STREAM RESTORATION DESIGN REPORT AND SPECIFICATIONS

DIAMOND HILLS PARK

CHRISTIANSBURG, VA

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1 Introduction

1.1 Project Summary

This design report will describe and document the design process and results for **Diamond Hills Park (DHP) Stream Restoration**. The overall design methodology chosen for this project is Natural Channel Design (NCD), which means that the project was designed to mimic the mechanics, geomorphology, and ecologic function of natural stable streams in a particular setting using a combination of analog (reference reach), empirical (regional curve), and analytic (process based) design approaches. This design also incorporated design elements from Regenerative Stormwater Conveyance Channel (RSCC) design and Step Pool Storm Conveyance design methodologies. The NCD design methodology requires that the designer assess the accuracy and applicability of each approach and look for converging lines of evidence to arrive at a suitable design. Due to the urban and sub-urban nature of the watershed, special consideration for the unique challenges that this presents were considered and influenced the design to a significant degree.

The project site is contained within an approximately 19.94 acre property located just south of Independence Boulevard and north of the Norfolk Southern Railroad and Crab Creek in Christiansburg, Virginia. The site is located within the southern region of the Valley and Ridge Physiographic Province and is part of the Upper New River Watershed. The Diamond Hills Park Creek flows southwest into Crab Creek. Currently the property is managed open space consisting of shrubs, grasses, and a few mature hardwoods. The property is currently owned by the Town of Christiansburg. Stream restoration practices will consist of Priority 1 restoration creating a new 2,322 linear foot stream as well as an anabranched stream system consisting of off-line wetland detention cells; however these areas are for stormwater control only and will not be held to the success criteria of created wetlands.

1.2 Project Goals

The goal of this stream restoration project is to restore and preserve self-sustaining functional stream, wetland, and riparian corridors to replace the functions and values lost from unavoidable adverse impacts associated with the Wytheville Industrial Park known as Progress Park. The design goals for this phase of the project are as follows:

- To restore a geomorphically stable stream reach that will not aggrade or degrade over a long period of time.
- To hydrologically connect the stream channel to its abandoned floodplain.
- To create increased habitat and refugia opportunities.
- To restore and preserve a defined buffer that will evolve towards a mature ecosystem consistent with reference conditions.
- To provide stormwater quantity and quality treatment for the Edgemont Watershed.

Restoration activities intend to improve or maintain stream and riparian functions that can be classified in five broad categories: 1) System Dynamic, 2) Hydrologic Balance, 3) Sediment

Processes and Character, 4) Biologic Support, 5) Chemical processes and landscape pathways (Fischenich, 2006). This project will attempt to improve all of these functions. Due to the urbabnized condition of the watershed, it can be expected that biologic functions within the stream will be limited even after restoration; however, structures and features shall be implemented that address both system dynamic and biologic support functions. Various targeted ecologic functions include, but are not limited to, improvements in terrestrial and aquatic fauna community population and diversity; improvements to habitat density, diversity, and food production; and effective energy and nutrient processing (Lake, 2007). Other functions include water quality, water quantity, nutrient and sediment control.

In order to accomplish these goals, it is proposed that the existing streams are restored by creating a channel with the geomorphic characteristics (cross-section, pattern, and profile) of a stable natural channel where possible or to create a bankfull bench where constraints exist. The use of structures is also proposed to assist in the recovery of a stable geometry and to increase ecologic functional lift by providing habitat, refugia, and woody debris to the stream system. Restoration activities will also include the removal of invasive vegetation and the establishment of native vegetation to create a buffer area within a permanent conservation easement.

This project will consist of Priority 1 Restoration for Reach 1 also referred to as the Diamond Hills Park Creek. In addition, adjacent floodplains and riparian buffers will be restored and enhanced. Also, stormwater management will be incorporated into the floodplain in the form of an anabranched stream system in which flood flows will be conveyed to a system of off-line wetland detention cells. A summary of the mitigation credits and restoration activities is provided in the table below:

Table 1.1

Mitigation Summary

Project Reach	Existing Stream Length (LF)	Design Stream Length (LF)	Type of Mitigation	Approach	Mitigation Credits
Reach 1	2,005	2,322	Restoration	Priority 1	3,228

It is the goal of this project and future phases of the Diamond Hills Park Stream Restoration that improvements to this area will enhance the water quality and help alleviate any future TMDL requirements associated with Crab Creek.

1.3 Site Selection

The site was carefully chosen for its probability of restoration success and its functional contribution to the watershed. The Diamond Hills Park property is currently owned by the Town of Christiansburg and will remain Town property after restoration. The watershed is close to its final development and significant changes to the watershed land use are unlikely. This contributes to a higher success rate for restoration practices by ensuring that watershed disturbances or hydrologic regime changes are unlikely. All hydrologic and hydraulic modeling used the final build-out of the watershed as the design land condition. The Diamond Hills Park Creek is similar in stream type and function to those found in other parts of the geographic region, and as such is a good candidate to provide compensatory mitigation for adverse impacts associated with the Wythe County Industrial Park.

1.4 Existing Conditions

The Diamond Hills Park Creek site encompasses approximately 18 acres and is situated within the western limits of the town of Christiansburg, Virginia specifically within the Ridge and Valley Physiographic Province. The study area contains approximately 2,005 linear feet of a perennial unnamed tributary (UT) to Upper Crab Creek which flows in a southwesterly direction until it reaches the confluence with Crab Creek. Upper Crab Creek flows from east to west along the north side of the Norfolk Southern Railroad then takes a ninety degree turn to the south and flows under the railroad and offsite. Crab Creek and all associated tributaries are part of the Upper New River Basin (Hydrologic Unit Code 05050001).

The contributing subwatershed of UT to Crab Creek is approximately 496 acres (0.78 mi^2) and encompasses a highly urbanized landscape consisting of residential, commercial, and industrial development. A majority of this watershed is dominated by the presence of high density single family homes. Several sources of water quality and aquatic and riparian habitat degradation result from the urbanization of this small subwatershed. These sources consist of, but are not limited to: 1) unspecified domestic waste from leaking or failing sewer lines 2) wastes from pets 3) discharges from municipal separate storm sewer systems 4) loss of riparian habitat 5) altered hydrology 6) post-development erosion and sedimentation 7) utility and road crossings 8) stream instability. A more specific discussion of each reach's condition under Simon's Channel Evolution Model can be found in section 2.3.1.

Upper Crab Creek is listed as an impaired water according to the 2008 Water Quality 305(b)/303(d) Integrated Report for not supporting uses for aquatic life and recreation. Escherichia coli (E. coli) and Benthic Macroinvertebrate are the listed impairments and therefore do not meet the State Water Quality Standards.

The Virginia Department of Environmental Quality completed a Total Maximum Daily Load (TMDL) Study on Crab Creek (lower, middle, and upper) and other tributaries of the New River in 2004 in order to identify, address, and alleviate these listed impairments.

It is important to note that the UT to Crab Creek which is within the Diamond Hills Park Creek study area is not listed as an impaired stream reach; however, the contributing watershed and water quality of this system has a direct effect on Crab Creek. Therefore any proposed ecological restoration and watershed management would greatly benefit Crab Creek and other receiving waters downstream.

1.4.1 Ecology & Geology

The geology of Diamond Hills Park can be generally described as carbonates underlain with Cambrian clastic sediments. The NRCS SSURGO database describes the soils as being either

Weaver soils or Duffield-Ernest complex soils both characterized as well drained residuum of limestone and shale.

The majority of the site is cleared and vacant made up of maintained land with very few trees or shrubs. Upland community vegetation within this site is dominated by Elaeagnus umbellata (Autumn Olive), Festuca arundinacea (Tall Fescue), Dactylis glomerata (Orchardgrass), Rubus allegheniensis (Blackberry), Trifolium repens (White Clover), Plantago major (Broadleaf Plantain), and Plantago lanceolata (Buckhorn Plantain).

Wetland community vegetation consists of Setaria glauca (Yellow Foxtail), Eulalia viminea (Microstegium), Cinna latifolia (Drooping woodreed), Juncus effusus (Soft-stem Bulrush), Carex sp. (Sedge), Panicum dichotomiflorum (Witchgrass), Typha latifolia (Broad-leaf Cattail), Vernonia noveboracensis (New York Ironweed), Scirpus mircocarpus (Small-fruit Bulrush), Salix babylonica (Weeping Willow), and Conium maculatum (Poison Hemlock).

2 Watershed and Geomorphic Assessment

2.1 Watershed Assessment

The watershed assessment was completed by using a combination of historical data and field investigation. Initially the drainage areas and land uses were assessed using aerial imagery, Geographic Information System (GIS) data, past engineering reports for the watershed, and National Resource Conservation Service (NRCS) Soil Survey Maps. Then, field investigations were used to observe the drainage area, land use, and soil characteristics to determine if the prior conclusions were valid. A Drainage Area Map provided by the Town is provided on the following page. This data was then used to complete preliminary hydrologic modeling using the HEC-HMS (See Appendix D). The following table outlines the result of this study:

Table 2.1

Watershed Assessment						
Project Condition	Drainage Area (Acre)	Majority Land Cover	Land Use Curve Number (% Impervious)	Bankfull Storm Event (cfs)	10-Year Storm Event (cfs)	100-Year Storm Event (cfs)
Pre-developed	491.4	Grass open space	81.30 (14%)	TBD	1,001	NA
Existing	493.7	Sub-urban	84.36 (33%)	NA	NA	NA
Future	496.45	Sub-urban	85 (+/-48%)	39.6	1336	2,411
Restoration	496.45	Sub-urban	85 (48%)	TBD	TBD	TBD
Restoration + Upstream Det.	496.45	Grass/Forest	85 (48%)	TBD	TBD	TBD

The land use Curve Number uses the percent cover of the different land uses (e.g. forested, grass, impervious) and a hydrologic soil group to predict the amount of runoff generated by a given precipitation event. The land cover in the area of the project site is predominately managed grass cover with few areas of overstory and impervious area in the form of pavement, and roof cover associated with residential and commercial development. The soils in the project area are considered to be in hydrologic soil group B and C. Although the area has been developed to a great extent, there are still undeveloped lots that are expected to be developed in the watershed. In order to ensure the restoration activities take into account this future development, land cover for these areas were estimated with the help of the Town of Christiansburg. The following equation is used to determine flowrates for the TR-55 Small Watershed Hydrology model:

Runoff Equation

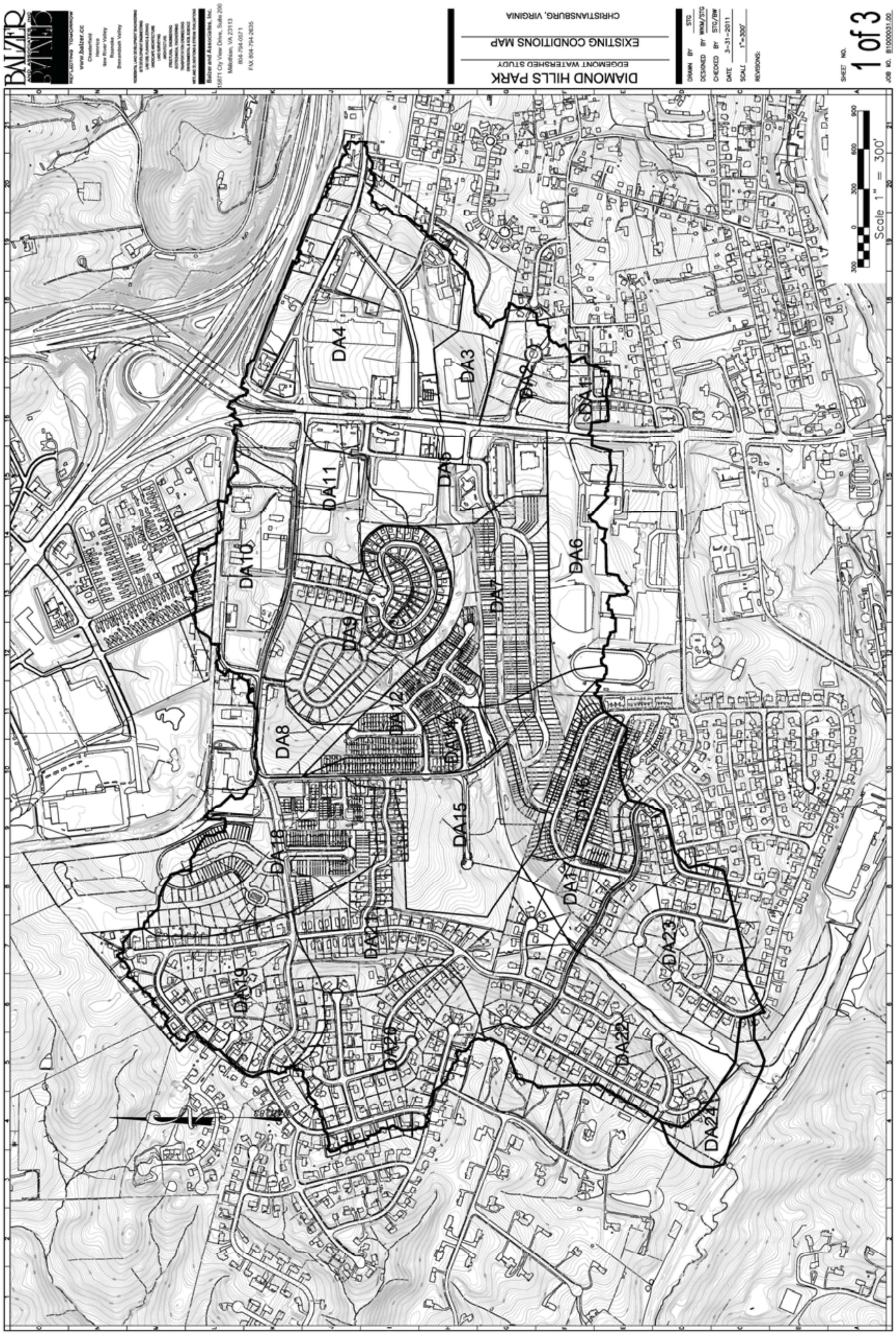
$$Q = \frac{\left[P - 0.2 \left(\frac{1000}{CN} - 10 \right) \right]^2}{P + 0.8 \left(\frac{1000}{CN} - 10 \right)}$$

Where:

Q=runoff (in)

P=rainfall(in), and

CN = runoff curve number



Drainage Area Map

The results of this model were used in the hydraulic modeling (Section 2.4) to verify the design of Reach 1 and also as a comparison to the bankfull flowrate derived from the geomorphic characteristics of the existing channel and regional curve discharge data. This comparison can be helpful since it has been shown that the channel forming discharge is closely related to the bankfull flowrate and the flowrate generated by the 1.5 year storm event (i.e. the storm event that has a 67% probability of occurring each year).

2.2 Basemapping

Diamond Hills Park was surveyed using a Total Station Survey Instrument to identify the location and elevation of structures, trees, rock outcrops, and topographic features in the region of anticipated restoration activities. The survey resulted in a detailed basemap to a precision of at least ½' in elevation that was then used for stream restoration design. All coordinates displayed on the resulting map reference the North American Vertical Datum (NAVD) of 1988 as a vertical datum and the State Plane Coordinate System (SPCS) Virginia South Zone North American Datum (NAD) of 1983 as a horizontal datum.

2.3 Geomorphic Assessment

A Geomorphic Assessment was conducted to determine the current stream type, condition, and stability of the stream and to inform the type of restoration that would most effectively return the stream to a stable condition and provide the most functional lift. The geomorphic assessment consisted of a survey of representative cross-sections of the existing stream reach, a planform analysis to understand the stream's pattern and profile, and a substrate analysis (Appendix A). Also as part of the geomorphic assessment, the stream was assessed using the Unified Stream Methodology (USM) (Appendix B). A geomorphic assessment was also conducted on the upstream Diamond Hills Park stream and the reference reach (Appendix B).

2.3.1 Existing Geomorphic Stability

Geomorphic stability was assessed by analyzing the stream dimensions and observing the current stream condition while noting prevalence and extent of aggradation, degradation, bank vegetative cover, bank angle, and comparing the results to known stability standards. The following table summarizes the geomorphic characteristics of the existing stream.

Table 2.2	
Existing Geomorphic Characteristics	
Parameter	**Reach 1**
Drainage Area (DA), Acre (Mile^2)	496 (0.78)
Bankfull Width (Wbkf), ft	8.82
Bankfull Depth (Dbkf), ft	0.93
Cross-Sectional Area (Abkf), ft^2	8.24
Width to Depth Ratio (W/D)	9.48
Maximum Depth (Dmax), ft	1.25
Floodprone Width (Wfp), ft	10.42
Entrenchment Ratio (E)	1.18
Mean Substrate Classification	Coarse Gravel
Water Surface Slope, %	1
Sinuosity (K)	1.10
Stream Type	G4c
Note: Parameters represent one typical cross-section; variability does occur within each stream reach. Individual Cross-Sections and Design Parameter Appendices should be consulted for conditions at specific locations and range of parameters.	

Substrate material was observed to be predominately gravel. A reachwide Wolman Pebble Count was conducted to determine the substrate classification. Due to the degradation that has occurred in the incised channel, the Pebble Count was conducted in the stable channel just upstream of Independence Boulevard. The substrate in this area should accurately represent the bedload supply to the design reach. The Pebble Count analysis classified the substrate of Reach 1 as Coarse Gravel. The Pebble Count analysis is located in Appendix A.

Shear stress was analyzed for a typical cross-section to assess what size particle would be moved during a bankfull event by using the modified Shield's diagram. When available stream power exceeds the resisting power of the channel bed and bank, system-wide degradation and bank erosion can occur (Simon, 1995). This analysis verified field observations of system-wide channel adjustments. According to Rosgen's modified diagram or the Leopold / Miller data set (see Appendix G), the estimated shear stresses are capable of moving a particle size in excess of the existing substrate. In addition the dimensionless shear stress value was used to calculate a minimum depth and slope that would be required to move the substrate size and both were less than the existing bankfull depth and slope. Therefore, the reach has the capability to continue to degrade at the present bankfull depth and slope.

The existing stream was classified according to Rosgen's Stream Classification system based on the observed morphological parameters. A copy of Rosgen's Stream Classification Key is located in Appendix G. It is important to note that sinuosity values result in values lower than would be expected for the valley and stream type; however, this can be attributed to past channel straightening and the lower sinuosity of streams draining small watersheds.

Reach 1 was classified as a G4c stream type. Based on the upstream reach, the valley type, and streams of similar size in this geographic area, the anticipated pre-disturbance classification would be an E stream type. The channel has undergone significant degradation and active bank sloughing is evident throughout the reach.

Rapid changes to a channel's condition and stability are often the result of anthropogenic influences (Simon, 1989). By observing the current condition of a channel within the context of Simon's Channel Evolution Model (CEM), it is possible to predict the expected recovery and gain some insight into the fluvial processes causing any observed instability.

According to the CEM, Reach 1 is currently undergoing channel degradation and widening (Class IV) as evidenced by its incised condition and active bank erosion. Combining the observations of stream type and channel evolution, the expected changes to stream type can be predicted using Rosgen's Channel Evolution by Stream Type. The observed E to G stream type is typical of the Class IV stage. A stream undergoing this type of adjustment will typically overwiden to an F stream type before aggrading to C and then back to an E stream type at a lower elevation.

The current observed stream condition and related stage of channel evolution would suggest that Reach 1 are still adapting to their current hydrologic regime and watershed condition. With no additional anthropogenic influences, the streams would be expected to recover unassisted, given enough time; however this process can take 50 to 100 years in sand bed streams and may still remain disconnected from their historical floodplain after recovery (Simon, 1989).

2.3.2 Bankfull Verification

Natural Channel Design relies heavily on the correct identification of the bankfull stage. Many of the geomorphic relationships used for stream assessment and design are directly related to this parameter. The bankfull stage is the stream flood elevation which corresponds to the discharge that is responsible for the average morphologic characteristics of the observed channel (Leopold, 1978). In other words it is the elevation of the channel forming flow. The channel forming flow is also called the effective discharge or the dominant discharge. It is a theoretic discharge used as a surrogate for the long term fluvial processes that create and maintain a stream through the movement and distribution of sediment. The channel forming flow is also estimated as the 1.5 year storm or the storm event that has a 67% probability of occurring within a given year (Leopold, 1994).

The bankfull stage is estimated by locating bankfull indicators, such as flat depositional features or the uppermost scour line on the bank of a channel. On stable streams that are connected to their floodplain, the bankfull stage should be equivalent with the top of bank. These and other investigative techniques that were referenced for field assessment include those outlined in *A Natural Channel Design Handbook* by the North Carolina Stream Restoration Institute and North Carolina Sea Grant, the United States Forest Service's *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* by Potyondy et al., and the North Carolina Cooperative Extension *River Course Fact Sheet #3* by Will Harman.

After these characteristics are located and flagged in the field, they are compared to the current water surface as a relative datum. If they are within a similar range of elevation then cross-sections are surveyed at representative riffles. Typically bankfull elevations are within at least six (6) inches of each other. The bankfull depth is then calculated as the average channel depth from the bankfull elevation. This average depth, or bankfull depth, is then compared to regional curve information based on the drainage area of the stream reach. If the measurements are in an acceptable range, as determined by regional curve standard deviation and professional experience, then the investigation is considered successful. If the measurements do not agree with published regional curve relationships, then bankfull characteristics are reassessed or the watershed is investigated for evidence of potential causes that would affect the hydrologic regime.

Reach 1, the upstream reference reach, and the Blacksburg Reference Reach were assessed according to this methodology. Urban Streams that are in a state of disequilibrium are difficult if not impossible to determine bankfull characteristics from field information. In this case the bankfull elevation is estimated from upstream characteristics in addition to field investigation of consistent high scour lines on the banks. This information was then used to assess stability, define stream type, and estimate bankfull discharge by using Manning's equation.

The existing channel characteristics suggested Manning's values of 0.03 for the Upstream reach. When compared to other estimates of the channel forming flow (Table 2.3) an analysis of the most accurate design flow could be evaluated.

The existing stream is in a state of adjustment, and the cross-section data for Reach 1 consisted of unstable sections resulting in a much larger cross-section and a much larger corresponding storm event. The regional curve data provided a considerable range of data and the TR-55 model, as is common, provided a flowrate much higher than the other estimates. The design flowrate corresponding with the design geomorphic parameters and a Manning's value of 0.035 resulted in a flowrate between the regional curve values and the upstream Manning's derived flowrate. This value suggested a good estimate that is within an acceptable range from the bankfull discharge of the existing channel and also the Regional Curve estimates. Since the channel forming flow estimates covered a considerable range, the design approach relied upon the hydraulic assessment using the upstream bankfull estimate to make sure that this flow would be contained within the channel.

Table 2.3

Channel Forming Flow Comparison (all values are in cfs)

Project Reach	Existing Channel (Manning's)	Proposed Channel (Manning's)	Regional Curve (compiled)	Regional Curve (VA V&R USGS)	TR-55 1.5yr Storm
Reach 1	32.8 (0.03)	31.95 (0.04)	72	35	TBD
Upstream Reference	33.25 (0.04)	NA	51	20	NA
Blacksburg Reference	21.38 (0.04)	NA	112	72	NA

2.4 Hydraulic Assessment

A hydraulic assessment was conducted to verify the hydraulic function of the proposed design. The hydraulic assessment consisted of a HEC-RAS model of the proposed design reach. Outputs from this model can be found in Appendix E. The results of this assessment assisted to inform the design of riffle bed material in conjunction with the sediment transport competency analysis by the comparison of shear stress values to particle size. Changes to the channel profile and the use of structures could be determined by evaluating areas of high velocity and shear stress. It also provided a check of the estimated channel forming flow from Manning's equation, the 1.5 year storm, and regional curve estimated discharges. By modeling higher flood events like the 100 year storm, it was possible to ensure that the extents of flooding would not affect adjacent property or important infrastructure. In addition, it provides maximum shear stresses that structures must be able to withstand.

Table 2.4

Summary of Hydraulic Assessment

Parameter	Reach 1
Design Bankfull Flowrate from design geometry, hydrology, and regional curves, cfs	39
100 year Flowrate, cfs	1,857
Average Shear Stress, lb/ft^2	0.91 (10yr: 2.52)
Maximum Shear Stress, lb/ft^2	4.9
Average Velocity, ft/s	1.87 (10yr : 4.07)
Maximum Velocity, ft/s	4.3

Note: Shear Stress and velocity parameters shown above are for bankfull stage model flow rates unless otherwise specified.

3 Restoration Design

3.1 Design Criteria

The design criteria was developed by using information from stable cross-sections from the upstream reach, a selected reference reach, regional curve information, and commonly observed parameters from similar stream types. Each of these methods presents their own attendant flaws, and proper design is incumbent upon the successful determination of how applicable each method is to the project and its setting. Natural Channel Design is a synthesis of design approaches and as such, the proper identification of converging lines of evidence is essential for a successful outcome to be possible. The resulting design parameters can be found in Appendix C. The following discussion outlines the design process and the resulting determinations.

Since the existing reach was observed to be undergoing changes (Section 2.3.1), the designer was careful not to rely too heavily on these values; however, the upstream reach, although previously modified, is currently stable and provides the only clues to the existing hydrologic regime. Parameters such as cross-sectional area and bankfull discharge have a higher weighted applicability to the design reach because they represent the channel’s response to flood flows in the context of the particular valley and land use setting. Pool to pool spacing is another parameter that provides insight into how the channel is adjusting to the current hydrology; however, this parameter is dependent upon the overall stream pattern and the other energy dissipating influences in the stream.

A reference reach search was undertaken to find geomorphically stable streams in similar settings. The search first investigated the upstream reach and streams in the same watershed. Since instability is widespread in this watershed and the upstream portions of Reach 1 had been previously modified it was necessary to expand the search to consider streams in similar nearby watersheds. After a search using aerial imagery and side-of-the-road investigation, a stream in Blacksburg, Virginia approximately 8.65 miles north of Diamond Hills Park was chosen for its analogous setting, watershed size, substrate size, and stream type. The Reference Reach had a watershed that was approximately 14% impervious cover. Land uses in the watershed consisted of forest, pasture, and residential development. The drainage area is approximately 1.68 square-miles. The stream was classified as an E4 stream type. The stream was characterized by dense stream bank vegetation, shallow inner berm or aquatic bench features, and stable undercut banks. The stream was very stable and was assessed after a significant rainfall event that approached bankfull.

Regional curves are regression relations for bankfull stream characteristics that are typically based on drainage area. The relationship between hydraulic geometry and drainage area is made indirectly through the relationship between drainage area and flowrate (Federal Interagency Stream Restoration Working Group, 1998). Regional Curve relationships were used as a check for the design parameters. Regression equations from the Virginia and North Carolina Valley and Ridge Physiographic Province were relied upon for geomorphic geometries (Harman, 1999; Keaton, 2005). Geometry relationships for similar stream types (E and C streams) and watershed sizes from these two studies, the upstream DHP, and the reference reach were compiled to create a local regional curve. The three different geometry relationships were compared to design values to ensure that design values were in the appropriate range.

Empirical data used to check the design ratios were compiled by William A. Harman and Richard R. Starr. These design ratios were used as secondary evidence to ensure that design geomorphology was in the range of expected values for the design stream type.

The design parameters are expressed as a range of values that are expected to maintain stable channel geometry. A range of values rather than a single design value is used because natural stable channels also exhibit a range of parameters that have resulted by the gradual and incremental adjustment to local stressors. It should be noted that when design ratios and parameters are applied to a stream reach, the designer chooses a parameter within this range that anticipates these natural responses to local stressors such as bedrock, existing vegetation, confluences with drainage swales, and valley slope. In the circumstance that a parameter does not fall within the expected design criteria, it is most likely due to constraints or in response to local conditions, and the design should compensate for these situations to ensure stability and proper function. The resulting dimension, pattern, and profile are a synthesis of input from different design methodologies, local constraints, and adjustments based on hydraulic and sediment transport analysis.

3.2 Design Narrative

To achieve the stated goals for this project and to address the level of instability assessed for the stream reach, an appropriate action in the form of restoration is recommended. In order to achieve the highest probability of success, priority restoration is considered in priority order with priority 1 restoration being the preferred action (Doll, B.A. et al., 2003). After a careful review of the existing instability and watershed conditions the following restoration actions are proposed:

- Restoration of 2,005 linear feet of existing stream resulting in 2,322 linear feet of restored stream in the form of a new E4 type channel dimension, pattern, and profile; structures to promote a stable pattern through grade control, flow deflection, and to provide enhanced ecologic function, planting of live stakes along both stream banks; and a vegetated buffer that ranges from 30 feet to 200 feet from both the left and right bank.

Restoration is proposed to Reach 1 because current instability and expected future channel adjustment can be most effectively solved with Priority 1 restoration and current site conditions allow for this action. The proposed design also incorporates an anabranched stream system in order to accomplish the Town's goals of reducing storm flows and additional water quality treatment. Anabranched stream systems are common in areas that have been affected by beavers or that have been obstructed due to debris in a natural system. Anabranched stream systems are not braided channels. Anabranched stream systems are created by reducing the cross-sectional area of the stream channel which consequently conveys stream flows over-bank and through floodplain wetlands. This helps to reduce downstream peak flood flows by providing flood storage in the floodplain wetlands. It also increases infiltration by retaining flood flows and encourages nutrient uptake and removal through biological processes.

3.2.1 Cross-Section

Restoration activities include creating a new stream dimension and will be designed with a stream cross-section that is based on stable geomorphology. This will facilitate the transport of the stream's sediment load and will hydrologically connect the stream to the floodplain.

The design cross-section must be stable immediately after construction as well as after bank vegetation has been established. For this reason, the width to depth ratios of the design cross-sections are towards the upper limits of an E stream type and in the lower range of a C stream type. E stream types typically have low width to depth ratios and steep banks with dense vegetation on them, while C stream types have a higher width to depth ratio and more moderate bank slopes. In order to maintain a stable geometry immediately after construction, the channel dimension of the restored reach is designed with a minimum 2:1 bank slope. It is expected that as vegetation becomes established the channel width will narrow slightly and the banks will steepen to mimic a natural E stream type. To help encourage this aggradation, wetland grass plugs will be installed to increase roughness on the slopes, thus reducing velocities and allowing fines to settle out. As the cross-sectional area reduces to more closely resemble reference conditions, the stream will stabilize and stop aggrading.

3.2.2 Pattern

Restoration activities will create a new channel pattern in order to distribute flood flows to more of the floodplain, dissipate stream energy through meanders while still transporting the stream's sediment load, and maximize the ecologic value of the stream corridor. Reach 1 will have a restored sinuosity of 1.12. This value is below the range for sinuous E stream types; however, the drainage area is small and as such, is not delivering the runoff rates that would alter a channels pattern to the degree of most sinuous streams.

The design pattern was derived using dimensionless values reference reach conditions, accounting for topographic changes in the floodplain, and empirical data gathered from stable streams.

The existing stream sinuosity is 1.02. The very low sinuosity for the determined stream type and evidence of lateral instability is indicative that the stream is still undergoing adjustment to achieve a stable state and most likely recovering from previous straightening. It is expected that the proposed pattern will achieve this stable form.

3.2.3 Profile

The profile of Reach 1 will be altered from its current condition due to restoration activities. Reach 1 will have an average water surface slope of 1.3%. A riffle-pool sequence will be created to provide bedform diversity and mimic reference conditions. Due to the low sinuosity of the design stream, a step-pool sequence will facilitate the dissipation of energy. A pool to pool spacing of 4 to 7.5 times the bankfull width is proposed to maintain the natural dissipation of energy through the riffle-pool sequence. This is based on reference conditions and empirical data from observed stable streams published by David Rosgen (Rosgen, 2006).

Reach 1 will have an increased bed slope when compared to the existing stream reach in order to raise the bed elevation to re-connect the stream to its floodplain. This increase in slope and resulting increase in energy will be mitigated through the use of step/pool structures, vegetation, and deep pools that will dissipate energy and maintain a stable profile.

Reach 1 will have substrate amendments based on expected shear stress forces. This material will be installed in the riffle sections of the stream to the specifications shown on the construction plans. This material should be heterogeneous in size and should be of the character of natural streams in color and shape. Harvested material from the existing stream bed shall be incorporated into the sub-pavement material as appropriate.

3.3 Sediment Transport

One of the natural functions of a stream is the movement of sediment from the watershed down-valley. There are two types of sediment found in a stream: washload consisting of finer material that is typically suspended during stream flow; and bedload, which consists of larger material that maintains the channel profile (Leopold, 1994). Sediment transport analysis consists of verifying that a stream can move its attendant sediment washload (Capacity analysis) and that the stream does not significantly degrade or aggrade while still entraining the bedload during storm events (Competency analysis) (Rosgen, WARSSS). The applicability of these two analyses is dependent upon the sediment input and the project goals.

The sediment supply for Reach 1 limited due to upstream development and stream impediments. As previously mentioned the watershed is approaching build-out, so disturbances that could produce a continued sediment supply are expected to be minimal; however, urban streams do frequently have upstream disturbances that will result in downstream aggradation. This accumulated sediment is expected to “flush” out after a significant storm event. The current sediment supply is predominately from bank erosion and degradation. The existing stream condition was analyzed for shear stress to confirm observations of degradation. Reach 1 had shear stress able to move the largest particle in its bed, thus causing degradation.

Due to the limited sediment supply and lack of riffle material input, the design must have substrate sizes that will not move during storm events. In stable natural alluvial systems there is a constant sediment supply that replenishes bed material as it is removed during larger storm events, rendering the bed elevation close to constant. The design reach does not have a consistent sediment supply due to upstream development of the watershed. The sediment transport analysis analyzed the ability of the design stream to move riffle material found upstream in order to ensure that bed material would not aggrade.

With sediment supply lacking, the proposed streams were assessed for sediment competency to make sure that the proposed bed material would not move during bankfull flood events. Competency was assessed by calculating bankfull shear stresses using the typical riffle cross-section and the range of shear stress provided by the HEC-RAS model. The shear stress values were then compared to Shield's diagram and Rosgen's modified diagram to assess what size particle would be moved with what corresponding shear stress. This analysis was used to select the design pavement and sub-pavement material. Material in the reduced cross-section riffles (overflow sections) shall have substrate material sized according to average bankfull shear stresses reported in these sections.

It should be noted that the design shear stresses are still capable of transporting the maximum sediment particle size that is likely to be supplied to the stream by the watershed.

Stone used for the construction of riffle pavement and sub-pavement shall be natural river rock. Riprap will not be considered an acceptable alternative. All stone material will be harvested from abandoned stream beds on the project site or an approved commercial quarry operation.

3.4 Structures

Stream structures accomplish numerous goals in stream restoration practices. Three primary types of stream structures are used for this project: grade control structures, flow deflection structures, and bank stabilization structures. Unfortunately, structures have been installed in many restoration projects without the proper understanding of the stream mechanics that they affect and result in further instability (Rosgen, 2006).

The structures proposed for this project have been selected to complement a stable dimension, pattern, and profile and provide stability while vegetation and bed material naturally stabilizes through fluvial processes. Vegetation typically achieves significant bank protection only after two to four growing seasons. This project uses predominately wood structures for a number of reasons: although limited, there is wood material on-site and material that will be generated through construction that can be used rather than wasted; wood structures are easier to scale down than rock structures for use in small streams such as the design reach; and it is expected that these structures only need to be temporary over the life of the stream and their short term effect will ensure a stable transition. Wood structures have the added benefit of supplying refugia and an energy supply to the stream's biotic community in the form of woody debris as the structures decompose over a long period of time.

Structure specifications are adapted from The Virginia Stream Restoration & Stabilization Best Management Practices (BMP) Guide and current stream restoration practices. In the case of any missing or incomplete information, Balzer and Associates should be consulted for additional information or if Balzer and Associates can not be reached the guidelines in The Virginia Stream Restoration & Stabilization BMP Guide shall be followed.

Installation of all structures shall be overseen by a representative from the design firm to ensure that structures are constructed properly and to ensure that minor changes due to site constraints do not compromise stream mechanics.

All structures will be tested after construction to ensure that they function properly.

All rock used for the construction of in-stream structures shall be nearly flat on three sides, be natural in color, and obtained from an approved source. Concrete will not be an acceptable alternative.

3.4.1 Rock Cross Vanes and Double Step Rock Cross Vanes

Rock step-pool structures are used to control and maintain grade control. This type of structure will prevent a change in grade and encourage pool scour and proper pool-to-pool spacing.

- Rock header material will be sized according to the following table (based on maximum shear stress and the Rosgen modified Shield’s diagram):

Rock Size Specification	
Stream Reach	Reach 1
Intermediate axis rock size, mm	*620 (1.38 feet)*

- Rock footer material will be large enough to achieve the design height and should be angular and uniform in size. Footers will be placed together with as little gap between as is possible.
- Header rocks shall be placed with gaps between them of no less than 0.3’.
- Spacing between pools will be dependant on channel slope but will average 49’. The maximum drop between the top of one header rock and the top of the subsequent header rock shall be 4”.
- Rock sills shall extend a minimum of 6’ beyond the bankfull width to prevent the structure from being undermined.

3.4.2 Log Step-Pool/ Log Riffle

Log Step-Pools and Log Riffles are used in the design to provide grade control and restore geomorphic riffle-pool spacing. These structures are used in straighter sections of streams where energy dissipation through meandering is not possible due to constraints. This structure promotes flow diversity and helps to maintain pool depth and spacing for aquatic habitat.

- Logs are placed at angles of 5 to 20° from perpendicular to stream flow.
- Logs should alternate the direction of flow as shown on the construction plans.
- Logs shall be a minimum of 8” in diameter and be of a hardwood species unless otherwise specified.
- Logs shall extend at least 2’ beyond the bankfull width or extend 5’ into the stream bank, whichever is greater.
- Logs shall not be placed at an elevation greater than ½ the bankfull depth of the channel at the point where logs tie into the bank soil.
- Log header will be placed slightly downstream of footer log to produce a small overhang.
- There should be no gap between the footer and header logs.
- The upstream side of the log structure should be wrapped in geotextile fabric and backfilled with natural riffle pavement and sub-pavement material.

- Scour pools shall be excavated to the max pool depth as shown on the construction plans.

3.4.3 Log Sill

Log Sill structures are used as grade control at the upstream side of a pool just before a meander bend. These structures are intended to maintain stream profile while substrate adjusts and riffle-pool sequence is stabilized naturally. The log sill encourages a scour pool to develop just downstream of the structure, which provides habitat and dissipates energy through the meander bend. It is very important that the header log not be above the grade of the bed to prevent bank scour and widening.

- Logs are placed at angles of 10˚ to 25̊ from perpendicular to stream flow away from the outside meander bend as shown on construction plans.
- Logs shall be a minimum of 8" in diameter and be of a hardwood species unless otherwise specified.
- Logs shall extend at least 2' beyond the bankfull width or extend 5' into the stream bank, whichever is greater.
- Header Log should be placed flush with the bottom of the channel. Logs shall not be placed at an elevation greater than ½ the bankfull depth of the channel at the point where logs tie into the bank soil.
- Log header will be placed slightly downstream of footer log to produce a small overhang.
- There should be no gap between the footer and header logs.
- The upstream side of the log structure should be wrapped in geotextile fabric and backfilled with natural riffle pavement and sub-pavement material.
- Scour pools shall be excavated to the max pool depth as shown on the construction plans.

3.4.4 Log Vane Rock J-Hook

Log Vane Rock J-Hook structures are used as flow deflection to direct flows away from the outside meander bend and as grade control. These structures ensure that a stream adapts to a geomorphically stable pattern while bank vegetation and riffle-pool sequence is stabilizing.

- Rock header material will be sized according to the following table (based on maximum shear stress and the Rosgen modified Shield's diagram):

Rock Size Specification	
Stream Reach	Reach 1
Intermediate axis rock size, mm	*620 (1.38 feet)*

- Rock footer material will be large enough to achieve the design height and should be angular and uniform in size. Footers will be placed together with as little gap between as is possible.
- Header rocks shall be placed with gaps between them of no less than 0.3'.

- Spacing between pools will be dependant on channel slope but will average 49'. The maximum drop between the top of one header rock and the top of the subsequent header rock shall be 4".
- Rock sills shall extend a minimum of 2' beyond the bankfull width to prevent the structure from being undermined.
- Logs shall be a minimum of 8" in diameter and be of a hardwood species unless otherwise specified.
- Logs shall extend at least 2' beyond the bankfull width or extend 5' into the stream bank, whichever is greater.
- Logs shall not be placed at an elevation greater than ½ the bankfull depth of the channel at the point where logs tie into the bank soil.
- Log header will be placed slightly downstream of footer log to produce a small overhang.
- There should be no gap between the footer and header logs.
- The upstream side of the log structure should be wrapped in geotextile fabric and backfilled with natural riffle pavement and sub-pavement material.
- Scour pools shall be excavated to the max pool depth as shown on the construction plans.

3.4.5 Log Vane Rock J-Hook with Root Wad

Log Vane Rock J-Hook structures with root wads are used for the same reasons as the log j-hook with the added function of providing additional woody debris and refugia within the scour pool in the form of a root wad.

- Root wads shall be at least 6" in diameter and extend at least 2' beyond the bankfull width.
- There should be no gap between the bottom of the scour pool and the bottom of the root wad. In other words, the root wad should be placed at the bottom elevation of the channel.
- Root wads should not be deteriorated at the time of installation.
- The top of the root wad should not extend above 2/3 of the max depth of the scour pool or the low flow elevation, whichever is higher.

3.4.6 Log Vane & Log Cross Vane

Log Vane structures are used for flow deflection to direct flows away from the outside meander bend. These structures ensure that a stream adapts to a geomorphically stable pattern while bank vegetation and riffle-pool sequence is stabilizing.

- Logs shall be a minimum of 8" in diameter and be of a hardwood species unless otherwise specified.
- Logs shall extend at least 2' beyond the bankfull width or extend 5' into the stream bank, whichever is greater.
- Logs shall not be placed at an elevation greater than ½ the bankfull depth of the channel at the point where logs tie into the bank soil.
- Log header will be placed slightly downstream of footer log to produce a small overhang.
- There should be no gap between the footer and header logs.

- The upstream side of the log structure should be wrapped in geotextile fabric and backfilled with natural riffle pavement and sub-pavement material.
- Scour pools shall be excavated to the max pool depth as shown on the construction plans.

3.4.7 Live Stake

Live Stake specifications and placement shall be in conformance with the details and specifications of the construction plans. Generally, live stakes shall be planted along both stream banks to provide bank stability, provide organic material to the stream, and provide vegetative cover to the stream.

3.4.8 Brush Mattress

Brush Mattresses reduce shear stress on channel banks and provides instant vegetative erosion protection while vegetation becomes established. These structures are placed on the outside meander bend, especially the downstream 1/3, to prevent erosion while vegetation becomes established.

- Live branches should be soaked for a minimum of 1 day before installation.
- Branches should be oriented with the basal or bottom end towards the interior of the channel and the bud end toward the top of bank.
- Branches should be placed 5 to 15 live branches per linear foot of streambank length.
- The thickness of the mattress should be at least 6”.
- Topsoil should be worked into the interstices of the brush mattress layer with the aid of water until the depth of soil equals ¾ of the depth of the mattress.
- The mattress should be watered after installation to encourage growth.

3.4.9 Toe-wood

Toe-wood structures are used to reduce near bank stress, provide habitat and food for aquatic insects, and provide protection to the bank while vegetation is established. The toe-wood structure will be placed in the outside meander bend.

- Footer logs shall be a minimum of 8” in diameter.
- A minimum of two footer logs should be used and should be placed 16 to 20˚ from tangent to the outside stream bank.
- Root wad logs should be a minimum of 6” in diameter and should be placed cantilevered over foundation logs.
- Woody material should include material harvested on-site including small logs, limbs, tree tops, and brush. Material should be placed parallel with root wads.
- During construction a counter weight or compaction with machinery should be placed on top of woody material to submerge the logs and ensure a dense lattice of material.
- Cuttings and backfill procedure should comply with details provided on the construction plans.

3.4 Planting Plan

The planting plan for the Diamond Hills Park was formed on the basis of existing vegetation on site, geology, soil type, hydrology, slope, aspect, observations of reference habitat in the Valley and Ridge Physiographic Province, and wildlife considerations. This analysis led to the development of five different habitat types: Wetland BMP Areas; Aquatic Bench; Immediate Riparian Zone; Steep Slopes; and Piedmont-Mountain Alluvial Forest.

The Aquatic Bench will consist of the areas in-channel that are above the low flow elevation. This area is to be planted using plugs and transplants only. Soft Rush in particular shall be harvested from the existing stream to be used as transplants.

The Immediate Riparian Zone shall consist of an area 5'-25' from bankfull on both stream reaches. This area is to be overseeded immediately after final grade with the specified seed mix containing warm and cool season native grasses, matted, and then planted with live stakes at a minimum spacing of 5' off center. Any live stakes that can be harvested on site will be used. This planting is designed to provide immediate soil stabilization to the riparian area and provide lateral bank stability. The live stakes should also provide shading of the water surface within the first growing season.

The Wetland BMP areas will be seeded with wetland species capable of being inundated for short periods of time and have adapted to saturated soil. The wetland seed-mix shall be applied at 9 lbs./acre.

Floodplain areas that have 2:1 slopes or steeper shall be planted with vegetation with thick root structures and other adaptations. Trees and shrubs will be planted at a minimum density of 400 stems per acre. A minimum of 10% of the planted species are required to be of a one gallon or comparable size. This provides for some age and size distribution.

The Piedmont-Mountain Alluvial Forest area is located in the majority of Reach 1's Floodplain with the exception of the Wetland BMP areas. These areas will be seeded with a native woody shrub mix immediately after reaching final grade and then planted with native trees and shrubs at a minimum density of 400 stems per acre. A minimum of 10% of the planted species are required to be of a one gallon or comparable size. This provides for some age and size distribution. All of the selected species provide mast in the form of fruit or nuts and are expected to provide habitat and food for wildlife.

All existing native trees and shrubs located outside of the areas of proposed grading will be protected during construction and stabilization. All disturbed areas will be seeded immediately after final grade with a temporary stabilization mix and in selected areas described above, a permanent seed mix specifically designed for the unique habitat situation.

4 Maintenance and Monitoring

Maintenance issues will be inspected by Balzer and Associates and remediation measures will be documented and provided to the Corps and DEQ project manager upon request. Maintenance issues will be resolved during construction by the contractor. During monitoring, maintenance will be the responsibility of the Design-Build Team. All maintenance issues and measures to remediate maintenance issues will be documented and detailed in the as-built plan or monitoring reports.

Monitoring will be conducted for the 1st, 2nd, 3rd, 5th, 7th and 10th year following completed construction of restoration activities. Monitoring shall occur during the growing season. Stream surveys may occur outside of the growing season after year 3. Monitoring shall also take place after a 1-year 24-hour storm duration to inspect for any damages. Photographs and any remediation activities will be documented and submitted to the Corps and DEQ within 1 week of inspection.

The stream parameters that will be monitored include dimension (cross-sections), pattern, and profile (longitudinal survey). Photographic documentation shall also be included as part of the monitoring requirements. In addition, a bankfull gage will be installed and all bankfull events will be documented and reported. Specific monitoring requirements are discussed in the following sections.

Cross-sections:
An annual cross-section survey shall be conducted at one riffle and one pool location per 1,000 linear feet of restored or enhanced stream channel. One channel cross-section shall be conducted at a riffle location per 1,000 linear feet of preserved stream channel. These cross-sections will be marked with permanent survey pins and will be located on a monitoring plan to ensure consistent and comparable measurements. Cross-section surveys shall consist of points measured at each break in slope within the bankfull width of the channel. The Bank Erodibility Hazard Index (BEHI) will be assessed at each cross-section, and beginning with year 2, the U.S. Forest Service Stream Reach Inventory and Channel Stability Evaluation will be performed as well. Bankfull shear stress will be calculated for each riffle cross-section assessed. Each riffle cross-section will also be classified using the Rosgen Stream Classification System, and assessed for stability.

Any change between yearly as-built cross-sections will be documented and evaluated to determine if the change exhibits characteristics that may be indicative of a trend towards a more unstable condition (e.g. incision or significant lateral erosion) or a more stable condition (e.g. decreased width to depth or bank deposition). The following measurements will be used to aid in making this determination each monitoring year:

- The Width/Depth Ratio Stability Rating (measured Width/Depth Ratio divided by the approved as-built Width/Depth Ratio) shall be between 0.7 and 1.3.
- The Bank Height Ratio shall not increase or decrease by an amount greater than 0.2 of the approved as-built Bank Height Ratio.
- The BEHI rating shall be equal to or less than the previous year’s Index Value. In addition, the total score shall be equal to or less than the previous year’s total score, and shall have a total score of “Moderate” by year 3, and a total score of “Low” thereafter through the monitoring period.
- The U.S. Forest Service Stream Reach Inventory and Channel Stability Evaluation rating shall be “Good” each monitoring year, beginning with year 2.

All channel parameters must fall within those of the designed stream type or be determined otherwise acceptable by the approval granting agencies to be considered a success.

Longitudinal Profile:
A longitudinal profile shall be conducted for the total length of all restored or enhanced streams. Each longitudinal profile survey will consist of points locating the thalweg, top of bank, bankfull, inner berm, and water surface. All structure locations and inverts will also be recorded. The longitudinal profiles will correspond to a permanent benchmark to ensure consistent and comparable measurements. Longitudinal profiles will be compared to previous as-built surveys to assess any aggradation or degradation. Pools and riffles should be evaluated to determine if slopes and depths are consistent with the design stream type and not trending towards a more unstable condition (e.g. down-cutting or significant aggradation). The following measurements will be used to aid in making this determination each monitoring year:

- Location, depths, and slopes of stream features shall not have significantly altered.
- There can be no significant erosion or signs of instability associated with any instream structure, excluding any minor channel scour within the thalweg immediately downstream of a structure caused by its intended redirection of flow.
- Structure invert elevations shall not vary more than 0.2 feet from the approved as-built.

Longitudinal profiles will be evaluated in planform as well in order for pattern to be assessed. Stream pattern should not change significantly between monitoring years. Any change from previous as-built surveys shall be documented and assessed to determine if the change is toward a more unstable condition (e.g. downward migration or lateral erosion) or a more stable condition (e.g. bank deposition or slightly reduced belt width). The following measurements will be used to aid in making this determination each monitoring year:

- The sinuosity of the stream does not increase or decrease by an amount greater than 0.1 of the approved as-built pattern.
- The thalweg of each channel cross-section does not move by more than 10% of the width of the approved as-built channel width in any given year.
- The radius of curvature/bankfull width ratio (Rc/Wbkf) does not increase or decrease by an amount greater than 0.2 of the as-built condition.
- There can be no significant erosion or signs of instability associated with any instream structure, excluding any minor channel scour within the thalweg immediately downstream of a structure caused by its intended redirection of flow.
- Structure invert elevations shall not vary more than 0.2 feet from the approved as-built.

All channel parameters must fall within those of the designed stream type or be determined otherwise acceptable by the IRT to be considered a success.

Substrate Analysis:
A substrate analysis shall be conducted and compared to previous analyses to evaluate any change in bed material. Substrate analysis will coincide with one riffle and one pool permanent cross-sections for each project reach. Analysis shall be conducted by either sieve or Wolman

Pebble Count procedure and shall include pavement and subpavement samples. The substrate analysis should generally show data that indicates either maintenance or relative coarsening at riffle locations and a maintenance or relative fining at pool locations.

Photographic Documentation:
Photograph reference stations shall be established at each permanent cross-section. One downstream and one upstream photograph shall be taken at each reference station before construction and each monitoring year thereafter. Photographs shall also be taken at each structure location and any locations of interest (e.g. rare, threatened, or endangered species habitat or specimen; evidence of large storm event; or evidence of significant erosion).

Chemical and Biological Monitoring:
Chemical and biological monitoring event shall occur in years 1, 2, 3, 5, 7, and 10 and consistently in either spring or fall of each monitoring year for all restored streams. Spring sampling shall be conducted between March 1 and May 31. Fall sampling shall be conducted between September 1 and November 30. Water chemistry and benthic samples shall be collected simultaneously at each of the monitoring locations. The number and location of monitoring stations shall be determined, and approved by the IRT, on a case-specific basis and shall remain consistent throughout the monitoring period.

Scientific Collection permits for conducting benthic sampling shall be obtained from Virginia Department of Game and Inland Fisheries. All field sampling as well as laboratory sample processing shall be performed by or under supervision of a professional aquatic biologist.

Chemistry sampling shall consist of the following parameters: Temperature, total dissolved oxygen, pH, and conductivity shall be collected at each designated monitoring location site using a multi-probe meter.

A quantitative survey for benthic macroinvertebrates and a habitat assessment shall be conducted at designated monitoring locations. Benthic macroinvertebrates shall be identified to the genus level.

The Virginia Department of Environmental Quality has developed the "Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers" (2008) for their biological monitoring program. This document shall serve as the basis for the field monitoring and laboratory data collection methods. Two sampling procedures are presented:

- Single Habitat is used for streams in which riffles with appropriate substrate (cobble) are available for sampling and are large enough so that at least $1m^2$ of the substrate can be sampled.
- Multiple Habitat is used in cases where no riffles are present, the riffles in the reach are too small and/or too few to sample $1m^2$ of substrate. Multi-habitat sampling is most commonly performed in, but not limited to, low gradient streams.

A habitat assessment shall be conducted at each bioassessment site. The resulting benthic macroinvertebrate data will be used to calculate the Stream Condition Index for Virginia Non-Coastal Streams (VSCI).

The objective of habitat and benthic macroinvertebrate sampling is to allow for comparison between restoration activities involving stream channel restoration; to identify issues that may need to be addressed in the restoration design; to determine realistic expectations for the post-restoration aquatic community; and to inform future stream restoration efforts.

Vegetative Monitoring:
The monitoring program for upland buffer, restoration, and enhancement areas shall consist of visual descriptions and sample plots. Specific monitoring requirements are provided below.

Visual descriptions shall be provided with each monitoring report by ground level photographs, taken facing north, south, east and west, from stations located adjacent to each vegetation plot [permanent markers shall be established to ensure that the same locations (and view directions) are monitored in each monitoring period]

Sample plots shall be located on a stratified random basis over the site in order to sample all habitat areas of buffer at locations adjacent to each photo location marker. The following minimum numbers of samples will be required:

- If the buffer area is < 5 acres, then a minimum of 3 plots/acre is necessary
- If the buffer area is > 5 acres but less than 20 acres, then a minimum of 2 plots/acre is necessary.
- If the buffer area is > 20 acres, then a minimum of 1 plot/acre is necessary

However, all cells, fields, or blocks shall be sampled.

Each plot shall be of a size no less than 400 square feet for woody plants and 3'x3' for herbaceous plants (or circular with approximately the same surface area). The vegetation data shall be collected in each sample plot during the growing season and shall include:

- For herbaceous plots, identification of all herbaceous species found in the sampling plot (with corresponding estimate of percent cover, indicator status, native status, planted/volunteer category for each species), and the percent of bare ground and open water.
- For woody plots, identification of all live woody species found in the sampling plot (with corresponding indicator status, native status, planted/volunteer category, stem count, extrapolated stems/acre), number of dead stems.
- Vegetation species identification by common and scientific name
- Estimates of percentage cover overall, and for each species utilizing the following cover classes:

Cover class, range and midpoint used in data analysis.

Description	Range	Midpoint
Cover class 1	1 – 5	2.5

Cover class 2	6 – 25	15
Cover class 3	26 – 50	37.5
Cover class 4	51 – 75	62.5
Cover class 5	76 – 95	85
Cover class 6	95 – 100	97.5

*Mueller-Dombois and Ellenberg (1974).

Cover class data shall be relativized within each plot to 100% cover to allow for comparison between plots of varying sizes

- Identification of dominant species in each vegetation stratum
- Species Richness – the number of species found at the site at time of data collection (include all species found in a plot with individual % cover estimates)
- Survival of planted species (per plot and per acre); and
- Percent cover and/or stem count of non-native or invasive species in each vegetation layer,
- Average height of planted woody species in each sample plot and percent change in height by species since previous monitoring event

At all stream cross-sections where streambank plantings were completed, sample plots (10 square feet in size) shall be located on each bank 100 feet upstream or downstream from the cross-section location. Plot sampling shall be conducted in accordance with the sampling procedures provided above.

In all restoration Buffer areas the success of the buffer will be determined by the following criteria:

- A minimum of 400 woody stems of native trees and shrubs per acre (including volunteers) from the top of the stream bank landward and/or within the wetland shall be achieved by the end of the first growing season following planting and maintained each monitoring year until canopy coverage is 30%. Canopy coverage shall be at least 30% each monitoring year thereafter. (The number of woody stems per acre may vary under certain circumstances. For example, if invasive species need to be controlled upon implementation of the project, then a lower density may be appropriate in order to mow and/or spray).
- Native non-invasive herbaceous plant coverage shall be at least 60% by the end of the first growing season, and at least 80% each monitoring year thereafter. Any seeds used for plant establishment should conform to the Virginia Seed Law (Sections 3.1-262 Code of Virginia) and Virginia Seed Regulations (2 VAC 5-290-10 et seq) and shall be free of tall fescue, Bermuda grass, and other allelopathic turf grass species, as well as plant species on the Virginia Department of Conservation and Recreation's Invasive Alien Plant List.
- No more than 5% aerial cover per 500 linear foot stream segment, and/or buffer cell, field, or block may be made up by invasive species.

The Year 5 and the final monitoring report (typically Year 10) shall contain documentation by cell, field, or block that demonstrates that all vegetation within the buffer area is healthy and thriving and the average tree height of all surviving trees within sample plots are at least 5 feet in height.

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Appendix A
Geomorphic Assessment

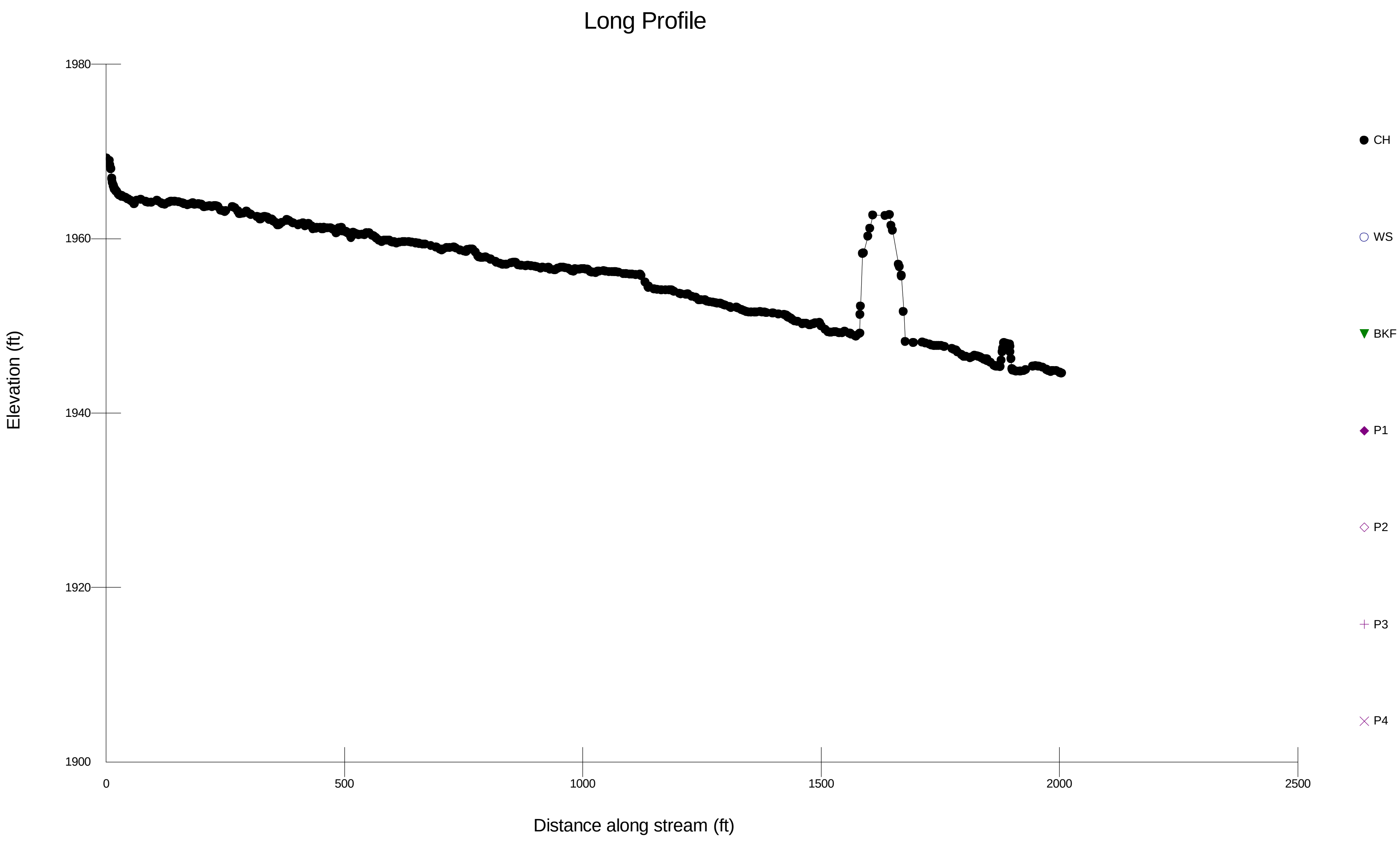
Impaired Reach
Diamond Hills Park

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

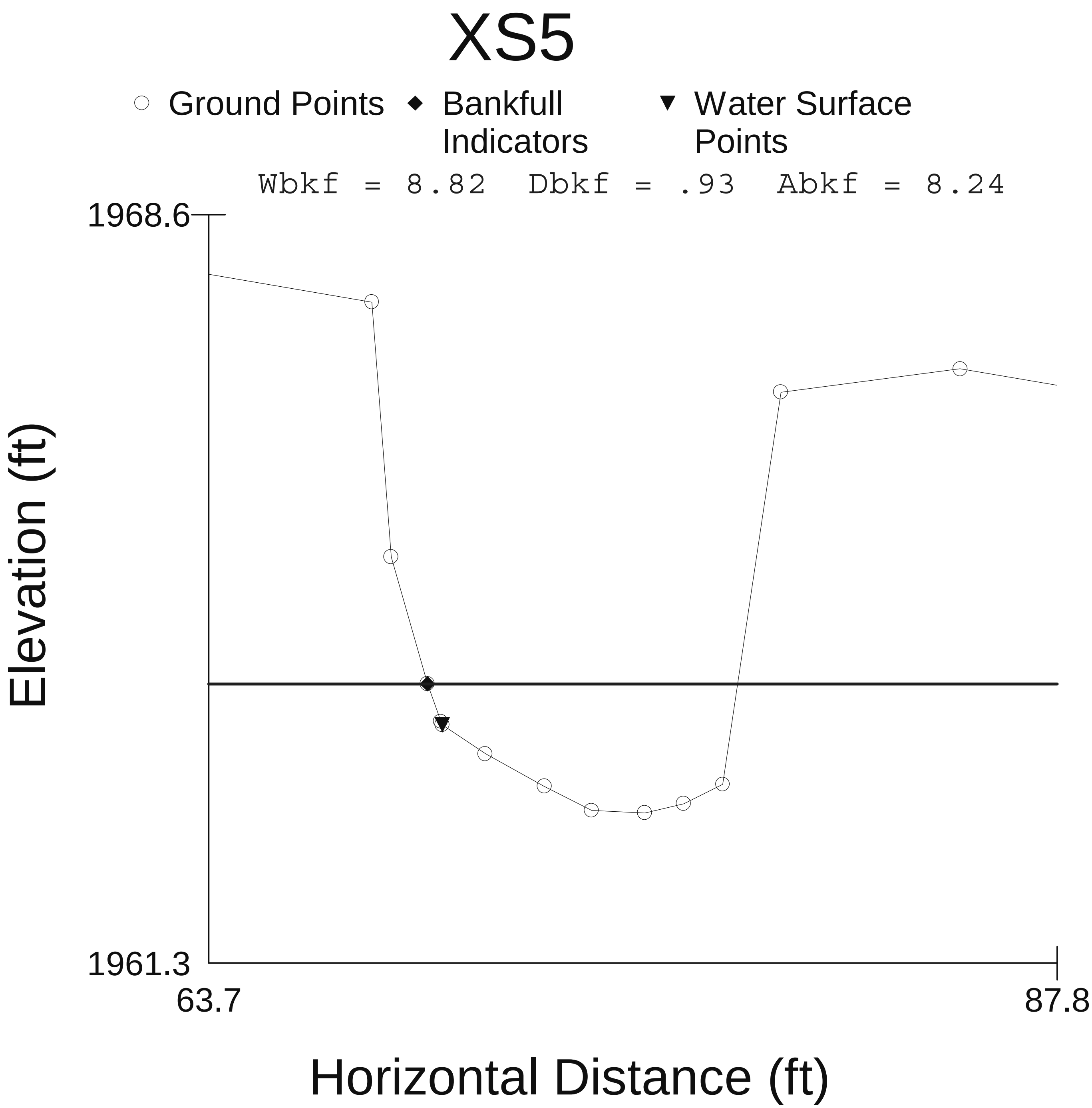
Stream: **Diamond Hills, Reach - Diamond Hills Park Creek**			
Basin:	Drainage Area: **499.2** acres	**0.78**	mi^2
Location:			
Twp.&Rge: **;**	Sec.&Qtr.: **;**		
Cross-Section Monuments (Lat./Long.): **37.27167 Lat / 80.41714 Long**		Date: **04/21/11**	
Observers:		Valley Type: **II**	

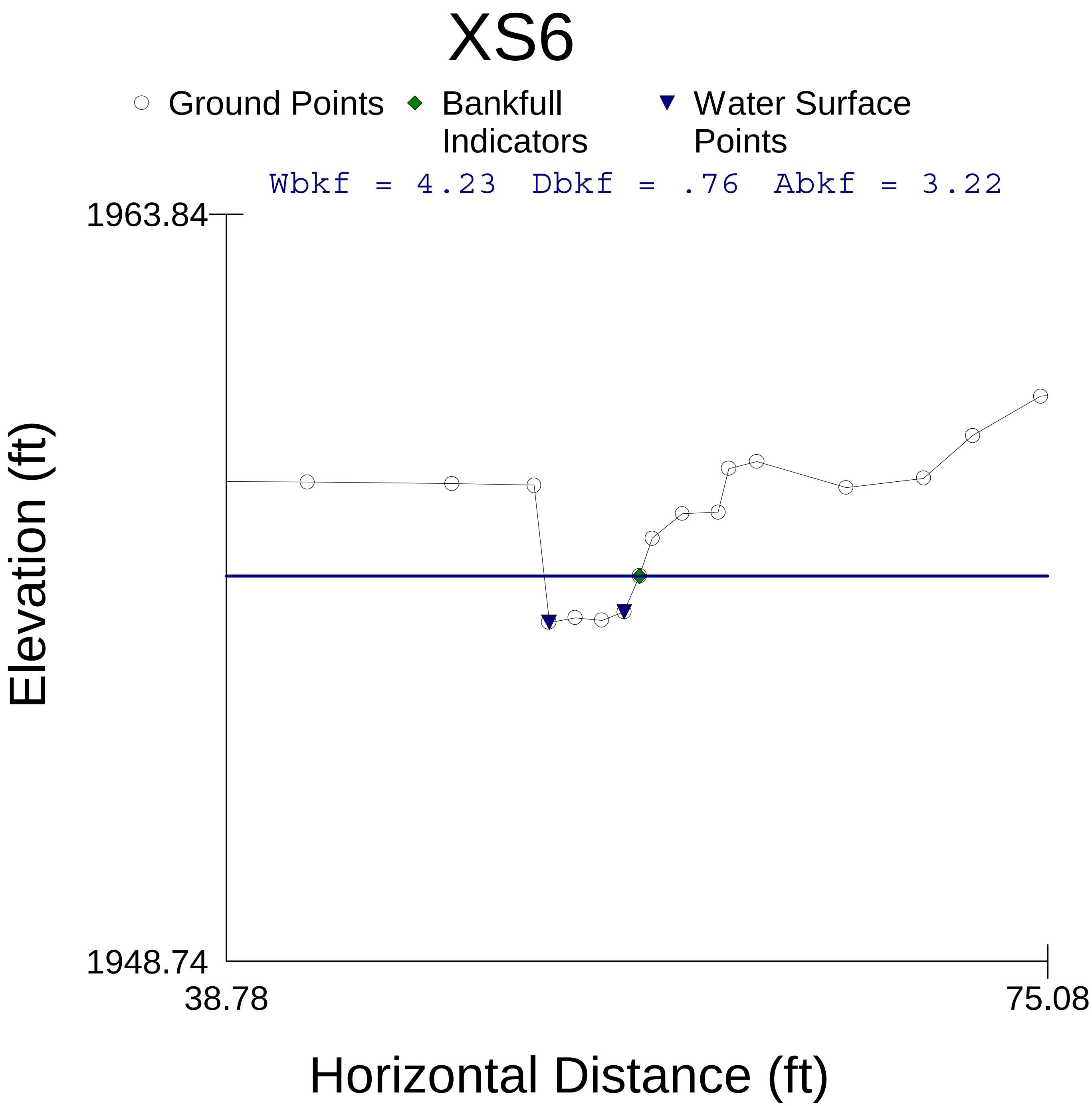
Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**8.82**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.93**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**8.24**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**9.48**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.25**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**10.42**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.18**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**28.39**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00974**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.02**	

Stream Type **G 4c** (See **Figure 2-14**)



Long Profile
Elevation (ft)
1980
1960
1940
1920
1900
0
500
1000
1500
2000
2500
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4


XS5
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 8.82 Dbkf = .93 Abkf = 8.24
1968.6
1961.3
63.7
87.8
Elevation (ft)
Horizontal Distance (ft)


XS6
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 4.23 Dbkf = .76 Abkf = 3.22
1963.84
1948.74
38.78
75.08
Elevation (ft)
Horizontal Distance (ft)

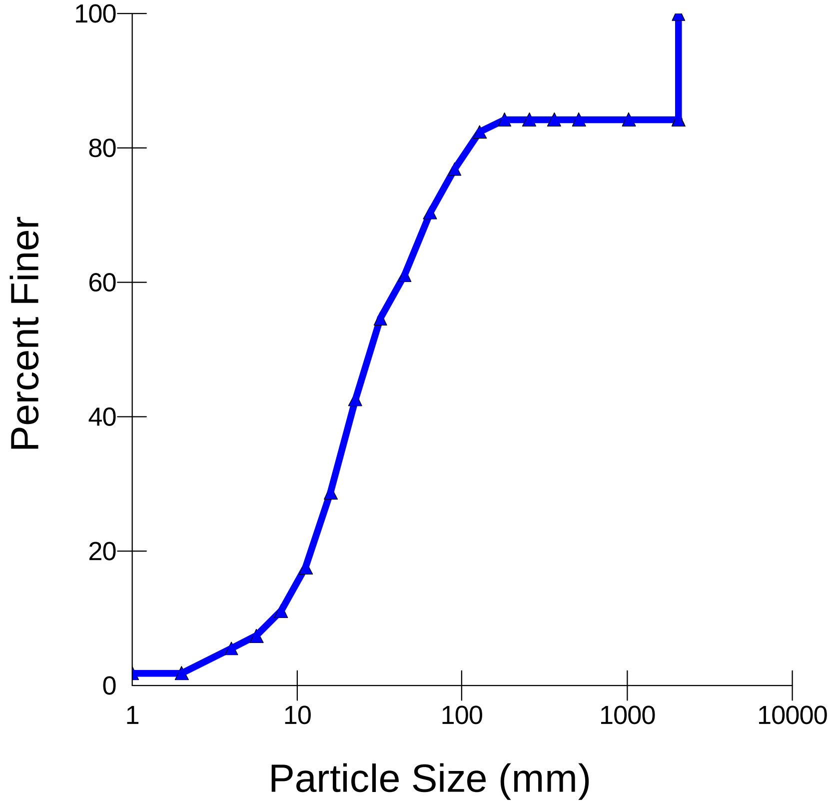
RIVERMORPH PARTICLE SUMMARY

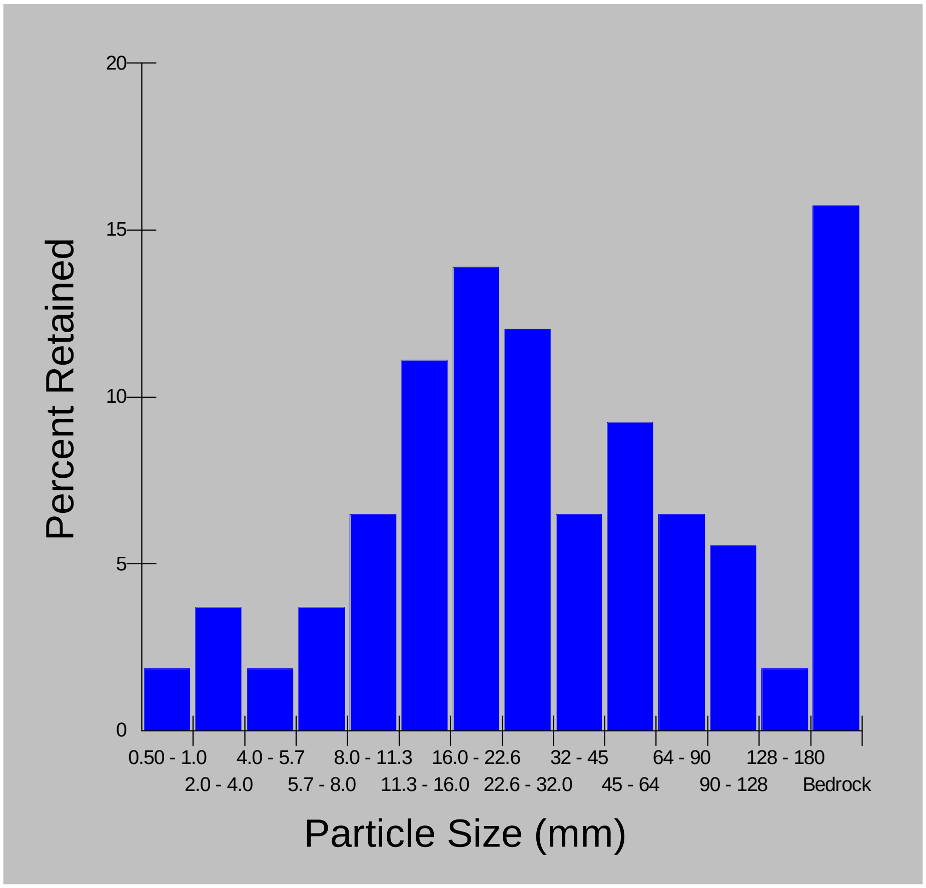
River Name:	Diamond Hills
Reach Name:	Upstream Diamond Hills Park Creek
Sample Name:	2011-04-26 Reach
Survey Date:	04/26/2011

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	2	1.85	1.85
1.0 - 2.0	0	0.00	1.85
2.0 - 4.0	4	3.70	5.56
4.0 - 5.7	2	1.85	7.41
5.7 - 8.0	4	3.70	11.11
8.0 - 11.3	7	6.48	17.59
11.3 - 16.0	12	11.11	28.70
16.0 - 22.6	15	13.89	42.59
22.6 - 32.0	13	12.04	54.63
32 - 45	7	6.48	61.11
45 - 64	10	9.26	70.37
64 - 90	7	6.48	76.85
90 - 128	6	5.56	82.41
128 - 180	2	1.85	84.26
180 - 256	0	0.00	84.26
256 - 362	0	0.00	84.26
362 - 512	0	0.00	84.26
512 - 1024	0	0.00	84.26
1024 - 2048	0	0.00	84.26
Bedrock	17	15.74	100.00

D16 (mm)	10.49
D35 (mm)	18.99
D50 (mm)	28.39
D84 (mm)	172.69
D95 (mm)	Bedrock
D100 (mm)	Bedrock
Silt/Clay (%)	0
Sand (%)	1.85
Gravel (%)	68.52
Cobble (%)	13.89
Boulder (%)	0
Bedrock (%)	15.74

Total Particles = 108.


100
80
60
40
20
0
Percent Finer
1
10
100
1000
10000
Particle Size (mm)



Percent Retained
20
15
10
5
0
0.50 - 1.0
2.0 - 4.0
4.0 - 5.7
5.7 - 8.0
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
Bedrock
Particle Size (mm)

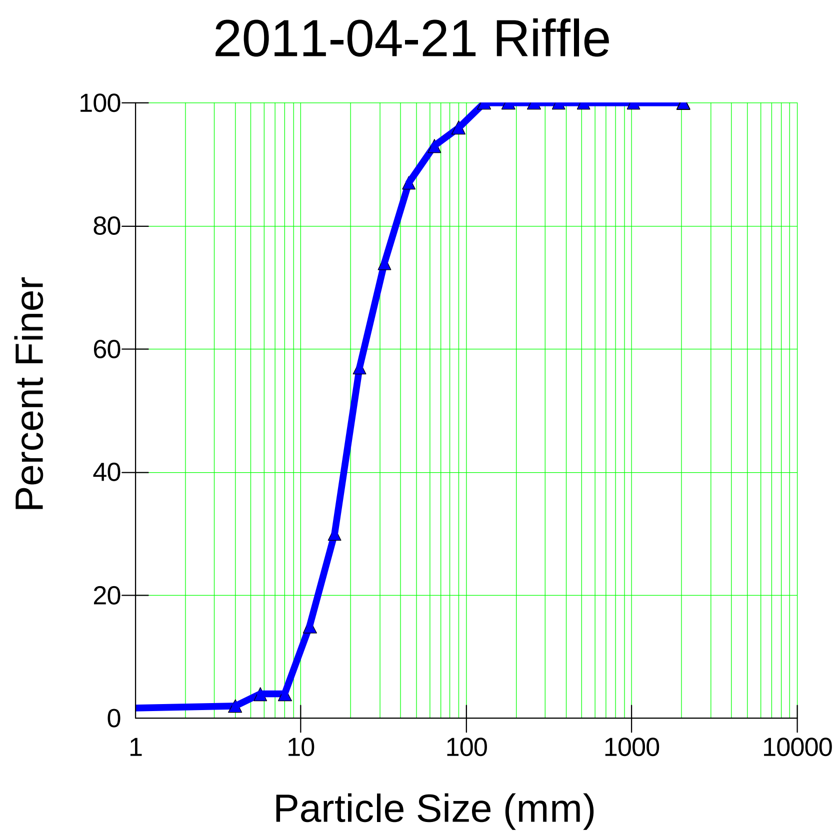
RIVERMORPH PARTICLE SUMMARY

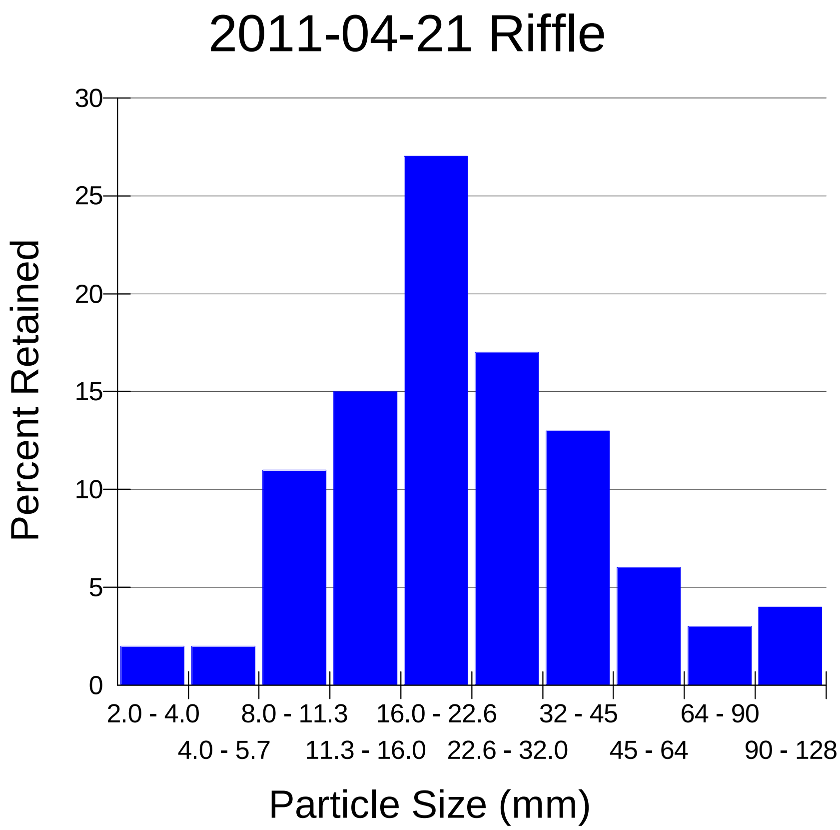
River Name: Diamond Hills
Reach Name: Upstream Diamond Hills Park Creek
Sample Name: 2011-04-26 Riffle
Survey Date: 04/26/2011

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	0	0.00	0.00
1.0 - 2.0	0	0.00	0.00
2.0 - 4.0	2	2.00	2.00
4.0 - 5.7	2	2.00	4.00
5.7 - 8.0	0	0.00	4.00
8.0 - 11.3	11	11.00	15.00
11.3 - 16.0	15	15.00	30.00
16.0 - 22.6	27	27.00	57.00
22.6 - 32.0	17	17.00	74.00
32 - 45	13	13.00	87.00
45 - 64	6	6.00	93.00
64 - 90	3	3.00	96.00
90 - 128	4	4.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	11.61
D35 (mm)	17.22
D50 (mm)	20.89
D84 (mm)	42
D95 (mm)	81.33
D100 (mm)	128
Silt/Clay (%)	0
Sand (%)	0
Gravel (%)	93
Cobble (%)	7
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.


2011-04-21 Riffle
Percent Finer
100
80
60
40
20
0
1
10
100
1000
10000
Particle Size (mm)


2011-04-21 Riffle
Percent Retained
30
25
20
15
10
5
0
2.0 - 4.0
4.0 - 5.7
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
Particle Size (mm)

RIVERMORPH PARTICLE SUMMARY

River Name: Diamond Hills
Reach Name: Upstream Diamond Hills Park Creek
Sample Name: 2011-06-02
Survey Date: 06/02/2011

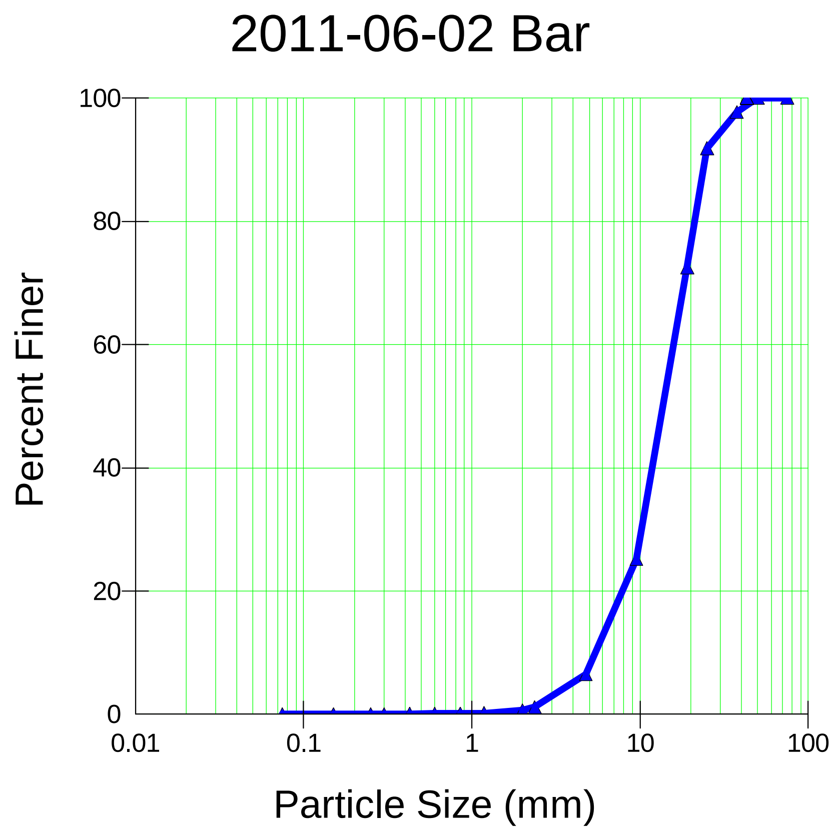
SIEVE (mm)	NET WT
75	0
50	0
37.5	79.58
25	202.6
19	665.89
9.5	1634.53
4.75	644.22
2.36	184.16
2	17.75
1.18	15.15
0.85	2.57
0.6	.98
0.425	.71
0.3	.52
0.25	.78
0.15	1.09
0.075	1
PAN	.2

D16 (mm)	7.16
D35 (mm)	11.47
D50 (mm)	14.48
D84 (mm)	22.57
D95 (mm)	31.77
D100 (mm)	43
Silt/Clay (%)	0
Sand (%)	0.67
Gravel (%)	99.33
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

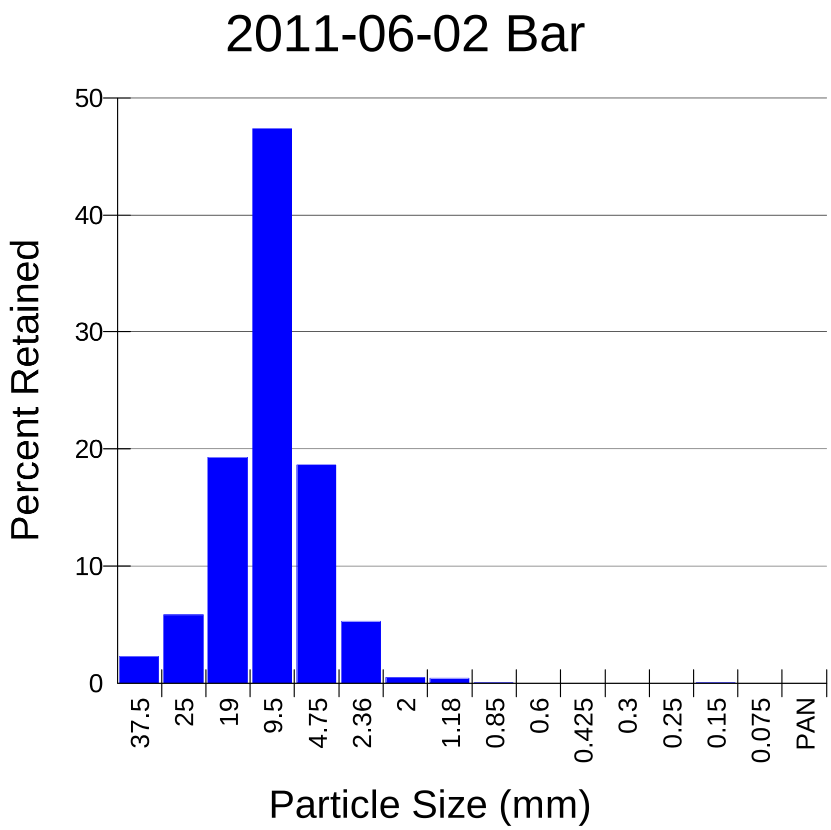
Total Weight = 3451.8700.

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	43	0.08
Particle 2:	29	0.06



2011-06-02 Bar
Percent Finer
100
80
60
40
20
0
0.01
0.1
1
10
100
Particle Size (mm)


2011-06-02 Bar
Percent Retained
50
40
30
20
10
0
37.5
25
19
9.5
4.75
2.36
2
1.18
0.85
0.6
0.425
0.3
0.25
0.15
0.075
PAN
Particle Size (mm)

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Diamond Hills
Reach Name: Diamond Hills Park Creek
BEHI Name: Downstream
Survey Date: 04/15/2011

Bankfull Height: 0.8 ft
Bank Height: 3.2 ft
Root Depth: 1.4 ft
Root Density: 20 %
Bank Angle: 100 Degrees
Surface Protection: 5 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: Yes 5

Erosion Loss Curve: Yellowstone

NBS Method #6: Near-Bank Shear Stress

Mean Depth: 0.93 ft
NB Max Depth: 1.25 ft
Shear Stress: 0.57 lb/sq/ft
Stress Ratio: 1.38

Average Slope: 0.00974 ft/ft
NB Slope: 0.01 ft/ft
NB Shear Stress: 0.78 lb/sq/ft

BEHI Numerical Rating: 46.4
BEHI Adjective Rating: Extreme
NBS Numerical Rating: 1.38
NBS Adjective Rating: Very High
Total Bank Length: 12 ft
Estimated Sediment Loss: 3.27 Cu Yds per Year
Estimated Sediment Loss: 4.25 Tons per Year

RIVERMORPH PFANKUCH SUMMARY

River Name: Diamond Hills
Reach Name: Diamond Hills Park Creek
Survey Date: 04/21/2011

Upper Bank

Landform Slope:	8
Mass Wasting:	12
Debris Jam Potential:	4
Vegetative Protection:	9

Lower Bank

Channel Capacity:	1
Bank Rock Content:	8
Obstructions to Flow:	6
Cutting:	16
Deposition:	16

Channel Bottom

Rock Angularity:	2
Brightness:	2
Consolidation of Particles:	2
Bottom Size Distribution:	12
Scouring and Deposition:	24
Aquatic Vegetation:	4

Channel Stability Evaluation

Sediment Supply:	Low
Stream Bed Stability:	Degrading
W/D Condition:	High
Stream Type:	E4

Rating - 126
Condition - Poor

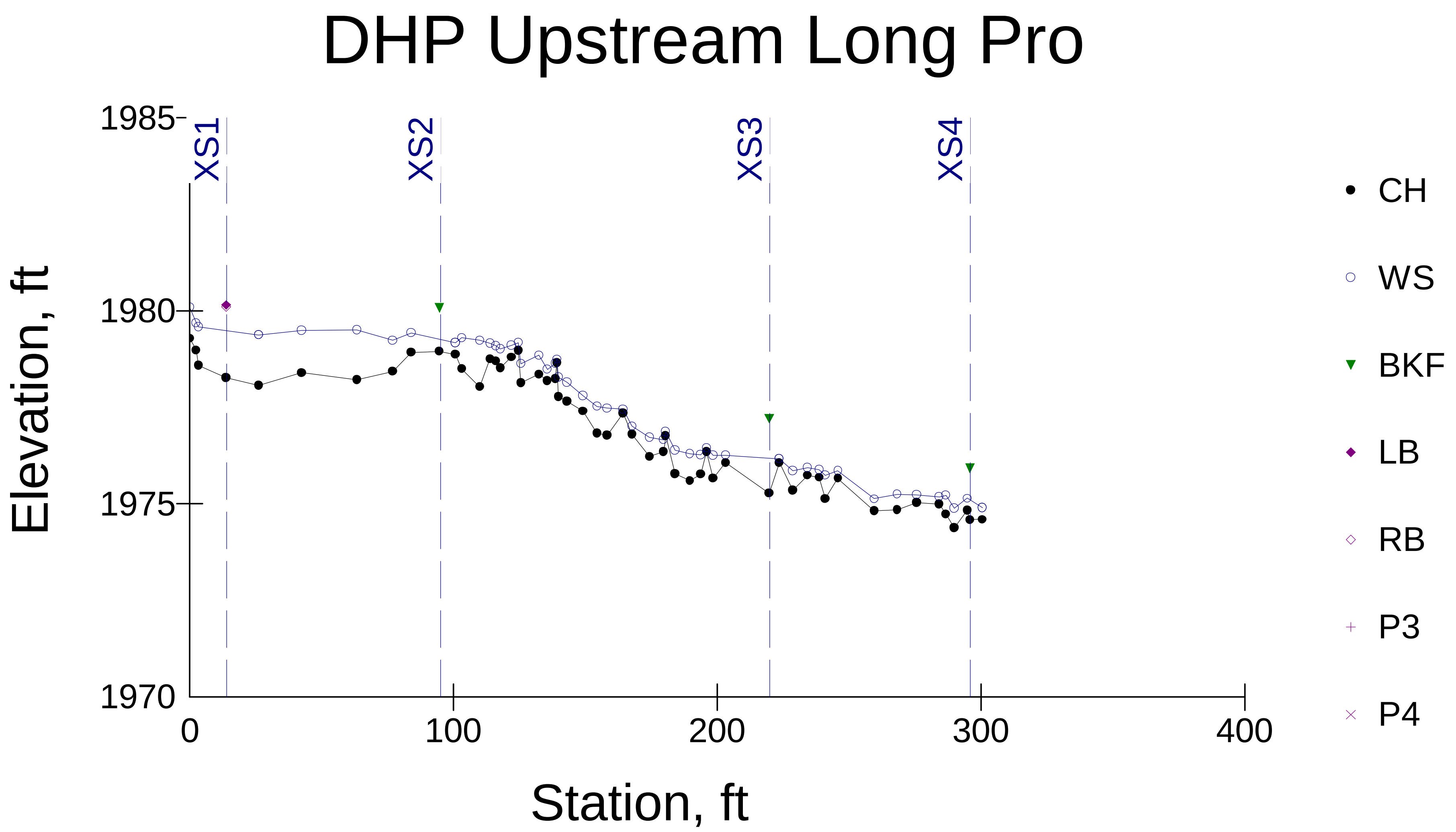
Upstream
Diamond Hills Park

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

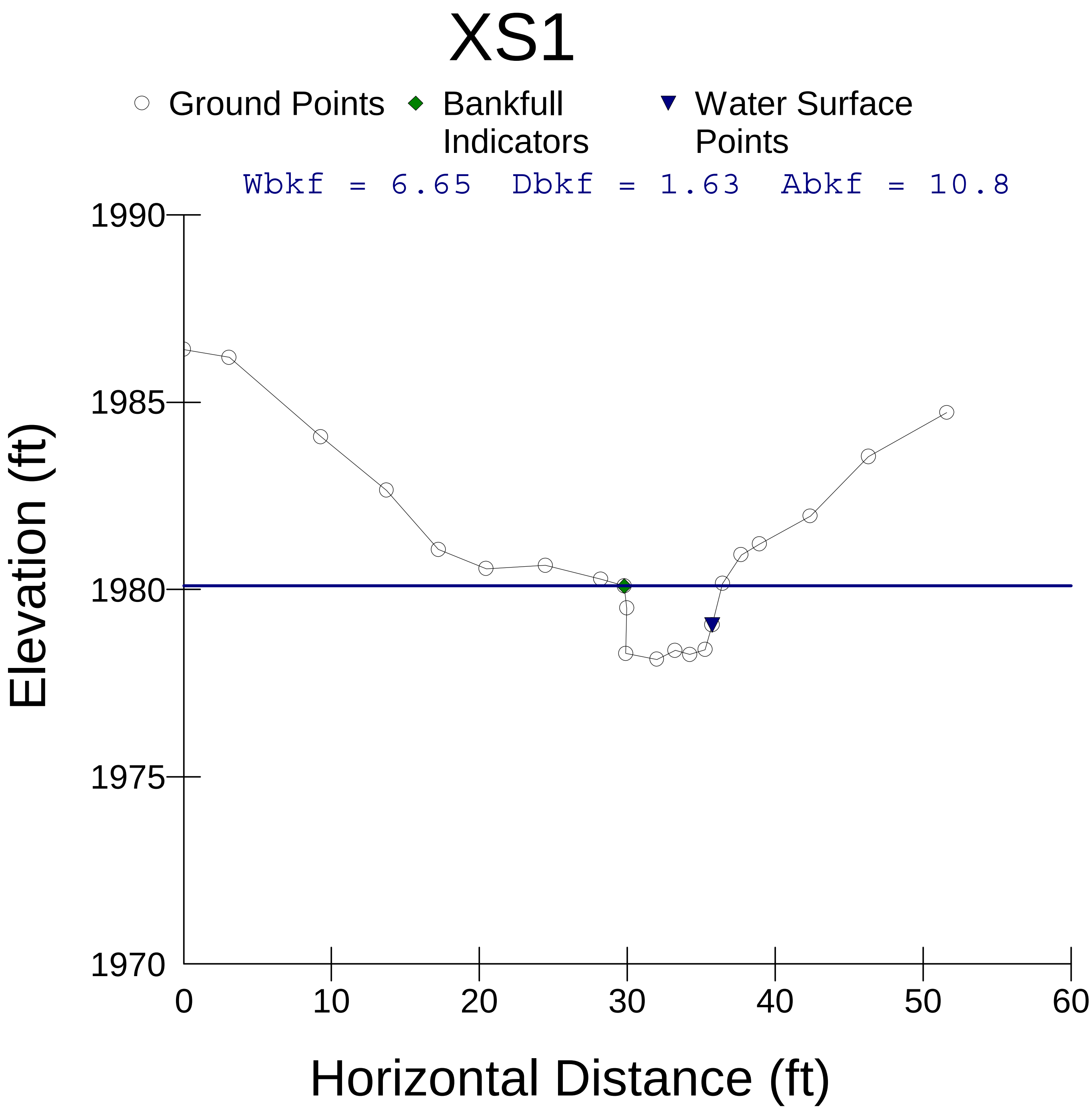
Stream:	**Diamond Hills, Reach - Upstream Diamond Hills Park Creek**			
Basin:	Drainage Area:	**275.2** acres	**0.43**	mi^2
Location:				
Twp.&Rge: **;**	Sec.&Qtr.: **;**			
Cross-Section Monuments (Lat./Long.):	**37.14661 Lat / 80.429 Long**		Date:	**04/15/11**
Observers:			Valley Type:	**II**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**7.2**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.94**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**6.8**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**7.66**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.35**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**21.57**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**28.39**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.02141**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1**	

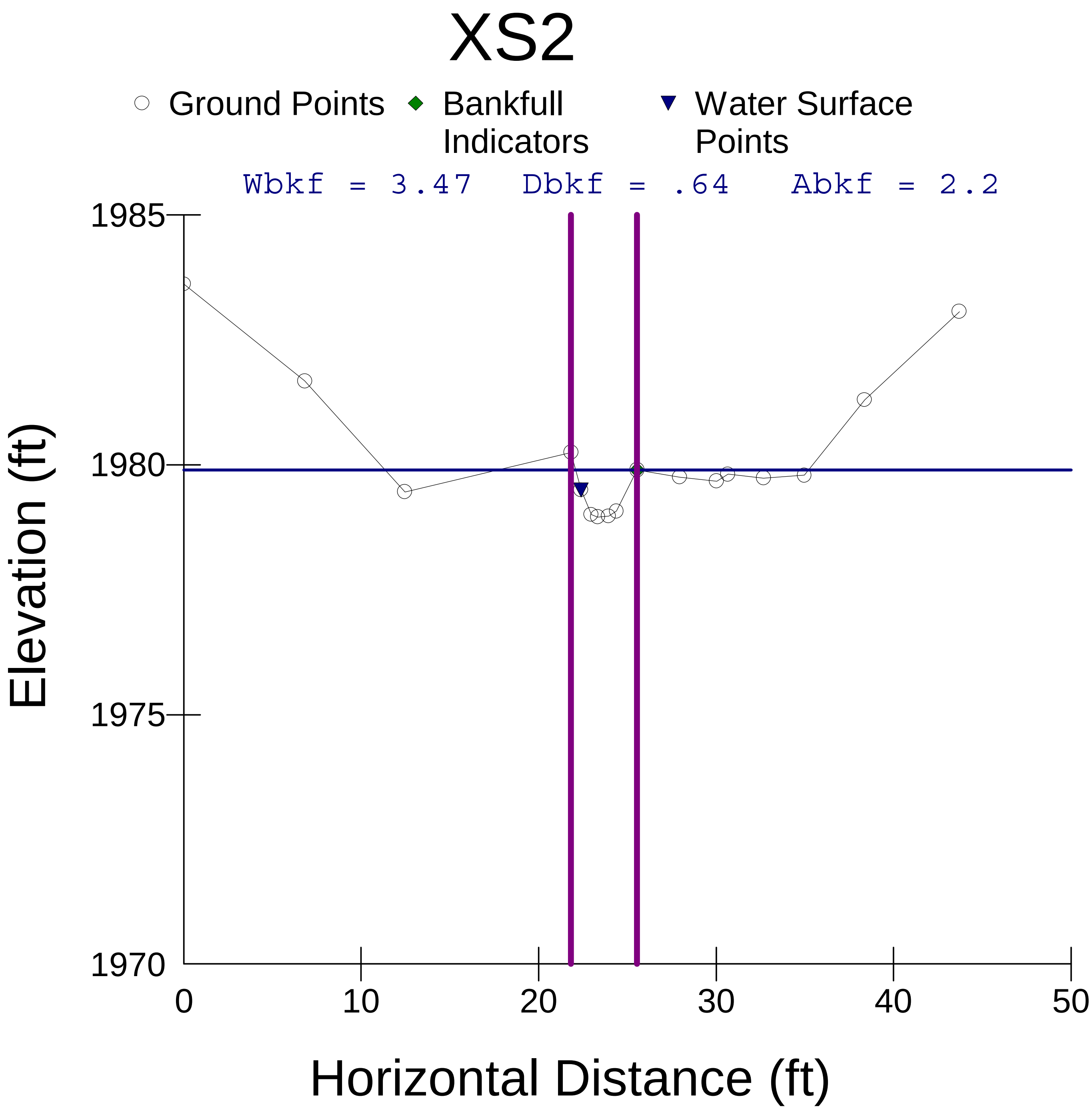
Stream Type **E 4/1b** (See **Figure 2-14**)

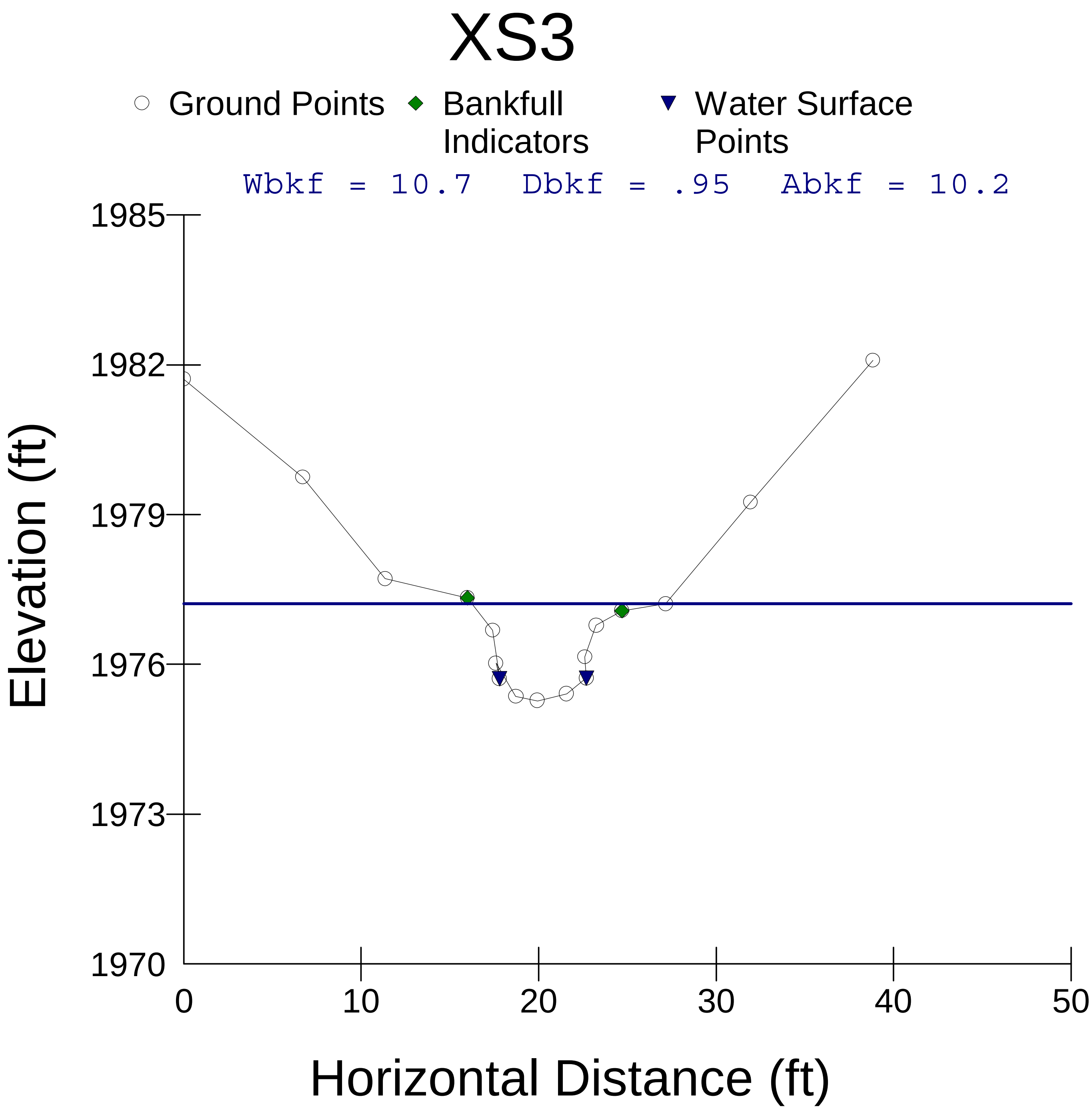


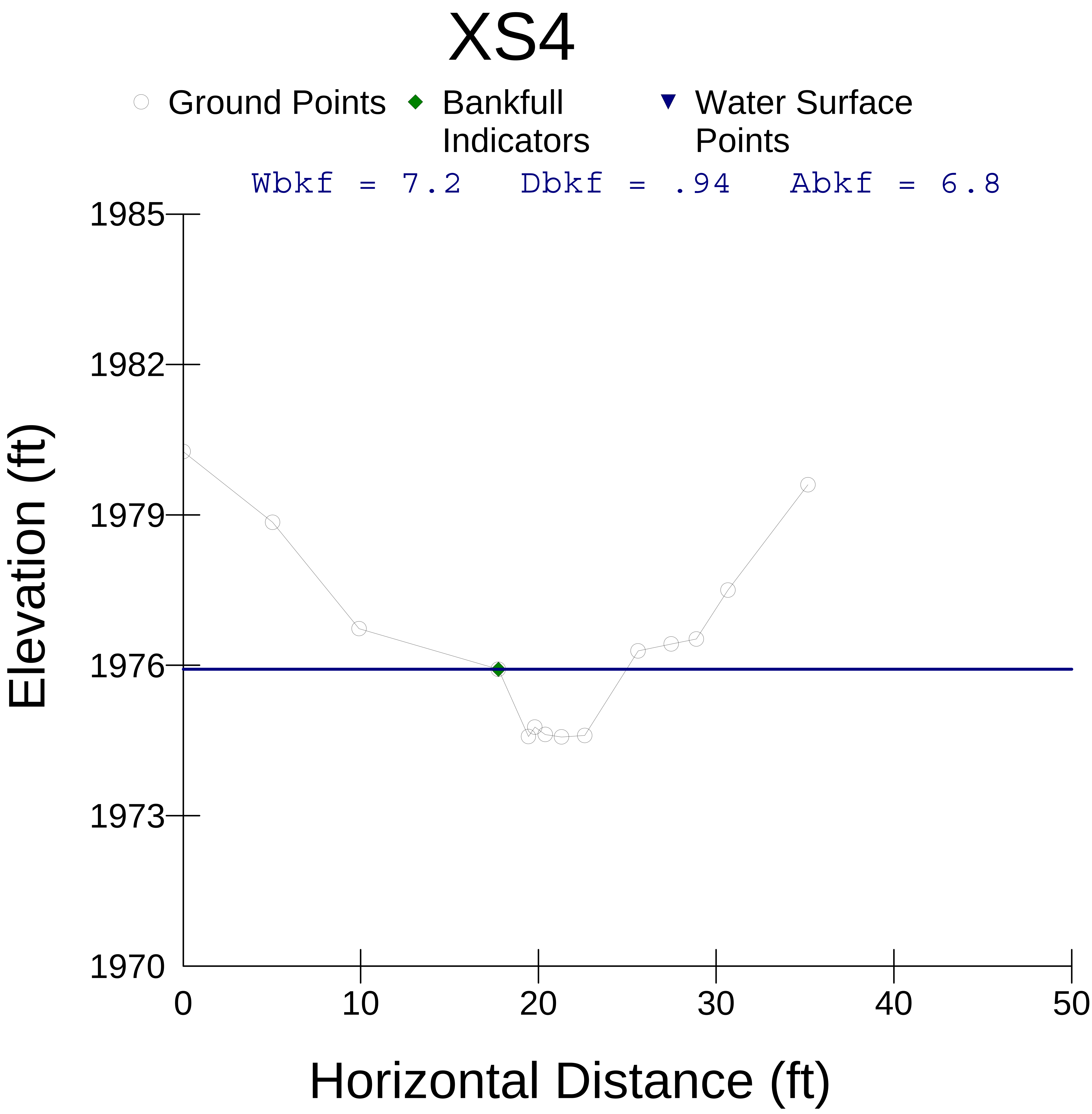
DHP Upstream Long Pro
Elevation, ft
Station, ft
1985
1980
1975
1970
0
100
200
300
400
XS1
XS2
XS3
XS4
CH
WS
BKF
LB
RB
P3
P4



XS1
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 6.65 Dbkf = 1.63 Abkf = 10.8
Elevation (ft)
1990
1985
1980
1975
1970
0
10
20
30
40
50
60
Horizontal Distance (ft)


XS2
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 3.47
Dbkf = .64
Abkf = 2.2
1985
1980
1975
1970
0
10
20
30
40
50
Elevation (ft)
Horizontal Distance (ft)


XS3
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 10.7 Dbkf = .95 Abkf = 10.2
1985
1982
1979
1976
1973
1970
Elevation (ft)
0
10
20
30
40
50
Horizontal Distance (ft)


XS4
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 7.2   Dbkf = .94   Abkf = 6.8
1985
1982
1979
1976
1973
1970
Elevation (ft)
0
10
20
30
40
50
Horizontal Distance (ft)

RIVERMORPH PFANKUCH SUMMARY

River Name: Diamond Hills
Reach Name: Upstream Diamond Hills Park Creek
Survey Date: 04/13/2011

Upper Bank

Landform Slope:	4
Mass Wasting:	6
Debris Jam Potential:	2
Vegetative Protection:	6

Lower Bank

Channel Capacity:	1
Bank Rock Content:	6
Obstructions to Flow:	4
Cutting:	4
Deposition:	4

Channel Bottom

Rock Angularity:	1
Brightness:	2
Consolidation of Particles:	2
Bottom Size Distribution:	8
Scouring and Deposition:	6
Aquatic Vegetation:	1

Channel Stability Evaluation

Sediment Supply:	Moderate
Stream Bed Stability:	Stable
W/D Condition:	Normal
Stream Type:	E4/1B

Rating - 57
Condition - Good

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Diamond Hills
Reach Name: Upstream Diamond Hills Park Creek
BEHI Name: XS 7
Survey Date: 04/15/2011

Bankfull Height: 1.5 ft
Bank Height: 1.5 ft
Root Depth: 1.5 ft
Root Density: 80 %
Bank Angle: 40 Degrees
Surface Protection: 85 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Colorado

NBS Method #7: Vertical Velocity Near-Bank Shear Stress Method

Velocity at Surface: 0 fps	Velocity at Bed: 0 fps
Depth: 0 ft	Hydraulic Radius: 0 ft
Bankfull Slope: 0	Shear Stress: 0.00 lb/sq/ft
NB Shear Stress: 0.00 lb/sq/ft	Shear Ratio: 0.00

BEHI Numerical Rating: 8.5
BEHI Adjective Rating: Very Low
NBS Numerical Rating: 0.00
NBS Adjective Rating:
Total Bank Length: 1 ft
Estimated Sediment Loss: 0 Cu Yds per Year
Estimated Sediment Loss: 0 Tons per Year

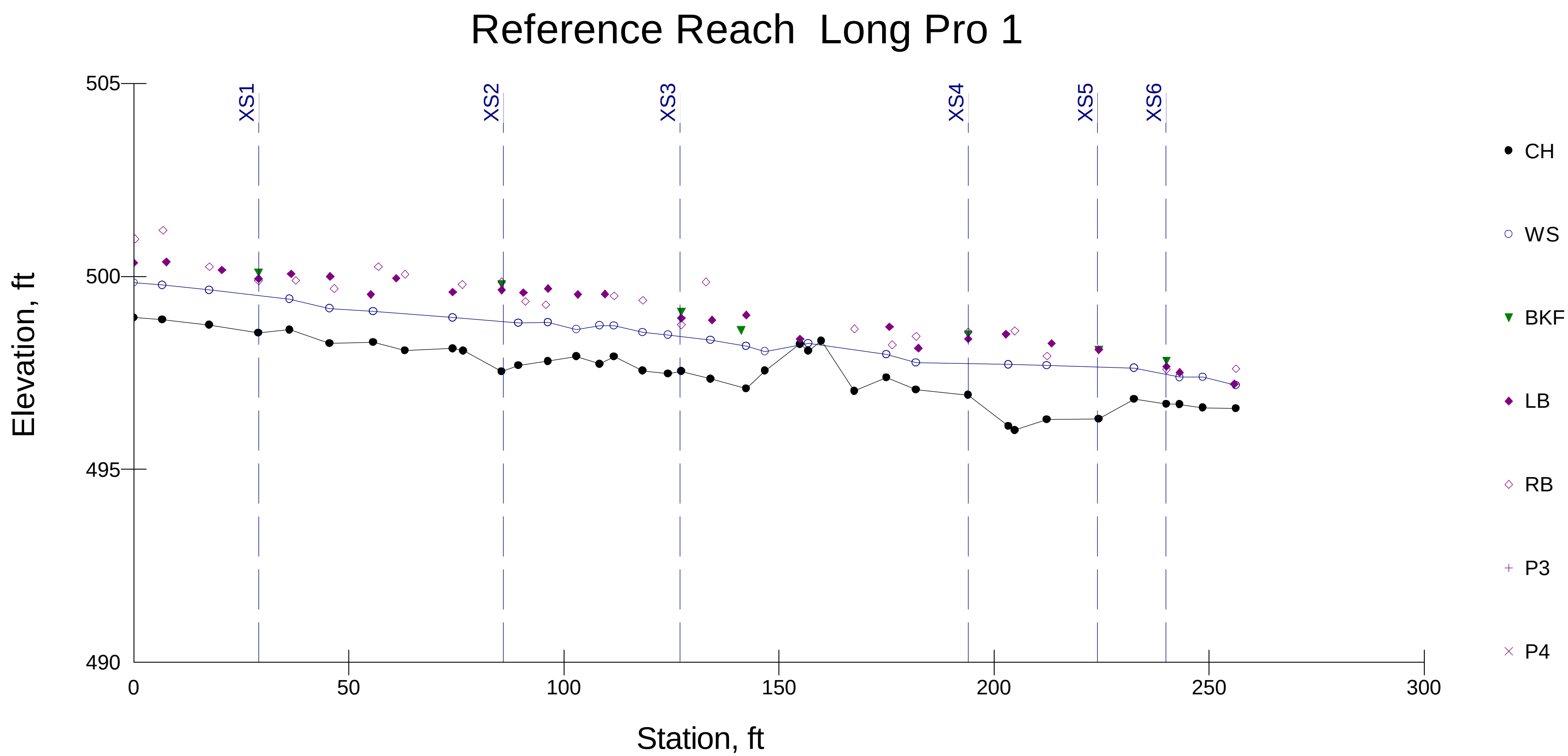
Reference Reach
Bishop Road
Blacksburg, Virginia

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

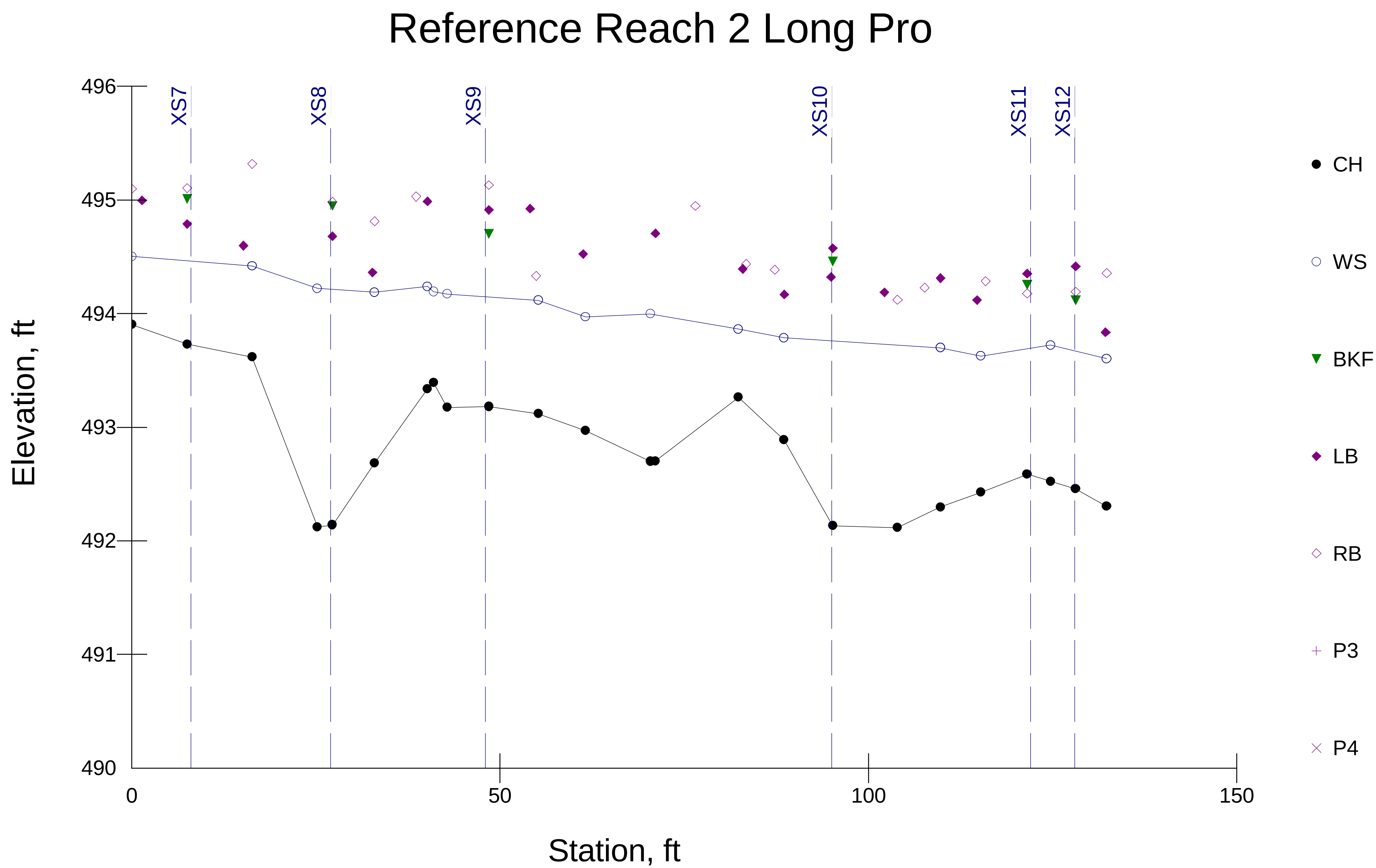
Stream: **Diamond Hills, Reach - Bishop Road Ref**	
Basin:	Drainage Area: **1075.2** acres **1.68** mi^2
Location:	
Twp.&Rge: **;**	Sec.&Qtr.: **;**
Cross-Section Monuments (Lat./Long.): **37.27167 Lat / 80.41714 Long**	Date: **04/21/11**
Observers:	Valley Type: II

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**8.24**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.81**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**6.68**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**10.17**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.55**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**22.92**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.78**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**48.17**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.01145**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.12**	

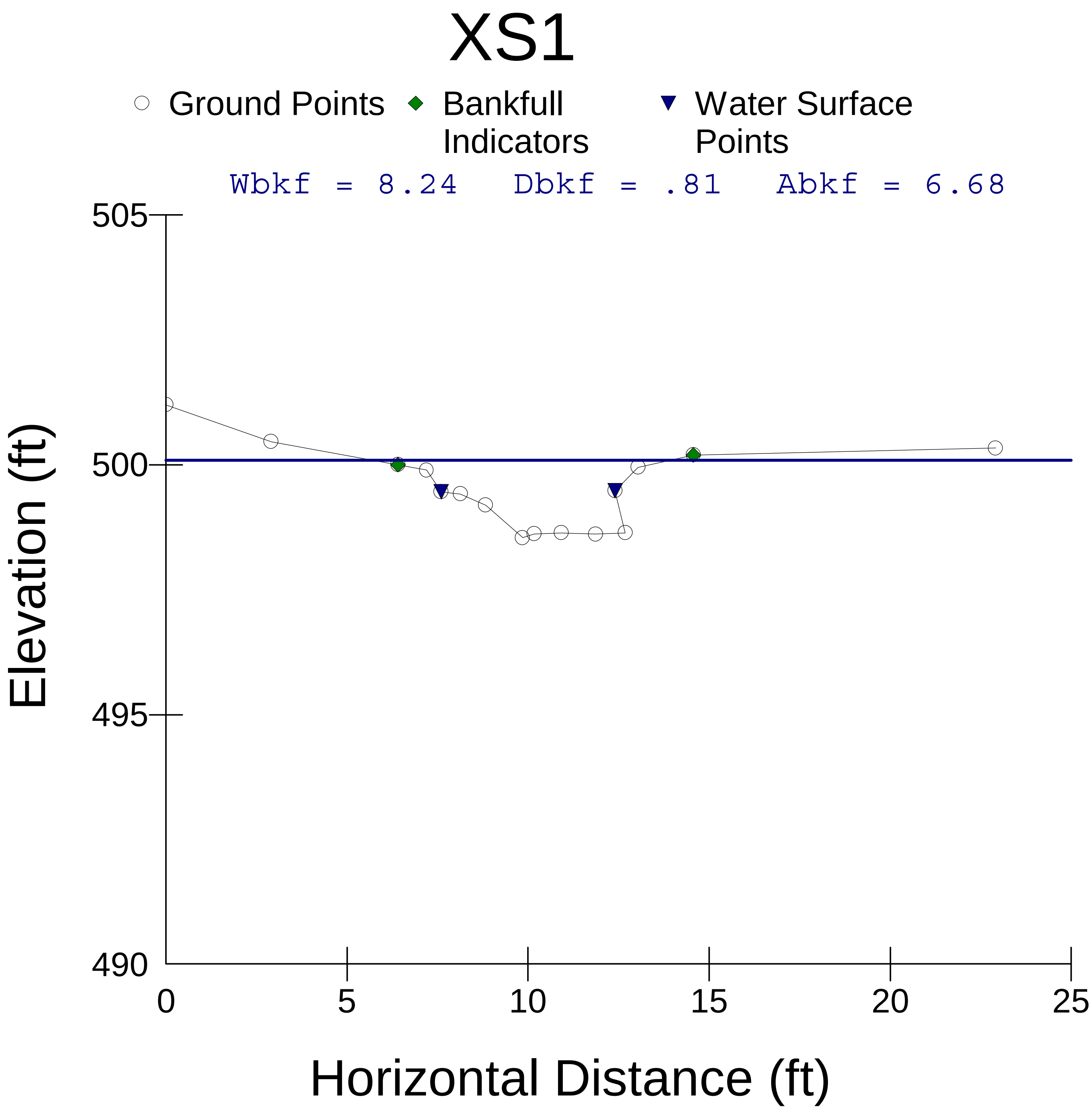
Stream Type **E 4** (See **Figure 2-14**)

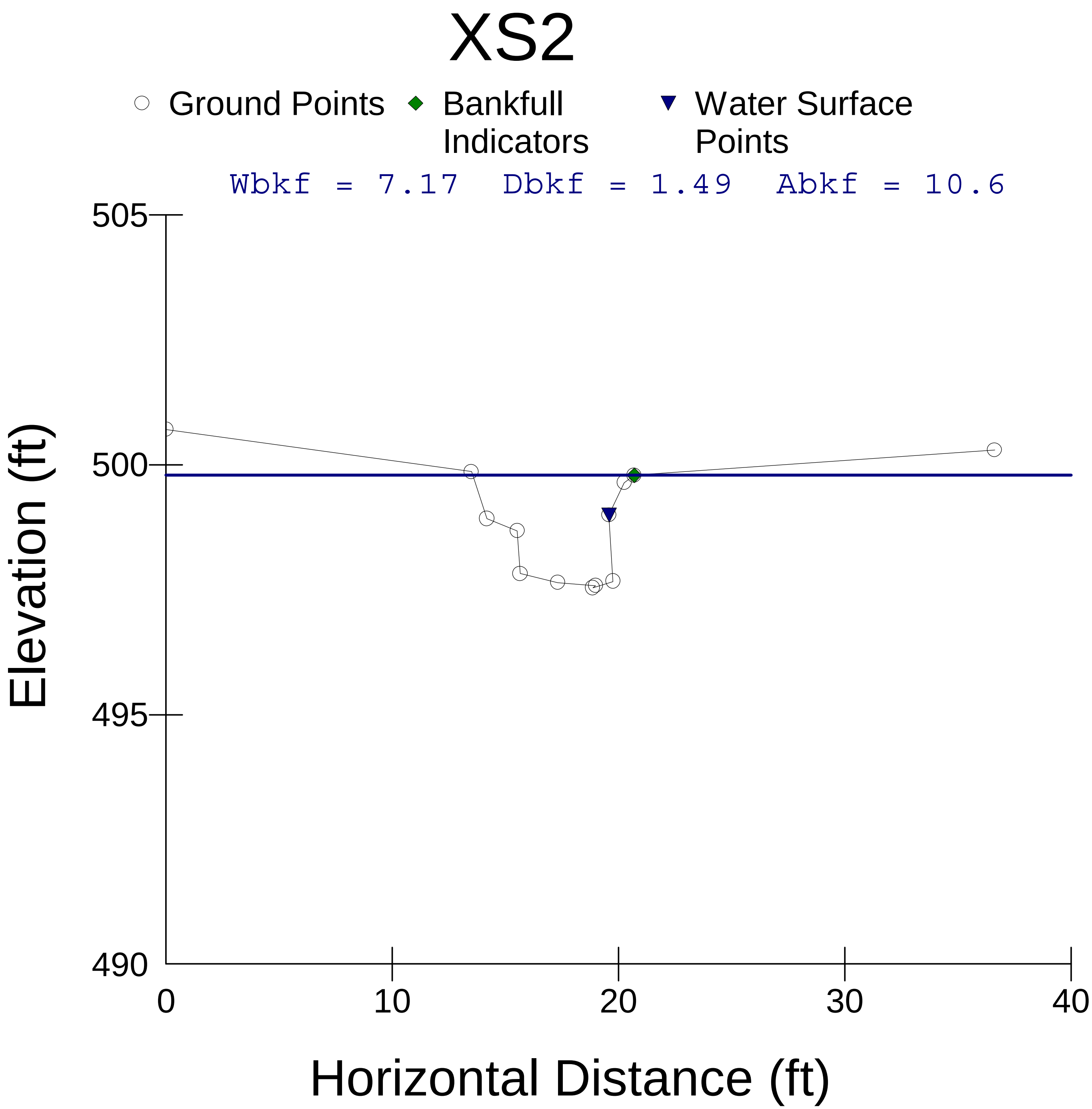


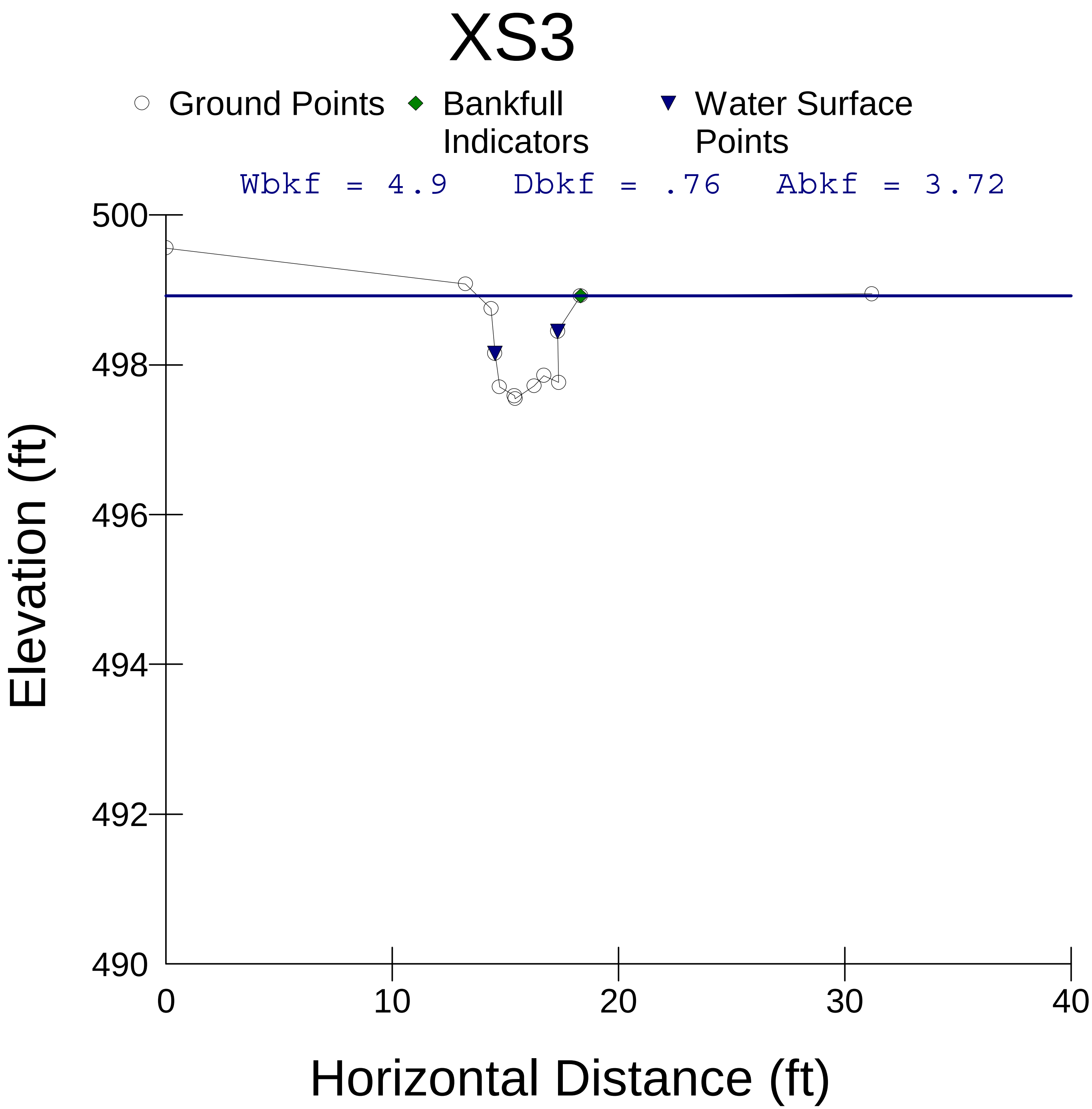
Reference Reach Long Pro 1
Elevation, ft
Station, ft
505
500
495
490
0
50
100
150
200
250
300
XS1
XS2
XS3
XS4
XS5
XS6
CH
WS
BKF
LB
RB
P3
P4

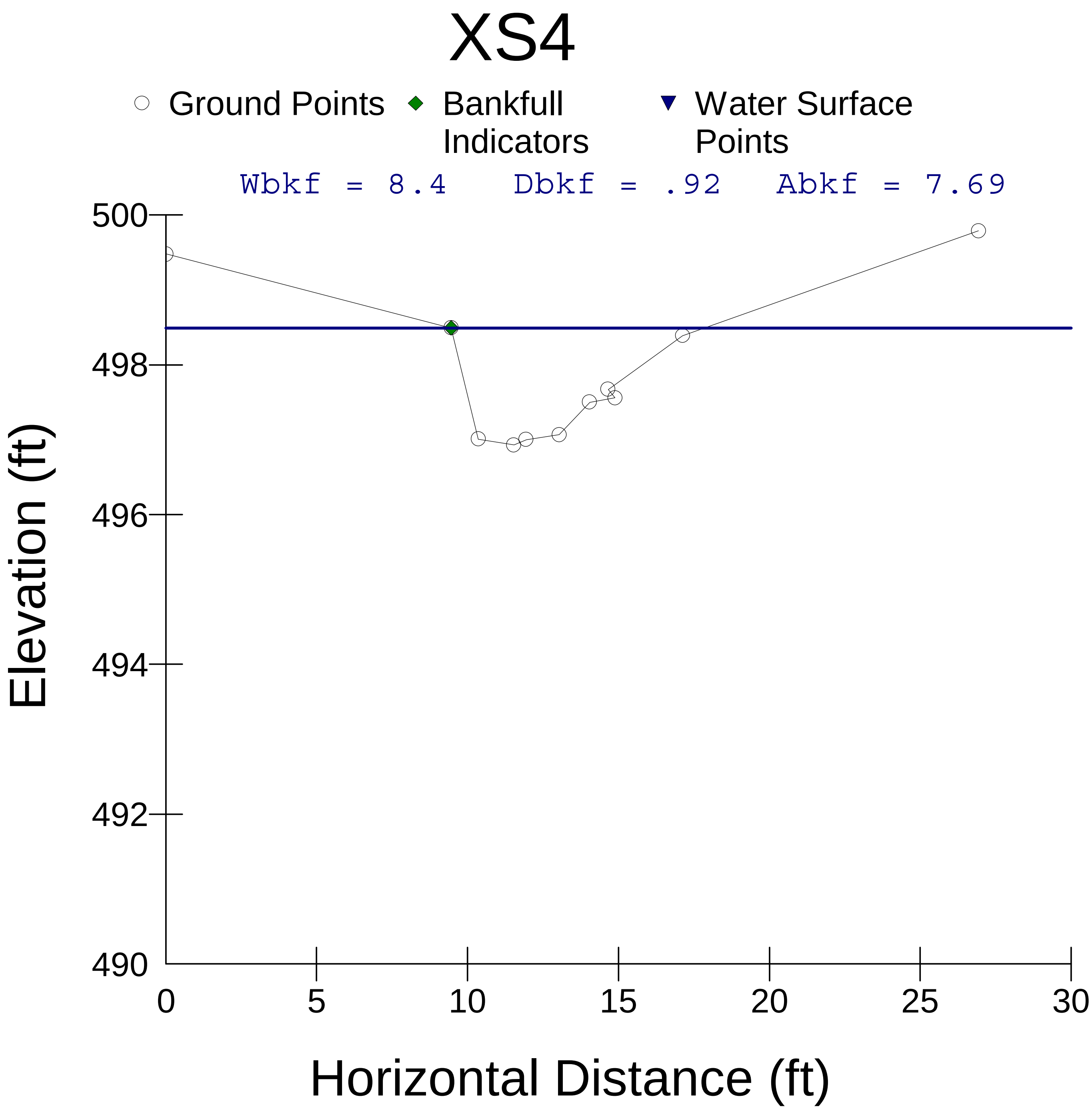


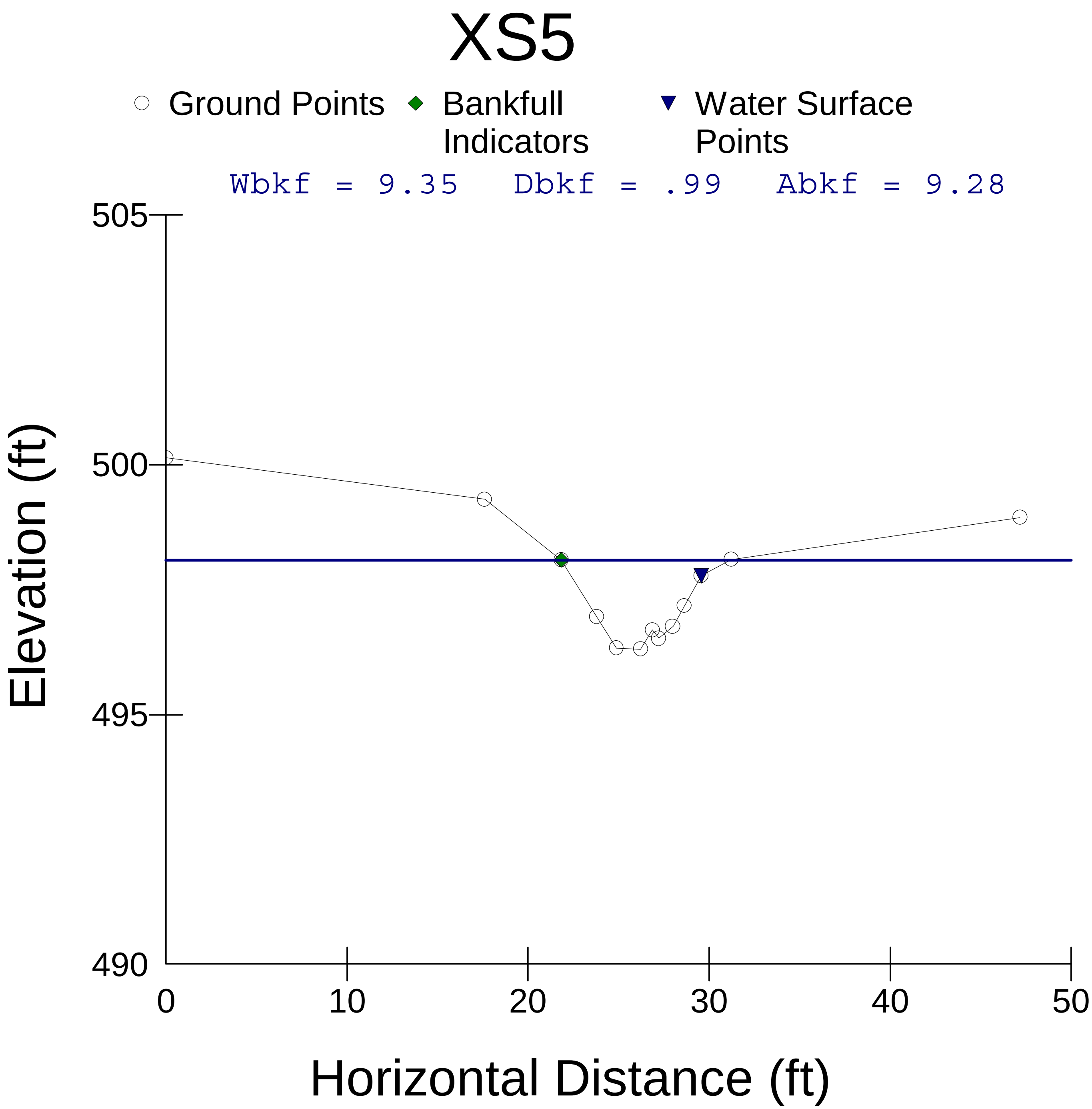
Reference Reach 2 Long Pro
Elevation, ft
Station, ft
496
495
494
493
492
491
490
0
50
100
150
XS7
XS8
XS9
XS10
XS11
XS12
CH
WS
BKF
LB
RB
P3
P4

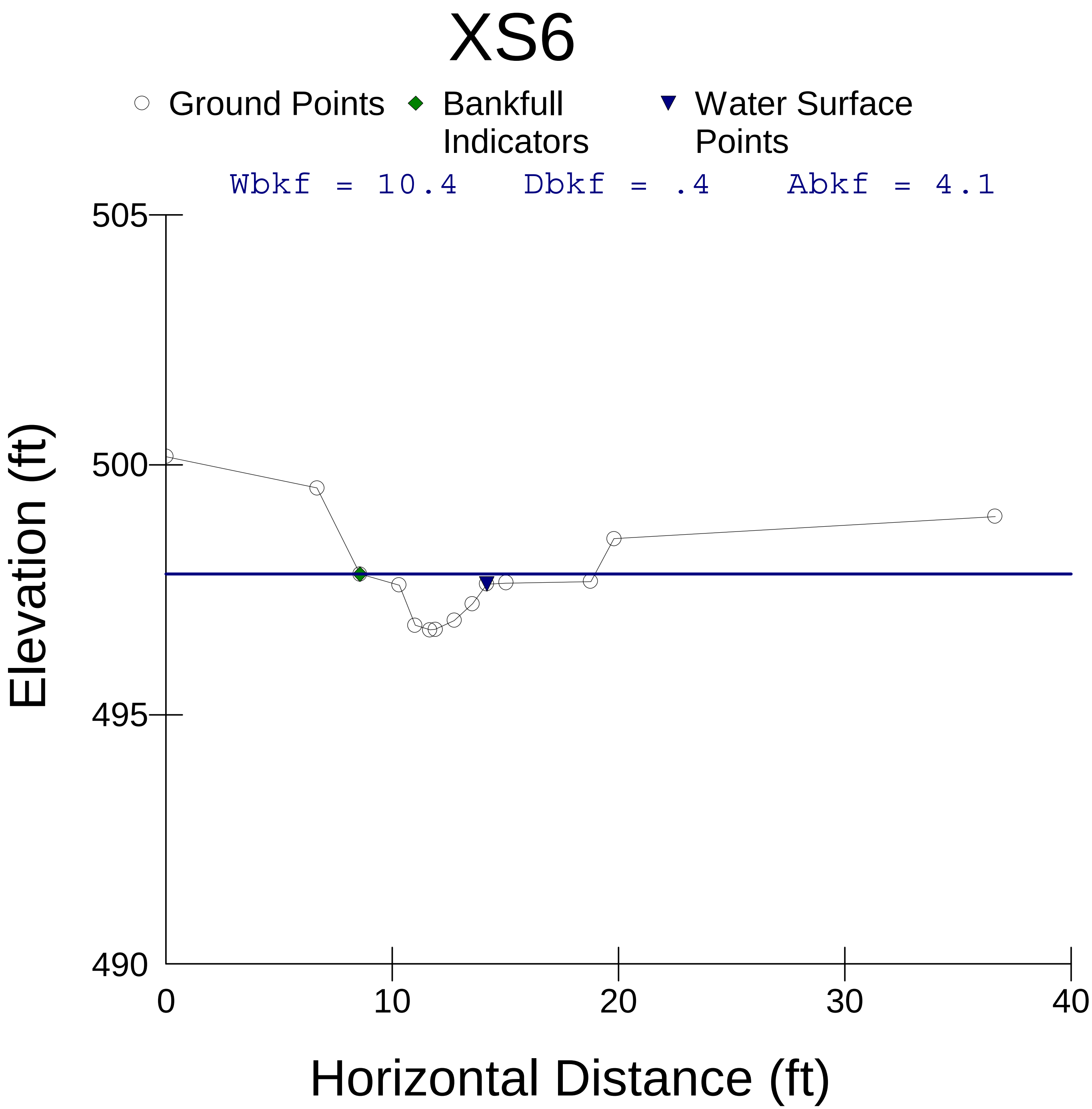

XS1
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 8.24   Dbkf = .81   Abkf = 6.68
505
500
495
490
0
5
10
15
20
25
Elevation (ft)
Horizontal Distance (ft)

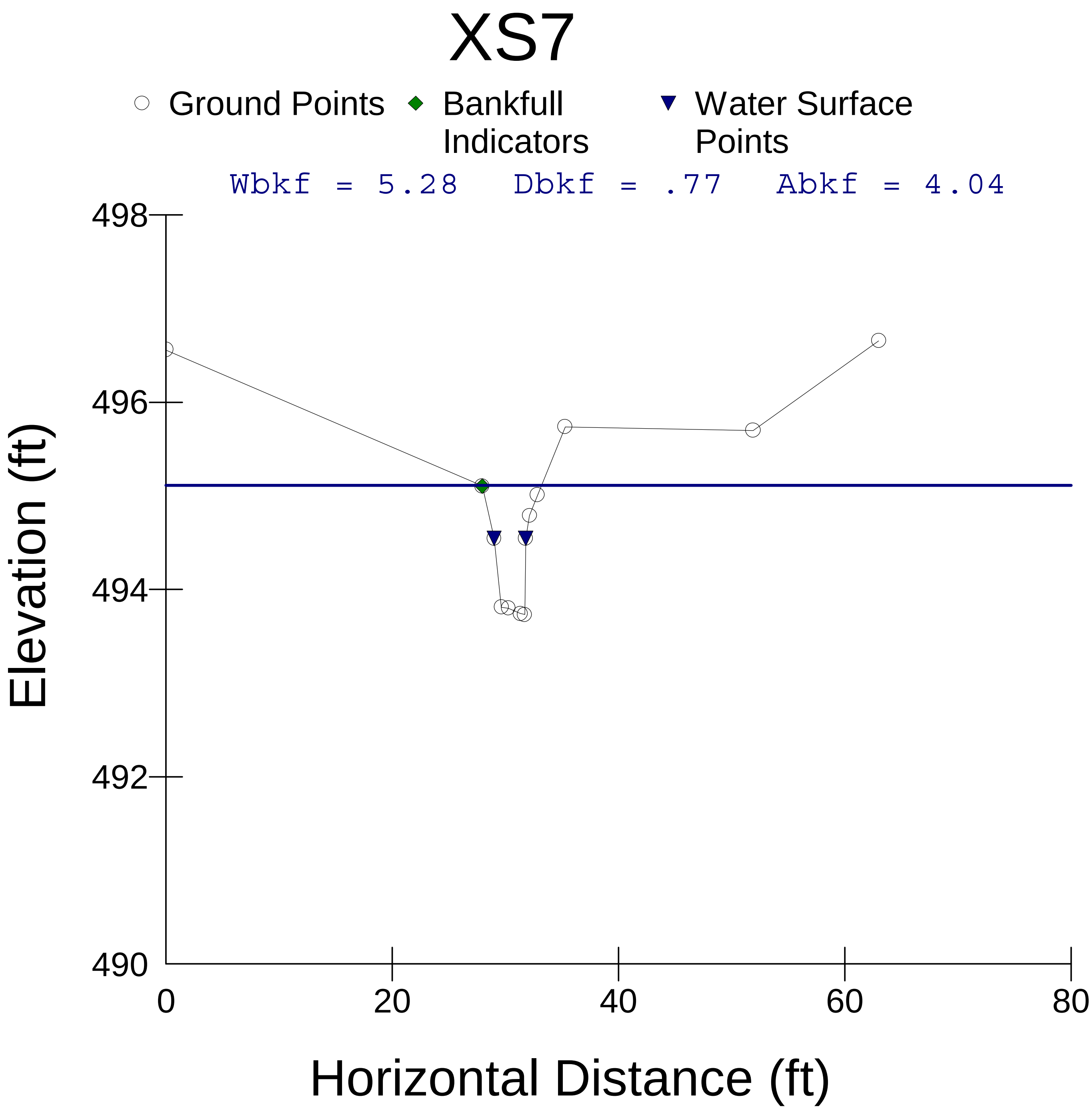

XS2
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 7.17 Dbkf = 1.49 Abkf = 10.6
505
500
495
490
0
10
20
30
40
Elevation (ft)
Horizontal Distance (ft)


XS3
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 4.9 Dbkf = .76 Abkf = 3.72
500
498
496
494
492
490
0
10
20
30
40
Elevation (ft)
Horizontal Distance (ft)

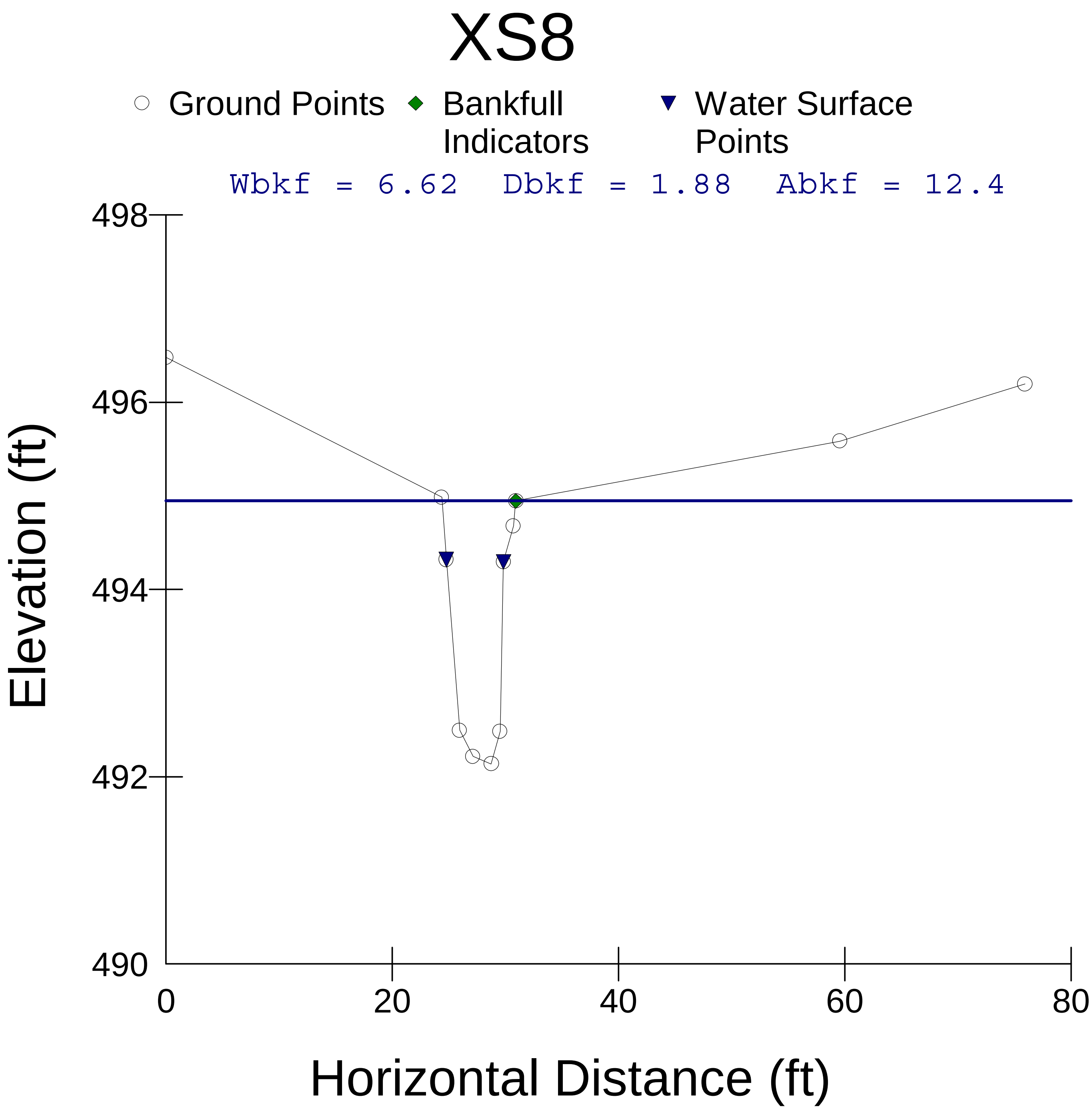

XS4
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 8.4
Dbkf = .92
Abkf = 7.69
Elevation (ft)
500
498
496
494
492
490
0
5
10
15
20
25
30
Horizontal Distance (ft)

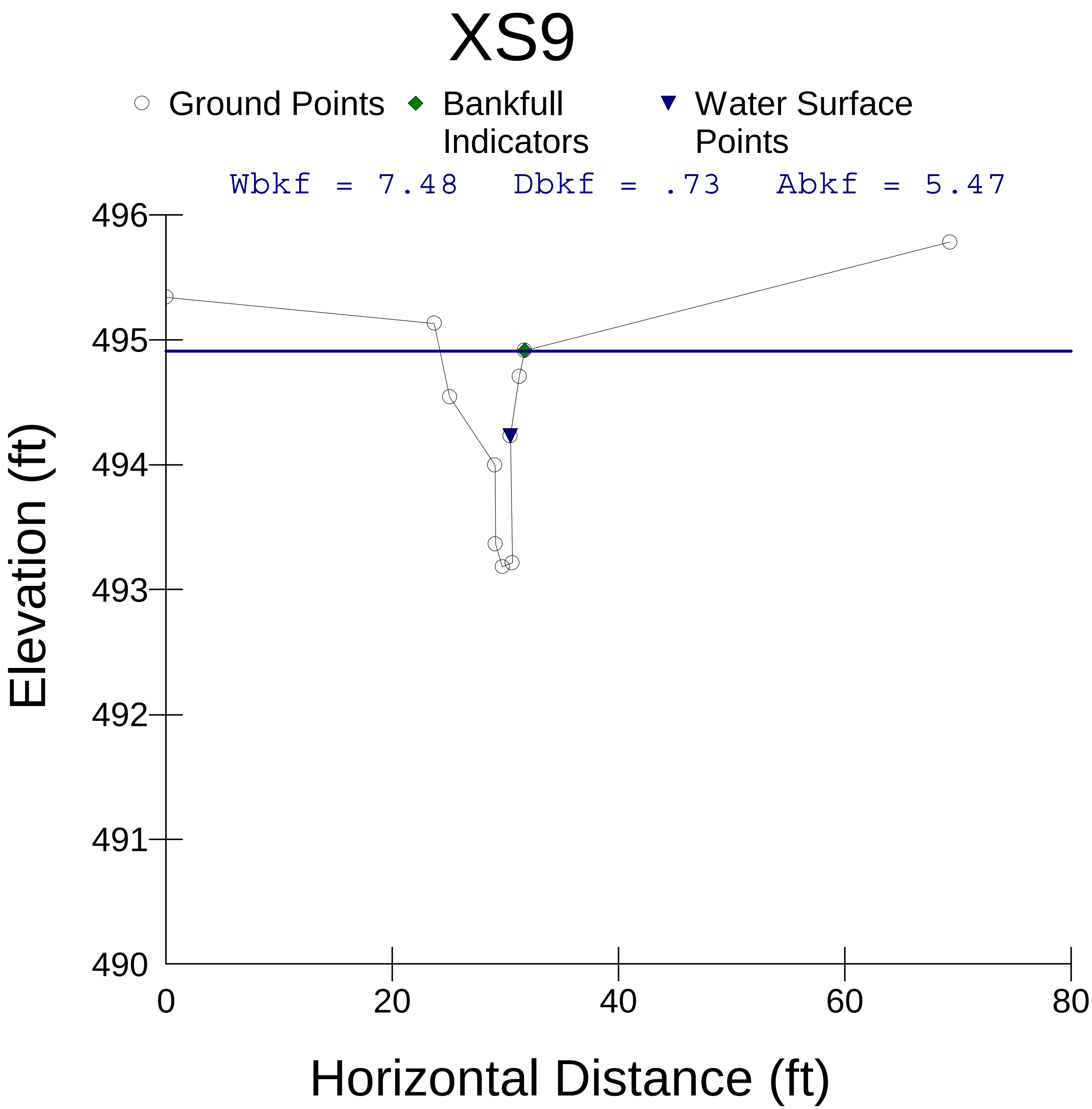

XS5
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 9.35
Dbkf = .99
Abkf = 9.28
505
500
495
490
0
10
20
30
40
50
Elevation (ft)
Horizontal Distance (ft)

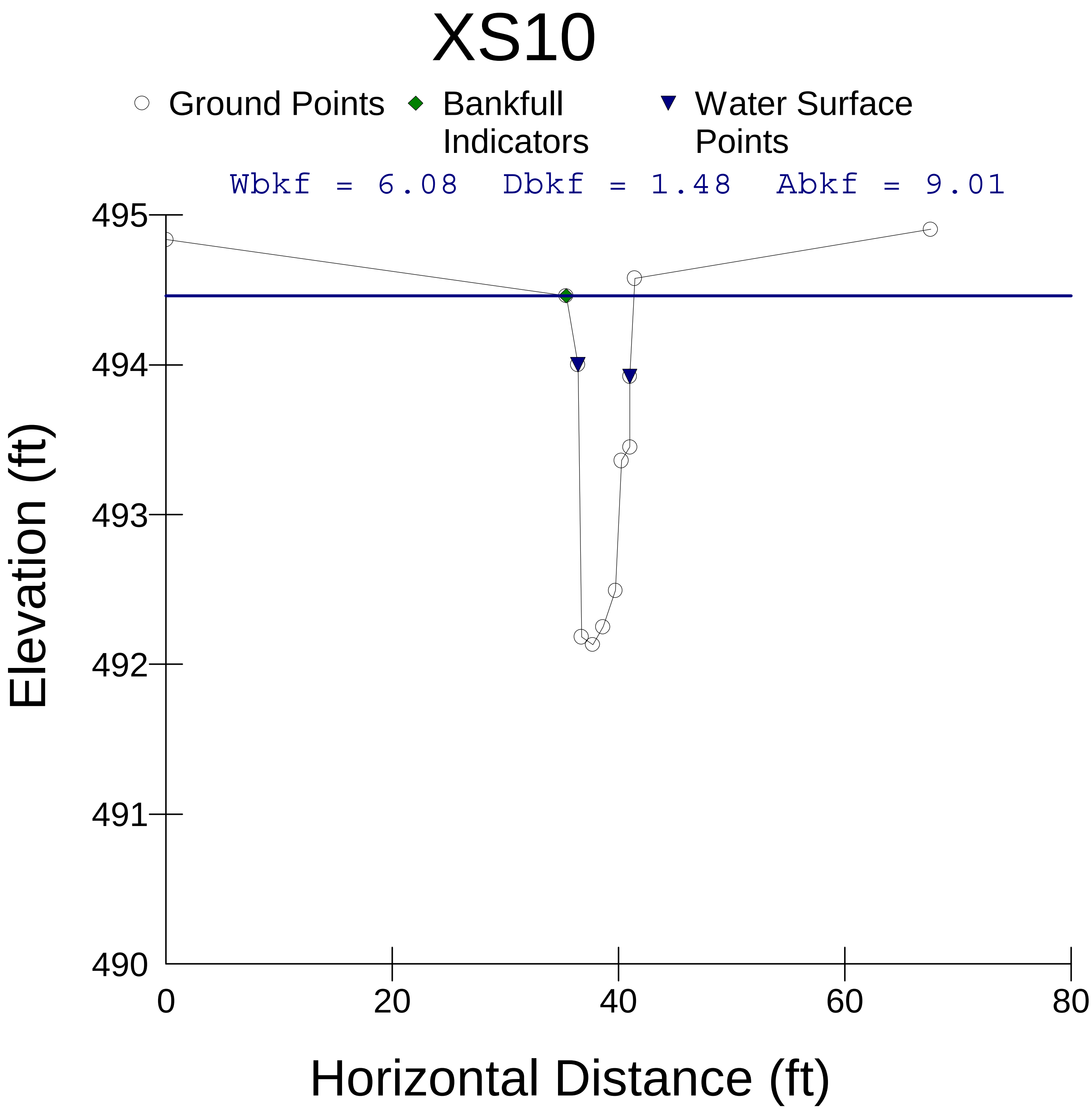

XS6
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 10.4
Dbkf = .4
Abkf = 4.1
505
500
495
490
0
10
20
30
40
Elevation (ft)
Horizontal Distance (ft)

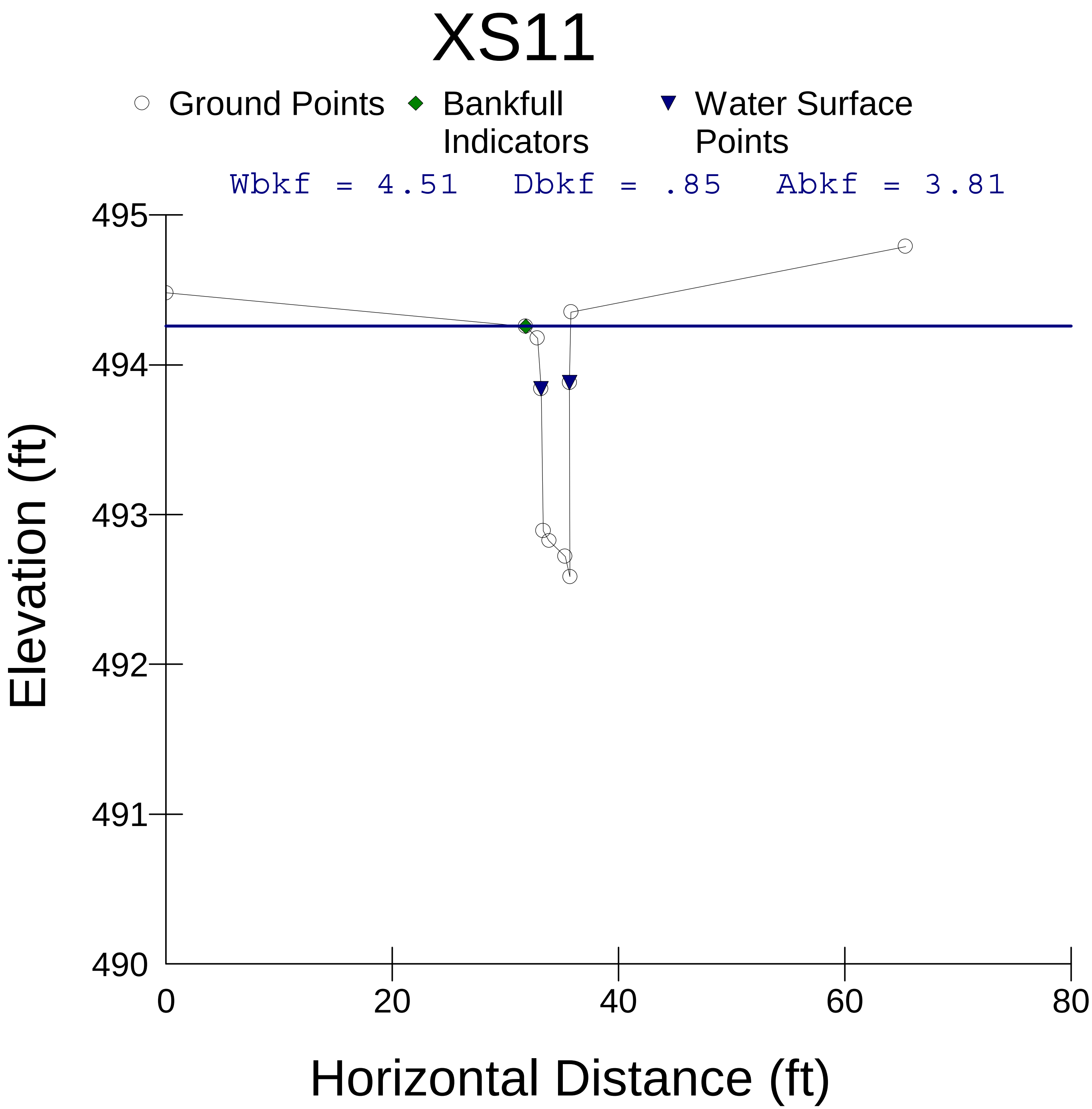


XS7
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 5.28   Dbkf = .77   Abkf = 4.04
498
496
494
492
490
0
20
40
60
80
Elevation (ft)
Horizontal Distance (ft)

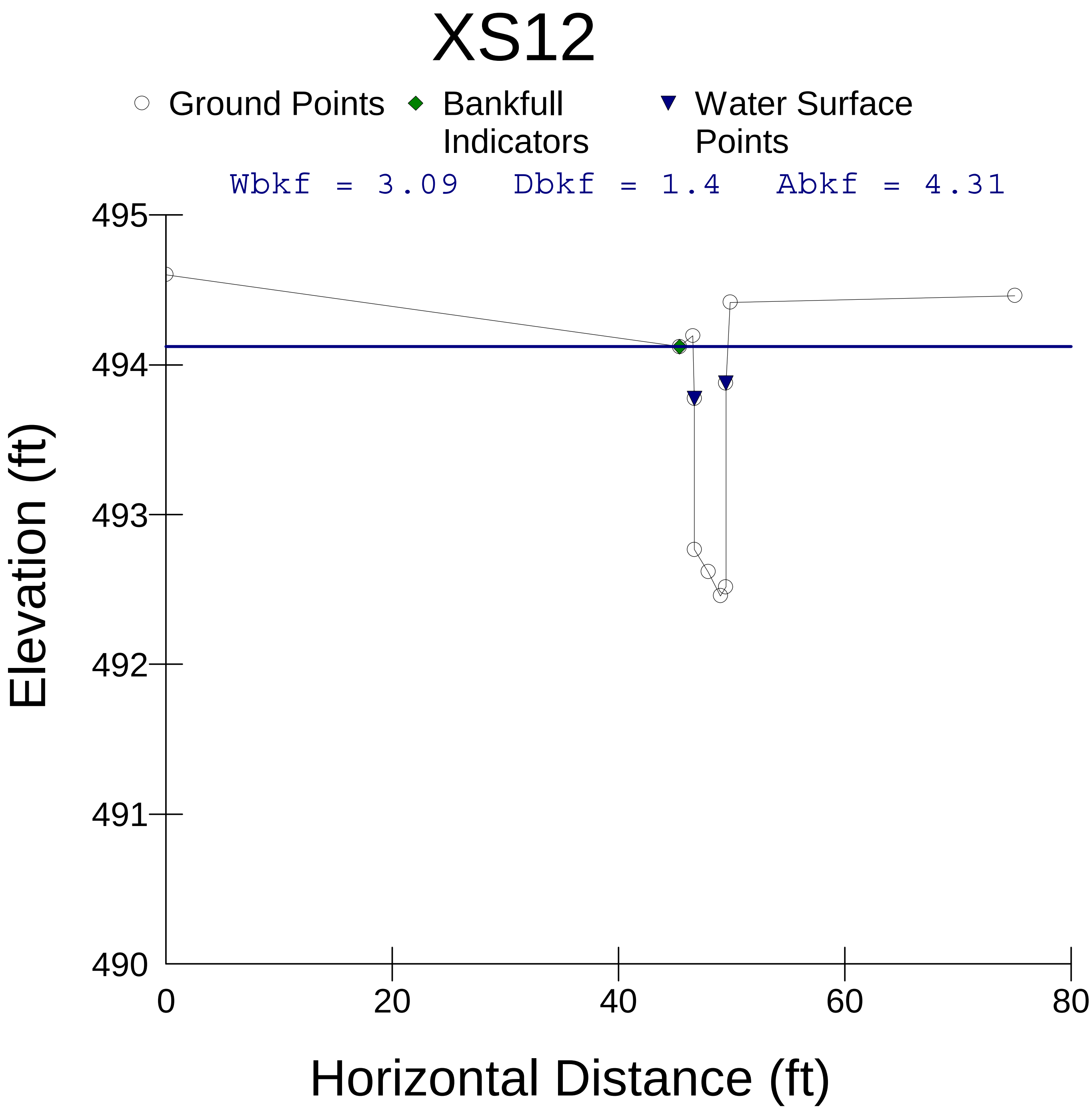

XS8
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 6.62 Dbkf = 1.88 Abkf = 12.4
498
496
494
492
490
0
20
40
60
80
Elevation (ft)
Horizontal Distance (ft)


XS9
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 7.48 Dbkf = .73 Abkf = 5.47
Elevation (ft)
Horizontal Distance (ft)
496
495
494
493
492
491
490
0
20
40
60
80


XS10
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 6.08 Dbkf = 1.48 Abkf = 9.01
495
494
493
492
491
490
0
20
40
60
80
Elevation (ft)
Horizontal Distance (ft)



XS11
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 4.51 Dbkf = .85 Abkf = 3.81
495
494
493
492
491
490
0
20
40
60
80
Elevation (ft)
Horizontal Distance (ft)


XS12
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 3.09 Dbkf = 1.4 Abkf = 4.31
495
494
493
492
491
490
0
20
40
60
80
Elevation (ft)
Horizontal Distance (ft)

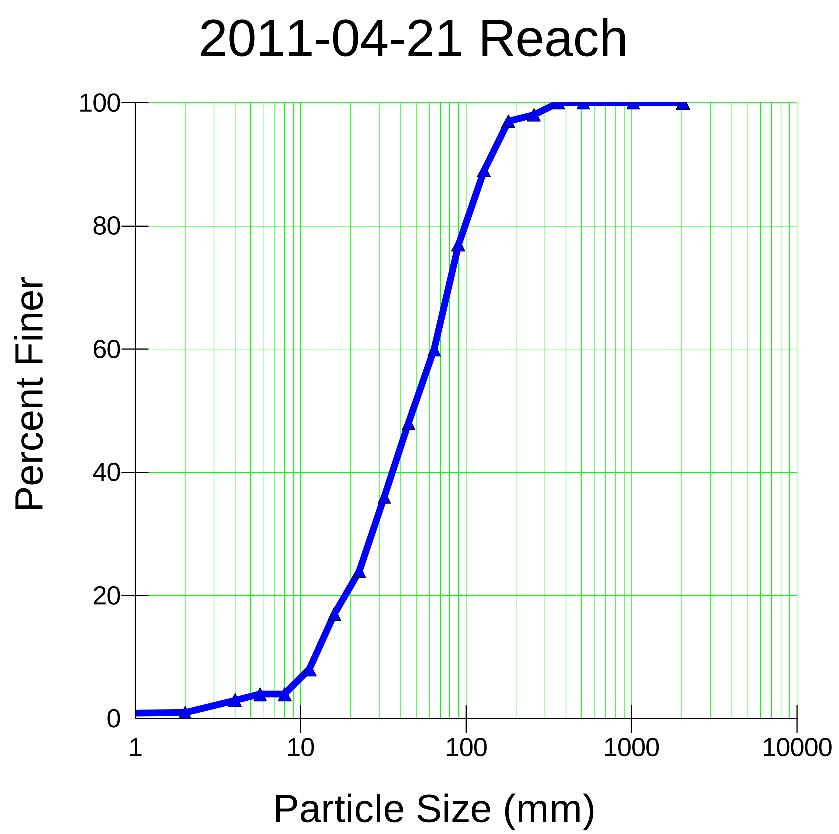
RIVERMORPH PARTICLE SUMMARY

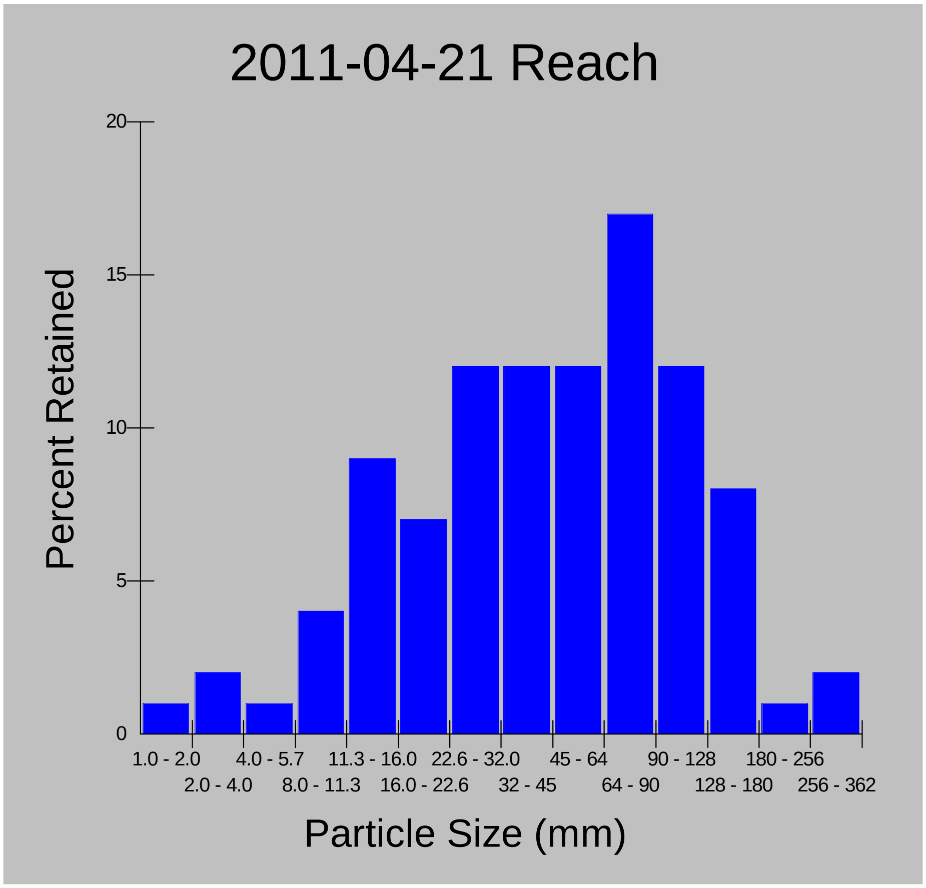
River Name:	Diamond Hills
Reach Name:	Bishop Road Ref
Sample Name:	2011-04-21 Reach
Survey Date:	04/21/2011

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	0	0.00	0.00
1.0 - 2.0	1	1.00	1.00
2.0 - 4.0	2	2.00	3.00
4.0 - 5.7	1	1.00	4.00
5.7 - 8.0	0	0.00	4.00
8.0 - 11.3	4	4.00	8.00
11.3 - 16.0	9	9.00	17.00
16.0 - 22.6	7	7.00	24.00
22.6 - 32.0	12	12.00	36.00
32 - 45	12	12.00	48.00
45 - 64	12	12.00	60.00
64 - 90	17	17.00	77.00
90 - 128	12	12.00	89.00
128 - 180	8	8.00	97.00
180 - 256	1	1.00	98.00
256 - 362	2	2.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	15.48
D35 (mm)	31.22
D50 (mm)	48.17
D84 (mm)	112.17
D95 (mm)	167
D100 (mm)	361.99
Silt/Clay (%)	0
Sand (%)	1
Gravel (%)	59
Cobble (%)	38
Boulder (%)	2
Bedrock (%)	0

Total Particles = 100.


2011-04-21 Reach
Percent Finer
0
20
40
60
80
100
1
10
100
1000
10000
Particle Size (mm)


2011-04-21 Reach
Percent Retained
0
5
10
15
20
1.0 - 2.0
2.0 - 4.0
4.0 - 5.7
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
180 - 256
256 - 362
Particle Size (mm)

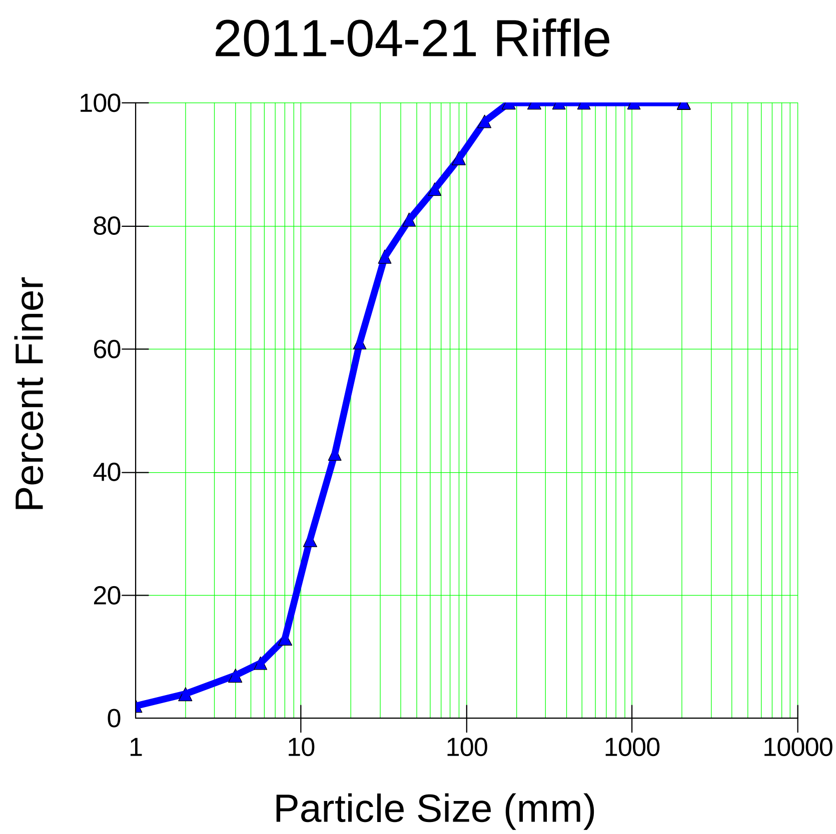
RIVERMORPH PARTICLE SUMMARY

River Name: Diamond Hills
Reach Name: Bishop Road Ref
Sample Name: 2011-04-21 Riffle
Survey Date: 04/21/2011

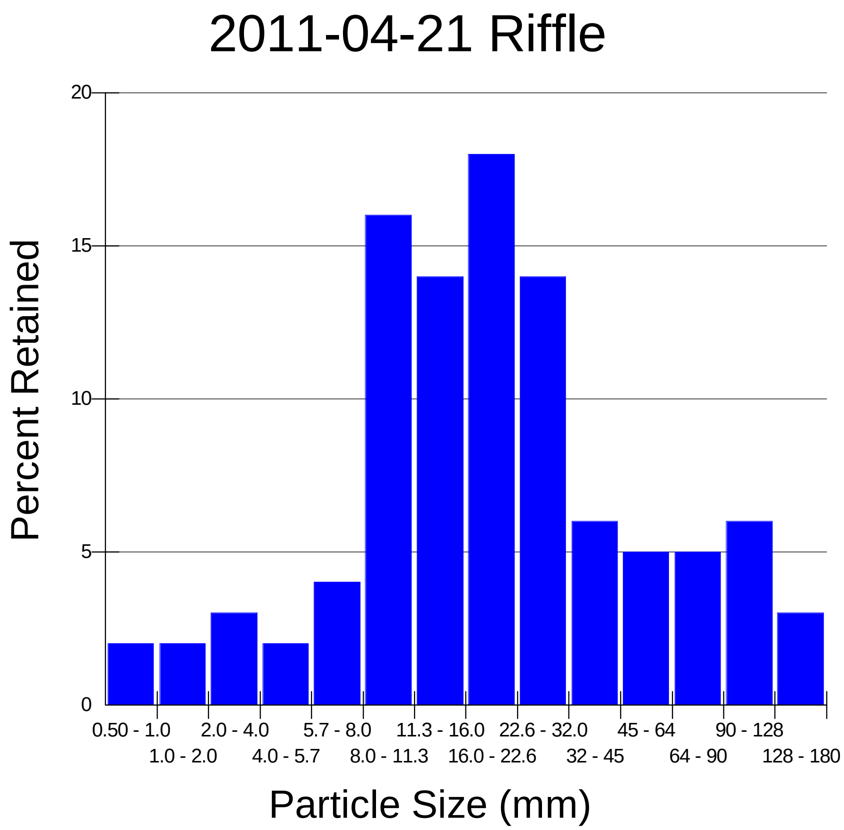
Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	2	2.00	2.00
1.0 - 2.0	2	2.00	4.00
2.0 - 4.0	3	3.00	7.00
4.0 - 5.7	2	2.00	9.00
5.7 - 8.0	4	4.00	13.00
8.0 - 11.3	16	16.00	29.00
11.3 - 16.0	14	14.00	43.00
16.0 - 22.6	18	18.00	61.00
22.6 - 32.0	14	14.00	75.00
32 - 45	6	6.00	81.00
45 - 64	5	5.00	86.00
64 - 90	5	5.00	91.00
90 - 128	6	6.00	97.00
128 - 180	3	3.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	8.62
D35 (mm)	13.31
D50 (mm)	18.57
D84 (mm)	56.4
D95 (mm)	115.33
D100 (mm)	180
Silt/Clay (%)	0
Sand (%)	4
Gravel (%)	82
Cobble (%)	14
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.



2011-04-21 Riffle
Percent Finer
0
20
40
60
80
100
1
10
100
1000
10000
Particle Size (mm)



2011-04-21 Riffle
Percent Retained
20
15
10
5
0
0.50 - 1.0
1.0 - 2.0
2.0 - 4.0
4.0 - 5.7
5.7 - 8.0
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
Particle Size (mm)

RIVERMORPH PFANKUCH SUMMARY

River Name: Diamond Hills
Reach Name: Bishop Road Ref
Survey Date: 04/21/2011

Upper Bank

Landform Slope:	8
Mass Wasting:	3
Debris Jam Potential:	2
Vegetative Protection:	6

Lower Bank

Channel Capacity:	1
Bank Rock Content:	8
Obstructions to Flow:	2
Cutting:	4
Deposition:	4

Channel Bottom

Rock Angularity:	2
Brightness:	1
Consolidation of Particles:	3
Bottom Size Distribution:	8
Scouring and Deposition:	6
Aquatic Vegetation:	1

Channel Stability Evaluation

Sediment Supply:	Low
Stream Bed Stability:	Stable
W/D Condition:	Normal
Stream Type:	E4

Rating - 59
Condition - Good

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Diamond Hills
Reach Name: Bishop Road Ref
BEHI Name: UPSTREAM
Survey Date: 04/21/2011

Bankfull Height: 1.48 ft
Bank Height: 1.48 ft
Root Depth: 1.25 ft
Root Density: 95 %
Bank Angle: 75 Degrees
Surface Protection: 65 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #1: Channel Pattern and/or Depositional Features for
Adjustments in Near-Bank Stress
Rating: Very Low

BEHI Numerical Rating: 13.6
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 1 ft
Estimated Sediment Loss: 0 Cu Yds per Year
Estimated Sediment Loss: 0 Tons per Year

Appendix B
Unified Stream Methodology
Compensation Credit Worksheets

Stream Assessment Form (Form 1)

Unified Stream Methodology for use in Virginia

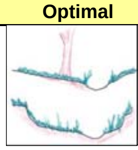
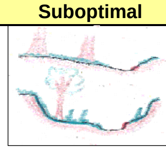
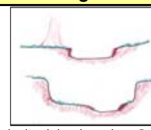
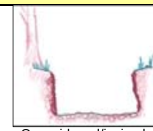
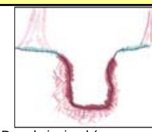
For use in wadeable channels classified as intermittent or perennial

Project #	Project Name	Locality	Cowardin Class.	HUC	Date	SAR #	Impact/SAR length	Impact Factor
B100031.00	Diamond Hills Mitigation Site	Christiansburg	R3UB1	05050001	10/14/10	1	2005	1

Name(s) of Evaluator(s)	Stream Name and Information
Brian D. Wagner & Jon Roller	Tributary to Crab Creek

1. Channel Condition: Assess the cross-section of the stream and prevailing condition (erosion, aggradation)

Conditional Category

	Optimal	Suboptimal	Marginal	Poor	Severe	
						
Channel Condition	Very little incision or active erosion; 80-100% stable banks. Vegetative surface protection or natural rock, prominent (80-100%). AND/OR Stable point bars/bankfull benches are present. Access to their original floodplain or fully developed wide bankfull benches. Mid-channel bars, and transverse bars few. Transient sediment deposition covers less than 10% of bottom.	Slightly incised, few areas of active erosion or unprotected banks. Majority of banks are stable (60-80%). Vegetative protection or natural rock prominent (60-80%) AND/OR Depositional features contribute to stability. The bankfull and low flow channels are well defined. Stream likely has access to bankfull benches, or newly developed floodplains along portions of the reach. Transient sediment covers 10-40% of the stream bottom.	Often incised, but less than Severe or Poor. Banks more stable than Severe or Poor due to lower bank slopes. Erosion may be present on 40-60% of both banks. Vegetative protection on 40-60% of banks. Streambanks may be vertical or undercut. AND/OR 40-60% of stream is covered by sediment. Sediment may be temporary/transient, contribute instability. Deposition that contribute to stability, may be forming/present. AND/OR V-shaped channels have vegetative protection on > 40% of the banks and depositional features which contribute to stability.	Overwidened/incised. Vertically/laterally unstable. Likely to widen further. Majority of both banks are near vertical. Erosion present on 60-80% of banks. Vegetative protection present on 20-40% of banks, and is insufficient to prevent erosion. AND/OR 60-80% of the stream is covered by sediment. Sediment is temporary/transient in nature, and contributing to instability. AND/OR V-shaped channels have vegetative protection is present on > 40% of the banks and stable sediment deposition is absent.	Deeply incised (or excavated), vertical/lateral instability. Severe incision, flow contained within the banks. Streambed below average rooting depth, majority of banks vertical/undercut. Vegetative protection present on less than 20% of banks, is not preventing erosion. Obvious bank sloughing present. Erosion/raw banks on 80-100%. AND/OR Aggrading channel. Greater than 80% of stream bed is covered by deposition, contributing to instability. Multiple thread channels and/or subterranean flow.	**CI**
Score	3	2.4	2	1.6	1	**1.0**
NOTES>>						

2. RIPARIAN BUFFERS: Assess both bank's 100 foot riparian areas along the entire SAR. (rough measurements of length & width may be acceptable)

	Conditional Category							NOTES>>
	Optimal	Suboptimal		Marginal		Poor		
Riparian Buffers	Tree stratum (dbh > 3 inches) present, with > 60% tree canopy cover and a non-maintained understory. Wetlands located within the riparian areas.	**High Suboptimal:** Riparian areas with tree stratum (dbh > 3 inches) present, with 30% to 60% tree canopy cover and containing both herbaceous and shrub layers or a non-maintained understory.	**Low Suboptimal:** Riparian areas with tree stratum (dbh > 3 inches) present, with > 30% tree canopy cover and a maintained understory. Recent cutover (dense vegetation).	**High Marginal:** Non-maintained, dense herbaceous vegetation with either a shrub layer or a tree layer (dbh > 3 inches) present, with <30% tree canopy cover.	**Low Marginal:** Non-maintained, dense herbaceous vegetation, riparian areas lacking shrub and tree stratum, hay production, ponds, open water. If present, tree stratum (dbh >3 inches) present, with <30% tree canopy cover with maintained understory.	**High Poor:** Lawns, mowed, and maintained areas, nurseries; no-till cropland; actively grazed pasture, sparsely vegetated non-maintained area, recently seeded and stabilized, or other comparable condition.	**Low Poor:** Impervious surfaces, mine spoil lands, denuded surfaces, row crops, active feed lots, trails, or other comparable conditions.	
		High	Low	High	Low	High	Low	
Condition Scores	1.5	1.2	1.1	0.85	0.75	0.6	0.5	

1. Delineate riparian areas along each stream bank into Condition Categories and Condition Scores using the descriptors.
2. Determine square footage for each by measuring or estimating length and width. Calculators are provided for you below.
3. Enter the % Riparian Area and Score for each riparian category in the blocks below.

Ensure the sums of % Riparian Blocks equal 100

Right Bank	% Riparian Area>	100%							100%		
	Score >	0.6									
										CI= (Sum % RA * Scores*0.01)/2	
Left Bank	% Riparian Area>	100%							100%	Rt Bank CI > 0.60	**CI**
	Score >	0.6								Lt Bank CI > 0.60	**0.60**

3. INSTREAM HABITAT: Varied substrate sizes, water velocity and depths; woody and leafy debris; stable substrate; low embededness; shade; undercut banks; root mats; SAV; riffle poole complexes, stable features.

	Conditional Category				NOTES>>	
	Optimal	Suboptimal	Marginal	Poor		
Instream Habitat/ Available Cover	Habitat elements are typically present in greater than 50% of the reach.	Stable habitat elements are typically present in 30-50% of the reach and are adequate for maintenance of populations.	Stable habitat elements are typically present in 10-30% of the reach and are adequate for maintenance of populations.	Habitat elements listed above are lacking or are unstable. Habitat elements are typically present in less than 10% of the reach.		**CI**
Score	1.5	1.2	0.9	0.5		**0.90**

Stream Impact Assessment Form Page 2

Project #	Applicant	Locality	Cowardin Class.	HUC	Date	Data Point	SAR length	Impact Factor
							2005	1

4. CHANNEL ALTERATION: Stream crossings, riprap, concrete, gabions, or concrete blocks, straightening of channel, channelization, embankments, spoil piles, constrictions, livestock

NOTES>>

	Conditional Category						
	Negligible	Minor		Moderate		Severe	
Channel Alteration	Channelization, dredging, alteration, or hardening absent. Stream has an unaltered pattern or has naturalized.	Less than 20% of the stream reach is disrupted by any of the channel alterations listed in the parameter guidelines.	20-40% of the stream reach is disrupted by any of the channel alterations listed in the parameter guidelines.	40 - 60% of reach is disrupted by any of the channel alterations listed in the parameter guidelines. If stream has been channelized, normal stable stream meander pattern has not recovered.	60 - 80% of reach is disrupted by any of the channel alterations listed in the parameter guidelines. If stream has been channelized, normal stable stream meander pattern has not recovered.	Greater than 80% of reach is disrupted by any of the channel alterations listed in the parameter guidelines AND/OR 80% of banks shored with gabion, riprap, or cement.	
SCORE	1.5	1.3	1.1	0.9	0.7	0.5	0.50

REACH CONDITION INDEX and STREAM CONDITION UNITS FOR THIS REACH

NOTE: **The CIs and RCI should be rounded to 2 decimal places. The CR should be rounded to a whole number.**

THE REACH CONDITION INDEX (RCI) >>	0.60
RCI= (Sum of all CI's)/5	
COMPENSATION REQUIREMENT (CR) >>	1203
CR = RCI X LF X IF	

INSERT PHOTOS:

DESCRIBE PROPOSED IMPACT:

Compensation Crediting Form (Form 3)

Unified Stream Methodology for use in Virginia

Project #	Project Name	Locality	Cowardin Class.	HUC	Date	Reach #	Reach Length
B1000031	DIAMOND HILLS RESTORATION	C'BURG	RUSB3	05050001	08/20/2010	1	2322

Name(s) of Evaluator(s)	Steam Name and Information
BRIAN WAGNER/ KIP MUMAW	TRIBUTARY DOWNSTREAM OF INDEPENDENCE BLVD TO THE CONFLUENCE WITH CRAB CREEK

Project Credits

Restoration: Includes Priority 1, 2, and 3 restoration activities. Does not include buffer width.

			Credit per foot	Project Credits
List Reaches that will receive full Restoration:	Total length of Full Restoration	2322	1	2322
	Credits = Stream Length X 1.0			

Enhancement With Instream Structures: Addressing Streambank Stability, Grade Control (Vanes, Weirs, Step-Pools), Constructed Riffles

			Credit per foot	Project Credits
Discuss Length Affected by Instream Structures (justify length):	Length Affected by Instream Structures		0.3	0
	Credits = Stream Length X 0.3			

Enhancement: Addressing Streambank Stability, Entrenchment Ratios, Access to Floodplain

Mitigation Categories

	Mechanical Bank Work			Biological Bank Work	
	Credit Per Length	Pick One Per Length		May Be Cumulative Per Length	
Activities	Habitat Structures	Create Bankfull Bench	Lay Back Banks	Bio-Remediation Techniques	Stream Bank Plantings
Credit per foot per bank	0.1	0.15	0.1	0.1	0.09

Right Bank	Length							0
	Credit>							
Left Bank	Length							0
	Credit >							

CREDITS			
Rt Bank >	0.00	Credit	
Lt Bank >	0.00	*SUM of banks*	0

Σ(Length X Credit) for all areas (banks done separately)

Riparian Areas: Assess the proposed 100 foot buffer on both banks based on the activity proposed. Enter the percentage of area and the credit below. (Widths of buffer above 100' will be determined below)

Activities	Buffer Re-establishment (removal of invasives)	Buffer Planting - Heavy	Buffer Planting - Light	Preservation *High Quality, Restoration, Enhancement*	Preservation *Low Quality*	Buffer area not within preservation width
Credit for 0'-100'	0.4	0.38	0.29	0.14	0.07	0
Credit for beyond 100'	0.2	0.19	0.15	0.07		0

Calculation of "Goal" riparian buffer for each side (SAR length times 100') >>>> 232,200 square feet

WITHIN FIRST 100' - Mitigation Categories

One vegetative community maintained	Subtract 0.03
Two vegetative communities maintained	Subtract 0.06

Ensure the sums of % Riparian Blocks equal 100

Right Bank	Area #	1						
	Sq, Footage	232200						
	% Area	99%	0%	0%	0%	0%	0%	99%
	Credit>	0.38						
Left Bank	Area #	1						
	Sq, Footage	232200						
	% Area	82%	0%	0%	0%	0%	0%	82%
	Credit>	0.38						

CREDITS			
Rt Bank >	0.38	Credit	
Lt Bank >	0.31	0.35	813

Σ(% Area X Credit) for all areas (banks done separately)
AVE of credit for banks X length of project

Outside First 100' - Mitigation Categories

One vegetative community maintained	Subtract 0.03
Two vegetative communities maintained	Subtract 0.06

Right Bank	Area #							
	Sq, Footage	232200						
	% Area	20%	0%	0%	0%	0%	0%	20%
	Credit>	0.19						
Left Bank	Area #							
	Sq, Footage	232200						
	% Area	22%	0%	0%	0%	0%	0%	22%
	Credit >	0.19						

CREDITS			
Rt Bank >	0.04	Credit	
Lt Bank >	0.04	0.04	92.88

Σ(% Area X Credit) for all areas (banks done separately)
AVE of credit for banks X length of project

Adjustment Factors: These factors are applied as a multiplier to length of a reach for which they apply

Adjustment Factor Categories

Activity	Rare, Threatened, or Endangered Species or Communities	Livestock Exclusion	Watershed Preservation
Credit	0.1 - 0.3	0.1 - 0.3	0.1 - 0.3
Stream Length Affected			
Credit>			

Credits are cumulative and can apply to more than one reach. Each reach can have more than one Adjustment Factors

Record AF length /credit beneath the AF activity. Provide a narrative explanation of the applicable site conditions that warrant an adjustment and justify the AF credit chosen.

Credits > 0

ΣLength X Credit) for all areas

Total Compensation Credit Provided by Project | **3228**

Appendix C
Design Parameters

Morphological characteristics of the existing, proposed design and reference reaches.

Existing Reach Stream & Location: Upstream of Independence Blvd. Diamond Hills Park Creek

Reference Reach Stream & Location: Bishop Road Reference, Blacksburg, Virginia

	Entry Number & Variable		Existing Reach	Proposed Design Reach	Reference Reach	Regional Curve Information: Compiled	NCSU Valley &	USGS Valley & Ridge
	1	Valley Type	II	II	II	NA	NA	NA
	2	Valley Width	100-300	100-300	150-400	NA	NA	NA
	3	Stream Type	E4 (G4c)	E4/C4	E4	E/C	E/C/B	E/C/B
	4	Drainage Area, mi^2	0.43 (upstream)	0.78	1.68	0.78	0.78	0.78
	5	Bankfull Discharge, cfs (Q_{bkf})	33.25	31.95	21.38	72	83	35
Riffle Dimensions	6	Riffle Width, ft (W_{bkf})	*Mean:* 5.3	*Mean:* 7.5	*Mean:* 6.1	10.8	17.4	11.2
			Min: 3.5	*Min:* 6.1	*Min:* 4.5			
			Max: 7.2	*Max:* 10.8	*Max:* 8.2			
	7	Riffle Mean Depth, ft (d_{bkf})	*Mean:* 0.79	*Mean:* 0.94	*Mean:* 0.78	1.1	1.0	0.9
			Min: 0.64	*Min:* 0.65	*Min:* 0.73			
			Max: 0.94	*Max:* 1.15	*Max:* 0.85			
	8	Riffle Width/Depth Ratio (W_{bkf}/d_{bkf})	*Mean:* 6.5	*Mean:* 8.0	*Mean:* 7.8	9.6	16.9	12.0
			Min: 5.4	*Min:* 5.3	*Min:* 5.3	5.0		
			Max: 7.7	*Max:* 16.6	*Max:* 10.3	12.0		
	9	Riffle Cross-Sectional Area, ft^2 (A_{bkf})	*Mean:* 4.5	*Mean:* 7.0	*Mean:* 4.7	12.2	18.3	10.5
			Min: 2.2	7.0	*Min:* 3.7			
			Max: 6.8	12.0	*Max:* 6.7			
	10	Riffle Maximum Depth (d_{max})	*Mean:* 1.15	*Mean:* 1.40	*Mean:* 1.54			
			Min: 0.94	*Min:* 1.65	*Min:* 1.38			
			Max: 1.35	*Max:* 2.07	*Max:* 1.73			
	11	Riffle Maximum Depth to Riffle Mean Depth (d_{max}/d_{bkf})	*Mean:* 1.456	*Mean:* 1.500	*Mean:* 1.974			
			Min: 1.190	*Min:* 1.769	*Min:* 1.769	1.2	1.2	1.2
			Max: 1.709	*Max:* 2.218	*Max:* 2.218	1.4	1.4	1.4
	12	Width of Flood-Prone Area at Elevation of 2* d_{max}, ft (W_{fpa})	*Mean:* 25.0	*Mean:*	*Mean:* 49.7			
			Min:	*Min:*	*Min:*			
			Max:	*Max:*	*Max:*			
	13	Entrenchment Ratio (W_{fpa}/W_{bkf})	*Mean:* 4.7	*Mean:* 0.0	*Mean:* 8.2			
			Min: 4.0	*Min:* 0.0	*Min:* 3.8			
			Max: 5.3	*Max:* 0.0	*Max:* 11.4			
Riffle Inner Berm Dimensions	14	Riffle Inner Berm Width, ft (W_{ib})	*Mean:* N/A	*Mean:* 6.5	*Mean:* 5.3			
			Min: N/A	*Min:* 4.5	*Min:* 3.7			
			Max: N/A	*Max:* 8.5	*Max:* 6.9			
	15	Riffle Inner Berm Width to Riffle Width (W_{ib}/W_{bkf})	*Mean:* N/A	*Mean:* 0.863	*Mean:* 0.863			
			Min: N/A	*Min:* 0.604	*Min:* 0.604			
			Max: N/A	*Max:* 1.137	*Max:* 1.137			
	16	Riffle Inner Berm Mean Depth ft (d_{ib})	*Mean:* N/A	*Mean:* 0.84	*Mean:* 0.70			
			Min: N/A	*Min:* 0.22	*Min:* 0.18			
			Max: N/A	*Max:* 1.15	*Max:* 0.96			
	17	Riffle Inner Berm Mean Depth to Riffle Mean Depth (d_{ib}/d_{bkf})	*Mean:* N/A	*Mean:* 0.897	*Mean:* 0.897			
			Min: N/A	*Min:* 0.231	*Min:* 0.231			
			Max: N/A	*Max:* 1.231	*Max:* 1.231			
	18	Riffle Inner Berm Width/Depth Ratio (W_{ib}/d_{ib})	*Mean:* N/A	*Mean:* 7.7	*Mean:* 7.0			
			Min: N/A	*Min:* 3.9	*Min:* 3.9			
			Max: N/A	*Max:* 39.4	*Max:* 9.2			
	19	Riffle Inner Berm Cross-Sectional Area (A_{ib})	*Mean:* N/A	*Mean:* 5.9	*Mean:* 4.0			
			Min: N/A	*Min:* 1.2	*Min:* 0.8			
			Max: N/A	*Max:* 8.9	*Max:* 6.0			
	20	Riffle Inner Berm Cross-Sectional Area to Riffle Cross-Sectional Area (A_{ib}/A_{bkf})	*Mean:* N/A	*Mean:* 0.844	*Mean:* 0.844			
			Min: N/A	*Min:* 0.169	*Min:* 0.169			
			Max: N/A	*Max:* 1.266	*Max:* 1.266			

Morphological characteristics of the existing, proposed design and reference reaches.

Entry Number & Variable			Existing Reach		Proposed Design Reach		Reference Reach		Compiled	NCSU Valley &	USGS Valley & Ridge
Pool Dimensions	**21**	Pool Width, ft (W_{bkfp})	*Mean:*	**8.7**	*Mean:*	**11.2**	*Mean:*	**7.1**			
			Min:	**6.7**	*Min:*	**7.5**	*Min:*	**6.1**			
			Max:	**10.7**	*Max:*	**10.3**	*Max:*	**8.4**			
	22	Pool Width to Riffle Width (W_{bkfp}/W_{bkf})	*Mean:*	**1.627**	*Mean:*	**1.500**	*Mean:*	**1.163**			
			Min:	**1.245**	*Min:*	**1.000**	*Min:*	**1.000**	**1.3**	**1.3**	**1.3**
			Max:	**2.009**	*Max:*	**1.700**	*Max:*	**1.382**	**1.7**	**1.7**	**1.7**
	23	Pool Mean Depth, ft (d_{bkfp})	*Mean:*	**1.29**	*Mean:*	**1.73**	*Mean:*	**1.44**			
			Min:	**0.95**	*Min:*	**1.10**	*Min:*	**0.92**			
			Max:	**1.63**	*Max:*	**2.25**	*Max:*	**1.88**			
	24	Pool Mean Depth to Riffle Mean Depth (d_{bkfp}/d_{bkf})	*Mean:*	**1.633**	*Mean:*	**1.846**	*Mean:*	**1.846**			
			Min:	**1.203**	*Min:*	**1.179**	*Min:*	**1.179**			
			Max:	**2.063**	*Max:*	**2.410**	*Max:*	**2.410**			
	25	Pool Width/Depth Ratio (W_{bkfp}/d_{bkfp})	*Mean:*	**7.7**	*Mean:*	**6.5**	*Mean:*	**4.9**			
			Min:	**4.1**	*Min:*	**3.3**	*Min:*	**3.2**	**0.8**	**0.8**	**0.8**
			Max:	**11.3**	*Max:*	**9.4**	*Max:*	**9.1**	**1.2**	**1.2**	**1.2**
	26	Pool Cross-Sectional Area, ft^2 (A_{bkfp})	*Mean:*	**10.5**	*Mean:*	**14.7**	*Mean:*	**9.9**			
			Min:	**10.2**	*Min:*	**11.4**	*Min:*	**7.7**			
			Max:	**10.8**	*Max:*	**18.4**	*Max:*	**12.4**			
	27	Pool Area to Riffle Area (A_{bkfp}/A_{bkf})	*Mean:*	**2.342**	*Mean:*	**2.097**	*Mean:*	**2.097**			
			Min:	**2.276**	*Min:*	**1.622**	*Min:*	**1.622**			
			Max:	**2.409**	*Max:*	**2.622**	*Max:*	**2.622**			
	28	Pool Maximum Depth (d_{maxp})	*Mean:*	**1.95**	*Mean:*	**2.69**	*Mean:*	**2.24**			
			Min:	**1.93**	*Min:*	**1.87**	*Min:*	**1.56**			
			Max:	**1.96**	*Max:*	**3.37**	*Max:*	**2.81**			
	29	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	*Mean:*	**2.468**	*Mean:*	**2.872**	*Mean:*	**2.872**			
			Min:	**2.443**	*Min:*	**2.000**	*Min:*	**2.000**	**2.0**	**2.0**	**2.0**
			Max:	**2.481**	*Max:*	**3.603**	*Max:*	**3.603**	**3.5**	**3.5**	**3.5**
	30	Point Bar Slope (S_{pb})	*Mean:*	**N/A**	*Mean:*	**"8:1"**	*Mean:*	**n/a**			
			Min:	**N/A**	*Min:*	**"10:1"**	*Min:*	**n/a**			
			Max:	**N/A**	*Max:*	**"6:1"**	*Max:*	**n/a**			
Pool Inner Berm Dimensions	**31**	Pool Inner Berm Width, ft (W_{ibp})	*Mean:*	**N/A**	*Mean:*	**6.0**	*Mean:*	**5.7**			
			Min:	**N/A**	*Min:*	**4.8**	*Min:*	**4.5**			
			Max:	**N/A**	*Max:*	**7.3**	*Max:*	**6.9**			
	32	Pool Inner Berm Width to Pool Width (W_{ibp}/W_{bkfp})	*Mean:*	**N/A**	*Mean:*	**0.538**	*Mean:*	**0.807**			
			Min:	**N/A**	*Min:*	**0.424**	*Min:*	**0.636**			
			Max:	**N/A**	*Max:*	**0.652**	*Max:*	**0.977**			
	33	Pool Inner Berm Mean Depth, ft (d_{ibp})	*Mean:*	**N/A**	*Mean:*	**1.25**	*Mean:*	**1.04**			
			Min:	**N/A**	*Min:*	**1.10**	*Min:*	**0.92**			
			Max:	**N/A**	*Max:*	**1.51**	*Max:*	**1.26**			
	34	Pool Inner Berm Mean Depth to Pool Mean Depth (d_{ibp}/d_{bkfp})	*Mean:*	**N/A**	*Mean:*	**0.722**	*Mean:*	**0.722**			
			Min:	**N/A**	*Min:*	**0.639**	*Min:*	**0.639**			
			Max:	**N/A**	*Max:*	**0.875**	*Max:*	**0.875**			
	35	Pool Inner Berm Width/Depth Ratio (W_{ibp}/d_{ibp})	*Mean:*	**N/A**	*Mean:*	**4.8**	*Mean:*	**5.5**			
			Min:	**N/A**	*Min:*	**3.2**	*Min:*	**3.6**			
			Max:	**N/A**	*Max:*	**6.6**	*Max:*	**7.5**			
	36	Pool Inner Berm Cross-Sectional Area (A_{ibp})	*Mean:*	**N/A**	*Mean:*	**8.9**	*Mean:*	**6.0**			
			Min:	**N/A**	*Min:*	**8.4**	*Min:*	**5.7**			
			Max:	**N/A**	*Max:*	**9.4**	*Max:*	**6.4**			
	37	Pool Inner Berm Cross-Sectional Area to Pool Cross-Sectional Area (A_{ibp}/A_{bkfp})	*Mean:*	**N/A**	*Mean:*	**0.605**	*Mean:*	**0.605**			
			Min:	**N/A**	*Min:*	**0.570**	*Min:*	**0.570**			
			Max:	**N/A**	*Max:*	**0.640**	*Max:*	**0.640**			

Morphological characteristics of the existing, proposed design and reference reaches.

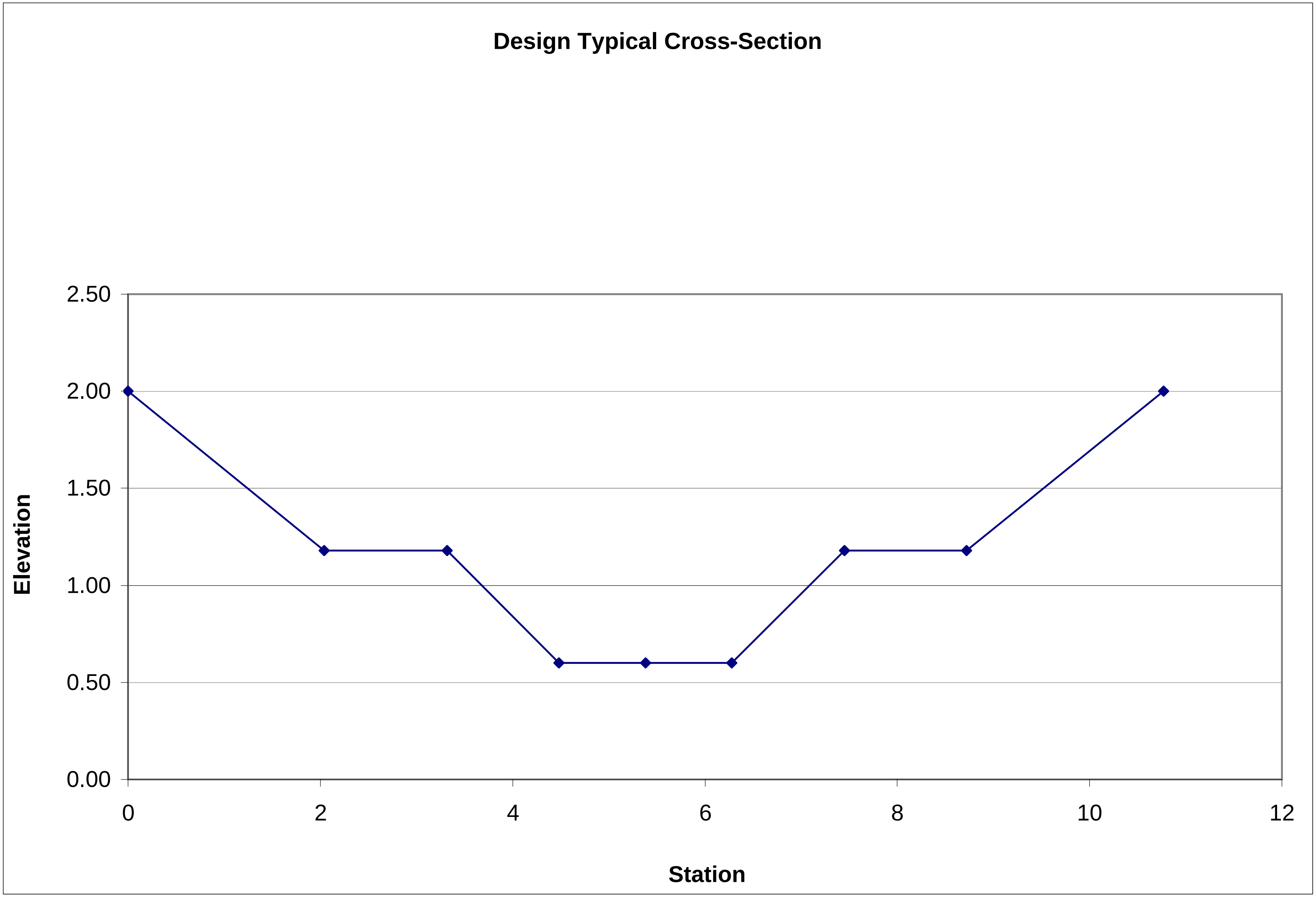
Entry Number & Variable			Existing Reach		Proposed Design Reach		Reference Reach		Compiled	NCSU Valley &	USGS Valley & Ridge
Channel Pattern	**72**	Linear Wavelength, ft (λ)	*Mean:*	**51.7**	*Mean:*	**78.6**	*Mean:*	**39.0**			
			Min:	**26.4**	*Min:*	**29.2**	*Min:*	**23.7**			
			Max:	**82.9**	*Max:*	**89.8**	*Max:*	**58.4**			
	73	Linear Wavelength to Riffle Width (λ/W_{bkf})	*Mean:*	**9.678**	*Mean:*	**10.500**	*Mean:*	**6.414**			
			Min:	**4.944**	*Min:*	**3.898**	*Min:*	**3.898**			
			Max:	**15.532**	*Max:*	**12.000**	*Max:*	**9.605**			
	74	Stream Meander Length, ft (L_m)	*Mean:*	**51.7**	*Mean:*	**78.6**	*Mean:*	**39.0**			
			Min:	**26.4**	*Min:*	**29.2**	*Min:*	**23.7**			
			Max:	**82.9**	*Max:*	**89.8**	*Max:*	**58.4**			
	75	Stream Meander Length Ratio (L_m/W_{bkf})	*Mean:*	**9.682**	*Mean:*	**10.500**	*Mean:*	**6.414**			
			Min:	**4.944**	*Min:*	**3.898**	*Min:*	**3.898**	**7.0**		
			Max:	**15.524**	*Max:*	**12.000**	*Max:*	**9.605**	**12.0**		
	76	Belt Width, ft (W_{blt})	*Mean:*	**3.5**	*Mean:*	**19.0**	*Mean:*	**15.4**			
			Min:	**1.8**	*Min:*	**10.3**	*Min:*	**8.4**			
			Max:	**5.3**	*Max:*	**27.8**	*Max:*	**22.6**			
	77	Meander Width Ratio (W_{blt}/W_{bkf})	*Mean:*	**0.655**	*Mean:*	**2.533**	*Mean:*	**2.533**			
			Min:	**0.337**	*Min:*	**1.382**	*Min:*	**1.382**	**3.5**		
			Max:	**0.983**	*Max:*	**3.717**	*Max:*	**3.717**	**8.0**		
	78	Radius of Curvature, ft (R_c)	*Mean:*	**34.7**	*Mean:*	**22.4**	*Mean:*	**9.8**			
			Min:	**16.3**	*Min:*	**15.0**	*Min:*	**3.4**			
			Max:	**60.8**	*Max:*	**44.9**	*Max:*	**14.8**			
	79	Radius of Curvature to Riffle Width (R_c/W_{bkf})	*Mean:*	**6.489**	*Mean:*	**3.000**	*Mean:*	**1.612**			
			Min:	**3.058**	*Min:*	**2.000**	*Min:*	**0.559**	**2.0**		
			Max:	**11.391**	*Max:*	**6.000**	*Max:*	**2.434**	**3.0**		
	80	Arc Length, ft (L_a)	*Mean:*	**18.0**	*Mean:*	**28.7**	*Mean:*	**23.3**			
			Min:	**9.6**	*Min:*	**13.3**	*Min:*	**10.8**			
			Max:	**38.9**	*Max:*	**44.9**	*Max:*	**36.5**			
	81	Arc Length to Riffle Width (L_a/W_{bkf})	*Mean:*	**3.361**	*Mean:*	**3.839**	*Mean:*	**3.839**			
			Min:	**1.805**	*Min:*	**1.781**	*Min:*	**1.781**			
			Max:	**7.281**	*Max:*	**5.997**	*Max:*	**5.997**			
	82	Riffle Length (L_r), ft	*Mean:*	**7.9**	*Mean:*	**30.2**	*Mean:*	**24.6**			
			Min:	**2.0**	*Min:*	**23.4**	*Min:*	**19.0**			
			Max:	**14.0**	*Max:*	**46.0**	*Max:*	**37.3**			
	83	Riffle Length to Riffle Width (L_r/W_{bkf})	*Mean:*	**1.483**	*Mean:*	**4.041**	*Mean:*	**4.041**			
			Min:	**0.373**	*Min:*	**3.125**	*Min:*	**3.125**			
			Max:	**2.614**	*Max:*	**6.141**	*Max:*	**6.141**			
	84	Individual Pool Length, ft (L_p)	*Mean:*	**18.0**	*Mean:*	**28.7**	*Mean:*	**23.3**			
			Min:	**9.6**	*Min:*	**13.3**	*Min:*	**10.8**			
			Max:	**38.9**	*Max:*	**44.9**	*Max:*	**36.5**			
	85	Pool Length to Riffle Width (L_p/W_{bkf})	*Mean:*	**3.361**	*Mean:*	**3.839**	*Mean:*	**3.839**			
			Min:	**1.805**	*Min:*	**1.781**	*Min:*	**1.781**			
			Max:	**7.281**	*Max:*	**5.997**	*Max:*	**5.997**			
	86	Pool to Pool Spacing, ft (P_s)	*Mean:*	**24.3**	*Mean:*	**48.6**	*Mean:*	**42.4**			
			Min:	**9.0**	*Min:*	**31.0**	*Min:*	**25.2**			
			Max:	**47.2**	*Max:*	**56.1**	*Max:*	**56.8**			
	87	Pool to Pool Spacing to Riffle Width (P_s/W_{bkf})	*Mean:*	**4.554**	*Mean:*	**6.500**	*Mean:*	**6.970**	**6.4**		
			Min:	**1.680**	*Min:*	**4.143**	*Min:*	**4.143**	**2.5**		
			Max:	**8.835**	*Max:*	**7.500**	*Max:*	**9.340**	**7.0**		

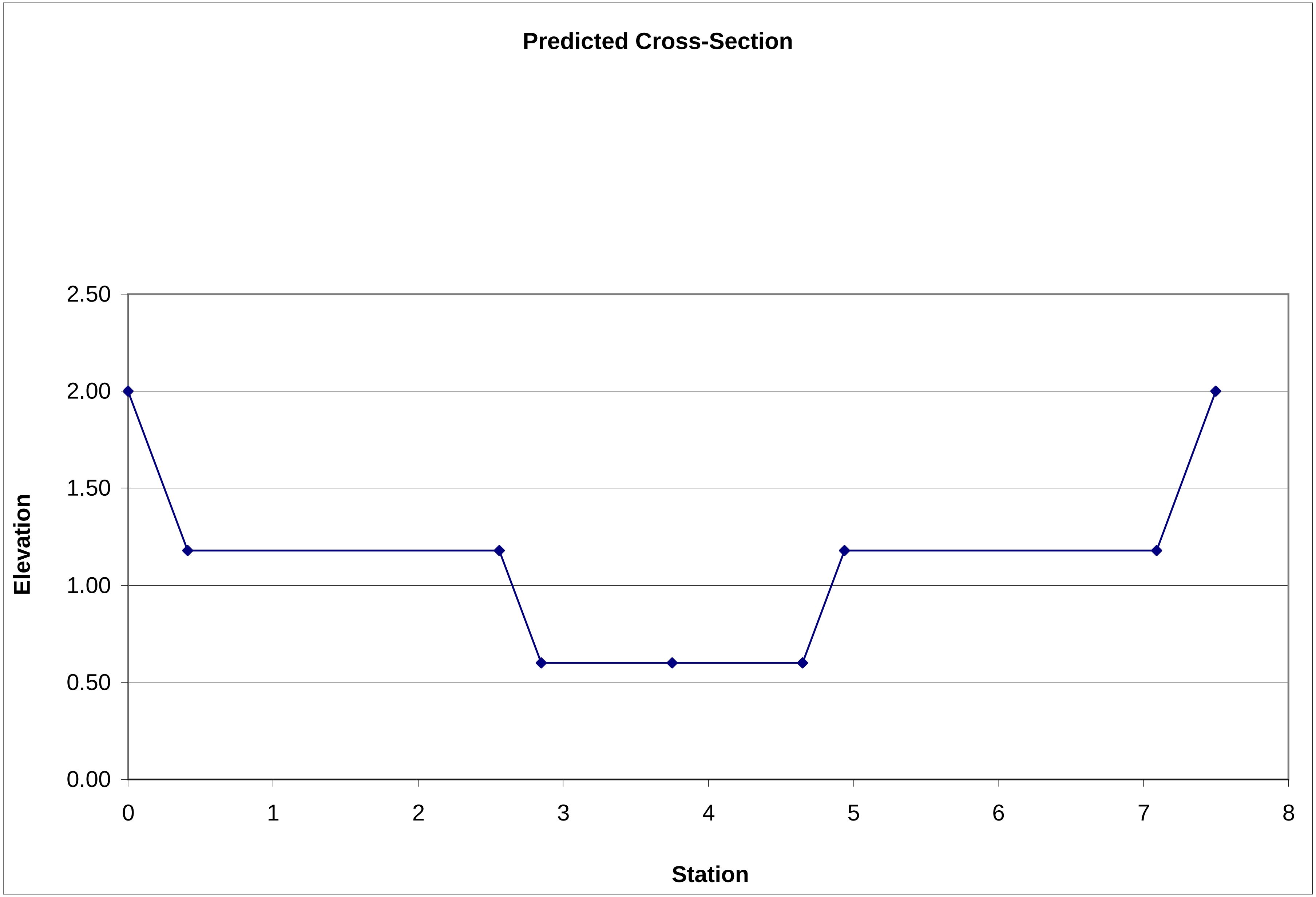
Morphological characteristics of the existing, proposed design and reference reaches.

	Entry Number & Variable		Existing Reach		Proposed Design Reach		Reference Reach		Compiled	NCSU Valley &	USGS Valley & Ridge
Sinuosity and Slope	**88**	Stream Length (SL)		**301**		**2322**		**250**			
	89	Valley Length (VL)		**295**		**2077**		**223**			
	90	Valley Slope (S_{val})		**0.0215**		**0.0139**		**0.0128**			
	91	Sinuosity (k)	SL/VL:	**1.02**	SL/VL:	**1.12**	SL/VL:	**1.12**	**1.2**		
			VS/S:	**1.00**			VS/S:	**1.12**	**1.6**		
	92	Average Water Surface Slope (S)		**0.0214**	$S = S_{val}/k$	**0.0130**		**0.0115**			
Bed Feature Water Surface Facet Slopes and Dimensionless Ratios from Profile	**105**	Riffle Slope (water surface facet slope) (S_{rif})	*Mean:*	**0.0311**	*Mean:*	**0.0195**	*Mean:*	**0.0162**			
			Min:	**0.0207**	*Min:*	**0.0195**	*Min:*	**0.0083**			
			Max:	**0.0423**	*Max:*	**0.0228**	*Max:*	**0.0238**			
	106	Riffle Slope to Average Water Surface Slope (S_{rif}/S)	*Mean:*	**1.4521**	*Mean:*	**1.5000**	*Mean:*	**1.4140**			
			Min:	**0.9687**	*Min:*	**1.0000**	*Min:*	**0.7214**	**1.5**		
			Max:	**1.9734**	*Max:*	**1.7500**	*Max:*	**2.0786**	**2.0**		
	107	Pool Slope (water surface facet slope) (S_p)	*Mean:*	**0.0084**	*Mean:*	**0.0091**	*Mean:*	**0.0081**			
			Min:	**0.0018**	*Min:*	**0.0033**	*Min:*	**0.0029**	**0.0**		
			Max:	**0.0166**	*Max:*	**0.0175**	*Max:*	**0.0155**	**0.2**		
	108	Pool Slope to Average Water Surface Slope (S_p/S)	*Mean:*	**0.3909**	*Mean:*	**0.7031**	*Mean:*	**0.7031**			
			Min:	**0.0827**	*Min:*	**0.2541**	*Min:*	**0.2541**			
			Max:	**0.7758**	*Max:*	**1.3493**	*Max:*	**1.3493**			
	109	Run Slope (water surface facet slope) (S_{run})	*Mean:*		*Mean:*	**0.0230**	*Mean:*	**0.0203**			
			Min:		*Min:*	**0.0113**	*Min:*	**0.0099**			
			Max:		*Max:*	**0.0393**	*Max:*	**0.0346**			
	110	Run Slope to Average Water Surface Slope (S_{run}/S)	*Mean:*		*Mean:*	**1.7703**	*Mean:*	**1.7703**			
			Min:		*Min:*	**0.8681**	*Min:*	**0.8681**	**0.5**		
			Max:		*Max:*	**3.0210**	*Max:*	**3.0210**	**0.8**		
	111	Glide Slope (water surface facet slope) (S_g)	*Mean:*		*Mean:*	**0.0255**	*Mean:*	**0.0224**			
			Min:		*Min:*	**0.0060**	*Min:*	**0.0053**			
			Max:		*Max:*	**0.0574**	*Max:*	**0.0506**			
	112	Glide Slope to Average Water Surface Slope (S_g/S)	*Mean:*		*Mean:*	**1.9590**	*Mean:*	**1.9590**			
			Min:		*Min:*	**0.4594**	*Min:*	**0.4594**	**0.3**		
			Max:		*Max:*	**4.4166**	*Max:*	**4.4166**	**0.5**		
	113	Step Slope (water surface facet slope) (S_s)	*Mean:*	**N/A**	*Mean:*	**N/A**	*Mean:*	**N/A**			
			Min:	**N/A**	*Min:*	**N/A**	*Min:*	**N/A**			
			Max:	**N/A**	*Max:*	**N/A**	*Max:*	**N/A**			
	114	Step Slope to Average Water Surface Slope (S_s/S)	*Mean:*	**N/A**	*Mean:*	**N/A**	*Mean:*	**N/A**			
			Min:	**N/A**	*Min:*	**N/A**	*Min:*	**N/A**			
			Max:	**N/A**	*Max:*	**N/A**	*Max:*	**N/A**			

Morphological characteristics of the existing, proposed design and reference reaches.

Category	No.	Entry Number & Variable	Stat	Existing Reach	Proposed Design Reach	Reference Reach	Compiled	NCSU Valley &	USGS Valley & Ridge
Bed Feature Max Depth Measurements and Dimensionless Ratios from Profile	**115**	Riffle Maximum Depth, ft (d_{max})	*Mean:*	**1.15**	**1.85**	**1.54**			
			Min:	**0.94**	**1.65**	**1.38**			
			Max:	**1.35**	**2.07**	**1.73**			
	116	Riffle Maximum Depth to Riffle Mean Depth (d_{max}/d_{bkf})	*Mean:*	**1.456**	**1.974**	**1.974**			
			Min:	**1.190**	**1.769**	**1.769**			
			Max:	**1.709**	**2.218**	**2.218**			
	117	Pool Maximum Depth, ft (d_{maxp})	*Mean:*	**1.95**	**2.69**	**2.24**			
			Min:	**1.93**	**1.87**	**1.56**			
			Max:	**1.96**	**3.37**	**2.81**			
	118	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	*Mean:*	**2.468**	**2.872**	**2.872**			
			Min:	**2.443**	**2.000**	**2.000**			
			Max:	**2.481**	**3.603**	**3.603**			
	119	Run Maximum Depth, ft (d_{maxr})	*Mean:*	**1.43**	**1.99**	**1.66**			
			Min:	**1.43**	**1.99**	**1.66**			
			Max:	**1.43**	**1.99**	**1.66**			
	120	Run Maximum Depth to Riffle Mean Depth (d_{maxr}/d_{bkf})	*Mean:*	**1.810**	**2.128**	**2.128**			
			Min:	**1.810**	**2.128**	**2.128**			
			Max:	**1.810**	**2.128**	**2.128**			
	121	Glide Maximum Depth, ft (d_{maxg})	*Mean:*	**0.54**	**2.15**	**1.79**			
			Min:	**0.54**	**2.15**	**1.79**			
			Max:	**0.54**	**2.15**	**1.79**			
	122	Glide Maximum Depth to Riffle Mean Depth (d_{maxg}/d_{bkf})	*Mean:*	**0.684**	**2.295**	**2.295**			
			Min:	**0.684**	**2.295**	**2.295**			
			Max:	**0.684**	**2.295**	**2.295**			
	123	Step Maximum Depth, ft (d_{maxs})	*Mean:*	**N/A**	**N/A**	**N/A**			
			Min:	**N/A**	**N/A**	**N/A**			
			Max:	**N/A**	**N/A**	**N/A**			
	124	Step Maximum Depth to Riffle Mean Depth (d_{maxs}/d_{bkf})	*Mean:*	**N/A**	**N/A**	**N/A**			
			Min:	**N/A**	**N/A**	**N/A**			
			Max:	**N/A**	**N/A**	**N/A**			
Channel Materials	**125**	**Particle Size Distribution of Channel Material (Active Bed) or Pavement**							
		D_{16} (mm)		**10**		**15**			
		D_{35} (mm)		**19**		**31**			
		D_{50} (mm)		**28**		**48**			
		D_{84} (mm)		**173**		**112**			
		D_{95} (mm)		**BEDROCK**		**167**			
		D_{100} (mm)		**BEDROCK**		**362**			
	126	**Particle Size Distribution of Bar Material or Sub-pavement**							
		D_{16} (mm)		**7**					
		D_{35} (mm)		**11**					
		D_{50} (mm)		**14**					
		D_{84} (mm)		**23**					
		D_{95} (mm)		**32**					
		D_{max}: Largest size particle at the toe (lower third) of bar (mm) or sub-pavement		**43**					


Design Typical Cross-Section
Elevation
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
Station



Predicted Cross-Section
Elevation
2.50
2.00
1.50
1.00
0.50
0.00
0
1
2
3
4
5
6
7
8
Station

Plunge Pool Design Calculation

Project:	Diamond Hills Park B1000031		Input
Date:	May 12, 2011		Calc.
Outfall:	Independence Blvd.		Check
By:	WKM		

Input Data

Value	Symbol	Description		Value	Unit
497	DA	Drainage Area (acres)	=	2.01	km^2
1355	Q_{10}	10yr Flowrate (cfs)	=	38.37	cms
4.5	Rc	Hydraulic Radius @ full flow (ft)	=	1.37	m
72	D	Culvert Diameter (in)	=	1.83	m
3	N	Quantity of Culverts			
0.01	S	Slope (ft/ft)			
56.4	D84	Particle Size 84 Index (mm)			
8.62	D16	Particle Size 16 Index (mm)			
12	H	Drop height from invert (in)			
0	Hd	Drop height ratio (H/D)			
2.56	σ	Material Standard Deviation			
30	T	Peak Flow Duration (min)			

Existing Scour Dimensions (if any)

Value	Symbol	Description		Value	Unit
	V	Volume of Scour (ft^3)	=	0	m^3
1.5	D_{max}	Maximum Scour Depth (ft)	=	0	m
31	W_{max}	Maximum Scour Width (ft)	=	9	m
28	L_{max}	Maximum Scour Length (ft)	=	9	m

Estes Scour Design

Value	Symbol	Description		Value	Unit
2516	V	Volume of Scour (ft^3) using DA	=	71	m^3
3230	V	Volume of Scour (ft^3) using Q_{10}	=	91	m^3
5.6	D_{max}	Maximum Scour Depth (ft)	=	2	m
41	W_{max}	Maximum Scour Width (ft)	=	13	m
53	L_{max}	Maximum Scour Length (ft)	=	16	m

Modified FHWA Scour Design

C_h Coefficient for Outlets above the Bed

D	W	L	V
1	1	1	1

C_s Coefficient for Culvert Slope

D	W	L	V
1	1	1	1

α Coefficient for Cohesionless Soils

D	W	L	V
2.27	6.94	17.1	127.08

β Coefficient for Cohesionless Soils

D	W	L	V
0.39	0.53	0.47	1.24

θ Coefficient for Cohesionless Soils

D	W	L	V
0.06	0.08	0.1	0.18

Scour Dimensions

Value	Symbol	Description		Value	Unit
46522	V	Volume of Scour (ft^3)	=	1317	m^3
12.7	D_{max}	Maximum Scour Depth (ft)	=	4	m
47	W_{max}	Maximum Scour Width (ft)	=	14	m
100	L_{max}	Maximum Scour Length (ft)	=	30	m

Appendix D
Hydrologic Analysis

Project: DIAMOND HILLS
Simulation Run: Ultimate-Bankfull Junction: J24

Start of Run:	01Mar2011, 00:00	Basin Model:	Diamond Hills-Ultimate
End of Run:	03Mar2011, 00:00	Meteorologic Model:	Bankfull
Compute Time:	10Jun2011, 10:56:54	Control Specifications:	Control 1

Volume Units: IN

Computed Results

Peak Outflow :	39.6 (CFS)	Date/Time of Peak Outflow :	01Mar2011, 12:22
Total Outflow :	1.43 (IN)		

Project: DIAMOND HILLS
Simulation Run: Ultimate-10year Junction: J24

Start of Run:	01Mar2011, 00:00	Basin Model:	Diamond Hills-Ultimate
End of Run:	03Mar2011, 00:00	Meteorologic Model:	Montgomery County 10 year
Compute Time:	16Jun2011, 10:22:53	Control Specifications:	Control 1

Volume Units: IN

Computed Results

Peak Outflow :	1336.0 (CFS)	Date/Time of Peak Outflow :	01Mar2011, 12:12
Total Outflow :	4.07 (IN)		

Project: DIAMOND HILLS
Simulation Run: Ultimate-100year Junction: J24

Start of Run:	01Mar2011, 00:00	Basin Model:	Diamond Hills-Ultimate
End of Run:	03Mar2011, 00:00	Meteorologic Model:	Montgomery County 100 year
Compute Time:	16Jun2011, 10:34:04	Control Specifications:	Control 1

Volume Units: IN

Computed Results

Peak Outflow :	2410.9 (CFS)	Date/Time of Peak Outflow :	01Mar2011, 12:11
Total Outflow :	6.27 (IN)		

Appendix E
Hydraulic Analysis

HEC-RAS Plan: Bkf River: DiamondHills Reach: REACH 1 Profile: Max WS

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	2607	Max WS	5.25	1970.25	1972.01		0.00	0.00	0.00	0.24	0.00	22.54	30.21
REACH 1	2536	Max WS	64.52	1970.00	1971.05		0.13		0.13	1.65	0.21	39.21	44.42
REACH 1	2466.9		Culvert										
REACH 1	2402	Max WS	38.77	1965.00	1968.85	0.00	0.00	0.00	0.00	0.21	0.00	187.00	60.18
REACH 1	2377	Max WS	38.71	1966.51	1968.85	0.00	0.01	0.00	0.01	0.63	0.01	65.52	45.21
REACH 1	2352	Max WS	38.67	1967.43	1968.75	0.25	0.56	0.42	0.41	1.65	0.50	32.12	42.13
REACH 1	2322.1	Max WS	38.65	1966.60	1968.36	0.44	1.75	0.40	0.95	2.72	2.15	17.13	27.47
REACH 1	2290.47	Max WS	38.61	1965.33	1968.02	0.15	0.87	0.13	0.41	1.96	0.69	23.20	31.56
REACH 1	2275.9	Max WS	38.59	1965.01	1967.95	0.06	0.51	0.15	0.25	1.41	0.28	35.32	50.92
REACH 1	2261.32	Max WS	38.56	1966.28	1967.86	0.10	0.62	0.31	0.34	1.58	0.39	34.31	64.85
REACH 1	2246.52	Max WS	38.53	1966.05	1967.77	0.13	0.52	0.21	0.25	1.48	0.25	39.61	74.54
REACH 1	2235.33	Max WS	38.51	1964.78	1967.74	0.07	0.35	0.11	0.15	1.17	0.13	46.92	74.28
REACH 1	2224.14	Max WS	38.50	1966.05	1967.68	0.13	0.65	0.26	0.31	1.63	0.33	35.93	74.78
REACH 1	2210		Lat Struct										
REACH 1	2209.75	Max WS	37.02	1965.86	1967.57	0.21	0.86	0.27	0.33	2.31	0.42	29.63	69.62
REACH 1	2197.34	Max WS	36.07	1965.70	1967.51	0.17	0.62	0.20	0.27	1.64	0.28	33.85	67.05
REACH 1	2183.89	Max WS	36.05	1964.43	1967.47	0.07	0.48	0.08	0.17	1.38	0.17	35.18	68.04
REACH 1	2170.45	Max WS	36.02	1965.70	1967.34	0.34	1.79	0.28	0.60	2.70	1.16	18.62	55.12
REACH 1	2150.5	Max WS	35.97	1965.39	1967.17	0.30	1.06	0.20	0.36	2.13	0.50	25.62	66.41
REACH 1	2140.31	Max WS	35.97	1964.12	1967.13	0.11	0.51	0.07	0.17	1.43	0.19	33.61	67.42
REACH 1	2130.12	Max WS	35.93	1965.39	1967.06	0.27	1.30	0.24	0.43	2.43	0.69	22.27	64.94
REACH 1	2103.41	Max WS	30.73	1965.06	1966.90	0.18	0.75	0.13	0.26	1.80	0.32	24.81	60.47
REACH 1	2090.4	Max WS	29.19	1963.79	1966.87	0.05	0.29	0.04	0.09	1.07	0.07	38.02	80.06
REACH 1	2077.39	Max WS	35.85	1965.06	1966.64	0.34	2.31	0.35	0.93	3.04	2.25	14.74	38.13
REACH 1	2052.73	Max WS	35.83	1964.74	1966.09		4.90		4.90	4.30	21.03	8.34	10.54
REACH 1	2040.52	Max WS	35.81	1963.14	1965.96	0.06	0.57	0.11	0.20	1.46	0.20	34.74	78.48
REACH 1	2028.31	Max WS	35.80	1964.41	1965.85	0.03	0.86	0.36	0.41	1.81	0.50	29.55	74.77
REACH 1	2020		Lat Struct										
REACH 1	2018.67	Max WS	35.69	1964.28	1965.75	0.03	0.48	0.29	0.28	1.36	0.28	36.40	71.34
REACH 1	2009.03	Max WS	35.59	1964.14	1965.64	0.07	0.74	0.33	0.37	1.70	0.43	30.59	69.70
REACH 1	1999.07	Max WS	35.59	1962.54	1965.57	0.06	0.50	0.08	0.23	1.51	0.29	27.76	40.09
REACH 1	1989.1	Max WS	35.57	1963.81	1965.45	0.32	1.86	0.32	0.75	2.76	1.63	16.49	39.63
REACH 1	1963.56	Max WS	35.53	1963.48	1965.08	0.26	1.62	0.41	0.67	2.56	1.24	19.29	47.52
REACH 1	1952.68	Max WS	35.52	1961.88	1965.00	0.10	0.45	0.07	0.20	1.36	0.21	32.54	47.54
REACH 1	1941.8	Max WS	35.51	1963.15	1964.92	0.30	1.19	0.26	0.50	2.25	0.81	21.78	45.61
REACH 1	1914.33	Max WS	35.48	1962.82	1964.70	0.27	0.99	0.23	0.45	2.08	0.70	22.75	39.93
REACH 1	1901.37	Max WS	35.48	1961.55	1964.63	0.10	0.49	0.08	0.23	1.40	0.26	30.53	43.12
REACH 1	1888.41	Max WS	35.46	1962.82	1964.47	0.34	1.76	0.35	0.77	2.69	1.62	16.90	37.11
REACH 1	1867.55	Max WS	35.44	1962.54	1964.13	0.27	1.58	0.41	0.68	2.53	1.25	19.36	46.08
REACH 1	1857.01	Max WS	35.42	1960.94	1964.05	0.10	0.45	0.08	0.19	1.35	0.21	32.59	47.32
REACH 1	1846.47	Max WS	35.80	1962.21	1963.97	0.28	1.21	0.26	0.50	2.27	0.81	21.82	46.80
REACH 1	1818.13	Max WS	35.76	1961.87	1963.77	0.23	0.90	0.22	0.40	2.00	0.59	24.48	43.44
REACH 1	1804.91	Max WS	35.74	1960.60	1963.71	0.07	0.37	0.07	0.18	1.40	0.21	30.81	40.09
REACH 1	1791.69	Max WS	35.73	1961.87	1963.57	0.31	1.65	0.31	0.74	2.63	1.55	17.07	35.12
REACH 1	1766.4	Max WS	35.71	1961.55	1963.33	0.22	0.96	0.28	0.42	2.02	0.59	25.38	50.72
REACH 1	1754.71	Max WS	35.70	1960.28	1963.28	0.07	0.49	0.11	0.20	1.40	0.21	33.32	55.90
REACH 1	1743.01	Max WS	35.69	1961.55	1963.16	0.23	1.45	0.37	0.50	2.43	0.80	22.12	65.50
REACH 1	1730		Lat Struct										
REACH 1	1729.97	Max WS	35.15	1961.38	1962.95	0.17	1.51	0.36	0.45	3.76	1.02	15.45	53.93
REACH 1	1716.92	Max WS	34.77	1961.21	1962.77	0.24	1.99	0.55	0.82	2.82	1.78	15.93	41.23
REACH 1	1703.52	Max WS	34.75	1959.61	1962.66	0.05	0.47	0.08	0.21	1.45	0.27	27.76	40.42
REACH 1	1690.12	Max WS	34.74	1960.88	1962.50	0.27	2.02	0.30	0.81	2.87	1.87	14.92	37.43
REACH 1	1665.14	Max WS	34.68	1960.57	1962.14	0.23	1.69	0.43	0.70	2.60	1.33	18.24	46.14
REACH 1	1654.04	Max WS	34.67	1958.97	1962.05	0.10	0.46	0.08	0.21	1.37	0.23	31.13	44.63
REACH 1	1642.93	Max WS	34.65	1960.24	1961.96	0.26	1.28	0.28	0.51	2.32	0.87	20.54	46.54
REACH 1	1617.15	Max WS	34.62	1959.85	1961.75	0.22	0.87	0.22	0.39	1.95	0.56	24.02	42.15
REACH 1	1602.93	Max WS	34.61	1958.58	1961.68	0.08	0.45	0.08	0.21	1.35	0.24	30.92	42.21
REACH 1	1588.7	Max WS	34.60	1959.85	1961.55	0.30	1.57	0.28	0.67	2.56	1.35	17.20	37.29
REACH 1	1565.62	Max WS	34.58	1959.54	1961.13	0.31	2.26	0.29	0.96	3.02	2.43	13.65	33.30
REACH 1	1554.61	Max WS	34.58	1957.94	1961.00	0.08	0.51	0.06	0.24	1.43	0.29	28.19	39.06
REACH 1	1543.6	Max WS	34.57	1959.21	1960.88	0.28	1.69	0.31	0.72	2.64	1.52	16.44	36.64
REACH 1	1520.57	Max WS	34.56	1958.89	1960.50	0.29	2.05	0.33	0.86	2.88	2.05	14.56	34.68
REACH 1	1507.82	Max WS	34.55	1957.29	1960.38	0.06	0.52	0.10	0.24	1.38	0.29	29.24	40.28
REACH 1	1495.13	Max WS	34.54	1958.56	1960.26	0.27	1.56	0.31	0.69	2.55	1.40	16.96	35.65
REACH 1	1469.66	Max WS	34.51	1958.23	1959.91	0.30	1.69	0.34	0.81	2.64	1.77	15.85	30.89
REACH 1	1457.21	Max WS	34.50	1956.63	1959.82	0.09	0.42	0.07	0.25	1.31	0.29	29.72	29.46
REACH 1	1444.75	Max WS	34.49	1957.90	1959.68	0.34	1.41	0.23	0.83	2.45	1.76	16.24	23.57
REACH 1	1435		Lat Struct										
REACH 1	1433.6	Max WS	33.68	1957.74	1959.51	0.39	1.70	0.27	0.80	3.20	1.99	13.57	24.47
REACH 1	1422.45	Max WS	32.72	1957.57	1959.41	0.26	1.10	0.19	0.62	2.18	1.14	17.76	25.80
REACH 1	1411.4	Max WS	32.72	1956.30	1959.36	0.08	0.46	0.08	0.23	1.35	0.27	28.15	36.17
REACH 1	1400.34	Max WS	29.53	1957.57	1959.25	0.23	1.22	0.21	0.53	2.25	0.95	16.45	35.78
REACH 1	1381.13	Max WS	32.72	1957.26	1958.82	0.26	1.96	0.37	0.83	2.79	1.84	14.80	37.17
REACH 1	1371.21	Max WS	32.71	1955.67	1958.71	0.10	0.48	0.06	0.24	1.39	0.29	26.88	35.21
REACH 1	1361.28	Max WS	32.68	1956.94	1958.58	0.33	1.66	0.26	0.75	2.61	1.60	15.28	33.00
REACH 1	1342.23	Max WS	32.64	1956.62	1958.29	0.32	1.60	0.29	0.81	2.57	1.73	15.20	28.67
REACH 1	1331.95	Max WS	32.61	1955.02	1958.22	0.07	0.36	0.07	0.19	1.22	0.19	31.57	35.78
REACH 1	1321.67	Max WS	32.60	1956.29	1958.13	0.26	0.95	0.22	0.46	2.03	0.72	20.72	35.29
REACH 1	1298.14	Max WS	32.56	1955.99	1957.90	0.25	0.78	0.19	0.39	1.86	0.55	22.82	36.05
REACH 1	1285.54	Max WS	32.54	1954.72	1957.83	0.09	0.41	0.07	0.22	1.28	0.24	29.54	35.46
REACH 1	1272.95	Max WS	32.51	1955.99	1957.73	0.26	1.24	0.25	0.57	2.29	1.03	17.94	34.97
REACH 1	1254.08	Max WS	32.44	1955.72	1957.59	0.21	0.85	0.21	0.39	1.93	0.57	22.33	39.35
REACH 1	1242.1	Max WS	32.43	1954.45	1957.54	0.07	0.42	0.07	0.20	1.30	0.22	29.77	39.82
REACH 1	1230.11	Max WS	32.40	1955.72	1957.47	0.25	1.18	0.16	0.42	2.23	0.70	19.16	48.47

HEC-RAS Plan: Bkf River: DiamondHills Reach: REACH 1 Profile: Max WS (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	1206.25	Max WS	32.35	1955.40	1957.33	0.23	0.77	0.19	0.38	1.85	0.55	22.62	34.97
REACH 1	1194.55	Max WS	32.34	1954.13	1957.28	0.10	0.39	0.07	0.23	1.27	0.25	29.01	30.38
REACH 1	1182.85	Max WS	32.33	1955.40	1957.19	0.28	1.13	0.26	0.61	2.20	1.10	17.90	28.50
REACH 1	1171		Lat Struct										
REACH 1	1169.83	Max WS	30.76	1955.24	1956.99	0.36	1.43	0.22	0.79	3.07	1.97	12.26	19.15
REACH 1	1156.8	Max WS	29.39	1955.09	1956.88	0.25	1.01	0.15	0.62	2.08	1.14	16.09	22.07
REACH 1	1144.07	Max WS	29.38	1953.82	1956.83	0.07	0.40	0.06	0.19	1.26	0.21	27.08	38.31
REACH 1	1131.33	Max WS	29.30	1955.09	1956.72	0.21	1.17	0.24	0.48	2.19	0.78	17.95	43.56
REACH 1	1106.24	Max WS	29.14	1954.79	1956.55	0.17	0.68	0.16	0.26	1.69	0.30	25.58	58.72
REACH 1	1093.69	Max WS	29.14	1953.52	1956.51	0.06	0.33	0.06	0.13	1.14	0.11	33.82	59.91
REACH 1	1081.14	Max WS	29.11	1954.79	1956.45	0.15	0.86	0.20	0.31	1.88	0.38	23.30	63.00
REACH 1	1052.64	Max WS	29.08	1954.45	1955.94	0.29	1.47	0.30	0.56	2.39	0.96	16.88	50.57
REACH 1	1040.74	Max WS	29.07	1952.84	1955.80	0.04	0.41	0.05	0.15	1.27	0.15	27.93	55.50
REACH 1	1028.84	Max WS	27.96	1954.12	1955.70	0.20	1.27	0.16	0.41	2.26	0.66	17.11	56.05
REACH 1	1006.93	Max WS	29.06	1953.81	1955.34	0.34	1.24	0.14	0.54	2.21	0.87	17.85	45.37
REACH 1	997.42	Max WS	29.05	1952.21	1955.26	0.09	0.31	0.05	0.18	1.10	0.16	31.56	36.67
REACH 1	987.91	Max WS	29.04	1953.48	1955.18	0.24	1.07	0.13	0.50	2.12	0.84	17.22	34.31
REACH 1	975		Lat Struct										
REACH 1	974.71	Max WS	28.38	1953.33	1954.98	0.24	1.36	0.16	0.66	3.20	1.73	10.74	21.02
REACH 1	961.51	Max WS	27.93	1953.17	1954.74	0.26	1.60	0.14	0.97	2.53	2.22	12.13	20.89
REACH 1	946.83	Max WS	27.72	1951.57	1954.59	0.05	0.35	0.05	0.17	1.17	0.17	27.25	37.65
REACH 1	932.15	Max WS	27.30	1952.84	1954.49	0.19	1.02	0.21	0.43	2.04	0.67	17.59	40.52
REACH 1	906.37	Max WS	27.95	1952.54	1954.06	0.15	1.31	0.29	0.52	2.27	0.86	16.80	47.25
REACH 1	895.42	Max WS	27.93	1950.93	1953.96	0.07	0.34	0.05	0.14	1.17	0.13	29.03	47.35
REACH 1	884.47	Max WS	27.91	1952.21	1953.89	0.21	0.98	0.18	0.38	2.01	0.56	18.73	46.10
REACH 1	857.4	Max WS	27.88	1951.89	1953.71	0.18	0.72	0.15	0.33	1.76	0.44	20.70	38.00
REACH 1	843.91	Max WS	27.87	1950.62	1953.67	0.06	0.34	0.06	0.18	1.16	0.18	27.81	35.30
REACH 1	830.43	Max WS	27.85	1951.89	1953.53	0.22	1.23	0.23	0.61	2.24	1.14	14.92	29.28
REACH 1	806.03	Max WS	27.68	1951.60	1953.32	0.17	0.79	0.19	0.33	1.82	0.44	20.90	45.62
REACH 1	793.59	Max WS	27.56	1950.33	1953.28	0.05	0.36	0.06	0.15	1.20	0.15	28.20	46.93
REACH 1	781.14	Max WS	27.25	1951.60	1953.20	0.19	0.85	0.17	0.29	1.85	0.35	22.52	67.00
REACH 1	754.18	Max WS	27.00	1951.29	1953.03	0.10	0.44	0.10	0.14	1.37	0.11	33.76	95.66
REACH 1	741.66	Max WS	26.90	1950.02	1953.00	0.04	0.21	0.03	0.06	0.91	0.03	47.32	115.58
REACH 1	729.14	Max WS	26.87	1951.29	1952.97	0.08	0.33	0.07	0.11	1.17	0.07	42.07	125.90
REACH 1	704.11	Max WS	26.84	1950.99	1952.83	0.18	0.57	0.15	0.29	1.57	0.35	22.50	35.17
REACH 1	691.29	Max WS	26.83	1949.72	1952.78	0.07	0.27	0.04	0.15	1.04	0.13	30.52	36.33
REACH 1	678.46	Max WS	26.82	1950.99	1952.66	0.27	1.10	0.22	0.64	2.13	1.17	14.63	23.60
REACH 1	652.16	Max WS	26.80	1950.69	1952.43	0.21	0.72	0.16	0.36	1.74	0.48	20.11	35.60
REACH 1	639.45	Max WS	26.79	1949.42	1952.38	0.08	0.33	0.05	0.17	1.14	0.17	27.87	36.72
REACH 1	626.73	Max WS	26.79	1950.69	1952.27	0.28	1.14	0.15	0.50	2.14	0.83	16.04	37.80
REACH 1	602.51	Max WS	26.78	1950.39	1951.90	0.20	1.66	0.18	0.68	2.55	1.48	12.23	33.19
REACH 1	590.06	Max WS	26.77	1948.79	1951.80	0.08	0.34	0.03	0.18	1.17	0.18	25.51	32.68
REACH 1	577.6	Max WS	26.76	1950.06	1951.70	0.26	1.15	0.17	0.55	2.17	1.00	14.68	29.89
REACH 1	549.5	Max WS	26.74	1949.72	1951.25	0.23	1.63	0.18	0.89	2.54	2.04	11.62	23.01
REACH 1	536.16	Max WS	26.73	1948.12	1951.13	0.07	0.34	0.06	0.21	1.16	0.23	25.30	27.03
REACH 1	522.82	Max WS	26.71	1949.39	1951.03	0.24	1.08	0.19	0.49	2.10	0.81	15.91	34.52
REACH 1	501.45	Max WS	26.70	1949.12	1950.87	0.23	0.78	0.14	0.32	1.82	0.44	19.35	41.64
REACH 1	491.45	Max WS	26.69	1947.85	1950.83	0.07	0.34	0.04	0.14	1.17	0.14	26.97	43.76
REACH 1	481.45	Max WS	26.68	1949.12	1950.76	0.25	1.10	0.15	0.43	2.12	0.72	15.84	39.73
REACH 1	452.26	Max WS	26.67	1948.73	1950.20	0.15	1.98	0.13	1.12	2.76	2.94	10.16	20.69
REACH 1	437.05	Max WS	26.67	1947.13	1950.00	0.05	0.45	0.05	0.28	1.30	0.35	21.81	24.99
REACH 1	421.84	Max WS	26.66	1948.40	1949.86	0.02	0.38	0.02	0.23	2.81	0.61	9.90	19.40
REACH 1	399.73	Max WS	26.65	1948.12	1949.61	0.20	1.80	0.15	0.78	2.65	1.82	11.34	29.85
REACH 1	387.68	Max WS	26.64	1946.52	1949.51	0.08	0.35	0.03	0.20	1.18	0.21	24.90	29.57
REACH 1	375.64	Max WS	26.63	1947.79	1949.38	0.26	1.36	0.19	0.71	2.34	1.46	13.05	25.17
REACH 1	349.17	Max WS	26.51	1947.43	1949.02	0.29	1.25	0.20	0.67	2.25	1.27	13.92	26.52
REACH 1	336.06	Max WS	26.49	1945.83	1948.94	0.07	0.28	0.06	0.18	1.07	0.18	27.50	26.42
REACH 1	322.95	Max WS	26.43	1947.10	1948.83	0.16	0.95	0.19	0.52	1.99	0.90	15.41	24.77
REACH 1	300.24	Max WS	26.33	1946.80	1948.65	0.18	0.56	0.13	0.26	1.57	0.30	22.43	39.58
REACH 1	288.67	Max WS	26.31	1945.53	1948.62	0.07	0.27	0.04	0.12	1.04	0.10	30.55	42.54
REACH 1	277.06	Max WS	26.26	1946.80	1948.54	0.22	0.78	0.14	0.34	1.81	0.47	18.84	38.51
REACH 1	248.57	Max WS	26.19	1946.47	1948.35	0.20	0.55	0.14	0.30	1.56	0.37	21.30	30.66
REACH 1	234.41	Max WS	26.15	1945.20	1948.30	0.07	0.27	0.05	0.16	1.03	0.14	29.18	31.24
REACH 1	220.24	Max WS	26.13	1946.47	1948.20	0.24	0.84	0.18	0.46	1.88	0.71	16.86	27.36
REACH 1	195.05	Max WS	26.06	1946.16	1948.02	0.20	0.58	0.14	0.30	1.58	0.37	20.97	32.01
REACH 1	182.23	Max WS	26.04	1944.89	1947.98	0.07	0.28	0.05	0.16	1.05	0.15	28.25	30.87
REACH 1	169.42	Max WS	26.03	1946.16	1947.88	0.25	0.89	0.18	0.48	1.94	0.78	16.08	26.75
REACH 1	144.47	Max WS	25.99	1945.86	1947.70	0.19	0.52	0.13	0.28	1.51	0.32	22.74	34.68
REACH 1	132.12	Max WS	25.97	1944.59	1947.66	0.07	0.25	0.05	0.13	1.00	0.10	31.78	38.98
REACH 1	119.78	Max WS	25.94	1945.86	1947.57	0.23	0.83	0.17	0.42	1.86	0.62	17.62	31.84
REACH 1	90.67	Max WS	25.80	1945.54	1947.36	0.13	0.43	0.10	0.18	1.37	0.17	27.63	54.74
REACH 1	76.53	Max WS	25.79	1944.27	1947.31	0.06	0.23	0.03	0.10	0.96	0.08	34.41	50.47
REACH 1	62.4	Max WS	25.78	1945.54	1947.22	0.25	0.75	0.14	0.37	1.77	0.50	19.03	36.70
REACH 1	44.67	Max WS	25.76	1945.27	1947.10	0.19	0.48	0.11	0.24	1.43	0.26	23.84	37.71
REACH 1	34.39	Max WS	25.76	1944.02	1947.07	0.03	0.09	0.02	0.05	1.06	0.04	30.52	36.65
REACH 1	24.46	Max WS	25.75	1945.27	1947.04	0.20	0.53	0.11	0.26	1.50	0.29	22.99	40.76

HEC-RAS Plan: 10year River: DiamondHills Reach: REACH 1 Profile: Max WS

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	2607	Max WS	1196.17	1970.25	1981.08	0.01	0.01	0.01	0.01	0.84	0.01	1602.26	234.41
REACH 1	2536	Max WS	1195.11	1970.00	1981.06	0.02	0.04	0.01	0.03	1.42	0.04	950.54	126.54
REACH 1	2466.9		Culvert										
REACH 1	2402	Max WS	1194.88	1965.00	1972.93	0.03	0.19	0.05	0.14	2.81	0.35	470.85	85.17
REACH 1	2377	Max WS	1194.60	1966.51	1972.74	0.23	0.71	0.33	0.41	5.27	1.37	357.16	106.59
REACH 1	2352	Max WS	1194.22	1967.43	1972.69	1.42	3.19	2.43	2.10	5.12	7.28	345.21	108.73
REACH 1	2322.1	Max WS	1193.87	1966.60	1972.22	2.31	4.91	2.77	2.81	5.81	11.00	305.06	110.07
REACH 1	2290.47	Max WS	1193.51	1965.33	1971.62	2.73	6.10	2.91	3.18	6.27	13.14	288.62	115.19
REACH 1	2275.9	Max WS	1193.20	1965.01	1971.42	1.89	4.45	2.59	2.60	5.07	9.63	322.44	120.80
REACH 1	2261.32	Max WS	1193.03	1966.28	1971.27	1.46	3.06	2.14	2.02	4.49	6.60	365.55	131.37
REACH 1	2246.52	Max WS	1192.75	1966.05	1971.13	1.36	2.68	1.87	1.83	4.21	5.69	383.77	130.07
REACH 1	2235.33	Max WS	1192.62	1964.78	1970.99	1.39	3.07	2.05	2.09	4.20	6.91	360.14	120.01
REACH 1	2224.14	Max WS	1192.37	1966.05	1970.84	1.66	3.24	2.28	2.28	4.58	7.83	347.05	122.05
REACH 1	2210		Lat Struct										
REACH 1	2209.75	Max WS	1115.32	1965.86	1970.71	1.54	2.70	1.92	1.90	5.10	6.04	350.21	124.07
REACH 1	2197.34	Max WS	1053.55	1965.70	1970.63	1.32	2.49	1.69	1.68	4.04	5.00	354.67	125.99
REACH 1	2183.89	Max WS	1053.36	1964.43	1970.49	1.30	2.72	1.76	1.78	3.91	5.38	348.63	125.28
REACH 1	2170.45	Max WS	1053.06	1965.70	1970.37	1.33	2.40	1.70	1.68	3.93	4.91	360.16	131.69
REACH 1	2150.5	Max WS	1052.84	1965.39	1970.19	1.12	2.17	1.52	1.52	3.76	4.27	375.46	132.51
REACH 1	2140.31	Max WS	1052.57	1964.12	1970.11	1.10	2.26	1.51	1.54	3.58	4.35	373.75	130.41
REACH 1	2130.12	Max WS	1052.44	1965.39	1970.02	1.17	2.11	1.49	1.49	3.86	4.13	378.67	139.22
REACH 1	2103.41	Max WS	1051.94	1965.06	1969.77	1.41	2.40	1.59	1.61	3.94	4.55	370.72	140.73
REACH 1	2090.4	Max WS	1051.91	1963.79	1969.62	1.47	2.82	1.81	1.82	3.95	5.53	347.04	133.53
REACH 1	2077.39	Max WS	1051.74	1965.06	1969.37	2.23	4.23	2.57	2.61	5.13	9.25	296.73	135.19
REACH 1	2052.73	Max WS	1051.23	1964.74	1969.03	1.42	2.77	2.02	1.94	4.15	6.02	338.28	136.04
REACH 1	2040.52	Max WS	1050.90	1963.14	1968.91	1.32	2.64	1.73	1.73	3.81	5.10	356.41	136.94
REACH 1	2028.31	Max WS	1050.77	1964.41	1968.77	1.46	2.51	1.78	1.75	3.97	5.17	355.72	141.20
REACH 1	2020		Lat Struct										
REACH 1	2018.67	Max WS	1001.10	1964.28	1968.70	1.31	2.20	1.62	1.55	3.70	4.31	361.32	141.39
REACH 1	2009.03	Max WS	940.39	1964.14	1968.64	1.14	1.91	1.33	1.31	3.48	3.35	367.38	143.52
REACH 1	1999.07	Max WS	940.27	1962.54	1968.55	1.21	2.30	1.29	1.37	3.86	3.63	354.06	142.02
REACH 1	1989.1	Max WS	940.17	1963.81	1968.47	1.26	2.17	1.27	1.33	3.73	3.41	367.44	153.59
REACH 1	1963.56	Max WS	939.80	1963.48	1968.28	0.98	1.86	1.14	1.16	3.47	2.78	391.07	156.14
REACH 1	1952.68	Max WS	939.43	1961.88	1968.20	0.88	1.99	1.10	1.13	3.40	2.74	389.03	152.90
REACH 1	1941.8	Max WS	939.41	1963.15	1968.11	0.91	2.13	1.24	1.22	3.74	3.04	376.76	157.83
REACH 1	1914.33	Max WS	939.24	1962.82	1967.89	1.01	2.16	1.19	1.21	3.78	3.01	378.80	157.23
REACH 1	1901.37	Max WS	939.14	1961.55	1967.79	0.92	2.11	1.19	1.21	3.47	3.02	377.60	149.68
REACH 1	1888.41	Max WS	938.88	1962.82	1967.63	1.40	2.96	1.51	1.59	4.38	4.45	334.88	154.60
REACH 1	1867.55	Max WS	938.89	1962.54	1967.46	1.01	2.13	1.21	1.23	3.73	3.07	377.25	157.37
REACH 1	1857.01	Max WS	938.24	1960.94	1967.38	0.88	2.05	1.04	1.09	3.46	2.59	395.35	161.53
REACH 1	1846.47	Max WS	975.40	1962.21	1967.29	1.13	2.15	1.15	1.21	3.77	2.99	395.23	162.98
REACH 1	1818.13	Max WS	975.04	1961.87	1966.98	1.77	3.17	1.50	1.72	4.59	5.10	327.85	139.61
REACH 1	1804.91	Max WS	974.81	1960.60	1966.80	1.81	3.11	1.38	1.73	4.81	5.40	312.68	127.73
REACH 1	1791.69	Max WS	974.56	1961.87	1966.61	2.42	3.92	1.83	2.23	5.03	7.47	290.37	127.44
REACH 1	1766.4	Max WS	973.95	1961.55	1966.26	2.11	3.43	1.82	2.03	4.70	6.45	306.51	131.07
REACH 1	1754.71	Max WS	973.67	1960.28	1966.08	2.45	3.88	1.94	2.28	4.66	7.69	289.10	122.43
REACH 1	1743.01	Max WS	973.47	1961.55	1965.90	2.55	3.57	1.92	2.24	4.72	7.44	293.56	129.35
REACH 1	1730		Lat Struct										
REACH 1	1729.97	Max WS	920.47	1961.38	1965.71	2.13	2.91	1.50	1.81	6.48	5.72	290.51	132.38
REACH 1	1716.92	Max WS	870.52	1961.21	1965.62	1.86	2.63	1.22	1.58	4.06	4.47	308.15	139.46
REACH 1	1703.52	Max WS	870.09	1959.61	1965.48	1.59	2.57	1.07	1.43	4.02	3.94	316.27	139.54
REACH 1	1690.12	Max WS	870.11	1960.88	1965.35	1.69	2.59	1.16	1.46	4.05	3.92	323.93	154.91
REACH 1	1665.14	Max WS	869.78	1960.57	1965.10	1.30	2.37	1.30	1.38	3.88	3.56	336.78	153.35
REACH 1	1654.04	Max WS	869.58	1958.97	1964.97	1.19	2.97	1.40	1.51	4.10	4.17	315.10	148.17
REACH 1	1642.93	Max WS	869.41	1960.24	1964.85	1.31	2.70	1.36	1.44	4.15	3.82	328.52	159.67
REACH 1	1617.15	Max WS	869.08	1959.85	1964.60	1.27	2.39	1.16	1.29	3.93	3.25	345.37	160.95
REACH 1	1602.93	Max WS	868.92	1958.58	1964.45	1.32	2.57	1.20	1.39	3.78	3.63	332.90	152.15
REACH 1	1588.7	Max WS	868.62	1959.85	1964.30	1.52	2.67	1.35	1.52	4.11	4.11	321.27	153.26
REACH 1	1565.62	Max WS	868.38	1959.54	1964.07	1.43	2.25	1.16	1.34	3.78	3.42	339.47	151.28
REACH 1	1554.61	Max WS	868.26	1957.94	1963.97	1.36	2.37	1.06	1.29	3.66	3.30	340.31	147.73
REACH 1	1543.6	Max WS	868.14	1959.21	1963.86	1.50	2.40	1.16	1.38	3.92	3.60	332.32	148.93
REACH 1	1520.57	Max WS	867.97	1958.89	1963.67	1.35	2.01	1.00	1.22	3.60	3.04	348.75	142.67
REACH 1	1507.82	Max WS	867.90	1957.29	1963.58	1.26	2.04	0.95	1.20	3.27	2.96	351.98	134.42
REACH 1	1495.13	Max WS	867.79	1958.56	1963.47	1.41	2.12	1.03	1.28	3.73	3.28	338.24	135.44
REACH 1	1469.66	Max WS	867.52	1958.23	1963.20	1.91	2.93	1.27	1.61	4.39	4.69	298.18	128.72
REACH 1	1457.21	Max WS	867.38	1956.63	1963.01	2.26	3.90	1.39	1.92	4.74	6.23	267.60	119.37
REACH 1	1444.75	Max WS	866.54	1957.90	1962.74	3.24	5.46	1.98	2.63	5.96	9.89	230.64	117.10
REACH 1	1435		Lat Struct										
REACH 1	1433.6	Max WS	869.80	1957.74	1962.52	3.20	4.85	1.83	2.43	6.65	8.90	237.41	119.76
REACH 1	1422.45	Max WS	829.91	1957.57	1962.43	2.19	3.41	1.37	1.79	4.71	5.51	269.99	123.44
REACH 1	1411.4	Max WS	829.79	1956.30	1962.31	1.82	3.06	1.37	1.71	4.17	5.06	280.24	117.42
REACH 1	1400.34	Max WS	829.68	1957.57	1962.20	1.77	2.81	1.46	1.67	4.24	4.80	288.24	124.68
REACH 1	1381.13	Max WS	829.51	1957.26	1961.98	1.69	2.79	1.47	1.63	4.24	4.65	291.02	125.21
REACH 1	1371.21	Max WS	829.41	1955.67	1961.87	1.58	3.04	1.39	1.63	4.18	4.70	286.60	122.24
REACH 1	1361.28	Max WS	829.32	1956.94	1961.74	1.60	3.31	1.62	1.76	4.63	5.24	278.59	129.03
REACH 1	1342.23	Max WS	829.03	1956.62	1961.52	1.63	3.00	1.42	1.62	4.43	4.63	289.60	129.76
REACH 1	1331.95	Max WS	828.81	1955.02	1961.45	1.03	2.17	1.08	1.19	3.56	2.94	334.61	133.18
REACH 1	1321.67	Max WS	828.60	1956.29	1961.35	1.26	2.45	1.17	1.30	4.03	3.34	322.32	141.22
REACH 1	1298.14	Max WS	827.84	1955.99	1961.12	1.25	2.71	1.25	1.36	4.24	3.60	312.97	142.27
REACH 1	1285.54	Max WS	827.54	1954.72	1961.01	1.25	2.41	1.05	1.24	3.71	3.12	328.65	143.66
REACH 1	1272.95	Max WS	826.57	1955.99	1960.91	1.50	2.29	1.07	1.27	3.87	3.24	324.04	140.54
REACH 1	1254.08	Max WS	825.72	1955.72	1960.76	1.34	2.13	0.97	1.18	3.75	2.90	335.12	142.30
REACH 1	1242.1	Max WS	824.92	1954.45	1960.67	1.26	2.16	0.96	1.17	3.52	2.88	336.35	140.79
REACH 1	1230.11	Max WS	818.68	1955.72	1960.60	1.00	1.64	0.90	0.98	3.27	2.17	370.06	150.43

HEC-RAS Plan: 10year River: DiamondHills Reach: REACH 1 Profile: Max WS (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	1206.25	Max WS	814.46	1955.40	1960.47	0.80	1.46	0.82	0.86	3.11	1.80	390.30	153.96
REACH 1	1194.55	Max WS	801.39	1954.13	1960.40	0.68	1.59	0.84	0.89	3.03	1.89	376.31	151.43
REACH 1	1182.85	Max WS	765.94	1955.40	1960.36	0.65	1.33	0.75	0.77	2.96	1.50	390.67	162.10
REACH 1	1171		Lat Struct										
REACH 1	1169.83	Max WS	958.74	1955.24	1960.16	1.46	3.14	1.47	1.55	5.65	4.38	338.37	169.12
REACH 1	1156.8	Max WS	998.95	1955.09	1959.92	1.92	3.97	1.66	1.89	5.08	5.77	326.72	169.26
REACH 1	1144.07	Max WS	994.52	1953.82	1959.79	1.29	2.80	1.31	1.43	3.96	3.80	375.70	177.30
REACH 1	1131.33	Max WS	993.51	1955.09	1959.67	1.30	2.47	1.20	1.29	3.97	3.20	400.97	200.63
REACH 1	1106.24	Max WS	989.10	1954.79	1959.43	1.12	2.32	1.13	1.19	3.85	2.84	414.99	207.86
REACH 1	1093.69	Max WS	988.04	1953.52	1959.32	0.98	2.38	1.09	1.16	3.65	2.73	420.09	216.33
REACH 1	1081.14	Max WS	985.58	1954.79	1959.22	1.24	2.01	0.97	1.07	3.56	2.41	438.88	224.13
REACH 1	1052.64	Max WS	981.82	1954.45	1959.04	0.94	1.33	0.64	0.74	2.92	1.41	516.76	242.82
REACH 1	1040.74	Max WS	980.86	1952.84	1958.99	0.73	1.10	0.52	0.60	2.49	1.04	565.98	241.16
REACH 1	1028.84	Max WS	978.94	1954.12	1958.94	0.77	1.05	0.52	0.60	2.62	1.04	565.40	244.45
REACH 1	1006.93	Max WS	975.83	1953.81	1958.84	0.92	1.26	0.57	0.66	2.89	1.22	533.50	238.31
REACH 1	997.42	Max WS	974.96	1952.21	1958.79	0.99	1.44	0.58	0.69	2.90	1.30	516.51	230.00
REACH 1	987.91	Max WS	967.71	1953.48	1958.75	1.04	1.46	0.61	0.71	3.13	1.37	505.61	230.72
REACH 1	975		Lat Struct										
REACH 1	974.71	Max WS	1081.44	1953.33	1958.63	1.28	1.88	0.77	0.90	4.80	2.00	488.72	229.93
REACH 1	961.51	Max WS	1186.44	1953.17	1958.52	1.37	2.19	0.93	1.08	3.85	2.53	506.50	227.06
REACH 1	946.83	Max WS	1178.23	1951.57	1958.44	0.89	1.62	0.75	0.84	3.10	1.74	567.15	221.12
REACH 1	932.15	Max WS	1176.65	1952.84	1958.36	0.89	1.55	0.78	0.84	3.25	1.74	568.66	222.05
REACH 1	906.37	Max WS	1174.69	1952.54	1958.25	0.64	1.20	0.66	0.69	2.89	1.29	623.16	222.97
REACH 1	895.42	Max WS	1172.43	1950.93	1958.22	0.56	1.19	0.60	0.63	2.71	1.16	641.57	225.89
REACH 1	884.47	Max WS	1171.77	1952.21	1958.18	0.48	1.13	0.60	0.59	2.81	1.04	665.38	246.45
REACH 1	857.4	Max WS	1170.96	1951.89	1958.08	0.52	1.37	0.67	0.65	3.13	1.20	631.31	250.16
REACH 1	843.91	Max WS	1170.54	1950.62	1958.01	0.59	1.62	0.74	0.73	3.15	1.45	593.52	241.58
REACH 1	830.43	Max WS	1167.10	1951.89	1957.93	0.82	2.10	0.91	0.93	3.85	2.04	529.97	231.42
REACH 1	806.03	Max WS	1166.52	1951.60	1957.82	0.61	1.45	0.78	0.73	3.22	1.46	587.47	216.68
REACH 1	793.59	Max WS	1166.20	1950.33	1957.79	0.50	1.01	0.53	0.54	2.51	0.92	688.45	234.06
REACH 1	781.14	Max WS	1166.04	1951.60	1957.77	0.39	0.67	0.36	0.39	2.18	0.56	809.55	260.28
REACH 1	754.18	Max WS	1165.42	1951.29	1957.74	0.25	0.36	0.17	0.23	1.62	0.26	1030.93	296.16
REACH 1	741.66	Max WS	1165.13	1950.02	1957.73	0.20	0.28	0.14	0.19	1.33	0.19	1131.07	297.22
REACH 1	729.14	Max WS	1164.80	1951.29	1957.72	0.19	0.26	0.11	0.17	1.37	0.17	1168.81	317.42
REACH 1	704.11	Max WS	1164.33	1950.99	1957.49	2.11	3.13	1.35	1.62	4.77	4.96	380.46	125.19
REACH 1	691.29	Max WS	1164.20	1949.72	1957.39	1.99	2.93	1.21	1.53	4.27	4.55	392.11	126.38
REACH 1	678.46	Max WS	1163.95	1950.99	1957.12	2.42	5.25	2.30	2.60	6.11	10.12	299.07	109.23
REACH 1	652.16	Max WS	1163.65	1950.69	1956.80	2.80	4.02	1.82	2.23	5.34	7.97	325.91	106.46
REACH 1	639.45	Max WS	1163.33	1949.42	1956.66	2.51	3.77	1.68	2.09	4.78	7.17	339.43	110.33
REACH 1	626.73	Max WS	1163.10	1950.69	1956.54	2.36	3.34	1.62	1.90	4.83	6.12	360.33	121.55
REACH 1	602.51	Max WS	1162.60	1950.39	1956.31	1.31	3.12	1.67	1.77	4.68	5.47	376.06	125.55
REACH 1	590.06	Max WS	1162.25	1948.79	1956.21	1.18	2.80	1.38	1.53	4.17	4.50	394.96	127.14
REACH 1	577.6	Max WS	1162.12	1950.06	1956.09	1.33	3.04	1.58	1.69	4.63	5.20	377.33	126.05
REACH 1	549.5	Max WS	1161.21	1949.72	1955.73	1.90	4.13	1.98	2.18	5.40	7.64	330.95	116.51
REACH 1	536.16	Max WS	1161.09	1948.12	1955.59	1.28	3.64	1.66	1.88	4.73	6.16	354.44	119.63
REACH 1	522.82	Max WS	1160.86	1949.39	1955.48	1.31	3.16	1.62	1.74	4.74	5.34	377.30	126.11
REACH 1	501.45	Max WS	1160.62	1949.12	1955.34	0.95	2.25	1.22	1.29	4.01	3.48	428.96	134.60
REACH 1	491.45	Max WS	1160.19	1947.85	1955.28	0.94	2.14	1.14	1.23	3.65	3.22	442.66	135.81
REACH 1	481.45	Max WS	1159.97	1949.12	1955.21	1.02	2.31	1.27	1.34	4.04	3.67	423.40	134.02
REACH 1	452.26	Max WS	1159.58	1948.73	1954.84	1.70	4.07	2.00	2.18	5.38	7.76	325.84	110.64
REACH 1	437.05	Max WS	1159.28	1947.13	1954.66	1.62	4.11	1.89	2.17	5.04	7.70	327.07	106.19
REACH 1	421.84	Max WS	1157.78	1948.40	1954.22	1.02	2.69	1.30	1.42	10.07	5.57	295.60	107.28
REACH 1	399.73	Max WS	1158.00	1948.12	1954.33	1.35	2.79	1.47	1.57	4.46	4.68	389.49	123.44
REACH 1	387.68	Max WS	1157.72	1946.52	1954.25	1.29	2.67	1.29	1.45	4.10	4.17	403.21	123.56
REACH 1	375.64	Max WS	1157.74	1947.79	1954.12	1.39	3.10	1.56	1.68	4.72	5.22	372.82	120.30
REACH 1	349.17	Max WS	1156.96	1947.43	1953.78	2.41	4.17	1.91	2.20	5.48	7.82	325.68	106.69
REACH 1	336.06	Max WS	1156.52	1945.83	1953.64	1.09	3.79	1.83	2.07	4.87	7.29	328.20	97.78
REACH 1	322.95	Max WS	1156.08	1947.10	1953.54	0.24	3.19	1.78	1.85	4.80	6.12	348.75	102.57
REACH 1	300.24	Max WS	1155.86	1946.80	1953.42	0.56	2.04	1.20	1.24	3.86	3.32	431.78	118.13
REACH 1	288.67	Max WS	1155.62	1945.53	1953.37	0.70	1.80	1.04	1.11	3.38	2.82	453.60	120.93
REACH 1	277.06	Max WS	1155.35	1946.80	1953.30	0.79	1.93	1.15	1.19	3.75	3.16	436.46	119.86
REACH 1	248.57	Max WS	1154.57	1946.47	1953.08	1.31	2.64	1.46	1.56	4.39	4.70	383.78	107.24
REACH 1	234.41	Max WS	1154.45	1945.20	1952.97	1.29	2.67	1.46	1.61	4.09	4.89	380.62	103.29
REACH 1	220.24	Max WS	1154.24	1946.47	1952.85	1.46	2.86	1.66	1.76	4.54	5.60	363.09	101.22
REACH 1	195.05	Max WS	1154.01	1946.16	1952.68	1.09	2.35	1.34	1.42	4.14	4.07	402.48	112.51
REACH 1	182.23	Max WS	1153.57	1944.89	1952.59	1.09	2.48	1.35	1.47	3.93	4.29	396.00	110.93
REACH 1	169.42	Max WS	1153.71	1946.16	1952.46	1.28	3.02	1.65	1.76	4.66	5.62	360.54	108.46
REACH 1	144.47	Max WS	1153.18	1945.86	1952.19	2.40	3.64	1.72	2.03	5.12	6.86	340.47	106.25
REACH 1	132.12	Max WS	1153.01	1944.59	1952.08	2.33	3.46	1.50	1.90	4.64	6.28	349.07	109.48
REACH 1	119.78	Max WS	1152.71	1945.86	1951.93	2.34	3.77	1.76	2.02	5.17	6.85	340.42	116.35
REACH 1	90.67	Max WS	1152.42	1945.54	1951.78	1.26	1.65	0.79	0.94	3.44	2.18	499.11	157.45
REACH 1	76.53	Max WS	1152.38	1944.27	1951.71	1.25	1.69	0.78	0.95	3.22	2.18	501.01	158.85
REACH 1	62.4	Max WS	1152.08	1945.54	1951.59	1.63	2.38	1.14	1.30	4.11	3.45	433.30	147.85
REACH 1	44.67	Max WS	1151.97	1945.27	1951.46	1.60	2.42	1.15	1.30	4.15	3.46	431.73	145.34
REACH 1	34.39	Max WS	1151.86	1944.02	1951.36	0.90	1.54	0.75	0.84	5.50	2.17	447.01	146.62
REACH 1	24.46	Max WS	1151.84	1945.27	1951.38	1.12	1.66	0.89	0.97	3.43	2.22	503.22	158.60

HEC-RAS Plan: 100YR River: DiamondHills Reach: REACH 1 Profile: Max WS

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	2607	Max WS	1859.71	1970.25	1995.55	0.00	0.00	0.00	0.00	0.33	0.00	6075.20	334.92
REACH 1	2536	Max WS	1857.38	1970.00	1995.54	0.00	0.00	0.00	0.00	0.55	0.00	4205.00	267.73
REACH 1	2466.9		Culvert										
REACH 1	2402	Max WS	1857.32	1965.00	1973.89	0.06	0.33	0.11	0.24	3.83	0.79	555.63	91.81
REACH 1	2377	Max WS	1857.02	1966.51	1973.61	0.43	1.11	0.55	0.67	6.78	2.74	453.12	112.78
REACH 1	2352	Max WS	1856.76	1967.43	1973.64	1.79	4.24	3.30	2.70	6.07	10.96	457.52	125.33
REACH 1	2322.1	Max WS	1856.38	1966.60	1973.12	2.85	6.08	3.73	3.58	6.65	16.23	409.40	121.84
REACH 1	2290.47	Max WS	1855.95	1965.33	1972.52	3.41	6.85	3.77	3.93	6.82	18.44	395.86	122.21
REACH 1	2275.9	Max WS	1855.79	1965.01	1972.33	2.51	5.18	3.33	3.27	5.62	13.96	435.41	127.37
REACH 1	2261.32	Max WS	1855.59	1966.28	1972.18	1.95	3.69	2.72	2.57	5.09	9.75	488.65	137.65
REACH 1	2246.52	Max WS	1855.38	1966.05	1972.03	1.80	3.34	2.47	2.39	4.85	8.80	504.52	135.58
REACH 1	2235.33	Max WS	1855.33	1964.78	1971.88	1.83	3.89	2.80	2.78	4.87	11.00	469.10	125.39
REACH 1	2224.14	Max WS	1855.02	1966.05	1971.72	2.12	4.04	3.02	2.96	5.28	12.02	456.68	127.38
REACH 1	2210		Lat Struct										
REACH 1	2209.75	Max WS	1744.68	1965.86	1971.60	1.99	3.38	2.56	2.49	5.88	9.39	462.26	129.46
REACH 1	2197.34	Max WS	1655.54	1965.70	1971.52	1.76	3.13	2.27	2.22	4.67	7.83	469.03	131.56
REACH 1	2183.89	Max WS	1655.48	1964.43	1971.37	1.76	3.37	2.37	2.35	4.49	8.44	461.30	130.79
REACH 1	2170.45	Max WS	1655.15	1965.70	1971.24	1.74	2.99	2.24	2.19	4.53	7.59	477.85	137.05
REACH 1	2150.5	Max WS	1654.93	1965.39	1971.06	1.46	2.77	2.07	2.03	4.38	6.82	492.58	137.62
REACH 1	2140.31	Max WS	1654.81	1964.12	1970.96	1.43	2.89	2.09	2.09	4.16	7.08	487.85	135.53
REACH 1	2130.12	Max WS	1654.72	1965.39	1970.87	1.52	2.66	2.00	1.96	4.47	6.48	499.85	144.57
REACH 1	2103.41	Max WS	1654.29	1965.06	1970.61	1.84	2.97	2.12	2.10	4.51	7.07	491.44	146.00
REACH 1	2090.4	Max WS	1654.08	1963.79	1970.45	1.99	3.47	2.43	2.41	4.51	8.67	459.54	138.58
REACH 1	2077.39	Max WS	1653.87	1965.06	1970.21	2.68	4.60	3.10	3.09	5.54	12.37	412.75	140.70
REACH 1	2052.73	Max WS	1653.62	1964.74	1969.90	1.88	3.35	2.52	2.42	4.73	8.69	460.37	145.58
REACH 1	2040.52	Max WS	1653.36	1963.14	1969.77	1.79	3.23	2.24	2.23	4.35	7.69	479.02	146.23
REACH 1	2028.31	Max WS	1653.17	1964.41	1969.64	1.88	3.05	2.23	2.19	4.52	7.52	482.33	150.50
REACH 1	2020		Lat Struct										
REACH 1	2018.67	Max WS	1580.36	1964.28	1969.57	1.74	2.72	2.02	1.96	4.26	6.31	491.28	153.91
REACH 1	2009.03	Max WS	1492.19	1964.14	1969.52	1.52	2.41	1.67	1.67	4.04	4.98	499.75	157.32
REACH 1	1999.07	Max WS	1492.00	1962.54	1969.42	1.60	2.78	1.66	1.75	4.36	5.40	483.53	153.92
REACH 1	1989.1	Max WS	1491.95	1963.81	1969.35	1.55	2.52	1.59	1.64	4.15	4.82	507.42	164.45
REACH 1	1963.56	Max WS	1491.66	1963.48	1969.16	1.26	2.24	1.46	1.46	3.93	4.09	533.28	167.57
REACH 1	1952.68	Max WS	1491.52	1961.88	1969.07	1.17	2.42	1.45	1.47	3.85	4.14	528.39	165.13
REACH 1	1941.8	Max WS	1491.47	1963.15	1968.99	1.16	2.53	1.56	1.51	4.21	4.32	521.78	174.39
REACH 1	1914.33	Max WS	1491.02	1962.82	1968.77	1.20	2.63	1.51	1.48	4.30	4.18	528.52	183.16
REACH 1	1901.37	Max WS	1491.05	1961.55	1968.66	1.16	2.70	1.55	1.53	4.03	4.41	519.54	176.46
REACH 1	1888.41	Max WS	1490.60	1962.82	1968.51	1.54	3.26	1.82	1.83	4.75	5.70	479.73	174.97
REACH 1	1867.55	Max WS	1489.98	1962.54	1968.34	1.18	2.55	1.52	1.50	4.21	4.26	525.31	178.84
REACH 1	1857.01	Max WS	1490.07	1960.94	1968.27	1.15	2.41	1.32	1.37	3.85	3.73	547.12	178.34
REACH 1	1846.47	Max WS	1538.24	1962.21	1968.18	1.46	2.47	1.41	1.49	4.17	4.21	544.82	175.09
REACH 1	1818.13	Max WS	1537.64	1961.87	1967.86	2.16	3.72	1.82	2.05	5.12	6.79	463.65	162.29
REACH 1	1804.91	Max WS	1537.40	1960.60	1967.67	2.43	3.79	1.76	2.18	5.46	7.77	431.14	144.60
REACH 1	1791.69	Max WS	1537.17	1961.87	1967.48	3.02	4.51	2.17	2.63	5.57	9.87	408.79	144.79
REACH 1	1766.4	Max WS	1536.70	1961.55	1967.14	2.62	4.13	2.17	2.42	5.33	8.63	430.59	153.37
REACH 1	1754.71	Max WS	1536.17	1960.28	1966.94	2.84	4.82	2.43	2.76	5.35	10.45	405.67	147.80
REACH 1	1743.01	Max WS	1535.77	1961.55	1966.78	2.94	4.29	2.28	2.61	5.36	9.57	418.12	154.99
REACH 1	1730		Lat Struct										
REACH 1	1729.97	Max WS	1481.57	1961.38	1966.59	2.59	3.57	1.84	2.18	7.44	7.73	417.15	157.62
REACH 1	1716.92	Max WS	1436.51	1961.21	1966.49	2.38	3.36	1.59	2.00	4.76	6.51	440.49	165.07
REACH 1	1703.52	Max WS	1436.45	1959.61	1966.34	2.14	3.31	1.48	1.89	4.70	6.09	445.36	161.21
REACH 1	1690.12	Max WS	1436.24	1960.88	1966.21	2.05	3.02	1.58	1.84	4.51	5.73	462.59	166.77
REACH 1	1665.14	Max WS	1435.94	1960.57	1965.96	1.61	2.80	1.73	1.77	4.36	5.39	472.62	162.21
REACH 1	1654.04	Max WS	1435.78	1958.97	1965.83	1.51	3.41	1.90	1.94	4.52	6.22	447.43	158.53
REACH 1	1642.93	Max WS	1435.69	1960.24	1965.73	1.56	3.00	1.75	1.77	4.52	5.38	473.01	170.83
REACH 1	1617.15	Max WS	1435.40	1959.85	1965.49	1.57	2.67	1.51	1.61	4.29	4.68	493.73	169.28
REACH 1	1602.93	Max WS	1435.24	1958.58	1965.35	1.68	2.91	1.61	1.76	4.15	5.33	473.94	160.78
REACH 1	1588.7	Max WS	1435.12	1959.85	1965.21	1.80	2.91	1.71	1.83	4.44	5.66	465.42	162.03
REACH 1	1565.62	Max WS	1434.85	1959.54	1965.00	1.70	2.56	1.52	1.66	4.17	4.91	485.70	160.25
REACH 1	1554.61	Max WS	1434.81	1957.94	1964.90	1.71	2.70	1.45	1.66	4.04	4.95	481.84	154.27
REACH 1	1543.6	Max WS	1434.58	1959.21	1964.80	1.82	2.67	1.52	1.71	4.29	5.16	475.44	154.94
REACH 1	1520.57	Max WS	1434.31	1958.89	1964.62	1.73	2.41	1.38	1.60	4.09	4.72	486.40	148.37
REACH 1	1507.82	Max WS	1434.34	1957.29	1964.52	1.73	2.57	1.40	1.66	3.78	4.95	480.72	140.08
REACH 1	1495.13	Max WS	1433.99	1958.56	1964.40	1.85	2.62	1.48	1.72	4.28	5.30	466.57	140.23
REACH 1	1469.66	Max WS	1433.03	1958.23	1964.12	2.39	3.48	1.83	2.14	4.93	7.34	418.23	133.11
REACH 1	1457.21	Max WS	1432.45	1956.63	1963.92	2.85	4.57	2.10	2.59	5.28	9.83	377.91	123.59
REACH 1	1444.75	Max WS	1428.32	1957.90	1963.67	3.60	5.67	2.63	3.16	6.28	13.15	342.99	123.36
REACH 1	1435		Lat Struct										
REACH 1	1433.6	Max WS	1448.34	1957.74	1963.47	3.58	5.12	2.48	2.97	7.06	12.19	353.32	125.59
REACH 1	1422.45	Max WS	1404.97	1957.57	1963.38	2.70	3.95	2.00	2.38	5.25	8.60	388.52	126.89
REACH 1	1411.4	Max WS	1404.81	1956.30	1963.25	2.47	3.82	2.03	2.37	4.80	8.47	393.32	122.98
REACH 1	1400.34	Max WS	1404.63	1957.57	1963.14	2.29	3.39	2.04	2.23	4.82	7.69	407.20	128.60
REACH 1	1381.13	Max WS	1404.25	1957.26	1962.92	2.15	3.38	2.05	2.18	4.83	7.46	410.97	130.28
REACH 1	1371.21	Max WS	1404.13	1955.67	1962.80	2.09	3.72	2.04	2.24	4.77	7.81	403.13	127.41
REACH 1	1361.28	Max WS	1403.93	1956.94	1962.69	1.91	3.81	2.16	2.22	5.14	7.68	406.80	140.38
REACH 1	1342.23	Max WS	1403.46	1956.62	1962.47	1.95	3.61	1.94	2.07	5.02	6.91	421.34	144.83
REACH 1	1331.95	Max WS	1403.28	1955.02	1962.40	1.41	2.83	1.57	1.65	4.18	4.96	467.74	146.32
REACH 1	1321.67	Max WS	1403.13	1956.29	1962.30	1.62	2.96	1.59	1.70	4.57	5.14	464.08	154.88
REACH 1	1298.14	Max WS	1402.58	1955.99	1962.08	1.50	3.24	1.63	1.71	4.79	5.19	461.83	165.32
REACH 1	1285.54	Max WS	1402.19	1954.72	1961.97	1.71	2.96	1.40	1.61	4.24	4.73	477.09	164.59
REACH 1	1272.95	Max WS	1401.62	1955.99	1961.86	2.00	2.91	1.41	1.65	4.51	4.91	469.57	163.86
REACH 1	1254.08	Max WS	1400.75	1955.72	1961.70	1.86	2.75	1.31	1.56	4.40	4.56	479.24	163.26
REACH 1	1242.1	Max WS	1400.33	1954.45	1961.60	1.80	2.81	1.32	1.59	4.15	4.66	477.21	161.16
REACH 1	1230.11	Max WS	1399.82	1955.72	1961.53	1.48	2.25	1.23	1.36	3.96	3.68	518.89	171.01

HEC-RAS Plan: 100YR River: DiamondHills Reach: REACH 1 Profile: Max WS (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Shear LOB	Shear Chan	Shear ROB	Shear Total	Vel Chnl	Power Total	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(lb/ft s)	(sq ft)	(ft)
REACH 1	1206.25	Max WS	1398.87	1955.40	1961.37	1.26	2.10	1.19	1.26	3.85	3.29	537.58	172.92
REACH 1	1194.55	Max WS	1397.27	1954.13	1961.28	1.17	2.34	1.30	1.37	3.78	3.71	516.25	167.49
REACH 1	1182.85	Max WS	1396.22	1955.40	1961.21	1.19	2.13	1.25	1.29	3.85	3.38	533.13	175.56
REACH 1	1171		Lat Struct										
REACH 1	1169.83	Max WS	1520.04	1955.24	1961.02	1.74	3.23	1.68	1.77	5.90	5.48	490.34	184.10
REACH 1	1156.8	Max WS	1644.18	1955.09	1960.81	2.20	4.20	2.01	2.20	5.40	7.43	485.99	189.50
REACH 1	1144.07	Max WS	1642.52	1953.82	1960.70	1.66	3.26	1.59	1.73	4.40	5.15	551.30	210.15
REACH 1	1131.33	Max WS	1640.61	1955.09	1960.59	1.48	2.64	1.38	1.47	4.25	4.00	601.42	230.73
REACH 1	1106.24	Max WS	1636.17	1954.79	1960.39	1.10	2.37	1.29	1.31	4.04	3.39	631.04	238.49
REACH 1	1093.69	Max WS	1635.89	1953.52	1960.30	1.11	2.28	1.20	1.25	3.69	3.17	647.04	241.24
REACH 1	1081.14	Max WS	1635.29	1954.79	1960.22	1.28	1.92	1.06	1.14	3.62	2.75	677.36	246.74
REACH 1	1052.64	Max WS	1634.21	1954.45	1960.08	0.98	1.33	0.76	0.84	3.03	1.75	778.73	257.60
REACH 1	1040.74	Max WS	1633.33	1952.84	1960.04	0.83	1.17	0.66	0.73	2.67	1.43	827.91	255.87
REACH 1	1028.84	Max WS	1633.04	1954.12	1960.00	0.85	1.13	0.65	0.72	2.81	1.41	832.17	258.92
REACH 1	1006.93	Max WS	1631.20	1953.81	1959.91	0.95	1.31	0.71	0.78	3.04	1.59	797.53	253.72
REACH 1	997.42	Max WS	1630.58	1952.21	1959.87	1.01	1.48	0.74	0.82	3.03	1.73	773.03	245.09
REACH 1	987.91	Max WS	1623.11	1953.48	1959.83	1.05	1.47	0.75	0.83	3.26	1.76	764.17	245.93
REACH 1	975		Lat Struct										
REACH 1	974.71	Max WS	1773.05	1953.33	1959.73	1.25	1.74	0.88	0.98	4.78	2.31	750.69	244.65
REACH 1	961.51	Max WS	1908.99	1953.17	1959.64	1.33	1.98	1.01	1.12	3.79	2.78	770.82	242.03
REACH 1	946.83	Max WS	1907.47	1951.57	1959.58	1.01	1.64	0.88	0.96	3.22	2.21	828.87	236.68
REACH 1	932.15	Max WS	1906.05	1952.84	1959.52	0.99	1.56	0.89	0.94	3.38	2.15	835.03	237.06
REACH 1	906.37	Max WS	1904.94	1952.54	1959.43	0.77	1.27	0.79	0.81	3.07	1.73	892.01	232.80
REACH 1	895.42	Max WS	1904.62	1950.93	1959.40	0.67	1.27	0.74	0.76	2.88	1.59	915.66	237.91
REACH 1	884.47	Max WS	1904.10	1952.21	1959.37	0.58	1.15	0.70	0.69	2.94	1.35	964.50	257.94
REACH 1	857.4	Max WS	1901.16	1951.89	1959.28	0.62	1.31	0.73	0.72	3.16	1.44	943.94	266.54
REACH 1	843.91	Max WS	1900.75	1950.62	1959.23	0.70	1.50	0.79	0.80	3.13	1.68	900.93	260.69
REACH 1	830.43	Max WS	1900.78	1951.89	1959.16	0.91	1.85	0.87	0.93	3.74	2.11	836.85	260.56
REACH 1	806.03	Max WS	1899.81	1951.60	1959.06	0.85	1.61	0.75	0.83	3.51	1.79	880.44	261.40
REACH 1	793.59	Max WS	1899.69	1950.33	1959.04	0.64	1.11	0.54	0.62	2.71	1.18	999.00	269.55
REACH 1	781.14	Max WS	1899.35	1951.60	1959.02	0.50	0.77	0.38	0.46	2.42	0.75	1153.90	298.38
REACH 1	754.18	Max WS	1898.73	1951.29	1958.99	0.33	0.45	0.22	0.30	1.86	0.40	1416.23	316.81
REACH 1	741.66	Max WS	1898.53	1950.02	1958.98	0.28	0.38	0.17	0.25	1.59	0.31	1529.02	335.68
REACH 1	729.14	Max WS	1898.01	1951.29	1958.97	0.26	0.33	0.15	0.23	1.61	0.27	1583.77	344.20
REACH 1	704.11	Max WS	1897.32	1950.99	1958.70	2.54	3.90	1.74	2.00	5.49	6.93	548.20	150.92
REACH 1	691.29	Max WS	1897.13	1949.72	1958.60	2.47	3.69	1.60	1.93	4.93	6.51	561.04	152.15
REACH 1	678.46	Max WS	1896.92	1950.99	1958.33	2.56	6.05	2.72	2.98	6.78	12.65	446.49	134.85
REACH 1	652.16	Max WS	1896.29	1950.69	1957.99	3.53	5.18	2.33	2.76	6.26	11.22	466.86	130.56
REACH 1	639.45	Max WS	1896.20	1949.42	1957.85	3.14	4.79	2.22	2.64	5.56	10.38	482.46	131.26
REACH 1	626.73	Max WS	1895.75	1950.69	1957.73	2.84	4.11	2.04	2.32	5.55	8.50	517.67	143.08
REACH 1	602.51	Max WS	1895.46	1950.39	1957.50	1.46	3.84	2.06	2.15	5.37	7.56	539.88	148.87
REACH 1	590.06	Max WS	1894.98	1948.79	1957.40	1.37	3.51	1.78	1.92	4.80	6.48	560.70	150.49
REACH 1	577.6	Max WS	1894.66	1950.06	1957.28	1.49	3.74	1.96	2.06	5.31	7.21	541.17	149.32
REACH 1	549.5	Max WS	1894.24	1949.72	1956.92	2.07	4.91	2.40	2.57	6.09	10.04	484.65	140.95
REACH 1	536.16	Max WS	1894.04	1948.12	1956.79	1.40	4.39	2.10	2.29	5.35	8.47	512.34	142.70
REACH 1	522.82	Max WS	1893.79	1949.39	1956.68	1.42	3.79	2.02	2.11	5.36	7.39	541.54	145.72
REACH 1	501.45	Max WS	1893.37	1949.12	1956.54	1.08	2.80	1.57	1.63	4.62	5.12	602.80	153.20
REACH 1	491.45	Max WS	1893.10	1947.85	1956.48	1.10	2.70	1.50	1.59	4.22	4.86	617.40	154.19
REACH 1	481.45	Max WS	1892.85	1949.12	1956.40	1.16	2.88	1.64	1.69	4.67	5.39	595.27	152.40
REACH 1	452.26	Max WS	1891.33	1948.73	1956.00	1.89	4.97	2.53	2.69	6.13	10.89	466.62	129.27
REACH 1	437.05	Max WS	1890.89	1947.13	1955.80	1.88	5.18	2.57	2.83	5.82	11.69	457.77	120.76
REACH 1	421.84	Max WS	1887.74	1948.40	1955.29	1.22	3.57	1.87	1.98	11.97	8.97	416.92	119.18
REACH 1	399.73	Max WS	1888.82	1948.12	1955.46	1.60	3.58	2.00	2.09	5.21	7.39	534.74	135.82
REACH 1	387.68	Max WS	1888.44	1946.52	1955.36	1.59	3.50	1.84	1.99	4.83	6.87	547.63	135.94
REACH 1	375.64	Max WS	1887.21	1947.79	1955.22	1.65	3.98	2.13	2.25	5.51	8.29	511.66	132.50
REACH 1	349.17	Max WS	1886.71	1947.43	1955.20	0.26	0.27	0.14	0.21	1.45	0.26	1568.02	271.91
REACH 1	336.06	Max WS	1886.24	1945.83	1954.92	1.20	4.72	2.44	2.65	5.61	10.81	461.63	111.16
REACH 1	322.95	Max WS	1886.17	1947.10	1954.82	0.25	3.99	2.31	2.36	5.56	9.11	487.84	115.01
REACH 1	300.24	Max WS	1885.88	1946.80	1954.70	0.64	2.65	1.62	1.64	4.55	5.24	591.47	130.02
REACH 1	288.67	Max WS	1885.59	1945.53	1954.65	0.84	2.36	1.44	1.49	3.99	4.57	616.36	132.39
REACH 1	277.06	Max WS	1885.60	1946.80	1954.57	0.93	2.51	1.56	1.59	4.41	5.01	596.76	131.08
REACH 1	248.57	Max WS	1885.17	1946.47	1954.32	1.59	3.46	2.01	2.10	5.19	7.54	524.13	118.03
REACH 1	234.41	Max WS	1884.76	1945.20	1954.20	1.58	3.51	2.10	2.23	4.82	8.20	512.29	109.82
REACH 1	220.24	Max WS	1884.70	1946.47	1954.06	1.77	3.72	2.34	2.42	5.35	9.31	488.75	105.96
REACH 1	195.05	Max WS	1884.36	1946.16	1953.89	1.29	3.04	1.90	1.94	4.85	6.77	541.31	117.33
REACH 1	182.23	Max WS	1884.15	1944.89	1953.79	1.31	3.21	1.94	2.04	4.60	7.23	531.83	116.14
REACH 1	169.42	Max WS	1884.00	1946.16	1953.65	1.45	3.77	2.28	2.35	5.37	9.00	491.75	113.37
REACH 1	144.47	Max WS	1883.57	1945.86	1953.36	2.94	4.60	2.40	2.69	5.94	10.74	471.58	116.01
REACH 1	132.12	Max WS	1883.52	1944.59	1953.24	3.02	4.55	2.11	2.53	5.48	9.80	486.12	126.47
REACH 1	119.78	Max WS	1883.38	1945.86	1953.10	2.69	4.53	2.29	2.52	5.85	9.79	485.17	131.50
REACH 1	90.67	Max WS	1883.00	1945.54	1952.96	1.57	2.06	1.08	1.24	3.97	3.34	696.30	172.52
REACH 1	76.53	Max WS	1882.82	1944.27	1952.89	1.54	2.08	1.08	1.24	3.68	3.35	698.86	172.60
REACH 1	62.4	Max WS	1882.58	1945.54	1952.77	1.85	2.79	1.48	1.61	4.59	4.91	618.17	162.48
REACH 1	44.67	Max WS	1882.41	1945.27	1952.64	1.82	2.85	1.50	1.63	4.65	4.99	613.54	159.62
REACH 1	34.39	Max WS	1882.23	1944.02	1952.53	1.10	1.95	1.06	1.14	6.38	3.42	628.84	160.03
REACH 1	24.46	Max WS	1882.19	1945.27	1952.56	1.32	2.01	1.19	1.26	3.90	3.40	697.43	167.70

Appendix F
Sediment Transport Analysis

ENTRAINMENT CALCULATION FORM

Stream:	Diamond Hills Park	Reach:	Impaired Reach XS5
Team:	Balzer	Date:	May-11

Information Input Area

20.9	D_{50}	Riffle bed material D50 (mm)			
14	$\hat{D}_{50}$	Bar sample D50 (mm)			
43.0	D_i	Largest particle from bar sample (mm)=	0.14	(Feet)	304.8 mm/foot
0.00974	S_e	Existing bankfull water surface slope (ft/ft)			
0.93	d_e	Existing bankfull mean depth (ft)			
0.84	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

1.49	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used: $\tau^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
2.06	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0202	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** **2**

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.48	d_r	Required bankfull mean depth (ft)	$d_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{S_e}$	
0.93	de	Existing bankfull mean depth (ft)	**Is Depth Sufficient?**	**Yes**

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0051	S_r	Required bankfull water surface slope (ft)	$S_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{d_e}$	
0.0097	Se	Existing bankfull water surface slope (ft)	**Is Slope Sufficient?**	**Yes**
Degradation Possible	**Stability Assessment Check**			

Sediment Transport Validation

0.51	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) where the Density of water = γ = 62.4 lbs/ft^3
133	Moveable particle size (mm) at bankfull shear stress (predicted by the Revised Shields Diagram by Rosgen, 2002)
0.16	Predicted shear stress required to initiate movement of D_i (mm) (see Revised Shields Diagram, Rosgen, 2002)
	Note: If available bankfull shear stress exceeds Predicted Shear Stress, degradation potential exists.
39	Moveable particle size (mm) at bankfull shear stress (Leopold)
0.56	Predicted shear stress required to initiate movement of D_i (mm) (Leopold)
Degradation	**Stability Assessment**

ENTRAINMENT CALCULATION FORM

Stream:	Diamond Hills Park	Reach:	Impaired Reach XS6
Team:	Balzer	Date:	May-11

Information Input Area

20.9	D_{50}	Riffle bed material D50 (mm)			
14	$\hat{D}_{50}$	Bar sample D50 (mm)			
43.0	D_i	Largest particle from bar sample (mm)=	0.14	(feet)	304.8 mm/foot
0.00974	S_e	Existing bankfull water surface slope (ft/ft)			
0.76	d_e	Existing bankfull mean depth (ft)			
0.61	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

1.49	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used: $\tau^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
2.06	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0202	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** **2**

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.48	d_r	Required bankfull mean depth (ft)	$d_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{S_e}$	
0.76	de	Existing bankfull mean depth (ft)	**Is Depth Sufficient?**	**Yes**

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0062	S_r	Required bankfull water surface slope (ft)	$S_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{d_e}$	
0.0097	Se	Existing bankfull water surface slope (ft)	**Is Slope Sufficient?**	**Yes**

Degradation Possible	**Stability Assessment Check**

Sediment Transport Validation

0.37	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) where the Density of water = γ = 62.4 lbs/ft^3
97	Moveable particle size (mm) at bankfull shear stress (predicted by the Revised Shields Diagram by Rosgen, 2002)
0.16	Predicted shear stress required to initiate movement of D_i (mm) (see Revised Shields Diagram, Rosgen, 2002)

Note: If available bankfull shear stress exceeds Predicted Shear Stress, degradation potential exists.

28	Moveable particle size (mm) at bankfull shear stress (Leopold)
0.56	Predicted shear stress required to initiate movement of D_i (mm) (Leopold)
Degradation	**Stability Assessment**

ENTRAINMENT CALCULATION FORM

Stream:	Diamond Hills Park	Reach:	Design Reach
Team:	Balzer	Date:	May-11

Information Input Area

48	D_{50}	Riffle bed material D50 (mm)			
17	$\hat{D}_{50}$	Bar sample D50 (mm)			
167.0	D_i	Largest particle from bar sample (mm)=	0.55	(feet)	304.8 mm/foot
0.013	S_e	Proposed bankfull water surface slope (ft/ft)			
0.82	d_e	Proposed bankfull mean depth (ft)			
0.78	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

2.82	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used:	$\tau^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
3.48	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used:	$\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0127	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:**	**NA**

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.88	d_r	Required bankfull mean depth (ft)	$d_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{S_e}$	
0.82	de	Proposed bankfull mean depth (ft)	**Is Depth Sufficient?**	**No**

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0139	S_r	Required bankfull water surface slope (ft)	$S_r = \dfrac{\tau^*_{ci}\gamma_s D_i}{d_e}$	
0.0130	Se	Proposed bankfull water surface slope (ft)	**Is Slope Sufficient?**	**No**

Okay	**Stability Assessment Check**

Sediment Transport Validation

0.63	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) where the Density of water = γ = 62.4 lbs/ft^3
163	Moveable particle size (mm) at bankfull shear stress (predicted by the Revised Shields Diagram by Rosgen, 2002)
0.65	Predicted shear stress required to initiate movement of D_i (mm) (see Revised Shields Diagram, Rosgen, 2002)

Note: If available bankfull shear stress exceeds Predicted Shear Stress, degradation potential exists.

48	Moveable particle size (mm) at bankfull shear stress (Leopold)
2.08	Predicted shear stress required to initiate movement of D_i (mm) (Leopold)
Stable	**Stability Assessment**

ENTRAINMENT CALCULATION FORM

Stream:	Diamond Hills Park	Reach:	Predicted Reach
Team:	Balzer	Date:	May-11

Information Input Area

48	D_{50}	Riffle bed material D50 (mm)			
17	$\hat{D}_{50}$	Bar sample D50 (mm)			
167.0	D_i	Largest particle from bar sample (mm)=	0.55	(feet)	304.8 mm/foot
0.013	S_e	Predicted bankfull water surface slope (ft/ft)			
0.94	d_e	Predicted bankfull mean depth (ft)			
0.76	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

2.82	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used:	$\tau^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
3.48	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used:	$\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0127	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:**	**NA**

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.88	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_i}{S_e}$	
0.94	de	Proposed bankfull mean depth (ft)	**Is Depth Sufficient?**	**Yes**

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0123	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_i}{d_e}$	
0.0130	Se	Proposed bankfull water surface slope (ft)	**Is Slope Sufficient?**	**Yes**
Okay		**Stability Assessment Check: is 80% of proposed > Required**		

Sediment Transport Validation

0.62	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) where the Density of water = γ = 62.4 lbs/ft^3
159	Moveable particle size (mm) at bankfull shear stress (predicted by the Revised Shields Diagram by Rosgen, 2002)
0.65	Predicted shear stress required to initiate movement of D_i (mm) (see Revised Shields Diagram, Rosgen, 2002)

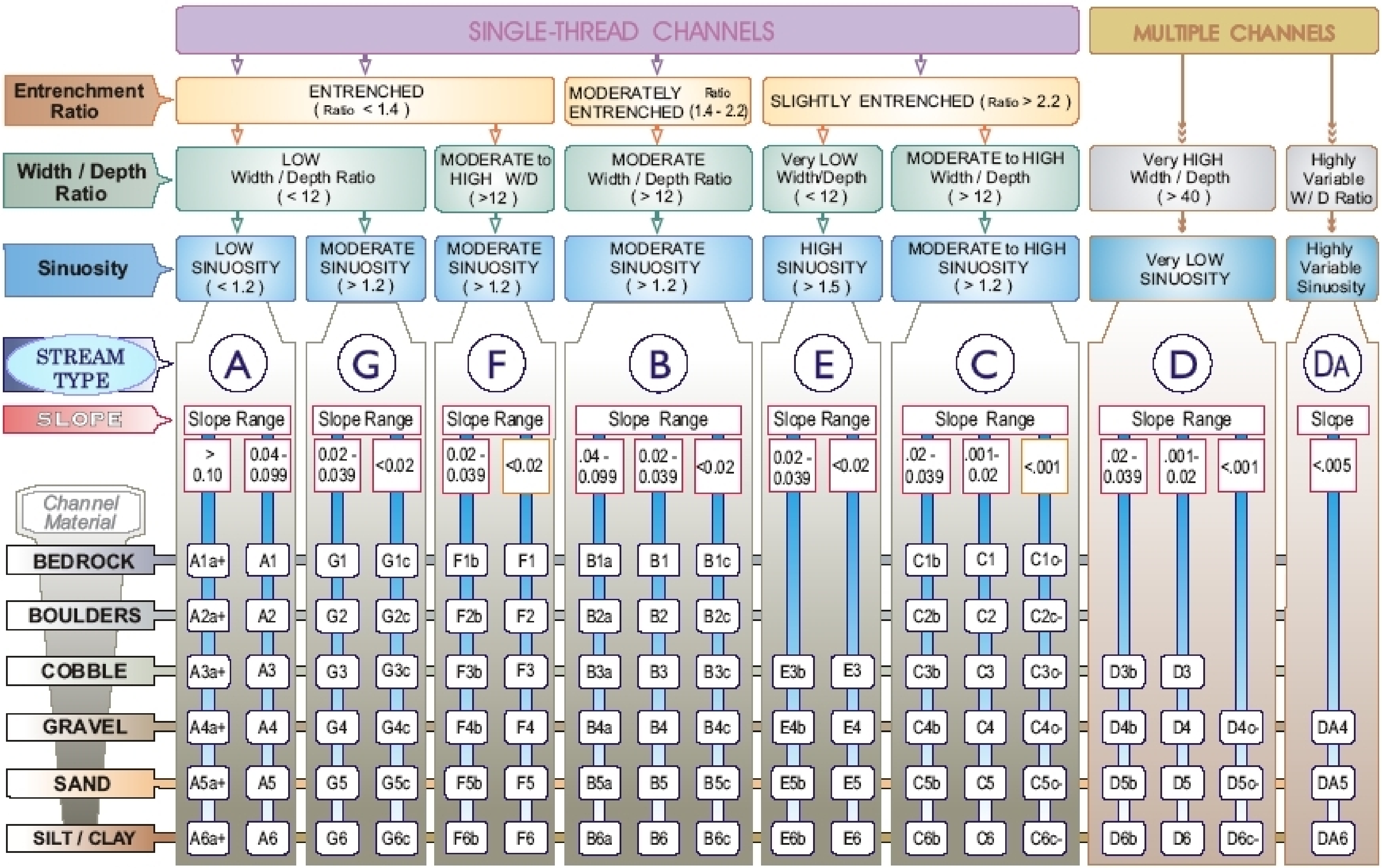
Note: If available bankfull shear stress exceeds Predicted Shear Stress, degradation potential exists.

47	Moveable particle size (mm) at bankfull shear stress (Leopold)
2.08	Predicted shear stress required to initiate movement of D_i (mm) (Leopold)
Stable	**Stability Assessment**

ENTRAINMENT CALCULATION FORM: Structure Sizing				
Stream:	Diamond Hills Park	Reach:	Design Reach Avg. HEC-RAS Shear Stress	
Team:	Balzer	Date:	May-11	
Information Input Area				
48	D_{50}	Riffle bed material D50 (mm)		
17	$\hat{D}_{50}$	Bar sample D50 (mm)		
167.0	D_i	Largest particle from bar sample (mm)=	0.55 (feet)	304.8 mm/foot
0.013	S_e	Proposed bankfull water surface slope (ft/ft)		
0.82	d_e	Proposed bankfull mean depth (ft)		
0.78	R	Hydraulic Radius of Riffle Cross Section (ft)		
1.65	γ_s	Submerged specific weight of sediment		
Sediment Transport Validation				
2.52	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) where the Density of water = γ = 62.4 lbs/ft^3			
620	Moveable particle size (mm) at bankfull shear stress (predicted by the Revised Shields Diagram by Rosgen, 2002)			
0.65	Predicted shear stress required to initiate movement of D_i (mm) (see Revised Shields Diagram, Rosgen, 2002)			
Note: If available bankfull shear stress exceeds Predicted Shear Stress, degradation potential exists.				
204	Moveable particle size (mm) at bankfull shear stress (Leopold)			
2.08	Predicted shear stress required to initiate movement of D_i (mm) (Leopold)			
~~Degradation~~	**Stability Assessment**			
Rosgen Stone Sizing				
	D Intermediate stone size (mm) (Rosgen, 2006) y=0.1724Ln(tc)+0.6349 where tc is in kg/m^2			

Appendix G
Reference Material

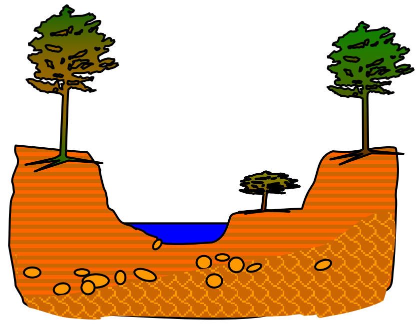
The Key to the Rosgen Classification of Natural Rivers



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

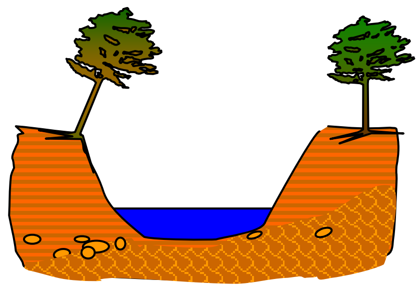
Stage I Pre-disturbance

- Bed and bank materials balanced with erosive forces
- Permanent woody vegetation near the water line
- Two-stage channel shape evident at about 1.8 year return interval



Stage II Disturbance

- Channel altered, hydrology or sediment inputs modified
- Removal of permanent woody vegetation near the water line
- Two-stage channel shape eliminated or no longer supported by flow conditions



Stage III Incision

- Downcutting liberates sediment
- Lost or perched bankfull floodplains
- "U" shaped channel
- Woody vegetation high on bank with many "surfer" trees

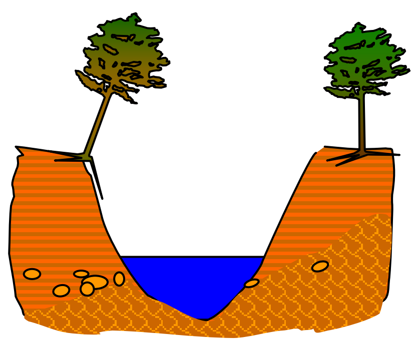
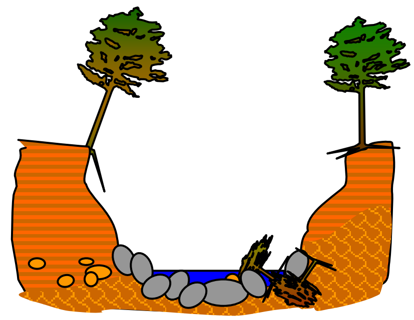


Figure 8-2
Channel Evolution Model (from Simon, 2001).

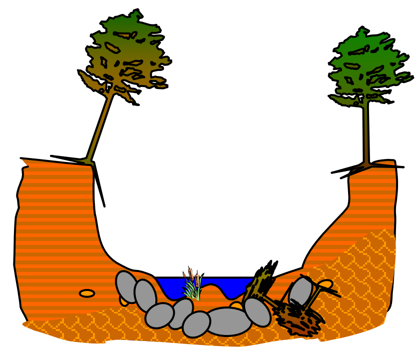
Stage IV Channel Widening

- Widespread bank failures as banks exceed critical height or were undercut by toe scour
- Channel adjusts to new flow regime
- Significant sediment loads generated; most significant erosion hazard in this phase
- Bank armoring generally ineffective



Stage V Deposition

- Deposition begins from liberated sediment
- Vegetation establishes near water line



Stage VI Recovery and Reconstruction

- Bankfull floodplains may be reconstructed from liberated sediment
- Woody vegetation establishes near water line
- Stability re-established

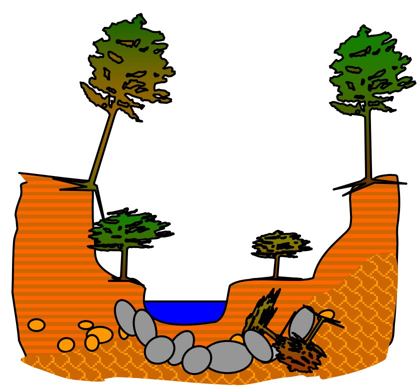
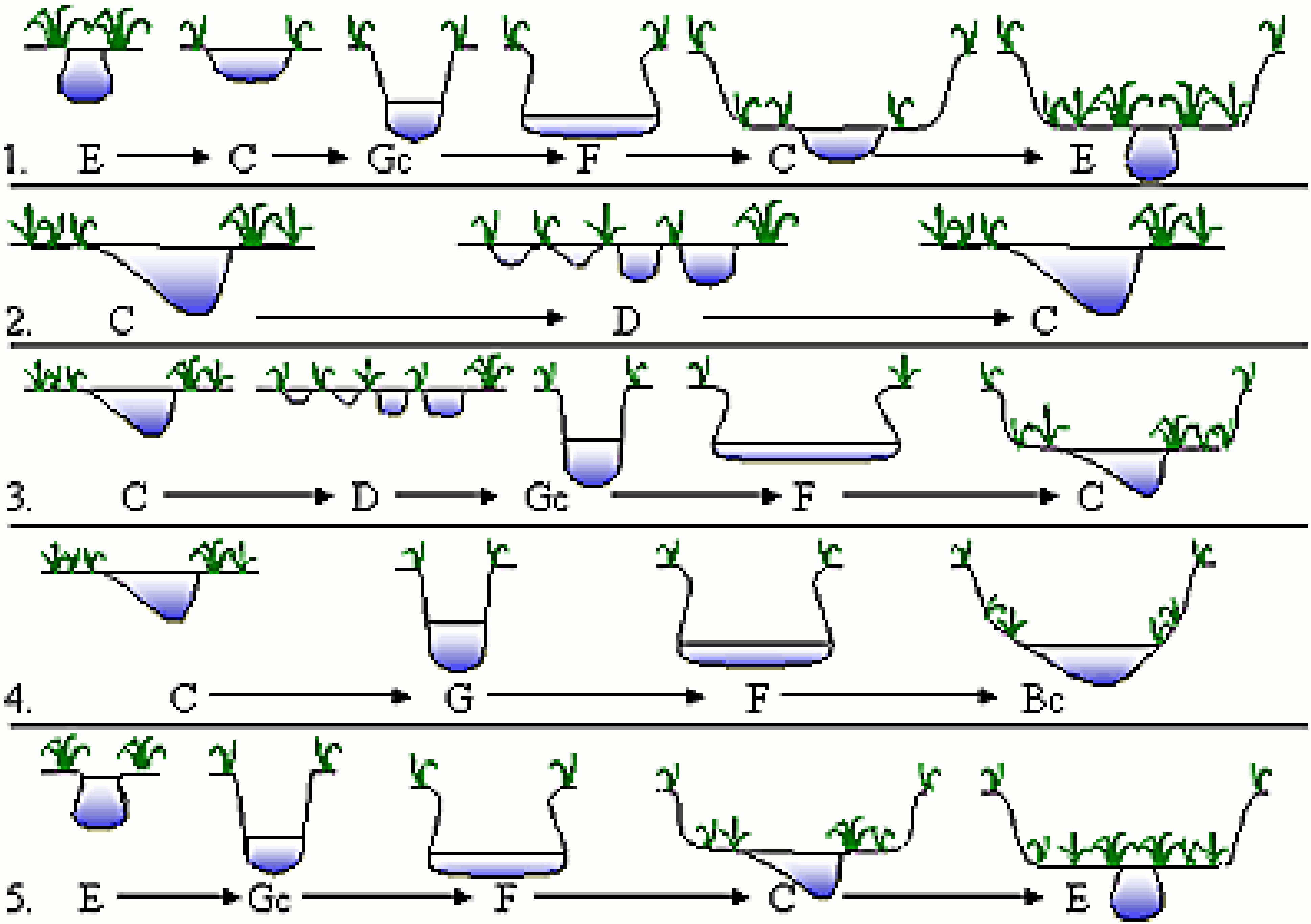


Figure 8-2
Channel Evolution Model (cont.).



1. E C Gc F C E
2. C D C
3. C D Gc F C
4. C G F Bc
5. E Gc F C E

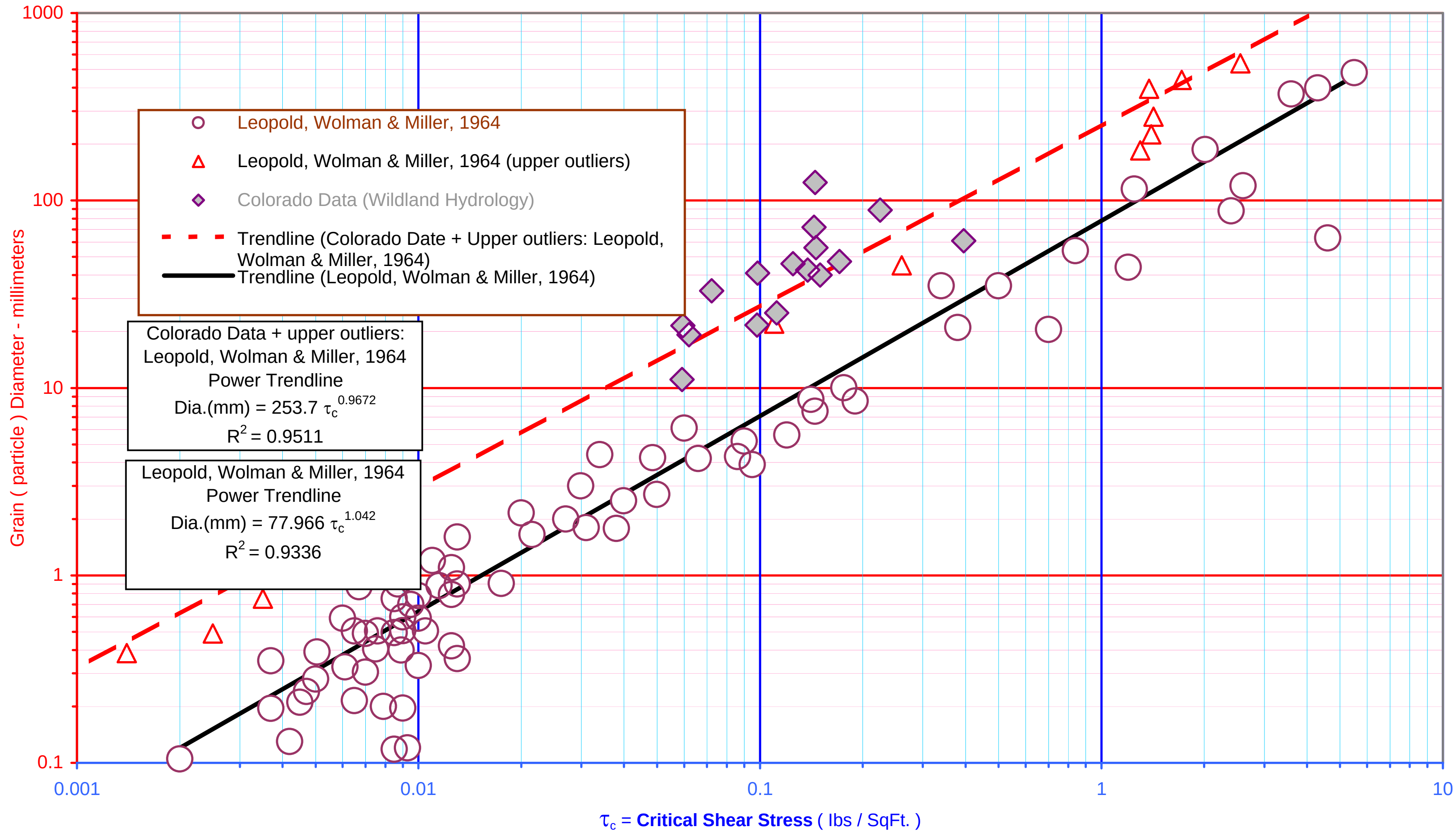


Figure 126. Critical Shear Stress (tc: Range .001 to 10) Required to Initiate Movement of Grains (particles), revised for Colorado Rivers.

Appendix H
Site Photographs

Site Photographs
Project: Diamond Hills

Photographs Taken: 01/19/11
Taken By: B. Wagner

Site Photographs
Project: Diamond Hills

Photographs Taken: 01/19/11
Taken By: B. Wagner

Site Photographs
Project: Diamond Hills

Photographs Taken: 01/19/11
Taken By: B. Wagner