Project Design Report
R.A. Hill Stables Demonstration Project
West Kill Creek

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Background

In accordance with USEPA's 2002 Filtration Avoidance Determination, the West Kill Stream Management Plan was completed in December 2005, in partnership with the Greene County Soil and Water Conservation District. The 2002 FAD also called for completion of a demonstration stream restoration project in the West Kill sub-basin, and several in the Schoharie basin (which includes the West Kill), at undetermined locations. The contract with GCSWCD for the West Kill Stream Management Plan Project called for completion of a minimum of two demonstration projects. The first, at Shoemaker Road, was largely completed in 2005, with only minor additional revegetation in 2006. The second, according to the contract, was to be determined following completion of the management plan.

Project Description

The second demonstration stream restoration project associated with the development of the West Kill Stream Management Plan (WKSMP) was constructed at R. A. Hill Stables, a small horse farm, during July through November, 2006. The site is about 5.5 miles upstream of the confluence of the West Kill with the Schoharie Creek (see Site Location Map, Appendix A). The project restored approximately 1600 feet of stream that bisected the horse farm. The site was chosen following a review of the twenty-one most significant bank erosion sites surveyed on the West Kill during the development of the WKSMP (see Section 3.3 of the Plan, Watershed Assessment and Inventory). In the prioritization of these sites, the site ranked in the High Priority category.

The project addressed bank erosion that had undermined several hundred feet of fencing along a horse pasture on the right bank, and threatened the main drive into the stables. Some sections of the restoration treatment area had become overwidened, and had developed large center bars. The erosion documented at the site during the Stream Feature Inventory conducted during the summer of 2004 worsened significantly as a result of the high flows that occurred in the West Kill watershed in April, 2005.


Bank Erosion, 2004

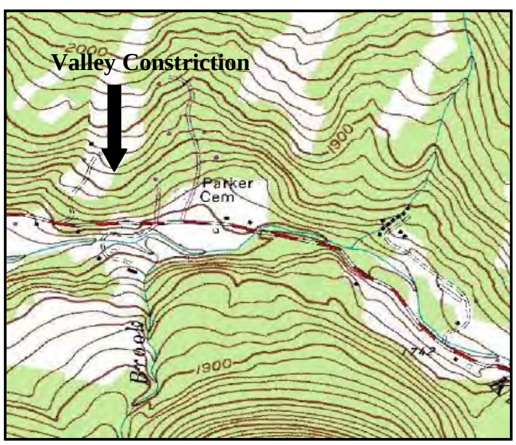

Worsening streambank erosion in 2005

One unique aspect of this project regards the arrangements for contracting the restoration work. Greene County Soil and Water Conservation District was approached by a local excavation contractor, Skip Dippold, who had been retained by the landowner to rip-rap the bank in place.

Mr. Dippold had attended a workshop for highway crews organized by GCSWCD and DEP, was familiar with the geomorphic restoration completed at Shoemaker Farm (just downstream of the R.A. Hill Stables site), was impressed with its performance, and requested some partnership that would allow him to incorporate elements of the approach used at Shoemaker. Mr. Dippold is an influential resident in the valley, is often hired to perform streambank stabilization and related excavation work in the area, and his adoption of these best practices was viewed as having a potentially significant impact on stream management practices throughout the watershed. Furthermore, GCSWCD and DEP SMP staff believed that the proposed rip-rap placement --as well as a contractor-proposed alternative involving a gabion-basket design-- would not be a lasting remedy at the site, as it did not address the geomorphic instability of the reach.

An arrangement was made whereby Greene County provided technical assistance in the design of a "hybrid" project, incorporating many aspects of the Natural Channel Design approach but, at the insistence of the landowner, using more rip-rap than would be customarily. The District also prepared the NYSDEC Article 15 / ACoE stream disturbance permit application, and performed all of the revegetation of the site. NYCDEP SMP would pay for the materials required, provide construction supervision and turbidity control equipment, and the landowner would cover the cost of labor and machine rental. The project thus represents a new model both in terms of its technical design and its contractual arrangements. The interest of the contractor demonstrates the potential effectiveness of having completed a demonstration project in the sub-basin. Assessments and analysis completed to support the first project were able to be adapted to the second, reducing the design effort. The landowner also agreed to and signed a 10-year management license agreement guaranteeing that the restoration, including the vegetation plantings, will remain undisturbed, and that GCSWCD will have access for maintenance and educational purposes. See Appendix A, Site Location Map.

Problem Assessment

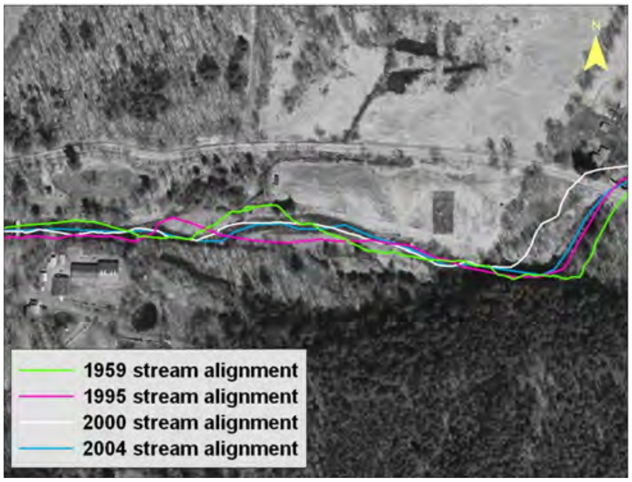


Excerpt of 1980 USGS topographic map

Several characteristics of the site contribute to chronic stream function problems. The bridge crossing to the stable complex on the terrace, left, is located at a pinch point in the valley morphology, and the bridge abutments further confine high flows. Both the left bank here upstream of the bridge, and the bed under the bridge, are exposed bedrock. The high right bank and left terrace just downstream of the bridge, however, are comprised largely of glacial till. Scour downstream of the bridge chronically erodes both banks.

Upstream of this valley pinch point, glacial lacustrine clay deposits underlie floodplain alluvium on both sides of the stream. Upstream of the pasture, the streambed is

again on bedrock. Vertical adjustment through the reach is controlled by
these bedrock sills at the top and bottom of the reach. High flows backwater at the bridge, causing channel aggradation upstream.



Historic Stream Channel Alignments

This aggradation has resulted in historic lateral adjustment of the channel; most recently, a center bar formed, splitting flow into several channels. The right channel thread incised deeply into the clay deposits, as shown in the pictures in the previous section, and seriously eroded the bank of the horse pasture.

Three stream banks on the site experienced significant erosion during the April 2005 flood. Extensive exposures of lacustrine clay deposits were documented at two of the three eroded banks (see photo above). Entrainment of colloidal clay materials from these deposits represents a water quality concern. Turbidity resulting from flowing water in direct contact with clay can degrade drinking water quality, fish habitat, and the aesthetic quality of the water resource. In addition to the water quality impacts on the site, the erosion has under-mined fencing for the pasturing facilities of the stable. Stabilization of the eroding banks will allow for replacement of the fencing and continued use of the facilities. This was of special concern to the project owner, as the compromised pasture is their primary grazing facility.

Damage to bridge abutments, grazing facilities, and stream banks had resulted in several health and safety concerns on the site. Scour at the private bridge on the site had left both bridge abutments and the approach on stream right compromised. As the private bridge is the only means of access to the homes and stabling facilities, repair was critical to the safety of the site. Emergency services, such as fire and rescue squad, rely on the bridge for access to the two residential structures as well as the stabling facilities.

<u>Restoration Strategy</u>

The valley constriction obviously cannot be corrected, and existing lateral bedrock outcrops make it impractical to significantly widen the opening between the bridge abutments. Backwatering at higher flows, then is likely to recur. The mitigation strategy selected, therefore, involved a variety of channel stabilization measures designed to hold a planform, cross-section and slope that would improve sediment conveyance through the reach, but limit shear stresses on high banks and on clay exposures in the channel.

Bankfull “benches” or terraces were installed along the face of each eroding stream bank, over approximately 1600 ft.. The face of each terrace was constructed of appropriately sized rock material to protect the bank from continued erosion at high flow, with rock “deadmen” or cutoffs placed perpendicular to streamflow at approximately 20’ intervals to forestall the development of channelized flow across the benches, and the bench itself was backfilled with soil. The toe and face of each bench were planted with willow stakes to increase long-term stability and resistance to erosive flows, and the bench and top of the upper slope were planted with containerized native tree and shrub species for improved stability and ecosystem function. The terrace was installed at a stage where the roots of the vegetation will be able to access adequate moisture to promote healthy growth. The root structure of the vegetation that will establish on the terrace will further reinforce the banks against erosion. The terraces serve to reduce the overall slope of the bank and stabilize channel cross section to promote sediment transport continuity through the reach and correct the aggradation problem. They will reduce the velocity and shear stress exerted by high flows on the toe of the upper bank. The upper banks were sloped to an angle that will allow vegetation to establish, and were also reinforced with erosion resistant rock material where necessary.

The erosion downstream of the bridge abutment was treated with rock material at the toe to establish a stable footing, and backfilled behind the wingwall of the bridge. This emergency work was completed by the contractor prior to the major channel reconstruction. The treatment will improve the safety and longevity of the bridge structure, while providing adequate access to the property for its residents and emergency services.

During construction, the decision was made to add four rock vanes and a constructed riffle head. The top and bottom meanders each received one vane, and the middle meander, at the eroded pasture bank, received two vanes. The riffle head was installed between the top and middle meander. Furthermore, three rock keyways were buried sub-surface in the point bars inside each of the top and bottom meanders. The bar opposite the middle meander had well-established willows at the bankfull stage line, which were left undisturbed. See Appendix E for post-construction photos.

Restoration Design

One of the distinguishing aspects of the project was its minimal design specifications, relative to the Natural Channel Design approaches taken elsewhere by the Greene County / NYCDEP project team. The specifications for the restoration design were prepared from existing data prepared for stream management plans, and for the Shoemaker restoration project just downstream, proportionally adjusted by drainage area. Drainage areas range from 14.5 mi^2 to 15.6 mi^2 through the RAH Stables project, and from 15.6 mi^2 to 16.8 mi^2 through the Shoemaker Project, so the data are readily transferrable. Table 1 shows the predicted values for bankfull discharge (Qbfl), bankfull cross-sectional area (Abfl) and Bankfull width (Wbfl), from the regional hydraulic geometry curves (Miller and Davis, 2003).

Table 1. Hydraulic geometry from regional curves (Miller and Davis, 2003)

DA	Qbfl	Abfl	Wbfl
14.5	1304.968	168.2219	63.60918
15.6	1378.534	177.3157	65.54507
16.8	1457.323	187.0339	67.56717

Six permanently monumented cross-sections were surveyed –two through each meander bend– for existing and proposed morphology, and to calculate cut and fills. These survey plots are included as Appendix B. These cross-sections set the planform, channel dimension and overall profile, and reestablished a single thread channel with generally Bc streamtype characteristics.

These typical cross-sections were designed using areas and depths calculated to result in shear stresses appropriate for the sediment supply as analyzed for the Shoemaker project; these are defined in the entrainment calculations included in Appendix C. The sinuosity increased slightly in the upper half of the project area, where chute cutoffs had previously breached overwide bars and incised into clays against the pasture fence.

The valley slope is 1.65%. While thalweg and bankfull elevations were set by points tied together in the permanently monumented cross-sections, a separate long profile was not prepared, and separate slope characteristics for riffle and pool reaches were not defined. Actual slopes were therefore set in the field, and were increased in cross-over reaches and decreased in the lower third of the bends. Design bankfull stage water surface slopes for cross-sections 2-5 ranged from 1.5% to 1.7%; the as-built slopes ranged from 0.8% to 2.0% (see RiverMorph summary sheets, Appendix C). Bed material size distribution is also presented in Appendix C, drawn from pebble counts taken during the assessments for the management plan.

These same cross-sections were surveyed as built following project completion, adding additional longitudinal survey points and breaklines for rock structures. As stated above, while project-specific design entrainment calculations were not made prior to construction, Appendix C presents specific calculations comparing design and as-built channel morphology. Appendix D includes the application for a NYSDEC/ ACOE Article 15 Stream Disturbance Permit. Appendix E shows photos of the project post-construction.

Project Costs

Apart from staff time spent on design, permit preparation, rock procurement and construction supervision, the costs of the project to DEP included: 1) rock, 2) dewatering equipment, and 3) time and materials for revegetation. As stated above, labor and equipment costs for the excavation contractor and crew were paid for under a contract between the landowner and contractor; these costs are unknown.

There was much more rock used per lineal foot of stream on this project than on most previous Natural Channel Design projects undertaken by NYCDEP, one of the defining features of this “hybrid” project. Rock volumes were estimated from the design and sizes were specified as follows:

Table 2. Calculated rock volumes for RAH Stables Project

Treatment	Height (ft)	Depth (ft)	Length (ft)	Area (ft^2)	Volume (yds^3)	Tons
Bench toe and face	8	3	1020	24480	907	1813
Back slope	7	2	1020	14280	529	1058
Bench checks	3	15	56	2520	93	187
Totals					1529	3058
+20% contingency					1835	3669
D50	>460mm	600lbs				
D10	>150mm	195lbs				

The contract for the rock was bid competitively by GCSWCD; final cost per ton delivered was $17.00. Total actually used was 3114 tons, for a total rock cost of $52,933.01. During the course of construction, a request was made to the supplier that the rock size be increased because the rock vanes required larger rock. D50 increased to approximately 1000mm, allowing the largest rocks to be stockpiled separately for this purpose. The design of vanes followed the typical specifications used in other restoration projects in the region, with the vanes facing upstream, sloping between 2-7 % to finish at the thalweg at grade, and with a deflection angle of 20-30 degrees off a tangent to the bankfull stream line.

About $180.00 was spent on the rental of two 2” pumps to clear turbid water from the work area during the final stage of construction.

Approximately 330 trees and shrubs were planted as potted material following completion of the earthwork in September. Species included Speckled Alder, Red Oak, Black Willow, Green Ash, Shadblow, Serviceberry, Peach Leaf Willow, River Birch, American Sycamore, Pussy Willow, Chokecherry, Hybrid Poplar, Silky Dogwood, White Pine, Red Maple, Hemlock, Silver Maple, and an additional 300 willow tublings. Approximately 250 willow stakes, harvested locally, were installed in November following dormancy. The entire site, including several acres of the pasture that were disturbed during the stockpiling of the rock, was hydroseeded using an annual and perennial rye mixture, and some areas were additionally hand-broadcast seeded. Costs of revegetation are still being calculated; these are difficult to fully account for, because none of the materials or labor costs are billed directly against the Construction Budget line for this project. Some of the material is wild-harvested locally; some is wild-harvested or purchased as seedling stock, potted and grown for a season or two before planting; and some is purchased potted as larger stock in the year it was planted. The labor to cover this materials development is thus billed over many months to several different contracts between DEP and the GCSWCD. Similarly, the billing for planting labor or hydroseeding on the RAH Stables project was not distinguished from the additional revegetation effort on the Shoemaker project. Four Student Conservation Corps members also provided planting labor, for different periods of time, under varying contract arrangements. Some of these costs have not yet been billed at the writing of this report. Total revegetation costs for materials development, planting and hydroseeding are estimated at this time at between $5000 and $10,000.

Assuming total costs of approximately $63,000, not including program staff time for design and construction supervision, cost to NYCDEP per lineal foot for the restoration was approximately $40.00.

Staging

The staging of the work proceeded from top bend, to bottom bend, to middle bend. The existing multiple channel threads and newly excavated temporary diversions were used to dewater each area in turn, using modest coffer dams at the upstream end. Turbid water created from groundwater leakage into work areas was pumped onto the floodplain for settling of fines. A considerable volume of clay was removed from the channel and buried in the pasture area. Cut and fill volumes were very close to being balanced, with an overall slight shortage of material, and high terrace alluvium displaced by the buried clay was used in the backfilling of the benches.

The contractor, Skip Dippold, had not performed natural channel design work before, but was eager to become acquainted with the approach, frequently offered good suggestions regarding design and staging decisions, and was conscientious regarding the management of turbid water. The novel contractual arrangements for the project were considered successful.

Monitoring

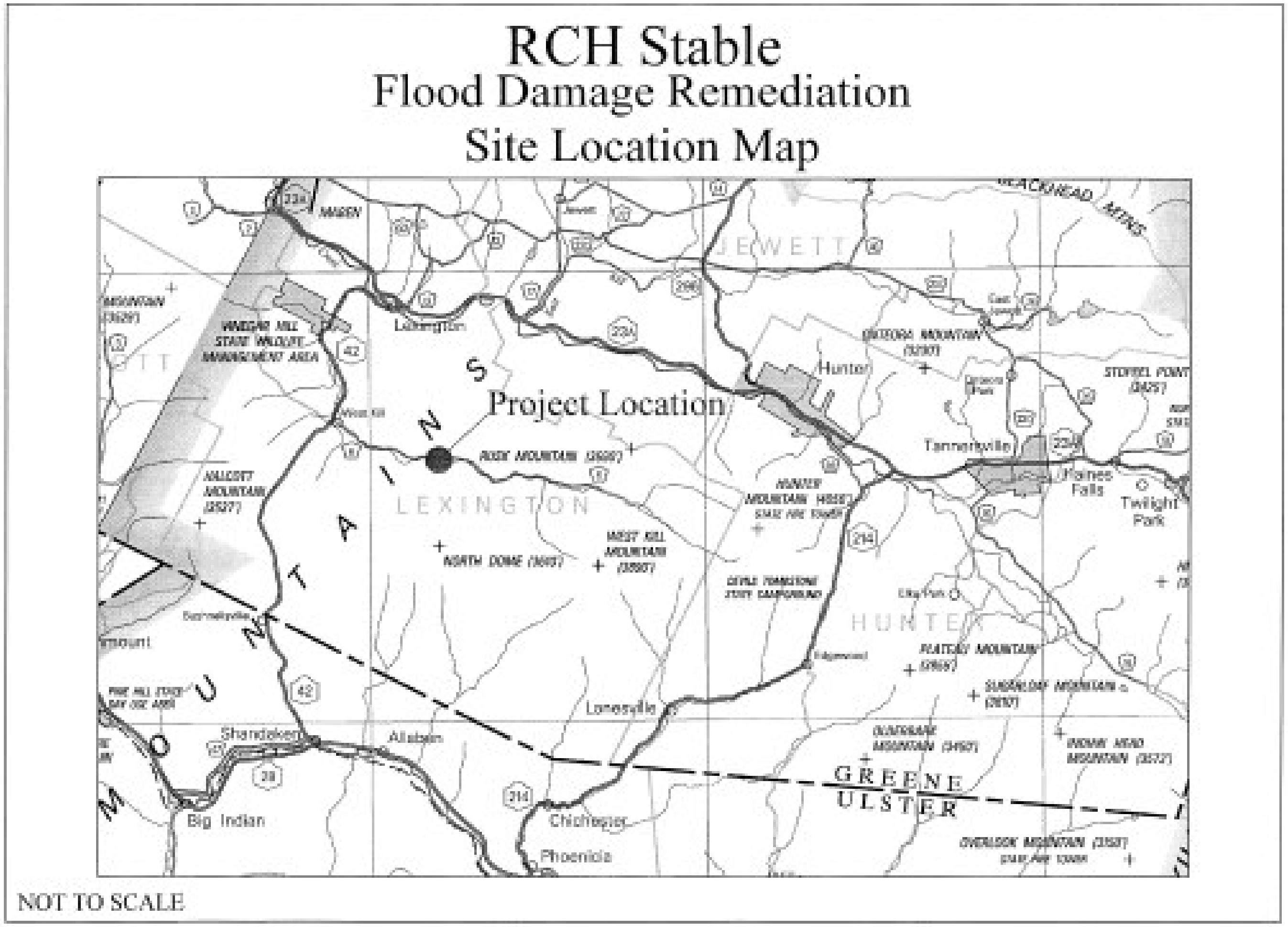
As stated above, the six monumented cross-sections as well as many breakpoints, bankfull stage levels and thalweg shots in the channel between cross-sections were surveyed post-construction. This survey was performed after several significant flows (>than 0.5 of bankfull discharge) had sorted bed materials. These sections and longitudinal profile will be surveyed annually for three years, and pebble counts will be repeated at the site for comparison. Three transects along the monumented cross-sections will be used to establish vegetation monitoring sample plots, one at each meander bend. Vegetation monitoring will commence in Spring 2007 using SMP's standard protocol.

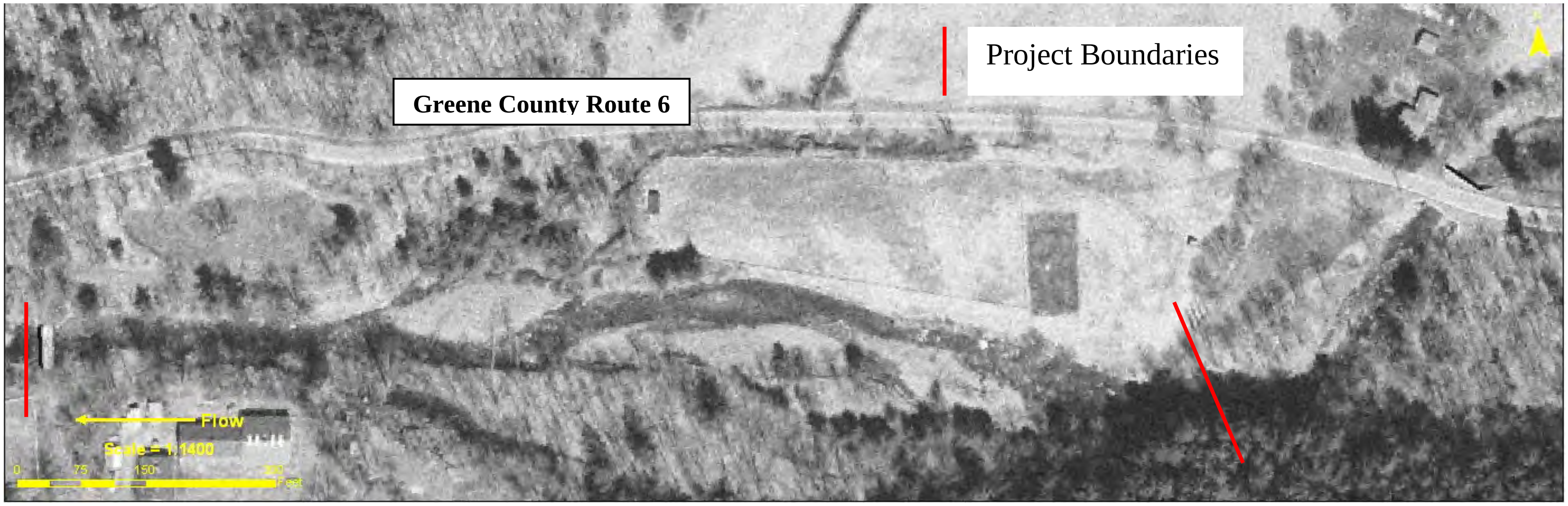
References

Miller, S. and D. Davis, 2003. *Optimizing Catskill Mountain Regional Bankfull Discharge and Hydraulic Geometry Relationships*, in Watershed Management for Water Supply Systems. AWRA's 2003 International Congress. AWRA: Middleburg, VA, US. TPS-03-2, CD-ROM.

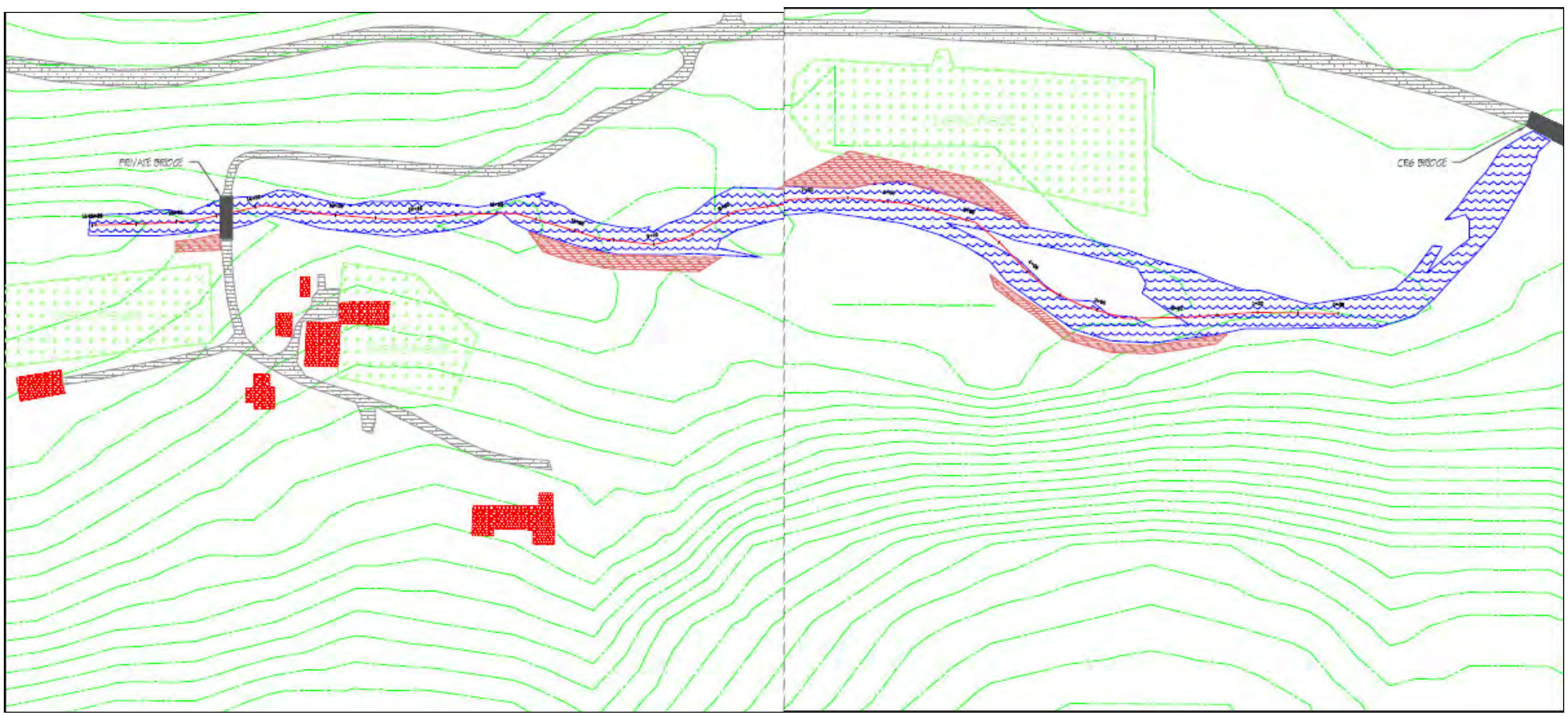
GCSWCD and NYCDEP, 2005. West Kill Stream Management Plan. http://www.gcswcd.com/stream/westkill/

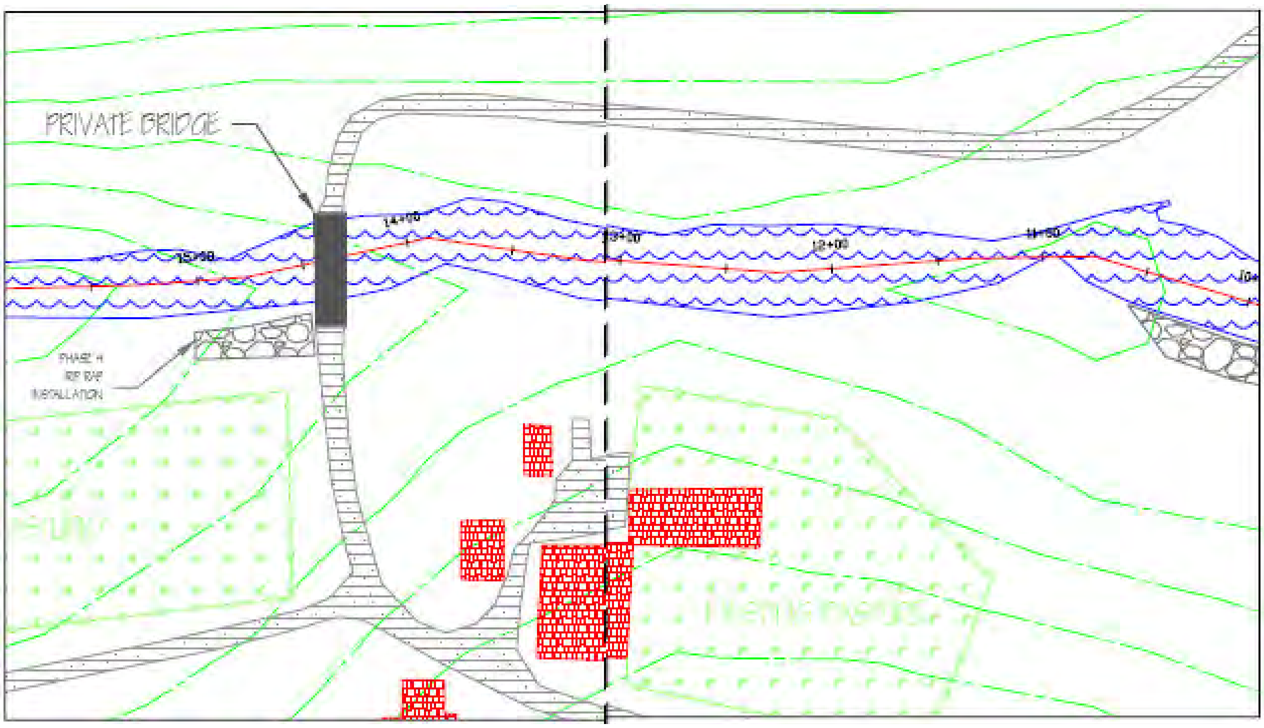
Appendix A. Site Location Map



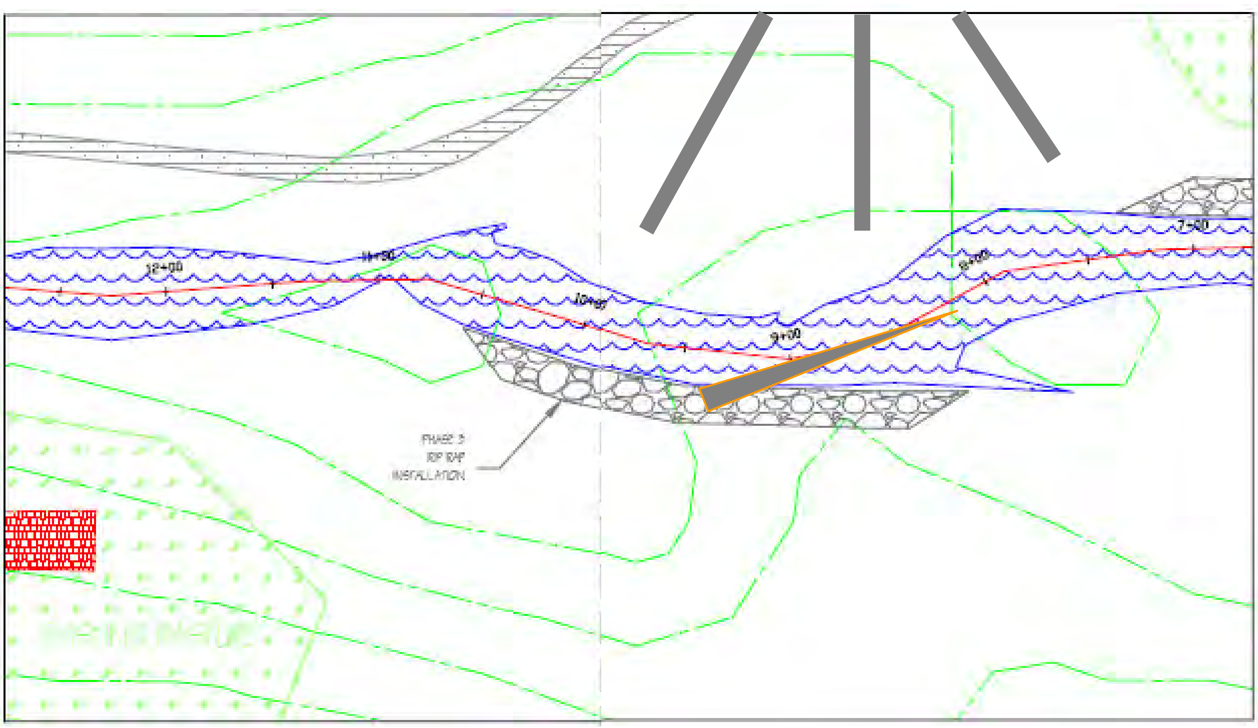


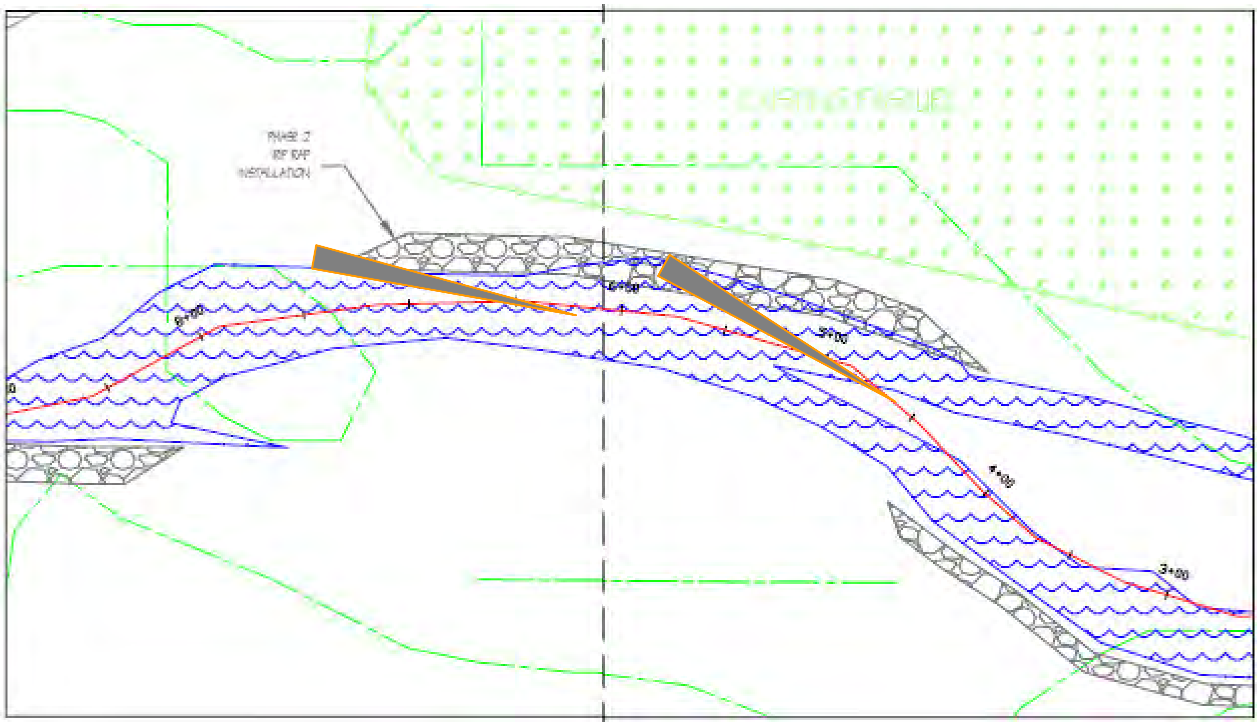
Above, 2004 Aerial photography showing multiple channels at RAH Stables.
Below, project area with erosion areas showing in shaded red.

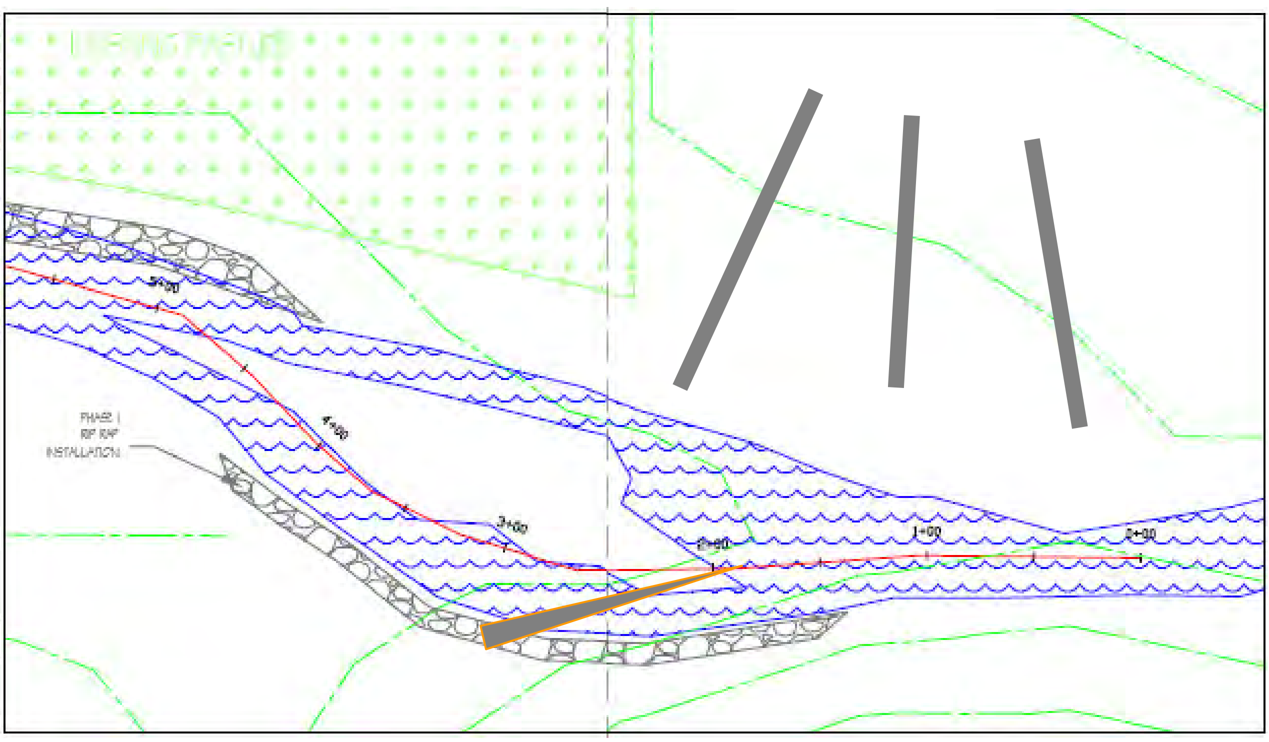




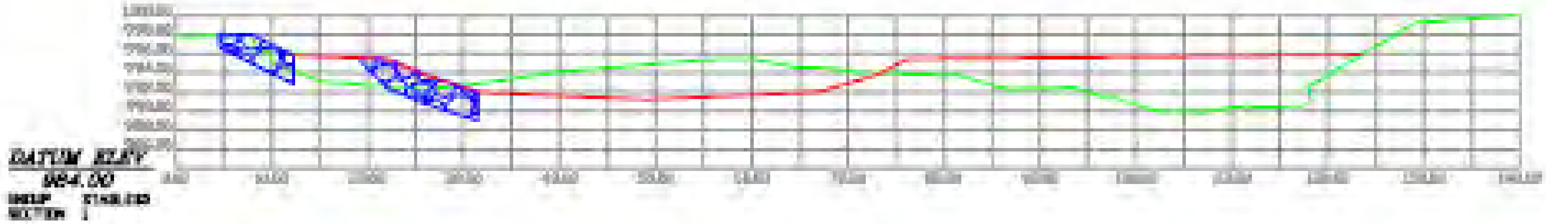
Proposed restoration design, at bridge crossing, above; lowest meander bend, below, with bankfull bench identified as "rip-rap installation". These areas are also the zones where trees and shrubs were planted. Grey triangles represent approximate locations of rock vanes. Grey bars opposite the vanes at the top and bottom meanders represent approximate locations of rock keyways in point bars.



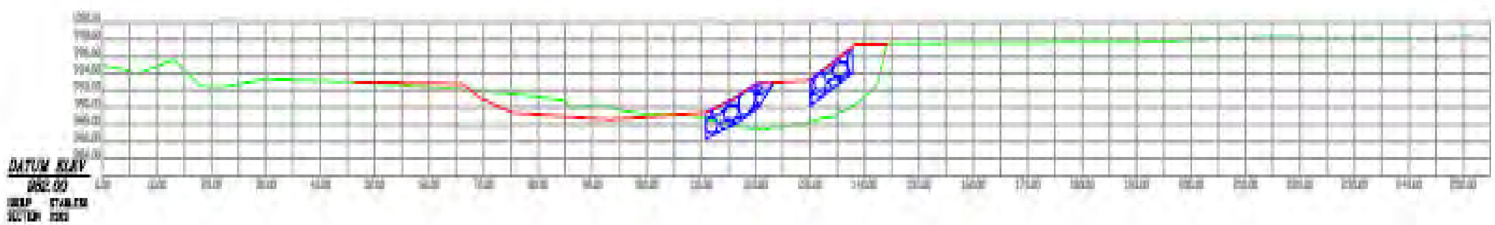

PHASE 2
RIP RAP
INSTALLATION
4+00
3+00


PHASE 1
RIP RAP
INSTALLATION
4+00
3+00
1+00
0+00

Appendix B. Existing and Proposed Survey


DATUM ELEV


DATUM ELEV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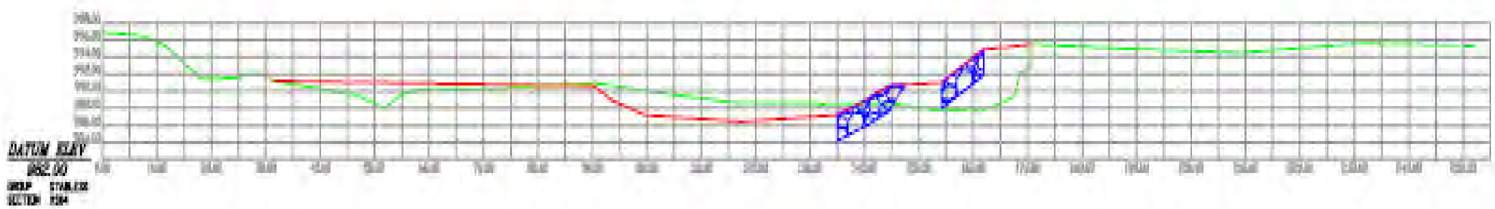
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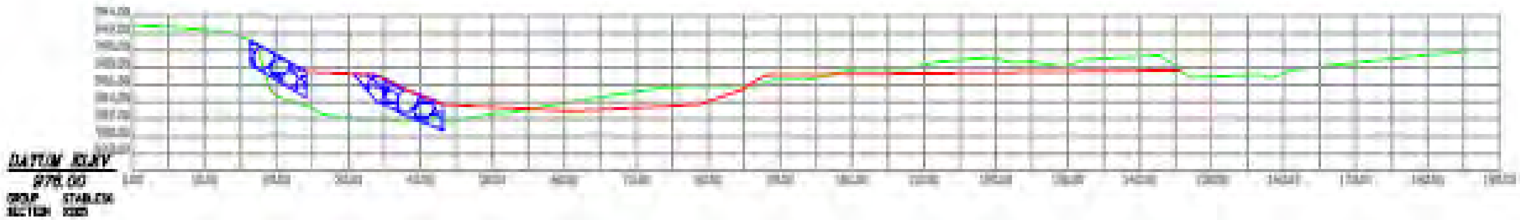
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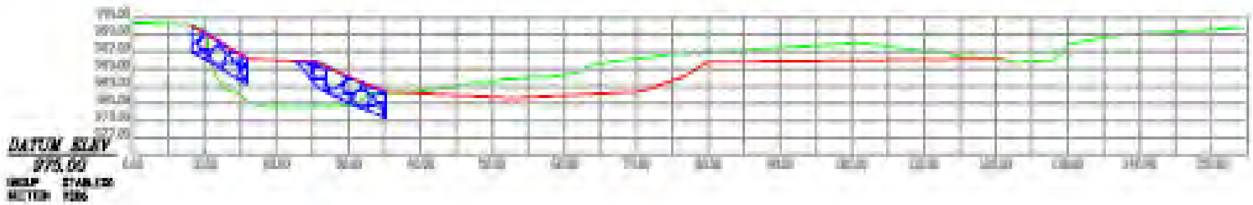
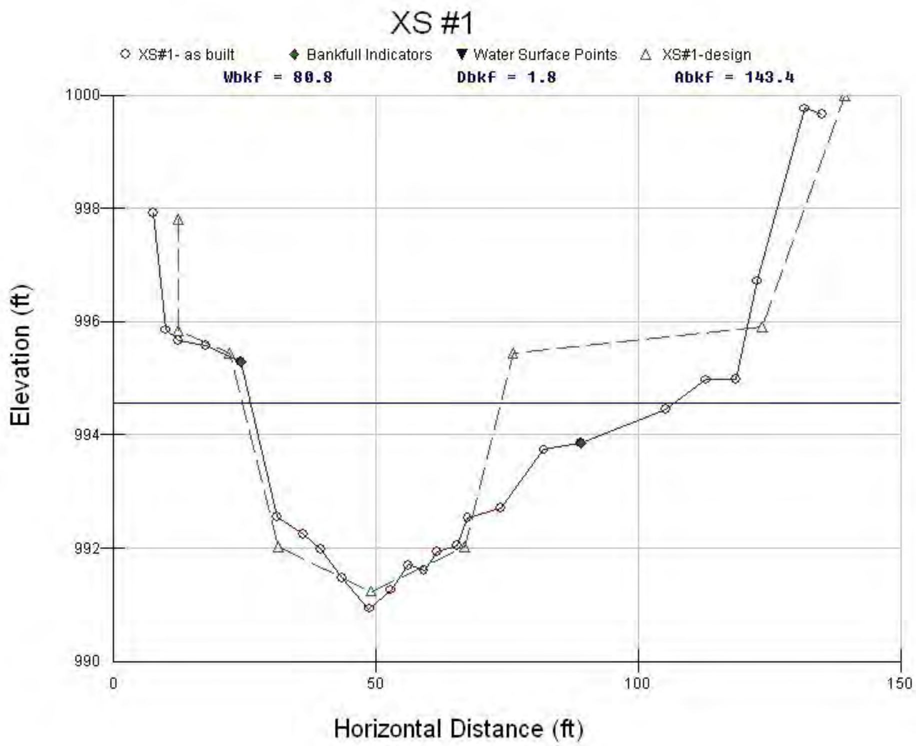
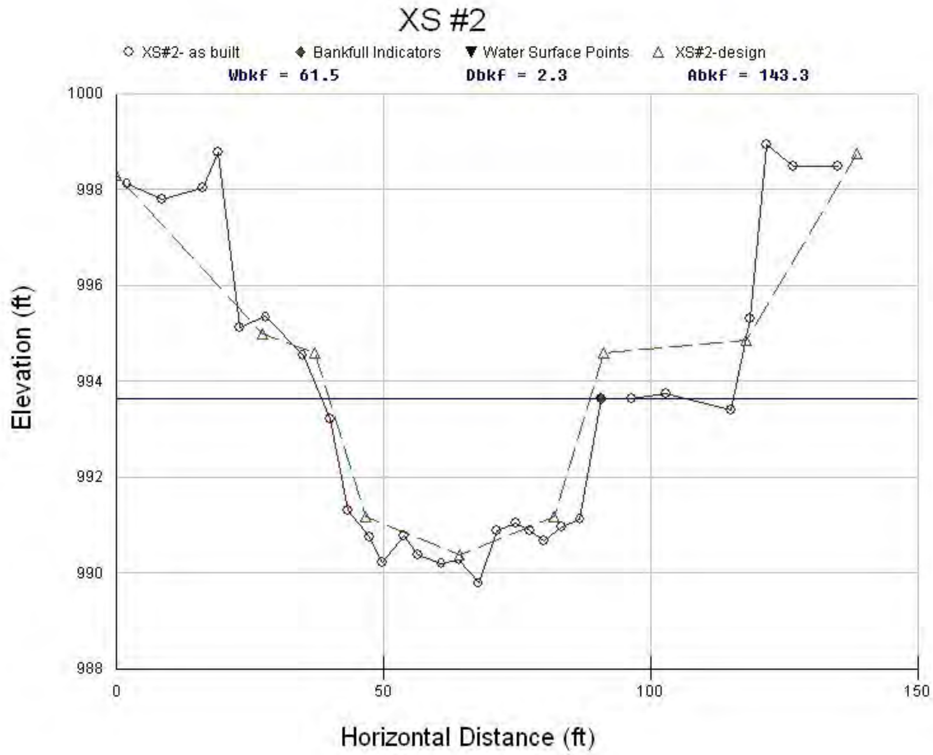
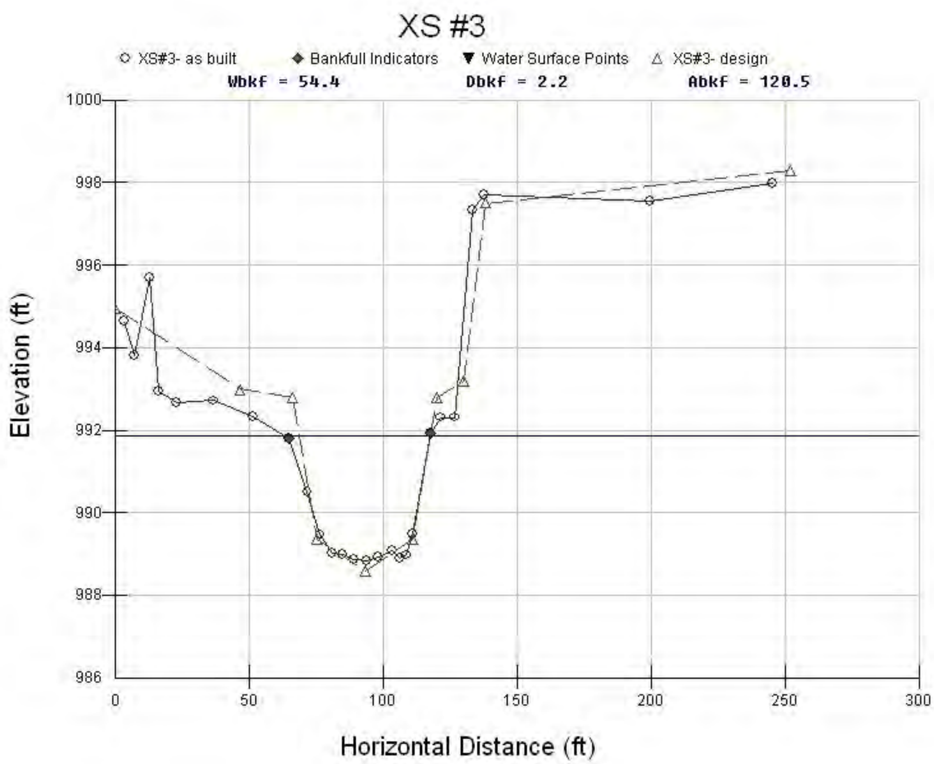

DATUM ELEV

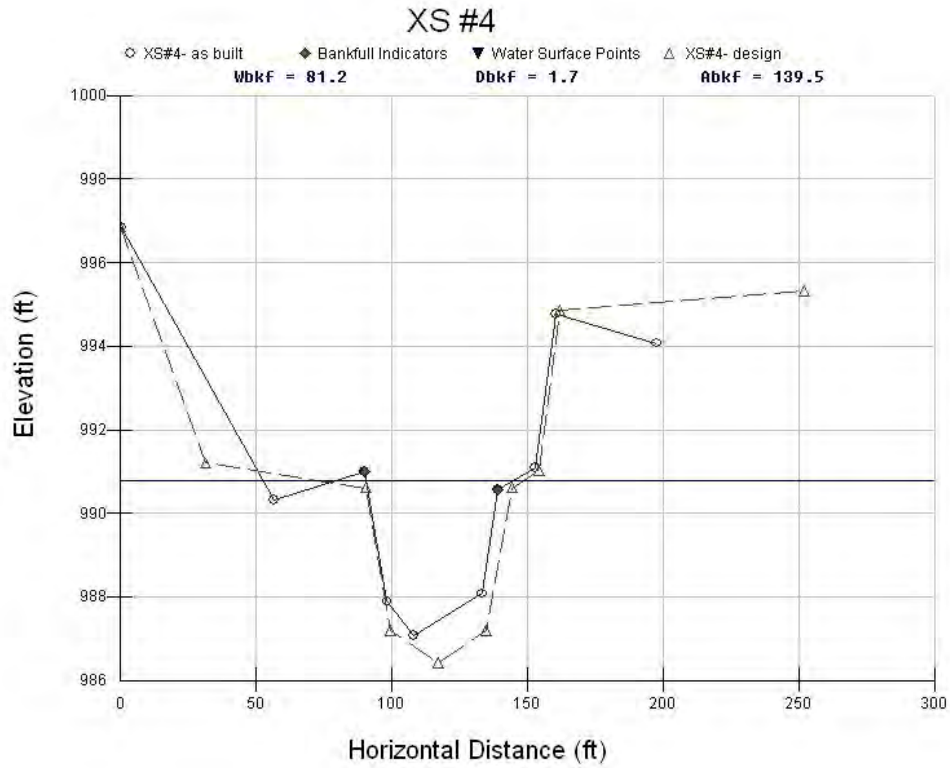
Appendix C. Design and As-built Channel Survey and Analysis

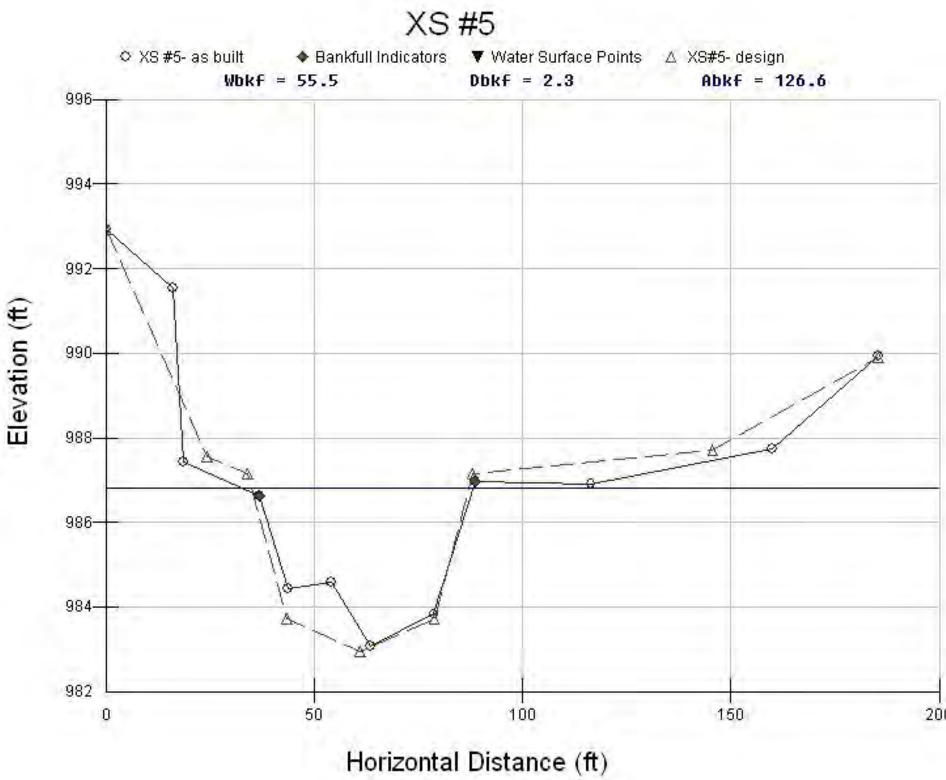
The following plots present design vs. as-built sections, and RiverMorph "screen shots" present summary morphology and hydraulic data. Entrainment calculations prepared for the Shoemaker project are provided because they are largely transferable.

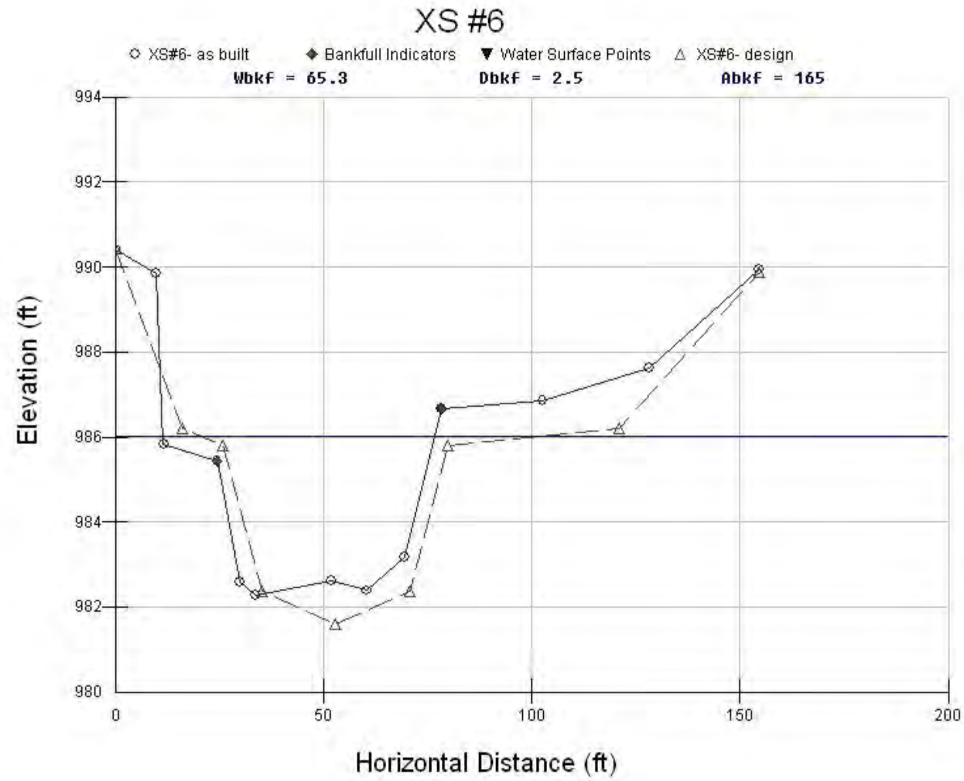

XS #1
XS#1- as built
Bankfull Indicators
Water Surface Points
XS#1-design
Wbkf = 80.8
Dbkf = 1.8
Abkf = 143.4
Elevation (ft)
Horizontal Distance (ft)
1000
998
996
994
992
990
0
50
100
150


XS #2
XS#2- as built
Bankfull Indicators
Water Surface Points
XS#2-design
WbkF = 61.5
DbkF = 2.3
AbkF = 143.3
Elevation (ft)
Horizontal Distance (ft)


XS #3
XS#3- as built
Bankfull Indicators
Water Surface Points
XS#3- design
WbkF = 54.4
DbkF = 2.2
AbkF = 120.5
Elevation (ft)
Horizontal Distance (ft)


XS #4
XS#4- as built
Bankfull Indicators
Water Surface Points
XS#4- design
Wbkf = 81.2
Dbkf = 1.7
Abkf = 139.5
Elevation (ft)
Horizontal Distance (ft)
1000
998
996
994
992
990
988
986
0
50
100
150
200
250
300

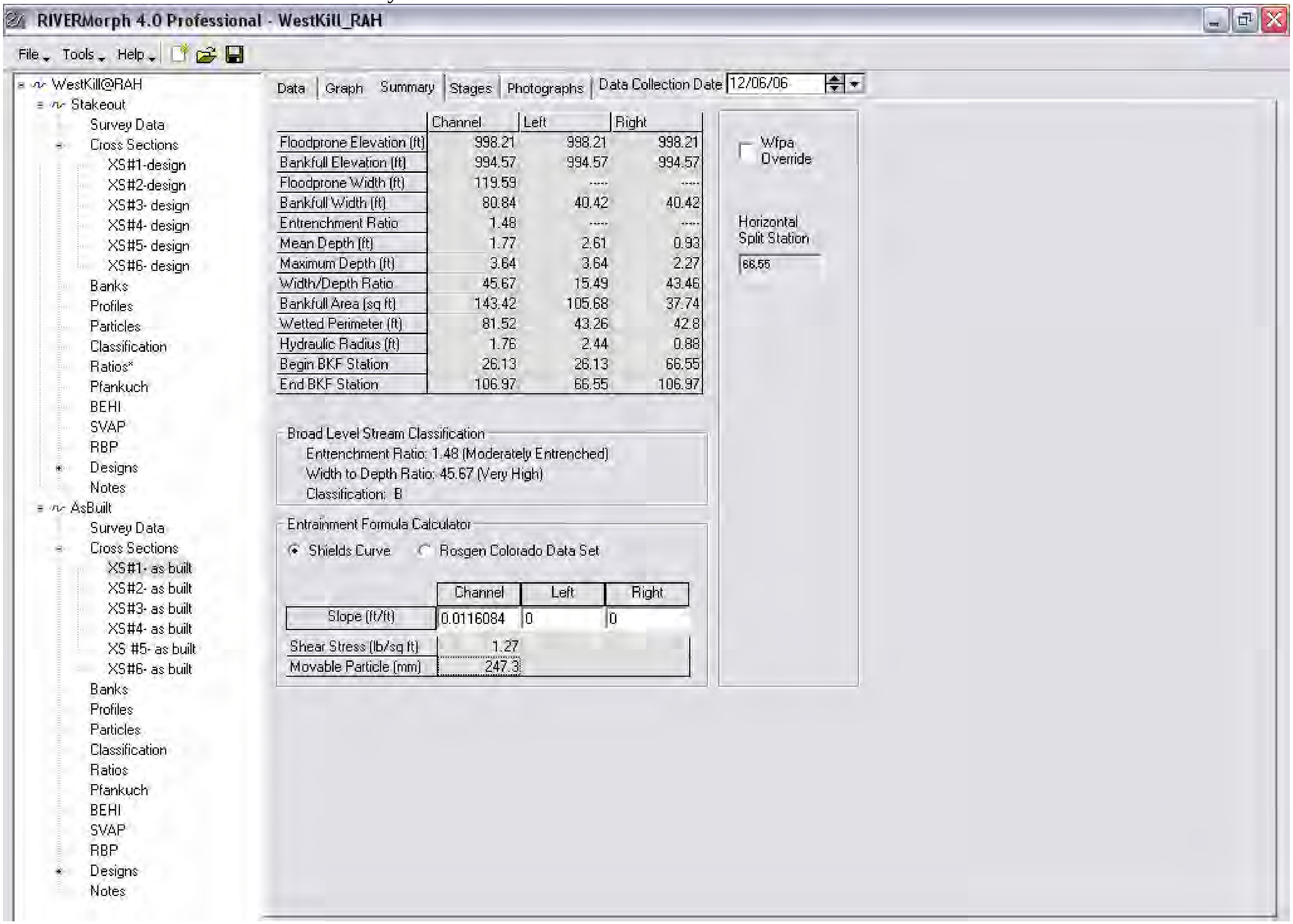

XS #5
XS #5- as built
Bankfull Indicators
Water Surface Points
XS#5- design
Wbkf = 55.5
Dbkf = 2.3
Abkf = 126.6
Elevation (ft)
Horizontal Distance (ft)
996
994
992
990
988
986
984
982
0
50
100
150
200



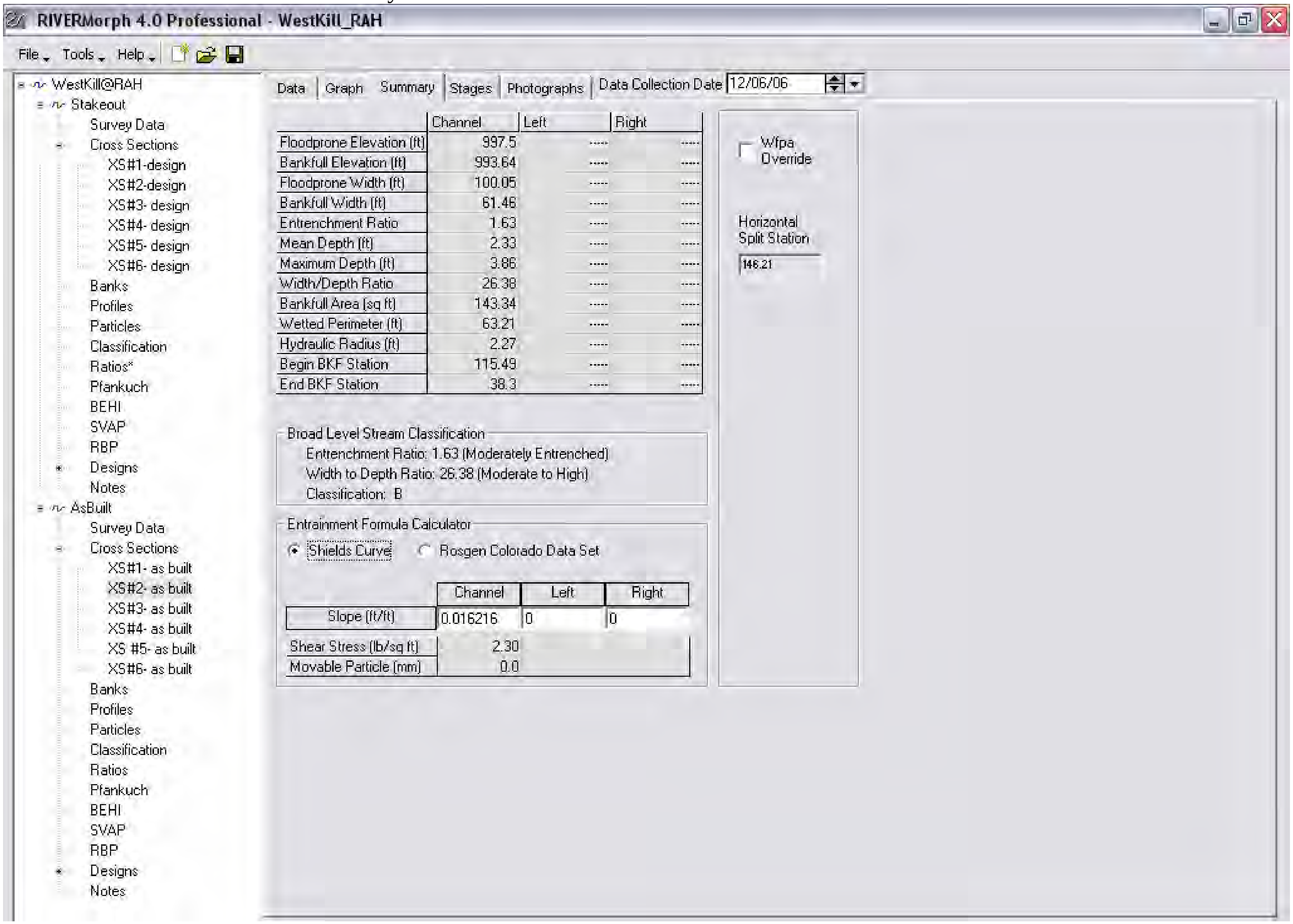
Q_{bfl} calculated from regional curves developed by Miller and Davis, 2003, using high Mean Annual Runoff curve. The entrainment calculations below are those prepared for the Shoemaker Project adjacent and downstream, and are transferable; no significant additional sediment sources occur between the two projects.

Differences between design and as-built bankfull bed-averaged shear stresses result from adjustments made in the field based on greater variation in as-built slopes between riffle and pool reaches. These shear stresses do not reflect increased transport capacity created by rock vanes, which were added as a design element during construction.

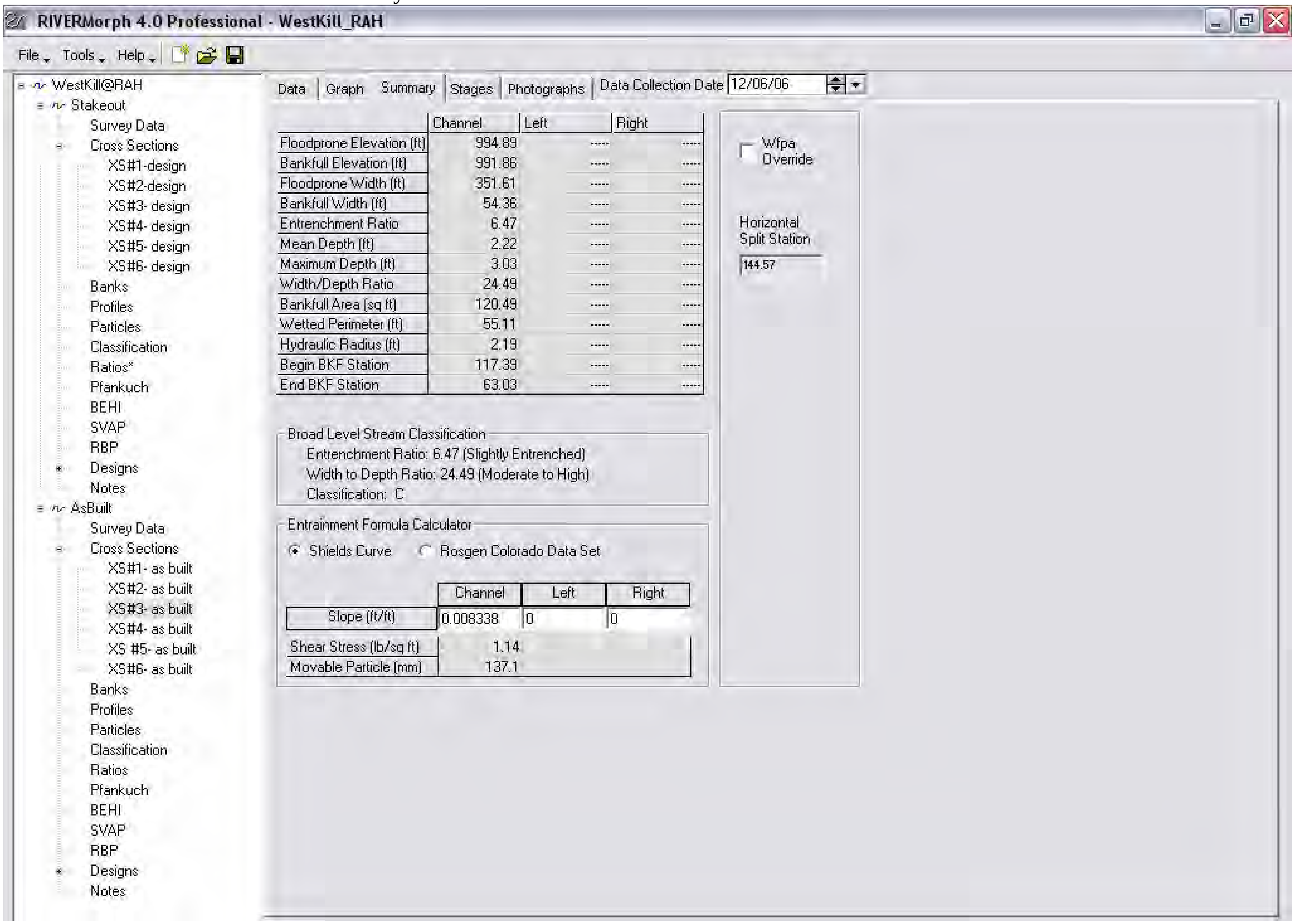
XS #1 – As-built cross section summary data



XS #2 – As-built cross section summary data



XS #3 – As-built cross section summary data



	Channel	Left	Right
Floodprone Elevation (ft)	994.89	-----	-----
Bankfull Elevation (ft)	991.86	-----	-----
Floodprone Width (ft)	351.61	-----	-----
Bankfull Width (ft)	54.36	-----	-----
Entrenchment Ratio	6.47	-----	-----
Mean Depth (ft)	2.22	-----	-----
Maximum Depth (ft)	3.03	-----	-----
Width/Depth Ratio	24.49	-----	-----
Bankfull Area (sq ft)	120.49	-----	-----
Wetted Perimeter (ft)	55.11	-----	-----
Hydraulic Radius (ft)	2.19	-----	-----
Begin BKF Station	117.39	-----	-----
End BKF Station	63.03	-----	-----

Broad Level Stream Classification

Entrenchment Ratio: 6.47 (Slightly Entrenched)

Width to Depth Ratio: 24.49 (Moderate to High)

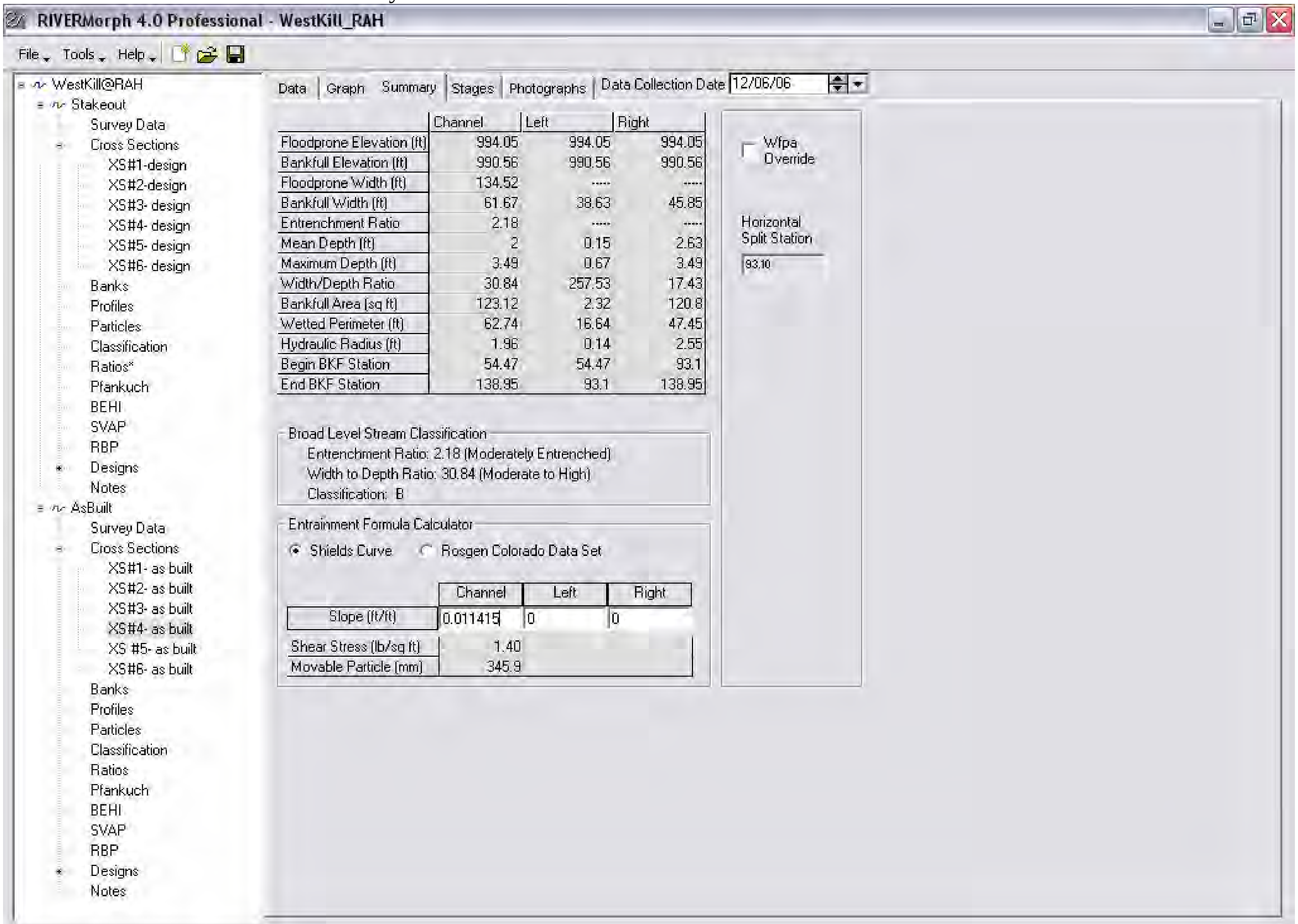
Classification: C

Entrainment Formula Calculator

Shields Curve Rosgen Colorado Data Set

	Channel	Left	Right
Slope (ft/ft)	0.008338	0	0
Shear Stress (lb/sq ft)	1.14		
Movable Particle (mm)	137.1		

XS #4 – As-built cross section summary data



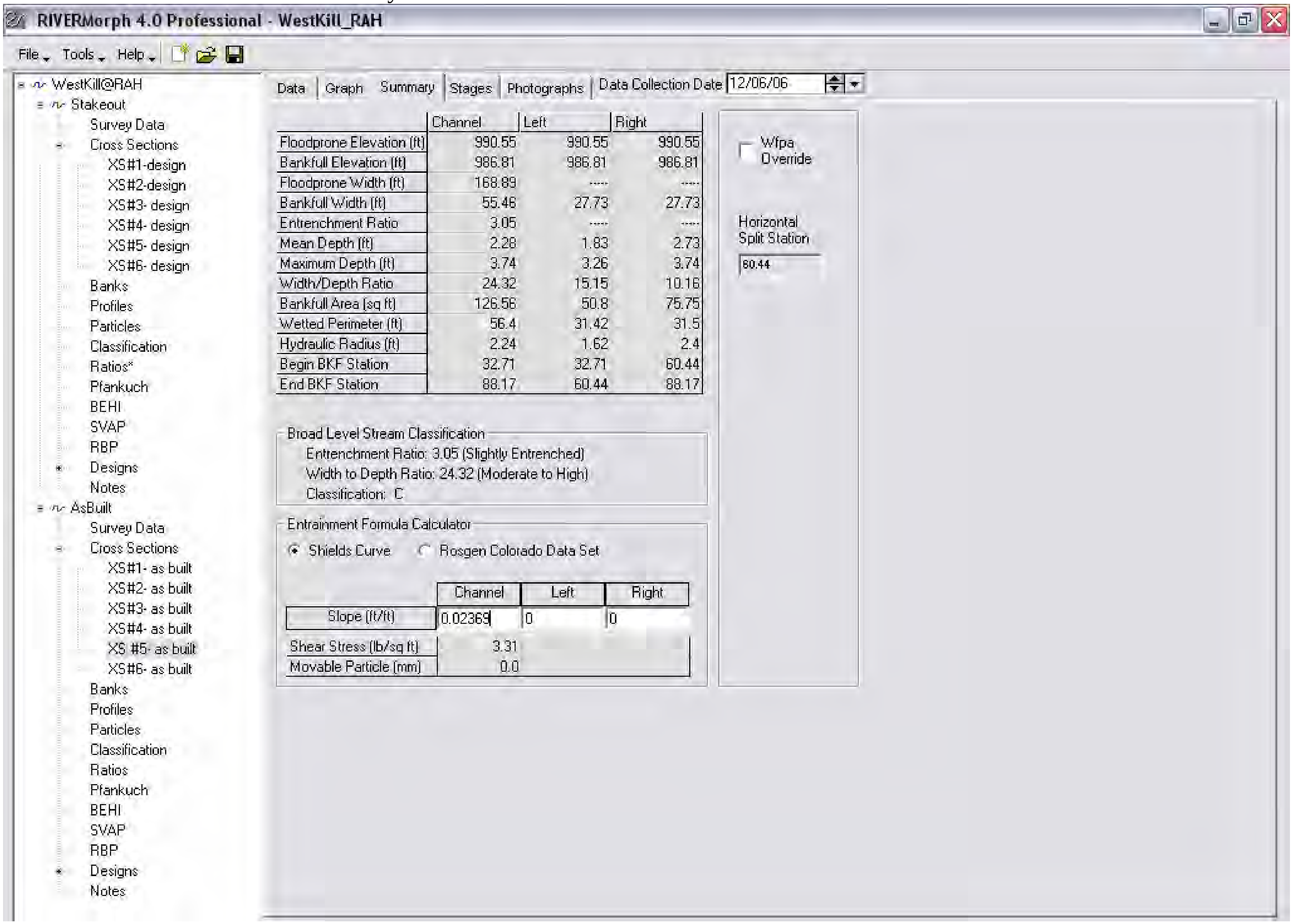
	Channel	Left	Right
Floodprone Elevation (ft)	994.05	994.05	994.05
Bankfull Elevation (ft)	990.56	990.56	990.56
Floodprone Width (ft)	134.52	-----	-----
Bankfull Width (ft)	61.67	38.63	45.85
Entrenchment Ratio	2.18	-----	-----
Mean Depth (ft)	2	0.15	2.63
Maximum Depth (ft)	3.49	0.67	3.49
Width/Depth Ratio	30.84	257.53	17.43
Bankfull Area (sq ft)	123.12	2.32	120.8
Wetted Perimeter (ft)	62.74	16.64	47.45
Hydraulic Radius (ft)	1.96	0.14	2.55
Begin BKF Station	54.47	54.47	93.1
End BKF Station	138.95	93.1	138.95

Broad Level Stream Classification
Entrenchment Ratio: 2.18 (Moderately Entrenched)
Width to Depth Ratio: 30.84 (Moderate to High)
Classification: B

Entrainment Formula Calculator
Shields Curve Rosgen Colorado Data Set

	Channel	Left	Right
Slope (ft/ft)	0.011415	0	0
Shear Stress (lb/sq ft)	1.40		
Movable Particle (mm)	345.9		

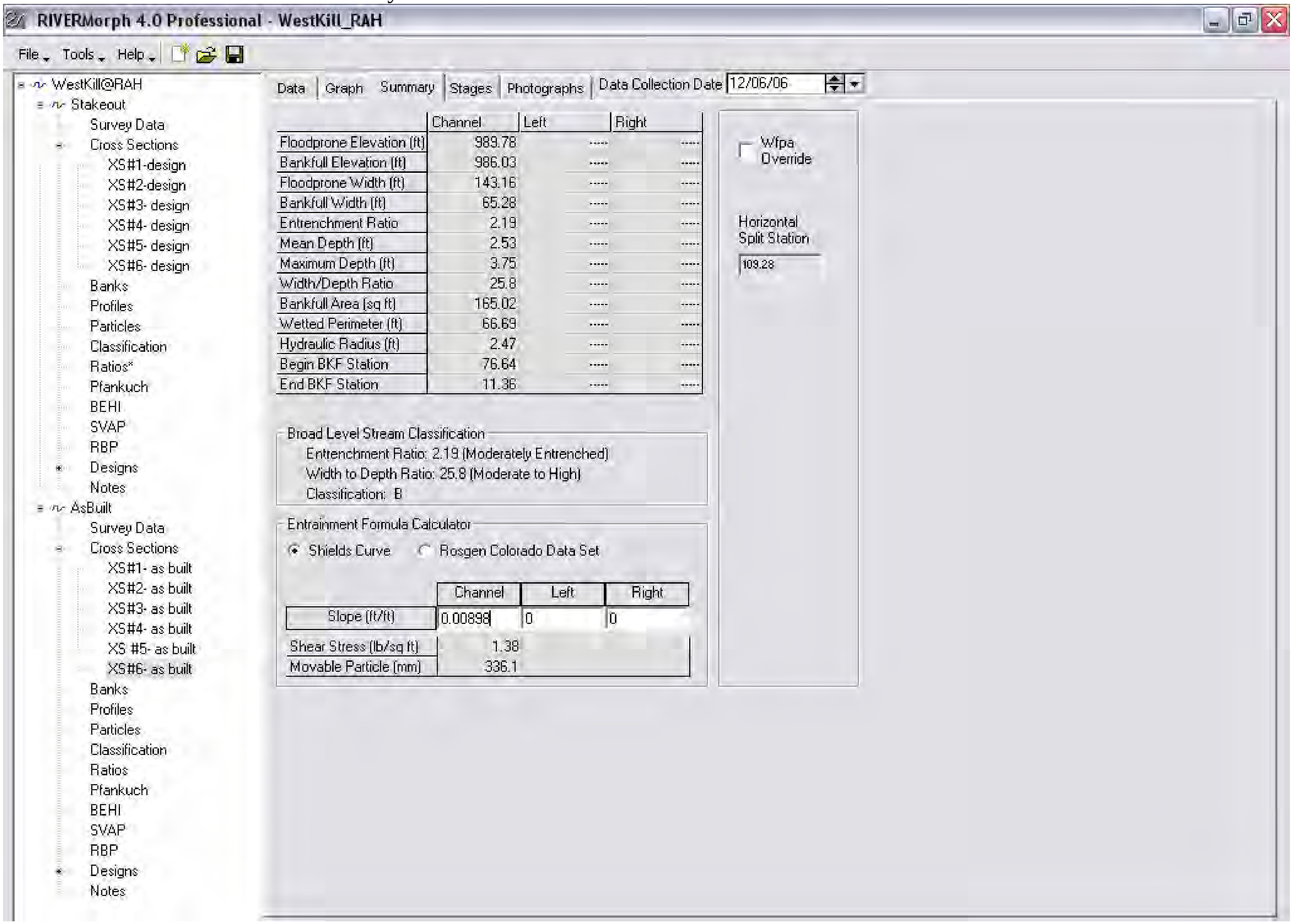
XS #5 – As-built cross section summary data



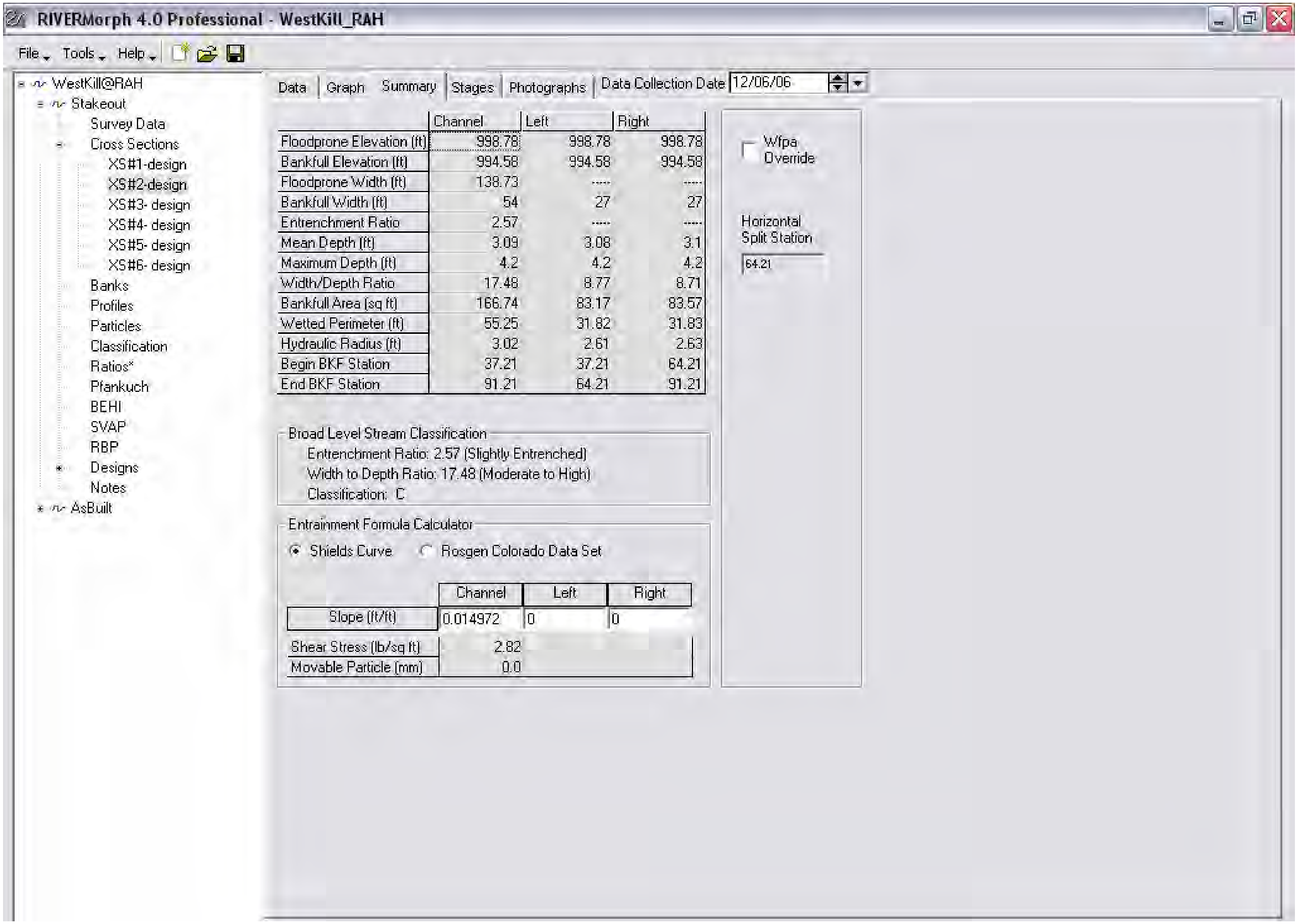
	Channel	Left	Right
Floodprone Elevation (ft)	990.55	990.55	990.55
Bankfull Elevation (ft)	986.81	986.81	986.81
Floodprone Width (ft)	168.89	-----	-----
Bankfull Width (ft)	55.46	27.73	27.73
Entrenchment Ratio	3.05	-----	-----
Mean Depth (ft)	2.28	1.83	2.73
Maximum Depth (ft)	3.74	3.26	3.74
Width/Depth Ratio	24.32	15.15	10.16
Bankfull Area (sq ft)	126.56	50.8	75.75
Wetted Perimeter (ft)	56.4	31.42	31.5
Hydraulic Radius (ft)	2.24	1.62	2.4
Begin BKF Station	32.71	32.71	60.44
End BKF Station	88.17	60.44	88.17

	Channel	Left	Right
Slope (ft/ft)	0.02369	0	0
Shear Stress (lb/sq ft)	3.31		
Movable Particle (mm)	0.0		

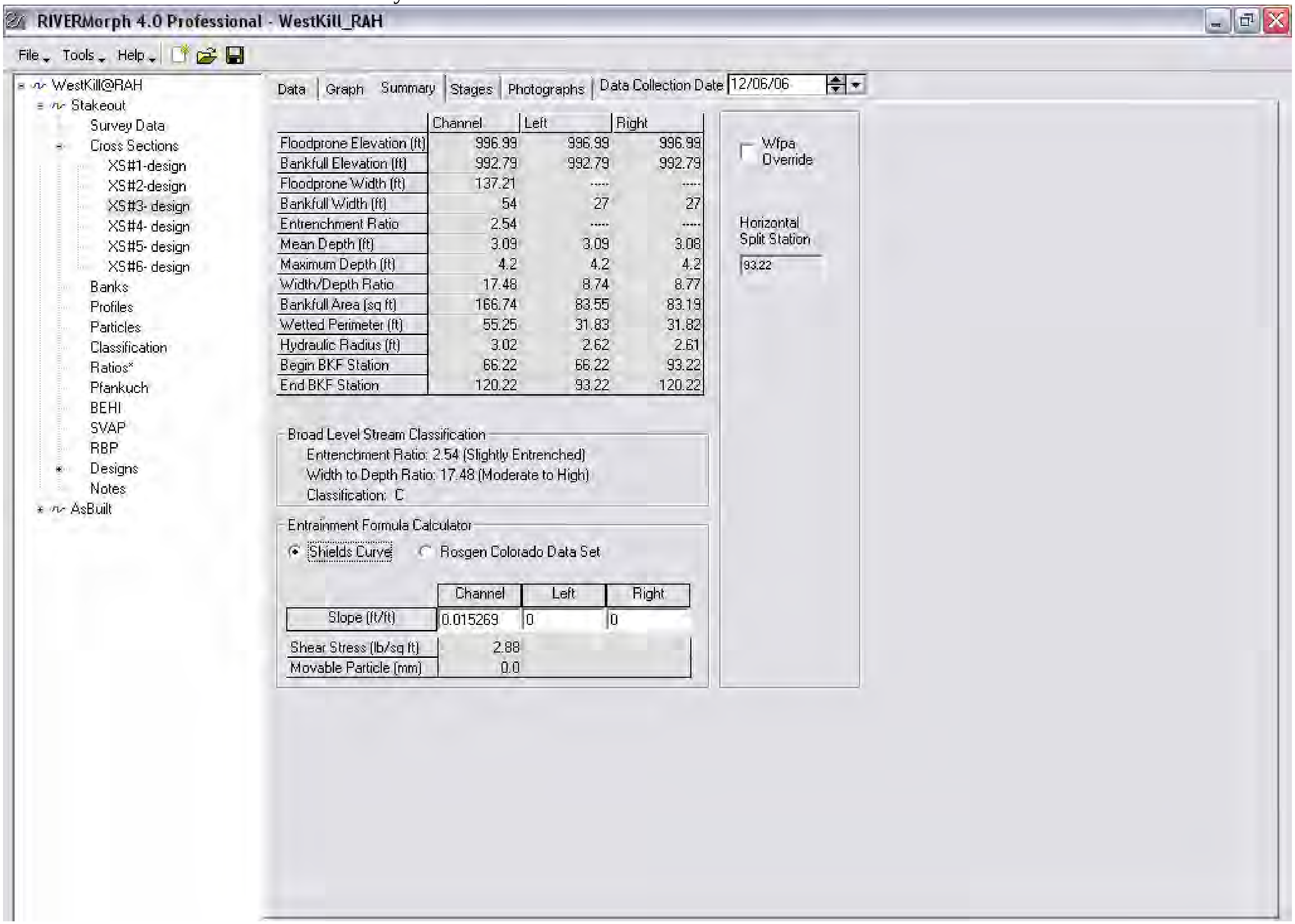
XS #6 – As-built cross section summary data



XS #2 – Stakeout cross section summary data


RIVERMorph 4.0 Professional - WestKill_RAH
File Tools Help
WestKill@RAH
Stakeout
Survey Data
Cross Sections
XS#1-design
XS#2-design
XS#3- design
XS#4- design
XS#5- design
XS#6- design
Banks
Profiles
Particles
Classification
Ratios*
Pfankuch
BEHI
SVAP
RBP
Designs
Notes
AsBuilt
Data
Graph
Summary
Stages
Photographs
Data Collection Date 12/06/06
Channel Left Right
Floodprone Elevation (ft) 998.78 998.78 998.78
Bankfull Elevation (ft) 994.58 994.58 994.58
Floodprone Width (ft) 138.73 ----- -----
Bankfull Width (ft) 54 27 27
Entrenchment Ratio 2.57 ----- -----
Mean Depth (ft) 3.09 3.08 3.1
Maximum Depth (ft) 4.2 4.2 4.2
Width/Depth Ratio 17.48 8.77 8.71
Bankfull Area (sq ft) 166.74 83.17 83.57
Wetted Perimeter (ft) 55.25 31.82 31.83
Hydraulic Radius (ft) 3.02 2.61 2.63
Begin BKF Station 37.21 37.21 64.21
End BKF Station 91.21 64.21 91.21
Wfpa Override
Horizontal Split Station
64.21
Broad Level Stream Classification
Entrenchment Ratio: 2.57 (Slightly Entrenched)
Width to Depth Ratio: 17.48 (Moderate to High)
Classification: C
Entrainment Formula Calculator
Shields Curve
Rosgen Colorado Data Set
Channel Left Right
Slope (ft/ft) 0.014972 0 0
Shear Stress (lb/sq ft) 2.82
Movable Particle (mm) 0.0

XS #3 – Stakeout cross section summary data



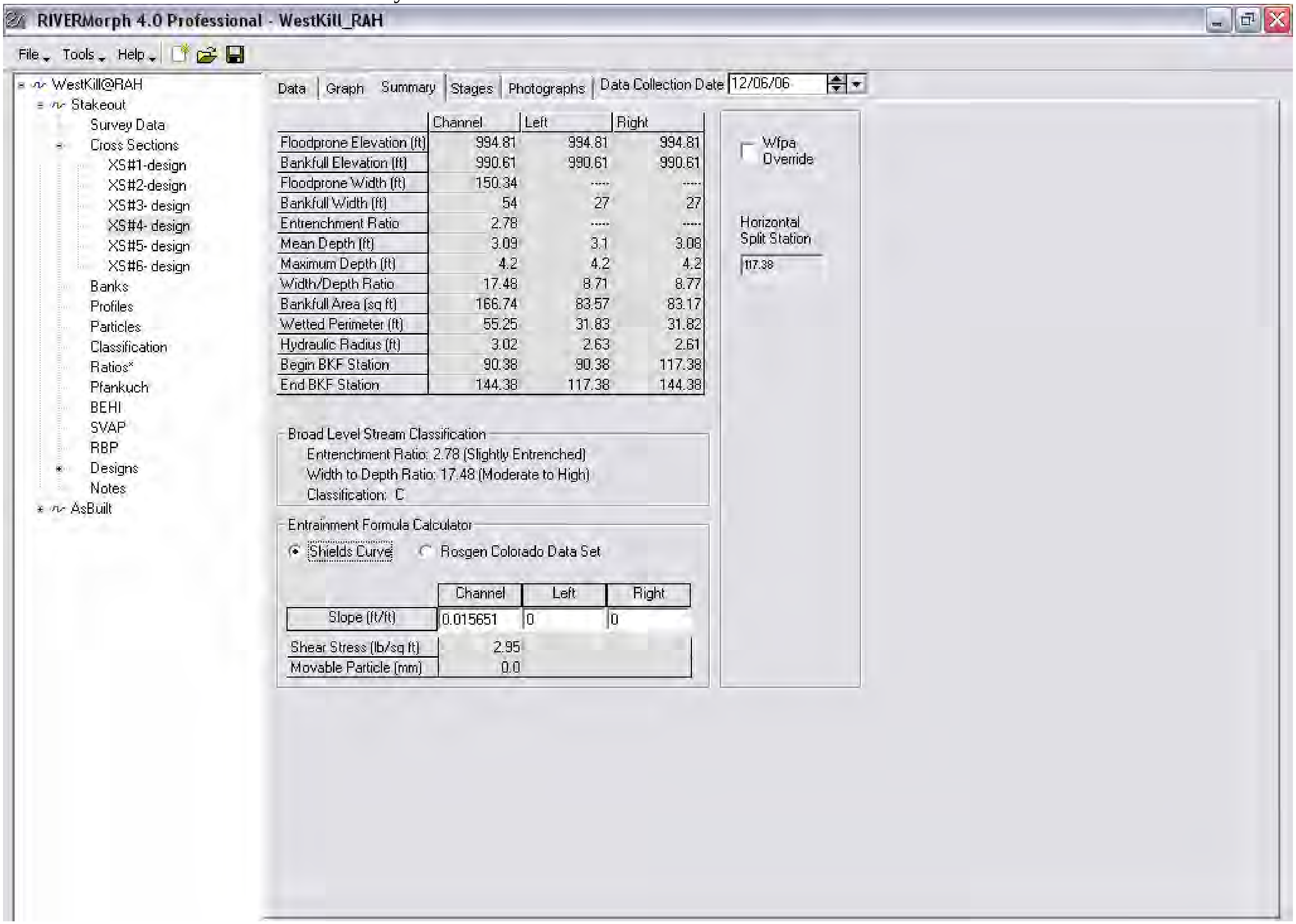
	Channel	Left	Right
Floodprone Elevation (ft)	996.99	996.99	996.99
Bankfull Elevation (ft)	992.79	992.79	992.79
Floodprone Width (ft)	137.21	-----	-----
Bankfull Width (ft)	54	27	27
Entrenchment Ratio	2.54	-----	-----
Mean Depth (ft)	3.09	3.09	3.08
Maximum Depth (ft)	4.2	4.2	4.2
Width/Depth Ratio	17.48	8.74	8.77
Bankfull Area (sq ft)	166.74	83.55	83.19
Wetted Perimeter (ft)	55.25	31.83	31.82
Hydraulic Radius (ft)	3.02	2.62	2.61
Begin BKF Station	66.22	66.22	93.22
End BKF Station	120.22	93.22	120.22

Broad Level Stream Classification
Entrenchment Ratio: 2.54 (Slightly Entrenched)
Width to Depth Ratio: 17.48 (Moderate to High)
Classification: C

Entrainment Formula Calculator
Shields Curve Rosgen Colorado Data Set

	Channel	Left	Right
Slope (ft/ft)	0.015269	0	0
Shear Stress (lb/sq ft)	2.88		
Movable Particle (mm)	0.0		

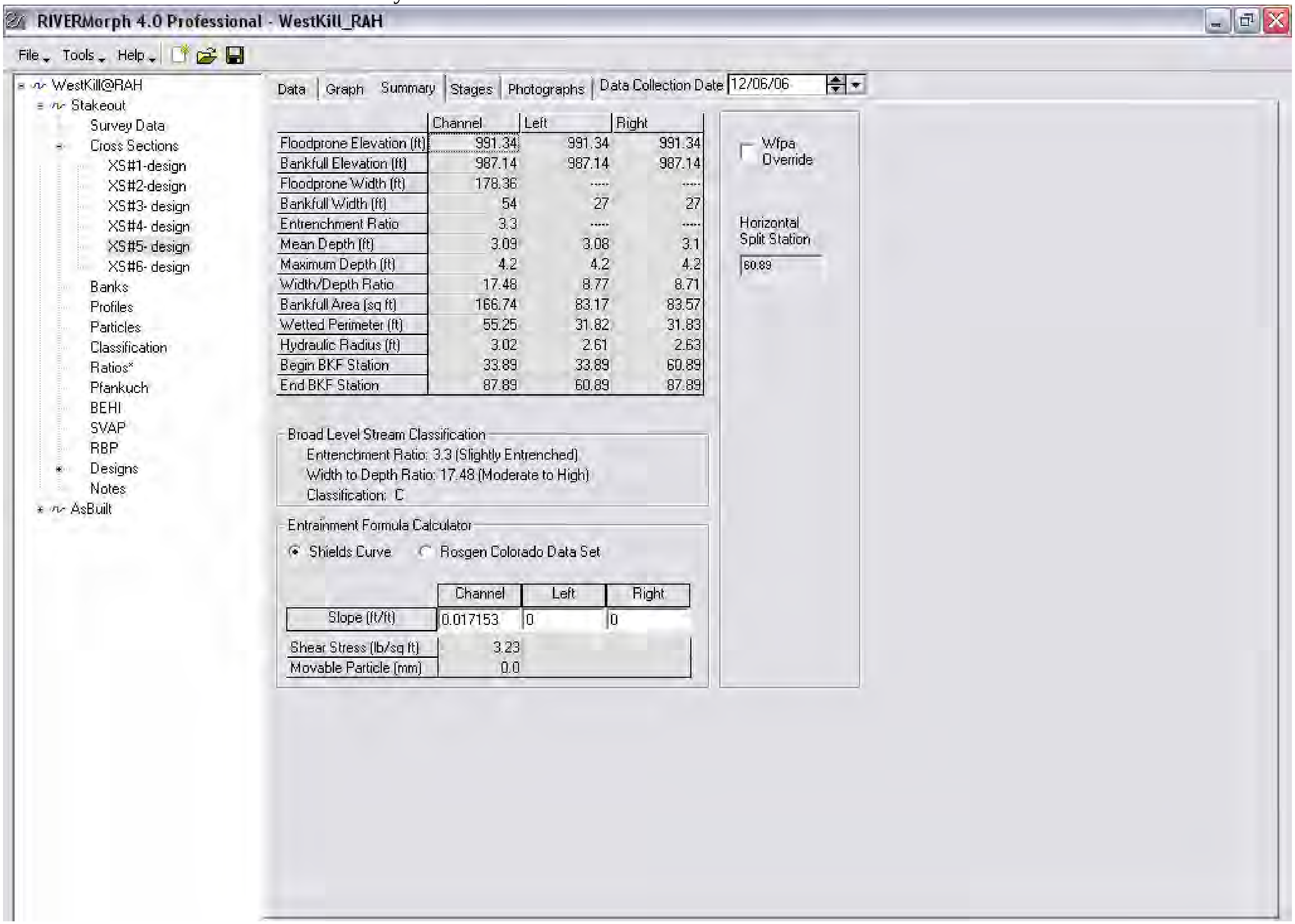
XS #4 – Stakeout cross section summary data



	Channel	Left	Right
Floodprone Elevation (ft)	994.81	994.81	994.81
Bankfull Elevation (ft)	990.61	990.61	990.61
Floodprone Width (ft)	150.34	-----	-----
Bankfull Width (ft)	54	27	27
Entrenchment Ratio	2.78	-----	-----
Mean Depth (ft)	3.09	3.1	3.08
Maximum Depth (ft)	4.2	4.2	4.2
Width/Depth Ratio	17.48	8.71	8.77
Bankfull Area (sq ft)	166.74	83.57	83.17
Wetted Perimeter (ft)	55.25	31.83	31.82
Hydraulic Radius (ft)	3.02	2.63	2.61
Begin BKF Station	90.38	90.38	117.38
End BKF Station	144.38	117.38	144.38

	Channel	Left	Right
Slope (ft/ft)	0.015651	0	0
Shear Stress (lb/sq ft)	2.95		
Movable Particle (mm)	0.0		

XS #5 – Stakeout cross section summary data



Entrainment

1. Critical Dimensionless Shear Stress is determined through a function of the ratio between the pavement and sub-pavement materials. The following is the procedure for this analysis:

    a. Collect and measure 4-5 of the largest particles resting on the lower third (tailout) of the point bar at an elevation half way between the point of maximum depth (thalweg) and bankfull. Calculate the average size (in feet) of the B-axis (median axis) of the particles collected.

    b. Collect a sediment sample from the point bar in the same location by pushing a two gallon bottomless bucket into the bar. Remove the bar material within the bucket to a depth twice the average size of the largest particles found in step "a." Process this sample through sieve analysis and determine the particle size distribution (i.e., D15, D35, D50, etc.) of the bar material by weight.

    c. Conduct a Wolman Pebble Count (100 particles) and determine the particle size distribution (i.e., D15, D35, D50, etc.) of the material on the bed of a narrow, stable riffle.

2. Using the following equations, determine the critical dimensionless shear stress.

    a. Determine ratio di / d50
    Where: di = bed material D50 of riffle
    d50 = subpavement D50 of bar sample

    b. If ratio = 3.0 – 7.0 then determine Critical Dimensionless Shear
    Stress using:
    Tci = .0834 (di / d50)-0.872

    c. If ratio = 1.3 – 3.0 then determine Critical Dimensionless Shear
    Stress using:
    Tci = .0384 (di / d50)-0.887

3. Once Critical Dimensionless Shear Stress is determined, the minimum mean bankfull depth required to move the largest particles from the lower third of the bar is calculated using:

    d = Tci (Ss)(Di) / s
    Where: d = minimum bankfull mean depth (ft)
    Ss = sediment density (1.65)
    Di = largest particle on lower third of point bar
    s = proposed average bankfull slope

Entrainment Calculation Form - Sample #1

Stream: Westkill	Reach: Near Phase I Project
Date: 10/29/01	Observers: AD, JD

Critical Dimensionless Shear Stress

$\tau_{ci} = 0.0384(d_i/d_{50})^{-0.887}$

Value	Variable	Definition
103.11	d_i (mm)	D_{50} Bed Material (D_{50} from riffle pebble count)
60.25	d_{50} (mm)	Bar Sample D_{50} or Sub-pavement D_{50}
0.024	τ_{ci}	**Critical Dimensionless Shear Stress**

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

$d_r = (\tau_{ci} * 1.65 * D_i)/S_e$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.024	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
0.0160	S_e (ft/ft)	Existing Bankfull Water Surface Slope
3.1	d_r (ft)	**Bankfull Mean Depth Required**
3.9	d_e (ft)	**Existing Bankfull Mean Depth (from riffle cross section)**
1.3	d_e/d_r	Ratio of Existing Mean Depth to Required Mean Depth

Check one: ☐ Stable (de/dr = 1) ☐ Aggrading (de/dr < 1) ☑ Degrading (de/dr > 1)

Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample:

$S_r = (\tau_{ci} * 1.65 * D_i)/d_e$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.024	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
3.9	d_e (ft)	Existing Bankfull Mean Depth (from riffle cross section)
0.0126	Sr (ft/ft)	Bankfull Water Surface Slope Required
1.3	S_e/S_r	Ratio of Existing Slope to Required Slope

Check one: ☐ Stable (Se/Sr = 1) ☐ Aggrading (Se/Sr < 1) ☑ Degrading (Se/Sr > 1)

Sediment Transport Validation

381	Largest Particle in Bar Sample D_i (mm)
3.8	Hydraulic Radius (ft)
3.79	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft^2) γ = 62.4 R=Hydraulic Radius S=Slope
650	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book: p238, Red field book: p190)
1.7	Predicted shear stress required to initiate movement of D_i (mm) (see Shields Diagram: Blue field book: p238, Red field book: p190)

Entrainment Calculation Form - Sample #2

Stream: Westkill	Reach: Near Phase I Project
Date: 10/29/01	Observers: AD, JD

Critical Dimensionless Shear Stress

$\tau_{ci} = 0.0834(d_i/d_{50})^{-0.872}$

Value	Variable	Definition
94.67	d_i (mm)	D_{50} Bed Material (D_{50} from riffle pebble count)
21.76	d_{50} (mm)	Bar Sample D_{50} or Sub-pavement D_{50}
0.023	τ_{ci}	**Critical Dimensionless Shear Stress**

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

$d_r = (\tau_{ci} * 1.65 * D_i)/S_e$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.023	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
0.0160	S_e (ft/ft)	Existing Bankfull Water Surface Slope
3.0	d_r (ft)	**Bankfull Mean Depth Required**
3.9	d_e (ft)	**Existing Bankfull Mean Depth (from riffle cross section)**
1.3	d_e/d_r	Ratio of Existing Mean Depth to Required Mean Depth

Check one: ☐ Stable (de/dr = 1) ☐ Aggrading (de/dr < 1) ☑ Degrading (de/dr > 1)

Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample:

$S_r = (\tau_{ci} * 1.65 * D_i)/d_e$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.023	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
3.9	d_e (ft)	Existing Bankfull Mean Depth (from riffle cross section)
0.0122	Sr (ft/ft)	Bankfull Water Surface Slope Required
1.3	S_e/S_r	Ratio of Existing Slope to Required Slope

Check one: ☐ Stable (Se/Sr = 1) ☐ Aggrading (Se/Sr < 1) ☑ Degrading (Se/Sr > 1)

Sediment Transport Validation

Value	Definition
381	Largest Particle in Bar Sample D_i (mm)
3.8	Hydraulic Radius (ft)
3.79	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft^2) $\gamma = 62.4$ R=Hydraulic Radius S=Slope
650	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book: p238, Red field book: p190)
1.7	Predicted shear stress required to initiate movement of D_i (mm) (see Shields Diagram: Blue field book: p238, Red field book: p190)

Entrainment Calculation Form - Sample #3

Stream: Westkill	Reach: Near Phase I Project
Date: 10/29/01	Observers: AD, JD

Critical Dimensionless Shear Stress

$$\tau_{ci} = 0.0384(d_i/d_{50})^{-0.887}$$

Value	Variable	Definition
114.02	d_i (mm)	D_{50} Bed Material (D_{50} from riffle pebble count)
72.23	d_{50} (mm)	Bar Sample D_{50} or Sub-pavement D_{50}
0.026	τ_{ci}	**Critical Dimensionless Shear Stress**

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

$$d_r = (\tau_{ci}*1.65*D_i)/S_e$$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.026	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
0.0160	S_e (ft/ft)	Existing Bankfull Water Surface Slope
3.3	d_r (ft)	**Bankfull Mean Depth Required**
3.9	d_e (ft)	**Existing Bankfull Mean Depth (from riffle cross section)**
1.2	d_e/d_r	Ratio of Existing Mean Depth to Required Mean Depth

Check one: ☐ Stable (de/dr = 1) ☐ Aggrading (de/dr < 1) ☑ Degrading (de/dr > 1)

Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample:

$$S_r = (\tau_{ci}*1.65*D_i)/d_e$$

1.65 = submerged specific weight of sediment

Value	Variable	Definition
0.026	τ_{ci}	Critical Dimensionless Shear Stress
1.25	D_i (ft)	Largest particle from bar sample
3.9	d_e (ft)	Existing Bankfull Mean Depth (from riffle cross section)
0.0135	Sr (ft/ft)	Bankfull Water Surface Slope Required
1.2	S_e/S_r	Ratio of Existing Slope to Required Slope

Check one: ☐ Stable (Se/Sr = 1) ☐ Aggrading (Se/Sr < 1) ☑ Degrading (Se/Sr > 1)

Sediment Transport Validation

381	Largest Particle in Bar Sample D_i (mm)
3.8	Hydraulic Radius (ft)
3.79	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft^2) γ = 62.4 R=Hydraulic Radius S=Slope
650	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book: p238, Red field book: p190)
1.7	Predicted shear stress required to initiate movement of D_i (mm) (see Shields Diagram: Blue field book: p238, Red field book: p190)

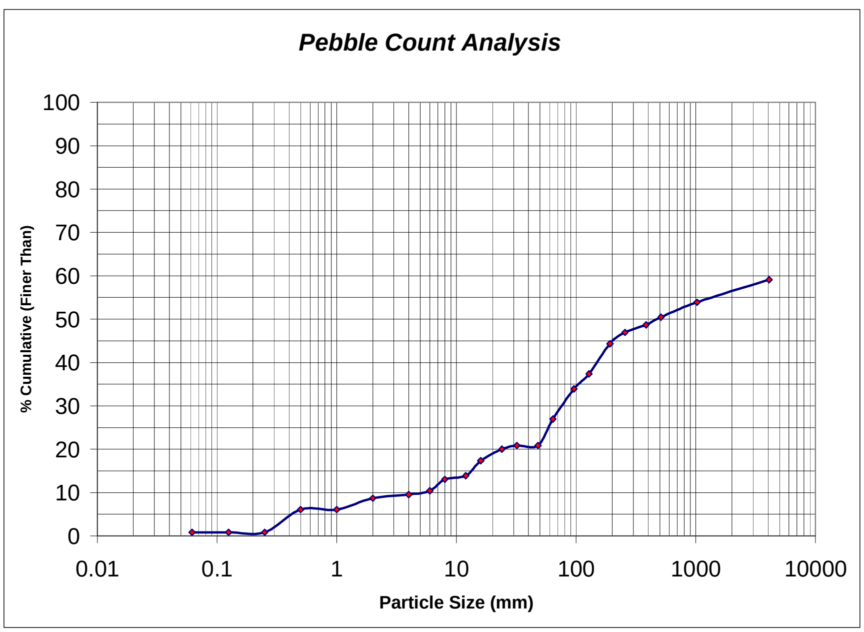
Bed material characterization, classification XS10-20, at the project site, prior to construction.

STREAM CHANNEL CLASSIFICATION -

From Graph:	
D95=	Bedrock
D84 =	Bedrock
D50 =	480.00
D35 =	106.00
D15=	13.25

Channel Material

INCHES	PARTICLE	MILLIMETERS	CLASS	TOTAL #	ITEM %	% CUM	X
	silt/clay	< .062	S/C	1	0.87	0.87	0.062
	Very Fine	.062 - .125	S			0.87	0.125
	Fine	.125 - .25	A			0.87	0.25
	Medium	.25 - .50	N	6	5.22	6.09	0.5
	Coarse	.50 - 1.0	D			6.09	1
.04 - .08	Very Coarse	1.0 - 2	S	3	2.61	8.70	2
.08 - .16	Very Fine	2 - 4		1	0.87	9.57	4
.16 - .24	Fine	4 - 6	G	1	0.87	10.43	6
.24 - .31	Fine	6 - 8	R	3	2.61	13.04	8
.31 - .47	Medium	8 - 12	A	1	0.87	13.91	12
.47 - .63	Medium	12 - 16	V	4	3.48	17.39	16
.63 - .94	Coarse	16 - 24	E	3	2.61	20.00	24
.94 - 1.26	Coarse	24 - 36	L	1	0.87	20.87	32
1.26 - 1.9	Very Coarse	32 -48	S			20.87	48
1.9 - 2.5	Very Coarse	48 - 64		7	6.09	26.96	64
2.5 - 3.8	Small	64 - 96	C	8	6.96	33.91	96
3.8 - 5.0	Small	96 - 128	O	4	3.48	37.39	128
5.0 - 7.6	Large	128 - 192	B	8	6.96	44.35	192
7.6 - 10	Large	192 - 256	L	3	2.61	46.96	256
10 - 15	Small	256 - 384	B	2	1.74	48.70	384
15 - 20	Small	384 - 512	L	2	1.74	50.43	512
20 - 40	Medium	512 - 1024	D	4	3.48	53.91	1024
40 - 160	Large	1024 - 4096	R	6	5.22	59.13	4096
	Bedrock			47	40.87	100.00	4097
			TOTAL	115	100		



Note: Bedrock samples are not included into graph

The statistics presented in the table above the chart for XS10-20 include the bedrock sampled during the pebble count. In the entrainment analysis below, we use the statistics for only the mobile portion of the bed material. Thus the D84 of the mobile portion is approximately the D50 (480mm) of the full count, and the D50 of the mobile portion is approximately the D30 (74mm) of the total count.

Appendix D. NYSDEC / ACOE Permit Application

JUN 22 2005

Table of Contents

Project Description

RCH Stable, in the Town of Lexington, NY, sustained significant damage as a result of the flooding that occurred, in the West Kill Watershed, in the first week of April, 2005. Damage to Bridge abutments, grazing facilities, and stream banks have resulted in several health and safety concerns on the site.

Damage to the private bridge on the site has left the bridge abutments compromised. As the private bridge is the only means of access to the homes and stabling facilities, repair is critical to the safety of the site. Emergency services, such as fire and rescue squad, rely on the bridge for access to the two residential structures as well as the stabling facilities.

Three stream banks on the site experienced significant erosion during the April flood. Extensive exposures of lacusterine clay deposits have been documented at two of the three eroded banks. Entrainment of colloidal clay materials poses a significant health concern from a water quality perspective. Turbidity resulting from flowing water in direct contact with clay can degrade drinking water quality, fisheries habitat, and the aesthetic quality of the water resource. In addition to the water quality impacts on the site, the erosion has under-mined fencing for the pasturing facilities of the stable. Stabilization of the eroding banks will allow for replacement of the fencing, and continued use of the facilities. This is of special concern to the project owner, as the compromised pasture is their primary grazing facility.

Mitigation Strategy

The mitigation strategy selected for the problems described above will include installation of bankfull terraces along the face of each eroding stream bank. The bankfull terrace will be constructed of appropriately sized rock material to protect the bank from continued erosion at high flow. The terrace will serve to reduce the overall slope of the bank while also reducing the velocity and shear stress exerted by high flows on the toe of the upper bank. The terrace will also provide a location for vegetation to establish. The terrace will be installed at a stage where the roots of the vegetation will be able to access adequate moisture to promote healthy growth. The root structure of the vegetation that will establish on the terrace will further reinforce the banks against erosion. As the remainders of the upper banks are currently sloped steeper than the angle of repose for the soil conditions on the site, vegetative reestablishment is unlikely without intervention. The upper banks will be sloped to an angle that will allow vegetation to establish, and will also be reinforced with erosion resistant rock material.

The erosion near the bridge abutment will be treated with rock material to establish a stable footing, and to backfill behind the wingwall of the bridge. The treatment will improve the safety and longevity of the bridge structure, while providing adequate access to the property for its residents and emergency services.

<u>Construction Sequencing</u>

<u>Phase 1</u> – Station 0+00 – 4+50

Phase 1 consists of rip rap installation on an approximately 5 ft. high eroding bank. The stream channel is divided into two threads in this reach, which will be an integral part of the dewatering plan for this portion of the project.

Phase 1a – Material Stock-piling

Stream flow will be diverted using a coffer dam into the left channel thread, removing flow from the right channel thread. This will allow access to the center bar of the channel, where rip rap material will be stock-piled. Upon completion of the stock-piling, the equipment necessary to install the rip rap will also be moved onto the center bar.

Phase 1b – Rip Rap Installation

The coffer dam installed in Phase 1a will be removed, and a new coffer dam will be installed to divert flow from the left channel thread into the right thread. While the left channel thread is de-watered, the rip rap will be installed on the eroded bank.

<u>Phase 2</u> – Station 4+50 – 8+00

Phase 2 consists of rip rap installation on an approximately 12 ft. high eroding bank. There is a large gravel bar at channel left. A passive diversion channel will be excavated through the point bar in order to de-water the work area. While in the de-watered condition, rip rap will be installed on the eroding bank. Upon completion of the rip rap installation, flow will be restored to the active channel, and the diversion channel will be removed.

<u>Phase 3</u> – Station 8+00 – 11+00

Phase 3 consists of rip rap installation on an approximately 10 ft. high eroding bank. There is a large gravel bar at channel right. A passive diversion channel will be excavated through the point bar in order to de-water the work area. While in the de-watered condition, rip rap will be installed on the eroding bank. Upon completion of the rip rap installation, flow will be restored to the active channel, and the diversion channel will be removed.

<u>Phase 4</u> – Station 14+50 – 15+00

Phase 4 consists of repair to the left downstream abutment of the private bridge. This bridge serves as the only access to two residential structures and the stabling facilities of RCH Stables. Repair of the bridge is critical for emergency services access to the homes and stable. Rip rap material will be used to armor the toe of the abutment while also filling voids behind the abutment which resulted from the flooding experienced in the watershed in April of 2005. A short piece of erosion downstream of the abutment will be armored with rip rap to ensure the stability of the bridge abutment.

Appendix E. Photos

The following pictures were taken post-construction, but before willow stakes were installed. The flow is on the recession limb of a near bankfull event. Note still water in vicinity of rock vanes.

Figure E1 Small tributary confluence through culvert

Figure E2 Bankfull bench, and backslope adjacent to pasture, looking downstream

Figure E3 Looking upstream from right bench at pasture

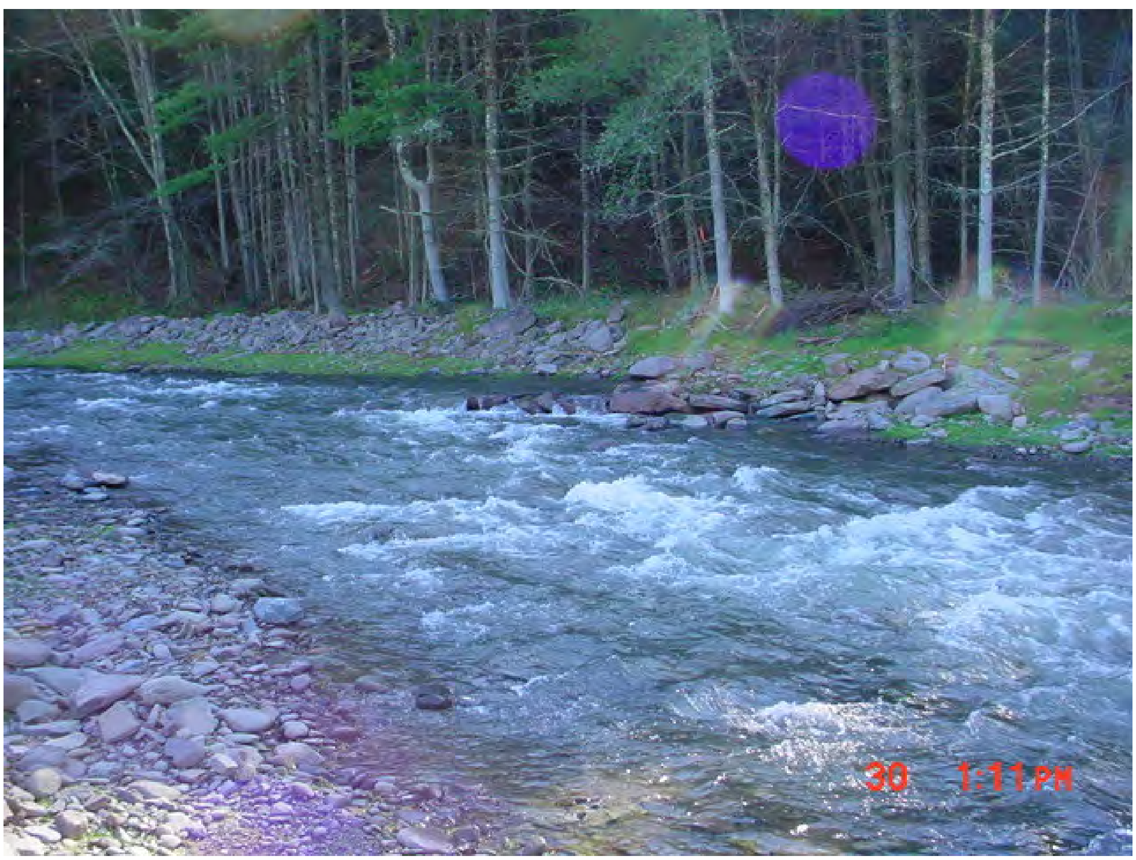


Figure E4 Looking upstream at top rock vane on left bank

Figure E5 Right bankfull bench, near bottom of pasture

Figure E6 Two rock vanes (red arrows) on lower third of right bankfull bench. Note that turbulent flow is moved off-bank, toward center of channel. Bench is seeded and planted with potted material.

Figure E7 Lower rock vane on right

Figure E8 Right bankfull bench, showing tree and shrub plantings

Figure E9 Lower bankfull bench, left

Figure E10 Point bar opposite lower bench, with plantings