Mitigation Plan for Stream Mitigation of Silver Creek and Unnamed Tributary

Silver Creek and Unnamed Tributary
Burke County, NC
SCO # D05016-1

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EXECUTIVE SUMMARY

As discussed in the Restoration Plan for Silver Creek and the associated Unnamed Tributary, the mitigation goals and objectives for the project streams were met by restoring physical and biological functions of the project streams beyond pre-existing conditions. Pre-restoration conditions consisted of impaired, channelized, eroding and entrenched stream channels. The mitigation goals and objectives were met by providing:

- Stable stream channels with features indicative of a biologically diverse environment;
- restored connections between the bankfull width and floodprone width of the channels by restoring the floodprone area;
- improved physical and aquatic habitat features;
- minimization of development and existing land use impacts to the stream; and
- long-term protection of the stream corridors.

Restoration of the streams has provided the desired habitat and stability features required to improve the quality of the stream for the long-term, such as:

- Reversing the effects of channelization;
- stabilizing eroding streambanks;
- creating instream habitat features;
- re-vegetating the riparian corridors with native trees and shrubs and preservation of existing corridors, where present; and
- restoring floodprone areas along the mainstem and unnamed tributary, thereby providing streambank and channel stability and sediment and nutrient storage.

The restoration techniques implemented on Silver Creek Mainstem and UT-A provide attributes described above using a variety of restoration practices recognized to improve stability and biological function. Restoration of the project streams re-established geomorphologic features consistent with natural stream channel characteristics. Results achieved are listed below:

- Stream channels with stable geometries to convey bankfull flows and entrain bedload and suspended sediment readily available to the streams;
- stable channel pattern based on reference reach conditions;
- in-stream channel stabilization structures, including cross vanes, step-pools, J-hook vanes, rock vanes, constructed riffles, jetties and boulder clusters that enhance aquatic habitat;
- extensive indigenous herbaceous, shrub, mid-story and canopy riparian plantings.

To demonstrate the success of the project, three forms of monitoring will be performed: (1) photo documentation; (2) ecological function assessment; and (3) channel stability measurements. Demonstration of long-term success of channel features will be tested in terms of a minimum exposure to two (2) bankfull events occurring in separate monitoring years. The monitoring shall be performed each year for the 5-year monitoring period. Long-term success criteria will be evaluated by monitoring and documenting the following:

- Channel aggradation or degradation
- streambank erosion;
- success of riparian vegetation;

- presence of instream bar deposits;
- health and survival of indigenous, non-invasive vegetation (80% survival of planted species after 5 years); and
- changes in as-built channel pattern, profile and dimension (should be minimal in comparison to as-built conditions, noting minor changes may represent increases in stability). Maintenance of floodplain connectivity, with respect to dimension, is a key success criteria.

The following table summarizes pre-existing and post-construction stream lengths, type of restoration and identification of the reaches restored as presented throughout this Mitigation Plan. The original Restoration Plan includes mitigation specific to the Silver Creek mainstem and a single unnamed tributary. As project construction progressed, it became apparent three additional unnamed tributaries were beneficially improved and protected by the restoration project. In each case the tributaries were enhanced geomorphologically and by the establishment of a riparian corridor. Geomorphologic enhancements include streambank stabilization and realignments of the channels to improve their confluences with the mainstem channel. For these reasons, the tributary channels have been included in this mitigation plan and preserved along their lengths within the established EEP Conservation Easement recorded for the Silver Creek mainstem. As a result of this change, the unnamed tributary included in the Restoration Plan is designated UT-A, and the three unnamed tributaries along the restored mainstem reach are designated UT-B, UT-C and UT-D. The tributary reach ID's used in this table are shown on the As-Built Plan Sheets in **Section 6.0** and on **Figure 2**.

Pre-Existing Conditions/Post-Construction Summary Project Number DD05016-1 (Silver Creek Restoration)					
Tributary Reach ID	Pre-existing length	Restored Length	Restoration Level	Credit Ratio*	SMUs
Silver Creek Mainstem	3,040 ft	2,905 ft	Priority Level II Restoration	1.0	2,905
Unnamed Tributary A (UT-A)	1,508 ft	1,552 ft	Priority Level II Restoration	1.0	1,552
Unnamed Tributary B (UT-B)	66 ft	66 ft	Preservation	5.0	13
Unnamed Tributary C (UT-C)	48 ft	48 ft	Preservation	5.0	10
Unnamed Tributary D (UT-D)	52 ft	52 ft	Preservation	5.0	10
Totals	**4,714 ft**	**4,623 ft**			**4,490**

*Feet of Stream/SMU credit.

The long-term monitoring of the constructed project includes ten monumented cross-sections, 3,000 linear feet of longitudinal profiles, pebble counts at each monumented cross-section, and ten monitoring plots for shrub, mid-story and canopy plantings representative of outside meanders, the 30-foot wide riparian buffer, streamside shrubs and floodplain zones. Two galvanized steel, USGS Type A, 4-foot crest gages have been installed on each restored reach; one at the bottom of the restored Silver Creek mainstem reach, and the other near the bottom of the UT-A restored reach as shown on the As-Built plans in **Section 6.0** to document bankfull and greater flows. Stream monitoring will be in accordance with the multi-agency, North Carolina Stream Mitigation

Guidelines (April 2003) applicable to Priority Level 2 Restoration projects following the template for *Content, Format and Data Requirements for EEP Monitoring Reports, Version 1.2* (11/16/06). Vegetation monitoring will be conducted in accordance with *CVS-EEP Protocol for Recording Vegetation, Version 4.0* (Lee, M.T., Peet, RK., Roberts, S.R., Wentworth, T.R. 2006) for Levels 1 and 2 Plot Sampling. Throughout the monitoring period, remedial action will be performed based on agency review of monitoring documents, and decision making between EEP and the provider to ensure the long-term success of the Silver Creek mitigation project.

1.0 PROJECT BACKGROUND

1.1 Project Site Location and Details

The project is located approximately 3,000 feet east of Dysartsville Road and approximately 2,500 feet south of Patton Road, west of the City of Morganton, in Burke County, North Carolina as shown on **Figures 1 and 2**. To locate the project site, exit I-40 at Exit 94 and travel south along Dysartsville Road and turn left (east) onto Seven Springs Lane. The project spans properties owned separately by Mr. and Mrs. Frank Queen and Mr. and Mrs. Richard Conway (Seven Springs Farms, Inc.).

The Silver Creek watershed is located in the Catawba River Basin. The project stream reaches are mapped on North Carolina Department of Transportation, Light Detection and Ranging (LiDAR) coverage and are located within USGS Catalog Unit Number 03050101 and Local Watershed 14-digit basin 03050101050050, as shown on **Figure 2**. The project includes a reach on Silver Creek mainstem and four unnamed tributary streams designated UT-A, UT-B, UT-C and UT-D. The restoration project on Silver Creek is located in a wide, Rosgen Valley Type VIII, approximately 8.25 miles upstream from the confluence of Silver Creek with the Catawba River.

The Silver Creek watershed is located in the Eastern Blue Ridge Foothills on the boundary between the Southern Inner Piedmont and Blue Ridge Mountains Physiographic Provinces of Western North Carolina. Soils are developed over fault-emplaced metamorphic and intrusive igneous rocks associated with the Smith River Allochthon and Sauratown Mountains Anticlinorium, uplifted and displaced during tectonic continental plate collision during the Alleghenian Orogeny about 356 million years (my) ago (Fullager and Odom, 1973).

Metamorphic rocks that outcrop within the Silver Creek watershed include biotite gneiss and schist, amphibolite, megacrystic biotite gneiss, and inequigranular biotite gneiss. The plutonic igneous rock formation that underlies the stream restoration project along the mainstem and the majority of UT-A is a migmatic granite gneiss (foliated to massive, granitic to quartz dioritic, biotite gneiss and amphibolite common). The spring that defines the top of UT-A emerges from an outcropping of metamorphosed plutonic granitic rock, radioactive dated to approximately 455-540 my. The exposed rock is equigranular to megacrystic, foliated to massive and includes the Toluca Granite (Fullager and Odom, 1973).

The soils along the mainstem of Silver Creek that have been derived from and developed over these metamorphic and plutonic igneous rock formations include the Colvard Series consisting of loamy sediments ranging from 40 to 60 inches or more in thickness over deposits of sandy, loamy gravelly to cobbly sediments. Rock fragments range from 0 to 15 percent to a depth of 40 inches, and from 0 to 80 percent below 40 inches. Flakes of mica range from a few to common (USDA NRCS, January 3, 2006).

Along UT-A the Rhodhiss Series is present and is residuum from the underlying felsic crystalline bedrock. The Rhodhiss sandy to sandy-clay loam is found on 25 to 40 percent hillside slopes with a depth to bedrock greater than 60 inches. The depth to the top of the argillaceous (clayey) horizon ranges from 2 to 20 inches. The depth to the base of the argillaceous horizon is 20 to 60 inches or more. The pedon contains 0 to 20 percent mica flakes throughout, with mica content ranging up to 35 percent below a depth of 40 inches when the C horizon is present. Soils mapping and taxonomic descriptions are from the NRCS Soil Survey of Burke County, North Carolina (USDA NRCS, January 3, 2006), and were provided by the Burke County Soil & Water Conservation District.

The drainage area tributary to the downstream limits of the project on the mainstem of Silver Creek is 8.26 square miles or 5,287 acres. UT-A has a contribution drainage area of 0.08 square miles or 48 acres. Although portions of UT-B, UT-C and UT-D are being preserved as a part of this Mitigation Plan, individual drainage areas for these first order tributaries have neither been delineated nor determined. Sub-watershed drainage areas for Silver Creek Mainstem and UT-A are shown on **Figure 3** and summarized in **Table 1**. Within the watershed boundaries of the project, land use is predominantly agricultural, including row crop production and pasture/hay land with wooded and cleared hillsides. Land use in the vicinity of the project is not expected to change in the foreseeable future.

TABLE 1
Drainage Areas
Project Number D05016-1 (Silver Creek and Unnamed Tributary)

Reach	Drainage Area (Acres)
Silver Creek Mainstem	5,287
UT-A to Silver Creek*	48
Total	5,287

*UT-A drainage area is included in the total drainage area for the Silver Creek Mainstem (See Figure 3).

1.2 Pre-Restoration Existing Conditions

Pre-restoration land use surrounding the project streams included active cattle pasture land along the Silver Creek mainstem. The pre-existing riparian corridor along Silver Creek, including UT-B, UT-C and UT-D, varied from wide to denuded within the project area. The wide portion consisted of a mature forested corridor, while narrow and denuded areas were the result of a recent pine beetle infestation. Active pasture is located to the east and west of UT-A. A sparsely wooded corridor is present along the reach and has been maintained. Typical species observed along the streams and adjacent forested areas include *Pinus taeda* (loblolly pine), *Platanus occidentalis* (sycamore) and *Ilex opaca* (American holly). Specific information regarding the pre-restoration condition of Silver Creek and UT-A is given in the following sections. No specific pre-restoration data was collected for UT-B, UT-C and UT-D.

Silver Creek Mainstem

Prior to restoration, agricultural land use and channel incision had altered the Silver Creek channel throughout the project reach, resulting in an unstable Rosgen F4 stream type. The incised nature of the channel was attributed to channelization and cattle intrusion, which resulted in vegetative denuding and bank destabilization due to hoof shear. The stable, natural channel form for Silver Creek mainstem was determined to be a Rosgen C4 stream type, based on detailed, quantitative analysis of a stable reference reach located approximately 2.4 miles upstream from the top of the mainstem altered reach in the Silver Creek watershed.

The Silver Creek channel's unstable width to depth ratio (5.36 – 65.14), entrenchment ratio (0.69 – 1.91), relatively flat average profile slope (0.0026 ft/ft) and poorly defined active streambed resulted in a deeply incised channel disconnected from its floodplain. Mid-channel, lateral, and transverse sand and gravel bar deposits were observed at locations throughout the entire reach, demonstrating the stream lacked stable pattern, profile and dimension to entrain its bedload. The locations of these depositional features in the near bank region deflected flows from the center of the channel toward

the incised vertical banks, accelerating streambank erosion. Near bank stress at a critical riffle cross-section, located at altered reach profile station 12+52.50, was approximately 2.24 lbs/square foot, based on design calculations. The near vertical, denuded 8-feet streambanks at this location were typical of the pre-existing impaired stream reach within the mainstem project corridor. Utilizing the near bank stress method algorithm in RiverMorph® v.4.0, it was estimated that approximately 5,570 cubic yards per year (or 6,980 tons per year) of sediment was being eroded from the unstable streambanks along the mainstem impaired reach into the Silver Creek watershed.

UT-A to Silver Creek

The UT-A channel was a classic Type I valley confined, A1-A2 stream type transitioning to a Type II colluvial valley, B4-B5 stream type in the lower third of the altered reach. The upper two-thirds of the reach exhibited some bedrock control, in-stream boulders together with flood placed woody debris from leaning or fallen trees along the unstable, steep to undercut streambanks. The impaired riparian vegetative communities were exacerbating streambank erosion rates and down-slope movement of colluvium. Cattle intrusion had adversely impacted the entire tributary as evidenced by vegetative denuding and bank failure attributed to hoof shear. Agricultural land use (pastureland) adjacent to the stream corridor and uncontrolled cattle access to the stream for drinking water and shade resulted in unstable, steep to undercut streambanks, and accelerated severe to extreme streambank erosion. The unstable streambanks were contributing large volumes of suspended sediment and bedload material to the larger Silver Creek watershed. Utilizing the near bank stress method, adjusted for channel pattern and depositional features algorithm in RiverMorph® v.4.0.1, it was estimated 290 cubic yards per year (or 375 tons per year) of sediment was being eroded from the unstable streambanks along UT-A.

UT-B, UT-C and UT-B

The pre-restoration conditions of these stream reaches were not independently evaluated in the Restoration Plan. UT-B and UT-C were located in active pastureland adjacent to Silver Creek. Defined channels were obscured by scrub herbaceous ground cover that emerged among the stumps remaining after the tree clearing associated with the pine beetle infestation. These channel reaches were poorly defined and, in some areas, denuded due to cattle intrusion. The UT-D reach, inside the EEP Conservation Easement established and recorded for the project, emerges from a mature, deciduous hardwood forested riparian corridor that was avoided and was not adversely impacted by the project.

SILVER CREEK PRE- AND POST-RESTORATION PHOTOGRAPHS

Top of Mainstem Reach – Pre-Restoration

Top of Mainstem Reach – Post Restoration – Upstream J-Hook Rock Vane No. 1 – Downstream Cross-Vane No. 1 with Root Wad/Boulder Cut-Off Sills – Looking Upstream

Mainstem Reach - Cross-Vane No. 1 with Root Wad/Boulder Cut-Off Sills, looking Downstream

Mainstem Reach – Cross-Vane No.1 - Post Revetment – Looking Upstream

General Vicinity of Cross-Vane No. 2 – Pre-Restoration – Looking Upstream

Mainstem Reach – Cross-Vane No. 2 – Post Restoration – Looking Downstream

Mainstem Reach – Cross-Vane No. 2 – Post Restoration – Looking Upstream

UT-B – Drain from Farm Pond - Post Restoration

Mainstem Reach – Over Tightened Meander – Pre-Restoration

Mainstem Reach – Over Tightened Meander – Post-Restoration Prior to Rock Vane, Log Vane - J-Hook – Root Wad Combination Channel Stabilization Structures Installation

Mainstem Reach – Over Tightened Meander – Post-Restoration - Rock Vane – Boulder Toe Bank Reinforcement – Upstream Bend – Looking Downstream

Mainstem Reach – Over Tightened Meander – Post-Restoration - Log Vane - J-Hook – Root Wad Combination Structure – Mid-Bend – Looking North (Downstream)

Mainstem Reach – Over Tightened Meander – Post-Restoration - Log Vane - J-Hook – Root Wad Combination Structure - Lower Bend – Looking Downstream

Mainstem Reach – Constructed Riffle – Downstream End – Over Tightened Meander

Mainstem Reach - Abandoned Oxbow – Pre-Restoration

Mainstem Reach – Abandoned Oxbow – Riffle Cross-Section – Looking Upstream – Pre-Restoration

Mainstem Reach – Abandoned Oxbow – Debris Jam – Looking Downstream – Pre-Restoration

Log-Vane J-Hook Structure – Upstream from former Abandoned Oxbow – Post-Restoration - Looking Upstream

Constructed Riffle with Rock Toe Bank Reinforcement - Location of former Abandoned Oxbow Post Remediation – Looking Downstream

Dual-Winged Jetty Riffle with Random Boulder Cluster - Location of former Abandoned Oxbow – Post Remediation – Looking Downstream

Rock Vane with Upstream Boulder Cluster – At confluence of UT-D – Looking Downstream

J-Hook Rock Vane – Looking Upstream at the confluence of UT-D – Post Restoration

Dual Winged Jetty Riffle with Random Boulder Cluster – Downstream from confluence of UT-D – Looking Downstream

Single Arm Rock Vane with Root Wad Bank Stabilization at approximate mid-point between confluences of UT-C and UT-D with Silver Creek – Looking Downstream

Single Arm Rock Vane with Root Wad Bank Stabilization (shown above) – Post-Restoration Looking Upstream

Log Vane J-hook Combination Structure – Upstream from Confluence of UT-C – Post Remediation

Rock Toe Channel Reinforcement upstream from confluence of UT-C with Mainstem – Post-Restoration Looking Upstream

Single Arm Rock Vane above confluence of UT-C with Silver Creek Mainstem

Confluence of UT-C with Silver Creek Mainstem

Bottom of Mainstem Reach – Pre-Restoration – Looking Upstream

Bottom of Mainstem Reach – Log-Vane, J-Hook, Root Wad Combination Structure followed by Cross-Vane No. 4 – During Construction - End of Mainstem Project

Mainstem Reach – Log-Vane, J-Hook, Root Wad Combination Structure – During Construction – February 2007

Mainstem Reach – Log-Vane, J-Hook, Root Wad Combination Structure – After Seeding, Mulching and Jute Matting Right Bank – February 2007

Mainstem Reach – Log-Vane, J-Hook, Root Wad Combination Structure – After Herbaceous Ground Cover Established – April 2007

Note: Complete photographic documentation of the Silver Creek Mainstem and UT-A restoration is keyed to the As-Built Plan sheets in **Section 6.0** and presented in **Appendix A**.

2.0 RESTORATION SUMMARY

2.1 Mitigation Goals and Objectives

As discussed in the Restoration Plan for Silver Creek and an associated Unnamed Tributary, the mitigation goals and objectives for the project streams were met by restoring physical and biological functions of the project streams beyond pre-existing conditions. Pre-restoration conditions consisted of impaired, channelized, eroding and entrenched stream channels. The mitigation goals and objectives were met by providing:

- Stable stream channels with features indicative of a biologically diverse environment
- Restored connections between the bankfull width and floodprone width of the channels by restoring the floodprone area
- Improved physical aquatic habitat features
- Minimization of development and existing land use impacts to the stream
- Long-term protection of the stream corridors

Restoration of the streams has provided the desired habitat and stability features required to improve the quality of the stream for the long-term, such as:

- Reversing the effects of channelization
- Stabilizing eroding and undercut streambanks
- Development of instream habitat features
- Re-vegetation of the riparian corridors with native trees and shrubs and preservation of existing corridors
- Restoration of the floodprone area along the mainstem providing sediment and nutrient storage.

The restoration techniques utilized for the project tributary streams provide attributes described above using a variety of features recognized to support stability and biological function essential to ecosystem enhancement. Prior to restoration, these features were absent or diminished.

Restoration of the project streams re-established geomorphologic features consistent with natural stream channel characteristics. Results achieved are listed below:

- Bankfull channels constructed with the appropriate geometries to convey bankfull flows and transport suspended sediment and bedload materials available to the streams
- Stable channel patterns consistent with natural streams in the region
- Grade control and bank stabilization features, such as cross vanes, J-hook vanes and rock vane deflector weirs that enhance environmental attributes of the stream channels though the use of natural materials and native plantings
- Streambed structures constructed using strategically placed boulder dual winged jetties, root wads and log vanes , to re-establish, sort and transport substrate materials available to the streams
- Reconnection of project stream channels to functional floodplains
- Extensive indigenous riparian plantings

2.2 Restoration Approach

Engineering Field Reconnaissance

Silver Creek Mainstem

The stable, natural channel form for the Silver Creek mainstem is a Rosgen C4 stream type, based on detailed, quantitative analysis of a stable reference reach located approximately 2.4 miles upstream from the top of the altered reach within the Silver Creek watershed. Agricultural land use, uncontrolled cattle intrusion and associated hoof shear and vegetative denuding, channelization, degradation and extreme streambank erosion have altered the channel throughout the project reach, resulted in its pre-restoration, unstable F4 stream type.

The mitigation plan for Silver Creek utilized proven geomorphologic techniques developed by understanding and implementing stable channel dimension, pattern and profile, based on data extrapolated from reference reach boundary conditions and superimposing stable dimension, pattern and profile on the unstable form. The restoration approach incorporated re-establishing the floodprone area with appropriate elevation, width and valley slope, using stable attributes measured, quantified and extrapolated from reference reach boundary conditions, to the extent practicable for online, Priority Level 2 restoration.

UT-A to Silver Creek

UT-A emerges from a granite bedrock spring at the top of the reach. Along the upper 1,000 linear feet of the altered reach, the channel form was a classic Type I valley-confined, A1-A2 stream type with some bedrock control. In-stream boulders and flood-placed woody debris from leaning or fallen trees were present along the reach. The banks were unstable and steep to undercut. The vegetated riparian corridor along UT-A was visibly impaired. Cattle intrusion had adversely impacted the entire tributary as evidenced by vegetative denuding and bank failure attributed to hoof shear. Agricultural land use (pastureland) adjacent to the stream corridor and uncontrolled cattle access to the stream for drinking water and shade resulted in unstable, steep to undercut stream banks, accelerated down-slope movement of colluvium into the stream channel resulting in severe to extreme streambank erosion. The denuded, unstable streambanks were contributing large volumes of sediment and suspended solids to the larger Silver Creek watershed.

UT-A, in its unaltered, natural form, is a Rosgen A1-A2, transitioning to a B4 stream type with bed materials ranging in size from silt and sand to large cobbles, boulders and bedrock from the bottom to the top of the reach. The transition from a v-shaped, Rosgen Type I Valley confined "A" channel to a Rosgen Type II colluvial valley "B" stream type occurs along the lower one-third of the reach. Along this final 500 linear feet stream segment, the thalweg profile gradient flattens to less than four percent (0.04 ft/ft) and the floodprone width increases enough to allow small meanders to form across the stream's narrow floodplain. Since the terrain is less rugged along this stream segment, it was the preferred watering location for cattle grazing in the adjacent pastureland within the small, 48-acre watershed. An abandoned terrace exists adjacent to and along the right (east) bank along the final 200 feet of the reach, where the stream emerges onto Silver Creek's Rosgen Type VIII Valley floodplain.

Bankfull Discharge

Silver Creek Mainstem

For Silver Creek, bankfull discharge was determined through quantitative analysis of stable reference reach boundary conditions and comparison of predicted bankfull discharge through a stable riffle section located approximately 2.4 miles upstream from the impaired reach (project area). The reference reach is a stable, Rosgen C4 stream type with excellent connection to its healthy, deciduous hardwood forest floodplain. Calculated discharge for the reference reach riffle section was compared to stratified C-type streams data from *Bankfull Regional Curves for North Carolina Mountain Streams* data set, as included in the appendices of the multi-agency *Stream Mitigation Guidelines* document (USACE Wilmington District et al., April 2003). The calculated discharge using quantified reference reach data provided a very close match to the stratified data set. Bankfull characteristics for the altered mainstem reach were extrapolated from the stratified dataset. Bankfull discharge at the top of the impaired reach, with a drainage area of 8.01 square miles and interpolated from the regional curve data set, is 460 cubic feet per second (cfs). Independent HEC-RAS modeling predicted the same flow for this position in the watershed, verifying the bankfull discharge for a 1.7-year return interval flow, extrapolated from the stratified dataset. Under pre-restoration conditions, detailed HEC-RAS analysis predicted the 5-year peak discharge storm event (2,300 cfs) would fill the existing channel (i.e., bankfull discharge) and flow out onto the abandoned floodplain.

Unnamed Tributary

Bankfull discharge for UT-A was interpreted directly from regression equations published with the *Bankfull Regional Curves for North Carolina Mountain Streams*. The mountain streams regional curves data sets do not include data for A and B stream types with drainage areas less than one square mile. Therefore the regression equations developed from the regional curves data sets were used to extrapolate beyond the lower limits of verified bankfull dimensions, discharge and drainage area relationships. The area of a surveyed riffle cross-section near the bottom of UT-A reach, however, very closely matches the empirical relationship between drainage area and bankfull cross-sectional area extrapolated from the published regional curve data for North Carolina mountain streams. The predicted bankfull discharge for UT-A using the regional curve dataset regression equations is 14.7 cfs. The calculated as-built discharge for the restored UT-A is 16.6 cfs, based on profile slope, channel dimensions and substrate particle distributions.

Channel Morphology

As previously noted, existing morphology along the Silver Creek mainstem altered reach is Rosgen Valley Type VIII. The pre-restoration channel was an unstable F4 stream type. The restoration goal was to re-establish pattern, profile and dimension consistent with the stable C4 reference reach boundary conditions, to the extent practicable using a Priority Level 2 restoration approach. Summary morphologic and hydraulic data for the Brindle Creek Reference Reach, Altered, Proposed and As-Built Mainstem and Unnamed Tributary are presented in **Table 2**. Supporting documentation for the data presented in **Table 2** are provided in **Appendix E**.

In the original restoration plan submittal, an average belt width of 110 feet and bankfull channel width, mean depth, maximum depth, channel side slopes and width/depth ratio of 30 feet, 1.59 feet, 3.0 feet, and 1:1 respectively, was proposed to consistently achieve "C" stream type channel and floodplain morphology relationships (i.e., entrenchment ratio > 2.2; width/depth ratio > 12). Due to the high sand composition of the impaired streambanks, during construction a design change was

made to lay the banks back to more stable 3:1 side slopes, resulting in wider bankfull channel with a higher width/depth ratio, ranging from 25.51 to 52.16 with a mean value of 41.60. As a result, the As-Built Silver Creek mainstem is a Rosgen Type 2 valley; B4c stream type (profile gradient < 2 percent). The B4c stream type is a stable, low sediment supply stream channel (Rosgen, 1998). Post restoration calculations of near-bank stress and predicted negligible streambank erosion rates are consistent with the textbook B4c stream type classification.

Table 2: Baseline Morphology and Hydraulic Summary
Silver Creek Stream Restoration / EEP Project No. D05016-01
Station/Reach: Silver Creek Mainstem

Parameter	Reference Reach			Pre-Existing Condition			Design			As-Built		
Dimension	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Drainage Area (mi^2)			1.16			8.26			8.26			8.26
BF Width (ft)			24.02	29.22	122.47	60.86			30.00	46.18	69.81	61.09
Floodprone Width (ft)			232.00	37.00	84.00	60.00	54.0	145.0	93.9	82.81	114.45	101.39
BF Cross Sectional Area (ft^2)			30.77	139.70	230.44	176.46			90.00	83.59	103.55	91.23
BF Mean Depth (ft)			1.28	1.88	5.45	3.95			1.59	1.29	1.81	1.53
BF Max Depth (ft)			1.72	6.57	7.62	7.04			3.00	2.80	3.75	3.32
Width/Depth (ft)			18.77	5.36	65.14	25.78			18.87	25.51	52.16	41.60
Entrenchment Ratio			9.66	0.69	1.91	1.29	1.80	4.83	3.13	1.59	1.79	1.67
Bank Height Ratio			1.00	3.89	4.07	3.98			1.00	0.93	1.02	0.98
Wetted Perimeter (ft)			26.58	35.78	152.95	75.32			33.18	46.98	70.20	61.84
Hydraulic Radius (ft)			1.16	1.51	4.28	3.23			2.71	1.27	1.78	1.51
Pattern												
*Channel Beltwidth (ft)	44.17	46.50	45.22	37	84	60	54.0	145.0	93.9	82.81	181.94	109.79
*Radius of Curvature (ft)	12.97	24.44	17.67				45.0	75.0	60.0	46.07	185.40	68.70
*Meander Wavelength (ft)	88.23	115.70	104.80						191.8	73.79	191.70	124.86
*Meander Width Ratio	1.84	1.94	1.88	0.61	1.38	0.99	1.8	4.8	3.1	1.3	3.0	1.8
Profile												
Riffle Length (ft)	19.0	31.0	25.7	6.5	10.5	12.5			32.9	9.4	47.7	28.4
Riffle Slope (ft/ft)	0.0125	0.0362	0.0211	0.0045	0.0096	0.0069			0.0056	0.0039	0.1787	0.0242
Pool Length (ft)	11.0	31.6	17.4	20.1	36.1	26.3			65.7	17.1	56.9	35.7
Pool Spacing (ft)	67.6	77.5	71.4	101.1	149.0	129.1			131.4	36.4	388.3	145.5
Substrate												
D50 (mm)			38.5	12.9	38.5	26.6	12.9	38.5	26.6	15.5	26.9	21.1
D84 (mm)			60.2	20.6	60.2	52.3	20.6	60.2	52.3	21.2	30.4	26.5
Additional Reach Parameters												
Valley Length (ft)			294.00			2077			2077			2077
Channel Length (ft)			353.00			3040			2959			2905
Sinuosity			1.2			1.46			1.43			1.40
Water Surface Slope (ft/ft)			0.0106	0.00218	0.00299	0.00259			0.0025			0.0026
BF Slope (ft/ft)			0.0115			**			0.0026			0.0027
Rosgen Classification			C4			F4	B4c	C4	C4			B4c
*Habitat Index												
*Macrobenthos												

* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria

Note: Blank fields = Historic project documentation necessary to provide these data were unavailable at the time of this report submission.

**Insufficient field indicators to estimate bankfull under altered F4 channel conditions.

Table 2: Baseline Morphology and Hydraulic Summary
Silver Creek Stream Restoration / EEP Project No. D05016-01
Station/Reach: UT-A

Parameter	Reference Reach			Pre-Existing Condition			Design			As-Built		
Dimension	Min	Max	Mean	Min	Max	Med	Min	Max	Med	Min	Max	Mean
Drainage Area (mi^2)			1.16			0.08			0.08			0.08
BF Width (ft)			24.02			13.72			8.00	6.81	8.11	
Floodprone Width (ft)			232.00	Confined	15.00	15.00	Confined	15.00	15.00	13.28	14.57	
BF Cross Sectional Area (ft^2)			30.77			3.54			3.50	3.51	3.59	
BF Mean Depth (ft)			1.28			0.26			0.50	0.43	0.53	
BF Max Depth (ft)			1.72			0.90			1.00	0.81	1.01	
Width/Depth (ft)			18.77			52.77			16.00	12.85	18.86	
Entrenchment Ratio			9.66			1.09			1.88	1.80	1.95	
Bank Height Ratio			1.00			1.91			1.00	1.00	1.00	
Wetted Perimeter (ft)			26.58			13.97			9.00	6.97	8.28	
Hydraulic Radius (ft)			1.16			0.25			0.39	0.42	0.50	
Pattern												
*Channel Beltwidth (ft)	44.17	46.50	45.22							10.80	14.57	12.95
*Radius of Curvature (ft)	12.97	24.44	17.67							9.32	124.90	23.59
*Meander Wavelength (ft)	88.23	115.70	104.80							58.82	106.30	73.72
*Meander Width Ratio	1.84	1.94	1.88							1.45	1.95	1.74
Profile												
Riffle Length (ft)	19.0	31.0	25.7							1.34	47.90	15.30
Riffle Slope (ft/ft)	0.0125	0.0362	0.0211							0.0344	0.6094	0.1389
Pool Length (ft)	11.0	31.6	17.4							6.07	22.79	12.43
Pool Spacing (ft)	67.6	77.5	71.4							10.19	143.20	55.63
Substrate												
D50 (mm)			38.5							6.9	15.8	11.4
D84 (mm)			60.2							20.2	42.4	31.3
Additional Reach Parameters												
Valley Length (ft)			294.00			1426			1426			1426
Channel Length (ft)			353.00			1508			1533			1552
Sinuosity			1.2			1.06			1.07			1.09
Water Surface Slope (ft/ft)			0.0106	0.0350	0.0500	0.0425	0.0350	0.0500	0.0425			0.0427
BF Slope (ft/ft)			0.0115			**	0.0375	0.0535	0.0455			0.0469
Rosgen Classification			C4			A-->B		A1/A2 --> B4a				B4a
*Habitat Index												
*Macrobenthos												

* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria
Note: Blank fields = Historic project documentation necessary to provide these data were unavailable at the time of this report submission.
**Insufficient field indicators to estimate bankfull under altered channel conditions.

Channel Stability Assessment

Silver Creek Mainstem

Silver Creek was a vertically contained stream that had abandoned its floodplain due to a lowering of base level and was characterized by 7 to 9 feet high, vertical to undercut streambanks. The consequences of channelization, cattle intrusion, confinement (lateral containment), major floods, changes in sediment regime and loss of riparian vegetation are attributed causes and effects for pre-existing conditions along the mainstem reach. The effects of these anthropogenic changes resulted in accelerated streambank erosion, land loss, aquatic habitat loss, lowering of the water table, land productivity reduction and in-stream and downstream sedimentation. Near-bank stress at a critical riffle cross-section, located at altered reach profile station 12+52.50, was approximately 2.24 lbs/square foot, based on design calculations. The near vertical, denuded 8-feet streambanks at this location were typical of the existing impaired 3,040 linear feet mainstem project corridor. Utilizing the near-bank stress method algorithm in RiverMorph® v.4.0.1, it was estimated 5,570 cubic yards per year (or 6,980 tons per year) of sediment was being eroded from the unstable streambanks along the mainstem prior to restoration.

Under restored conditions, the near-bank stress method algorithm in RiverMorph® v.4.0.1 was ran again, using bankfull geometry, hydraulic slope and existing streambank slopes at riffle cross-section number 4 at as-built profile station 12+80.37 (Riffle XS-4, 12+80.37). The model input parameters and predicted streambank erosion rates are as follow:

As-Built Predicted Streambank Erosion Rates for Silver Creek Mainstem

Input Parameters
Bankfull Mean Depth = 1.48 ft.
Average Bankfull Slope = 0.00265 ft/ft.
Near-Bank Maximum Depth = 2.8 ft.

Output Results
Shear Stress = 0.24 lbs/sq ft.
Near-Bank Shear Stress = 0.00 lbs/sq ft.
Near-Bank Adjective Streambank Erosion Rating = Very Low
Predicted Streambank Erosion Rates = 0.0 cubic yards/year, or 0.0 tons/year

UT-A to Silver Creek

UT-A channel was a classic Type I valley confined, A1-A2 stream type transitioning to a Type II colluvial valley, B4-B5 stream type in the lower third of the altered reach. The upper two-thirds of the reach exhibits some bedrock control, in-stream boulders together with flood placed woody debris from leaning or fallen trees along the unstable, steep to undercut streambanks under existing conditions. The impaired riparian vegetative communities exacerbated streambank erosion rates and down-slope movement of colluvium. Cattle intrusion had adversely impacted the entire tributary as evidenced by vegetative denuding and bank failure attributed to hoof shear. Agricultural land use (pastureland) adjacent to the stream corridor and uncontrolled cattle access to the stream for drinking water and shade resulted in unstable, steep to undercut streambanks, and accelerated severe to extreme streambank erosion. The unstable streambanks were contributing large volumes of suspended sediment and bedload material to the larger Silver Creek watershed. Utilizing the near bank stress method, adjusted for channel pattern and depositional features algorithm included in

RiverMorph® v.4.0, it was estimated 290 cubic yards per year (or 375 tons per year) of sediment is being eroded from the unstable stream banks along UT-A.

Under restored conditions, the near-bank stress method algorithm in RiverMorph® v.4.0.1 was utilized again, using bankfull geometry, hydraulic slope and existing streambank slopes at riffle cross-section number 1 at as-built profile station 3+21.30 (Riffle XS-1 – UT-A, 3+45.15). The model input parameters and predicted streambank erosion rates are as follow:

As-Built Predicted Streambank Erosion Rates for UT-A

Input Parameters

Bankfull Mean Depth = 0.53 ft.
Average Bankfull Slope = 0.04265 ft/ft.
Near-Bank Maximum Depth = 1.01 ft.

Output Results

Shear Stress = 1.41 lbs/sq ft.
Near-Bank Shear Stress = 0.00 lbs/sq ft.
Near-Bank Adjective Streambank Erosion Rating = Very Low
Predicted Streambank Erosion Rates = 0.0 cubic yards/year, or 0.0 tons/year

Reference Reach Data Collection

A stable reference reach, Brindle Creek, was selected using recent high-resolution (one pixel = six inches on the ground) aerial orthophotography (February 2005) obtained from the Burke County GIS Department and NCDOT LiDAR digital elevation model (DEM) used to generate 10-foot contours for Silver Creek Watershed tributary to the restoration. Two complete meander wavelengths along the reference reach were evaluated using accepted reference reach classification techniques and procedures (D.L. Rosgen, 1994).

The location of the reference reach in relation to the project is shown on **Figure 3**. The top of the reference reach begins at 35°37'07" North Latitude and 81°48'58" West Longitude (NAD 83, UTM Zone 17 Coordinates 691,930.8729 N, 1,163,198.3476 E GPS Reference Point). The drainage area tributary to the reference reach is 1.16 square miles.

Dimension, pattern, profile and substrate data were collected along the reference reach and quantitatively evaluated using RiverMorph® v.4.0.1 software application. Reference reach classification geomorphologic summary reports are presented in **Appendix B**.

Reference Reach Classification

The reference reach is a stable, Rosgen C4 stream type with excellent connection to its healthy, deciduous hardwood forest floodplain. Calculated discharge for a stable reference reach riffle cross-section was compared to stratified C Type streams data from *Bankfull Regional Curves for North Carolina Mountain Streams* data set. The calculated discharge using quantified reference reach data is a very close match to the stratified data's empirical relationships.

Reference Reach Discharge

The calculated bankfull discharge, using quantified and verified reference reach data collected at a stable riffle cross-section is 96.1 cfs and very closely matches the empirical relationship between drainage area and discharge using the *Bankfull Regional Curves for North Carolina Mountain Streams* dataset, stratified by C type streams.

Channel Morphology

Stream channel morphology data for the Brindle Creek reference reach, the Silver Creek mainstem, and UT-A is presented in tabular format on **Table 2**.

Channel Stability Assessment

The reference reach plant community extends over the streambanks into the active channel. High root densities and depths were observed at both stable riffle and pool locations throughout the reference reach, with healthy communities of canopy, mid-story, shrub and herbaceous species present. Best-fit trend lines drawn through the bankfull indicator points, water surface and thalweg points, respectively, on the longitudinal profile were essentially parallel. There is no indication of head cutting, downcutting, streambank erosion, aggradation or degradation. The reference reach is an extremely stable, second-order C4 stream channel, with a large gravel to small cobble streambed substrate, based on quantitative analysis of reference reach boundary conditions measured in the field.

Vegetation

The reference reach exists within a second-growth, forested floodplain containing mature trees, saplings, and some shrubs. Tree species observed along the reference reach include *Pinus taeda*, *Platanus occidentalis*, *Quercus rubra* (red oak), and *Fagus grandifolia* (American beech). Scattered *Symplocos tinctoria* (common sweetleaf) shrubs were also present. Vegetative cover along the reference reach is much more dense and intact than that along Silver Creek and UT-A. The reference reach flows through a wide forested area, rather than a narrow riparian corridor. Vegetation along the reference reach is undisturbed, and tree roots along the channel are providing stability along the reach.

Silver Creek Mainstem

The restoration approach implemented along the mainstem of Silver Creek restores stable pattern, profile, dimension and biological function. This was be accomplished by raising the streambed using grade control structures, including three (3) cross-vanes and eight (6) J-hook log vanes and two (2) J-hook rock vanes, two (2) dual winged jetties with random boulder placement to reduce critical shear stress in the near bank region while maintaining flow velocities required to entrain coarse gravel, based upon streambed particle size distributions collected from both the stable reference reach and the altered mainstem reach. Four (4) single arm rock vanes were installed in critical bends to divert bankfull flows away from the streambanks into the center of the channel. Four (4) constructed riffles were installed to maintain entrainment velocities and enhance aquatic habitat via natural aeration through the structures. Schools of fish returned to the reach during construction and built spawning beds in the gravels sorted out in the glides coming out of the pools. The streambed structures have created aquatic habitat and are preventing the development of deleterious mid-channel, lateral and transverse depositional sand and gravel bars features from forming within the active channel. The

As-Built plan sheets showing the improvements on the Silver Creek mainstem (Sheets AB-2/10 through AB-6/10) are included in **Section 6.0**.

Unnamed Tributary to Silver Creek

The fundamental approach used to stabilize UT-A within its valley confined stream corridor was accomplished by appropriately sizing the channel to convey bankfull flows, reshaping and stabilizing steep to undercut banks with heavy coir fabric jute matting, combined with implementing an aggressive native revetment plan and excluding cattle from the riparian corridor. Sixteen (16) step-pools were constructed at appropriate spacings to raise the streambed and dissipate energy during bankfull and greater flows along the reach. Additionally, ten (10) constructed riffles were installed to provide grade control and stability along the reach. Outside meander bends, near the bottom of the reach, are stabilized with rock toe, coir roll, jute matting, live stem bank reinforcement. The plan sheets showing the as-built condition of UT-A stream (AB-7/10 through AB-10/10) are included in Appendix 1.

As-Built Channel Classification

The as-built mainstem channel is a stable B4c (entrenchment ration < 2.2, profile gradient < 2%) Rosgen Stream Type, with restored pattern, profile, dimension to entrain its bedload without aggrading or degrading. The as-built Unnamed Tributary stream is a Rosgen B4a Stream Type (profile gradient > 4%). **Table 3** summarizes the restoration structure and objectives for Silver Creek and UT-A.

2.3 Restoration Summary

A summary of the restoration activities for the project are presented in **Table 3** below.

Table 3: Restoration Summary
Project Number DD05016-1 (Silver Creek Restoration)

Tributary Reach ID	Pre-existing length	Restored Length	Restoration Level	Credit Ratio*	SMUs
Silver Creek Mainstem	3,040 ft	2,905 ft	Priority Level II Restoration	1.0	2,905
Unnamed Tributary A (UT-A)	1,508 ft	1,552 ft	Priority Level II Restoration	1.0	1,552
Unnamed Tributary B (UT-B)	66 ft	66 ft	Preservation	5.0	13
Unnamed Tributary C (UT-C)	48 ft	48 ft	Preservation	5.0	10
Unnamed Tributary D (UT-D)	52 ft	52 ft	Preservation	5.0	10
Totals	**4,714 ft**	**4,623 ft**			**4,490**

*Feet of stream/SMU credit.

3.0 MONITORING PLAN

To demonstrate the success of the project, three forms of monitoring will be performed: (1) photo documentation; (2) ecological function; and (3) channel stability measurements. Long-term success criteria will be evaluated by monitoring and documenting the following:

- Channel aggradation or degradation
- Streambank erosion
- Effectiveness of erosion control measures
- Presence of instream bar deposits
- Health and survival of indigenous, non-invasive vegetation
- Changes in as-built channel pattern, profile and dimension

Parameters included in the annual stream monitoring to ensure the success of the restoration activities will include stream channel surveys along longitudinal profiles and monumented cross sections, pebble counts across representative riffle and pool cross-sections, photographs, and vegetation surveys.

The restoration site will be monitored for five consecutive years or until the required success criteria have been met as determined by North Carolina Division of Water Quality (DWQ) and the Wilmington District of the U.S. Army Corps of Engineers (USACE). Channel stability monitoring including measurements and photographs will be performed during the November 2007. Planting occurred during the spring of 2007. Per agreement reached with the EEP, the planted vegetation will be monitored during the 2007 growing season, during September or October. Monitoring will be conducted in accordance with the multi-agency, North Carolina Stream Mitigation Guidelines (April 2003) applicable to Restoration and Enhancement Level I projects and the template *Content, Format and Data Requirements for EEP Monitoring Reports, Version 1.2* (11/16/06). Vegetation monitoring will be conducting in accordance with *CVS-EEP Protocol for Recording Vegetation, Version 4.0* (Lee, M.T., Peet, RK., Roberts, S.R., Wentworth, T.R. 2006) for Levels 1 and 2 Plot Sampling

Monitoring reports and discussions of remedial actions will take place with EEP. EEP will review the monitoring documents and make them available to the agencies after the review period. Decision making regarding remediation will be between EEP and WRC and its agents or representatives. Agency interaction will take place through permit requests for maintenance should they become necessary. Agency interaction will take place at the end of the monitoring period.

3.1 Stream Channel Monitoring

Stream channel stability will be physically monitored at the 10 permanent, monumented cross-sections. Stream stability and pattern will also be evaluated along 3,000 linear feet of long-term monitoring longitudinal profiles (1,955 linear feet on the Silver Creek mainstem and 1,045 linear feet on UT-A) Photographs will be taken up-stream, down-stream and across channel at each monumented cross-section on an annual basis. The monumented cross-section locations and longitudinal profiles were surveyed immediately following construction as part of the "as-built" survey and are shown on the As-Built Plan sheets. The As-Built Plan sheets in **Section 6.0** include the dimension, pattern, and profiles of the constructed stream channels. The As-Built condition (Year 0) will be utilized as baseline to compare future monitoring surveys and subsequently to determine channel stability and transition. Year 0 "As-Built" Long-Term Monitoring Profiles are included in **Appendix C**. Year 0 "As-Built" Long-Term Monitoring Cross-Section summary templates are included in **Appendix D.**

Yearly monitoring will also include pebble counts to assess particle distributions of streambed materials. Pebble count data will be collected at each of the ten monumented cross-section locations representative of the constructed project reaches: five cross-sections through pools and five cross-sections through riffles. The number and particles in standard size classes will be reported each year to assess aquatic habitat, sediment transport, sorting and depositional trends, as well as stream stability over time. Annual inspection of in-stream structures will also occur to verify proper function and channel stability. Stream channel monitoring surveys will be completed annually for five consecutive years, starting in November 2007 (Year 1) six months after construction completion and permanent revetment of the stream corridors during April and May 2007.

Bankfull flow events will be documented at least twice during the five year monitoring period, during separate monitoring years. These events will be documented utilizing two (2) crest-stage stream gages installed on the project reaches and by photographic evidence after bankfull flows in the stream channels,. The locations of the crest-stage stream gages are shown on the As-Built Plan Sheets in **Section 6.0**. In the event two bankfull events do not occur during the five-year monitoring period, consultations with the U.S. Army Corps of Engineers, the Division of Water Quality and the resource agencies will be coordinated to determine if further monitoring is necessary to demonstrate success criteria have been achieved.

3.2 Planted Woody Vegetation Monitoring

Woody vegetation planted along the streams will be monitored for five consecutive years. Per mitigations between the provider and EEP a total of 10 ten by ten meter square plots (six along Silver Creek and four along UT-A) have been permanently established. Corner markers were permanently installed and one corner surveyed for future use. The species, density of living stems, and the cause of mortality if identifiable will be recorded for all planted woody species within each plot. Vegetation will be sampled annually and reported every year along with the data collected during the physical monitoring of the channel. The focus of the vegetative monitoring will be a stem count on planted individuals in the tree and shrub stratum, although percent cover of the plot will also be recorded and documented via photographs taken of each plot. Vegetative problem areas along the project area will be identified, mapped, and documented via photographs. Vegetation monitoring will occur between the months of September and October.

3.3 Performance Standards

The performance standards for the restoration project are those mandated in the multi-agency *Stream Mitigation Guidelines* (USACE Wilmington District, et al., April 2003). Performance goals for the site are:

- Minimal or negligible development of instream bar deposits.
- Minimal or negligible change in channel pattern, profile and dimension in comparison to As-Built conditions. Adjustments may occur and some may be indicative of increasing stability, such as moderate reductions in width/depth ratios as a result of slight channel narrowing and natural sorting and shaping of bed materials and features
- Maintenance of floodplain connectivity (only reductions or very small increases will be considered acceptable).
- Target density of 320 stems per acre after 3 years and 260 stems per acre after 5 years for planted woody vegetation (represents 80% survival after 5 years).

Subsequent monitoring reports will address the attainment of performance goals. If goals are not be attained, then the monitoring reports will document any remedial actions taken during the monitoring period and the success of these actions.

3.4 Additional Monitoring for DWQ

In addition to the monitoring described in the previous sections, additional monitoring has been required by the NC DWQ under the Section 401 permit issued for the project on May 25, 2007. The 401 permit conditions require monitoring data collection related to bank stability and success of vegetative plantings installed along Unnamed UT-B and UT-C, which were incidentally impacted during restoration construction along Silver Creek. Portions of these tributary channels are included in this Mitigation Plan under the category of EEP preservation credit. This additional monitoring data will be collected and summarized in the monitoring reports for Silver Creek and UT-A and will be provided to the DWQ Asheville District office at the same time it is submitted to the EEP for review.

4.0 MAINTENANCE AND CONTINGENCY PLANS

Adaptive management is a systematic process for developing knowledge and continually improving project development by learning from previous projects and their performance outcomes (River Institute, 2004). This project is large in scope and entails many new applications of natural stream channel design methodologies, making an adaptive management approach essential to the success of the project. Rather than following the conventional approach to construction projects where a plan is developed and closely constructed in a rigid and structured format, we will employ a adaptive management strategy in the truest sense. Essentially, we have initiated the initial restoration of the Silver Creek Mainstem and UT-A in the context of the data, methodologies and technology currently available. As the project is monitored, we will collect data to verify the streams are evolving in the direction of increased stability and biological diversity. As the data are collected and evaluated, the knowledge gained will be directly integrated into the management and maintenance of the project throughout the monitoring period.

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6.0 As-Built Plan Sheets

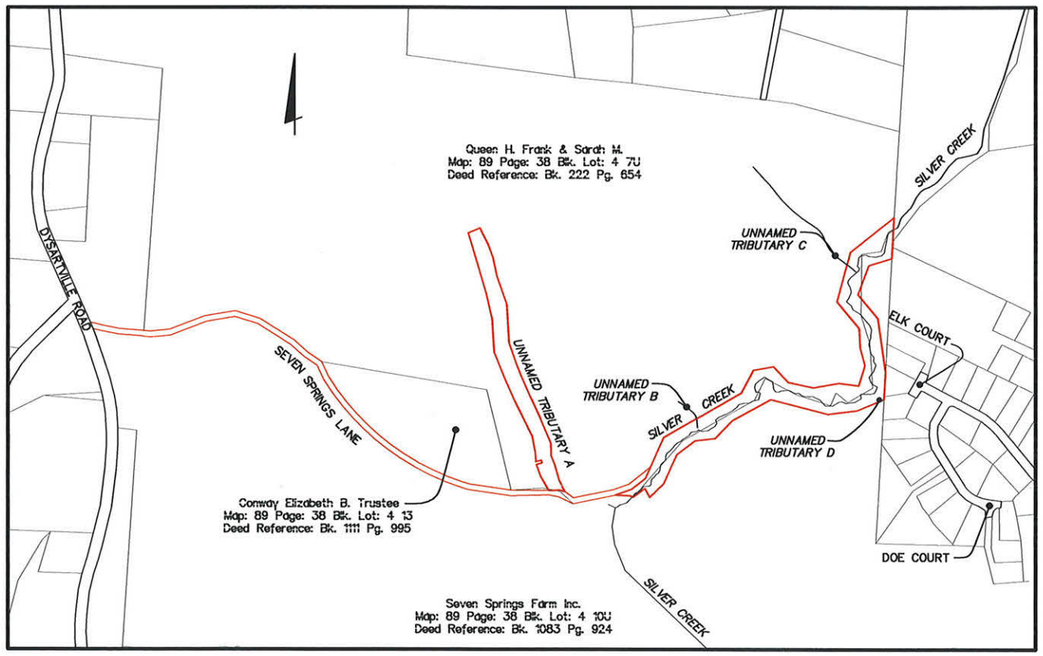
BURKE COUNTY, NORTH CAROLINA

STREAM AS-BUILT

FOR

SILVER CREEK AND UNNAMED TRIBUTARY

2007



LOCATION MAP
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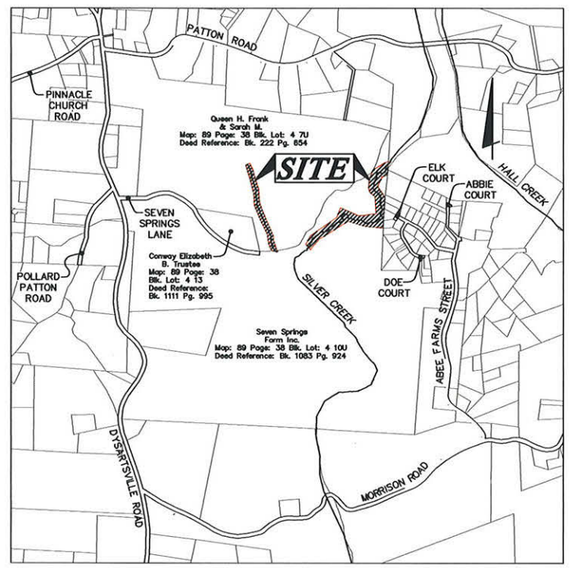

VICINITY MAP
Not To Scale

NORTH CAROLINA PROFESSIONAL SEAL PE 029095 ENGINEER SCOTT MCCLINTON

Registered Engineer No. PE-029095 Date 9/11/07

Note: The professional engineer's certificate on this plan is only with respect to the dipiction of the as-built information provided by Garber Surveying Company, and shown hereon.

Job No. 2005-1446
Sheet AB-01/10
Date September, 2007
Scale As Noted

BURKE COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
SILVER CREEK AND UNNAMED TRIBUTARY
SILVER CREEK

Ecosystem Enhancement PROGRAM

EMH&T
Evans, Mechwart, Hambleton & Tilton, Inc.
Engineers • Surveyors • Planners • Scientists
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M C M X X V I

REVISIONS

MARK	DATE	DESCRIPTION

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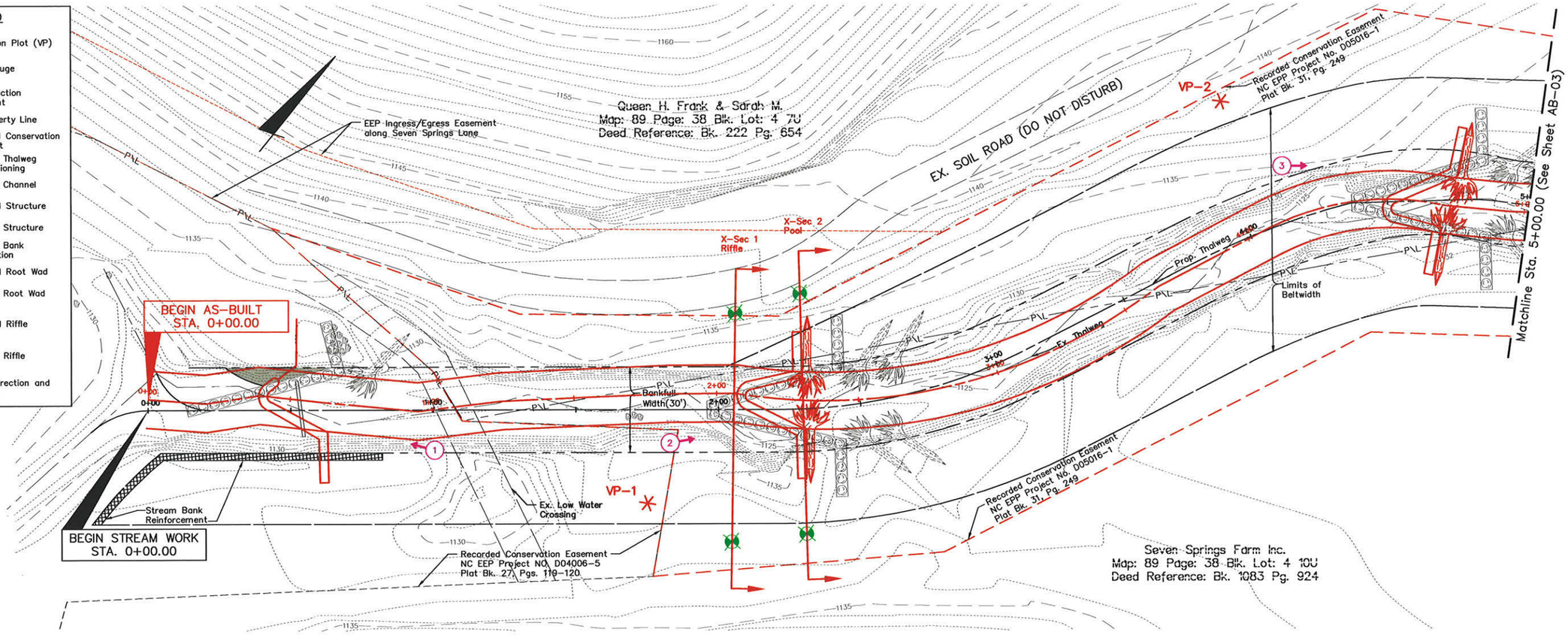
LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- As-Built Channel
- Proposed Structure
- As-Built Structure
- As-Built Bank Stabilization
- Proposed Root Wad
- As-Built Root Wad
- Proposed Riffle
- As-Built Riffle
- Photo Direction and Location



– Permanent fencing has been installed along or outside the limits of the conservation easement.

40 0 40 Feet
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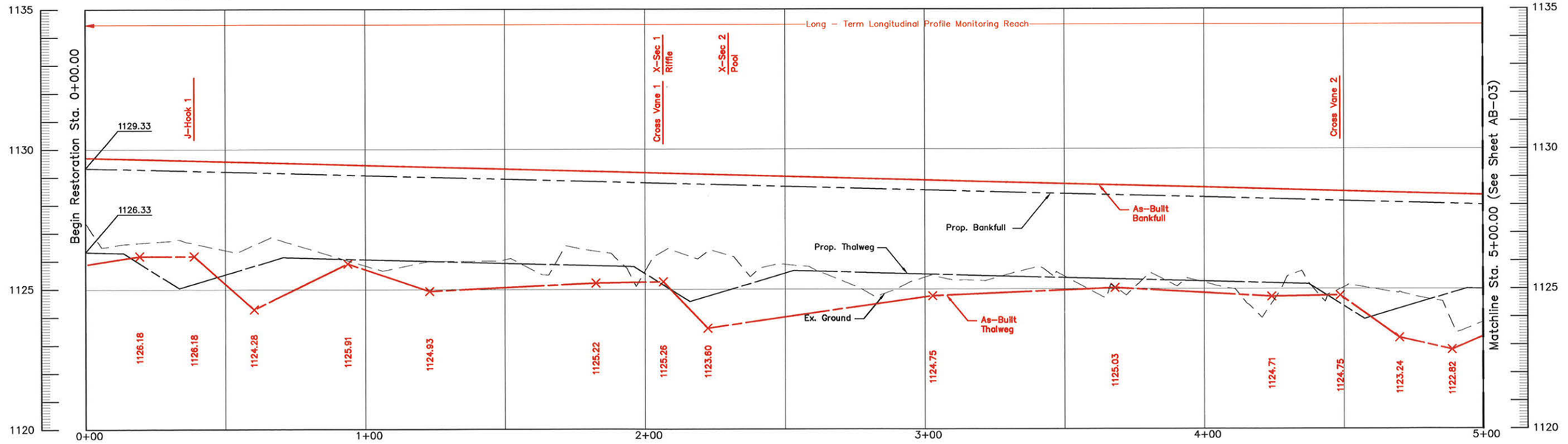
Scale: 1" = 40'



Profile stationing shown above is from the stream profile proposed in the restoration plan.

Job No. 2005-1446 | Sheet AB-02/10
Date September, 2007 | Scale Hor: 1" = 40' Ver: 1" = 4'

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STREAM AS-BUILT
FOR
SILVER CREEK AND UNNAMED TRIBUTARY
SILVER CREEK
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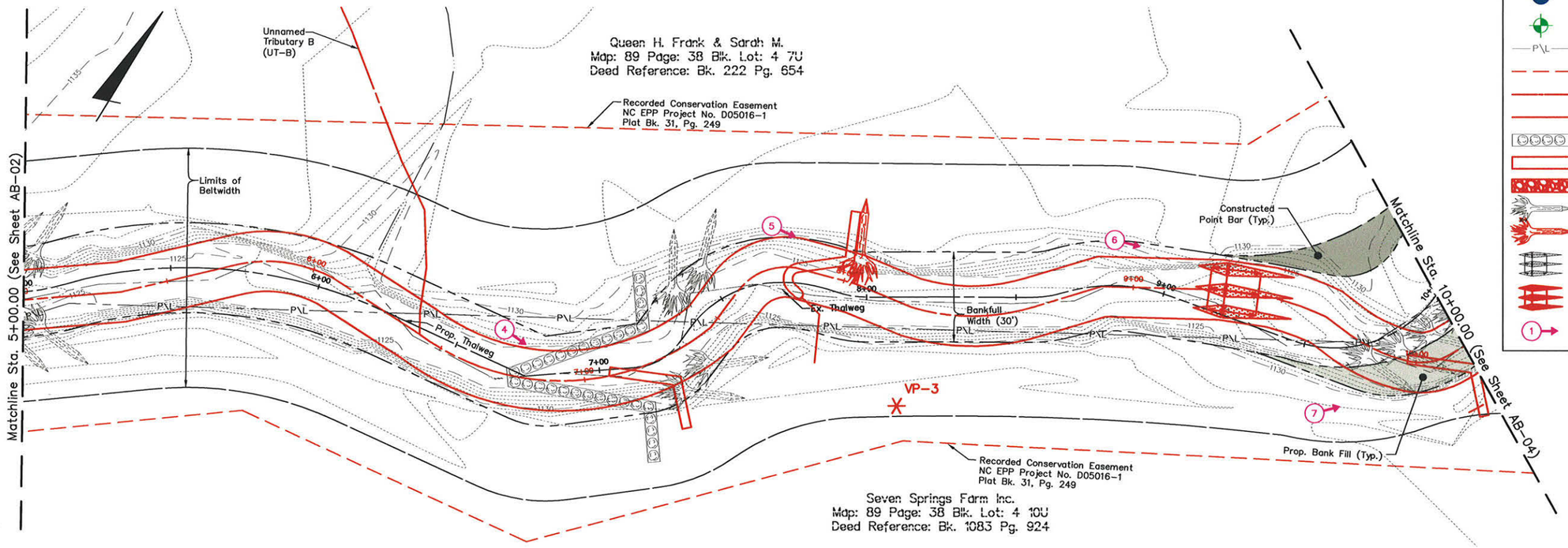
MARK	DATE	DESCRIPTION



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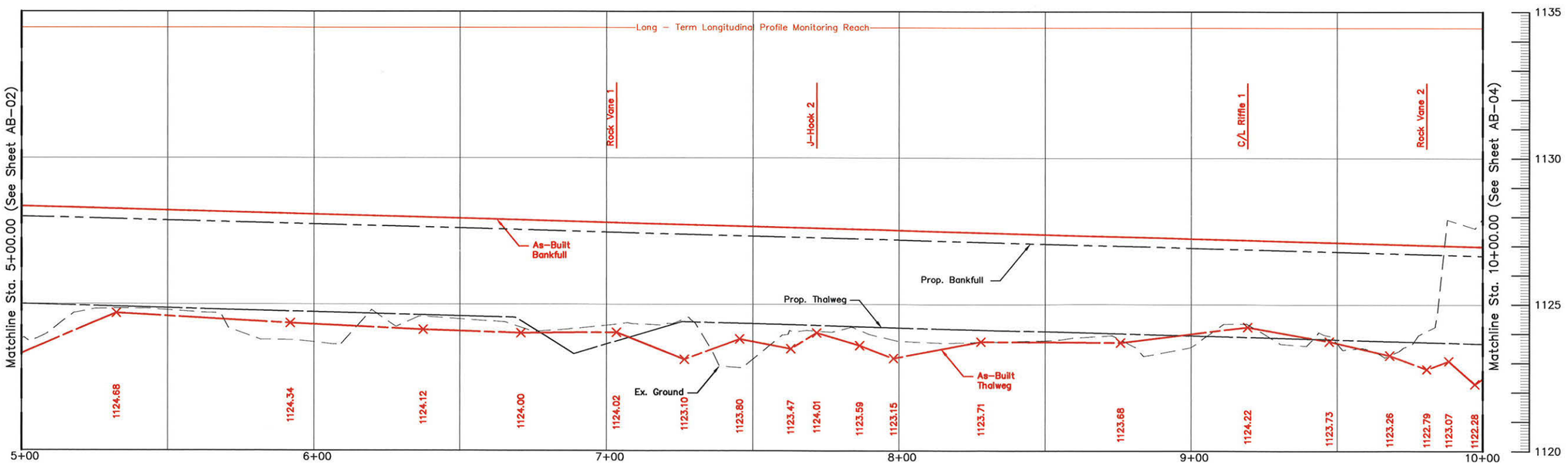

Profile stationing shown above is from the stream profile proposed in the restoration plan.

Job No. 2005-1446
Sheet AB-03/10
Date September, 2007
Scale Hor: 1" = 40' Ver: 1" = 4'

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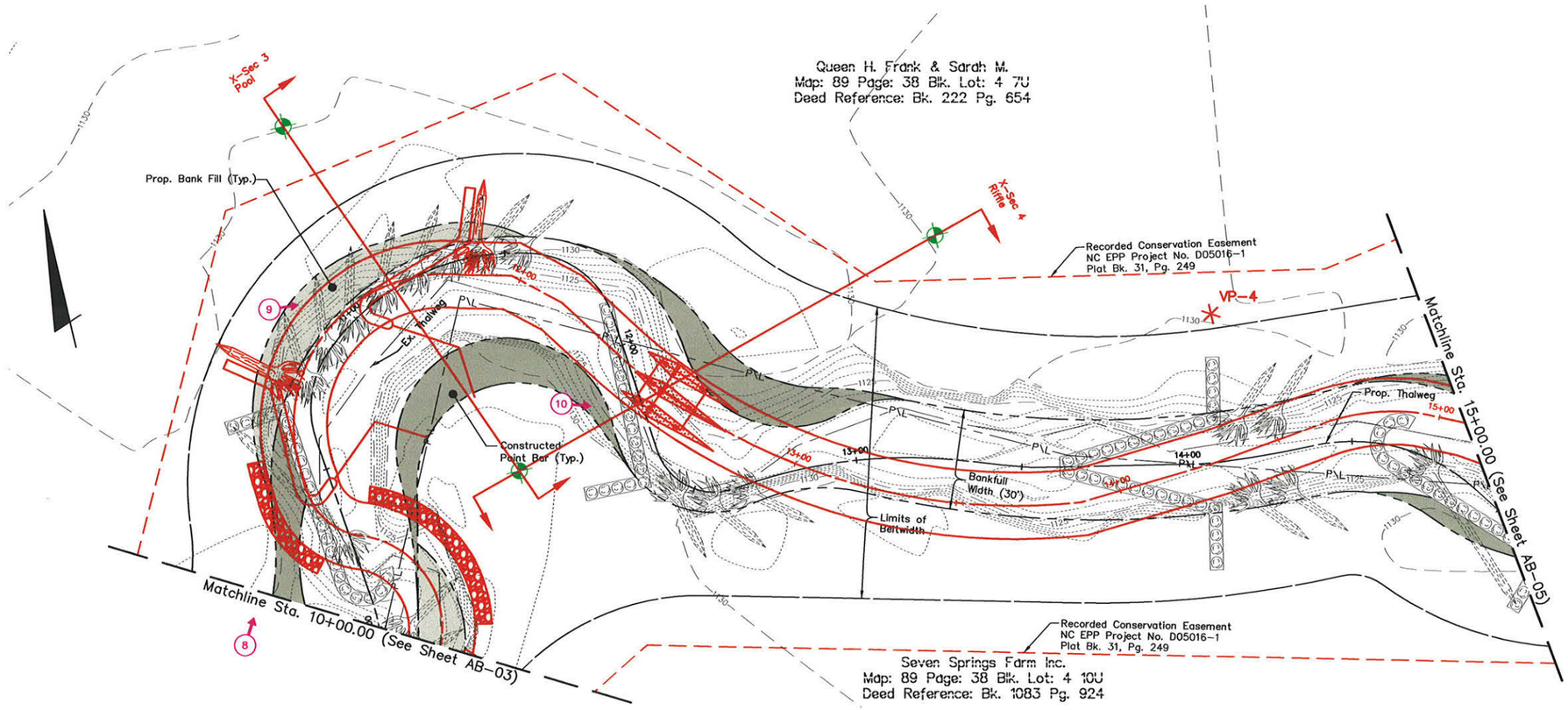

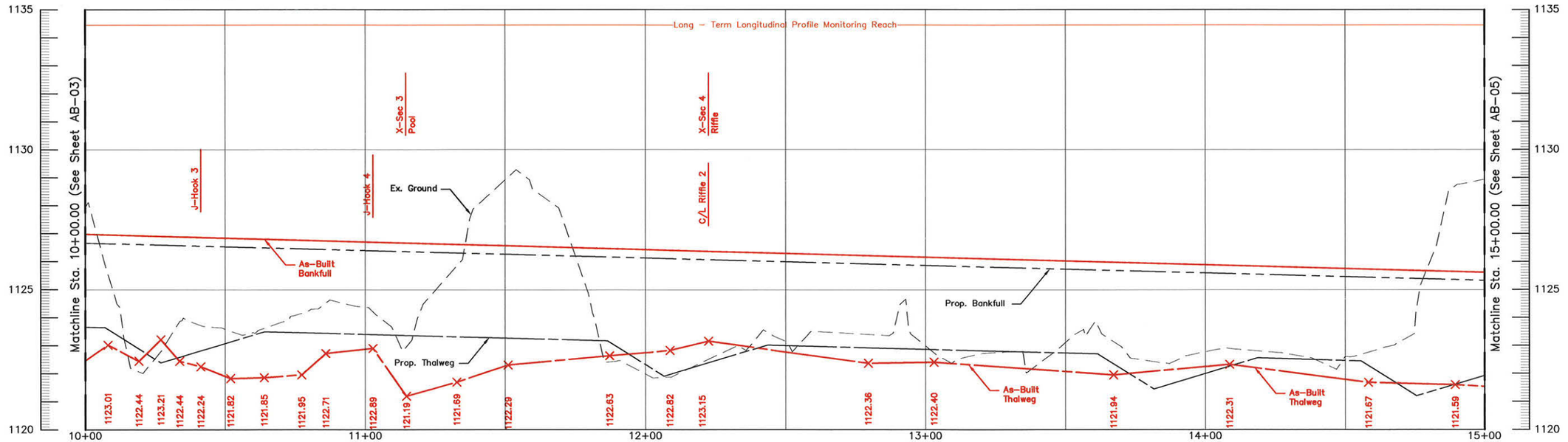

Profile stationing shown above is from the stream profile proposed in the restoration plan.

LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- As-Built Channel
- Proposed Structure
- As-Built Structure
- As-Built Bank Stabilization
- Proposed Root Wad
- As-Built Root Wad
- Proposed Riffle
- As-Built Riffle
- Photo Direction and Location

Job No. 2005-1446 | Sheet AB-04/10

Date September, 2007 | Scale Hor: 1" = 40' Ver: 1" = 4'

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MARK	DATE	DESCRIPTION

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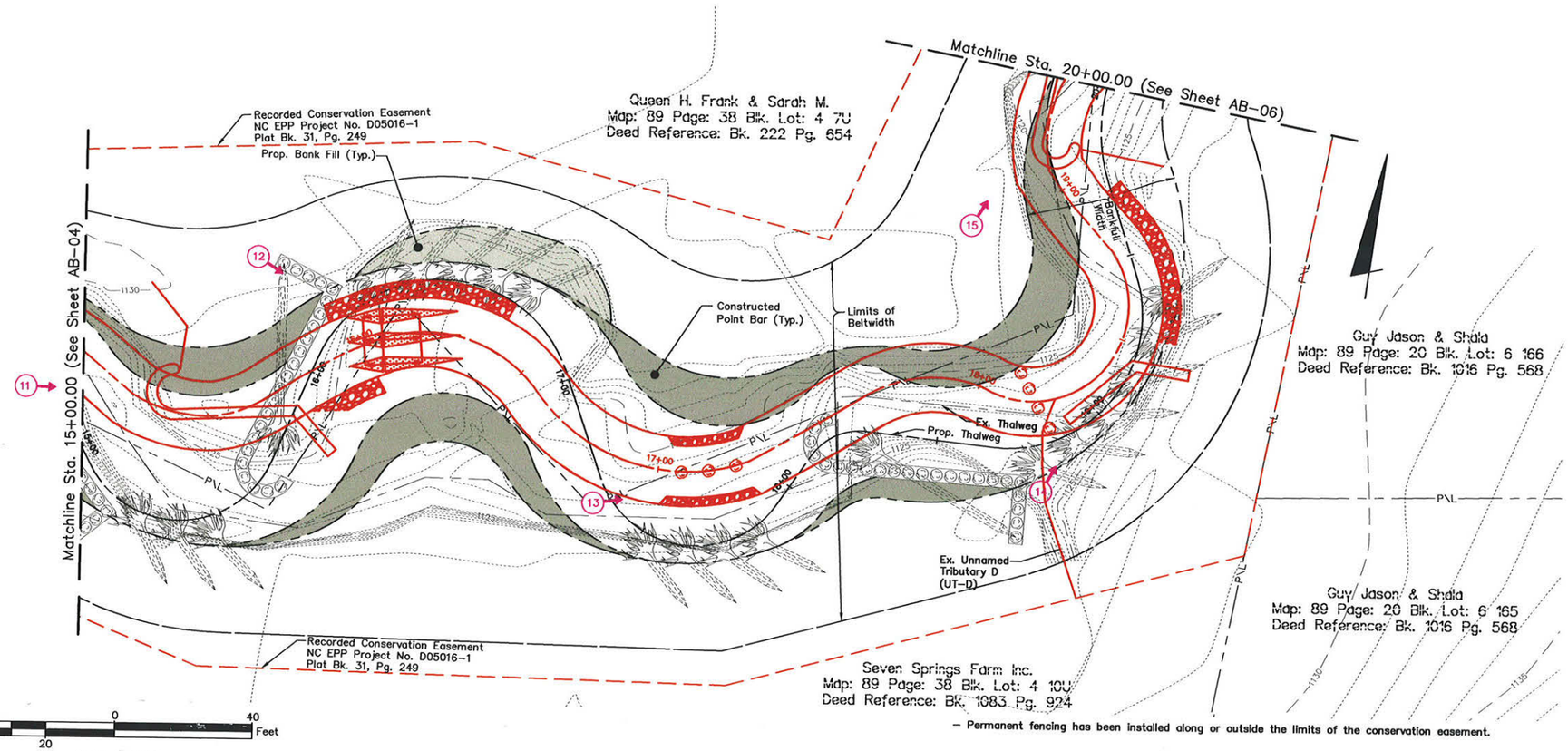
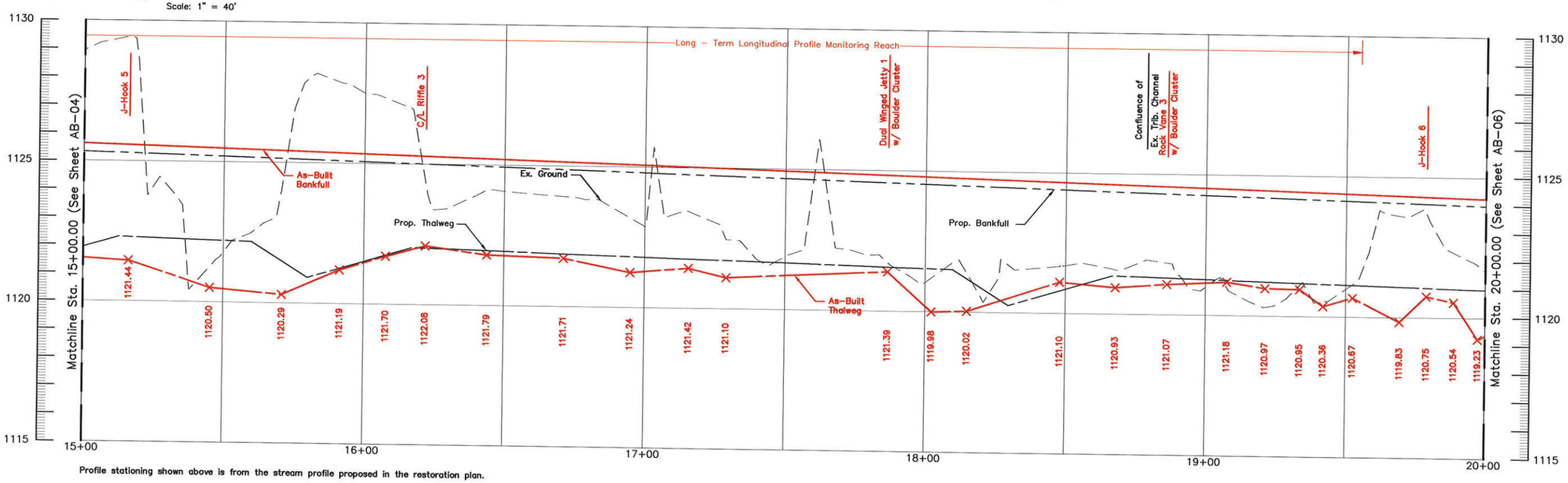


– Permanent fencing has been installed along or outside the limits of the conservation easement.



Profile stationing shown above is from the stream profile proposed in the restoration plan.

LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- As-Built Channel
- Proposed Structure
- As-Built Structure
- As-Built Bank Stabilization
- Proposed Root Wad
- As-Built Root Wad
- Proposed Riffle
- As-Built Riffle
- As-Built Dual Winged Jetty
- As-Built Boulders
- Photo Direction and Location

Job No. 2005-1446 | Sheet AB-05/10

Date September, 2007 | Scale Hor. 1" = 40' Ver. 1" = 4'

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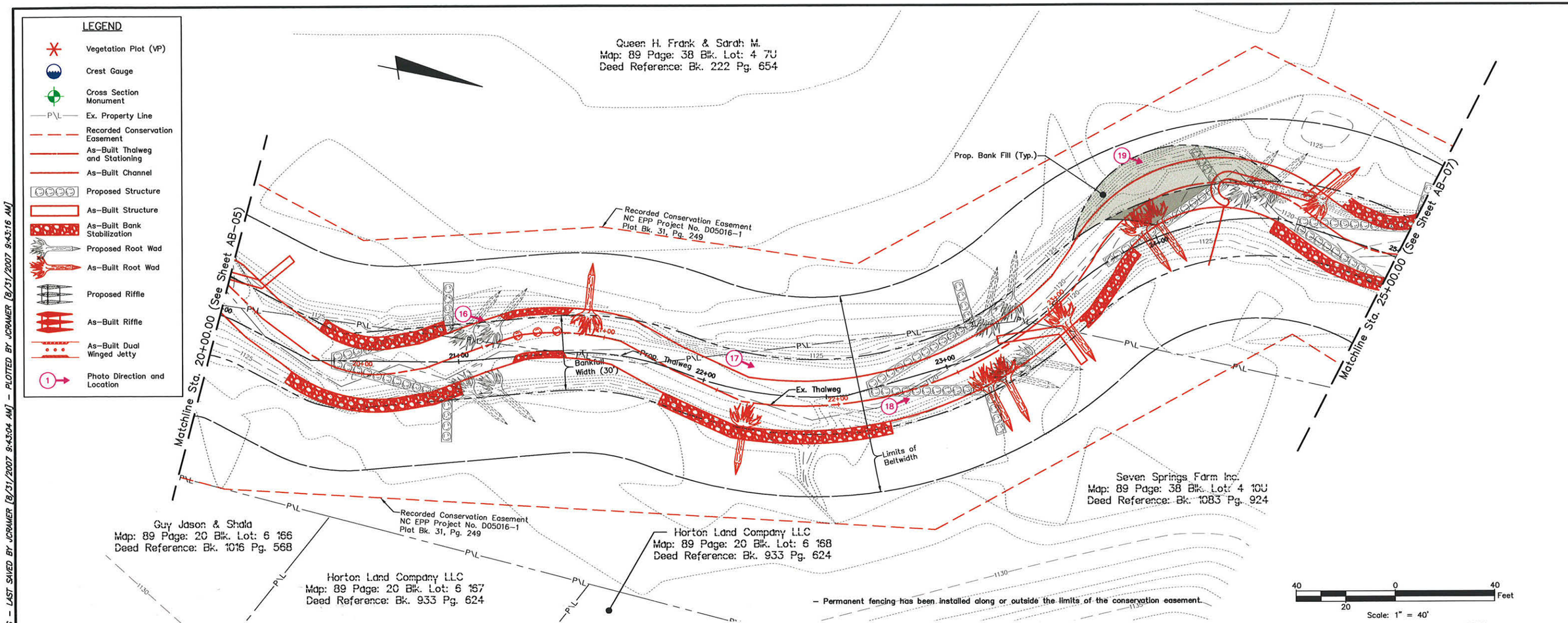

Profile stationing shown above is from the stream profile proposed in the restoration plan.

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Date	Job No.
September, 2007	2005-1446
Scale	Sheet
Hor: 1" = 40' Ver: 1" = 4'	AB-06/10

REVISIONS

MARK	DATE	DESCRIPTION

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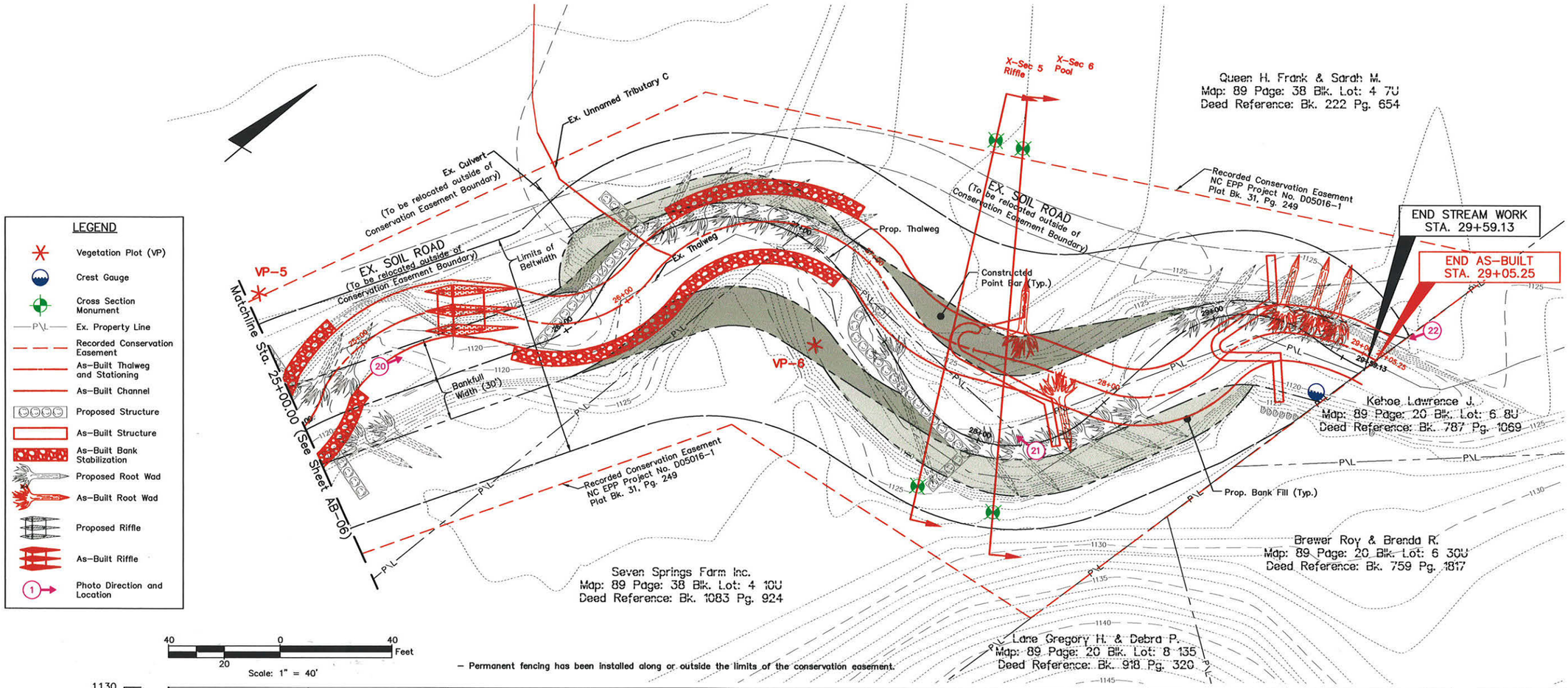

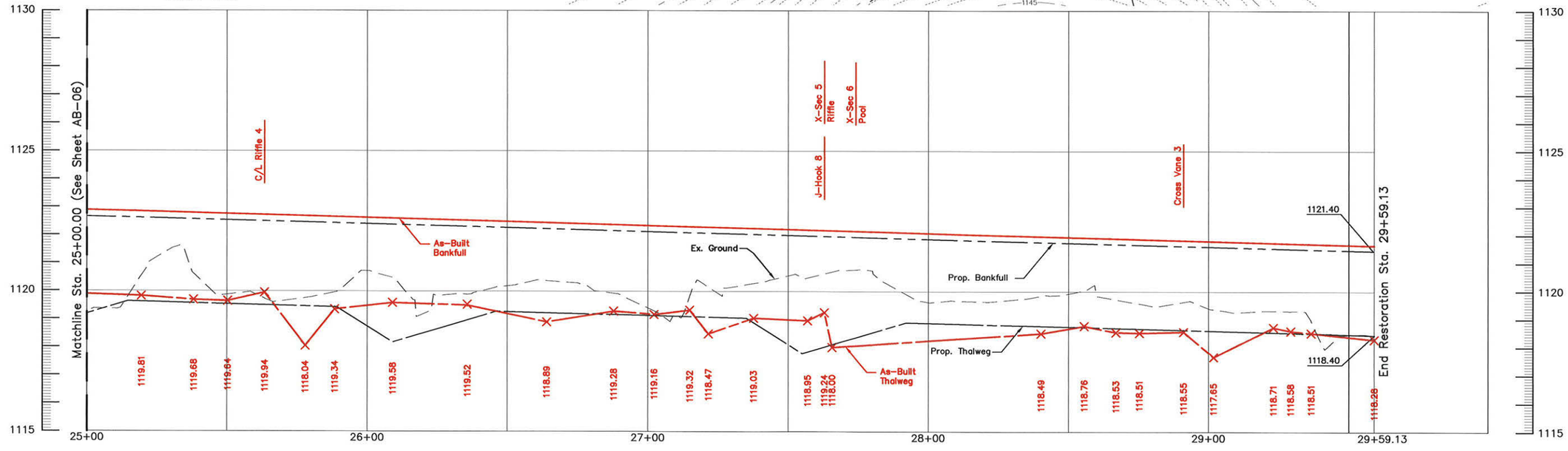

Profile stationing shown above is from the stream profile proposed in the restoration plan.

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Job No. 2005-1446
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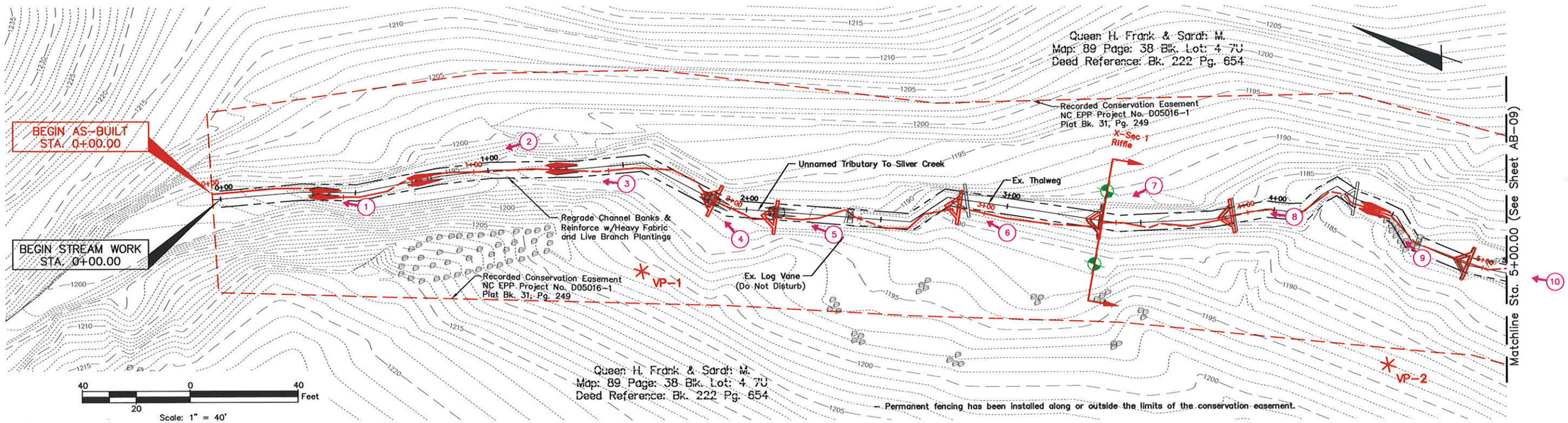

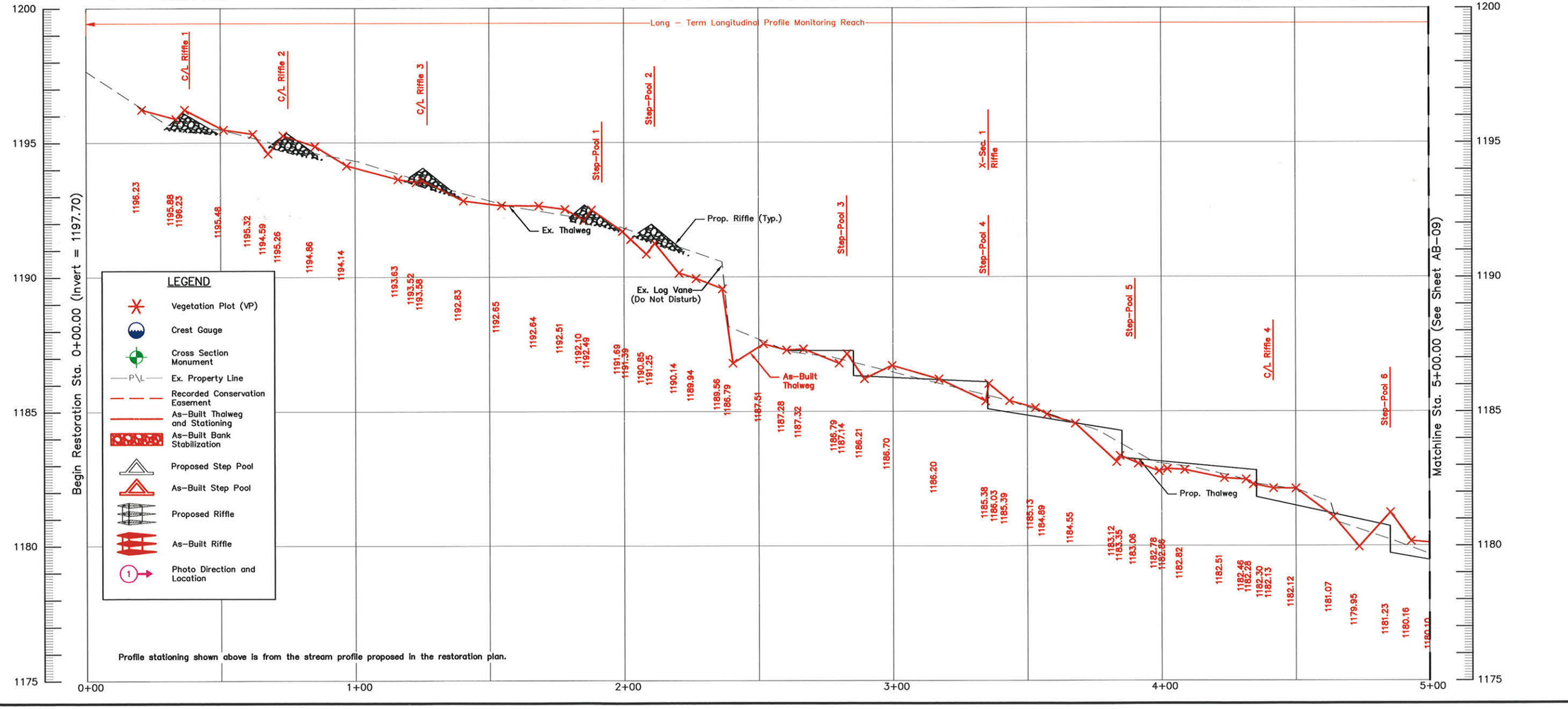

Job No. 2005-1446
Sheet AB-08/10
Date September, 2007
Scale Hor: 1" = 40' Ver: 1" = 4'

BURKE COUNTY, NORTH CAROLINA
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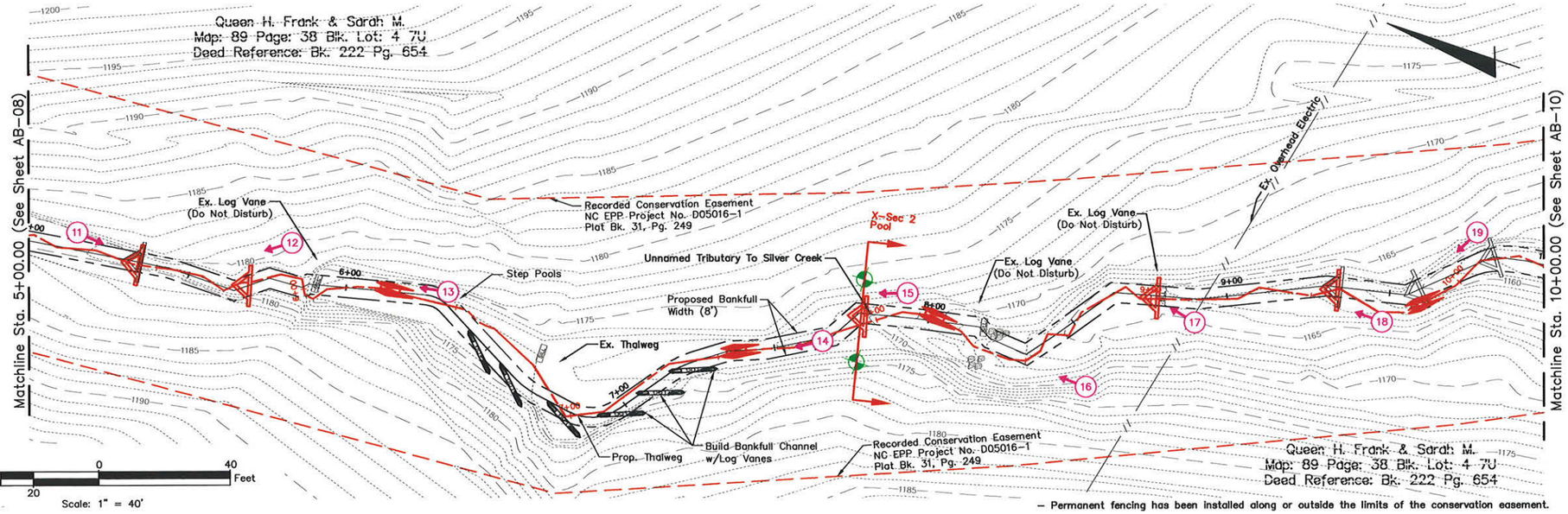

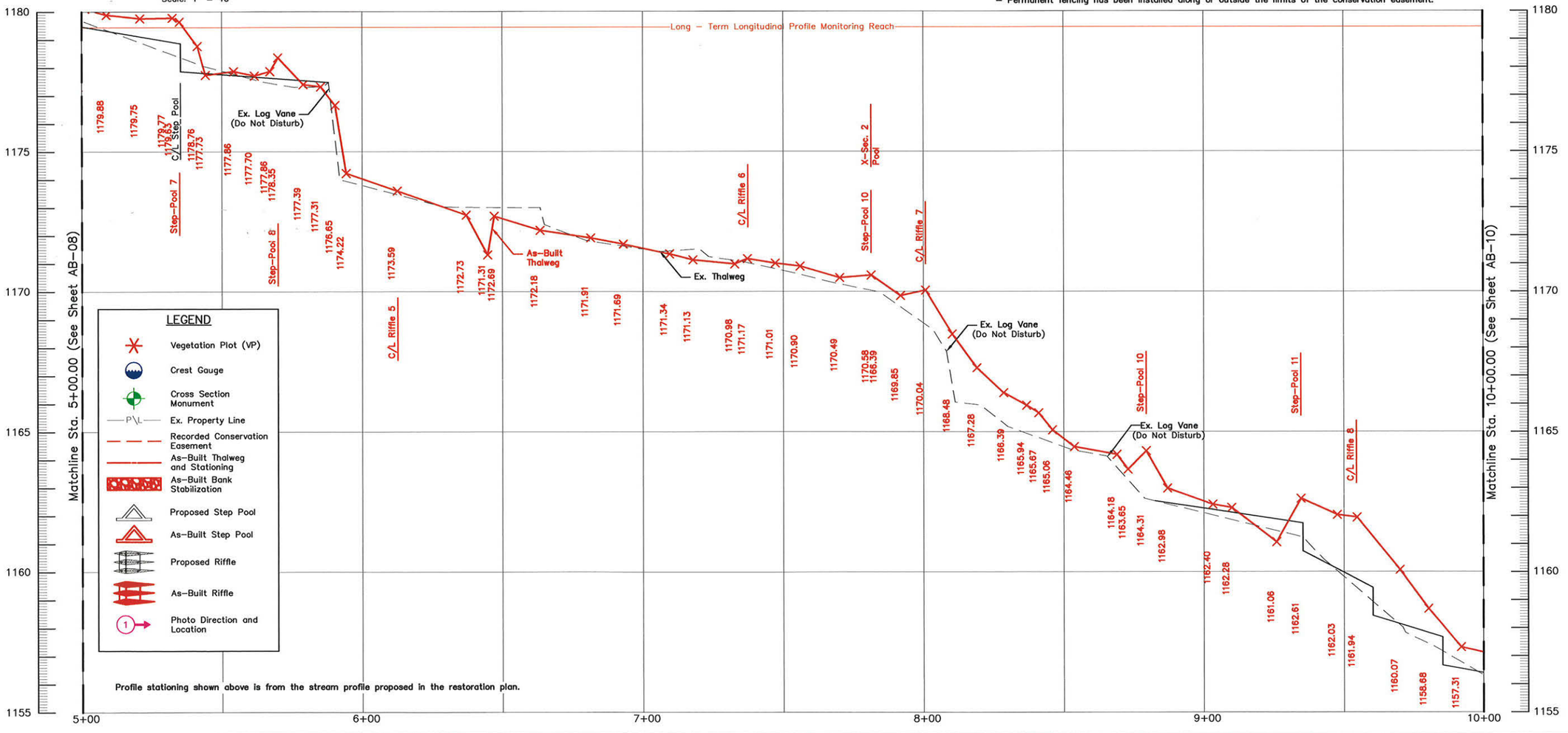

Job No. 2005-1446 | Sheet AB-09/10
Date September, 2007 | Scale Hor: 1" = 40' Ver: 1" = 4'

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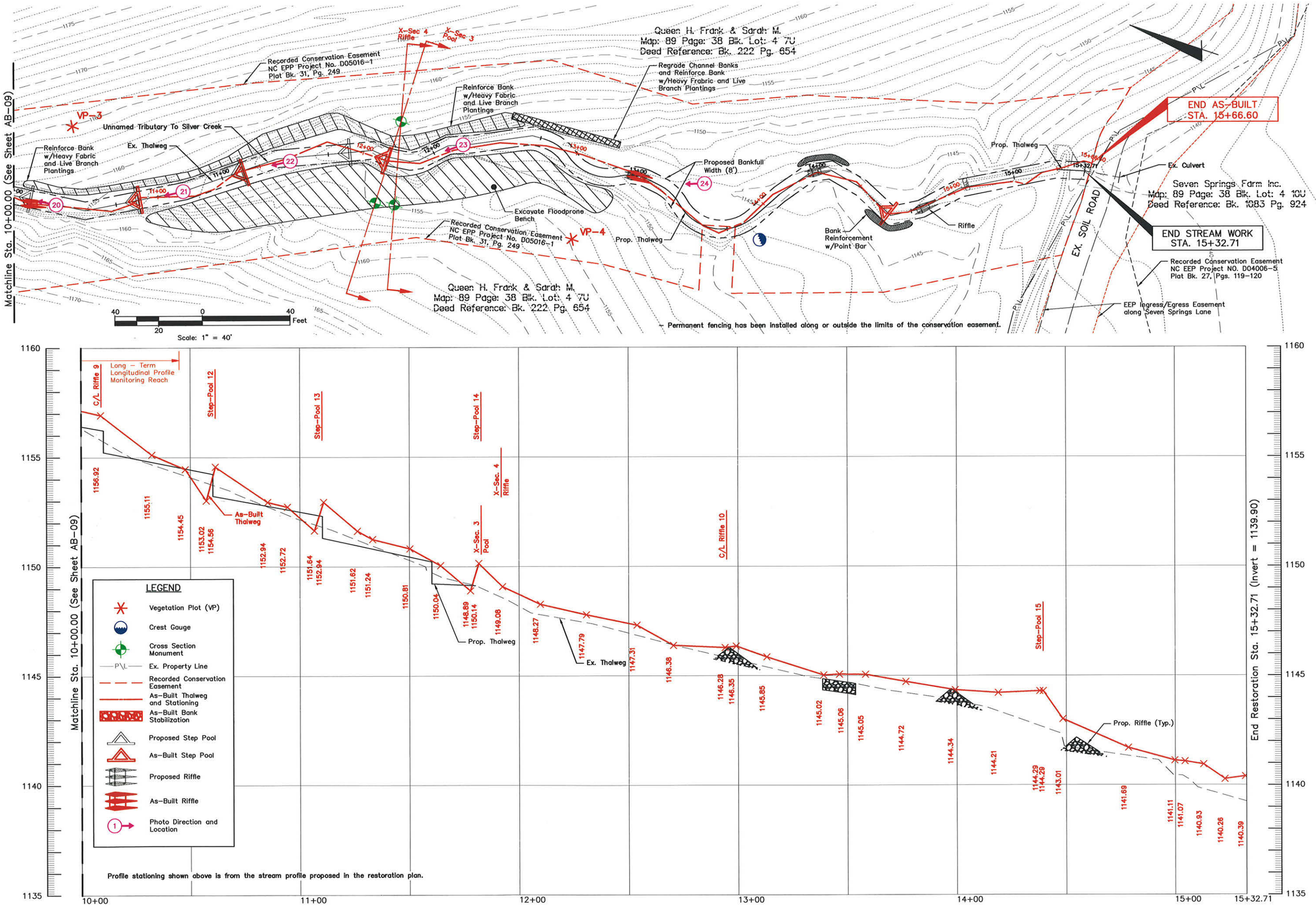
MARK	DATE	DESCRIPTION



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Job No. 2005-1446

Sheet AB-10/10

Date September, 2007

Scale Hor: 1" = 40' Ver: 1" = 4'

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7.0 Figures

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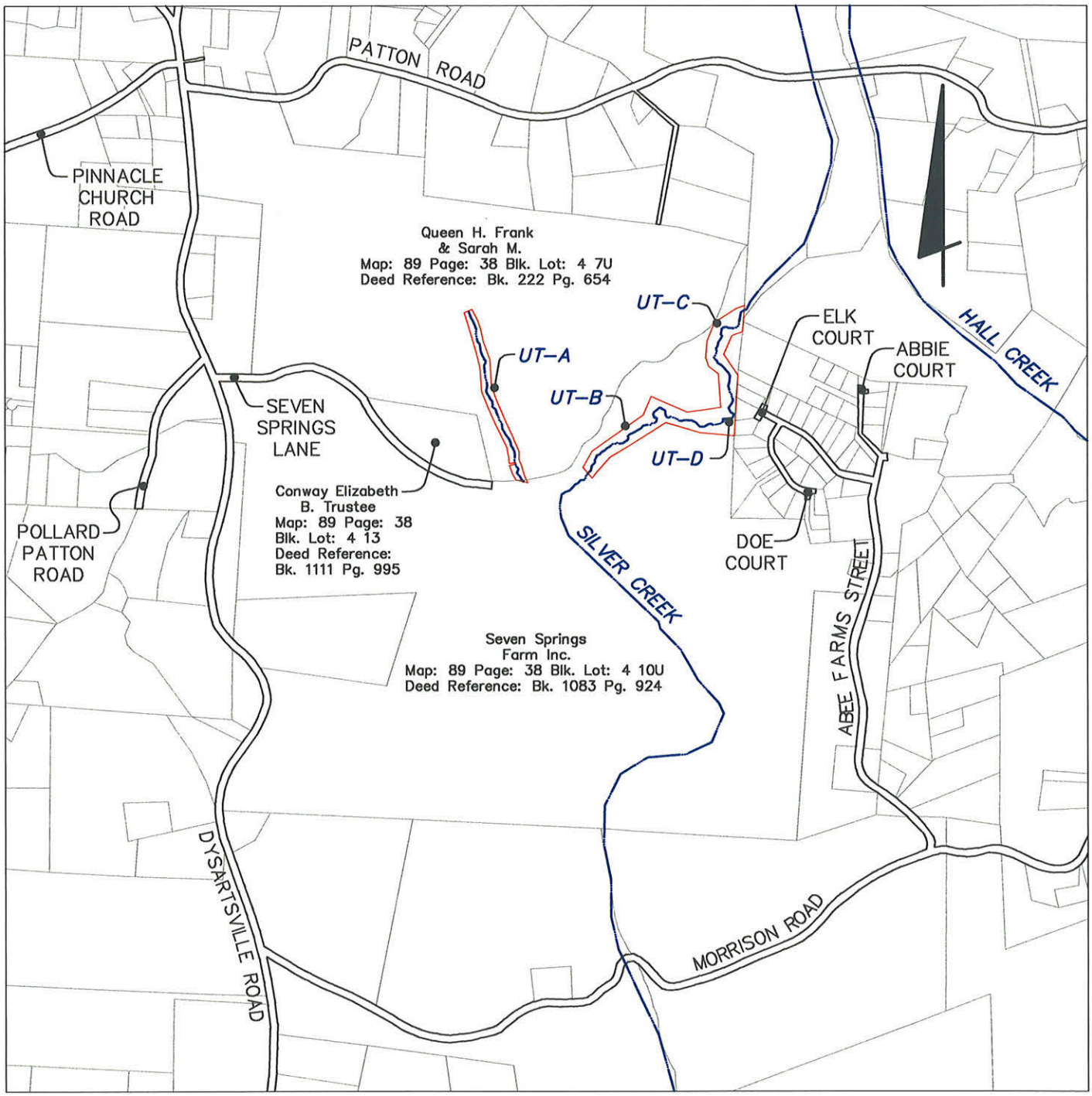
BURKE COUNTY, NORTH CAROLINA

SILVER CREEK

LOCATION MAP

FIGURE 1

Date:	August, 2007	Job No.	2005-1446	Scale:	Not To Scale



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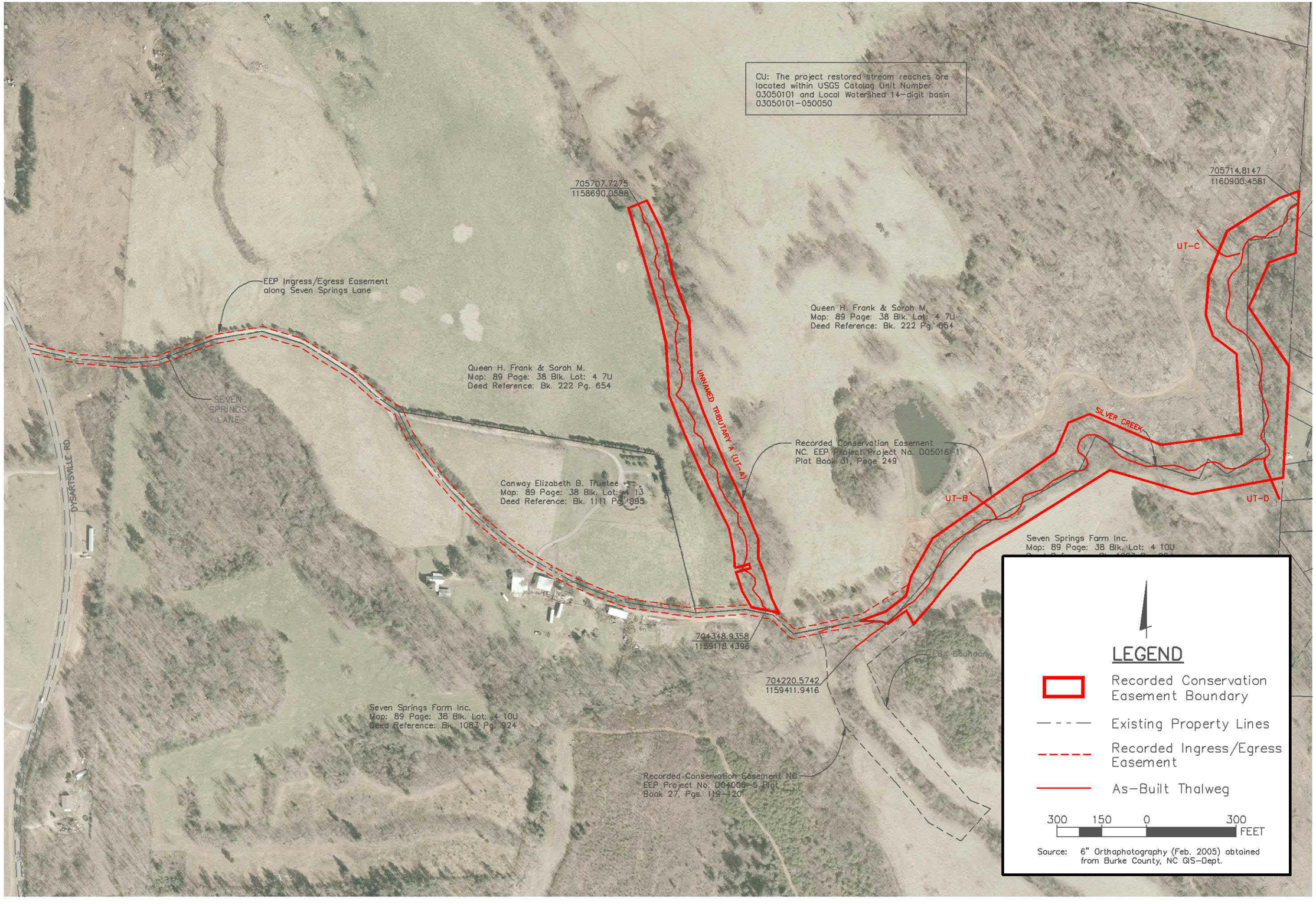

Date: August, 2007

Scale: 1" = 300'

Job No: 2005-1446

BURKE COUNTY, NORTH CAROLINA

SILVER CREEK AND UNNAMED TRIBUTARY

PROJECT STREAM REACHES

FIGURE 2

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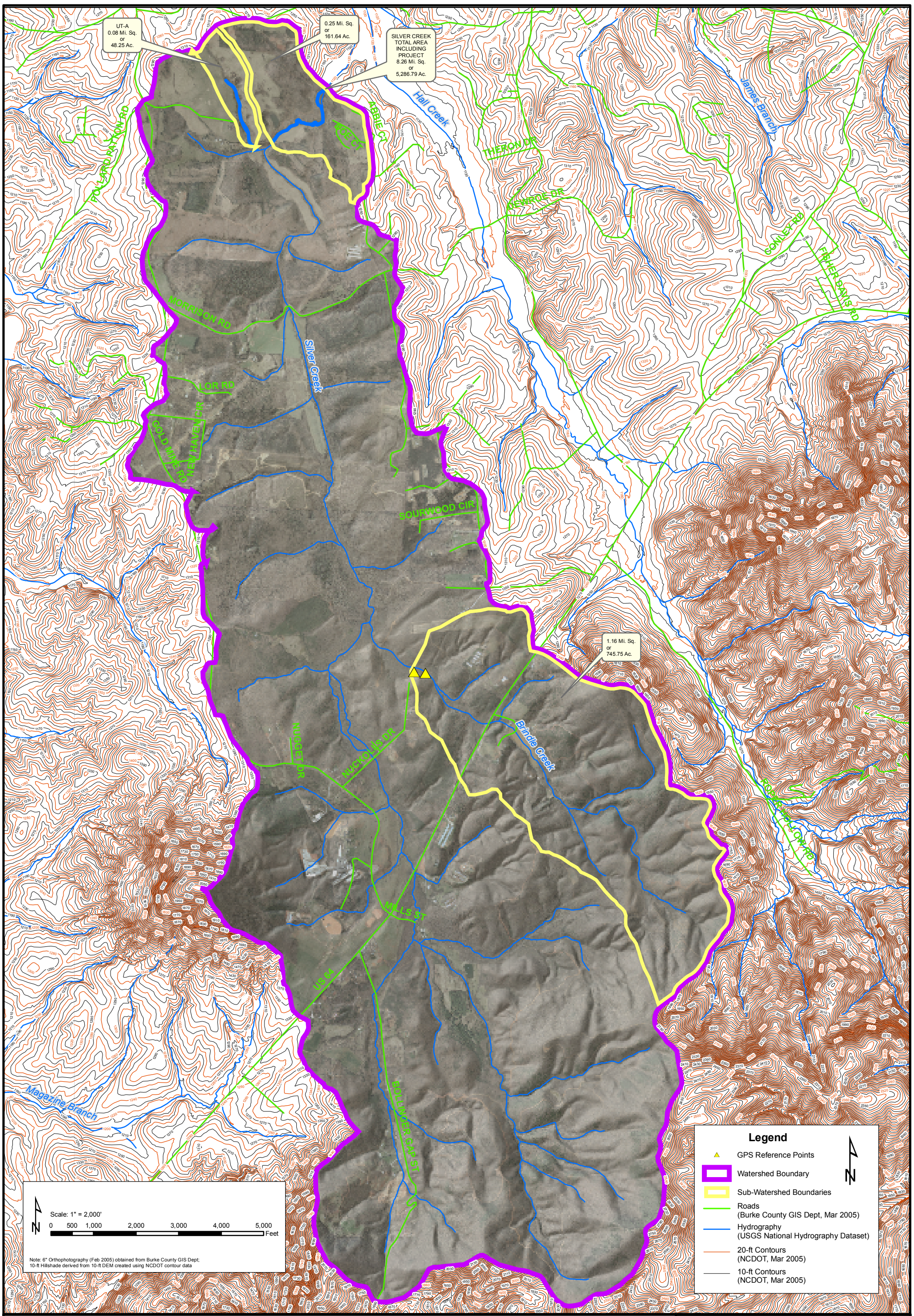
\\CMHDATA2\ENVIRON\PROJECT\20051446\DWG\FIGURES\FIGURE_2_PROJECT_STREAM_REACH.DWG<LAYOUT 1> - NO XREFS - LAST SAVED BY GTHOMAS [8/30/2007 1:48:52 PM] - PLOTTED BY JCRAMER [9/11/2007 3:59:11 PM]



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BURKE COUNTY, NORTH CAROLINA

SILVER CREEK WATERSHEDS
6" Orthophotography (Feb 2005) over 10-ft Hillshade
FIGURE 3A

Date: August, 2007

Ecosystem Enhancement Program

Appendix A
Silver Creek Mainstem and UT-A As-Built Photographic Documentation

Photograph No. 1- J-Hook 1 Looking Upstream

Photograph No. 2- Cross Vane 1 Looking Downstream

Photograph No. 3- Cross Vane 2 Looking Downstream

Photograph No. 4- Rock Vane 1 Looking Downstream

Photograph No. 5- J-Hook 2 Looking Downstream

Photograph No. 6- Riffle 1 Looking Downstream

Photograph No. 7- Rock Vane 2 Looking Downstream

Photograph No. 8- J-Hook 3 Looking Downstream

Photograph No. 9- J-Hook 4 Looking Downstream

Photograph No. 10- Riffle 2 Looking Downstream

Photograph No. 11- J-Hook 5 Looking Downstream

Photograph No. 12- Riffle 3 Looking Downstream

Photograph No. 13- Dual Winged Jetty With Boulder Cluster Looking Downstream

Photograph No. 14- Rock Vane 3 With Boulder Cluster Looking Downstream

Photograph No. 15- J-Hook 6 Looking Downstream

Photograph No. 16- Dual Winged Jetty With Boulder Cluster and Root Wad 1 Looking Downstream

Photograph No. 17- Root Wad 2 Looking Downstream

Photograph No. 18- Rock Vane 4 and Root Wad 3 Looking Downstream

Photograph No. 19- J-Hook 7 Looking Downstream

Photograph No. 20- Riffle 4 Looking Downstream

Photograph No. 21- J- Hook 8 Looking Upstream

Photograph No. 22- Cross Vane 3 Looking Upstream

Photograph No. 1- Riffle 1 Looking Upstream

Photograph No. 2- Riffle 2 Looking Upstream

Photograph No. 3- Riffle 3 Looking Upstream

Photograph No. 4- Step Pool 1 Looking Upstream

Photograph No. 5- Step Pool 2 Looking Upstream

Photograph No. 6- Step Pool 3 Looking Upstream

Photograph No. 7- Step Pool 4 Looking Upstream

Photograph No. 8- Step Pool 5 Looking Upstream

Photograph No. 9- Riffle 4 Looking Upstream

Photograph No. 10- Step Pool 6 Looking Upstream

Photograph No. 11- Step Pool 7 Looking Downstream

Photograph No. 12- Step Pool 8 Looking Upstream

Photograph No. 13- Riffle 5 Looking Upstream

Photograph No. 14- Riffle 6 Looking Upstream

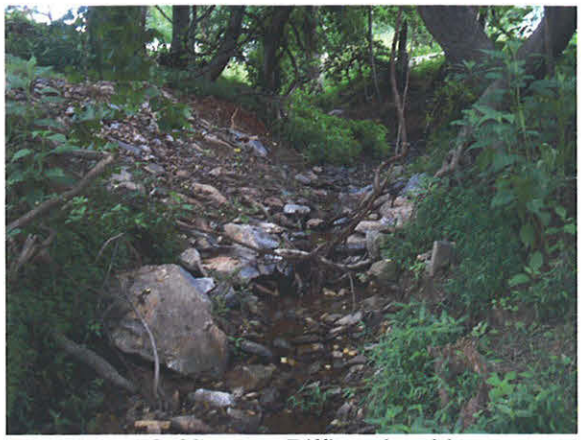
Photograph No. 15- Step Pool 9 Looking Upstream

Photograph No. 16- Riffle 7 Looking Upstream

Photograph No. 17- Step Pool 10 Looking Upstream

Photograph No. 18- Step Pool 11 Looking Upstream

Photograph No. 19- Riffle 8 Looking Upstream



Photograph No. 20- Riffle 9 Looking Upstream

Photograph No. 21- Step Pool 12 Looking Upstream

Photograph No. 22- Step Pool 13 Looking Upstream

Photograph No. 23- Step Pool 14 Looking Upstream

Photograph No. 24- Riffle 10 Looking Upstream

Appendix B
Brindle Creek Reference Reach Summary Data

RIVERMorph 4.0.1 Professional - Silver Creek Stream Restoration_4.0

File Tools Help

- Silver Creek & Trib Restoration
  - Reach 1 (Reference Reach)
    - Survey Data
    - Cross Sections
      - Riffle Section 0+22
      - Pool Section 3+20
    - Banks
    - Profiles
      - Ref Reach Long Pro
    - Particles
      - Riffle X-S 0+22
      - Pool X-S 3+20
      - Composite
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
      - NCD
      - Vanes
    - Notes
  - Reach 1 (Abandoned Oxbow - A
  - Reach 3 (Over Tightened Mean
  - Reach 4 (Top of Main Stem)
  - Reach 5 (Unnamed Tributary)
  - As-Built Mainstem
  - As-Built UT-A
  - As-Built UT2
  - As-Built UT3

Ratios | Riffle | Profile | D_{50} D50 | Reset Sliders | Extra Info

Profiles: Ref Reach Long Pro — Pebble Counts: Composite D50 = 27.73 mm

Riffle X-Sections: Riffle Section 0+22

Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.0138
Drainage Area (sq mi)	1.16

Location and Date of Survey

State	North Carolina
County	Burke
Latitude	35.61861
Longitude	81.81694
Date	01/13/06

Stream Classification

C 4

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification

☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	24.02
Mean Depth (ft)	1.28
Maximum Depth (ft)	1.72
Flood-Prone Width (ft)	232
Channel Materials D50 (mm)	38.5
Water Surface Slope (ft/ft)	0.01149
Sinuosity	1.2
Discharge (cfs)	98.16
Velocity (fps)	3.19
Cross Sectional Area (sq ft)	30.77
Entrenchment Ratio	9.66
Width to Depth Ratio	18.77

☑ This Reach is a Reference Reach

Brindle Creek Reference Reach
Stream Classification and Morphologic Data Summary

Start | Inbox - Microsoft Outlook | RIVERMorph 4.0.1 Profe... | 1:14 PM

Brindle Creek Reference Reach
Stream Classification and Morphologic
Data Summary

Stream NAME: Silver Creek & Trib Restoration, Reach - Reach 1 (Reference Reach)

Basin NAME: Catawba River Drainage AREA: 742.4 acre 1.16 mi^2

Location: Brindle Creek of Silver Creek, Burke County, North Carolina

Twp: _____ Rge: _____ Sec: _____ Qtr: _____ Lat: 35.6186 Long: 81.817

Observers: Miles F. Hebert, PE and Warren E. Knotts, PG Date: 1/13/2006

Bankfull WIDTH (W_{bkf}) — **24.02** Feet

WIDTH of the stream channel, at bankfull stage elevation, in a riffle section.

Mean DEPTH (d_{bkf}) — **1.28** Feet

Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section. ($d_{bkf}=A_{bkf}/W_{bkf}$)

Bankfull Cross Section Area (A_{bkf}) — **30.77** $Feet^2$

AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

WIDTH / DEPTH RATIO (W_{bkf}/d_{bkf}) — **18.77** Ft/Ft

Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mrif}) — **1.72** Feet

Maximum depth of the bankfull channel cross-section, or elevation between the bankfull stage and thalweg in a riffle section.

Flood-Prone Area WIDTH (W_{fpa}) — **232** Feet

The stage/elevation at which flood-prone area WIDTH is determined in a riffle section at twice maximum DEPTH, or ($2 \times d_{mrif}$)

Entrenchment RATIO (ER) — **9.66** Ft/Ft

The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa}/W_{bkf}) in a riffle section.

Channel Materials (Particle Size Index) D50 — **38.5** mm

The 50th percentile, or less than, from a pebble count frequency distribution of channel particles representing the median or dominant particle size.

Water Surface SLOPE (S) — **0.01149** Ft/Ft

Average water surface slope as measured between the same position of bed features in the profile over two meander wave lengths. This is similar to average bankfull slope.

Channel SINUOSITY (K) — **1.2**

Sinuosity: an index of channel pattern, determined from stream length / valley length, i.e. (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/ S).

Stream Type **C 4**

For Reference, see page 5-5, 5-6: Rosgen, 1996. Applied River Morphology.

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Brindle Creek Reference Reach
Stream Classification and Morphologic
Data Summary

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.28	feet	Mean Riffle Width (W_{bkf})	24.02	feet	Mean Riffle Area (A_{bkf})	30.77	$feet^2$
Mean Pool Depth (d_{bkfp})	2.33	feet	Mean Pool Width (W_{bkfp})	26.97	feet	Mean Pool Area (A_{bkfp})	62.77	$feet^2$
Ratio Mean Pool Depth/Mean Riffle Depth	1.820	d_{bkfp}/d_{bkf}	Ratio Pool Width/Riffle Width	1.123	W_{bkfp}/W_{bkf}	Ratio Pool Area/ Riffle Area	2.040	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mrif})	2.41	feet	Max Pool Depth (d_{mpool})	3.76	feet	Max riffle depth/Mean riffle depth	1.883	
Max pool depth/Mean riffle depth	2.938					Point Bar Slope	0.01	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})	3.19	ft/s				Estimation Method	Manning's Equation	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})	98.16	cfs				Drainage Area	1.16	mi^2

Channel Pattern

Geometry	Ave	Min	Max		Dimensionless Geometry Ratios	Ave	Min	Max
Meander Length (Lm)	104.8	88.23	115.7	feet	Meander Length Ratio (Lm/W_{bkf})	4.361	3.673	4.816
Radius of Curvature (Rc)	17.67	12.97	24.44	feet	Radius of Curvature/Riffle Width (Rc/W_{bkf})	0.736	0.540	1.017
Belt Width (W_{blt})	45.22	44.17	46.5	feet	Meander Width Ratio (W_{blt}/W_{bkf})	1.883	1.839	1.936
Individual Pool Length	17.42	11.01	31.56	feet	Pool Length/Riffle Width	0.725	0.458	1.314
Pool to Pool Spacing	71.36	67.6	77.5	feet	Pool to Pool Spacing/Riffle Width	2.971	2.814	3.226

Channel Profile

Valley Slope (VS)	0.0138	ft/ft	Average Water Surface Slope (S)	0.01149	ft/ft	Sinuosity (VS/S)	1.2	
Stream Length (SL)	353	feet	Valley Length (VL)	294	feet	Sinuosity (SL/VL)	1.201	

Low Bank Height (LBH)	start	1.62	feet	Max Riffle Depth	start	1.62	feet	Bank Height Ratio (LBH/Max Riffle Depth)	start	1
	end	1.86	feet		end	1.86	feet		end	1

Facet Slopes	Ave	Min	Max		Dimensionless Slope Ratios	Ave	Min	Max
Riffle Slope (S_{rif})	0.0246	0.0172	0.0346	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	2.144	1.500	3.008
Run Slope (S_{run})	0.0211	0.0125	0.0362	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	1.838	1.088	3.150
Pool Slope (S_p)	0.0043	0.0010	0.0095	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.372	0.086	0.824
Glide Slope (S_g)	0.0053	0.0020	0.0075	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	0.460	0.173	0.655

Feature Midpoint [a]	Ave	Min	Max		Dimensionless Depth Ratios	Ave	Min	Max
Riffle Depth (d_{mrif})	2.410	2.410	2.410	feet	Riffle Max Depth/Riffle Mean Depth (d_{mrif}/d_{bkf})	1.883	1.883	1.883
Run Depth (d_{mrun})	2.300	1.870	2.560	feet	Run Max Depth/Riffle Mean Depth (d_{mrun}/d_{bkf})	1.797	1.461	2.000
Pool Depth (d_{mp})	3.760	3.760	3.760	feet	Pool Max Depth/Riffle Mean Depth (d_{mp}/d_{bkf})	2.938	2.938	2.938
Glide Depth (d_{mg})	2.210	1.640	2.700	feet	Glide Max Depth/Riffle Mean Depth (d_{mg}/d_{bkf})	1.727	1.281	2.109

Channel Materials

Catagories	Reach[b]	Riffle[c]	Bar
% Silt/Clay	0	0	
% Sand	24	0	
% Gravel	63	90	
% Cobble	13	10	
% Boulder	0	0	
% Bedrock	0	0	

Indices	Reach[b]	Riffle[c]	Bar	
D16	0.84	19.96		mm
D35	18.64	29.65		mm
D50	27.73	38.5		mm
D84	58.3	60.2		mm
D95	87.11	77		mm
D100	179.99	90		mm

a. The range of "feature" mid-point maximum bankfull depths, including the minimum, maximum and average values. (Pool depths are obtained from the deepest portion of the feature.)

b. A composite sample of materials from riffle and pool features taken within the designated reach.

c. Sample obtained within the "active" bed of a riffle feature at the location of the cross section.

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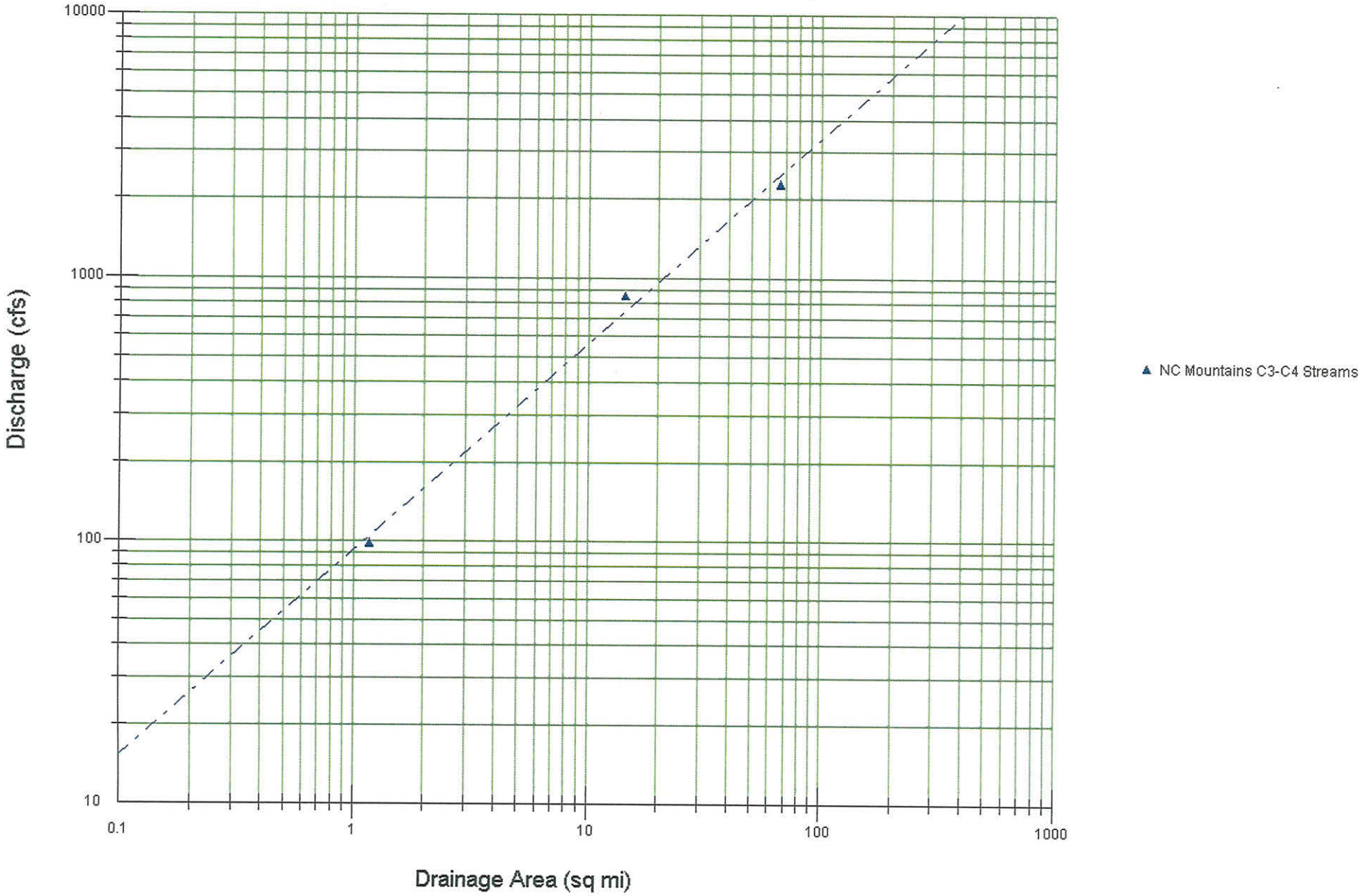
NC Mountains C3-C4 Regional Curve - Silver Ck, N Fork Swannanoa & Mills River



RIVERMORPH REACH SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
C 4	VIII	38.5	0.0097	98.16	1.16

Dimension Summary (DIMESIONLESS RATIOS)

Database based on the following Cross Sections:
Riffle Section 0+22
Pool Section 3+20

Variable	Min	Avg	Max
Wfpa / Wbkf	9.66	9.65862	9.65862
Abkf	30.77	30.77	30.77
Dmbkf	2.41	2.41	2.41
Dbkf	1.28	1.28	1.28
Wbkf	24.02	24.02	24.02
Pool Area / Abkf	2.03997	2.03997	2.03997
Max Pool Depth / Dbkf	2.9375	2.9375	2.9375
Mean Pool Depth / Dbkf	1.82031	1.82031	1.82031
Pool Width / Wbkf	1.12281	1.12281	1.12281
Run Area / Abkf	0	0	0
Max Run Depth / Dbkf	1.46094	1.79687	2
Mean Run Depth / Dbkf	0	0	0
Run Width / Wbkf	0	0	0
Glide Area / Abkf	0	0	0
Max Glide Depth / Dbkf	1.28125	1.92969	2.5625
Mean Glide Depth /Dbkf	0	0	0
Glide Width / Wbkf	0	0	0

Pattern Summary

Variable	Min	Avg	Max
Sinuosity		1.2	
Lm / W bkf	3.67319	4.36137	4.81557
Rc / W bkf	0.53997	0.73564	1.01749
Wblt / Wbkf (MWR)	1.83888	1.8826	1.93589

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle / S bkf (ft/ft)	1.49956	2.14447	3.00783
S pool / S bkf (ft/ft)	0.08616	0.37163	0.82419
S run / S bkf (ft/ft)	1.0879	1.83812	3.1497
S glide / S bkf (ft/ft)	0.17319	0.4604	0.65535
P - P / W bkf (ft)	2.81432	2.97086	3.22648
P length / W bkf (ft)	0.45837	0.72523	1.31391
Dmax riffle / D bkf (ft)	1.88281	1.88281	1.88281
Dmax pool / D bkf (ft)	2.9375	2.9375	2.9375
Dmax run / D bkf (ft)	1.46094	1.79687	2
Dmax glide / D bkf (ft)	1.28125	1.92969	2.5625
Low Bank Ht / Dmax riff (ft)	0	0	0

Bankfull Slope (ft/ft) 0.01149

Hydraulic Summary

Variable	Min	Avg	Max
Q bkf		98.16	
V bkf (fps)		3.19	
HR / D bkf (ft)	0.94531	0.94531	0.94531
Bkf Shear (lb/ sq ft)	0.87	0.87	0.87

RIVERMORPH REACH SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
C 4	VIII	38.5	0.0097	98.16	1.16

Dimension Summary

Database based on the following Cross Sections:
Riffle Section 0+22
Pool Section 3+20

Variable	Min	Avg	Max
Floodprone Width (ft)	232.0	232.0	232.0
Riffle Area (Sq ft)	30.77	30.77	30.77
Max Riffle Depth (ft)	2.41	2.41	2.41
Mean Riffle Depth (ft)	1.28	1.28	1.28
Riffle Width (ft)	24.02	24.02	24.02
Pool Area (Sq ft)	62.77	62.77	62.77
Max Pool Depth (ft)	3.76	3.76	3.76
Mean Pool Depth (ft)	2.33	2.33	2.33
Pool Width (ft)	26.97	26.97	26.97
Run Area (Sq ft)	0	0	0
Max Run Depth (ft)	1.87	2.3	2.56
Mean Run Depth (ft)	0	0	0
Run Width (ft)	0	0	0
Glide Area (Sq ft)	0	0	0
Max Glide Depth (ft)	1.64	2.47	3.28
Mean Glide Depth (ft)	0	0	0
Glide Width (ft)	0	0	0

Pattern Summary

Variable	Min	Avg	Max
Sinuosity		1.2	
Meander Wavelength (ft)	88.23	104.76	115.67
Radius of Curvature (ft)	12.97	17.67	24.44
Belt Width (ft)	44.17	45.22	46.5

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle (ft/ft)	0.01723	0.02464	0.03456
S pool (ft/ft)	0.00099	0.00427	0.00947
S run (ft/ft)	0.0125	0.02112	0.03619
S glide (ft/ft)	0.00199	0.00529	0.00753
P - P (ft)	67.6	71.36	77.5
P length (ft)	11.01	17.42	31.56
Dmax riffle (ft)	2.41	2.41	2.41
Dmax pool (ft)	3.76	3.76	3.76
Dmax run (ft)	1.87	2.3	2.56
Dmax glide (ft)	1.64	2.47	3.28
Low Bank Ht (ft)	0	0	0

Bankfull Slope (ft/ft) 0.01149

Hydraulic Summary

Variable	Min	Avg	Max
Discharge (cfs)		98.16	
Velocity (fps)		3.19	
Hyd Radius (ft)	1.21	1.21	1.21
Bkf Shear (lb/ sq ft)	0.87	0.87	0.87

RIVERMORPH PFANKUCH SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)
Survey Date: 01/13/06

Upper Bank

Landform Slope:	1
Mass Wasting:	2
Debris Jam Potential:	1
Vegetative Protection:	2

Lower Bank

Channel Capacity:	0
Bank Rock Content:	1
Obstructions to Flow:	1
Cutting:	3
Deposition:	3

Channel Bottom

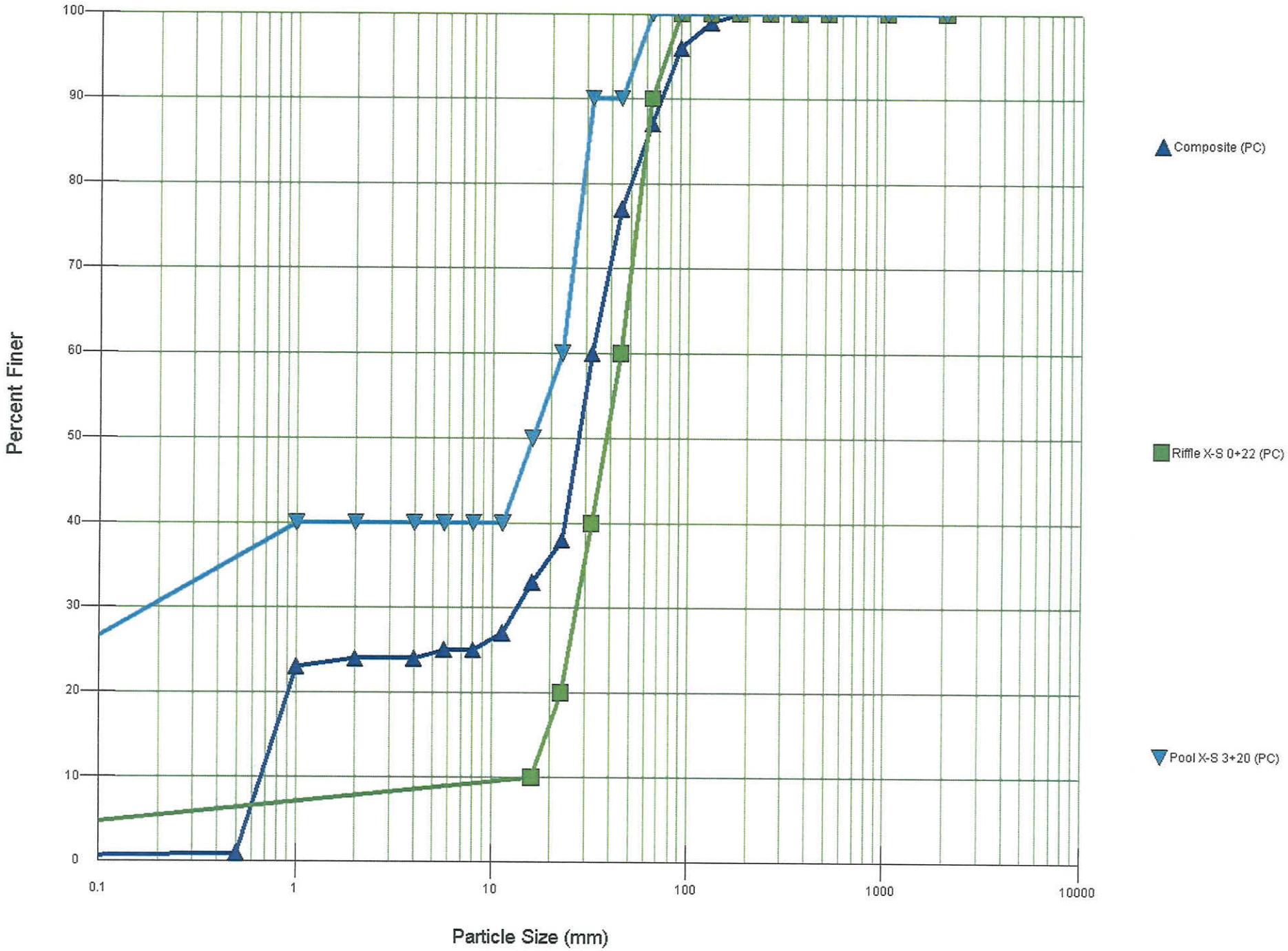
Rock Angularity:	0
Brightness:	0
Consolidation of Particles:	1
Bottom Size Distribution:	3
Scouring and Deposition:	5
Aquatic Vegetation:	1

Channel Stability Evaluation

Sediment Supply:	Moderate
Stream Bed Stability:	Stable
W/D Condition:	Normal
Stream Type:	C4

Rating - 24
Condition - Good

Reference Reach (Brindle Creek) Particle Distribution



01/13/2006

RIVERMORPH PARTICLE SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)
Sample Name: Composite
Survey Date: 01/13/06

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	1	1.00	1.00
0.50 - 1.0	22	22.00	23.00
1.0 - 2.0	1	1.00	24.00
2.0 - 4.0	0	0.00	24.00
4.0 - 5.7	1	1.00	25.00
5.7 - 8.0	0	0.00	25.00
8.0 - 11.3	2	2.00	27.00
11.3 - 16.0	6	6.00	33.00
16.0 - 22.6	5	5.00	38.00
22.6 - 32.0	22	22.00	60.00
32 - 45	17	17.00	77.00
45 - 64	10	10.00	87.00
64 - 90	9	9.00	96.00
90 - 128	3	3.00	99.00
128 - 180	1	1.00	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)	0.84
D35 (mm)	18.64
D50 (mm)	27.73
D84 (mm)	58.3
D95 (mm)	87.11
D100 (mm)	179.99
Silt/Clay (%)	0
Sand (%)	24
Gravel (%)	63
Cobble (%)	13
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.

NCDWQ Stream Classification Form

Reference Reach Brindle Creek

Project Name: Silver Creek & UT Restoration Plan
River Basin: Catawba
County: Burke
Evaluator: WARREN KNOTTS, PG
DWQ Project Number: DO5016-1
Nearest Named Stream: Silver Creek
Latitude: 35°37'07"N
Signature: Warren B Knotts
01/13/2006
USGS QUAD: Glen Alpine
Longitude 81°48'48"W
Location/Directions: GOLDMINE RD TO KNUCKOLLS DR.

PLEASE NOTE: *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
) Is There A Riffle-Pool Sequence?	0	1	2	(3)
) Is The USDA Texture In Streambed Different From Surrounding Terrain?	(0)	1	2	3
) Are Natural Levees Present?	(0)	1	2	3
) Is The Channel Sinuous?	0	1	(2)	3
) Is There An Active (Or Relic) loodplain Present?	0	1	2	(3)
) Is The Channel Braided?	(0)	1	2	3
) Are Recent Alluvial Deposits Present?	(0)	1	2	3
) Is There A Bankfull Bench Present?	0	1	2	(3)
) Is A Continuous Bed & Bank Present?	0	1	2	(3)

**NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*

0) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present? *Yes*=(3) *No*=0

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 17

I. Hydrology	Absent	Weak	Moderate	Strong
) Is There A Groundwater Discharge Present?	0	1	2	(3)

RIMARY HYDROLOGY INDICATOR POINTS: 3

II. Biology	Absent	Weak	Moderate	Strong
) Are Fibrous Roots Present In Streambed?	(3)	2	1	0
) Are Rooted Plants Present In Streambed?	(3)	2	1	0
) Is Periphyton Present?	(0)	1	2	3
) Are Bivalves Present?	(0)	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS: 6

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
) Is There A Head Cut Present In Channel?	(0)	.5	1	1.5
) Is There A Grade Control Point In Channel?	(0)	.5	1	1.5
) Does Topography Indicate A Natural Drainage Way?	0	.5	1	(1.5)

ECONDARY GEOMORPHOLOGY INDICATOR POINTS: 1.5

I. Hydrology	Absent	Weak	Moderate	Strong
) Is This Year's (Or Last's) Leaflitter Present In Streambed?	1.5	1	(.5)	0
) Is Sediment On Plants (Or Debris) Present?	(0)	.5	1	1.5
) Are Wrack Lines Present?	(0)	.5	1	1.5
Water In Channel ***And*** >48 Hrs. Since	0	.5	1	(1.5)
ast ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*				
) Is There Water In Channel During Dry onditions ***Or*** In Growing Season)?	0	.5	1	1.5

) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? *Yes=1.5* (*No*=0)

ECONDARY HYDROLOGY INDICATOR POINTS: 2

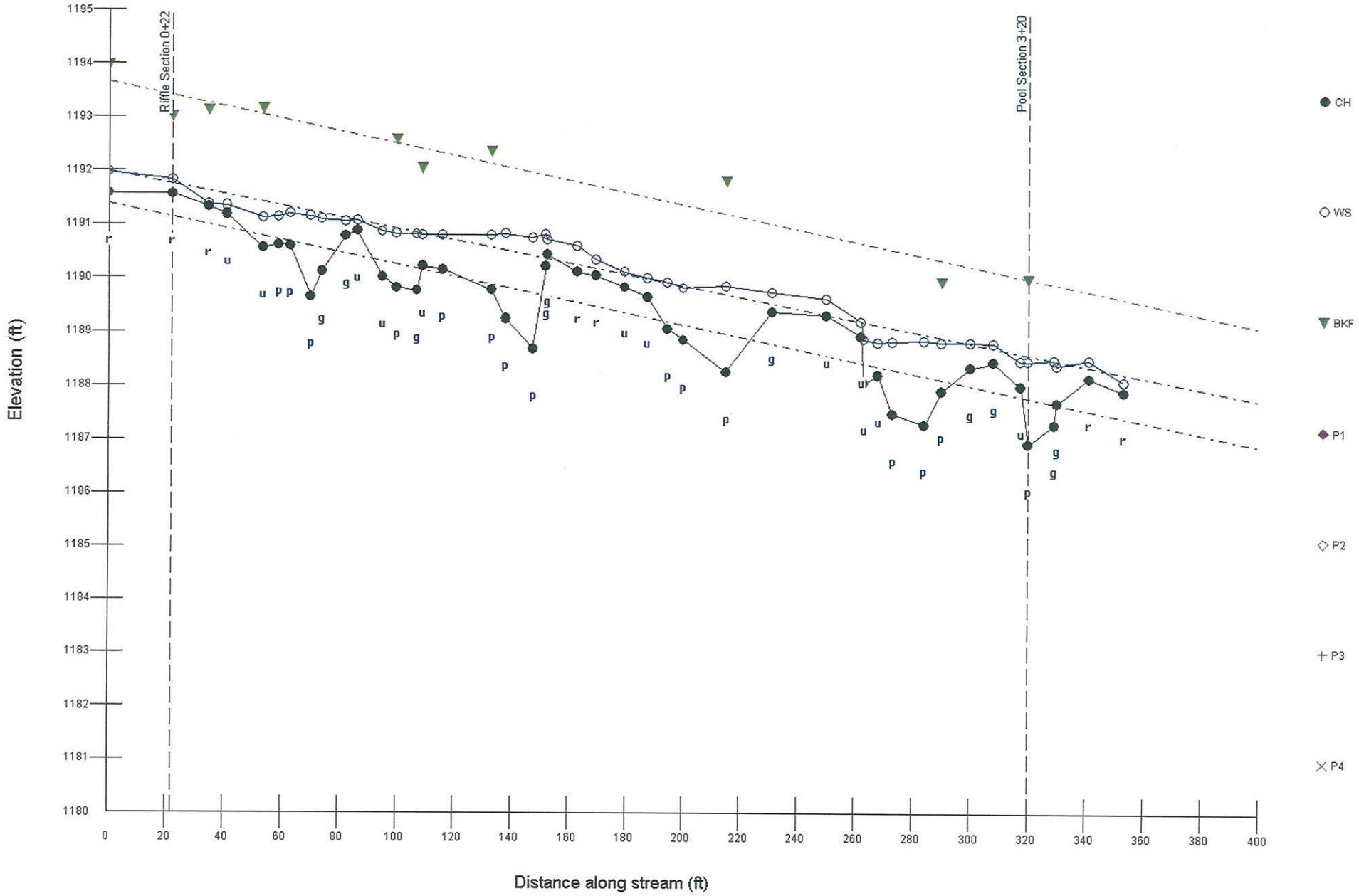
II. Biology	Absent	Weak	Moderate	Strong
) Are Fish Present?	0	(.5)	1	1.5
) Are Amphibians Present?	0	(.5)	1	1.5
) Are AquaticTurtles Present?	0	(.5)	1	1.5
) Are Crayfish Present?	0	(.5)	1	1.5
) Are Macrobenthos Present?	0	(.5)	1	1.5
) Are Iron Oxidizing Bacteria/Fungus Present?	(0)	.5	1	1.5
) Is Filamentous Algae Present?	(0)	.5	1	1.5

re Wetland Plants In Streambed?	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
- NOTE: If Total Absence Of All Plants In Streambed Is Noted Above Skip This Step UNLESS SAV Present).*	2	1	.75	.5	0	0

ECONDARY BIOLOGY INDICATOR POINTS: 2.5

TOTAL POINTS *(Primary + Secondary)*=32 *(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)*

Silver Creek Reference Reach (Brindle Creek) Longitudnal Profile



RIVERMORPH PROFILE SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)
Profile Name: Ref Reach Long Pro
Survey Date: 01/13/06

Survey Data

STA	CH	WS	BKF	P1	P2	P3	P4
0	8.43	8.02	6.02				
22	8.44	8.16	6.98				
34.6	8.67	8.62	6.86				
41	8.82	8.65					
53.5	9.44	8.88	6.84				
59	9.38	8.86					
63	9.4	8.8					
70	10.35	8.85					
74	9.88	8.9					
82.3	9.22	8.95					
86.3	9.12	8.93					
95	9.98	9.13					
100	10.18	9.17	7.4				
107	10.24	9.18					
109	9.78	9.2	7.94				
116	9.84	9.2					
133	10.22	9.2	7.62				
138	10.75	9.17					
147.5	11.31	9.25					
152	9.78	9.18					
152.5	9.56	9.28					
163	9.88	9.4					
169.6	9.95	9.66					
179.5	10.16	9.88					
187.5	10.35	10					
194.5	10.94	10.08					
200	11.15	10.18					
215	10.98	9.39	7.43				
231	9.86	9.51					
250	9.93	9.62					
262	10.32	10.05					
263	11.19	10.38					
268	11.04	10.44					
273	11.76	10.42					
284	11.96	10.4					
290	11.33	10.44	9.3				
300	10.9	10.44					
308	10.8	10.45					
317.5	11.26	10.78					
320	12.32	10.78	9.25				
329	11.96	10.76					
330	11.56	10.86					
341	11.1	10.76					
353	11.35	11.17					

Cross Section / Bank Profile Locations

Name	Type	Profile Station

Riffle Section 0+22		Riffle XS	22
Pool Section 3+20		Pool XS	320

Measurements from Graph

Bankfull Slope: 0.01149

Variable	Min	Avg	Max
S riffle	0.01723	0.02464	0.03456
S pool	0.00099	0.00427	0.00947
S run	0.0125	0.02112	0.03619
S glide	0.00199	0.00529	0.00753
P - P	67.6	71.36	77.5
P length	11.01	17.42	31.56
Dmax riffle	1.62	1.72	1.86
Dmax pool	2.71	3.06	3.29
Dmax run	1.87	2.3	2.56
Dmax glide	1.64	2.21	2.7
Low Bank Ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)
Profile Name: Ref Reach Long Pro
Survey Date: 01/13/06

STA	Note
0	Riffle Begin
22	Riffle X-S
34.6	Riffle End
41	Run
53.5	Run
59	Pool Top
63	Pool
70	Pool Center
74	Glide
82.3	Glide
86.3	Run
95	Run
100	Pool
107	Glide
109	Run
116	Pool
133	Pool Transition (Compound Pool)
138	Pool Center
147.5	Pool
152	Glide
152.5	Glide
163	Riffle
169.6	Riffle End
179.5	Run
187.5	Run
194.5	Pool
200	Pool Thalweg

215	Pool
231	Glide
250	Run
262	Run
263	Run
268	Run - Top Lat. Log Vane
273	Pool - Bottom Lat. Log Vane
284	Pool
290	Pool
300	Glide
308	Glide
317.5	Run
320	Pool (X-S)
329	Glide
330	Glide
341	Riffle
353	Riffle End

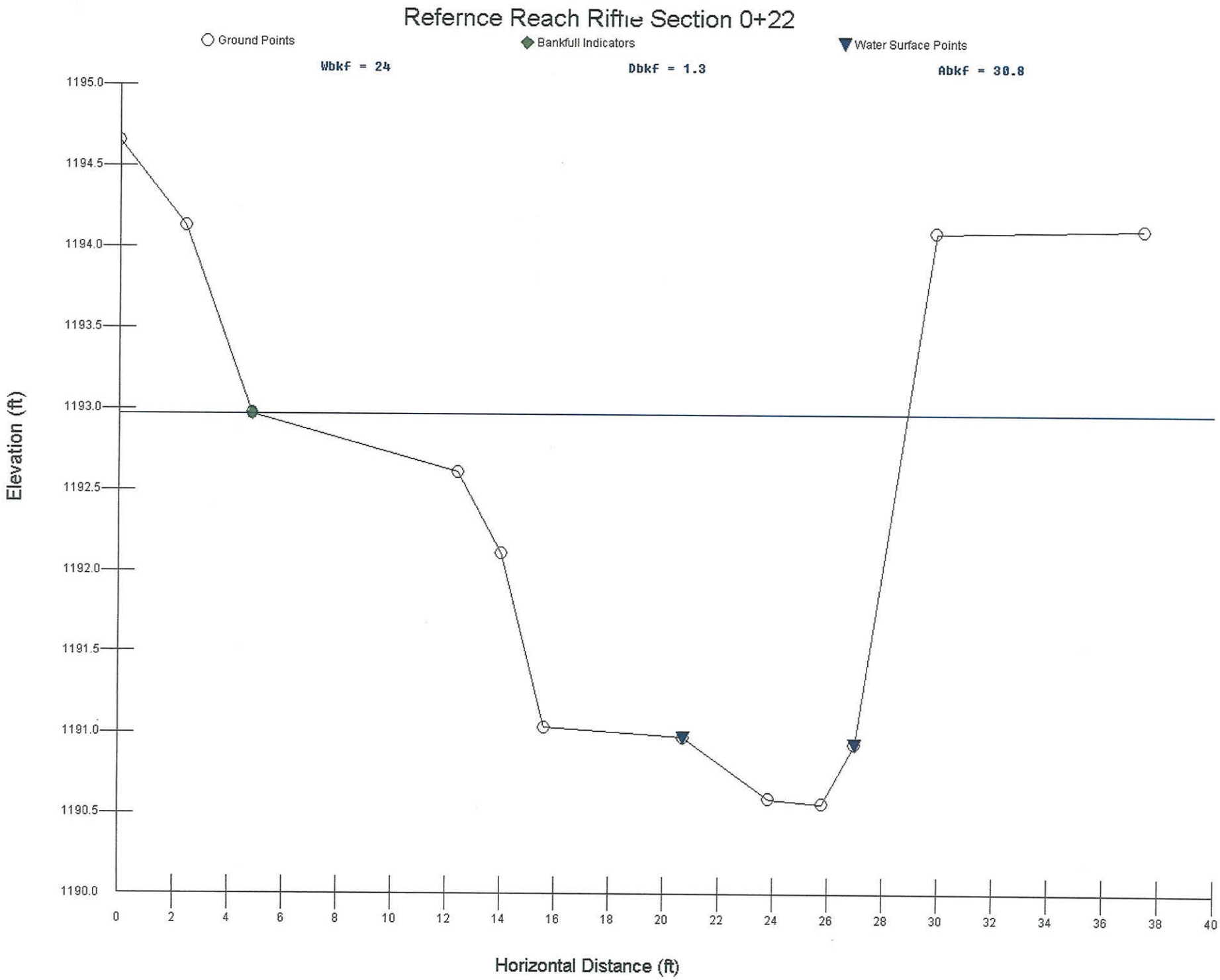
RIVERMORPH PARTICLE SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Reference Reach)
Sample Name: Riffle X-S 0+22
Survey Date: 01/19/06

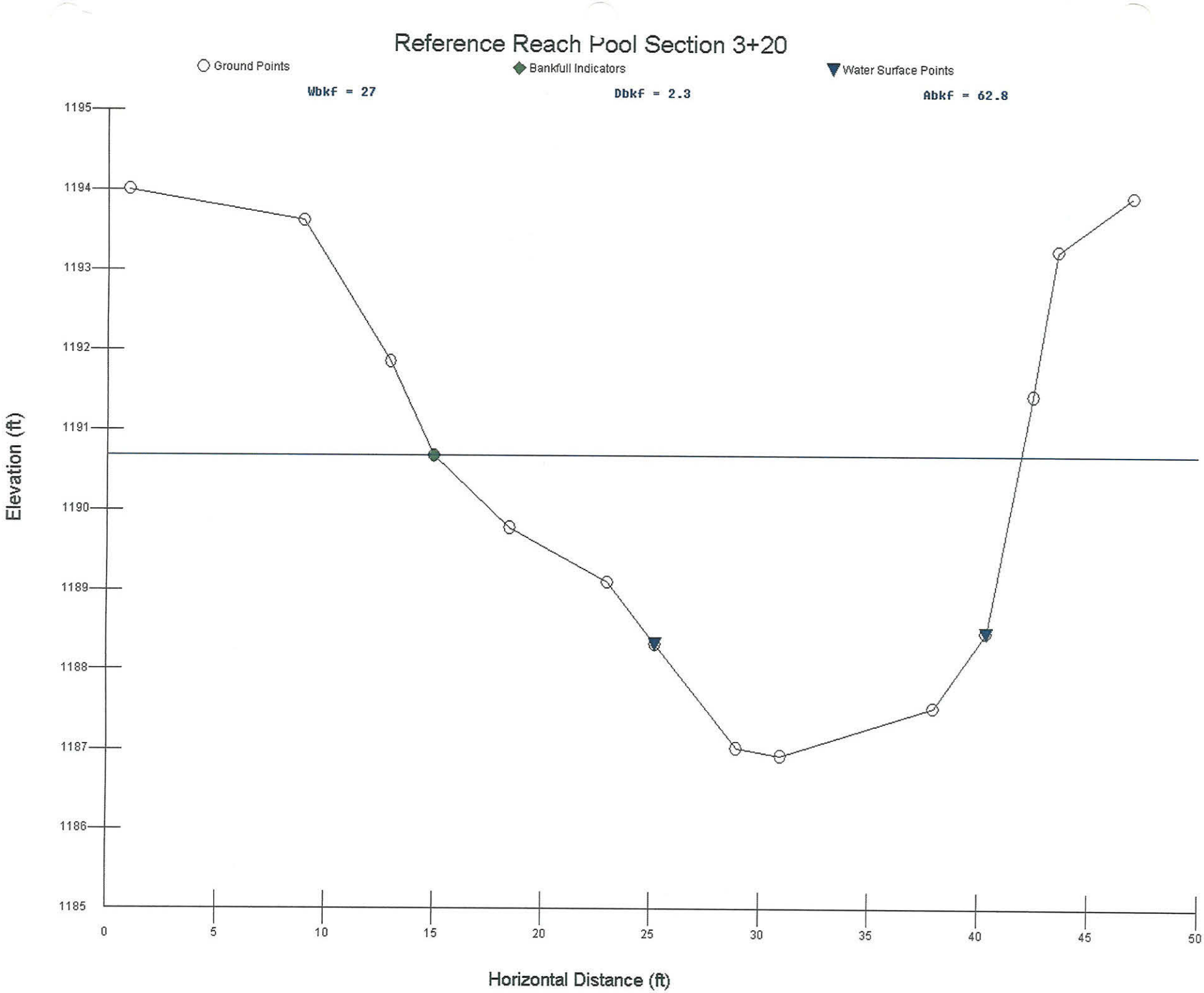
Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	0	0.00	0.00
1.0 - 2.0	0	0.00	0.00
2.0 - 4.0	0	0.00	0.00
4.0 - 5.7	0	0.00	0.00
5.7 - 8.0	0	0.00	0.00
8.0 - 11.3	0	0.00	0.00
11.3 - 16.0	1	10.00	10.00
16.0 - 22.6	1	10.00	20.00
22.6 - 32.0	2	20.00	40.00
32 - 45	2	20.00	60.00
45 - 64	3	30.00	90.00
64 - 90	1	10.00	100.00
90 - 128	0	0.00	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)	19.96
D35 (mm)	29.65
D50 (mm)	38.5
D84 (mm)	60.2
D95 (mm)	77
D100 (mm)	90
Silt/Clay (%)	0
Sand (%)	0
Gravel (%)	90
Cobble (%)	10
Boulder (%)	0
Bedrock (%)	0

Total Particles = 10 (need at least 60).


Refernce Reach Riffle Section 0+22
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 24
Dbkf = 1.3
Abkf = 30.8
Elevation (ft)
1195.0
1194.5
1194.0
1193.5
1193.0
1192.5
1192.0
1191.5
1191.0
1190.5
1190.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Horizontal Distance (ft)

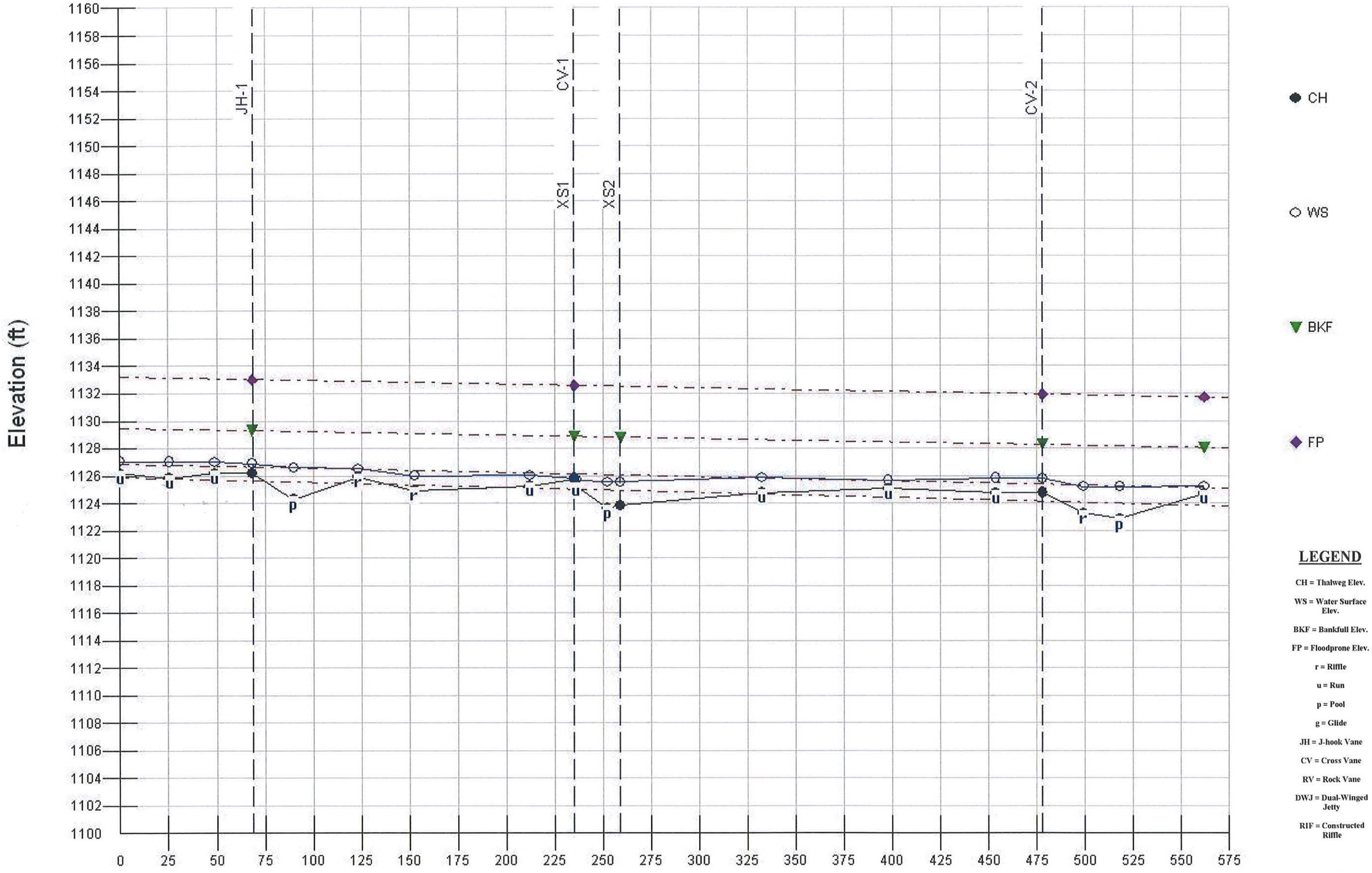
Reference Reach Riffle Cross-Section
Profile Station 0+22
January 13, 2006


Reference Reach Pool Section 3+20
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 27
Dbkf = 2.3
Abkf = 62.8
Elevation (ft)
1195
1194
1193
1192
1191
1190
1189
1188
1187
1186
1185
0
5
10
15
20
25
30
35
40
45
50
Horizontal Distance (ft)

Reference Reach Pool Cross-Section
Profile Station 3+20
January 13, 2006

Appendix C
As-Built Long-Term Monitoring Profiles

Silver Creek "As-Built" Longitudinal Profile Sta. 0+00 - 5+62.03 - Year 0



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

FP = Floodprone Elev.

r = Riffle

u = Run

p = Pool

g = Glide

JH = J-hook Vane

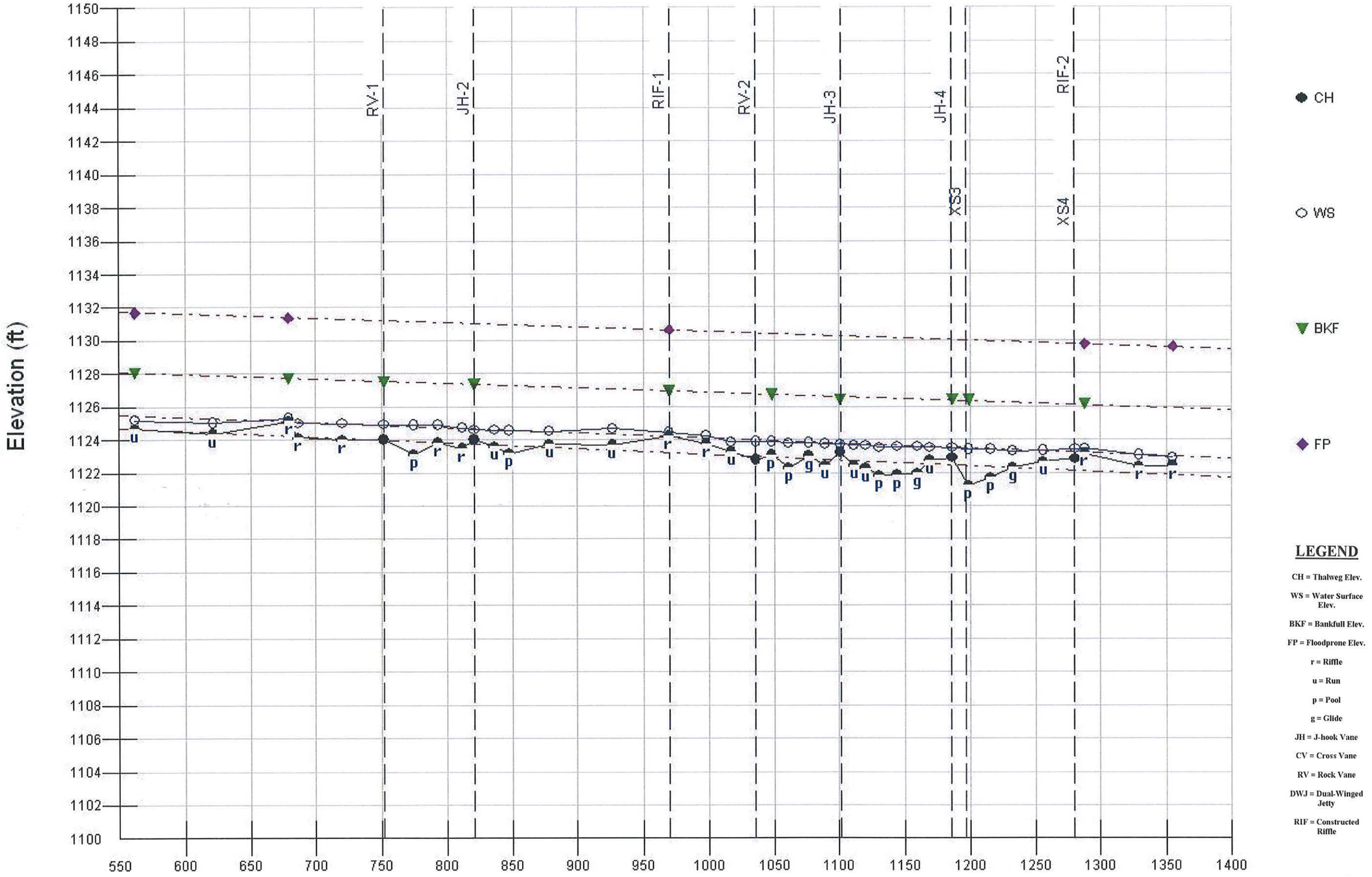
CV = Cross Vane

RV = Rock Vane

DWJ = Dual-Winged Jetty

RIF = Constructed Riffle

Silver Creek "As-Built" Longitudinal Profile Sta. 5+62.03 - 13+55.22 - Year 0



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

FP = Floodprone Elev.

r = Riffle

u = Run

p = Pool

g = Glide

JH = J-hook Vane

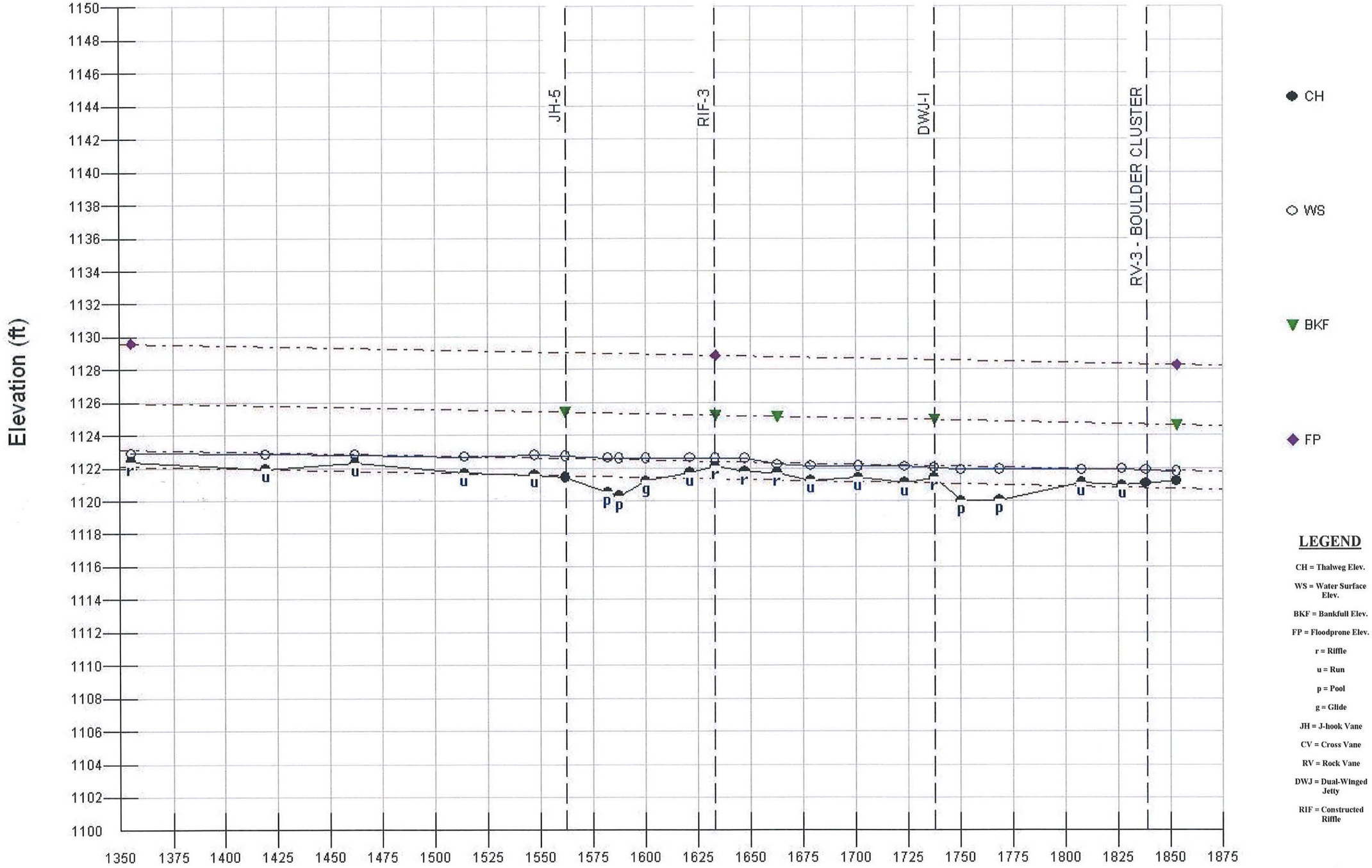
CV = Cross Vane

RV = Rock Vane

DWJ = Dual-Winged Jetty

RIF = Constructed Riffle

Silver Creek "As-Built" Longitudinal Profile Sta. 13+55.22 - 18+53.14 - Year 0



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

FP = Floodprone Elev.

r = Riffle

u = Run

p = Pool

g = Glide

JH = J-hook Vane

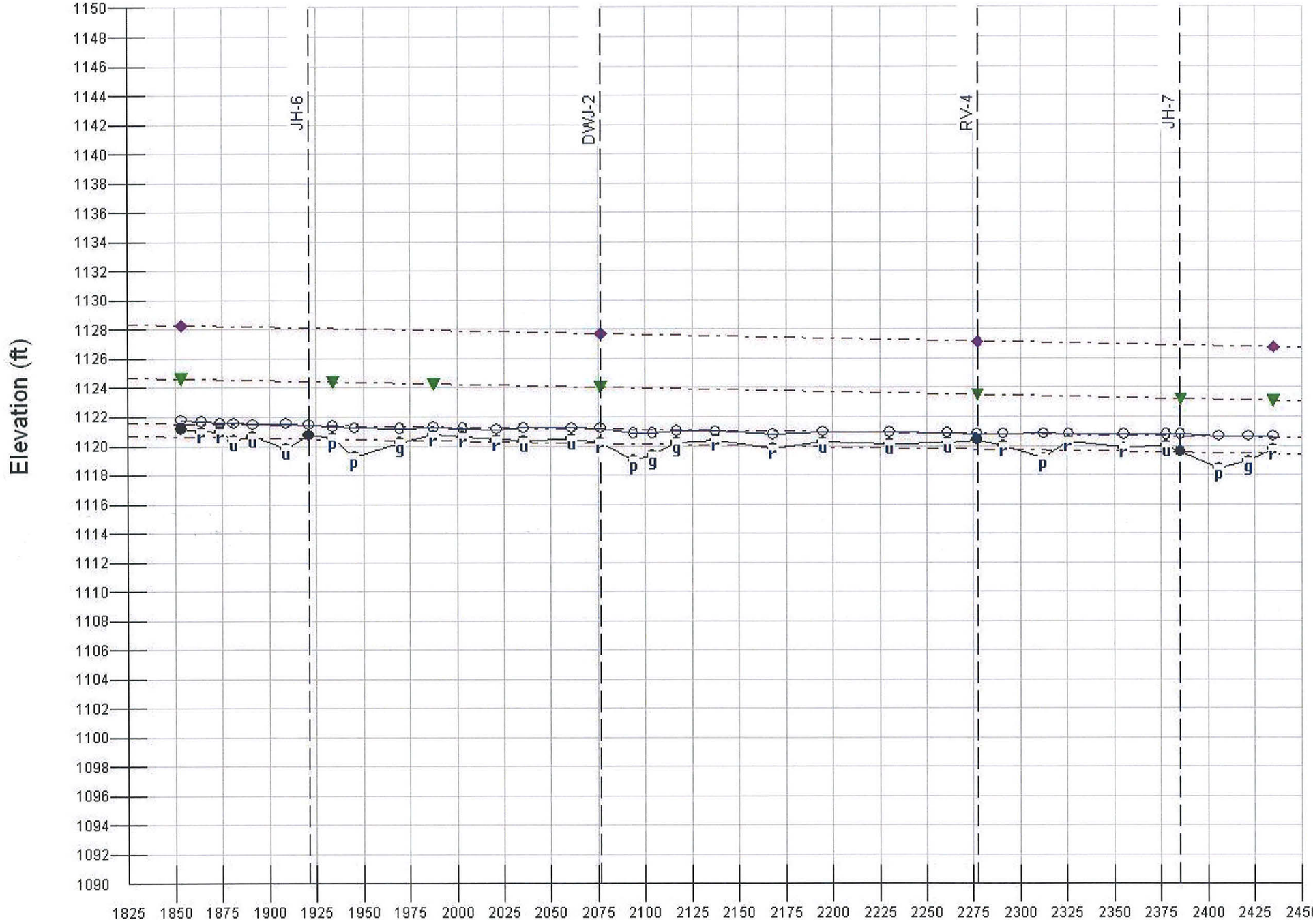
CV = Cross Vane

RV = Rock Vane

DWJ = Dual-Winged Jetty

RIF = Constructed Riffle

Silver Creek "As-Built" Longitudinal Profile Sta.18+53.14 - 24+35.21 - Year 0



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

FP = Floodprone Elev.

r = Riffle

u = Run

p = Pool

g = Glide

JH = J-hook Vane

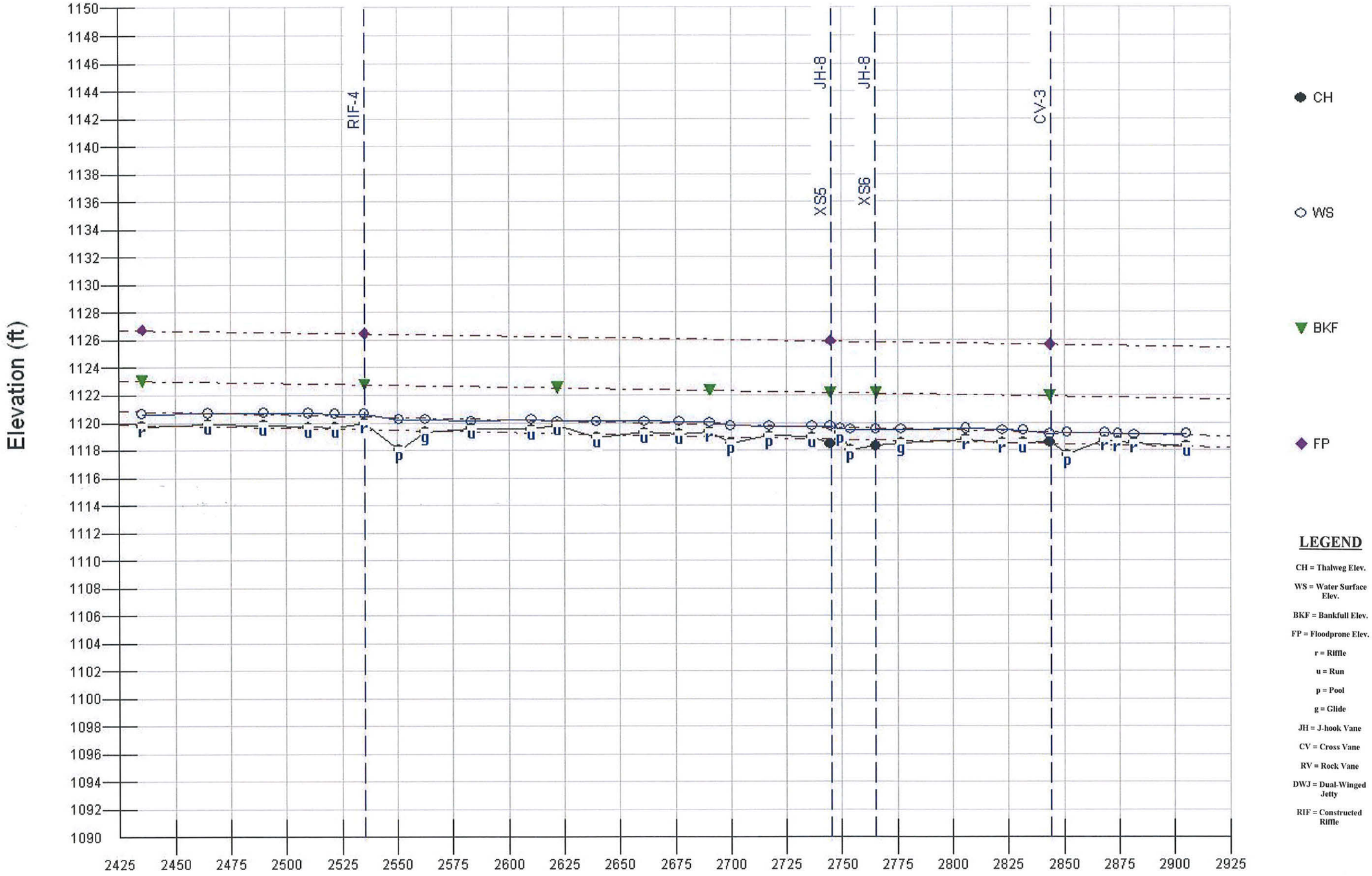
CV = Cross Vane

RV = Rock Vane

DWJ = Dual-Winged Jetty

RIF = Constructed Riffle

Silver Creek "As-Built" Longitudinal Profile Sta. 24+35.21 - 29+05.24 - Year 0



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

FP = Floodprone Elev.

r = Riffle

u = Run

p = Pool

g = Glide

JH = J-hook Vane

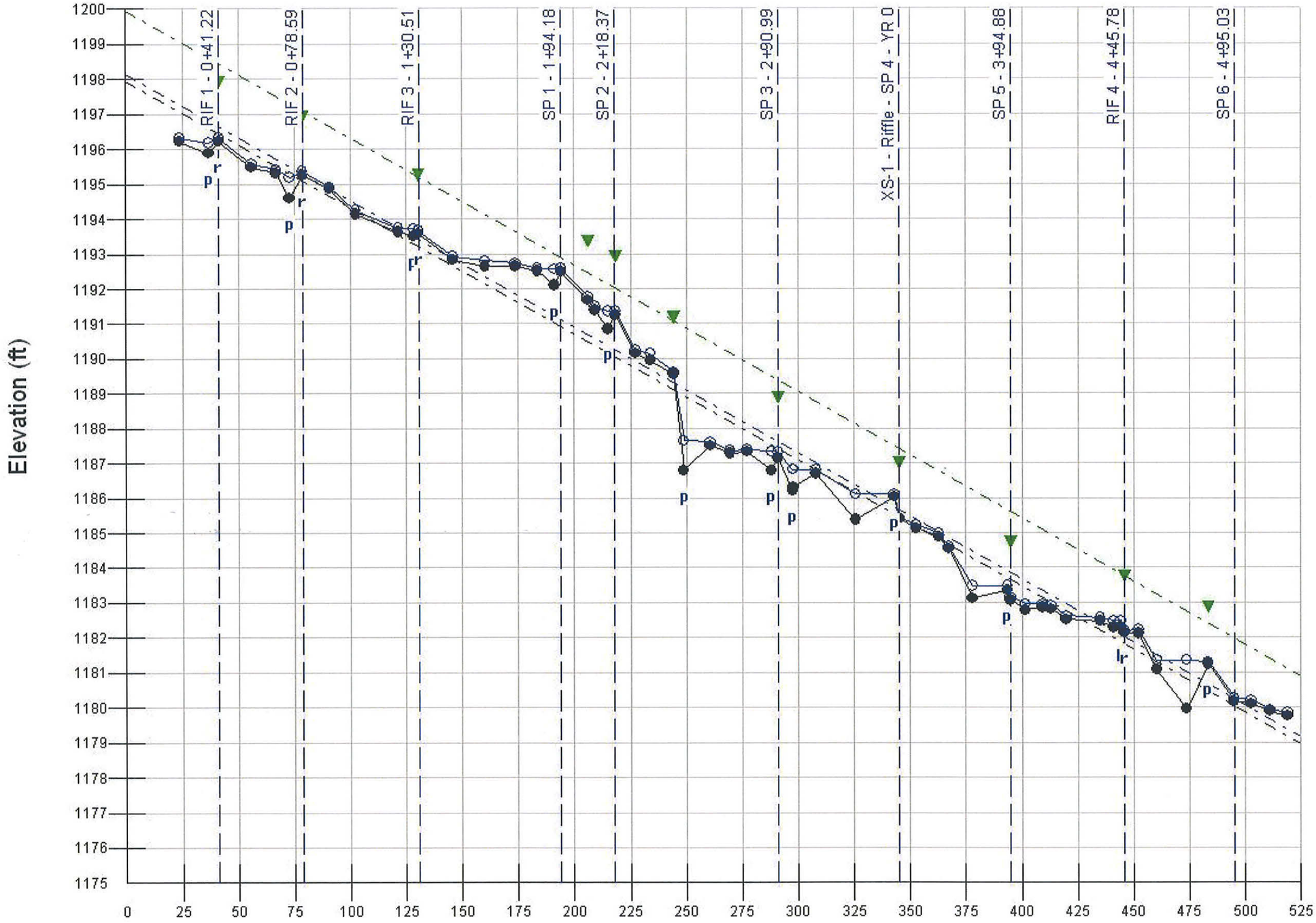
CV = Cross Vane

RV = Rock Vane

DWJ = Dual-Winged Jetty

RIF = Constructed Riffle

UT-A to Silver Creek - Sta. 0+23.85- 5+19.09 - As-Built - June 2007



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

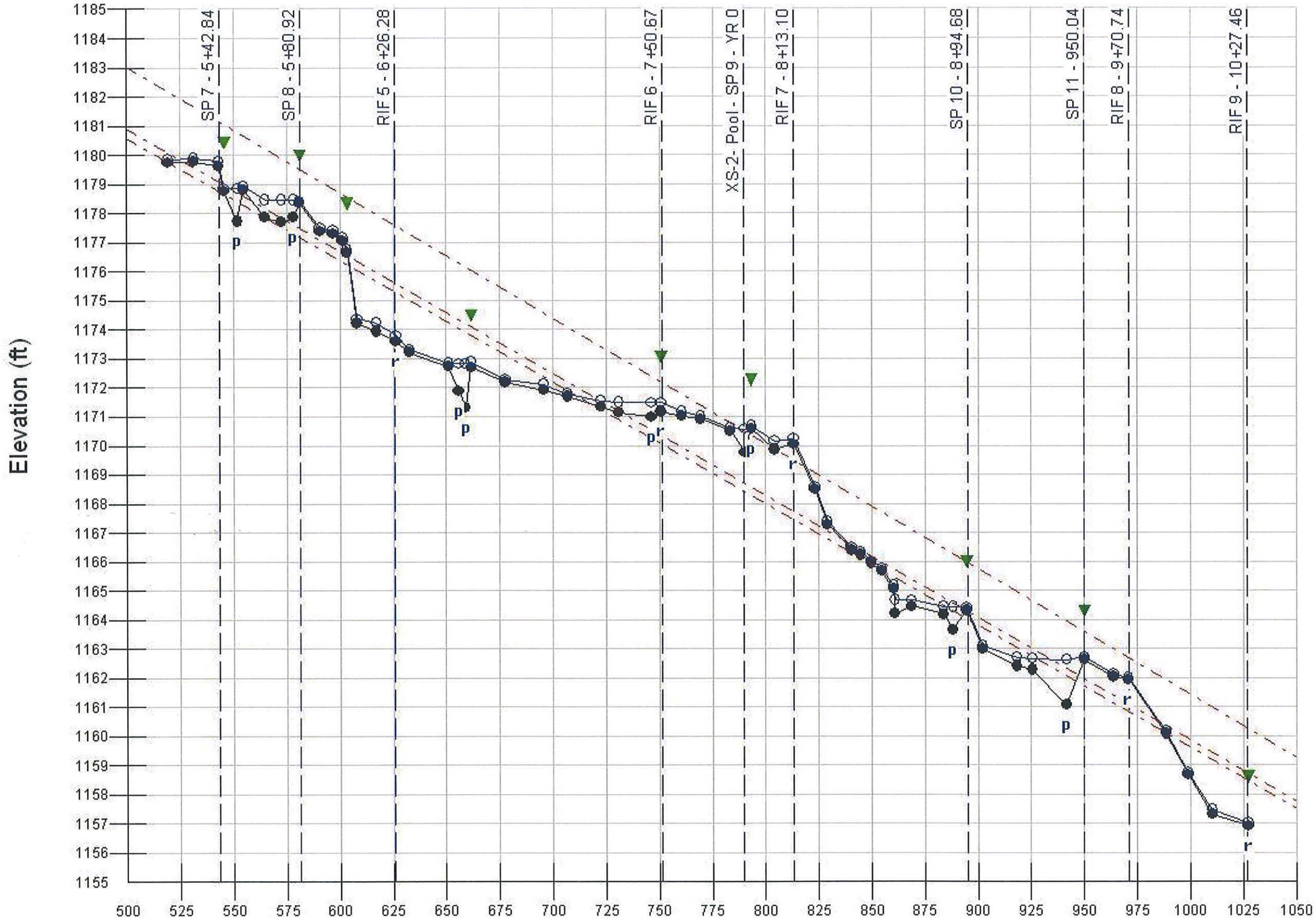
r = Riffle

p = Pool

SP = Constructed Step-Pool

RIF = Constructed Riffle

UT-A to Silver Creek - Sta. 5+19.09 - 10+27.46 - As-Built - June 2007



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

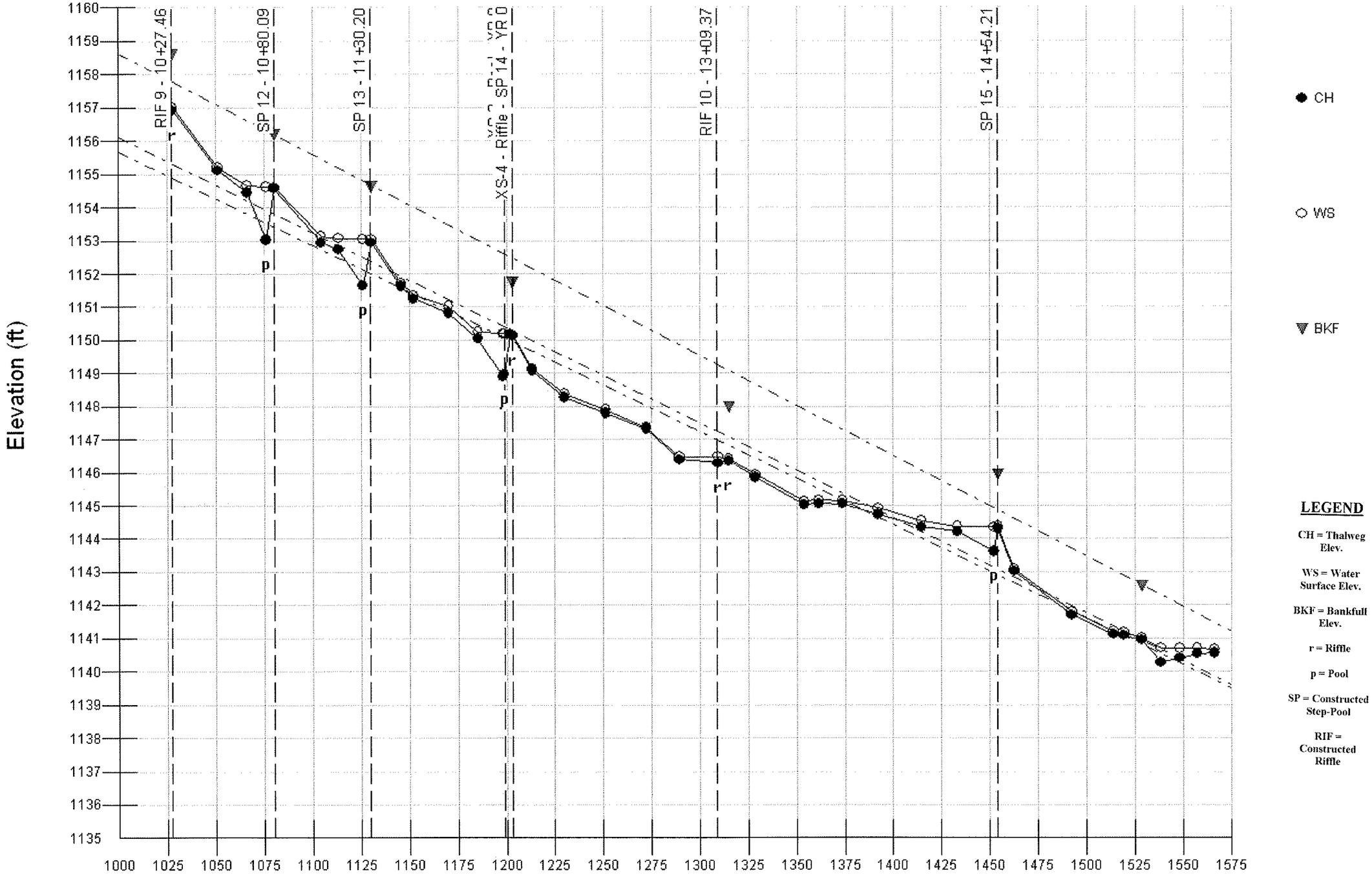
r = Riffle

p = Pool

SP = Constructed Step-Pool

RIF = Constructed Riffle

UT-A to Silver Creek - Sta. 10+27.46 - 15+66.60 - As-Built - June 2007



LEGEND

CH = Thalweg Elev.

WS = Water Surface Elev.

BKF = Bankfull Elev.

r = Riffle

p = Pool

SP = Constructed Step-Pool

RIF = Constructed Riffle

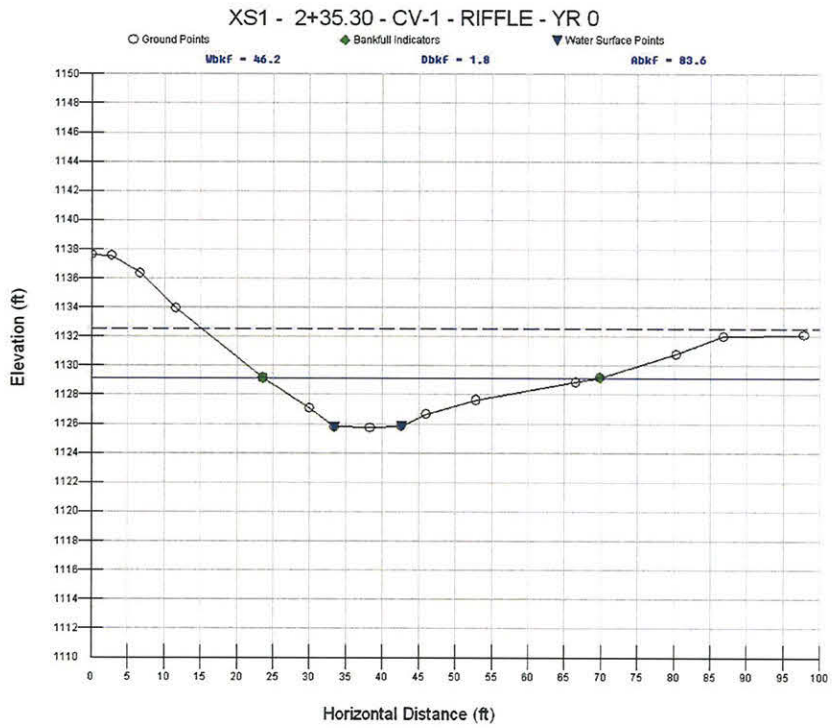
Appendix D
As-Built Long-Term Monitoring Cross-Section Summary Templates

Summary Data
All dimensions in feet.

Bankfull Area	83.59
Bankfull Width	46.18
Mean Depth	1.81
Maximum Depth	3.41
Width/Depth Ratio	25.51
Entrenchment Ratio	1.79
Classification	B4c

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	1
FEATURE:	Riffle at Cross Vane # 1

Cross-section photo – looking from right bank to left bank

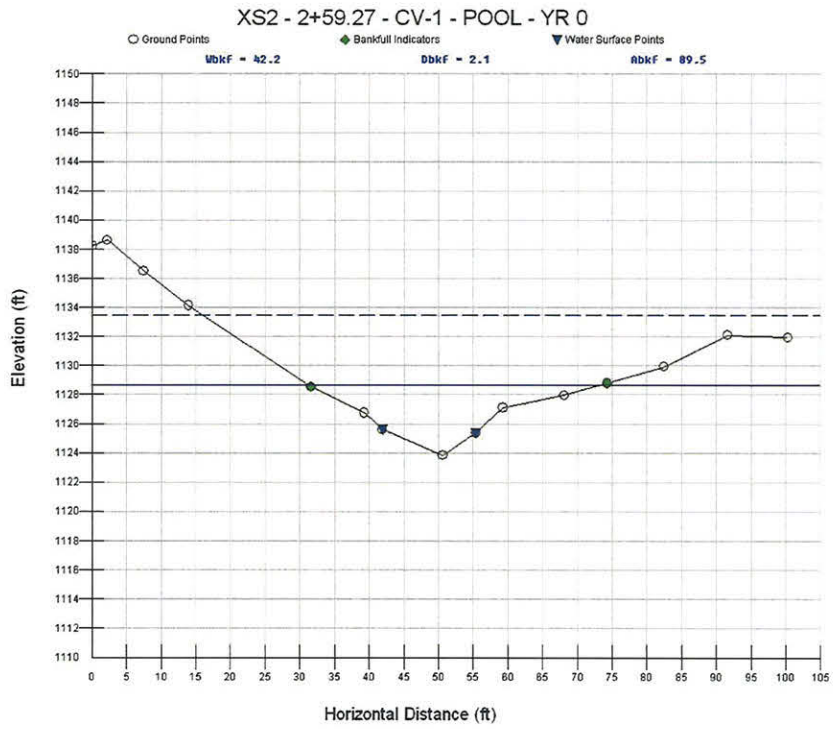


Summary Data
All dimensions in feet.

Bankfull Area	89.53
Bankfull Width	42.18
Mean Depth	2.12
Maximum Depth	4.84
Width/Depth Ratio	19.9
Entrenchment Ratio	2
Classification	B4c

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	2
FEATURE:	Pool at Cross Vane # 1

Cross-section photo – looking upstream

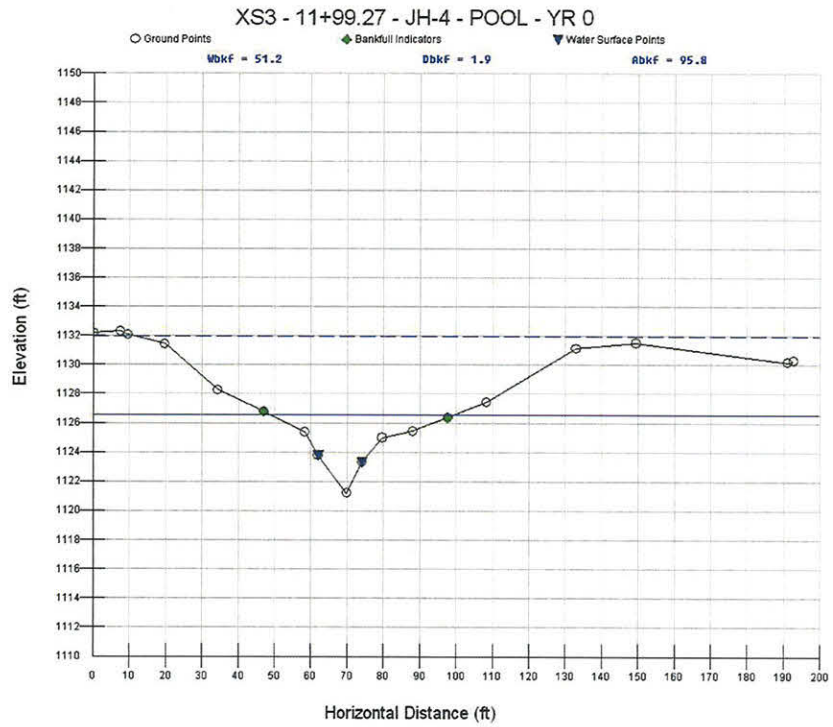


Summary Data
All dimensions in feet.

Bankfull Area	95.81
Bankfull Width	51.22
Mean Depth	1.87
Maximum Depth	5.39
Width/Depth Ratio	27.39
Entrenchment Ratio	3.55
Classification	B4c

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	3
FEATURE:	Pool at J-Hook # 4

Cross-section photo – looking across channel from right to left bank

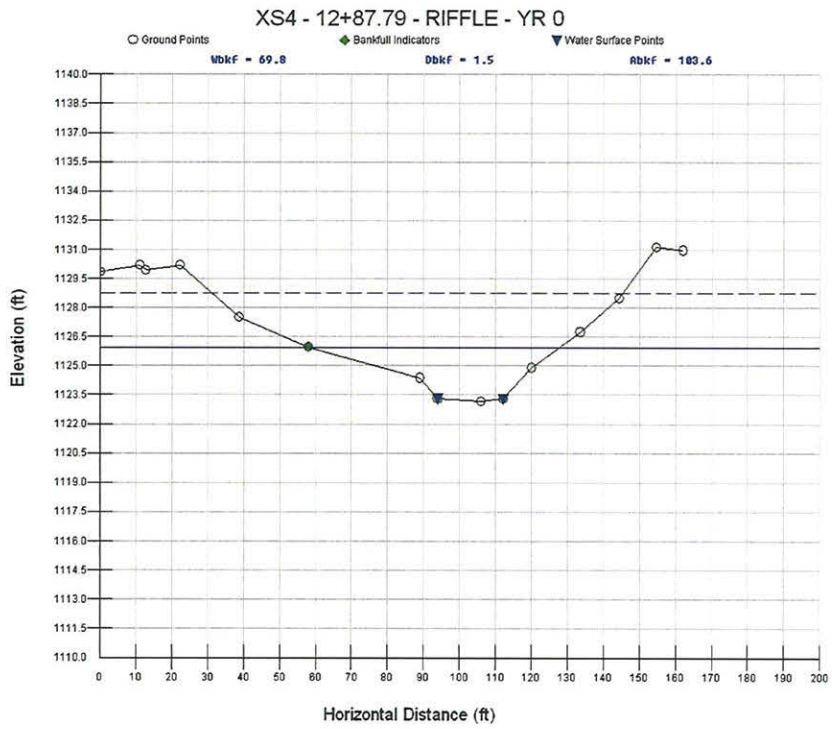


Summary Data
All dimensions in feet.

Bankfull Area	103.55
Bankfull Width	69.81
Mean Depth	1.48
Maximum Depth	2.8
Width/Depth Ratio	47.17
Entrenchment Ratio	1.64
Classification	B4c

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	4
FEATURE:	Riffle

Cross-section photo – looking downstream

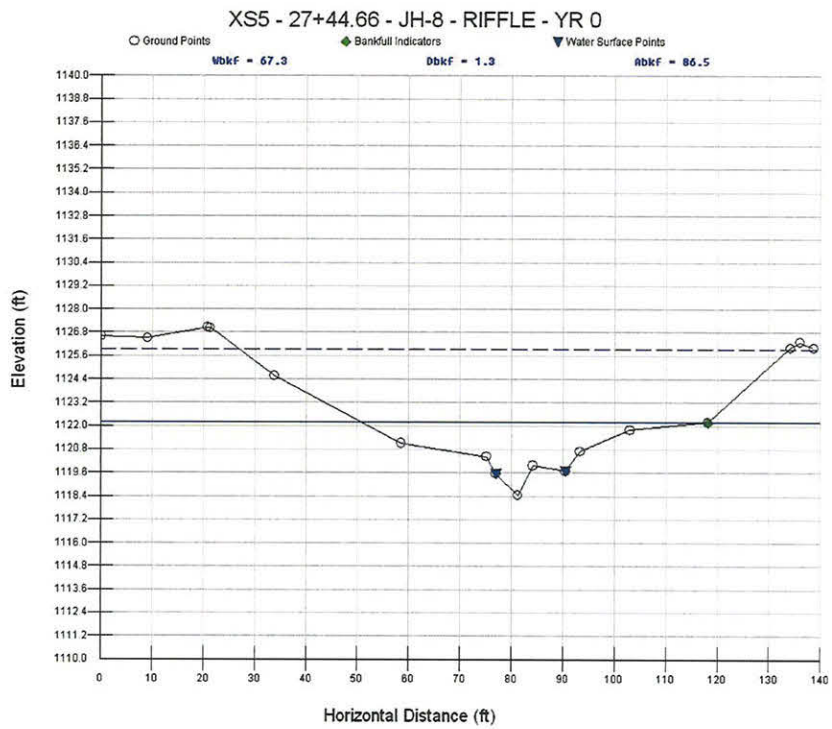


Summary Data
All dimensions in feet.

Bankfull Area	86.55
Bankfull Width	67.28
Mean Depth	1.29
Maximum Depth	3.75
Width/Depth Ratio	52.16
Entrenchment Ratio	1.59
Classification	B4a

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	5
FEATURE:	Riffle at J-Hook # 8

Cross-section photo – looking upstream

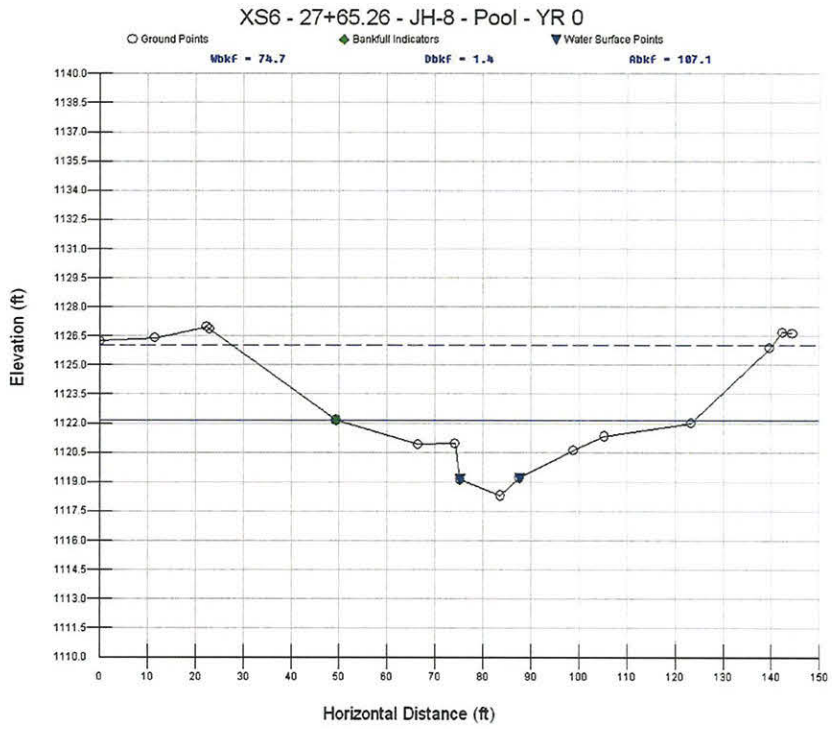


Summary Data
All dimensions in feet.

Bankfull Area	107.1
Bankfull Width	74.69
Mean Depth	1.43
Maximum Depth	3.87
Width/Depth Ratio	52.23
Entrenchment Ratio	1.51
Classification	B4c

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/22/07
CROSS SECTION:	6
FEATURE:	Pool at J-Hook # 8

Cross-section photo – looking upstream

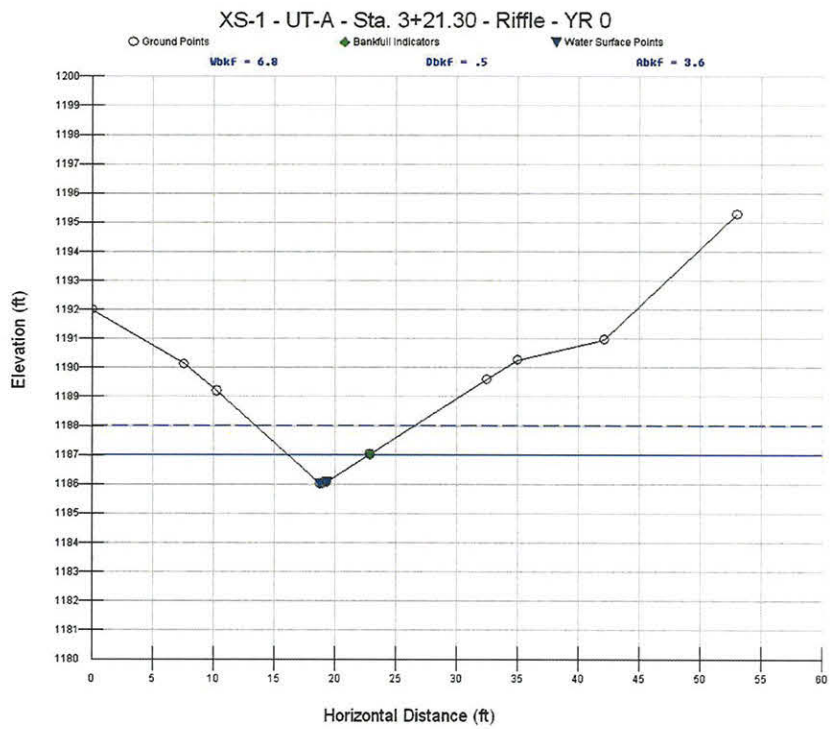


Summary Data
All dimensions in feet.

Bankfull Area	3.59
Bankfull Width	6.81
Mean Depth	0.53
Maximum Depth	1.01
Width/Depth Ratio	12.85
Entrenchment Ratio	1.95
Classification	B4a

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	UT-A
DATE	6/22/07
CROSS SECTION:	1
FEATURE:	Riffle

Cross-section photo – looking upstream

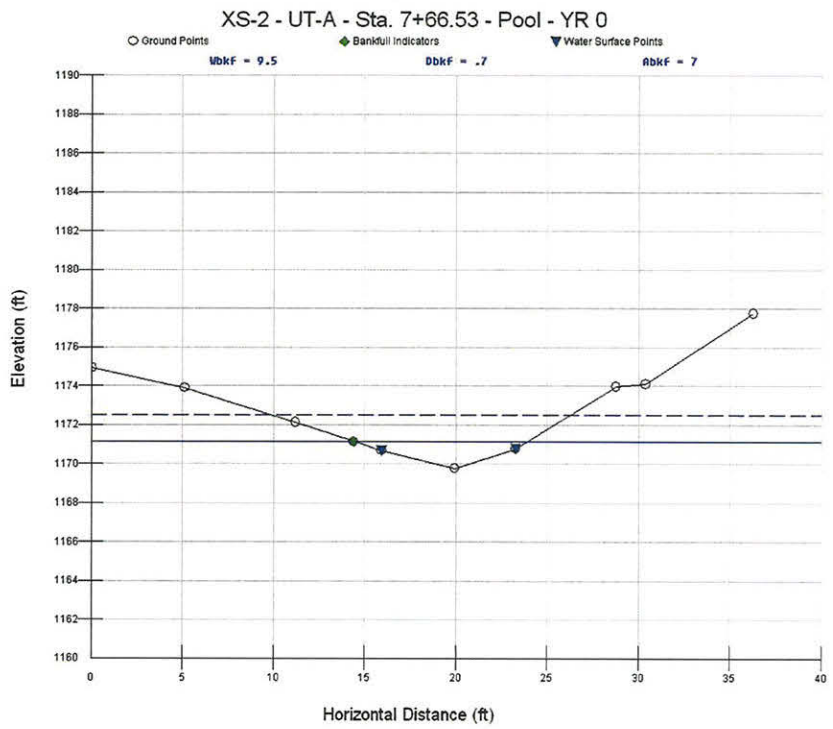


Summary Data
All dimensions in feet.

Bankfull Area	7.01
Bankfull Width	9.5
Mean Depth	0.74
Maximum Depth	1.37
Width/Depth Ratio	12.84
Entrenchment Ratio	1.72
Classification	B4a

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	UT-A
DATE	6/22/07
CROSS SECTION:	2
FEATURE:	Pool

Cross-section photo – looking from left bank to right bank



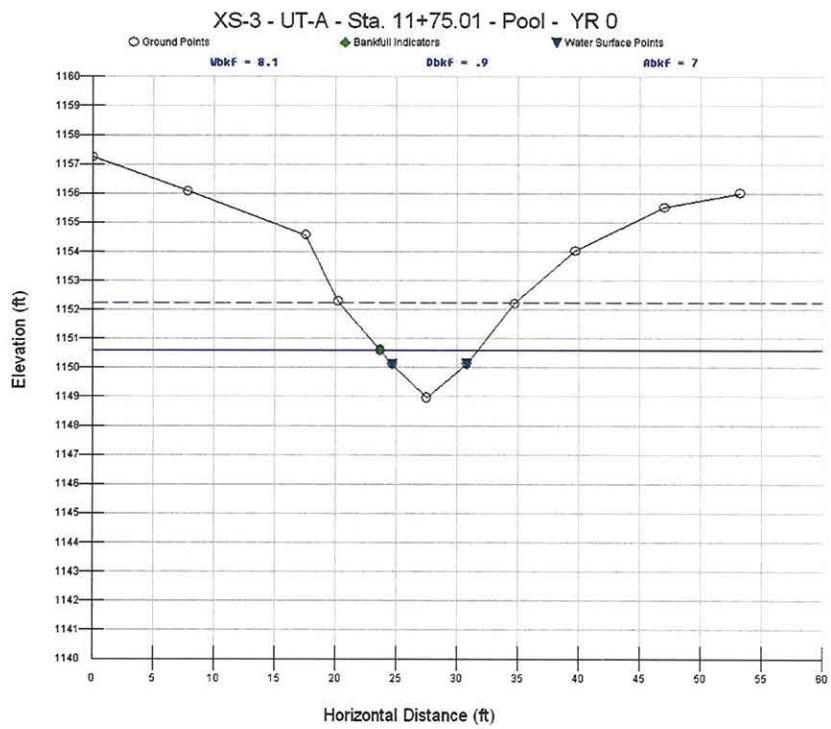
EMH&T

Summary Data
All dimensions in feet.

Bankfull Area	6.97
Bankfull Width	8.05
Mean Depth	0.87
Maximum Depth	1.64
Width/Depth Ratio	9.25
Entrenchment Ratio	1.81
Classification	B4a

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	UT-A
DATE	6/22/07
CROSS SECTION:	3
FEATURE:	Pool

Cross-section photo – looking from right bank to left bank

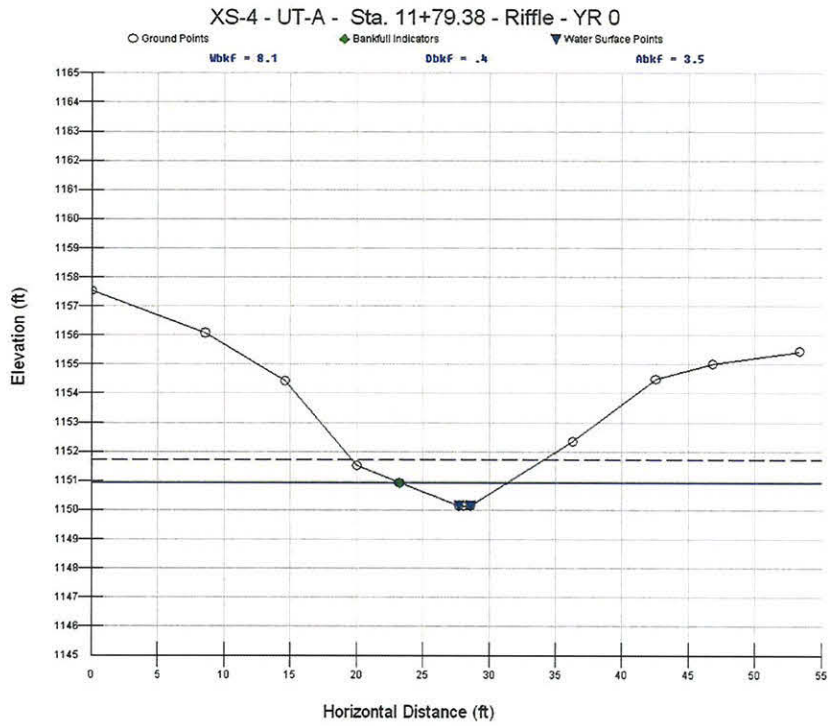


Summary Data
All dimensions in feet.

Bankfull Area	3.51
Bankfull Width	8.11
Mean Depth	0.43
Maximum Depth	0.81
Width/Depth Ratio	18.86
Entrenchment Ratio	1.8
Classification	B4a

PROJECT	Silver Creek
	D05016-1
	0-YEAR
TASK	Cross-Section
REACH	UT-A
DATE	6/22/07
CROSS SECTION:	4
FEATURE:	Riffle

Cross-section photo – looking from left bank to right bank



Appendix E
Supporting Documentation

RIVERMorph 4.0.1 Professional - Silver Creek Stream Restoration_4.0

File Tools Help

- Silver Creek & Trib Restoration
  - Reach 1 (Reference Reach)
    - Survey Data
    - Cross Sections
      - Riffle Section 0+22
      - Pool Section 3+20
    - Banks
    - Profiles
      - Ref Reach Long Pro
    - Particles
      - Riffle X-S 0+22
      - Pool X-S 3+20
      - Composite
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
      - NCD
      - Vanes
    - Notes
  - Reach 1 (Abandoned Oxbow - A
  - Reach 3 (Over Tightened Mean
  - Reach 4 (Top of Main Stem)
  - Reach 5 (Unnamed Tributary)
  - As-Built Mainstem
  - As-Built UT-A
  - As-Built UT2
  - As-Built UT3

Ratios | Riffle | Profile | D50 | Reset Sliders | Extra Info

Profiles: Ref Reach Long Pro — Pebble Counts: Composite D50 = 27.73 mm

Riffle X-Sections: Riffle Section 0+22

Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.0138
Drainage Area (sq mi)	1.16

Location and Date of Survey

State	North Carolina
County	Burke
Latitude	35.61861
Longitude	81.81694
Date	01/13/06

Stream Classification

C 4

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification
☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	24.02
Mean Depth (ft)	1.28
Maximum Depth (ft)	1.72
Flood-Prone Width (ft)	232
Channel Materials D50 (mm)	38.5
Water Surface Slope (ft/ft)	0.01149
Sinuosity	1.2
Discharge (cfs)	98.16
Velocity (fps)	3.19
Cross Sectional Area (sq ft)	30.77
Entrenchment Ratio	9.66
Width to Depth Ratio	18.77

☑ This Reach is a Reference Reach

Brindle Creek Reference Reach
Stream Classification and Morphologic Data Summary

Start | Inbox - Microsoft Outlook | RIVERMorph 4.0.1 Profe... | 1:14 PM

RIVERMorph 4.0.1 Professional - Silver Creek Stream Restoration_4.0

File Tools Help

- Silver Creek & Trib Restoration
  - Reach 1 (Reference Reach)
  - Reach 1 (Abandoned Oxbow - A
  - Reach 3 (Over Tightened Mean
  - Reach 4 (Top of Main Stem)
  - Reach 5 (Unnamed Tributary)
  - As-Built Mainstem
    - Survey Data
    - Cross Sections
      - XS1 - 2+35.30 - CV-1 - YF
      - XS2 - 2+59.27 - CV-1 - YF
      - XS3 - 11+99.27 - JH-4 - Y
      - XS4 - 12+80.37 - RIF-2 -
      - XS5 - 27+44.66 - JH-8 - Y
      - XS6 - 27+65.26 JH-8 - YF
      - JH-1 - 0+68.51
      - CV-2 - 4+78.13
      - JH-2 - 8+21.29
      - JH-3 - 11+00.58
      - JH-4 - 11+86.42
      - JH-5 - 15+61.82
      - CV-3 - 17+37.70
      - JH-6 - 19+20.98
      - RIF-4 - BOULDER CLUST
      - RV-4 - 22+77.01
      - JH-7 - 23+85.32
      - CV-4 - 28+43.59
      - RV-1 - 7+52.27
      - RIF-5 - 25+35.16
      - RV-2 10+36.17
      - RV-3 - BOULDER CLUST
      - RIF-3 - 16+33.26
      - RIF-1 9+69.80
    - Banks
    - Profiles
    - Particles
      - Reach Composite
      - XS1 - 2+35.30 - CV-1 - RI
      - XS2 - 2+59.27 - CV-1 - Pc
      - XS3 - 11+99.27 - JH-4 - P
      - XS4 - 12+80.37 - Riffle
      - XS5 - 27+44.66 - JH-8 - R
      - XS6- 27+65.26 - JH-8 - Pc
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
    - Notes
  - As-Built UT
  - As-Built UT2
  - As-Built UT3

Ratios | Riffle | Profile | D50 | Reset Sliders | Extra Info

Profiles: Mainstem Long Pro - Yr 0 — Pebble Counts: Reach Composite D50 = 27

Riffle X-Sections: XS4 - 12+80.37 - RIF-2 - YR 0

Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.0037
Drainage Area (sq mi)	8.01

Location and Date of Survey

State	North Carolina
County	Burke
Latitude	35.61861
Longitude	81.81611
Date	07/23/07

Stream Classification

B 4c

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification
☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	69.81
Mean Depth (ft)	1.48
Maximum Depth (ft)	2.8
Flood-Prone Width (ft)	114.45
Channel Materials D50 (mm)	4.25
Water Surface Slope (ft/ft)	0.00265
Sinuosity	1.4
Discharge (cfs)	378
Velocity (fps)	3.65
Cross Sectional Area (sq ft)	103.55
Entrenchment Ratio	1.64
Width to Depth Ratio	47.17

☐ This Reach is a Reference Reach

Resistance Equation Calculator

Manning | Chezy | Darcy-Weisbach | U/U* | Pipes

Manning Roughness Coefficient (n)

Limerinos n | Cowan n | Stream Type n | Ja

Hydraulic Radius (ft)	1.48
Bed Material D84 (mm)	26.9
Manning's n:	0.0274
Cross Sectional Area (sq ft)	103.55
Wetted Perimeter (ft)	70.2
Hydraulic Slope (ft/ft)	0.0027
Velocity (fps):	3.65
Discharge (cfs):	377.96

$$U = \frac{Cm}{n} R^{2/3} S^{1/2}$$

Silver Creek "As-Built" Reach
Stream Classification and Morphologic Data Summary

Start | As-Built Mainstem Classifi... | RIVERMorph 4.0.1 Profe... | 5:16 PM

RIVERMorph 4.0.1 Professional - Silver Creek Stream Restoration_4.0

File Tools Help

- Silver Creek & Trib Restoration
  - Reach 1 (Reference Reach)
  - Reach 1 (Abandoned Oxbow - A
  - Reach 3 (Over Tightened Mean
  - Reach 4 (Top of Main Stem)
  - Reach 5 (Unnamed Tributary)
  - As-Built Mainstem
  - As-Built UT
    - Survey Data
    - Cross Sections
    - Banks
    - Profiles
    - Particles
      - UT XS2 - Pool
      - UT XS4 - Riffle
      - UT XS1 - Riffle
      - UT XS3 - Pool
      - Reach Composite
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
    - Notes
  - As-Built UT2
  - As-Built UT3

Ratios | Riffle | Profile | D50 | Reset Sliders | Extra Info

Profiles: UT Sta. 0+00 - 4+95.24 — Pebble Counts: Reach Composite D50 = 11

Riffle X-Sections: XS-1 - UT-1 - Riffle - YR 0

Valley Morphology

Valley Type	Type I
Valley Slope (ft/ft)	0.046
Drainage Area (sq mi)	0.075

Location and Date of Survey

State	North Carolina
County	Burke
Latitude	35.6521
Longitude	81.82997
Date	06/22/07

Stream Classification

B 4a

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification
☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	8.11
Mean Depth (ft)	0.43
Maximum Depth (ft)	0.81
Flood-Prone Width (ft)	14.57
Channel Materials D50 (mm)	11.89
Water Surface Slope (ft/ft)	0.04265
Sinuosity	1.08
Discharge (cfs)	16.9
Velocity (fps)	4.81
Cross Sectional Area (sq ft)	3.51
Entrenchment Ratio	1.8
Width to Depth Ratio	18.86

☐ This Reach is a Reference Reach

Resistance Equation Calculator

Manning | Chezy | Darcy-Weisbach | U/U* | Pipes

Manning Roughness Coefficient (n)

Limerinos n | Cowan n | Stream Type n | Ja

Hydraulic Radius (ft)	0.42
Bed Material D84 (mm)	36.49
Manning's n:	0.0360
Cross Sectional Area (sq ft)	3.51
Wetted Perimeter (ft)	8.28
Hydraulic Slope (ft/ft)	0.0427
Velocity (fps):	4.81
Discharge (cfs):	16.88

$$U = \frac{Cm}{n} R^{2/3} S^{1/2}$$

Silver Creek Unnamed Tributary A
"As-Built" Reach Stream Classification and Morphologic Data Summary

Start | As-Built UT Classification | RIVERMorph 4.0.1 Profe... | 4:26 PM

RIVERMorph 4.0.1 Professional - Silver Creek Stream Restoration_4.0

File Tools Help

- Silver Creek & Trib Restoration
  - Reach 1 (Reference Reach)
  - Reach 1 (Abandoned Oxbow - A
    - Survey Data
    - Cross Sections
      - Pool X-S Sta. 13+77
      - Riffle Section 12+52.5
    - Banks
    - Profiles
      - Silver Ck Altered Profile - S
    - Particles
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
    - Notes
  - Reach 3 (Over Tightened Mean
  - Reach 4 (Top of Main Stem)
  - Reach 5 (Unnamed Tributary)
  - As-Built Mainstem
  - As-Built UT
  - As-Built UT2
  - As-Built UT3

Ratios | Riffle | Profile | D50 D50 | Reset Sliders | Extra Info

Profiles: Silver Ck Altered Profile - Station 12+0 | Pebble Counts:

Riffle X-Sections: Riffle Section 12+52.5

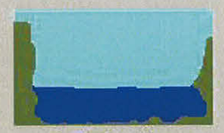
Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.0037
Drainage Area (sq mi)	8.01

Location and Date of Survey

State	North Carolina
County	Burke
Latitude	35.6186
Longitude	81.816
Date	02/08/06

Stream Classification



F 4

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification
☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	122.47
Mean Depth (ft)	1.88
Maximum Depth (ft)	7.62
Flood-Prone Width (ft)	84
Channel Materials D50 (mm)	38.5
Water Surface Slope (ft/ft)	0.00218
Sinuosity	1
Discharge (cfs)	461
Velocity (fps)	1.46
Cross Sectional Area (sq ft)	230.44
Entrenchment Ratio	0.69
Width to Depth Ratio	65.14

☐ This Reach is a Reference Reach

Start | Mitigation Plan - Microsof... | Existiing Conditions MS C... | RIVERMorph 4.0.1 Pro... | 11:28 AM

Silver Creek Altered Reach
Stream Classification and Morphologic Data Summary

Brindle Creek Reference Reach
Stream Classification and Morphologic Data Summary

Stream NAME: Silver Creek & Trib Restoration, Reach - Reach 1 (Reference Reach)

Basin NAME: Catawba River Drainage AREA: 742.4 acre 1.16 mi^2

Location: Brindle Creek of Silver Creek, Burke County, North Carolina

Twp: _____ Rge: _____ Sec: _____ Qtr: _____ Lat: 35.6186 Long: 81.817

Observers: Miles F. Hebert, PE and Warren E. Knotts, PG Date: 1/13/2006

Bankfull WIDTH (W_{bkf}) — **24.02** Feet
WIDTH of the stream channel, at bankfull stage elevation, in a riffle section.

Mean DEPTH (d_{bkf}) — **1.28** Feet
Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section.
($d_{bkf}=A_{bkf}/W_{bkf}$)

Bankfull Cross Section Area (A_{bkf}) — **30.77** $Feet^2$
AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

WIDTH / DEPTH RATIO (W_{bkf}/d_{bkf}) — **18.77** Ft/Ft
Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mrif}) — **1.72** Feet
Maximum depth of the bankfull channel cross-section, or elevation between the bankfull stage and thalweg in a riffle section.

Flood-Prone Area WIDTH (W_{fpa}) — **232** Feet
The stage/elevation at which flood-prone area WIDTH is determined in a riffle section at twice maximum DEPTH, or ($2 \times d_{mrif}$)

Entrenchment RATIO (ER) — **9.66** Ft/Ft
The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa}/W_{bkf}) in a riffle section.

Channel Materials (Particle Size Index) D50 — **38.5** mm
The 50th percentile, or less than, from a pebble count frequency distribution of channel particles representing the median or dominant particle size.

Water Surface SLOPE (S) — **0.01149** Ft/Ft
Average water surface slope as measured between the same position of bed features in the profile over two meander wave lengths. This is similar to average bankfull slope.

Channel SINUOSITY (K) — **1.2**
Sinuosity: an index of channel pattern, determined from stream length / valley length, i.e. (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/ S).

Stream Type **C 4**

For Reference, see page 5-5, 5-6: Rosgen, 1996. Applied River Morphology.

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Brindle Creek Reference Reach
Stream Classification and Morphologic Data Summary

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.28	feet	Mean Riffle Width (W_{bkf})	24.02	feet	Mean Riffle Area (A_{bkf})	30.77	$feet^2$
Mean Pool Depth (d_{bkfp})	2.33	feet	Mean Pool Width (W_{bkfp})	26.97	feet	Mean Pool Area (A_{bkfp})	62.77	$feet^2$
Ratio Mean Pool Depth/Mean Riffle Depth	1.820	d_{bkfp}/d_{bkf}	Ratio Pool Width/Riffle Width	1.123	W_{bkfp}/W_{bkf}	Ratio Pool Area/ Riffle Area	2.040	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mrif})	2.41	feet	Max Pool Depth (d_{mpool})	3.76	feet	Max riffle depth/Mean riffle depth	1.883	
Max pool depth/Mean riffle depth	2.938					Point Bar Slope	0.01	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				3.19	ft/s	Estimation Method	Manning's Equation	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				98.16	cfs	Drainage Area	1.16	mi^2

Channel Pattern

Geometry	Ave	Min	Max		Dimensionless Geometry Ratios	Ave	Min	Max
Meander Length (Lm)	104.8	88.23	115.7	feet	Meander Length Ratio (Lm/W_{bkf})	4.361	3.673	4.816
Radius of Curvature (Rc)	17.67	12.97	24.44	feet	Radius of Curvature/Riffle Width (Rc/W_{bkf})	0.736	0.540	1.017
Belt Width (W_{blt})	45.22	44.17	46.5	feet	Meander Width Ratio (W_{blt}/W_{bkf})	1.883	1.839	1.936
Individual Pool Length	17.42	11.01	31.56	feet	Pool Length/Riffle Width	0.725	0.458	1.314
Pool to Pool Spacing	71.36	67.6	77.5	feet	Pool to Pool Spacing/Riffle Width	2.971	2.814	3.226

Channel Profile

Valley Slope (VS)	0.0138	ft/ft	Average Water Surface Slope (S)	0.01149	ft/ft	Sinuosity (VS/S)	1.2	
Stream Length (SL)	353	feet	Valley Length (VL)	294	feet	Sinuosity (SL/VL)	1.201	
Low Bank Height (LBH)	start 1.62 / end 1.86	feet	Max Riffle Depth	start 1.62 / end 1.86	feet	Bank Height Ratio (LBH/Max Riffle Depth)	start 1 / end 1	

Facet Slopes	Ave	Min	Max		Dimensionless Slope Ratios	Ave	Min	Max
Riffle Slope (S_{rif})	0.0246	0.0172	0.0346	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	2.144	1.500	3.008
Run Slope (S_{run})	0.0211	0.0125	0.0362	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	1.838	1.088	3.150
Pool Slope (S_p)	0.0043	0.0010	0.0095	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.372	0.086	0.824
Glide Slope (S_g)	0.0053	0.0020	0.0075	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	0.460	0.173	0.655

Feature Midpoint[a]	Ave	Min	Max		Dimensionless Depth Ratios	Ave	Min	Max
Riffle Depth (d_{mrif})	2.410	2.410	2.410	feet	Riffle Max Depth/Riffle Mean Depth (d_{mrif}/d_{bkf})	1.883	1.883	1.883
Run Depth (d_{mrun})	2.300	1.870	2.560	feet	Run Max Depth/Riffle Mean Depth (d_{mrun}/d_{bkf})	1.797	1.461	2.000
Pool Depth (d_{mp})	3.760	3.760	3.760	feet	Pool Max Depth/Riffle Mean Depth (d_{mp}/d_{bkf})	2.938	2.938	2.938
Glide Depth (d_{mg})	2.210	1.640	2.700	feet	Glide Max Depth/Riffle Mean Depth (d_{mg}/d_{bkf})	1.727	1.281	2.109

Channel Materials

Catagories	Reach[b]	Riffle[c]	Bar	Indices	Reach[b]	Riffle[c]	Bar	
% Silt/Clay	0	0		D16	0.84	19.96		mm
% Sand	24	0		D35	18.64	29.65		mm
% Gravel	63	90		D50	27.73	38.5		mm
% Cobble	13	10		D84	58.3	60.2		mm
% Boulder	0	0		D95	87.11	77		mm
% Bedrock	0	0		D100	179.99	90		mm

a. The range of "feature" mid-point maximum bankfull depths, including the minimum, maximum and average values. (Pool depths are obtained from the deepest portion of the feature.)

b. A composite sample of materials from riffle and pool featutes taken within the designated reach.

c. Sample obtained within the "active" bed of a riffle feature at the location of the cross section.

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Silver Creek Altered Reach
Stream Classification and Morphologic Data Summary

Stream NAME: Silver Creek & Trib Restoration, Reach - Reach 1 (Abandoned Oxbow - Altered)

Basin NAME: Catawba River Drainage AREA: 5126.4 acre 8.01 mi^2

Location: Silver Creek, Abandoned Oxbow, Queen/Conway Property, Burke Co., North Carolina

Twp: _____ Rge: _____ Sec: _____ Qtr: _____ Lat: 35.6186 Long: 81.816

Observers: Warren E. Knotts, P.G. and Sean Peffer, Env. Sci. Date: 2/8/2006

Bankfull WIDTH (W_{bkf}) — **123.41** Feet
WIDTH of the stream channel, at bankfull stage elevation, in a riffle section.

Mean DEPTH (d_{bkf}) — **1.83** Feet
Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section.
($d_{bkf}=A_{bkf}/W_{bkf}$)

Bankfull Cross Section Area (A_{bkf}) — **225.53** $Feet^2$
AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

WIDTH / DEPTH RATIO (W_{bkf}/d_{bkf}) — **67.44** Ft/Ft
Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mrif}) — **7.58** Feet
Maximum depth of the bankfull channel cross-section, or elevation between the bankfull stage and thalweg in a riffle section.

Flood-Prone Area WIDTH (W_{fpa}) — **84** Feet
The stage/elevation at which flood-prone area WIDTH is determined in a riffle section at twice maximum DEPTH, or ($2 \times d_{mrif}$)

Entrenchment RATIO (ER) — **0.68** Ft/Ft
The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa}/W_{bkf}) in a riffle section.

Channel Materials (Particle Size Index) D50 — **38.5** mm
The 50th percentile, or less than, from a pebble count frequency distribution of channel particles representing the median or dominant particle size.

Water Surface SLOPE (S) — **0.00218** Ft/Ft
Average water surface slope as measured between the same position of bed features in the profile over two meander wave lengths. This is similar to average bankfull slope.

Channel SINUOSITY (K) — **1**
Sinuosity: an index of channel pattern, determined from stream length / valley length, i.e. (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/ S).

Stream Type **F 4**

For Reference, see page 5-5, 5-6: Rosgen, 1996. Applied River Morphology.

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Silver Creek Altered Reach
Stream Classification and Morphologic
Data Summary

Channel Dimension

Mean Riffle Depth (d_{bkf})	3.95	feet	Mean Riffle Width (W_{bkf})	60.86	feet	Mean Riffle Area (A_{bkf})	230.4	$feet^2$
Mean Pool Depth (d_{bkfp})	4.54	feet	Mean Pool Width (W_{bkfp})	72.2	feet	Mean Pool Area (A_{bkfp})	327.8	$feet^2$
Ratio Mean Pool Depth/Mean Riffle Depth	1.149	d_{bkfp}/d_{bkf}	Ratio Pool Width/Riffle Width	1.186	W_{bkfp}/W_{bkf}	Ratio Pool Area/ Riffle Area	1.422	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mrif})	7.04	feet	Max Pool Depth (d_{mpool})	7.12	feet	Max riffle depth/Mean riffle depth	1.782	
Max pool depth/Mean riffle depth	1.803					Point Bar Slope	0	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				1.46	ft/s	Estimation Method	Reference Reach & Re	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				461	cfs	Drainage Area	8.01	mi^2

Channel Pattern

Geometry	Ave	Min	Max		Dimensionless Geometry Ratios	Ave	Min	Max
Meander Length (Lm)	130	70	180	feet	Meander Length Ratio (Lm/W_{bkf})	2.136	1.150	2.958
Radius of Curvature (Rc)	90	50	170	feet	Radius of Curvature/Riffle Width (Rc/W_{bkf})	1.479	0.822	2.793
Belt Width (W_{blt})	60	37	84	feet	Meander Width Ratio (W_{blt}/W_{bkf})	0.986	0.608	1.380
Individual Pool Length	26.29	20.09	36.05	feet	Pool Length/Riffle Width	0.432	0.330	0.592
Pool to Pool Spacing	129.1	101.1	149	feet	Pool to Pool Spacing/Riffle Width	2.121	1.661	2.448

Channel Profile

Valley Slope (VS)	0.0037	ft/ft	Average Water Surface Slope (S)	0.00218	ft/ft	Sinuosity (VS/S)	1.4	
Stream Length (SL)	278	feet	Valley Length (VL)	278	feet	Sinuosity (SL/VL)	1	

Low Bank Height (LBH)	start	7.12	feet	Max Riffle Depth	start	1.83	feet	Bank Height Ratio (LBH/Max Riffle Depth)	start	3.891
	end	7.45	feet		end	1.83	feet		end	4.071

Facet Slopes	Ave	Min	Max		Dimensionless Slope Ratios	Ave	Min	Max
Riffle Slope (S_{rif})	0.0069	0.0045	0.0096	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	3.165	2.064	4.404
Run Slope (S_{run})	0.0014	0.0006	0.0025	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	0.619	0.257	1.138
Pool Slope (S_p)	0.0026	0.0004	0.0080	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	1.170	0.202	3.683
Glide Slope (S_g)	0.0119	0.0000	0.0320	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	5.440	0.000	14.661

Feature Midpoint [a]	Ave	Min	Max		Dimensionless Depth Ratios	Ave	Min	Max
Riffle Depth (d_{mrif})	7.040	6.570	7.620	feet	Riffle Max Depth/Riffle Mean Depth (d_{mrif}/d_{bkf})	1.782	1.663	1.929
Run Depth (d_{mrun})	4.940	4.940	4.940	feet	Run Max Depth/Riffle Mean Depth (d_{mrun}/d_{bkf})	1.251	1.251	1.251
Pool Depth (d_{mp})	7.120	7.120	7.120	feet	Pool Max Depth/Riffle Mean Depth (d_{mp}/d_{bkf})	1.803	1.803	1.803
Glide Depth (d_{mg})	0.000	0.000	0.000	feet	Glide Max Depth/Riffle Mean Depth (d_{mg}/d_{bkf})	0.000	0.000	0.000

Channel Materials

Catagories	Reach[b]	Riffle[c]	Bar	Indices	Reach[b]	Riffle[c]	Bar	
% Silt/Clay		0		D16		3.6		mm
% Sand		0		D35		7.42		mm
% Gravel		100		D50		12.87		mm
% Cobble		0		D84		20.62		mm
% Boulder		0		D95		27.3		mm
% Bedrock		0		D100		32		mm

a. The range of "feature" mid-point maximum bankfull depths, including the minimum, maximum and average values. (Pool depths are obtained from the deepest portion of the feature.)

b. A composite sample of materials from riffle and pool featutes taken within the designated reach.

c. Sample obtained within the "active" bed of a riffle feature at the location of the cross section.

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Silver Creek "As-Built" Reach
Stream Classification and Morphologic Data Summary

Stream NAME: Silver Creek & Trib Restoration, Reach - As-Built Mainstem

Basin NAME: Catawba River Drainage AREA: 5126.4 acre 8.01 mi^2

Location: Silver Creek, Burke County, NC

Twp: _____ Rge: _____ Sec: _____ Qtr: _____ Lat: 35.6186 Long: 81.816

Observers: Jud M. Hines, P.E. and Warren E. Knotts, P.G. Date: 7/18/2007

Bankfull WIDTH (W_{bkf}) — **69.81** Feet
WIDTH of the stream channel, at bankfull stage elevation, in a riffle section.

Mean DEPTH (d_{bkf}) — **1.48** Feet
Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section.
($d_{bkf}=A_{bkf}/W_{bkf}$)

Bankfull Cross Section Area (A_{bkf}) — **103.55** $Feet^2$
AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

WIDTH / DEPTH RATIO (W_{bkf}/d_{bkf}) — **47.17** Ft/Ft
Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mrif}) — **2.8** Feet
Maximum depth of the bankfull channel cross-section, or elevation between the bankfull stage and thalweg in a riffle section.

Flood-Prone Area WIDTH (W_{fpa}) — **114.45** Feet
The stage/elevation at which flood-prone area WIDTH is determined in a riffle section at twice maximum DEPTH, or ($2 \times d_{mrif}$)

Entrenchment RATIO (ER) — **1.64** Ft/Ft
The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa}/W_{bkf}) in a riffle section.

Channel Materials (Particle Size Index) D50 — **2.79** mm
The 50th percentile, or less than, from a pebble count frequency distribution of channel particles representing the median or dominant particle size.

Water Surface SLOPE (S) — **0.00265** Ft/Ft
Average water surface slope as measured between the same position of bed features in the profile over two meander wave lengths. This is similar to average bankfull slope.

Channel SINUOSITY (K) — **1.4**
Sinuosity: an index of channel pattern, determined from stream length / valley length, i.e. (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/ S).

Stream Type **B 4c**

For Reference, see page 5-5, 5-6: Rosgen, 1996. Applied River Morphology.

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Silver Creek "As-Built" Reach
Stream Classification and Morphologic
Data Summary

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.57	feet	Mean Riffle Width (W_{bkf})	61.7	feet	Mean Riffle Area (A_{bkf})	103.6	$feet^2$
Mean Pool Depth (d_{bkfp})	1.81	feet	Mean Pool Width (W_{bkfp})	56.03	feet	Mean Pool Area (A_{bkfp})	97.48	$feet^2$
Ratio Mean Pool Depth/Mean Riffle Depth	1.153	d_{bkfp}/d_{bkf}	Ratio Pool Width/Riffle Width	0.908	W_{bkfp}/W_{bkf}	Ratio Pool Area/ Riffle Area	0.941	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mrif})	3.39	feet	Max Pool Depth (d_{mpool})	4.7	feet	Max riffle depth/Mean riffle depth	2.159	
Max pool depth/Mean riffle depth	2.994					Point Bar Slope	0.01	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				3.65	ft/s	Estimation Method	Manning's Equation	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				378	cfs	Drainage Area	8.01	mi^2

Channel Pattern

Geometry	Ave	Min	Max		Dimensionless Geometry Ratios	Ave	Min	Max
Meander Length (Lm)	124.9	73.79	191.7	feet	Meander Length Ratio (Lm/W_{bkf})	2.024	1.196	3.107
Radius of Curvature (Rc)	68.7	46.07	185.4	feet	Radius of Curvature/Riffle Width (Rc/W_{bkf})	1.113	0.747	3.005
Belt Width (W_{blt})	109.8	82.81	181.9	feet	Meander Width Ratio (W_{blt}/W_{bkf})	1.779	1.342	2.949
Individual Pool Length	35.66	17.11	56.9	feet	Pool Length/Riffle Width	0.578	0.277	0.922
Pool to Pool Spacing	145.5	36.42	388.3	feet	Pool to Pool Spacing/Riffle Width	2.359	0.590	6.294

Channel Profile

Valley Slope (VS)	0.0037	ft/ft	Average Water Surface Slope (S)	0.00265	ft/ft	Sinuosity (VS/S)	1.4	
Stream Length (SL)	2905.24	feet	Valley Length (VL)	2076.51	feet	Sinuosity (SL/VL)	1.399	

Low Bank Height (LBH)	start	2.59	feet	Max Riffle Depth	start	2.8	feet	Bank Height Ratio (LBH/Max Riffle Depth)	start	0.925
	end	3.84	feet		end	3.75	feet		end	1.024

Facet Slopes	Ave	Min	Max		Dimensionless Slope Ratios	Ave	Min	Max
Riffle Slope (S_{rif})	0.0242	0.0039	0.1787	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	9.147	1.468	67.423
Run Slope (S_{run})	0.0000	0.0000	0.0000	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	0.000	0.000	0.000
Pool Slope (S_p)	0.0007	0.0000	0.0020	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.260	0.000	0.751
Glide Slope (S_g)	0.0000	0.0000	0.0000	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	0.000	0.000	0.000

Feature Midpoint[a]	Ave	Min	Max		Dimensionless Depth Ratios	Ave	Min	Max
Riffle Depth (d_{mrif})	3.390	2.800	3.750	feet	Riffle Max Depth/Riffle Mean Depth (d_{mrif}/d_{bkf})	2.159	1.783	2.389
Run Depth (d_{mrun})	0.000	0.000	0.000	feet	Run Max Depth/Riffle Mean Depth (d_{mrun}/d_{bkf})	0.000	0.000	0.000
Pool Depth (d_{mp})	4.700	3.870	5.390	feet	Pool Max Depth/Riffle Mean Depth (d_{mp}/d_{bkf})	2.994	2.465	3.433
Glide Depth (d_{mg})	0.000	0.000	0.000	feet	Glide Max Depth/Riffle Mean Depth (d_{mg}/d_{bkf})	0.000	0.000	0.000

Channel Materials

Catagories	Reach[b]	Riffle[c]	Bar
% Silt/Clay	0	0	
% Sand	44.89	38.75	
% Gravel	55.11	61.25	
% Cobble	0	0	
% Boulder	0	0	
% Bedrock	0	0	

Indices	Reach[b]	Riffle[c]	Bar	
D16	0.37	0.47		mm
D35	1.08	1.49		mm
D50	2.79	4.25		mm
D84	25.5	26.9		mm
D95	29.97	30.41		mm
D100	32	32		mm

a. The range of "feature" mid-point maximum bankfull depths, including the minimum, maximum and average values. (Pool depths are obtained from the deepest portion of the feature.)

b. A composite sample of materials from riffle and pool featutes taken within the designated reach.

c. Sample obtained within the "active" bed of a riffle feature at the location of the cross section.

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Silver Creek Unnamed Tributary A
"As-Built" Reach Stream Classification and Morphologic Data Summary

Stream NAME: Silver Creek & Trib Restoration, Reach - As-Built UT

Basin NAME: Catawba River Drainage AREA: 48 acre 0.075 mi^2

Location: Unnamed Tributary to Silver Creek, Burke County, North Carolina

Twp: _____ Rge: _____ Sec: _____ Qtr: _____ Lat: 35.6521 Long: 81.83

Observers: Jud M. Hines, P.E. and Warren E. Knotts, P.G. Date: 6/22/2007

Bankfull WIDTH (W_{bkf}) — **8.11** Feet
WIDTH of the stream channel, at bankfull stage elevation, in a riffle section.

Mean DEPTH (d_{bkf}) — **0.43** Feet
Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section.
($d_{bkf}=A_{bkf}/W_{bkf}$)

Bankfull Cross Section Area (A_{bkf}) — **3.51** $Feet^2$
AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

WIDTH / DEPTH RATIO (W_{bkf}/d_{bkf}) — **18.86** Ft/Ft
Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mrif}) — **0.81** Feet
Maximum depth of the bankfull channel cross-section, or elevation between the bankfull stage and thalweg in a riffle section.

Flood-Prone Area WIDTH (W_{fpa}) — **14.57** Feet
The stage/elevation at which flood-prone area WIDTH is determined in a riffle section at twice maximum DEPTH, or ($2 \times d_{mrif}$)

Entrenchment RATIO (ER) — **1.8** Ft/Ft
The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa}/W_{bkf}) in a riffle section.

Channel Materials (Particle Size Index) D50 — **11.89** mm
The 50th percentile, or less than, from a pebble count frequency distribution of channel particles representing the median or dominant particle size.

Water Surface SLOPE (S) — **0.04265** Ft/Ft
Average water surface slope as measured between the same position of bed features in the profile over two meander wave lengths. This is similar to average bankfull slope.

Channel SINUOSITY (K) — **1.08**
Sinuosity: an index of channel pattern, determined from stream length / valley length, i.e. (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/ S).

Stream Type **B 4a**

For Reference, see page 5-5, 5-6: Rosgen, 1996. Applied River Morphology.

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Silver Creek Unnamed Tributary A
"As-Built" Reach Stream Classification and Morphologic Data Summary

Channel Dimension

Mean Riffle Depth (d_{bkf})	0.48	feet	Mean Riffle Width (W_{bkf})	7.46	feet	Mean Riffle Area (A_{bkf})	3.51	$feet^2$
Mean Pool Depth (d_{bkfp})	0.81	feet	Mean Pool Width (W_{bkfp})	8.78	feet	Mean Pool Area (A_{bkfp})	6.99	$feet^2$
Ratio Mean Pool Depth/Mean Riffle Depth	1.688	d_{bkfp}/d_{bkf}	Ratio Pool Width/Riffle Width	1.177	W_{bkfp}/W_{bkf}	Ratio Pool Area/ Riffle Area	1.991	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mrif})	0.91	feet	Max Pool Depth (d_{mpool})	1.51	feet	Max riffle depth/Mean riffle depth	1.896	
Max pool depth/Mean riffle depth	3.146					Point Bar Slope	0	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				4.81	ft/s	Estimation Method	Manning's Equation	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				16.9	cfs	Drainage Area	0.075	mi^2

Channel Pattern

Geometry	Ave	Min	Max		Dimensionless Geometry Ratios	Ave	Min	Max
Meander Length (Lm)	73.72	58.82	106.3	feet	Meander Length Ratio (Lm/W_{bkf})	9.882	7.885	14.248
Radius of Curvature (Rc)	23.59	9.32	124.9	feet	Radius of Curvature/Riffle Width (Rc/W_{bkf})	3.162	1.249	16.739
Belt Width (W_{blt})	12.95	10.8	14.57	feet	Meander Width Ratio (W_{blt}/W_{bkf})	1.736	1.448	1.953
Individual Pool Length	12.43	6.07	22.79	feet	Pool Length/Riffle Width	1.666	0.814	3.055
Pool to Pool Spacing	55.63	10.19	143.2	feet	Pool to Pool Spacing/Riffle Width	7.457	1.366	19.193

Channel Profile

Valley Slope (VS)	0.046	ft/ft	Average Water Surface Slope (S)	0.04265	ft/ft	Sinuosity (VS/S)	1.08	
Stream Length (SL)	1542.75	feet	Valley Length (VL)	1426.11	feet	Sinuosity (SL/VL)	1.082	
Low Bank Height (LBH)	start 0.81 / end 1.01	feet	Max Riffle Depth	start 0.81 / end 1.01	feet	Bank Height Ratio (LBH/Max Riffle Depth)	start 1 / end 1	

Facet Slopes	Ave	Min	Max		Dimensionless Slope Ratios	Ave	Min	Max
Riffle Slope (S_{rif})	0.1389	0.0344	0.6094	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	3.257	0.806	14.289
Run Slope (S_{run})	0.0000	0.0000	0.0000	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	0.000	0.000	0.000
Pool Slope (S_p)	0.0019	0.0000	0.0048	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.044	0.000	0.113
Glide Slope (S_g)	0.0000	0.0000	0.0000	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	0.000	0.000	0.000

Feature Midpoint [a]	Ave	Min	Max		Dimensionless Depth Ratios	Ave	Min	Max
Riffle Depth (d_{mrif})	0.910	0.810	1.010	feet	Riffle Max Depth/Riffle Mean Depth (d_{mrif}/d_{bkf})	1.896	1.688	2.104
Run Depth (d_{mrun})	0.000	0.000	0.000	feet	Run Max Depth/Riffle Mean Depth (d_{mrun}/d_{bkf})	0.000	0.000	0.000
Pool Depth (d_{mp})	1.510	1.370	1.640	feet	Pool Max Depth/Riffle Mean Depth (d_{mp}/d_{bkf})	3.146	2.854	3.417
Glide Depth (d_{mg})	0.000	0.000	0.000	feet	Glide Max Depth/Riffle Mean Depth (d_{mg}/d_{bkf})	0.000	0.000	0.000

Channel Materials

Catagories	Reach[b]	Riffle[c]	Bar	Indices	Reach[b]	Riffle[c]	Bar	
% Silt/Clay	6.67	4.35		D16	0.31	0.52		mm
% Sand	24.16	14.49		D35	4.85	10.6		mm
% Gravel	63.34	75.36		D50	11.89	15.77		mm
% Cobble	5.83	5.8		D84	36.49	42.35		mm
% Boulder	0	0		D95	72.63	71.17		mm
% Bedrock	0	0		D100	179.99	180		mm

a. The range of "feature" mid-point maximum bankfull depths, including the minimum, maximum and average values. (Pool depths are obtained from the deepest portion of the feature.)

b. A composite sample of materials from riffle and pool featutes taken within the designated reach.

c. Sample obtained within the "active" bed of a riffle feature at the location of the cross section.

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Silver Creek and Unnamed Tributary
As-Built Pattern Analyses

August 7, 2007

Rc-UT	Lm-UT	Rc-MS	Lm-MS
87.5	76.09	73.6	116.65
36.55	71.8	55.8	124.76
41.85	58.82	90.4	124.86
49.41	106.29	47.97	191.73
10.91	73.72	108.89	166.76
65.86		145.22	73.49
53.67		181.06	147.42
21.83		48.53	143.22
21.83		185.4	123.29
21.83		46.07	75.46
9.32		79.88	154.49
99.93		51.79	
17.27		47.33	
124.87		69.19	
23.59		68.21	
19.4		143.26	
9.93		82.06	
14.88		60.67	
26.31		64.36	
12.53		60.39	
34.52			

Wfpa - UT	Wfpa - MS
13.28	82.81
12.62	84.45
10.8	181.94
14.57	114.45
	106.92
	112.66

SL - UT	VL - UT	SL - MS	VL - MS
1542.01	1426.11	2905.24	2076.51

Tot Rest SL
4447.25

K - UT = 1.08 **K - MS = 1.40**

Rc-UT		*Lm-UT*		*Rc-MS*		*Lm-MS*		*Wfpa - UT*		*Wfpa - MS*	
Mean	**38.28**	**Mean**	**77.34**	**Mean**	**85.50**	**Mean**	**131.10**	**Mean**	**12.82**	**Mean**	**113.87**
Standard Error	6.98	Standard Error	7.83	Standard Error	9.85	Standard Error	10.73	Standard Error	0.78	Standard Error	14.74
Median	**23.59**	**Median**	**73.72**	**Median**	**68.70**	**Median**	**124.86**	**Median**	**12.95**	**Median**	**109.79**
Mode	21.83	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Devia	31.97	Standard Devia	17.51	Standard Devia	44.03	Standard Deviation	35.60	Standard Deviatior	1.57	Standard Deviati	36.09
Sample Varianc	1022.17	Sample Varianc	306.61	Sample Varianc	1938.68	Sample Variance	1267.16	Sample Variance	2.46	Sample Variance	1302.78
Kurtosis	1.69	Kurtosis	2.91	Kurtosis	0.66	Kurtosis	-0.04	Kurtosis	0.79	Kurtosis	3.30
Skewness	1.52	Skewness	1.37	Skewness	1.34	Skewness	-0.22	Skewness	-0.47	Skewness	1.66
Range	115.55	Range	47.47	Range	139.33	Range	118.24	Range	3.77	Range	99.13
Minimum	**9.32**	**Minimum**	**58.82**	**Minimum**	**46.07**	**Minimum**	**73.49**	**Minimum**	**10.80**	**Minimum**	**82.81**
Maximum	**124.87**	**Maximum**	**106.29**	**Maximum**	**185.40**	**Maximum**	**191.73**	**Maximum**	**14.57**	**Maximum**	**181.94**
Sum	803.79	Sum	386.72	Sum	1710.08	Sum	1442.13	Sum	51.27	Sum	683.23
Count	21	Count	5	Count	20	Count	11	Count	4	Count	6

Silver Creek Mainstem
As-Built Monumented Cross-Sections
Summary Reports

XS1 - 2+35.30 - CV-1 - RIF - YR 0 SUMMARY.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS1 - 2+35.30 - CV-1 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1137.61	HT
2.74	0	1137.55	HT
6.7	0	1136.33	BM
11.6	0	1133.94	FP
23.59	0	1129.14	BKF
30.03	0	1127.06	LB
33.38	0	1125.79	LEW 0.05
38.31	0	1125.74	CV 0.1
42.65	0	1125.83	REW 0.05
46.01	0	1126.65	RB
52.88	0	1127.63	FP
66.53	0	1128.86	FP
69.86	0	1129.16	BKF
80.32	0	1130.78	FP
86.78	0	1132	BM
97.86	0	1132.1	LT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1132.56	1132.56	1132.56
Bankfull Elevation (ft)	1129.15	1129.15	1129.15
Floodprone Width (ft)	82.81	-----	-----
Bankfull Width (ft)	46.18	15.45	30.73
Entrenchment Ratio	1.79	-----	-----
Mean Depth (ft)	1.81	2.26	1.58
Maximum Depth (ft)	3.41	3.41	3.4
Width/Depth Ratio	25.51	6.84	19.45
Bankfull Area (sq ft)	83.59	34.99	48.59
Wetted Perimeter (ft)	46.98	19.41	34.36
Hydraulic Radius (ft)	1.78	1.8	1.41
Begin BKF Station	23.57	23.57	39.02
End BKF Station	69.75	39.02	69.75

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.29		
Movable Particle (mm)	61.8		

XS2 - 2+59.27 - CV-1 - POOL - YR 0 SUMMARY.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS2 - 2+59.27 - CV-1 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1138.23	FP
2.21	0	1138.62	BW/HT
7.44	0	1136.53	BM
13.88	0	1134.12	FP
31.62	0	1128.54	BKF
39.33	0	1126.75	LB
41.94	0	1125.61	LEW 0.05
50.64	0	1123.83	P 1.7
55.37	0	1125.39	REW 0.05
59.3	0	1127.1	RB
68.13	0	1127.95	FP
74.33	0	1128.8	BKF
82.5	0	1129.92	FP
91.65	0	1132.09	BM
100.27	0	1131.95	FP/LT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1133.51	1133.51	1133.51
Bankfull Elevation (ft)	1128.67	1128.67	1128.67
Floodprone Width (ft)	84.45	-----	-----
Bankfull Width (ft)	42.18	17.53	24.64
Entrenchment Ratio	2	-----	-----
Mean Depth (ft)	2.12	2.28	2.01
Maximum Depth (ft)	4.84	4.45	4.84
Width/Depth Ratio	19.9	7.69	12.26
Bankfull Area (sq ft)	89.53	39.97	49.56
Wetted Perimeter (ft)	43.51	22.59	29.83
Hydraulic Radius (ft)	2.06	1.77	1.66
Begin BKF Station	31.21	31.21	48.74
End BKF Station	73.38	48.74	73.38

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.34		
Movable Particle (mm)	68.9		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS3 - 11+99.27 - JH-4 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1132.16	FP
7.4	0	1132.3	BM
9.47	0	1132.05	LT
19.71	0	1131.41	BW
34.37	0	1128.25	FP
47.01	0	1126.77	BKF
58.42	0	1125.35	LB
62.06	0	1123.76	LEW 0.05
69.86	0	1121.19	P 2.2
74.12	0	1123.32	REW 0.05
79.74	0	1124.98	RB
88.05	0	1125.42	FP
97.74	0	1126.38	BKF
108.43	0	1127.44	FP
133	0	1131.12	BM
149.47	0	1131.49	FP
191.16	0	1130.15	BW
192.69	0	1130.28	HT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1131.97	1131.97	1131.97
Bankfull Elevation (ft)	1126.58	1126.58	1126.58
Floodprone Width (ft)	181.94	-----	-----
Bankfull Width (ft)	51.22	22.46	28.76
Entrenchment Ratio	3.55	-----	-----
Mean Depth (ft)	1.87	2.28	1.55
Maximum Depth (ft)	5.39	5.39	4.82
Width/Depth Ratio	27.39	9.85	18.55
Bankfull Area (sq ft)	95.81	51.29	44.52
Wetted Perimeter (ft)	52.85	28.24	34.25
Hydraulic Radius (ft)	1.81	1.82	1.3
Begin BKF Station	48.54	48.54	71
End BKF Station	99.76	71	99.76

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	62.6		

XS4 - 12+80.37 - RIFFLE - YR 0 SUMMARY.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS4 - 12+80.37 - RIF-2 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1129.85	LT
11.03	0	1130.17	BM
12.79	0	1129.92	LT
22.36	0	1130.17	BW
38.78	0	1127.5	FP
58.03	0	1125.95	BKF
89.04	0	1124.36	LB
93.98	0	1123.3	LEW 0.05
105.97	0	1123.15	R 0.3
112.22	0	1123.29	REW 0.05
120.05	0	1124.89	FP
133.64	0	1126.74	FP
144.46	0	1128.47	FP
154.67	0	1131.12	BM
162.06	0	1130.95	HT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1128.75	1128.75	1128.75
Bankfull Elevation (ft)	1125.95	1125.95	1125.95
Floodprone Width (ft)	114.45	-----	-----
Bankfull Width (ft)	69.81	43.2	26.61
Entrenchment Ratio	1.64	-----	-----
Mean Depth (ft)	1.48	1.27	1.84
Maximum Depth (ft)	2.8	2.74	2.8
Width/Depth Ratio	47.17	34.02	14.46
Bankfull Area (sq ft)	103.55	54.67	48.88
Wetted Perimeter (ft)	70.2	46.09	29.58
Hydraulic Radius (ft)	1.48	1.19	1.65
Begin BKF Station	58.03	58.03	101.23
End BKF Station	127.84	101.23	127.84

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.24		
Movable Particle (mm)	54.0		

XS5 - 27+44.66 - JH-8 - RIFFLE - YR 0 SUMMARY.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS5 - 27+44.66 - JH-8 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1126.6	FP
9.04	0	1126.49	BM
20.73	0	1127.06	LT
21.36	0	1127.02	BW
33.81	0	1124.57	FP
58.52	0	1121.11	FP
75.16	0	1120.42	LB
76.98	0	1119.54	LEW 0.05
81.28	0	1118.43	TW1.3
84.15	0	1119.96	JH
90.5	0	1119.69	REW 0.05
93.35	0	1120.7	RB
103.02	0	1121.79	FP
118.16	0	1122.18	BKF
134.15	0	1126.01	BW
135.96	0	1126.3	BM
138.66	0	1126.01	LT
138.66	0	1126.01	LT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1125.93	1125.93	1125.93
Bankfull Elevation (ft)	1122.18	1122.18	1122.18
Floodprone Width (ft)	106.92	-----	-----
Bankfull Width (ft)	67.28	31.49	35.79
Entrenchment Ratio	1.59	-----	-----
Mean Depth (ft)	1.29	1.56	1.05
Maximum Depth (ft)	3.75	3.75	3.17
Width/Depth Ratio	52.16	20.19	34.09
Bankfull Area (sq ft)	86.55	49.15	37.4
Wetted Perimeter (ft)	68.34	35.24	39.44
Hydraulic Radius (ft)	1.27	1.39	0.95
Begin BKF Station	50.88	50.88	82.37
End BKF Station	118.16	82.37	118.16

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.21		
Movable Particle (mm)	48.2		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built Mainstem
Cross Section Name: XS6 - 27+65.26 JH-8 - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1126.23	FP
11.59	0	1126.4	BM
22.38	0	1126.96	HT
23.03	0	1126.84	BW
49.36	0	1122.16	BKF
66.42	0	1120.92	FP
74.17	0	1120.96	LB
75.22	0	1119.13	LEW 0.05
83.58	0	1118.29	P 1.2
87.63	0	1119.21	REW 0.05
98.92	0	1120.61	RB
105.3	0	1121.32	FP
123.33	0	1121.99	FP
139.71	0	1125.86	BW
142.29	0	1126.68	BM
144.41	0	1126.62	LT

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1126.03	1126.03	1126.03
Bankfull Elevation (ft)	1122.16	1122.16	1122.16
Floodprone Width (ft)	112.66	-----	-----
Bankfull Width (ft)	74.69	38	36.69
Entrenchment Ratio	1.51	-----	-----
Mean Depth (ft)	1.43	1.69	1.17
Maximum Depth (ft)	3.87	3.87	3.01
Width/Depth Ratio	52.23	22.49	31.36
Bankfull Area (sq ft)	107.1	64.1	43
Wetted Perimeter (ft)	76.1	42.25	39.87
Hydraulic Radius (ft)	1.41	1.52	1.08
Begin BKF Station	49.36	49.36	87.36
End BKF Station	124.05	87.36	124.05

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00265	0	0
Shear Stress (lb/sq ft)	0.23		
Movable Particle (mm)	52.1		

Silver Creek Unnamed Tributary A
As-Built Monumented Cross-Sections
Summary Reports

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built UT
Cross Section Name: XS-1 - UT-1 - Riffle - YR 0
Survey Date: 07/09/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1191.98	FP
7.6	0	1190.12	BM
10.3	0	1189.19	LB
18.76	0	1186.02	LEW 0.05
19.01	0	1186.01	R 0.1
19.36	0	1186.08	REW 0.05
22.9	0	1187.02	BKF
32.51	0	1189.59	RB
35.03	0	1190.25	BM
42.15	0	1190.96	FP
53.04	0	1195.28	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1188.03	1188.03	1188.03
Bankfull Elevation (ft)	1187.02	1187.02	1187.02
Floodprone Width (ft)	13.28	-----	-----
Bankfull Width (ft)	6.81	4.65	2.16
Entrenchment Ratio	1.95	-----	-----
Mean Depth (ft)	0.53	0.64	0.29
Maximum Depth (ft)	1.01	1.01	0.57
Width/Depth Ratio	12.85	7.27	7.45
Bankfull Area (sq ft)	3.59	2.97	0.62
Wetted Perimeter (ft)	7.12	5.46	2.81
Hydraulic Radius (ft)	0.5	0.54	0.22
Begin BKF Station	16.09	16.09	20.74
End BKF Station	22.9	20.74	22.9

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.04338	0	0
Shear Stress (lb/sq ft)	1.35		
Movable Particle (mm)	189.9		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built UT
Cross Section Name: XS-2 - UT-1 - Pool - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1174.93	FP
5.12	0	1173.89	BM
11.19	0	1172.12	FP
14.41	0	1171.13	BKF
15.92	0	1170.68	LEW
19.95	0	1169.76	P 1.0
23.27	0	1170.76	REW
28.77	0	1173.96	FP
30.38	0	1174.1	BM
36.28	0	1177.75	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1172.5	1172.5	1172.5
Bankfull Elevation (ft)	1171.13	1171.13	1171.13
Floodprone Width (ft)	16.37	-----	-----
Bankfull Width (ft)	9.5	3.2	6.3
Entrenchment Ratio	1.72	-----	-----
Mean Depth (ft)	0.74	0.45	0.89
Maximum Depth (ft)	1.37	0.84	1.37
Width/Depth Ratio	12.84	7.11	7.08
Bankfull Area (sq ft)	7.01	1.43	5.59
Wetted Perimeter (ft)	9.91	4.14	7.44
Hydraulic Radius (ft)	0.71	0.34	0.75
Begin BKF Station	14.41	14.41	17.61
End BKF Station	23.91	17.61	23.91

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.04191	0	0
Shear Stress (lb/sq ft)	1.86		
Movable Particle (mm)	239.6		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built UT
Cross Section Name: XS-3 - UT-1 - Pool - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1157.24	FP
7.87	0	1156.07	BM
17.57	0	1154.56	FP
20.25	0	1152.28	FP
23.68	0	1150.6	BKF
24.69	0	1150.11	LEW
27.52	0	1148.96	P 1.1
30.84	0	1150.13	REW
34.76	0	1152.2	FP
39.74	0	1154.02	FP
47.06	0	1155.52	BM
53.26	0	1156	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1152.24	1152.24	1152.24
Bankfull Elevation (ft)	1150.6	1150.6	1150.6
Floodprone Width (ft)	14.54	-----	-----
Bankfull Width (ft)	8.05	5.79	2.26
Entrenchment Ratio	1.81	-----	-----
Mean Depth (ft)	0.87	1	0.52
Maximum Depth (ft)	1.64	1.64	0.95
Width/Depth Ratio	9.25	5.79	4.35
Bankfull Area (sq ft)	6.97	5.79	1.18
Wetted Perimeter (ft)	8.7	7.2	3.41
Hydraulic Radius (ft)	0.8	0.8	0.35
Begin BKF Station	23.68	23.68	29.47
End BKF Station	31.73	29.47	31.73

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.04	0	0
Shear Stress (lb/sq ft)	2.00		
Movable Particle (mm)	252.8		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: As-Built UT
Cross Section Name: XS-4 - UT-1 - Riffle - YR 0
Survey Date: 06/22/07

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	1157.53	FP
8.6	0	1156.07	BM
14.63	0	1154.42	FP
20.04	0	1151.52	FP
23.24	0	1150.93	BKF
27.73	0	1150.15	LEW 0.05
28.09	0	1150.12	R 0.05
28.6	0	1150.15	REW 0.05
36.31	0	1152.34	FP
42.56	0	1154.48	FP
46.85	0	1155	BM
53.36	0	1155.43	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1151.74	1151.74	1151.74
Bankfull Elevation (ft)	1150.93	1150.93	1150.93
Floodprone Width (ft)	14.57	-----	-----
Bankfull Width (ft)	8.11	5.26	2.85
Entrenchment Ratio	1.8	-----	-----
Mean Depth (ft)	0.43	0.45	0.4
Maximum Depth (ft)	0.81	0.81	0.79
Width/Depth Ratio	18.86	11.69	7.13
Bankfull Area (sq ft)	3.51	2.36	1.15
Wetted Perimeter (ft)	8.28	6.12	3.74
Hydraulic Radius (ft)	0.42	0.39	0.31
Begin BKF Station	23.24	23.24	28.5
End BKF Station	31.35	28.5	31.35

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.04	0	0
Shear Stress (lb/sq ft)	1.05		
Movable Particle (mm)	157.4		

Silver Creek Mainstem
Impaired Reach Cross-Sections
Summary Reports

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 1 (Abandoned Oxbow - Altered)
Cross Section Name: Riffle Section 12+52.5
Survey Date: 02/17/06

Cross Section Data Entry

BM Elevation: 1133.84 ft
Backsight Rod Reading: 0.16 ft

TAPE	FS	ELEV	NOTE
84	5.47	1128.53	FP
69.5	5.37	1128.63	FP
61	5.44	1128.56	
60.6	9.45	1124.55	
58.3	11.14	1122.86	
57.4	11.8	1122.2	REW
57.4	12.69	1121.31	
54.8	13.01	1120.99	TW
51.8	12.85	1121.15	
49.4	11.85	1122.15	
46.5	11.57	1122.43	
44.1	11.86	1122.14	
40.5	11.65	1122.35	LEW
39.3	11.35	1122.65	
37.7	10.88	1123.12	
34.7	10.61	1123.39	
30	10.13	1123.87	
27	8.9	1125.1	
23.5	7.81	1126.19	
19.6	7.48	1126.52	
17.1	6.31	1127.69	
17	5.39	1128.61	BKF
9.3	4.7	1129.3	LB
0	5.26	1128.74	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1136.23	1136.23	-----
Bankfull Elevation (ft)	1128.61	1128.61	-----
Floodprone Width (ft)	84	-----	-----
Bankfull Width (ft)	122.47	77.89	-----
Entrenchment Ratio	0.69	-----	-----
Mean Depth (ft)	1.88	1.85	-----
Maximum Depth (ft)	7.62	7.62	-----
Width/Depth Ratio	65.14	42.1	-----
Bankfull Area (sq ft)	230.44	227.03	-----
Wetted Perimeter (ft)	152.95	140.69	-----
Hydraulic Radius (ft)	1.51	1.61	-----
Begin BKF Station	0	0	-----
End BKF Station	17	17	-----

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00218	0	0
Shear Stress (lb/sq ft)	0.21		
Movable Particle (mm)	47.5		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 3 (Over Tightened Meander)
Cross Section Name: Riffle Section 18+31
Survey Date: 02/09/06

Cross Section Data Entry

BM Elevation: 1132.97 ft
Backsight Rod Reading: 2.12 ft

TAPE	FS	ELEV	NOTE
59	4.85	1130.24	FP
51	4.7	1130.39	FP
47.5	4.91	1130.18	BKF
43	5.92	1129.17	RB
38	11.05	1124.04	
37.8	11.23	1123.86	REW
34.2	11.83	1123.26	TW
30.5	11.6	1123.49	SB
27	11.39	1123.7	SB
23.6	11.13	1123.96	LEW
22.9	10.84	1124.25	
21	9.6	1125.49	
15.2	3.42	1131.67	LB
9	3.44	1131.65	FP
0	3.91	1131.18	FP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1137.1	-----	-----
Bankfull Elevation (ft)	1130.18	-----	-----
Floodprone Width (ft)	59	-----	-----
Bankfull Width (ft)	30.9	-----	-----
Entrenchment Ratio	1.91	-----	-----
Mean Depth (ft)	4.52	-----	-----
Maximum Depth (ft)	6.92	-----	-----
Width/Depth Ratio	6.84	-----	-----
Bankfull Area (sq ft)	139.7	-----	-----
Wetted Perimeter (ft)	35.78	-----	-----
Hydraulic Radius (ft)	3.9	-----	-----
Begin BKF Station	47.5	-----	-----
End BKF Station	16.6	-----	-----

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00218	0	0
Shear Stress (lb/sq ft)	0.53		
Movable Particle (mm)	95.4		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 4 (Top of Main Stem)
Cross Section Name: Riffle Section 29+73
Survey Date: 02/09/06

Cross Section Data Entry

BM Elevation: 1134.51 ft
Backsight Rod Reading: 3.04 ft

TAPE	FS	ELEV	NOTE
37	3.41	1134.14	
33	3.7	1133.85	RB
30.6	4.72	1132.83	BKF
27.3	10.71	1126.84	REW
27.3	10.81	1126.74	
22.6	11.21	1126.34	
18.3	11.28	1126.27	
15.4	11.01	1126.54	
13.1	10.85	1126.7	
10.1	11.29	1126.26	
7.3	11.26	1126.29	TW
5	11.01	1126.54	
5	10.7	1126.85	LEW
3	5.1	1132.45	LB
1	4.63	1132.92	
0	4.4	1133.15	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1139.4	-----	-----
Bankfull Elevation (ft)	1132.83	-----	-----
Floodprone Width (ft)	37	-----	-----
Bankfull Width (ft)	29.22	-----	-----
Entrenchment Ratio	1.27	-----	-----
Mean Depth (ft)	5.45	-----	-----
Maximum Depth (ft)	6.57	-----	-----
Width/Depth Ratio	5.36	-----	-----
Bankfull Area (sq ft)	159.25	-----	-----
Wetted Perimeter (ft)	37.24	-----	-----
Hydraulic Radius (ft)	4.28	-----	-----
Begin BKF Station	30.6	-----	-----
End BKF Station	1.38	-----	-----

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0027	0	0
Shear Stress (lb/sq ft)	0.72		
Movable Particle (mm)	119.5		

Silver Creek Unnamed Tributary A
Impaired Reach Cross-Section
Summary Report

RIVERMORPH CROSS SECTION SUMMARY

River Name: Silver Creek & Trib Restoration
Reach Name: Reach 5 (Unnamed Tributary)
Cross Section Name: Riffle Section 1+15
Survey Date: 01/14/06

Cross Section Data Entry

BM Elevation: 1141.75 ft
Backsight Rod Reading: 11.46 ft

TAPE	FS	ELEV	NOTE
0	8.2	1145.01	Bench Mark = 1141.75 from 4D Si
4	8.64	1144.57	
12	8.82	1144.39	
16	9	1144.21	
25	9.02	1144.19	BKF
26.15	9.36	1143.85	
27.2	9.75	1143.46	LEW
28.4	9.92	1143.29	TW
29.5	9.75	1143.46	REW
30.9	9.22	1143.99	
32.3	9.05	1144.16	RB
43	9	1144.21	
47.5	8.45	1144.76	
49.3	8.54	1144.67	
52.8	8.76	1144.45	Center FP High Water Channel
55	8.65	1144.56	
59	8.45	1144.76	
65	8.65	1144.56	
71.6	7.66	1145.55	
73.5	7.07	1146.14	
76.3	6.65	1146.56	
83	4.55	1148.66	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	1145.09	1145.09	1145.09
Bankfull Elevation (ft)	1144.19	1144.19	1144.19
Floodprone Width (ft)	68.53	-----	-----
Bankfull Width (ft)	13.72	3.7	10.02
Entrenchment Ratio	5	-----	-----
Mean Depth (ft)	0.26	0.54	0.15
Maximum Depth (ft)	0.9	0.9	0.85
Width/Depth Ratio	52.77	6.85	66.8
Bankfull Area (sq ft)	3.54	2	1.54
Wetted Perimeter (ft)	13.97	4.69	10.99
Hydraulic Radius (ft)	0.25	0.43	0.14
Begin BKF Station	25	25	28.7
End BKF Station	38.72	28.7	38.72

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.035	0	0
Shear Stress (lb/sq ft)	0.55		
Movable Particle (mm)	97.4		