Beaverdam Creek and Unnamed Tributaries Mitigation Plan

Union County
North Carolina
NC EEP Project Number: D06054-C

Prepared for:
NCDENR – EEP
2728 Capital Blvd, Suite 1H 103
Raleigh NC 27604

Ecosystem Enhancement PROGRAM

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Prepared by:

Wetlands Resource Center
3970 Bowen Road
Canal Winchester, Ohio 43110
Project Manager: Cal Miller
P: (614) 864-7511
F: (614) 866-3691

And

EMH&T, Inc.
5500 New Albany Road
Columbus, Ohio 43054
Project Manager: Miles F. Hebert, PE
P: (614) 775-4205
F: (614) 775-4802
Main: (614) 775-4500

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EXECUTIVE SUMMARY

As discussed in the Restoration Plan for Beaverdam Creek and two associated unnamed tributaries (UT1 and UT2), the mitigation goals and objectives for the project involved restoring stable physical and biological function of the project streams beyond pre-restoration (impaired reach) conditions. Pre-restoration conditions consisted of impaired, channelized, eroding, incised and entrenched stream channels. Nutrient and sediment loading, vegetative denuding and destabilized streambanks associated with hoof shear from uncontrolled cattle access was evident. The specific mitigation goals and objectives proposed and achieved for the project are listed below.

- Stable stream channels with features inherent of ecologically diverse environments, with appropriate streambed features including appropriately spaced pool and riffle sequences, and riparian corridors planted with diversified, indigenous vegetation.
- Superimposed reference reach boundary conditions on the impaired project reaches in the restoration design and construction of improvements.
- Constructed stream channels with the appropriate geometry and gradient to convey bankfull flows while entraining bedload and suspended sediment (wash load) readily available to the streams.
- Created an improved connection between the bankfull channels and their floodprone areas, with stable channel geometries, protective vegetation and jute coir fabric to prevent erosion.
- Minimized future land use impacts to project stream reaches by conveying a perpetual, restrictive conservation easement to the State of North Carolina, including stream corridor protection via livestock exclusion fencing at the surveyed and recorded conservation easement boundaries, with gates at the edge of the riparian corridor on river right and left at reserved conservation easement crossings adjacent to active pasture land.

The restoration of Beaverdam Creek mainstem, UT1 and UT2 met the project goals and objectives set forth in the restoration plan, by providing desired habitat and stability features required to enhance and provide long-term ecologic health for the project reaches. More specifically, the completed restoration project has accomplished the enhancements listed below.

Beaverdam Creek Mainstem:

- Reversed the effects of channelization using a Priority Level I restoration approach; restoration increased the width/depth ratio from 9.19 to 18.43.
- Restored natural pattern to the channel alignment, increasing the sinuosity from 1.07 to 1.49, while maintaining a stable relationship between the valley slope and bankfull slope (the bankfull slope was steeper than the valley slope prior to restoration and is now less than the valley slope with the completed restoration). Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Stabilized eroding streambanks by providing an appropriately sized channel with stable channel bank slopes built with a combination of embedded stone, topsoil, natural fabrics and hearty vegetative protective cover. The average Bank Height Ratio was decreased from 1.60 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by raising the bankfull channel to the elevation of the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 3.68 to 7.36.
- Created instream aquatic habitat features, including appropriately spaced pool and riffle sequences, and a stable transition of the mainstem reach thalweg to the invert of the downstream culvert carrying Beaverdam Creek under Snyders Store Road.

- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover, preserving existing forested riparian corridors where present.

Unnamed Tributary 1 (UT1):

- Reversed the effects of channelization through a combination of Priority Level I and Priority Level II restoration techniques. The average width/depth ratio of the restored UT1 project reach is 15.02. Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Restored natural pattern to the channel alignment, increasing stream channel sinuosity from 1.14 to 1.45.
- Stabilized eroding streambanks by providing appropriately sized channels with stable streambank slopes. The average Bank Height Ratio has been reduced from 1.76 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by a combination of raising the stream bed and/or lowering the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 2.74 to 8.68.
- Created instream aquatic habitat features including appropriately spaced pool and riffle sequences, including a stable transition of the UT1 reach thalweg at its confluence with Beaverdam Creek.
- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover, preserving existing forested riparian corridors where present.

Unnamed Tributary 2 (UT2):

- Reversed the effects of channelization through a combination of Priority Level I and Priority Level II restoration techniques. The width/depth ratio of the restored UT2 project reach was increased from 8.32 to 21.00. Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Restored natural pattern to the channel alignment, increasing stream channel sinuosity from 1.02 to 1.49
- Stabilized eroding streambanks by providing appropriately sized channels with stable streambank slopes. The average Bank Height Ratio has been reduced from 2.12 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by a combination of raising the stream bed and/or lowering the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 2.74 to 8.68.
- Created instream aquatic habitat features including appropriately spaced pool and riffle sequences, with a stable transition of the UT2 reach thalweg at its confluence with UT1.
- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover.

The following table summarizes pre-existing and post-restoration stream lengths, mitigation approach and identification of the reaches restored as presented throughout this Mitigation Plan. The original Restoration Plan includes mitigation specific to the Beaverdam Creek mainstem and the two unnamed tributaries. The stream segments and reach identifications used in this table are shown on the As-Built Plan Sheets in **Section 7.0** and on **Figure 2**.

Pre-Existing Conditions/Post-Construction Summary Project Number D06054-C (Beaverdam Creek & Unnamed Tributaries Restoration)					
Tributary Reach ID	Pre-existing length	Restored Length*	Restoration Level	Credit Ratio	SMUs**
Beaverdam Creek Mainstem	416 lf	460 lf	Priority Level I Restoration	1.0	460
UT1	1,867 lf	2,300 lf	Priority Level I/II Restoration	1.0	2,300
UT2	203 lf	284 lf	Priority Level I/II Restoration	1.0	284
Totals	**2,486 ft**	**3,044 ft**			**3,044**

*Restored Length excludes permanent conservation easement crossings.
**Restored Length divided by SMU Credit Ratio

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 items listed below.

1. Channel aggradation or degradation.
2. Streambank erosion.
3. Presence of in-stream bar deposits.
4. Health and survival of indigenous, non-invasive vegetation (80% survival of planted species after 5 years).
5. 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 long-term monitoring of the constructed project includes 3,044 linear feet of longitudinal profiles (the sum of the three project reaches), collection and analysis of particle distributions at each of the eight monumented cross-sections. Eight vegetation monitoring plots with shrub, mid-story and canopy plantings representative of outside meanders, the 50-foot wide riparian buffer, streamside shrubs and floodplain zones will be monitored annually. Two galvanized steel, USGS Type A, 4-foot crest gages have been installed on the project reaches; one crest gage is installed below the confluence of UT2 with UT1 and the second is installed at the confluence of UT1 with Beaverdam Creek mainstem as shown on the As-Built plans in **Section 7.0** 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 I and Level II Restoration projects, following the template for *Content, Format and Data Requirements for EEP Monitoring Reports, Version 1.2* (November 16, 2006). 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 Beaverdam Creek and Unnamed Tributaries Mitigation Project.

1.0 PROJECT BACKGROUND

1.1 Project Site Location and Details

The project is located northwest of the intersection of White Store Road (SR 1003) and Snyder Store Road (SR 1945), 3.8 miles south of the town of Wingate, Union County, North Carolina. The site location and vicinity map is presented on **Figure 1**. The project is located on properties owned by Mr. and Mrs. William Earl and Betty H. Parker. The project includes restoration activities along Beaverdam Creek mainstem and two unnamed tributaries, designated UT1 and UT2.

To travel to the site from Monroe, North Carolina, drive east on US-74. Approximately 3.5 miles east of Monroe, make a slight right turn onto US-601 and travel for 4.1 miles. Turn left at Hinson Street/McRorie Road (NC-1952) and travel 0.6 mile then turn right at Old Pageland Monroe Road (NC-1941) and go 0.3 mile. Turn left at Bivens Street/Nash Road (NC-1954) and travel 1.3 miles. Turn right at White Store Road (NC-1003) and go approximately 0.6 mile. Turn left onto Snyder Store Road (NC-1945) and arrive at the site. The Earl and Betty Parker residence is located at 1822 Snyder Store Road, Wingate, NC 28174. As a courtesy to the property owners, please inform Mr. and Mrs. Parker you are conducting at field visit along the restored project stream reaches when conducting a site visit.

The Beaverdam Creek watershed is located within the North Carolina Wetland Restoration Program (NCWRP) targeted USGS 14-digit HUC watershed 03040105081030 (Beaverdam Creek), in the Lower Yadkin River Basin. Beaverdam Creek is a tributary to Lanes Creek, which is tributary to the Rocky River in the Lower Yadkin Pee Dee River Basin. The project stream reaches are mapped on North Carolina Department of Transportation Light Detection and Ranging (LiDAR) coverage of Union County, North Carolina as shown on **Figure 2**.

The Beaverdam Creek watershed is located in the Piedmont Physiographic Province of south central North Carolina in the Carolina Slate Belt Ecoregion (Draft Level III and Level IV Ecoregions of North Carolina, USEPA, USDA-NRCS & NCDENR, August 17, 2000). Valley Type VIII (Rosgen, 1996) is the most readily identified landform along the mainstem and unnamed tributaries corridors, with subtle terraces positioned laterally along the broad valleys with gentle, down-valley elevation relief in the project vicinity. Alluvial terraces and floodplains are the predominant depositional features in this fluvial geomorphologic system and produce a high sediment supply. As shown on **Figure 2** the first and second order project stream reaches are located in the headwaters of the Beaverdam Creek watershed. Existing valley slopes for the project reaches range from 0.0068 ft/ft to 0.0300 ft/ft with elevations from the upstream watershed boundary to the downstream limits of the project ranging from 640 feet to 571 feet (NAVD 88), with total site vertical relief of 69 feet.

In the project vicinity, bedrock consists of heated and deformed sedimentary and volcanic rock. The Carolina Slate Belt was the site of a series of oceanic volcanic islands about 550 – 650 million years ago. Metamorphic rocks that occur in this region include meta-mudstone and meta-argillite (slate), thin to thickly bedded, bedding planes and axial-planar cleavage common; interbedded with meta-sandstone, meta-conglomerate and meta-volcanic rock. Four formations are recognized in the Union County section of the Carolina Slate Belt – from oldest to youngest, the Uwharrie Formation, Tillery Formation, McManus Formation and Yadkin Formation. Locally, the site is underlain by the McManus Formation, which comprises approximately 11,600 feet, or approximately 70 percent of the Union County section of the Carolina Slate Belt. Thickly bedded, tuffaceous argillite characterizes the McManus Formation, which also contains an appreciable amount of crystal tuff and very fine-grained sandstone.

The soils along Beaverdam Creek mainstem and along the lower 300-feet reach of UT1 within the project area have been derived from and developed over these metamorphic rock formations and include the Chewacla silt loam, 0 to 2 percent slopes, frequently flooded. This map unit consists mainly of very deep, nearly level, somewhat poorly drained soils developed on floodplains. It is mostly present on broad flats along major streams and rivers and on narrow flats along minor creeks and drainageways. Typically the surface layer is brown silt loam approximately seven inches thick. The subsoil is 45 inches thick. On site, the Chewacla unit is mapped adjacent to the Goldston soils. Where the Chewacla unit occurs adjacent to areas of Goldston soils, small areas of soils encounter bedrock at a depth of less than 60 inches below ground surface. Contrasting inclusions make up about 15 percent of this mapped unit.

The upper reach of UT1 and the entire length of UT2 is mapped Cid channery silt loam, 1 to 5 percent slopes. This map unit consists mainly of moderately deep, moderately well drained and somewhat poorly drained, nearly level and gently sloping Cid and similar soils on flats, on ridges in the uplands, in depressions and in headwater drainageways. Typically, the surface layer is light brownish gray channery silt loam four inches thick. The subsurface layer is a pale yellow channery silt loam 5 inches thick. The subsoil is 18 inches thick. Weathered, fractured bedrock is encountered at a depth of about 27 inches. Hard, fractured bedrock is encountered at a depth of about 32 inches. Permeability is slow in the Cid soil. Available water capacity is low to moderate. The shrink-swell potential is moderate. A seasonal high water table is perched between depths of 1.5 to 2.5 feet below ground surface from December through May. The depth to hard bedrock ranges from 20 to 40 inches. The hazard of erosion is moderate on construction sites if the ground cover is removed. Soils mapping and taxonomic descriptions are from the USDA NRCS, Soil Survey of Union County, North Carolina (USDA NRCS, January 1996).

The drainage area tributary to the downstream limits of the project on Beaverdam Creek mainstem is 0.4910 square miles or 314 acres. UT1 and UT2 have contribution drainage areas of 0.2375 square miles (152 acres) and 0.0765 square miles (49 acres), respectively. The project contribution drainage areas watershed map is presented on **Figure 3**. Drainage areas for the project reaches are summarized in **Table 1**.

TABLE 1
Drainage Areas
Project Number D06054-C (Beaverdam Creek and Unnamed Tributaries)

Reach	Drainage Area (Acres)
Beaverdam Creek Mainstem (downstream project limit)	314
UT1 to Beaverdam Creek*	152
UT2 to Beaverdam Creek*	49
Total	314

*UT1 and UT2 drainage areas are included in the total contribution drainage area for the Beaverdam Creek stream restoration project. Refer to **Figure 3** for delineation of project sub-watershed drainage areas.

1.2 Pre-Restoration Existing Conditions

A number of anthropogenic factors had impacted the project stream reaches and riparian corridors, resulting in its unstable deeply incised channel conditions. Pre-restoration land use surrounding the restoration project was active cattle pasture land. Historic stream relocation, channelization and cattle intrusion were the primary causes leading to instability along each of the project reaches. Cattle had unrestricted access to the project stream reaches for watering and, in areas where established riparian canopy corridors exists, cattle accessed the project reaches for shade. The unstable streambanks contributed significant quantities of sediment and nutrient laden runoff from the project stream reaches into the larger Beaverdam Creek and Lanes Creek watersheds due to head cutting and bank destabilization attributed to hoof-shear. **Table 2** provides baseline geomorphologic and hydraulic summaries for regional curve, reference, pre-existing, design and as-built channel dimensions, pattern, profile, substrate, and Rosgen stream type, together with additional reach parameters.

The upper two-thirds of the UT1 reach and the entire UT2 reach had sparse riparian vegetation along their stream corridors. Vegetation along the existing stream corridors was dysfunctional with respect to bank stabilization, nutrient uptake and sediment removal from overland runoff. The approximate lower one-third of the UT1 and Beaverdam Creek mainstem reaches have relatively narrow, pre-existing established hardwood forested riparian corridors. However, these corridors exhibited severe denuding of the understory, shrub and herbaceous ground cover vegetation due to cattle grazing and browsing. Typical species observed within the corridor included *Ulmus alata* (winged elm), *Quercus phellos* (willow oak), *Quercus velutina* (black oak), *Acer negundo* (boxelder), *Asimina triloba* (pawpaw), *Lonicera* species (honeysuckle), *Bignonia capreolata* (crossvine), *Carex* species (sedge), *Mitchella repens* (partridgeberry), and *Geranium* species (wild geranium).

2.0 RESTORATION SUMMARY

2.1 Mitigation Goals and Objectives

As discussed in the Restoration Plan for Beaverdam Creek and two associated unnamed tributaries (UT1 and UT2), the mitigation goals and objectives for the project involved restoring stable physical and biological function of the project streams beyond pre-restoration (impaired) conditions. Pre-restoration conditions consisted of channelized, eroding, incised and entrenched stream channels. Nutrient and sediment loading, vegetative denuding and destabilized streambanks associated with hoof shear from uncontrolled cattle access was evident. The specific mitigation goals and objectives proposed and achieved for the project are listed below.

- Stable stream channels with features inherent of ecologically diverse environments, with appropriate streambed features including appropriately spaced pool and riffle sequences, and riparian corridors planted with diversified, indigenous vegetation.
- Superimposed reference reach boundary conditions on the impaired project reaches in the restoration design and construction of improvements.
- Constructed stream channels with the appropriate geometry and gradient to convey bankfull flows while entraining bedload and suspended sediment (wash load) readily available to the streams.
- Created an improved connection between the bankfull channels and floodprone areas, with stable channel geometries, protective vegetation and jute coir fabric to prevent erosion.
- Minimized future land use impacts to project stream reaches by conveying a perpetual, restrictive conservation easement to the State of North Carolina, including stream corridor protection via livestock exclusion fencing at the surveyed and recorded conservation easement boundaries, with gates at the edge of the riparian corridor on river right and left at reserved conservation easement crossings adjacent to active pasture land.

The restoration of Beaverdam Creek mainstem, UT1 and UT2 met the project goals and objectives set forth in the restoration plan by providing desired aquatic habitat and stability features required to enhance and provide long-term ecologic health for the project reaches. More specifically, the completed restoration project has accomplished the enhancements listed below.

Beaverdam Creek Mainstem:

- Reversed the effects of channelization using a Priority Level I restoration approach; restoration increased the width/depth ratio from 9.19 to 18.43.
- Restored natural pattern to the channel alignment, increasing the sinuosity from 1.07 to 1.49, while maintaining a stable relationship between the valley slope and bankfull slope (the bankfull slope was steeper than the valley slope prior to restoration and is now less than the valley slope with the completed restoration). Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Stabilized eroding streambanks by providing an appropriately sized channel with stable channel bank slopes built with a combination of embedded stone, topsoil, natural fabrics and hearty vegetative protective cover. The average Bank Height Ratio was decreased from 1.60 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by raising the bankfull channel to the elevation of the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 3.68 to 7.36.

- Created instream aquatic habitat features, including appropriately spaced pool and riffle sequences, and a stable transition of the mainstem reach thalweg to the invert of the downstream culvert carrying Beaverdam Creek under Snyders Store Road.
- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover, preserving existing forested riparian corridors where present.

Unnamed Tributary 1 (UT1):

- Reversed the effects of channelization through a combination of Priority Level I and Priority Level II restoration techniques. The average width/depth ratio of the restored UT1 project reach is 15.02. Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Restored natural pattern to the channel alignment, increasing stream channel sinuosity from 1.14 to 1.45.
- Stabilized eroding streambanks by providing appropriately sized channels with stable streambank slopes. The average Bank Height Ratio has been reduced from 1.76 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by a combination of raising the stream bed and/or lowering the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 2.74 to 8.68.
- Created instream aquatic habitat features including appropriately spaced pool and riffle sequences, including a stable transition of the UT1 reach thalweg at its confluence with Beaverdam Creek.
- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover, preserving existing forested riparian corridors where present.

Unnamed Tributary 2 (UT2):

- Reversed the effects of channelization through a combination of Priority Level I and Priority Level II restoration techniques. The width/depth ratio of the restored UT2 project reach was increased from 8.32 to 21.00. Stable pattern, profile and dimension were restored based on extrapolation from reference reach boundary conditions.
- Restored natural pattern to the channel alignment, increasing stream channel sinuosity from 1.02 to 1.49
- Stabilized eroding streambanks by providing appropriately sized channels with stable streambank slopes. The average Bank Height Ratio has been reduced from 2.12 to 1.00 (extremely incised to stable).
- Created re-connection between the restored stream channel and the adjacent floodprone area by a combination of raising the stream bed and/or lowering the adjacent floodplain. The completed restoration increased the average entrenchment ratio from 2.74 to 8.68.
- Created instream aquatic habitat features including appropriately spaced pool and riffle sequences, with a stable transition of the UT2 reach thalweg at its confluence with UT1.
- Revegetated the riparian corridor with indigenous canopy, mid-story, shrub and herbaceous ground cover.

2.2 Restoration Approach

Engineering Field Reconnaissance

EMH&T scientists and engineers mobilized to the site on July 17, 2007 to assess the impaired project reaches. The following sections describe the results of the impaired conditions field assessment. Representative stream profiles ≥ 20 bankfull widths were surveyed using differential leveling techniques on each of the project reaches. Representative riffle and pool cross-sections were surveyed on each reach and riffle and pool streambed particle distributions were collected following standard NC EEP protocols. The following sections discuss, in detail, the results from engineering field reconnaissance, by project stream reach.

Beaverdam Creek Mainstem

In its impaired state, the stream's high degree of channel incision, expressed as the ratio of low bank height to maximum bankfull depth, or Bank Height Ratio (BHR range 1.56 - 1.60), low sinuosity (K = 1.08), denuded and destabilized streambanks composed of stratified silty soils, relatively steep profile slope (0.0169 ft/ft, or 89.2 ft/mi) had resulted in a deeply incised, unstable channel with a high erosion potential. The incised, vertical to undercut streambanks, accelerated streambank erosion rates. Utilizing the ratio of near-bank maximum bankfull depth to mean bankfull depth bank erosion hazard index (BEHI) algorithm in RiverMorph® v.4.1.1, it was estimated 21 cubic yards per year (or 28 tons per year) of sediment was being eroded from the unstable, vertical to undercut streambanks along the mainstem impaired reach into the larger Beaverdam Creek watershed. This estimate was calculated using the bank height (2.97 ft) measured at an impaired pool cross-section, located 107 feet upstream from the confluence of UT1 with Beaverdam Creek, and the total mainstem impaired reach length (386 lf), and represents a bank erosion rate of 0.5 ft/yr. BEHI and sediment export, bank erosion rate estimates, together with bank stability evaluation, BHR calculations, with RiverMorph® v.4.1.1 model inputs and results are presented in **Appendix 3** in the Beaverdam Creek and Unnamed Tributaries Restoration Plan, EEP Project No. D06054-C (EMH&T, January 16, 2008).

UT1

In its impaired state along the lower forested reach, the stream's high degree of channel incision (BHR range 1.41 - 1.76), low sinuosity (K = 1.16), denuded and destabilized streambanks, profile slope (0.0058 ft/ft, or 30.6 ft/mi) had resulted in a deeply incised, unstable channel with high streambank and streambed erosion potential. The incised, vertical to undercut denuded streambanks, accelerated erosion rates. Utilizing the ratio of near-bank maximum bankfull depth to mean bankfull depth BEHI algorithm in RiverMorph® v.4.1.1, it was estimated 67 cubic yards per year (or 87 tons per year) of sediment was being eroded from the unstable streambanks along the forested segment of UT1 impaired reach. This estimate was calculated using the bank height (2.68 ft) measured at an impaired pool cross-section located 212 feet upstream from the confluence of UT1 with Beaverdam Creek mainstem and the lower impaired reach length from the point where the existing channel enters the forested corridor to its confluence with Beaverdam Creek (1351 lf), and represents a bank erosion rate of 0.5 ft/yr. BEHI and sediment export, bank erosion rate estimates, together with bank stability evaluation, BHR calculations, with RiverMorph® v.4.1.1 model inputs and results are presented in **Appendix 3** in the cited project Restoration Plan.

Upstream of the forested corridor on UT1, pre-existing bank erosion hazard indices were not calculated. This segment of the impaired reach was significantly different from the forested reach. Aggradation was the dominant depositional process as the land use was open pasture land with non-uniform channel geometry, modified by hoof shear together with low profile gradient. In its existing state, the upper UT1 stream segment lacked suitable features for aquatic habitat.

UT2

In its impaired state, the stream's high degree of channel incision (BHR range 1.80 – 2.12), low sinuosity (K = 1.01), denuded and destabilized streambanks, relatively steep profile slope (0.0192 ft/ft, or 101.4 ft/mi) had resulted in a deeply incised, unstable stream channel with a high sediment supply. The incised, steep to near vertical denuded streambanks, accelerated erosion rates. Utilizing the ratio of near-bank maximum bankfull depth to mean bankfull depth BEHI algorithm in RiverMorph® v.4.1.1, it is estimated 4 cubic yards per year (or 5 tons per year) of sediment was being eroded from the unstable streambanks along the UT2 impaired reach. This estimate was calculated using the bank height (2.14 ft) measured at an impaired pool cross-section, located 227 feet upstream from the confluence of UT2 with UT1, and the total UT2 impaired reach length (203 lf), and represents a bank erosion rate of 0.25 ft/yr. BEHI and sediment export, bank erosion rate estimates, together with bank stability evaluation, BHR calculations, with RiverMorph® v.4.1.1 model inputs and results are presented in **Appendix 3** in the cited project Restoration Plan.

Channel Stability Summary

Summing the sediment export estimates for each of the project reaches under impaired conditions, the streams had the potential to contribute approximate 92 cubic yards (or 120 tons) of nutrient laden sediment off site into the larger Beaverdam Creek watershed on an annual basis. The rate of erosion, expressed in feet per year per linear foot, was based on estimates from field observations for each of the impaired project reaches and their potential for mass loading of nutrients and sediment due to channel instability from uncontrolled cattle intrusion, agricultural land use and channelization.

The consequence of channelization, cattle intrusion, confinement (lateral containment), incision (vertical containment) major floods, changes in sediment regime, and loss of riparian vegetation are attributed causes and effects for impaired conditions along the project reaches prior to restoration. The effects of these anthropogenic changes were accelerated streambank erosion, channel incision, land loss, aquatic habitat loss, lowering of the water table, land productivity reduction and in-stream and downstream sedimentation and nutrient loading. Weighting each of the mitigation types and categories available against stated projected goals, and based on engineering field reconnaissance and detailed topographic surveys of the impaired project reaches, it was determined only full-scale restoration could achieve stabilization and the establishment of fully functional aquatic and riparian habitat along the impaired project reaches.

2.3 Bankfull Verification

For the project stream reaches, bankfull discharge was evaluated through quantitative analysis of stable reference reach boundary conditions and comparison of predicted bankfull discharge through a stable, surveyed riffle cross-section, located 43 feet upstream from the confluence of Davis Branch with Gourdvine Creek, as shown on **Figure 4**. The contribution drainage area for the Davis Branch Reference Reach is 365.55 acres or 0.5712 square mile. Discharge versus drainage area relationships for the

reference reach riffle cross-section were compared to *Bankfull Hydraulic Geometry Relationships for North Carolina Streams (Rural Piedmont)* regional curve dataset. Through this analysis, it was determined the rural Piedmont regional curves underestimates bankfull discharge and geometric relationships for project stream reaches.

The *Bankfull Hydraulic Geometry Relationships for North Carolina Streams* (Rural Piedmont) power function regression equation for bankfull discharge is:

$Q_{bkf} = 66.57 \times A_w^{0.89}$ ($R^2 = 0.97$)

where Q_{bkf} = bankfull discharge (cfs) and A_w = watershed drainage area (mi^2). Inputting the Davis Branch Reference Reach drainage area (0.5712 mi^2) into the power function regression equation yields the following result:

$Q_{bkf} = 66.57 \times 0.5712^{0.89} = 40.4$ cfs

In an additional effort to validate bankfull discharge for the project reaches, The *Bankfull Hydraulic Geometry Relationships for North Carolina Streams* (Rural Piedmont) dataset was stratified by E stream type using the regional curve data editor in RiverMorph® v.4.1.1. The resulting Log-Pearson Type III distributions and regression analysis from the stratified regional curve dataset yielded the following power function regression equations for bankfull discharge, channel cross-sectional area, mean depth, width, and corresponding coefficient of determination, together with the empirical relationships (predicted values) for the Davis Branch Reference Reach, in bold, where $A_w = 0.5712$ mi^2.

$Q_{bkf} = 105.95 \times A_w^{0.6615}$ ($R^2 = 0.97$) **$Q_{bkf} = 73.1$ cfs**

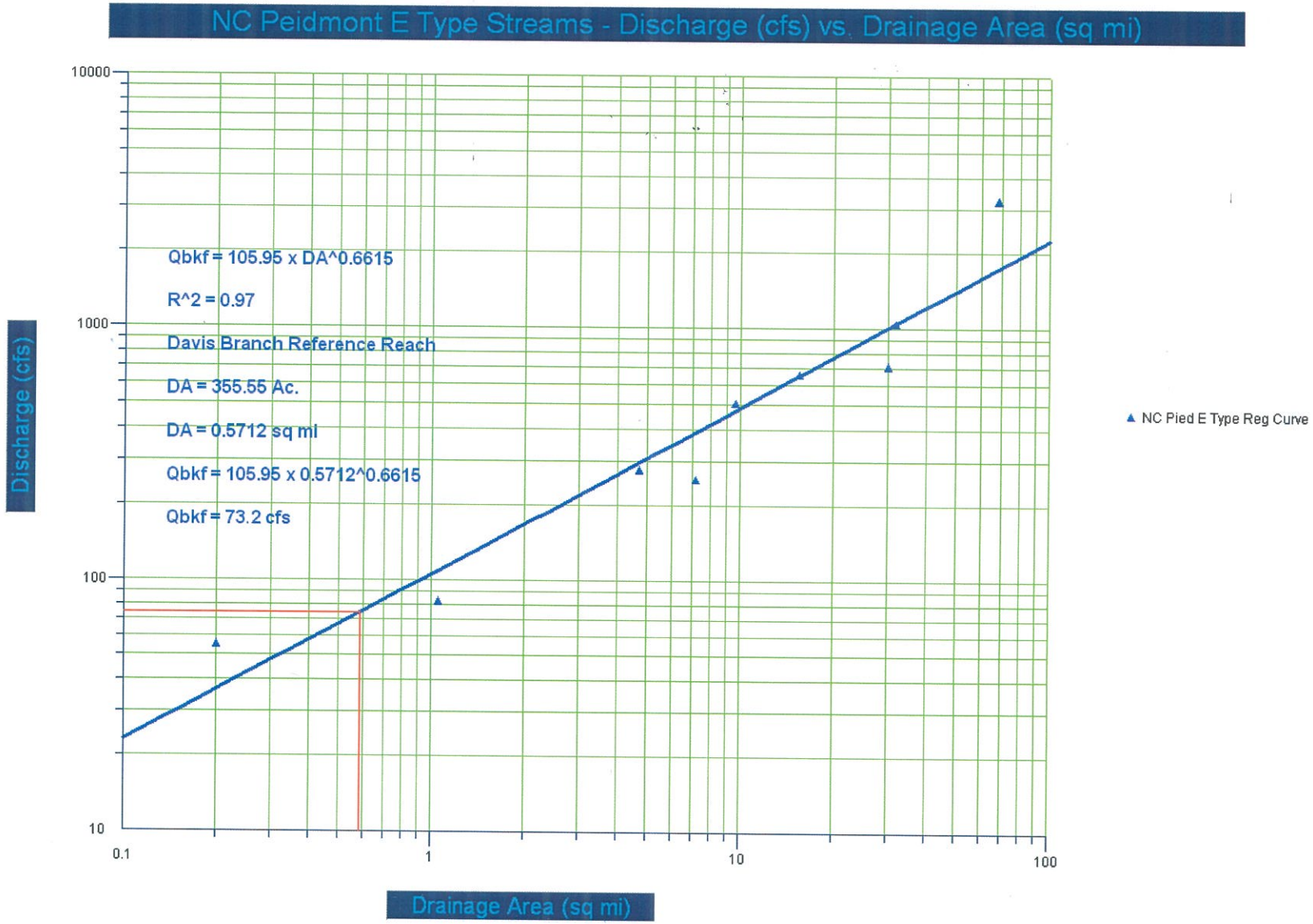
$A_{bkf} = 21.93 \times A_w^{0.6748}$ ($R^2 = 0.97$) **$A_{bkf} = 15.03$ sq ft**

$D_{bkf} = 1.60 \times A_w^{0.3257}$ ($R^2 = 0.89$) **$D_{bkf} = 1.33$ ft**

$W_{bkf} = 13.67 \times A_w^{0.3496}$ ($R^2 = 0.94$) **$W_{bkf} = 11.24$ ft**

The calculated discharge, using carefully delineated reference reach drainage area, quantified reference bankfull riffle geometry, profile slope, and bed roughness yielded a bankfull discharge of 77.6 cubic feet per second (cfs). The following Drainage Area versus Discharge, Rural Piedmont Regional Curve, stratified by Rosgen E stream type analysis predicts Q_{bkf} = 73.1 cfs and validates bankfull discharge estimates for the Davis Branch Reference Reach, and subsequently the bankfull discharge estimates for the Beaverdam Creek mainstem, UT1 and UT2 restored project stream reaches.

Since the quantitatively derived bankfull discharge of 77.6 cfs, based on carefully measured field parameters closely matches the stratified Rosgen E stream type Rural Piedmont Regional Curve empirically estimated bankfull discharge, the quantitatively derived bankfull discharge was carried forward into the design, proportionally adjusted for individual project reach drainage areas. Refer to **Tables 2** for reach specific estimates of bankfull discharge and hydraulic geometries from the stratified Rural Piedmont regional curve dataset, reference reach, pre-existing, design and as-built conditions.


NC Peidmont E Type Streams - Discharge (cfs) vs. Drainage Area (sq mi)
Discharge (cfs)
10000
1000
100
10
0.1
1
10
100
Drainage Area (sq mi)
Qbkf = 105.95 x DA^0.6615
R^2 = 0.97
Davis Branch Reference Reach
DA = 355.55 Ac.
DA = 0.5712 sq mi
Qbkf = 105.95 x 0.5712^0.6615
Qbkf = 73.2 cfs
NC Pied E Type Reg Curve

Channel Morphology

Landform morphology along the Beaverdam Creek mainstem, UT1 and UT2 reach is Rosgen Valley Type VIII. The pre-restoration channels were a deeply incised E4/1, C4/1 and E4 Rosgen stream types, respectively. The restoration goal to reconnect the project reaches to their adjacent floodplains and re-establish stable pattern, profile and dimension consistent with reference reach boundary conditions was achieved. The as-built Beaverdam Creek mainstem, UT1 and UT2 stream channels are Rosgen C4/1 stream types with areas of bedrock control. Summary morphologic and hydraulic data from the Regional Curves, Davis Branch Reference Reach, Pre-Existing, Design and As-Built conditions for Beaverdam Creek, UT1 and UT2 are presented in **Tables 2**.

Table 2: Baseline Morphologic and Hydraulic Summary
Beaverdam Creek and Tributaries Restoration / EEP Project No. D06054-C
Station/Reach: Beaverdam Creek Station 0+00 to 4+76

Parameter	Regional Curve Data			Davis Branch Reference Reach			Pre-Existing Condition			Design			As-Built		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Median	Min	Max	Median
Dimension															
Drainage Area (mi^2)			0.5712			0.5712			0.4910			0.4910			0.4910
BF Width (ft)			11.24			12.91			7.44			11.20			18.48
Floodprone Width (ft)						50.00			27.40			50.00			135.63
BF Cross Sectional Area (ft^2)			15.03			15.65			6.05			13.68			18.48
BF Mean Depth (ft)			1.33			1.21			0.81			1.22			1.00
BF Max Depth (ft)						1.61			1.14			1.80			2.30
Width/Depth Ratio			8.45			10.67			9.19			9.18			18.43
Entrenchment Ratio						3.87			3.68			4.46			7.36
Bank Height Ratio						1.00			1.60			1.00			1.00
Wetted Perimeter (ft)			13.90			13.72			8.05			12.05			19.09
Hydraulic Radius (ft)			1.08			1.14			0.75			1.14			0.97
Pattern															
*Channel Beltwidth (ft)				27.80	53.00	38.00						50.00			50.00
*Radius of Curvature (ft)				16.40	45.30	29.40				17.00	28.00	17.00	17.00	28.00	17.00
*Meander Wavelength (ft)				80.10	116.50	99.20				59.01	93.85	72.68	59.01	93.85	72.68
*Meander Width Ratio				2.15	4.11	2.94						4.46			2.71
Profile															
Riffle Length (ft)				12.0	18.5	15.0	41.0	62.0	51.3	11.7	38.7	24.0	14.7	22.9	17.6
Riffle Slope (ft/ft)				0.0283	0.0799	0.0520	0.0194	0.0328	0.0246	0.0285	0.0939	0.0458	0.0319	0.0720	0.0458
Pool Length (ft)				12.04	29.09	21.20	17.2	21.9	19.5	16.29	32.40	18.28	16.87	39.62	28.68
Pool Spacing (ft)				33.42	43.70	38.56	67.7	104.9	86.3	28.88	71.06	42.65	29.82	58.36	47.57
Substrate															
D50 (mm)						69.2			9.5			9.5			40.5
D84 (mm)						140.1			17.2			17.2			162.8
Additional Reach Parameters															
Valley Length (ft)						974			387			387			320
Channel Length (ft)						1129			416			463			475
Sinuosity						1.2			1.07			1.20			1.48
Water Surface Slope (ft/ft)						0.0311			0.0300			0.0158			0.0101
BF Slope (ft/ft)						0.0326			0.0300			0.0169			0.0106
Rosgen Classification						E3/1b**			E4/1			E4			C4/1
Bankfull Discharge (cfs)			73.1			77.6			66.7			66.7			66.7
Bankfull Velocity (ft/sec)			4.9			5.0			11.0			4.9			3.6

Notes: Blank fields = Historic project documentation necessary to provide these data were collected/compiled.
Where no min/max values is provided, and only one value was measured or computed, that value is presented as the mean or median value.
* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria
E3/1b ("E3/1"** E stream type channel morphology, large cobble substrate with bedrock control; E3/1**"b"** bankfull slope greater than 0.02 ft/ft.)

Table 2: Baseline Morphologic and Hydraulic Summary
Beaverdam Creek and Tributaries Restoration / EEP Project No. D06054-C
Station/Reach: UT1 Sta. 0+00 to 23+45

Parameter	Regional Curve Data			Davis Branch Reference Reach			Pre-Existing Condition			Design			As-Built		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Median	Min	Max	Median
Dimension															
Drainage Area (mi^2)			0.5712			0.5712			0.2371			0.2371			0.2371
BF Width (ft)			11.24			12.91			11.22			9.00	9.22	13.80	11.51
Floodprone Width (ft)						50.00			30.70			50.00	86.55	110.03	98.29
BF Cross Sectional Area (ft^2)			15.03			15.65			8.42			9.00	7.49	10.19	8.84
BF Mean Depth (ft)			1.33			1.21			0.75			1.00	0.74	0.81	0.78
BF Max Depth (ft)						1.61			1.17			1.50	1.64	1.95	1.80
Width/Depth Ratio			8.45			10.67			14.96			9.00	11.38	18.65	15.02
Entrenchment Ratio						3.87			2.74			5.56	7.97	9.39	8.68
Bank Height Ratio						1.00			1.76			1.00	1.00	1.00	1.00
Wetted Perimeter (ft)			13.90			13.72			14.52			11.00	9.82	14.22	12.02
Hydraulic Radius (ft)			1.08			1.14			1.00			0.82	0.72	0.76	0.74
Pattern															
*Channel Beltwidth (ft)				27.80	53.00	38.00						50.00			50.00
*Radius of Curvature (ft)				16.40	45.30	29.40				17.00	25.00	20.00	13.00	25.00	18.00
*Meander Wavelength (ft)				80.10	116.50	99.20				63.29	93.84	75.00	63.29	93.84	75.00
*Meander Width Ratio				2.15	4.11	2.94						5.56			4.34
Profile															
Riffle Length (ft)				12.0	18.5	15.0	47.0	60.0	53.5	10.5	46.1	28.6	7.6	30.2	15.5
Riffle Slope (ft/ft)				0.0283	0.0799	0.0520	0.0117	0.0185	0.0151	0.0228	0.0957	0.0381	0.0088	0.0702	0.0247
Pool Length (ft)				12.04	29.09	21.20	24.60	39.40	31.20	18.69	40.99	27.93	22.96	57.82	36.89
Pool Spacing (ft)				33.42	43.70	38.56	35.40	76.60	54.70	32.70	85.05	54.28	18.07	79.78	50.30
Substrate															
D50 (mm)						69.2			5.5			5.5	61.4	76.1	68.7
D84 (mm)						140.1			16.1			16.1	143.6	175.5	159.5
Additional Reach Parameters															
Valley Length (ft)						974			1637			1594			1622
Channel Length (ft)						1129			1867			2328			2345
Sinuosity						1.2			1.14			1.46			1.45
Water Surface Slope (ft/ft)						0.0311			0.0051			0.0047			0.0047
BF Slope (ft/ft)						0.0326			0.0058			0.0047			0.0042
Rosgen Classification						E3/1b**			C4/1			E4/1	E4/1	C4/1	C4/1
Bankfull Discharge (cfs)			73.1			77.6			32.2			32.2			32.2
Bankfull Velocity (ft/sec)			4.9			5.0			3.8			3.6			3.6

Notes: Blank fields = Historic project documentation necessary to provide these data were collected/compiled.
Where no min/max values is provided, and only one value was measured or computed, that value is presented as the mean or median value.
* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria
E3/1b ("E3/1"** E stream type channel morphology, large cobble substrate with bedrock control; E3/1**"b"** bankfull slope greater than 0.02 ft/ft.)

Table 2: Baseline Morphologic and Hydraulic Summary
Beaverdam Creek and Tributaries Restoration / EEP Project No. D06054-C
Station/Reach: UT2 Sta. 0+00 to 2+84

Parameter	Regional Curve Data			Davis Branch Reference Reach			Pre-Existing Condition			Design			As-Built		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Median	Min	Max	Median
Dimension															
Drainage Area (mi^2)			0.5712			0.5712			0.0765			0.0765			0.0765
BF Width (ft)			11.24			12.91			4.91			6.30			11.55
Floodprone Width (ft)						50.00			21.24			50.00			114.79
BF Cross Sectional Area (ft^2)			15.03			15.65			2.88			4.30			6.35
BF Mean Depth (ft)			1.33			1.21			0.59			0.68			0.55
BF Max Depth (ft)						1.61			0.99			1.00			1.31
Width/Depth Ratio			8.45			10.67			8.32			9.26			21.00
Entrenchment Ratio						3.87			4.33			7.94			9.94
Bank Height Ratio						1.00			2.12			1.00			1.00
Wetted Perimeter (ft)			13.90			13.72			5.70			6.77			11.95
Hydraulic Radius (ft)			1.08			1.14			0.51			0.63			0.53
Pattern															
*Channel Beltwidth (ft)				27.80	53.00	38.00						50.00			50.00
*Radius of Curvature (ft)				16.40	45.30	29.40				12.50	16.00	14.50	12.50	16.00	14.50
*Meander Wavelength (ft)				80.10	116.50	99.20				58.08	59.76	58.92	58.08	59.76	58.92
*Meander Width Ratio				2.15	4.11	2.94						7.94			4.33
Profile															
Riffle Length (ft)				12.0	18.5	15.0	33.0	72.4		13.2	27.1	22.7	12.4	23.9	15.7
Riffle Slope (ft/ft)				0.0283	0.0799	0.0520	0.0173	0.0306		0.0258	0.0532	0.0308	0.0115	0.0451	0.0213
Pool Length (ft)				12.0	29.1	21.2	25.0	26.9		19.4	51.1	25.8	23.7	41.0	30.1
Pool Spacing (ft)				33.4	43.7	38.6			141.2	42.0	64.3	51.9	35.6	70.0	49.3
Substrate															
D50 (mm)						69.2			7.8			7.8			90.0
D84 (mm)						140.1			21.6			21.6			210.4
Additional Reach Parameters															
Valley Length (ft)						974			200			194			191
Channel Length (ft)						1129			203			282			284
Sinuosity						1.2			1.02			1.45			1.49
Water Surface Slope (ft/ft)						0.0311			0.0171			0.0054			0.0075
BF Slope (ft/ft)						0.0326			0.0192			0.0054			0.0062
Rosgen Classification						E3/1b**			E4			E4			C4/1
Bankfull Discharge (cfs)			73.1			77.6			10.4			10.4			10.4
Bankfull Velocity (ft/sec)			4.9			5.0			3.6			2.4			1.6

Notes: Blank fields = Historic project documentation necessary to provide these data were collected/compiled.
Where no min/max values is provided, and only one value was measured or computed, that value is presented as the mean or median value.
* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria
E3/1b ("E3/1"** E stream type channel morphology, large cobble substrate with bedrock control; E3/1**"b"** bankfull slope greater than 0.02 ft/ft.)

2.4 As-Built Channel Stability Assessment

Beaverdam Creek Mainstem

Under as-built conditions, streambank erosion potential was evaluated using the Vertical Velocity Near-Bank Shear Stress Method algorithm in RiverMorph® v.4.1.1, with bankfull geometries inputs taken individually from the two (2) monumented cross-sections (cross-sections number 7 and 8) on the Beaverdam Creek mainstem reach. Hydraulic slope and percentage of the reach occupied by pools/glides along outside meander bends verses riffles/runs between bends (i.e.,70% pools/glides; 30% riffles/runs) was determined from the as-built mainstem longitudinal profile. The following table proportionally summarizes the estimated sediment loss from streambanks under as-built conditions. Individual BEHI study streambank input assumptions and output data are presented in **Appendix D**.

Table 3a. As-Built Estimated Sediment Loss for Beaverdam Creek Mainstem (Reach Summary)

Study Bank	Proportional Length (l.f.)	Loss (cu yd/yr)	Loss (tons/yr)
Pool XS-7	332.84	0.66	0.86
Riffle XS-8	142.65	0.40	0.52
Totals	**475.49**	**1.06**	**1.38**

Note: Estimated total sediment loss per foot of reach = 0.0029 tons/yr/ft = < 0.02 ft bank loss/year.

UT1

Under restored, as-built conditions, the Channel Pattern and/or Depositional Features for Adjustments in Near-Bank Stress algorithm in RiverMorph® v.4.1.1 was applied, using bankfull geometry, hydraulic slope and as-built streambank slopes from the four (4) as-built, monumented cross-sections on UT1. Based on longitudinal profile analysis, the reach is approximately 70 percent pools/glides and 30 percent riffles/runs. Each of the representative, monumented cross-section was selected to proportionally evaluate as-built streambank stability and estimate erosion rates on the UT1 2,345 lf restored reach. The model input parameters and estimated streambank erosion rates are presented in **Appendix D** and summarized in the following table:

Table 3b. As-Built Estimated Sediment Loss for Beaverdam Creek UT1 (Reach Summary)

Study Bank	Proportional Length (l.f.)	Loss (cu yd/yr)	Loss (tons/yr)
Riffle XS-3	351.77	0.43	0.56
Pool XS-4	820.79	1.05	1.37
Pool XS-5	820.79	1.34	1.74
Riffle XS-6	351.77	0.43	0.56
Totals	**2345.12**	**3.25**	**4.23**

Note: Estimated total sediment loss per foot of reach = 0.0018 tons/yr/ft = < 0.02 ft bank loss/year.

UT2

Under restored, as-built conditions, the Channel Pattern and/or Depositional Features for Adjustments in Near-Bank Stress algorithm in RiverMorph® v.4.1.1 was applied, using bankfull geometry, hydraulic slope and as-built streambank slopes from the two (2) as-built, monumented cross-sections on UT2. Based on longitudinal profile analysis, the reach is approximately 70 percent pools/glides and 30 percent riffles/runs. Each of the representative, monumented cross-section was selected to proportionally evaluate as-built streambank stability and estimate erosion rates on the UT2 284 lf restored reach. The model input parameters and estimated streambank erosion rates are presented in **Appendix D** and summarized in the following table:

Table 3c. As-Built Estimated Sediment Loss for Beaverdam Creek UT2 (Reach Summary)

Study Bank	Proportional Length (l.f.)	Loss (cu yd/yr)	Loss (tons/yr)
Pool XS-1	199.02	0.36	0.47
Riffle XS-2	85.29	0.00	0.00
Totals	**284.31**	**0.36**	**0.47**

Note: Estimated total sediment loss per foot of reach = 0.0017 tons/yr/ft = < 0.015 ft bank loss/year.

As-Built Channel Stability Summary

Summing the sediment export estimates for each of the restored project reaches, the streams have the potential to export approximate 4.7 cubic yards (or 6.1 tons) of sediment off site into the larger Beaverdam Creek watershed on an annual basis. Under pre-existing, impaired project reach conditions the estimated potential for mass wasting of nutrient laden sediment, attributed to streambank instability associated uncontrolled cattle intrusion, agricultural land use and channelization, was 92 cubic yards (or 120 tons) per year. Table 3.d provides a summary of pre- and post-restoration sediment erosion rates, and represents a 95 percent reduction in streambank erosion rate potential under as-built conditions.

As noted in the restoration plan, upstream of the forested corridor on UT1, streambank erosion rates were not calculated under pre-existing conditions. This segment of the impaired reach was significantly different from the lower forested reach. Aggradation was the dominant depositional process as the land use was open pasture with non-uniform channel geometry modified by hoof shear together with low profile gradient and herbaceous ground cover.

Table 3d. As-Built Estimated Sediment Loss for Beaverdam Creek (Project Summary)

Reach Identification	Pre-Existing Erosion Rate Estimate (tons/yr)	Restored Erosion Rate Estimate (tons/yr)	Net Reduction Post-Remediation Estimate (tons/yr)
Beaverdam Creek	28	1.4	26.6
UT1	87	4.2	62.8
UT2	5	0.5	4.5
Totals	**120**	**6.1**	**113.9**

The streambank erosion rate summary in **Table 3d** may be somewhat aggressive in that reductions in near-bank shear stress at banks that are protected by erosion control fabrics, rock toe bank protection, and other stream reinforcement measures are not taken into account. Annual surveys at the monumented cross-sections will provide absolute comparisons to the erosion rates summarized in the preceding table and presented in **Appendix D**.

As the revegetated riparian corridors canopy, mid-story, shrub, herbaceous and streamside vegetation matures, intuitively, annual streambank erosion rates should decrease as root mass and density along the restored stream reaches become more pervasive over time.

Reference Reach Data Collection

For Beaverdam Creek, bankfull discharge was determined through a quantitative assessment and analysis of reference reach boundary conditions and comparison of predicted bankfull discharge through a stable riffle cross-section located on Davis Branch, 43 feet upstream from its confluence with Gourdvine Creek. The Davis Branch Reference Reach is located 12.8 miles northeast of the Beaverdam Creek and Unnamed Tributaries Restoration Project. The reference reach is located along the same geologic structural feature, the Troy Anticlinorium (northwest limb near the axial plane of an unnamed syncline), in the same geologic formation, the McManus Formation, is mapped on the same soil series (Chewacla silt loam, Goldston soils and Cid channery silt loam), and is located in the same physiographic province and ecoregion as the Beaverdam Creek project impaired reaches. The reference reach is shown at watershed scale on **Figure 4**.

A complete Rosgen Level III watershed assessment and analysis of the reference reach conditions was conducted during August 8 and 9, 2006. Due to extremely thick riparian vegetation during August 2006, it was possible to collect profile and cross-section data only along a relatively short length of the stable reach. Approximately 118 linear feet of profile, capturing three pool and four riffle sequences, with one representative riffle and pool cross-section, were surveyed in the field. Geologic structural controls and lithology, fluvial geomorphologic processes, depositional materials, climatic influence, riparian vegetation, deposition pattern, debris occurrence, meander pattern, channel stability rating, sediment supply, streambed stability and width/depth ratio state were evaluated following Rosgen Level III stream assessment protocols. Visibility was limited in the field to dense vegetative cover along the Davis Branch Reference Reach; therefore, Union County orthoimagery (2/2004) was used to verify stream pattern.
A total of 1129 linear feet of the reach was assessed for each Level III stream state and condition parameter consistent with a Rosgen Level III methodologies. The assessment included GPS data spatial analysis to evaluate channel pattern upstream from the surveyed reach, beyond the point where additional differential level surveying was impracticable and channel pattern could not be discerned from recent aerial imagery.

Calculated bankfull discharge for the surveyed reference reach riffle cross-section, was computed using hydraulic radius, wetted perimeter, channel slope and a relative roughness (u/u*) method based on the average protrusion height of the steeply dipping bedrock (Rosgen, 1998). Additionally, a particle distribution was collected from the large angular cobble deposited along the reference reach riffle bed.

Reference reach survey data, analysis, classification and geomorphologic summary reports for the Davis Branch Reference Reach are presented in Appendix 3, Beaverdam Creek and Unnamed Tributaries Restoration Plan, NC EEP Project Number: D06054-C (EMH&T, January 16, 2008). The Davis Branch Reference Reach morphologic and hydraulic data are summarized in **Table 2.**

Reference Reach Classification

The reference reach is a Rosgen Valley Type VIII, E3/1b stream type (i.e., E channel morphology, large cobble substrate with strong bedrock control, profile gradient greater than 2 percent). The reference reach is located within a healthy, deciduous hardwood forested riparian corridor. The D84 particle size from the stable riffle particle distribution is 140.1 mm and is consistent with the observed bed thickness and axial splitting planes and observed joint sets in the folded and deformed slate bedrock.

Reference Reach Discharge

See Section 3.5 for a comprehensive analysis and of bankfull discharge for the Davis Branch Reference Reach and the Beaverdam Creek and Tributaries project reaches. Regional curve, reference reach, pre-existing, design and as-built bankfull discharge are presented in tabular format in **Table 2**.

Channel Morphology

Stream channel morphology data for the Davis Branch reference reach, the Beaverdam Creek mainstem, UT1 and UT2 is presented in tabular format on **Table 2**. The Davis Branch reference reach is a Rosgen Valley Type VIII, E3/1b stream type.

Channel Stability Assessment

Reference reach channel stability was analyzed using the vertical velocity near-bank stress method algorithm in RiverMorph® v.4.1.1 and reach streambank observations and channel morphology from reference reach Pool Cross-Section 1+83, located on Davis Branch 117 feet upstream from its confluence with Gourdvine Creek. The predicted annual erosion rate estimate was calculated for the entire 1,129 linear feet of stream evaluated as part of the Rosgen Level III reference reach study. Based on reference reach conditions, the predicted sediment loss is 3.23 cubic yards or 4.2 tons per year. This equates to 0.0043 tons/year per foot of reach, or two one hundredths of a foot (0.02 ft) streambank erosion on an annual basis. The near-bank adjective rating (0.35) is very low for the reference reach, indicating extremely stable channel conditions.

Vegetation

The Davis Branch reference reach flows through a deciduous hardwood forest area, which provides a wide riparian corridor. The canopy layer is dominated by native tree species including *Plantanus occidentalis* (American sycamore), *Carya* species (hickory), and *Acer negundo* (boxelder). The shrub/ sapling and herbaceous understory is extremely thick and provides significant protection against bank erosion. Species such as *Rosa multiflora* (multiflora rose), *Alnus serrulata* (hazel alder), *Bignonia capreolata* (crossvine), *Viola* sp. (violet), and *Convolvulus species* (bindweed) are present within the understory. This healthy, robust vegetation and associated root mass along the reference reach riparian corridor, extending overbank into the channel, is extremely stable and resistant to streambank erosion.

2.5 Restoration Summary

A summary of the restored stream lengths, restoration approach and associated SMU credits are presented in **Table 4** below.

Table 4: Pre-Existing Conditions/Post-Construction Summary
Project Number D06054-C (Beaverdam Creek & Tributaries Restoration)

Tributary Reach ID	Pre-existing length	Restored Length*	Restoration Level	Credit Ratio	SMUs**
Mainstem	416 lf	460 lf	Priority Level I Restoration	1.0	460
UT1	1,867 lf	2300 lf	Priority Level I /II Restoration	1.0	2,300
UT2	203 lf	284 lf	Priority Level I /II Restoration	1.0	284
Totals	**2,486 lf**	**3,044 lf**			**3,044**

*Restored Length excludes permanent conservation easement crossings.
**Restored Length divided by SMU Credit Ratio

3.0 MONITORING PLAN

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. 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, and
- 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 field surveys, including measurements and photographs, will be performed during June 2009. Planting will occur during the spring of 2009. The planted vegetation will first be monitored during the 2009 growing season, during September. 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 4.2* (Lee, M.T., Peet, RK., Roberts, S.R., Wentworth, T.R. 2008) 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 eight permanent, monumented cross-sections annually. This includes two cross-sections (1 riffle, 1 pool) on Beaverdam Creek mainstem, four cross-sections (2 riffles, 2 pools) on UT1, as well as two cross-sections (1 riffle, 1 pool) on UT2. Stream stability and pattern will also be evaluated along longitudinal profiles surveyed along the entire length of each restored reach.

Photographs will be taken upstream, downstream and across channel at each monumented cross-section at the time of survey. 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 in **Section 7.0**. The As-Built Plan sheets 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 B**. Year 0 "As-Built" Long-Term Monitoring Cross-Section summary templates and particle distribution summary templates are included in **Appendix C.**

Yearly monitoring will also include pebble counts to evaluate streambed particle distributions. Pebble count data will be collected at each of the eight monumented cross-section locations. The number of particles in standard size classes will be reported each year to assess sediment transport capacity and competency, streambed particle sorting and depositional trends, and stream stability over time. Annual inspection of in-stream structures, which for this project includes only constructed riffles, will also occur to verify proper function and channel stability. Stream channel monitoring surveys will be completed annually for five consecutive years, starting in June 2009 (Year 1), greater than six months post-construction completion. Annual stream profile and cross-section surveys will be compared to the as-built conditions stream corridor survey (Year 0, December 2008).

A minimum of two bankfull flow events will be documented during the five year monitoring period, occurring separate monitoring years. Bankfull flow events will be documented utilizing two 4-feet, USGS Type A crest-stage stream gages installed on the project reaches; one crest-gage set at bankfull stage at the confluence of Davis Branch and UT1, and one crest-gage set at bankfull stage near monumented cross-section number four (XS-4) on UT1. Photo-documentation after bankfull flows will be presented in the monitoring reports. The locations of the crest-stage stream gages are shown on the As-Built Plan Sheets in **Section 7.0**. 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 on April 8, 2009 will be monitored for five consecutive years. Per the required plots calculation from EEP, a total of eight (8) ten by ten meter square plots (one plot along Davis Branch mainstem, six along UT1 and one along the UT2) have been permanently established. The mainstem plot is five by twenty meters in dimension. Corner markers were permanently installed and one corner surveyed for future reference. 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 each year along with the data collected during the physical monitoring of the project stream reaches. The focus of the vegetative monitoring will be a stem count of planted individuals in the tree and shrub stratum. Data on height and diameter will also be recorded according to the *CVS-EEP* protocol. Percent cover of the plot will be documented via photographic documentation at each vegetative 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. Vegetation plots photo documentation is included in Appendix A. Vegetation plot locations are shown on the As-Built Plan Sheets.

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 substrate sorting and shaping of bedform 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.

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 Beaverdam Creek Mainstem, UT1 and UT2 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.

5.0 REFERENCES

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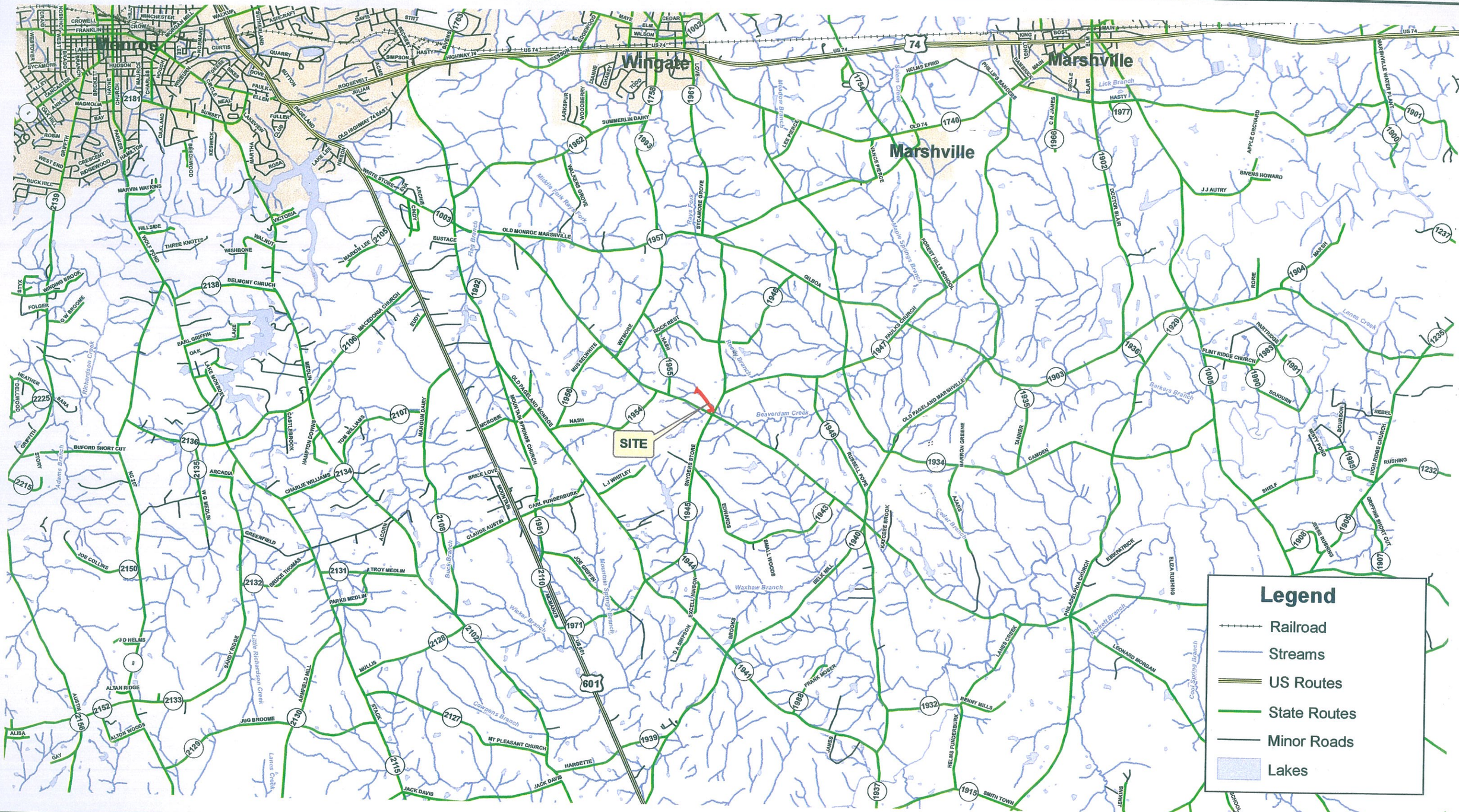
6.0 FIGURES



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M C M X X V I

Scale: 1" = 5000'

0 2,500 5,000 10,000 15,000 Feet

UNION COUNTY, NORTH CAROLINA

BEAVERDAM CREEK & UNNAMED TRIBUTARIES (PARKER SITE)
SITE VICINITY MAP
FIGURE 1

Sources:
- Roads - NCDOT GIS Branch
- Streams and Lakes - National Hydrography Dataset (medium resoultion)
- Contours - NCDOT GIS Branch, based on the Flood Mapping LIDAR data Mar. 2005

N

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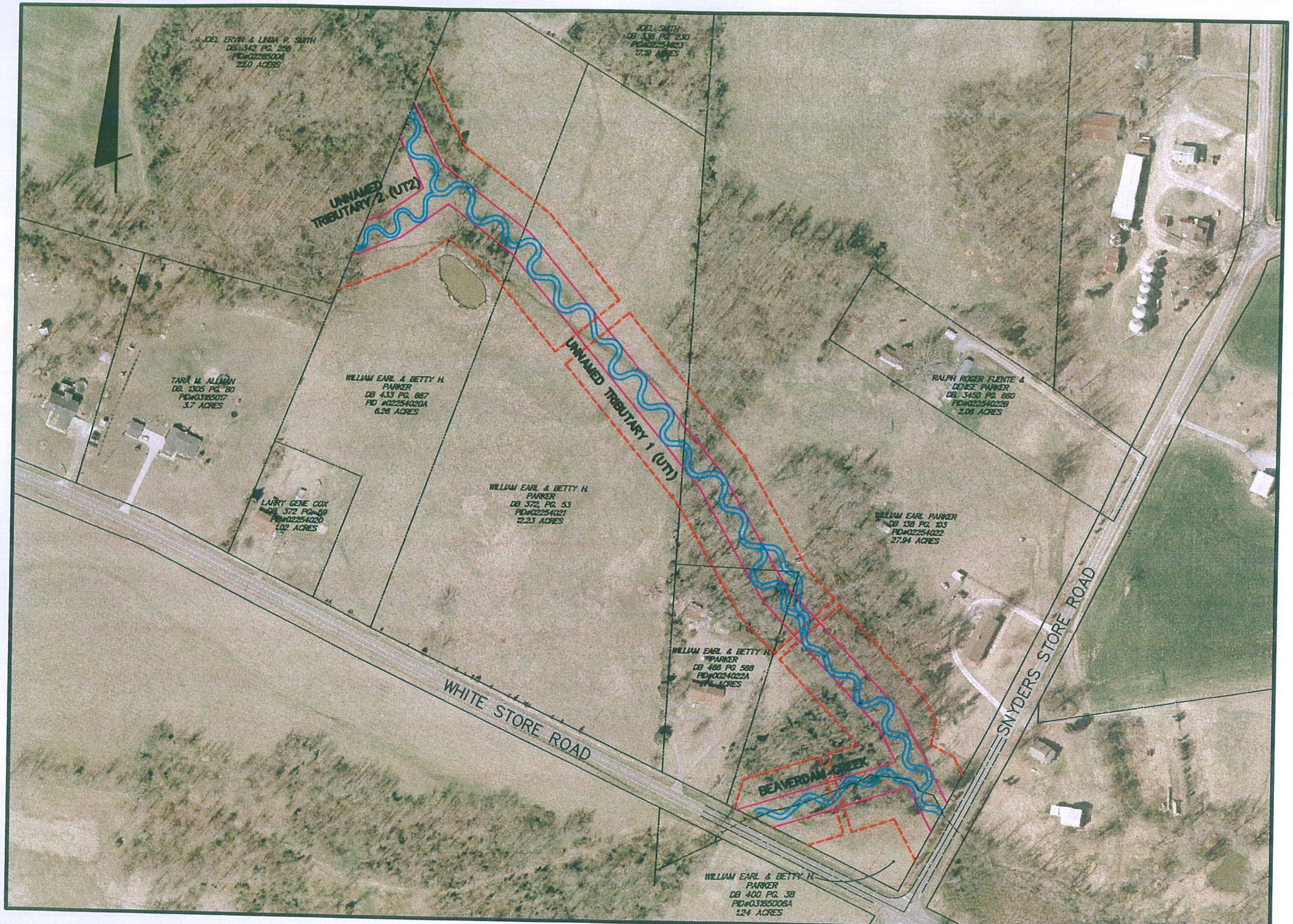

LEGEND

- PROP. BANKFULL
- PROP. BELTWIDTH
- PROP. CONSERVATION EASEMENT

INDEX MAP
Scale: 1" = 200'

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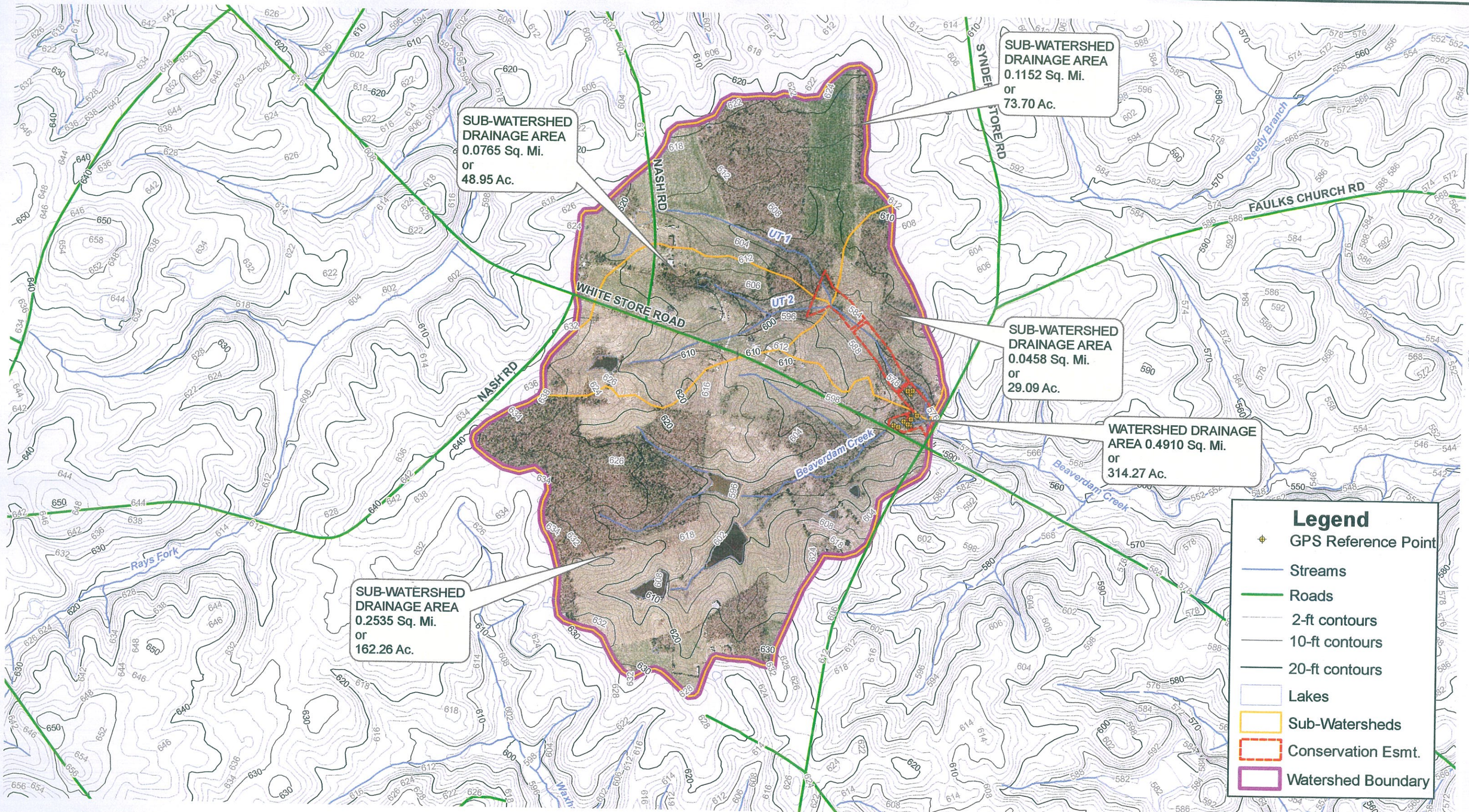
Scale: 1" = 200'
0 100 200 400 800

UNION COUNTY, NORTH CAROLINA

BEAVERDAM CREEK & UNNAMED TRIBUTARIES (PARKER SITE)
STREAM REACHES MAP
FIGURE 2

Sources:
- Contours - NCDOT GIS Branch, based on the Flood Mapping LIDAR data Mar 2005
- Ortho Imagery - Feb. 2004



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M C M X X V I

Scale: 1" = 800'

0 400 800 1,600 2,400 Feet

UNION COUNTY, NORTH CAROLINA

BEAVERDAM CREEK & UNNAMED TRIBUTARIES (PARKER SITE)
WATERSHED MAP
FIGURE 3

Sources:
- Contours - NCDOT GIS Branch, based on the Flood Mapping LIDAR data Mar 2005
- Lakes, Streams, Road Centerlines, - Union County GIS Dept
- Stream Names - National Hydrography Dataset (medium resoultion)
- Ortho Imagery - Feb. 2004)

N

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REFERENCE REACH
DRAINAGE AREA
0.57 Sq. Mi.
or
365.55 Ac.

DAVIS BRANCH
REFERENCE REACH

OLIVE BRANCH RD

MARSHVILLE OLIVE BRANCH RD

HWY 218

HWY 218

218

UT

Davis Branch

Gourdvine Creek

LANESBORO RD

Legend

- GPS Reference Points
- Streams
- Roads
- 2-ft contours
- 10-ft contours
- 20-ft contours
- Lakes
- Watershed Boundary

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Scale: 1" = 800'

0 400 800 1,600 2,400 Feet

UNION COUNTY, NORTH CAROLINA

DAVIS BRANCH REFERENCE REACH AND SITE WATERSHED MAP
FIGURE 4

Sources:
- Contours - NCDOT GIS Branch, based on the Flood Mapping LIDAR data Mar 2005
- Lakes, Streams, Road Centerlines, - Union County GIS Dept
- Stream Names - National Hydrography Dataset (medium resoultion)

N

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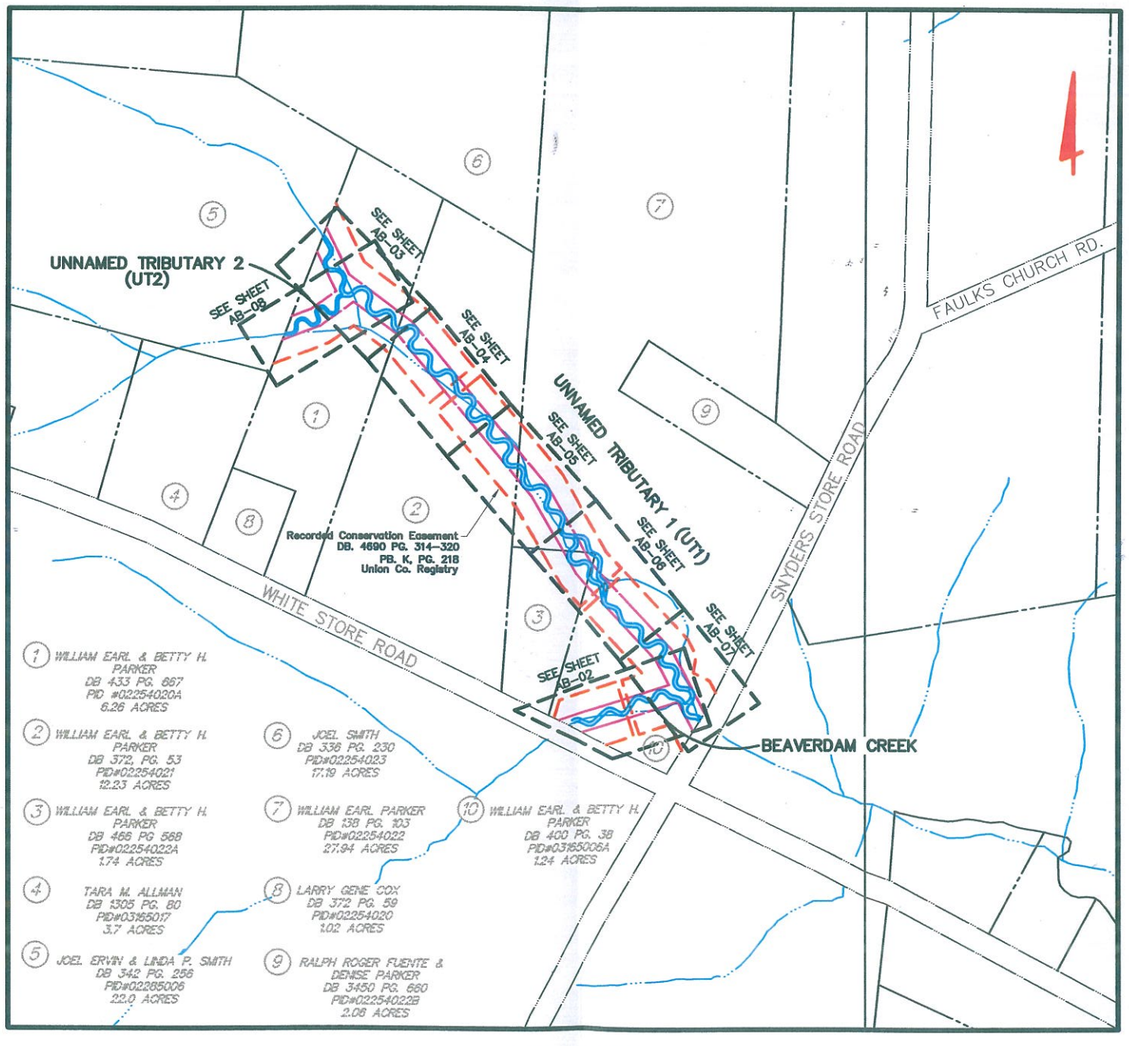
7.0 AS-BUILT PLAN SHEETS

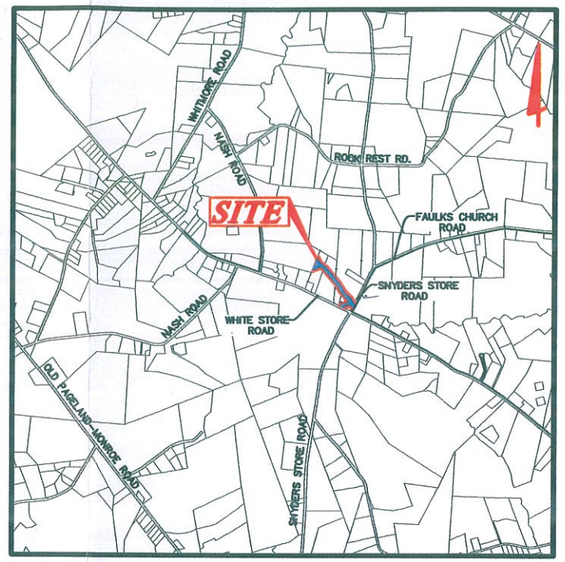
UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
2009

Pre-Existing Conditions/Post-Construction Summary Project Number D06054-C (Beaverdam Creek & Unnamed Tributaries Restoration)					
Tributary Reach ID	Pre-existing Length	Restored Length *	Restoration Level	Credit Ratio	SMUs**
Beaverdam Creek Mainstem	416 lf.	460 lf.	Priority Level I Restoration	1.0	460
UT1	1,867 lf.	2,300 lf.	Priority Level I/II Restoration	1.0	2,300
UT2	203 lf.	284 lf.	Priority Level I/II Restoration	1.0	284
Totals	2,486 lf.	3,044 lf.			3,044

* Restored Length excludes permanent Conservation Easement crossings.
** Restored Length divided by SMU Credit Ratio.



LOCATION MAP
Scale: 1"=400'



VICINITY MAP
Not To Scale

NORTH CAROLINA PROFESSIONAL SEAL PE NO. 034154 ENGINEER JUDD M. HINES

Judd M. Hines 4-28-09
Registered Engineer No. Date

Job No. 2006-1398 | Sheet AB-01/08
Date January, 2009 | Scale As Noted

UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
TITLE SHEET

Ecosystem Enhancement Program

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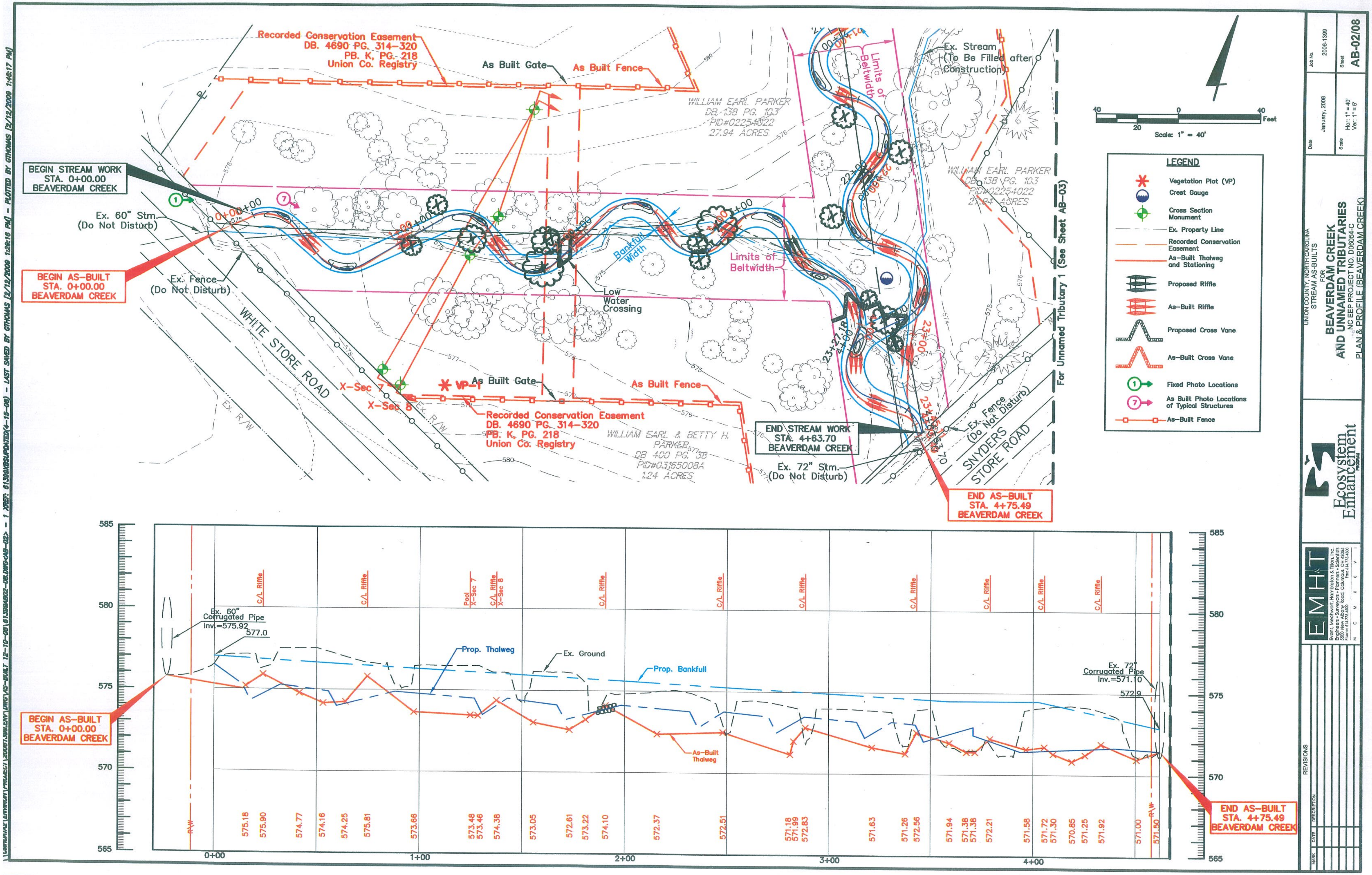
REVISIONS		


Recorded Conservation Easement
DB. 4690 PG. 314-320
PB. K, PG. 218
Union Co. Registry
As Built Gate
As Built Fence
WILLIAM EARL PARKER
DB 138 PG. 103
PID#02254022
27.94 ACRES
Ex. Stream
(To Be Filled after Construction)
Limits of Beltwidth
BEGIN STREAM WORK
STA. 0+00.00
BEAVERDAM CREEK
Ex. 60" Stm.
(Do Not Disturb)
BEGIN AS-BUILT
STA. 0+00.00
BEAVERDAM CREEK
Ex. Fence
(Do Not Disturb)
WHITE STORE ROAD
Ex. R/W
Bankfull Width
Low Water Crossing
X-Sec 7
X-Sec 8
VP-1
WILLIAM EARL & BETTY H. PARKER
DB 400 PG. 38
PID#03185008A
1.24 ACRES
END STREAM WORK
STA. 4+63.70
BEAVERDAM CREEK
Ex. 72" Stm.
(Do Not Disturb)
Ex. Fence
(Do Not Disturb)
SNYDERS STORE ROAD
END AS-BUILT
STA. 4+75.49
BEAVERDAM CREEK
For Unnamed Tributary 1 (See Sheet AB-03)
Scale: 1" = 40'
Feet
LEGEND
Vegetation Plot (VP)
Crest Gauge
Cross Section Monument
Ex. Property Line
Recorded Conservation Easement
As-Built Thalweg and Stationing
Proposed Riffle
As-Built Riffle
Proposed Cross Vane
As-Built Cross Vane
Fixed Photo Locations
As Built Photo Locations of Typical Structures
As-Built Fence
Ex. 60" Corrugated Pipe
Inv.=575.92
577.0
Prop. Thalweg
Ex. Ground
Prop. Bankfull
As-Built Thalweg
Ex. 72" Corrugated Pipe
Inv.=571.10
572.9
C/L Riffle
Pool X-Sec 7
C/L Riffle X-Sec 8
R/W
575.18 575.90 574.77 574.16 574.25 575.81 573.66 573.48 573.46 574.38 573.05 572.61 573.22 574.10 572.37 572.51 571.18 571.99 572.83 571.63 571.26 572.56 571.94 571.38 571.38 572.21 571.58 571.72 571.30 570.85 571.25 571.92 571.00 571.50
0+00
1+00
2+00
3+00
4+00
585
580
575
570
565
UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK
AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (BEAVERDAM CREEK)
Ecosystem Enhancement PROGRAM
EMHT
Evans, Mechwart, Hambleton & Tilton, Inc.
Engineers • Surveyors • Planners • Scientists
Date January, 2008
Scale Hor: 1" = 40' Ver: 1" = 5'
Job No. 2006-1399
Sheet AB-02/08
REVISIONS
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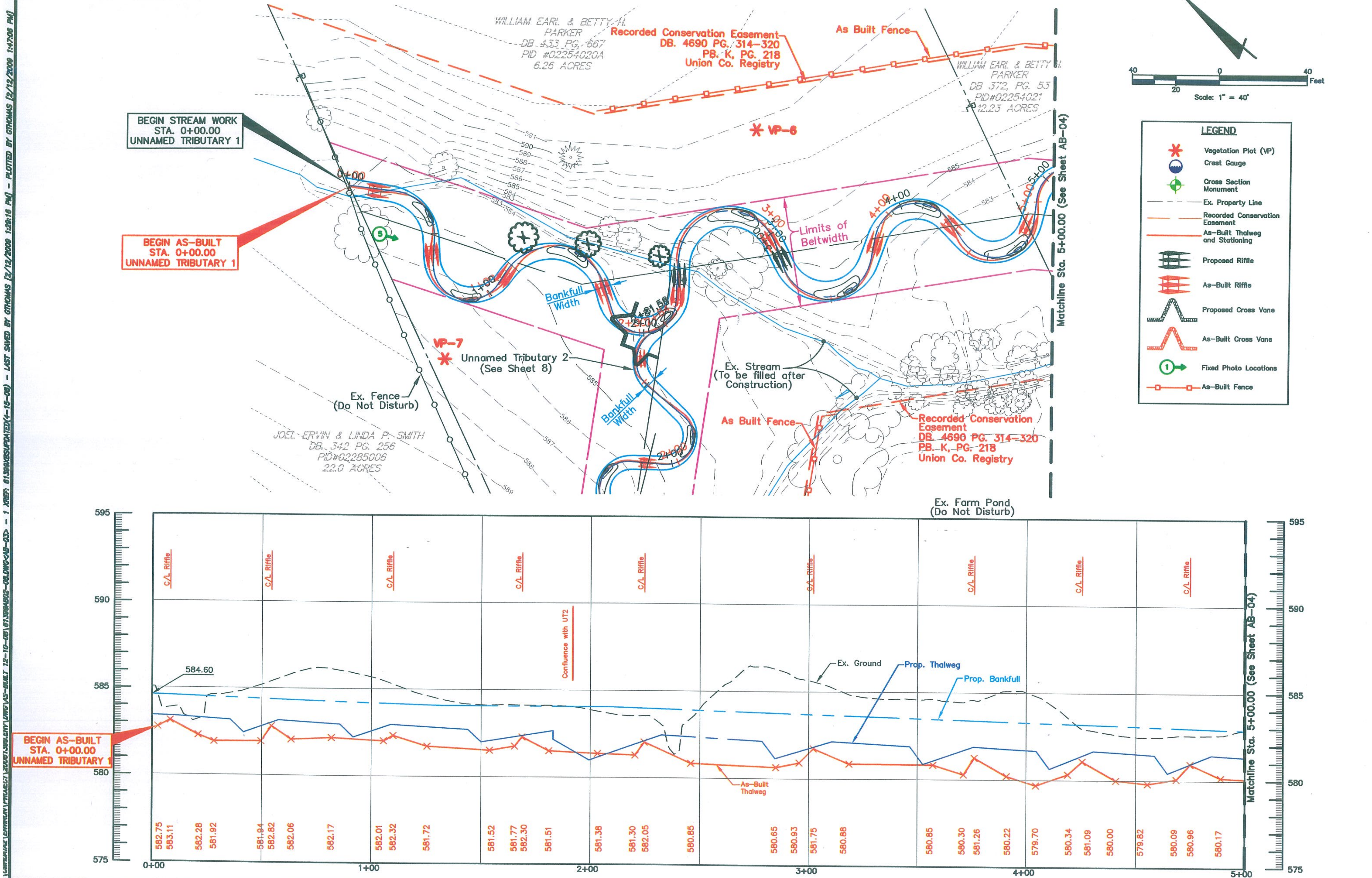

Job No. 2006-1399

Sheet AB-03/08

Date January, 2008

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UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (UT1)

Ecosystem Enhancement PROGRAM

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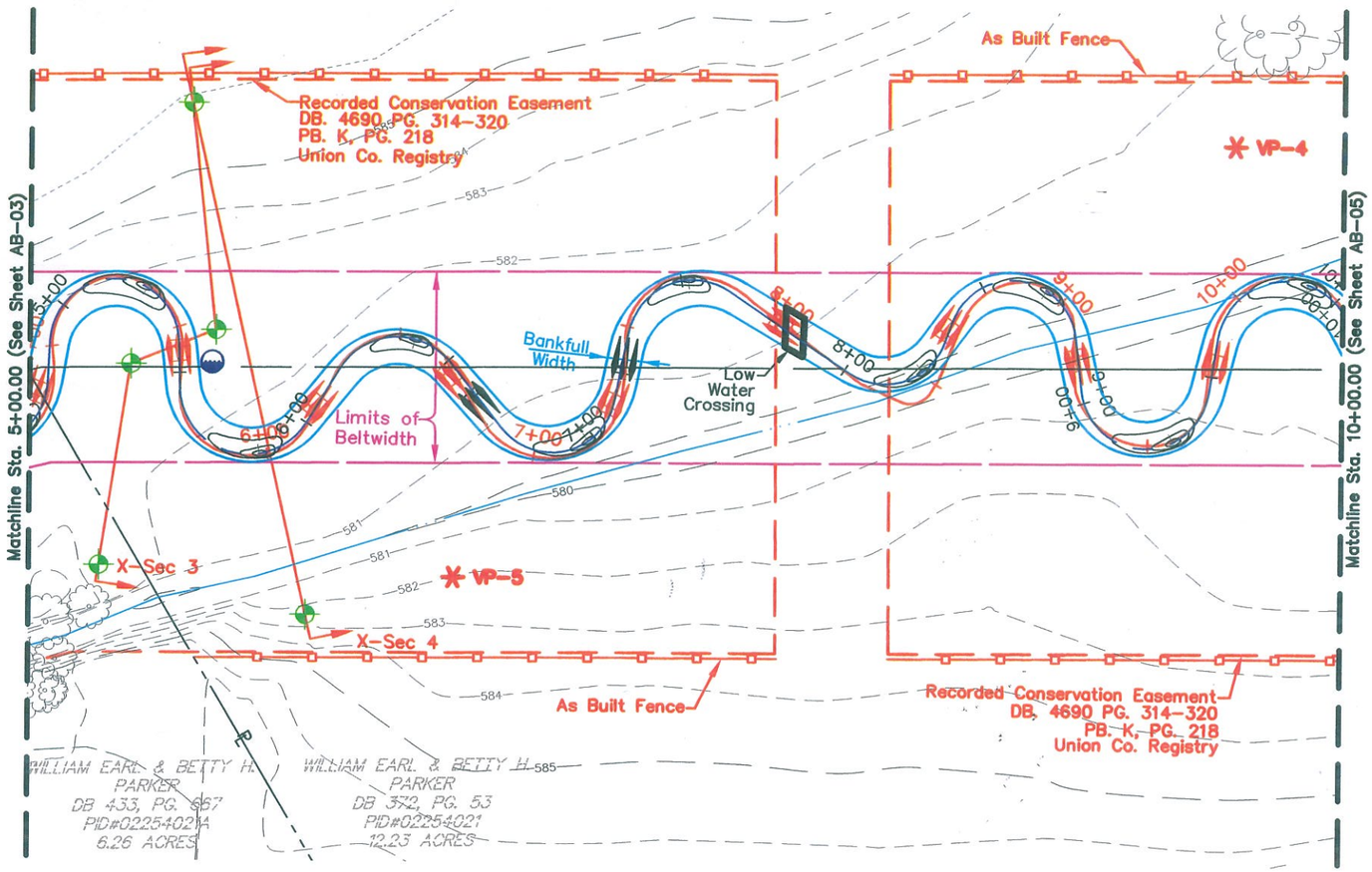
MARK	DATE	DESCRIPTION

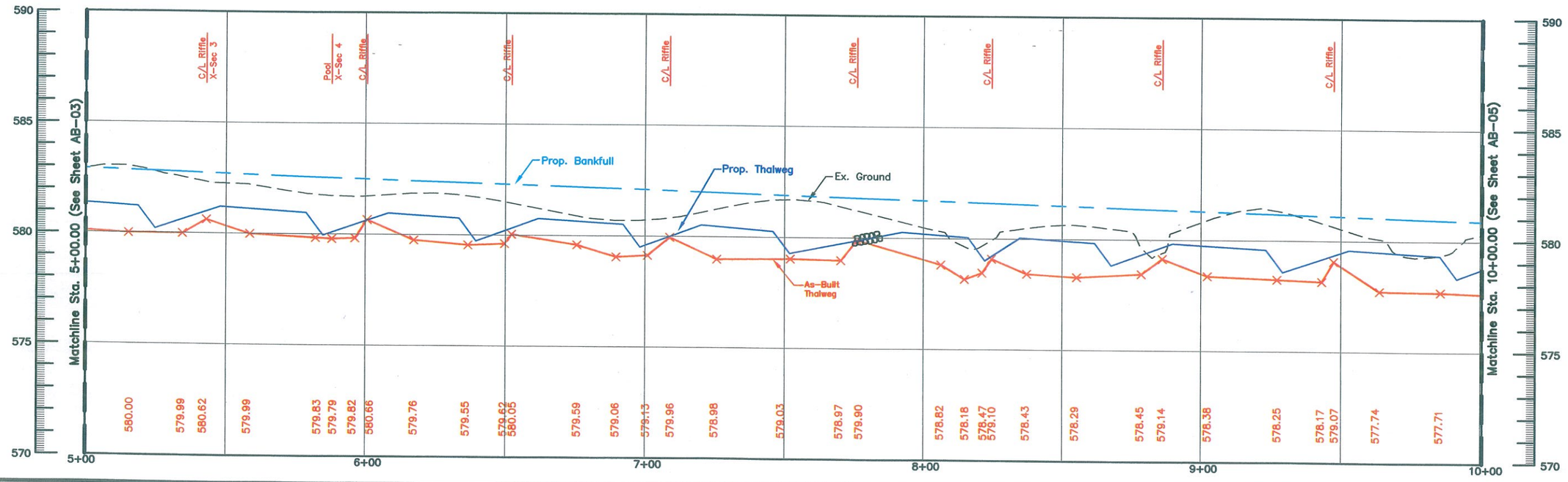
Note:
Gates were not required at the crossing at Approx. Sta. 8+00 because the current land use is row crops.



40 0 40 Feet
20
Scale: 1" = 40'

LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- Proposed Riffle
- As-Built Riffle
- Proposed Cross Vane
- As-Built Cross Vane
- Fixed Photo Locations
- As-Built Fence



Job No. 2006-1399
Sheet AB-04/08
Date January, 2008
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UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (UT1)

Ecosystem Enhancement Program

EMH&T
Environmental, Water Resources, Civil Engineering, Surveying, Planning & Landscape Architecture
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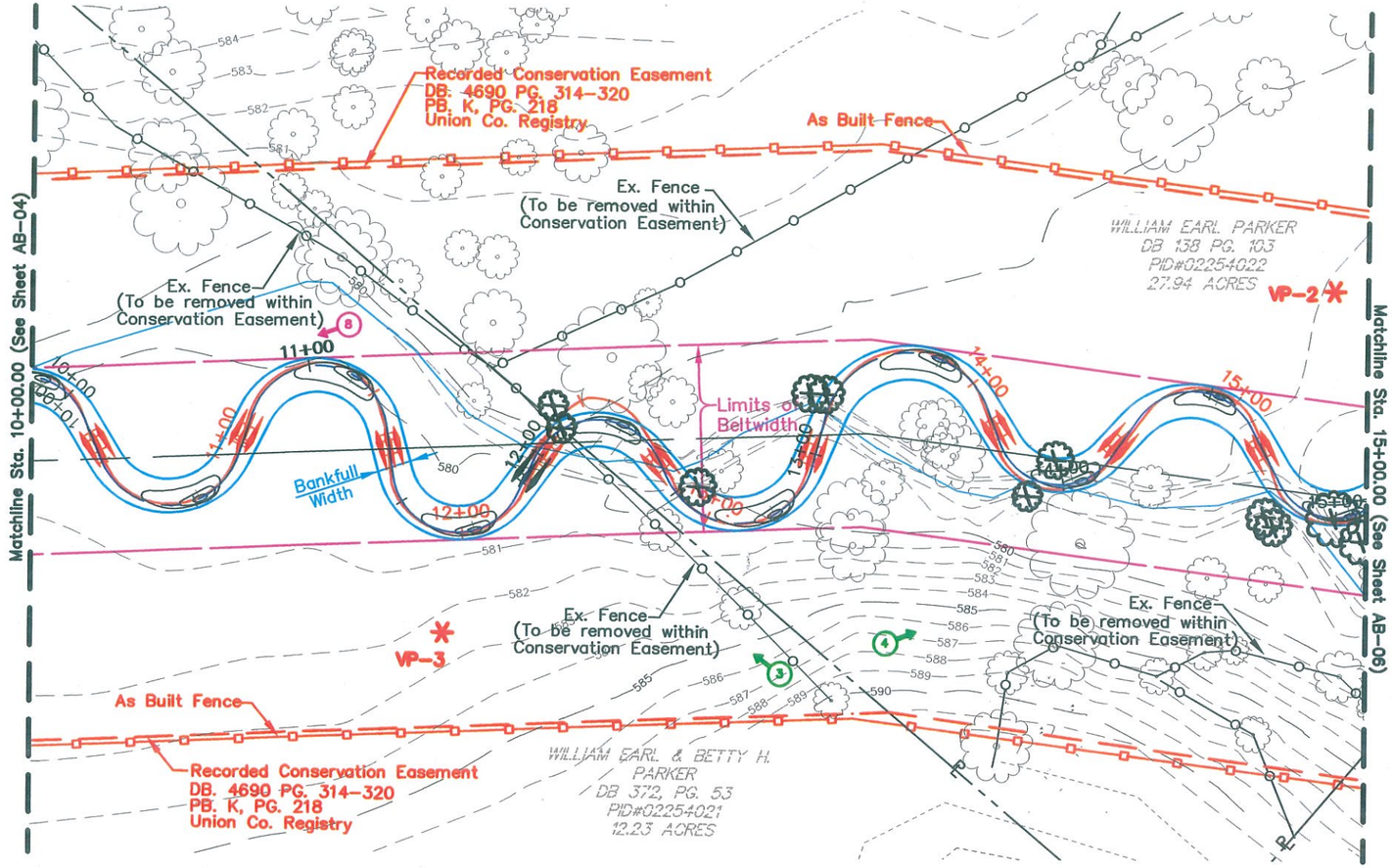
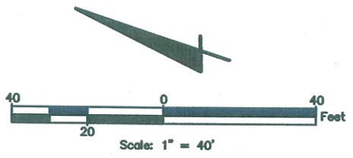
REVISIONS

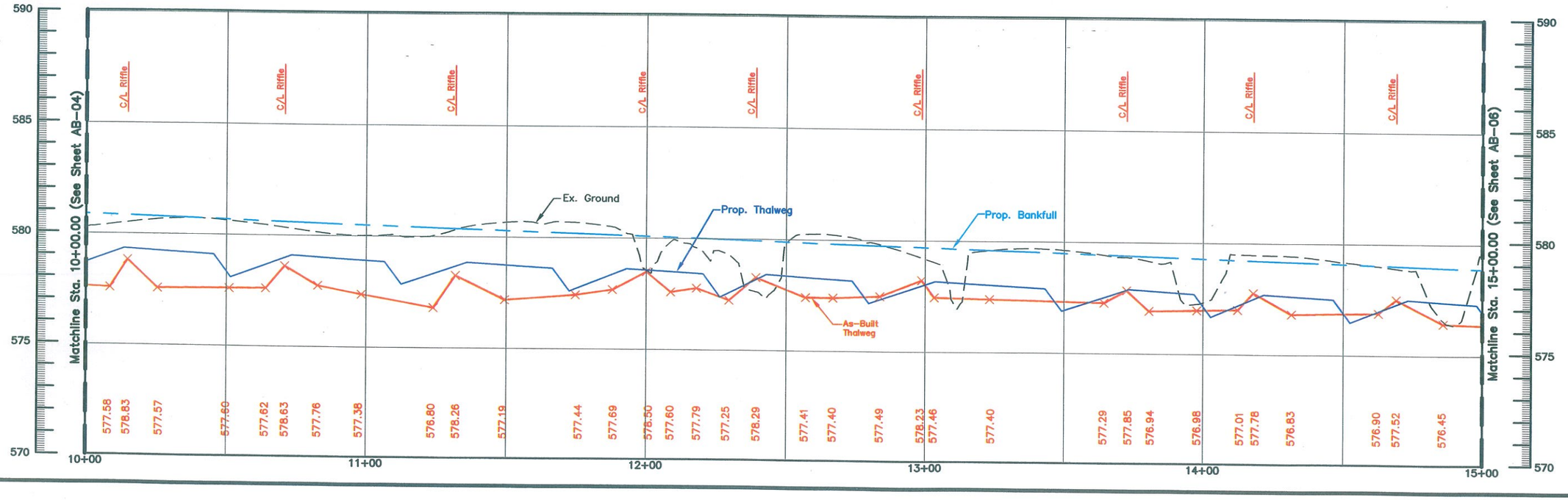
MARK	DATE	DESCRIPTION





LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- Proposed Riffle
- As-Built Riffle
- Proposed Cross Vane
- As-Built Cross Vane
- Fixed Photo Locations
- As Built Photo Locations of Typical Structures
- As-Built Fence



Job No. 2006-1399 | Sheet AB-05/08

Date January, 2008 | Scale Hor: 1" = 40' Ver: 1" = 5'

UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR

BEAVERDAM CREEK AND UNNAMED TRIBUTARIES

NC EEP PROJECT NO. D06054-C

PLAN & PROFILE (UT1)

Ecosystem Enhancement Program

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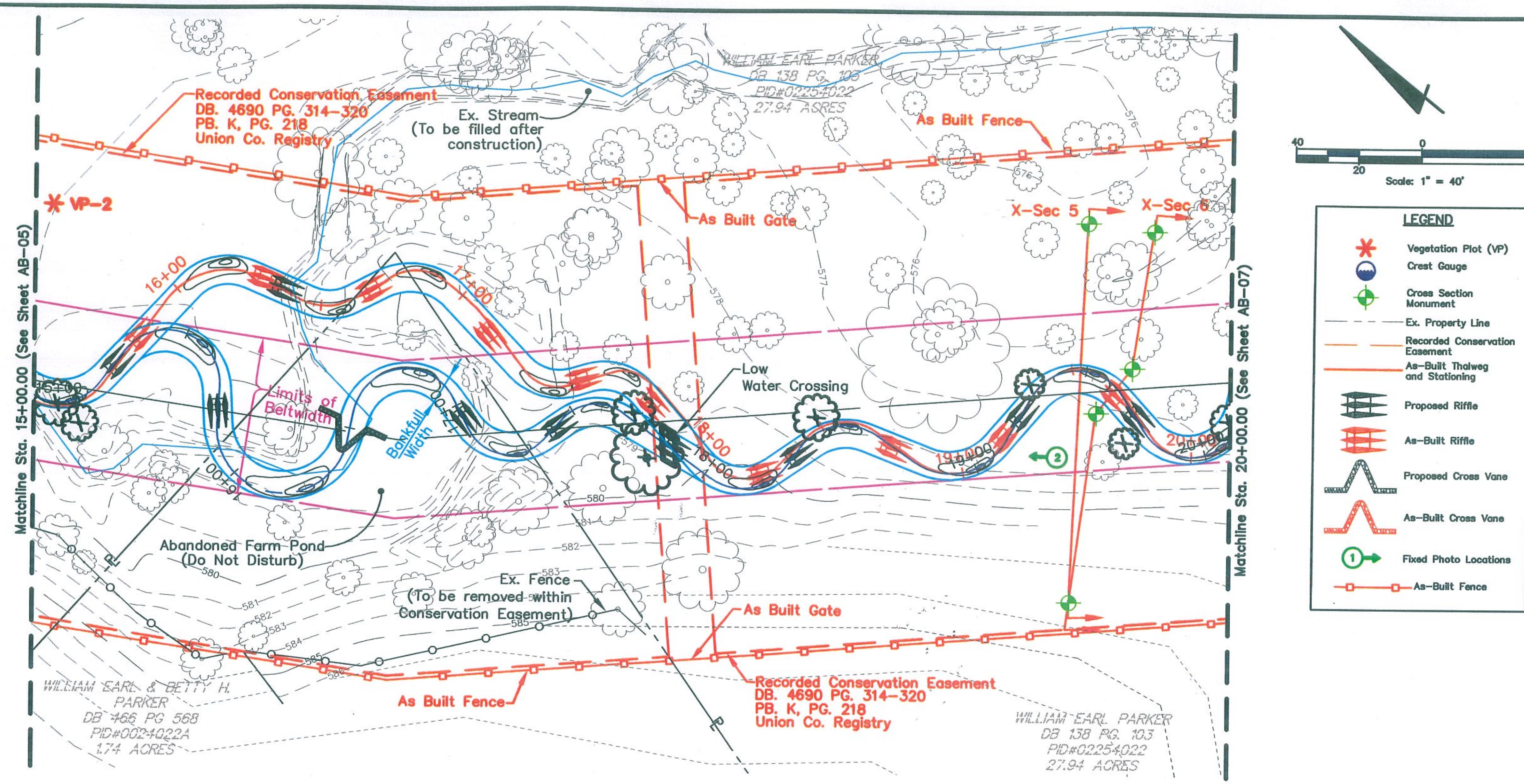
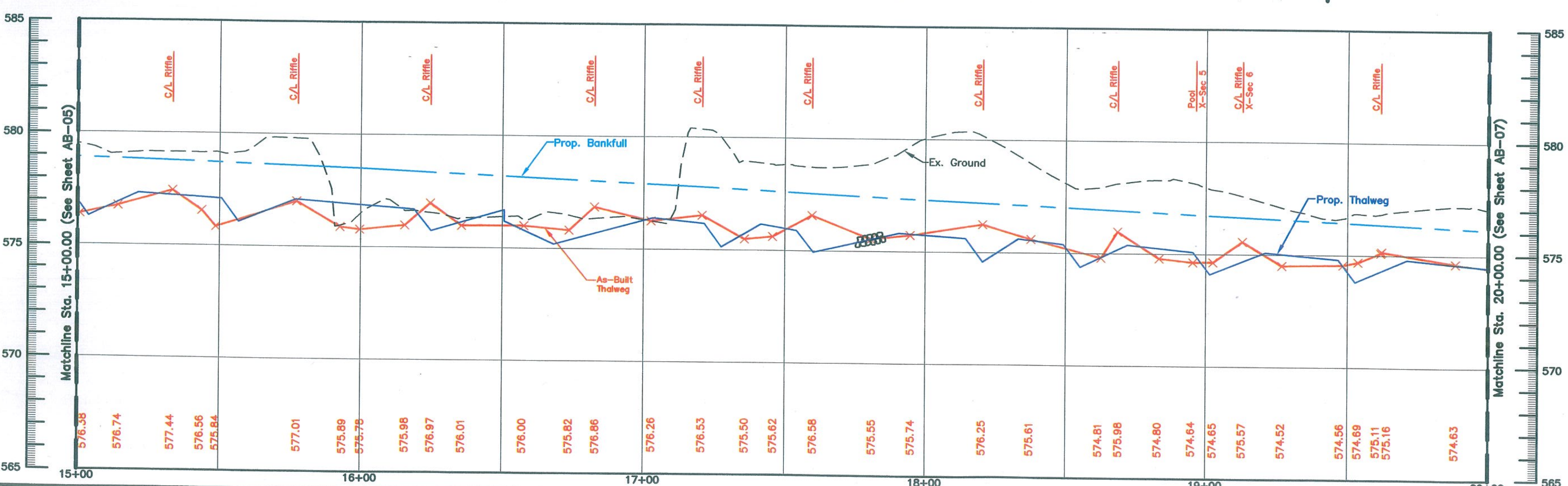
REVISIONS

MARK	DATE	DESCRIPTION

NOTES:
The channel location was adjusted between station 15+50 and station 18+00 in order to preserve the abandoned farm pond.





UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (UT1)

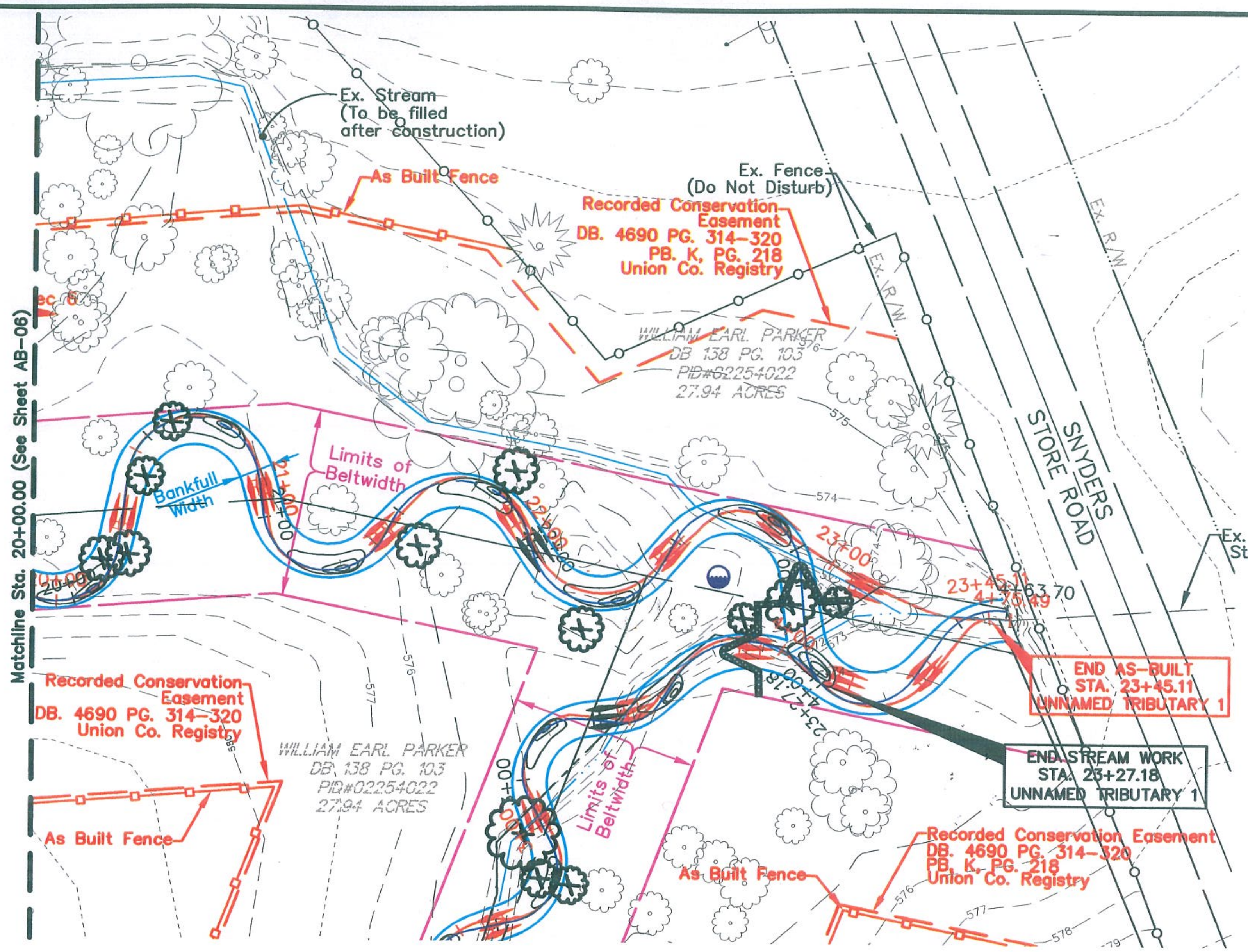
Job No.	2006-1399
Sheet	AB-06/08
Date	January, 2008
Scale	Hor: 1" = 40' Ver: 1" = 5'

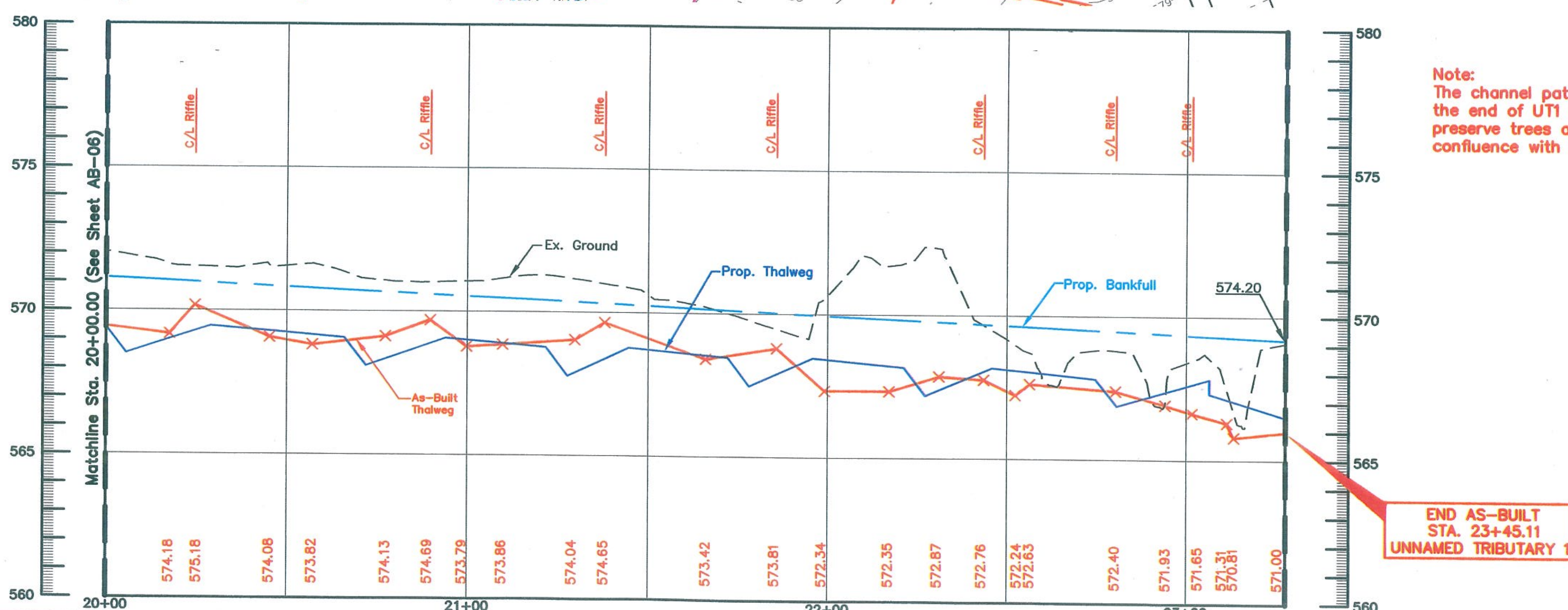
Ecosystem Enhancement PROGRAM

EMHT
Evans, Mechwart, Hambleton & Tilton, Inc.
Engineers • Surveyors • Planners • Scientists

REVISIONS

MARK	DATE	DESCRIPTION





Scale: 1" = 40'

LEGEND

- Vegetation Plot (VP)
- Crest Gauge
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- Proposed Riffle
- As-Built Riffle
- Proposed Cross Vane
- As-Built Cross Vane
- Fixed Photo Locations
- As-Built Fence

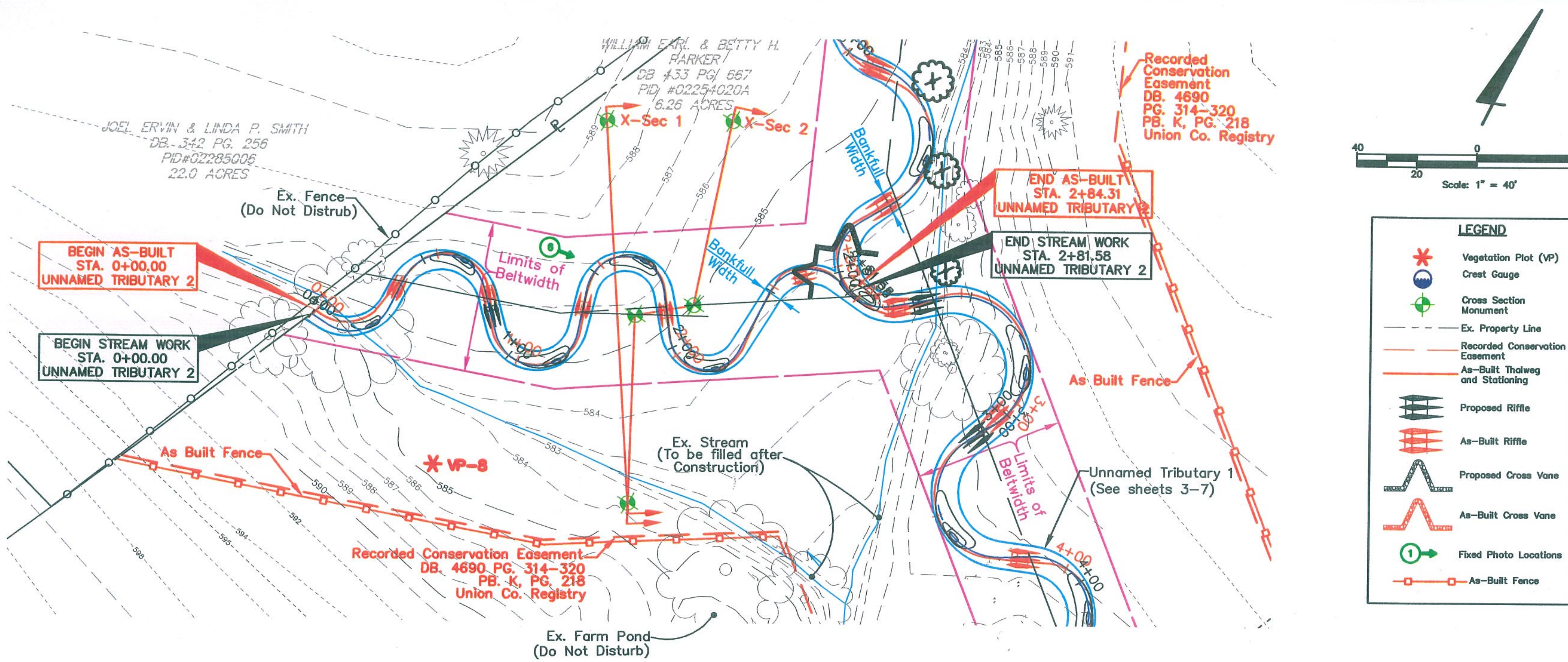
Note:
The channel pattern from Sta. 22+75 to the end of UT1 was adjusted to preserve trees and form a better confluence with Beaverdam Creek.

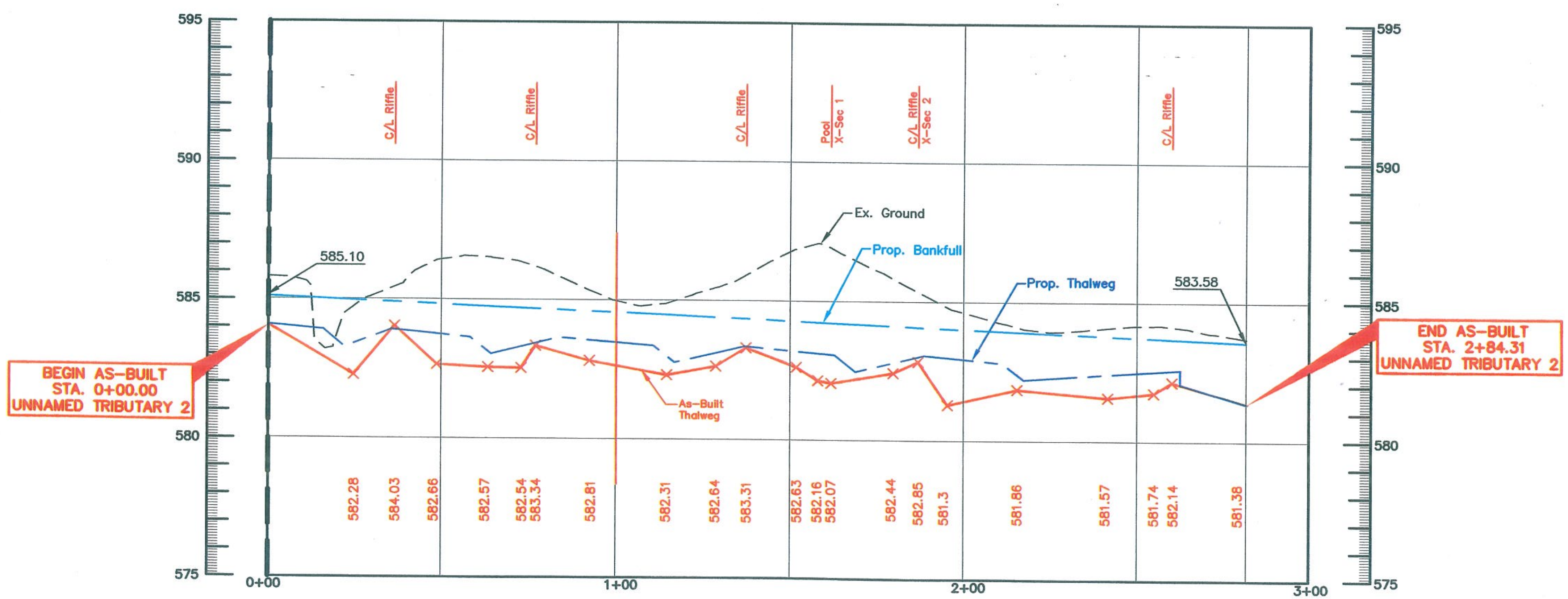
UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (UT1)

Date: January, 2008
Job No.: 2006-1399
Scale: Hor: 1" = 40', Ver: 1" = 5'
Sheet: AB-07/08

Ecosystem Enhancement Program

EMH&T — Evans, Mechwart, Hambleton & Tilton, Inc.





UNION COUNTY, NORTH CAROLINA
STREAM AS-BUILTS
FOR
BEAVERDAM CREEK AND UNNAMED TRIBUTARIES
NC EEP PROJECT NO. D06054-C
PLAN & PROFILE (UT2)

Ecosystem Enhancement PROGRAM

EMH&T
Evans, Mechwart, Hambleton & Tilton, Inc.

Job No.	Date	Scale	Sheet
2006-1399	January, 2008	Hor: 1" = 40' Ver: 1" = 5'	AB-08/08

REVISIONS

MARK	DATE	DESCRIPTION

LAST SAVED BY GTHOMAS [2/12/2009 1:26:16 PM] – PLOTTED BY GTHOMAS [2/12/2009 1:49:22 PM]

Appendix A

Beaverdam Creek Mainstem and Unnamed Tributaries

Fixed Station As-Built Photographic Documentation

Photograph 1
Fixed Station 1. Overview of Beaverdam Creek, looking downstream.

Photograph 2
Fixed Station 2. Overview of UT1, looking upstream near station 19+00.

Photograph 3
Fixed Station 3. Overview of valley along UT1, looking upstream near station 13+00.

Photograph 4
Fixed Station 4. Overview of valley along UT1, looking downstream near station 13+00.

Photograph 5
Fixed Station 5. Overview of UT1, looking downstream from upstream project limits.

Photograph 6
Fixed Station 6. Overview of UT2, looking downstream.

Photograph 7
Example Structure. Riffle at Station 0+32 on Beaverdam Creek, looking downstream.

Photograph 8
Example Structure. Riffle at Station 10+73 on UT1, looking upstream.

Vegetation Plot No. 1
5 m x 20 m. Beaverdam Creek Mainstem Station 0+75, looking downstream.

Vegetation Plot No. 2
10 m x 10 m. UT1 Station 15+50, looking downstream.

Vegetation Plot No. 3
10 m x 10 m. UT1 Station 11+50, looking downstream.

Vegetation Plot No. 4
10 m x 10 m. UT1 Station 10+00, looking downstream.

Vegetation Plot No. 5
10 m x 10 m. UT1 Station 6+50, looking downstream.

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Vegetation Plot No. 6
10 m x 10 m. UT1 Station 3+50, looking downstream.

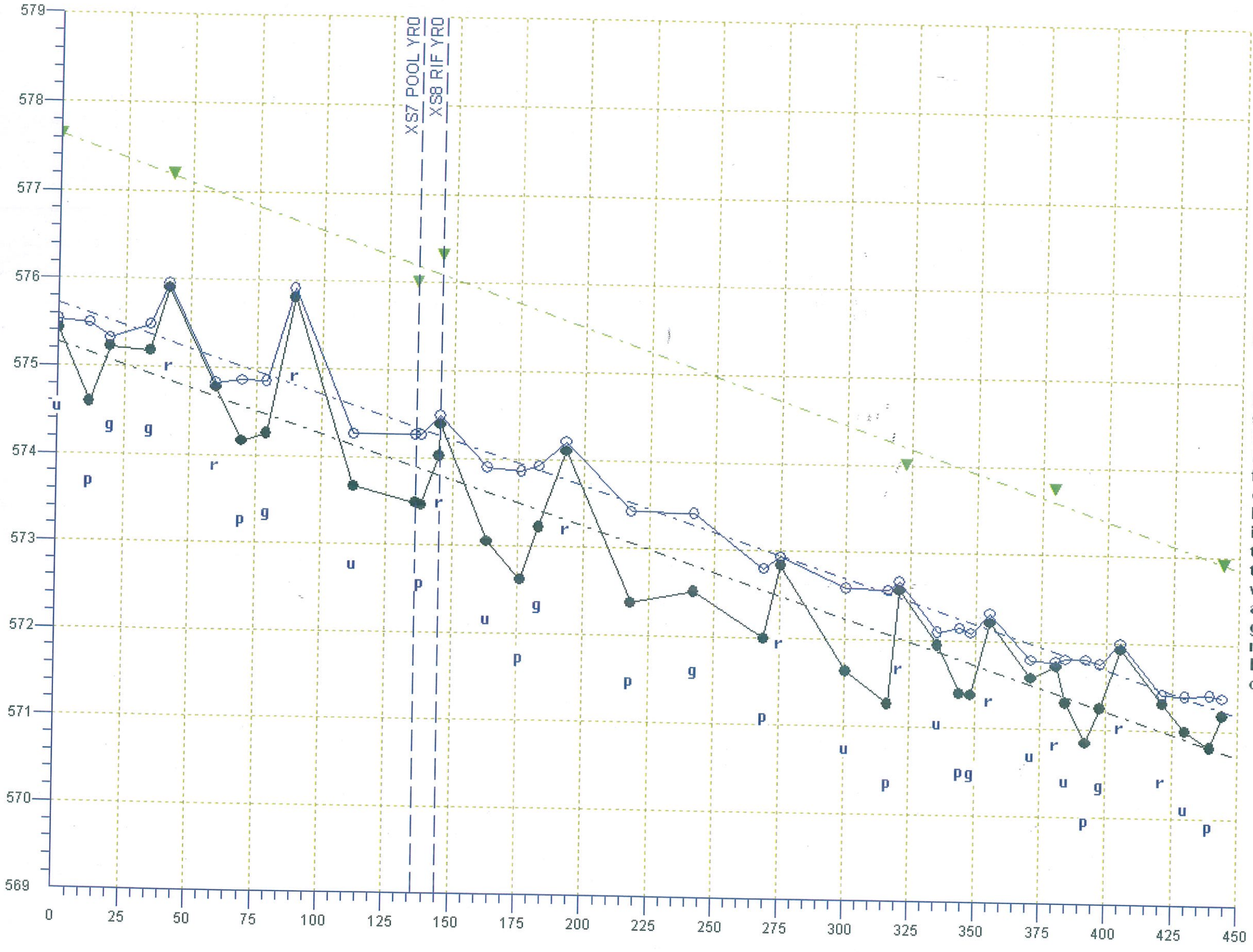
Vegetation Plot No. 7
10 m x 10 m. UT1 Station 1+50, looking downstream.

Vegetation Plot No. 8
10 m x 10 m. UT2 Station 0+50, looking downstream.

Appendix B

As-Built Long-Term Monitoring Profiles

Beaverdam Mainstem As-Built Profile -12/10/2008



LEGEND

- BKF
- WS
- CH

As-Built Best Fit Trendlines 12/10/08

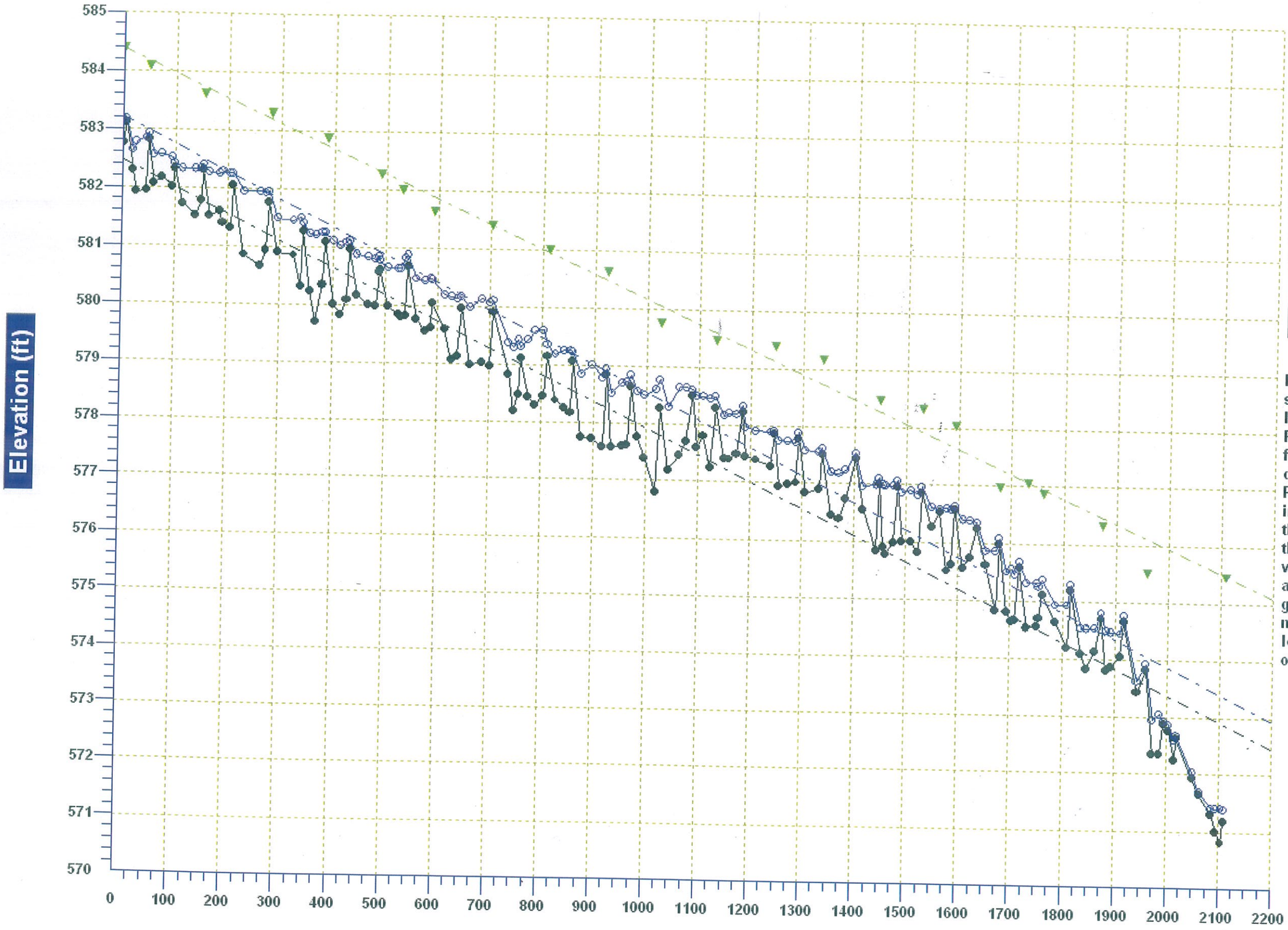
Sbkf = 0.0106 ft/ft

Sws = 0.0101 ft/ft

Sch = 0.0101 ft/ft

Note: As-Built profile stationing and stream lengths in RiverMorph differ from the As-Built CAD drawings in that RiverMorph interpolates from thaleg point to thalweg point without taking into account meander geometry (i.e. Lm - meander wave length and Rc - radii of curvature).

Beaverdam Creek - Unnamed Tributary 1 As-Built Profile - 12/10/2008



LEGEND

- BKF
- WS
- CH

As-Built Best Fit Trendlines 12/10/08

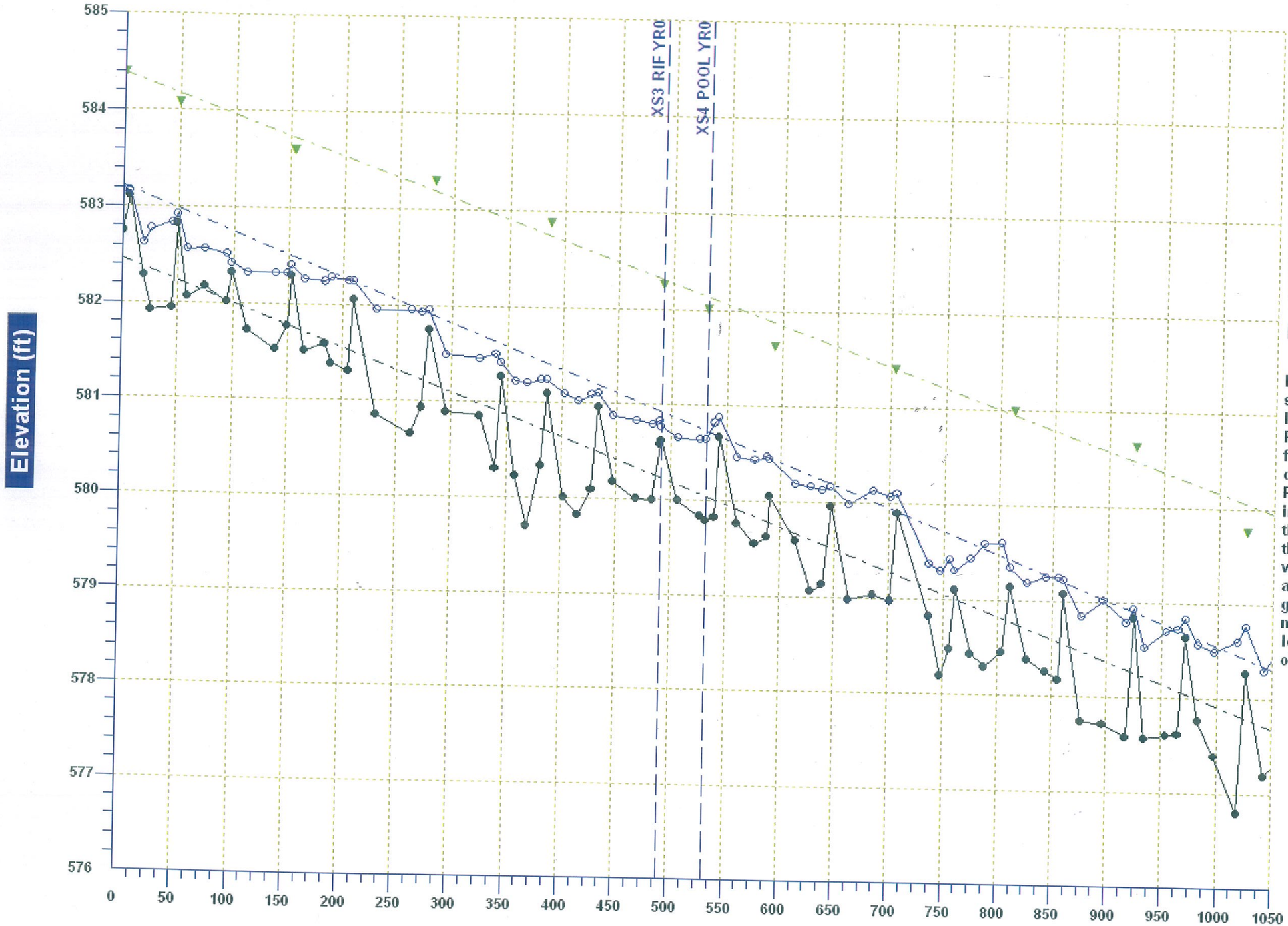
Sbkf = 0.0042 ft/ft

Sws = 0.0047 ft/ft

Sch = 0.0045 ft/ft

Note: As-Built profile stationing and stream lengths in RiverMorph differ from the As-Built CAD drawings in that RiverMorph interpolates from thaleg point to thalweg point without taking into account meander geometry (i.e. Lm - meander wave length and Rc - radii of curvature).

Beaverdam Creek - Unnamed Tributary 1 As-Built Profile - 12/10/2008



Station 0+00 to 10+50

LEGEND

- BKF
- WS
- CH

As-Built Best Fit Trendlines 12/10/08

Sbkf = 0.0042 ft/ft

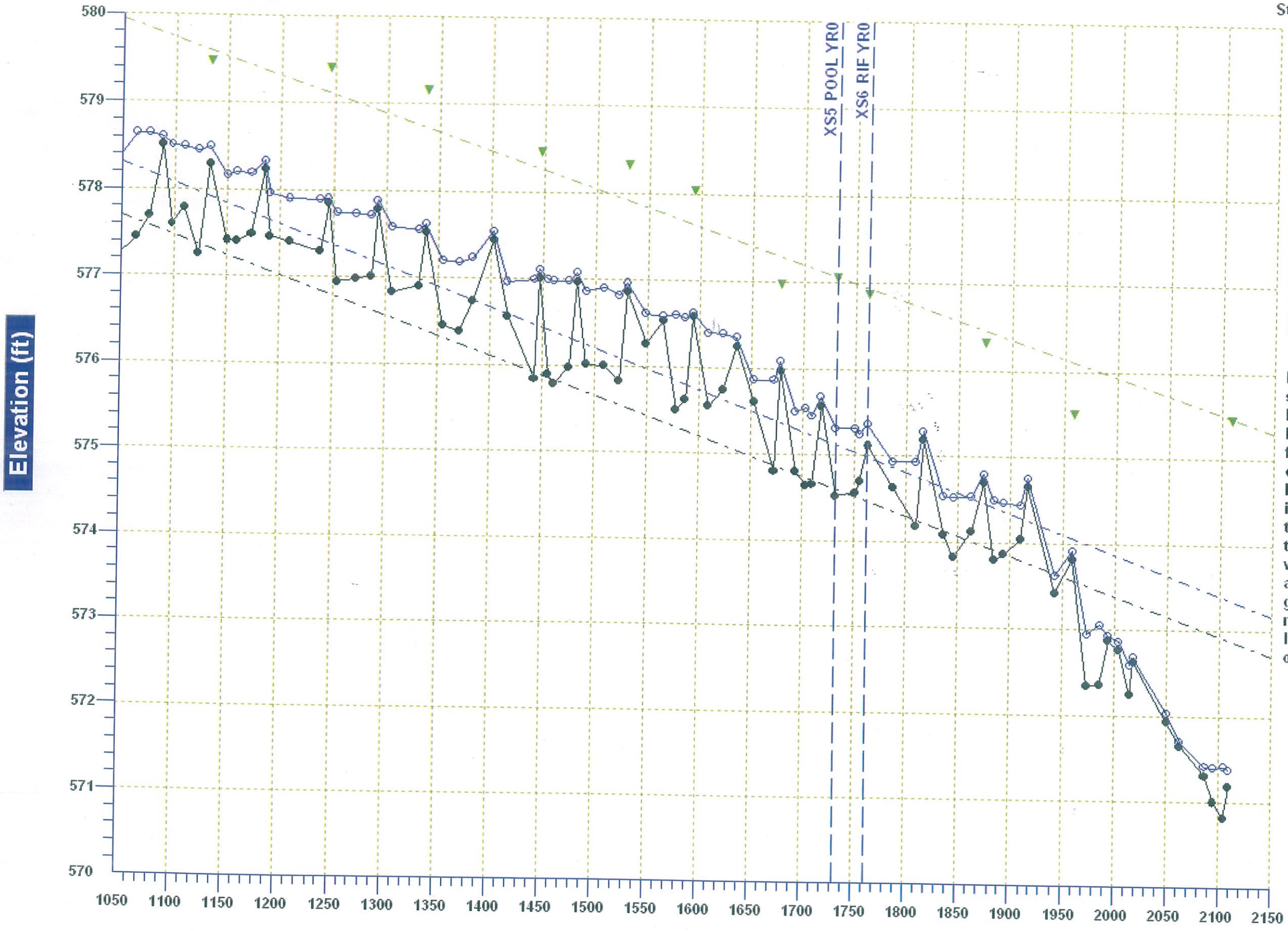
Sws = 0.0047 ft/ft

Sch = 0.0045 ft/ft

Note: As-Built profile stationing and stream lengths in RiverMorph differ from the As-Built CAD drawings in that RiverMorph interpolates from thaleg point to thalweg point without taking into account meander geometry (i.e. Lm - meander wave length and Rc - radii of curvature).

Beaverdam Creek - Unnamed Tributary 1 As-Built Profile - 12/10/2008

Station 10+50 to 21+09.74



Elevation (ft)

Distance along stream (ft)

LEGEND

- BKF
- WS
- CH

As-Built Best Fit Trendlines 12/10/08

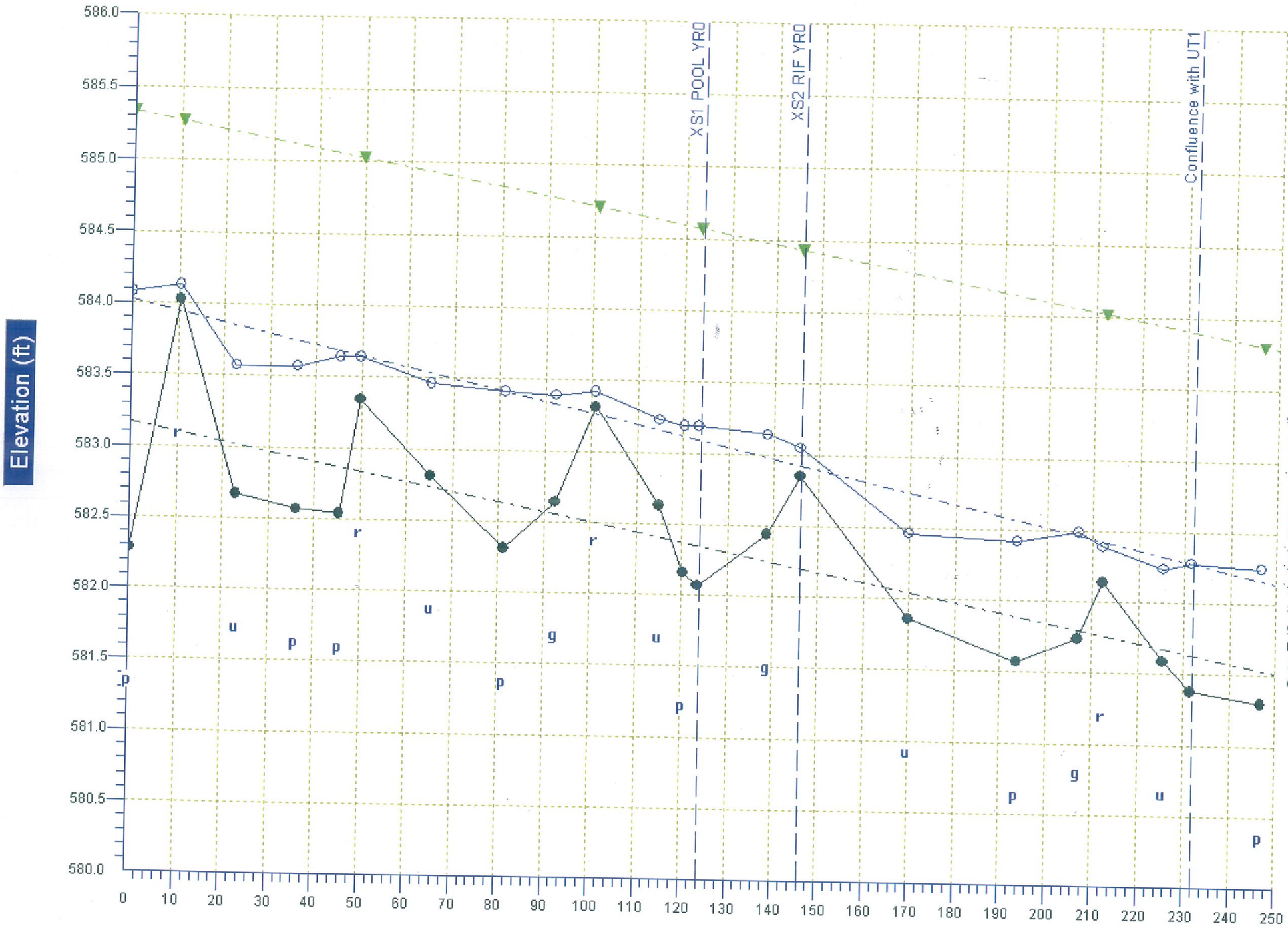
Sbkf = 0.0042 ft/ft

Sws = 0.0047 ft/ft

Sch = 0.0045 ft/ft

Note: As-Built profile stationing and stream lengths in RiverMorph differ from the As-Built CAD drawings in that RiverMorph interpolates from thaleg point to thalweg point without taking into account meander geometry (i.e. Lm - meander wave length and Rc - radii of curvature).

Beaverdam Creek - UT2 As-Built Profile - 12/10/2008



LEGEND

- BKF
- WS
- CH

As-Built Best Fit Trendlines 12/10/08

Sbkf = 0.00623 ft/ft

Sws = 0.00749 ft/ft

Sch = 0.00665 ft/ft

Note: As-Built profile stationing and stream lengths in RiverMorph differ from the As-Built CAD drawings in that RiverMorph interpolates from thaleg point to thalweg point without taking into account meander geometry (i.e. Lm - meander wave length and Rc - radii of curvature).

Appendix C

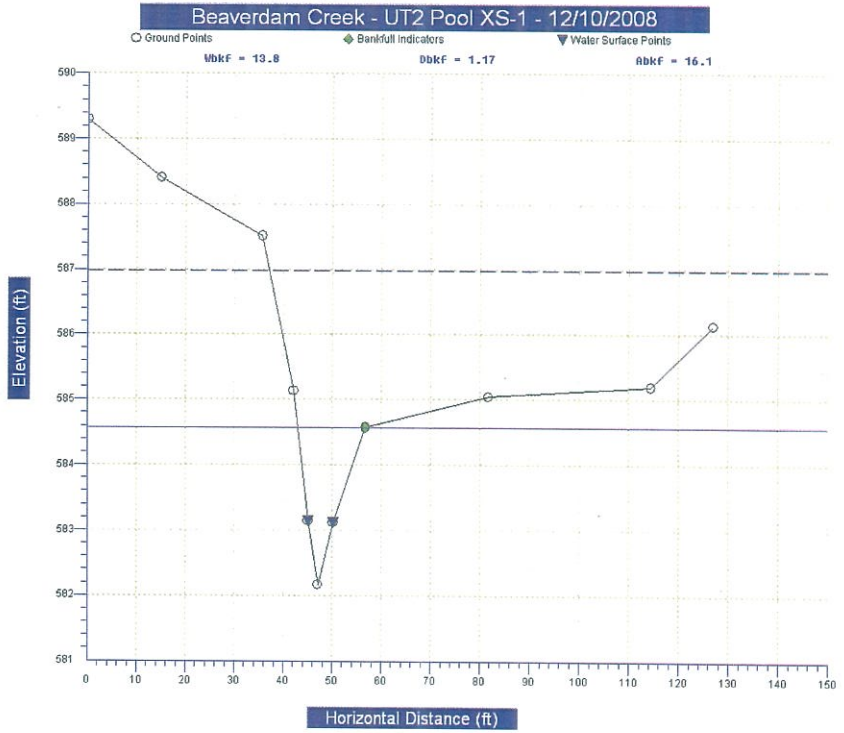
As-Built Long-Term Monitoring Cross-Section Summary Templates
and
Particle Distribution Summary Templates

Summary Data
All dimensions in feet.

Bankfull Area	16.15 ft^2
Bankfull Width	13.77 ft
Mean Depth	1.17 ft
Maximum Depth	2.41 ft
Width/Depth Ratio	11.77
Entrenchment Ratio	6.52
Classification	E4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT2
DATE	12/10/08
CROSS SECTION:	1
FEATURE:	Pool

Cross-section photo – looking upstream



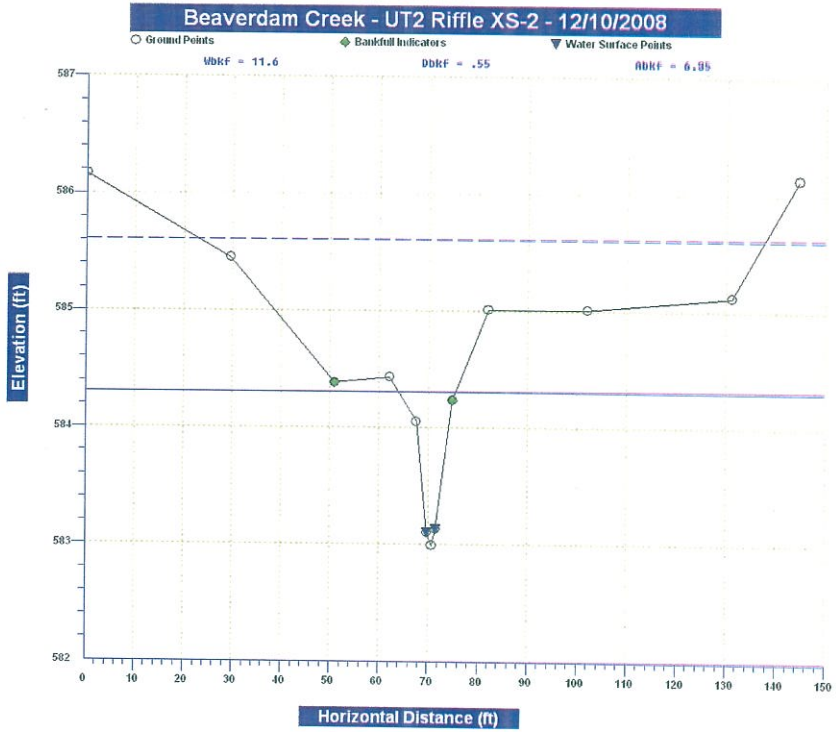
Summary Data
All dimensions in feet.

Bankfull Area	6.35 ft^2
Bankfull Width	11.55 ft
Mean Depth	0.55 ft
Maximum Depth	1.31 ft
Width/Depth Ratio	21
Entrenchment Ratio	9.94
Classification	C4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT2
DATE	12/10/08
CROSS SECTION:	2
FEATURE:	Riffle

Ecosystem Enhancement

Cross-section photo – looking upstream



EMH&T

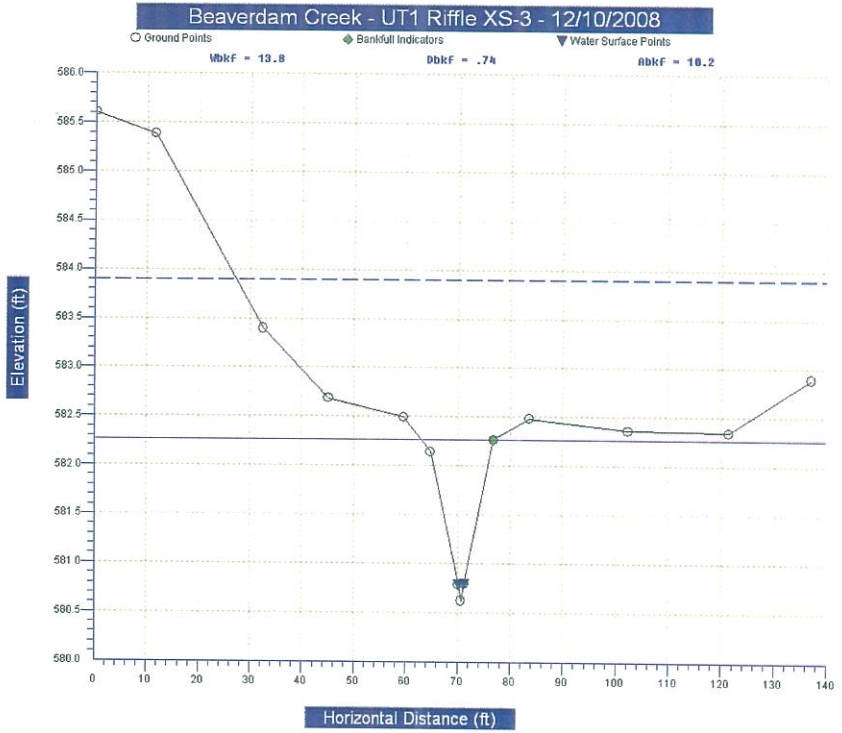
Summary Data
All dimensions in feet.

Bankfull Area	10.19 ft^2
Bankfull Width	13.8 ft
Mean Depth	0.74 ft
Maximum Depth	1.64 ft
Width/Depth Ratio	18.65
Entrenchment Ratio	7.97
Classification	C4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT1
DATE	12/10/08
CROSS SECTION:	3
FEATURE:	Riffle

Ecosystem Enhancement

Cross-section photo – looking upstream



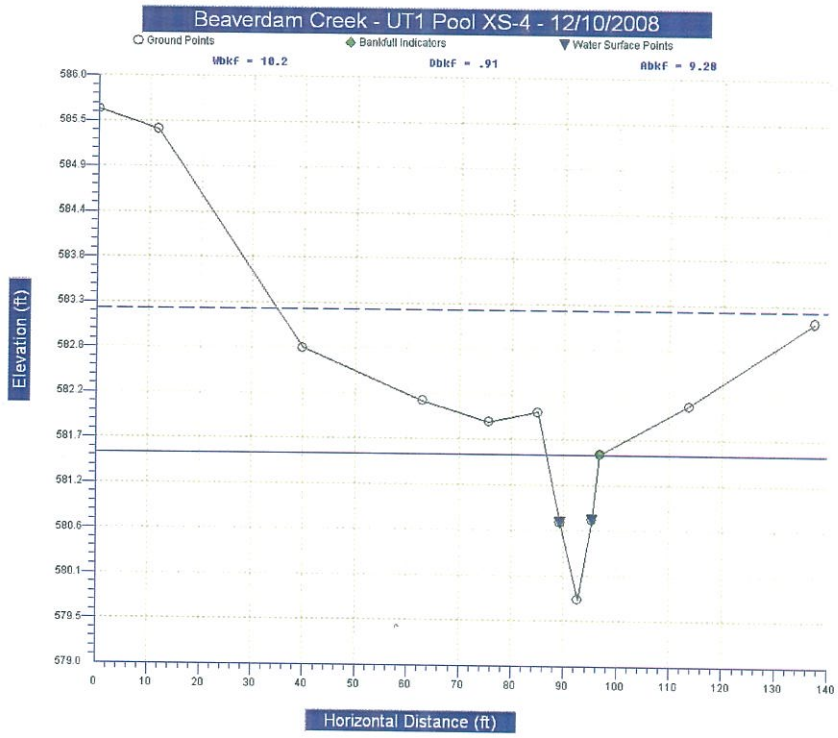
EMH&T

Summary Data
All dimensions in feet.

Bankfull Area	9.28 ft^2
Bankfull Width	10.22 ft
Mean Depth	0.91 ft
Maximum Depth	1.72 ft
Width/Depth Ratio	11.23
Entrenchment Ratio	10.05
Classification	E4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT1
DATE	12/10/08
CROSS SECTION:	4
FEATURE:	Pool

Cross-section photo – looking upstream

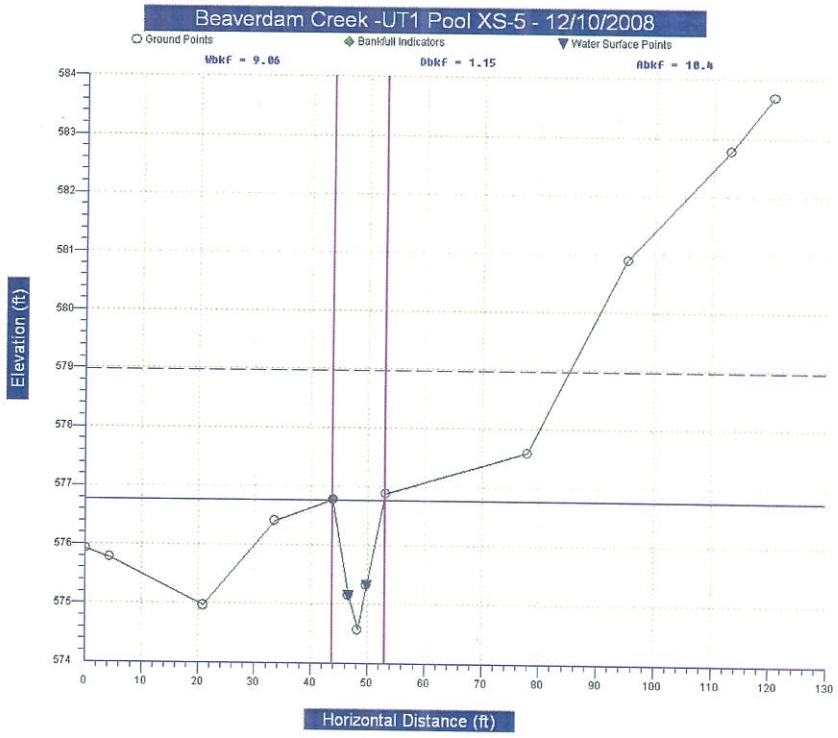


Summary Data
All dimensions in feet.

Bankfull Area	10.44 ft^2
Bankfull Width	9.06 ft
Mean Depth	1.15 ft
Maximum Depth	2.21 ft
Width/Depth Ratio	7.88
Entrenchment Ratio	9.41
Classification	E4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT1
DATE	12/10/08
CROSS SECTION:	5
FEATURE:	Pool

Cross-section photo – looking upstream

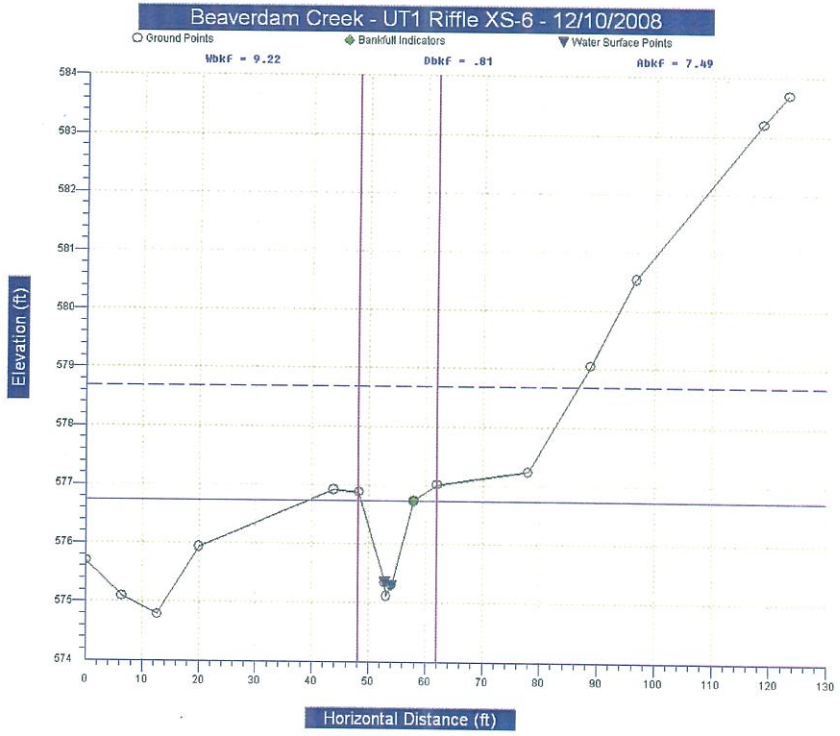


Summary Data
All dimensions in feet.

Bankfull Area	7.49 ft^2
Bankfull Width	9.22 ft
Mean Depth	0.81 ft
Maximum Depth	1.95 ft
Width/Depth Ratio	11.38
Entrenchment Ratio	9.39
Classification	E4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	UT1
DATE	12/10/08
CROSS SECTION:	6
FEATURE:	Riffle

Cross-section photo – looking upstream

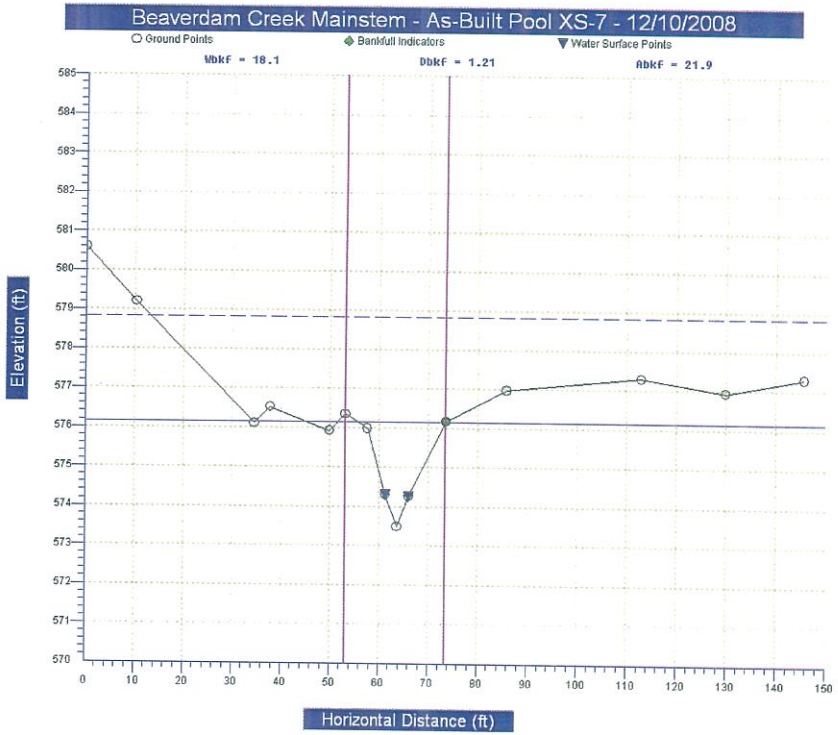


Summary Data
All dimensions in feet.

Bankfull Area	21.87 ft^2
Bankfull Width	18.08 ft
Mean Depth	1.21 ft
Maximum Depth	2.67 ft
Width/Depth Ratio	14.94
Entrenchment Ratio	7.32
Classification	C4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	12/10/08
CROSS SECTION:	7
FEATURE:	Pool

Cross-section photo – looking upstream



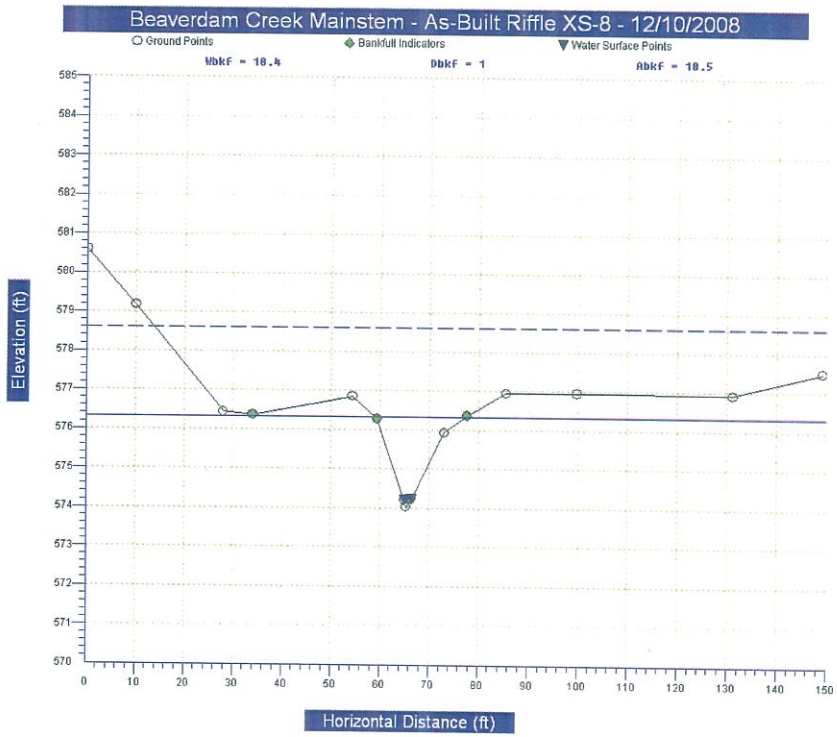
Summary Data
All dimensions in feet.

Bankfull Area	18.48 ft^2
Bankfull Width	18.43 ft
Mean Depth	1 ft
Maximum Depth	2.3 ft
Width/Depth Ratio	18.43
Entrenchment Ratio	7.36
Classification	C4/1

PROJECT	Beaverdam Creek
	D06054-C
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	12/10/08
CROSS SECTION:	8
FEATURE:	Riffle

Ecosystem Enhancement

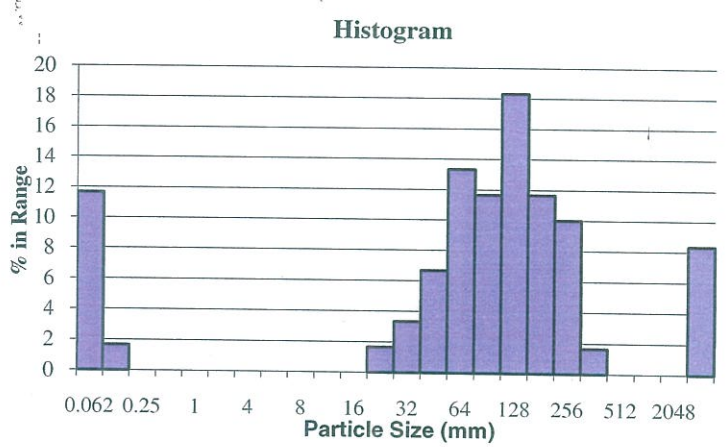
Cross-section photo – looking upstream

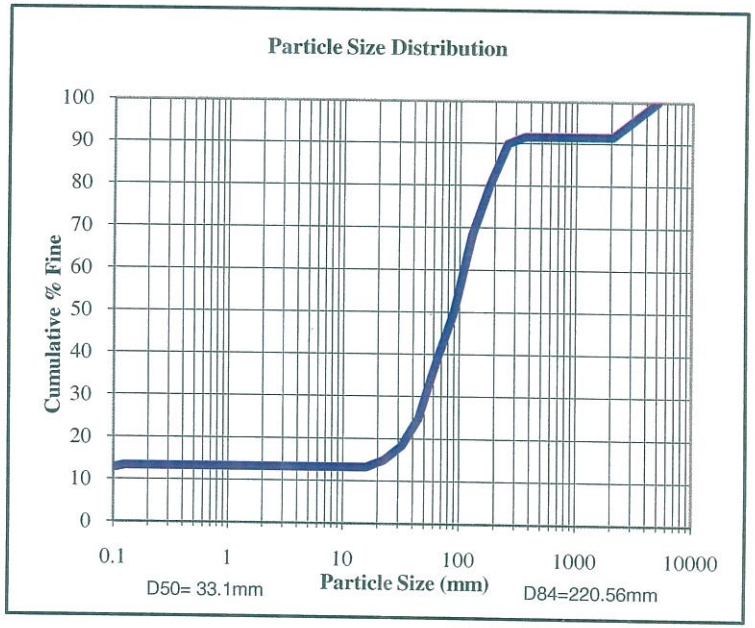


EMH&T

Pebble Count - Pool				
Material	Particle Size (mm)	Count	% in Range	% Cumulative
Silt/Clay	<0.062	7	12	12
Very Fine Sand	0.062-0.125	1	2	13
Fine Sand	0.125-0.25	0	0	13
Medium Sand	0.25-0.5	0	0	13
Coarse Sand	0.5-1.0	0	0	13
Very Coarse Sand	1.0-2.0	0	0	13
Very Fine Gravel	2.0-4.0	0	0	13
Fine Gravel	4.0-5.7	0	0	13
Fine Gravel	5.7-8.0	0	0	13
Medium Gravel	8.0-11.3	0	0	13
Medium Gravel	11.3-16.0	0	0	13
Coarse Gravel	16.0-22.6	1	2	15
Coarse Gravel	22.6-32	2	3	18
Very Coarse Gravel	32-45	4	7	25
Very Coarse Gravel	45-64	8	13	38
Small Cobble	64-90	7	12	50
Small Cobble	90-128	11	18	68
Large Cobble	128-180	7	12	80
Large Cobble	180-256	6	10	90
Small Boulder	256-362	1	2	92
Small Boulder	362-512	0	0	92
Medium Boulder	512-1024	0	0	92
Large Boulder	1024-2048	0	0	92
Bedrock	<2048	5	8	100
Totals		60	100	

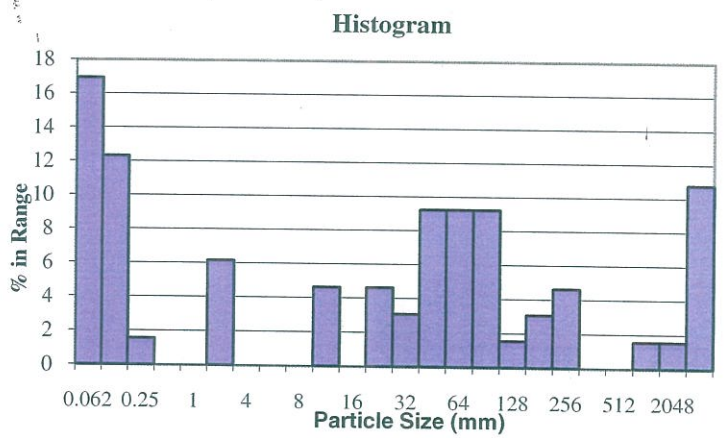
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT2	X Sec	1
Date	11/20/2008	Sta No.	1+23.57

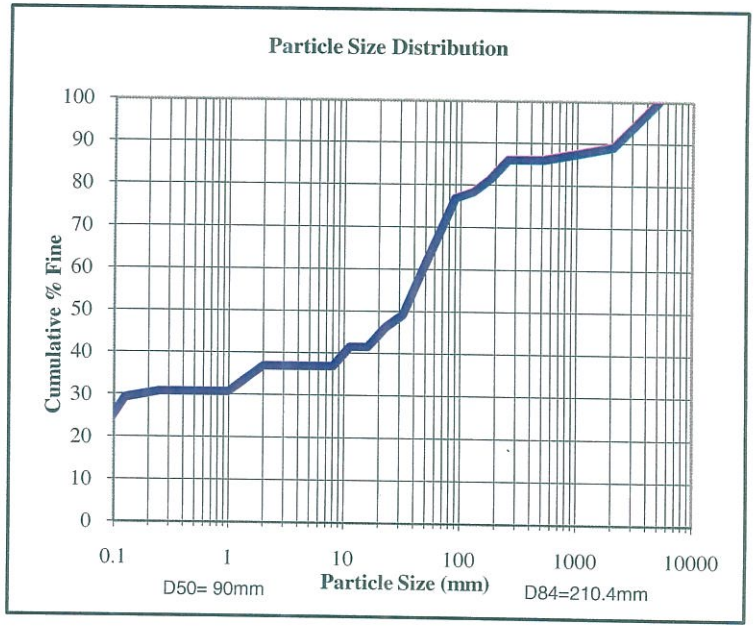




Pebble Count – Riffle				
Material	Particle Size (mm)	Count	% in Range	% Cumulative
Silt/Clay	<0.062	11	17	17
Very Fine Sand	0.062-0.125	8	12	29
Fine Sand	0.125-0.25	1	2	31
Medium Sand	0.25-0.5	0	0	31
Coarse Sand	0.5-1.0	0	0	31
Very Coarse Sand	1.0-2.0	4	6	37
Very Fine Gravel	2.0-4.0	0	0	37
Fine Gravel	4.0-5.7	0	0	37
Fine Gravel	5.7-8.0	0	0	37
Medium Gravel	8.0-11.3	3	5	42
Medium Gravel	11.3-16.0	0	0	42
Coarse Gravel	16.0-22.6	3	5	46
Coarse Gravel	22.6-32	2	3	49
Very Coarse Gravel	32-45	6	9	58
Very Coarse Gravel	45-64	6	9	68
Small Cobble	64-90	6	9	77
Small Cobble	90-128	1	2	78
Large Cobble	128-180	2	3	82
Large Cobble	180-256	3	5	86
Small Boulder	256-362	0	0	86
Small Boulder	362-512	0	0	86
Medium Boulder	512-1024	1	2	88
Large Boulder	1024-2048	1	2	89
Bedrock	<2048	7	11	100
Totals		65	100	

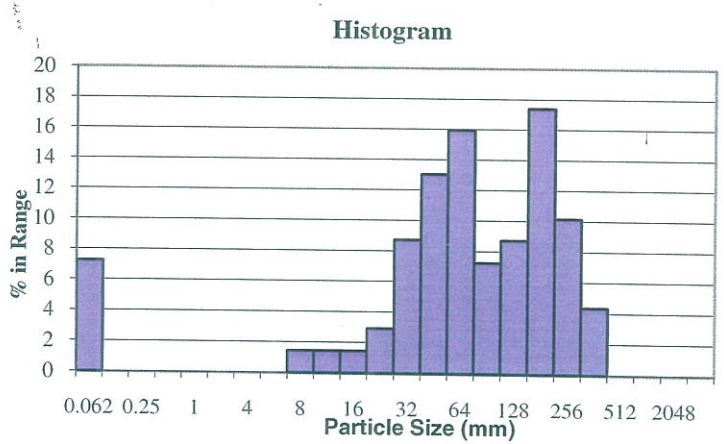
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT2	X Sec	2
Date	11/20/2008	Sta No.	1+46.40

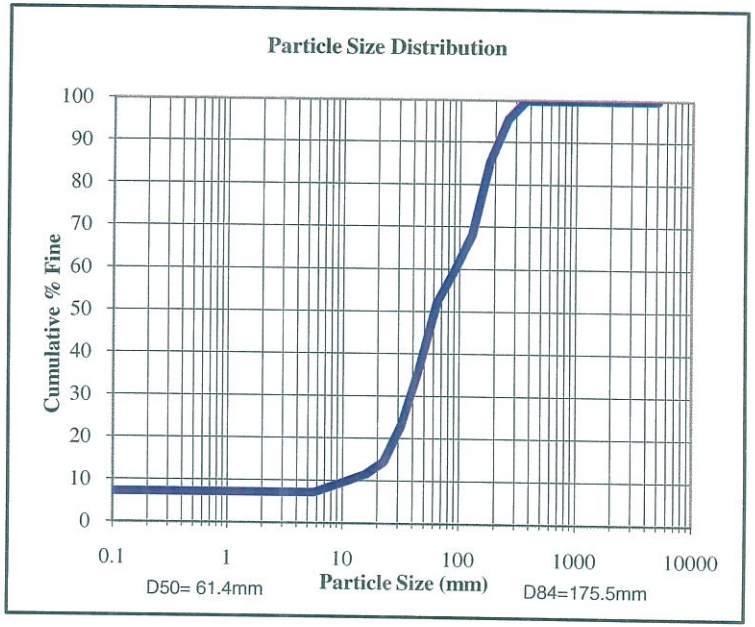




Pebble Count - Riffle				
Material	Particle Size (mm)	Count	% in Range	% Cumulative
Silt/Clay	<0.062	5	7	7
Very Fine Sand	0.062-0.125	0	0	7
Fine Sand	0.125-0.25	0	0	7
Medium Sand	0.25-0.5	0	0	7
Coarse Sand	0.5-1.0	0	0	7
Very Coarse Sand	1.0-2.0	0	0	7
Very Fine Gravel	2.0-4.0	0	0	7
Fine Gravel	4.0-5.7	0	0	7
Fine Gravel	5.7-8.0	1	1	9
Medium Gravel	8.0-11.3	1	1	10
Medium Gravel	11.3-16.0	1	1	12
Coarse Gravel	16.0-22.6	2	3	14
Coarse Gravel	22.6-32	6	9	23
Very Coarse Gravel	32-45	9	13	36
Very Coarse Gravel	45-64	11	16	52
Small Cobble	64-90	5	7	59
Small Cobble	90-128	6	9	68
Large Cobble	128-180	12	17	86
Large Cobble	180-256	7	10	96
Small Boulder	256-362	3	4	100
Small Boulder	362-512	0	0	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		69	100	

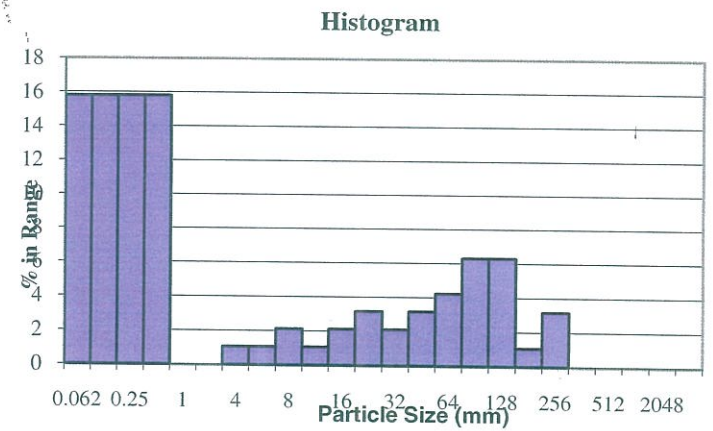
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT1	X Sec	3
Date	11/20/2008	Sta No.	4+90.86

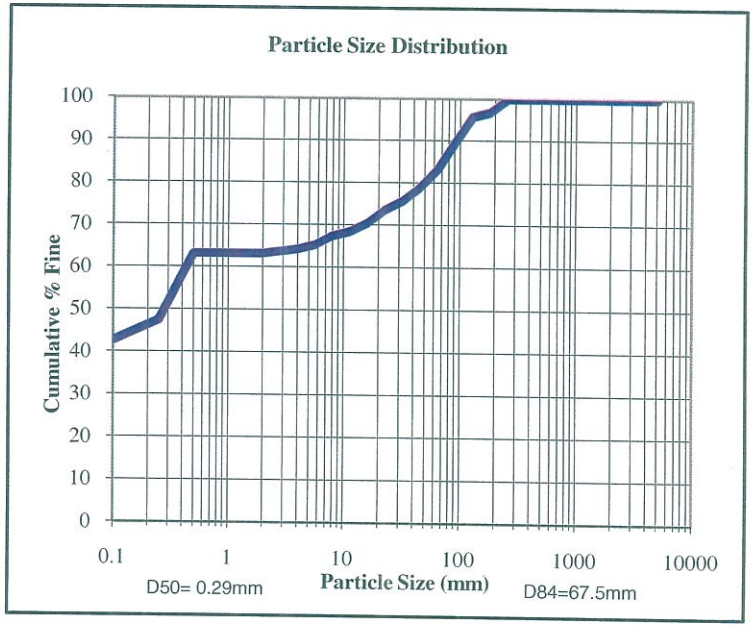




Pebble Count - Pool				
Material	Particle Size (mm)	Count	% in Range	% Cumulative
Silt/Clay	<0.062	15	16	16
Very Fine Sand	0.062-0.125	15	16	32
Fine Sand	0.125-0.25	15	16	47
Medium Sand	0.25-0.5	15	16	63
Coarse Sand	0.5-1.0	0	0	63
Very Coarse Sand	1.0-2.0	0	0	63
Very Fine Gravel	2.0-4.0	1	1	64
Fine Gravel	4.0-5.7	1	1	65
Fine Gravel	5.7-8.0	2	2	67
Medium Gravel	8.0-11.3	1	1	68
Medium Gravel	11.3-16.0	2	2	71
Coarse Gravel	16.0-22.6	3	3	74
Coarse Gravel	22.6-32	2	2	76
Very Coarse Gravel	32-45	3	3	79
Very Coarse Gravel	45-64	4	4	83
Small Cobble	64-90	6	6	89
Small Cobble	90-128	6	6	96
Large Cobble	128-180	1	1	97
Large Cobble	180-256	3	3	100
Small Boulder	256-362	0	0	100
Small Boulder	362-512	0	0	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		95	100	

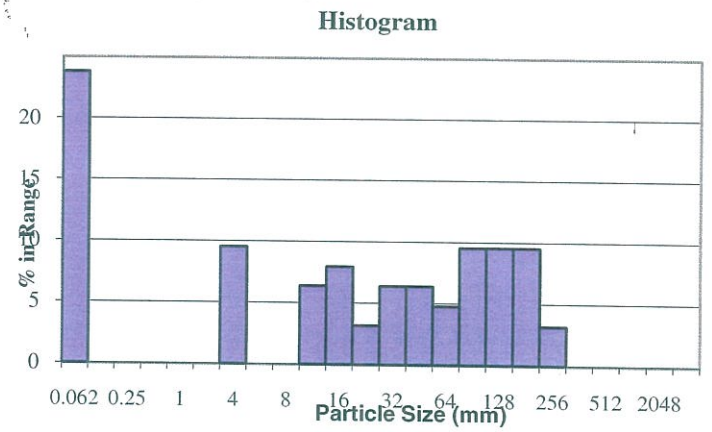
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT1	X Sec	4
Date	11/20/2008	Sta No.	5+31.80

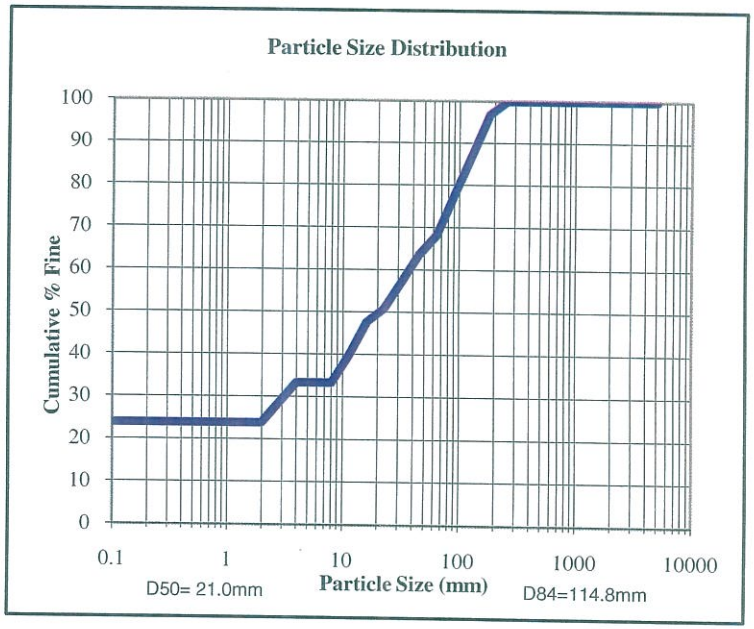




Pebble Count - Pool				
Material	**Particle Size (mm)**	**Count**	**% in Range**	**% Cumulative**
Silt/Clay	<0.062	15	24	24
Very Fine Sand	0.062-0.125	0	0	24
Fine Sand	0.125-0.25	0	0	24
Medium Sand	0.25-0.5	0	0	24
Coarse Sand	0.5-1.0	0	0	24
Very Coarse Sand	1.0-2.0	0	0	24
Very Fine Gravel	2.0-4.0	6	10	33
Fine Gravel	4.0-5.7	0	0	33
Fine Gravel	5.7-8.0	0	0	33
Medium Gravel	8.0-11.3	4	6	40
Medium Gravel	11.3-16.0	5	8	48
Coarse Gravel	16.0-22.6	2	3	51
Coarse Gravel	22.6-32	4	6	57
Very Coarse Gravel	32-45	4	6	63
Very Coarse Gravel	45-64	3	5	68
Small Cobble	64-90	6	10	78
Small Cobble	90-128	6	10	87
Large Cobble	128-180	6	10	97
Large Cobble	180-256	2	3	100
Small Boulder	256-362	0	0	100
Small Boulder	362-512	0	0	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		63	100	

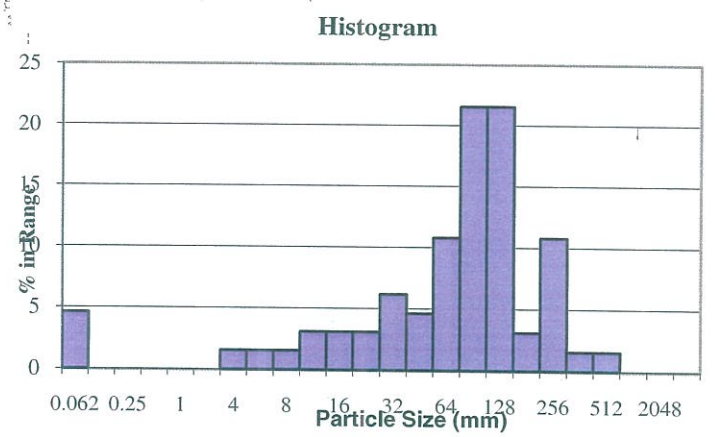
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT1	**X Sec**	5
Date	11/20/2008	**Sta No.**	17+31.58

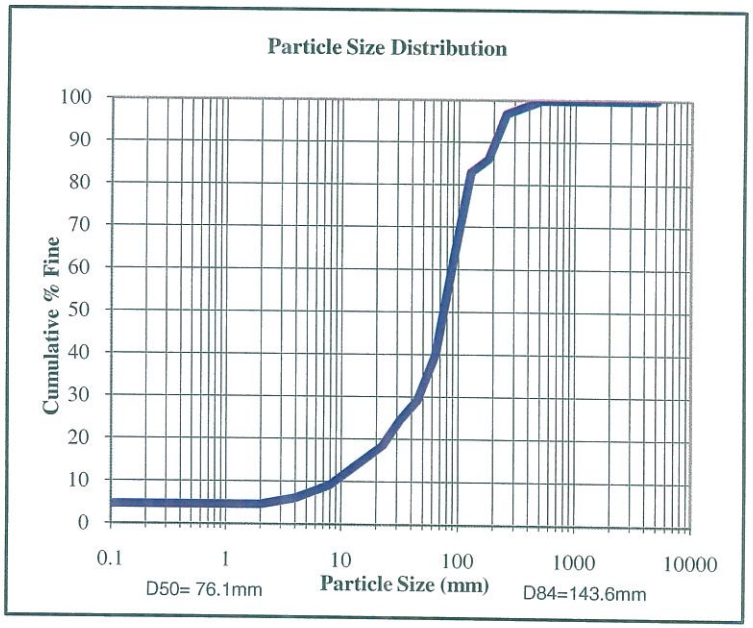




Pebble Count - Riffle				
Material	**Particle Size (mm)**	**Count**	**% in Range**	**% Cumulative**
Silt/Clay	<0.062	3	5	5
Very Fine Sand	0.062-0.125	0	0	5
Fine Sand	0.125-0.25	0	0	5
Medium Sand	0.25-0.5	0	0	5
Coarse Sand	0.5-1.0	0	0	5
Very Coarse Sand	1.0-2.0	0	0	5
Very Fine Gravel	2.0-4.0	1	2	6
Fine Gravel	4.0-5.7	1	2	8
Fine Gravel	5.7-8.0	1	2	9
Medium Gravel	8.0-11.3	2	3	12
Medium Gravel	11.3-16.0	2	3	15
Coarse Gravel	16.0-22.6	2	3	18
Coarse Gravel	22.6-32	4	6	25
Very Coarse Gravel	32-45	3	5	29
Very Coarse Gravel	45-64	7	11	40
Small Cobble	64-90	14	22	62
Small Cobble	90-128	14	22	83
Large Cobble	128-180	2	3	86
Large Cobble	180-256	7	11	97
Small Boulder	256-362	1	2	98
Small Boulder	362-512	1	2	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		65	100	

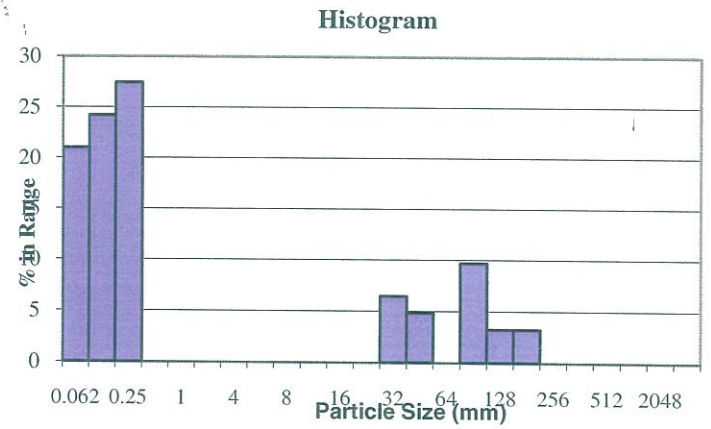
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	UT1	**X Sec**	6
Date	11/20/2008	**Sta No.**	17+62.09

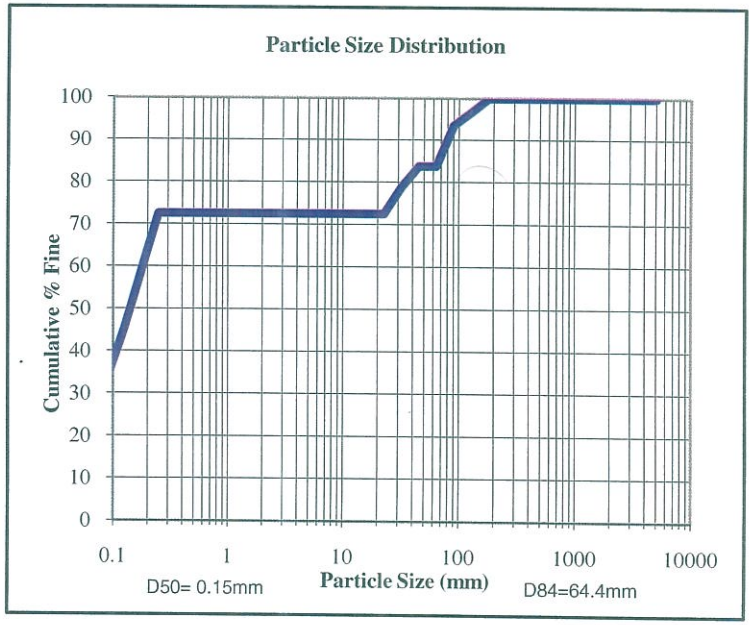




Pebble Count - Pool				
Material	**Particle Size (mm)**	**Count**	**% in Range**	**% Cumulative**
Silt/Clay	<0.062	13	21	21
Very Fine Sand	0.062-0.125	15	24	45
Fine Sand	0.125-0.25	17	27	73
Medium Sand	0.25-0.5	0	0	73
Coarse Sand	0.5-1.0	0	0	73
Very Coarse Sand	1.0-2.0	0	0	73
Very Fine Gravel	2.0-4.0	0	0	73
Fine Gravel	4.0-5.7	0	0	73
Fine Gravel	5.7-8.0	0	0	73
Medium Gravel	8.0-11.3	0	0	73
Medium Gravel	11.3-16.0	0	0	73
Coarse Gravel	16.0-22.6	0	0	73
Coarse Gravel	22.6-32	4	6	79
Very Coarse Gravel	32-45	3	5	84
Very Coarse Gravel	45-64	0	0	84
Small Cobble	64-90	6	10	94
Small Cobble	90-128	2	3	97
Large Cobble	128-180	2	3	100
Large Cobble	180-256	0	0	100
Small Boulder	256-362	0	0	100
Small Boulder	362-512	0	0	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		62	100	

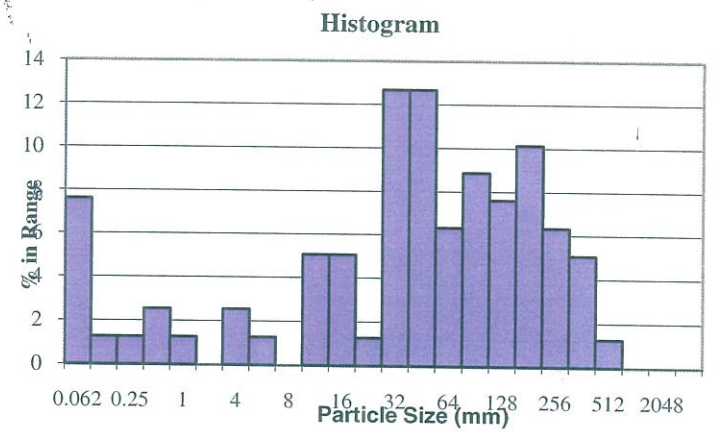
Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	Beaverdam Creek	**X Sec**	7
Date	11/20/2008	**Sta No.**	1+35.96

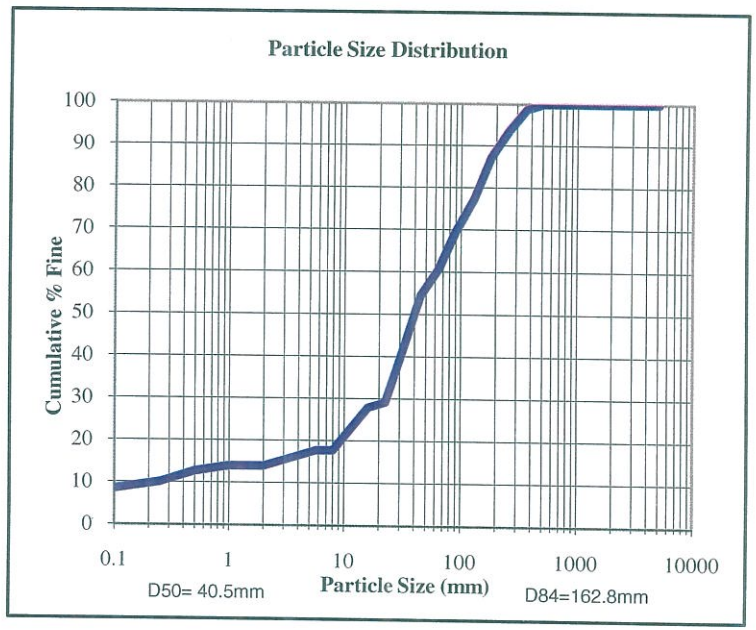




Pebble Count - Riffle				
Material	**Particle Size (mm)**	**Count**	**% in Range**	**% Cumulative**
Silt/Clay	<0.062	6	8	8
Very Fine Sand	0.062-0.125	1	1	9
Fine Sand	0.125-0.25	1	1	10
Medium Sand	0.25-0.5	2	3	13
Coarse Sand	0.5-1.0	1	1	14
Very Coarse Sand	1.0-2.0	0	0	14
Very Fine Gravel	2.0-4.0	2	3	16
Fine Gravel	4.0-5.7	1	1	18
Fine Gravel	5.7-8.0	0	0	18
Medium Gravel	8.0-11.3	4	5	23
Medium Gravel	11.3-16.0	4	5	28
Coarse Gravel	16.0-22.6	1	1	29
Coarse Gravel	22.6-32	10	13	42
Very Coarse Gravel	32-45	10	13	54
Very Coarse Gravel	45-64	5	6	61
Small Cobble	64-90	7	9	70
Small Cobble	90-128	6	8	77
Large Cobble	128-180	8	10	87
Large Cobble	180-256	5	6	94
Small Boulder	256-362	4	5	99
Small Boulder	362-512	1	1	100
Medium Boulder	512-1024	0	0	100
Large Boulder	1024-2048	0	0	100
Bedrock	<2048	0	0	100
Totals		79	100	

Beaverdam Creek Restoration EEP Project No. D06054-C			
Reach	Beaverdam Creek	**X Sec**	8
Date	11/20/2008	**Sta No.**	1+44.70





Appendix D

Supporting Documentation

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

Stream:	**Beaverdam Creek Mainstem Reach**		
Basin:	**Lower Yadkin - Pee Dee**	Drainage Area: **162.24** acres	**0.2535** mi^2
Location:	**South of Wingate, Union Co., NC (Parker Site)**		
Twp.&Rge:	**;**	Sec.&Qtr.: **;**	
Cross-Section Monuments (Lat./Long.):	**34.92778 Lat / 80.43639 Long**		Date: **12/10/2008**
Observers:	**MFH, WEK, JMH**		Valley Type: VIII

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**18.43**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**1.00**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**18.48**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**18.43**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.30**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**135.63**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**7.36**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**24.28**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0106**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.21**	

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

Worksheet 5-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen and Silvey, 2005).

Stream: **Beaverdam Creek Mainstem Reach** Location: **South of Wingate, Union Co., NC (Parker Site)**

Observers: **MFH, JMH, WEK** Date: **12/10/2008** Valley Type: **VIII** Stream Type: **C 4/1**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.00	ft	Riffle Width (W_{bkf})	18.43	ft	Riffle Area (A_{bkf})	18.48	ft^2
Mean Pool Depth (d_{bkfp})	1.21	ft	Pool Width (W_{bkfp})	18.08	ft	Pool Area (A_{bkfp})	21.87	ft^2
Mean Pool Depth/Mean Riffle Depth	1.21	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	0.98	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	1.18	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	1.50	ft	Max Pool Depth (d_{mbkfp})	2.77	ft	Max Riffle Depth/Mean Riffle Depth	1.50	
Max Pool Depth/Mean Riffle Depth	2.77					Point Bar Slope	0	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				1.89	ft/s	Estimation Method	V = Q/A	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				34.5	cfs	Drainage Area	0.2535	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	17.00	17.00	28.00	ft	Meander Length Ratio (Lm/W_{bkf})	0.92	0.92	1.52
Radius of Curvature (Rc)	72.68	59.01	93.85	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	3.94	3.20	5.09
Belt Width (W_{blt})	50.00	50.00	50.00	ft	Meander Width Ratio (W_{blt}/W_{bkf})	2.71	2.71	2.71
Individual Pool Length	28.68	16.87	39.62	ft	Pool Length/Riffle Width	1.56	0.92	2.15
Pool to Pool Spacing	47.57	29.82	58.36	ft	Pool to Pool Spacing/Riffle Width	2.58	1.62	3.17
Riffle Length	17.62	14.71	22.91	ft	Riffle Length/Riffle Width	0.96	0.80	1.24

Channel Profile

Valley Slope (VS)	0.0158	ft/ft	Average Water Surface Slope (S)	0.0106	ft/ft	Sinuosity (VS/S)	1.48	
Stream Length (SL)	475.49	ft	Valley Length (VL)	320.35	ft	Sinuosity (SL/VL)	1.48	
Low Bank Height (LBH)	start 0.88 / end 1.88	ft	Max Riffle Depth	start 0.88 / end 1.88	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start 1.00 / end 1.00	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0458	0.0319	0.0720	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	4.31	3.00	6.77
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)	0.0027	0.0005	0.0089	ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)	0.26	0.05	0.83
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Riffle Depth (d_{rif})	1.50	0.88	1.88	ft	Riffle Depth/Mean Riffle Depth (d_{rif} / d_{bkf})	1.50	0.88	1.88
Run Depth (d_{run})				ft	Run Depth/Mean Riffle Depth (d_{run} / d_{bkf})			
Pool Depth (d_p)	2.77	2.16	3.15	ft	Pool Depth/Mean Riffle Depth (d_p / d_{bkf})	2.77	2.16	3.15
Glide Depth (d_g)				ft	Glide Depth/Mean Riffle Depth (d_g / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	13.5	7.6		D_{16}	0.1	3.6		0	mm
% Sand	26.2	6.3		D_{35}	0.2	27.0		0	mm
% Gravel	31.2	46.8		D_{50}	24.3	40.5		0	mm
% Cobble	25.5	32.9		D_{84}	115.8	162.8		0	mm
% Boulder	3.6	6.3		D_{95}	224.9	283.9		0	mm
% Bedrock	0	0		D_{100}	512.0	512.0		0	mm

a Min, max, mean depths are the average mid-point values except pools, which are taken at deepest part of pool.
b Composite sample of riffles and pools within the designated reach.
c Active bed of a riffle.
d Height of roughness feature above bed.

RIVERMORPH BEHI SUMMARY REPORT

River Name: Beaverdam Creek
Reach Name: Beaverdam Mainstem

Table 1. Bank Identification Summary

Bank	Name
1	XS-7 Pool BEHI
2	XS-8 Riffle BEHI

Table 2. Predicted Annual Bank Erosion Rates

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
1	16.4	Low	Very Low	332.84	0.66	0.86
2	15.1	Low	Low	142.65	0.4	0.52
Totals				475.49	1.06	1.38

Total Reach Ln: 475.49 Total Loss (tons/yr) per ft of Reach: 0.0029

XS-7 Pool Vert Vel N-B Stress Method.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: Beaverdam Mainstem
BEHI Name: XS-7 Pool BEHI
Survey Date: 01/16/2009

Bankfull Height: 2.67 ft
Bank Height: 2.67 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 15.12 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 3.24 fps
Depth: 2.67 ft
Bankfull Slope: 0.01064
lb/sq/ft
NB Shear Stress: 0.51 lb/sq/ft

Velocity at Bed: 1.87 fps
Hydraulic Radius: 1.15 ft
Shear Stress: 0.76

Shear Ratio: 0.67

BEHI Numerical Rating: 16.4
BEHI Adjective Rating: Low
NBS Numerical Rating: 0.67
NBS Adjective Rating: Very Low
Total Bank Length: 332.84 ft
Estimated Sediment Loss: 0.66 Cu Yds per Year
Estimated Sediment Loss: 0.86 Tons per Year

XS-8 Riffle Vert Vel N-B Stress Method.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: Beaverdam Mainstem
BEHI Name: XS-8 Riffle BEHI
Survey Date: 01/17/2009

Bankfull Height: 2.3 ft
Bank Height: 2.3 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 10.74 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 3.24 fps
Depth: 2.3 ft
Bankfull Slope: 0.01064
lb/sq/ft
NB Shear Stress: 0.69 lb/sq/ft

Velocity at Bed: 1.87 fps
Hydraulic Radius: 0.97 ft
Shear Stress: 0.64

Shear Ratio: 1.07

BEHI Numerical Rating: 15.1
BEHI Adjective Rating: Low
NBS Numerical Rating: 1.07
NBS Adjective Rating: Low
Total Bank Length: 142.65 ft
Estimated Sediment Loss: 0.4 Cu Yds per Year
Estimated Sediment Loss: 0.52 Tons per Year

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

Stream:	**Beaverdam Creek, Reach - UT1 (Riffle XS-6)**			
Basin:	**Yadkin - Pee Dee**	Drainage Area: **151.74** acres	**0.2371**	mi^2
Location:	**South of Wingate, Union Co., NC (Parker Site)**			
Twp.&Rge:	**;**	Sec.&Qtr.: **;**		
Cross-Section Monuments (Lat./Long.):	**34.92778 Lat / 80.43639 Long**		Date:	**12/10/2008**
Observers:	**MFH, WEK, JMH**		Valley Type:	**VIII**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**9.22**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.81**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**7.49**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.38**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.95**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**86.55**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**9.39**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**36.1**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0042**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.49**	

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

Worksheet 5-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen and Silvey, 2005).

Stream: **Beaverdam Creek, Reach - UT1 (Riffle XS-6)** Location: **South of Wingate, Union Co., NC (Parker Site)**

Observers: **MFH, WEK, JMH** Date: **12/10/2008** Valley Type: **VIII** Stream Type: **E 4/1**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	0.81	ft	Riffle Width (W_{bkf})	9.22	ft	Riffle Area (A_{bkf})	7.49	ft^2
Mean Pool Depth (d_{bkfp})	1.03	ft	Pool Width (W_{bkfp})	9.64	ft	Pool Area (A_{bkfp})	9.86	ft^2
Mean Pool Depth/Mean Riffle Depth	1.27	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	1.05	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	1.32	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	1.46	ft	Max Pool Depth (d_{mbkfp})	2.51	ft	Max Riffle Depth/Mean Riffle Depth	1.80	
Max Pool Depth/Mean Riffle Depth	3.10					Point Bar Slope	N/A	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				4.3	ft/s	Estimation Method	V = Q/A	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				32.2	cfs	Drainage Area	0.2371	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	75.00	63.29	93.84	ft	Meander Length Ratio (Lm/W_{bkf})	8.13	6.86	10.18
Radius of Curvature (Rc)	20.00	17.00	25.00	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	2.17	1.84	2.71
Belt Width (W_{blt})	50.00	50.00	50.00	ft	Meander Width Ratio (W_{blt}/W_{bkf})	5.42	5.42	5.42
Individual Pool Length	36.89	22.96	57.82	ft	Pool Length/Riffle Width	4.00	2.49	6.27
Pool to Pool Spacing	50.30	18.07	79.78	ft	Pool to Pool Spacing/Riffle Width	5.46	1.96	8.65
Riffle Length	15.54	7.60	30.18	ft	Riffle Length/Riffle Width	1.69	0.82	3.27

Channel Profile

Valley Slope (VS)	0.0061	ft/ft	Average Water Surface Slope (S)	0.0042	ft/ft	Sinuosity (VS/S)	1.45	
Stream Length (SL)	2345.11	ft	Valley Length (VL)	1622.22	ft	Sinuosity (SL/VL)	1.45	
Low Bank Height (LBH) start	1.02	ft	Max Riffle Depth start	1.02	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	1.00	
Low Bank Height (LBH) end	1.84	ft	Max Riffle Depth end	1.84	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	1.00	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0247	0.0088	0.0702	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	5.84	2.08	16.58
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)			
Pool Slope (S_p)	0.0009	0.0000	0.0023	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.22	0.00	0.55
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Riffle Depth (d_{rif})	1.46	1.02	1.84	ft	Riffle Depth/Mean Riffle Depth (d_{rif}/d_{bkf})	1.80	1.26	2.27
Run Depth (d_{run})				ft	Run Depth/Mean Riffle Depth (d_{run}/d_{bkf})			
Pool Depth (d_p)	2.51	2.02	3.28	ft	Pool Depth/Mean Riffle Depth (d_p/d_{bkf})	3.10	2.49	4.05
Glide Depth (d_g)				ft	Glide Depth/Mean Riffle Depth (d_g/d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	13.01	4.62		D_{16}	0.1	17.33		0	mm
% Sand	15.41	0		D_{35}	10.14	55.18		0	mm
% Gravel	34.59	35.38		D_{50}	36.1	76.07		0	mm
% Cobble	35.28	56.92		D_{84}	125.95	143.58		0	mm
% Boulder	1.71	3.08		D_{95}	217.59	242.45		0	mm
% Bedrock	0	0		D_{100}	511.96	511.99		0	mm

a Min, max, mean depths are the average mid-point values except pools, which are taken at deepest part of pool.

b Composite sample of riffles and pools within the designated reach.

c Active bed of a riffle.

d Height of roughness feature above bed.

RIVERMORPH BEHI SUMMARY REPORT

River Name: Beaverdam Creek
Reach Name: UT1

Table 1. Bank Identification Summary

Bank	Name
1	XS3 Riffle BEHI
2	XS4 Pool BEHI
3	XS5 Pool BEHI
4	XS6 Riffle BEHI

Table 2. Predicted Annual Bank Erosion Rates

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
1	13.1	Low	Very Low	351.77	0.43	0.56
2	13.8	Low	Very Low	820.79	1.05	1.37
3	15.7	Low	Very Low	820.79	1.34	1.74
4	12.9	Low	Very Low	351.77	0.43	0.56
Totals				2345.12	3.25	4.23

Total Reach Ln: 2345.11 Total Loss (tons/yr) per ft of Reach: 0.0018

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT1
BEHI Name: XS3 Riffle BEHI
Survey Date: 01/17/2009

Bankfull Height: 1.64 ft
Bank Height: 1.64 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 15.12 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 13.1
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 351.77 ft
Estimated Sediment Loss: 0.43 Cu Yds per Year
Estimated Sediment Loss: 0.56 Tons per Year

XS4 Pool BEHI.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT1
BEHI Name: XS4 Pool BEHI
Survey Date: 01/17/2009

Bankfull Height: 1.72 ft
Bank Height: 1.72 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 22.86 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 13.8
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 820.79 ft
Estimated Sediment Loss: 1.05 Cu Yds per Year
Estimated Sediment Loss: 1.37 Tons per Year

XS5 Pool BEHI.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT1
BEHI Name: XS5 Pool BEHI
Survey Date: 01/17/2009

Bankfull Height: 2.21 ft
Bank Height: 2.21 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 26.51 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 15.7
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 820.79 ft
Estimated Sediment Loss: 1.34 Cu Yds per Year
Estimated Sediment Loss: 1.74 Tons per Year

XS6 Riffle BEHI.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT1
BEHI Name: XS6 Riffle BEHI
Survey Date: 01/17/2009

Bankfull Height: 1.95 ft
Bank Height: 1.65 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 22.11 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 12.9
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 351.77 ft
Estimated Sediment Loss: 0.43 Cu Yds per Year
Estimated Sediment Loss: 0.56 Tons per Year

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

Stream:	**Beaverdam Creek, Reach - UT2**				
Basin:	**Yadkin - Pee Dee**	Drainage Area:	**48.96** acres	**0.0765**	mi^2
Location:	**Beaverdam Creek (Parker Site)**				
Twp.&Rge:	**;**	Sec.&Qtr.:	**;**		
Cross-Section Monuments (Lat./Long.):	**34.92778 Lat / 80.43639 Long**			Date:	**12/10/08**
Observers:	**MFH, WEK, JMH**			Valley Type:	**VIII**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**11.55**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.55**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**6.35**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**21**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.31**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**114.79**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**9.94**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**57.89**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00623**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.45**	

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

Worksheet 5-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen and Silvey, 2005).

Stream: **Beaverdam Creek, Reach - UT2** Location: **South of Wingate, Union Co., NC (Parker Site)**

Observers: **MFH, JMH, WEK** Date: **12/10/2008** Valley Type: **VIII** Stream Type: **C 4/1**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	0.55	ft	Riffle Width (W_{bkf})	11.55	ft	Riffle Area (A_{bkf})	6.35	ft^2
Mean Pool Depth (d_{bkfp})	1.17	ft	Pool Width (W_{bkfp})	13.77	ft	Pool Area (A_{bkfp})	16.15	ft^2
Mean Pool Depth/Mean Riffle Depth	2.13	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	1.19	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	2.54	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	1.56	ft	Max Pool Depth (d_{mbkfp})	2.53	ft	Max Riffle Depth/Mean Riffle Depth	2.84	
Max Pool Depth/Mean Riffle Depth	4.60					Point Bar Slope	0	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				2.54	ft/s	Estimation Method	V = Q/A	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				10.4	cfs	Drainage Area	0.0765	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	58.92	58.08	59.76	ft	Meander Length Ratio (Lm/W_{bkf})	5.10	5.03	5.17
Radius of Curvature (Rc)	14.50	12.50	16.00	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	1.26	1.08	1.39
Belt Width (W_{blt})	50.00	50.00	50.00	ft	Meander Width Ratio (W_{blt}/W_{bkf})	4.33	4.33	4.33
Individual Pool Length	30.09	23.73	40.97	ft	Pool Length/Riffle Width	2.61	2.05	3.55
Pool to Pool Spacing	49.34	35.62	70.04	ft	Pool to Pool Spacing/Riffle Width	4.27	3.08	6.06
Riffle Length	15.74	12.41	23.86	ft	Riffle Length/Riffle Width	1.36	1.07	2.07

Channel Profile

Valley Slope (VS)	0.0093	ft/ft	Average Water Surface Slope (S)	0.0062	ft/ft	Sinuosity (VS/S)	1.49	
Stream Length (SL)	284.31	ft	Valley Length (VL)	190.71	ft	Sinuosity (SL/VL)	1.49	
Low Bank Height (LBH)	start 1.24 / end 1.87	ft	Max Riffle Depth	start 1.24 / end 1.87	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start 1.00 / end 1.00	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0213	0.0115	0.0451	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	3.42	1.84	7.25
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)			
Pool Slope (S_p)	0.0020	0.0007	0.0038	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.32	0.12	0.61
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Riffle Depth (d_{rif})	1.56	1.24	1.87	ft	Riffle Depth/Mean Riffle Depth (d_{rif}/d_{bkf})	2.84	2.25	3.40
Run Depth (d_{run})				ft	Run Depth/Mean Riffle Depth (d_{run}/d_{bkf})			
Pool Depth (d_p)	2.53	2.50	2.56	ft	Pool Depth/Mean Riffle Depth (d_p/d_{bkf})	4.60	4.55	4.65
Glide Depth (d_g)				ft	Glide Depth/Mean Riffle Depth (d_g/d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar
% Silt/Clay	14.4	11.7	
% Sand	11.2	1.7	
% Gravel	28.0	25.0	
% Cobble	34.4	51.7	
% Boulder	2.4	1.7	
% Bedrock	9.6	8.3	

	Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
D_{16}	0.1	25.4		0	mm
D_{35}	33.0	59.3		0	mm
D_{50}	57.9	90.0		0	mm
D_{84}	213.8	210.4		0	mm
D_{95}	2048	2048		0	mm
D_{100}	2048	2048		0	mm

a Min, max, mean depths are the average mid-point values except pools, which are taken at deepest part of pool.

b Composite sample of riffles and pools within the designated reach.

c Active bed of a riffle.

d Height of roughness feature above bed.

UT2 A-B Bank Erosion Rate Estimate.txt
RIVERMORPH BEHI SUMMARY REPORT

River Name: Beaverdam Creek
Reach Name: UT2

Table 1. Bank Identification Summary

Bank	Name
1	XS1 Pool BEHI
2	XS2 Riffle BEHI

Table 2. Predicted Annual Bank Erosion Rates

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
1	16.1	Low	Very Low	199.02	0.36	0.47
2	9.6	Very Low	Very Low	85.29	0	0
Totals				284.31	0.36	0.47

Total Reach Ln: 284.31 Total Loss (tons/yr) per ft of Reach: 0.0017

XS2 Riffle BEHI.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT2
BEHI Name: XS2 Riffle BEHI
Survey Date: 01/17/2009

Bankfull Height: 1.31 ft
Bank Height: 1.06 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 18.38 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 9.6
BEHI Adjective Rating: Very Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 85.29 ft
Estimated Sediment Loss: 0 Cu Yds per Year
Estimated Sediment Loss: 0 Tons per Year

XS1 Pool BEHI.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Beaverdam Creek
Reach Name: UT2
BEHI Name: XS1 Pool BEHI
Survey Date: 01/17/2009

Bankfull Height: 2.41 ft
Bank Height: 2.41 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 25 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Silt/Clay 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

BEHI Numerical Rating: 16.1
BEHI Adjective Rating: Low
NBS Numerical Rating:
NBS Adjective Rating: Very Low
Total Bank Length: 199.02 ft
Estimated Sediment Loss: 0.36 Cu Yds per Year
Estimated Sediment Loss: 0.47 Tons per Year

Beaverdam Creek & Tributaries

RiverMorph® Version 4.3.0

As-Built Monumented Cross-Section Summary Reports

December 10, 2008

XS1 Pool Yr0.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT2
Cross Section Name: XS1 POOL YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	589.29	MON.2
15.02	0	588.4	GND
35.67	0	587.51	LB
42.1	0	585.13	
45.05	0	583.14	LEW
47.15	0	582.16	TW 0.95 P
50.16	0	583.11	REW
56.7	0	584.57	BKF RB
81.69	0	585.04	GND
114.43	0	585.19	GND
126.86	0	586.13	MON.1

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	586.98	586.98	586.98
Bankfull Elevation (ft)	584.57	584.57	584.57
Floodprone Width (ft)	89.76	-----	-----
Bankfull Width (ft)	13.77	6.89	6.88
Entrenchment Ratio	6.52	-----	-----
Mean Depth (ft)	1.17	1.58	0.77
Maximum Depth (ft)	2.41	2.41	1.57
Width/Depth Ratio	11.77	4.36	8.94
Bankfull Area (sq ft)	16.15	10.86	5.29
Wetted Perimeter (ft)	14.73	9.24	8.62
Hydraulic Radius (ft)	1.1	1.17	0.61
Begin BKF Station	42.93	42.93	49.82
End BKF Station	56.7	49.82	56.7

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00665	0	0
Shear Stress (lb/sq ft)	0.46		
Movable Particle (mm)	85.4		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT2
Cross Section Name: XS2 RIF YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	586.16	MON.4
29.49	0	585.45	GND
50.87	0	584.38	BKF
62.12	0	584.43	MON. 3
67.58	0	584.05	LB
69.8	0	583.1	LEW
70.77	0	582.99	TW 0.10 R
71.56	0	583.13	REW
74.9	0	584.23	BKF
82.01	0	585.01	MON.2
101.99	0	585.01	GND
131.14	0	585.12	GND
144.52	0	586.13	MON.1

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	585.61	585.61	585.61
Bankfull Elevation (ft)	584.3	584.3	584.3
Floodprone Width (ft)	114.79	-----	-----
Bankfull Width (ft)	11.55	5.95	5.6
Entrenchment Ratio	9.94	-----	-----
Mean Depth (ft)	0.55	0.37	0.74
Maximum Depth (ft)	1.31	1.22	1.31
Width/Depth Ratio	21	16.08	7.57
Bankfull Area (sq ft)	6.35	2.23	4.12
Wetted Perimeter (ft)	11.95	7.37	7.01
Hydraulic Radius (ft)	0.53	0.3	0.59
Begin BKF Station	63.99	63.99	69.94

End BKF Station	75.54	69.94	75.54

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00665	0	0
Shear Stress (lb/sq ft)	0.22		
Movable Particle (mm)	49.9		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT1
Cross Section Name: XS3 RIF YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	585.6	MON.1
11.57	0	585.38	GND
32.39	0	583.39	GND
45.06	0	582.68	GND
59.52	0	582.49	MON.2
64.72	0	582.14	LB
70.2	0	580.78	LEW
70.67	0	580.62	TW 0.15 R
71.28	0	580.79	REW
76.74	0	582.26	BKF
83.54	0	582.48	MON.3
102.35	0	582.36	GND
121.52	0	582.34	FP
137.08	0	582.89	MON.4

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	583.9	583.9	583.9
Bankfull Elevation (ft)	582.26	582.26	582.26
Floodprone Width (ft)	110.03	-----	-----
Bankfull Width (ft)	13.8	6.9	6.9
Entrenchment Ratio	7.97	-----	-----
Mean Depth (ft)	0.74	0.58	0.9
Maximum Depth (ft)	1.64	1.39	1.64
Width/Depth Ratio	18.65	11.9	7.67
Bankfull Area (sq ft)	10.19	3.97	6.21
Wetted Perimeter (ft)	14.22	8.45	8.55
Hydraulic Radius (ft)	0.72	0.47	0.73

Begin BKF Station	62.94	62.94	69.84
End BKF Station	76.74	69.84	76.74

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00423	0	0
Shear Stress (lb/sq ft)	0.19		
Movable Particle (mm)	44.8		

XS4 Pool.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT1
Cross Section Name: XS4 POOL YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	585.6	MON.1
11.53	0	585.36	GND
39.72	0	582.76	GND
62.84	0	582.14	GND
75.56	0	581.89	FP
84.9	0	582.01	LB
89.26	0	580.71	LEW
92.72	0	579.79	TW 0.85 P
95.37	0	580.74	REW
96.8	0	581.51	BKF
113.67	0	582.09	GND
137.39	0	583.09	MON.2

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	583.23	583.23	583.23
Bankfull Elevation (ft)	581.51	581.51	581.51
Floodprone Width (ft)	102.77	-----	-----
Bankfull Width (ft)	10.22	10	0.22
Entrenchment Ratio	10.05	-----	-----
Mean Depth (ft)	0.91	0.93	0.06
Maximum Depth (ft)	1.72	1.72	0.12
Width/Depth Ratio	11.23	10.75	3.67
Bankfull Area (sq ft)	9.28	9.27	0.01
Wetted Perimeter (ft)	10.82	10.69	0.37
Hydraulic Radius (ft)	0.86	0.87	0.04
Begin BKF Station	86.58	86.58	96.58
End BKF Station	96.8	96.58	96.8

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00423	0	0
Shear Stress (lb/sq ft)	0.23		
Movable Particle (mm)	51.1		

XS5 Pool.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT1
Cross Section Name: XS5 POOL YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	575.92	MON.2
4.37	0	575.77	GND
20.96	0	574.96	GND
33.56	0	576.4	GND
43.84	0	576.77	BKF
46.61	0	575.15	LEW
48.27	0	574.56	TW0.75 P
49.78	0	575.32	REW
53.11	0	576.87	RB
77.94	0	577.58	GND
95.22	0	580.89	GND
113.05	0	582.77	GND
120.52	0	583.69	MON.1

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	578.98	578.98	578.98
Bankfull Elevation (ft)	576.77	576.77	576.77
Floodprone Width (ft)	85.25	-----	-----
Bankfull Width (ft)	9.06	4.53	4.53
Entrenchment Ratio	9.41	-----	-----
Mean Depth (ft)	1.15	1.25	1.06
Maximum Depth (ft)	2.21	2.21	2.16
Width/Depth Ratio	7.88	3.62	4.27
Bankfull Area (sq ft)	10.44	5.64	4.8
Wetted Perimeter (ft)	10.1	7.24	7.17
Hydraulic Radius (ft)	1.03	0.78	0.67
Begin BKF Station	43.84	43.84	48.37

End BKF Station	52.9	48.37	52.9

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00423	0	0
Shear Stress (lb/sq ft)	0.27		
Movable Particle (mm)	58.3		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: UT1
Cross Section Name: XS6 RIF YR0
Survey Date: 01/02/2009

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	575.68	MON.4
6.38	0	575.09	GND
12.67	0	574.78	GND
20.01	0	575.93	GND
43.76	0	576.91	MON.3
48.26	0	576.87	LB
52.88	0	575.34	LEW
53.1	0	575.11	TW0.25 R
54.07	0	575.29	REW
57.9	0	576.73	BKF RB
62.02	0	577	MON.2
77.93	0	577.23	GND
88.69	0	579.04	GND
96.59	0	580.53	GND
118.54	0	583.19	GND
122.97	0	583.69	MON.1

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	578.68	578.68	578.68
Bankfull Elevation (ft)	576.73	576.73	576.73
Floodprone Width (ft)	86.55	-----	-----
Bankfull Width (ft)	9.22	3.35	5.87
Entrenchment Ratio	9.39	-----	-----
Mean Depth (ft)	0.81	0.55	0.96
Maximum Depth (ft)	1.95	1.11	1.62
Width/Depth Ratio	11.38	6.09	6.11
Bankfull Area (sq ft)	7.49	1.86	5.63

Wetted Perimeter (ft)	9.82	4.63	7.4
Hydraulic Radius (ft)	0.76	0.4	0.76
Begin BKF Station	48.68	48.68	52.03
End BKF Station	57.9	52.03	57.9

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00423	0	0
Shear Stress (lb/sq ft)	0.20		
Movable Particle (mm)	46.6		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: Beaverdam Mainstem
Cross Section Name: XS7 POOL YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	580.59	MON.1
10.35	0	579.19	GRD
34.54	0	576.09	GRD
37.78	0	576.5	GRD
49.82	0	575.91	FP
53.14	0	576.34	GRD
57.65	0	575.97	LB
61.27	0	574.28	LEW
63.66	0	573.48	TW0.8 P
65.98	0	574.24	REW
73.54	0	576.15	BKF RB
85.79	0	576.96	GND
112.85	0	577.28	GND
129.91	0	576.92	GND
145.62	0	577.29	MON. 2

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	578.82	578.82	578.82
Bankfull Elevation (ft)	576.15	576.15	576.15
Floodprone Width (ft)	132.38	-----	-----
Bankfull Width (ft)	18.08	9.72	8.36
Entrenchment Ratio	7.32	-----	-----
Mean Depth (ft)	1.21	1.34	1.06
Maximum Depth (ft)	2.67	2.67	2.17
Width/Depth Ratio	14.94	7.25	7.89
Bankfull Area (sq ft)	21.87	13.01	8.85
Wetted Perimeter (ft)	18.96	12.49	10.81

Hydraulic Radius (ft)	1.15	1.04	0.82
Begin BKF Station	55.46	55.46	65.18
End BKF Station	73.54	65.18	73.54

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0106	0	0
Shear Stress (lb/sq ft)	0.76		
Movable Particle (mm)	124.3		

XS8 Riffle Yr 0.txt
RIVERMORPH CROSS SECTION SUMMARY

River Name: Beaverdam Creek
Reach Name: Beaverdam Mainstem
Cross Section Name: XS8 RIF YR0
Survey Date: 12/10/2008

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	580.59	MON.1
10	0	579.16	GND
27.99	0	576.43	GND
34.04	0	576.35	BKF
54.36	0	576.83	MON. 2
59.35	0	576.27	BKF
64.91	0	574.2	LEW
65.38	0	574.02	TW0.2 R
66.42	0	574.22	REW
73.02	0	575.92	RB
77.66	0	576.35	BKF
85.45	0	576.93	GND
99.8	0	576.94	GND
131.16	0	576.91	GND
149.19	0	577.49	MON.4

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	578.62	578.62	-----
Bankfull Elevation (ft)	576.32	576.32	-----
Floodprone Width (ft)	135.63	-----	-----
Bankfull Width (ft)	18.43	23.52	-----
Entrenchment Ratio	7.36	-----	-----
Mean Depth (ft)	1	1	-----
Maximum Depth (ft)	2.3	2.3	-----
Width/Depth Ratio	18.43	23.52	-----
Bankfull Area (sq ft)	18.48	18.48	-----
Wetted Perimeter (ft)	19.09	19.09	-----

Hydraulic Radius (ft)	0.97	0.97	-----
Begin BKF Station	58.9	58.9	-----
End BKF Station	77.34	77.34	-----

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0106	0	0
Shear Stress (lb/sq ft)	0.64		
Movable Particle (mm)	109.7		