Thompsons Fork and Unnamed Tributary Mitigation Plan (Lowdermilk Properties)

Nebo Township, McDowell County
North Carolina
NC EEP Project Number: D06030-A

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Ecosystem Enhancement PROGRAM

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EXECUTIVE SUMMARY

As discussed in the Restoration Plan for Thompsons Fork and the associated Unnamed Tributary (UT), the mitigation goals and objectives for the project streams are related to restoring stable physical and biological function of the project streams beyond pre-restoration (impaired) conditions. Pre-restoration conditions consisted of impaired, channelized, eroding, incised and entrenched stream channels. The specific mitigation goals for the project are listed below.

- Provide stable stream channels with features inherent of ecologically diverse environments, including appropriate stream-bed features, such as pools and riffles, and a riparian corridor with diverse and native vegetation. Utilize reference reach information as the foundation of the restoration design.
- Provide stream channels with the appropriate geometry and slope to convey bankfull flows while entraining bedload and suspended sediment readily available to the streams.
- Provide a connection between the bankfull channel and the floodprone area, and stable channel geometry and protective cover to prevent erosion.
- Provide a minimization of future land use impacts to the streams and a perpetual stream corridor protection via livestock exclusion fencing and restrictive conservation easement conveyances to the State of North Carolina.

Restoration of the streams has met the objective of the project along both the mainstem of Thompsons Fork and the UT, providing the desired habitat and stability features required to improve and enhance the ecologic health of the streams for the long-term. Specifically, the completed restoration project has accomplished the items listed below.

Thompsons Fork Mainstem:

- Reversed the effects of channelization through a combination of Priority I and Priority II restoration techniques. The restoration has changed the average width/depth ratio from 7.7 to 27.1.
- Restored a natural and stable sinuosity to the stream channel, increasing the sinuosity of the channel from 1.1 to 1.2, and providing a more stable relationship between the valley and bankfull slopes (the bankfull slope was higher than the valley slope in the pre-restoration condition and is now less than the valley slope with the completed restoration).
- Stabilized eroding streambanks by providing an appropriately sized channel with stable channel bank slopes with a combination of embedded stone, natural fabrics and hearty vegetation as protective cover. The average Bank Height Ratio has been changed from 2.36 to 1.0.
- Provided a re-connection between the restored stream channel and the adjacent floodprone area by both raising the stream bed and excavating the adjacent floodplain. The completed restoration changed the average entrenchment ratio from 1.53 to 3.0.
- Created instream aquatic habitat features such as deep pools supported by riffles, including rock cross vanes with deep pools to transition the channel thalweg from the restored reach to the downstream existing channel.
- Re-vegetated the riparian corridor with indigenous trees and shrubs and preservation of existing riparian corridors where possible.

Unnamed Tributary (UT):

- Reversed the effects of channelization through a combination of Priority I and Priority II restoration techniques, as well as Enhancement Level I activities and Preservation of a short reach at the upstream end of the project. The average width/depth ratio of the restored stream channel is 17.4. In the restoration reach, stable pattern, profile and

dimension were all restored to the stream channel. In the enhancement reach, a stable profile was provided and dimension of the stream channel was modified accordingly. The preservation reach is in a stable and heavily wooded corridor that will be protected by the conservation easement for the project.

- Restored a natural and stable sinuosity to the stream channel, increasing the sinuosity of the channel from 1.1 to more than 1.3, and providing a more stable relationship between the valley and bankfull slopes (the bankfull and valley slopes were nearly identical in the pre-restoration condition and is substantially less than the valley slope with the completed restoration).
- Stabilized eroding streambanks by providing an appropriately sized channel with stable channel bank slopes. The average Bank Height Ratio has been changed from 1.63 to 1.0.
- Provided a re-connection between the restored stream channel and the adjacent floodprone area by both raising the stream bed and excavating the adjacent floodplain. The completed restoration changed the average entrenchment ratio from 3.4 to 5.9.
- Created instream aquatic habitat features such as pools supported a combination of riffles and step-log structures.
- Re-vegetated the riparian corridor with indigenous trees and shrubs and preservation of existing riparian corridors where possible.

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 Thompsons Fork mainstem and the UT. 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 D06030-A (Thompsons Fork Restoration)					
Tributary Reach ID	Pre-existing length	Restored Length*	Restoration Level	Credit Ratio	SMUs**
Mainstem Priority Level I Restoration	2,530 lf	2,727 ft	Priority Level I Restoration	1.0	2,727
UT Preservation	356 lf	356 ft	Preservation	5.0	71
UT Enhancement Level I	400 lf	390 ft	Enhancement Level I	1.5	260
UT Priority Level I Restoration	1,598 lf	1,948 ft	Priority Level I Restoration	1.0	1,948
Totals	**4,884 ft**	**5,421 ft**			**5,006**

*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 3,000 linear feet of longitudinal profiles (1,750 lf on the mainstem and 1,250 lf on the UT restoration reach), collection and analysis of particle distributions at each of the twelve monumented cross-sections. Eight vegetation monitoring plots with shrub, mid-story and canopy plantings representative of outside meanders, the 30-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 on the project reaches; one near the bottom of the restored Thompsons Fork mainstem reach, and the other near the bottom of the UT restored reach 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 Restoration and Enhancement Level I 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 Thompsons Fork mitigation project.

1.0 PROJECT BACKGROUND

1.1 Project Site Location and Details

The project is located near the intersection of Watson Road and South Creek Road on the north side of Interstate 40, approximately 7 miles east of the City of Marion, in Nebo Township, McDowell County, North Carolina as shown on **Figures 1 and 2**. To travel to the site, exit I-40 at Exit 94 and travel north on Dysartsville Road for 0.6 mile. Turn left and travel west onto US-70 for 3.2 miles then turn left onto Watson Road. Travel 1.1 miles south on Watson Road to the intersection of South Creek Road. Zeb Lowdermilk's residence (1394 South Creek Road, Nebo, NC 28761) is located on the right (south) side of South Creek Road at the intersection of Watson Road. The project spans four tracts of land – (Tract 1) owned by Zeb B. Lowdermilk and wife Francis M. Lowdermilk (deceased), Francis McNeely Lowdermilk (Life Estate), Susan Delene Lowdermilk, Don Lance Lowdermilk, and Dane Scott Lowdermilk (Tract 2) and Zeb B. Lowdermilk and daughter Susan Lowdermilk Walker Icard (Tracts 3 and 4).

The Thompsons Fork watershed is located within the Upper Catawba River Basin. The project stream reaches are mapped on North Carolina Department of Transportation Light Detection and Ranging (LiDAR) coverage and are located within USGS Catalog Unit Number 03050101 (Upper Catawba River Basin) and Local Targeted Watershed 14-digit basin 03050101040010 (North Muddy Creek), as shown on **Figure 3**. The lower extent of the Thompsons Fork restoration project is located in a wide, Rosgen Valley Type VIII, approximately 800 feet upstream from the confluence of Thompsons Fork with North Muddy Creek.

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

Metamorphic rocks that outcrop within the Thompsons Fork watershed include biotite gneiss and schist, mica schist, amphibolite, megacrystic biotite gneiss, and inequigranular biotite gneiss. The intrusive igneous rock formation that underlies portions of the stream restoration project along the Thompsons Fork mainstem and the UT includes the Henderson Gneiss (monzonitic to granodicritic, inequigranular, granitic to quartz dioritic, biotite gneiss and amphibolite common) radioactive dated to approximately 524 my. Exposed rock is equigranular to megacrystic, foliated to massive and includes the Toluca Granite (Fullager and Odom, 1973).

The soils along the Thompsons Fork mainstem and its associated UT are derived from and developed over the metamorphic and intrusive igneous rock formations include the Colvard Series. The Colvard Series consists of very deep, well drained soils that have formed on floodplains in the southern Appalachian Mountains. The mean annual temperature ranges from 46 to 57 degrees Fahrenheit. The mean annual precipitation ranges from 38 to 65 inches. Slopes range from 0 to 4 percent. The pedon contains loamy sediments ranging from 40 to 60 inches or more in thickness over deposits of stratified sandy, loamy gravelly to cobbly sediments. Rock fragments range from 0 to 15 percent to a depth of 40 inches, and from 0 to 80 percent below 40 inches. The soil ranges from strongly acid to mildly alkaline. Flakes of mica range from few to common (USDA NRCS, January 3, 2006). Soils taxonomic descriptions are from the NRCS Soil Survey of McDowell County, North Carolina (USDA NRCS, September 1995).

The drainage area tributary to the downstream limits of the project on Thompsons Fork mainstem is 7.57 square miles or 4,847 acres. The associated UT has a contribution drainage area of 0.16 square miles or 104 acres. These watershed areas are shown on **Figure 3**. Drainage areas for the project site are summarized in **Table 1**.

TABLE 1
Drainage Areas
Project Number D06030-A (Thompsons Fork and UT)

Reach	Drainage Area (Acres)
Thompsons Fork Mainstem (downstream project limits)	4847 (7.57 sq mi)
UT to Thompsons Fork*	104 (0.16 sq mi)
Total	4847 (7.57 sq mi)

*The UT drainage area is included in the total drainage area for the Thompsons Fork Mainstem (See **Figure 3**).

1.2 Pre-Restoration Existing Conditions

Within the project watershed boundaries, land use is predominantly agricultural, including row crop production and pasture/hayland with wooded and cleared hillsides. Pre-restoration land use surrounding the Thompsons Fork restoration reach was active cattle pasture land. The pre-existing riparian corridor was absent to extremely narrow (5 to 10 feet wide) along the Thompsons Fork mainstem, widening for only a short distance near the downstream limits of the mainstem project reach. Streambanks were denuded and extremely unstable, with vertical to undercut banks up to 15 feet in height from the former farm stream crossing to the bottom of the mainstem reach.

A hayland meadow is present along the UT right bank. Annual mowing to the top of bank for hay production precluded riparian plant communities growth along the UT right bank Along the UT left bank the riparian corridor consists of mature hardwood forested hill slope. Along the 356 lf UT preservation reach, beginning at the granite outcrop spring from which the perennial UT emerges, the stream exists in a mature mixed hardwood and evergreen forest with diversified herbaceous, shrub, mid-story and canopy species present. Typical species observed along the streams and adjacent forested areas include *Alnus rugosa* (tag alder), *Platanus occidentalis* (Eastern sycamore), *Abies* species (fir), *Pinus taeda* (loblolly pine), *Pinus elliottii* (slash pine), *Ostrya virginiana* (Eastern hophornbeam), *Diospyros virginiana* (persimmon), *Kalmia latifolia* (mountain laurel), *Cornus amomum* (silky dogwood), *Ilex opaca* (American holly), and the invasive species *Ligustrum sinense* (Chinese privet) and *Lonicera japonica* (Japanese honeysuckle). Specific information regarding the pre-restoration condition of Thompsons Fork and the UT is given in the following sections.

Thompsons Fork Mainstem

Prior to restoration, a combination of historical and recent anthropogenic factors and practices impacted the channel along the impaired mainstem reach, resulting in its unstable Rosgen G4 stream type. The deeply incised and entrenched condition of the channel, prior to restoration, is attributed to aggressive vegetative management of the riparian corridor for hay production, cattle intrusion resulting in streambank hoof shear and vegetative denuding from grazing and browsing, combined with the erosive nature of the clear water discharge of "sediment hungry" water from the 30-inch reinforced concrete pipe

primary drop-outfall from Muddy Creek Flood Control Dam Number 8, constructed in 1964 and located approximately 5,575 feet upstream from the top of the impaired mainstem reach as shown on **Figure 3**.

Additionally, during the 1960's, a shift in stream base level occurred during the construction of Interstate 40 (I-40), when the invert of the 3-chamber box culvert carrying Thompsons Fork under I-40 was set 12 to 15 feet below the pre-disturbance invert of the streambed (personal communication with Zeb Lowdermilk). The hard-engineered lowering of the streambed triggered extreme channel incision, head cutting, floodplain abandonment, and lowering of the water table as the Thompsons Fork mainstem cut down into the floodplain in a natural response to re-establish profile equilibrium. The stable, natural channel form for Thompsons Fork mainstem is a Rosgen E4 stream type, based on detailed, quantitative analysis of a stable reference reach located approximately 2,800 feet upstream from the top of the impaired mainstem reach in the Thompsons Fork watershed.

The Thompsons Fork mainstem unstable bank height ratio (BHR = low bank height divided by bankfull maximum depth = LBH/D_{max} = 2.36), entrenchment ratio (flood prone width/bankfull width = 1.33), channel slope (0.0039 ft/ft) greater than valley slope (0.0031 ft/ft) and poorly defined bedform features shows the instability of the deeply incised, unstable, degrading stream channel disconnected from its floodplain prior to restoration. Mid-channel, lateral, and transverse sand and gravel bars were present at locations throughout the mainstem reach, demonstrating the stream lacked stable pattern, profile, dimension, capacity and competency to entrain the extremely high sediment load coming out of its unstable streambanks. The locations of these depositional features in the near-bank region deflected flows from the center of the channel toward the incised vertical to undercut, steep, denuded streambanks, resulting in accelerated erosion rates. Near-bank stress at a critical riffle cross-section was approximately 2.24 lbs/square foot, based on design calculations. The near vertical, denuded streambanks at this location were typical of the existing impaired stream reach conditions throughout the mainstem project corridor up to the former farm stream crossing. Utilizing the near-bank stress method algorithm included in RiverMorph® v.4.0.1a, it was estimated 2,076 cubic yards per year (or 2,700 tons per year) of sediment was being eroded from the streambanks along the mainstem.

Thompsons Fork was a vertically incised, laterally confined stream channel that abandoned its floodplain due to a lowering of stream base level and was characterized by up to 15 feet high, near vertical to undercut streambanks. The consequence of channelization, cattle intrusion, confinement (lateral containment), major floods, changes in sediment regime, loss of riparian vegetation and shift in stream base level at the invert of the 3-chamber box culvert carrying Thompsons Fork under I-40, constructed in the 1960's, and clear water discharge from Muddy Creek Flood Control Dam No. 8 that hydraulically regulates flow from two-thirds (4.99 square miles) of the 7.57 square mile watershed tributary to the project are attributed causes and effects for pre-existing conditions documented along the impaired mainstem reach. The effects of these anthropogenic changes resulted in accelerated streambank erosion, channel incision, land loss, aquatic habitat loss, lowering of the water table, land productivity reduction and in-stream and downstream sedimentation.

<u>UT to Thompsons Fork</u>

The UT channel is a classic Rosgen Type I valley confined, A1-A2 stream type transitioning to a Type II colluvial valley, B3 stream type at the point where the stream emerges from its mixed deciduous hardwood and evergreen forested corridor into an open meadow at the top of the impaired reach. The forested reach segment has some bedrock control, in-stream boulders with negligible instream woody debris accumulation. The indigenous, well established, healthy riparian vegetative communities in the channel and in the overbank regions provide extremely stable channel conditions for this reach, are preserved within the conservation easement recorded for the project.

Agricultural land use (hayland meadow) adjacent to the stream corridor together with aggressive vegetative management (mowing to the top of the right streambank) resulted in steep to undercut streambanks, accelerated streambank erosion and channel incision along the Enhancement Level II and Priority Level I Restoration reaches. The unstable streambanks were contributing large volumes of suspended sediment and bedload material to the larger Thompsons Fork mainstem. Utilizing the near-bank stress method, adjusted for channel pattern and depositional features algorithm included in RiverMorph® v.4.0.1a, it is estimated 291 cubic yards per year (or 378 tons per year) of sediment was being eroded from streambanks along the UT under existing conditions.

THOMPSONS FORK PRE- AND POST-RESTORATION PHOTOGRAPHS

Thompsons Fork Mainstem Pool Cross-Section – Pre-Restoration
Photograph taken near confluence with the UT, looking upstream.

Thompsons Fork Mainstem– Post-Restoration
Photograph taken at Station 26+45, near confluence with the UT, looking upstream.

Thompsons Fork UT Riffle Cross-Section – Pre-Restoration
Photograph taken from left to right, looking upstream.

Thompsons Fork UT Riffle Cross-Section – Post-Restoration
Photograph taken at Station 18+30, looking upstream.

Thompsons Fork Mainstem – Pre-Restoration
Photograph taken near downstream limits of project.
15-ft Vertical to Undercut Stream Bank

Thompsons Fork UT – Post-Restoration
Photograph taken at Station 27+57, near downstream limit of project, looking upstream.

Note: Complete photographic documentation of the Thompsons Fork Mainstem and UT restoration is in presented in **Appendix A** and keyed to the As-Built Plan sheets in **Section 7.0**.

2.0 RESTORATION SUMMARY

2.1 Mitigation Goals and Objectives

As discussed in the Restoration Plan for Thompsons Fork and the associated UT, the mitigation goals and objectives for the project were met by restoring physical and biological function and attributes of the project streams to stable, self-maintaining conditions. Pre-restoration conditions consisted of extremely incised, eroding and entrenched impaired stream channels. The mitigation goals and objectives were met by providing:

- Stable stream channels with attributes supporting biologically diverse environments;
- reconnection between the bankfull width and floodprone width of the channels by restoring the floodprone area;
- stable streambanks;
- functional, native revegetated riparian floodplain corridors, where deficient, and preservation of existing forested riparian corridors;
- improved physical and aquatic habitat features;
- minimization of future development and land use impacts on the streams; and
- perpetual protection of the stream corridors via conveyance of conservation easements to the State of North Carolina.

The mitigation approaches utilized for Thompsons Fork mainstem and the UT stream provide the functions described above by incorporating a variety of attributes recognized to support stream stability and biodiversity essential to ecosystem enhancement. Prior to restoration, these features were absent or diminished. The mitigation of the Thompsons Fork mainstem and the UT stream included assessing and quantifying stable geomorphologic reference reach conditions that became the foundation for the design and construction of stable natural channels. Considerations applied to the natural channel design and construction of the stream mitigation project achieved the results listed below:

- Stream channels with appropriate pattern, profile and dimensions, extrapolated from reference reach boundary conditions, to convey anticipated bankfull flows and entrain bedload readily available to the streams;
- grade control and bank stabilization structures to enhance the physical, aquatic and ecological attributes of the stream channels using natural materials;
- in-stream habitat features, to re-establish stable riffle-run-pool-glide sequences that naturally sort and redistribute substrate materials readily available to project reaches from the contribution watersheds;
- rock vanes, cross-vanes, J-hook vanes, log vanes, step-pools, and combinations thereof, were installed to alleviate near-bank stress, prevent streambed scour, and create natural, functional aquatic habitat;
- reconnection of the stream channels to functional floodplains by making improvements to floodprone areas and riparian corridors; and
- extensive, indigenous instream, overbank and riparian corridor herbaceous ground cover, shrub, understory and canopy species planting throughout the restored project reaches, providing sediment storage and nutrient uptake.

2.2 Restoration Approach

Engineering Field Reconnaissance

Thompsons Fork Mainstem

EMH&T scientists and engineers initially mobilized to the site during February 2006 to assess the impaired project reaches. Based on personal communications with the land owners, Zeb Lowdermilk and wife, Frances McNeely Lowdermilk (now deceased), prior to the 1960's the Thompsons Fork mainstem on their property was a stable, wadeable stream channel with low banks connected to its floodplain. The hydro-modifications associated with the construction of the 62-feet high impoundment (normal freeboard 31.5 feet; hydraulic height 30.5 feet) Muddy Creek Flood Control Dam Number 8 during 1964 combined with construction of a major Interstate highway transecting the property during the 1960's with the invert of the 3-chamber box culvert set 15 feet below the natural invert of the channel, collectively and drastically modified the Thompsons Fork watershed's natural flow regime and sediment budget downstream from the impoundment, and created hard-engineered changes in stream profile base level at the dam as well as the at the box culvert that carries Thompsons Fork under I-40. Channel incision and head-cutting, under these conditions, were inevitable on the Lowdermilk properties.

During August 2006, detailed, quantitative analysis of a reference reach located approximately 2,800 feet upstream from the top of the Lowdermilk's impaired mainstem reach in the Thompsons Fork watershed, reveals today's stable state of the stream, with observed slight "nesting" of the channel attributed to the streambed scour and armoring (substrate embeddedness) from the discharge of clear, 'sediment hungry' water from Muddy Creek Flood Control Dam Number 8, located approximately 3,050 feet upstream from the top of the reference reach (and approximately 5,575 feet upstream from the top of the mainstem project reach).

A number of anthropogenic factors leading to instability, in addition to clear water discharge, were identified during the 2006 project and watershed scale engineering field reconnaissance. Exacerbating factors along the project reach include aggressive on-site riparian corridor vegetative management, cattle intrusion (streambank destabilization attributed to hoof-shear and vegetative denuding from grazing and browsing), together with the installation of the 3-chamber box culvert under I-40, set 15 feet below historic base level of the lower mainstem streambed, impaired the entire mainstem project reach and resulted in its pre-restoration, unstable G4 stream type morphology.

The mitigation plan for Thompsons Fork utilized proven geomorphologic approaches developed by quantifying and interpreting stable channel pattern, profile and dimension based on data from reference reach boundary conditions and then superimposing that stable dimension, pattern and profile, extrapolated to the project scale, on the unstable form. The Priority Level I, off-line restoration design approach for the impaired mainstem reach included reconnecting the stream channel with the existing floodplain with appropriate elevation, valley slope, floodprone width and channel pattern, profile and dimensions, from geomorphologic dimensionless ratios and hydraulic parameters measured, quantified and extrapolated from reference reach boundary conditions approximately 2,800 feet upstream from the project in the Thompsons Fork watershed.

The proposed mainstem channel was originally designed with E4 stream type dimensions, pattern and profile, consistent with the reference condition. During pre-construction meetings with the contractor, a decision was reached to build the mainstem channel with C4 cross-sectional geometry, while maintaining pattern, profile or cross-sectional area, based on reference reach, E4 stream type boundary conditions. Due to the high sand content of the Colvard soil series, it was agreed a 'C' channel with flatter side slopes would be more stable during construction. Channel geometries required for the mainstem to entrain its bedload without either aggrading or degrading at bankfull stage were carried forward into the valley/channel staking construction plans. In-stream structures are strategically located throughout the reach to reduce shear stress in the near-bank region. Grade control structures are in place to prevent the clear water discharge from the upstream flood control dam from degrading the streambed and banks. For

added stability, streambank and channel reinforcement measures are present in high vertical near-bank shear stress regions (i.e., along outside meander bends). Reinforcement materials consist of a combination of rock toe, jute coir matting secured with 36-inch hardwood stakes, live branches plantings and aggressive seeding and mulching of streambanks and the riparian corridor during construction.

UT to Thompsons Fork

The UT stream emerges from a perennial granite bedrock spring at its headwaters. The spring defines the top of the 356 lf UT Preservation reach. At its headwaters the colluvial – fluvial landform is a classic Type I valley-confined, A1 stream type with strong bedrock control transitioning to a B3 stream type near the bottom of the preservation reach. The streambanks are stable along the A1 reach, located within a second- to third-growth mixed deciduous hardwood and evergreen forested riparian corridor.

The 400 lf UT Enhancement Level II reach begins where the stream emerges from its forested riparian corridor into a narrow mowed meadow, the profile gradient flattens to less than four percent and the stream channel transitions to a B3 stream type. Vegetative management, combined with a relatively steep profile gradient and low sinuosity, destabilized the streambank along channel right. The left bank is characterized by a narrow floodplain along the toe of a steep, forested hillside. The Enhancement Level II mitigation approach along this segment of the UT stabilized channel profile by re-establishing stable riffle-run-pool-glide sequences. Grade control is provided by strategically placed log sill step-pools and riffles, with minimal modification to channel dimensions. Now protected inside a fenced, perpetual conservation easement, re-establishment of in-stream, overbank and floodplain vegetation provides favorable conditions for the streambanks to heal and stabilize. Streambank stability will be further promoted by the decreased profile gradient. Grade controls now in place will prevent further head-cutting, thereby increasing streambank stability over time.

Stable pattern, profile and dimension for the UT was extrapolated from the stable C4 boundary conditions quantified at the Brindle Creek Reference Reach located in the Silver Creek catchment. **Table 2a** summarizes geomorphic data from the Brindle Creek Reference Reach study. **Figure 3b** shows the location of the Brindle Creek Reference Reach in the Silver Creek Watershed. See Appendix 6 in the Thompsons Fork and Unnamed Tributary Restoration Plan (EMH&T, April 9, 2007) for quantified data from the Rosgen Level III Reference Reach Assessment on Brindle Creek.

The pre-existing channel along the 1,948 lf UT Priority Level I restoration reach exhibited Rosgen C3b cross-sectional geometry. The near vertical right bank and adjacent, mowed meadow laterally confined this reach, preventing the stream from establishing stable pattern, profile and dimension to dissipate energy without eroding its banks. The Priority Level I restoration approach along this reach was selected and implemented to design and construct a stable, natural C3b channel by increasing the belt width to the extent that an average sinuosity of 1.36 was achieved. The sinuous pattern re-establishes riffle, run, pool and glide sequences that enable the channel to entrain its bedload without either aggrading or degrading at bankfull stage. The belt width along this reach was widened to a median width of 73 feet and reconnects the channel to its floodplain by restoring the floodprone area. Step-pools, constructed riffles and pool sequences, streambank reinforcement, and combinations thereof, are in place to reduce vertical near-bank shear stress and prevent stream channel degradation and streambank erosion. Additionally, rock toe streambank and channel reinforcement measures were constructed in high vertical shear stress regions (i.e., along outside meander bends). Reinforcement materials consist of a combination of rock toe protection, jute coir matting secured with 36-inch hardwood stakes, live branches plantings and aggressive, permanent seeding and mulching of streambanks and the riparian corridor during construction.

Bankfull Discharge

Thompsons Fork Mainstem

For Thompsons Fork, 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 section located approximately 2,800 feet upstream from the top of the impaired mainstem reach. The reference reach is a Rosgen E4 stream type that is slightly nested in its healthy, deciduous hardwood forested riparian corridor and floodplain. Muddy Creek Flood Control Dam No. 8, constructed during 1964 and located approximately 3,050 feet upstream from the top of the reference reach, regulates peak flows in the mainstem channel below the dam.

The North Carolina Piedmont and Mountains Regional Curve datasets (North Carolina Stream Mitigation Guidelines, April 2003), stratified by E type streams, grossly overestimates the bankfull discharge characteristics, channel geomorphology and hydraulic relationships for the drainage area tributary to the reference reach, and the mainstem impaired reach, due to the 925 acre-feet of available storage at crest stage of the upstream flood control dam. Given the poor regional curve fit, and since the flow from the dam's primary outfall structure is not gaged, it became necessary to use runoff curves and regression equations to estimate bankfull discharge for areas in the Thompsons Fork catchment uncontrolled by the dam. (USGS Water Resources Investigations Report 01-4207, Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina (Revised), Benjamin F. Pope, Gary D. Tasker and Jeanne C. Robins, 2001). A 1.8-year flow rate of 285 cfs for the impaired mainstem, downstream from the reference reach is based on an interpolated peak flow of 250 cfs from the hydraulically unregulated areas below the dam (drainage area = 2.59 square miles), using the regression equations, plus an estimated 35 cfs maximum outflow from the dam during a 2-year return interval flow, quantified using a TR-20 based watershed model. Reference Thompsons Fork and Unnamed Tributary Restoration Plan, Appendix 3 for the detailed Thompsons Fork Watershed Hydraulic Assessment (EMH&T, April 9, 2007). Bankfull discharge under as built conditions is 285.7 cfs. Calculations are presented in Appendix D.

UT to Thompsons Fork

Bankfull discharge for the UT was extrapolated from reference reach boundary conditions at the Brindle Creek Reference Reach located in the USGS Upper Catawba River Basin 8-digit HUC 03050101, Silver Creek Watershed, Local Watershed 14-digit basin 03050101050050. Quantified reference reach conditions were compared to empirical relationships using regression equations published with the *Bankfull Regional Curves for North Carolina Mountain Streams* (stratified by Rosgen C stream types). A very good match between the quantified reference reach drainage area, discharge, and bankfull geometry relationships with the regional curve stratified dataset was observed (e.g., quantified bankfull discharge, cross-sectional area, width and mean depth verses regional curve empirical relationship 98.2 cfs vs. 103.4 cfs, 30.8 ft^2 vs. 32.5 ft^2, 24.0 ft vs. 26.2 ft, and 1.28 ft vs. 1.25 ft, respectively). The stratified regional curve dataset does not include data for streams with drainage areas less than one square mile (UT drainage area = 104 acres or 0.16 square mile). However, given the very close match between quantified reference reach boundary conditions and the *Bankfull Regional Curves for North Carolina Mountain Streams* stratified by Rosgen C stream type, the regression equations derived from the regional curve dataset were used to extrapolate beyond the lower limits of verified bankfull drainage area, discharge and bankfull geometry relationships. The surveyed bankfull cross-sectional area, width and mean depth (10.73 ft^2, 13.1 ft, 0.82 ft) at a pre-existing riffle cross-section near the bottom of the UT reach (near approximate as-built profile station 16+98), closely matches the stratified empirical relationships between drainage area and bankfull cross-sectional area, width and mean depth extrapolated from the stratified regional curve dataset (10.1 ft^2, 14.7 ft, 0.82 ft), respectively. The calculated bankfull discharge based on pre-

existing channel geometry, slope, wetted perimeter, hydraulic radius, and bed roughness is 54.9 cfs. The quantified "as-built" discharge for the restored UT is 54.0 cfs, based on best fit trend line profile slope, median riffle cross-section dimensions (i.e., hydraulic radius) and substrate particle distributions (Manning's roughness coefficient "n" based on the UT riffle median D_{84} particle size of 71.8 mm = small cobble). As-built bankfull discharge calculations are presented in Appendix D.

Channel Morphology

As previously noted Section 1.2, morphology along the Thompsons Fork impaired mainstem reach is Rosgen Valley Type VIII. The pre-restoration channel was a deeply incised G4 Rosgen stream type. The restoration goal was to reconnect the channel to its abandoned floodplain and re-establish stable pattern, profile and dimension consistent with reference reach boundary conditions. The as-built mainstem channel is a Rosgen C4 stream type. The post-restoration UT channel is a stable C3b stream type. Summary morphologic and hydraulic data for the Thompsons Fork Reference Reach, Brindle Creek Reference Reach, Impaired, Proposed and As-Built Mainstem and UT are presented in **Tables 2a** and **2b**. Supporting documentation for the data presented in **Table 2** are provided in **Appendix D**.

Table 2a: Baseline Morphology and Hydraulic Summary

Thompsons Fork & Unnamed Tributary Mitigation Plan / EEP Project No. D06030-A

Station/Reach: Thompsons Fork Mainstem Priority I Restoration Reach - Station 0+00.00 to 27+42.47

Parameter	Thompsons Fork Reference Reach			Pre-Existing Condition**			Design			As-Built Riffle XSs 7, 9, 10 & 11		
Dimension	Min	Max	Mean	Min	Max	Mean	Min	Max	Med.	Min	Max	Med.
Drainage Area (mi^2)			5.57			7.57			7.57			7.57
BF Width (ft)			15.38			20.90			21.50	34.52	39.81	37.74
Floodprone Width (ft)			18.89			32.00	39.0	100.0	90.0	89.89	143.71	113.53
BF Cross Sectional Area (ft^2)			23.80			56.50			52.00	48.51	59.39	52.85
BF Mean Depth (ft)			1.55			2.70			2.40	1.30	1.60	1.40
BF Max Depth (ft)			2.09			5.05			3.00	2.16	2.88	2.52
Width/Depth (ft)			9.92			7.74			8.96	23.21	30.16	27.07
Entrenchment Ratio			1.23			1.53	1.81	4.65	4.19	2.30	4.16	3.00
Bank Height Ratio			1.18			2.36			1.00	1.00	1.00	1.00
Wetted Perimeter (ft)			18.50			24.77			26.30	34.91	40.28	38.84
Hydraulic Radius (ft)			1.29			2.28			1.98	1.28	1.57	1.38
Pattern												
*Channel Beltwidth (ft)	16.30	56.00	36.40				39.00	100.00	90.00	40.00	90.00	90.00
*Radius of Curvature (ft)	9.70	48.90	25.40				18.70	48.90	28.30	18.70	48.90	27.70
*Meander Wavelength (ft)	49.50	119.40	104.30				89.20	119.90	110.40	84.17	119.85	110.35
*Meander Width Ratio	1.06	3.64	2.37				4.15	5.58	5.13	1.04	2.34	2.34
Profile												
Riffle Length (ft)	15.0	21.6	18.3				14.3	39.4	21.8	8.6	30.6	17.2
Riffle Slope (ft/ft)	0.0099	0.0127	0.0113				0.0099	0.0127	0.0113	0.0051	0.0571	0.0166
Pool Length (ft)	17.0	32.1	24.3				28.6	105.0	42.6	21.5	82.9	39.3
Pool Spacing (ft)	73.1	77.1	75.1				42.6	83.2	61.5	25.0	145.0	63.8
Substrate												
D50 (mm)			29.4			13.7			13.7	5.7	10.6	9.1
D84 (mm)			50.1			26.2			26.2	35.9	66.3	43.4
Additional Reach Parameters												
Valley Length (ft)			188.00			2261			2295			2295
Channel Length (ft)			140.00			2530			2799			2742
Sinuosity			1.3			1.12			1.22			1.19
Valley Slope (ft/ft)			0.0031			0.0031			0.0031			0.0036
Bankfull Slope (ft/ft)			0.0024			0.0039			0.0024			0.0030
Rosgen Classification			E4			G4			E4			C4
*Habitat Index												
*Macrobenthos												

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

**Insufficient field indicators to estimate pattern and bedform features under impaired G4 channel conditions.

Blank fields = Historic project documentation necessary to provide these data were unavailable at the time of this report submission.
Where no min/max values are provided, only one value was measured or computed and is presented as the mean value.
As-Built data were evaluated using RiverMorph v 4.1.1. Data input and output parameter summary reports are presented in Appendix D.

Table 2b: Baseline Morphology and Hydraulic Summary

Thompsons Fork & Unnamed Tributary Mitigation Plan / EEP Project No. D06030-A
Station/Reach: UT Priority Level I Restoration Reach - Station 4+00.00 to 23+48.17

Parameter	Brindle Creek Reference Reach			Pre-Existing Condition			Design			As-Built XS-4 & XS-6		
Dimension	Min	Max	Mean	Min	Max	Med	Min	Max	Med	Min	Max	Med
Drainage Area (mi^2)			1.16			0.16			0.16			0.16
BF Width (ft)			24.02			13.10			12.00	13.94	14.08	14.01
Floodprone Width (ft)			232.00			44.80	45.00	85.00	71.50	78.48	88.08	83.28
BF Cross Sectional Area (ft^2)			30.77			10.70			11.50	11.17	11.37	11.27
BF Mean Depth (ft)			1.28			0.82			0.96	0.80	0.81	0.81
BF Max Depth (ft)			1.72			1.12			1.20	1.64	1.76	1.70
Width/Depth (ft)			18.77			15.98			12.50	17.38	17.42	17.40
Entrenchment Ratio			9.66			3.42	3.75	7.08	5.96	5.63	6.26	5.95
Bank Height Ratio			1.00			1.63			1.00	1.00	1.00	1.00
Wetted Perimeter (ft)			26.58			14.74			13.92	14.41	14.56	14.49
Hydraulic Radius (ft)			1.16			0.73			0.83	0.77	0.78	0.78
BF Discharge (cfs)			98.2			54.9			54.9	49.0	56.4	53.5
BF Mean Velocity (ft/sec)			3.19			5.13			4.77	4.33	5.05	4.79
Pattern												
*Channel Beltwidth (ft)	44.17	46.50	45.22				45.00	85.00	71.50	44.00	75.41	73.33
*Radius of Curvature (ft)	12.97	24.44	17.67				14.40	40.90	22.60	10.39	40.91	22.57
*Meander Wavelength (ft)	88.23	115.70	104.80				64.20	124.00	100.00	64.19	124.91	99.37
*Meander Width Ratio	1.84	1.94	1.88				3.75	7.08	5.96	3.14	5.38	5.23
Profile												
Riffle Length (ft)	19.0	31.0	25.7				22.60	46.60	36.40	6.08	55.10	23.40
Riffle Slope (ft/ft)	0.0125	0.0362	0.0211				0.0603	0.1215	0.0578	0.0350	0.0940	0.0595
Pool Length (ft)	11.0	31.6	17.4				18.40	43.00	27.60	8.19	48.20	24.71
Pool Spacing (ft)	67.6	77.5	71.4				63.40	112.00	78.40	20.94	159.00	65.21
Substrate												
D50 (mm)			38.5			37.5			37.5	7.7	37.5	16.0
D84 (mm)			60.2			73.4			73.4	68.2	73.7	71.8
Additional Reach Parameters												
Valley Length (ft)			294.00			1485			1437			1437
Channel Length (ft)			353.00			1617			1966			1948
Sinuosity			1.2			1.09			1.37			1.36
Valley Slope (ft/ft)			0.0106			0.0353			0.0353			0.0353
Bankfull Slope (ft/ft)			0.0115			0.0324			0.0258			0.0243
Rosgen Classification			C4			C3b			C3b			C3b
*Habitat Index												
*Macrobenthos												

Notes: * Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria
Blank fields = Historic project documentation necessary to provide these data were unavailable at the time of this report submission.
Where no min/max values provided, only one value was measured or computed and is presented as the median value.
As-Built data were evaluated using RiverMorph v 4.1.1. Data input and output parameter summary reports are presented in Appendix D.

Channel Stability Assessment

Thompsons Fork Mainstem

Prior to restoration, the mainstem channel's unstable width to depth ratio, entrenchment ratio (flood prone width/bankfull width = 1.33), profile slope (0.0039 ft/ft) steeper than valley slope (0.0031 ft/ft) and poorly defined active streambed has resulted in a deeply incised, unstable channel disconnected from its floodplain. Mid-channel, lateral, and transverse sand and gravel bar deposits were present at locations throughout the reach, demonstrating the stream lacked stable pattern, profile, dimension, capacity and competency to entrain the extremely high sediment supply coming from its unstable streambanks. The locations of these instream depositional features in the near bank region deflect flows from the center of the channel toward the incised vertical to undercut banks, accelerating streambank erosion. Near-bank stress at a critical riffle cross-section, was approximately 2.24 lbs/square foot, based on design calculations. The near vertical, denuded streambanks at this location are typical of the existing impaired stream reach throughout the mainstem project corridor to the location of the pre-existing culverted farm stream crossing. Utilizing the near bank stress method algorithm included in RiverMorph® v.4.0.1a, it was estimated 2,076 cubic yards per year (2,700 tons per year or 1.07 tons/yr/ft) of sediment was being eroded from the unstable, vertical to undercut, deeply incised streambanks along the 2,530 l.f. impaired mainstem reach prior to restoration. Pre-existing Bank Erosion Hazard Index (BEHI), sediment volume export rates, streambank erosion rate estimates, streambank stability analyses and Bank Height Ratio (BHR) calculations, together with RiverMorph® model inputs and results are presented in Appendix 4 of the Thompsons Fork and Unnamed Tributary Restoration Plan (EMH&T, April 9, 2007).

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 each of the six (6) monumented cross-sections (cross-sections number 7 through 12) on the Thompsons Fork 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.

As-Built Estimated Sediment Loss for Thompsons Fork Mainstem (Reach Summary)

Study Bank	Proportional Length (l.f.)	Loss (cu yd/yr)	Loss (tons/yr)
Riffle XS-7	204.5	25.15	32.70
Pool XS-8	954.5	6.72	8.74
Riffle XS-9	204.5	36.81	47.85
Riffle XS-10	204.5	33.47	43.51
Riffle XS-11	204.5	32.72	42.54
Pool XS-12	954.5	16.49	21.44
Totals	**2,727**	**151.36**	**196.78**

Note: Estimated total sediment loss per foot of reach = 0.0722 tons/yr/ft = 0.30 foot bank loss/year.

The preceding streambank erosion rate summary is somewhat aggressive in that reductions in near-bank shear stress at banks that are protected by log vanes, rock vanes, cross-vanes, or combinations thereof are not taken into account. Additionally, soil and bank stability provided by erosion control fabrics and other streambank reinforcement measures are not taken into account. Annual surveys of the monumented cross-sections will provide absolute comparisons to the erosion rates presented in the preceding table and in Appendix D.

Unnamed Tributary to Thompsons Fork

The Unnamed Tributary channel, from the headwater granite bedrock spring from where it emerges is a classic Rosgen Type I valley confined, A1-A2 stream type transitioning to a Type II colluvial valley, B3 stream type at the point where the stream emerges from its deciduous hardwood forested corridor into an open meadow at the top of the impaired reach. The forested segment of the reach exhibits some bedrock control, in-stream boulders with negligible instream woody debris accumulation. The indigenous, well established, healthy riparian vegetative communities in the channel and in the overbank regions provide extremely stable channel conditions. Preservation is proposed for this reach as the aquatic that insects, amphibians and crustations exist in the streambed substrate should serve as a source population to repopulate restored aquatic habit features along the Enhancement Level II and Priority Level I reaches of the Unnamed Tributary and the restored mainstem.

Agricultural land use (hayland meadow) adjacent to the stream corridor together with aggressive vegetative management (mowing to the top of the right streambank) had resulted in steep to undercut streambanks, accelerated streambank erosion and channel incision. The unstable streambanks were contributing large volumes of suspended sediment and bedload material to the larger Thompsons Fork mainstem. Utilizing the near bank stress method, adjusted for channel pattern and depositional features algorithm included in RiverMorph® v.4.0.1a, it was estimated 291 cubic yards per year (or 378 tons per year) of sediment was being eroded from streambanks along the Unnamed Tributary under pre-existing conditions. BEHI sediment export and bank erosion rate estimates together with BHR calculations, including RiverMorph® model inputs and results are presented in Appendix 4 of the Thompsons Fork and Unnamed Tributary Restoration Plan (EMH&T, April 2007).

Under restored, as-built conditions, the Vertical Velocity Near-Bank Shear Stress Method algorithm in RiverMorph® v.4.1.1 was applied, using bankfull geometry, hydraulic slope and as-built streambank slopes at pool cross-section number 3 (Pool XS-3, Station 8+08.92) and riffle cross-section number 6 (Riffle XS-6, 17+94.46) for the 1,948 lf UT Restoration Reach. Based on longitudinal profile analysis, the reach is approximately 50 percent pools/glides and 50 percent riffles/runs. Therefore one representative monumented pool and one representative monumented riffle cross-section was selected to proportionally evaluate as-built streambank stability and estimate erosion rates on the UT restoration reach. The model input parameters and predicted streambank sediment loss rates are presented in **Appendix D** and summarized in the following table:

As-Built Estimated Sediment Loss for Thompsons Fork UT (Reach Summary)

Study Bank	Proportional Length (l.f.)	Loss (cu yd/yr)	Loss (tons/yr)
Pool XS-3	974	2.39	3.11
Riffle XS-6	974	2.40	3.12
Totals	1,948	4.79	6.23

Note: Estimated total sediment loss per foot of reach = 0.0032 tons/yr/ft = 0.02 foot bank loss/year.

Reference Reach Data Collection

A stable reference reach was selected using aerial ortho-imagery (1998), NCDOT LiDAR contour data coverages for the drainage area tributary to the restoration project and field reconnaissance in the Thompsons Fork watershed. A stable reach on Thompsons Fork located in a mature, wide deciduous hardwood forested was identified and selected to be representative of reference reach boundary conditions for the hydro-modified Thompsons Fork Watershed below the flood control dam; the Brindle Creek reference reach in the Silver Creek Watershed catchment was selected as a stable, representative reference reach for the UT.

The location of the Thompsons Fork reference reach in relation to the mainstem impaired reach is shown on **Figure 3**. The top of the reference reach begins at 35.69417^{o} North Latitude and 81.90667^{o} West Longitude. The drainage area tributary to the reference reach is 5.57 square miles. Muddy Creek Flood Control Dam No. 8 regulates flows from 4.99 square miles of the watershed area and regulates 89.6 percent of the runoff and sediment budget available to the reference reach and 65.9 percent of the runoff and sediment budget available to the project mainstem reach.

The Brindle Creek reference reach, located 6.5 miles southeast from the Thompsons Fork and UT project site, near the headwaters in the Silver Creek catchment (Targeted Watershed 50050, Subbasin 31) begins at 35^{o}37’07” North Latitude and 81^{o}48’58” West Longitude (NAD 83, UTM Zone 17 Coordinates 691,930.87 N, 1,163,198.35 E GPS Reference Point). The drainage area tributary to the second order reference reach stream is 1.16 square miles. The location of the reference reach is shown on **Figure 3a**.

Dimension, pattern, profile and substrate data were collected along the reference reaches and quantitatively evaluated using the RiverMorph® v.4.0.1a software application. Two complete meander wavelengths along the reference reaches were evaluated using accepted stream assessment methodologies and procedures (D.L. Rosgen, 1994). Reference reach survey data, analysis, classification and geomorphologic summary reports for the Thompsons Fork Reference Reach and the Brindle Creek Reference Reach are presented in Appendix 6, Thompsons Fork and Unnamed Tributary Restoration Plan, NC EEP Project Number: D06030-A (EMH&T, April 9, 2007). The Thompsons Fork and Bridle Creek Reference Reaches morphologic and hydraulic data are summarized in **Tables 2a** and **2b**, respectively.

Reference Reach Classification

The reference reach along Thompsons Fork is located approximately 2,800 feet upstream from the impaired mainstem reach. The reference reach is a slightly nested, Rosgen E4 stream type in an adjacent healthy, mature deciduous hardwood forested riparian corridor. Muddy Creek Flood Control Dam No. 8, constructed in 1964 and located approximately 3,000 feet upstream from the top of the reference reach, regulates peak flows on the mainstem channel below the dam. Additionally, clear water "sediment hungry" discharge from the dam has resulted in a concave profile along the reference reach, as determined by a Rosgen Level III assessment and analysis of the reference conditions during August 2006.

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

Reference Reach Discharge

Thompsons Fork Reference Reach

The calculated bankfull discharge for the Thompsons Fork reference reach, using quantified reference reach data collected at a stable riffle cross-section 2,800 feet upstream from the impaired mainstem reach, is 64.8 cfs. Calculated discharge at the reference reach riffle cross-section was compared to the stratified E Type streams data from *Bankfull Regional Curves for North Carolina Piedmont and Mountain Streams* dataset with a contribution drainage area of 5.57 square miles. The regional curve predicts bankfull discharge at this position in the watershed at 330 cfs. The calculated discharge using quantified reference reach data provides an extremely poor match in comparison to the stratified data's empirical relationships between discharge versus drainage area due to discharge from the 4.99 square miles of the total drainage area tributary to the reference reach being regulated by Muddy Creek Flood Control Dam Number 8. Of interest, using only the drainage area tributary to the Thompsons Fork Reference Reach downstream from the dam (i.e., 373.81 acres or 0.58 square miles) the stratified regional curve dataset estimates a bankfull discharge of 73.9 cfs, much closer to the calculated discharge of 64.8 cfs based on carefully measured and quantified field variables (a difference of 9.1 cfs).

Characterizing the effects the 925 ac-ft of storage behind the dam has on peak discharge and flow duration prevented a gross over-estimation of bankfull discharge at the reference reach scale as well as the project scale, which otherwise would have been carried forward into the design. Had watershed-scale hydro-modification not been taken into account, the mainstem reach would have been designed with dimensions to convey 404 cfs at bankfull stage, rather than 285 cfs as presented in detail in Section 2.2, a difference of 199 cfs. To put this in terms one can easily visualize, 1.0 cfs = 449 gal/min = 646,317 gal/day. 646,317 times 199 equals 128,617,083 gal/day. 1.0 ac-ft = 43,560 ft^3 = 325,852 gallons. 128,617,083 gal/day divided by 325,852 gal/ac-ft = 394.7 ac-ft day.

Brindle Creek Reference Reach

The calculated bankfull discharge for Brindle Creek, using quantified and verified reference reach data collected at a stable riffle cross-section is 96.1 cfs and very closely matches the empirical relationship between drainage area and discharge using the *Bankfull Regional Curves for North Carolina Mountain Streams* dataset, stratified by C type streams of 103.4 cfs.

Channel Morphology

Stream channel morphology data for the Brindle Creek reference reach, the Thompsons Fork reference reach, the Thompsons Fork mainstem, and the UT is presented in tabular format on **Table 2a** and **2b**. Brindle Creek is a stable Rosgen C4 stream type. The Thompsons Fork Reference Reach is a slightly nested, Rosgen E4 stream type.

Channel Stability Assessment

The plant community along the reference reach of Thompsons Fork exists over the streambanks into the active channel. High root densities and depths were observed at both stable riffle and pool locations throughout the reference reach, with healthy communities of canopy, understory, shrub and herbaceous species present. Best-fit trend lines drawn through the bankfull indicator points, water surface and thalweg points, respectively, on the longitudinal profile were essentially parallel. There is no indication of head cutting, downcutting, aggradation or degradation. When a best fit curve was plotted through the reference reach thalweg points, the bedform exhibits a concave profile. This is characteristic of moderate streambed scour and armoring (substrate embeddedness) resulting from the clear water discharge from Muddy Creek Flood Control Dam No. 8, located approximately 3,000 feet upstream from the top of the reference reach. Otherwise, the reference reach is a stable, third-order E4 stream channel, with a large gravel to small cobble streambed substrate, based on quantitative analysis of reference reach boundary conditions measured in the field.

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

Vegetation

The reference reach along the Thompsons Fork mainstem exists within a second- to third-growth, forested floodplain containing herbaceous ground cover, shrubs, understory and mature upper canopy trees. Tree species observed along the reference reach include *Pinus taeda*, *Platanus occidentalis*, *Ostrya virginiana,* and *Alnus serrulata*. *Quercus species* (oak) were also observed further out from the stream within the forested valley. Invasive *Ligustrim sinense* was the dominant shrub adjacent to the

stream in this area, and a few *Cornus florida* (flowering dogwood) shrubs were also noted. Vegetative cover along the reference reach is much more intact than along the Thompsons Fork impaired mainstem reach. The reference reach flows through a wide forested area, rather than a sparsely vegetated and disconnected riparian corridor, typical of the mainstem impaired reach. Vegetation along the reference reach is largely undisturbed, and tree roots along the channel are providing bank stability along the reach.

The Brindle Creek reference reach flows through a second-growth, forested floodplain containing mature trees, understory saplings, shrubs and herbaceous ground cover. Tree species observed along the reference reach include *Pinus taeda*, *Platanus occidentalis*, *Quercus rubra* (red oak), and *Fagus grandifolia* (American beech). Scattered *Symplocos tinctoria* (common sweetleaf) shrubs were also present. Vegetative cover along the reference reach is more diverse, dense and intact than along Enhancement Level II and Priority I impaired reaches on the Thompsons Fork UT. The reference reach flows through a healthy deciduous hardwood forest, rather than a narrow mowed riparian corridor. Vegetation along the reference reach is undisturbed. Tree root systems along the streambanks are providing lateral stability along the reach.

2.3 Restoration Summary

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

Table 3: Pre-Existing Conditions/Post-Construction Summary
Project Number D06030-A (Thompsons Fork Restoration)

Tributary Reach ID	Pre-existing length	Restored Length*	Restoration Level	Credit Ratio	SMUs**
Mainstem Priority Level I Restoration	2,530 lf	2,727 ft	Priority Level I Restoration	1.0	2,727
UT Preservation	356 lf	356 ft	Preservation	5.0	71
UT Enhancement Level I	400 lf	390 ft	Enhancement Level I	1.5	260
UT Priority Level I Restoration	1,598 lf	1,948 ft	Priority Level I Restoration	1.0	1,948
Totals	**4,884 ft**	**5,421 ft**			**5,006**

*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 February 2009. Planting occurred during the spring of 2008. The planted vegetation will first be monitored during the 2009 growing season, during September or October. Monitoring will be conducted in accordance with the multi-agency, North Carolina Stream Mitigation Guidelines (April 2003) applicable to Restoration and Enhancement Level II projects and the template *Content, Format and Data Requirements for EEP Monitoring Reports, Version 1.2* (11/16/06). Vegetation monitoring will be conducting in accordance with *CVS-EEP Protocol for Recording Vegetation, Version 4.0* (Lee, M.T., Peet, RK., Roberts, S.R., Wentworth, T.R. 2006) for Levels 1 and 2 Plot Sampling

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

3.1 Stream Channel Monitoring

Stream channel stability will be physically monitored at the 12 permanent, monumented cross-sections annually. Stream stability and pattern will also be evaluated along 3,000 linear feet of long-term monitoring longitudinal profiles. 1,750 linear feet of longitudinal profile on the Thompsons Fork mainstem, beginning at the top of the reach (as-built profile station 0+00 to profile station 17+50) will be surveyed on an annual basis throughout the 5-year monitoring period. 1,250 linear feet of longitudinal profile on the UT restoration reach (beginning at as-built profile station 4+00 to station 21+50) will be surveyed annually.

Photographs will be taken up-stream, down-stream 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. The As-Built Plan sheets in **Section 7.0** include the dimension, pattern, and profiles of the constructed stream channels. The As-Built condition (Year 0) will be utilized as baseline to compare future monitoring surveys and subsequently to determine channel stability and transition. Year 0 "As-Built" Long-Term Monitoring Profiles are included in **Appendix B**. Year 0 "As-Built" Long-Term Monitoring Cross-Section 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 twelve (12) monumented cross-section locations representative of the constructed project reaches: two (2) cross-sections through pools and four (4) cross-sections through riffles on the mainstem, and three (3) cross-sections through pools and three (3) cross-sections through riffles on the UT. The number and particles in standard size classes will be reported each year to assess aquatic habitat, sediment transport, sorting and depositional trends, as well as stream stability over time. Annual inspection of in-stream structures will also occur to verify proper function and channel stability. Stream channel monitoring surveys will be completed annually for five consecutive years, starting in February 2009 (Year 1), over six months after construction completion and permanent revetment of the stream corridors during June 2007.

Bankfull flow events will be documented at least twice during the five year monitoring period, during separate monitoring years. Bankfull flow events will be documented utilizing two (2) 4-feet, USGS Type A crest-stage stream gages installed on the project reaches; one (1) crest-gage set at bankfull stage at monumented riffle cross-section number six (Riffle XS-6) on the UT, and one (1) crest-gage set at bankfull stage at monumented riffle cross-section number seven (Riffle XS-7) on the Thompsons Fork mainstem. 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 6.0**. In the event two bankfull events do not occur during the five-year monitoring period, consultations with the U.S. Army Corps of Engineers, the Division of Water Quality and the resource agencies will be coordinated to determine if further monitoring is necessary to demonstrate success criteria have been achieved.

3.2 Planted Woody Vegetation Monitoring

Woody vegetation planted along the streams will be monitored for five consecutive years. Per the required plots calculation from EEP, a total of 8 ten by ten meter square plots (five along the mainstem and three along the UT) have been permanently established. Corner markers were permanently installed and one corner surveyed for future use. The species, density of living stems, and the cause of mortality if identifiable will be recorded for all planted woody species within each plot. Vegetation will be sampled annually and reported every year along with the data collected during the physical monitoring of the channel. The focus of the vegetative monitoring will be a stem count on planted individuals in the tree and shrub stratum, although data on height and diameter will also be recorded according to the *CVS-EEP* protocol. Percent cover of the plot will be documented via photographs taken of each plot. Vegetative problem areas along the project area will be identified, mapped, and documented via photographs. Vegetation monitoring will occur between the months of September and October.

3.3 Performance Standards

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

- Minimal or negligible development of instream bar deposits.
- Minimal or negligible change in channel pattern, profile and dimension in comparison to As-Built conditions. Adjustments may occur and some may be indicative of increasing stability, such as moderate reductions in width/depth ratios as a result of slight channel narrowing and natural 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 Thompsons Fork Mainstem and UT 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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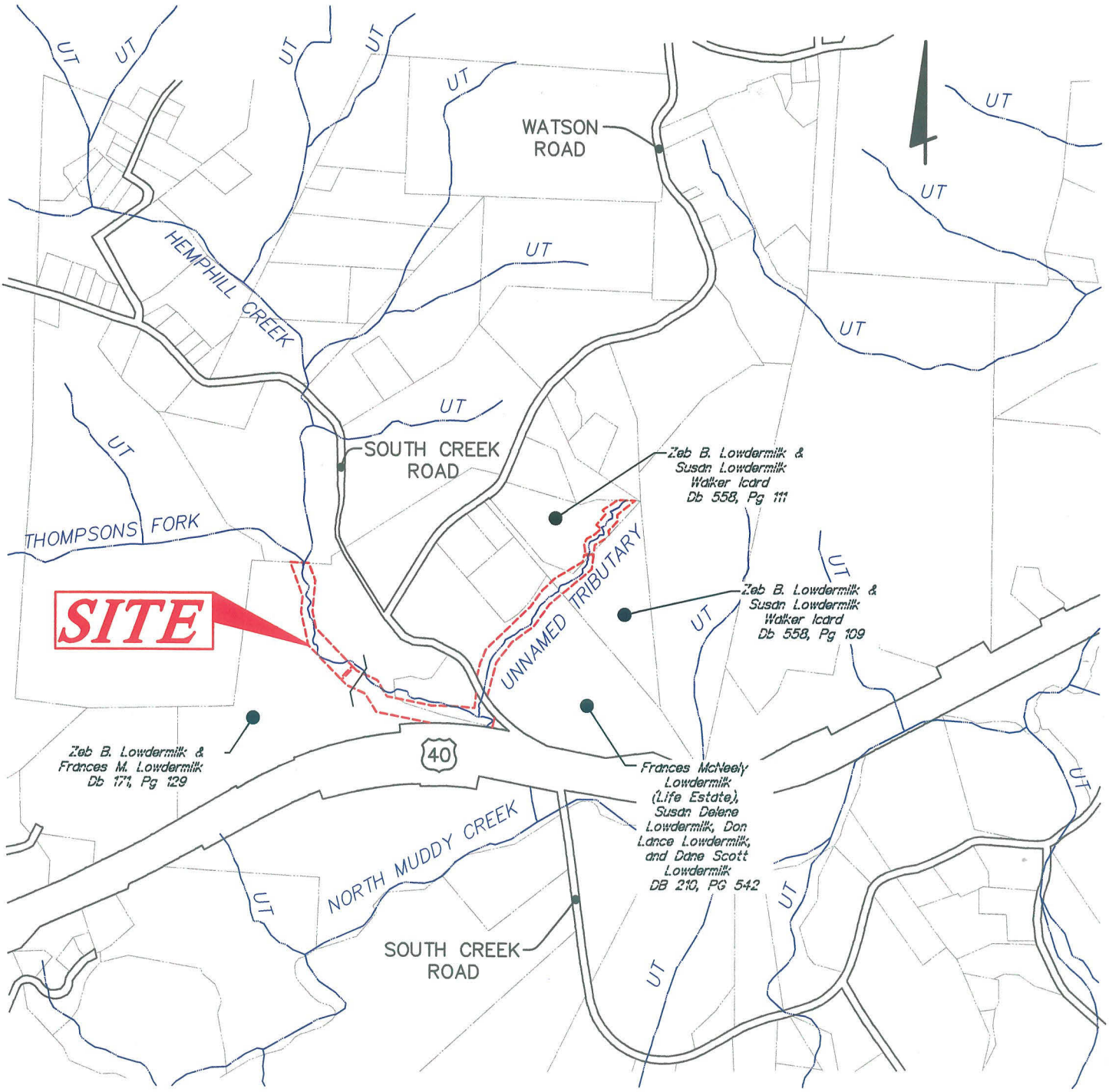
MCDOWELL COUNTY, NORTH CAROLINA

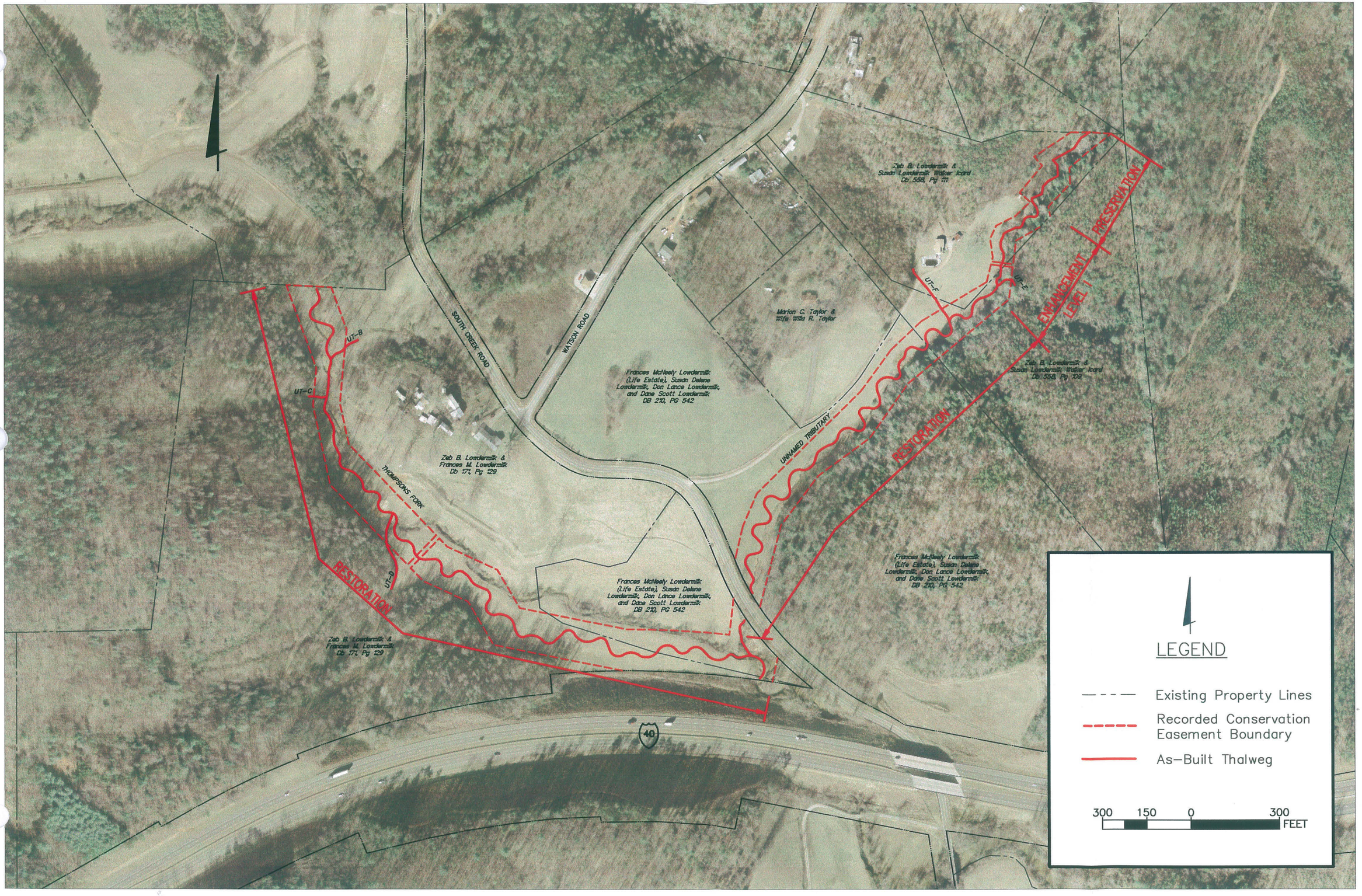
THOMPSONS FORK AND UNNAMED TRIBUTARY

SITE VICINITY MAP

FIGURE 1

Date:	August, 2007	Job No.	2006-1398	Scale:	1" = 1200'





MCDOWELL COUNTY, NORTH CAROLINA

THOMPSONS FORK AND UNNAMED TRIBUTARY

PROJECT STREAM REACHES

FIGURE 2

Date	Job No.
October, 2008	2006-1386
Scale	Sheet
1" = 300'	1/1

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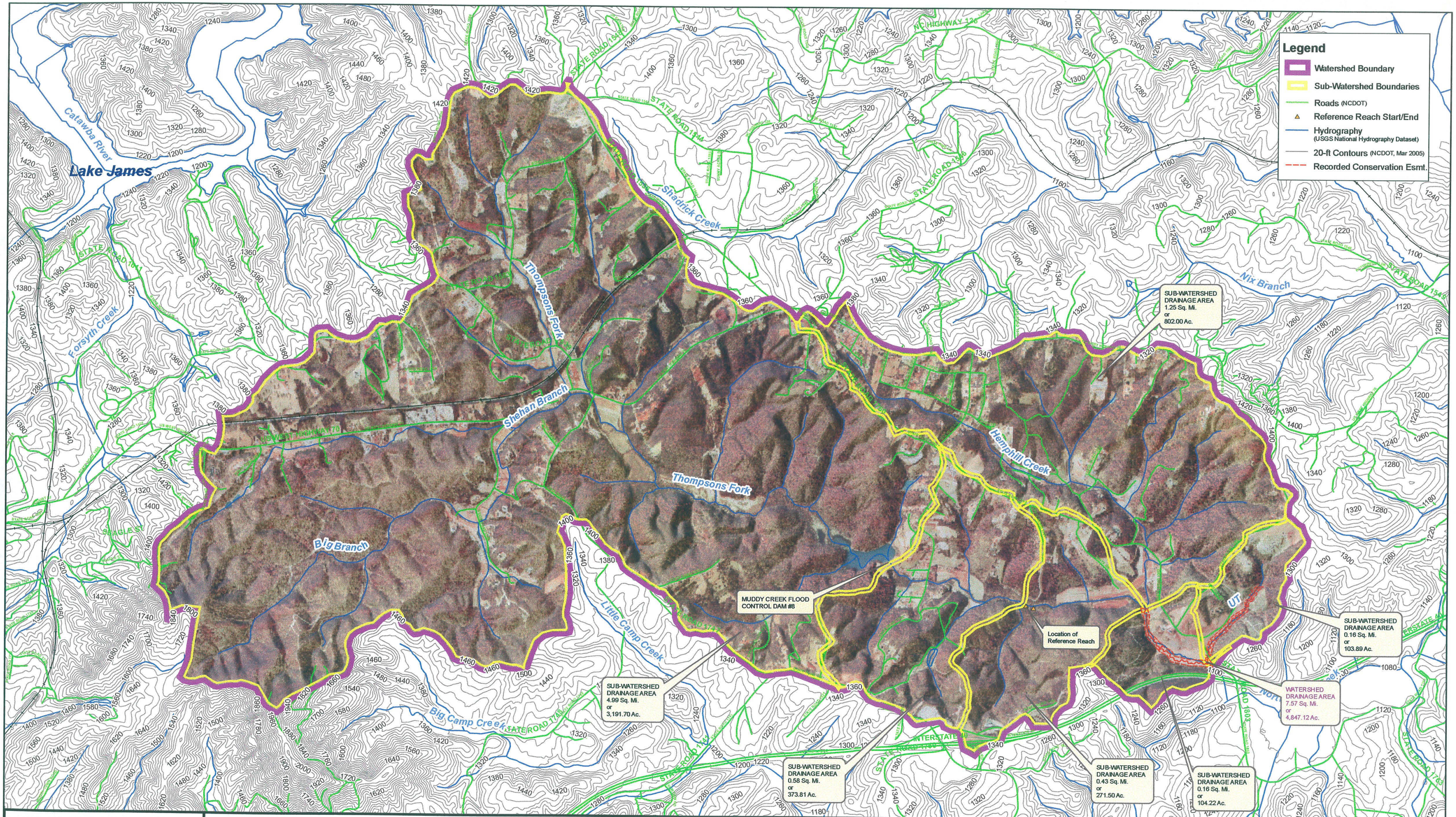

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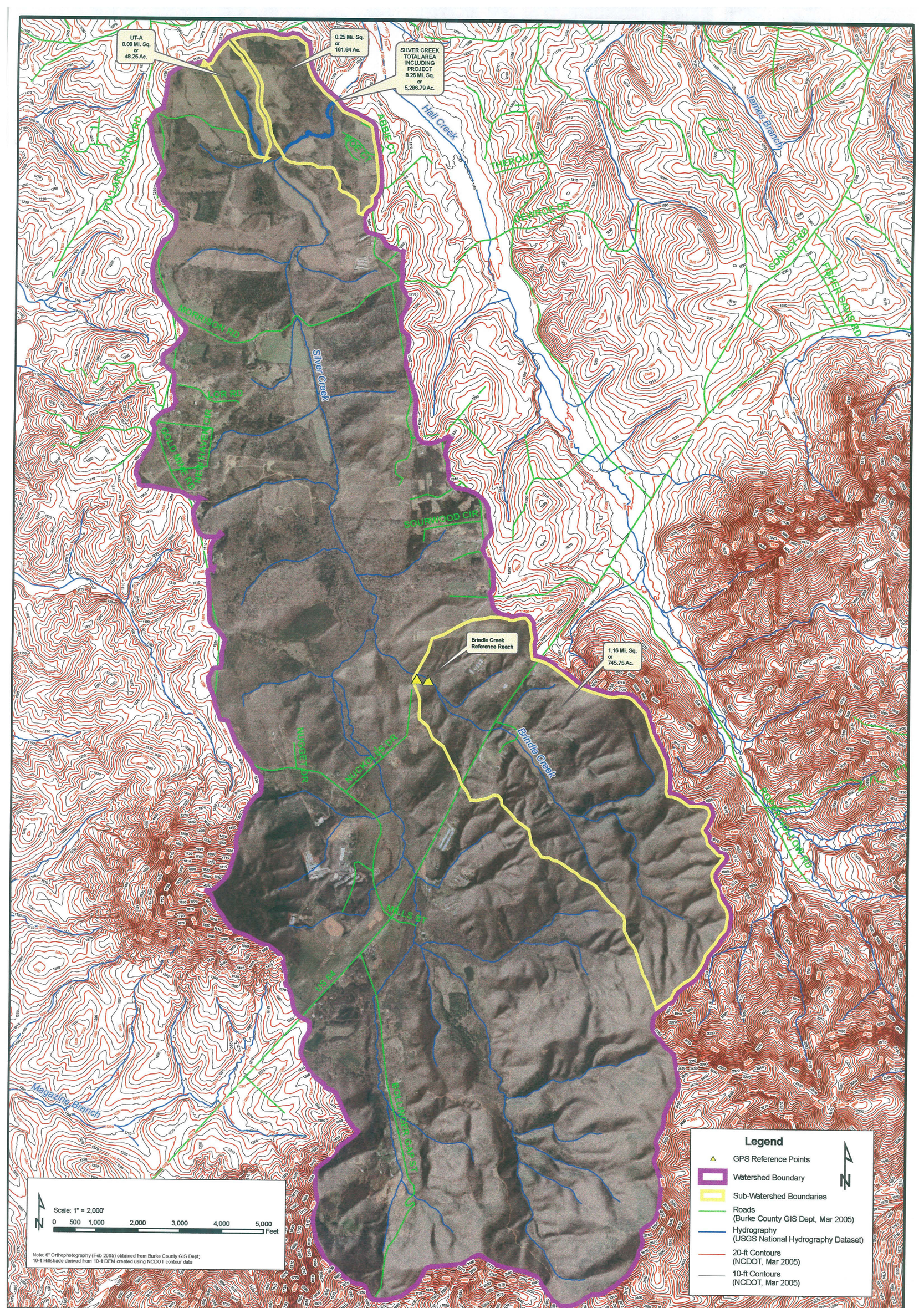
UNION COUNTY, NORTH CAROLINA

Figure 3 - Site Watershed Map
Thompsons Fork Watersheds:
DOQQ Orthophotography (1998) over 10-ft Hillshade
McDowell County, NC
2006-1398

N

Ecosystem Enhancement Program

Q:\PROJECT\20061398.ENV\shapefile\Figures\Figure 3 - Site Watershed Map(11x17).mxd



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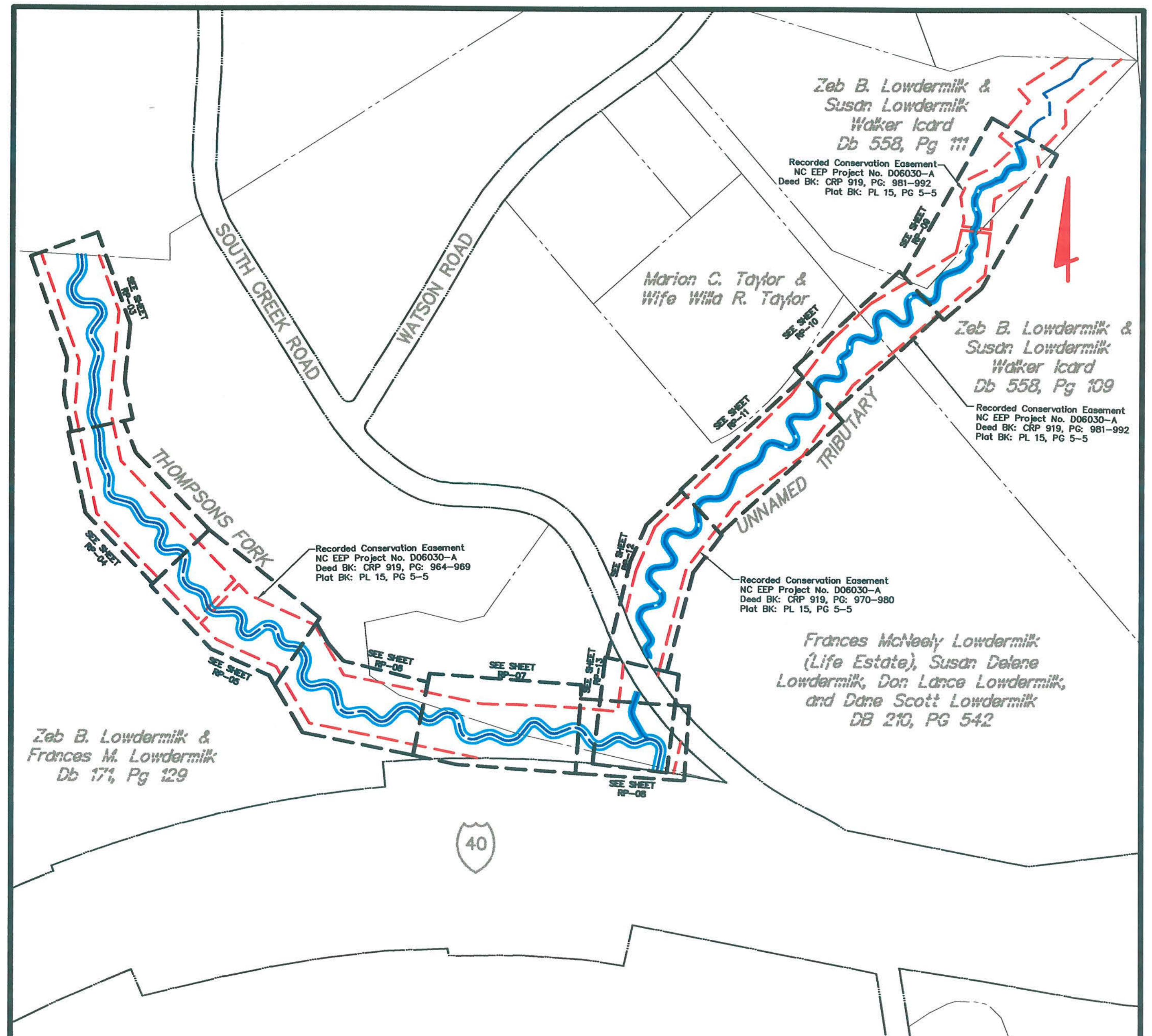
BURKE COUNTY, NORTH CAROLINA

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

Ecosystem Enhancement Program

7.0 AS-BUILT PLAN SHEETS

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
2008



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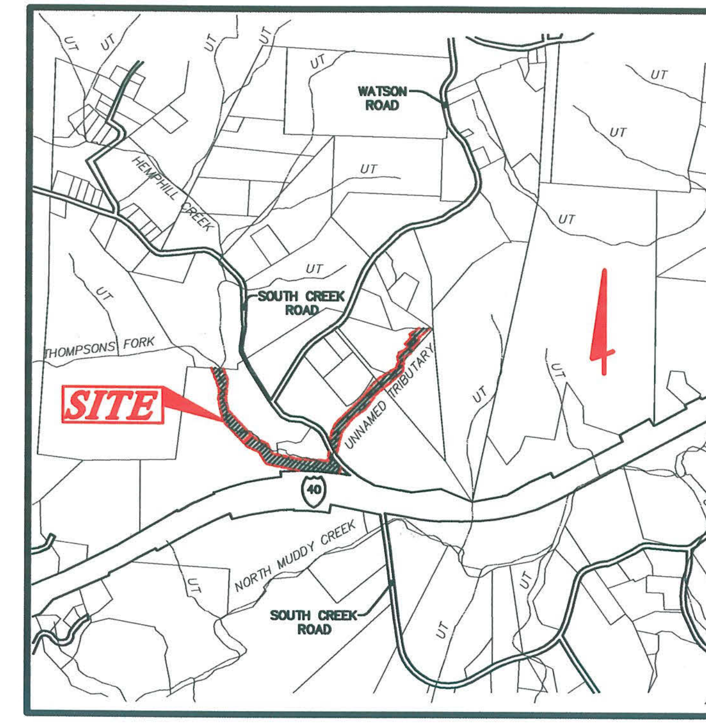

VICINITY MAP
Not To Scale

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

Jud M. Hines 9-3-08
Registered Engineer No. 034154 Date

Job No.	Sheet
2006-1398	AB-01/12

Date	Scale
July, 2008	As Noted

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
STREAM RESTORATION PROJECT
TITLE SHEET

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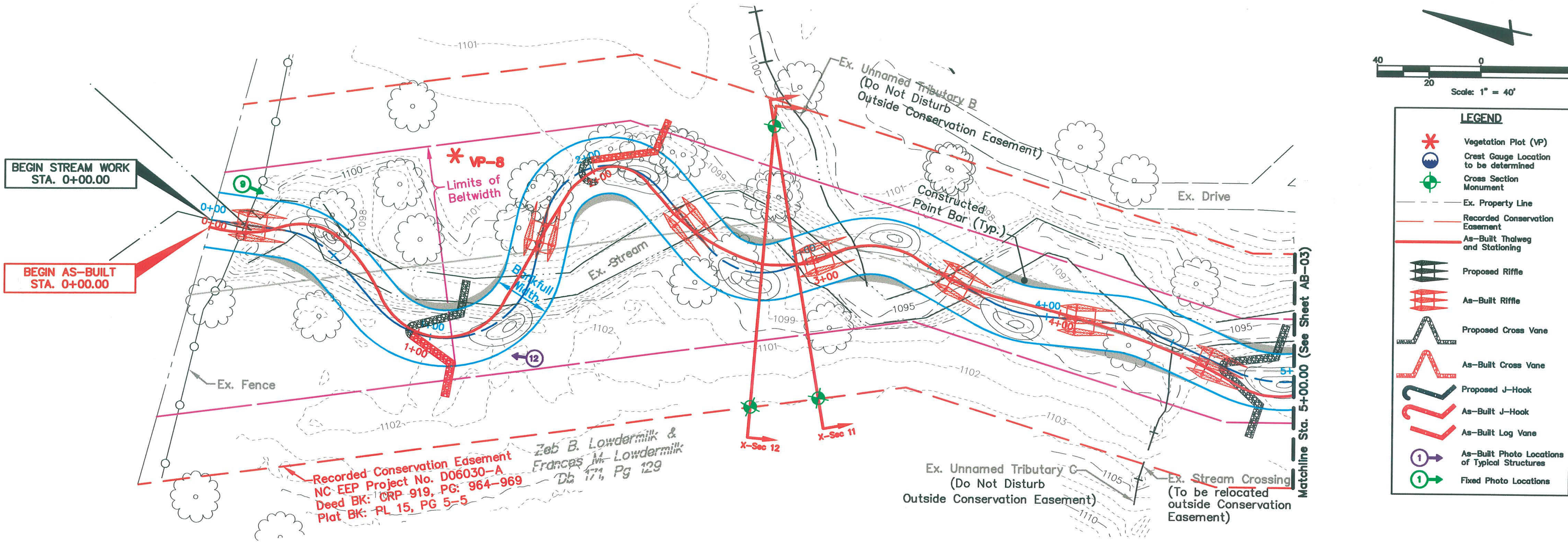

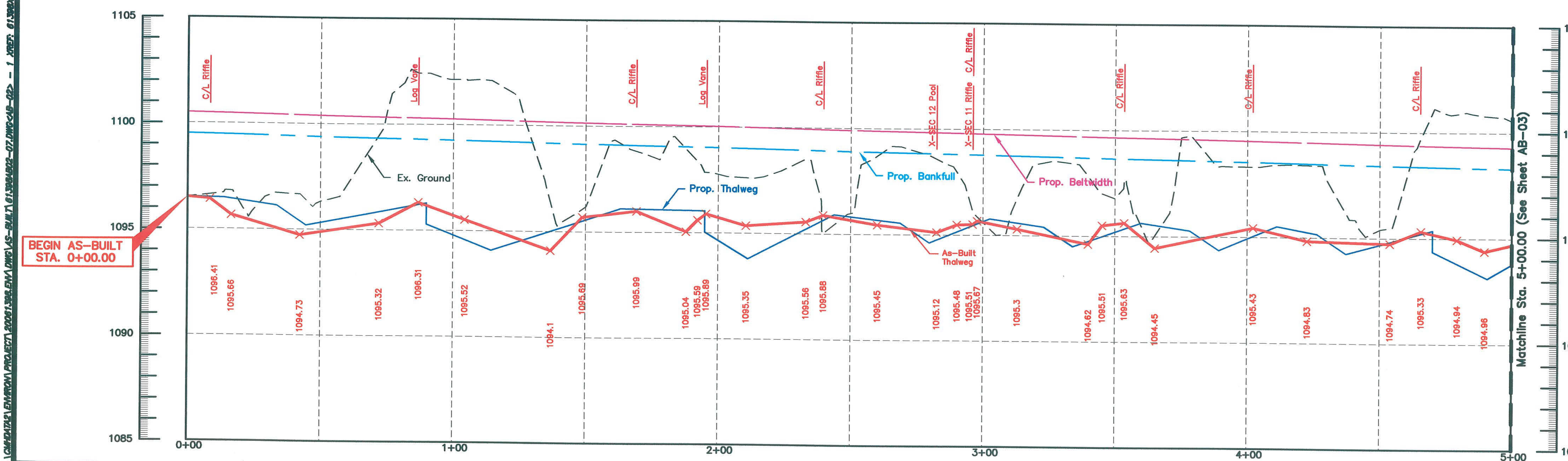

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
THOMPSONS FORK CREEK
PLAN & PROFILE

Job No. 2006-1398
Sheet AB-02/12
Date July, 2008
Scale Hor: 1" = 40' Ver: 1" = 5'

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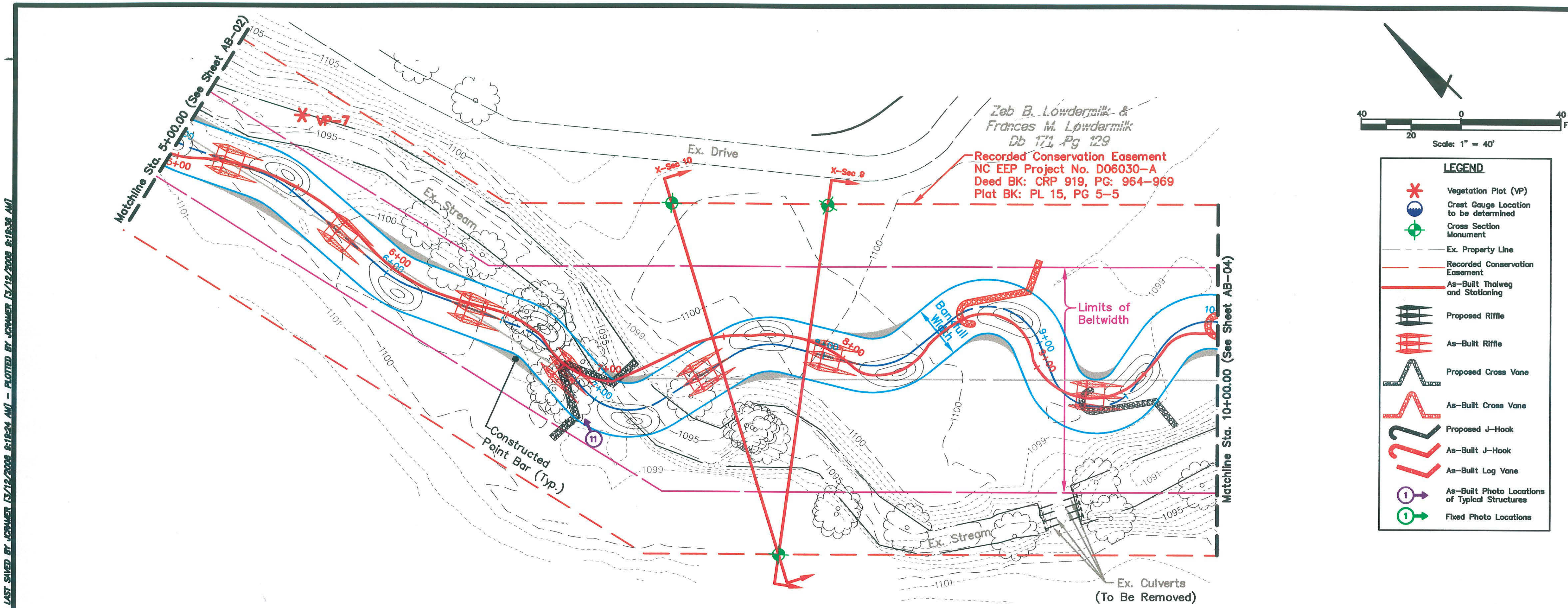

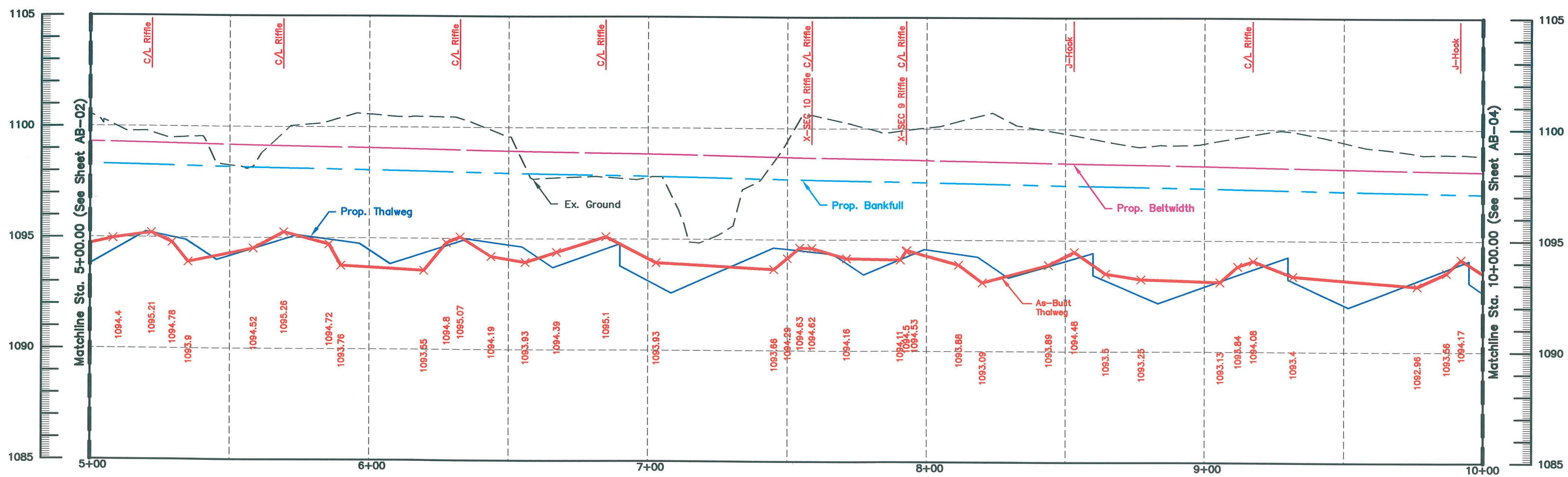

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STREAM AS-BUILT
FOR

THOMPSONS FORK AND UNNAMED TRIBUTARY

THOMPSONS FORK CREEK
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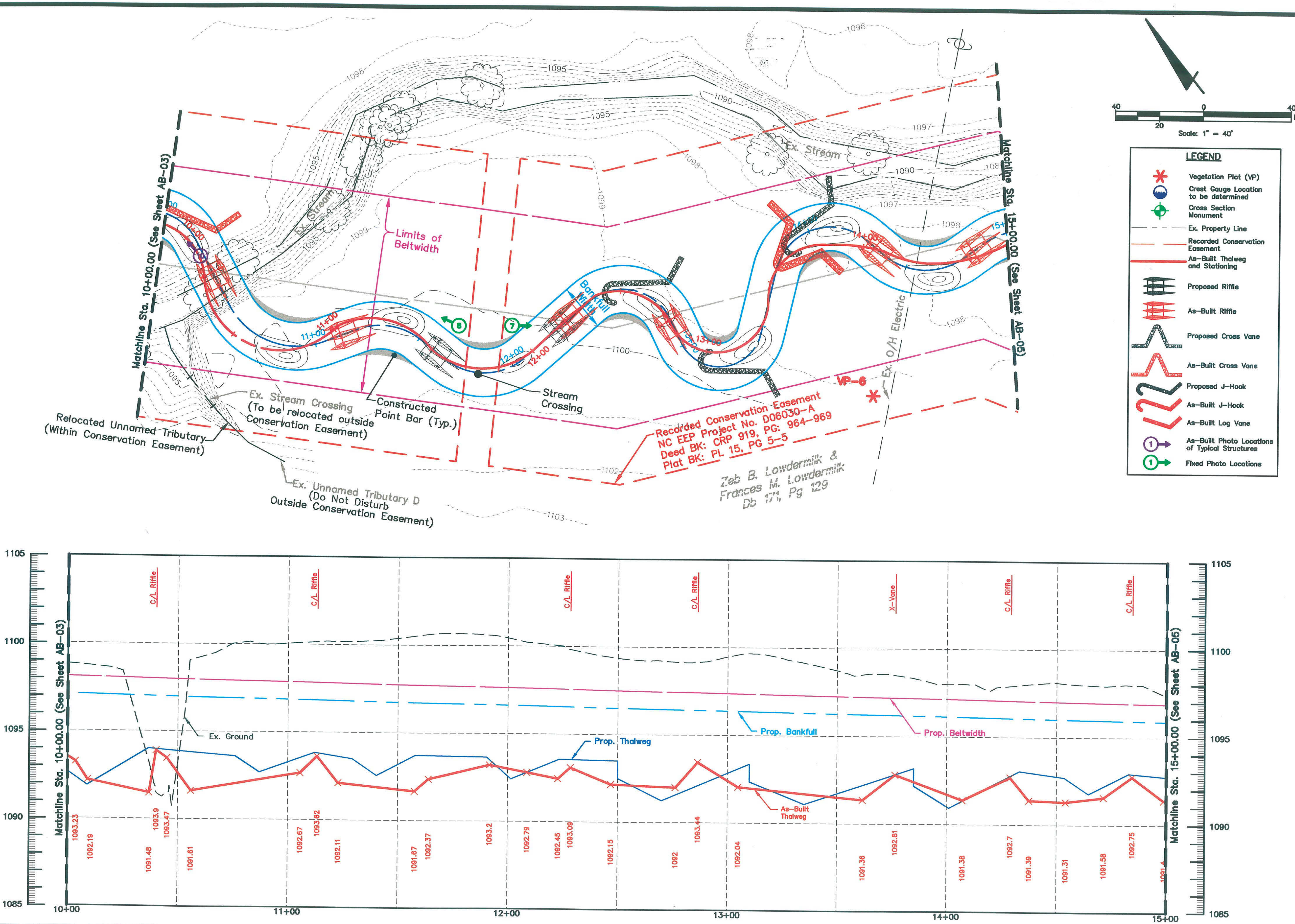

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STREAM AS-BUILT
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THOMPSONS FORK AND UNNAMED TRIBUTARY
THOMPSONS FORK CREEK
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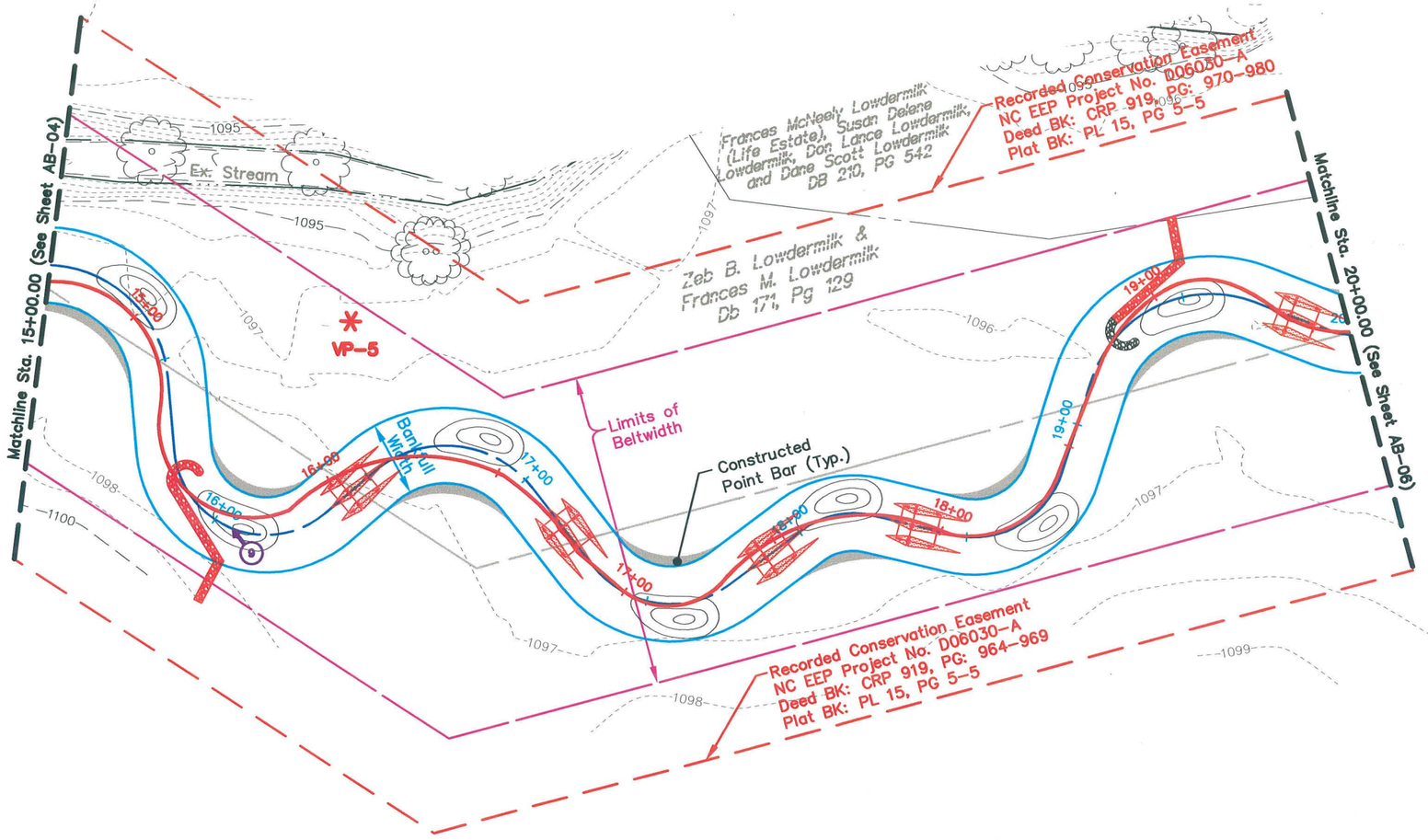
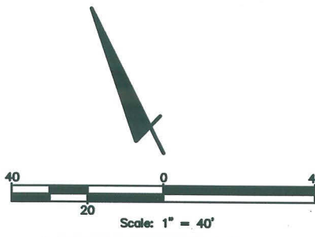
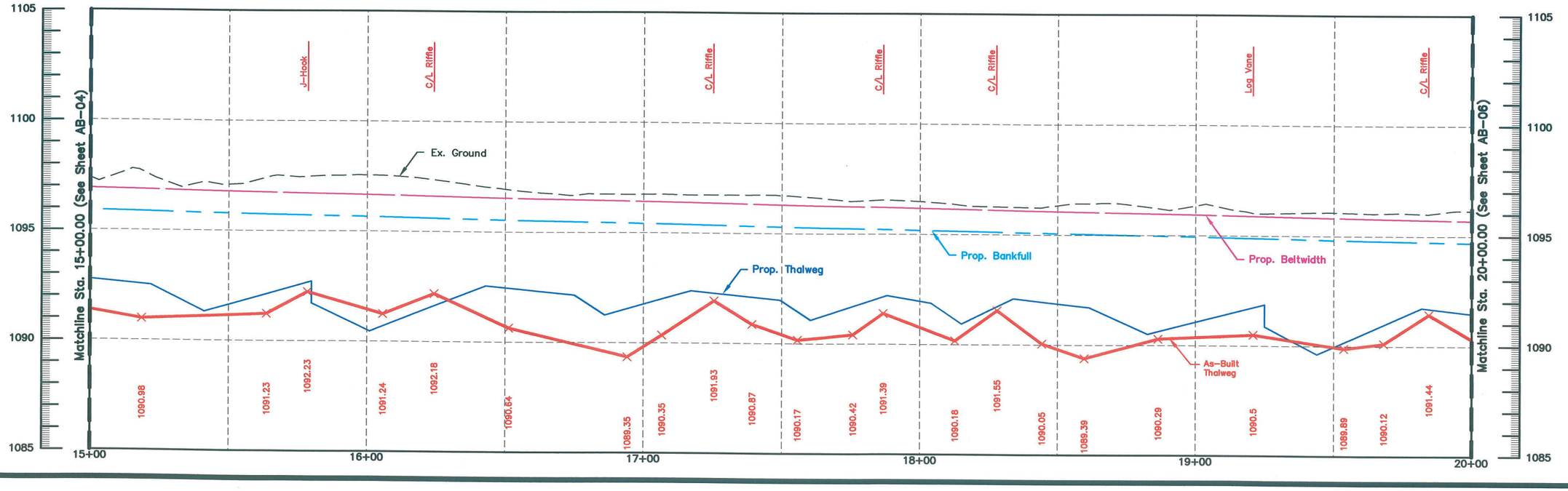




LEGEND

- Vegetation Plot (VP)
- Crest Gauge Location to be determined
- 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
- Proposed J-Hook
- As-Built J-Hook
- As-Built Log Vane
- As-Built Photo Locations of Typical Structures
- Fixed Photo Locations



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

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR

THOMPSONS FORK AND UNNAMED TRIBUTARY

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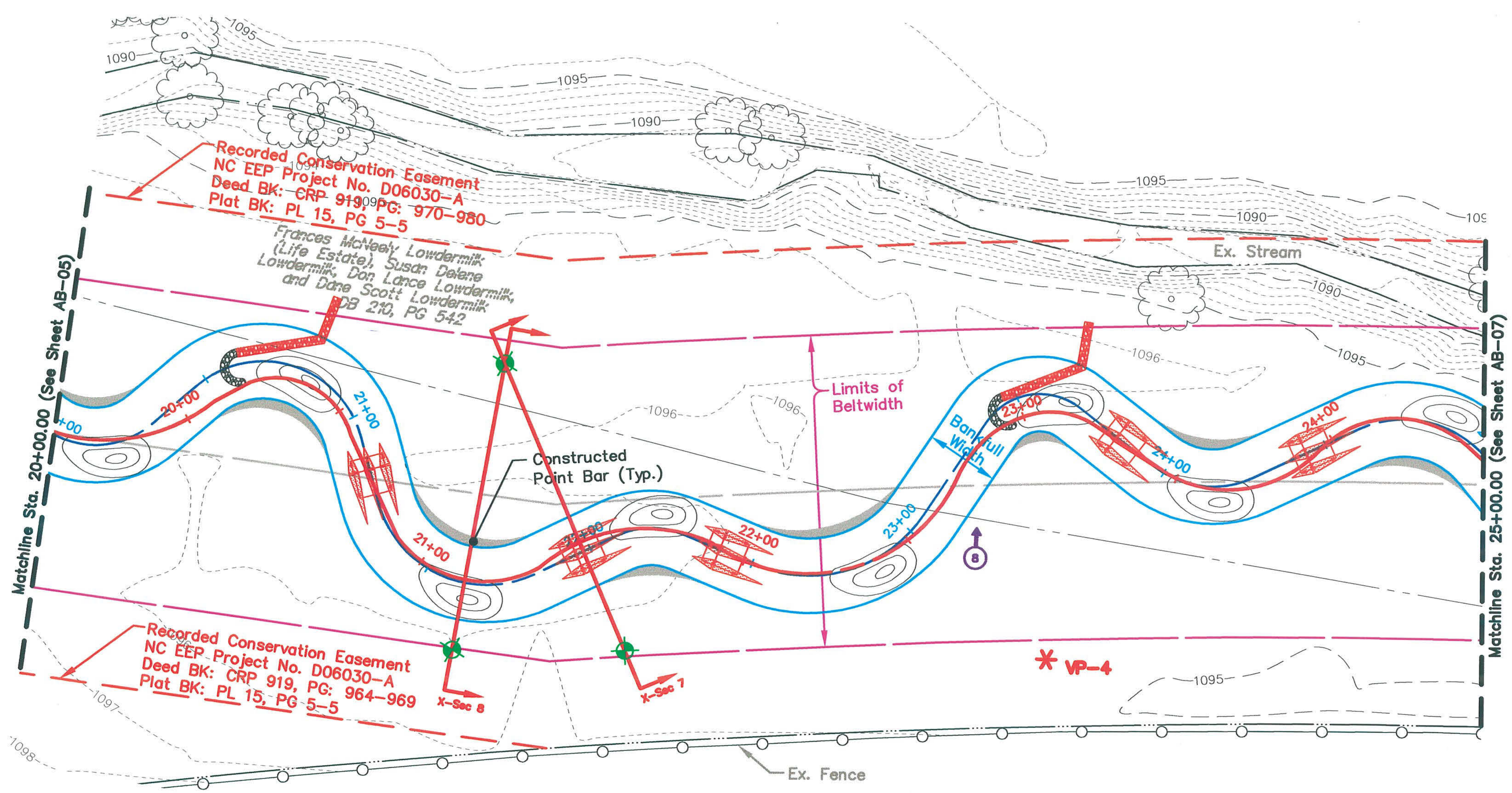

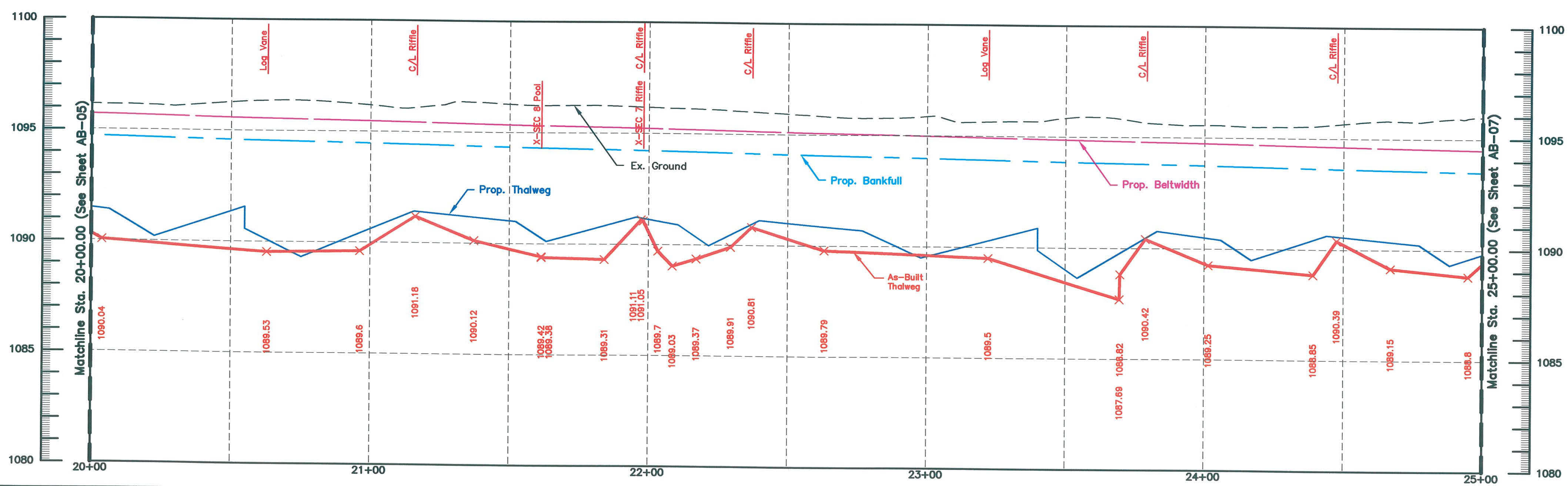

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Scale: 1" = 40'

LEGEND

- Vegetation Plot (VP)
- Crest Gauge Location to be determined
- 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
- Proposed J-Hook
- As-Built J-Hook
- As-Built Log Vane
- As-Built Photo Locations of Typical Structures
- Fixed Photo Locations

Job No. 2006-1398

Sheet AB-06/12

Date July, 2008

Scale Hor: 1" = 40' Ver: 1" = 5'

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
THOMPSONS FORK CREEK
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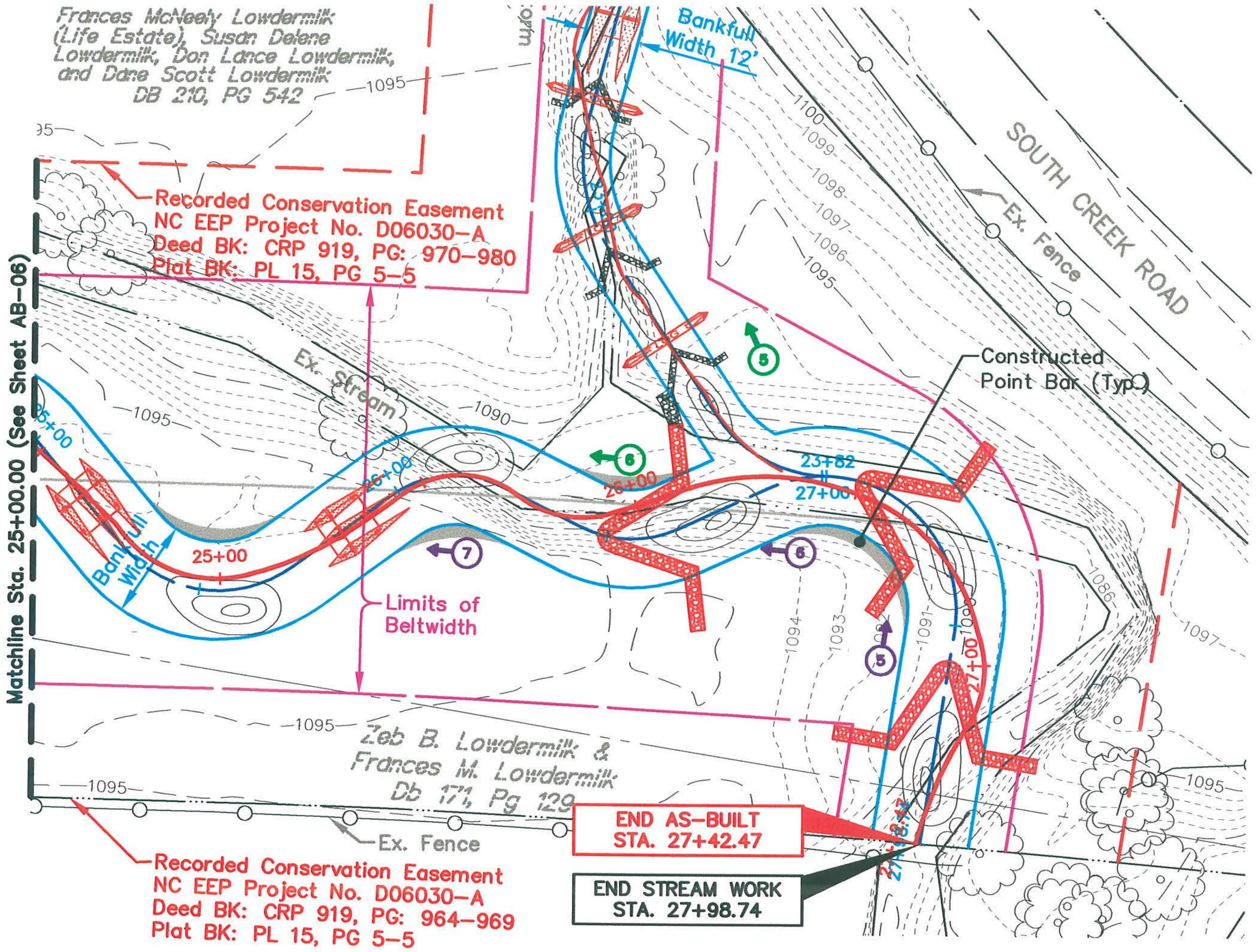

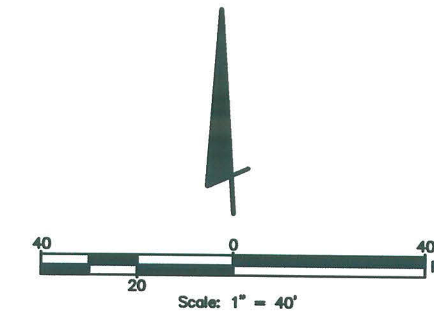

LEGEND

- Vegetation Plot (VP)
- Crest Gauge Location to be determined
- Cross Section Monument
- Ex. Property Line
- Recorded Conservation Easement
- As-Built Thalweg and Stationing
- Proposed Riffle
- As-Built Riffle
- Proposed Cross Vane
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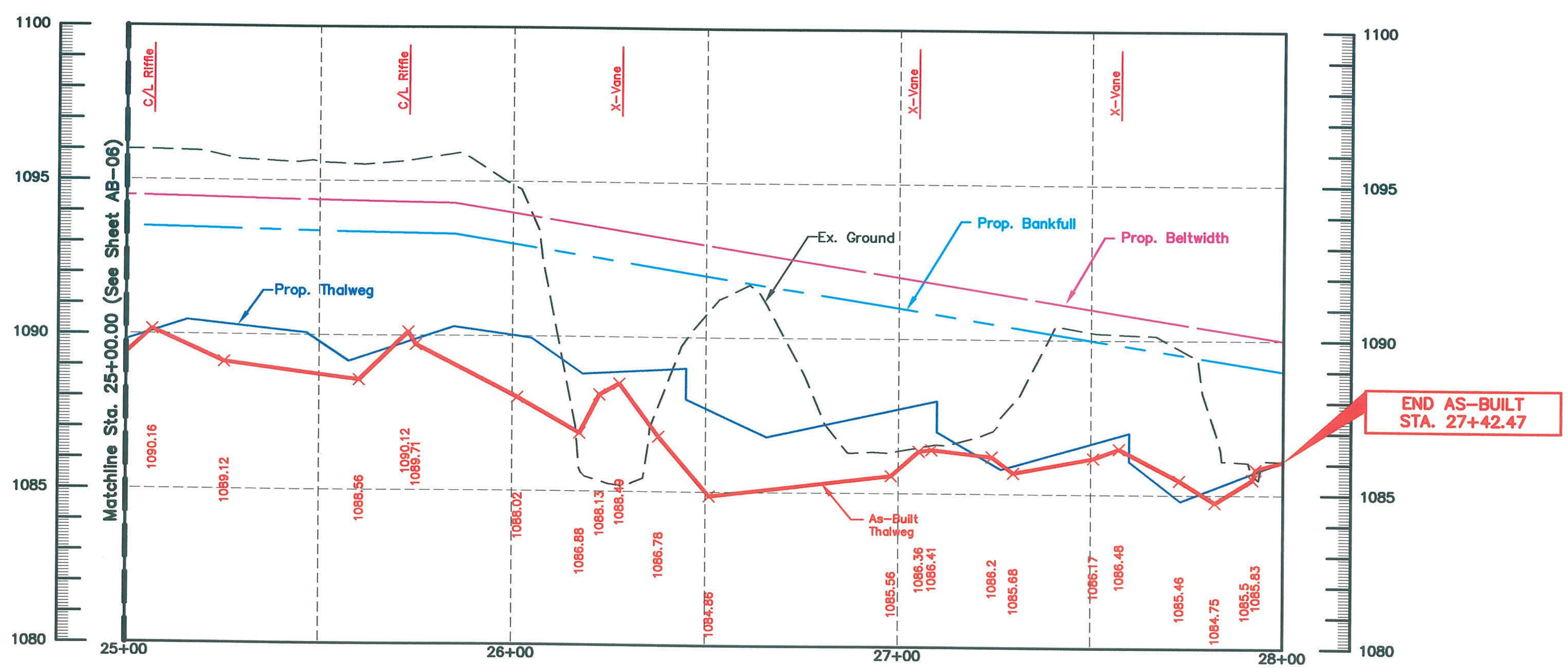

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
THOMPSONS FORK CREEK
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Job No.	2006-1398
Sheet	AB-07/12
Date	July, 2008
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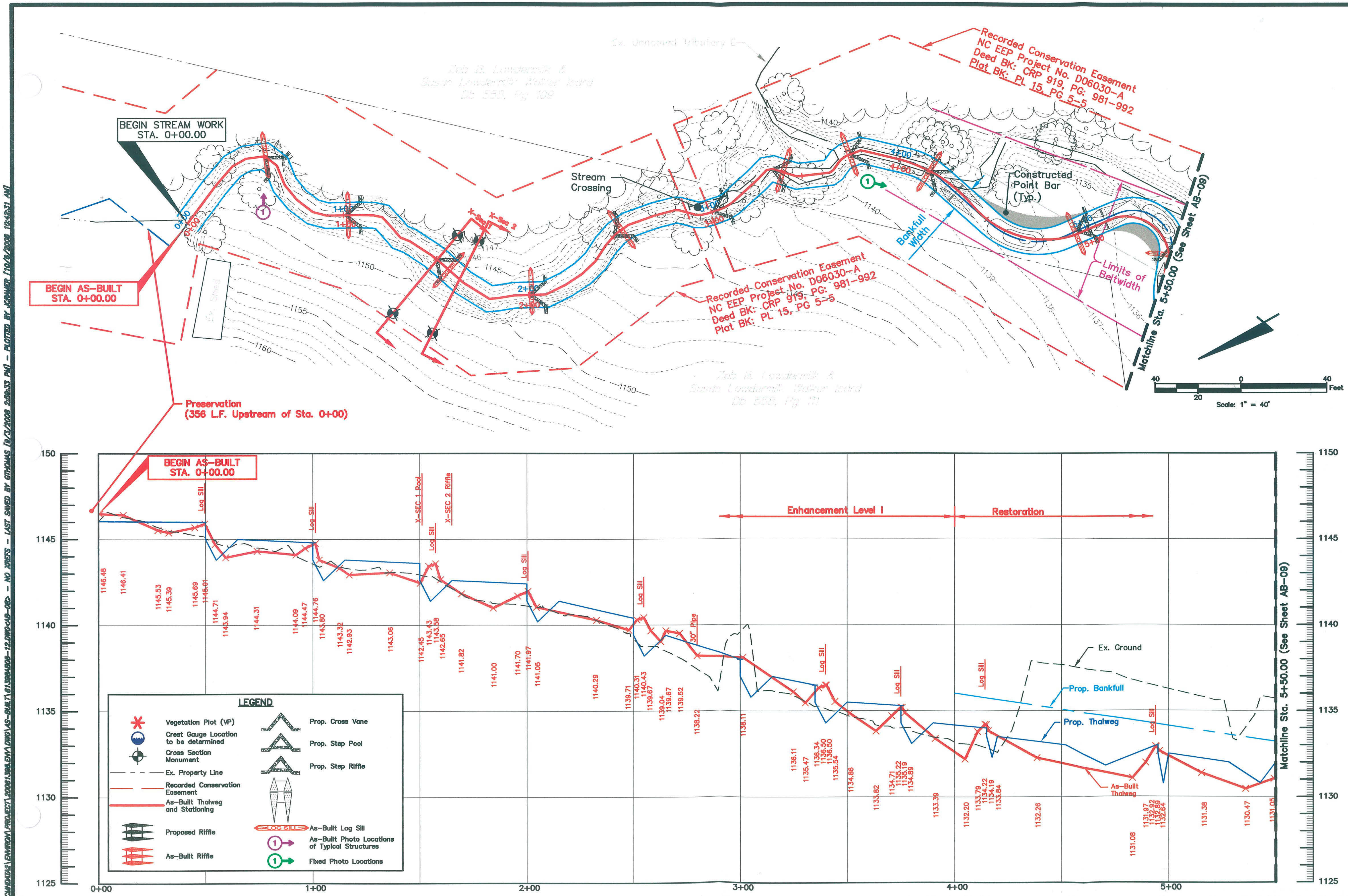

BEGIN STREAM WORK
STA. 0+00.00
BEGIN AS-BUILT
STA. 0+00.00
Stream Crossing
Constructed Point Bar (Typ.)
Bankfull Width
Limits of Beltwidth
Recorded Conservation Easement
NC EEP Project No. D06030-A
Deed BK: CRP 919, PG: 981-992
Plat BK: PL 15, PG 5-5
Preservation
(356 L.F. Upstream of Sta. 0+00)
Matchline Sta. 5+50.00 (See Sheet AB-09)
Scale: 1" = 40'
Enhancement Level I
Restoration
Ex. Ground
Prop. Bankfull
Prop. Thalweg
As-Built Thalweg
Log Sill
X-SEC 1 Pool
X-SEC 2 Riffle
30" Pipe
LEGEND
Vegetation Plot (VP)
Crest Gauge Location to be determined
Cross Section Monument
Ex. Property Line
Recorded Conservation Easement
As-Built Thalweg and Stationing
Proposed Riffle
As-Built Riffle
Prop. Cross Vane
Prop. Step Pool
Prop. Step Riffle
As-Built Log Sill
As-Built Photo Locations of Typical Structures
Fixed Photo Locations

Job No. 2006-1398

Sheet AB-08/12

Date October, 2008

Scale Hor: 1" = 40' Ver: 1" = 5'

MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
UNNAMED TRIBUTARY
PLAN & PROFILE

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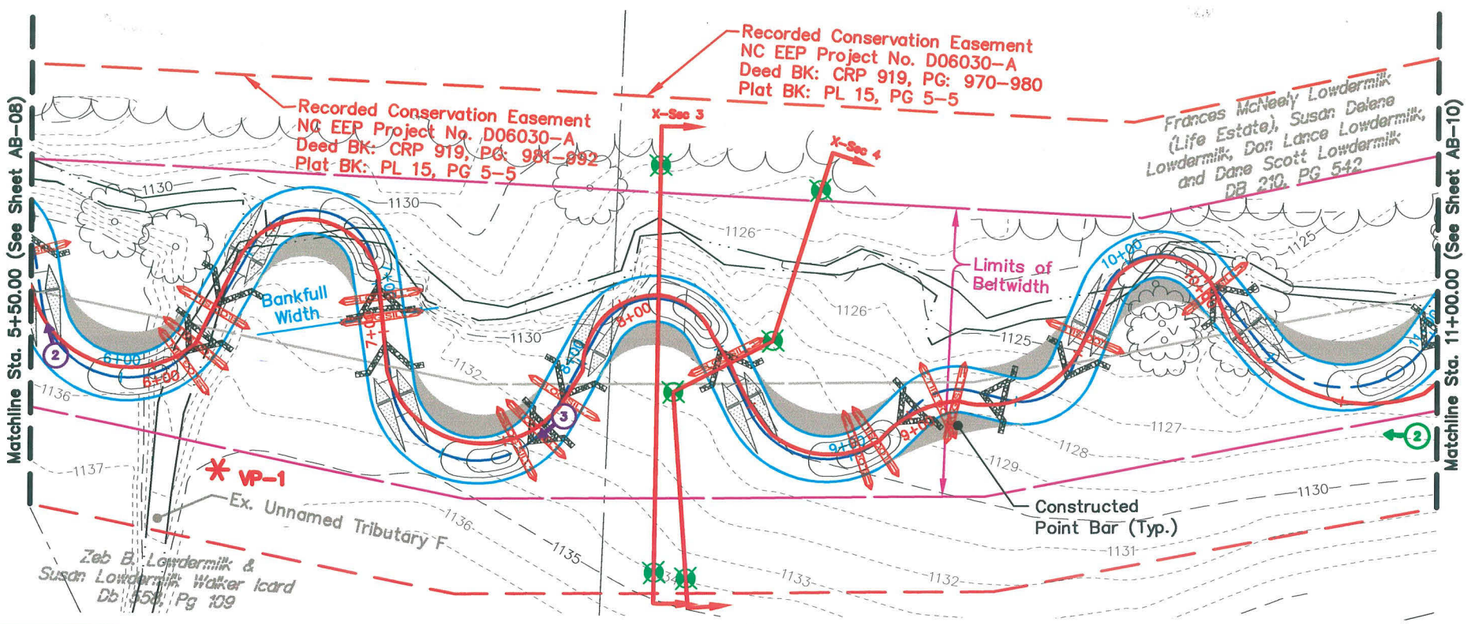
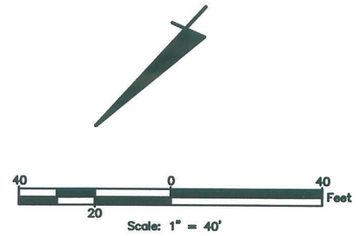
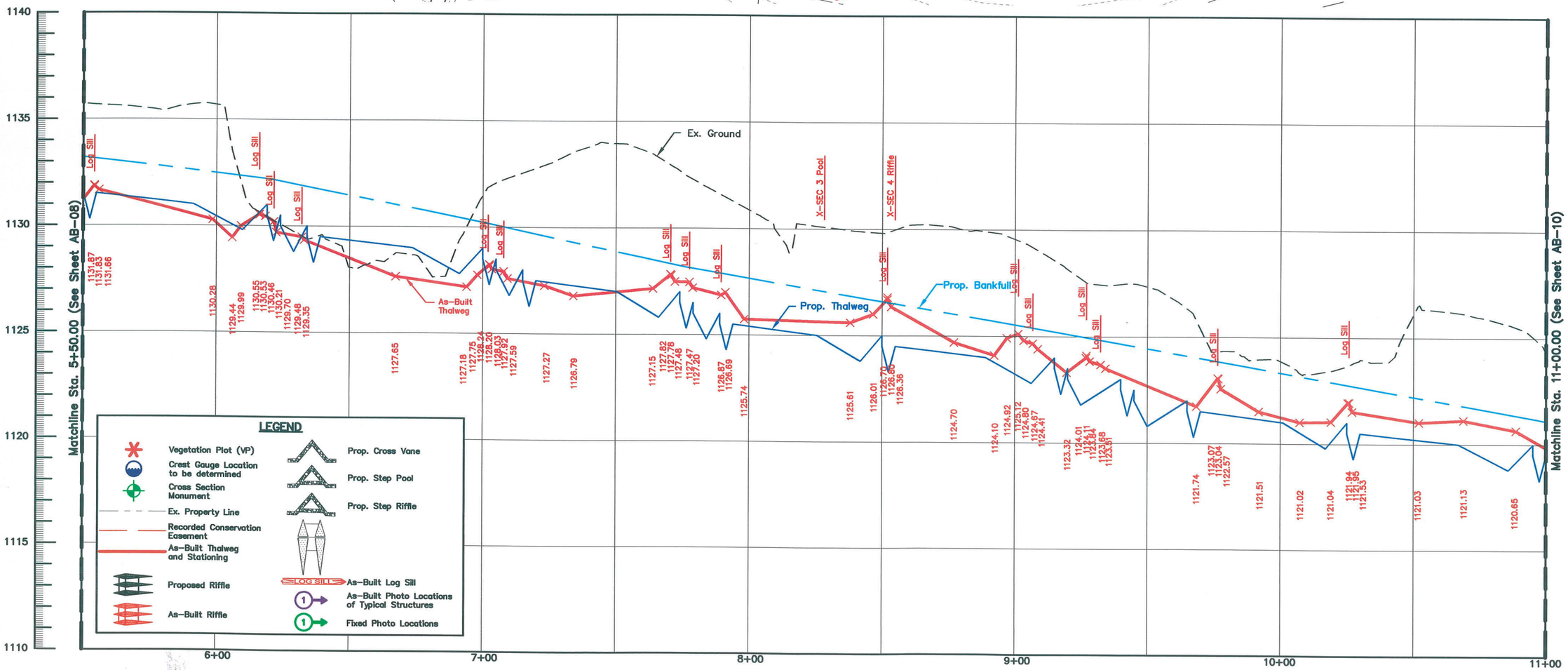
REVISIONS

MARK	DATE	DESCRIPTION







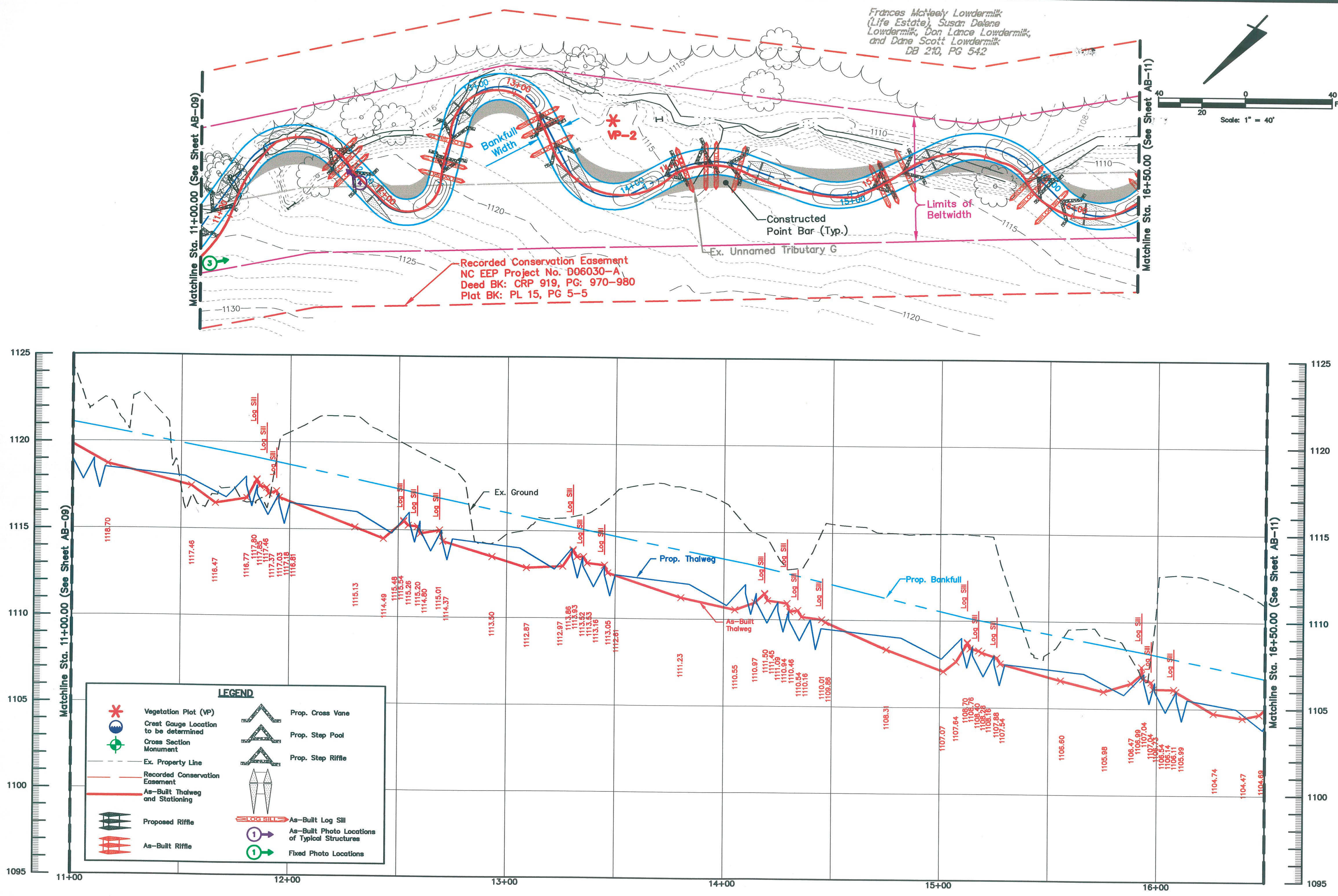
Job No.	2006-1398
Date	July, 2008
Scale	Hor: 1" = 40' Ver: 1" = 5'
Sheet	AB-09/12

McDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
UNNAMED TRIBUTARY
PLAN & PROFILE

Ecosystem Enhancement Program

EMH&T
Evans, Mechwart, Hambleton & Tilton, Inc.
Engineers Surveyors Planners Scientists
5500 New Albany Road, Columbus, OH 43054
Phone: 614.775.4500 Fax: 614.775.4800

MARK	DATE	DESCRIPTION
		REVISIONS



MCDOWELL COUNTY, NORTH CAROLINA
STREAM AS-BUILT
FOR
THOMPSONS FORK AND UNNAMED TRIBUTARY
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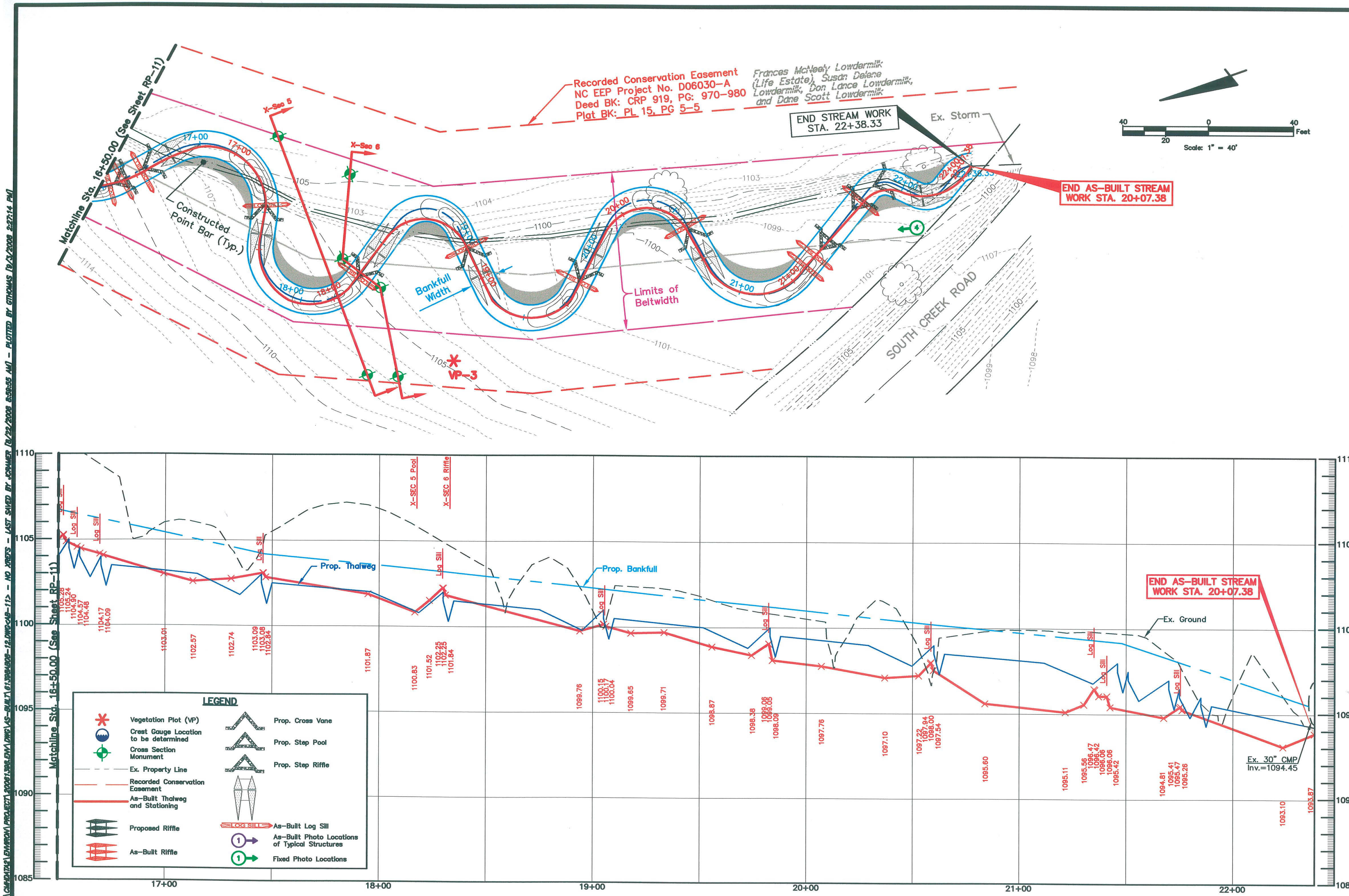
REVISIONS		
MARK	DATE	DESCRIPTION

Job No.	2006-1398
Date	July, 2008
Scale	Hor: 1" = 40' Ver: 1" = 5'
Sheet	AB-10/12



MCDOWELL COUNTY, NORTH CAROLINA
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Job No. 2006-1398
Date: July, 2008
Scale: Hor: 1" = 40' Ver: 1" = 5'
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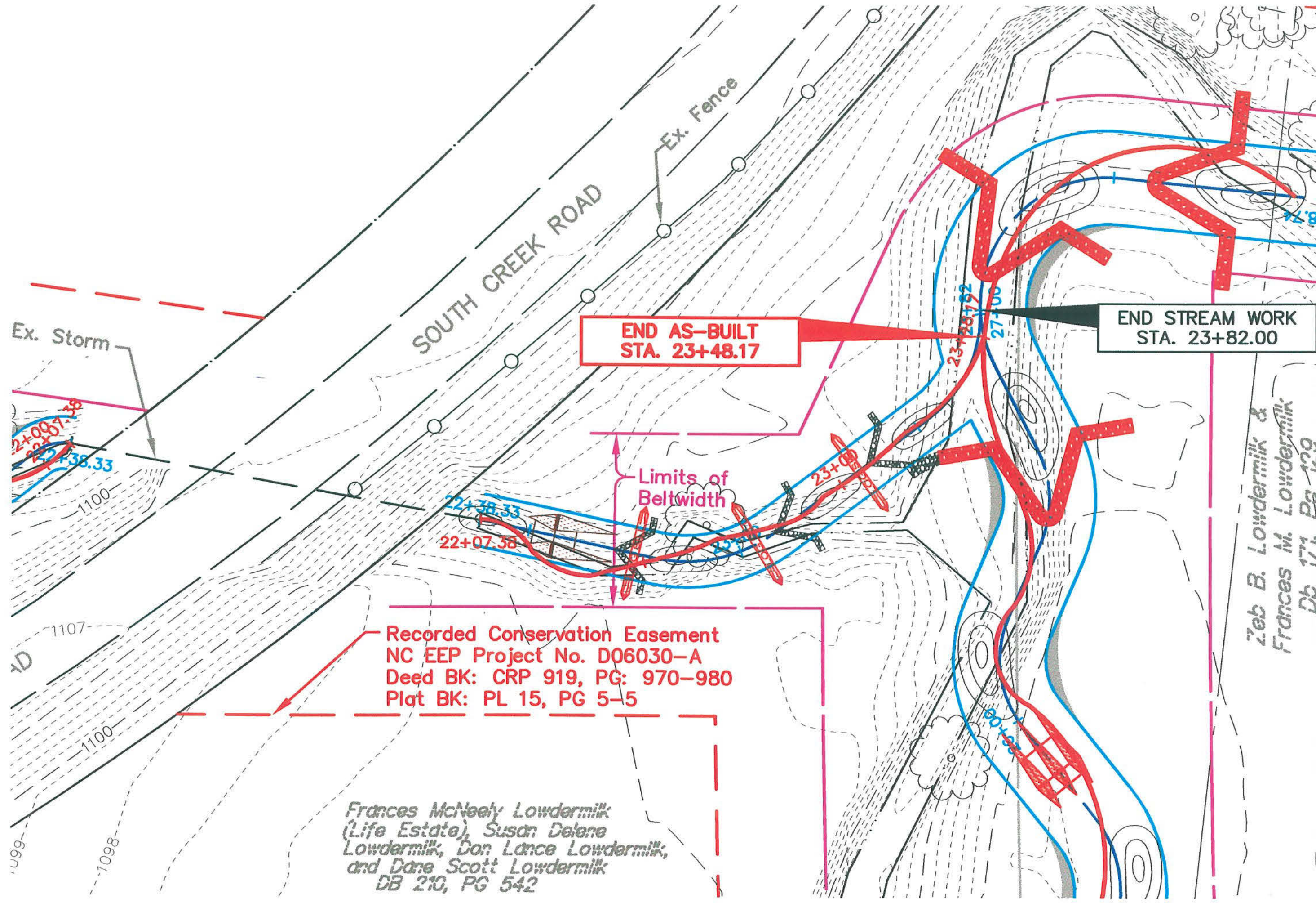
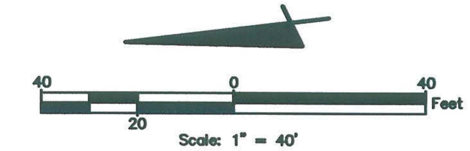
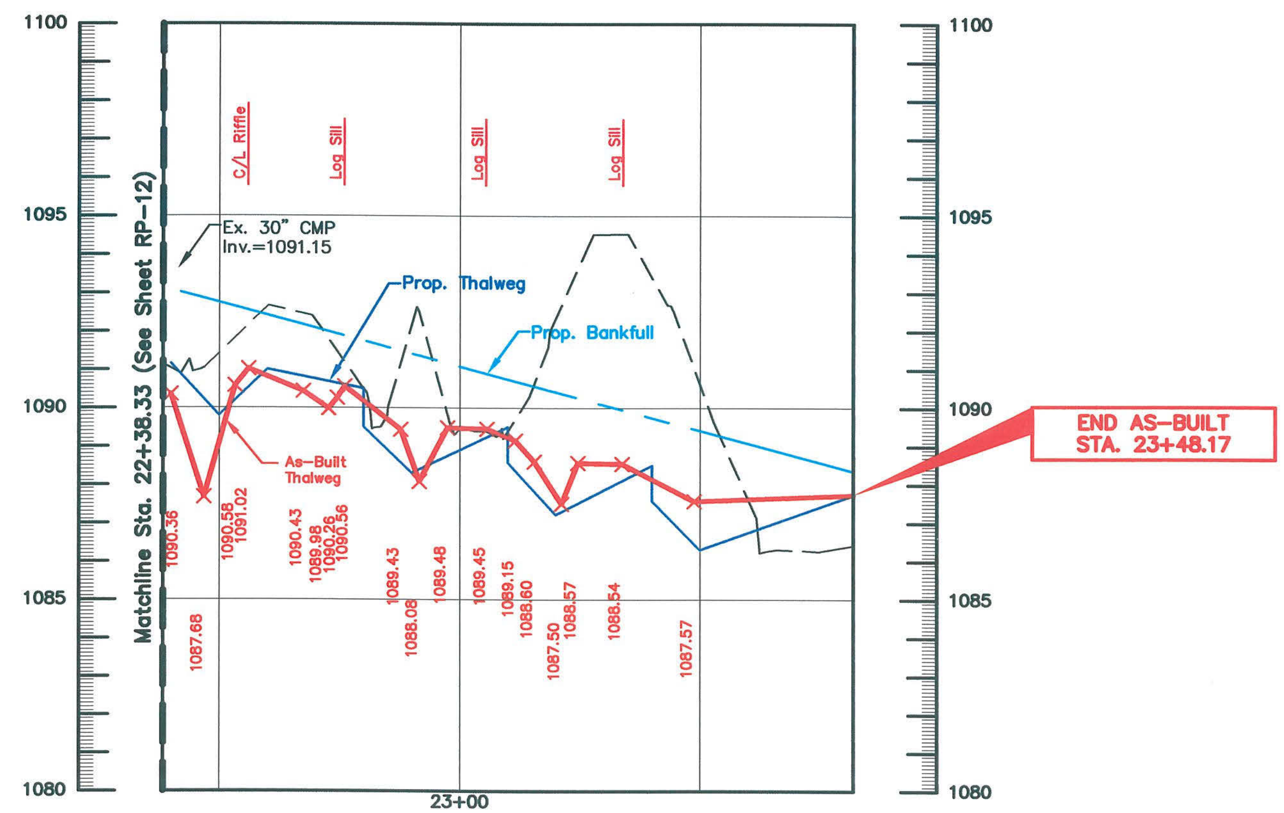
REVISIONS
MARK | DATE | DESCRIPTION



Recorded Conservation Easement
NC EEP Project No. D06030-A
Deed BK: CRP 919, PG: 964-969
Plat BK: PL 15, PG 5-5





LEGEND

Vegetation Plot (VP)	Prop. Cross Vane
Crest Gauge Location to be determined	Prop. Step Pool
Cross Section Monument	Prop. Step Riffle
Ex. Property Line	
Recorded Conservation Easement	
As-Built Thalweg and Stationing	
Proposed Riffle	As-Built Log Sill
	As-Built Photo Locations of Typical Structures
As-Built Riffle	Fixed Photo Locations

MCDOWELL COUNTY, NORTH CAROLINA
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Date	July, 2008
Job No.	2006-1398
Scale	Hor: 1" = 40' Ver: 1" = 5'
Sheet	AB-12/12

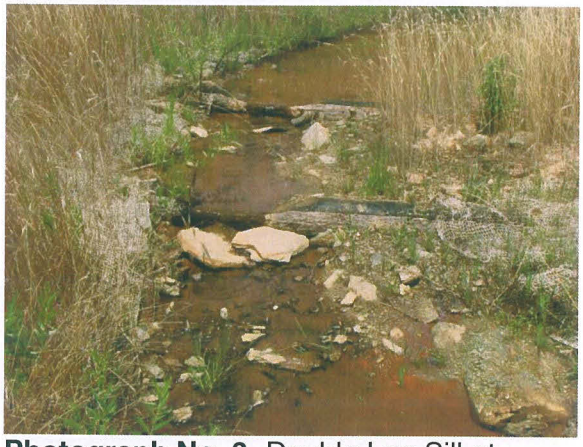
REVISIONS

MARK	DATE	DESCRIPTION

Appendix A
Thompsons Fork Mainstem and UT As-Built Photographic Documentation

Photograph No. 1- Single Log Sill at Station 0+50 on Unnamed Tributary, Looking Across Stream

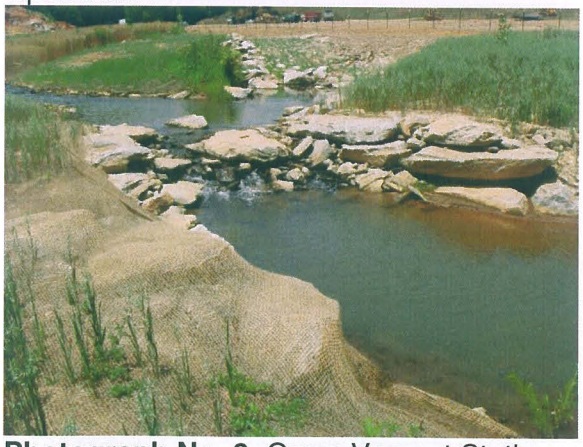
Photograph No. 2- Single Log Sill at Station 5+50 on Unnamed Tributary, Looking Upstream



Photograph No. 3- Double Log Sill at Station 7+74 on Unnamed Tributary, Looking Upstream

Photograph No. 4- Triple Log Sill at Station 11+95 on Unnamed Tributary, Looking Upstream

Photograph No.5- Cross Vane at Station 27+57 on Mainstem, Looking Upstream



Photograph No. 6- Cross Vane at Station 26+45 on Mainstem, Looking Upstream

Photograph No. 7- Riffle at Station 25+84 on Mainstem, Looking Upstream

Photograph No. 8- Log Vane at Station 23+40 on Mainstem, Looking Downstream

Photograph No. 9- J-Hook at Station 15+80 on Mainstem, Looking Upstream

Photograph No. 10- J-Hook at Station 9+95 on Mainstem, Looking Upstream

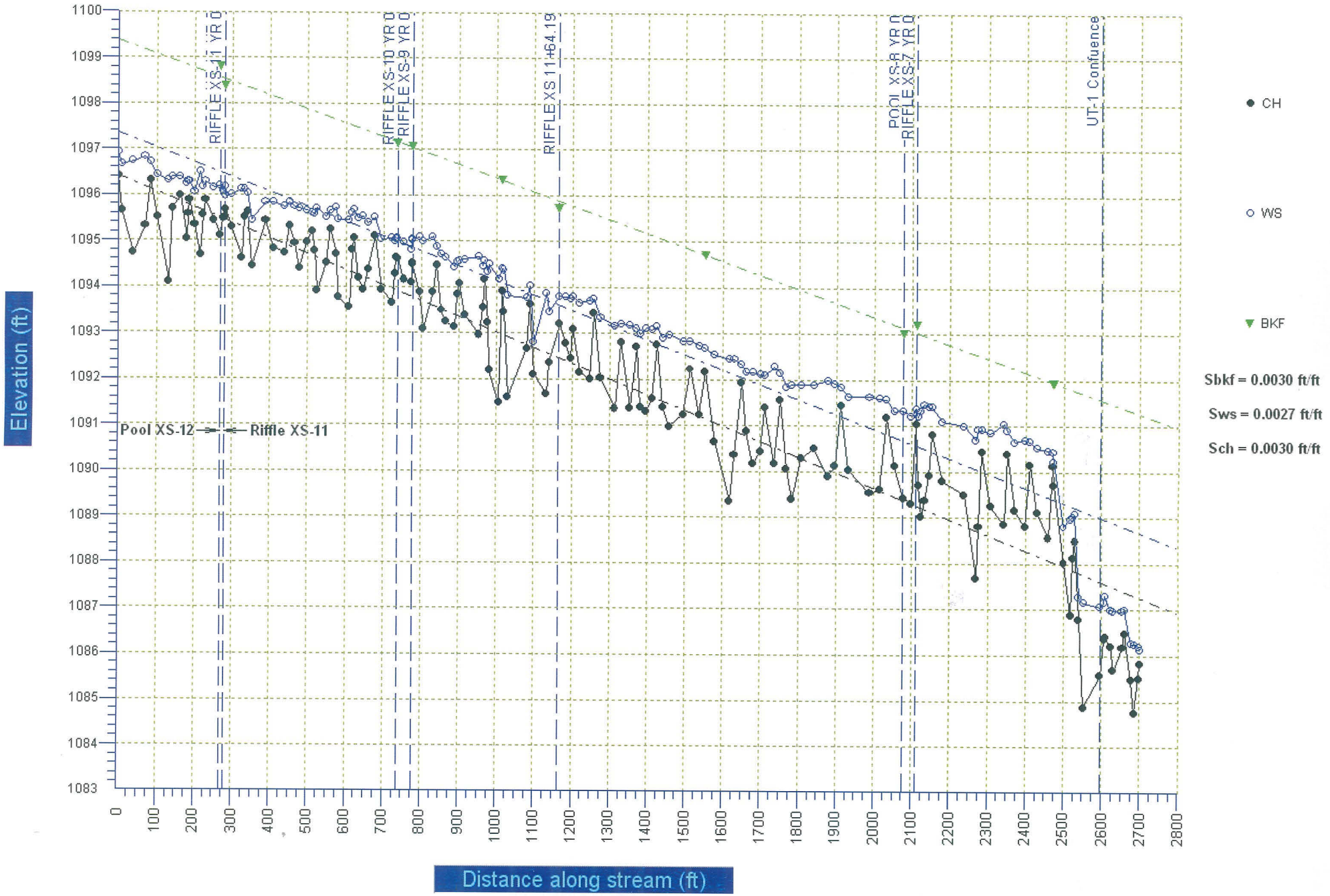
Photograph No. 11- Riffle at Station 6+80 on Mainstem, Looking Upstream

Photograph No. 12- Log Vane at Station 1+95 on Mainstem, Looking Upstream

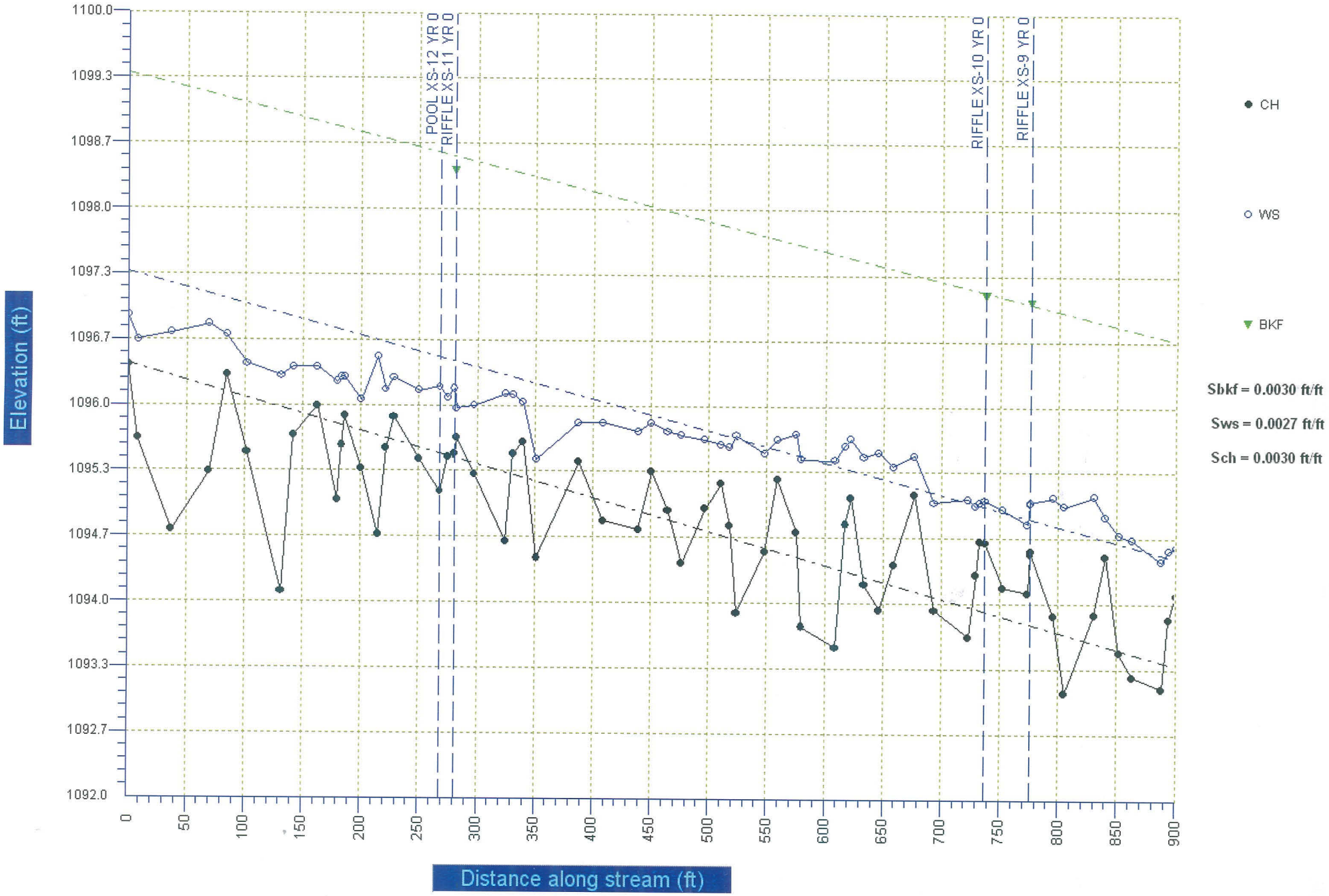
Appendix B

As-Built Long-Term Monitoring Profiles

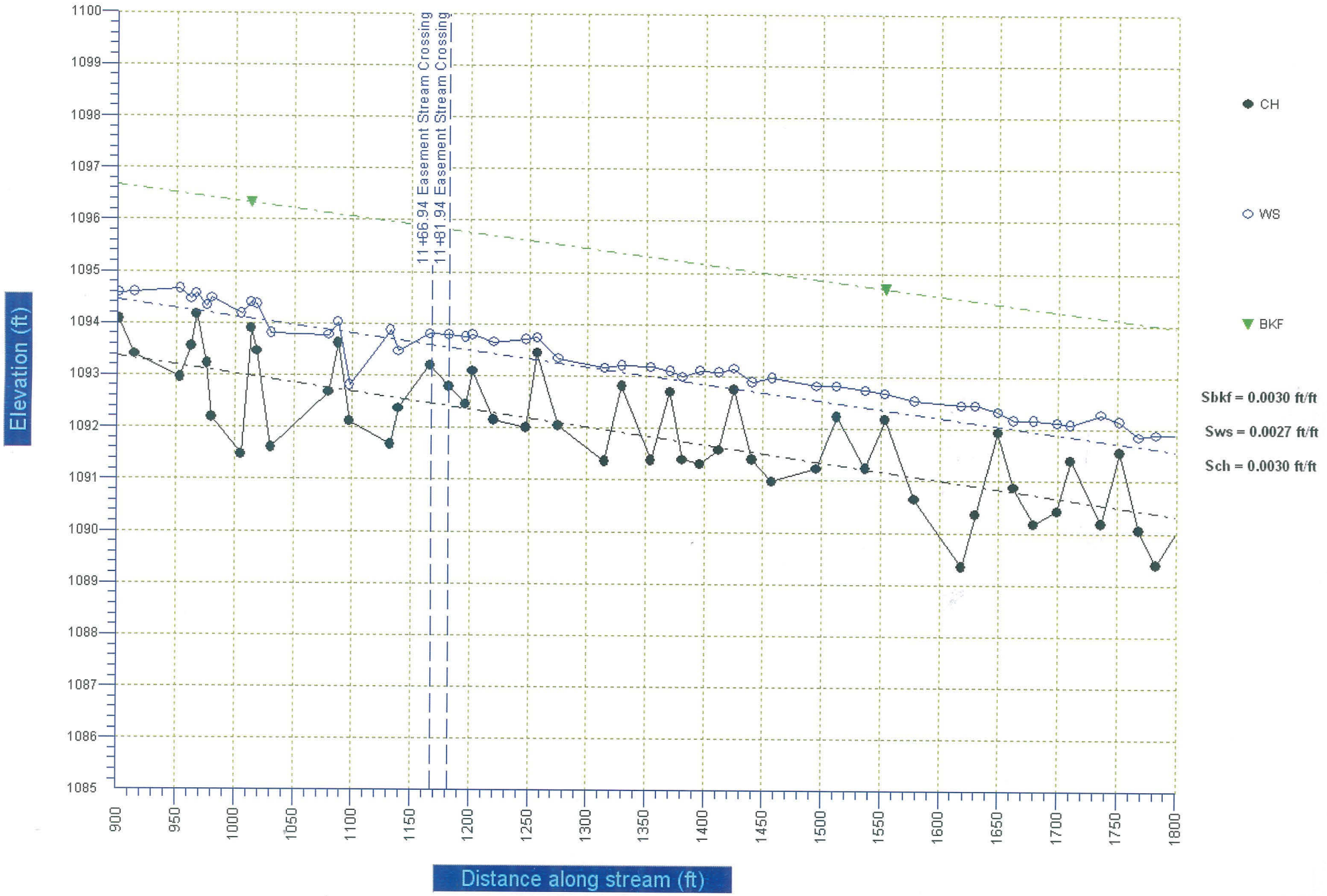
Thompsons Fork Mainstem Long Pro - YR 0 - 06/12/2008



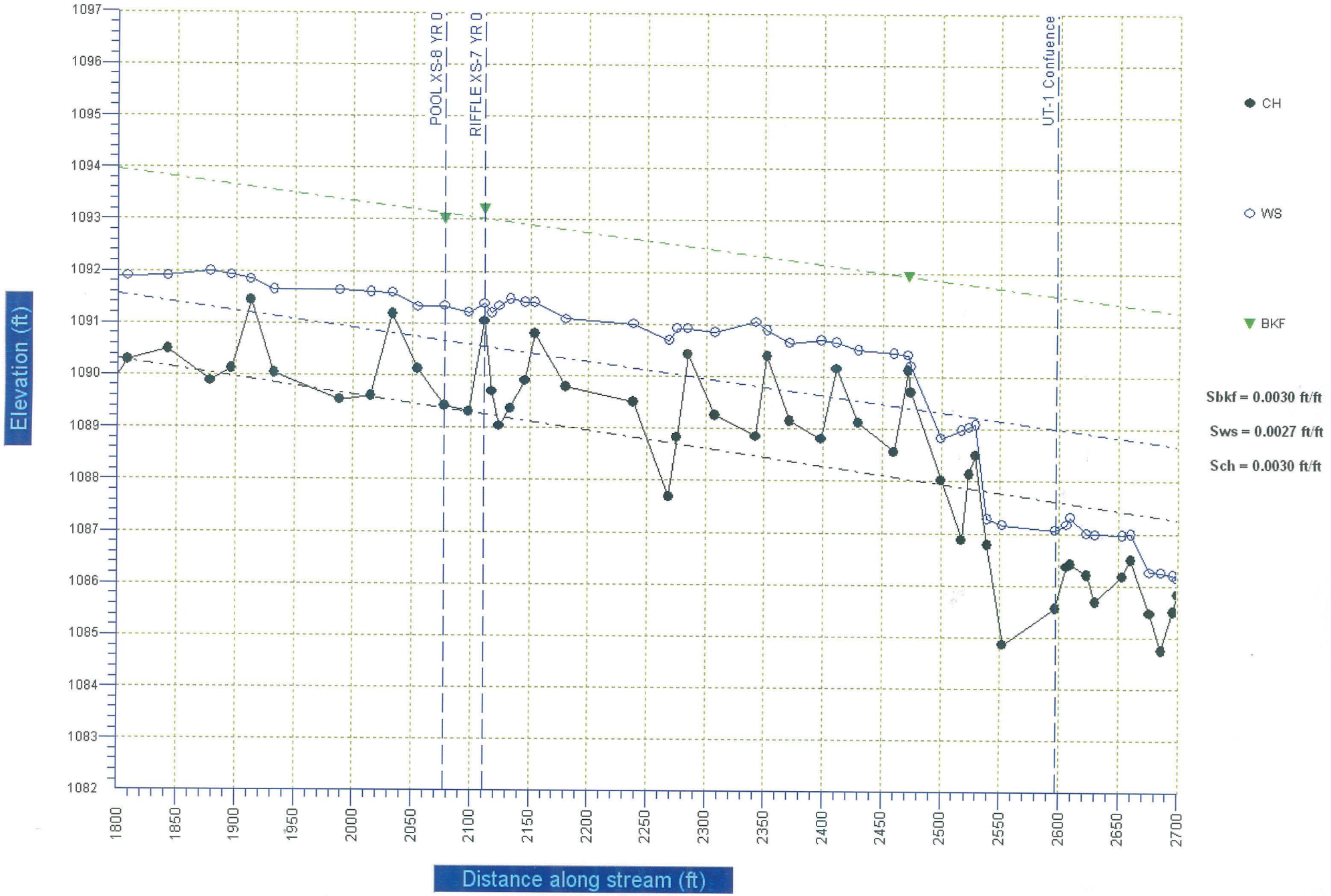
Thompsons Fork 'As-Built' Longitudinal Profile - Station 0+00 - 9+00 - Yr 0



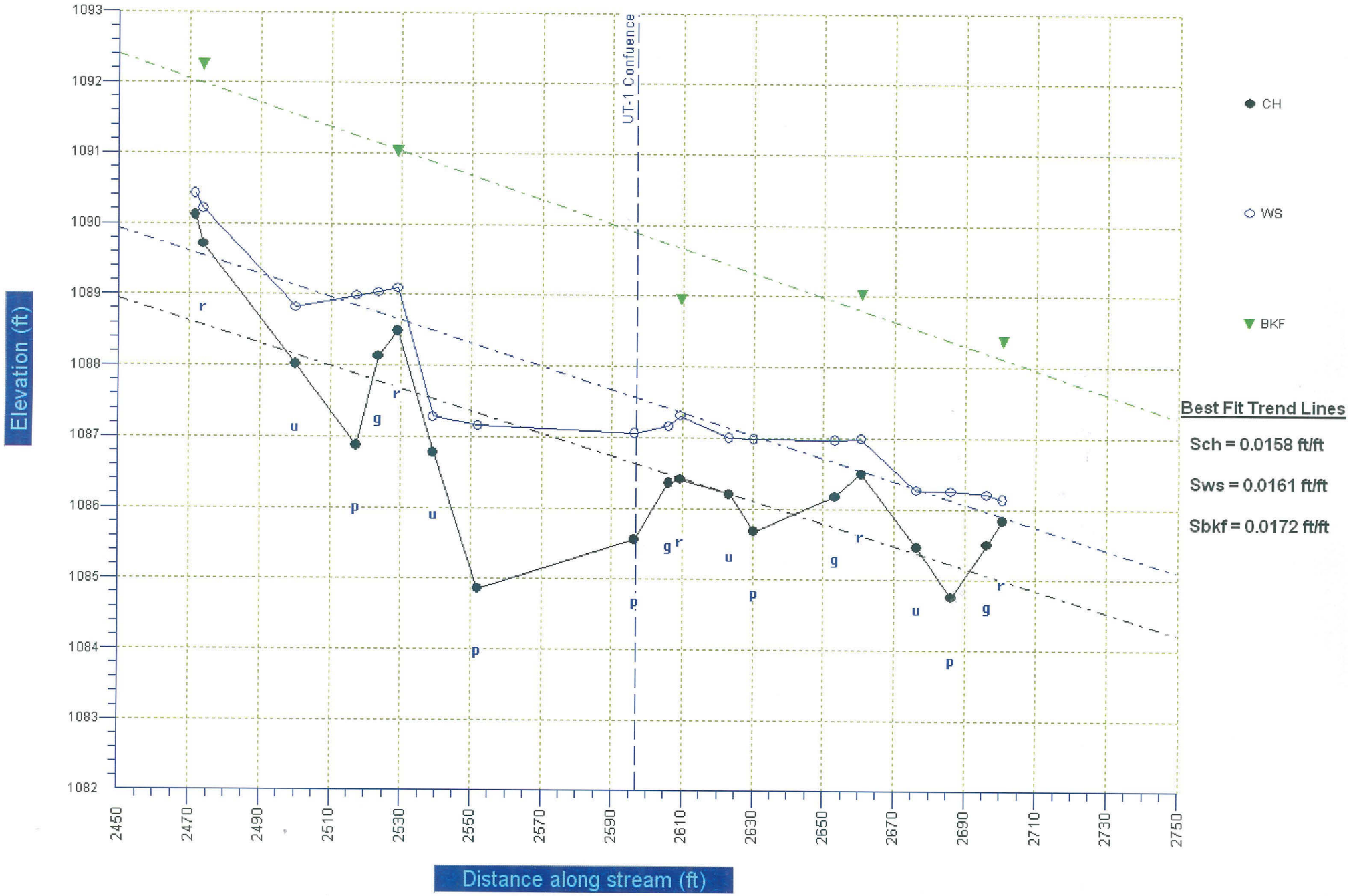
Thompsons Fork 'As-Built' Longitudinal Profle - Station 9+00 to 18+00 - Yr 0



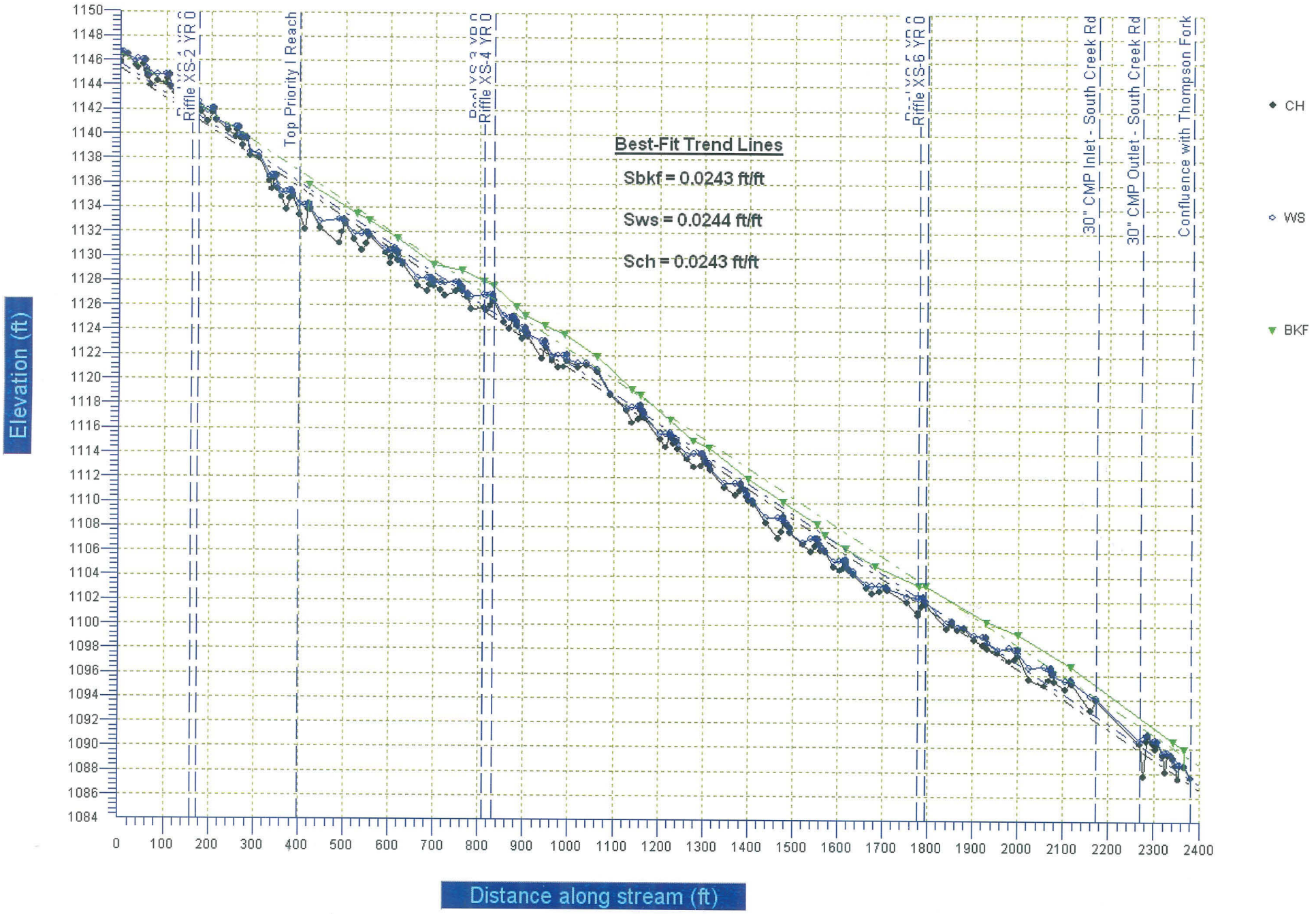
Thompsons Fork 'As-Built' Longitudinal Profile - Station 18+00 - 27+00



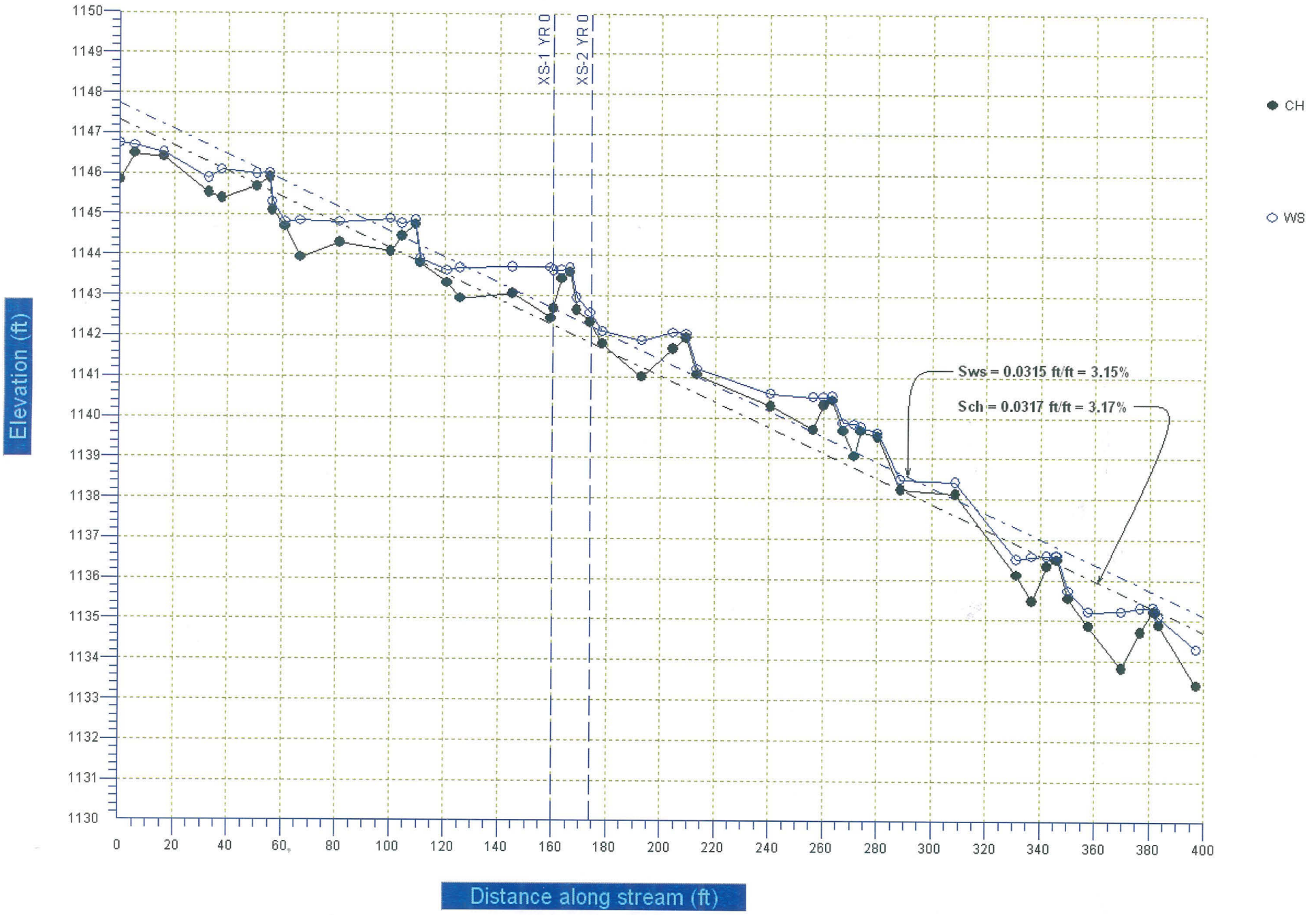
Thompsons Fork Mainstem -- Tie to Existing Thalweg - Bottom of Reach -- Yr 0



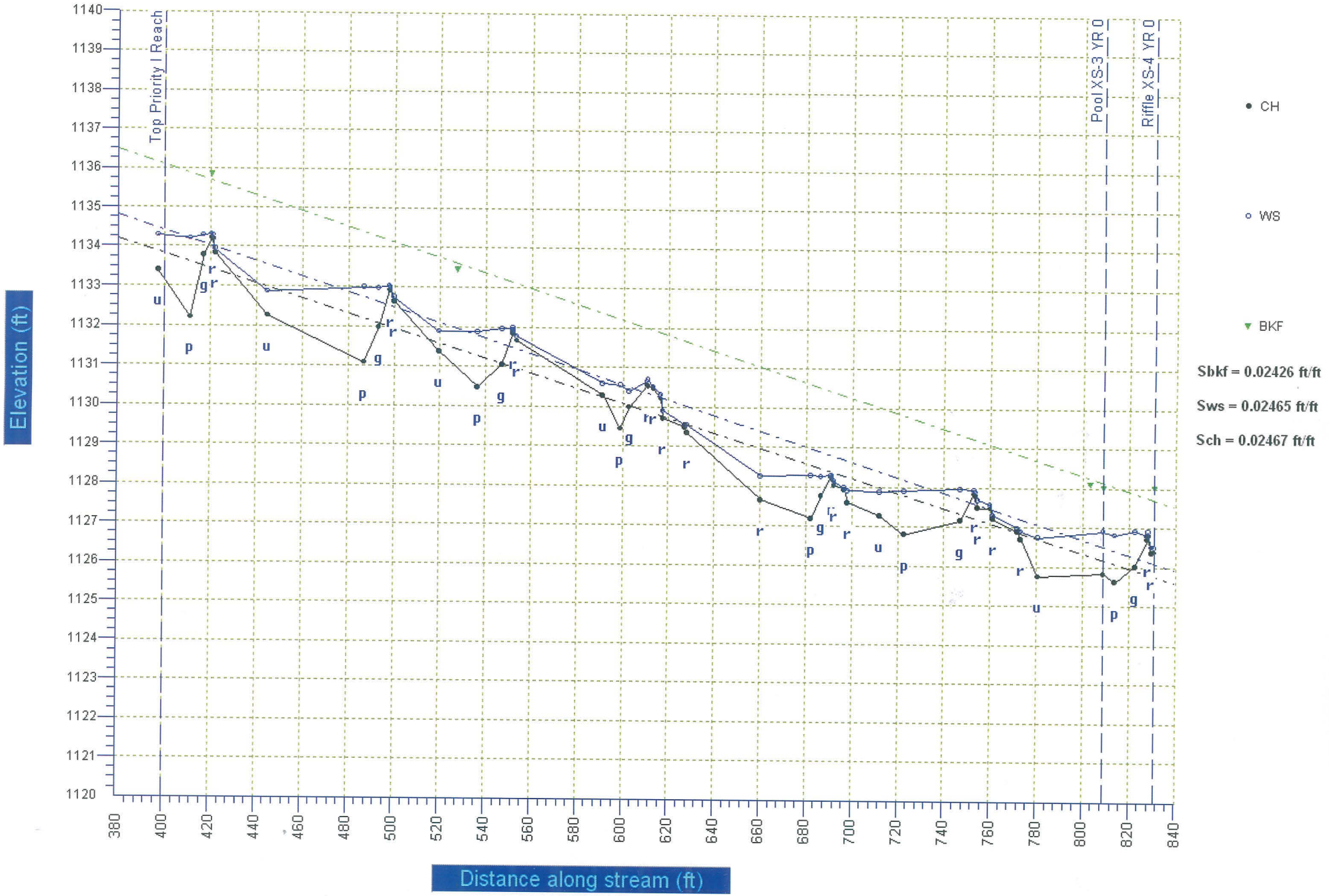
Thompsons Fork UT-1 "As-Built" Longitudinal Profile - 3/26/2008

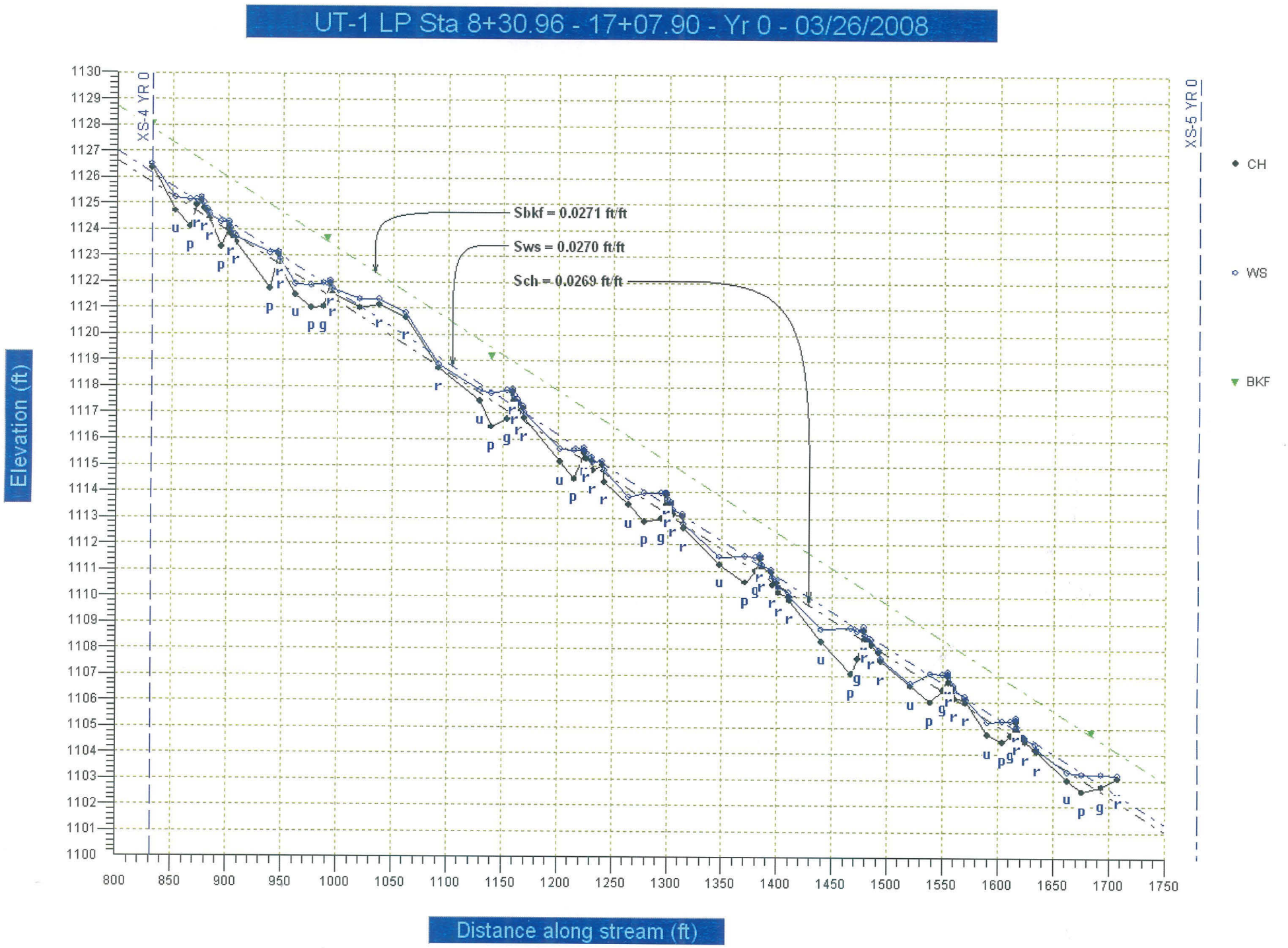


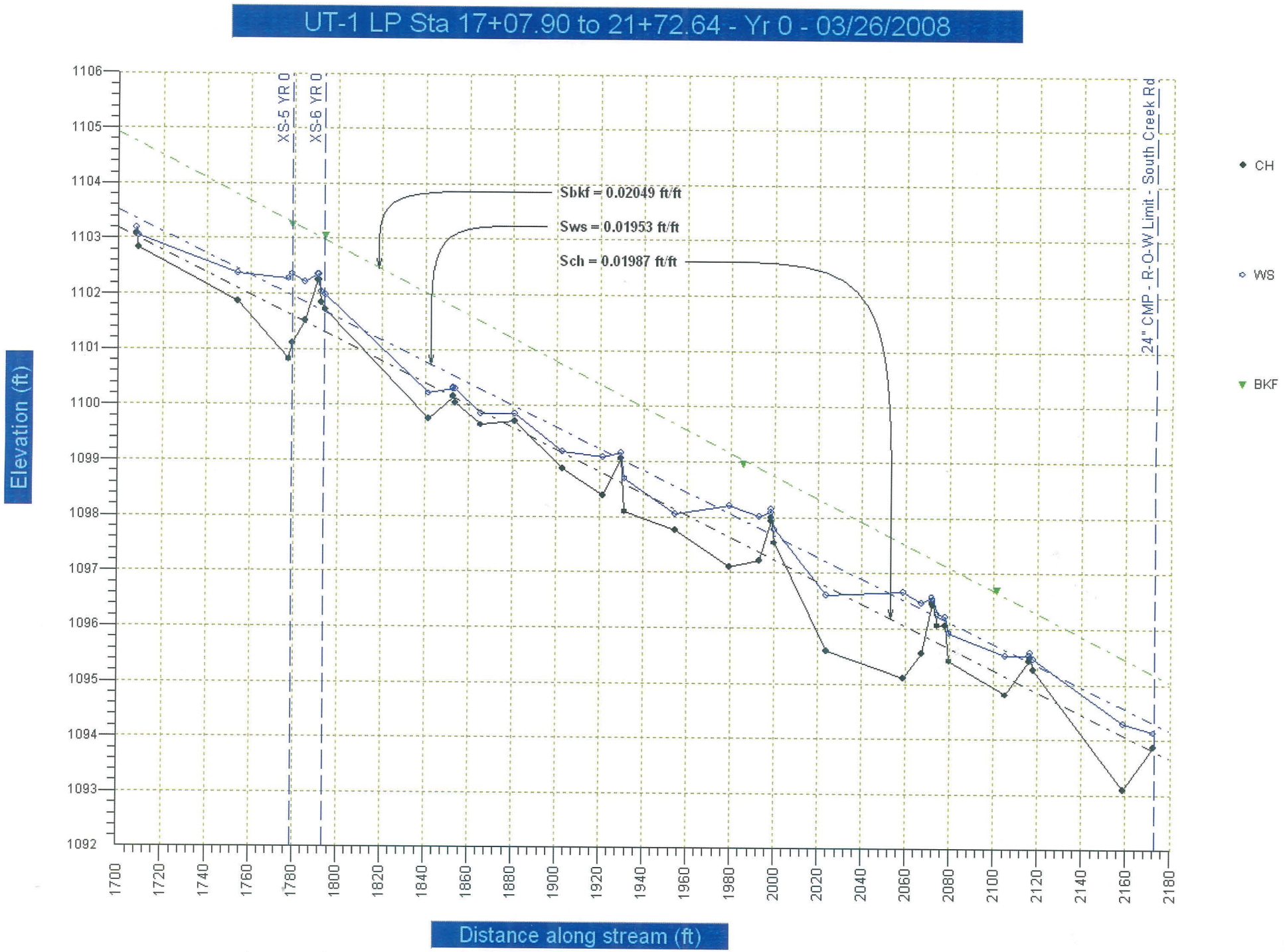
UT-1 - E2 Reach - Longitudinal Profile Sta. 0+00 to 3+97.22 - YR 0 - 03/26/08



UT Restoration Reach 3+97.22 - 8+30.96 - Yr 0 - 03/26/2008




UT-1 LP Sta 8+30.96 - 17+07.90 - Yr 0 - 03/26/2008
Elevation (ft)
Distance along stream (ft)
XS-4 YR 0
XS-5 YR 0
Sbkf = 0.0271 ft/ft
Sws = 0.0270 ft/ft
Sch = 0.0269 ft/ft
CH
WS
BKF
1130
1129
1128
1127
1126
1125
1124
1123
1122
1121
1120
1119
1118
1117
1116
1115
1114
1113
1112
1111
1110
1109
1108
1107
1106
1105
1104
1103
1102
1101
1100
800
850
900
950
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750


UT-1 LP Sta 17+07.90 to 21+72.64 - Yr 0 - 03/26/2008
Elevation (ft)
Distance along stream (ft)
XS-5 YR 0
XS-6 YR 0
24" CMP - R-O-W Limit - South Creek Rd
Sbkf = 0.02049 ft/ft
Sws = 0.01953 ft/ft
Sch = 0.01987 ft/ft
CH
WS
BKF
1106
1105
1104
1103
1102
1101
1100
1099
1098
1097
1096
1095
1094
1093
1092
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180

Appendix C

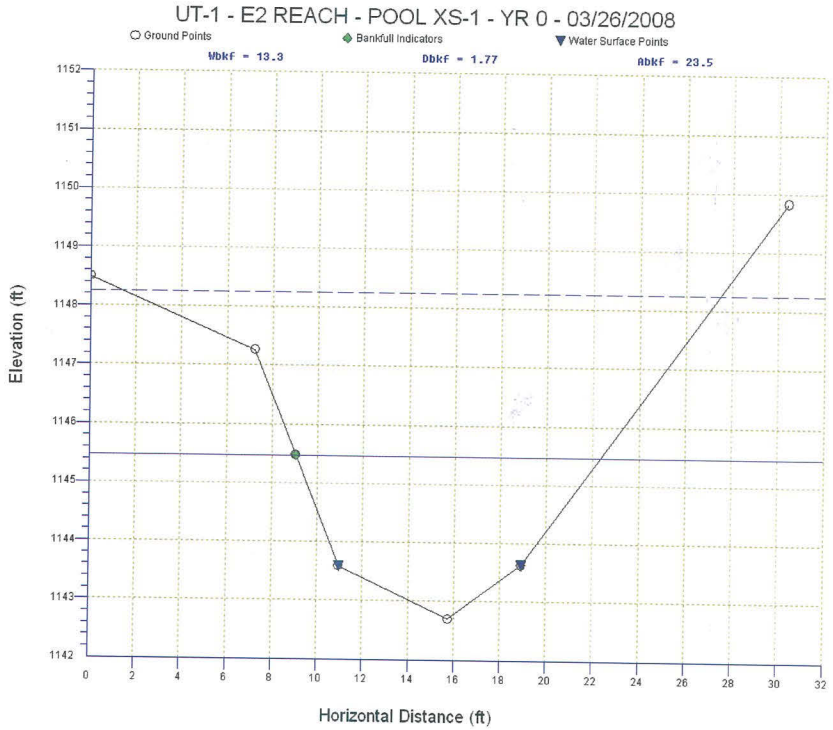
As-Built Long-Term Monitoring Cross-Section Summary Templates

Summary Data
All dimensions in feet.

Bankfull Area	23.51 ft^2
Bankfull Width	13.31 ft
Mean Depth	1.77 ft
Maximum Depth	2.78 ft
Width/Depth Ratio	7.52
Entrenchment Ratio	1.96
Classification	B

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	1
FEATURE:	Pool

Cross-section photo – looking upstream

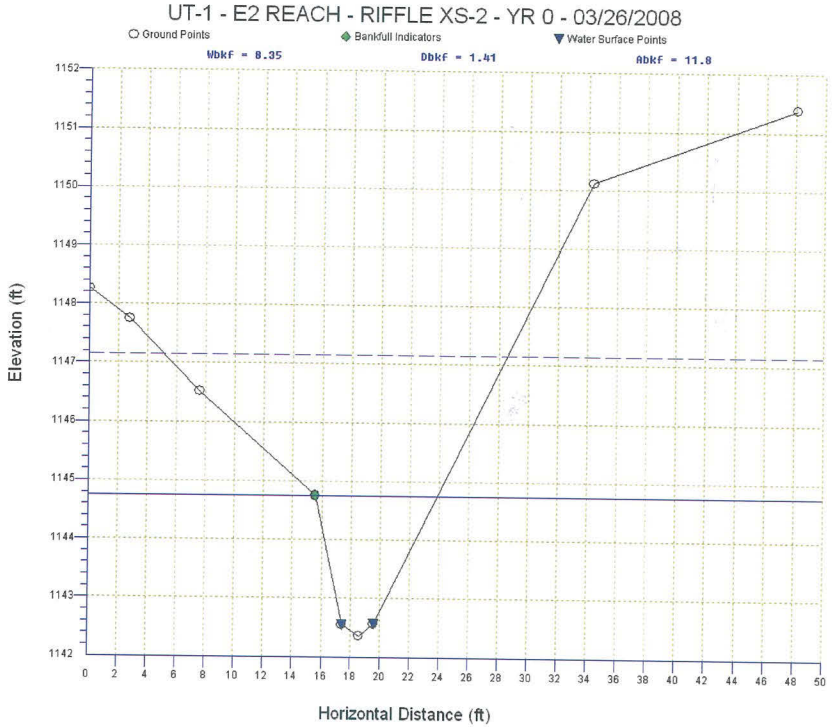


Summary Data
All dimensions in feet.

Bankfull Area	11.78 ft^2
Bankfull Width	8.35 ft
Mean Depth	1.41 ft
Maximum Depth	2.4 ft
Width/Depth Ratio	5.92
Entrenchment Ratio	2.81
Classification	E

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	2
FEATURE:	Riffle

Cross-section photo – looking upstream

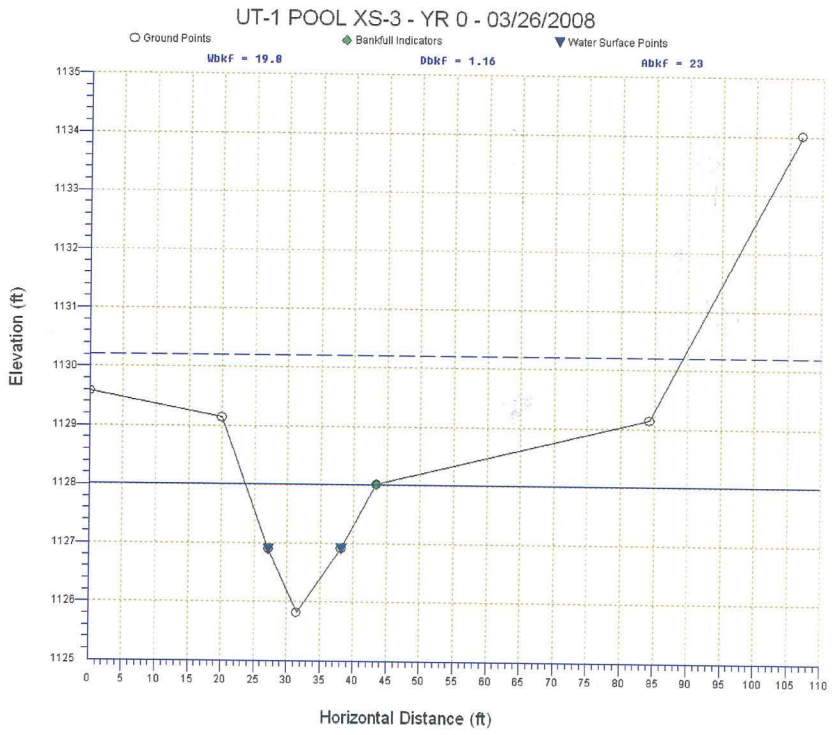


Summary Data
All dimensions in feet.

Bankfull Area	23.03 ft^2
Bankfull Width	19.78 ft
Mean Depth	1.16 ft
Maximum Depth	2.2 ft
Width/Depth Ratio	17.05
Entrenchment Ratio	4.51
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	3
FEATURE:	Pool

Cross-section photo – looking downstream

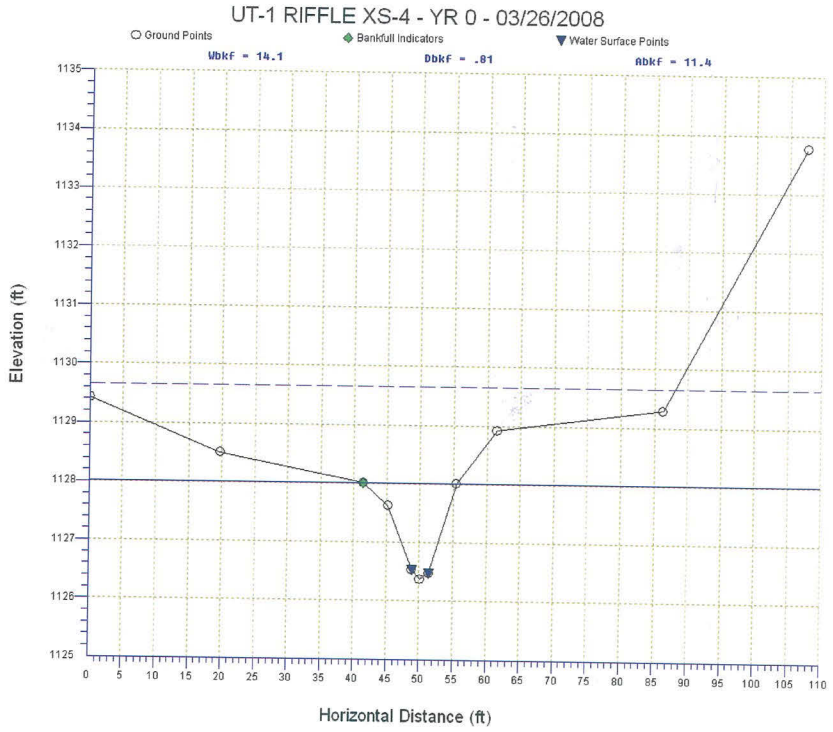


Summary Data
All dimensions in feet.

Bankfull Area	11.37 ft^2
Bankfull Width	14.08 ft
Mean Depth	0.81 ft
Maximum Depth	1.64 ft
Width/Depth Ratio	17.38
Entrenchment Ratio	6.26
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	4
FEATURE:	Riffle

Cross-section photo – looking downstream



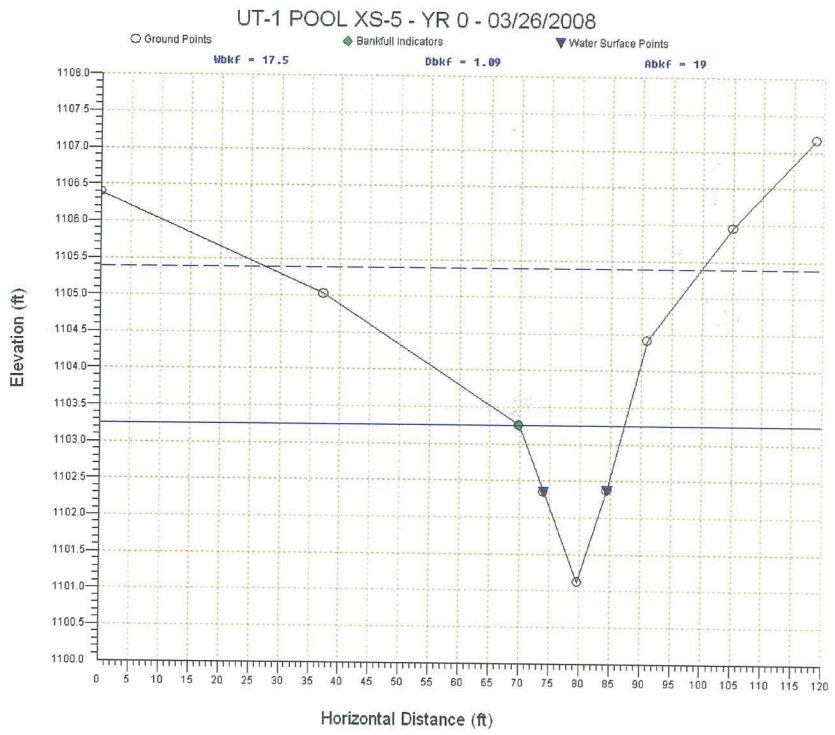
EMH&T

Summary Data
All dimensions in feet.

Bankfull Area	19 ft^2
Bankfull Width	17.47 ft
Mean Depth	1.09 ft
Maximum Depth	2.14 ft
Width/Depth Ratio	16.03
Entrenchment Ratio	4.17
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	5
FEATURE:	Pool

Cross-section photo – looking downstream

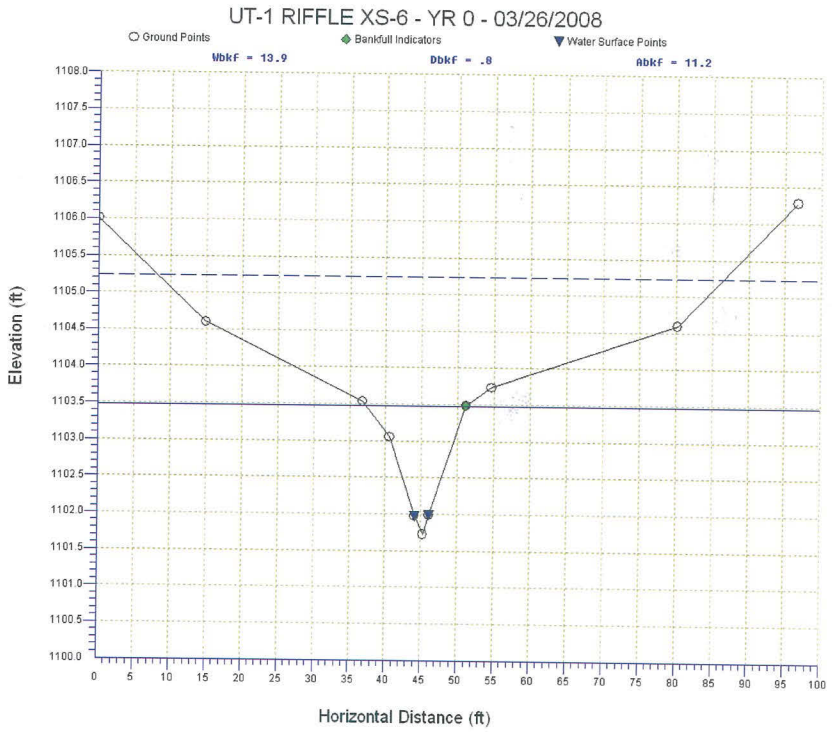


Summary Data
All dimensions in feet.

Bankfull Area	11.17 ft^2
Bankfull Width	13.94 ft
Mean Depth	0.8 ft
Maximum Depth	1.76 ft
Width/Depth Ratio	17.42
Entrenchment Ratio	5.63
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	UT-1
DATE	3/26/08
CROSS SECTION:	6
FEATURE:	Riffle

Cross-section photo – looking upstream



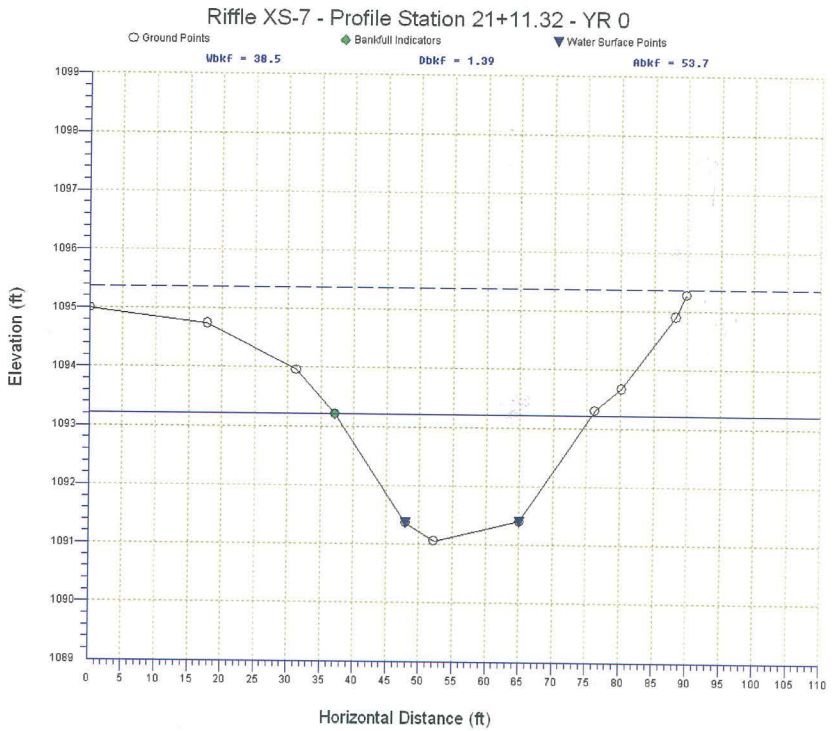
EMH&T

Summary Data
All dimensions in feet.

Bankfull Area	53.71 ft^2
Bankfull Width	38.51 ft
Mean Depth	1.39 ft
Maximum Depth	2.16 ft
Width/Depth Ratio	27.71
Entrenchment Ratio	2.33
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/16/08
CROSS SECTION:	7
FEATURE:	Riffle

Cross-section photo – looking downstream



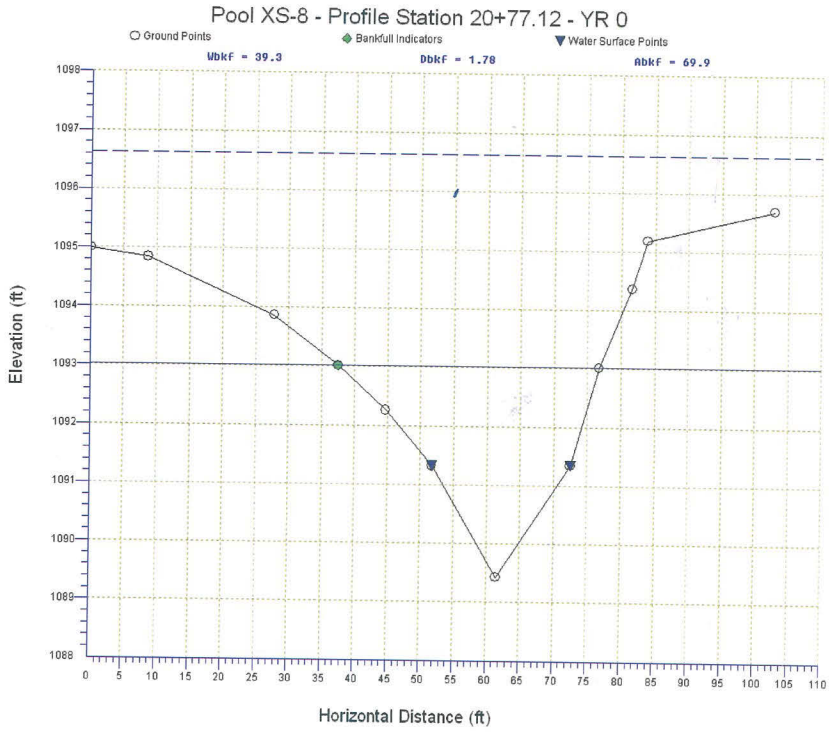
Summary Data
All dimensions in feet.

Bankfull Area	69.91 ft^2
Bankfull Width	39.25 ft
Mean Depth	1.78 ft
Maximum Depth	3.6 ft
Width/Depth Ratio	22.05
Entrenchment Ratio	2.62
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/12/08
CROSS SECTION:	8
FEATURE:	Pool

Ecosystem Enhancement

Cross-section photo – looking downstream



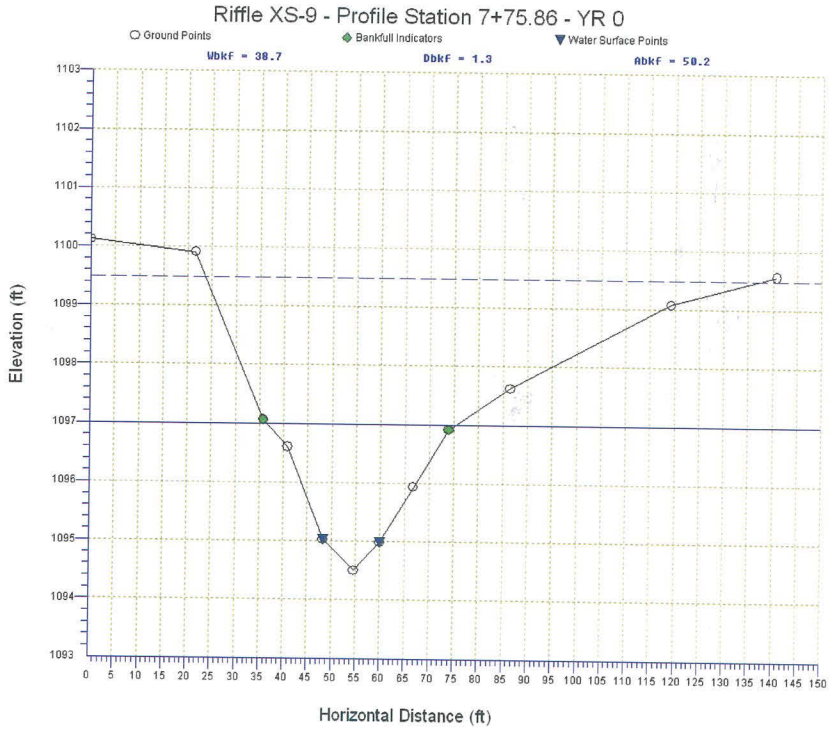
EMH&T

Summary Data
All dimensions in feet.

Bankfull Area	50.2 ft^2
Bankfull Width	38.74 ft
Mean Depth	1.3 ft
Maximum Depth	2.49 ft
Width/Depth Ratio	29.8
Entrenchment Ratio	2.93
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/16/08
CROSS SECTION:	9
FEATURE:	Riffle

Cross-section photo – looking upstream

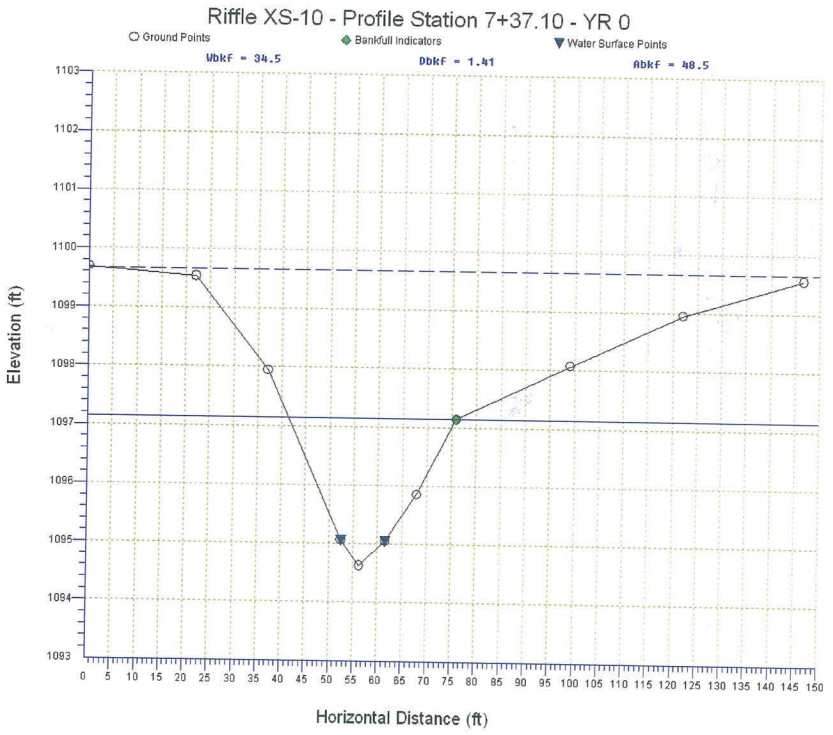


Summary Data
All dimensions in feet.

Bankfull Area	48.51 ft^2
Bankfull Width	34.52 ft
Mean Depth	1.41 ft
Maximum Depth	2.52 ft
Width/Depth Ratio	24.48
Entrenchment Ratio	4.16
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/12/08
CROSS SECTION:	10
FEATURE:	Riffle

Cross-section photo – looking downstream

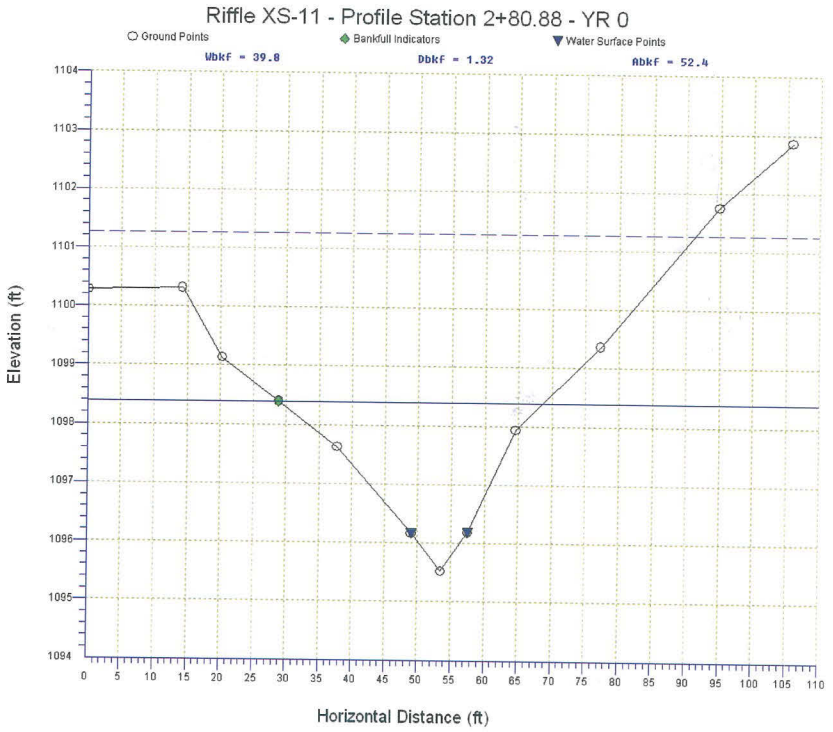


Summary Data
All dimensions in feet.

Bankfull Area	52.43 ft^2
Bankfull Width	39.81 ft
Mean Depth	1.32 ft
Maximum Depth	2.88 ft
Width/Depth Ratio	30.16
Entrenchment Ratio	2.3
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/12/08
CROSS SECTION:	11
FEATURE:	Riffle

Cross-section photo – looking downstream

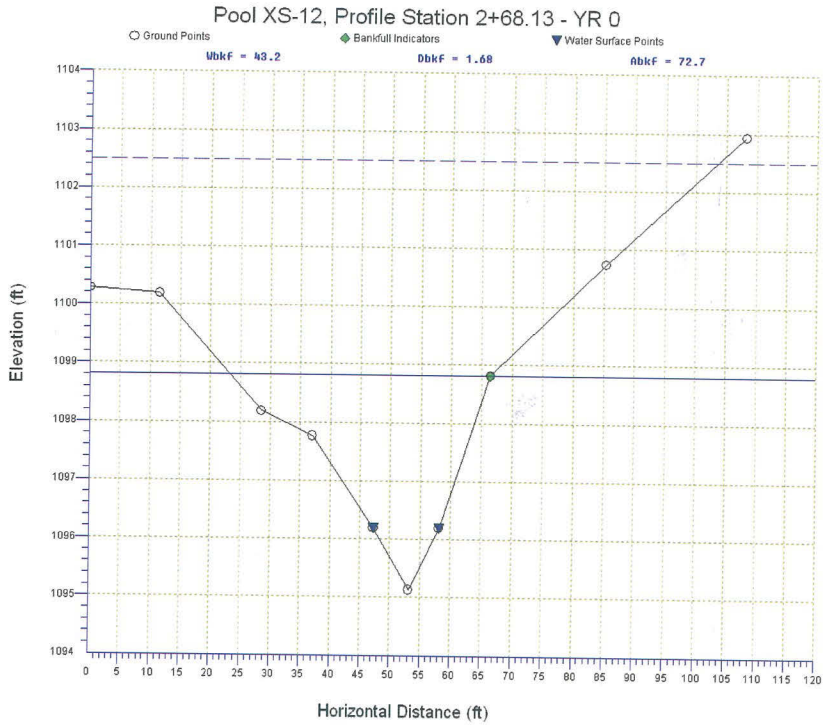


Summary Data
All dimensions in feet.

Bankfull Area	72.7 ft^2
Bankfull Width	43.16 ft
Mean Depth	1.68 ft
Maximum Depth	3.69 ft
Width/Depth Ratio	25.69
Entrenchment Ratio	2.4
Classification	C

PROJECT	Thompsons Fork
	D06030-A
	0-YEAR
TASK	Cross-Section
REACH	Mainstem
DATE	6/12/08
CROSS SECTION:	12
FEATURE:	Pool

Cross-section photo – looking downstream



Appendix D

Supporting Documentation

RIVERMorph 4.1.1 Professional - Thompsons Fork & Unnamed Trib Restoration_4.1

File Tools Help

- Thompsons Fork
  - Altered Mainstem
  - Brindle Creek Ref Reach
  - Thompsons Fk Ref Reach
  - UT (Ablove S Ck Rd)
  - UT (Below S Ck Rd)
  - UT1 As-Built 03-26-2008
  - Mainstem As-Built 6-12-2008
    - Survey Data
    - Cross Sections
      - POOL XS-12 YR 0
      - RIFFLE XS-11 YR 0
      - RIFFLE XS-10 YR 0
      - RIFFLE XS-9 YR 0
      - POOL XS-8 YR 0
      - RIFFLE XS-7 YR 0
      - RIFFLE XS 11+64.19
    - Banks
    - Profiles
      - MS FP LP YR 0
      - MS LP YR 0
    - Particles
      - Riffle XS-7
      - Riffle XS-9
      - Riffle XS-11
      - Reach Composite
    - Classification
    - Ratios*
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
    - Notes

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

Profiles: MS FP LP YR 0 — Pebble Counts: Reach Composite D50 = 8.!

Riffle X-Sections: RIFFLE XS 11+64.19

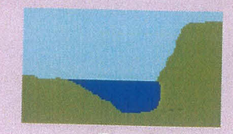
Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.0037
Drainage Area (sq mi)	7.57

Location and Date of Survey

State	North Carolina
County	McDowell
Latitude	0
Longitude	0
Date	06/12/2008

Stream Classification



C 4

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☐ Override Calculated Classification

☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	37.14
Mean Depth (ft)	1.6
Maximum Depth (ft)	2.88
Flood-Prone Width (ft)	122.54
Channel Materials D50 (mm)	8.94
Water Surface Slope (ft/ft)	0.00301
Sinuosity	1.22
Discharge (cfs)	285.74
Velocity (fps)	5.32
Cross Sectional Area (sq ft)	59.39
Entrenchment Ratio	3.3
Width to Depth Ratio	23.21

☐ This Reach is a Reference Reach

Resistance Equation Calculator

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

Manning Roughness Coefficient (n)

Limerinos n | Cowan n | Stream Type n | Ja

Stream Size: Medium to Large — Type: C4

After D.L. Rosgen, "A Classification of Natural Rivers", Catena 22, 1994. — Manning's n: 0.0190

Cross Sectional Area (sq ft)	53.71
Wetted Perimeter (ft)	38.84
Hydraulic Slope (ft/ft)	0.0030
Velocity (fps):	5.32
Discharge (cfs):	285.74

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

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Thompsons Fork Mainstem

"As-Built" Conditions

Rosgen Stream Classification

Construction Completed: June 12, 2008

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

Stream:	**Thompsons Fork, Reach - Mainstem As-Built 6-12-2008**			
Basin:	**Upper Catawba River**	Drainage Area: **4844.8** acres	**7.57**	mi^2
Location:	**Lowdermilk Properties, Nebo Township, McDowell County, NC**			
Twp.&Rge:	**;**	Sec.&Qtr.: **;**		
Cross-Section Monuments (Lat./Long.):	**35.69397 Lat / 81.89194 Long**		Date:	**06/12/08**
Observers:	**Hebert, Hines & Knotts**		Valley Type:	VIII

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**38.51**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.39**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**53.71**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**27.71**	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.	**2.16**	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.	**89.89**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.33**	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.	**8.94**	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.	**0.00301**	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).	**1.22**	

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

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

Stream: **Thompsons Fork Mainstem As-Built 6-12-2008** Location: **Lowdermilk Properties**

Observers: **Hebert, Hines & Knotts** Date: **06/12/2008** Valley Type: **VIII** Stream Type: **C 4**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.4	ft	Riffle Width (W_{bkf})	37.74	ft	Riffle Area (A_{bkf})	53.71	ft^2
Mean Pool Depth (d_{bkfp})	1.73	ft	Pool Width (W_{bkfp})	41.21	ft	Pool Area (A_{bkfp})	71.31	ft^2
Mean Pool Depth/Mean Riffle Depth	1.24	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	1.09	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	1.35	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	2.47	ft	Max Pool Depth (d_{mbkfp})	3.96	ft	Max Riffle Depth/Mean Riffle Depth	1.76	
Max Pool Depth/Mean Riffle Depth	2.83					Point Bar Slope	0.1	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				5.32	ft/s	Estimation Method	Manning's Eq.	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				285.74	cfs	Drainage Area	7.57	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	110.35	84.17	120	ft	Meander Length Ratio (Lm/W_{bkf})	2.92	2.23	3.18
Radius of Curvature (Rc)	27.7	18.7	48.9	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	0.73	0.50	1.30
Belt Width (W_{blt})	90	40	90	ft	Meander Width Ratio (W_{blt}/W_{bkf})	2.38	1.06	2.38
Individual Pool Length	39.3	21.47	82.9	ft	Pool Length/Riffle Width	1.04	0.57	2.20
Pool to Pool Spacing	63.84	25.03	145	ft	Pool to Pool Spacing/Riffle Width	1.69	0.66	3.85
Riffle Length	17.18	8.57	30.6	ft	Riffle Length/Riffle Width	0.46	0.23	0.81

Channel Profile

Valley Slope (VS)	0.0037	ft/ft	Average Water Surface Slope (S)	0.00301	ft/ft	Sinuosity (VS/S)	1.22	
Stream Length (SL)	2742	ft	Valley Length (VL)	2248	ft	Sinuosity (SL/VL)	1.22	
Low Bank Height (LBH)	start 1.8 / end 2.97	ft	Max Riffle Depth	start 1.8 / end 2.97	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start 1 / end 1	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0166	0.0051	0.0571	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	5.50	1.69	18.96
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)	0.0009	0.0000	0.0019	ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)	0.29	0.00	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})	2.47	1.8	2.97	ft	Riffle Depth/Mean Riffle Depth (d_{rif} / d_{bkf})	1.76	1.29	2.12
Run Depth (d_{run})				ft	Run Depth/Mean Riffle Depth (d_{run} / d_{bkf})			
Pool Depth (d_p)	3.96	3.34	5.15	ft	Pool Depth/Mean Riffle Depth (d_p / d_{bkf})	2.83	2.39	3.68
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	9.41	10.61		D_{16}	0.24	0.16		0	mm
% Sand	19.8	19.69		D_{35}	3.8	4.06		0	mm
% Gravel	59.9	53.03		D_{50}	8.94	9.1		0	mm
% Cobble	10.39	16.67		D_{84}	43.93	66.3		0	mm
% Boulder	0.5	0		D_{95}	114.14	146.19		0	mm
% Bedrock	0	0		D_{100}	1023.9	256		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 4.1.1 Professional - Thompsons Fork & Unnamed Trib Restoration_4.1

File Tools Help

- Thompsons Fork
  - Altered Mainstem
  - Brindle Creek Ref Reach
  - Thompsons Fk Ref Reach
  - UT (Ablove S Ck Rd)
  - UT (Below S Ck Rd)
  - UT1 As-Built 03-26-2008
    - Survey Data
    - Cross Sections
      - Pool XS-1 YR 0
      - Riffle XS-2 YR 0
      - Pool XS-3 YR 0
      - Riffle XS-4 YR 0
      - Pool XS-5 YR 0
      - Riffle XS-6 YR 0
      - 30" CMP Inlet - South Cre
      - Top Priority I Reach
      - 30" CMP Outlet - South C
      - Confluence with Thompsc
    - Banks
    - Profiles
      - UT-1 LP Yr 0
      - UT-1 E2 Reach YR 0
      - UT-1 - R1 Reach - Yr 0
      - UT-1 LP Sta 3+97.22 - 8+
      - UT-1 LP Sta 8+30.96 - 17
      - UT-1 LP Sta 17+07.90 to
    - Particles
      - UT-1 Ex Conds Riffle Sub
      - Riffle XS-4
      - Riffle XS-6
      - Bar @ Confluence
    - Classification
    - Ratios
    - Pfankuch
    - BEHI
    - SVAP
    - RBP
    - Designs
    - Notes
  - Mainstem As-Built 6-12-2008

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

Profiles: UT-1 LP Yr 0 — Pebble Counts: Riffle XS-4 D50 = 16 mm.

Riffle X-Sections: Riffle XS-6 YR 0

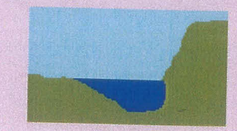
Valley Morphology

Valley Type	Type VIII
Valley Slope (ft/ft)	0.035
Drainage Area (sq mi)	0.16

Location and Date of Survey

State	North Carolina
County	McDowell
Latitude	35.69397
Longitude	81.88953
Date	03/26/2008

Stream Classification



C3b

Entrenchment Ratio Adjustment

Width to Depth Ratio Adjustment

☑ Override Calculated Classification
☐ This Reach has bedrock control

Bankfull Channel Data (Riffle Cross Section)

◉ Single Thread ○ Multiple Channels

Width (ft)	14.38
Mean Depth (ft)	0.74
Maximum Depth (ft)	1.55
Flood-Prone Width (ft)	76.11
Channel Materials D50 (mm)	16
Water Surface Slope (ft/ft)	0.02433
Sinuosity	1.44
Discharge (cfs)	50.71
Velocity (fps)	4.77
Cross Sectional Area (sq ft)	10.63
Entrenchment Ratio	5.29
Width to Depth Ratio	19.43

☐ This Reach is a Reference Reach

Resistance Equation Calculator

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

Manning Roughness Coefficient (n)

Limerinos n | Cowan n | Stream Type n | Ja

Hydraulic Radius (ft)	0.73
Bed Material D84 (mm)	68.15
Manning's n:	0.0406
Cross Sectional Area (sq ft)	10.63
Wetted Perimeter (ft)	13.92
Hydraulic Slope (ft/ft)	0.0243
Velocity (fps):	4.77
Discharge (cfs):	50.71

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

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Thompsons Fork - Unnamed Tributary

"As-Built" Rosgen Stream Classification

and

Morphologic & Hydraulic Analyses

Construction Completion: March 26, 2008

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

Stream:	**Thompsons Fork, Reach - UT1 As-Built 03-26-2008**			
Basin:	**Upper Catawba River**	Drainage Area: **102.4** acres	**0.16**	mi^2
Location:	**Thompsons Fork of North Muddy Creek of Catawba R.**			
Twp.&Rge:	**Nebo Township**	Sec.&Qtr.: **; McDowell County, NC**		
Cross-Section Monuments (Lat./Long.):	**35.69397 Lat / 81.88953 Long**		Date: **03/26/08**	
Observers:	**Hebert, Hines & Knotts**		Valley Type: VIII	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**14.38**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.74**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**10.63**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**19.43**	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.	**1.55**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**76.11**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.29**	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.	**7.67**	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.	**0.02433**	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).	**1.44**	

Stream Type **C3b** (See **Figure 2-14**)

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

Stream: **UT-1 "As-Built" Restoration Reach** Location: **Nebo Township, McDowell County, NC**

Observers: **Hebert, Hines & Knotts** Date: **03/26/2008** Valley Type: **VIII** Stream Type: **C3b**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	0.75	ft	Riffle Width (W_{bkf})	14.02	ft	Riffle Area (A_{bkf})	10.63	ft^2
Mean Pool Depth (d_{bkfp})	1.13	ft	Pool Width (W_{bkfp})	18.63	ft	Pool Area (A_{bkfp})	21.02	ft^2
Mean Pool Depth/Mean Riffle Depth	1.51	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	1.33	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	2.02	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	1.54	ft	Max Pool Depth (d_{mbkfp})	2.75	ft	Max Riffle Depth/Mean Riffle Depth	2.05	
Max Pool Depth/Mean Riffle Depth	3.67					Point Bar Slope	0.1	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				4.77	ft/s	Estimation Method	Manning's Eq.	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				50.71	cfs	Drainage Area	0.16	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	100	64.2	124	ft	Meander Length Ratio (Lm/W_{bkf})	7.13	4.58	8.84
Radius of Curvature (Rc)	22.6	14.4	40.9	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	1.61	1.03	2.92
Belt Width (W_{blt})	71.5	45	85	ft	Meander Width Ratio (W_{blt}/W_{bkf})	5.10	3.21	6.06
Individual Pool Length	24.71	8.19	48.2	ft	Pool Length/Riffle Width	1.76	0.58	3.44
Pool to Pool Spacing	65.21	20.94	159	ft	Pool to Pool Spacing/Riffle Width	4.65	1.49	11.32
Riffle Length	23.4	6.08	55.1	ft	Riffle Length/Riffle Width	1.67	0.43	3.93

Channel Profile

Valley Slope (VS)	0.03310	ft/ft	Average Water Surface Slope (S)	0.02433	ft/ft	Sinuosity (VS/S)	1.36	
Stream Length (SL)	2382	ft	Valley Length (VL)	1751	ft	Sinuosity (SL/VL)	1.36	
Low Bank Height (LBH)	start 1.2 / end 2.17	ft	Max Riffle Depth	start 1.2 / end 2.17	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start 1 / end 1	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0595	0.0350	0.0940	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	2.45	1.44	3.87
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)	0.0017	0.0000	0.0066	ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)	0.07	0.00	0.27
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})	1.54	1.2	2.17	ft	Riffle Depth/Mean Riffle Depth (d_{rif} / d_{bkf})	2.05	1.6	2.89
Run Depth (d_{run})				ft	Run Depth/Mean Riffle Depth (d_{run} / d_{bkf})			
Pool Depth (d_p)	2.75	2.12	3.58	ft	Pool Depth/Mean Riffle Depth (d_p / d_{bkf})	3.67	2.83	4.77
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	7.35	4.29	0.15	D_{16}	0.32	0.87	1.2	0	mm
% Sand	20.59	15.71	22.2	D_{35}	3.92	8.23	4.39	0	mm
% Gravel	54.41	62.86	77.64	D_{50}	7.67	16	7.72	0	mm
% Cobble	17.65	17.14	0	D_{84}	73.73	68.15	18.49	0	mm
% Boulder	0	0	0	D_{95}	138.38	134.47	27.45	0	mm
% Bedrock	0	0	0	D_{100}	255.99	180	31.5	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.

Warren E. Knotts, PG

Thompson Fork and Unnamed Tributary Pattern Analysis
North Carolina EEP Project Number: D06030-A
Nebo Township, McDowell County, North Carolina

July 15, 2008

As-Built Mitigation Plan - Patten Analysis											
Thompson Fok Mainstem						Unnamed Tibutay 1					
Rc	Lm	Wbkf	MLR	Wblt	MWR	Rc	Lm	Wbkf	MLR	Wblt	MWR
35.00	111.63	38.51	2.90	40.00	1.04	33.10	87.25	13.65	6.22	74.03	5.28
35.00	114.74	38.74	2.98	58.29	1.51	18.51	94.93	14.38	6.77	62.45	4.45
25.00	103.66	34.52	2.69	79.07	2.05	22.57	92.28		6.58	73.33	5.23
27.00	103.58	39.81	2.69	90.00	2.34	17.04	64.19		4.58	75.41	5.38
35.00	119.85	37.14	3.11	90.00	2.34	22.57	78.80		5.62	71.87	5.13
47.50	90.76		2.36	90.00	2.34	17.04	124.91		8.91	75.30	5.37
48.90	98.16		2.55	90.00	2.34	22.57	84.60		6.03	44.00	3.14
47.50	84.17		2.19	90.00	2.34	15.96	112.47		8.02		
45.70	118.44		3.08	90.00	2.34	14.38	123.25		8.79		
42.60	111.88		2.91	90.00	2.34	15.96	117.87		8.41		
24.70	86.25		2.24	90.00	2.34	27.09	111.45		7.95		
23.40	109.29		2.84			27.09	104.79		7.47		
27.70	110.35		2.87			15.96	95.02		6.78		
25.80	110.38		2.87			20.05					
22.20	109.24		2.84			23.43					
18.70	117.38		3.05			40.91					
23.70	113.29		2.94			40.91					
34.70	116.80		3.03			35.50					
29.10	115.76		3.01			29.11					
27.80	107.75		2.80			28.83					
23.90	101.64		2.64			24.93					
19.40						16.91					
25.40						22.13					
29.60						20.75					
35.50						25.86					
26.30						10.39					
31.70						10.39					
28.30						10.39					
24.20						35.00					
26.80						30.00					
35.90											
25.20											
29.50											
32.70											
23.20											
40.00											
19.00											
27.70											
31.20											
27.70											
24.60											
25.00											
29.50											

Warren E. Knotts, PG

Thompson Fork and Unnamed Tributary Pattern Analysis
North Carolina EEP Project Number: D06030-A
Nebo Township, McDowell County, North Carolina

July 15, 2008

Thompson Fork Mainstem											
Rc		*Lm*		*Wbkf*		*MLR*		*Wblt*		*MWR*	
Mean	**29.98**	**Mean**	**107.38**	**Mean**	**37.74**	**Mean**	**2.79**	**Mean**	**81.58**	**Mean**	**2.12**
Std Error	1.18	Std Error	2.23	Std Error	0.91	Std Error	0.06	Std Error	5.09	Std Error	0.13
Median	**27.70**	**Median**	**110.35**	**Median**	**38.51**	**Median**	**2.87**	**Median**	**90.00**	**Median**	**2.34**
Mode	35.00	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	90.00	Mode	2.34
Std Dev	7.71	Std Dev	10.24	Std Dev	2.04	Std Dev	0.27	Std Dev	16.87	Std Dev	0.44
Variance	59.48	Variance	104.85	Variance	4.15	Variance	0.07	Variance	284.48	Variance	0.19
Kurtosis	0.48	Kurtosis	0.43	Kurtosis	1.26	Kurtosis	0.43	Kurtosis	3.36	Kurtosis	3.36
Skewnes	1.01	Skewness	-1.08	Skewness	-1.16	Skewnes	-1.08	Skewnes	-2.03	Skewnes	-2.03
Range	30.20	Range	35.68	Range	5.29	Range	0.93	Range	50.00	Range	1.30
Min	**18.70**	**Min**	**84.17**	**Min**	**34.52**	**Min**	**2.19**	**Min**	**40.00**	**Min**	**1.04**
Max	**48.90**	**Max**	**119.85**	**Max**	**39.81**	**Max**	**3.11**	**Max**	**90.00**	**Max**	**2.34**
Sum	1289.30	Sum	2255.00	Sum	188.72	Sum	58.56	Sum	897.36	Sum	23.30
Count	43	Count	21	Count	5	Count	21	Count	11	Count	11

Unnamed Tributary 1											
Rc		*Lm*		*Wbkf*		*MLR*		*Wblt*		*MWR*	
Mean	**23.18**	**Mean**	**99.37**	**Mean**	**14.02**	**Mean**	**7.09**	**Mean**	**68.06**	**Mean**	**4.85**
Std Error	1.54	Std Error	5.08	Std Error	0.37	Std Error	0.36	Std Error	4.35	Std Error	0.31
Median	**22.57**	**Median**	**95.02**	**Median**	**14.02**	**Median**	**6.78**	**Median**	**73.33**	**Median**	**5.23**
Mode	22.57	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Std Dev	8.41	Std Dev	18.32	Std Dev	0.52	Std Dev	1.31	Std Dev	11.51	Std Dev	0.82
Variance	70.76	Variance	335.53	Variance	0.27	Variance	1.71	Variance	132.45	Variance	0.67
Kurtosis	-0.34	Kurtosis	-0.62	Kurtosis	#N/A	Kurtosis	-0.62	Kurtosis	3.74	Kurtosis	3.74
Skewnes	0.47	Skewness	-0.27	Skewness	#N/A	Skewnes	-0.27	Skewnes	-1.98	Skewnes	-1.98
Range	30.52	Range	60.72	Range	0.73	Range	4.33	Range	31.41	Range	2.24
Min	**10.39**	**Min**	**64.19**	**Min**	**13.65**	**Min**	**4.58**	**Min**	**44.00**	**Min**	**3.14**
Max	**40.91**	**Max**	**124.91**	**Max**	**14.38**	**Max**	**8.91**	**Max**	**75.41**	**Max**	**5.38**
Sum	695.33	Sum	1291.81	Sum	28.03	Sum	92.14	Sum	476.39	Sum	33.98
Count	30	Count	13	Count	2	Count	13	Count	7	Count	7

Warren E. Knotts, PG

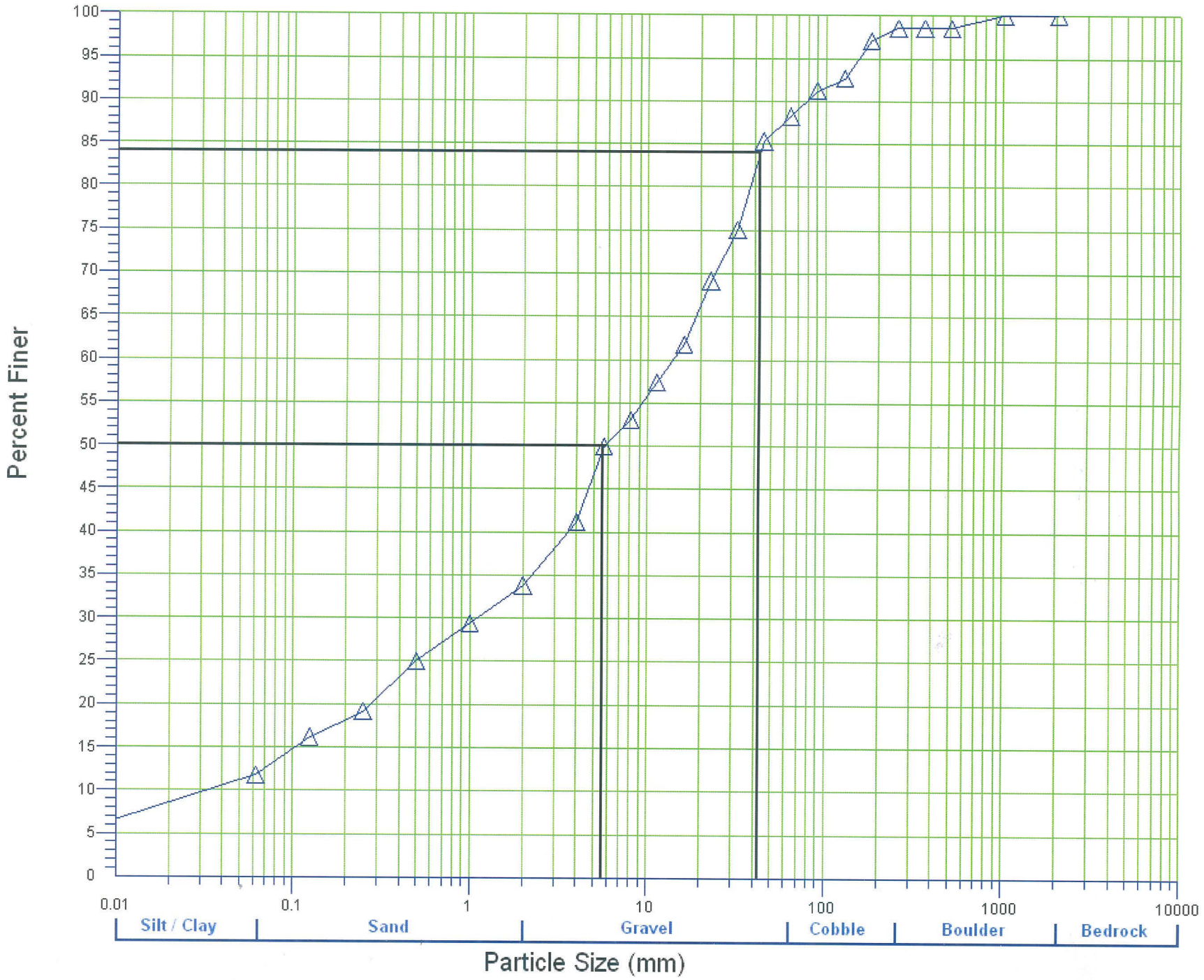
Thompson Fork Mainstem Dimension and Substrate Statistics

July 15, 2008

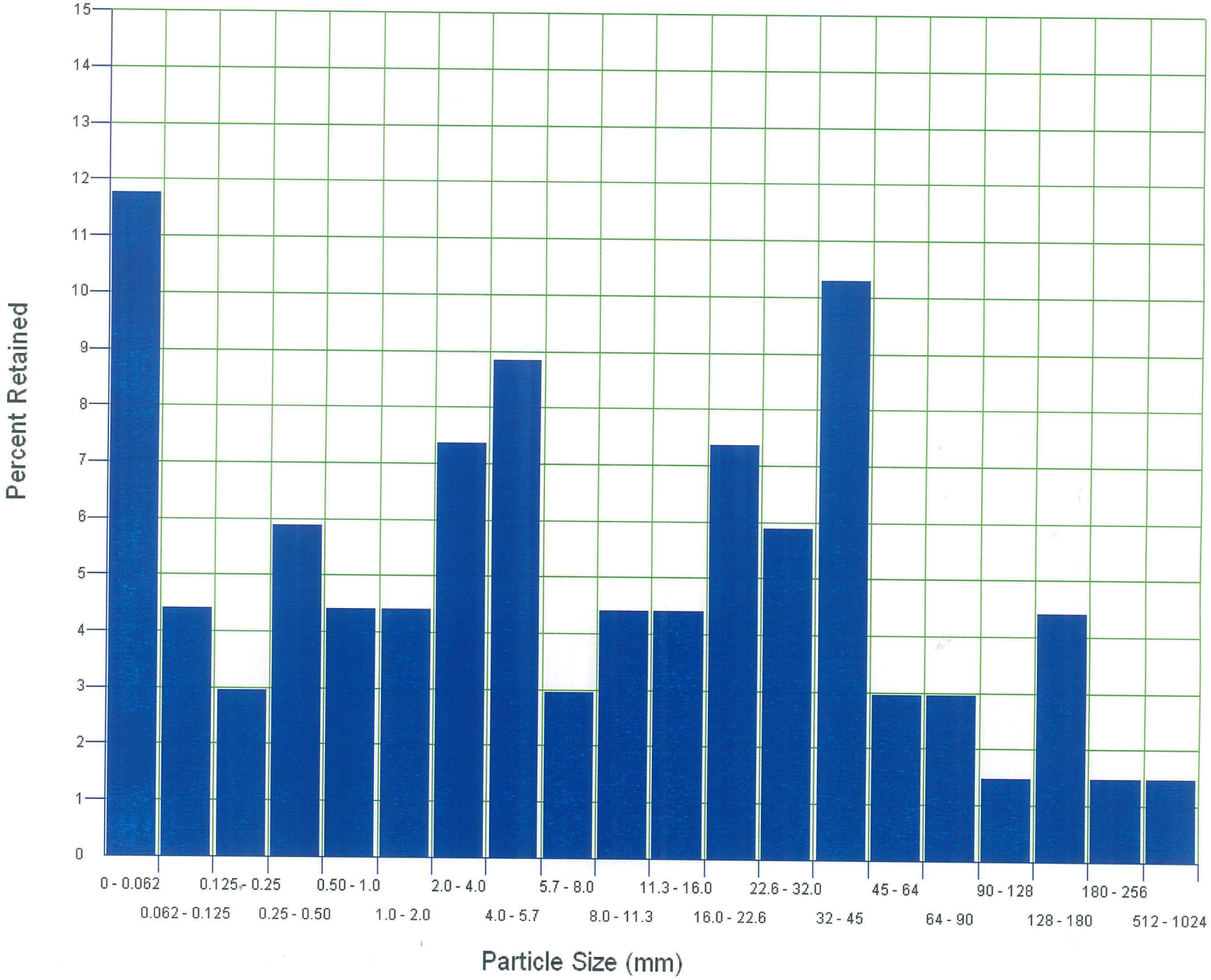
Thompson Fork Mainstem - Riffle Geometry & Substrate										
Wfpa	**Wbkf**	**Abkf**	**Dbkf**	**Dmax**	**W/D**	**ER**	**WP**	**R**	**D50**	**D84**
89.89	38.51	53.71	1.39	2.16	27.71	2.33	38.84	1.38	9.10	66.30
113.53	38.74	50.20	1.30	2.49	29.80	2.93	39.10	1.28	10.64	35.94
143.71	34.52	48.51	1.41	2.52	24.48	4.16	34.91	1.39	5.70	43.37
91.41	39.81	52.43	1.32	2.88	30.16	2.30	40.28	1.30		
122.54	37.14	59.39	1.60	2.88	23.21	3.30	37.80	1.57		

Wfpa		*Wbkf*		*Abkf*		*W/D*		*Dbkf*		*Dmax*		*ER*		*WP*		*R*		*D50*		*D84*	
Mean	**112.22**	**Mean**	**37.74**	**Mean**	**52.85**	**Mean**	**27.07**	**Mean**	**1.40**	**Mean**	**2.59**	**Mean**	**3.00**	**Mean**	**38.19**	**Mean**	**1.38**	**Mean**	**8.48**	**Mean**	**48.54**
Std Error	10.08	Std Error	0.91	Std Error	1.86	Std Error	1.40	Std Error	0.05	Std Error	0.14	Std Error	0.34	Std Error	0.91	Std Error	0.05	Std Error	1.46	Std Error	9.14
Median	**113.53**	**Median**	**38.51**	**Median**	**52.43**	**Median**	**27.71**	**Median**	**1.39**	**Median**	**2.52**	**Median**	**2.93**	**Median**	**38.84**	**Median**	**1.38**	**Median**	**9.10**	**Median**	**43.37**
Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	2.88	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Std Dev	22.54	Std Dev	2.04	Std Dev	4.17	Std Dev	3.12	Std Dev	0.12	Std Dev	0.30	Std Dev	0.77	Std Dev	2.03	Std Dev	0.11	Std Dev	2.53	Std Dev	15.83
Variance	507.88	Variance	4.15	Variance	17.39	Variance	9.74	Variance	0.01	Variance	0.09	Variance	0.59	Variance	4.13	Variance	0.01	Variance	6.39	Variance	250.45
Kurtosis	-1.07	Kurtosis	1.26	Kurtosis	1.24	Kurtosis	-2.56	Kurtosis	2.28	Kurtosis	-0.91	Kurtosis	-0.07	Kurtosis	1.91	Kurtosis	1.89	Kurtosis	#DIV/0!	Kurtosis	#DIV/0!
Skewnes	0.44	Skewnes	-1.16	Skewnes	1.04	Skewnes	-0.34	Skewnes	1.44	Skewnes	-0.41	Skewnes	0.83	Skewnes	-1.24	Skewnes	1.31	Skewnes	-1.04	Skewnes	1.31
Range	53.82	Range	5.29	Range	10.88	Range	6.95	Range	0.30	Range	0.72	Range	1.86	Range	5.37	Range	0.29	Range	4.94	Range	30.36
Min	**89.89**	**Min**	**34.52**	**Min**	**48.51**	**Min**	**23.21**	**Min**	**1.30**	**Min**	**2.16**	**Min**	**2.30**	**Min**	**34.91**	**Min**	**1.28**	**Min**	**5.70**	**Min**	**35.94**
Max	**143.71**	**Max**	**39.81**	**Max**	**59.39**	**Max**	**30.16**	**Max**	**1.60**	**Max**	**2.88**	**Max**	**4.16**	**Max**	**40.28**	**Max**	**1.57**	**Max**	**10.64**	**Max**	**66.30**
Sum	561.08	Sum	188.72	Sum	264.24	Sum	135.36	Sum	7.02	Sum	12.93	Sum	15.02	Sum	190.93	Sum	6.92	Sum	25.44	Sum	145.61
Count	5	Count	5	Count	5	Count	5	Count	5	Count	5	Count	5	Count	5	Count	5	Count	3	Count	3

Thompsons Fork Mainstem - Riffle XS-11 - Particle Distribution



Thompsons Fork Mainstem - Riffle XS-11 - Particle Distribution



RIVERMORPH PARTICLE SUMMARY

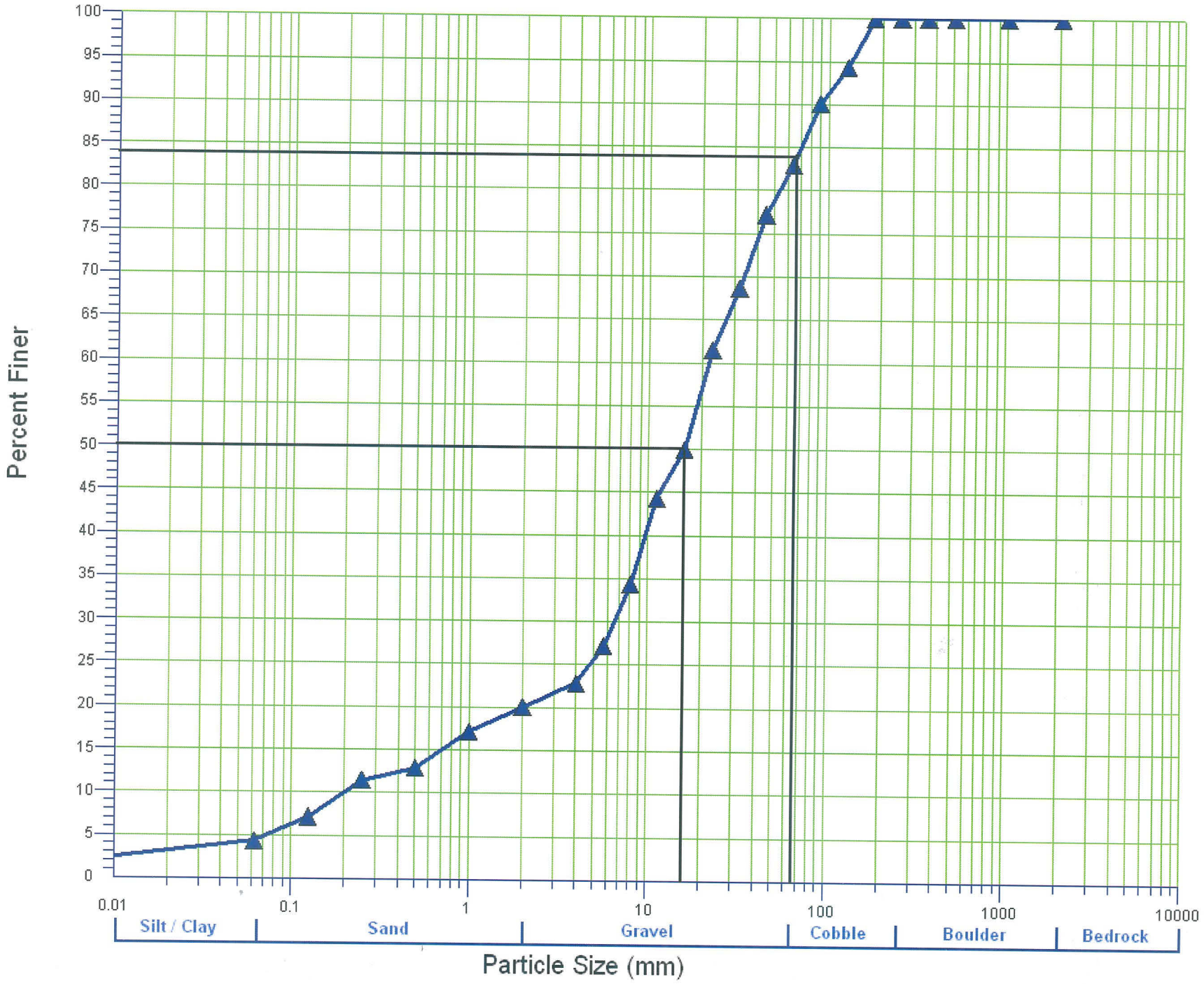
River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
Sample Name: Riffle XS-11
Survey Date: 06/12/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	8	11.76	11.76
0.062 - 0.125	3	4.41	16.18
0.125 - 0.25	2	2.94	19.12
0.25 - 0.50	4	5.88	25.00
0.50 - 1.0	3	4.41	29.41
1.0 - 2.0	3	4.41	33.82
2.0 - 4.0	5	7.35	41.18
4.0 - 5.7	6	8.82	50.00
5.7 - 8.0	2	2.94	52.94
8.0 - 11.3	3	4.41	57.35
11.3 - 16.0	3	4.41	61.76
16.0 - 22.6	5	7.35	69.12
22.6 - 32.0	4	5.88	75.00
32 - 45	7	10.29	85.29
45 - 64	2	2.94	88.24
64 - 90	2	2.94	91.18
90 - 128	1	1.47	92.65
128 - 180	3	4.41	97.06
180 - 256	1	1.47	98.53
256 - 362	0	0.00	98.53
362 - 512	0	0.00	98.53
512 - 1024	1	1.47	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.12
D35 (mm)	2.32
D50 (mm)	5.7
D84 (mm)	43.37
D95 (mm)	155.71
D100 (mm)	1023.97
Silt/Clay (%)	11.76
Sand (%)	22.06
Gravel (%)	54.42
Cobble (%)	10.29
Boulder (%)	1.47
Bedrock (%)	0

Total Particles = 68.

Thompsons Fork - UT-1 - Riffle XS-4 - Particle Distribution



Riffle XS-4 Particle Distribution.txt
RIVERMORPH PARTICLE SUMMARY

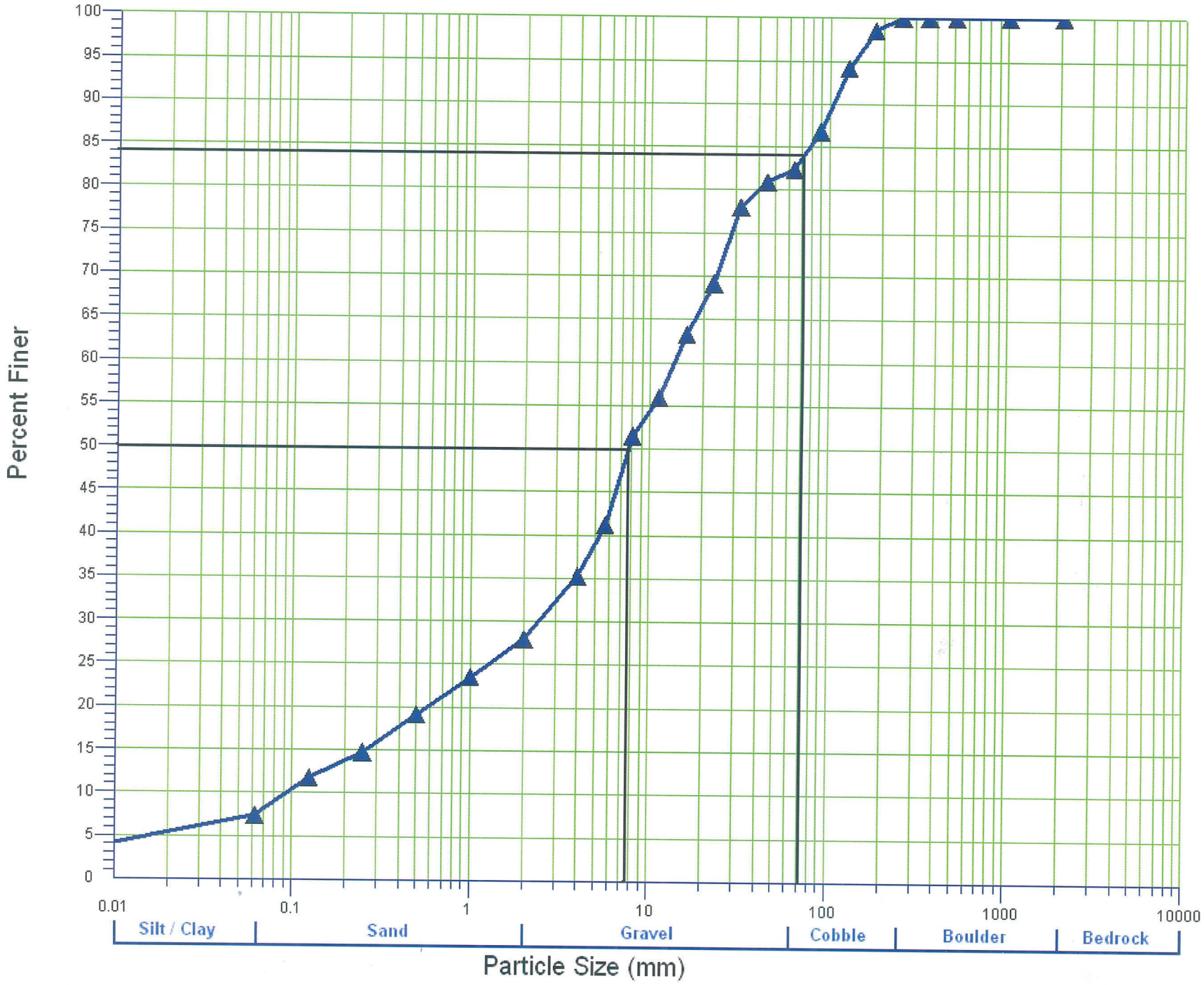
River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
Sample Name: Riffle XS-4
Survey Date: 03/26/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	3	4.29	4.29
0.062 - 0.125	2	2.86	7.14
0.125 - 0.25	3	4.29	11.43
0.25 - 0.50	1	1.43	12.86
0.50 - 1.0	3	4.29	17.14
1.0 - 2.0	2	2.86	20.00
2.0 - 4.0	2	2.86	22.86
4.0 - 5.7	3	4.29	27.14
5.7 - 8.0	5	7.14	34.29
8.0 - 11.3	7	10.00	44.29
11.3 - 16.0	4	5.71	50.00
16.0 - 22.6	8	11.43	61.43
22.6 - 32.0	5	7.14	68.57
32 - 45	6	8.57	77.14
45 - 64	4	5.71	82.86
64 - 90	5	7.14	90.00
90 - 128	3	4.29	94.29
128 - 180	4	5.71	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.87
D35 (mm)	8.23
D50 (mm)	16
D84 (mm)	68.15
D95 (mm)	134.47
D100 (mm)	180
Silt/Clay (%)	4.29
Sand (%)	15.71
Gravel (%)	62.86
Cobble (%)	17.14
Boulder (%)	0
Bedrock (%)	0

Total Particles = 70.

Thompsons Fork - UT-1 - Riffle XS-6 - Particle Distribution



Riffle XS-6 Particle Distribution.txt
RIVERMORPH PARTICLE SUMMARY

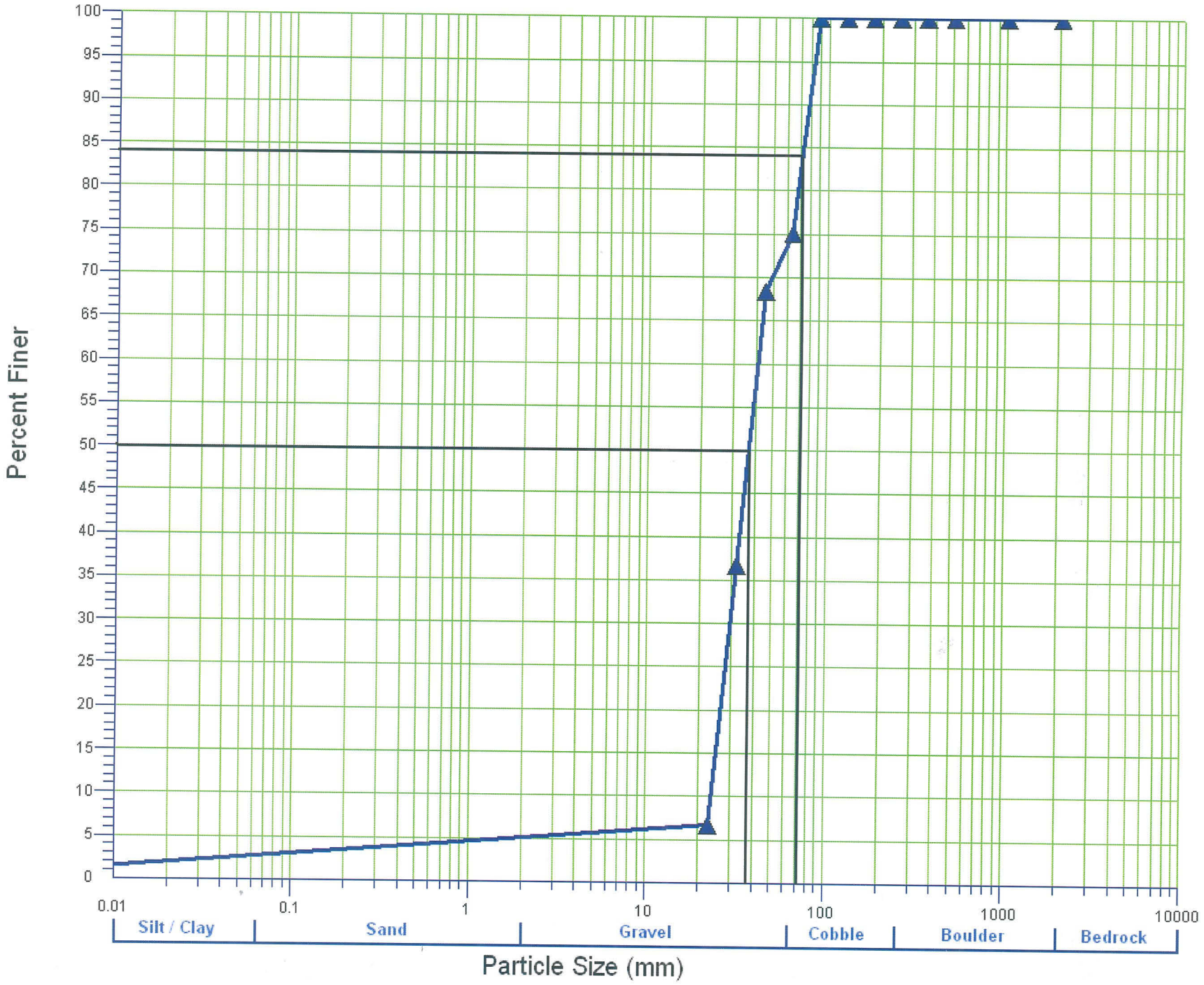
River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
Sample Name: Riffle XS-6
Survey Date: 03/26/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	5	7.35	7.35
0.062 - 0.125	3	4.41	11.76
0.125 - 0.25	2	2.94	14.71
0.25 - 0.50	3	4.41	19.12
0.50 - 1.0	3	4.41	23.53
1.0 - 2.0	3	4.41	27.94
2.0 - 4.0	5	7.35	35.29
4.0 - 5.7	4	5.88	41.18
5.7 - 8.0	7	10.29	51.47
8.0 - 11.3	3	4.41	55.88
11.3 - 16.0	5	7.35	63.24
16.0 - 22.6	4	5.88	69.12
22.6 - 32.0	6	8.82	77.94
32 - 45	2	2.94	80.88
45 - 64	1	1.47	82.35
64 - 90	3	4.41	86.76
90 - 128	5	7.35	94.12
128 - 180	3	4.41	98.53
180 - 256	1	1.47	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.32
D35 (mm)	3.92
D50 (mm)	7.67
D84 (mm)	73.73
D95 (mm)	138.38
D100 (mm)	255.99
Silt/Clay (%)	7.35
Sand (%)	20.59
Gravel (%)	54.41
Cobble (%)	17.65
Boulder (%)	0
Bedrock (%)	0

Total Particles = 68.

Thompsons Fork UT-1 - Existing Conditions Riffle Particle Distribution



UT-1 Ex Conds Riffle Particle Distribution.txt
RIVERMORPH PARTICLE SUMMARY

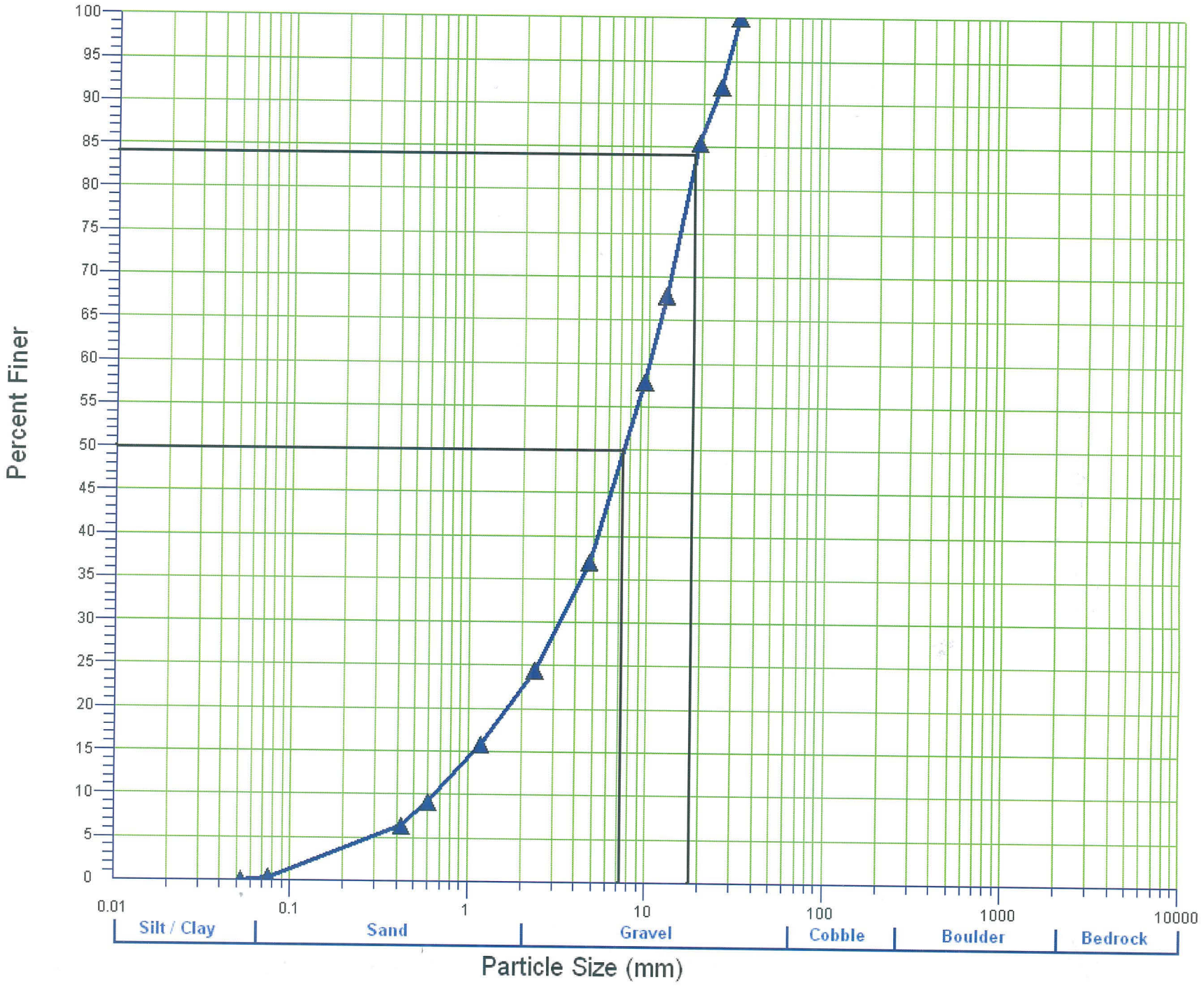
River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
Sample Name: Ex Conds Riffle Substrate
Survey Date: 03/13/2007

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	0	0.00	0.00
1.0 - 2.0	0	0.00	0.00
2.0 - 4.0	0	0.00	0.00
4.0 - 5.7	0	0.00	0.00
5.7 - 8.0	0	0.00	0.00
8.0 - 11.3	0	0.00	0.00
11.3 - 16.0	0	0.00	0.00
16.0 - 22.6	4	6.67	6.67
22.6 - 32.0	18	30.00	36.67
32 - 45	19	31.67	68.33
45 - 64	4	6.67	75.00
64 - 90	15	25.00	100.00
90 - 128	0	0.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	25.52
D35 (mm)	31.48
D50 (mm)	37.47
D84 (mm)	73.36
D95 (mm)	84.8
D100 (mm)	90
Silt/Clay (%)	0
Sand (%)	0
Gravel (%)	75
Cobble (%)	25
Boulder (%)	0
Bedrock (%)	0

Total Particles = 60.

Bar Sample at Confluence of UT-1 & Thompsons Fork



Bar @ Conflunence Particle Distribution.txt
RIVERMORPH PARTICLE SUMMARY

River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
Sample Name: Bar @ Confluence
Survey Date: 07/23/2008

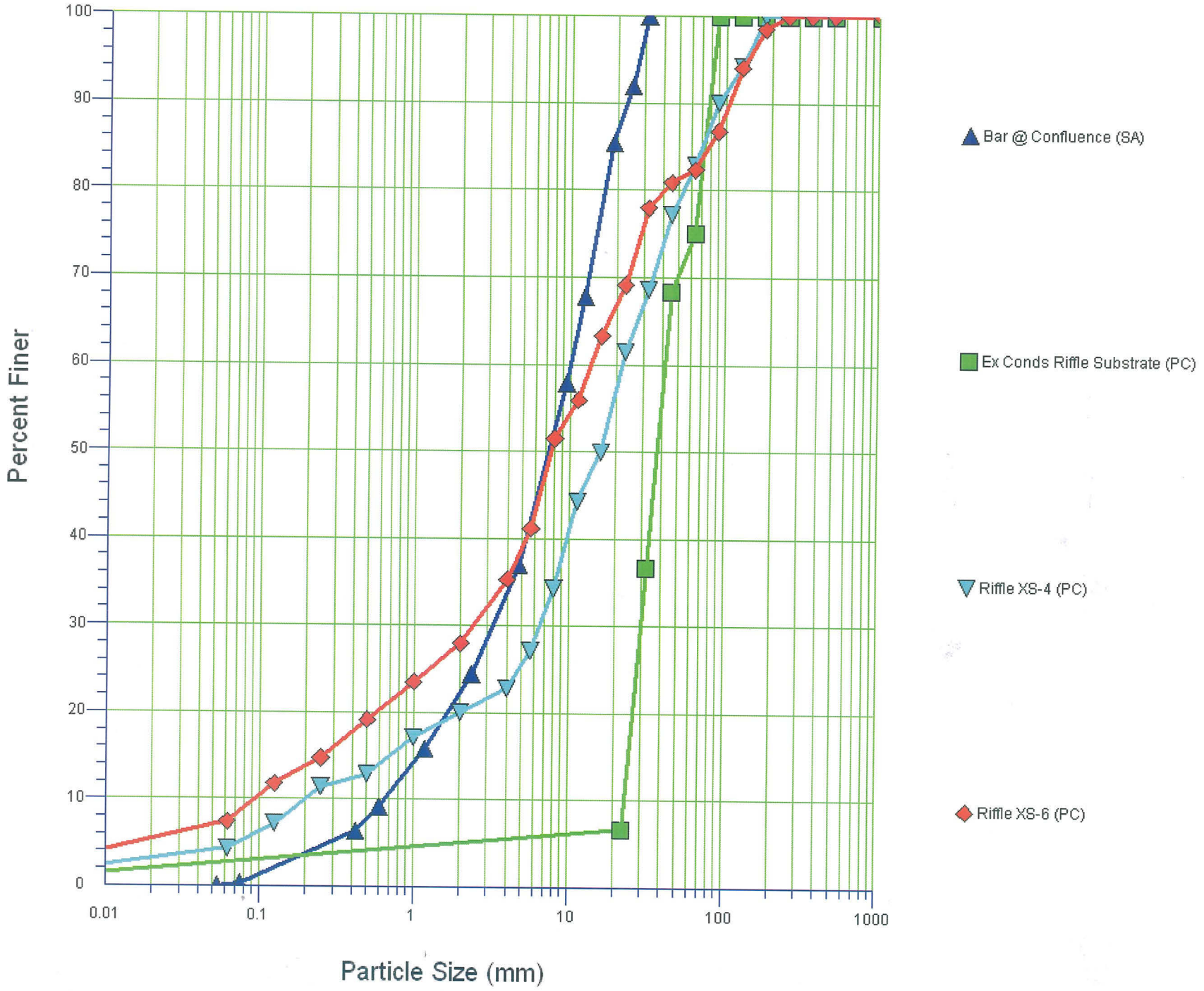
SIEVE (mm)	NET WT
25	66.7
19	54.8
12.5	146.3
9.5	83
4.75	174
2.36	104
1.18	71.4
0.6	55.6
0.425	23
0.075	50.2
0.053	2.8
PAN	0
D16 (mm)	1.2
D35 (mm)	4.39
D50 (mm)	7.72
D84 (mm)	18.49
D95 (mm)	27.45
D100 (mm)	31.5
Silt/Clay (%)	0.15
Sand (%)	22.2
Gravel (%)	77.64
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

Total Weight = 831.8000.

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	31.5	
Particle 2:	25	

Bar Sample Sieve Analysis: Confluence UT-1 & Mainstem



RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Riffle XS-7
Survey Date: 08/20/2008

Bankfull Height: 2.16 ft
Bank Height: 3.69 ft
Root Depth: 0.75 ft
Root Density: 95 %
Bank Angle: 8 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.75 fps
Depth: 2.16 ft	Hydraulic Radius: 1.38 ft
Bankfull Slope: 0.00301	Shear Stress: 0.26 lb/sq/ft
NB Shear Stress: 1.02 lb/sq/ft	Shear Ratio: 3.95

BEHI Numerical Rating: 13.7
BEHI Adjective Rating: Low
NBS Numerical Rating: 3.95
NBS Adjective Rating: Extreme
Total Bank Length: 204.5 ft
Estimated Sediment Loss: 25.15 Cu Yds per Year
Estimated Sediment Loss: 32.7 Tons per Year

Pool XS-8 BEHI Calcs.txt
RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Pool XS-8
Survey Date: 08/20/2008

Bankfull Height: 3.6 ft
Bank Height: 5.76 ft
Root Depth: 0.75 ft
Root Density: 85 %
Bank Angle: 14 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.75 fps
Depth: 3.6 ft	Hydraulic Radius: 1.75 ft
Bankfull Slope: 0.00301	Shear Stress: 0.33 lb/sq/ft
NB Shear Stress: 0.37 lb/sq/ft	Shear Ratio: 1.12

BEHI Numerical Rating: 15.3
BEHI Adjective Rating: Low
NBS Numerical Rating: 1.12
NBS Adjective Rating: Low
Total Bank Length: 954.5 ft
Estimated Sediment Loss: 6.72 Cu Yds per Year
Estimated Sediment Loss: 8.74 Tons per Year

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Riffle XS-9
Survey Date: 08/21/2008

Bankfull Height: 2.49 ft
Bank Height: 5.4 ft
Root Depth: 0.5 ft
Root Density: 85 %
Bank Angle: 13.5 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.5 fps
Depth: 2.49 ft	Hydraulic Radius: 1.28 ft
Bankfull Slope: 0.00301	Shear Stress: 0.24 lb/sq/ft
NB Shear Stress: 1.04 lb/sq/ft	Shear Ratio: 4.31

BEHI Numerical Rating: 18.2
BEHI Adjective Rating: Low
NBS Numerical Rating: 4.31
NBS Adjective Rating: Extreme
Total Bank Length: 204.5 ft
Estimated Sediment Loss: 36.81 Cu Yds per Year
Estimated Sediment Loss: 47.85 Tons per Year

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Riffle XS-10
Survey Date: 08/21/2008

Bankfull Height: 2.52 ft
Bank Height: 4.91 ft
Root Depth: 0.5 ft
Root Density: 85 %
Bank Angle: 8.5 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.5 fps
Depth: 2.52 ft	Hydraulic Radius: 1.39 ft
Bankfull Slope: 0.00301	Shear Stress: 0.26 lb/sq/ft
NB Shear Stress: 1.01 lb/sq/ft	Shear Ratio: 3.88

BEHI Numerical Rating: 17.3
BEHI Adjective Rating: Low
NBS Numerical Rating: 3.88
NBS Adjective Rating: Extreme
Total Bank Length: 204.5 ft
Estimated Sediment Loss: 33.47 Cu Yds per Year
Estimated Sediment Loss: 43.51 Tons per Year

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Riffle XS-11
Survey Date: 08/21/2008

Bankfull Height: 2.88 ft
Bank Height: 4.8 ft
Root Depth: 0.5 ft
Root Density: 0.85 %
Bank Angle: 6.75 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.5 fps
Depth: 2.88 ft	Hydraulic Radius: 1.3 ft
Bankfull Slope: 0.00301	Shear Stress: 0.24 lb/sq/ft
NB Shear Stress: 0.77 lb/sq/ft	Shear Ratio: 3.17

BEHI Numerical Rating: 17.3
BEHI Adjective Rating: Low
NBS Numerical Rating: 3.17
NBS Adjective Rating: Extreme
Total Bank Length: 204.5 ft
Estimated Sediment Loss: 32.72 Cu Yds per Year
Estimated Sediment Loss: 42.54 Tons per Year

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
BEHI Name: Pool XS-12
Survey Date: 08/21/2008

Bankfull Height: 3.69 ft
Bank Height: 5.07 ft
Root Depth: 0.5 ft
Root Density: 0.85 %
Bank Angle: 7 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 5.32 fps	Velocity at Bed: 3.5 fps
Depth: 3.69 ft	Hydraulic Radius: 1.64 ft
Bankfull Slope: 0.00301	Shear Stress: 0.31 lb/sq/ft
NB Shear Stress: 0.47 lb/sq/ft	Shear Ratio: 1.53

BEHI Numerical Rating: 16.1
BEHI Adjective Rating: Low
NBS Numerical Rating: 1.53
NBS Adjective Rating: Moderate
Total Bank Length: 954.5 ft
Estimated Sediment Loss: 16.49 Cu Yds per Year
Estimated Sediment Loss: 21.44 Tons per Year

RIVERMORPH BEHI SUMMARY REPORT

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008

Table 1. Bank Identification Summary

Bank	Name
1	Riffle XS-7
2	Pool XS-8
3	Pool XS-12
4	Riffle XS-11
5	Riffle XS-10
6	Riffle XS-9

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	13.7	Low	Extreme	204.5	25.15	32.7
2	15.3	Low	Low	954.5	6.72	8.74
3	16.1	Low	Moderate	954.5	16.49	21.44
4	17.3	Low	Extreme	204.5	32.72	42.54
5	17.3	Low	Extreme	204.5	33.47	43.51
6	18.2	Low	Extreme	204.5	36.81	47.85
Totals				2727	151.36	196.78

Total Reach Ln: 2727 Total Loss (tons/yr) per ft of Reach: 0.0722

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
BEHI Name: Riffle XS-6
Survey Date: 08/18/2008

Bankfull Height: 1.55 ft
Bank Height: 2.01 ft
Root Depth: 0.5 ft
Root Density: 85 %
Bank Angle: 26.5 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 4.77 fps	Velocity at Bed: 3.5 fps
Depth: 1.55 ft	Hydraulic Radius: 0.72 ft
Bankfull Slope: 0.02433	Shear Stress: 1.09 lb/sq/ft
NB Shear Stress: 1.30 lb/sq/ft	Shear Ratio: 1.19

BEHI Numerical Rating: 11.7
BEHI Adjective Rating: Low
NBS Numerical Rating: 1.19
NBS Adjective Rating: Low
Total Bank Length: 974 ft
Estimated Sediment Loss: 2.39 Cu Yds per Year
Estimated Sediment Loss: 3.11 Tons per Year

RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)

River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008
BEHI Name: Pool XS-3
Survey Date: 08/20/2008

Bankfull Height: 2.2 ft
Bank Height: 3.33 ft
Root Depth: 0.5 ft
Root Density: 85 %
Bank Angle: 26.5 Degrees
Surface Protection: 95 %

Bank Material Adjustment: Cobble -10

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

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

Velocity at Surface: 4.77 fps	Velocity at Bed: 3.5 fps
Depth: 2.2 ft	Hydraulic Radius: 1.13 ft
Bankfull Slope: 0.02433	Shear Stress: 1.72 lb/sq/ft
NB Shear Stress: 0.65 lb/sq/ft	Shear Ratio: 0.38

BEHI Numerical Rating: 15.1
BEHI Adjective Rating: Low
NBS Numerical Rating: 0.38
NBS Adjective Rating: Very Low
Total Bank Length: 974 ft
Estimated Sediment Loss: 2.4 Cu Yds per Year
Estimated Sediment Loss: 3.12 Tons per Year

RIVERMORPH BEHI SUMMARY REPORT

River Name: Thompsons Fork
Reach Name: UT1 As-Built 03-26-2008

Table 1. Bank Identification Summary

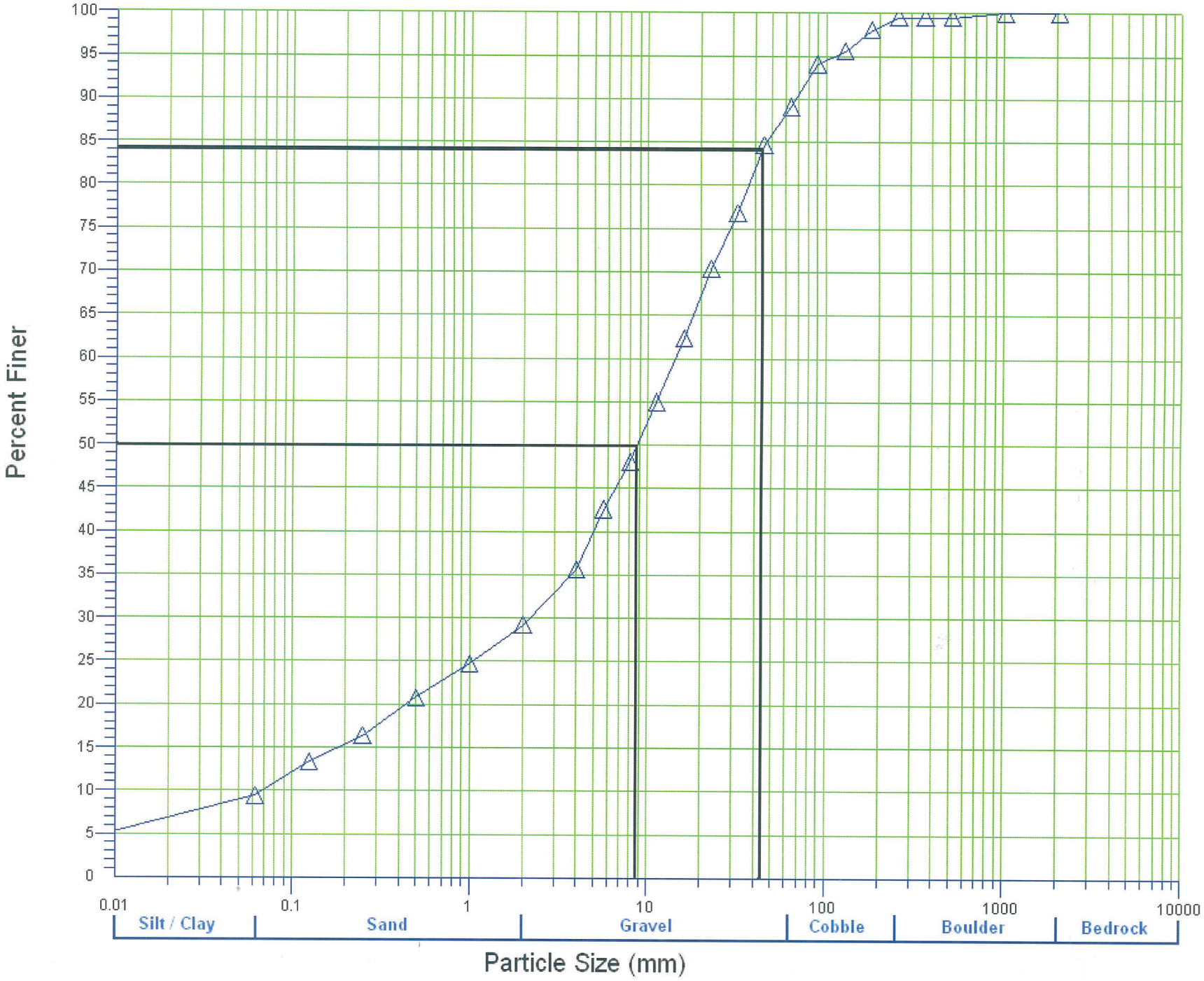
Bank	Name
1	Riffle XS-6
2	Pool XS-3

Table 2. Predicted Annual Bank Erosion Rates

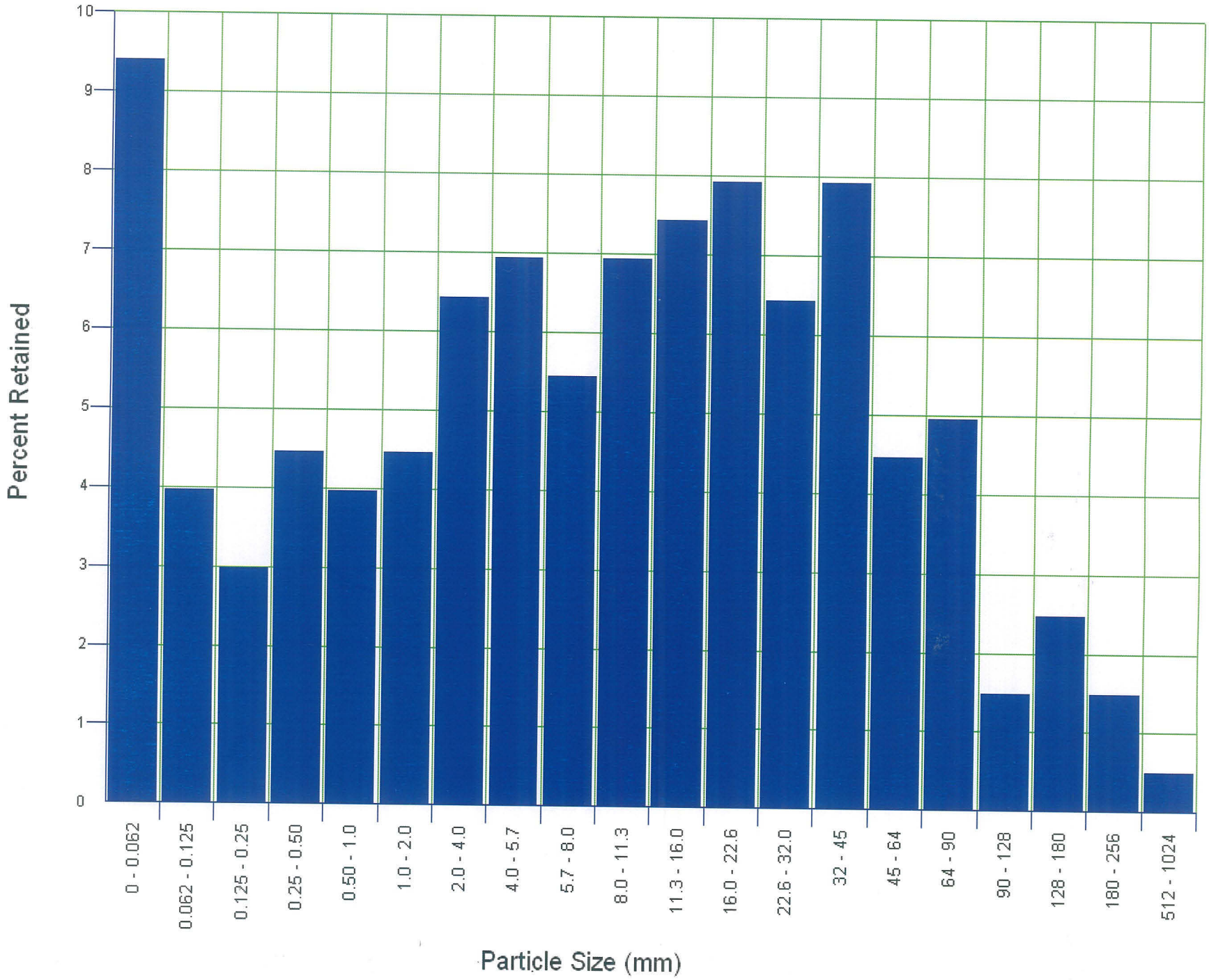
Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
1	11.7	Low	Low	974	2.39	3.11
2	15.1	Low	Very Low	974	2.4	3.12
Totals				1948	4.79	6.23

Total Reach Ln: 1948 Total Loss (tons/yr) per ft of Reach: 0.0032

Thompsons Fork Mainstem - Reach Composite Particle Distribution



Thompsons Fork Mainstem - Reach Composite Particle Distribution



RIVERMORPH PARTICLE SUMMARY

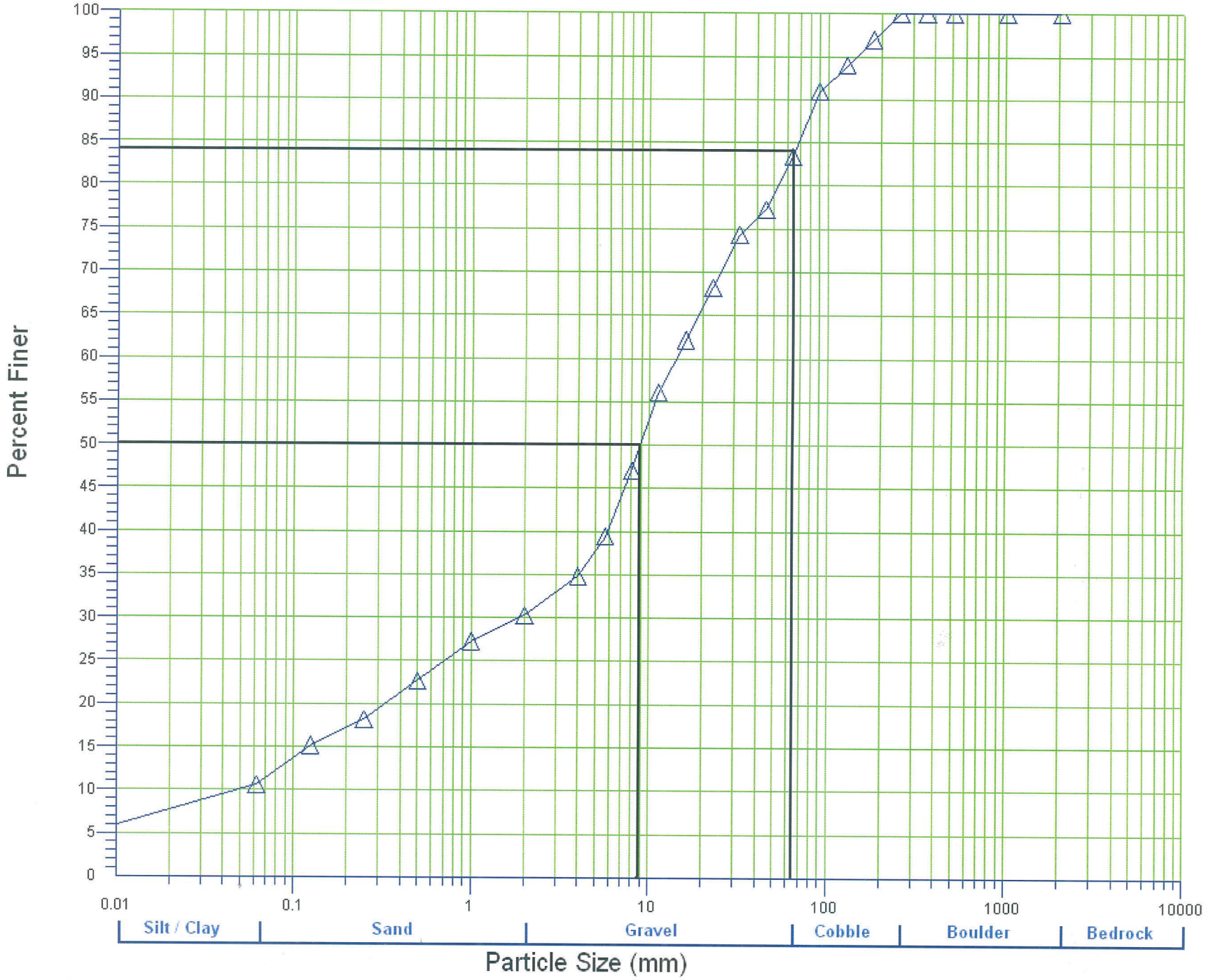
River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
Sample Name: Reach Composite
Survey Date: 06/12/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	19	9.41	9.41
0.062 - 0.125	8	3.96	13.37
0.125 - 0.25	6	2.97	16.34
0.25 - 0.50	9	4.46	20.79
0.50 - 1.0	8	3.96	24.75
1.0 - 2.0	9	4.46	29.21
2.0 - 4.0	13	6.44	35.64
4.0 - 5.7	14	6.93	42.57
5.7 - 8.0	11	5.45	48.02
8.0 - 11.3	14	6.93	54.95
11.3 - 16.0	15	7.43	62.38
16.0 - 22.6	16	7.92	70.30
22.6 - 32.0	13	6.44	76.73
32 - 45	16	7.92	84.65
45 - 64	9	4.46	89.11
64 - 90	10	4.95	94.06
90 - 128	3	1.49	95.54
128 - 180	5	2.48	98.02
180 - 256	3	1.49	99.50
256 - 362	0	0.00	99.50
362 - 512	0	0.00	99.50
512 - 1024	1	0.50	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

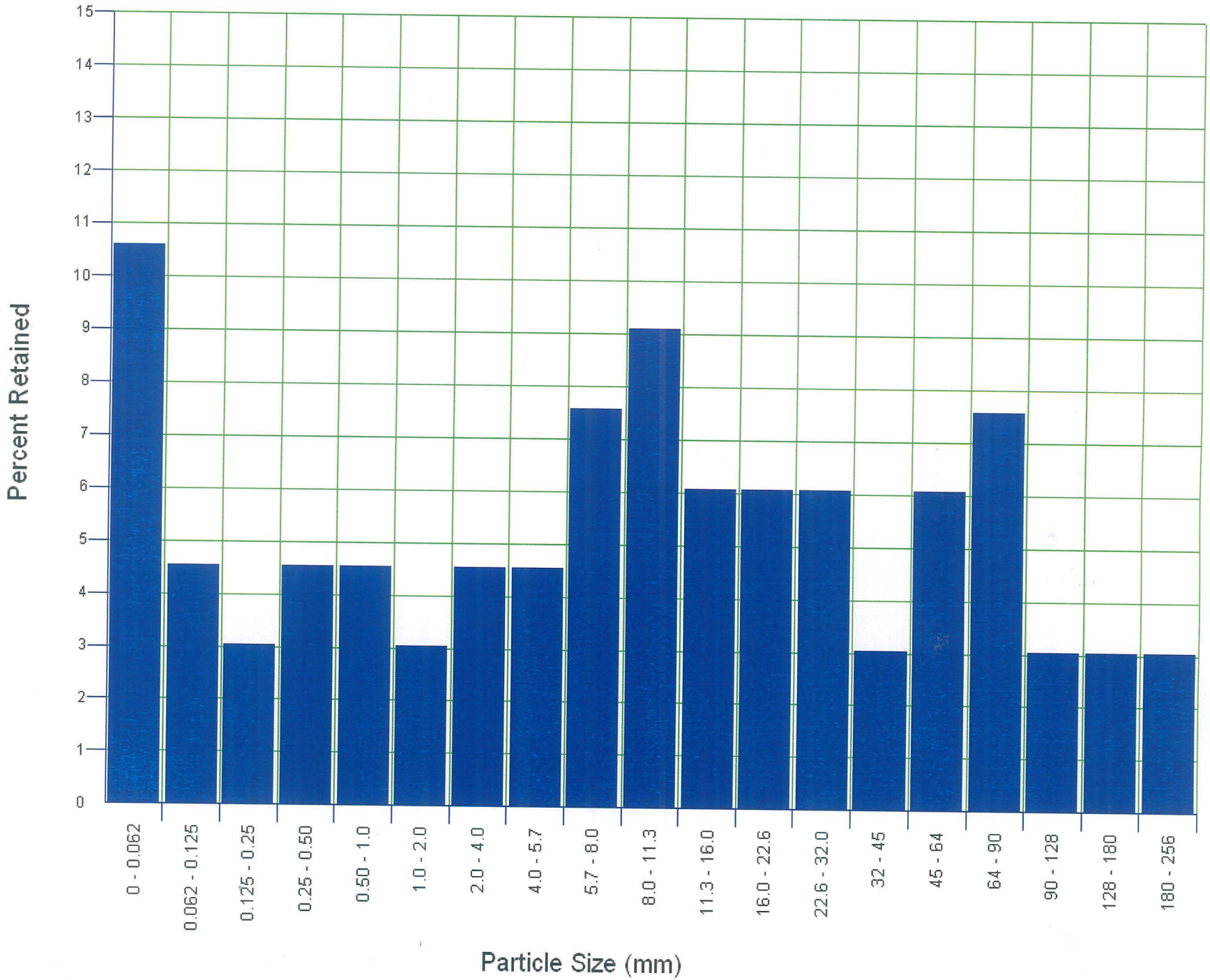
D16 (mm)	0.24
D35 (mm)	3.8
D50 (mm)	8.94
D84 (mm)	43.93
D95 (mm)	114.14
D100 (mm)	1023.9
Silt/Clay (%)	9.41
Sand (%)	19.8
Gravel (%)	59.9
Cobble (%)	10.39
Boulder (%)	0.5
Bedrock (%)	0

Total Particles = 202.

Thompsons Fork Mainstem - Riffle XS-7 - Particle Distribution



Thompsons Fork Mainstem - Riffle XS-7 - Particle Distribution



RIVERMORPH PARTICLE SUMMARY

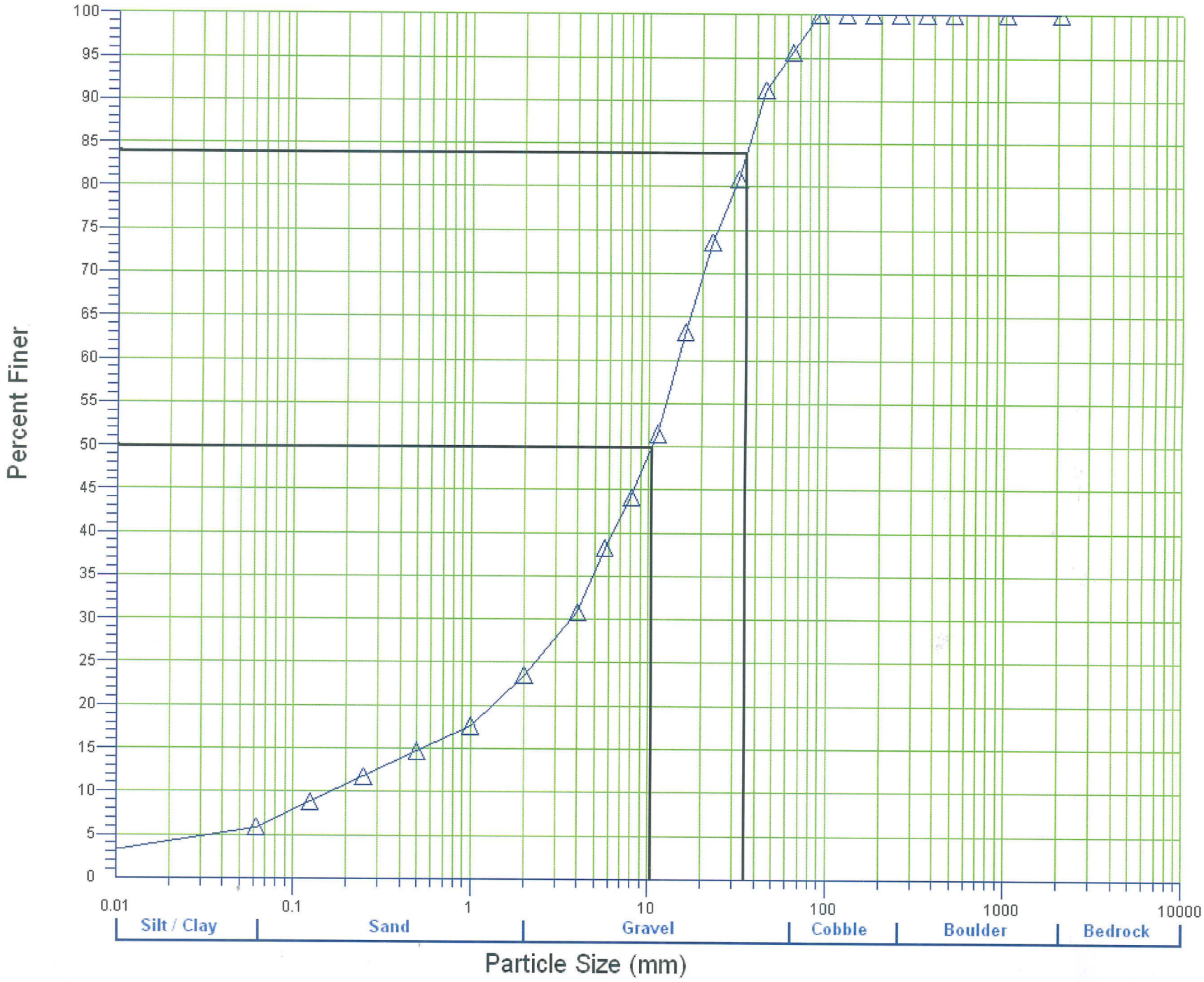
River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
Sample Name: Riffle XS-7
Survey Date: 06/12/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	7	10.61	10.61
0.062 - 0.125	3	4.55	15.15
0.125 - 0.25	2	3.03	18.18
0.25 - 0.50	3	4.55	22.73
0.50 - 1.0	3	4.55	27.27
1.0 - 2.0	2	3.03	30.30
2.0 - 4.0	3	4.55	34.85
4.0 - 5.7	3	4.55	39.39
5.7 - 8.0	5	7.58	46.97
8.0 - 11.3	6	9.09	56.06
11.3 - 16.0	4	6.06	62.12
16.0 - 22.6	4	6.06	68.18
22.6 - 32.0	4	6.06	74.24
32 - 45	2	3.03	77.27
45 - 64	4	6.06	83.33
64 - 90	5	7.58	90.91
90 - 128	2	3.03	93.94
128 - 180	2	3.03	96.97
180 - 256	2	3.03	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

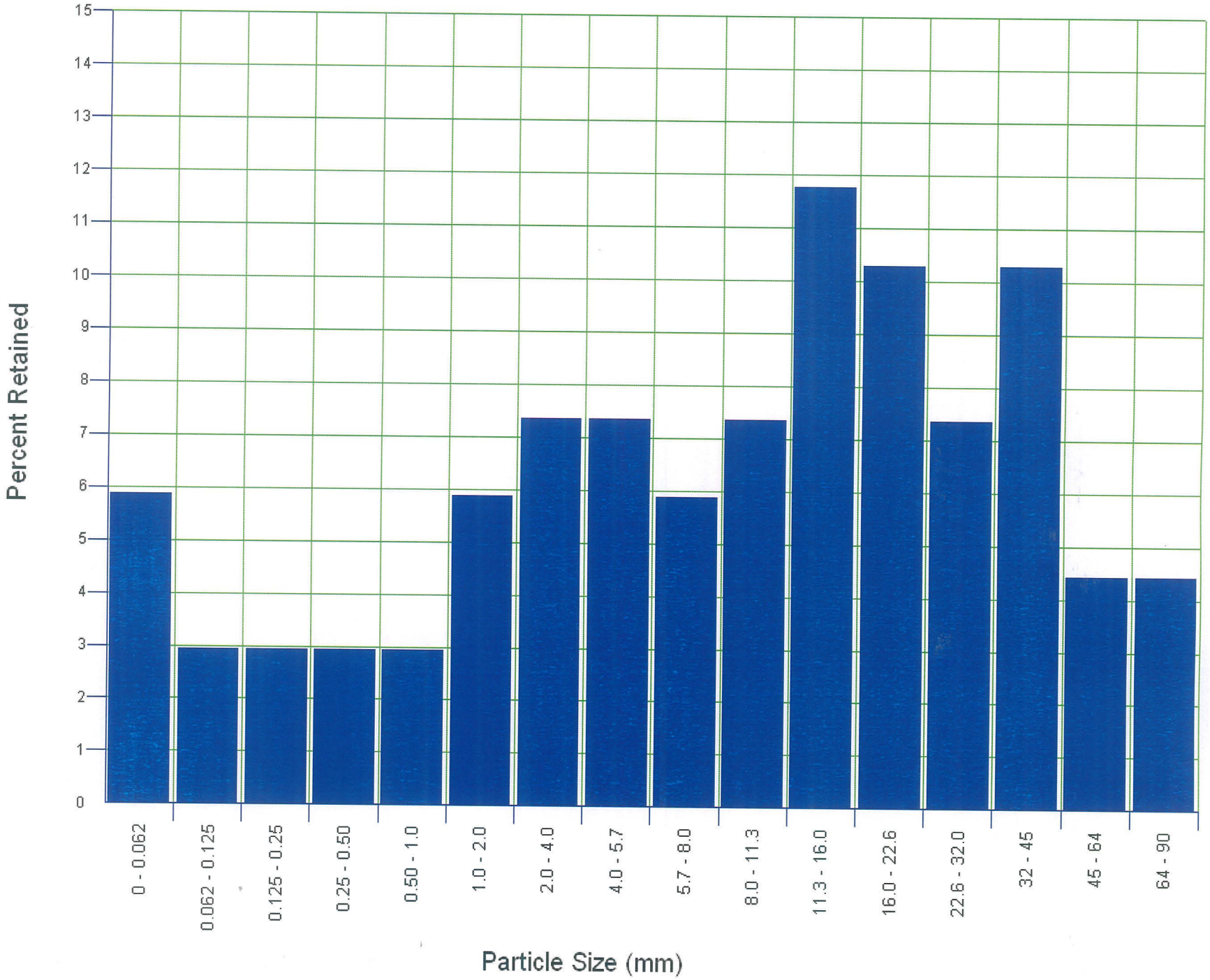
D16 (mm)	0.16
D35 (mm)	4.06
D50 (mm)	9.1
D84 (mm)	66.3
D95 (mm)	146.19
D100 (mm)	256
Silt/Clay (%)	10.61
Sand (%)	19.69
Gravel (%)	53.03
Cobble (%)	16.67
Boulder (%)	0
Bedrock (%)	0

Total Particles = 66.

Thompsons Fork Mainstem - Riffle XS-9 - Particle Distribution



Thompsons Fork Mainstem - Riffle XS-9 - Particle Distribution



RIVERMORPH PARTICLE SUMMARY

River Name: Thompsons Fork
Reach Name: Mainstem As-Built 6-12-2008
Sample Name: Riffle XS-9
Survey Date: 07/09/2008

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	4	5.88	5.88
0.062 - 0.125	2	2.94	8.82
0.125 - 0.25	2	2.94	11.76
0.25 - 0.50	2	2.94	14.71
0.50 - 1.0	2	2.94	17.65
1.0 - 2.0	4	5.88	23.53
2.0 - 4.0	5	7.35	30.88
4.0 - 5.7	5	7.35	38.24
5.7 - 8.0	4	5.88	44.12
8.0 - 11.3	5	7.35	51.47
11.3 - 16.0	8	11.76	63.24
16.0 - 22.6	7	10.29	73.53
22.6 - 32.0	5	7.35	80.88
32 - 45	7	10.29	91.18
45 - 64	3	4.41	95.59
64 - 90	3	4.41	100.00
90 - 128	0	0.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.72
D35 (mm)	4.95
D50 (mm)	10.64
D84 (mm)	35.94
D95 (mm)	61.46
D100 (mm)	90
Silt/Clay (%)	5.88
Sand (%)	17.65
Gravel (%)	72.06
Cobble (%)	4.41
Boulder (%)	0
Bedrock (%)	0

Total Particles = 68.