Water Surface Slope | $S_{run}/S$ | | Mean | 0.7 | n/a | n/a | 0.9 | 0.9 | 0.7 | 0.9 |
| | | | | Min | 0.5 | n/a | n/a | 0.0 | n/a | 0.5 | 0.0 |
| | | | | Max | 0.8 | n/a | n/a | 2.2 | n/a | 0.8 | 2.2 |
| 43 | Pool Slope (water surface facet slope) | $S_{pool}$ | ft/ft | Mean | n/a | n/a | n/a | 0.0001 | 0.0000 | 0.0012 | 0.0000 |
| | | | | Min | n/a | n/a | n/a | n/a | 0.0000 | 0.0009 | 0.0000 |
| | | | | Max | n/a | n/a | n/a | n/a | 0.0819 | 0.0014 | n/a |
| 44 | Ratio of Pool Slope/ Average Water Surface Slope | $S_{pool}/S$ | | Mean | 0.3 | n/a | n/a | 0.0 | 0.0 | 0.3 | 0.0 |
| | | | | Min | 0.2 | n/a | n/a | n/a | 0.0 | 0.2 | 0.0 |
| | | | | Max | 0.3 | n/a | n/a | n/a | 16.1 | 0.3 | n/a |
| 45 | Glide Slope (water surface facet slope) | $S_{glide}$ | ft/ft | Mean | n/a | n/a | n/a | 0.0001 | 0.0070 | 0.0019 | 0.0001 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | 0.0014 | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | 0.0024 | n/a |
| 46 | Ratio of Glide Slope/ Average Water Surface Slope | $S_{glide}/S$ | | Mean | 0.4 | n/a | n/a | 0.0 | 0.9 | 0.4 | 0.0 |
| | | | | Min | 0.3 | n/a | n/a | n/a | n/a | 0.3 | n/a |
| | | | | Max | 0.5 | n/a | n/a | n/a | n/a | 0.5 | n/a |
| | Step Slope (water surface facet slope) | $S_{step}$ | ft/ft | Mean | n/a | n/a | n/a | 0.1200 | n/a | n/a | 0.1654 |
| | | | | Min | n/a | n/a | n/a | 0.0600 | n/a | n/a | 0.0827 |
| | | | | Max | n/a | n/a | n/a | 0.1700 | n/a | n/a | 0.2343 |
| | Ratio of Step Slope/ Average Water Surface Slope | $S_{step}/S$ | | Mean | n/a | n/a | n/a | 32.4 | n/a | n/a | 32.4 |
| | | | | Min | n/a | n/a | n/a | 16.2 | n/a | n/a | 16.2 |
| | | | | Max | n/a | n/a | n/a | 45.9 | n/a | n/a | 45.9 |
| 47 | Max. Run Depth | $d_{mbkfrun}$ | ft | Mean | n/a | n/a | n/a | 6.1 | 3.3 | 2.6 | 2.3 |
| | | | | Min | n/a | n/a | n/a | 5.6 | n/a | 2.4 | 2.1 |
| | | | | Max | n/a | n/a | n/a | 6.7 | n/a | 2.8 | 2.5 |
| 48 | Ratio of Max. Run Depth/ Mean Bankfull Depth | $d_{mbkfrun}/d_{bkf}$ | | Mean | 2.1 | n/a | n/a | 1.6 | 1.9 | 2.1 | 1.6 |
| | | | | Min | 1.9 | n/a | n/a | 1.5 | n/a | 1.9 | 1.5 |
| | | | | Max | 2.2 | n/a | n/a | 1.8 | n/a | 2.2 | 1.8 |
| 49 | Max. Glide Depth | $d_{mbkfglide}$ | ft | Mean | n/a | n/a | n/a | 5.1 | 3.3 | n/a | 2.3 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | 1.9 |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | 2.7 |
| 50 | Ratio of Max. Glide Depth/ Mean Bankfull Depth | $d_{mbkfglide}/d_{bkf}$ | | Mean | n/a | n/a | n/a | 1.3 | 1.9 | n/a | 1.6 |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | 1.3 |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | 1.9 |
| | Max. Step Depth | $d_{mbkfstep}$ | ft | Mean | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Ratio of Max. Step Depth/ Mean Bankfull Depth | $d_{mbkfstep}/d_{bkf}$ | | Mean | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Min | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | Max | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Materials** | | | | | | | | | | | |
| 51 | Particle Size Distribution of Stream | $D_{16}$ | mm | | n/a | n/a | n/a | 0.4 | n/a | n/a | n/a |
| | | $D_{35}$ | mm | | n/a | n/a | 0.1 | 21.3 | n/a | n/a | n/a |
| | | $D_{50}$ | mm | | n/a | n/a | 0.4 | 54.5 | n/a | n/a | n/a |
| | | $D_{84}$ | mm | | n/a | n/a | 32.0 | 238.2 | n/a | n/a | n/a |
| | | $D_{95}$ | mm | | n/a | n/a | 59.6 | 402.0 | n/a | n/a | n/a |

**Daniels Run**
**Reference Reach Design Criteria**

| No. | Variable | Symbol | Units | Colorado[1] | Maryland Piedmont[2] | | Rock Creek, Washington, D.C.[3] | Silas Creek, Winston, NC[4] | Proposed | |
|---|---|---|---|---|---|---|---|---|---|---|
| 52 | Particle Size Distribution of Channel Material (active bed) | $D_{16}$ | mm | n/a | n/a | 0.1 | n/a | 0.3 | n/a | n/a |
| | | $D_{35}$ | mm | n/a | n/a | 6.0 | n/a | 0.9 | n/a | n/a |
| | | $D_{50}$ | mm | n/a | n/a | 12.7 | n/a | 22.6 | n/a | n/a |
| | | $D_{84}$ | mm | n/a | n/a | 36.4 | n/a | 200.0 | n/a | n/a |
| | | $D_{95}$ | mm | n/a | n/a | 59.6 | n/a | >2048 | n/a | n/a |
| 53 | Particle Size Distribution of Bar Material | $D_{16}$ | mm | n/a | n/a | n/a | n/a | 1.8 | n/a | n/a |
| | | $D_{35}$ | mm | n/a | n/a | n/a | n/a | 15.0 | n/a | n/a |
| | | $D_{50}$ | mm | n/a | n/a | n/a | n/a | 32.0 | n/a | n/a |
| | | $D_{84}$ | mm | n/a | n/a | n/a | n/a | 96.0 | n/a | n/a |
| | | $D_{95}$ | mm | n/a | n/a | n/a | n/a | 117.0 | n/a | n/a |
| 54 | Largest Size Particle at | mm | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

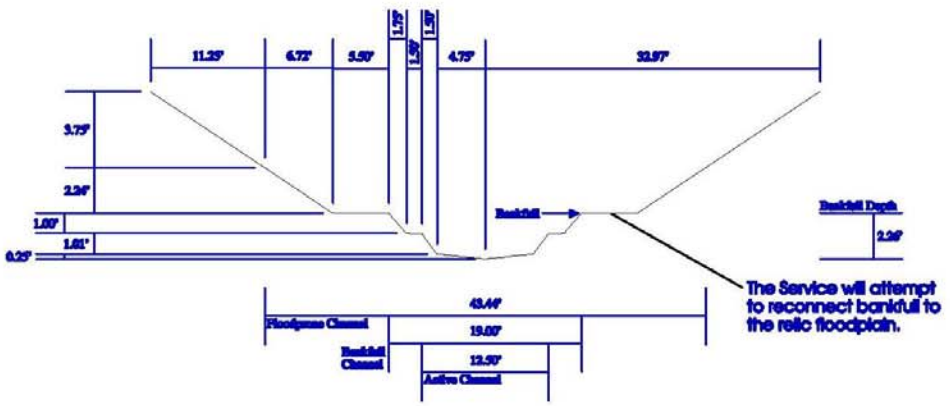
1. Data collected by Wildland Hydrology, Inc.
2. Data collected by the Service for the Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region (McCandless and Everett 2002)
3. Data collected by the Service
4. Data collected by Clear Creeks Consultants, Inc.

# Appendix B
# Cross Section Typicals

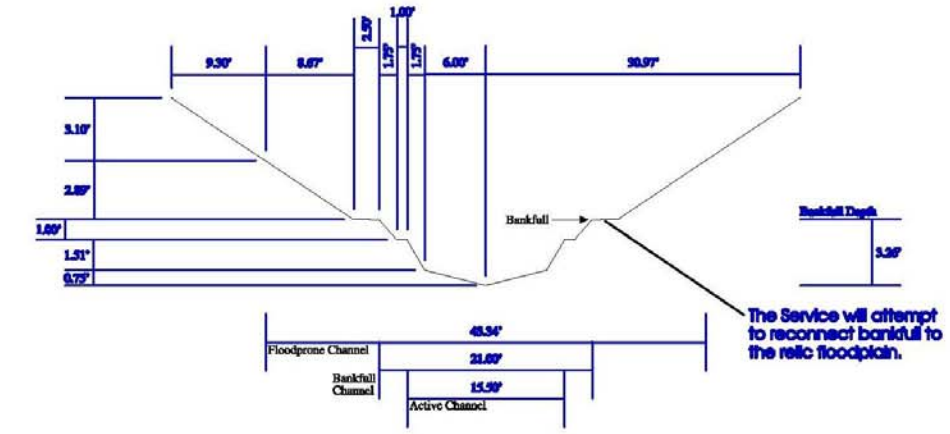
| CROSS SECTION SUMMARY OF PROPOSED C4 ROSGEN STREAM TYPE (PROJECT AREA 1) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Channel Characteristic** | **Symbol** | **Unit** | **Riffle** | | **Pool** | | **Glide** | |
| | | | **Active** | **Bankfull** | **Active** | **Bankfull** | **Active** | **Bankfull** |
| Thalweg Elevation | $Z_0$ | | n/a | n/a | n/a | n/a | n/a | n/a |
| Bankfull Discharge (computed) | $Q_{bf}$ | $ft^3/sec$ | 34.7 | 104.8 | 87.9 | 179.0 | 49.4 | 126.3 |
| Bankfull Area | $A_{bf}$ | $ft^2$ | 12.2 | 29.4 | 25.1 | 44.3 | 17.0 | 35.2 |
| Mean Bankfull Depth | $d_{bf}$ | ft | 1.0 | 1.5 | 1.6 | 2.1 | 1.2 | 1.8 |
| Bankfull Width | $W_{bf}$ | ft | 12.5 | 19.0 | 15.5 | 21.0 | 14.0 | 20.0 |
| Width/Depth ratio | $W_{bf}/d_{bf}$ | | 12.8 | 12.3 | 9.6 | 9.9 | 11.5 | 11.4 |
| Maximum Depth | $d_{max}$ | ft | 1.3 | 2.3 | 2.3 | 3.3 | 1.5 | 2.5 |
| Bankfull Composite "n" | $n_{bf}$ | | 0.0330 | 0.0356 | 0.0370 | 0.0381 | 0.0370 | 0.0383 |
| Bankfull Hydraulic Radius | $R_{bf}$ | ft | 0.9 | 1.5 | 1.5 | 2.0 | 1.1 | 1.6 |
| Average Bankfull Velocity | $V_{bf}$ | ft/sec | 2.8 | 3.6 | 3.5 | 4.0 | 2.9 | 3.6 |
| Bankfull Shear Stress | $t_o$ | $lbs/ft^2$ | 0.3 | 0.4 | 0.4 | 0.5 | 0.3 | 0.5 |
| Froude (Bankfull) | $Fr_{bf}$ | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Critical Sediment Size at Bankfull | $D_{crit}$ | mm | 25.2 | 39.6 | 40.8 | 52.9 | 30.9 | 44.5 |
| Bankfull Wetted Perimeter | $P_{bf}$ | ft | 13.1 | 20.1 | 16.7 | 22.7 | 14.9 | 21.4 |
| Entrenchment Ratio | $W_{fp}/W_{bf}$ | | 2.5 | 2.3 | n/a | n/a | n/a | n/a |
| Floodprone Elevation | $Z_{fp}$ | ft | 12.3 | 14.3 | n/a | n/a | n/a | n/a |
| Floodprone Discharge (computed) | $Q_{fp}$ | $ft^3/sec$ | 104.1 | 514.0 | n/a | n/a | n/a | n/a |
| Floodprone Area | $A_{fp}$ | $ft^2$ | 37.0 | 111.9 | n/a | n/a | n/a | n/a |
| Mean Floodprone Depth | $d_{fp}$ | ft | 1.2 | 4.5 | n/a | n/a | n/a | n/a |
| Floodprone Width | $W_{fp}$ | ft | 31.4 | 43.4 | n/a | n/a | n/a | n/a |
| Floodprone Composite "n" | $n_{fp}$ | | 0.0381 | 0.0392 | n/a | n/a | n/a | n/a |
| Floodprone Hydraulic Radius | $R_{fp}$ | ft | 1.1 | 2.5 | n/a | n/a | n/a | n/a |
| Average Floodprone Velocity | $V_{fp}$ | ft/sec | 2.8 | 4.6 | n/a | n/a | n/a | n/a |
| Floodprone Shear Stress | $t_o$ | $lbs/ft^2$ | 0.3 | 0.7 | n/a | n/a | n/a | n/a |
| Critical Sediment Size at Floodprone | $D_{crit}$ | mm | 30.7 | 66.9 | n/a | n/a | n/a | n/a |
| Floodprone Wetted Perimeter | $P_{fp}$ | ft | 32.7 | 45.3 | n/a | n/a | n/a | n/a |

# Rosgen C4 Stream Type Typical Cross Section

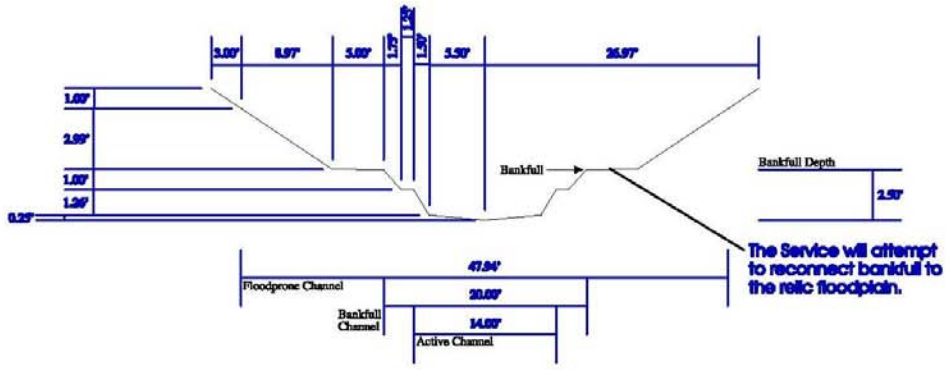
## Riffle Cross Section




## Pool Cross Section



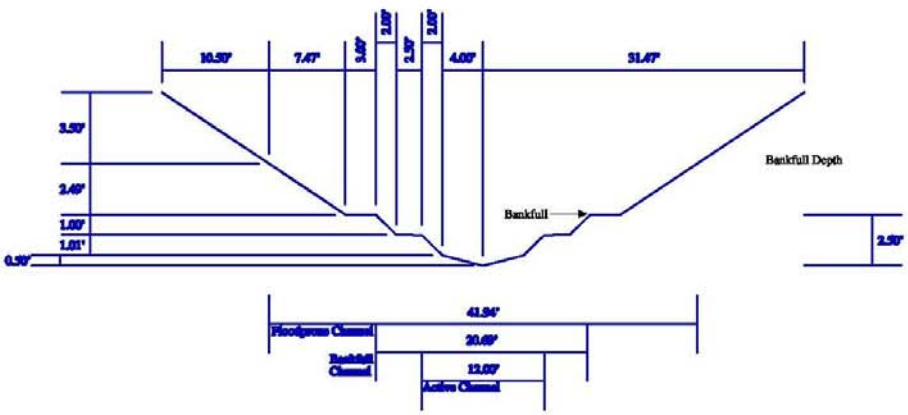

## Glide Cross Section



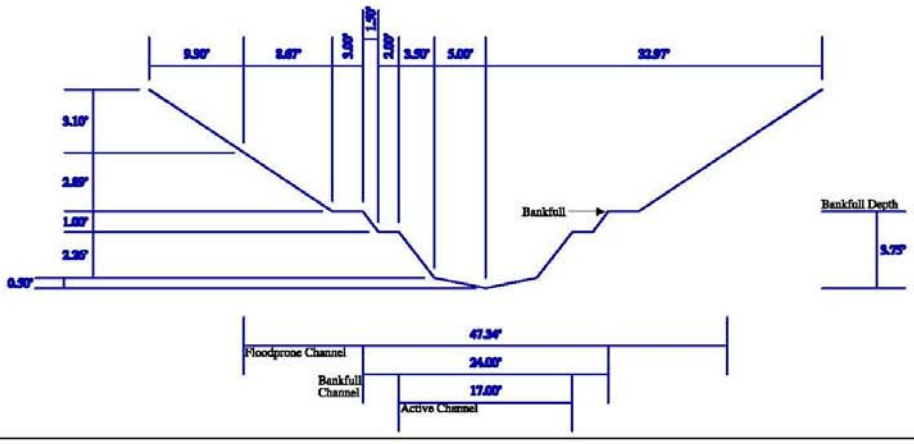
| CROSS SECTION SUMMARY OF PROPOSED B4c ROSGEN STREAM TYPE (PROJECT AREA 1) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Channel Characteristic** | **Symbol** | **Unit** | **Riffle** | | **Pool** | | **Glide** | |
| | | | **Active** | **Bankfull** | **Active** | **Bankfull** | **Active** | **Bankfull** |
| Thalweg Elevation | $Z_0$ | | 9.5 | 9.5 | 8.3 | 8.3 | 9.3 | 9.3 |
| Bankfull Discharge (computed) | $Q_{bf}$ | $ft^3/sec$ | 34.8 | 106.5 | 129.1 | 237.1 | 62.2 | 149.0 |
| Bankfull Area | $A_{bf}$ | $ft^2$ | 12.0 | 31.0 | 32.9 | 55.3 | 20.0 | 41.0 |
| Mean Bankfull Depth | $d_{bf}$ | ft | 1.0 | 1.5 | 1.9 | 2.3 | 1.3 | 1.8 |
| Bankfull Width | $W_{bf}$ | ft | 12.0 | 21.0 | 17.0 | 24.0 | 15.0 | 23.0 |
| Width/Depth ratio | $W_{bf}/d_{bf}$ | | 12.0 | 14.2 | 8.8 | 10.4 | 11.3 | 12.9 |
| Maximum Depth | $d_{max}$ | ft | 1.5 | 2.5 | 2.8 | 3.8 | 1.8 | 2.8 |
| Bankfull Composite "n" | $n_{bf}$ | | 0.0330 | 0.0360 | 0.0370 | 0.0381 | 0.0370 | 0.0384 |
| Bankfull Hydraulic Radius | $R_{bf}$ | ft | 1.0 | 1.4 | 1.8 | 2.1 | 1.3 | 1.7 |
| Average Bankfull Velocity | $V_{bf}$ | ft/sec | 2.9 | 3.4 | 3.9 | 4.3 | 3.1 | 3.6 |
| Bankfull Shear Stress | $t_o$ | $lbs/ft^2$ | 0.3 | 0.4 | 0.5 | 0.6 | 0.3 | 0.5 |
| Froude (Bankfull) | $Fr_{bf}$ | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Critical Sediment Size at Bankfull | $D_{crit}$ | mm | 25.9 | 38.1 | 48.5 | 57.7 | 34.2 | 45.7 |
| Bankfull Wetted Perimeter | $P_{bf}$ | ft | 12.5 | 22.0 | 18.4 | 26.0 | 15.8 | 24.3 |
| Entrenchment Ratio | $W_{fp}/W_{bf}$ | | 2.5 | 2.0 | n/a | n/a | n/a | n/a |
| Floodprone Elevation | $Z_{fp}$ | ft | 12.5 | 14.5 | n/a | n/a | n/a | n/a |
| Floodprone Discharge (computed) | $Q_{fp}$ | $ft^3/sec$ | 151.0 | 569.6 | n/a | n/a | n/a | n/a |
| Floodprone Area | $A_{fp}$ | $ft^2$ | 45.1 | 117.0 | n/a | n/a | n/a | n/a |
| Mean Floodprone Depth | $d_{fp}$ | ft | 1.5 | 5.0 | n/a | n/a | n/a | n/a |
| Floodprone Width | $W_{fp}$ | ft | 29.9 | 41.9 | n/a | n/a | n/a | n/a |
| Floodprone Composite "n" | $n_{fp}$ | | 0.0378 | 0.0390 | n/a | n/a | n/a | n/a |
| Floodprone Hydraulic Radius | $R_{fp}$ | ft | 1.5 | 2.7 | n/a | n/a | n/a | n/a |
| Average Floodprone Velocity | $V_{fp}$ | ft/sec | 3.3 | 4.9 | n/a | n/a | n/a | n/a |
| Floodprone Shear Stress | $t_o$ | $lbs/ft^2$ | 0.4 | 0.7 | n/a | n/a | n/a | n/a |
| Critical Sediment Size at Floodprone | $D_{crit}$ | mm | 39.3 | 72.5 | n/a | n/a | n/a | n/a |
| Floodprone Wetted Perimeter | $P_{fp}$ | ft | 31.1 | 43.7 | n/a | n/a | n/a | n/a |

# Rosgen B4c Stream Type Typical Cross Section

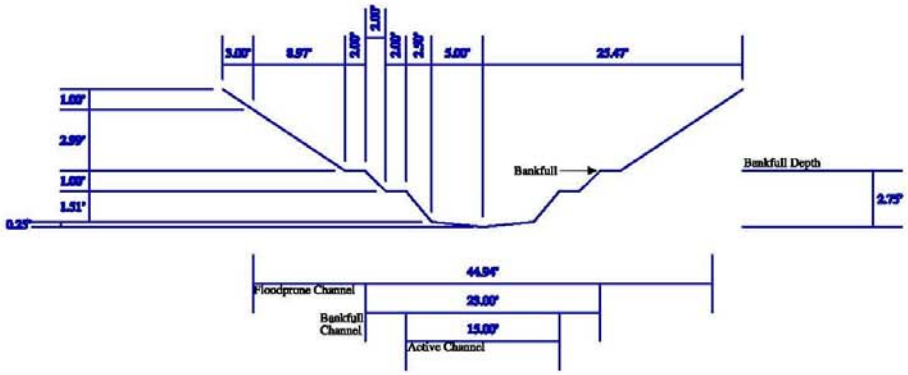
## Riffle Cross Section




## Pool Cross Section




## Glide Cross Section



# Appendix C
# Sediment Analysis

The objective of sediment transportation for the project is to maintain existing sediment transport capabilities and rates because Daniels Run does not appear to have a significant aggradation or degradation stability problem. This is supported by the results of the vertical stability assessment, which show that Daniels Run - Reach 1 is vertically stable and Reach 2 is vertically stable even though there is evidence of past downcutting. Furthermore, the entrainment calculations, if using the Rosgen's power trend line on Shields critical shear stress relationship, predict a similar critical shear stress as the existing conditions critical shear stress. The stability problems within Daniels Run are mostly related to lateral instability problem (e.g., widespread bank erosion). A sediment capacity analysis was not conducted since Daniels Run does not appear to have a significant aggradation or degradation stability problem.

Since the objective of the project sediment transportation is to maintain existing sediment transport capabilities and rates, the critical sediment size used for analysis came from field-collected data (i.e., bar samples and riffle pebble counts). This particle size becomes the test size for cross section design.

Sediment transportation of an existing C4 riffle cross section in Reach 1 was compared to a typical C4 riffle cross section, which developed to meet specific shape and discharge capacities. A cross section table was developed for both the existing and proposed C4 cross sections to show discharge, cross section area, and cross section depth (Tables 1 and 2). The cross section tables also calculate the maximum sediment size transportable at the riffles. This was based on the Shields equation using the shields parameter value for the riffles, and by computing the shear stress based on the bankfull slope and hydraulic radius. The existing conditions cross section has a critical shear stress of 0.46 lbs/ft and can transport a particle size of 45 mm. The proposed cross section has a critical shear stress of 0.40 lbs/ft and can transport a particle size of 40 mm. This process was also completed for Reach 2, which has a proposed B4 stream type (Tables 3 and 4). The existing conditions cross section has a critical shear stress of 0.53 lbs/ft and can transport a particle size of 52 mm. The proposed cross section has a critical shear stress of 0.39 lbs/ft and can transport a particle size of 38 mm. The existing and proposed shear stresses and critical particle sizes are very similar between the existing and proposed cross sections; therefore, the proposed stream design should have a stable stream bed.

**Table 1 - Existing C4 Riffle Cross Section Reach 1 Analysis**

| Symbol | Quantity | Value | Units |
|---|---|---|---|
| *Cross Section Controls:* | | | |
| S | HEC-RAS Energy Slope | 0.0047 | |
| $d_{50}$ | Median Grain Diameter | 33.0 | |
| $\tau^*$ | Shields Parameter | 0.030 | mm |
| | | | |
| *User Input:* | | | |
| $Z_{bf}$ | Bankfull Water Surface Elevation | 92.70 | ft |
| $Z_{AC}$ | Active Channel Elevation | 90.90 | ft |
| | | | |
| *Rating Curve Controls:* | | | |
| $Z_t$ | Terminating Elevation | 94.00 | |
| $Z_i$ | Elevation Incremetns | 0.100 | |
| | | | |
| *Bankfull Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 90.57 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 116 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 29.2 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 1.80 | ft |
| $W_{bf}$ | Bankfull Width | 16.2 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 9.0 | |
| $d_{max}$ | Maximum Depth | 2.13 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.035 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 1.56 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 3.96 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.46 | lbs/$ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.52 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 45 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 18.8 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 4.25 | |
| $Z_{fp}$ | Floodprone Elevation | 94.8 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 873.0 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 106.5 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 4.26 | ft |
| $W_{fp}$ | Floodprone Width | 69.0 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.016 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 1.46 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 8.20 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.43 | lbs/$ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 42 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 72.9 | ft |
| | | | |
| *Active Channel Analysis:* | | | |
| | | | |
| $Z_0$ | Thalweg Elevation | 90.57 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 2 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 1.8 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 0.15 | ft |
| $W_{bf}$ | Bankfull Width | 11.6 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 75.3 | |
| $d_{max}$ | Maximum Depth | 0.33 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.033 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 0.15 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 0.88 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.04 | lbs/$ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.40 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 4 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 11.6 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 1.25 | |
| $Z_{fp}$ | Floodprone Elevation | 91.2 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 10.5 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 6.2 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 0.43 | ft |
| $W_{fp}$ | Floodprone Width | 14.5 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.033 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 0.42 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 1.70 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.12 | lbs/$ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 12 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 14.9 | ft |

**Stream Channel Cross Sectional Survey Data:**

Riffle

| Cross Section Survey | | | | $Z_i$ | $Q_i$ | $A_i$ | $d_i$ | $W_i$ | $W_i/d_i$ | $d_{max(i)}$ | $n_i$ | $R_i$ | $V_i$ | $\tau_o$ | $Fr_i$ | $D_{crit(i)}$ | $P_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Features | Station (X) | Elev. (Z) | Mannings | Elevation | Discharge | Cross Section Area | Mean Depth | Width | Width/ Depth Ratio | Maximum Depth | Composite "n" | Hydraulic Radius | Mean Velocity | Shear Stress | Froude Number | Critical Sediment Size | Wetted Perimeter |
| | (feet) | (feet) | "n" | | | | | | | | | | | | | | |
| | | | | ft | $ft^3$/sec | $ft^2$ | ft | ft | | ft | | ft | ft/sec | lbs/$ft^2$ | | mm | ft |
| GS | 0.00 | 94.64 | | | | | | | | | | | | | | | |
| GS | 7.00 | 94.71 | | | | | | | | | | | | | | | |
| GS | 15.00 | 94.54 | | 90.570 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| GS | 20.00 | 94.30 | | 90.670 | 0.1 | 0.2 | 0.07 | 2.5 | 38.00 | 0.10 | 0.033 | 0.07 | 0.51 | 0.02 | 0.35 | 1.9 | 2.6 |
| LTOB | 22.00 | 93.68 | 0.042 | 90.770 | 0.3 | 0.5 | 0.09 | 5.9 | 65.16 | 0.20 | 0.033 | 0.09 | 0.62 | 0.03 | 0.36 | 2.6 | 5.9 |
| UNDERCUT | 21.75 | 92.75 | 0.042 | 90.870 | 1.1 | 1.4 | 0.13 | 11.0 | 84.47 | 0.30 | 0.033 | 0.13 | 0.79 | 0.04 | 0.39 | 3.8 | 11.1 |
| LBF | 21.76 | 92.70 | 0.042 | 90.970 | 2.8 | 2.6 | 0.21 | 12.6 | 60.38 | 0.40 | 0.033 | 0.21 | 1.08 | 0.06 | 0.42 | 6.0 | 12.7 |
| LEW | 21.77 | 90.90 | 0.033 | 91.070 | 5.2 | 3.9 | 0.29 | 13.8 | 48.35 | 0.50 | 0.033 | 0.28 | 1.32 | 0.08 | 0.44 | 8.1 | 14.0 |
| CS | 23.00 | 90.58 | 0.033 | 91.170 | 8.4 | 5.3 | 0.38 | 14.2 | 37.81 | 0.60 | 0.033 | 0.37 | 1.57 | 0.11 | 0.45 | 10.6 | 14.6 |
| CS | 24.00 | 90.57 | 0.033 | 91.270 | 12.1 | 6.8 | 0.46 | 14.6 | 31.51 | 0.70 | 0.034 | 0.45 | 1.78 | 0.13 | 0.46 | 13.0 | 15.1 |
| CS | 27.00 | 90.82 | 0.033 | 91.370 | 16.3 | 8.3 | 0.55 | 15.0 | 27.32 | 0.80 | 0.034 | 0.53 | 1.97 | 0.16 | 0.47 | 15.3 | 15.6 |
| CS | 29.50 | 90.74 | 0.033 | 91.470 | 21.3 | 9.8 | 0.64 | 15.2 | 23.55 | 0.90 | 0.034 | 0.62 | 2.18 | 0.18 | 0.48 | 17.8 | 15.9 |
| CS | 32.75 | 90.86 | 0.033 | 91.570 | 26.7 | 11.3 | 0.74 | 15.3 | 20.77 | 1.00 | 0.034 | 0.70 | 2.36 | 0.21 | 0.48 | 20.3 | 16.2 |
| REW | 35.50 | 91.05 | 0.033 | 91.670 | 32.6 | 12.8 | 0.83 | 15.5 | 18.63 | 1.10 | 0.034 | 0.78 | 2.54 | 0.23 | 0.49 | 22.6 | 16.4 |
| TOE | 36.80 | 91.37 | 0.042 | 91.770 | 38.9 | 14.4 | 0.92 | 15.6 | 16.94 | 1.20 | 0.034 | 0.86 | 2.70 | 0.25 | 0.50 | 24.9 | 16.7 |
| SLP BRK | 37.50 | 91.85 | 0.042 | 91.870 | 45.6 | 16.0 | 1.01 | 15.7 | 15.53 | 1.30 | 0.034 | 0.94 | 2.86 | 0.28 | 0.50 | 27.2 | 17.0 |
| RBF | 38.00 | 92.70 | 0.042 | 91.970 | 52.9 | 17.5 | 1.11 | 15.8 | 14.24 | 1.40 | 0.034 | 1.02 | 3.01 | 0.30 | 0.50 | 29.5 | 17.2 |
| GS | 40.80 | 92.91 | | 92.070 | 60.5 | 19.1 | 1.21 | 15.9 | 13.16 | 1.50 | 0.034 | 1.10 | 3.16 | 0.32 | 0.51 | 31.8 | 17.4 |
| GS | 43.00 | 93.19 | | 92.170 | 68.4 | 20.7 | 1.30 | 15.9 | 12.24 | 1.60 | 0.034 | 1.18 | 3.30 | 0.34 | 0.51 | 34.0 | 17.6 |
| GS | 47.00 | 93.64 | | 92.270 | 76.7 | 22.3 | 1.40 | 16.0 | 11.45 | 1.70 | 0.034 | 1.25 | 3.44 | 0.37 | 0.51 | 36.2 | 17.8 |
| GS | 58.00 | 93.96 | | 92.370 | 85.3 | 23.9 | 1.49 | 16.0 | 10.76 | 1.80 | 0.034 | 1.32 | 3.57 | 0.39 | 0.51 | 38.3 | 18.1 |
| GS | 69.00 | 93.88 | | 92.470 | 94.2 | 25.5 | 1.59 | 16.1 | 10.16 | 1.90 | 0.035 | 1.40 | 3.69 | 0.41 | 0.52 | 40.4 | 18.3 |
| | | | | 92.570 | 103.4 | 27.1 | 1.68 | 16.2 | 9.63 | 2.00 | 0.035 | 1.47 | 3.81 | 0.43 | 0.52 | 42.5 | 18.5 |
| | | | | 92.670 | 112.9 | 28.8 | 1.77 | 16.2 | 9.15 | 2.10 | 0.035 | 1.54 | 3.92 | 0.45 | 0.52 | 44.5 | 18.7 |
| | | | | 92.770 | 123.1 | 30.4 | 1.77 | 17.2 | 9.70 | 2.20 | 0.034 | 1.54 | 4.05 | 0.45 | 0.54 | 44.5 | 19.8 |
| | | | | 92.870 | 134.8 | 32.2 | 1.74 | 18.5 | 10.61 | 2.30 | 0.032 | 1.52 | 4.18 | 0.45 | 0.56 | 43.9 | 21.2 |
| | | | | 92.970 | 147.6 | 34.1 | 1.75 | 19.5 | 11.11 | 2.40 | 0.031 | 1.53 | 4.33 | 0.45 | 0.58 | 44.2 | 22.3 |
| | | | | 93.070 | 161.4 | 36.1 | 1.78 | 20.2 | 11.33 | 2.50 | 0.031 | 1.55 | 4.47 | 0.46 | 0.59 | 45.0 | 23.2 |
| | | | | 93.170 | 176.2 | 38.1 | 1.82 | 21.0 | 11.54 | 2.60 | 0.030 | 1.58 | 4.62 | 0.46 | 0.60 | 45.8 | 24.1 |
| | | | | 93.270 | 192.0 | 40.3 | 1.85 | 21.8 | 11.82 | 2.70 | 0.029 | 1.61 | 4.77 | 0.47 | 0.62 | 46.5 | 25.1 |
| | | | | 93.370 | 209.1 | 42.5 | 1.87 | 22.7 | 12.10 | 2.80 | 0.029 | 1.63 | 4.92 | 0.48 | 0.63 | 47.1 | 26.1 |
| | | | | 93.470 | 227.3 | 44.8 | 1.90 | 23.5 | 12.37 | 2.90 | 0.028 | 1.65 | 5.07 | 0.49 | 0.65 | 47.9 | 27.1 |
| | | | | 93.570 | 246.8 | 47.2 | 1.93 | 24.4 | 12.62 | 3.00 | 0.028 | 1.68 | 5.23 | 0.49 | 0.66 | 48.7 | 28.1 |
| | | | | 93.670 | 267.6 | 49.7 | 1.91 | 26.0 | 13.63 | 3.10 | 0.027 | 1.67 | 5.38 | 0.49 | 0.69 | 48.2 | 29.9 |
| | | | | 93.770 | 289.1 | 52.5 | 1.76 | 29.8 | 16.87 | 3.20 | 0.025 | 1.56 | 5.51 | 0.46 | 0.73 | 45.2 | 33.6 |
| | | | | 93.870 | 314.1 | 55.7 | 1.66 | 33.5 | 20.18 | 3.30 | 0.024 | 1.49 | 5.64 | 0.44 | 0.77 | 43.1 | 37.4 |
| | | | | 93.970 | 348.5 | 59.8 | 1.25 | 47.9 | 38.45 | 3.40 | 0.019 | 1.15 | 5.83 | 0.34 | 0.92 | 33.4 | 51.8 |

11/2/2007 Shear Stress (Existing Condition) XS 1 (Riffle)

**Table 2 - Proposed Riffle C4 Cross Section Analysis**

| Symbol | Quantity | Value | Units |
|---|---|---|---|
| *Cross Section Controls:* | | | |
| S | HEC-RAS Energy Slope | 0.0044 | |
| $d_{50}$ | Median Grain Diameter | 32.7 | |
| $\tau^*$ | Shields Parameter | 0.030 | mm |
| *User Input:* | | | |
| $Z_{bf}$ | Bankfull Water Surface Elevation | 12.00 | ft |
| $Z_{AC}$ | Active Channel Elevation | 11.00 | ft |
| *Rating Curve Controls:* | | | |
| $Z_t$ | Terminating Elevation | 18.00 | |
| $Z_i$ | Elevation Incremetns | 0.100 | |
| *Bankfull Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 9.75 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 105 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 29.4 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 1.55 | ft |
| $W_{bf}$ | Bankfull Width | 19.0 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 12.3 | |
| $d_{max}$ | Maximum Depth | 2.25 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.036 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 1.46 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 3.57 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.40 | $lbs/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.51 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 40 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 20.1 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 2.29 | |
| $Z_{fp}$ | Floodprone Elevation | 14.3 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 514.0 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 111.9 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 4.50 | ft |
| $W_{fp}$ | Floodprone Width | 43.4 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.039 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 2.47 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 4.59 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.68 | $lbs/ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 67 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 45.3 | ft |
| *Active Channel Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 9.75 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 35 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 12.2 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 0.98 | ft |
| $W_{bf}$ | Bankfull Width | 12.5 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 12.8 | |
| $d_{max}$ | Maximum Depth | 1.25 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.033 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 0.99 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 2.84 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.26 | $lbs/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.51 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 25 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 13.1 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 2.52 | |
| $Z_{fp}$ | Floodprone Elevation | 12.3 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 104.1 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 37.0 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 1.18 | ft |
| $W_{fp}$ | Floodprone Width | 31.4 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.038 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 1.13 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 2.81 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.31 | $lbs/ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 31 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 32.7 | ft |

**Stream Channel Cross Sectional Survey Data:**

Riffle

**Cross Section Survey**

| Features | Station (X) (feet) | Elev. (Z) (feet) | Mannings "n" |
|---|---|---|---|
| 3:1 Extension | 17.03 | 18.00 | 0.042 |
| FP | 28.28 | 14.25 | 0.042 |
| Toe FP | 35.00 | 12.01 | 0.042 |
| BF | 40.50 | 12.00 | 0.042 |
| Toe BF | 42.25 | 11.01 | 0.042 |
| AC | 43.75 | 11.00 | 0.033 |
| Toe AC | 45.25 | 10.00 | 0.033 |
| Thalweg | 50.00 | 9.75 | 0.033 |
| | 54.75 | 10.00 | 0.033 |
| | 56.25 | 11.00 | 0.033 |
| | 57.75 | 11.01 | 0.042 |
| | 59.50 | 12.00 | 0.042 |
| | 65.00 | 12.01 | 0.042 |
| | 71.72 | 14.25 | 0.042 |
| | 82.97 | 18.00 | 0.042 |

| $Z_i$ Elevation | $Q_i$ Discharge | $A_i$ Cross Section Area | $d_i$ Mean Depth | $W_i$ Width | $W_i/d_i$ Width/ Depth Ratio | $d_{max(i)}$ Maximum Depth | $n_i$ Composite "n" | $R_i$ Hydraulic Radius | $V_i$ Mean Velocity | $\tau_o$ Shear Stress | $Fr_i$ Froude Number | $D_{crit(i)}$ Critical Sediment Size | $P_i$ Wetted Perimeter |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ft | $ft^3$/sec | $ft^2$ | ft | ft | | ft | | ft | ft/sec | $lbs/ft^2$ | | mm | ft |
| 9.750 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9.850 | 0.1 | 0.2 | 0.05 | 3.8 | 76.00 | 0.10 | 0.033 | 0.05 | 0.41 | 0.01 | 0.32 | 1.4 | 3.8 |
| 9.950 | 0.5 | 0.8 | 0.10 | 7.6 | 76.00 | 0.20 | 0.033 | 0.10 | 0.64 | 0.03 | 0.36 | 2.7 | 7.6 |
| 10.050 | 1.5 | 1.7 | 0.17 | 9.7 | 55.89 | 0.30 | 0.033 | 0.17 | 0.92 | 0.05 | 0.39 | 4.7 | 9.7 |
| 10.150 | 3.2 | 2.6 | 0.27 | 10.0 | 37.41 | 0.40 | 0.033 | 0.26 | 1.23 | 0.07 | 0.42 | 7.1 | 10.1 |
| 10.250 | 5.4 | 3.7 | 0.36 | 10.3 | 28.74 | 0.50 | 0.033 | 0.35 | 1.49 | 0.10 | 0.44 | 9.5 | 10.4 |
| 10.350 | 8.1 | 4.7 | 0.45 | 10.6 | 23.70 | 0.60 | 0.033 | 0.44 | 1.72 | 0.12 | 0.45 | 11.8 | 10.8 |
| 10.450 | 11.1 | 5.8 | 0.53 | 10.9 | 20.42 | 0.70 | 0.033 | 0.52 | 1.93 | 0.14 | 0.47 | 14.0 | 11.1 |
| 10.550 | 14.5 | 6.9 | 0.62 | 11.2 | 18.11 | 0.80 | 0.033 | 0.60 | 2.12 | 0.16 | 0.48 | 16.2 | 11.5 |
| 10.650 | 18.4 | 8.0 | 0.70 | 11.5 | 16.40 | 0.90 | 0.033 | 0.67 | 2.30 | 0.19 | 0.48 | 18.3 | 11.9 |
| 10.750 | 22.6 | 9.2 | 0.78 | 11.8 | 15.08 | 1.00 | 0.033 | 0.75 | 2.46 | 0.21 | 0.49 | 20.3 | 12.2 |
| 10.850 | 27.1 | 10.3 | 0.86 | 12.1 | 14.03 | 1.10 | 0.033 | 0.82 | 2.62 | 0.23 | 0.50 | 22.3 | 12.6 |
| 10.950 | 32.1 | 11.6 | 0.94 | 12.4 | 13.19 | 1.20 | 0.033 | 0.89 | 2.77 | 0.25 | 0.50 | 24.2 | 12.9 |
| 11.050 | 37.3 | 13.0 | 0.83 | 15.6 | 18.89 | 1.30 | 0.034 | 0.80 | 2.49 | 0.22 | 0.48 | 21.6 | 16.3 |
| 11.150 | 38.2 | 14.5 | 0.91 | 16.0 | 17.60 | 1.40 | 0.034 | 0.87 | 2.63 | 0.24 | 0.49 | 23.6 | 16.7 |
| 11.250 | 44.6 | 16.1 | 0.99 | 16.3 | 16.55 | 1.50 | 0.034 | 0.94 | 2.76 | 0.26 | 0.49 | 25.6 | 17.1 |
| 11.350 | 51.4 | 17.8 | 1.07 | 16.7 | 15.67 | 1.60 | 0.035 | 1.02 | 2.88 | 0.28 | 0.49 | 27.6 | 17.5 |
| 11.450 | 58.5 | 19.5 | 1.14 | 17.1 | 14.93 | 1.70 | 0.035 | 1.09 | 3.00 | 0.30 | 0.49 | 29.5 | 17.9 |
| 11.550 | 66.1 | 21.2 | 1.22 | 17.4 | 14.29 | 1.80 | 0.035 | 1.16 | 3.11 | 0.32 | 0.50 | 31.4 | 18.3 |
| 11.650 | 74.0 | 23.0 | 1.29 | 17.8 | 13.73 | 1.90 | 0.035 | 1.23 | 3.22 | 0.34 | 0.50 | 33.2 | 18.7 |
| 11.750 | 82.3 | 24.8 | 1.37 | 18.1 | 13.25 | 2.00 | 0.035 | 1.29 | 3.32 | 0.36 | 0.50 | 35.1 | 19.1 |
| 11.850 | 91.1 | 26.6 | 1.44 | 18.5 | 12.83 | 2.10 | 0.035 | 1.36 | 3.42 | 0.37 | 0.50 | 36.9 | 19.5 |
| 11.950 | 100.2 | 28.5 | 1.51 | 18.8 | 12.45 | 2.20 | 0.036 | 1.43 | 3.52 | 0.39 | 0.50 | 38.7 | 19.9 |
| 12.050 | 79.2 | 30.9 | 1.02 | 30.2 | 29.64 | 2.30 | 0.038 | 0.98 | 2.57 | 0.27 | 0.45 | 26.6 | 31.4 |
| 12.150 | 91.3 | 33.9 | 1.10 | 30.8 | 28.05 | 2.40 | 0.038 | 1.06 | 2.69 | 0.29 | 0.45 | 28.7 | 32.0 |
| 12.250 | 104.1 | 37.0 | 1.18 | 31.4 | 26.70 | 2.50 | 0.038 | 1.13 | 2.81 | 0.31 | 0.46 | 30.7 | 32.7 |
| 12.350 | 117.7 | 40.2 | 1.25 | 32.0 | 25.54 | 2.60 | 0.038 | 1.21 | 2.93 | 0.33 | 0.46 | 32.7 | 33.3 |
| 12.450 | 132.0 | 43.4 | 1.33 | 32.6 | 24.53 | 2.70 | 0.038 | 1.28 | 3.04 | 0.35 | 0.46 | 34.7 | 33.9 |
| 12.550 | 147.0 | 46.7 | 1.41 | 33.2 | 23.65 | 2.80 | 0.038 | 1.35 | 3.15 | 0.37 | 0.47 | 36.6 | 34.6 |
| 12.650 | 162.7 | 50.1 | 1.48 | 33.8 | 22.87 | 2.90 | 0.038 | 1.42 | 3.25 | 0.39 | 0.47 | 38.6 | 35.2 |
| 12.750 | 179.1 | 53.5 | 1.55 | 34.4 | 22.17 | 3.00 | 0.038 | 1.49 | 3.35 | 0.41 | 0.47 | 40.5 | 35.8 |
| 12.850 | 196.3 | 57.0 | 1.63 | 35.0 | 21.55 | 3.10 | 0.039 | 1.56 | 3.45 | 0.43 | 0.48 | 42.3 | 36.5 |
| 12.950 | 214.2 | 60.5 | 1.70 | 35.6 | 20.99 | 3.20 | 0.039 | 1.63 | 3.54 | 0.45 | 0.48 | 44.2 | 37.1 |
| 13.050 | 232.9 | 64.1 | 1.77 | 36.2 | 20.49 | 3.30 | 0.039 | 1.70 | 3.63 | 0.47 | 0.48 | 46.0 | 37.7 |
| 13.150 | 252.2 | 67.7 | 1.84 | 36.8 | 20.03 | 3.40 | 0.039 | 1.77 | 3.72 | 0.49 | 0.48 | 47.9 | 38.4 |
| 13.250 | 272.3 | 71.5 | 1.91 | 37.4 | 19.62 | 3.50 | 0.039 | 1.83 | 3.81 | 0.50 | 0.49 | 49.7 | 39.0 |
| 13.350 | 293.1 | 75.2 | 1.98 | 38.0 | 19.23 | 3.60 | 0.039 | 1.90 | 3.90 | 0.52 | 0.49 | 51.5 | 39.6 |
| 13.450 | 314.7 | 79.1 | 2.05 | 38.6 | 18.88 | 3.70 | 0.039 | 1.96 | 3.98 | 0.54 | 0.49 | 53.2 | 40.2 |
| 13.550 | 337.0 | 83.0 | 2.11 | 39.2 | 18.56 | 3.80 | 0.039 | 2.03 | 4.06 | 0.56 | 0.49 | 55.0 | 40.9 |
| 13.650 | 360.0 | 86.9 | 2.18 | 39.8 | 18.26 | 3.90 | 0.039 | 2.09 | 4.14 | 0.57 | 0.49 | 56.7 | 41.5 |
| 13.750 | 383.8 | 90.9 | 2.25 | 40.4 | 17.98 | 4.00 | 0.039 | 2.16 | 4.22 | 0.59 | 0.50 | 58.5 | 42.1 |
| 13.850 | 408.3 | 95.0 | 2.31 | 41.0 | 17.73 | 4.10 | 0.039 | 2.22 | 4.30 | 0.61 | 0.50 | 60.2 | 42.8 |
| 13.950 | 433.6 | 99.1 | 2.38 | 41.6 | 17.49 | 4.20 | 0.039 | 2.28 | 4.37 | 0.63 | 0.50 | 61.9 | 43.4 |
| 14.050 | 459.6 | 103.3 | 2.45 | 42.2 | 17.27 | 4.30 | 0.039 | 2.35 | 4.45 | 0.64 | 0.50 | 63.6 | 44.0 |
| 14.150 | 486.4 | 107.6 | 2.51 | 42.8 | 17.06 | 4.40 | 0.039 | 2.41 | 4.52 | 0.66 | 0.50 | 65.2 | 44.7 |
| 14.250 | 514.0 | 111.9 | 2.58 | 43.4 | 16.86 | 4.50 | 0.039 | 2.47 | 4.59 | 0.68 | 0.50 | 66.9 | 45.3 |
| 14.350 | 542.3 | 116.3 | 2.64 | 44.0 | 16.68 | 4.60 | 0.039 | 2.53 | 4.66 | 0.69 | 0.51 | 68.6 | 45.9 |
| 14.450 | 571.5 | 120.7 | 2.70 | 44.6 | 16.51 | 4.70 | 0.039 | 2.59 | 4.73 | 0.71 | 0.51 | 70.2 | 46.6 |
| 14.550 | 601.3 | 125.2 | 2.77 | 45.2 | 16.35 | 4.80 | 0.039 | 2.65 | 4.80 | 0.73 | 0.51 | 71.9 | 47.2 |
| 14.650 | 632.0 | 129.8 | 2.83 | 45.8 | 16.19 | 4.90 | 0.039 | 2.71 | 4.87 | 0.74 | 0.51 | 73.5 | 47.8 |
| 14.750 | 663.5 | 134.4 | 2.89 | 46.4 | 16.05 | 5.00 | 0.039 | 2.77 | 4.94 | 0.76 | 0.51 | 75.1 | 48.5 |
| 14.850 | 695.8 | 139.0 | 2.96 | 47.0 | 15.91 | 5.10 | 0.039 | 2.83 | 5.00 | 0.78 | 0.51 | 76.7 | 49.1 |
| 14.950 | 728.8 | 143.8 | 3.02 | 47.6 | 15.78 | 5.20 | 0.039 | 2.89 | 5.07 | 0.79 | 0.51 | 78.3 | 49.7 |
| 15.050 | 762.7 | 148.6 | 3.08 | 48.2 | 15.66 | 5.30 | 0.039 | 2.95 | 5.13 | 0.81 | 0.52 | 79.9 | 50.4 |
| 15.150 | 797.4 | 153.4 | 3.14 | 48.8 | 15.55 | 5.40 | 0.040 | 3.01 | 5.20 | 0.83 | 0.52 | 81.5 | 51.0 |
| 15.250 | 832.9 | 158.3 | 3.20 | 49.4 | 15.44 | 5.50 | 0.040 | 3.07 | 5.26 | 0.84 | 0.52 | 83.1 | 51.6 |
| 15.350 | 869.2 | 163.3 | 3.26 | 50.0 | 15.33 | 5.60 | 0.040 | 3.12 | 5.32 | 0.86 | 0.52 | 84.7 | 52.3 |
| 15.450 | 906.3 | 168.4 | 3.32 | 50.6 | 15.23 | 5.70 | 0.040 | 3.18 | 5.38 | 0.87 | 0.52 | 86.2 | 52.9 |
| 15.550 | 944.3 | 173.4 | 3.38 | 51.2 | 15.14 | 5.80 | 0.040 | 3.24 | 5.44 | 0.89 | 0.52 | 87.8 | 53.5 |
| 15.650 | 983.1 | 178.6 | 3.45 | 51.8 | 15.05 | 5.90 | 0.040 | 3.30 | 5.50 | 0.91 | 0.52 | 89.3 | 54.2 |
| 15.750 | 1022.7 | 183.8 | 3.51 | 52.4 | 14.96 | 6.00 | 0.040 | 3.35 | 5.56 | 0.92 | 0.52 | 90.9 | 54.8 |
| 15.850 | 1063.2 | 189.1 | 3.56 | 53.0 | 14.88 | 6.10 | 0.040 | 3.41 | 5.62 | 0.94 | 0.52 | 92.4 | 55.4 |
| 15.950 | 1104.5 | 194.4 | 3.62 | 53.6 | 14.80 | 6.20 | 0.040 | 3.47 | 5.68 | 0.95 | 0.53 | 94.0 | 56.1 |
| 16.050 | 1146.7 | 199.8 | 3.68 | 54.2 | 14.72 | 6.30 | 0.040 | 3.52 | 5.74 | 0.97 | 0.53 | 95.5 | 56.7 |
| 16.150 | 1189.8 | 205.3 | 3.74 | 54.8 | 14.65 | 6.40 | 0.040 | 3.58 | 5.80 | 0.98 | 0.53 | 97.0 | 57.3 |
| 16.250 | 1233.7 | 210.8 | 3.80 | 55.4 | 14.58 | 6.50 | 0.040 | 3.64 | 5.85 | 1.00 | 0.53 | 98.5 | 58.0 |
| 16.350 | 1278.5 | 216.4 | 3.86 | 56.0 | 14.52 | 6.60 | 0.040 | 3.69 | 5.91 | 1.01 | 0.53 | 100.1 | 58.6 |
| 16.450 | 1324.2 | 222.0 | 3.92 | 56.6 | 14.45 | 6.70 | 0.040 | 3.75 | 5.97 | 1.03 | 0.53 | 101.6 | 59.2 |
| 16.550 | 1370.8 | 227.7 | 3.98 | 57.2 | 14.39 | 6.80 | 0.040 | 3.80 | 6.02 | 1.04 | 0.53 | 103.1 | 59.9 |
| 16.650 | 1418.2 | 233.4 | 4.04 | 57.8 | 14.33 | 6.90 | 0.040 | 3.86 | 6.08 | 1.06 | 0.53 | 104.6 | 60.5 |
| 16.750 | 1466.6 | 239.3 | 4.09 | 58.4 | 14.27 | 7.00 | 0.040 | 3.91 | 6.13 | 1.07 | 0.53 | 106.1 | 61.1 |
| 16.850 | 1515.8 | 245.1 | 4.15 | 59.0 | 14.22 | 7.10 | 0.040 | 3.97 | 6.18 | 1.09 | 0.53 | 107.5 | 61.8 |
| 16.950 | 1566.0 | 251.1 | 4.21 | 59.6 | 14.17 | 7.20 | 0.040 | 4.02 | 6.24 | 1.10 | 0.54 | 109.0 | 62.4 |
| 17.050 | 1617.0 | 257.1 | 4.27 | 60.2 | 14.12 | 7.30 | 0.040 | 4.08 | 6.29 | 1.12 | 0.54 | 110.5 | 63.0 |
| 17.150 | 1669.0 | 263.1 | 4.32 | 60.8 | 14.07 | 7.40 | 0.040 | 4.13 | 6.34 | 1.13 | 0.54 | 112.0 | 63.6 |
| 17.250 | 1721.9 | 269.2 | 4.38 | 61.4 | 14.02 | 7.50 | 0.040 | 4.19 | 6.40 | 1.15 | 0.54 | 113.5 | 64.3 |
| 17.350 | 1775.7 | 275.4 | 4.44 | 62.0 | 13.98 | 7.60 | 0.040 | 4.24 | 6.45 | 1.16 | 0.54 | 114.9 | 64.9 |
| 17.450 | 1830.5 | 281.6 | 4.50 | 62.6 | 13.93 | 7.70 | 0.040 | 4.30 | 6.50 | 1.18 | 0.54 | 116.4 | 65.5 |
| 17.550 | 1886.2 | 287.9 | 4.55 | 63.2 | 13.89 | 7.80 | 0.040 | 4.35 | 6.55 | 1.19 | 0.54 | 117.9 | 66.2 |
| 17.650 | 1942.8 | 294.3 | 4.61 | 63.8 | 13.85 | 7.90 | 0.040 | 4.40 | 6.60 | 1.21 | 0.54 | 119.3 | 66.8 |
| 17.750 | 2000.4 | 300.7 | 4.67 | 64.4 | 13.81 | 8.00 | 0.040 | 4.46 | 6.65 | 1.22 | 0.54 | 120.8 | 67.4 |
| 17.850 | 2058.9 | 307.2 | 4.72 | 65.0 | 13.77 | 8.10 | 0.040 | 4.51 | 6.70 | 1.24 | 0.54 | 122.2 | 68.1 |
| 17.950 | 2118.4 | 313.7 | 4.78 | 65.6 | 13.73 | 8.20 | 0.040 | 4.57 | 6.75 | 1.25 | 0.54 | 123.7 | 68.7 |

11/2/2007 Proposed Typical C4 Cross Section Riffle

**Table 3 - Existing B4 Riffle Cross Section Reach 2 Analysis**

| Symbol | Quantity | Value | Units |
|---|---|---|---|
| *Cross Section Controls:* | | | |
| S | HEC-RAS Energy Slope | 0.0058 | |
| $d_{50}$ | Median Grain Diameter | 34.0 | |
| $\tau^*$ | Shields Parameter | 0.030 | mm |
| | | | |
| *User Input:* | | | |
| $Z_{bf}$ | Bankfull Water Surface Elevation | 91.70 | ft |
| $Z_{AC}$ | Active Channel Elevation | 89.61 | ft |
| | | | |
| *Rating Curve Controls:* | | | |
| $Z_f$ | Terminating Elevation | 94.00 | |
| $Z_i$ | Elevation Incremetns | 0.100 | |
| | | | |
| *Bankfull Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 89.30 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 131 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 33.8 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 1.58 | ft |
| $W_{bf}$ | Bankfull Width | 21.4 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 13.6 | |
| $d_{max}$ | Maximum Depth | 2.40 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.038 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 1.47 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 3.87 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.53 | $lbs/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.54 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 52 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 23.1 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 1.71 | |
| $Z_{fp}$ | Floodprone Elevation | 94.1 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 541.1 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 101.8 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 4.80 | ft |
| $W_{fp}$ | Floodprone Width | 36.7 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.040 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 2.58 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 5.32 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.93 | $lbs/ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 92 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 39.5 | ft |
| | | | |
| *Active Channel Analysis:* | | | |
| | | | |
| $Z_0$ | Thalweg Elevation | 89.30 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 2 | $ft^3$/sec |
| $A_{bf}$ | Bankfull Area | 1.8 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 0.18 | ft |
| $W_{bf}$ | Bankfull Width | 10.1 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 56.4 | |
| $d_{max}$ | Maximum Depth | 0.31 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.034 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 0.18 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 1.06 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.06 | $lbs/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.44 | |
| $D_{crit}$ | Critical Sediment Size at Bankfull | 6 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 10.2 | ft |
| $W_{fp}/W_{bf}$ | Entrenchment Ratio | 1.20 | |
| $Z_{fp}$ | Floodprone Elevation | 89.9 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 10.3 | $ft^3$/sec |
| $A_{fp}$ | Floodprone Area | 5.4 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 0.44 | ft |
| $W_{fp}$ | Floodprone Width | 12.2 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.034 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 0.43 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 1.90 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.16 | $lbs/ft^2$ |
| $D_{crit}$ | Critical Sediment Size at Floodprone | 15 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 12.5 | ft |

**Stream Channel Cross Sectional Survey Data:**

Riffle

| Cross Section Survey | | | |
|---|---|---|---|
| Features | Station (X) (feet) | Elev. (Z) (feet) | Mannings "n" |
| GS | 0.00 | 95.01 | |
| GS | 2.00 | 94.96 | |
| LTOB | 3.90 | 94.88 | |
| SLP BRK | 5.40 | 94.40 | 0.043 |
| SLP BRK | 6.80 | 93.92 | 0.043 |
| SLP BRK | 8.50 | 93.19 | 0.043 |
| IP | 9.50 | 92.52 | 0.043 |
| LBF | 9.86 | 91.70 | 0.043 |
| SLP BRK | 10.00 | 91.39 | 0.043 |
| SLP BRK | 11.00 | 90.66 | 0.043 |
| LEW | 12.60 | 89.61 | 0.034 |
| CS | 12.70 | 89.49 | 0.034 |
| CS | 13.50 | 89.42 | 0.034 |
| CS | 15.00 | 89.35 | 0.034 |
| CS | 17.50 | 89.30 | 0.034 |
| CS | 19.00 | 89.51 | 0.034 |
| CS | 20.50 | 89.47 | 0.034 |
| REW | 22.90 | 89.62 | 0.034 |
| TOE | 24.30 | 89.74 | 0.034 |
| IP | 24.50 | 90.60 | 0.043 |
| FLAT | 26.50 | 90.90 | 0.043 |
| BCK FLAT | 29.00 | 91.19 | 0.043 |
| RBF | 31.30 | 91.70 | 0.043 |
| SLP BRK | 34.50 | 92.36 | 0.043 |
| SLP BRK | 37.00 | 93.09 | 0.043 |
| SLP BRK | 40.00 | 93.48 | 0.043 |
| SLP BRK | 41.90 | 93.79 | 0.043 |
| FLAT | 44.70 | 94.60 | 0.043 |
| GS | 47.50 | 94.83 | |

| $Z_i$ Elevation ft | $Q_i$ Discharge $ft^3$/sec | $A_i$ Cross Section Area $ft^2$ | $d_i$ Mean Depth ft | $W_i$ Width ft | $W_i/d_i$ Width/ Depth Ratio | $d_{max(i)}$ Maximum Depth ft | $n_i$ Composite "n" | $R_i$ Hydraulic Radius ft | $V_i$ Mean Velocity ft/sec | $\tau_o$ Shear Stress $lbs/ft^2$ | $Fr_i$ Froude Number | $D_{crit(i)}$ Critical Sediment Size mm | $P_i$ Wetted Perimeter ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 89.300 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 89.400 | 0.1 | 0.3 | 0.06 | 4.3 | 73.47 | 0.10 | 0.034 | 0.06 | 0.50 | 0.02 | 0.36 | 2.1 | 4.3 |
| 89.500 | 0.6 | 0.8 | 0.10 | 7.8 | 75.64 | 0.20 | 0.034 | 0.10 | 0.73 | 0.04 | 0.40 | 3.7 | 7.9 |
| 89.600 | 1.8 | 1.7 | 0.17 | 10.0 | 57.69 | 0.30 | 0.034 | 0.17 | 1.03 | 0.06 | 0.44 | 6.1 | 10.0 |
| 89.700 | 3.6 | 2.8 | 0.25 | 11.4 | 46.27 | 0.40 | 0.034 | 0.24 | 1.30 | 0.09 | 0.48 | 8.7 | 11.5 |
| 89.800 | 6.3 | 4.0 | 0.33 | 12.0 | 36.23 | 0.50 | 0.034 | 0.33 | 1.57 | 0.12 | 0.48 | 11.6 | 12.2 |
| 89.900 | 9.6 | 5.2 | 0.43 | 12.2 | 28.60 | 0.60 | 0.034 | 0.42 | 1.85 | 0.15 | 0.50 | 14.8 | 12.5 |
| 90.000 | 13.4 | 6.4 | 0.52 | 12.4 | 23.80 | 0.70 | 0.034 | 0.50 | 2.09 | 0.18 | 0.51 | 17.9 | 12.8 |
| 90.100 | 17.7 | 7.7 | 0.61 | 12.5 | 20.51 | 0.80 | 0.034 | 0.59 | 2.31 | 0.21 | 0.52 | 21.0 | 13.0 |
| 90.200 | 22.5 | 8.9 | 0.70 | 12.7 | 18.10 | 0.90 | 0.034 | 0.67 | 2.52 | 0.24 | 0.53 | 23.9 | 13.3 |
| 90.300 | 27.7 | 10.2 | 0.79 | 12.9 | 16.27 | 1.00 | 0.034 | 0.75 | 2.71 | 0.27 | 0.54 | 26.7 | 13.6 |
| 90.400 | 33.2 | 11.5 | 0.88 | 13.1 | 14.83 | 1.10 | 0.034 | 0.83 | 2.89 | 0.30 | 0.54 | 29.5 | 13.9 |
| 90.500 | 39.2 | 12.8 | 0.97 | 13.2 | 13.67 | 1.20 | 0.035 | 0.90 | 3.06 | 0.33 | 0.55 | 32.2 | 14.2 |
| 90.600 | 45.6 | 14.1 | 1.05 | 13.4 | 12.71 | 1.30 | 0.035 | 0.98 | 3.22 | 0.35 | 0.55 | 34.9 | 14.5 |
| 90.700 | 50.6 | 15.5 | 1.09 | 14.2 | 13.03 | 1.40 | 0.035 | 1.01 | 3.28 | 0.37 | 0.55 | 36.2 | 15.3 |
| 90.800 | 56.0 | 17.0 | 1.13 | 15.0 | 13.29 | 1.50 | 0.035 | 1.05 | 3.30 | 0.38 | 0.55 | 37.5 | 16.2 |
| 90.900 | 61.9 | 18.5 | 1.17 | 15.8 | 13.52 | 1.60 | 0.036 | 1.09 | 3.34 | 0.39 | 0.54 | 38.9 | 17.0 |
| 91.000 | 67.7 | 20.2 | 1.20 | 16.8 | 14.05 | 1.70 | 0.036 | 1.12 | 3.36 | 0.40 | 0.54 | 39.9 | 18.0 |
| 91.100 | 74.1 | 21.9 | 1.23 | 17.8 | 14.52 | 1.80 | 0.037 | 1.15 | 3.38 | 0.42 | 0.54 | 41.0 | 19.1 |
| 91.200 | 81.1 | 23.7 | 1.26 | 18.8 | 14.87 | 1.90 | 0.037 | 1.18 | 3.42 | 0.43 | 0.54 | 42.2 | 20.1 |
| 91.300 | 90.0 | 25.6 | 1.32 | 19.4 | 14.64 | 2.00 | 0.037 | 1.24 | 3.51 | 0.45 | 0.54 | 44.2 | 20.7 |
| 91.400 | 99.3 | 27.6 | 1.38 | 20.0 | 14.42 | 2.10 | 0.037 | 1.29 | 3.60 | 0.47 | 0.54 | 46.2 | 21.3 |
| 91.500 | 109.3 | 29.6 | 1.45 | 20.4 | 14.12 | 2.20 | 0.037 | 1.35 | 3.69 | 0.49 | 0.54 | 48.3 | 21.9 |
| 91.600 | 119.8 | 31.7 | 1.51 | 20.9 | 13.84 | 2.30 | 0.038 | 1.41 | 3.78 | 0.51 | 0.54 | 50.3 | 22.5 |
| 91.700 | 130.7 | 33.8 | 1.58 | 21.4 | 13.60 | 2.40 | 0.038 | 1.47 | 3.87 | 0.53 | 0.54 | 52.4 | 23.1 |
| 91.800 | 142.0 | 36.0 | 1.64 | 22.0 | 13.41 | 2.50 | 0.038 | 1.52 | 3.95 | 0.55 | 0.54 | 54.3 | 23.7 |
| 91.900 | 153.8 | 38.2 | 1.70 | 22.5 | 13.25 | 2.60 | 0.038 | 1.57 | 4.03 | 0.57 | 0.54 | 56.2 | 24.3 |
| 92.000 | 166.1 | 40.5 | 1.76 | 23.0 | 13.10 | 2.70 | 0.038 | 1.63 | 4.10 | 0.59 | 0.55 | 58.1 | 24.9 |
| 92.100 | 178.8 | 42.8 | 1.82 | 23.6 | 12.96 | 2.80 | 0.038 | 1.68 | 4.18 | 0.61 | 0.55 | 60.0 | 25.5 |
| 92.200 | 192.1 | 45.2 | 1.88 | 24.1 | 12.84 | 2.90 | 0.038 | 1.73 | 4.25 | 0.63 | 0.55 | 61.9 | 26.1 |
| 92.300 | 205.9 | 47.6 | 1.93 | 24.6 | 12.72 | 3.00 | 0.039 | 1.78 | 4.32 | 0.65 | 0.55 | 63.7 | 26.7 |
| 92.400 | 220.6 | 50.1 | 2.00 | 25.1 | 12.56 | 3.10 | 0.039 | 1.84 | 4.40 | 0.67 | 0.55 | 65.7 | 27.2 |
| 92.500 | 236.3 | 52.6 | 2.07 | 25.5 | 12.32 | 3.20 | 0.039 | 1.90 | 4.49 | 0.69 | 0.55 | 67.9 | 27.7 |
| 92.600 | 252.1 | 55.2 | 2.13 | 25.9 | 12.19 | 3.30 | 0.039 | 1.96 | 4.57 | 0.71 | 0.55 | 69.9 | 28.2 |
| 92.700 | 268.4 | 57.8 | 2.19 | 26.4 | 12.08 | 3.40 | 0.039 | 2.01 | 4.64 | 0.73 | 0.55 | 71.8 | 28.8 |
| 92.800 | 285.3 | 60.5 | 2.25 | 26.9 | 11.98 | 3.50 | 0.039 | 2.07 | 4.72 | 0.75 | 0.55 | 73.8 | 29.3 |
| 92.900 | 302.7 | 63.2 | 2.31 | 27.4 | 11.89 | 3.60 | 0.039 | 2.12 | 4.79 | 0.77 | 0.56 | 75.7 | 29.8 |
| 93.000 | 320.6 | 66.0 | 2.36 | 27.9 | 11.80 | 3.70 | 0.039 | 2.17 | 4.86 | 0.79 | 0.56 | 77.6 | 30.4 |
| 93.100 | 338.8 | 68.8 | 2.42 | 28.4 | 11.76 | 3.80 | 0.039 | 2.22 | 4.92 | 0.80 | 0.56 | 79.4 | 30.9 |
| 93.200 | 354.4 | 71.7 | 2.44 | 29.4 | 12.03 | 3.90 | 0.039 | 2.25 | 4.94 | 0.81 | 0.56 | 80.2 | 31.9 |
| 93.300 | 370.3 | 74.7 | 2.46 | 30.4 | 12.35 | 4.00 | 0.039 | 2.27 | 4.96 | 0.82 | 0.56 | 81.0 | 32.9 |
| 93.400 | 387.1 | 77.8 | 2.48 | 31.4 | 12.66 | 4.10 | 0.039 | 2.29 | 4.98 | 0.83 | 0.56 | 81.8 | 34.0 |
| 93.500 | 404.9 | 80.9 | 2.50 | 32.3 | 12.92 | 4.20 | 0.040 | 2.32 | 5.00 | 0.84 | 0.56 | 82.7 | 35.0 |
| 93.600 | 424.6 | 84.2 | 2.54 | 33.2 | 13.08 | 4.30 | 0.040 | 2.35 | 5.04 | 0.85 | 0.56 | 83.9 | 35.8 |
| 93.700 | 445.1 | 87.6 | 2.57 | 34.0 | 13.23 | 4.40 | 0.040 | 2.39 | 5.08 | 0.86 | 0.56 | 85.2 | 36.7 |
| 93.800 | 466.6 | 91.0 | 2.61 | 34.9 | 13.35 | 4.50 | 0.040 | 2.42 | 5.13 | 0.88 | 0.56 | 86.6 | 37.6 |
| 93.900 | 491.0 | 94.5 | 2.67 | 35.4 | 13.28 | 4.60 | 0.040 | 2.48 | 5.19 | 0.90 | 0.56 | 88.5 | 38.2 |
| 94.000 | 515.8 | 98.1 | 2.72 | 36.1 | 13.25 | 4.70 | 0.040 | 2.53 | 5.26 | 0.91 | 0.56 | 90.2 | 38.8 |

11/2/2007 Shear Stress (Existing Condition) XS 3 (Riffle)

**Table 4 - Proposed Riffle B4 Cross Section Analysis**

| Symbol | Quantity | Value | Units |
|---|---|---|---|
| *Cross Section Controls:* | | | |
| S | HEC-RAS Energy Slope | 0.0044 | |
| $d_{50}$ | Median Grain Diameter | 32.7 | |
| $\tau^*$ | Shields Parameter | 0.030 | mm |
| | | | |
| *User Input:* | | | |
| $Z_{bf}$ | Bankfull Water Surface Elevation | 12.00 | ft |
| $Z_{AC}$ | Active Channel Elevation | 11.00 | ft |
| | | | |
| *Rating Curve Controls:* | | | |
| $Z_t$ | Terminating Elevation | 18.00 | |
| $Z_i$ | Elevation Incrementns | 0.100 | |
| | | | |
| *Bankfull Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 9.50 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 107 | $ft^3/sec$ |
| $A_{bf}$ | Bankfull Area | 31.0 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 1.47 | ft |
| $W_{bf}$ | Bankfull Width | 21.0 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 14.2 | |
| $d_{max}$ | Maximum Depth | 2.50 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.036 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 1.41 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 3.44 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.39 | $lb/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.50 | |
| $D_{cri}$ | Critical Sediment Size at Bankfull | 38 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 22.0 | ft |
| $W_b/W_{bf}$ | Entrenchment Ratio | 2.00 | |
| $Z_{fp}$ | Floodprone Elevation | 14.5 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 569.6 | $ft^3/sec$ |
| $A_{fp}$ | Floodprone Area | 117.0 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 5.00 | ft |
| $W_{fp}$ | Floodprone Width | 41.9 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.039 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 2.68 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 4.87 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.73 | $lb/ft^2$ |
| $D_{cri}$ | Critical Sediment Size at Floodpron | 72 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 43.7 | ft |
| | | | |
| *Active Channel Analysis:* | | | |
| $Z_0$ | Thalweg Elevation | 9.50 | |
| $Q_{bf}$ | Bankfull Discharge (computed) | 35 | $ft^3/sec$ |
| $A_{bf}$ | Bankfull Area | 12.0 | $ft^2$ |
| $d_{bf}$ | Mean Bankfull Depth | 1.00 | ft |
| $W_{bf}$ | Bankfull Width | 12.0 | ft |
| $W_{bf}/d_{bf}$ | Width/Depth ratio | 12.0 | |
| $d_{max}$ | Maximum Depth | 1.50 | ft |
| $n_{bf}$ | Bankfull Composite "n" | 0.033 | |
| $R_{bf}$ | Bankfull Hydraulic Radius | 0.96 | ft |
| $V_{bf}$ | Average Bankfull Velocity | 2.90 | ft/sec |
| $\tau_o$ | Bankfull Shear Stress | 0.26 | $lb/ft^2$ |
| $Fr_{bf}$ | Froude (Bankfull) | 0.51 | |
| $D_{cri}$ | Critical Sediment Size at Bankfull | 26 | mm |
| $P_{bf}$ | Bankfull Wetted Perimeter | 12.5 | ft |
| $W_b/W_{bf}$ | Entrenchment Ratio | 2.50 | |
| $Z_{fp}$ | Floodprone Elevation | 12.5 | ft |
| $Q_{fp}$ | Floodprone Discharge (computed) | 151.0 | $ft^3/sec$ |
| $A_{fp}$ | Floodprone Area | 45.1 | $ft^2$ |
| $d_{fp}$ | Mean Floodprone Depth | 1.51 | ft |
| $W_{fp}$ | Floodprone Width | 29.9 | ft |
| $n_{fp}$ | Floodprone Composite "n" | 0.038 | |
| $R_{fp}$ | Floodprone Hydraulic Radius | 1.45 | ft |
| $V_{fp}$ | Average Floodprone Velocity | 3.34 | ft/sec |
| $\tau_o$ | Floodprone Shear Stress | 0.40 | $lb/ft^2$ |
| $D_{cri}$ | Critical Sediment Size at Floodpron | 39 | mm |
| $P_{fp}$ | Floodprone Wetted Perimeter | 31.1 | ft |

**Stream Channel Cross Sectional Survey Data:**

Riffle

| Cross Section Survey | | | |
|---|---|---|---|
| Features | Station (X) (feet) | Elev. (Z) (feet) | Mannings "n" |
| 3:1 Extension | 18.53 | 18.00 | 0.042 |
| FP | 29.03 | 14.60 | 0.042 |
| Toe FP | 36.50 | 12.01 | 0.042 |
| BF | 39.50 | 12.00 | 0.042 |
| Toe BF | 41.50 | 11.01 | 0.042 |
| AC | 44.00 | 11.00 | 0.033 |
| Toe AC | 46.00 | 10.00 | 0.033 |
| Thalweg | 50.00 | 9.50 | 0.033 |
| | 54.00 | 10.00 | 0.033 |
| | 56.00 | 11.00 | 0.033 |
| | 58.50 | 11.01 | 0.042 |
| | 60.50 | 12.00 | 0.042 |
| | 63.50 | 12.01 | 0.042 |
| | 70.97 | 14.50 | 0.042 |
| | 81.47 | 18.00 | 0.042 |

| $Z_i$ Elevation (ft) | $Q_i$ Discharge ($ft^3/sec$) | $A_i$ Cross Section Area ($ft^2$) | $d_i$ Mean Depth (ft) | $W_i$ Width (ft) | $W_i/d_i$ Width/ Depth Ratio | $d_{max(i)}$ Maximum Depth (ft) | $n_i$ Composite "n" | $R_i$ Hydraulic Radius (ft) | $V_i$ Mean Velocity (ft/sec) | $\tau_o$ Shear Stress ($lbs/ft^2$) | $Fr_i$ Froude Number | $D_{cri(i)}$ Critical Sediment Size (mm) | $P_i$ Wetted Perimeter (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.500 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9.600 | 0.0 | 0.1 | 0.05 | 1.6 | 32.00 | 0.10 | 0.033 | 0.05 | 0.40 | 0.01 | 0.32 | 1.3 | 1.6 |
| 9.700 | 0.2 | 0.3 | 0.10 | 3.2 | 32.00 | 0.20 | 0.033 | 0.10 | 0.64 | 0.03 | 0.36 | 2.7 | 3.2 |
| 9.800 | 0.6 | 0.7 | 0.15 | 4.8 | 32.00 | 0.30 | 0.033 | 0.15 | 0.84 | 0.04 | 0.38 | 4.0 | 4.8 |
| 9.900 | 1.3 | 1.3 | 0.20 | 6.4 | 32.00 | 0.40 | 0.033 | 0.20 | 1.02 | 0.05 | 0.40 | 5.4 | 6.4 |
| 10.000 | 2.4 | 2.0 | 0.25 | 8.0 | 32.00 | 0.50 | 0.033 | 0.25 | 1.18 | 0.07 | 0.42 | 6.7 | 8.1 |
| 10.100 | 4.0 | 2.8 | 0.34 | 8.4 | 25.02 | 0.60 | 0.033 | 0.33 | 1.43 | 0.09 | 0.44 | 9.0 | 8.5 |
| 10.200 | 6.1 | 3.7 | 0.42 | 8.8 | 21.04 | 0.70 | 0.033 | 0.41 | 1.65 | 0.11 | 0.45 | 11.1 | 9.0 |
| 10.300 | 8.5 | 4.6 | 0.50 | 9.2 | 18.48 | 0.80 | 0.033 | 0.49 | 1.86 | 0.13 | 0.46 | 13.2 | 9.4 |
| 10.400 | 11.2 | 5.5 | 0.58 | 9.6 | 16.70 | 0.90 | 0.033 | 0.56 | 2.03 | 0.15 | 0.47 | 15.2 | 9.9 |
| 10.500 | 14.3 | 6.5 | 0.65 | 10.0 | 15.38 | 1.00 | 0.033 | 0.63 | 2.20 | 0.17 | 0.48 | 17.1 | 10.3 |
| 10.600 | 17.7 | 7.5 | 0.72 | 10.4 | 14.38 | 1.10 | 0.033 | 0.70 | 2.35 | 0.19 | 0.49 | 19.0 | 10.7 |
| 10.700 | 21.5 | 8.6 | 0.79 | 10.8 | 13.59 | 1.20 | 0.033 | 0.77 | 2.50 | 0.21 | 0.49 | 20.8 | 11.2 |
| 10.800 | 25.6 | 9.7 | 0.86 | 11.2 | 12.96 | 1.30 | 0.033 | 0.83 | 2.64 | 0.23 | 0.50 | 22.5 | 11.6 |
| 10.900 | 30.0 | 10.8 | 0.93 | 11.6 | 12.44 | 1.40 | 0.033 | 0.90 | 2.77 | 0.25 | 0.51 | 24.3 | 12.1 |
| 11.000 | 34.8 | 12.0 | 1.00 | 12.0 | 12.00 | 1.50 | 0.033 | 0.96 | 2.90 | 0.26 | 0.51 | 25.9 | 12.5 |
| 11.100 | 32.6 | 13.7 | 0.79 | 17.4 | 22.02 | 1.60 | 0.035 | 0.76 | 2.38 | 0.21 | 0.47 | 20.7 | 17.9 |
| 11.200 | 39.0 | 15.4 | 0.87 | 17.8 | 20.44 | 1.70 | 0.035 | 0.84 | 2.53 | 0.23 | 0.48 | 22.8 | 18.4 |
| 11.300 | 45.9 | 17.2 | 0.95 | 18.2 | 19.15 | 1.80 | 0.035 | 0.92 | 2.66 | 0.25 | 0.48 | 24.8 | 18.8 |
| 11.400 | 53.2 | 19.1 | 1.03 | 18.6 | 18.08 | 1.90 | 0.035 | 0.99 | 2.79 | 0.27 | 0.48 | 26.8 | 19.3 |
| 11.500 | 61.0 | 21.0 | 1.10 | 19.0 | 17.19 | 2.00 | 0.035 | 1.06 | 2.91 | 0.29 | 0.49 | 28.8 | 19.7 |
| 11.600 | 69.2 | 22.9 | 1.18 | 19.4 | 16.42 | 2.10 | 0.035 | 1.13 | 3.03 | 0.31 | 0.49 | 30.7 | 20.2 |
| 11.700 | 77.9 | 24.8 | 1.26 | 19.8 | 15.77 | 2.20 | 0.036 | 1.20 | 3.14 | 0.33 | 0.49 | 32.6 | 20.6 |
| 11.800 | 87.0 | 26.8 | 1.33 | 20.2 | 15.19 | 2.30 | 0.036 | 1.27 | 3.24 | 0.35 | 0.50 | 34.5 | 21.1 |
| 11.900 | 96.5 | 28.9 | 1.40 | 20.6 | 14.69 | 2.40 | 0.036 | 1.34 | 3.34 | 0.37 | 0.50 | 36.3 | 21.5 |
| 12.000 | 106.5 | 31.0 | 1.47 | 21.0 | 14.25 | 2.50 | 0.036 | 1.41 | 3.44 | 0.39 | 0.50 | 38.1 | 22.0 |
| 12.100 | 98.9 | 33.6 | 1.22 | 27.5 | 22.54 | 2.60 | 0.037 | 1.18 | 2.94 | 0.32 | 0.47 | 31.9 | 28.6 |
| 12.200 | 111.0 | 36.4 | 1.29 | 28.1 | 21.73 | 2.70 | 0.037 | 1.25 | 3.05 | 0.34 | 0.47 | 33.0 | 29.2 |
| 12.300 | 123.7 | 39.3 | 1.37 | 28.7 | 21.03 | 2.80 | 0.038 | 1.32 | 3.15 | 0.36 | 0.47 | 35.7 | 29.8 |
| 12.400 | 137.0 | 42.2 | 1.44 | 29.3 | 20.41 | 2.90 | 0.038 | 1.38 | 3.25 | 0.38 | 0.48 | 37.6 | 30.5 |
| 12.500 | 151.0 | 45.1 | 1.51 | 29.9 | 19.86 | 3.00 | 0.038 | 1.45 | 3.34 | 0.40 | 0.48 | 39.3 | 31.1 |
| 12.600 | 165.6 | 48.2 | 1.58 | 30.5 | 19.36 | 3.10 | 0.038 | 1.52 | 3.44 | 0.42 | 0.48 | 41.1 | 31.7 |
| 12.700 | 180.9 | 51.3 | 1.65 | 31.1 | 18.92 | 3.20 | 0.038 | 1.58 | 3.53 | 0.43 | 0.48 | 42.9 | 32.4 |
| 12.800 | 196.8 | 54.4 | 1.71 | 31.7 | 18.52 | 3.30 | 0.038 | 1.65 | 3.62 | 0.45 | 0.49 | 44.7 | 33.0 |
| 12.900 | 213.3 | 57.6 | 1.78 | 32.3 | 18.16 | 3.40 | 0.038 | 1.71 | 3.70 | 0.47 | 0.49 | 46.4 | 33.6 |
| 13.000 | 230.5 | 60.9 | 1.85 | 32.9 | 17.83 | 3.50 | 0.038 | 1.78 | 3.79 | 0.49 | 0.49 | 48.1 | 34.3 |
| 13.100 | 248.3 | 64.2 | 1.91 | 33.5 | 17.53 | 3.60 | 0.038 | 1.84 | 3.87 | 0.51 | 0.49 | 49.8 | 34.9 |
| 13.200 | 266.8 | 67.6 | 1.98 | 34.1 | 17.25 | 3.70 | 0.038 | 1.90 | 3.95 | 0.52 | 0.49 | 51.5 | 35.5 |
| 13.300 | 286.0 | 71.0 | 2.04 | 34.7 | 16.99 | 3.80 | 0.038 | 1.96 | 4.03 | 0.54 | 0.50 | 53.2 | 36.2 |
| 13.400 | 305.8 | 74.5 | 2.11 | 35.3 | 16.76 | 3.90 | 0.038 | 2.03 | 4.10 | 0.56 | 0.50 | 54.9 | 36.8 |
| 13.500 | 326.4 | 78.1 | 2.17 | 35.9 | 16.54 | 4.00 | 0.039 | 2.09 | 4.18 | 0.57 | 0.50 | 56.5 | 37.4 |
| 13.600 | 347.5 | 81.7 | 2.24 | 36.5 | 16.34 | 4.10 | 0.039 | 2.15 | 4.25 | 0.59 | 0.50 | 58.2 | 38.1 |
| 13.700 | 369.4 | 85.4 | 2.30 | 37.1 | 16.15 | 4.20 | 0.039 | 2.21 | 4.33 | 0.61 | 0.50 | 59.8 | 38.7 |
| 13.800 | 392.0 | 89.1 | 2.36 | 37.7 | 15.98 | 4.30 | 0.039 | 2.27 | 4.40 | 0.62 | 0.50 | 61.4 | 39.3 |
| 13.900 | 415.2 | 92.9 | 2.42 | 38.3 | 15.82 | 4.40 | 0.039 | 2.33 | 4.47 | 0.64 | 0.51 | 63.0 | 40.0 |
| 14.000 | 439.2 | 96.8 | 2.49 | 38.9 | 15.66 | 4.50 | 0.039 | 2.39 | 4.54 | 0.65 | 0.51 | 64.6 | 40.6 |
| 14.100 | 463.8 | 100.7 | 2.55 | 39.5 | 15.52 | 4.60 | 0.039 | 2.44 | 4.60 | 0.67 | 0.51 | 66.2 | 41.2 |
| 14.200 | 489.2 | 104.7 | 2.61 | 40.1 | 15.39 | 4.70 | 0.039 | 2.50 | 4.67 | 0.69 | 0.51 | 67.8 | 41.8 |
| 14.300 | 515.3 | 108.8 | 2.67 | 40.7 | 15.26 | 4.80 | 0.039 | 2.56 | 4.74 | 0.70 | 0.51 | 69.4 | 42.5 |
| 14.400 | 542.1 | 112.9 | 2.73 | 41.3 | 15.14 | 4.90 | 0.039 | 2.62 | 4.80 | 0.72 | 0.51 | 70.9 | 43.1 |
| 14.500 | 569.6 | 117.0 | 2.79 | 41.9 | 15.03 | 5.00 | 0.039 | 2.68 | 4.87 | 0.73 | 0.51 | 72.5 | 43.7 |
| 14.600 | 597.9 | 121.2 | 2.85 | 42.5 | 14.93 | 5.10 | 0.039 | 2.73 | 4.93 | 0.75 | 0.51 | 74.0 | 44.4 |
| 14.700 | 626.9 | 125.5 | 2.91 | 43.1 | 14.83 | 5.20 | 0.039 | 2.79 | 4.99 | 0.77 | 0.52 | 75.6 | 45.0 |
| 14.800 | 656.6 | 129.9 | 2.97 | 43.7 | 14.73 | 5.30 | 0.039 | 2.85 | 5.06 | 0.78 | 0.52 | 77.1 | 45.6 |
| 14.900 | 687.1 | 134.3 | 3.03 | 44.3 | 14.64 | 5.40 | 0.039 | 2.90 | 5.12 | 0.80 | 0.52 | 78.6 | 46.3 |
| 15.000 | 718.3 | 138.7 | 3.09 | 44.9 | 14.56 | 5.50 | 0.039 | 2.96 | 5.18 | 0.81 | 0.52 | 80.1 | 46.9 |
| 15.100 | 750.3 | 143.3 | 3.15 | 45.5 | 14.48 | 5.60 | 0.039 | 3.01 | 5.24 | 0.83 | 0.52 | 81.6 | 47.5 |
| 15.200 | 783.1 | 147.9 | 3.20 | 46.1 | 14.40 | 5.70 | 0.039 | 3.07 | 5.30 | 0.84 | 0.52 | 83.2 | 48.2 |
| 15.300 | 816.7 | 152.5 | 3.26 | 46.7 | 14.33 | 5.80 | 0.039 | 3.12 | 5.36 | 0.86 | 0.52 | 84.7 | 48.8 |
| 15.400 | 851.0 | 157.2 | 3.32 | 47.3 | 14.26 | 5.90 | 0.039 | 3.18 | 5.41 | 0.87 | 0.52 | 86.2 | 49.4 |
| 15.500 | 886.1 | 162.0 | 3.38 | 47.9 | 14.19 | 6.00 | 0.039 | 3.23 | 5.47 | 0.89 | 0.52 | 87.6 | 50.1 |
| 15.600 | 922.0 | 166.8 | 3.44 | 48.5 | 14.13 | 6.10 | 0.039 | 3.29 | 5.53 | 0.90 | 0.53 | 89.1 | 50.7 |
| 15.700 | 958.7 | 171.7 | 3.49 | 49.1 | 14.07 | 6.20 | 0.039 | 3.34 | 5.58 | 0.92 | 0.53 | 90.6 | 51.3 |
| 15.800 | 996.2 | 176.6 | 3.55 | 49.7 | 14.01 | 6.30 | 0.040 | 3.40 | 5.64 | 0.93 | 0.53 | 92.1 | 52.0 |
| 15.900 | 1034.5 | 181.6 | 3.61 | 50.3 | 13.95 | 6.40 | 0.040 | 3.45 | 5.70 | 0.95 | 0.53 | 93.5 | 52.6 |
| 16.000 | 1073.6 | 186.7 | 3.66 | 50.9 | 13.90 | 6.50 | 0.040 | 3.51 | 5.75 | 0.96 | 0.53 | 95.0 | 53.2 |
| 16.100 | 1113.5 | 191.8 | 3.72 | 51.5 | 13.85 | 6.60 | 0.040 | 3.56 | 5.81 | 0.98 | 0.53 | 96.5 | 53.9 |
| 16.200 | 1154.3 | 197.0 | 3.78 | 52.1 | 13.80 | 6.70 | 0.040 | 3.61 | 5.86 | 0.99 | 0.53 | 97.9 | 54.5 |
| 16.300 | 1195.9 | 202.2 | 3.83 | 52.7 | 13.75 | 6.80 | 0.040 | 3.67 | 5.91 | 1.01 | 0.53 | 99.4 | 55.1 |
| 16.400 | 1238.3 | 207.5 | 3.89 | 53.3 | 13.71 | 6.90 | 0.040 | 3.72 | 5.97 | 1.02 | 0.53 | 100.8 | 55.8 |
| 16.500 | 1281.6 | 212.9 | 3.95 | 53.9 | 13.67 | 7.00 | 0.040 | 3.78 | 6.02 | 1.04 | 0.53 | 102.3 | 56.4 |
| 16.600 | 1325.7 | 218.3 | 4.00 | 54.5 | 13.62 | 7.10 | 0.040 | 3.83 | 6.07 | 1.05 | 0.53 | 103.7 | 57.0 |
| 16.700 | 1370.7 | 223.8 | 4.06 | 55.1 | 13.58 | 7.20 | 0.040 | 3.88 | 6.12 | 1.07 | 0.54 | 105.2 | 57.7 |
| 16.800 | 1416.5 | 229.4 | 4.11 | 55.7 | 13.55 | 7.30 | 0.040 | 3.93 | 6.18 | 1.08 | 0.54 | 106.6 | 58.3 |
| 16.900 | 1463.2 | 235.0 | 4.17 | 56.3 | 13.51 | 7.40 | 0.040 | 3.99 | 6.23 | 1.09 | 0.54 | 108.0 | 58.9 |
| 17.000 | 1510.7 | 240.6 | 4.23 | 56.9 | 13.47 | 7.50 | 0.040 | 4.04 | 6.28 | 1.11 | 0.54 | 109.5 | 59.6 |
| 17.100 | 1559.2 | 246.3 | 4.28 | 57.5 | 13.44 | 7.60 | 0.040 | 4.09 | 6.33 | 1.12 | 0.54 | 110.9 | 60.2 |
| 17.200 | 1608.5 | 252.1 | 4.34 | 58.1 | 13.41 | 7.70 | 0.040 | 4.15 | 6.38 | 1.14 | 0.54 | 112.3 | 60.8 |
| 17.300 | 1658.7 | 258.0 | 4.39 | 58.7 | 13.37 | 7.80 | 0.040 | 4.20 | 6.43 | 1.15 | 0.54 | 113.7 | 61.5 |
| 17.400 | 1709.8 | 263.9 | 4.45 | 59.3 | 13.34 | 7.90 | 0.040 | 4.25 | 6.48 | 1.17 | 0.54 | 115.2 | 62.1 |
| 17.500 | 1761.8 | 269.8 | 4.50 | 59.9 | 13.31 | 8.00 | 0.040 | 4.30 | 6.53 | 1.18 | 0.54 | 116.6 | 62.7 |
| 17.600 | 1814.7 | 275.9 | 4.56 | 60.5 | 13.29 | 8.10 | 0.040 | 4.35 | 6.58 | 1.20 | 0.54 | 118.0 | 63.4 |
| 17.700 | 1868.5 | 282.0 | 4.61 | 61.1 | 13.26 | 8.20 | 0.040 | 4.41 | 6.63 | 1.21 | 0.54 | 119.4 | 64.0 |
| 17.800 | 1923.3 | 288.1 | 4.67 | 61.7 | 13.23 | 8.30 | 0.040 | 4.46 | 6.68 | 1.22 | 0.54 | 120.8 | 64.6 |
| 17.900 | 1978.9 | 294.3 | 4.72 | 62.3 | 13.21 | 8.40 | 0.040 | 4.51 | 6.72 | 1.24 | 0.55 | 122.2 | 65.2 |
| 18.000 | 2035.5 | 300.6 | 4.78 | 62.9 | 13.18 | 8.50 | 0.040 | 4.56 | 6.77 | 1.25 | 0.55 | 123.6 | 65.9 |

11/2/2007 Proposed Typical B4c Cross Section Riffle