UT to Barnes Creek Restoration Plan
Montgomery County, North Carolina

Prepared for

Ecosystem Enhancement PROGRAM

Prepared By

BUCK ENGINEERING

1347 Harding Place
Suite 100
Charlotte, North Carolina 28204
Phone: 704.334.4454
Fax: 704.334.4492
www.buckengineering.com

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Design Report Prepared By Buck Engineering PC

Shawn D. Wilkerson
Project Manager

Emily E. Godbold, PE
Water Resources Engineer

Executive Summary

The North Carolina Department of Environment and Natural Resources Ecosystem Enhancement Program (NCDENR EEP) proposes to restore 4,063 linear feet (LF) of stream and 4.89 acres of wetland along an unnamed tributary (UT) to Barnes Creek near Flint Hill, NC. The project site is located in Montgomery County, NC. The site lies in the Yadkin River Basin within North Carolina Division of Water Quality sub-basin 03-07-09 and United States Geologic Survey (USGS) hydrologic unit 03040103050080.

Three stream reaches are located on the site: two reaches along the mainstem of the UT to Barnes Creek and a small tributary referred to herein as the Harris tributary. The UT begins off-site and enters the site from the south via a culvert under Flint Hill Road. The stream flows across the site from south to north adjacent to the Hurley property for 2,170 LF and then adjacent to the Harris property for 861 LF. The creek exits the site to the northwest via a culvert under Love Joy Road. After exiting the project site, the UT flows approximately 8,500 feet to its confluence with Barnes Creek. The Harris tributary enters on the northeast side of the site and flows 381 LF before joining the UT approximately 200 feet upstream of Love Joy Road.

The current total length of the UT mainstem on the project property is 3,031 LF. The drainage area of the UT is approximately 2.0 square miles at the downstream end of the project site. The current length of the Harris tributary is 381 LF; the Harris tributary contributes 0.18 square miles of drainage area to the project.

The design goals of the project include:

- Restore 4,063 LF of channel dimension, pattern and profile;
- Enhance 3.12 acres of existing wetland by planting vegetation in previously grazed wetland areas;
- Restore 1.38 acres of wetland by raising the water table and providing wetland hydrology to soils with hydric tendencies;
- Create 0.39 acres of wetland as ephemeral pools in the existing stream bed after construction of the proposed meandering channel;
- Improve floodplain functionality by matching floodplain elevation with bankfull stage;
- Establish native stream bank and floodplain vegetation in the buffer;
- Improve the water quality in the Barnes Creek watershed by fencing cattle out of the stream and reducing bank erosion.

TABLE ES.1
Restoration Overview
UT to Barnes Creek Restoration Plan

Project Feature	Existing Condition	Design Condition	Approach
Mainstem Hurley Reach	2,170 LF	2,475 LF	Priority 1 Restoration
Mainstem Harris Reach	861 LF	965 LF	Priority 1/2 Restoration
Harris Tributary	381 LF	623 LF	Priority 2 Restoration
Wetland Enhancement	3.12 acres	3.12 acres	Planting
Wetland Restoration	0 acres	1.38 acres	Grading and Planting
Wetland Creation	0 acres	0.39 acres	Grading and Planting

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1 Introduction and Background

1.1 Brief Project Description and Location

The North Carolina Department of Environment and Natural Resources Ecosystem Enhancement Program (NCDENR EEP) proposes to restore 3,412 linear feet (LF) of channelized stream and restore and enhance 3.12 acres of existing wetlands along an unnamed tributary (UT) to Barnes Creek. The project will result in 4,063 feet of stream restoration and 4.89 acres of wetland restoration and enhancement. Figures 1.1 and 1.2 provide an overview of the project site.

The UT to Barnes Creek stream and wetland restoration site is located north of Troy in Montgomery County, North Carolina. Land adjacent to the stream has been recently purchased by the State of North Carolina. The site has a recent history of pasture and general agricultural usage. The UT has been channelized and riparian vegetation has been cleared. Cattle have been allowed to graze on the banks and access the channel. The UT flows 3,031 LF from Flint Hill Road at the south end of the site to Love Joy Road at the northwest end of the site. The Harris tributary enters at the northeast edge of the site and flows 381 LF to the UT as illustrated in Figure 1.2. The watershed for the UT is 2.0 square miles at the downstream project limit; the Harris tributary contributes 0.18 square miles of drainage. The watershed boundaries for the UT and the Harris tributary are delineated in Figure 1.3.

1.2 Project Goals and Objectives

The specific goals for the UT to Barnes Creek restoration project are as follows:

- Restore 4,063 LF of channel dimension, pattern and profile;
- Enhance 3.12 acres of existing wetland by planting vegetation in previously grazed wetland areas;
- Restore 1.38 acres of wetland by raising the water table and providing wetland hydrology to soils with hydric tendencies;
- Create 0.39 acres of wetland as ephemeral pools in the existing stream bed after construction of the proposed meandering channel;
- Improve floodplain functionality by matching floodplain elevation with bankfull stage;
- Establish native stream bank and floodplain vegetation in the buffer;
- Improve the water quality in the Barnes Creek watershed by fencing cattle out of the stream and reducing bank erosion.
- Improve riparian habitat by creating deeper pools, areas of re-aeration, planting a riparian buffer, and reducing bank erosion.

To accomplish these goals, the existing incised, eroding, and channelized streams will be filled and new meandering channels will be constructed across the floodplain. Invasive vegetation will be removed and native vegetation will be established.

1.3 Report Overview

This report has been arranged and formatted to maximize its utility. Section 2 provides new readers with a review of the background science and methodologies applied by Buck Engineering in the practice of natural channel design. This section can be passed over by those readers already familiar with our design processes and procedures. Sections 3, 4, 5, and 6 of the report are specific to the project site. These sections cover the site assessment findings, selection and application of design criteria, and site design. Section 7 presents the monitoring and evaluation procedures for the post-implementation period.

2 Background Science and Methods

2.1 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain comprise a dynamic environment where the floodplain, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflect all of these factors (Leopold et al., 1992; Knighton, 1988). The result is a dynamic equilibrium where the stream maintains its dimension, pattern, and profile over time, and neither degrades nor aggrades. Land use changes in the watershed, including increases in imperviousness and removal of riparian vegetation, can upset this balance. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). By understanding and applying natural stream processes to stream restoration projects, a self-sustaining stream can be designed and constructed that maximizes stream and biological potential (Leopold et al., 1992; Leopold, 1994; Rosgen, 1996).

In addition to transporting water and sediment, natural streams provide the habitat for many aquatic organisms including fish, amphibians, insects, mollusks, and plants. Trees and shrubs along the banks provide a food source and regulate water temperatures. Channel features such as pools, riffles, steps, and undercut banks provide diversity of habitat, oxygenation, and cover (Dune and Leopold, 1978). Stream restoration projects can repair these features in concert with the return of a stable dimension, pattern, and profile. The following sections provide an overview of the primary channel forming process and typical stream morphology.

2.1.1 Channel Forming Discharge

The channel forming discharge, also referred to as bankfull discharge, effective discharge, or dominant discharge, creates a natural and predictable channel size and shape (Leopold et al., 1992; Leopold, 1994). Channel forming discharge theory states that there is a unique flow that over a long period of time would yield the same channel morphology that is shaped by the natural sequence of flows. At this discharge, equilibrium is most closely approached and the tendency to change is the least (Inglis, 1947). Uses of the channel forming discharge include channel stability assessment, river management using hydraulic geometry relationships, and natural channel design (Soar and Thorne, 2001).

Proper determination of bankfull stage in the field is vital to stream classification and the natural channel design process. The bankfull discharge is the point at which flooding occurs on the floodplain (Leopold, 1994). This flood stage may or may not be the top of the stream bank. On average, bankfull discharge occurs every 1.5 years (Leopold, 1994; Harman et al., 1999; McCandless, 2003). If the stream has incised due to changes in the watershed or streamside vegetation, the bankfull stage may be a small depositional bench or scour line on the stream bank (Harman et al., 1999). In this case, the top of the bank, which was formerly the floodplain, is called a terrace. A stream with terraces at the top of its banks is incised.

2.1.2 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials are largely dependent on valley slope and geology. In simple terms, steep, straight streams are found in steep, colluvial valleys, while flat, meandering streams are found in flat, alluvial valleys. Colluvial valleys have slopes between 2% and 4%, while alluvial channels have slopes less than 2%. A colluvial valley forms through hillslope processes. Sediment supply in colluvial valleys is controlled by hillslope erosion and mass wasting, i.e., the sediments in the stream bed originated from the hillslopes. Sediments reaching the channel in a colluvial valley are typically poorly sorted mixtures of fine and coarse grained materials ranging in size from sand to boulders. In contrast, an alluvial valley forms through stream and floodplain processes. Sediments in alluvial valleys include some coarse gravel and cobble transported from steeper upland areas, but are predominantly fine grained particles such as gravel and sand. Grain size generally decreases with valley slope (Leopold et al., 1992).

2.1.2.1 Step/Pool Streams

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and plunge pool downstream. Smaller particles collect in the interstices of steps creating stable, interlocking structures (Knighton, 1988).

In contrast to meandering streams that dissipate energy through meander bends, step/pool streams dissipate energy through drops and turbulence. Step/pool streams have relatively low sinuosity. Pattern variations are commonly the result of debris jams, topographic features, and bedrock outcrops.

2.1.2.2 Gravel Bed Streams

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger size particles. During low flow periods, the water depth at a riffle is relatively shallow and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, providing oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1988). Pools are typically located on the outside bends of meanders between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features and riffles are scour features.

At high flows, the water surface becomes more uniform: the water surface slope at the riffles decreases and the water surface slope at the pools increases. The increase in pool slope coupled with the greater water depth at the pools causes an increase in shear stress at the bed elevation. The opposite is true at riffles. With a relative increase in shear stress, pools scour. The relative decrease in shear stress at riffles causes bed material deposits at these features during the falling limb of the hydrograph.

2.1.2.3 Sand Bed Streams

While gravel bed streams have riffle/pool sequences, with riffles composed of gravel-size particles, sand bed channels are characterized by median bed material sizes less than 2 millimeters (Bunte and Abt, 2001). Bed material features called ripples, dunes, planebeds, and antidunes characterize the sand bedform. Although sand bed streams technically do not have riffles, the term is often used to describe the crossover reach between pools. We use “riffle” in this report as equivalent to the crossover section.

The size, stage, and variation of sand bedforms are formed by changes in unit stream power as described below. These bedforms are symptomatic of local variations in the sediment transport rate and cause minor to major variations in aggradation and degradation (Gomez, 1991). Sand bedforms can be divided between low flow regimes and high flow regimes with a transitional zone between the two. Ripples occur at low flows where the unit stream power is just high enough to entrain sand size particles. This entrainment creates small wavelets from random accumulation of sediment that are triangular in profile with gentle upstream and steep downstream slopes. The ripple dimensions are independent of flow depth and heights are less than 0.02 meters.

As unit stream power increases, dunes eventually replace ripples. Dunes are the most common type of sand bedform and have a larger height and wavelength than ripples. Unlike ripples, dune height and wavelength are proportional to flow depth. The movement of dunes is the major cause of variability in bed-load transport rates in sand bed streams. Dunes are eventually washed out to leave an upper-flow plane bed characterized by intense bedload transport. This plane bed prevents the patterns of erosion and deposition required for dune development. This stage of bedform development is called the transitional flow regime between the low flow features and the high flow regime features (Knighton, 1998).

As flow continues to increase, standing waves develop at the water surface and the bed develops a train of sediment waves (antidunes), which mirror the surface forms. Antidunes migrate upstream by way of scour on the downstream face and deposition on the upstream face, a process that is opposite of ripples and dunes. Antidunes can also move downstream or remain stationary for short periods (Knighton, 1998).

2.1.3 Stream Classification

The Rosgen stream classification system categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system presents several stream types based on a hierarchical system. The classification system is illustrated on Figure 2.1. The first level of classification distinguishes between single and multiple thread channels. Streams are then separated based on degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are also evaluated to subdivide the streams. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

Bankfull stage is the basis for measuring the width/depth and entrenchment ratios, two of the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. A detailed discussion of bankfull stage was provided in Section 2.1.1.

2.1.4 Stream Stability

A naturally stable stream must be able to transport the sediment load supplied by its watershed while maintaining dimension, pattern, and profile over time so that it does not degrade or aggrade (Rosgen, 1994). Stable streams migrate across alluvial landscapes slowly over long periods of time while maintaining their form and function. Instability occurs when scouring causes the channel to incise (degrade) or excessive deposition causes the channel bed to rise (aggrade). A generalized relationship of stream stability proposed by Lane (1955) is shown as a schematic drawing in Figure 2.2. The drawing shows that the product of sediment load and sediment size is proportional to the product of stream slope and discharge or stream power. A change in any one of these variables causes a rapid physical adjustment in the stream channel.

2.1.5 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in runoff due to build-out in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) channel evolution model characterizes evolution in six steps, including

I sinuous, pre-modified,
II channelized,
III degradation,
IV degradation and widening,
V aggradation and widening, and
VI quasi-equilibrium.

Figure 2.3 illustrates the six steps of the Simon channel evolution model.

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks and, when critical bank heights are exceeded, the banks begin to fail and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually the mass wasting slows and the stream begins to aggrade. A new low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form with a new floodplain constructed of alluvial material (FISRWG, 1998).

2.1.6 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. High, steep stream banks, poor or absent in-stream or riparian habitat, increased erosion and sedimentation, and low sinuosity are all characteristics of incised streams. Complete restoration of the stream, where the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is ideally the overriding project objective. There may be scenarios, however, where such an objective is impractical due to encroachment into the abandoned floodplain terrace by homes, roadways, utilities, etc. A priority system for the restoration of incised streams, developed and used by Rosgen (1997), considers a range of options to provide the best level of stream restoration possible for the given setting. Figure 2.4 illustrates various restoration/stabilization options for incised channels within the framework of the Rosgen's priority system. Generally:

- Priority 1 – Re-establishes the channel on a previous floodplain (i.e., raises channel elevation); meanders a new channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel. This option requires that the upstream start point of the project not be incised.
- Priority 2 – Establishes a new floodplain at the existing bankfull elevation (i.e., excavates a new floodplain); meanders channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised.
- Priority 3 – Converts a straight channel to a different stream type while leaving the existing channel in place by excavating bankfull benches at the existing bankfull elevation. Effectively, the valley for the stream is made more bowl-shaped. This approach uses in-stream structures to dissipate energy through a step/pool channel type.
- Priority 4 – Stabilizes the channel in place using in-stream structures and bioengineering to decrease stream bed and stream bank erosion. This approach is typically used in highly constrained environments.

2.2 Natural Channel Design Overview

Restoration design of degraded stream reaches first involves accurately diagnosing their current condition. Understanding valley type, stream type, channel stability, bedform diversity, and potential for restoration is essential to developing adequate restoration measures (Rosgen, 1996). This combination of assessment and design is often referred to as natural channel design.

The first step in a stream restoration design is to assess the reach, its valley, and its watershed to understand the relationship between the stream and its drainage basin and to evaluate the causes of stream impairment. Bankfull discharge is estimated for the watershed. After sources of stream impairment are identified and channel geometry is assessed, a plan for restoration can be formulated.

Design commences at the completion of the assessment stage. A series of iterative calculations are performed using data from reference reaches, pertinent literature, and evaluation of past projects to develop an appropriate stable cross-section, profile, and plan form dimensions for the design reach. A thorough discussion of design parameter selection is provided in Section 2.5. The alignment should avoid an entirely symmetrical layout to mimic natural variability, create a diversity of aquatic habitats, and improve aesthetics.

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.6.

After the sediment transport assessment, additional structural elements are then added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.7 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared showing dimension, pattern, profile, and location of additional structures. These drawings are used in the construction of the project.

Following the implementation of the design, a monitoring plan is established to:

- Ensure that stabilization structures are functioning properly,
- Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, and sediment transport and stream bank erosion rates,
- Determine biological response (food chains, standing crop, species diversity, etc.), and
- Determine the extent to which the restoration objectives have been met.

2.3 Geomorphic Characterization Methodology

Geomorphic characterization of stream features includes the bankfull identification, bed material characterization and analysis, and stream classification.

2.3.1 Bankfull Identification

Correct identification of bankfull is important to the determination of geomorphic criteria such as stream type, bank height ratios, width to depth ratios, and entrenchment ratios. Buck Engineering's field techniques for bankfull identification are as follows:

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high. In that case, the bar may flatten and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.

- Measure the difference in height between the water surface and the bankfull indicator. For example, the indicator may be 2.2 feet above water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the watershed.
- Go to a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator. For example, measure 2.2 feet above water surface and place a flag in both the right and left bank.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross-sectional area.
- Obtain the appropriate regional curve (e.g., rural Piedmont, urban Piedmont, Mountain, or Coastal Plain) and determine the cross-sectional area associated with the drainage area of the reach.
- Compare the measured cross-sectional area to the regional curve cross-sectional. If the measured cross-sectional area is not a close fit, look for other bankfull indicators and test them. If there are no other indicators, look for reasons to explain the difference between the two cross-sectional areas. For example, if the cross-sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross-sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle using indicators from depositional features. The cross-sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or maintenance. In such cases, it is important to verify bankfull through other means such as a gage station survey or reference bankfull information that is specific to the geographic location. The gage information can be used, along with regional curve information, to estimate bankfull elevation in the a project reach that contains no bankfull indicators.

2.3.2 Bed Material Characterization

Buck Engineering performs bed material characterization using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed in transects across the streambed, with the number of riffle and pool transects being proportional to the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median particle size of the modified Wolman procedure is known as the d_{50}. The d_{50} describes the bed material classification for that reach. The bed material classification is shown on Figure 2.1 and ranges from a classification of 1 for a channel d_{50} of bedrock to a classification of 6 for a channel d_{50} in the silt/clay particle size range.

2.3.3 Stream Classification

Cross-sections are surveyed along stable riffles for the purpose of stream classification. Values for entrenchment ratio and width/depth ratio, along with sinuosity and slope, are used to classify the stream. The entrenchment ratio (ER) is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The width/depth ratio (w/d ratio) is calculated by dividing bankfull width by mean bankfull depth) Figure 2.5 shows examples of the channel dimension measurements used in the Rosgen stream classification system.

Finally, the numbers that coincide with each bed material classification are to further classify the stream type. For example, a Rosgen E3 stream type is a narrow and deep cobble-dominated channel with access to a floodplain that is greater than two times its bankfull width.

2.4 Channel Stability Assessment Methodology

Buck Engineering uses a modified version of stream channel stability assessment methodology developed by Rosgen (2001). The Rosgen method is a field assessment of the following stream channel characteristics:

- Stream Channel Condition,
- Vertical Stability,
- Lateral Stability,
- Channel Pattern,
- River Profile and Bed Features,
- Channel Dimension Relations, and
- Channel Evolution.

This field exercise is followed by the evaluation of various channel dimension relationships.

Evaluation of the above categories and ratios leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each category is provided in the following sections.

2.4.1 Stream Channel Condition Observations

Stream channel conditions are observed during initial field inspection (stream walk). Buck Engineering notes the follow characteristics:

- Riparian vegetation – concentration, composition, and rooting depth and density;
- Sediment depositional patterns – such as mid-channel bars and other depositional features that indicate aggradation and can lead to negative geomorphic channel adjustments;
- Debris occurrence – presence or absence of woody debris;
- Meander patterns – general observations with regard to the type of adjustments a stream will make to reach equilibrium; and
- Altered states due to direct disturbance – such as channelization, berm construction, and floodplain alterations.

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows comparison across different sets of conditions. The observations also help explain the quantitative measurements described below.

2.4.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to assess vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.1 shows the relationship between bank height ratio (BHR) and vertical stability developed by Rosgen (2001).

TABLE 2.1
Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability (Rosgen, 2001a)

Adjective Stability Rating	Bank Height Ratio
Stable (low risk of degradation)	1.0 – 1.05
Moderately unstable	1.06 – 1.3
Unstable (high risk of degradation)	1.3 – 1.5
Highly unstable	> 1.5

The entrenchment ratio is measured as the width of the floodplain at twice the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is considered entrenched (Rosgen, 1996).

2.4.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral erosion are assessed in the field by measuring the meander width ratio (MWR) and the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001a). The MWR is the meander belt width divided by the bankfull channel width, and provides insight into lateral channel adjustment processes depending on stream type and degree of confinement. For example, a MWR of 3.0 often corresponds with a sinuosity of 1.2, which is the minimum value for a stream to be classified as meandering. If the MWR is less than 3.0, lateral adjustment is probable. BEHI ratings along with near bank shear stress estimates can be compared to data from monitored sites and used to estimate the annual lateral stream bank erosion rate.

2.4.4 Channel Pattern

Channel pattern is assessed in the field by measuring the stream's plan features including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width). These dimensionless ratios are compared to reference reach data for the same valley and stream type to assess whether channel pattern has been impacted.

2.4.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. Profile points are surveyed at prescribed intervals and at significant breaks in slope such as the head of a riffle or the head of a pool. This profile can be used to assess changes in river slope compared to valley slope, which affect sediment transport, stream competence, and the balance of energy. For example, the removal of large woody debris may increase the step/pool spacing and result in excess energy and subsequent channel degradation. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design.

2.4.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and relates to channel instability. A greater width/depth ratio compared to reference conditions may indicate accelerated stream bank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and downcutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.2 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001).

TABLE 2.2
Conversion of Width/Depth Ratios to Adjective Ranking of Stability from Stability Conditions (Rosgen, 2001a)

Stability Rating	Ratio of Project to Reference Width/Depth
Very stable	1.0
Stable	1.0 – 1.2
Moderately unstable	1.21 – 1.4
Unstable	> 1.4

While an *increase* in width/depth ratio is associated with channel *widening*, a *decrease* in width/depth ratio is associated with channel *incision*. Hence, for incised channels, the ratio of channel width/depth ratio to reference reach width/depth ratio will be less than 1.0. The reduction in width/depth ratio indicates excess shear stress and movement of the channel toward an unstable condition.

2.4.7 Channel Evolution

Simon's channel evolution model (introduced in Section 2.1.5) relies on a qualitative, visual assessment of the existing stream channel characteristics (bank height, evidence of degradation/aggradation, presence of bank slumping, direction of bed and bank movement, etc.). Establishing the evolutionary stage of the channel helps ascertain whether the system is moving towards greater stability or instability. The model also provides a better understanding of the cause and effect of channel change. This information, combined with Rosgen's (1994) priority levels of restoration aids in determining the restoration potential of unstable reaches.

2.5 Design Parameter Selection Methodology

Buck Engineering uses a combination of approaches to develop design criteria for channel dimension, pattern, and profile. These approaches are described in the following sections. A flow chart for selecting design criteria is shown in Figure 2.6.

2.5.1 Upstream Reference Reaches

The best option for developing design criteria is to locate a reference reach upstream of the project site. A reference reach is a channel segment that is stable—neither aggrading nor degrading— and is of the same morphological type as the channel under consideration for restoration. The reference reach should also have a similar valley slope as the project reach. The reference reach is then used as the blueprint for the channel design (Rosgen, 1998). To account for differences in drainage area and discharge between a reference site and a project site, data on channel characteristics (dimension, pattern, and profile), in the form of dimensionless ratios, are developed for the reference reach. If the reach upstream of the project does not have sufficient pattern, but does have a stable riffle cross-section, only dimension ratios are calculated. It is ideal to measure a reference bankfull dimension that was formed under the same environmental influences as the project reach.

2.5.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is performed. A database search is conducted to locate known reference reaches in close proximity to the project site. The search includes streams with the same valley as the project reach and stream type as the design. If references are found meeting these criteria, the reference reach is field-surveyed for validation and comparison with the database values which may have been originally collected and provided by a third party. If a search of the database reveals no references which meet the appropriate criteria, a field search is performed locally to identify a reference reach which has not yet been surveyed.

Potential reference reaches are identified by first evaluating USGS topographic quadrangles and aerial photography for an area. In general, the search is limited to subwatersheds within or adjacent to the project watershed. In certain cases, a reference reach may be identified farther away that matches the same valley and stream type as the proposed design of the project site. In such a case, care is taken to ensure that the potential reference reach lies within the same physiographic region as the project reach. Potential reference sites identified on maps are then field-evaluated to determine if they are stable systems of the appropriate stream and valley type. If appropriate, reference reach surveys are conducted. When potential sites are located on private property, landowner permission is acquired prior to any survey work being conducted.

2.5.3 Reference Reach Databases

If a reference reach is not found in close proximity to the project site, a reference reach database is consulted and summary ratios are acquired for all streams with the same valley and stream type within the project's physiographic region. These ratios are then compared to literature values and regime equations along with ratios developed through the evaluation of successful projects.

2.5.4 Regime Equations

Buck Engineering uses a variety of published journals, books, and design manuals to cross-reference North Carolina database values with peer-reviewed regime equations. Examples include *Fluvial Forms and Processes* by David Knighton (1998), *Mountain Rivers* by Ellen Wohl (2000), and the *Hydraulic Design of Stream Restoration Projects* by the US Army Corps of Engineers (Copeland et al., 2001). The most common regime equations used in our designs are for pattern. For example, most reference reach surveys in the eastern United States show radius of curvature divided by bankfull width ratios much less than 1.5. However, the Corps manual recommends a ratio greater than 2.0 to maintain stability in free-forming systems. Since most stream restoration projects are constructed on floodplains denude of woody vegetation, we often use the Corps-recommended value rather than reference reach data. Meander wavelength and pool-to-pool spacing ratios are examples of other parameters that are sometimes designed with higher ratios than those observed on reference reaches, for similar reasons as described for radius of curvature.

2.5.5 Comparison to Past Projects

All of the above techniques for developing ratios and/or regime equations are compared to past projects built with similar conditions. Ultimately, these sites provide the best pattern and profile ratios because they reflect site conditions after construction. While most reference reaches are in mature forests, restoration sites are in floodplains with little or no mature woody vegetation. This lack of mature woody vegetation severely alters floodplain processes and stream bank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used. Conversely, if past project ratios created stable channels with optimal bedform diversity; they will be incorporated into the design.

Ultimately, the design criteria are selections of ratios and equations made upon a thorough evaluation of the above tasks. Combinations of approaches may be used to optimize the design. The final selection of design criteria for the restoration site is discussed in Section 5.

2.6 Sediment Transport Competency and Capacity Methodology

Stream restoration designs must be tested to ensure that the new channel dimensions (in particular, the design bankfull mean depth) create a stream that has the ability to move its sediment load without aggrading or degrading over long periods of time. The ability of the stream to transport its total sediment load is quantified through two measures: sediment transport competency and sediment transport capacity. Competency is a stream's ability to move particles of a given size and is a measurement of force, often expressed as units of pounds per square foot (lbs/ft^2). Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of watts/square meter. Sediment transport capacity is also calculated as a sediment transport rating curve, which provides an estimate of the quantity of total sediment load transported through a cross-section per unit time. The curve is provided as a sediment transport rate in pounds per second (lbs/sec) versus discharge or stream power.

The total volume of sediment transported through a cross-section consists of bedload plus suspended load fractions. Suspended load is normally composed of fine sand, silt, and clay particles transported in the water column. Bedload is generally composed of larger particles, such as course sand, gravels, and cobbles, which are transported by rolling, sliding, or hopping (saltating) along the bed.

2.6.1 Competency Analysis

Median substrate size has an important influence on the mobility of particles in stream beds. Critical dimensionless shear stress (τ*ci) is the measure of force required to initiate general movement of particles in a bed of a given composition. At shear stresses exceeding this critical value, essentially all grain sizes are transported at rates in proportion to their presence in the bed (Wohl, 2000). τ*ci can be calculated for gravel-bed stream reaches using surface and subsurface particle samples from a stable, representative riffle in the reach (Andrews, 1983). Critical dimensionless shear stress is calculated as follows (Rosgen, 2001a):

1. Using the following equations, determine the critical dimensionless shear stress required to mobilize and transport the largest particle from the bar sample (or subpavement sample).

a) Calculate the ratio d50/d^50

Where: d50 = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)

d^50 = median diameter of the bar sample (or subpavement)

If the ratio d50/d^50 is between the values of 3.0 and 7.0, then calculate the critical dimensionless shear stress using Equation 1.

$$\tau^*ci = 0.0834\ (d50/\hat{d}50)^{-0.872} \qquad \text{(Equation 1)}$$

b) If the ratio d50/D^50 is not between the values of 3.0 and 7.0, then calculate the ratio of di/d50

Where: di = Largest particle from the bar sample (or subpavement) d50 = median diameter of the riffle bed (from 100 count in the riffle or the pavement sample)

If the ratio di/d50 is between the values of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

$$\tau^*_{ci} = 0.0384\,(d_i/d_{50})^{-0.887} \qquad \text{(Equation 2)}$$

2.6.2 Aggradational Analysis

The aggradation analysis is based on calculations of the required depth and slope needed to transport large sediment particles, in this case defined as the largest particle of the riffle subpavement sample. Required depth can be compared with the existing/design mean riffle depth and required slope can be compared to the existing/design slope to verify that the stream has sufficient competency to move large particles and thus prevent thalweg aggradation. The required depth and slope are calculated by:

$$d_r = \frac{1.65\tau^*_{ci}d_i}{S_e} \qquad \text{(Equation 3)}$$

$$s_r = \frac{1.65\tau^*_{ci}d_i}{d_e} \qquad \text{(Equation 4)}$$

Where: dr (ft) = Required bankfull mean depth

de (ft)= Design bankfull mean depth

1.65 = Sediment density (submerged specific weight)

= density of sediment (2.65) – density of water (1.0)

t*ci = Critical dimensionless shear stress

di (ft) = Largest particle from bar sample (or subpavement)

sr (ft/ft) = Required bankfull water surface slope

se (ft/ft) = Design bankfull water surface slope

The aggradation analysis is used to assess both existing and design conditions. For example, if the calculated value for the existing critical depth is significantly larger than the measured maximum bankfull depth, this indicates that the stream is aggrading. Alternately, if the proposed design depth significantly differs from the calculated critical depth and the analysis is deemed appropriate for the site conditions, the design dimensions should be revised accordingly.

2.6.3 Competency Analysis using Shield's Curve

As a complement to the required depth and slope calculations, boundary shear stresses for a design riffle cross-section can be compared with a modified Shield's curve to predict sediment transport competency. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma R s \qquad \text{(Equation 5)}$$

Where,
τ = shear stress (lb/ft^2)
γ = specific gravity of water (62.4 lb/ft^3)
R = hydraulic radius (ft)
s = average channel slope (ft/ft)

The boundary shear stress can be estimated for the design cross-section and plotted on a modified Shield's curve, as shown in Figure 2.7. The particle size that Shield's curve predicts will be moved is compared to the D_i of the site subpavement. Shield's curve predicts whether the design conditions will have enough shear stress to move a particle larger than the largest subpavement particle found in the creek and prevent aggradation.

2.6.4 Sediment Transport Capacity

For sand bed streams, sediment transport capacity is much more important than competency. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross-section per unit time in pounds/second or tons/year. Sediment transport capacity can be assessed directly using actual monitored data from bankfull events if a sediment transport rating curve has been developed for the project site. Since this curve development is extremely difficult, other empirical relationships are used to assess sediment transport capacity. The most common capacity equation is stream power. Stream power can be calculated a number of ways, but the most common is:

$w = \gamma\, QS/W_{bkf}$, where (Equation 6)

w = mean stream power in W/m^2

γ = specific weight of water (9810 N/m3). $\gamma = \rho$ g where ρ is the density of the water-sediment mixture (1,000 kg/m^3) and g is the acceleration due to gravity (9.81 m/s^2)

Q = bankfull discharge in m^3/s

S = Design channel slope (meters per meter)

W_{bkf} = Bankfull channel width in meters

Note: 1 ft-lb/sec/ft^2 = 14.56 W/m^2

Equation 6 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work, i.e., move sediment. Calculated stream power values are compared to reference and published values. If deviations from known stable values for similar stream types and slopes are observed, the design should be reassessed to confirm that sediment will be adequately transported through the system without containing excess energy in the channel.

2.7 In-Stream Structures

There are a variety of in-stream structural elements used in restoration. Figure 2.8 illustrates a few typical structures. These elements are comprised of natural materials such as stone, wood, and live vegetation. Their shape and location works with the flow dynamics to reinforce, stabilize, and enhance the function of the stream channel. In-stream structures provide three primary functions: grade control, stream bank protection, and habitat enhancement.

2.7.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5% is seldom able to maintain the desired slopes and bed features (riffles, runs, pools and glides) until a pavement/subpavement layer has been established. Stone and/or log structures installed at the bed elevation and at critical locations in the plan view help to set up the new stream bed for long-term vertical stability. Over time as the new channel adjusts to its sediment transport regime and vegetative root mass establishes on the banks, the need for grade control diminishes.

2.7.2 Bank Protection

Bank protection is critical during and after construction as bank and floodplain vegetation is establishing a reinforcing root mass. This vegetation establishment lasts for several years, but vegetation is typically providing meaningful bank protection after two to four growing seasons. Bank protection structures generally provide both reinforcement to the stream banks and re-direction of flow away from the banks and toward the center of the channel.

2.7.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. Flow over vanes and wing deflectors creates scour pools, which provide diversity of in-stream habitat. Boulder clusters form eddies that provide resting places for aquatic species. Constructed riffles and vane structures encourage oxygenation of the water. Root wads provide cover and shade, and encourage the formation of deep pools at the outside of meander bends.

2.7.4 Selection of Structure Types

Table 2.3 summarizes the names and functions of several in-stream structures.

TABLE 2.3
Functions of In-Stream Structures

Structure	Function (Primary = 1, Secondary = 2)		
	Grade Control	Bank Protection	Habitat Enhancement
Cross Vane	1	1	2
Single Arm Vane		1	2
J-Hook Vane	2	1	2
Constructed Riffle	1	1	2
Log Weir	1		2
Wing Deflector	2	1	1

Boulder Cluster		1
Root Wad	1	1
Brush Mattress	1	2
Cover Log		1

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structures comprise the main, or possibly only, effort to restore a stream. More often, structures are used in conjunction with grading, realignment, and planting in an effort to improve channel stability and aquatic habitat.

2.8 Vegetation

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize stream banks, creates habitat and a food source for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of a restoration project typically includes live dormant staking of the stream banks, riparian buffer plantings, invasive species removal, and seeding for erosion control. The stream banks and the riparian area are typically planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Vegetating the stream banks is a very desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration. During high flows, plants lie flat and stems and leaves shield and protect the soil surface from erosion. In most settings, vegetation is more aesthetically appropriate than engineered stabilization structures.

Stream banks are delineated into four zones when considering a planting scheme:

1. Channel bottom - extending up to the low flow stage. Emergent, aquatic plants dominate bank range, extending from the low flow stage to the bankfull stage
2. Lower bank - frequently flooded, extending from the low flow stage to the bankfull stage. A mix of herbaceous and woody plants including sedges, grasses, shrubs and trees
3. Upper bank – occasionally flooded, but most often above water. Dominated by shrubs and small trees.
4. Riparian area – infrequently flooded, terrestrial and naturally forested with canopy-forming trees.

The most appropriate source of plant material for any project is the site itself. Desirable plants that need to be removed in the course of construction should be salvaged and transplanted as part of the restoration plan. The next best alternative is to obtain permission to collect and transplant native plants from areas nearby. This transplant process ensures that the plants are native and adapted to the locale. Finally, plants may need to be purchased. They should be obtained from a nearby reputable nursery that guarantees that the plants are native and appropriate for the locale and climate of the project site.

2.8.1 Live Staking

Live staking is a method of revegetation that utilizes live, dormant cuttings from appropriate species to cheaply, and effectively establish vegetation. The installation of live stakes on stream banks serves to protect the banks from erosion and at the same time provide habitat, shade and improved aesthetics. Live staking must take place during the dormant season (November – March in the Southeast US). Live stakes can be gathered locally or purchased from a reputable commercial supplier. Stakes should be at least ½ inches in diameter and no more than 2 inches in diameter, between 2 and 3 feet in length, and living based on the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet.

2.8.2 Riparian Buffer Re-Vegetation

Riparian buffers are naturally occurring ecosystems adjacent to rivers and streams and are associated with a number of benefits. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow groundwater flow. Buffers also provide habitat and travel corridors for wildlife populations and are an important recreational resource. It is also important to note that riparian buffer areas help to moderate the quantity and timing of runoff from the upland landscape and contribute to the groundwater recharge process.

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Although width generally increases the capacity of riparian buffers to improve water quality and provide greater habitat value, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd et al., 1987). An estimated minimum width of 30 feet is required for creating beneficial forest structure and riparian habitat.

In stream and wetland restoration, where buffer width is often limited, the following design principles apply:

- Design for sheet flow into and across the riparian buffer area.
- If possible, the width of the riparian buffer area should be proportional to the watershed area, the slope of the terrain, and the velocity of the flow through the buffer.
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat.
- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat.

2.9 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and, most importantly, the execution of the construction phase. There are many factors that ultimately determine the success of these projects and many of the factors are beyond the influence of a designer. To compile all of the factors is beyond the scope of this report. Further, it is impossible to consider and to design for all of them. However, it is important to acknowledge that factors such as daily temperatures, the amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics, are beyond the control of the designer.

Many restoration sites will require some post-construction maintenance, primarily because newly planted vegetation plays a large role in channel and floodplain stability. Stream restoration projects are most vulnerable to adjustment and erosion immediately after construction, before vegetation has had a chance to establish fully. Risk of instability diminishes with each growing season. Streams and floodplains usually become self maintaining after the second year of growth. However, unusually heavy floods often cause erosion, deposition and/or loss of vegetation in even the most stable channels and forested floodplains.

3 Watershed Assessment Results

3.1 Watershed Delineation

The site lies in the Yadkin River Basin within North Carolina Division of Water Quality sub-basin 03-07-09 and United States Geologic Survey (USGS) hydrologic unit 03040103050080. Figure 1.3 shows the watershed boundaries for the project.

3.2 Site Hydrology/Hydraulics

3.2.1 Surface Water Classification

The North Carolina Division of Water Quality (NCDWQ) designates surface water classifications for water bodies such as streams, rivers, and lakes, which define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications carry with them an associated set of water quality standards to protect those uses. All surface waters in North Carolina must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Classifications and their associated protection rules may also be designed to protect the free flowing nature of a stream or other special characteristics.

The section of Barnes Creek that receives water from the UT is classified by the NCDWQ as Class C ORW [DWQ Index No. 13-2-18-(0.5)]. Class ORW is defined as Outstanding Resource Waters. Approximately five miles further downstream from the UT confluence, Barnes Creek is classified as WS-IV ORW [DWQ Index No. 13-2-18-(2.5)].

3.2.2 Site Hydrologic and Hydraulic Characteristics

The Federal Emergency Management Agency Flood Insurance Rate Map (FIRM) for Montgomery County, NC (Community Number 370336) indicates that the there is no regulatory floodplain associated with either the project site or the downstream reach of the UT to Barnes Creek.

3.3 Geology

The project area in northwestern Montgomery County, N.C is located within the Carolina Slate Belt of central North Carolina. The underlying geology of the project area consists of Cambrian age felsic metavolcanic rock, specifically metamorphosed dacitic to rhyolitic flows and tuffs, which are interbedded with more mafic metavolcanics as well as metamudstone. Outcrops found within the project area likely belong to the Uwharrie Formation. The vicinity topography is characterized by gently rolling hills and wide alluvial valleys. Local relief within the project site is approximately 32 feet, with the highest point located adjacent to Flint Hill Road at the southeast edge of the site (637 ft NGVD) and the lowest point located at the northwest corner of the site (605 NGVD). The site topography is shown on Figure 1.3.

3.4 Soils

Soils at the site were determined using NRCS Soil Survey data for Montgomery County, along with preliminary on-site evaluations to determine any hydric soil areas (USDA 2000). A map depicting the boundaries of each soil type is presented in Figure 3.1. There are two general soil types found within the project boundaries. These soils will support stream restoration activities. A discussion of each soil type and its locations is presented in Table 3.1.

Soils within the lower floodplain areas are mapped primarily as the Chenneby series and contain several areas of hydric inclusions. The land containing these soils is generally suitable for efforts to restore stability to stream banks and to manipulate riparian vegetation and wetland areas, as long as care is taken during months of flooding (November through April).

Soils on the higher elevation areas of the site include the Herndon series. Descriptions of this series, as given in the county soil survey, are provided in Table 3.1 below.

TABLE 3.1
Project Soil Types and Descriptions
From Montgomery County Soil Survey, USDA-NRCS, 1968

Soil Name	Location	Description
Chenneby Silt Loam	Main channel and Floodplain	This soil type occurs on slopes from 1 to 2 percent in areas frequently flooded and generally has a very deep soil profile, somewhat poor drainage, moderate permeability, and a very shallow depth to the seasonal high water table. The surface layer and subsurface layers are loamy in texture with an increase in clay content starting at about 3 feet below the surface. Due to wetness and flooding, these soils are often poorly suited for growing crops, pasture, and any kind of urban development.
Herndon Silt Loam	Hillside	The Herndon Silt Loam is well drained and well suited for pastureland and occurs on slopes between 15 to 25 percent.

3.5 Land Use

The UT drains surrounding agricultural, forested, and isolated residential areas. The overall Barnes Creek watershed is mostly rural with land uses that include agriculture, timber logging, forested area and some residential property. Paved roads bound the project site on the west and south boundaries.

3.6 Endangered/Threatened Species

Some populations of plants and animals are declining either as a result of natural forces or their difficulty competing with humans for resources. Plants and animals with a federal classification of Endangered (E), Threatened (T), Proposed Endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. Federally classified species listed for Montgomery County, and any likely impacts to these species as a result of the proposed project construction, are discussed in the following sections.

Species that the North Carolina Natural Heritage Program (NHP) lists under federal protection for Montgomery County as of March 9, 2004 are listed in Table 3.2. Other Federal Species of Concern are also included. A brief description of the characteristics and habitat requirements of these species follow the table, along with a conclusion regarding potential project impact.

TABLE 3.2
Species Under Federal Protection and Species of Concern in Montgomery County
UT to Barnes Creek Restoration Plan

Family	Scientific Name	Common Name	Federal Status	Date Listed	State Status	Habitat Present / Biological Conclusion
		Vertebrates				
Felidae	*Puma concolor cougar*	Eastern cougar	E	06-04-1973	E	No /No Effect
Accipitridae	*Haliaeetus leucocephalus*	Bald eagle	T	08-11-1995 (originally E 04-11-1967) PD 07-06-1999	T	No /No Effect
Picidae	*Picoides borealis*	Red-cockaded woodpecker	E	10-13-1970	E	No /No Effect
	Pituophis melanoleucus melanoleucus	Northern Pinesnake	FSC		SC	No /No Effect
	Etheostoma collis pop 1	Carolina Darter - central Piedmont Population	FSC		SC	Unresolved
	Etheostoma mariae	Pinewoods Darter	FSC		SC	No/No Effect
	Semotilus lumbee	Sandhills Chub	FSC		E	No/No Effect
		Vascular Plants				
Asteraceae	*Echinacea laevigata*	Smooth coneflower	E	10-08-1992	E-SC	No /No Effect
Asteraceae	*Helianthus schweinitzii*	Schweinitz's sunflower	E	5-7-1991	E	Yes /Unresolved
	Carex impressinervia	Ravine Sedge	FSC		SR-T	Not Applicable
	Lindera subcoriacea	Bog Spicebush	FSC		T	Not Applicable
	Solidago plumosa	Yadkin River Goldenrod	FSC		E	Not Applicable

TABLE 3.2
Species Under Federal Protection and Species of Concern in Montgomery County
UT to Barnes Creek Restoration Plan

Mollusk-Freshwater Bivalves					
	Alasmidonta varicosa	Brook Floater	FSC	E	Not Applicable
	Fusconaia masoni	Atlantic Pigtoe	FSC	E	Not Applicable
	Lampsilis cariosa	Yellow Lampmussel	FSC	E	Not Applicable
	Toxolasma pullus	Savannah Lilliput	FSC	E	Not Applicable
	Villosa vaughaniana	Carolina Creekshell	FSC	E	Not Applicable

Notes:

E	An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.
T	Threatened
PE	Proposed Endangered
PT	Proposed Threatened
PD	These species have been proposed for delisting from the current status.
FSC	Federal Species of Concern
SC	A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).
SR	A Significantly Rare species is not listed as "E," "T," or "SC," but which exists in the state in small numbers and has been determined to need monitoring.

3.6.1 Federally Protected Species

3.6.1.1 Vertebrates

Eastern Cougar

The Eastern cougar is described as a large, unspotted, long-tailed cat. Its body and legs are a uniform fulvous or tawny hue. Its belly is pale reddish or reddish white. The inside of this cat's ears are light-colored, with blackish color behind the ears. Cougars feed primarily on deer, but their diet may also include small mammals, wild turkeys, and occasionally domestic livestock, when available.

In the southeast region, there have been a number of sightings, but the best evidence for a small permanent population has come from the Great Smoky Mountain National Park Region. Based on a National Park Service study that included both sighting reports and field observations, there were an estimated three to six cougars living in the park in 1975. Sightings have also been reported in three other North Carolina areas including the Nantahala National Forest, the northern portion of the Uwharrie National Forest, and the State's southeastern counties. The remaining population of this species is extremely small; exact numbers are unknown. No preference for specific habitat types has been noted. The primary need is apparently for a large wilderness area with an adequate food supply. Male cougars of other subspecies have been observed to occupy a range of 25 or more square miles (65 or more square kilometers), and females from 5 to 20 square miles (13 to 52 square kilometers).

Cougars are reported to live in remote areas; therefore suitable habitat does not exist in the project area. In addition, a search of the NHP database on January 23, 2003 listed only a historical record for the county with no reported records in the vicinity of the project. The proposed project is not expected to affect this species.

Bald Eagle

Bald eagles are large raptors, 32 to 43 inches long, with a white head, white tail, yellow bill, yellow eyes, and yellow feet. The lower section of the leg has no feathers. Wingspread is about seven feet. The characteristic plumage of adults is dark brown to black with young birds completely dark brown. Juveniles have a dark bill, pale markings on the belly, tail, and under the wings and do not develop the white head and tail until five to six years old.

Bald eagles in the Southeast frequently build their nests in the transition zone between forest and marsh or open water. Nests are cone-shaped, six to eight feet from top to bottom, and six feet or more in diameter. They are typically constructed of sticks lined with a combination of leaves, grasses, and Spanish moss. Nests are built in dominant live pines or cypress trees that provide a good view and clear flight path, usually less than 0.5 miles from open water. Winter roosts are usually in dominant trees, similar to nesting trees, but may be somewhat farther from water. In North Carolina, nest building takes place in December and January, with egg laying (clutch of one to three eggs) in February and hatching in March. Bald eagles are opportunistic feeders consuming a variety of living prey and carrion. Up to 80% of their diet is fish, which is self caught, scavenged, or robbed from osprey. They may also take various small mammals and birds, especially those weakened by injury or disease.

Potential habitat for the bald eagle does not exist in the study area. The site does not provide suitable nesting areas less than 2 miles from open water. In addition, a search of the NHP database on February 24, 2003 found no occurrences of the bald eagle within the vicinity of the proposed project; therefore the proposed project is not expected to have an impact on this species.

Red-Cockaded Woodpecker

The red-cockaded woodpecker once occurred from New Jersey to southern Florida and west to eastern Texas. It occurred inland in Kentucky, Tennessee, Arkansas, Oklahoma, and Missouri. The red-cockaded woodpecker is now found only in coastal states of its historic range and inland in southeastern Oklahoma and southern Arkansas. In North Carolina moderate populations occur in the Sand Hills and southern Coastal Plain. The few populations found in the Piedmont and northern Coastal Plain are believed to be relics of former populations.

The red-cockaded woodpecker is approximately eight inches long with a wingspan of 14 inches. Plumage includes black and white horizontal stripes on its back, with white cheeks and under parts. Its flanks are streaked black. The cap and stripe on the throat and side of neck are black, with males having a small red spot on each side of the cap. Eggs are laid from April through June. Maximum clutch size is seven eggs with an average of three to five.

Red-cockaded woodpeckers are found in open pine stands that are between 80 and 120 years old. Longleaf pine stands are most commonly utilized. Dense stands are avoided. A forested stand must contain at least 50% pine, lack a thick understory, and be contiguous with other stands to be appropriate habitat for the red-cockaded woodpecker. These birds forage in pine and pine hardwood stands, with preference given to pine trees that are 10 inches or larger in diameter. The foraging range of the red cockaded woodpecker is up to 500 acres. The acreage must be contiguous with suitable nesting sites. While other woodpeckers bore out cavities in dead trees where the wood is rotten and soft, the red-cockaded woodpecker is the only one that excavates cavities exclusively in living pine trees. The older pines favored by the red-cockaded woodpecker often suffer from a fungus called red heart disease which attacks the center of the trunk, causing the inner wood to become soft. Cavities generally take one to three years to excavate. The red-cockaded woodpecker feeds mainly on beetles, ants, roaches, caterpillars, wood-boring insects and spiders, and occasionally fruits and berries.

Mature pinewoods and pocosin species are not prevalent in the immediate area of the proposed project. A search of the NHP database, conducted on February 24, 2003, does not record a historic occurrence of the red-cockaded woodpecker in the project vicinity. It is concluded that the project will not impact this endangered species.

3.6.1.2 Vascular Plants

Schweinitz's Sunflower

Schweinitz's sunflower, usually three to six feet tall, is a perennial herb with one to several fuzzy purple stems growing from a cluster of carrot-like tuberous roots. Leaves are two to seven inches long, 0.4 to 0.8 inches wide, lance shaped, and usually opposite, with upper leaves alternate. Flowers are yellow and generally smaller then other sunflowers in North America. Flowering and fruiting occurs from mid-September to frost.

The Schweinitz's sunflower grows in clearings and along edges of upland woods, thickets, and pastures. It is also found along roadsides, power line clearings, and woodland openings. It prefers full sunlight or partial shade and is intolerant of full shade.

Schweinitz's sunflower has been identified in several disturbed sites and utility right of ways including recently documented populations less than 3 miles from the Hurley/Harris parcels. Although grazing and farming activities do not favor the establishment of this protected species, there is some potential for habitat along the edges of grazed land. Prior to project construction, plant by plant surveys should be conducted from mid-September to mid-October, during peak blooming season. Grading plans may need to be adjusted to avoid impacts to any populations on site.

Smooth Coneflower

Smooth coneflower grows up to 1.5 meters tall with smooth stems and few elliptical to lanceolate leaves. Flowers are normally solitary, raylike, and light pink to purplish in color. Smooth coneflower can be distinguished from its popular relative *Echinacaea purpurea* (Purple Coneflower) by its leaves, which are never cordate like purple coneflower. Also, the awn of the pale is incurved while Purple Coneflower's is straight.

There are 24 known populations of Smooth Coneflower with 6 known in North Carolina. Historically, the species habitat was prairie-like, often controlled by fire. Now, due to urbanization and fire suppression, known populations are limited to open woods, cedar barrens, utility right of ways, and dry limestone bluffs normally with magnesium or calcium rich soils associated with mafic rock.

The study site does not have favorable habitat for Smooth Coneflower since it has been heavily disturbed by grazing, and its soils are not magnesium or calcium rich. A February 24, 2003 search of the NHP database indicated no known populations within the immediate project area and according to the NHP website, no populations have been observed in the last twenty years within Montgomery County. It is concluded that the project will not impact this endangered species.

3.6.2 Federal Species of Concern and State Status

Federal Species of Concern (FSC) are not legally protected under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. Table 5 includes FSC species listed for Montgomery County and their state classifications. Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded state protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979. However, the level of protection given to state-listed species does not apply to NCDENR EEP activities.

No FSC species have been recorded within 1.0 mile of the project area based upon the NHP database checked on January 14, 2004.

3.7 Cultural Resources

Buck Engineering sent a letter on January 27, 2003 requesting that the North Carolina State Historic Preservation Office (SHPO) review the potential for cultural resources in the vicinity of the UT to Barnes Creek restoration site. A response was received on April 15, 2003 indicating that the SHPO had reviewed the proposed project and was not aware of any historic resources which would be affected by the project. A copy of the SHPO correspondence is included in Appendix A.

3.8 Potentially Hazardous Environmental Sites

Buck Engineering obtained an EDR Transaction Screen Map Report that identifies and maps real or potential hazardous environmental sites within the distance required by the American Society of Testing and Materials (ASTM) Transaction Screen Process (E 1528). A copy of the report with an overview map is included in Appendix B. The overall environmental risk for this site was determined to be low. Environmental sites including Superfund (National Priorities List, NPL); hazardous waste treatment, storage, or disposal facilities; the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS); suspect state hazardous waste, solid waste or landfill facilities; or leaking underground storage tanks were not identified by the report in the proposed project area. During field data collection, there was no evidence of these sites in the proposed project vicinity and conversations with the prior landowners did not reveal any further knowledge of hazardous environmental sites in the area.

3.9 Potential Constraints

Buck Engineering assessed the UT to Barnes Creek project site in regards to potential fatal flaws and site constraints. No constraints or fatal flaws with the possible exception of Schweinitz's sunflower, which is unresolved at this time, have been identified during project design development.

3.9.1 Property Ownership and Boundary

All property needed for construction and required easements on the UT to Barnes Creek site are owned fee-simple by the State of North Carolina as shown in Figure 1.2.

3.9.2 Hydrologic Trespass

The topography of the site supports the design without creating the potential for hydrologic trespass. The site is not a FEMA mapped area.

3.9.3 Site Access

The site is connected to NCDOT ROW and can be accessed for construction and post-restoration monitoring.

3.9.4 Utilities

No known utilities are located on site. One utility pole is located in the NCDOT right-of-way adjacent to Love Joy Road. Construction activities should not disturb this pole.

3.9.5 Threatened and Endangered Species

Rare, threatened and endanger species occurrences were examined as part of the existing conditions survey and was discussed earlier. No rare, threatened or endangered species will be affected by this project, with the possible exception of Schweinitz's sunflower, which is unresolved at this time. If Schweinitz's Sunflower is present, minor adjustments to the grading plan to avoid disturbance are anticipated.

3.9.6 Cultural Resources

No known cultural or archaeological sites are recorded within the property boundary. It is anticipated that this project will have no impact on such sites.

3.9.7 Farm Operations

The Hurley Parcel is actively used for agricultural purposes. Therefore, the project must not interfere with the operational needs of the farm. The final project design will need to incorporate stream crossings, fencing, and field access.

3.9.8 Soils

Soils have been investigated and no constraints or fatal flaws were identified.

4 Stream Corridor Assessment Results

4.1 Reach Identification

For analysis and design purposes, we divided on-site streams into three reaches: the two UT to Barnes Creek mainstem reaches (Hurley and Harris mainstem reaches) and the Harris tributary reach which flows into the UT at the downstream end of the site. The reach locations are shown on Figure 1.2. The Hurley mainstem reach begins off-site and enters the site from the south via two 72" RCP culverts under Flint Hill Road. It flows across the site to the northwest and ends at the entrance to a mature privet forest adjacent to the Harris property (this section of stream was originally owned by Harris). The Harris mainstem reach begins at this point and flows for several hundred feet until it exits the site at the northwest corner via a 72" RCP culvert under Love Joy Road. The Harris tributary begins off-site and flows onto the project site in the northeast corner and joins the UT mainstem approximately 200 feet upstream of Love Joy Road.

Both the UT to Barnes Creek and the Harris tributary are blue-line streams on the USGS topographic map of the area as shown on Figure 1.3. The total current length of the UT on the project property is approximately 3,031 LF. The total current length of the Harris tributary on the project property is 381 LF.

4.2 Geomorphic Characterization

Buck Engineering performed a longitudinal and cross-section survey of the stream reaches to assess the current condition and overall stability of the channels. Figure 4.1 illustrates the locations of cross-section surveys on the project reaches. The following report sections summarize the survey results for the UT mainstem reaches and the Harris tributary.

4.2.1 Channel Geomorphology

4.2.1.1 UT Mainstem Channel Geomorphology

The UT mainstem channel is depicted in Figure 1.2. Watershed sizes were calculated at the point where the main channel enters the site and at the terminus of each reach (see Figure 1.3 and Table 4.1).

TABLE 4.1
UT Mainstem Reach Descriptions
UT to Barnes Creek Restoration Plan

Reach	Proposed Reach Length (linear feet)	Watershed Size at Upstream End of Reach (square miles)	Watershed Size at Downstream End of Reach (square miles)
Hurley Mainstem Reach	2,475	1.6	1.7
Harris Mainstem Reach	965	1.7	2.0

Both the Hurley and Harris mainstem reaches classify as incised E5 (modified) stream type in the Rosgen classification system. An E5 stream type is characterized by slight entrenchment with very low width/depth ratios, high sinuosity, and sandy bed material. The overall sinuosity for the reaches was low due to past channelization. Both reaches have high entrenchment ratios (above 2.2), indicating access to a large floodplain. Much of the substrate is composed of sand, but in isolated sections gravel and cobble are dominant. Debris jams, isolated large boulders, and hardpan clay have limited the incision of the channel. Where vegetation exists, the channel banks are moderately stable. In several sections of the mainstem small meanders have begun to re-form through erosive processes.

The Hurley mainstem reach is under active pressure from cattle access and recent vegetation removal by the former property owner. During our visit on January 29, 2003, the current landowner was removing streamside vegetation, thus eliminating the root structure holding the banks and allowing cattle to cross the stream from all locations. In a subsequent visit on March 10, 2003, more vegetation removal had occurred such that stream banks consisted of only bare, loose soil, and erosion had increased. This removal of vegetation will result in the stream's movement toward instability and substantial bank erosion. If the vegetation is allowed to re-colonize the banks unhindered, widening may only occur in localized sections. This sequence appears to be the recent historical pattern for this reach: a continuous cycle of disturbance from the prior land owner with cattle grazing and trampling of the banks, and subsequent stabilization due to re-vegetation. This cycle appears to have occurred every five to eight years based on discussions with the former landowner. A 72" corrugated metal pipe (CMP) culvert crossing bisects the UT, allowing the farmer and cows to cross the stream.

The Harris mainstem reach appears to have been undisturbed for several years. A monoculture of privet has grown up along the banks and in the floodplain. The reach is relatively stable due to the privet but has undercut banks and appears to be incising due to past channelization. This reach is confined by the Love Joy Road embankment in several locations. The Harris mainstem reach is dominated by long moderately deep runs behind debris jams. Most of the vertical drop in this reach occurs over a few steep riffle sections, which is indicative of headcutting. This reach is beginning to incise and appears to be in Stage III of the Simon channel evolution model.

Table 4.2 summarizes the geomorphology of the Hurley mainstem reach and the Harris mainstem reach. The detailed profile and cross-section survey results are included in Appendix C.

TABLE 4.2
Geomorphic Data for UT Mainstem - Stream Channel Classification Level II
UT to Barnes Creek Restoration Plan

Parameter	Value		Units
	Reach [1]		
	UT Mainstem Hurley Reach	UT Mainstem Harris Reach	
Bankfull Width (Wbkf)	10.8 – 23.1	8.6	Feet
Bankfull Mean Depth (d bkf)	0.9 – 1.7	2.0	Feet
Cross-sectional Area (Abkf)	17.2 – 21.0	16.8	Square Feet
Width/Depth Ratio (W/D ratio)	6.8 – 25.9	4.4	
Bankfull Max Depth (d_{mbkf})	1.5 – 3.1	2.4	Feet
Floodprone Area Width (W_{fpa})	52 – 92+	70+	Feet
Entrenchment Ratio (ER)	2.3 – 9.7	8.1	
Channel Materials (Particle Size Index – d_{50})	Coarse sand/ fine	Medium sand	

TABLE 4.2
Geomorphic Data for UT Mainstem - Stream Channel Classification Level II
UT to Barnes Creek Restoration Plan

Parameter	Value		Units
	Reach [1]		
	UT Mainstem Hurley Reach	UT Mainstem Harris Reach	
	gravel		
d_{15}	< 0.062	< 0.062	mm
d_{34}	0.125	0.105	mm
d_{50}	2.0	0.3	mm
d_{84}	22	24	mm
d_{95}	64	140	mm
Water Surface Slope (s)	0.0059	0.0063	Feet per foot
Channel Sinuosity (K)	1.24	1.29	
Rosgen Stream Type	**E5[2]**	**E5**	

NOTES:

1 Where multiple cross-sections were surveyed in a single reach and data varied, the data are presented as a range of values.

2 Predominately, this reach classifies as an E5, although values at isolated, severely impacted cattle crossings may not support this classification.

4.2.1.2 Harris Tributary Geomorphology

One distinct tributary discharges into the UT mainstem within the project site. Due to its entrance to the UT from what was originally the Harris property, it is denoted as the Harris Tributary. The tributary is shown in Figure 1.1, 1.2, and 1.3. The watershed size is detailed in Table 4.3.

Table 4.3
Harris Tributary Reach Description
UT to Barnes Creek Restoration Plan

Reach	Reach Length (linear feet)	Watershed Size (square miles)
Harris Tributary	381	0.2

The Harris tributary drains a recently deforested area and exhibits signs of excessive sedimentation. Investigation of the upstream headwaters does show an intact buffer throughout the deforested area. Despite this management activity, it appears that the reach has been channelized and deepened in the past, causing localized instability. Some deposition is apparent within the channel where the stream is redeveloping a floodplain at a lower elevation than the original floodplain. A moderately mature forest is located on the left bank and an old field is located on the right bank. Near the downstream end of the reach a relic channel conveys flood flows and is generally filled with water, evidence that the existing channel has been re-routed from its former path. Table 4.4 presents the summary of geomorphic data for the Harris tributary. Detailed survey information for the reach is presented in Appendix C.

TABLE 4.4
Geomorphic Data for Harris Tributary - Stream Channel Classification Level II
UT to Barnes Creek Restoration Plan

Parameter	Value Reach [1] Harris Tributary	Units
Bankfull Width (Wbkf)	8.5	Feet
Bankfull Mean Depth (d bkf)	0.8	Feet
Cross-sectional Area (Abkf)	6.8	Square Feet
Width/Depth Ratio (w/d ratio)	10.6	
Bankfull Max. Depth (dmbkf)	1.3	Feet
Floodprone Area Width (Wfpa)	92+	Feet
Entrenchment Ratio (ER)	10.9	
Channel Materials (d_{50})	Coarse sand	
d_{15}	< 0.062	mm
d_{34}	< 0.062	mm
d_{50}	1.0	mm
d_{84}	16	mm
d_{95}	21	mm
Water Surface Slope (s)	0.0087	Feet per foot
Channel Sinuosity (K)	1.02	
Rosgen Stream Type	**E5**	

4.2.2 Channel Stability Assessment

4.2.2.1 UT Mainstem Channel Stability

The mainstem channel within the project area is a perennial, channelized stream with a flow regime dominated by storm water runoff from a forested and agricultural watershed. Along the Hurley mainstem reach, the channel is adversely impacted by cattle crossings and a lack of substantial riparian vegetation. Generally, the channel is only slightly incised; incision has been resisted by some embedded cobble and boulder, a hardpan clay layer, and numerous debris jams from the upstream forest. The majority of the banks are only slightly eroding; cohesive soils and sparse vegetation has protected the banks. Following past channelization, meanders are re-developing through moderate erosion in some sections where vegetation has been removed. At cattle crossings and where vegetation has been physically removed by the prior land owner, the bank erosion is severe and threatens to spread to the remainder of the reach if not managed properly.

The Harris mainstem reach is showing more signs of active incision as several steep riffles seem to indicate headcutting from the elevation of the downstream Love Joy Road culvert. Again, this process appears to be slowed by debris jams and isolated sections of larger substrate. Bank erosion is gradual in this reach due to a dense stand of privet which dominates the riparian zone. Steady undercutting of banks where privet rooting depth is not sufficient for protection is threatening the local stability of banks. Both of the mainstem reaches are in Stages II and III of the Simon evolution model.

As part of the stability assessment, six cross-sections and a longitudinal profile were surveyed on the Hurley mainstem reach and four cross-sections were surveyed on the Harris mainstem reach. The cross-sections are provided in Appendix C and summarized in Table 4.5 below.

TABLE 4.5
Stability Indicators – UT Mainstem
UT to Barnes Creek Restoration Plan

Parameter	**Reach [1]**	
	Mainstem Hurley Reach	**Mainstem Harris Reach**
Stream Type	E5	E5
Riparian Vegetation	Open field dominated by fescue and typical pasture species.	Extensive cover of privet.
Channel Dimension		
Bankfull Area (ft^2)	17.2 – 21.0	16.8
Width/Depth Ratio	6.8 – 25.9	4.4
Channel Pattern		
Meander Width Ratio	2.4	2.4
Sinuosity	1.24	1.29
Vertical Stability		
Bank Height Ratio (BHR)	1.0 – 1.4	1.0 – 1.5
Entrenchment Ratio (ER)	2.3 – 9.7	8.1
Evolution Scenario	E-G-F-C-E	E-G-F-C-E
Simon Evolution Stage	II/ III	II/ III

NOTES:

1 Where multiple cross-sections were surveyed in a single reach the data are presented as a range of values.

The width/depth ratios are generally very low (less than 10), with one cross-section of moderate to high w/d ratio greater than 18 at a cattle crossing. These values indicate the channel has not begun to widen. A bankfull w/d ratio of 10 is common for similar streams in alluvial channels of the North Carolina Piedmont.

The mainstem project stream appears to exhibit stage II and III of the Simon channel evolution model, in which modification and incision occurs.

The ER values are greater than 2.2, which indicate that the stream is slightly entrenched. Slightly entrenched streams have access to a wide floodplain, where excess energy can be dissipated. For this reason, only moderate instability is evident.

The BHR values demonstrate that the stream is becoming vertically unstable. While at many locations BHRs are 1.0, local incision shows values of up to 1.8 indicating a trend of downcutting. BHRs of greater than 1.0 are almost always associated with more unstable banks and higher erosion rates.

4.2.2.2 Harris Tributary Channel Stability

The Harris tributary channel appears to be channelized and shows signs of instability in several locations due to old fords. The upper section of the tributary is moderately entrenched in a steep valley and has good bank vegetation. Downstream, where the tributary enters the mainstem's floodplain, the channel remains vertically stable but begins to show signs of excessive lateral migration as it attempts to re-establish pattern.

As part of the stability assessment, one riffle cross-section was surveyed on the tributary reach. The cross-section is provided in Appendix C and is summarized in Table 4.6 below.

TABLE 4.6
Stability Indicators – Harris Tributary
UT to Barnes Creek Restoration Plan

Parameter	Reach Harris Tributary
Stream Type	E5
Riparian Vegetation	Minimal buffer but adequate bank vegetation. Left floodplain has been deforested and right floodplain is fescue.
Channel Dimension	
Bankfull Area (square feet)	6.8
Width/Depth Ratio	10.6
Channel Pattern	
Meander Width Ratio	-- [1]
Sinuosity	1.02
Vertical Stability	
Bank Height Ratio (BHR)	1.0
Entrenchment Ratio (ER)	10.9
Evolution Scenario	E-G-F-C-E
Simon Evolution Stage	V

NOTES:

1 No pattern-related parameters were computed for the main channel given the very low sinuosity.

The width/depth ratio is less than 12 which is considered low, but in several locations the stream shows signs of lateral migration especially where old fords have eliminated vegetation. The ER values greater than 2.2 indicate that the stream is, for the most part, slightly entrenched. The tributary has frequent access to its floodplain, where excess energy can be dissipated. The channel is thus described as vertically un-contained. For this reason, moderately to slightly entrenched streams tend toward stability. The Harris tributary appears to exhibit stage V characteristics of the Simon channel evolution model.

4.2.3 Bankfull Verification

The bankfull stage in the UT mainstem channel and the tributary channel was identified in the field; the indicators were a break in slope on a flat depositional feature, a high scour line, and the top of bank. Vegetation trends were used as validation for this stage selection. These indicators are consistent with other North Carolina rural Piedmont streams. Bankfull data for the project reach is compared with the North Carolina Piedmont regional curve in Figure 4.2. The project's cross-sectional areas consistently plot close to the regional curve data, indicating that bankfull stage was adequately selected within acceptable limits.

As additional bankfull stage verification, two reference reaches were surveyed in the Spencer Creek watershed located two miles to the south of the project site, as illustrated on Figure 4.3. One site on Spencer Creek and one site on a UT to Spencer Creek were selected based on the confidence with which bankfull features were identified, the apparent cross-section stability, and the natural state of the stream. Two representative riffle cross-sections were surveyed at each site. The drainage areas were determined based on watershed delineation from USGS topographic quadrangles. These points were plotted with the North Carolina rural Piedmont regional curves, along with the data from the UT to Barnes Creek site. The data plotted within the 95% confidence interval limits of the regional curve and thus verify that the morphological relationships in the Spencer Creek basin are similar to those of the rural Piedmont region.

One USGS gage is active nearby: the Dutchman's Creek gage (USGS Gage Number 02123567) is located 10 miles from the project site, as shown in Figure 4.3. The watershed size at the gage is 3.44 square miles. The gage is located immediately upstream of two 72" CMP culverts under River Road which likely cause backwater at the bankfull stage. Due to this condition, the typical straight line projection of bankfull elevation through the gage was not used. Buck performed a survey at the gage and prepared a HEC-RAS hydraulic model using the survey data. A hypothetical flow corresponding to the bankfull elevation upstream of the gage was routed through the gage station and related to the gage plate height. Using the USGS gage rating table, a discharge of 215 cfs was established for the bankfull stage. The primary bankfull indicators at this site were a break in slope in the bank and a bench feature.

The computer program PEAKFQ was used to perform a log-Pearson Type III flood frequency analysis on the 18 years of peak flow record for the gage. This flood frequency analysis indicated that a 215-cfs event has a recurrence interval of approximately 1.3 years at this site on Dutchman's Creek. This recurrence interval of 1.3 years is close to the average value of 1.5 years observed for many streams and within the accepted range of one to two years.

The Dutchman's Creek discharge data were plotted on the regional curve along with the bankfull discharges predicted using Manning's equation with the surveyed channel geometry for the UT to Barnes Creek, the

Harris tributary, and the reference reaches. As shown in Figure 4.2, all of the values fall within the 95% confidence limits of the rural Piedmont regional curve.

4.3 Vegetation

The existing stream buffer on the Hurley property is limited to a narrow corridor five to ten feet wide on each bank. Mature vegetation was removed in 2003 by the property owner. The remaining vegetation is primarily multiflora rose (*Rosa multiflora),* Chinese privet (*Ligustrum sinense),* tag alder (*Alnus serrulata*), black willow (*Salix nigra*), red maple (*Acer rubrum*), goldenrod (*Solidago spp.*) and aster (*Aster spp.*). Vegetation surrounding the stream has been grazed by cattle.

Much of the area adjacent to the stream on the Hurley property is pastureland, composed primarily of fescue (*Festuca spp*.) and soft-stem rush (*Juncus effusus*). The pasture areas are heavily grazed, especially during the summer months when the high water table of the floodplain area is conducive to pasture growth.

Vegetation on the Harris property is limited to a thick stand of Chinese privet (*Ligustrum sinense*). A few mature beech (*Fagus grandifolia*) and white oak (*Quercus alba*) trees are located slightly upstream from the culvert at Love Joy Road. The tributary has slightly more diverse vegetation including tag alder *(Alnus serrulata*), ironwood *(Carpinus caroliniana*), and flowering dogwood (*Cornus florida*) as well as some privet (*Ligustrum sinense*) and honeysuckle (*Lonicera japonica*). The left bank of the tributary had a fairly mature forest with sweet gum (*Liquidambar styraciflua*), beech (*Fagus grandifolia*), white oak (*Quercus alba*) and American holly (*Ilex opaca*); however, this area was recently logged and most of these trees were removed.

4.4 Wetlands

The proposed project area was reviewed for the presence of wetlands and waters of the United States in accordance with the provisions of Executive Order 11990, the Clean Water Act, and subsequent federal regulations. Wetlands have been defined by the U.S. Army Corps of Engineers as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (33 CFR 328.3(b) and 40 CFR 230.3 (t)). The areas in the project area that displayed one or more wetland characteristics were reviewed to determine the presence of wetlands. The wetland characteristics included:

1) Prevalence of hydrophytic vegetation;
2) Permanent or periodic inundation or saturation; and
3) Hydric soils.

Vegetation was not used to determine wetland areas, because the majority of the project area had been previously converted to pastureland and currently does not support wetland vegetation. Wetland determinations, both jurisdictional and historical, were made by evaluating soils within the project reach. Site hydrology monitoring was also established to evaluate pre- and post-wetland restoration design conditions.

4.4.1 Wetland Soils

Soils in all areas identified for wetland restoration and/or enhancement were confirmed to be hydric by a trained professional. Soils within the lower floodplain areas of the project site are mapped primarily as the Chenneby series and contain several areas of hydric inclusions. Chenneby soils are considered to be hydric by the Natural Resource Conservation Service (NRCS). The soils present on the project site are further discussed in Section 3.4 and are shown on Figure 3.1. Boundaries of hydric soil areas were located, flagged, and surveyed and are shown as existing wetlands in Figure 4.4.

4.4.2 Site Hydrology

The area proposed for restoration and enhancement on the project site consists of both degraded jurisdictional wetlands and degraded historic wetlands. Hydrology in the jurisdictional zones is driven largely by seepage from adjacent hillslopes with a small component of overbank flow during large runoff events. In the non-jurisdictional areas proposed for restoration, the presence of remnant hydric soils is evidence that these portions of the site historically supported a wetland ecosystem. As is the case in much of rural North Carolina, local drainage patterns have been altered over the last two centuries to increase drainage and promote agricultural production. The project reaches have been channelized and straightened to provide drainage for agricultural livestock and to maximize the area for pastureland. This channelization led to vertical instability and stream incision, which has resulted in more effective site drainage and degraded wetland hydrology.

During December 2003, five groundwater monitoring gauges were installed throughout the areas proposed for restoration and enhancement. Monitoring gauge locations are illustrated on Figure 4.4. The gauges were located in areas where hydrology would likely be affected by restoration efforts for the purpose of providing information for comparing pre- and post-restoration hydrology. Water table data have been collected since installation and will continue to be collected throughout the restoration design and monitoring phases. Hydrographs showing data collected to date are attached in Appendix E. Summary statistics are provided in Table 4.7.

Groundwater monitoring gauges were used to determine site hydrology. The longest consecutive wet period (days) and the number of wet periods were monitored for each gauge. Hydrology was controlled by different factors across the site. For discussion purposes these gauges are grouped based on similar controlling factors. Gauges 1, 3 and 5 were located in existing wetland areas adjacent to the stream. Gauge 1 had the longest consecutive wet period with 44.8 days and 4 wet periods. Gauges 3 and 5 had shorter consecutive wet periods (9.5 and 28.8, respectively) and 5 wet periods. Gauges 2 and 4 were located further from the stream and at a higher in elevation than the other three gauges. Table 4.7 indicates that there were 4 wet periods for Gauge 2 with the longest period lasting 15.8 days. There were 6 wet periods for Gauge 4 with the longest period lasting 31.8 days.

The growing season for Montgomery County is 254 days long, beginning in mid-March and ending in mid-November, according to the Montgomery County Soil Survey (1968). Montgomery County, North Carolina has an average annual rainfall of 47.9 inches (NRCS WETS Tables NC4464 for Jackson Springs). The groundwater data indicates that most of the site was saturated during the monitoring period to date with the water table often near the ground surface in the wetter areas. It is anticipated that gauges 1, 3, and 5, which are located in jurisdictional wetlands, will have a water table depth within 12 inches of the ground surface for a minimum of two weeks during the growing season.

TABLE 4.7
Site Wetland Hydrologic Parameters
UT to Barnes Creek Restoration Plan

Gauge #	Lowest Recorded Water Table Depth (inches)	Highest Recorded Water Table Depth (inches)	Longest Consecutive Wet Period During Growing Season (days)	Number of Wet Periods During Growing Season[1]
1	-18.3	1.8	44.8	4
2	-26.7	0.1	15.8	4
3	-25.5	1.0	9.5	5
4	-16.6	0.3	31.8	6
5	-18.3	0.9	28.8	5
Reference Gauge	-40.0	0.5	8	2

NOTES

1 A wet period is defined as the number of separate occurrences when the water table rises to within 12 inches of the ground surface.
2 Data recorded from 12/04/03-05/27/04

4.5 Biological Assessment

Benthic macroinvertebrate samples were collected at three sites within and upstream of the project area on December 16, 2003. Site 1 was established as a reference sampling site is located upstream of Flint Hill Road, just upstream of the project reach. The other two sampling sites, Sites 2 and 3, are located within the UT mainstem downstream of Flint Hill Road. These sites are illustrated on Figure 4.1. The sampling methodology followed the Qual-4 protocol listed in the NCDWQ's *Standard Operating Procedures for Benthic Macroinvertebrates*. A summary of the results of benthic macroinvertebrate sampling for the project reach is presented in Table 4.8 with complete results presented in Appendix F.

The benthic macroinvertebrate community of Site 1 reflected a much healthier community compared to the other two sites. A healthier community is characterized by higher total and EPT taxa richness values and lower biotic index values. Site 1 had both high total taxa richness (54) and EPT taxa richness (23) values. Its biotic index of 4.96 was lower than the other two sites as well.

Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), collectively referred to as EPT taxa, are considered by aquatic ecologists to be less tolerant of pollution or other forms of environmental degradation. Therefore, the presence of substantial numbers of EPT taxa and individuals are considered indicative of relatively undisturbed "higher quality" streams.

The land use for Site 1 is primarily forested and undeveloped. Site 1 received an excellent habitat assessment score of 89 out of a possible 100. The benthic community in Site 1 corresponded well with its habitat conditions.

Lower total taxa richness, lower EPT taxa richness and higher biotic index values recorded for Sites 2 and 3 compared to Site 1 indicate water quality decline downstream of Site 1. Water quality decline downstream corresponds to a decrease of suitable habitat downstream (habitat assessment scores of 35 and 67 for Sites 2 and 3, respectively). The majority of the UT mainstem and Harris tributary has virtually no canopy cover or woody riparian vegetation to provide adequate shade, organic matter, or habitat such as root mats for aquatic organisms. As habitat degrades, more tolerant organisms replace organisms sensitive to impairment. This replacement is reflected in the EPT taxa richness and biotic index values discussed previously. Another parameter to analyze impairment to riparian habitat is the evaluation of the shredder community. Shredders are important organisms that break down coarse particulate organic matter (CPOM) such as leaves and woody debris for food and cover. As a response to the lack of allochthonous woody debris and leaves provided by riparian vegetation, the shredder community is lower both in taxa and abundance within the project site compared to the reference site.

While benthos metrics were similar at Site 2 and Site 3, the overall benthos community structure was different, reflecting differences in habitat cover between the two sites. Site 2, located in the middle of the restoration reach, has completely open canopy while Site 3, located in the downstream section of the restoration reach, has more canopy cover. The higher abundance of herbivore/scraper taxa in Site 2 may be in response to more available food source (periphyton) caused by the more open canopy at Site 2. The differences in size and heterogeneity of bottom substrate between Sites 2 and 3 appear to affect the community structure between the sites. For instance, Site 3 having larger substrate, supported larger stonefly species (i.e. *Eccoptura xanthenes*) whereas Site 2, composed of primarily sand and gravel, only supported smaller species.

Establishing a forested riparian buffer along the project reaches will provide shading and reduce photosynthetic rate of algae and macrophytes, reduce siltation and sedimentation, and provide habitat and organic matter to aquatic organisms. As a result, recruitment of additional species, especially shredders, should occur. Also the upstream reference site (Site 1) provides excellent refuge for those additional species.

TABLE 4.8
Benthic Summary Table
UT to Barnes Creek Restoration Plan

Sites	Total Taxa Richness	EPT Taxa Richness	Biotic Index	EPT Biotic Index	EPT Abundance
1	54	23	4.96	3.74	91
2	26	11	5.17	4.81	71
3	26	12	5.56	4.83	36

5 Selected Design Criteria

5.1 Potential for Restoration

There are few potential obstacles for achieving Priority 1 stream restoration at the majority of the project site. The project is located in a rural watershed, with no plans indicating land use changes in the foreseeable future. Therefore, there are no known present or future constraints at the site associated with structure and/or infrastructure encroachments.

Otherwise, there are two situations where site conditions necessitate the use of techniques that will not fully reclaim the abandoned floodplain at the site. The downstream reach of the project must tie in to the existing culvert at Love Joy Road. In order to effect this transition, a section of Priority 2 restoration will be required, creating an active floodplain at a lower elevation. In addition, the Harris tributary must tie into the downstream end of the UT mainstem and will also be partially a Priority 2 restoration.

5.1.1 UT Mainstem Channel Restoration Potential

The UT mainstem channel is under severe pressure due to cattle and human impacts both past and present. The majority of the stream length is beginning to incise and showing a tendency toward lateral migration. If left alone, it is possible that incision would stop but the redevelopment of meanders would continue through erosion. As a result, the majority of the restoration on the main channel at the UT to Barnes Creek site should attempt to speed up the evolutionary process already occurring. A Rosgen E stream type will be constructed. An E stream type has steeper banks than other stream types and as a result, significant soil bioengineering structural reinforcement and revetment will be needed for this restoration approach. However, due to the stable nature of the soil and vegetation conditions at the site, this restoration approach should be a reasonable goal. Major invasive vegetative species removal efforts and native reforestation of the riparian buffer will complement the channel form design.

5.1.2 Harris Tributary Channel Restoration Potential

The tributary channel at the Harris property will be designed with the same philosophy as the UT mainstem with one major departure: a new channel will be re-routed to what appears to be the former stream bed. This re-routing will include some additional grading where some of the floodplain has been filled in the past. The downstream half of this tributary will be a Priority 2 restoration.

5.2 Design Criteria Selection

Selection of natural channel design criteria is based on a combination of approaches including reference reach surveys, review of reference reach databases, regime equations, and evaluation of results from past projects, as discussed in Section 2.5.

Selection of a general restoration approach was the first step in selecting design criteria at the UT to Barnes Creek site. The approach was based on each reach's potential for restoration as determined during the site assessment. After selection of the general restoration approach, specific design criteria were developed so each reach's plan view layout, cross-section dimensions, and profile could be described for the purpose of developing construction documents.

5.2.1 Reference Reach Survey

Two reference reaches were identified off the project site in the Uwharrie National Forest in the Spencer Branch watershed. The reference reaches are located on Spencer Creek and a UT to Spencer Creek in a mature forested area with 20- to 50-year-old forest growth. Both reference reaches are vertically and horizontally stable, have excellent pattern with a sinuosity measurement greater than 2.2, have deep pools at outside of bends, have several points of aeration in the form of both riffles and woody debris jams, and show excellent habitat potential. The geomorphic survey summaries are located in Table 5.1. Detailed survey cross-sections are provided in Appendix C. The reference reach data were useful in evaluating the evolutionary endpoint of the project with the realization that without the mature vegetation observed on the reference reaches, the extreme dimensionless ratios are not appropriate for a newly-restored stream with little or no bank and floodplain vegetation.

TABLE 5.1
Geomorphic Characteristics of the Surveyed Reference Reaches
UT to Barnes Creek Restoration Plan

	Spencer Creek		UT to Spencer Creek	
	Min	**Max**	**Min**	**Max**
1. Stream Type	E4		E5	
2. Drainage Area – square miles	0.96		0.014	
3. Bankfull Width (w_{bkf}) – feet	10.7	11.2	7.0	
4. Bankfull Mean Depth (d_{bkf}) – feet	1.6	1.8	1.1	
5. Width/Depth Ratio (w/d ratio)	5.8	7.1	6.4	
6. Cross-sectional Area (A_{bkf}) – SF	17.8	19.7	7.7	
7. Bankfull Mean Velocity (v_{bkf}) - fps	4.9	5.4	3.2	
8. Bankfull Discharge (Q_{bkf}) – cfs	97		25	
9. Bankfull Max Depth (d_{mbkf}) - feet	2.1	2.6	2.0	
10. d_{mbkf} / d_{bkf} ratio	1.3	1.4	1.8	
11. Low Bank Height to d_{mbkf} Ratio	1.0	1.0	1.0	
12. Floodprone Area Width (w_{fpa}) – feet	60	114+	81+	
13. Entrenchment Ratio (ER)	5.5	10.2	11.6	
14. Meander length (L_m) – feet	46	48	37.7	42.5
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	4.1	4.4	5.4	6.1
16. Radius of curvature (R_c) – feet	10.9	14.6	5.8	15.8
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	1.3	1.4	0.8	2.3
18. Belt width (w_{blt}) – feet	38.3	40.8	11.4	26.7
19. Meander Width Ratio (w_{blt}/W_{bkf})	3.4	3.6	1.6	3.8

TABLE 5.1
Geomorphic Characteristics of the Surveyed Reference Reaches
UT to Barnes Creek Restoration Plan

	Spencer Creek		UT to Spencer Creek	
	Min	**Max**	**Min**	**Max**
20. Sinuosity (K) Stream Length/ Valley Distance	2.32		2.45	
21. Valley Slope – feet per foot	0.0109		0.0081	
22. Channel Slope ($s_{channel}$) – feet per foot	0.0047		0.0033	
23. Pool Slope (s_{pool}) – feet per foot	0.0007	0.0009	0.0013	0.0014
24. Ratio of Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	0.15	0.19	0.40	0.42
25. Maximum Pool Depth (d_{pool}) – feet	3.3		2.5	
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	1.8	2.0	2.3	
27. Pool Width (w_{pool}) – feet	17.5		6.5	
28. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	1.6	1.6	0.9	
29. Pool Area (A_{pool}) – square feet	24.5		8.8	
30. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.2	1.4	1.1	
31. Pool-to-Pool Spacing – feet	71		19	41.7
32. Ratio of Pool-to-Pool Spacing to Bankfull Width (p-p/w_{bkf})	6.3	6.6	2.7	6.0
33. Riffle Slope (s_{riffle}) – feet per foot	0.013		0.014	
34. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	2.8		4.2	
Particle Size Distribution of Channel Material				
Material (d_{50})	Fine gravel		Coarse sand	
d_{16} – mm	< 0.062		< 0.062	
d_{35} – mm	3.0		0.062	
d_{50} – mm	8.8		1.0	
d_{84} – mm	42		16.0	
d_{95} – mm	90		22.3	

5.2.2 Reference Reach Database

A reference reach database was also consulted for additional design parameters. Two reference reach datasets were selected from the database: a previous survey of Spencer Creek at an upstream location and Mill Creek in Surry County (Clinton, 1999). Data from these two reference reaches were considered in the design criteria selection.

5.2.3 Design Criteria Selection Method

Specific design parameters were developed using a combination of reference reach data, past project experiences, and best professional judgment. Dimensionless ratios from an internal reference reach database were also used to develop the design values. The design philosophy at the UT to Barnes Creek Site is to use average values for the selected stream types and to allow the extremes to form over long periods of time under the processes of flooding, re-colonization of vegetation, and geologic influences.

5.3 Design Criteria for UT to Barnes Creek

After examining the assessment data collected at the site and exploring the site's potential for restoration, an approach to the stream restoration was developed. First, an appropriate stream type for the valley type present at the site was selected. The design stream types were further refined based on the channel evolution sequence exhibited by the stream after examination of existing conditions survey data and other field observations, as well as conditions observed on reference streams under similar conditions. Available belt width, existing wetlands, and channel incision were considered as well. The proposed stream types for the project are summarized in Table 5.2.

TABLE 5.2
Project Design Stream Types
UT to Barnes Creek Restoration Plan

Reach	Proposed Stream Type	Rationale
Hurley Mainstem	E	Continuous impacts from cattle and property owner continue to degrade stream stability and function. Sinuosity and pool formation is poor with riparian vegetation consisting of fescue and privet. Wide, flat wetland dominated floodplain exists throughout the reach. Priority 1 restoration will increase sinuosity and pool development and native re-vegetation will improve habitat.
Harris Mainstem	E	This reach is impacted by a substantial privet forest. Minimal riffle formation exists and eroding banks are common. Priority 1 restoration will increase sinuosity and pool development and native re-vegetation will improve habitat. The Priority 2 section will transition the upper end of the reach into the Love Joy Road culvert.
Harris Tributary	E	The Harris tributary has been channelized and is impacted by two stream crossings causing bank erosion. Priority 1 restoration will improve pattern and enhance bedform diversity. The Priority 2 section will tie in the bed elevation with the UT mainstem while providing the tributary channel access to its floodplain at bankfull flows.

6 Restoration Design

6.1 Restoration Approach

The primary objective of the restoration design is to re-establish floodplain access at bankfull flows In addition, existing wetland areas will be enhanced, remnant wetlands will be restored, and additional wetlands will be created. Riparian vegetation will be established in the permanent buffer. The proposed design includes the following elements:

- Priority 1 Stream Restoration
  - UT Hurley mainstem reach – entire reach will be restored to an E stream type.
  - UT Harris mainstem reach – the reach will be restored to an E stream type. A short downstream section will require limited floodplain grading and will use Rosgen Priority 2 restoration in order to tie in with the receiving incised downstream channel.
  - Harris tributary – the reach will be restored to an E stream type. A short downstream section will require limited floodplain grading and will use Rosgen Priority 2 restoration in order to tie in with the UT Harris Mainstem Reach.
- Wetlands Enhancement, Restoration, and Creation
  - Project-wide planting to enhance existing wetland areas.
  - Restoration of remnant wetland areas through improved hydrology.
  - Creation of new wetland areas as ephemeral pools.
- Riparian Buffer Enhancement
  - Project-wide planting and preservation of the riparian zone.

Preliminary plans for the UT to Barnes Creek restoration are attached. Details of the design are discussed in the following sections.

6.2 Design Rationale (Channel Dimension, Pattern, and Profile)

6.2.1 UT Mainstem Channel Restoration

The Hurley reach and the Harris reach of the mainstem have very similar geomorphic conditions. Because the two reaches are similar and have similar drainage areas, the same design parameters will be used for both reaches.

The stream banks are unstable along the mainstem because the channel is incising, riparian vegetation has been removed, and cattle have frequently trampled and eroded the banks. A stable cross-section will be achieved by widening the channel and increasing the width/depth ratio. The channel will remain an E-type stream, and the sinuosity will be increased by adding meanders to lengthen the channel. Grade control at the bed will be provided by in-stream structures such as constructed riffles and log weirs. These in-stream structures will also help to improve bedform diversity.

Table 6.1 presents the stream restoration dimensions for the UT mainstem channel. Existing data and design criteria are shown also.

TABLE 6.1
Geomorphic Characteristics of the Existing and Proposed UT Mainstem Reaches [1]
UT to Barnes Creek Restoration Plan

	Existing Hurley Mainstem Reach		**Existing Harris Mainstem Reach**		**Design Criteria [2]**		**Proposed Mainstem Reach**	
	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	E5		E5		--	--	E	
2. Drainage Area – square miles	1.7		2.0		--	--	2.0	
3. Bankfull Width (w_{bkf}) – feet	10.8	23.1	8.6		--	--	15.0	
4. Bankfull Mean Depth (d_{bkf}) – feet	0.9	1.7	2.0		--	--	1.4	
5. Width/Depth Ratio (w/d ratio)	6.8	25.9	4.4		10	15	10.9	
6. Cross-sectional Area (A_{bkf}) – SF	17.2	21.0	16.8		--	--	20.6	
7. Bankfull Mean Velocity (v_{bkf}) - fps	4.6	5.6	5.8				4.7	
8. Bankfull Discharge (Q_{bkf}) – cfs	97		97				97	
9. Bankfull Max Depth (d_{mbkf}) - feet	1.5	3.1	2.4		--	--	2.25	
10. d_{mbkf} / d_{bkf} ratio	0.9	3.4			1.2	1.6	1.6	
11. Bank Height Ratio	1.0	1.4	1.0	1.5	1.0		1.0	
12. Floodprone Area Width (w_{fpa}) – feet	52	92+	70+		--	--	100+	
13. Entrenchment Ratio (ER)	2.3	9.7+	8.1+		5.5	>10	5	10+
14. Meander length (L_m) – feet	41.9	82.5	40.5	52.6	--	--	170	188
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	1.8	7.6	4.7	6.1	11.3	12.5	11.3	12.5
16. Radius of curvature (R_c) – feet	7.7	19.9	7.3	19.1	--	--	30	45
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	0.3	1.8	0.8	2.2	2.0	3.0	2.0	3.0
18. Belt width (w_{blt}) – feet	28.2	38.2	18.9	27.9	--	--	53	120
19. Meander Width Ratio (w_{blt}/W_{bkf})	2.0	2.9	2.0	2.9	3.5	8.0	3.5	8.0
20. Sinuosity (K) Stream Length/ Valley Distance	1.24		1.29		1.3	1.8	1.43	
21. Valley Slope – feet per foot	0.0074		0.0081		--	--	0.0076	
22. Channel Slope ($s_{channel}$) – feet per foot	0.0059		0.0063		--	--	0.0053	
23. Pool Slope (s_{pool}) – feet per foot	0.0002	0.0015	0.0001	0.0006	--	--	0.00053	0.00212
24. Ratio of Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	0.03	0.25	0.01	0.11	0.10	0.40	0.10	0.40
25. Maximum Pool Depth (d_{pool}) – feet	3.8	4.2	2.5	3.3	--	--	2.75	3.75

TABLE 6.1
Geomorphic Characteristics of the Existing and Proposed UT Mainstem Reaches [1]
UT to Barnes Creek Restoration Plan

	Existing Hurley Mainstem Reach		Existing Harris Mainstem Reach		Design Criteria [2]		Proposed Mainstem Reach	
	Min	Max	Min	Max	Min	Max	Min	Max
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	2.2	4.7	1.3	1.7	2.0	3.0	2.0	2.7
27. Pool Width (w_{pool}) – feet	8.9	13.5	9.6	13.1	--	--	20	23.5
28. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	0.4	1.3	1.1	1.5	1.2	1.6	1.3	1.6
29. Pool Area (A_{pool}) – square feet	21.6	33.9	20.9	36.7	--	--	40.6	46.8
30. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.0	2.0	1.2	2.2	1.7	2.3	2.0	2.3
31. Pool-to-Pool Spacing – feet	65	206	63	155	--	--	45	109
32. Ratio of Pool-to-Pool Spacing to Bankfull Width ($p\text{-}p/w_{bkf}$)	2.8	19.1	7.3	18.0	3.0	6.6	3.0	7.3
33. Riffle Slope (s_{riffle}) – feet per foot	0.0142	0.0174	0.009	0.011	0.008	0.0159	0.008	0.0159
34. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	2.4	2.9	1.4	1.7	1.5	3.0	1.5	3.0

Particle Size Distribution of Channel Material

	Existing Hurley Mainstem Reach	Existing Harris Mainstem Reach	Design Criteria	Proposed Mainstem Reach
Material (d_{50})	Coarse sand/ fine gravel	Medium sand	--	--
d_{16} – mm	< 0.062	< 0.062	--	--
d_{35} – mm	0.125	0.105	--	--
d_{50} – mm	2.0	0.3	--	--
d_{84} – mm	22	24	--	--
d_{95} – mm	64	140	--	--

NOTES:

1 If data are not presented, they were not collected, not calculated, or not applicable.

2 Specific remarks regarding selection of design criteria follow in the detailed design narratives on dimension, pattern, and profile.

6.2.1.1 Dimension

The existing channel dimension is unstable throughout the project area due mainly to a lack of dense and deep root structure from an intact woody riparian buffer. To address the erosion throughout the project, the stream cross-section (dimension) will be adjusted in order to reduce velocities and near bank shear stress. A Rosgen E stream with a w/d ratio of 10.9 will be created with the cross-section. The ratio of low bank height to maximum bankfull depth (BHR) will be set to 1.0. In areas along the mainstem channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, minimal grading will be used to transition bankfull stage to the floodplain. Once flood water rises above the bankfull stage, erosion-causing stress in the near bank region will be reduced when the storm flow is able to spread out on the floodplain. Root wads, brush mattresses, and log vanes will be used to provide bank protection and maintain pool cross-sections at the outside of meander bends where necessary. Typical cross-sections are shown on the plan sheets.

6.2.1.2 Pattern

The existing mainstem channel through the project site has a sinuosity measurement of 1.2. The proposed project will increase the sinuosity of the stream to 1.4 by adding approximately 400 linear feet of stream. Currently, the mainstem channel is 3,031 linear feet; the stream length after restoration will be approximately 3,440 linear feet. The meander length ratio on the restored channel will be between 11.3 and 12.5, as recommended by the US Army Corps of Engineers *Hydraulic Design of Stream Restoration Projects* (Copeland et al., 2001). These lengthy meanders will dissipate energy, thereby reducing erosion. The additional deep pools with add valuable habitat and reduce water temperatures. The channel slope will be effectively decreased by the addition of the meandering length, also helping to slow the mean velocity in the channel.

Curve radii will range between 30 and 45 feet, or two to three times the channel's proposed bankfull width. The surveyed reference reaches exhibited radius of curvature ratios of less than 2; however, the project was designed with larger ratios in an effort to enhance stability immediately after construction before a stabilizing vegetative root mass is established. The meander width ratio (MWR) of the stream will be increased as part of the restoration. Belt width will be 3.5 to 8 times wider than bankfull width. Plan views of the main channel are shown on the attached plan sheets.

6.2.1.3 Profile/Bedform

The profile of the existing mainstem channel is somewhat stable but is threatened by cattle access and removal of vegetation. There is very little diversity in the existing channel bedform: pools, riffles, glides, and runs are nearly indistinguishable from each other with few exceptions. The stream restoration will include the construction of a riffle-pool stream bed with additional habitat and diversity provided by constructed riffles and log weirs at selected locations. The slopes for the constructed riffles vary from 1.5 to 3 times the proposed channel slope. The reference reaches indicated that this ratio range will be appropriate for this stream size and type. Similarly, pool slopes were designed using the reference reach guidance of slope ratios 0.2 to 0.4 times the design channel slope. The maximum pool depth (two to three times the riffle mean depth) in the pool will be constructed from the meander curve apex to a point one-third of the distance along the profile from the apex to the head of the next downstream riffle. This maximum pool location was selected based on guidance from the US Army Corps of Engineers manual (Copeland et al., 2001).

6.2.2 Harris Tributary Channel Restoration

The restoration rationale for the Harris tributary is similar to the rationale for the UT mainstem. A stable cross-section will be achieved by widening the channel and increasing the width/depth ratio. The channel will remain an E-type stream, and the sinuosity will be increased by adding meanders to lengthen the channel.

Vertical control will be provided by in-stream structures such as constructed riffles and log weirs. These in-stream structures will also help to improve bedform diversity.

Table 6.2 presents the stream restoration dimensions for the Harris tributary.

TABLE 6.2
Geomorphic Characteristics of the Existing and Proposed Harris Tributary Channel[1]
UT to Barnes Creek Restoration Plan

	Existing Harris Tributary	Design Criteria [2]		Proposed Harris Tributary	
		Min	Max	Min	Max
1. Stream Type	E5	--	--	E5	
2. Drainage Area – square miles	0.2	--		0.2	
3. Bankfull Width (w_{bkf}) – feet	8.5	--	--	10.0	
4. Bankfull Mean Depth (d_{bkf}) – feet	0.8	--	--	0.8	
5. Width/Depth Ratio (w/d ratio)	10.6	10	15	13.3	
6. Cross-sectional Area (A_{bkf}) – SF	6.8	--	--	7.5	
7. Bankfull Mean Velocity (v_{bkf}) - fps	4.0	--	--	3.6	
8. Bankfull Discharge (Q_{bkf}) – cfs	27	--	--	27	
9. Bankfull Max Depth (d_{mbkf}) - feet	1.6	--	--	1.25	
10. d_{mbkf} / d_{bkf} ratio	1.3	1.2	1.6	1.6	
11. Low Bank Height to d_{mbkf} Ratio	1.0	1.0		1.0	
12. Floodprone Area Width (w_{fpa}) – feet	92+	--	--	30	60
13. Entrenchment Ratio (ER)	10.9		>2.2	2.5	10+
14. Meander length (L_m) – feet	--	--	--	113	125
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	--	11.3	12.5	11.3	12.5
16. Radius of curvature (R_c) – feet	--	--	--	20	30
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	--	2.0	3.0	2.0	3.0
18. Belt width (w_{blt}) – feet	--	--	--	35	80
19. Meander Width Ratio (w_{blt}/W_{bkf})	--	3.5	8.0	3.5	8.0
20. Sinuosity (K) Stream Length/ Valley Distance	1.02	1.3	1.8	1.28	
21. Valley Slope – feet per foot	0.0089	--	--	0.0127[3]	
22. Channel Slope ($s_{channel}$) – feet per foot	0.0087	--	--	0.0067	
23. Pool Slope (s_{pool}) – feet per foot	0.0011 – 0.0013	--	--	0.0014	0.0021

TABLE 6.2
Geomorphic Characteristics of the Existing and Proposed Harris Tributary Channel[1]
UT to Barnes Creek Restoration Plan

	Existing Harris Tributary	Design Criteria [2]		Proposed Harris Tributary	
		Min	Max	Min	Max
24. Ratio of Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	0.13 – 0.15	0.10	0.40	0.21	0.31
25. Maximum Pool Depth (d_{pool}) – feet	2.2	--	--	2.5	
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	2.8	2.2	3.1	3.1	
27. Pool Width (w_{pool}) – feet	7.6	--	--	14.8	
28. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	0.9			1.5	
29. Pool Area (A_{pool}) – square feet	11.9	--	--	17.2	
30. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.8	1.7	2.3	2.3	
31. Pool-to-Pool Spacing – feet	29.4 – 129.7	--	--	22.2	57.5
32. Ratio of Pool-to-Pool Spacing to Bankfull Width ($p\text{-}p/w_{bkf}$)	3.5 – 15.3			2.2	5.8
33. Riffle Slope (s_{riffle}) – feet per foot	0.020 – 0.026	--	--	0.0105	0.021
34. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	2.3 – 3.0	1.2	2.2	1.6	3.1
Particle Size Distribution of Channel Material					
Material (d_{50})	Coarse sand	--		--	
d_{16} – mm	<0.062	--		--	
d_{35} – mm	<0.062	--		--	
d_{50} – mm	1.0	--		--	
d_{84} – mm	16	--		--	
d_{95} – mm	21	--		--	

TABLE 6.2
Geomorphic Characteristics of the Existing and Proposed Harris Tributary Channel[1]
UT to Barnes Creek Restoration Plan

	Existing Harris Tributary	Design Criteria [2]		Proposed Harris Tributary	
		Min	Max	Min	Max

NOTES:

1 If data are not presented, they were not collected, not calculated, or not applicable.

2 Specific remarks regarding selection of design criteria can be found in the detailed design narratives on dimension, pattern, and profile.

3 The valley length and slope change from existing to proposed conditions on this reach because the Harris tributary will be re-routed to join the mainstem further downstream than present conditions.

6.3 Sediment Transport

6.3.1 Sediment Transport Analysis

The Hurley mainstem reach, the Harris mainstem reach, and the Harris tributary reach have median particle sizes that result in their classification as small gravel, medium sand, and coarse sand bed streams, respectively. While these median particle sizes indicate some diversity, the overall composition is fairly similar. Each of the streams has 50% to 60% sand, 30% to 50% gravel, and less than 10% cobble as bed substrate. In isolated locations, coarse material in riffles appears to control grade. The streams also receive significant quantities of fine materials from both bank erosion and contributions from the upstream catchment. While restoration of the channel will reduce localized bank erosion, the channel will still need to transport the fine materials from upstream sources. In sand bed streams, sediment transport capacity is a critical analysis, whereas in gravel bed streams, sediment transport competency is a critical analysis. Since the design reaches must transport both sand and gravel sized particles, both capacity and competency were analyzed.

Sediment transport capacity, measured as unit stream power (W/m^2) as discussed in Section 2.6, was compared for the existing stream channels and the design conditions. Table 6.3 shows bankfull boundary shear stress and stream power values for existing and design conditions. Stream power values for the existing and design conditions all compare well to values for similar streams and valley types described by Bledsoe (2002). The average stream power for the stable streams in the Bledsoe study is 30 W/m^2 for the 2-year storm event. Therefore, the 1.5-year recurrence interval bankfull event in the Bledsoe channels probably creates stream power in the 20 W/m^2 range. As shown in Table 6.3, the proposed project design reduces stream power and boundary shear stress to more stable levels for each reach.

Sediment transport competency is measured in terms of the relationship between critical and actual depth at a given slope and occurs when the critical depth produces enough shear stress to move the largest (d_{100}) subpavement particle. As shown in Table 6.3, the UT mainstem design reach has a design depth equal to the critical depth, signifying stability in terms of competency. The Harris tributary has a design depth greater than the critical depth which may indicate the tendency to degrade. The concern for degradation will be addressed by grade control structures which will be installed as discussed in Section 6.4. As a second check of sediment transport competency, boundary shear stress was plotted on Shield's Curve (as discussed in Section 2.6.3) to estimate the largest moveable particle. In both streams, as shown in Table 6.3, the Shield's

Curve predicts the mobility of particles larger than the d_{100} observed in the subpavement. Both of these sediment transport competency analyses confirm the ability of the design channel to transport the coarse sediment load.

TABLE 6.3
Boundary Shear Stresses and Stream Power for Existing and Proposed Conditions
UT to Barnes Creek Restoration Plan

Parameter	Value			
	UT Mainstem Existing Conditions	UT Mainstem Proposed Conditions	Harris Tributary Existing Conditions	Harris Tributary Proposed Conditions
Bankfull Discharge, Q (cfs)	97	97	27	27
Bankfull Area (square feet)	16.8 – 21.0	20.6	6.8	7.5
Mean Bankfull Velocity (cfs)	4.6 – 5.8	4.7	4.0	3.6
Bankfull Width, W (feet)	8.6 – 23.1	15.0	8.5	10.0
Bankfull Mean Depth, D (feet)	0.9 – 2.0	1.4	0.8	0.8
Width to Depth Ratio, w/d (feet/ foot)	4.4 – 25.9	10.9	10.6	13.3
Wetted Perimeter (feet)	15.5	17.8	10.1	11.6
Hydraulic Radius, R (feet)	1.3	1.2	0.7	0.6
Channel Slope (feet/ foot)	0.0060	0.0053	0.0087	0.0067
Boundary Shear Stress, τ (lbs/ft^2)	0.48 – 0.53	0.38	0.37	0.24
Subpavement D_{100} (mm)	72	72	23	23
Largest Moveable Particle (mm) per Shield's Curve	100 – 150	75 – 125	75 – 100	50 – 75
Critical Depth (feet)	1.2	1.4	0.19	0.25
Critical Slope (feet/ foot)	0.0044	0.0053	0.002	0.002
Stream Power (W/m^2)	44.3 – 64.5	31.1	25.1	16.4

6.4 In-Stream Structures

A variety of in-stream structures are proposed for the UT to Barnes Creek site. Structures such as root wads, constructed riffles, and log vanes will be used to stabilize the newly-restored stream. Table 6.4 summarizes the use of in-stream structures at the site.

TABLE 6.4
In-Stream Structure Types and Locations
UT to Barnes Creek Restoration Plan

Structure Type	Location
Root Wad	UT Mainstem and Harris Tributary
Brush Mattress	UT Mainstem and Harris Tributary
Constructed Riffle	UT Mainstem and Harris Tributary
Log Vane	UT Mainstem
Log Weir	UT Mainstem and Harris Tributary
Cover Log	UT Mainstem

6.4.1 Root Wad

Root wads are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also serve as a food source for aquatic insects. Root wads will be placed throughout the UT to Barnes Creek project.

6.4.2 Brush Mattress

Brush mattresses are placed on bank slopes on the outside of meander bends for stream bank protection. Layers of live woody cuttings are wired together and staked into the bank. Brush mattresses help to establish vegetation on the bank to secure the soil. Once the vegetation is established, the cover also provides habitat for wildlife.

6.4.3 Constructed Riffle

A constructed riffle consists of the placement of coarse bed material in the stream at the specific riffle locations along the profile. A buried log at the upstream and downstream end of each riffle will control the slope through the riffle. The purpose of this structure is to provide grade control and improve riffle habitat. Constructed riffles will be placed throughout the mainstem and tributary channels.

6.4.4 Log Vane

A log vane is used to protect the stream bank. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes are located just downstream of the point where the stream flow intersects the bank at an acute angle in a meander bend. Log vanes will be placed in the UT mainstem reach. The Harris tributary is too narrow to allow for appropriate log vane installation.

6.4.5 Log Weir

A log weir consists of placing a header log and a footer log in the bed of the stream channel, perpendicular to the stream flow. The logs extend into the stream banks on both sides of the structure to prevent erosion and bypassing of the structure. The logs are installed flush with the channel bottom upstream of the log. The footer log is placed to the depth of scour expected to prevent the structure from being undermined. Although a pool is often excavated downstream of the weir during installation, a pool will typically form naturally downstream of the structure. Log weirs provide bedform diversity, maintain channel profile, and provide pool and cover habitat. Debris jams similar to log weirs were observed in the Spencer Creek reference reach; these log weir structures will be used in both the mainstem and the Harris tributary.

6.4.6 Cover Log

A cover log is placed in the outside of a meander bend to provide habitat in the pool area. The log is buried into the outside bank of the meander bend; the opposite end extends through the deepest part of the pool and may be buried in the inside of the meander bend, in the bottom of the point bar. The placement of the cover log near the bottom of the bank slope on the outside of the bend encourages scour in the pool. This increased scour provides a deeper pool for bedform variability. Cover logs will be used on the UT mainstem reaches. The Harris tributary is too narrow to allow adequate space for cover log installation.

6.5 Wetland Enhancement, Restoration and Creation

Wetland enhancement will include re-vegetating existing on site wetlands with hydrophytic vegetation. Specific areas adjacent to the existing wetlands that have been identified as having soils with hydric tendencies will also be planted with hydrophytic vegetation. As wetland hydrology returns to the site, we anticipate that these areas will be restored to fully functioning wetland systems.

Wetlands will also be created in abandoned portions of the existing stream, as shown on Figure 4.1. When the new mainstem channel is completed, ephemeral pools will be constructed at select locations by partially backfilling the existing stream. These ephemeral pools will become wetland areas over time. The vegetation that will be planted in all wetland areas will be the same vegetation used riparian areas. Section 6.6 discusses the proposed vegetation plan for the site.

The presence of hydric soils over much of the project site is evidence that the site historically supported a wetland ecosystem. Hydrology in this system is driven by groundwater seepage from the surrounding hill slopes as well as overbank flow. Due to agricultural activities over the last two centuries, the wetlands in the project area have degraded. The stream has been straightened and has incised slightly which has dropped the water table within these wetlands. The wetlands have also been drained by small ditches in order to promote agricultural production in areas that would normally have been determined unsuitable.

Proposed wetland restoration areas have similar elevations as the existing jurisdictional wetlands but are more effectively drained by the UT mainstem due to landscape position and manmade ditches. By raising the profiles at the restored stream reaches during the Priority 1 stream restoration effort, an overbank flooding regime will be restored to the riverine wetland areas. Raising of the streambeds will also raise the local water table and restore or enhance wetland hydrology. Plugging of manmade ditches will allow adjacent hillslope seepage to support additional wetland hydrology in restoration areas.

Rough grading will be used to create micro-topographic changes across the site that will reduce surface drainage and runoff. In this manner, rainfall and hillslope seepage will collect in areas away from the stream channel and help to restore hydrology to the riverine wetlands.

Hydrology models were not considered necessary for development of the wetland restoration plan for this site. Restoration of wetland hydrology was considered incidental to the stream restoration design since raising the stream bed will provide the major hydrologic lift to the site.

6.6 Vegetation

The vegetative components of this project include stream bank, floodplain, wetland, hillslope planting, and invasive species removal. In addition, any areas of the site that are disturbed, lack diversity, or might be adversely impacted by the construction process will be replanted.

6.6.1 Stream Bank, Floodplain, Wetland, and Hillslope Re-Vegetation

The stream banks and the adjacent riparian area, including wetland areas, will be planted with both woody and herbaceous vegetation as shown on the attached plan sheets. Any stream banks with a 2:1 slope or steeper will be vegetated using live stake or brush mattress techniques. A buffer of woody and herbaceous species will be installed within the buffer limits.

A schedule of plants for use on this project is shown in Table 6.5.

TABLE 6.5
Plant Schedule
UT to Barnes Creek Site Restoration Plan

COMMON NAME	BOTANICAL NAME
Riparian Buffer Plantings	
Trees	
River Birch	*Betula nigra*
Green Ash	*Fraxinus pennsylvanica*
Sycamore	*Platanus occidentalis*
Water Oak	*Quercus nigra*
Large Shrubs/Small Trees	
Tag Alder	*Alnus serrulata*
Ninebark	*Physocarpus opulifolius*
Small Shrubs	
Common Pawpaw	*Asimina triloba*
Spicebush	*Lindera benzoin*
Native Species for Stream Banks and Buffers	
Switchgrass	*Panicum virgatum*
Soft Rush	*Juncus effusus*
Fringed Sedge	*Carex crinata*
Virginia Wild Rye	*Elymus virginicus*
Joe Pye Weed	*Eupatorium fistulosum*

TABLE 6.5
Plant Schedule
UT to Barnes Creek Site Restoration Plan

COMMON NAME	BOTANICAL NAME
Woody Vegetation for Live Stakes	
Silky Dogwood	*Cornus amomum*
Silky Willow	*Salix sericea*
Elderberry	*Sambucus canadensis*
Hillside Plantings	
Trees	
Southern Sugar Maple	*Acer floridanum*
Bitternut Hickory	*Carya cordiformus*
Red Oak	*Quercus rubra*
Large Shrubs/Small Trees	
Serviceberry	*Amelanchier arborea*
Ninebark	*Physocarpus opulifolius*
Small Shrubs	
Common Pawpaw	*Asimina triloba*
Sweetshrub	*Calycanthus floridus*
Hillside Seeding	
Switchgrass	*Panicum virgatum*
Big Bluestem	*Andropogon gerardii*
Indiangrass	*Sorghastrum nutans*
Virginia Wild Rye	*Elymus virginicus*
Black Eyed Susan	*Rudbeckia hirta*

6.6.2 Invasive Species Removal

The site has minimal existing native riparian vegetation other than field grasses. Invasive species such as Multiflora rose (*Rosa multiflora)* and privet (*Ligustrum sinense*) are present, primarily along the UT Harris mainstem reach. Grading operations will remove these invasive species. If these or other invasive species re-establish and persist after more than three years after the stream restoration has been constructed, hand cutting and herbicide treatment will be required.

7 Monitoring and Evaluation

Channel stability, vegetation survival, and viability of wetland function will all be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success.

An as-built report will be produced for the site within 90 days following completion of construction. The report will include a detailed as-built survey, photographs, sampling plot locations, and a list of the species planted and the associated densities. Following the as-built report, monitoring reports will be produced annually for five years. These reports will be prepared and submitted to NCDENR EEP by November 30 during each monitoring year. Annual monitoring reports will document the specific parameters described below.

7.1 Stream Monitoring

Geomorphic monitoring of restored stream reaches will be conducted for five years to evaluate the effectiveness of the restoration practices. Monitored stream parameters include stream dimension (cross-sections), pattern (longitudinal survey), profile (profile survey), and photographic documentation. The methods used and any related success criteria are described below for each parameter.

7.1.1 Cross-Sections

Permanent cross-sections (either surveyed or located using a GPS) will be established at a spacing of one per 20 bankfull-width lengths, with an effort made to include both riffles and pools. Each cross-section will be marked on both banks with permanent pins to establish the exact transect used. A common benchmark will be used for cross-sections and consistently used to facilitate the comparison of year-to-year data. The annual cross-section survey will include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg, and at two-foot intervals between. Calculations will be made of width/depth ratio, entrenchment ratio, and low bank height ratio. Riffle cross-sections will be classified using the Rosgen stream classification system.

There should be little or no change in as-built cross-sections from year to year. If changes do take place they should be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting, erosion) or are minor changes that represent an increase in stability (e.g., settling, vegetative changes, deposition along the banks, decrease in width/depth ratio and/or cross-sectional area).

7.1.2 Pattern

Annual measurements taken for the plan view of the restoration site will include sinuosity, meander width ratio, and radius of curvature. The radius of curvature measurements will be taken on newly constructed meanders for the first year of monitoring only.

7.1.3 Longitudinal Profile

A complete longitudinal profile will be completed during the first year and then every two years over the course of a five-year period (for a total of three times). Measurements will include average channel slope, pool slope, riffle slope, and pool-to-pool spacing. Survey points will include thalweg, water surface, inner berm, bankfull, and top of bank. Each of these survey points will be taken at prescribed intervals and at the head of each feature: riffle, run, pool, glide, and the maximum pool depth location. The survey will be tied to a permanent benchmark.

The longitudinal profile data should show that the bedform features are remaining stable, and are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steep and shallow.

7.1.4 Photo Reference Sites

Photographs used to evaluate restored sites will be made with a digital camera. There will be one photo reference site per cross-section showing both banks and the stream channel. Several of the in-stream structures (e.g., rock vanes, cross vanes, and root wads) will also be photographed. Reference sites will be photographed before construction and once per year for at least 5 years following construction. After construction is complete, photo reference sites will be marked with wooden stakes.

The stream will be photographed longitudinally beginning at the downstream end of the restoration site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to provide an overall view of the reach. The angle of the shot will depend on what angle provides the best view and will be noted and continued in future shots. When modifications to photo position must be made due to obstructions or other reasons, the position will be noted along with any landmarks and the same position will used in the future.

Reference photo transects will also be taken at each permanent cross-section. Photographs will be taken of both banks at each cross-section. A survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame and as much of the bank as possible included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time. Photos of areas that have been treated differently should also be included; for example, two different types of erosion control material used. This detailed photo log will allow for future comparisons.

Photographs will be used to qualitatively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of in-stream structures and erosion control measures. Longitudinal photos should indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral photos should indicate stable banks over time. A series of photos over time should indicate successional maturation of riparian vegetation. Vegetative succession should include initial herbaceous growth, followed by increasing densities of woody vegetation, and then ultimately a mature overstory with herbaceous understory.

7.2 Wetland Monitoring

7.2.1 Wetland Hydrologic Monitoring

Groundwater-monitoring stations will be installed across the project area to document hydrologic conditions of the restored site. Eight groundwater monitoring stations will be installed, with four stations being automated groundwater gauges, and four stations being manually read stations. Ground water monitoring stations will follow the USACE standard methods found in WRP Technical Notes ERDC TN-WRAP-00-02 (July 2000).

In order to determine if the rainfall is normal for the given year, rainfall amounts will be tallied using data obtained from the Jackson Springs, Albemarle, Mt. Gilead, and Asheboro automated weather stations (COOP: 314464, COOP: 310090, COOP: 315898, COOP: 310286).

The monitoring data will show the site has been saturated within 12 inches of the soil surface for at least 5-12.5% of the growing season and that the site has exhibited an increased frequency of flooding. The restored site will be compared to a reference site where the groundwater and surface water levels (overbank events) will be monitored. In addition, the restored site's hydrology will be compared to pre-restoration conditions both in terms of groundwater and frequency of overbank events.

7.3 Vegetation Monitoring

Vegetation monitoring will be in accordance with the "Vegetation Monitoring Plan for Riparian Buffer and Wetland Restoration Projects", which is currently in draft form. All woody vegetation will be flagged and evaluated for at least five years to determine survival. At least two staked survival plots shall be evaluated. Plots should include both live staked and other planted areas. Plots will be 100 m^2 and all flagged stems will be counted in those plots. Invasive and Non-Native species should be noted during data collection. Success of woody vegetation plantings will be defined as 320 stems per acre after five years. When woody vegetation does not survive, a determination will be made as to the need for replacement; in general, if greater than 25% die, replacement will be required. The presence of Non-native species shall be evaluated on a yearly basis and removal may be required by hand cutting and/or herbicide treatment.

Herbaceous vegetation, primarily native grasses, planted at the site shall have at least 95% coverage of the seeded/planted area. No bare patches shall exceed 10 square feet. Any herbaceous vegetation not meeting these criteria shall be replaced. At a minimum, at all times ground cover at the project site shall be in compliance with the North Carolina Erosion and Sedimentation Control Ordinance.

7.4 Maintenance Issues

Maintenance requirements vary from site to site and are generally driven by the following conditions:

- Projects without established woody floodplain vegetation are more susceptible to erosion from floods than those with a mature hardwood forest.
- Projects with sandy non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- Extreme and/or frequent flooding can cause floodplain and channel erosion.
- Extreme hot, cold, wet, or dry weather during and after construction can limit vegetation growth, particularly temporary and permanent seed.
- The presence and aggressiveness of invasive species can affect the extent to which a native buffer can be established.

Maintenance issues and recommended remediation measures will be detailed and documented in the As-Built and Monitoring Reports. Factors which may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

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Figures

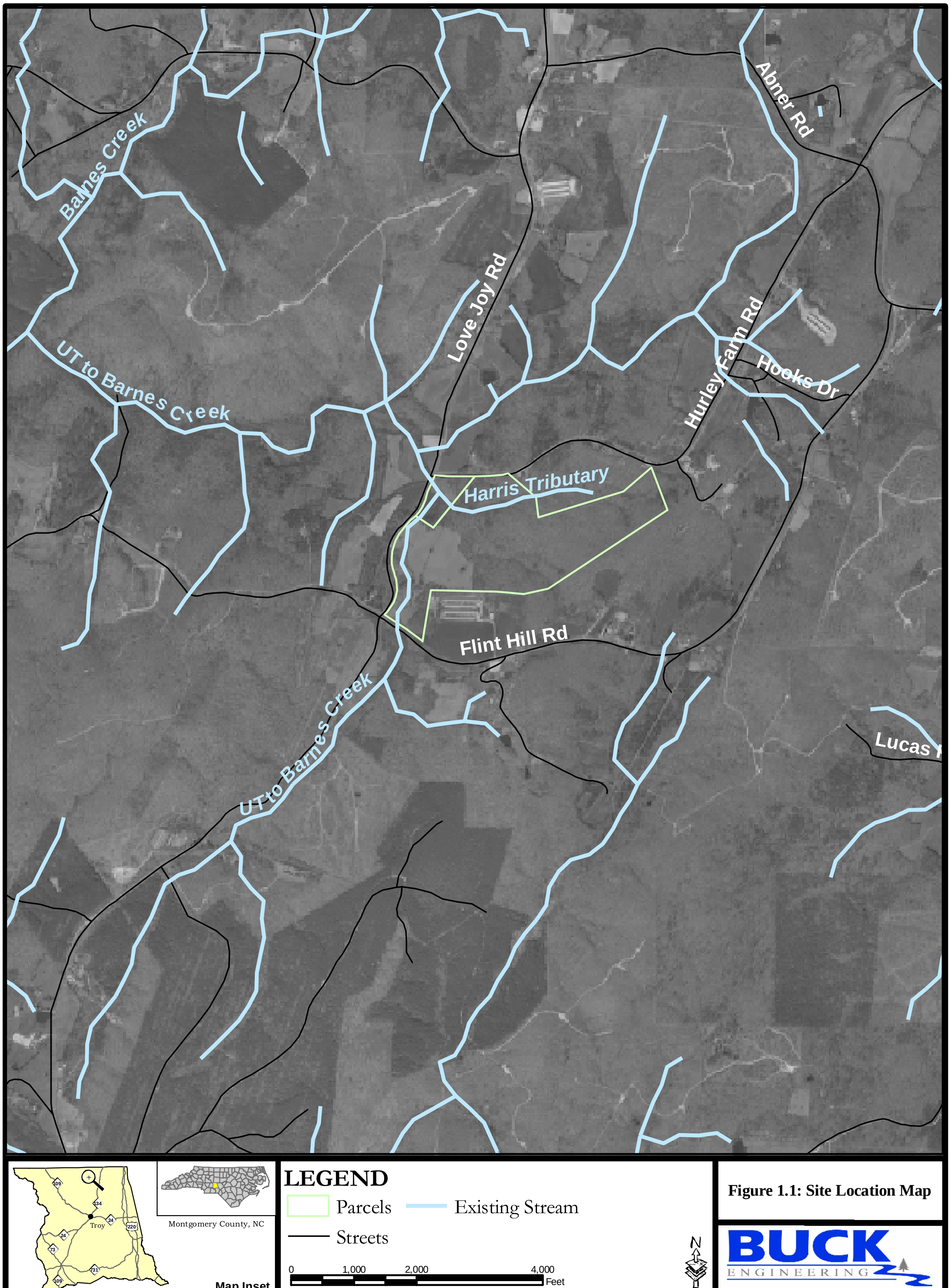

Figure 1.1: Site Location Map

BUCK ENGINEERING

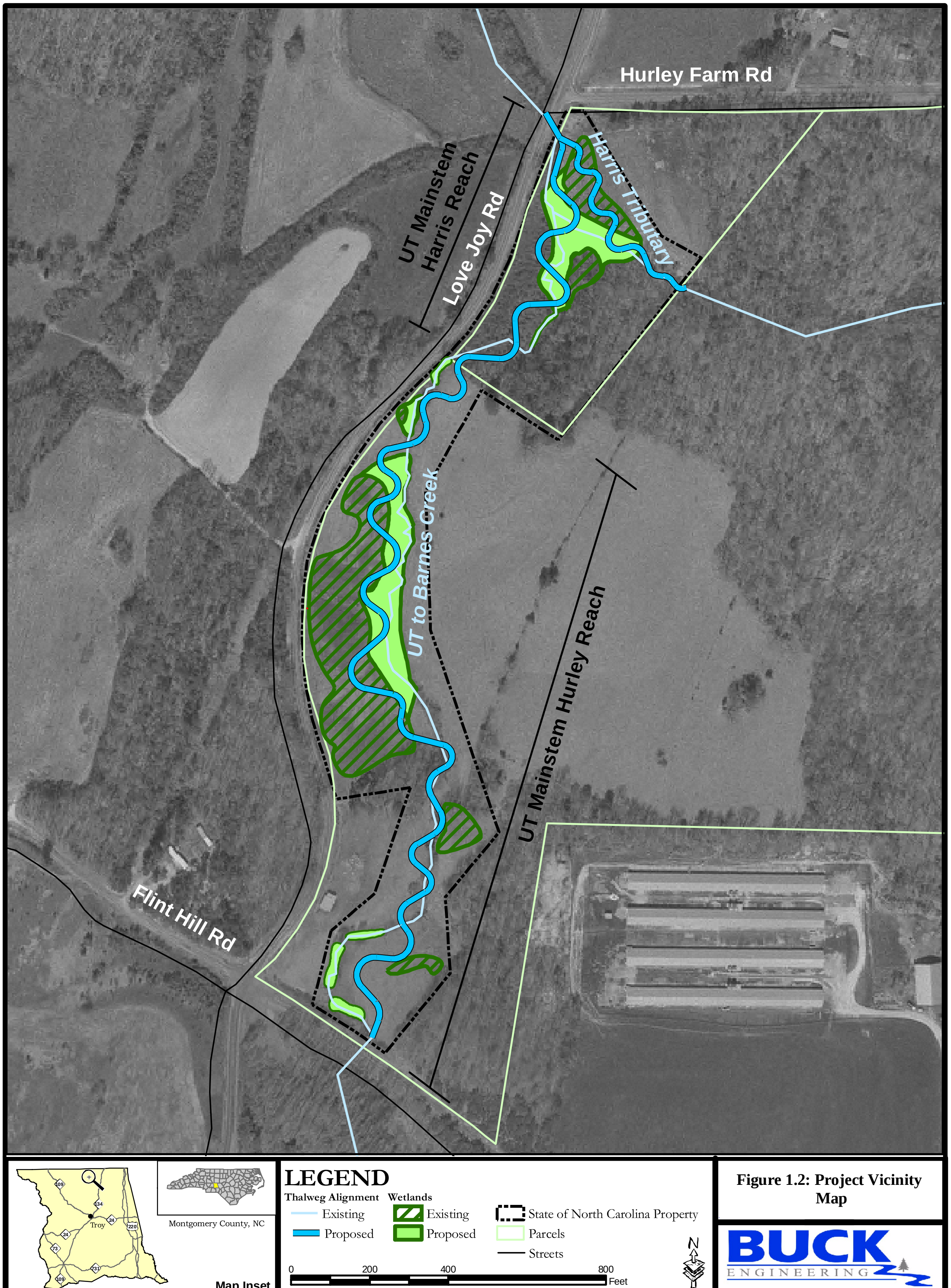

Figure 1.2: Project Vicinity Map

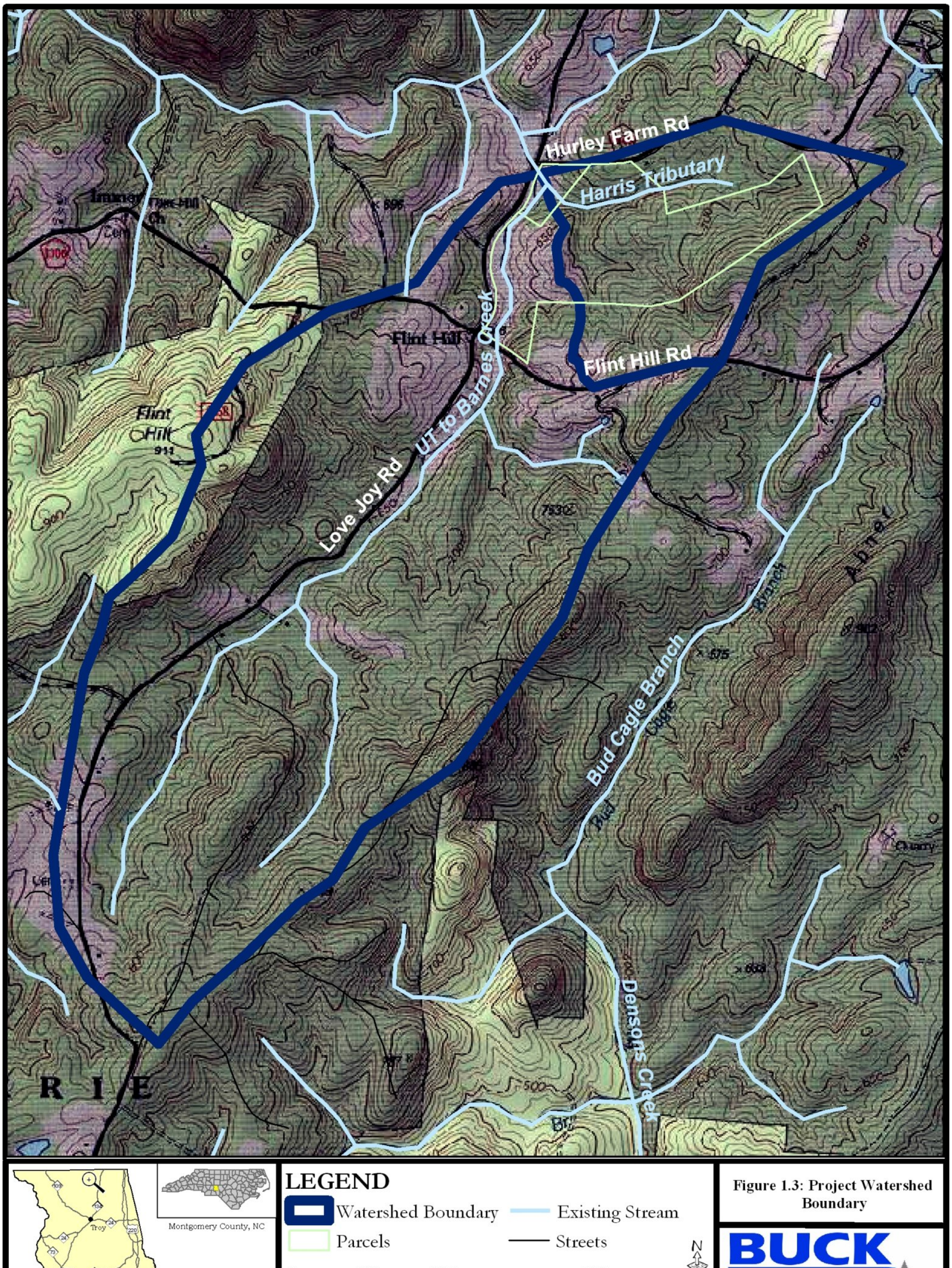

Figure 1.3: Project Watershed Boundary

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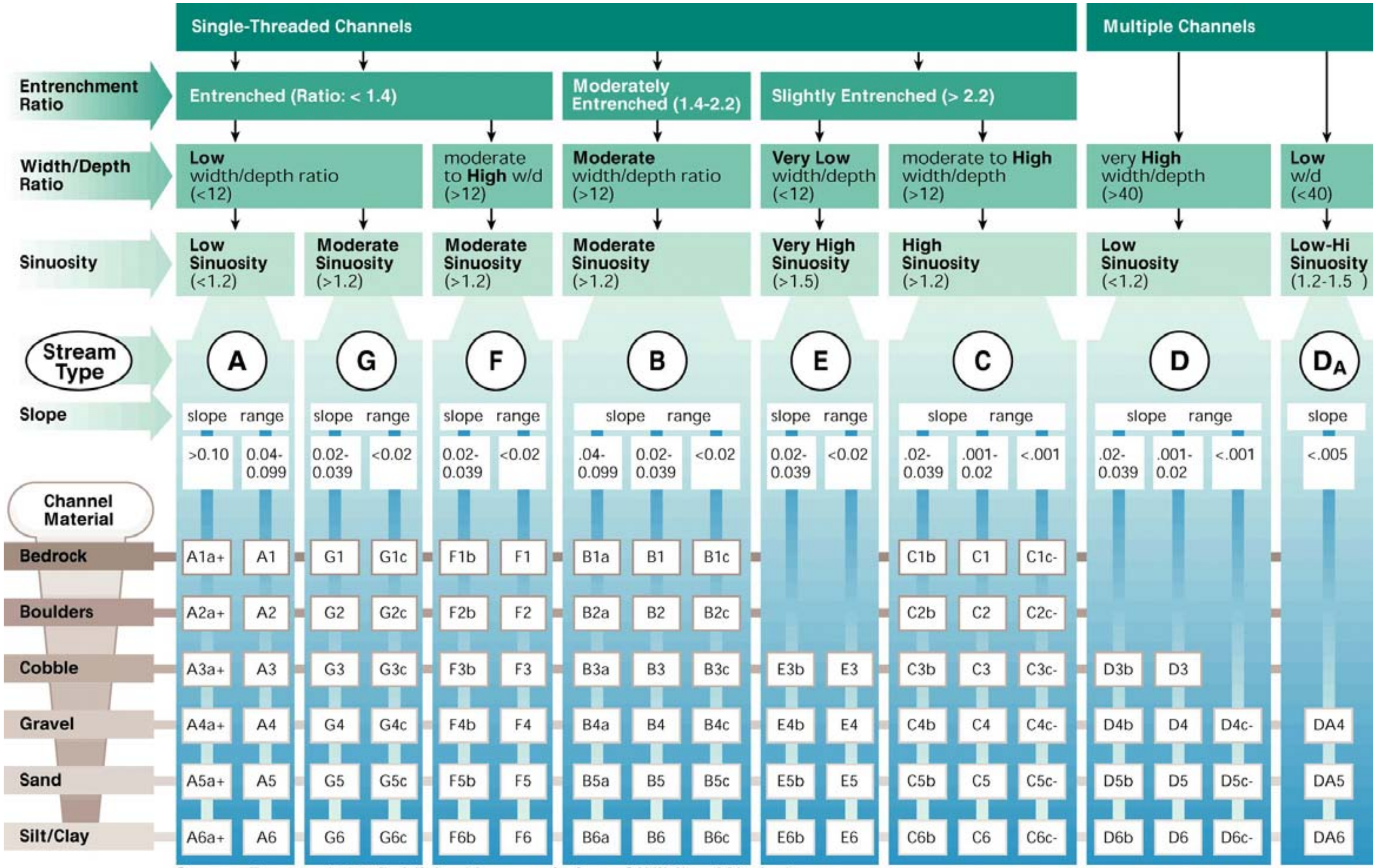
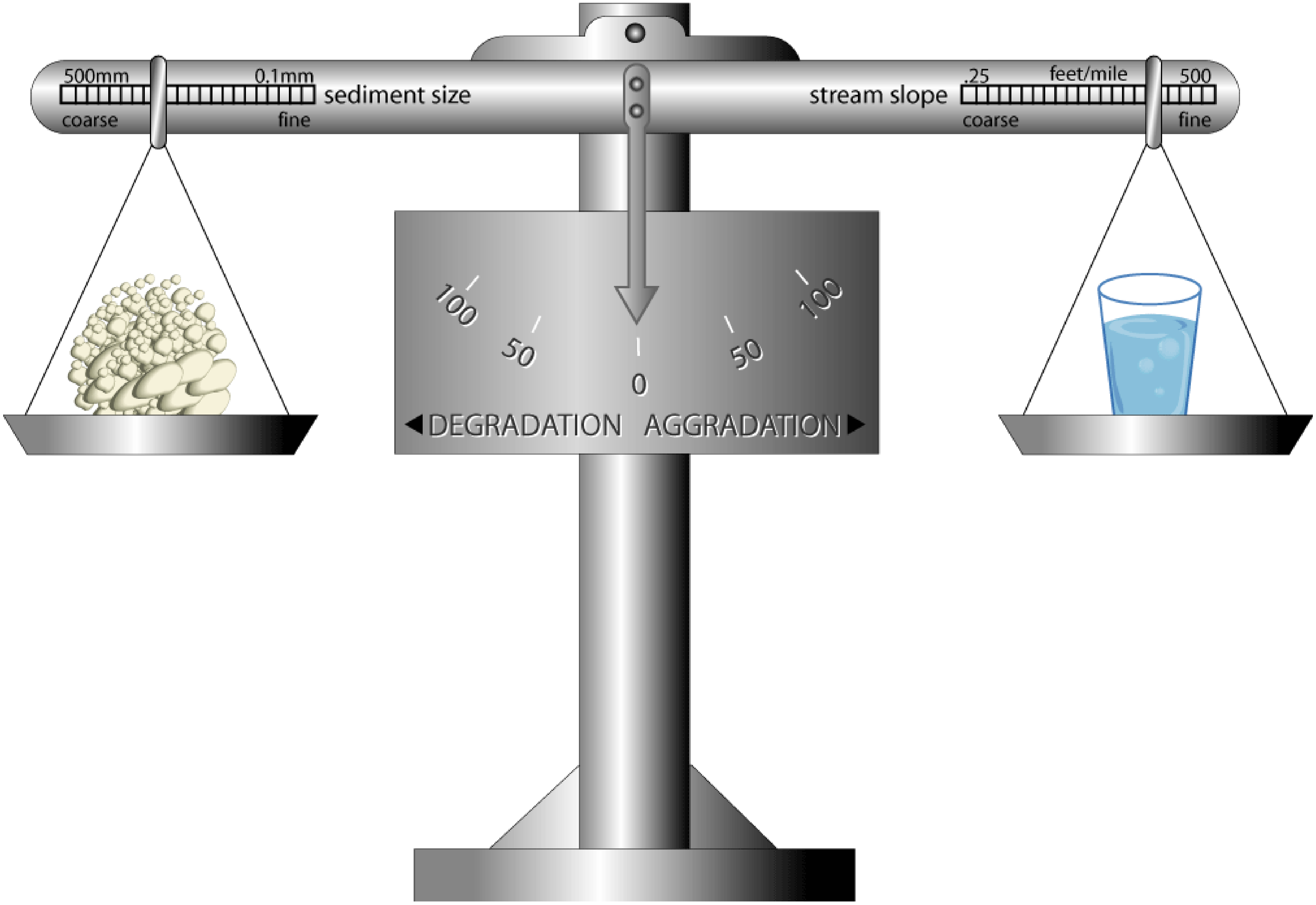


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

Fig. 7.12 -- Rosgen's stream classification system (Level II).
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

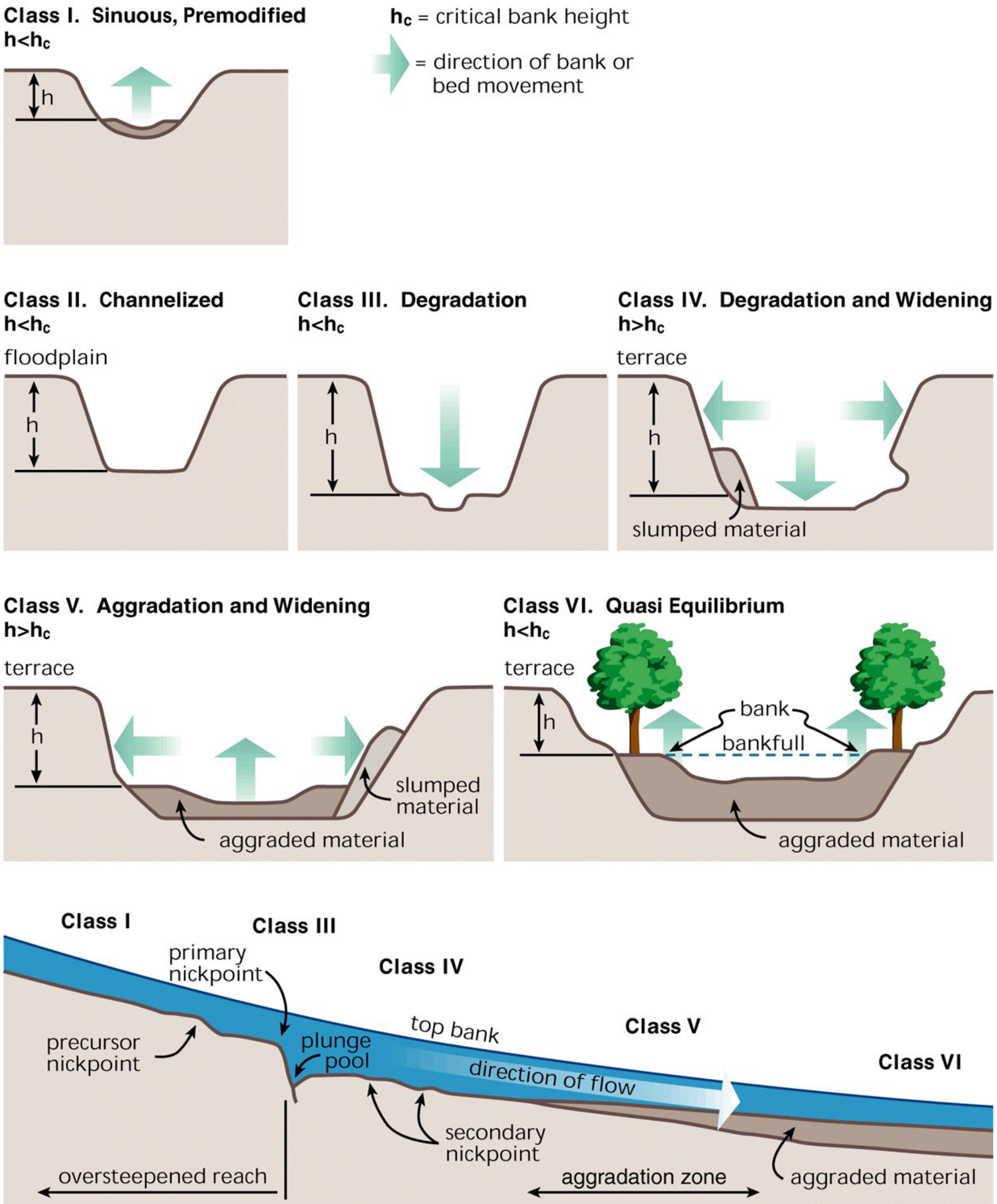
Figure 2.1
Rosgen Stream Classification
UT to Barnes Creek Restoration Plan

Source: Rosgen, David L., *Applied River Morphology*, Wildland Hydrology, 1996



After: Lane, 1955

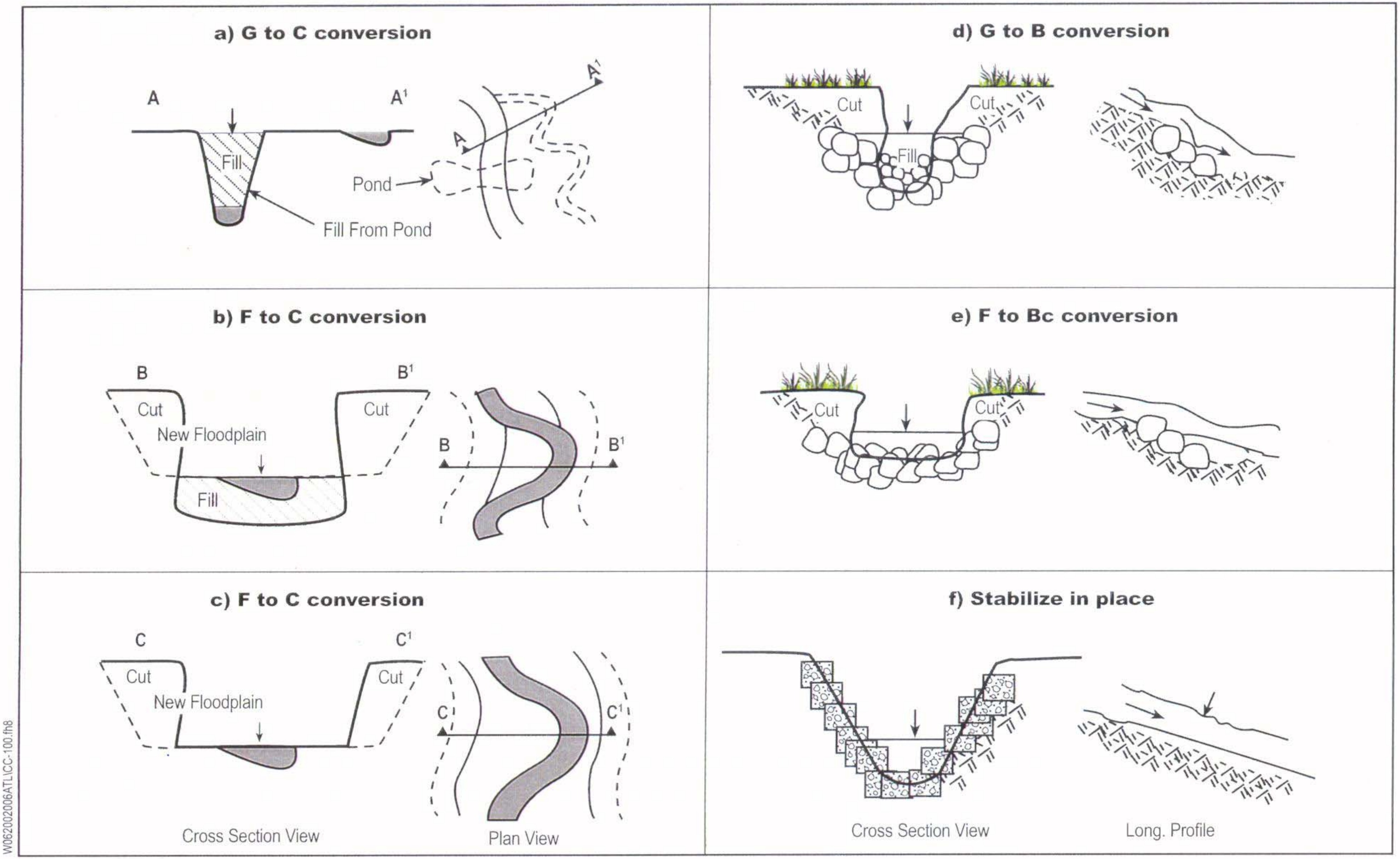
Figure 2.2
Factors Influencing Stream Stability
UT to Barnes Creek Restoration Plan



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

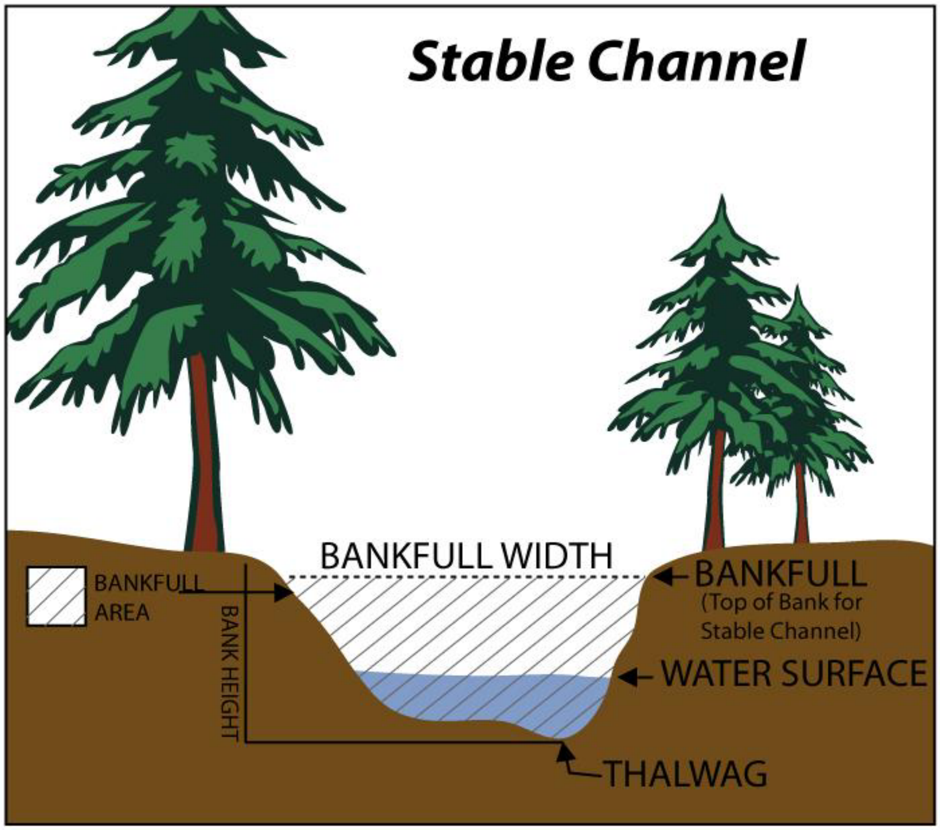
Figure 2.3
Simon Channel Evolution Model
UT to Barnes Creek Restoration Plan

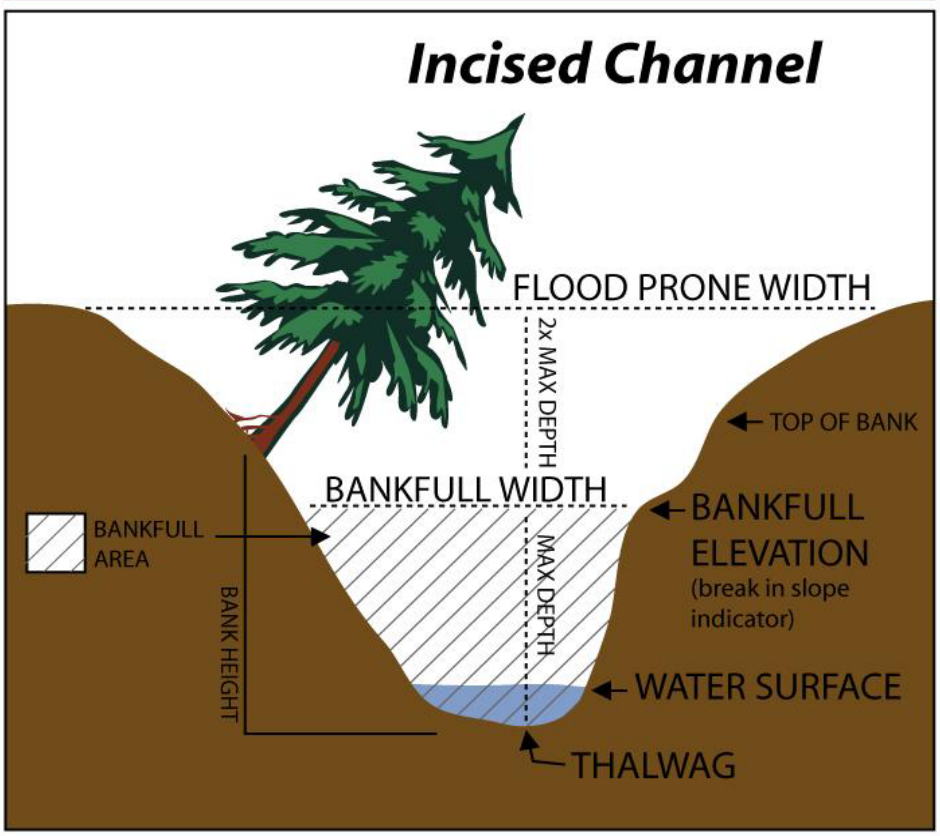
Source: Simon, 1989



Source: Rosgen, David L., "A Geomorphological Approach to Restoration of Incised Rivers," *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*, 1997

Figure 2.4
Restoration Priorities for Incised Channels
UT to Barnes Creek Restoration Plan





Channel Dimension Measurements

Bankfull Elevation is associated with the channel forming discharge. It is the point where channel processes and flood plain processes begin.

Bankfull width: the distance between the left bank bankfull elevation and the right bank bankfull elevation

Bankfull mean depth: the average depth from bankfull elevation to the bottom of the stream channel

Max depth (dmax): the deepest point within the cross-section measured to the bankfull elevation

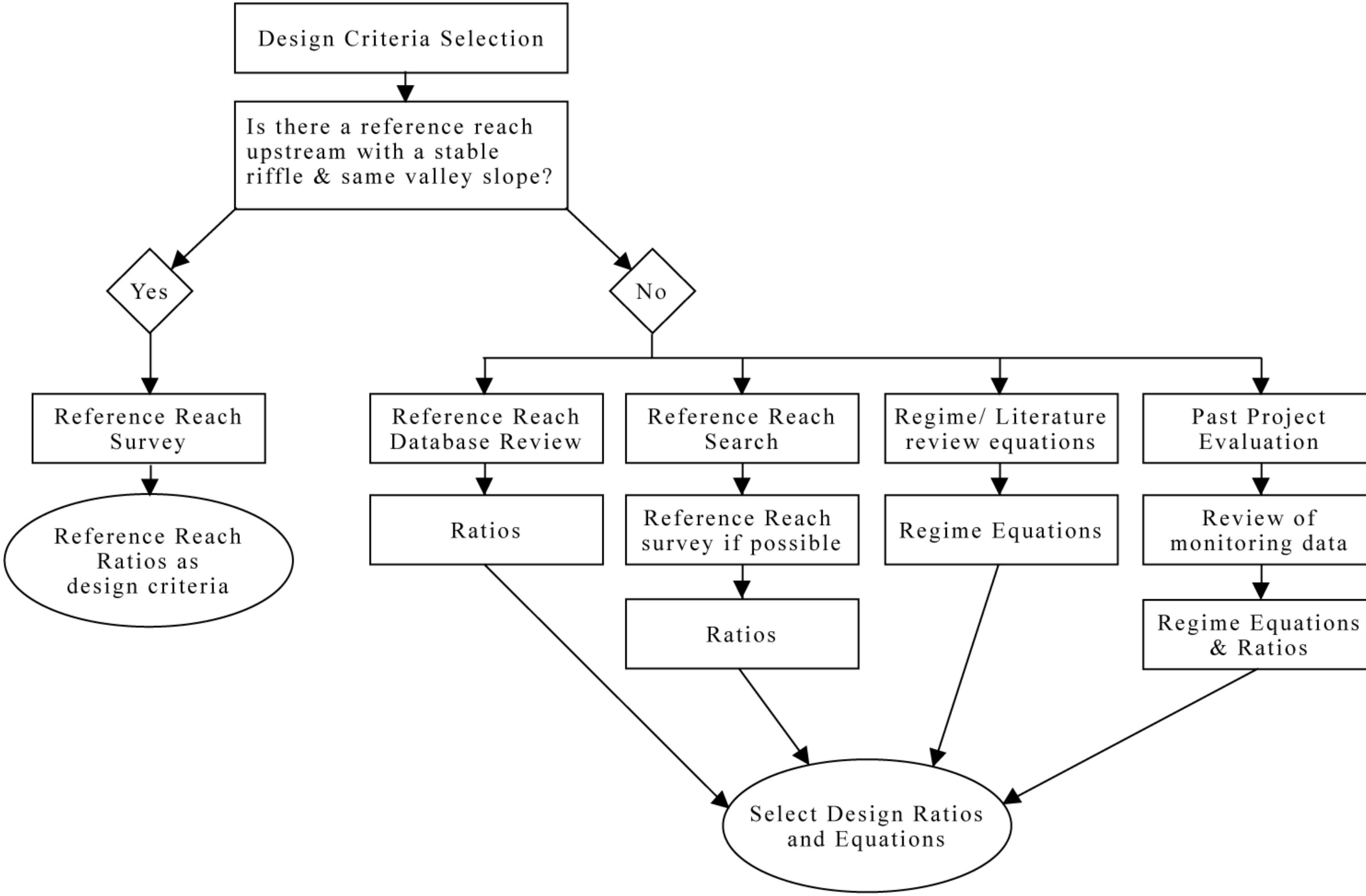
Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

Bank Height Ratio: Bank height (measured from top of bank to the bottom of the stream channel) ÷ the max depth of the bankfull elevation (dmax)

Flood Prone Width: Width measured at the elevation of two times (2x) the maximum depth at bankfull (dmax)

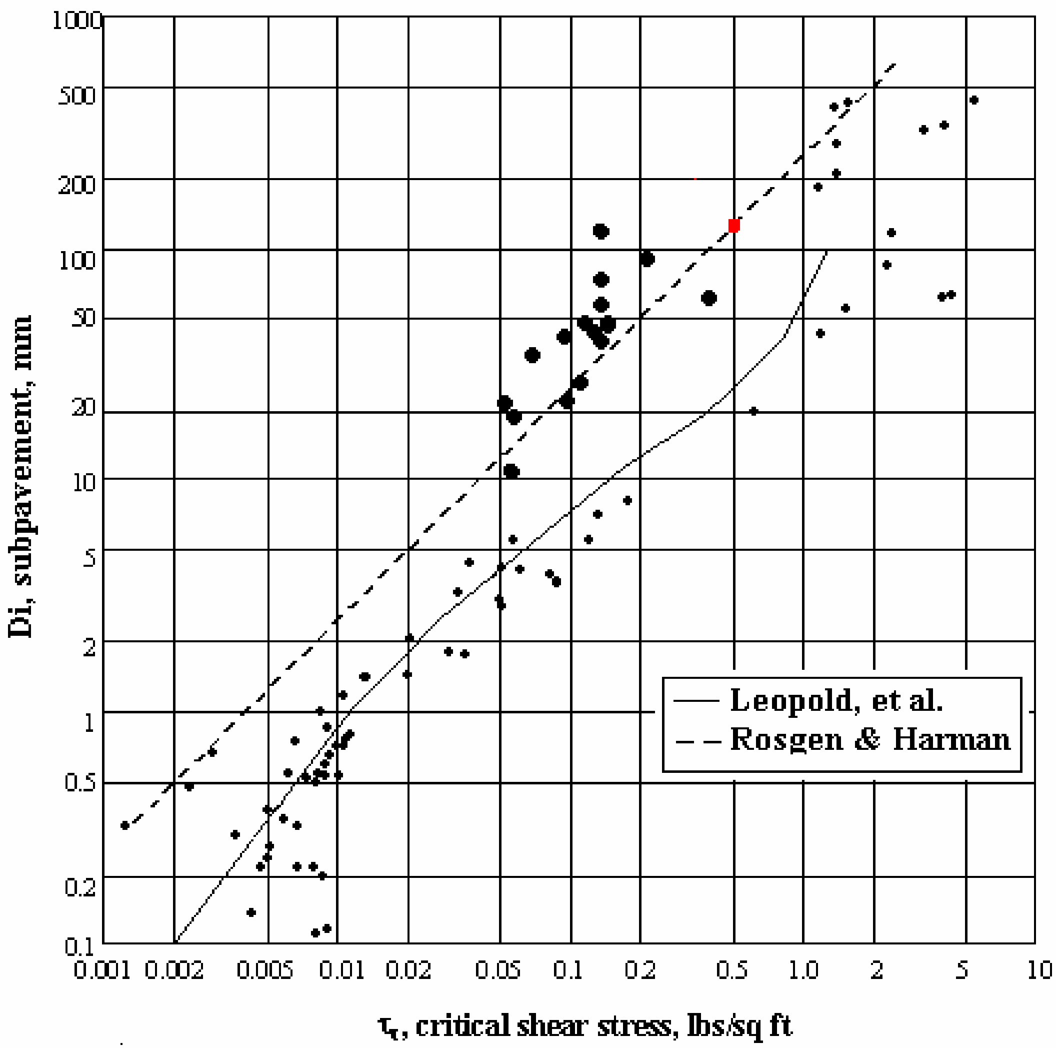
Entrenchment Ratio: Floodprone width ÷ bankfull width

Figure 2.5
Channel Dimension Measurements
UT to Barnes Creek Restoration Plan



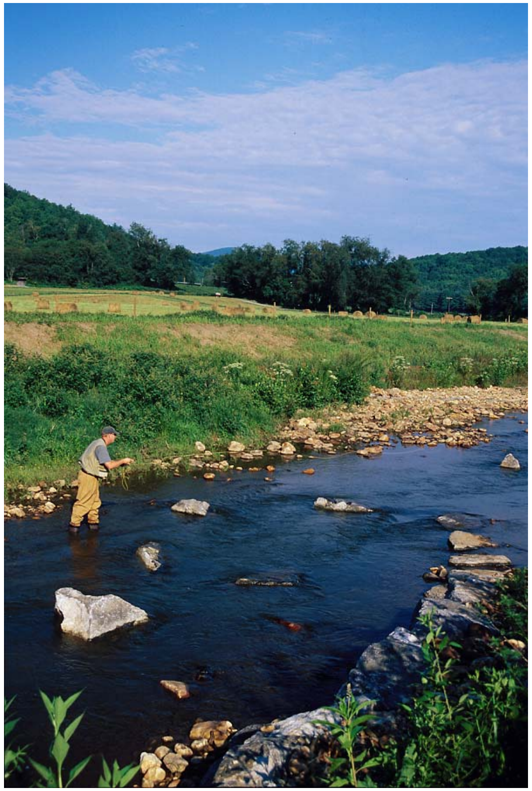
BUCK ENGINEERING

Figure 2.6
Design Criteria Selection
UT to Barnes Creek Restoration Plan



(Data from: Leopold, Wolman, and Miller 1964; Rosgen, personal commun.; and Harman, personal commun.)

Figure 2.7
Shields Curve
UT to Barnes Creek Restoration Plan



J-Hook

Double Wing Deflector

Rock Vane

Double Drop Rock Cross Vane

Figure 2.8
Examples of In-Stream Structures
UT to Barnes Creek Restoration Plan

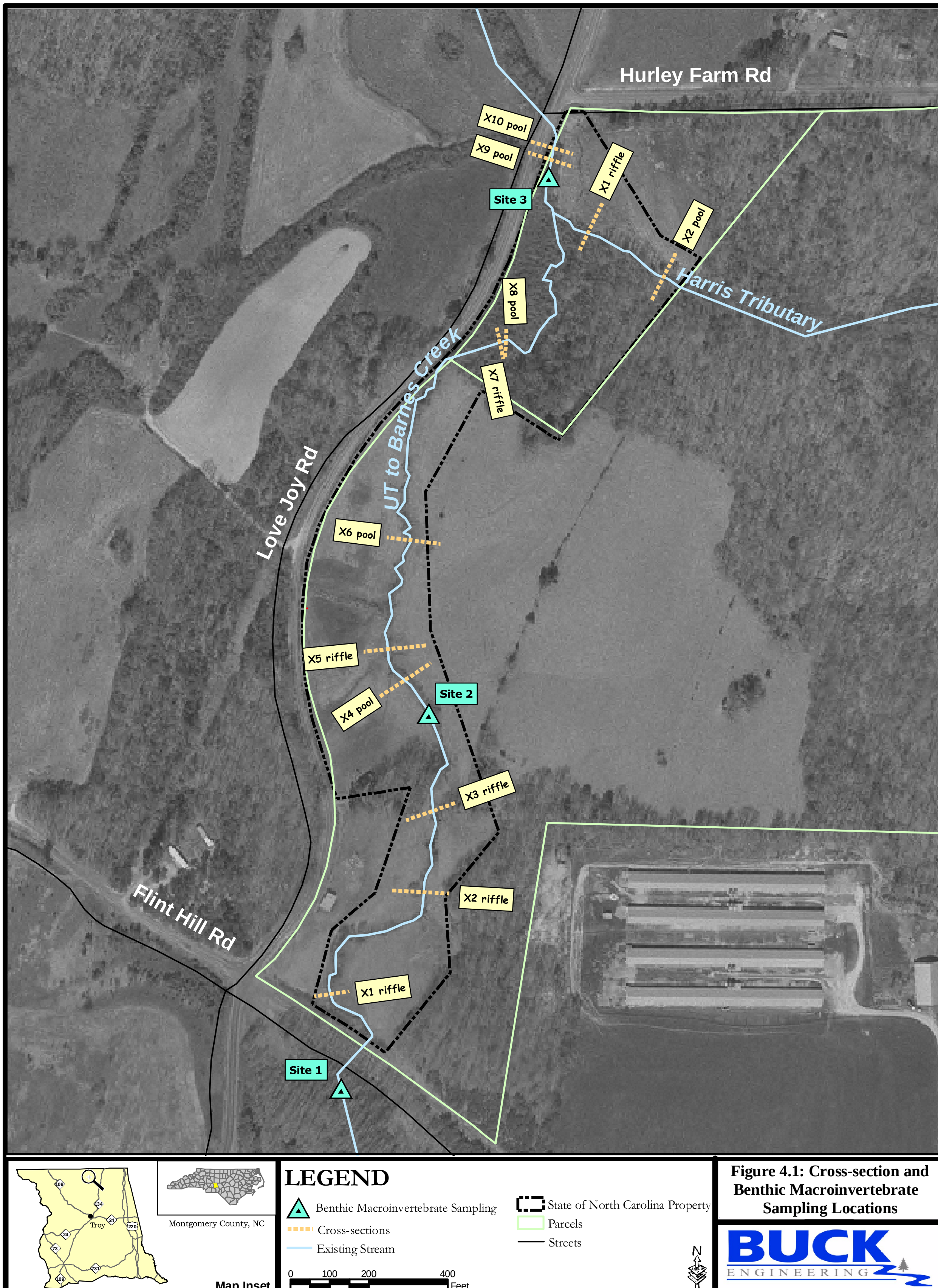
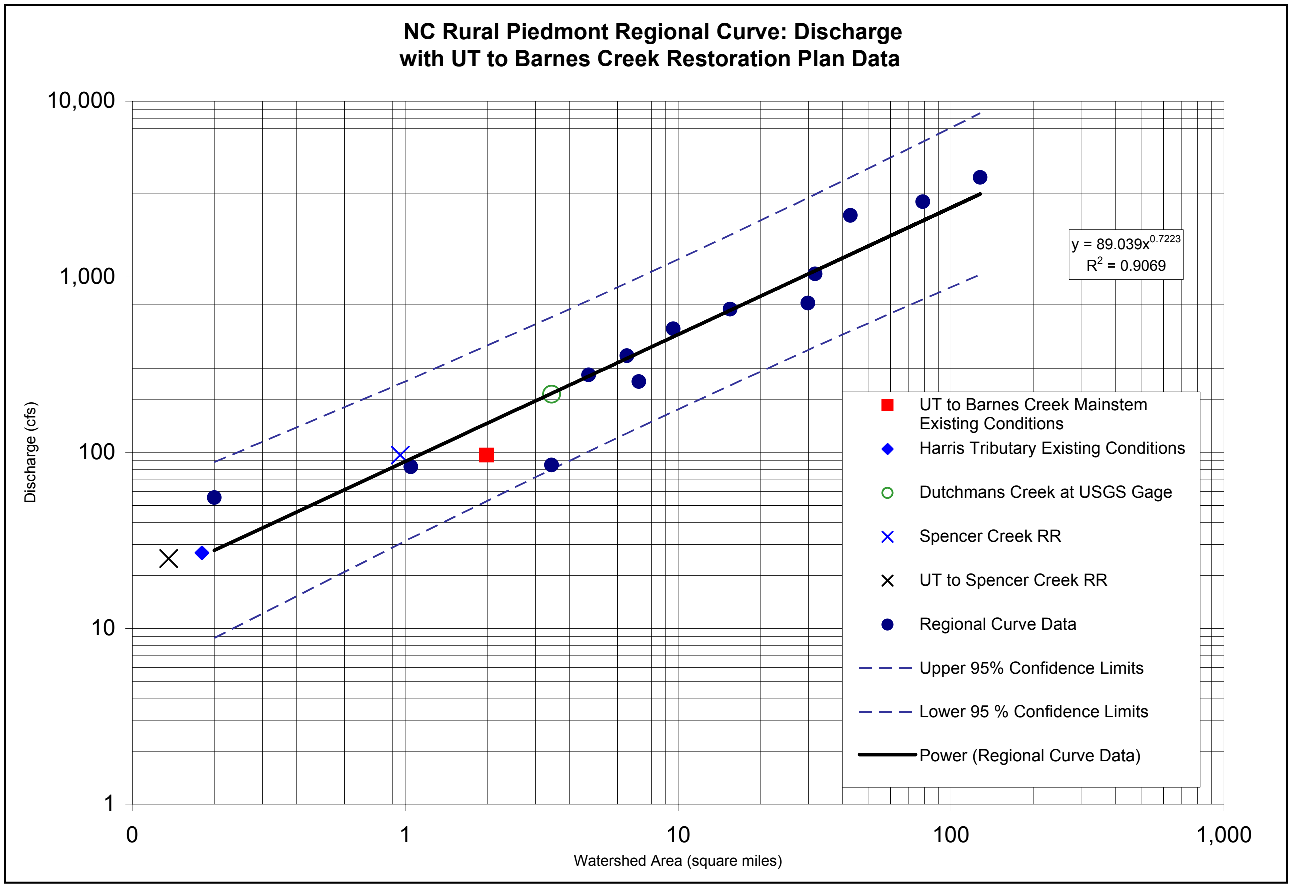
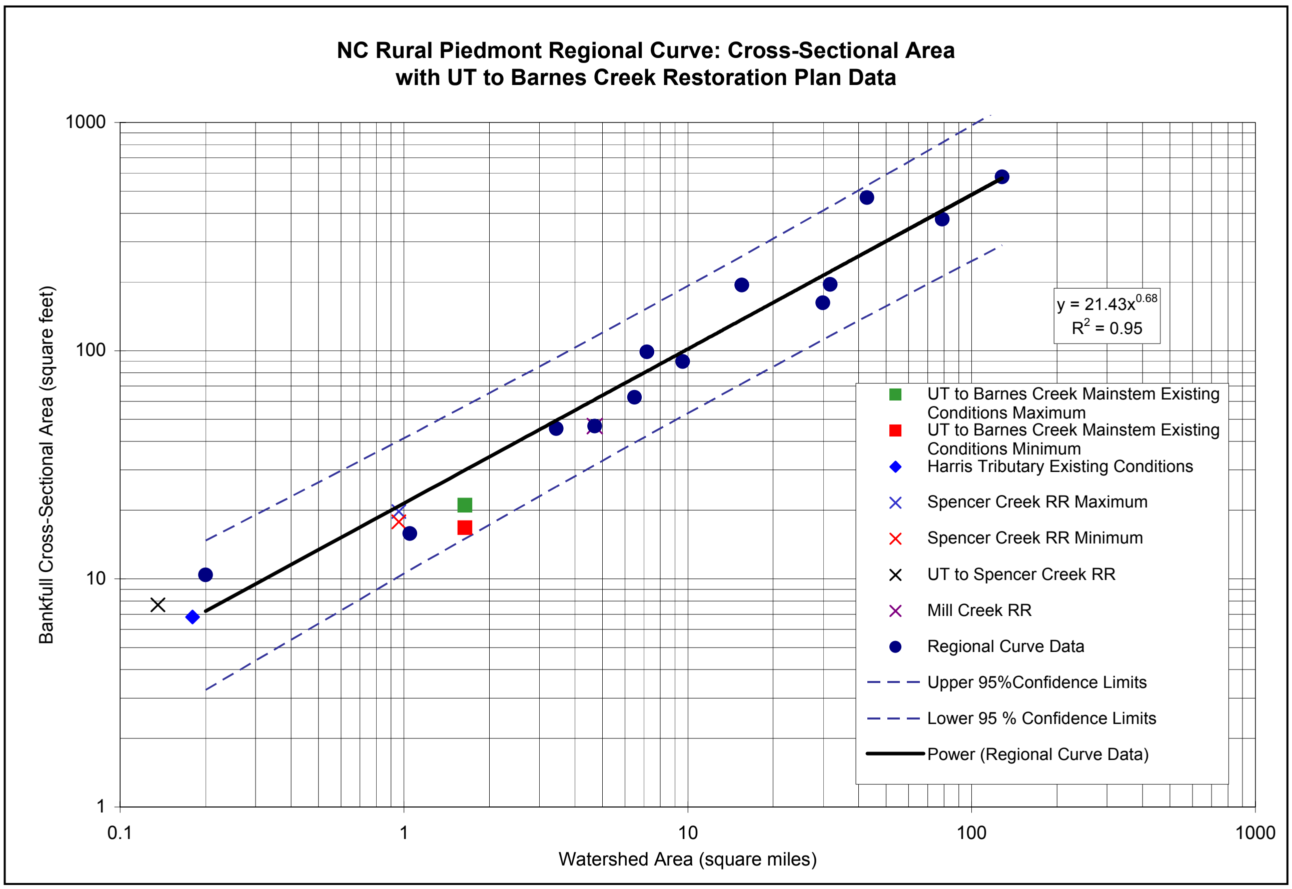


Figure 4.1: Cross-section and Benthic Macroinvertebrate Sampling Locations

BUCK ENGINEERING





Note: Project data were not considered in regional curve development.

Figure 4.2
NC Piedmont Rural Regional Curve with Bankfull Discharge
For Project Reaches and Reference Cross-Sections
UT to Barnes Creek Restoration Plan

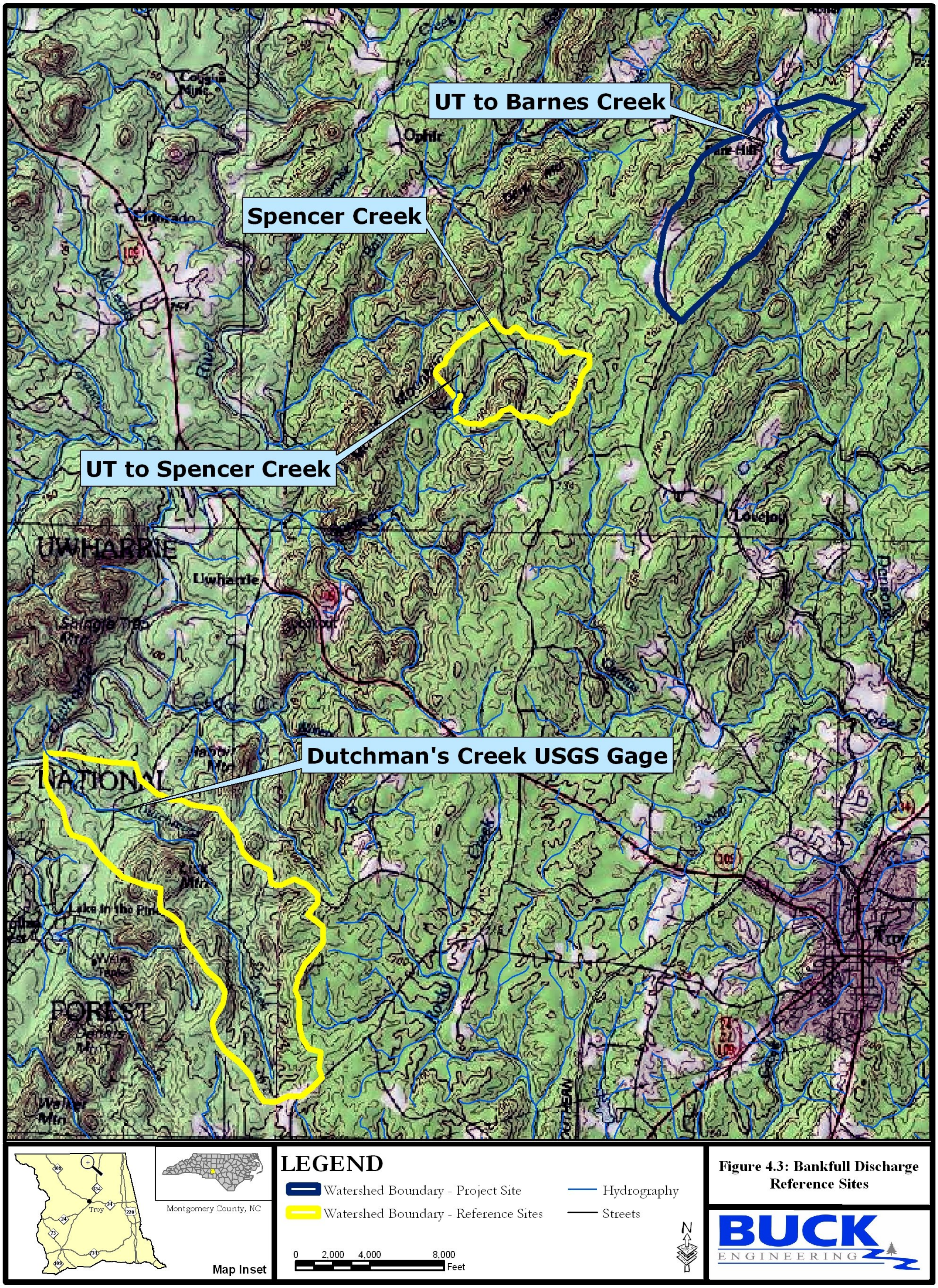


Figure 4.3: Bankfull Discharge Reference Sites

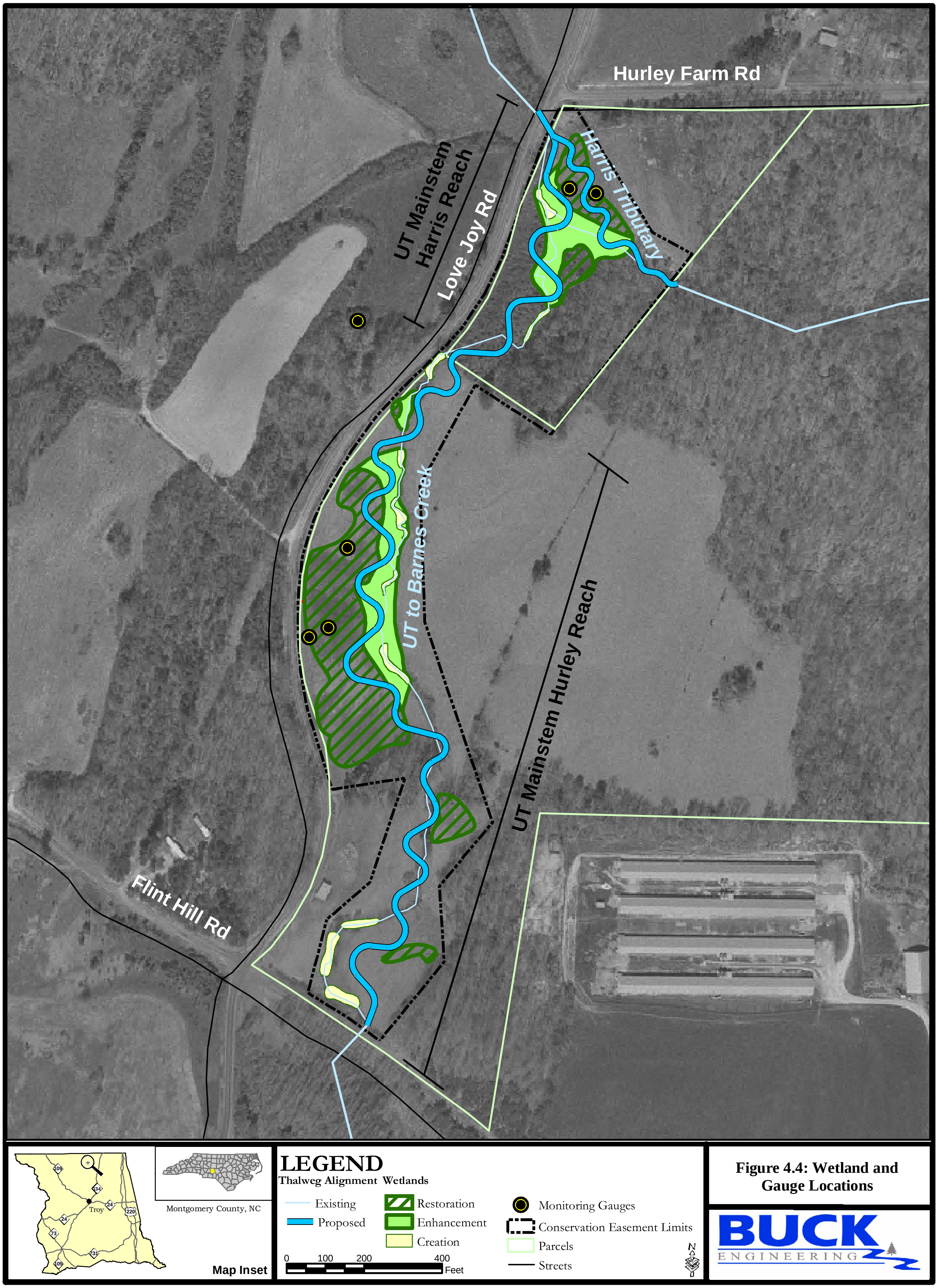


Figure 4.4: Wetland and Gauge Locations

Appendix A

Cultural Resources Correspondence

North Carolina Department of Cultural Resources
State Historic Preservation Office
David L. S. Brook, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Division of Historical Resources
David J. Olson, Director

April 15, 2003

Karen Missell
Buck Engineering
1347 Harding Place, Suite 100
Charlotte, NC 28204

Re: Hurley Site stream & wetland restoration, Montgomery County, ER03-0227

Dear Ms. Missell:

Thank you for your letter of February 27, 2003 concerning the above project.

We have conducted a review of the project and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the project as proposed.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, please contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763. In all future communication concerning this project, please cite the above-referenced tracking number.

Sincerely,

Renee Gledhill-Earley
~~David Brook~~

Appendix B

EDR Transaction Screen Map Report

The EDR-Transaction Screen™ Map Report
With Toxicheck/® Analysis

Hurley Parcel
Lovejoy Road/Flint Hill Road
Star, NC 27356

Inquiry Number: 919368.1s

January 30, 2003

Environmental Data Resources, Inc.

The Source For Environmental Risk Management Data

3530 Post Road
Southport, Connecticut 06890

Nationwide Customer Service

Telephone: 1-800-352-0050
Fax: 1-800-231-6802
Internet: www.edrnet.com

TABLE OF CONTENTS

APPENDICES

Thank you for your business.
Please contact EDR at 1-800-352-0050
with any questions or comments.

TOXICHECK®

Subject Property: HURLEY PARCEL
LOVEJOY ROAD/FLINT HILL ROAD
STAR, NC 27356

Environmental Risk Code: LOW

This code results from the subject property not being listed in those databases as indicated in the Report and not located within : 1/2 mile of a reported Superfund Site (NPL) ; 1/2 mile of a reported Hazardous Waste Treatment, Storage or Disposal Facility (RCRIS-TSDF); 1/4 mile of a reported known or suspect CERCLIS hazardous waste site ; 1/4 mile of a reported known or suspect State Hazardous Waste site (SHWS); 1/2 mile of a reported Solid Waste Facility or Landfill (SWF/LF); or 1/8 mile of a site with a reported Leaking Underground Storage Tank incident (LUST).

This code is based solely on the results of searches of databases comprised of certain governmental records as made available to EDR and reflected in the attached report. Without further confirmation by completing the ASTM Standard E-1528 Transaction Screen and/or a Phase I Environmental Site Assessment, the conditions affecting the property are unknown. Further investigation by an environmental professional may be appropriate. **This Report is not a substitute for a Phase I Environmental Site Assessment conducted by an environmental professional .** Nothing in this Report should be construed to mean that any environmental remediation is or is not necessary with respect to the subject property.

If this information is being used for a commercial property transaction, the government records searched complies with the requirements of the ASTM Standard E-1528 Transaction Screen. However, the ASTM Standard's requirements are not fulfilled until the Applicant Questionnaire and Site Visit (including an investigation of the property's historical use) are completed and reviewed. If this information is being used for an industrial property transaction, the ASTM Standard requires that a Phase I Environmental Site Assessment be performed by an environmental professional.

EXECUTIVE SUMMARY

The EDR-Transaction Screen Map Report is a screening tool which maps sites with potential liability or existing environmental liabilities. Specified government databases are searched in accordance with ASTM Standard E 1528-00.

The ASTM E 1528-00 Transaction Screen property due diligence standard consists of four major components: a government records check, an historical inquiry, an owner/occupant questionnaire, and a site survey. This report contains the results of the government records search on the target property and surrounding area in accordance with the government records search requirements of the ASTM E 1528-00 standard.

The results of the government records search in accordance with **QUESTIONS 21 and 22** (page 15, E 1528-00) of the standard indicated the following:

QUESTION 21
*Do any of the following **Federal** government record systems list the property or any property within the circumference of the area noted below:*

National Priorities List (NPL)	☐ on the property	☐ Within 1 Mile
CERCLIS List	☐ on the property	☐ Within 1/2 Mile
CERCLIS NFRAP List	☐ on the property	☐ Within 1/4 Mile
RCRA-CORRACTS Facilities	☐ on the property	☐ Within 1 Mile
RCRA-TSD Non-CORRACTS Facilities	☐ on the property	☐ Within 1/2 Mile
RCRA LQG Facilities	☐ on the property	☐ Within 1/4 Mile
RCRA SQG Facilities	☐ on the property	☐ Within 1/4 Mile
ERNS	☐ on the property	

QUESTION 22
*Do any of the following **state** government record systems list the property or any property within the circumference of the area noted below:*

State equivalent to NPL	☐ on the property	☐ Within 1 Mile
State equivalent to CERCLIS	☐ on the property	☐ Within 1/2 Mile
Solid Waste/Landfill Facilities (SWF/LS)	☐ on the property	☐ Within 1/2 Mile
Leaking Underground Storage Tank List (LUST)	☐ on the property	☐ Within 1/2 Mile
Underground Storage Tank List (UST)	☐ on the property	☐ Within 1/4 Mile

*In accordance with Section 5.6 (page 10, E 1528) if the answer is **(yes) or unknown,** then the user will have to decide what further action, if any, is appropriate. Answers should be evaluated in light of the other information obtained in the transaction screen process. If the user decides no further inquiry is warranted, the rationale must be documented. If the user decides that further inquiry is warranted, it may be necessary to contact an environmental professional.*

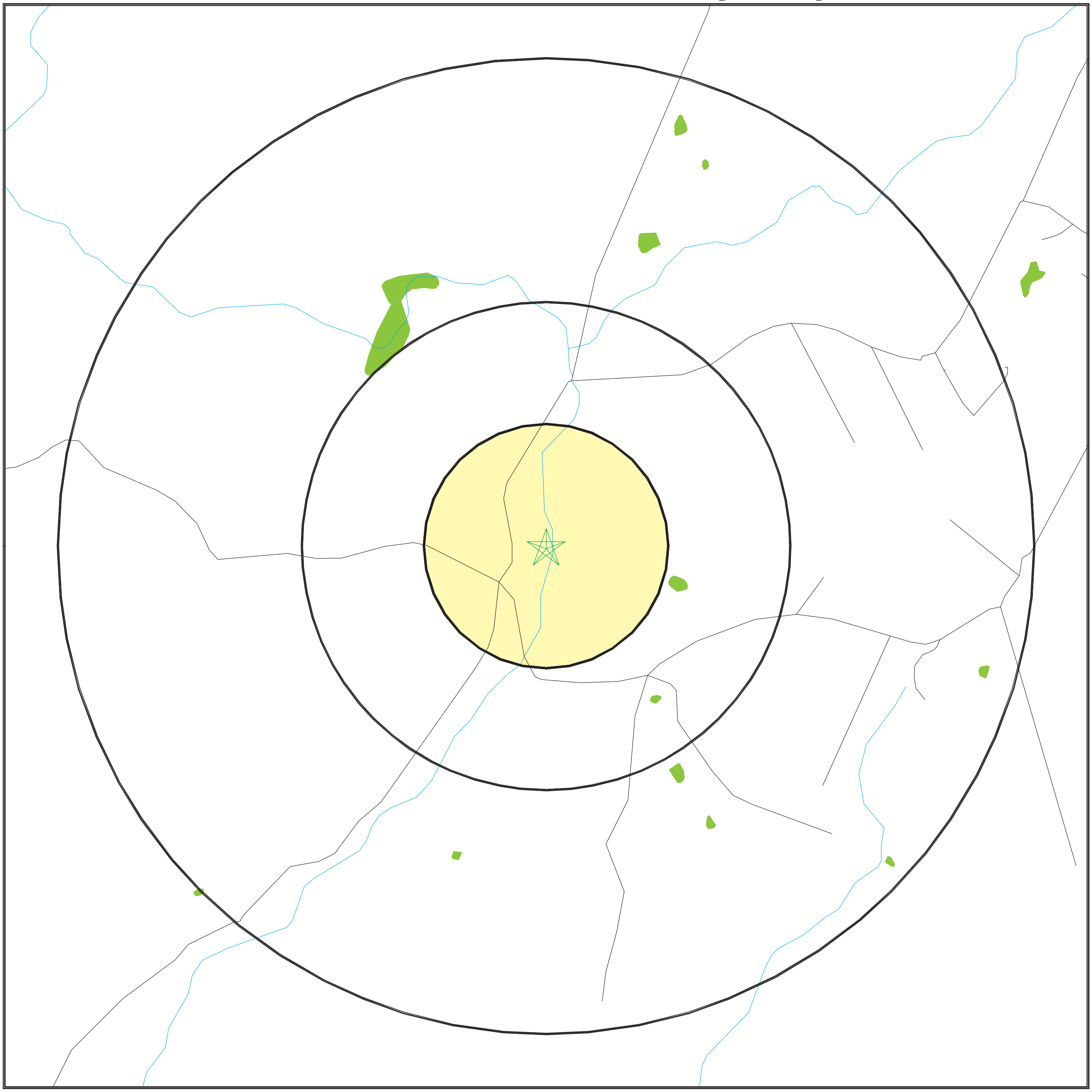
Additional Research - ASTM Supplemental Government Databases

To provide additional information which may assist in the assessment of other components of the ASTM E 1528-00 Transaction Screen, EDR also searches government databases ***not*** included in Questions 21 and 22 of ASTM E 1528-00. This information may be useful in completing the owner/occupant questionnaire.

The results of the search of these additional government records indicated affirmative **(yes)** responses on the target property for the following government databases:

No affirmative responses found in the non-ASTM E 1528-00 government databases.

OVERVIEW MAP - 919368.1s - Buck Engineering



0 1/4 1/2 1 Miles

- Target Property
- Sites at elevations higher than or equal to the target property
- Sites at elevations lower than the target property
- Coal Gasification Sites
- National Priority List Sites
- Landfill Sites
- Power transmission lines
- Oil & Gas pipelines
- Wetlands
- Hazardous Substance Disposal Sites

TARGET PROPERTY:	Hurley Parcel	CUSTOMER:	Buck Engineering
ADDRESS:	Lovejoy Road/Flint Hill Road	CONTACT:	Karen Missell
CITY/STATE/ZIP:	Star NC 27356	INQUIRY #:	919368.1s
LAT/LONG:	35.4795 / 79.9119	DATE:	January 30, 2003 2:43 pm

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
FEDERAL ASTM STANDARD								
NPL		1.000	0	0	0	0	NR	0
Proposed NPL		1.000	0	0	0	0	NR	0
CERCLIS		0.500	0	0	0	NR	NR	0
CERC-NFRAP		0.250	0	0	NR	NR	NR	0
CORRACTS		1.000	0	0	0	0	NR	0
RCRIS-TSD		0.500	0	0	0	NR	NR	0
RCRIS Lg. Quan. Gen.		0.250	0	0	NR	NR	NR	0
RCRIS Sm. Quan. Gen.		0.250	0	0	NR	NR	NR	0
ERNS		TP	NR	NR	NR	NR	NR	0
STATE ASTM STANDARD								
State Haz. Waste		1.000	0	0	0	0	NR	0
State Landfill		0.500	0	0	0	NR	NR	0
LUST		0.500	0	0	0	NR	NR	0
UST		0.250	0	0	NR	NR	NR	0
OLI		0.500	0	0	0	NR	NR	0
INDIAN UST		0.250	0	0	NR	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0
FEDERAL ASTM SUPPLEMENTAL								
Delisted NPL		1.000	0	0	0	0	NR	0
FINDS		TP	NR	NR	NR	NR	NR	0
HMIRS		TP	NR	NR	NR	NR	NR	0
MLTS		TP	NR	NR	NR	NR	NR	0
MINES		TP	NR	NR	NR	NR	NR	0
NPL Liens		TP	NR	NR	NR	NR	NR	0
PADS		TP	NR	NR	NR	NR	NR	0
RAATS		TP	NR	NR	NR	NR	NR	0
TRIS		TP	NR	NR	NR	NR	NR	0
TSCA		TP	NR	NR	NR	NR	NR	0
SSTS		TP	NR	NR	NR	NR	NR	0
FTTS		TP	NR	NR	NR	NR	NR	0
STATE OR LOCAL ASTM SUPPLEMENTAL								
NC HSDS		1.000	0	0	0	0	NR	0
AST		TP	NR	NR	NR	NR	NR	0
LUST TRUST		0.500	0	0	0	NR	NR	0
IMD		TP	NR	NR	NR	NR	NR	0
EDR PROPRIETARY HISTORICAL DATABASES								
Coal Gas		1.000	0	0	0	0	NR	0
BROWNFIELDS DATABASES								
Brownfields		0.500	0	0	0	NR	NR	0

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
VCP		0.500	0	0	0	NR	NR	0

NOTES:

TP = Target Property

NR = Not Requested at this Search Distance

Sites may be listed in more than one database

Map ID Direction Distance Distance (ft.) Elevation	Site	Database(s)	EDR ID Number EPA ID Number

Coal Gas Site Search: No site was found in a search of Real Property Scan's ENVIROHAZ database.

NO SITES FOUND

City	EDR ID	Site Name	Site Address	Zip	Database(s)
STAR	U001187041	HAYES SAUNDERS	RTE 1 STAR	27356	UST
STAR	U001199372	CALLICUTT'S GROCERY	RT 1	27356	UST
STAR	U003145548	BLACK ANKLE GROCERY	ROUTE 1	27356	UST
STAR	U000820373	JP GROCERY	HWY 220 S. PO BOX 404	27356	UST
STAR	S101574180	SMITH AND SON GARAGE	HWY 220-A (SOUTHSIDE OF STAR)		IMD, LUST
STAR	S104402465	BFI ORGANICS/PIONEER SOUTHERN	P.O. BOX 627	27356	SWF/LF
STAR	U001199422	W.P. MCDANIELS	OLD HWY 220	27356	UST
TROY	U001186590	CARL FUTRELL GROCERY	RTE 1 STATE ROAD 1303	27371	UST
TROY	U001199312	VANHOY'S GULF SER	RT 1 HWY 109 N	27371	UST
TROY	U001199313	MATHESON GROCERY	RT 1 HWY 109	27371	UST
TROY	U001199320	ROBERT MULLINIX GROCERY	RT 1 BOX 23	27371	UST
TROY	U001199371	ELDORADO COUNTRY STORE	RT 1 109 NORTH	27371	UST
TROY	U001200101	MONTGOMERY CO HDQ	RT 1 BOX 32-7	27371	UST
TROY	S101572780	JAMES L. BLAKE RESIDENCE	SR 1005	27371	IMD, LUST
TROY	U001188213	MCRAE CHEVROLET-BUICK. STATIO	HIGHWAY 109 AT WEST CITY LIMITS	27371	UST
TROY	U001205477	POOLES GROCERY	HWY 109	27371	UST
TROY	S105485813	TROY LANDFILL	HWY 109, 2 MI NW OF TROY ON RT	27371	OLI
TROY	U001199424	TROY RADIO TOWER	S.R. 1134	27371	UST
TROY	S105163923	MONTGOMERY COUNTY LANDFILL	SR 1137	27371	SWF/LF
TROY	S101523929	DOT-MONTGOMERY CO. MAINT.FAC.	SR 1324	27371	IMD, LUST
TROY	S105593093	NCDOT-TROY	SR 1324	27371	LUST TRUST
TROY	U001199377	TROJAN #1	HIGHWAY 134 NORTH	27371	UST
TROY	U003138593	CAPEL INC - PEE DEE PLANT	HIGHWAY 134 NORTH	27371	UST
TROY	U001199314	AUMAN GROCERY	RT 2 STATE ROAD 1310	27371	UST
TROY	U001203053	TROY READY MIX. INC.	HWY 24 & 27 WEST-PO BOX 137	27371	UST
TROY	U003145488	TROGAN #2	HIGHWAY 24 & 27 WEST	27371	UST
TROY	U003145590	HICKMAN OIL & ICE INC.	HWY 24 WEST, P. O. BOX 563	27371	UST
TROY	S105119712	QUIK CHEK	HWY 24/27 WEST	27371	IMD, LUST
TROY	S101572076	SANDHILLS/TROY WILDLIFE DEPORT	HWY 27 WEST ALBEMARLE RD	27371	IMD, LUST
TROY	U001200522	KELLY MOTOR COMPANY	RT.1 BOX 53 HWY 109 NORTH	27371	UST
TROY	S101573995	TOMS GROCERY	US HWY 220 ALT / SPEIL RD	27371	IMD, LUST
TROY	U003138255	ELDORADO OUTPOST. INC	4021 N HWY 109	27371	UST
TROY	U003179223	MULLINIX GROCERY	3079 NC HWY 109 NORTH	27371	UST
TROY	U001188118	YELLOW FREIGHT SYSTEM. INC.	OLD DAIRY ROAD, HIGHWAY 109	27371	UST
UWHARRIE	S102611289	LINDA SPARKMAN WATER SUP.WELL	3109 HWY 109	27371	IMD, LUST

AREA RADON INFORMATION

- Federal EPA Radon Zone for MONTGOMERY County, NC: 3

Note : Zone 1 indoor average level > 4 pCi/L.
: Zone 2 indoor average level >= 2 pCi/L and <= 4 pCi/L.
: Zone 3 indoor average level < 2 pCi/L.

- Federal Area Radon Information for MONTGOMERY County, NC

Number of sites tested: 3

Area	Average Activity	% <4 pCi/L	% 4-20 pCi/L	% >20 pCi/L
Living Area - 1st Floor	0.867 pCi/L	100%	0%	0%
Living Area - 2nd Floor	Not Reported	Not Reported	Not Reported	Not Reported
Basement	Not Reported	Not Reported	Not Reported	Not Reported

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

To maintain currency of the following federal and state databases, EDR contacts the appropriate governmental agency on a monthly or quarterly basis, as required.

Elapsed ASTM days: Provides confirmation that this EDR report meets or exceeds the 90-day updating requirement of the ASTM standard.

FEDERAL ASTM STANDARD RECORDS

NPL: National Priority List
Source: EPA
Telephone: N/A
National Priorities List (Superfund). The NPL is a subset of CERCLIS and identifies over 1,200 sites for priority cleanup under the Superfund Program. NPL sites may encompass relatively large areas. As such, EDR provides polygon coverage for over 1,000 NPL site boundaries produced by EPA's Environmental Photographic Interpretation Center (EPIC) and regional EPA offices.

Date of Government Version: 10/24/02
Date Made Active at EDR: 12/09/02
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 11/04/02
Elapsed ASTM days: 35
Date of Last EDR Contact: 11/04/02

NPL Site Boundaries

Sources:

EPA's Environmental Photographic Interpretation Center (EPIC)
Telephone: 202-564-7333

EPA Region 1
Telephone 617-918-1143

EPA Region 3
Telephone 215-814-5418

EPA Region 4
Telephone 404-562-8033

EPA Region 6
Telephone: 214-655-6659

EPA Region 8
Telephone: 303-312-6774

Proposed NPL: Proposed National Priority List Sites
Source: EPA
Telephone: N/A

Date of Government Version: 10/24/02
Date Made Active at EDR: 12/09/02
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 11/04/02
Elapsed ASTM days: 35
Date of Last EDR Contact: 11/04/02

CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System
Source: EPA
Telephone: 703-413-0223
CERCLIS contains data on potentially hazardous waste sites that have been reported to the USEPA by states, municipalities, private companies and private persons, pursuant to Section 103 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLIS contains sites which are either proposed to or on the National Priorities List (NPL) and sites which are in the screening and assessment phase for possible inclusion on the NPL.

Date of Government Version: 12/13/02
Date Made Active at EDR: 01/15/03
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 12/26/02
Elapsed ASTM days: 20
Date of Last EDR Contact: 12/26/02

CERCLIS-NFRAP: CERCLIS No Further Remedial Action Planned
Source: EPA
Telephone: 703-413-0223
As of February 1995, CERCLIS sites designated "No Further Remedial Action Planned" (NFRAP) have been removed from CERCLIS. NFRAP sites may be sites where, following an initial investigation, no contamination was found, contamination was removed quickly without the need for the site to be placed on the NPL, or the contamination was not serious enough to require Federal Superfund action or NPL consideration. EPA has removed approximately 25,000 NFRAP sites to lift the unintended barriers to the redevelopment of these properties and has archived them as historical records so EPA does not needlessly repeat the investigations in the future. This policy change is part of the EPA's Brownfields Redevelopment Program to help cities, states, private investors and affected citizens to promote economic redevelopment of unproductive urban sites.

Date of Government Version: 12/13/02
Date Made Active at EDR: 01/15/03
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 12/26/02
Elapsed ASTM days: 20
Date of Last EDR Contact: 12/26/02

CORRACTS: Corrective Action Report
Source: EPA
Telephone: 800-424-9346
CORRACTS identifies hazardous waste handlers with RCRA corrective action activity.

Date of Government Version: 09/29/02
Date Made Active at EDR: 12/26/02
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 10/15/02
Elapsed ASTM days: 72
Date of Last EDR Contact: 12/09/02

RCRIS: Resource Conservation and Recovery Information System
Source: EPA/NTIS
Telephone: 800-424-9346
Resource Conservation and Recovery Information System. RCRIS includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA).

Date of Government Version: 09/09/02
Date Made Active at EDR: 10/28/02
Database Release Frequency: Varies
Date of Data Arrival at EDR: 09/24/02
Elapsed ASTM days: 34
Date of Last EDR Contact: 12/26/02

ERNS: Emergency Response Notification System
Source: National Response Center, United States Coast Guard
Telephone: 202-260-2342
Emergency Response Notification System. ERNS records and stores information on reported releases of oil and hazardous substances.

Date of Government Version: 12/31/01
Date Made Active at EDR: 07/15/02
Database Release Frequency: Annually
Date of Data Arrival at EDR: 07/02/02
Elapsed ASTM days: 13
Date of Last EDR Contact: 10/28/02

FEDERAL ASTM SUPPLEMENTAL RECORDS

BRS: Biennial Reporting System
Source: EPA/NTIS
Telephone: 800-424-9346
The Biennial Reporting System is a national system administered by the EPA that collects data on the generation and management of hazardous waste. BRS captures detailed data from two groups: Large Quantity Generators (LQG) and Treatment, Storage, and Disposal Facilities.

Date of Government Version: 12/31/99
Database Release Frequency: Biennially
Date of Last EDR Contact: 12/17/02
Date of Next Scheduled EDR Contact: 03/17/03

DELISTED NPL: National Priority List Deletions
Source: EPA
Telephone: N/A
The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) establishes the criteria that the EPA uses to delete sites from the NPL. In accordance with 40 CFR 300.425.(e), sites may be deleted from the NPL where no further response is appropriate.

Date of Government Version: 10/18/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 11/04/02
Date of Next Scheduled EDR Contact: 02/03/03

FINDS: Facility Index System/Facility Identification Initiative Program Summary Report
Source: EPA
Telephone: N/A
Facility Index System. FINDS contains both facility information and 'pointers' to other sources that contain more detail. EDR includes the following FINDS databases in this report: PCS (Permit Compliance System), AIRS (Aerometric Information Retrieval System), DOCKET (Enforcement Docket used to manage and track information on civil judicial enforcement cases for all environmental statutes), FURS (Federal Underground Injection Control), C-DOCKET (Criminal Docket System used to track criminal enforcement actions for all environmental statutes), FFIS (Federal Facilities Information System), STATE (State Environmental Laws and Statutes), and PADS (PCB Activity Data System).

Date of Government Version: 10/10/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 01/06/03
Date of Next Scheduled EDR Contact: 04/07/03

HMIRS: Hazardous Materials Information Reporting System
Source: U.S. Department of Transportation
Telephone: 202-366-4555
Hazardous Materials Incident Report System. HMIRS contains hazardous material spill incidents reported to DOT.

Date of Government Version: 07/31/02
Database Release Frequency: Annually
Date of Last EDR Contact: 10/21/02
Date of Next Scheduled EDR Contact: 01/20/03

MLTS: Material Licensing Tracking System
Source: Nuclear Regulatory Commission
Telephone: 301-415-7169
MLTS is maintained by the Nuclear Regulatory Commission and contains a list of approximately 8,100 sites which possess or use radioactive materials and which are subject to NRC licensing requirements. To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 10/21/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 01/06/03
Date of Next Scheduled EDR Contact: 04/07/03

MINES: Mines Master Index File
Source: Department of Labor, Mine Safety and Health Administration
Telephone: 303-231-5959

Date of Government Version: 09/10/02
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 01/03/03
Date of Next Scheduled EDR Contact: 03/31/03

NPL LIENS: Federal Superfund Liens
Source: EPA
Telephone: 205-564-4267
Federal Superfund Liens. Under the authority granted the USEPA by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, the USEPA has the authority to file liens against real property in order to recover remedial action expenditures or when the property owner receives notification of potential liability. USEPA compiles a listing of filed notices of Superfund Liens.

Date of Government Version: 10/15/91
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 11/25/02
Date of Next Scheduled EDR Contact: 02/24/03

PADS: PCB Activity Database System
Source: EPA
Telephone: 202-564-3887
PCB Activity Database. PADS Identifies generators, transporters, commercial storers and/or brokers and disposers of PCB's who are required to notify the EPA of such activities.

Date of Government Version: 09/20/02
Database Release Frequency: Annually
Date of Last EDR Contact: 11/13/02
Date of Next Scheduled EDR Contact: 02/10/03

RAATS: RCRA Administrative Action Tracking System
Source: EPA
Telephone: 202-564-4104
RCRA Administration Action Tracking System. RAATS contains records based on enforcement actions issued under RCRA pertaining to major violators and includes administrative and civil actions brought by the EPA. For administration actions after September 30, 1995, data entry in the RAATS database was discontinued. EPA will retain a copy of the database for historical records. It was necessary to terminate RAATS because a decrease in agency resources made it impossible to continue to update the information contained in the database.

Date of Government Version: 04/17/95
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 12/10/02
Date of Next Scheduled EDR Contact: 03/10/03

TRIS: Toxic Chemical Release Inventory System
Source: EPA
Telephone: 202-260-1531
Toxic Release Inventory System. TRIS identifies facilities which release toxic chemicals to the air, water and land in reportable quantities under SARA Title III Section 313.

Date of Government Version: 12/31/00
Database Release Frequency: Annually
Date of Last EDR Contact: 12/26/02
Date of Next Scheduled EDR Contact: 03/24/03

TSCA: Toxic Substances Control Act
Source: EPA
Telephone: 202-260-5521
Toxic Substances Control Act. TSCA identifies manufacturers and importers of chemical substances included on the TSCA Chemical Substance Inventory list. It includes data on the production volume of these substances by plant site.

Date of Government Version: 12/31/98
Database Release Frequency: Every 4 Years
Date of Last EDR Contact: 12/10/02
Date of Next Scheduled EDR Contact: 03/10/03

FTTS INSP: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA
Telephone: 202-564-2501

Date of Government Version: 10/24/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 12/26/02
Date of Next Scheduled EDR Contact: 03/24/03

SSTS: Section 7 Tracking Systems
Source: EPA
Telephone: 202-564-5008
Section 7 of the Federal Insecticide, Fungicide and Rodenticide Act, as amended (92 Stat. 829) requires all registered pesticide-producing establishments to submit a report to the Environmental Protection Agency by March 1st each year. Each establishment must report the types and amounts of pesticides, active ingredients and devices being produced, and those having been produced and sold or distributed in the past year.

Date of Government Version: 12/31/00
Database Release Frequency: Annually
Date of Last EDR Contact: 01/21/03
Date of Next Scheduled EDR Contact: 04/21/03

FTTS: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA/Office of Prevention, Pesticides and Toxic Substances
Telephone: 202-564-2501
FTTS tracks administrative cases and pesticide enforcement actions and compliance activities related to FIFRA, TSCA and EPCRA (Emergency Planning and Community Right-to-Know Act). To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 10/24/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 12/26/02
Date of Next Scheduled EDR Contact: 03/24/03

STATE OF NORTH CAROLINA ASTM STANDARD RECORDS

SHWS: Inactive Hazardous Sites Inventory
Source: Department of Environment, Health and Natural Resources
Telephone: 919-733-2801
State Hazardous Waste Sites. State hazardous waste site records are the states' equivalent to CERCLIS. These sites may or may not already be listed on the federal CERCLIS list. Priority sites planned for cleanup using state funds (state equivalent of Superfund) are identified along with sites where cleanup will be paid for by potentially responsible parties. Available information varies by state.

Date of Government Version: 10/16/02
Date Made Active at EDR: 11/25/02
Database Release Frequency: Annually
Date of Data Arrival at EDR: 10/21/02
Elapsed ASTM days: 35
Date of Last EDR Contact: 01/14/03

SWF/LF: List of Solid Waste Facilities
Source: Department of Environment and Natural Resources
Telephone: 919-733-0692
Solid Waste Facilities/Landfill Sites. SWF/LF type records typically contain an inventory of solid waste disposal facilities or landfills in a particular state. Depending on the state, these may be active or inactive facilities or open dumps that failed to meet RCRA Subtitle D Section 4004 criteria for solid waste landfills or disposal sites.

Date of Government Version: 11/05/02
Date Made Active at EDR: 11/25/02
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 11/05/02
Elapsed ASTM days: 20
Date of Last EDR Contact: 11/13/02

LUST: Incidents Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Leaking Underground Storage Tank Incident Reports. LUST records contain an inventory of reported leaking underground storage tank incidents. Not all states maintain these records, and the information stored varies by state.

Date of Government Version: 11/22/02
Date Made Active at EDR: 01/10/03
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 12/09/02
Elapsed ASTM days: 32
Date of Last EDR Contact: 12/09/02

UST: Petroleum Underground Storage Tank Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1308
Registered Underground Storage Tanks. UST's are regulated under Subtitle I of the Resource Conservation and Recovery Act (RCRA) and must be registered with the state department responsible for administering the UST program. Available information varies by state program.

Date of Government Version: 11/08/02
Date Made Active at EDR: 12/09/02
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 11/13/02
Elapsed ASTM days: 26
Date of Last EDR Contact: 12/09/02

OLI: Old Landfill Inventory
Source: Department of Environment & Natural Resources
Telephone: 919-733-4996

Date of Government Version: 09/30/02
Date Made Active at EDR: 11/25/02
Database Release Frequency: Varies
Date of Data Arrival at EDR: 10/28/02
Elapsed ASTM days: 28
Date of Last EDR Contact: 10/28/02

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 09/16/02
Date Made Active at EDR: 11/15/02
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 10/14/02
Elapsed ASTM days: 32
Date of Last EDR Contact: 01/14/03

INDIAN UST: Underground Storage Tanks on Indian Land
Source: EPA Region 4
Telephone: 404-562-9424

Date of Government Version: N/A
Date Made Active at EDR: N/A
Database Release Frequency: Varies
Date of Data Arrival at EDR: N/A
Elapsed ASTM days: 0
Date of Last EDR Contact: N/A

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

STATE OF NORTH CAROLINA ASTM SUPPLEMENTAL RECORDS

HSDS: Hazardous Substance Disposal Site
Source: North Carolina Center for Geographic Information and Analysis
Telephone: 919-733-2090
Locations of uncontrolled and unregulated hazardous waste sites. The file includes sites on the National Priority List as well as those on the state priority list.

Date of Government Version: 06/21/95
Database Release Frequency: Biennially
Date of Last EDR Contact: 12/03/02
Date of Next Scheduled EDR Contact: 03/03/03

AST: AST Database
Source: Department of Environment and Natural Resources
Telephone: 919-715-6170
Facilities with aboveground storage tanks that have a capacity greater than 21,000 gallons.

Date of Government Version: 07/01/02
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 01/20/03
Date of Next Scheduled EDR Contact: 04/21/03

LUST TRUST: State Trust Fund Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
This database contains information about claims against the State Trust Funds for reimbursements for expenses incurred while remediating Leaking USTs.

Date of Government Version: 11/08/02
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 11/13/02
Date of Next Scheduled EDR Contact: 02/10/03

IMD: Incident Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Groundwater and/or soil contamination incidents

Date of Government Version: 10/25/02
Database Release Frequency: Quarterly
Date of Last EDR Contact: 10/28/02
Date of Next Scheduled EDR Contact: 01/27/03

EDR PROPRIETARY HISTORICAL DATABASES

Former Manufactured Gas (Coal Gas) Sites: The existence and location of Coal Gas sites is provided exclusively to EDR by Real Property Scan, Inc. ©Copyright 1993 Real Property Scan, Inc. For a technical description of the types of hazards which may be found at such sites, contact your EDR customer service representative.

Disclaimer Provided by Real Property Scan, Inc.

The information contained in this report has predominantly been obtained from publicly available sources produced by entities other than Real Property Scan. While reasonable steps have been taken to insure the accuracy of this report, Real Property Scan does not guarantee the accuracy of this report. Any liability on the part of Real Property Scan is strictly limited to a refund of the amount paid. No claim is made for the actual existence of toxins at any site. This report does not constitute a legal opinion.

STATE OF NORTH CAROLINA BROWNFIELDS DATABASES RECORDS

Brownfields: Brownfields Projects Inventory
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996
A brownfield site is an abandoned, idled, or underused property where the threat of environmental contamination has hindered its redevelopment. All of the sites in the inventory are working toward a brownfield agreement for cleanup and liabitliy control.

Date of Government Version: 03/31/02
Database Release Frequency: Varies

Date of Last EDR Contact: 11/07/02
Date of Next Scheduled EDR Contact: 02/03/03

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 09/16/02
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 09/16/02
Date of Next Scheduled EDR Contact: 01/13/03

OTHER DATABASE(S)

Depending on the geographic area covered by this report, the data provided in these specialty databases may or may not be complete. For example, the existence of wetlands information data in a specific report does not mean that all wetlands in the area covered by the report are included. Moreover, the absence of any reported wetlands information does not necessarily mean that wetlands do not exist in the area covered by the report.

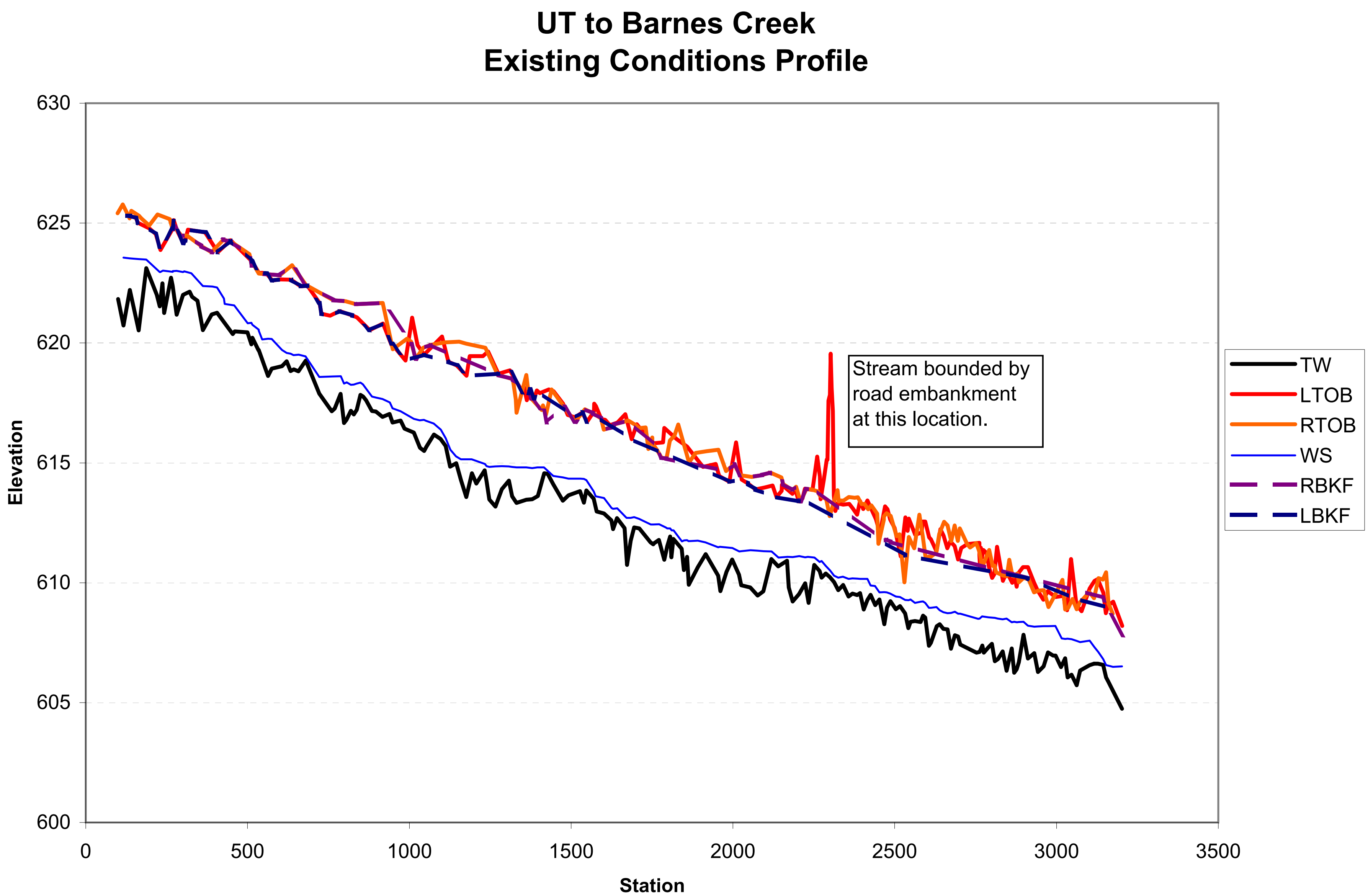
Flood Zone Data: This data, available in select counties across the country, was obtained by EDR in 1999 from the Federal Emergency Management Agency (FEMA). Data depicts 100-year and 500-year flood zones as defined by FEMA.

NWI: National Wetlands Inventory. This data, available in select counties across the country, was obtained by EDR in 2002 from the U.S. Fish and Wildlife Service.

STREET AND ADDRESS INFORMATION

Appendix C

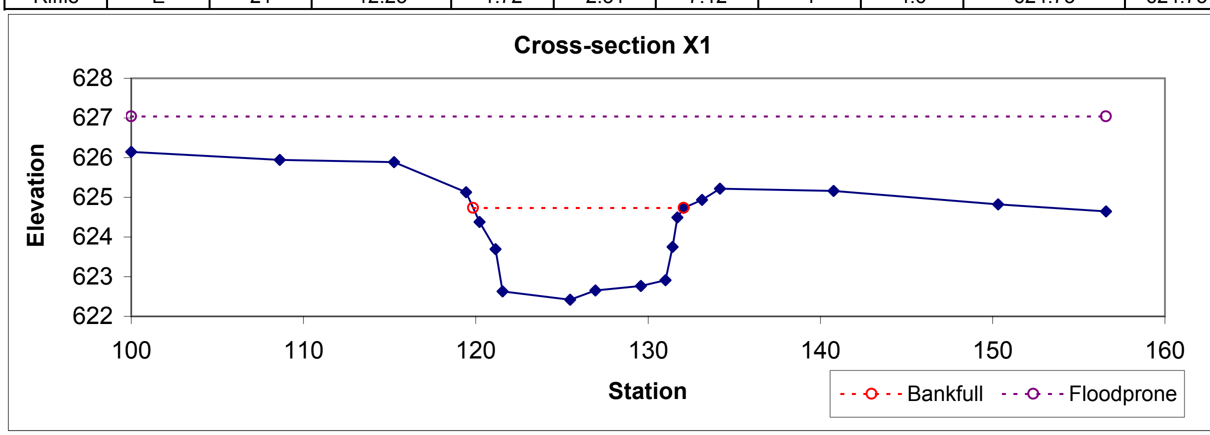
Existing Condition Data



L:\Projects\0172C\Assessment\Exist_Cond\Geomorphic\UTtoBarnes.xls, Profile Chart

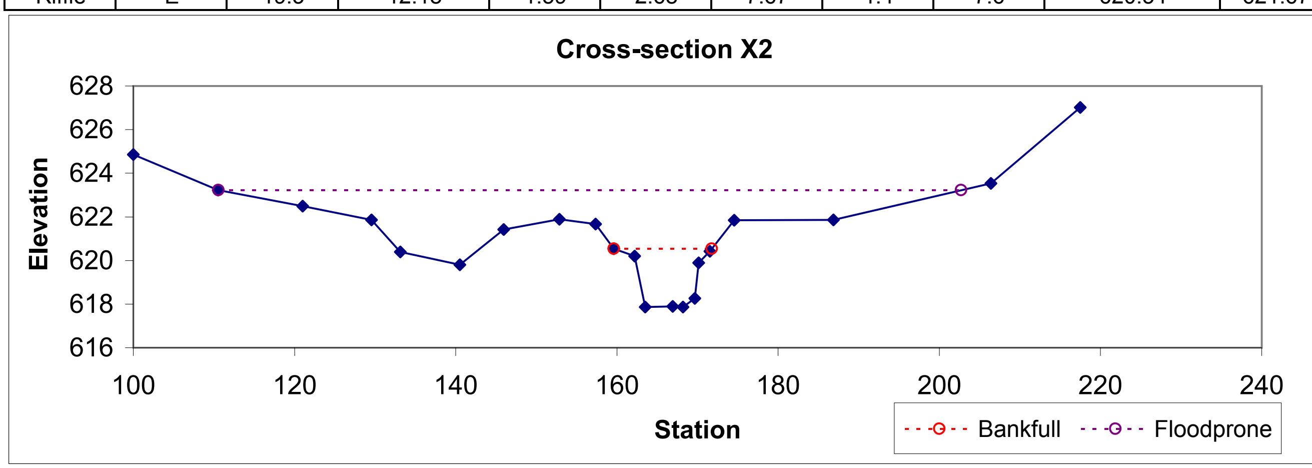
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	21	12.23	1.72	2.31	7.12	1	4.6	624.73	624.73



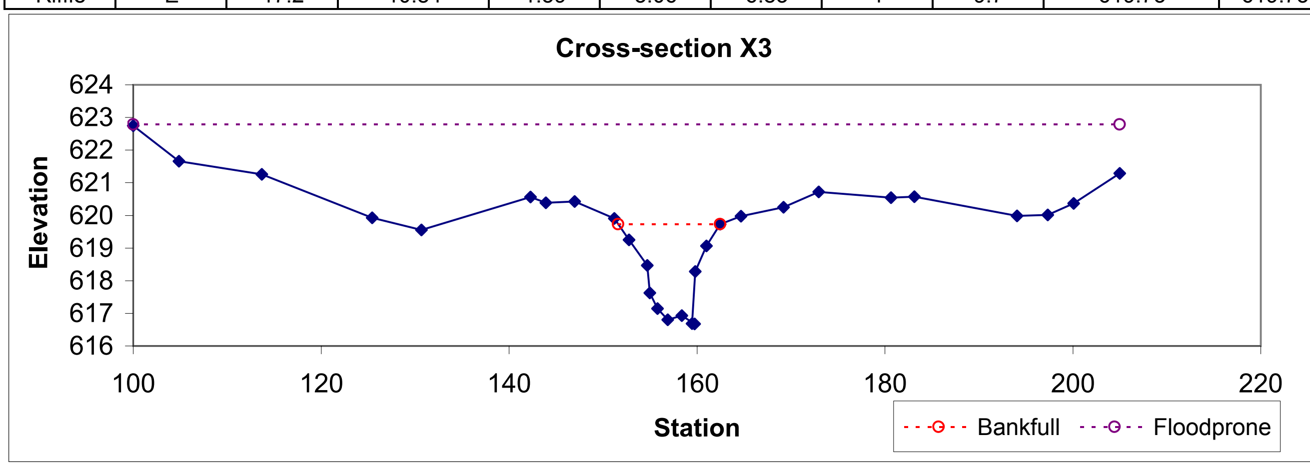
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	19.3	12.18	1.59	2.68	7.67	1.4	7.6	620.54	621.67



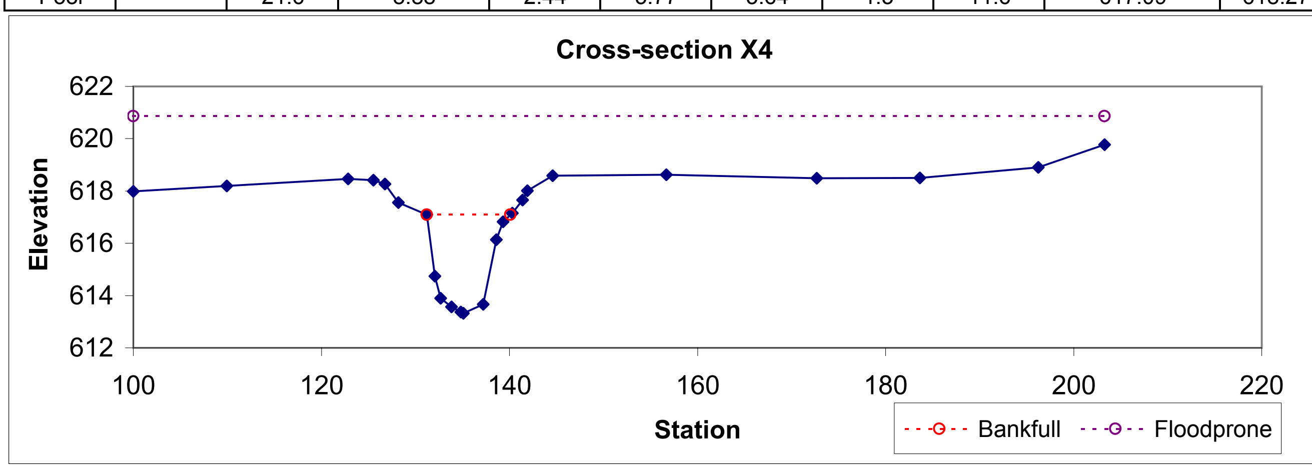
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	17.2	10.84	1.59	3.06	6.83	1	9.7	619.73	619.73



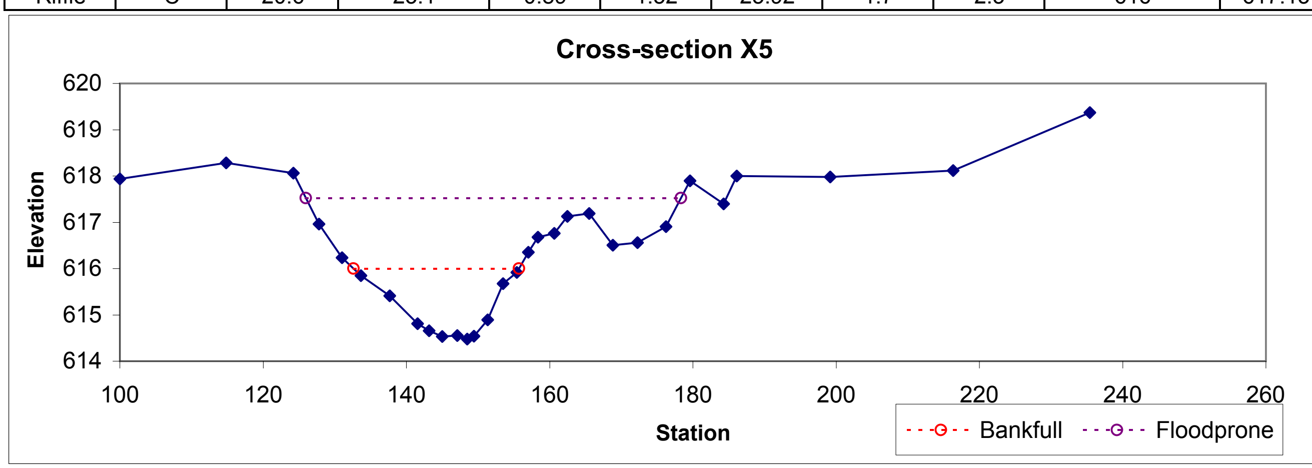
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		21.6	8.88	2.44	3.77	3.64	1.3	11.6	617.09	618.27



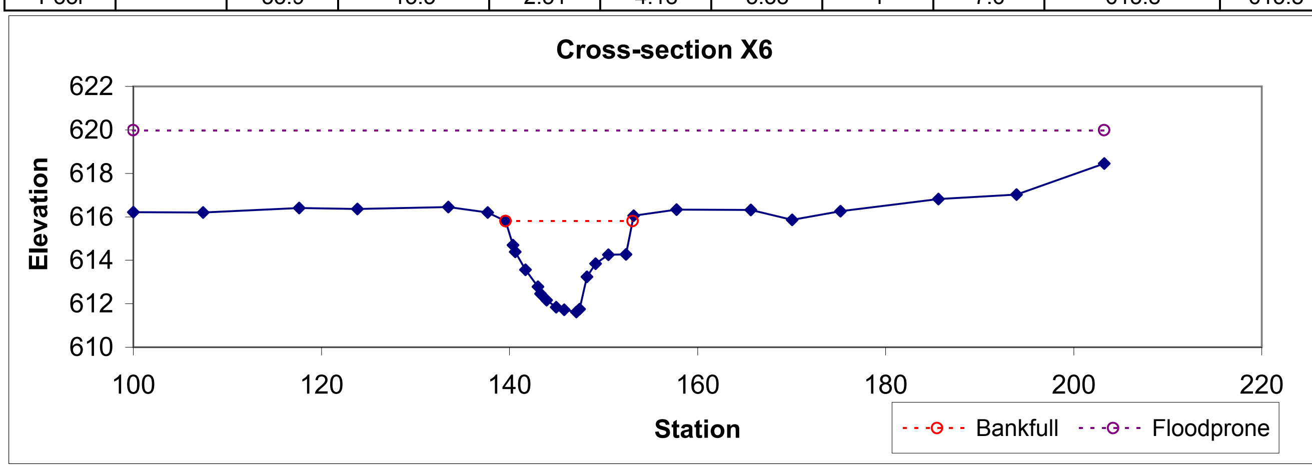
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	20.6	23.1	0.89	1.52	25.92	1.7	2.3	616	617.13



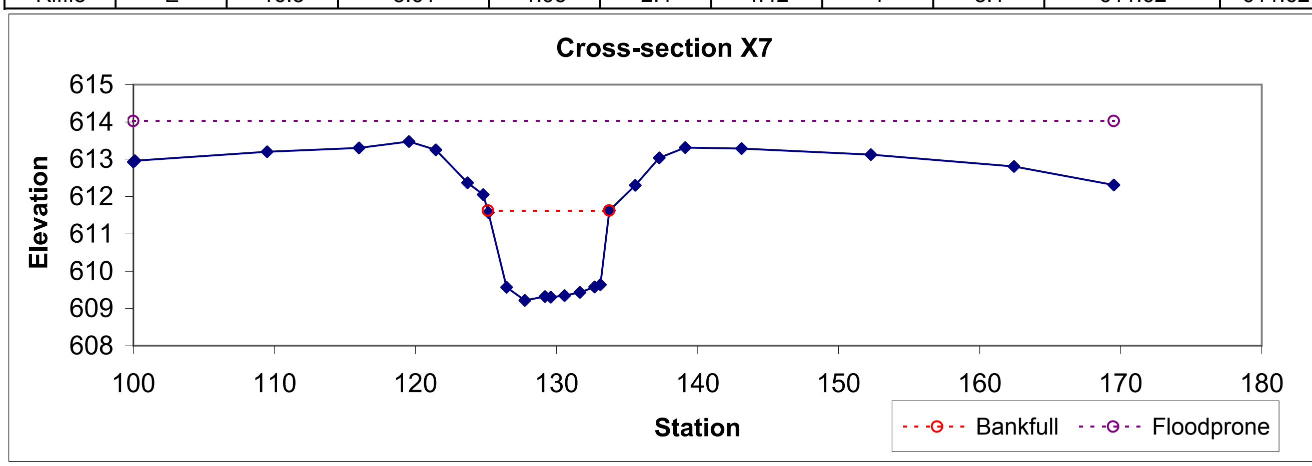
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		33.9	13.5	2.51	4.18	5.38	1	7.6	615.8	615.8



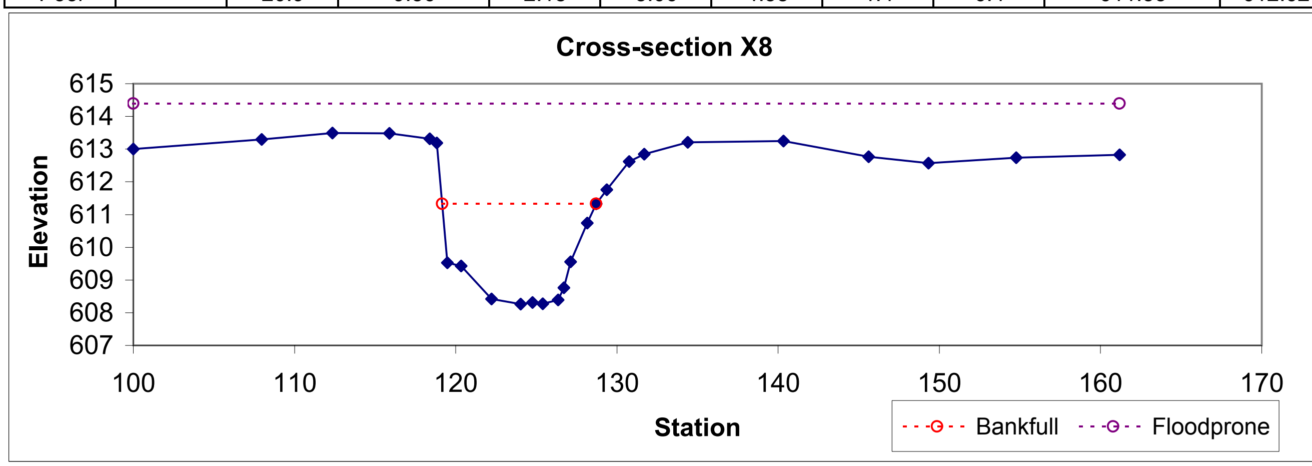
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	16.8	8.61	1.95	2.4	4.42	1	8.1	611.62	611.62



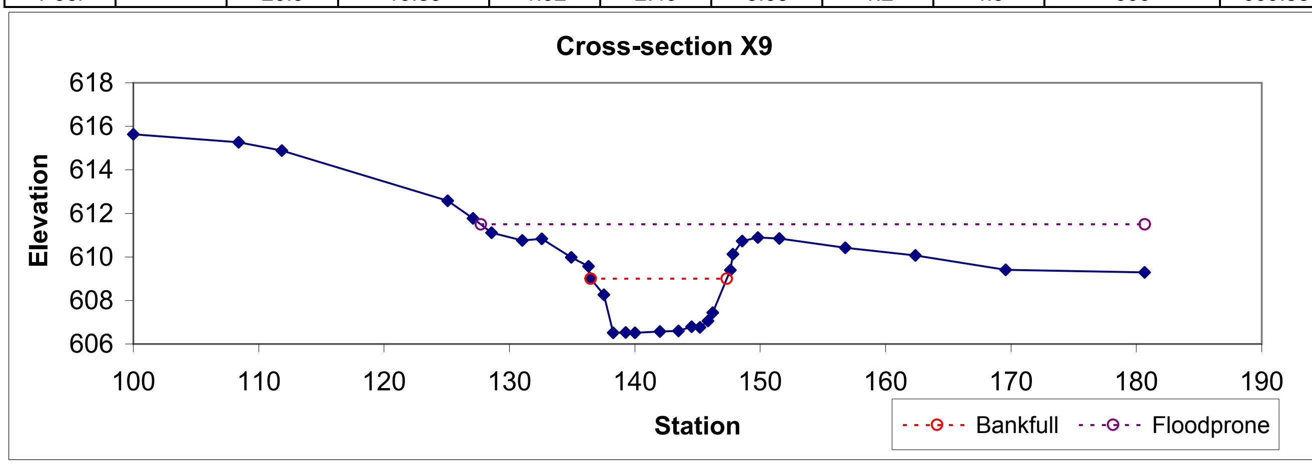
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		20.9	9.56	2.18	3.06	4.38	1.4	6.4	611.33	612.62



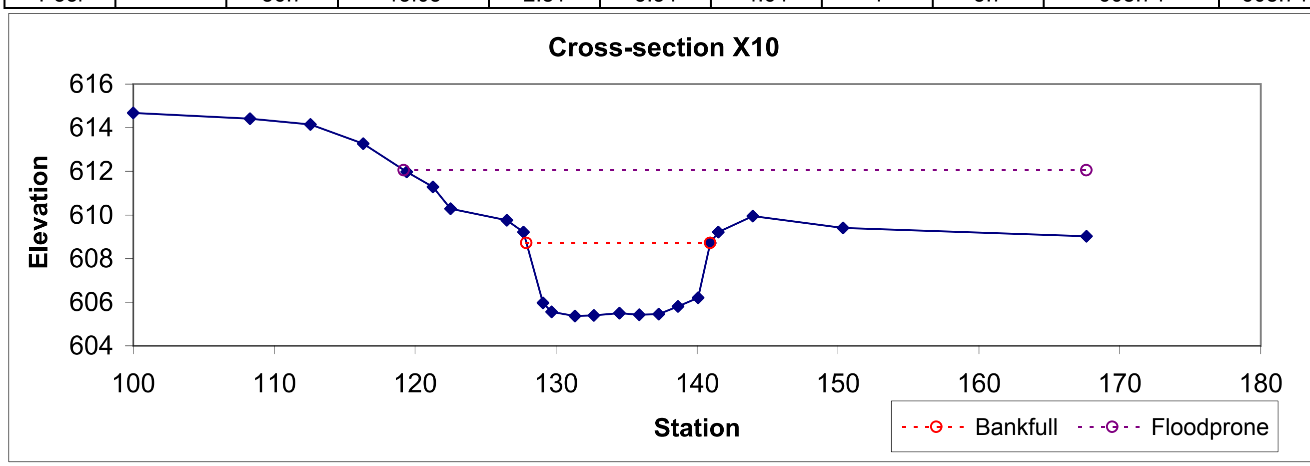
Cross-section Data:

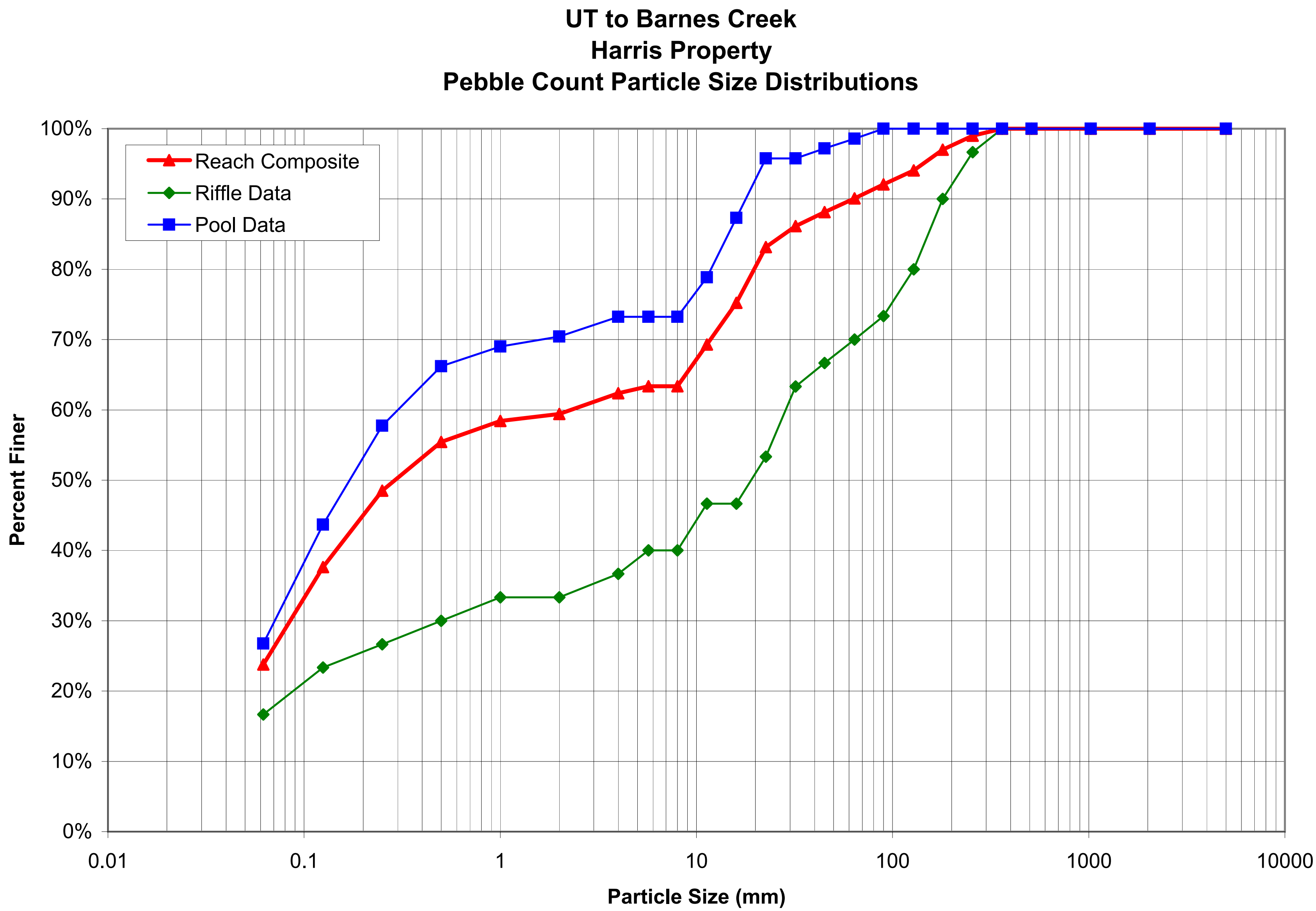
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		20.9	10.85	1.92	2.49	5.65	1.2	4.9	609	609.58

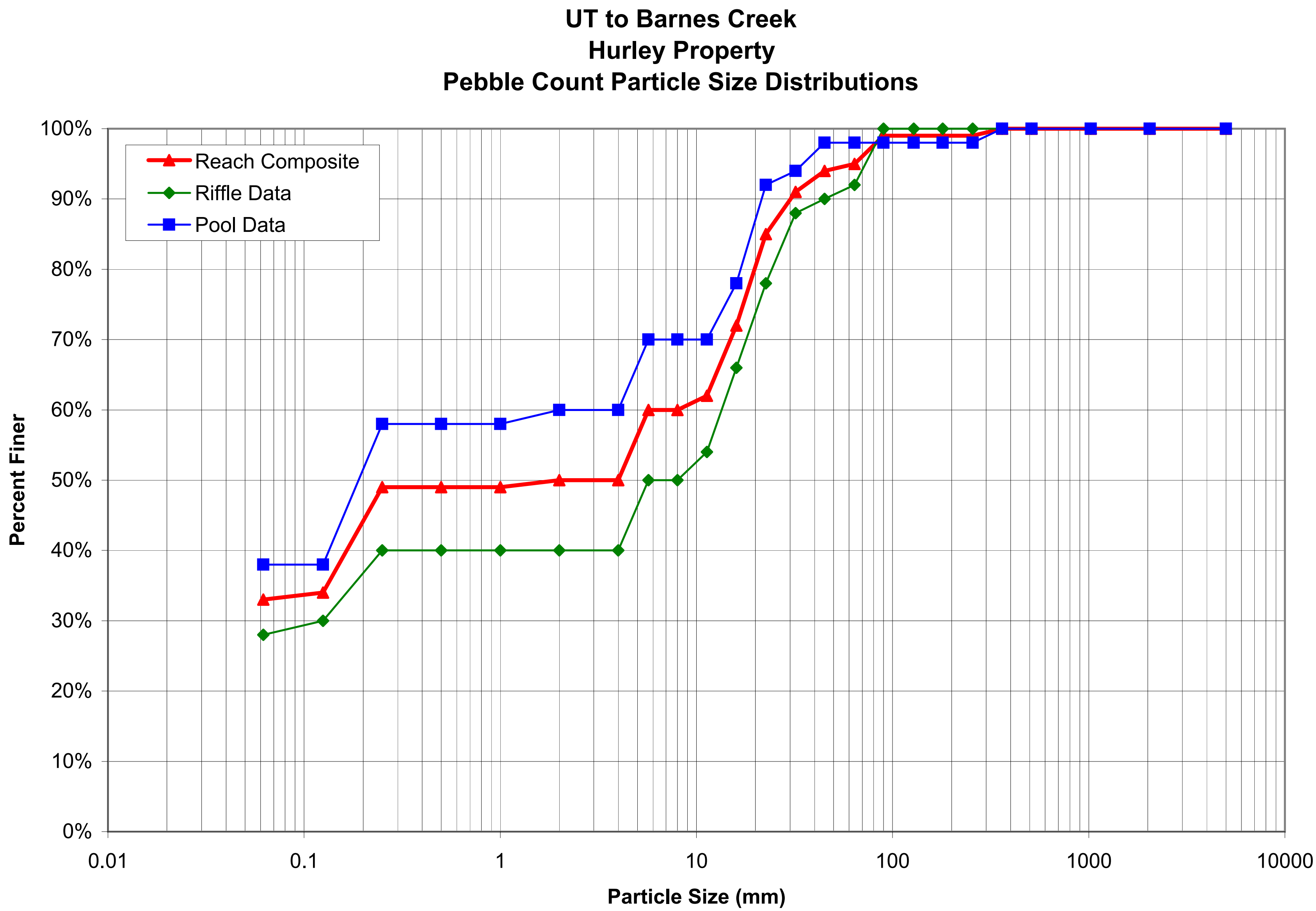


Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		36.7	13.05	2.81	3.34	4.64	1	3.7	608.71	608.71

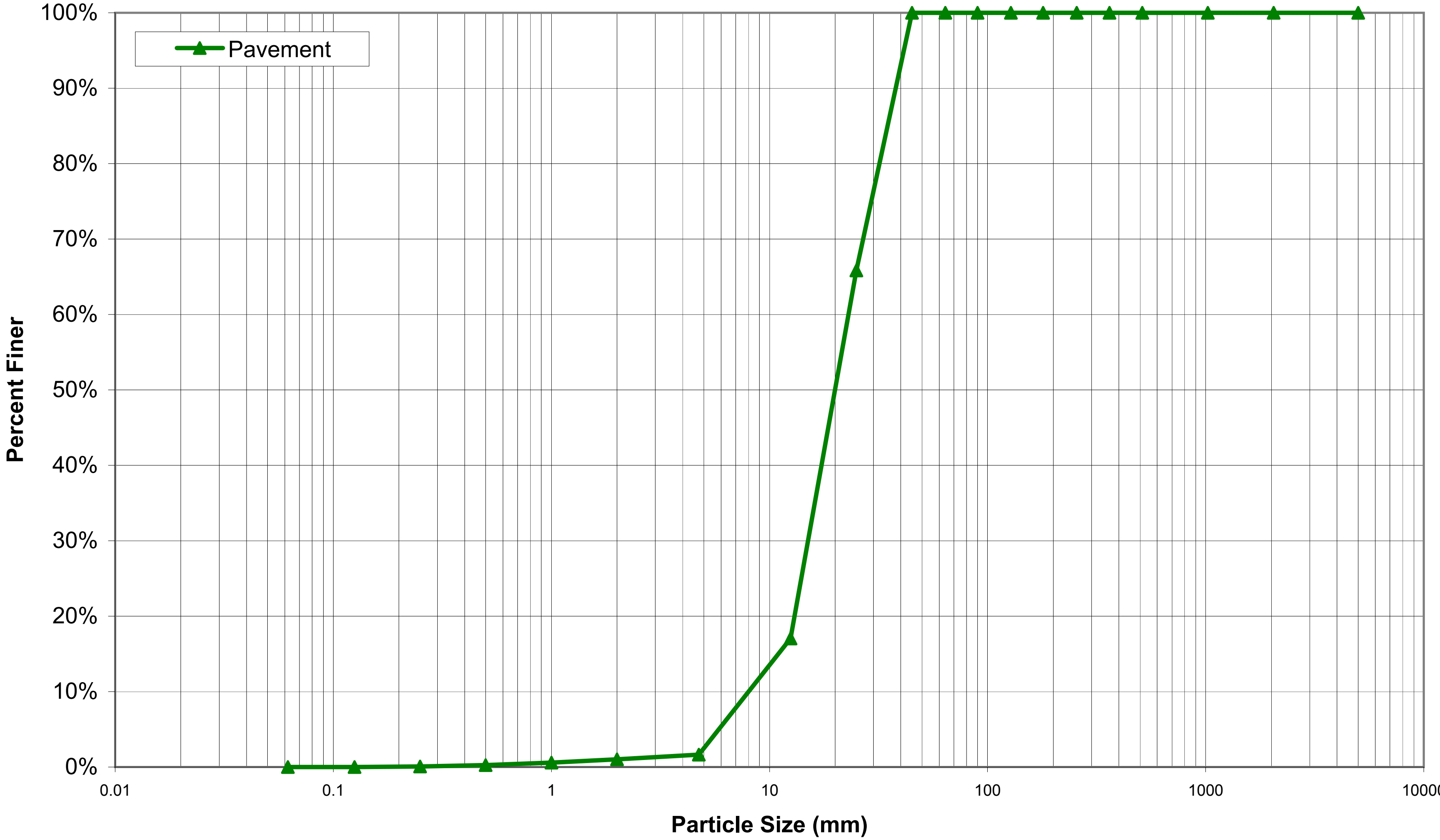



UT to Barnes Creek
Harris Property
Pebble Count Particle Size Distributions
Reach Composite
Riffle Data
Pool Data
Percent Finer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)

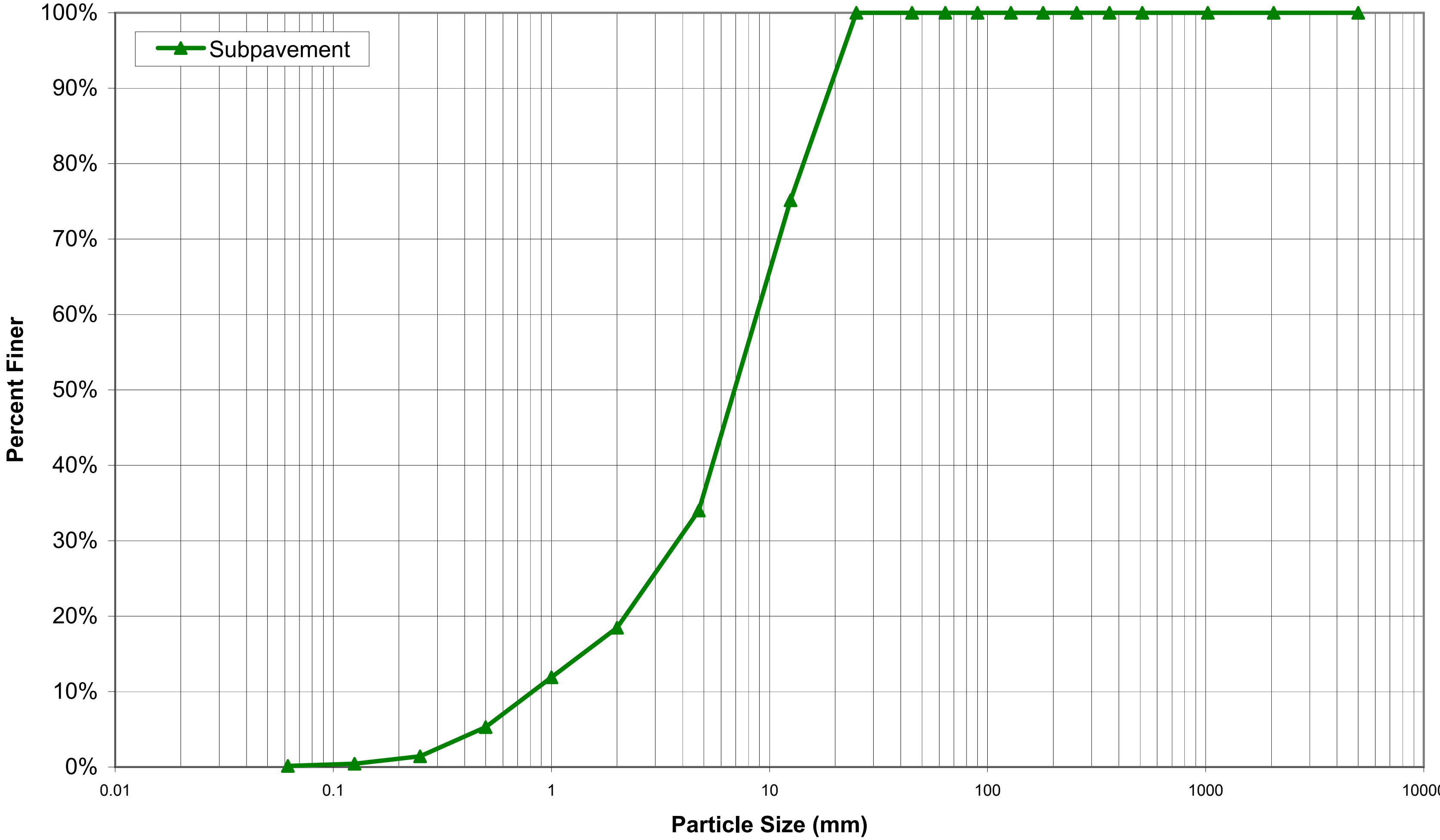


UT to Barnes Creek
Hurley Property
Pebble Count Particle Size Distributions
Reach Composite
Riffle Data
Pool Data
Percent Finer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)

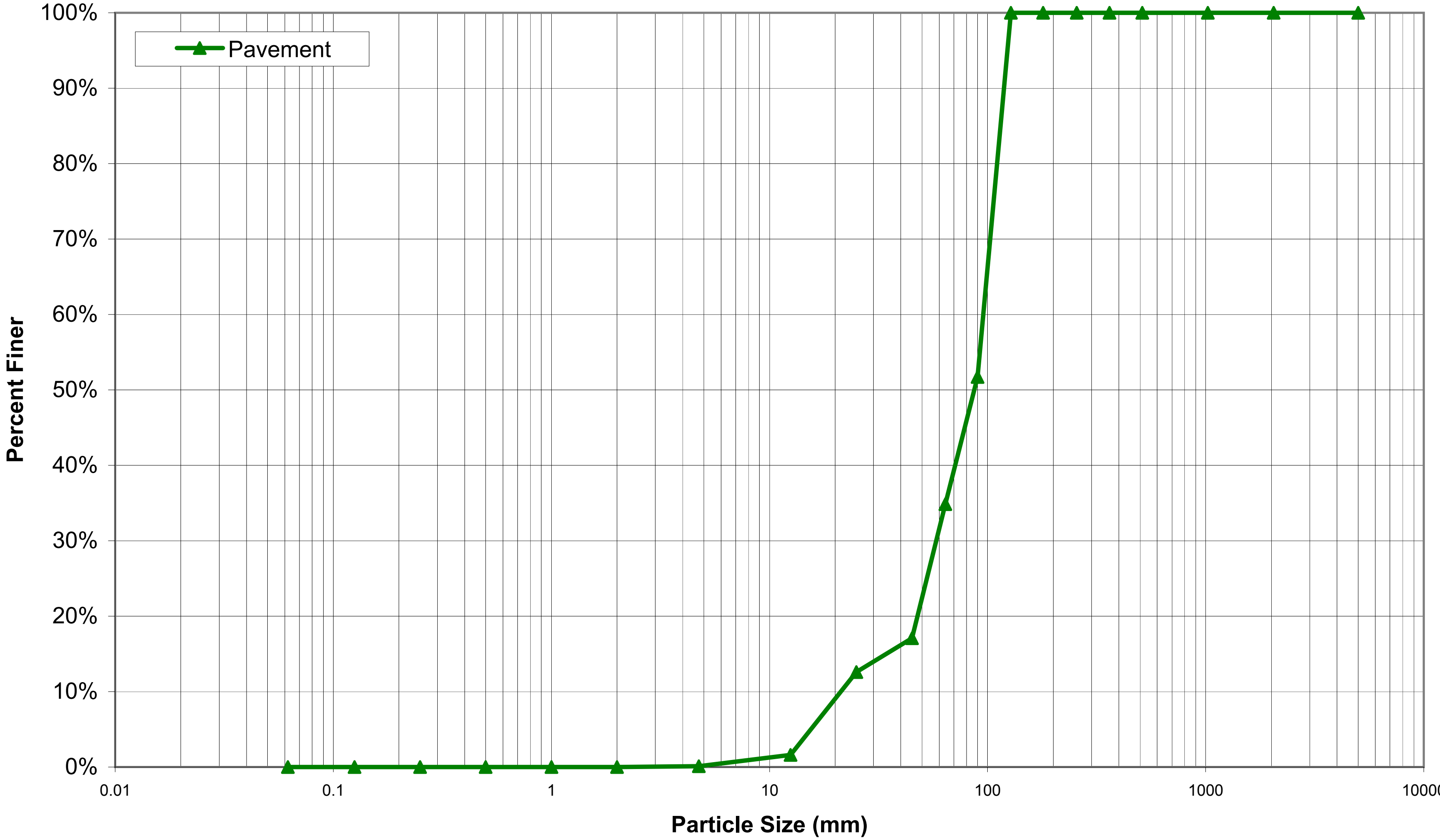
UT to Barnes Creek
on Harris Property
Pavement Particle Size Distribution



UT to Barnes Creek
UT on Harris Property
Subpavement Particle Size Distribution

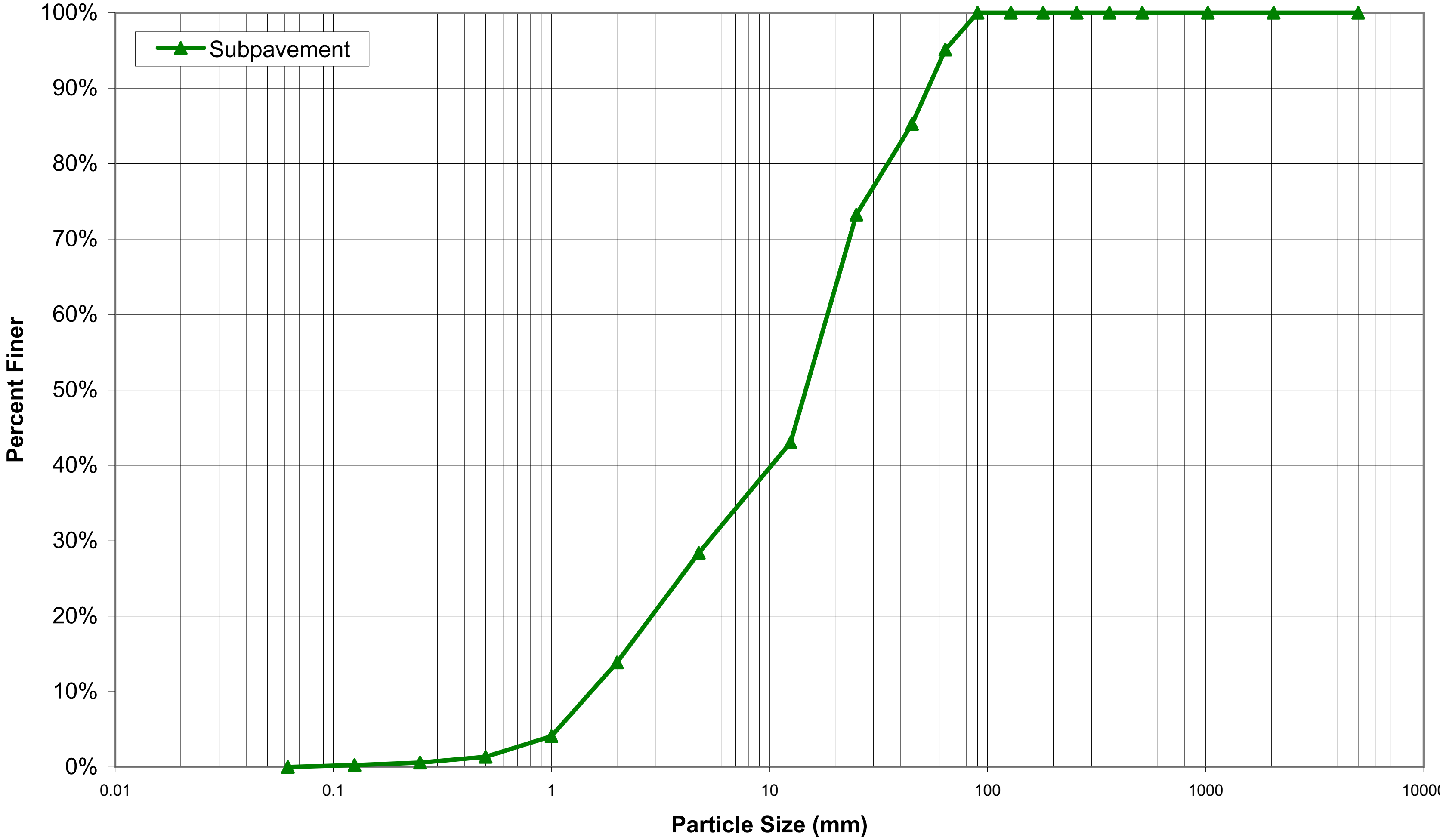


UT to Barnes Creek
Reach 1
Pavement Particle Size Distribution



L:\Projects\0172C\Assessment\Exist_Cond\Sediment\Reach1_pavement.xls, Distribution Graph 7/6/2004

UT to Barnes Creek
Reach 1
Subpavement Particle Size Distribution



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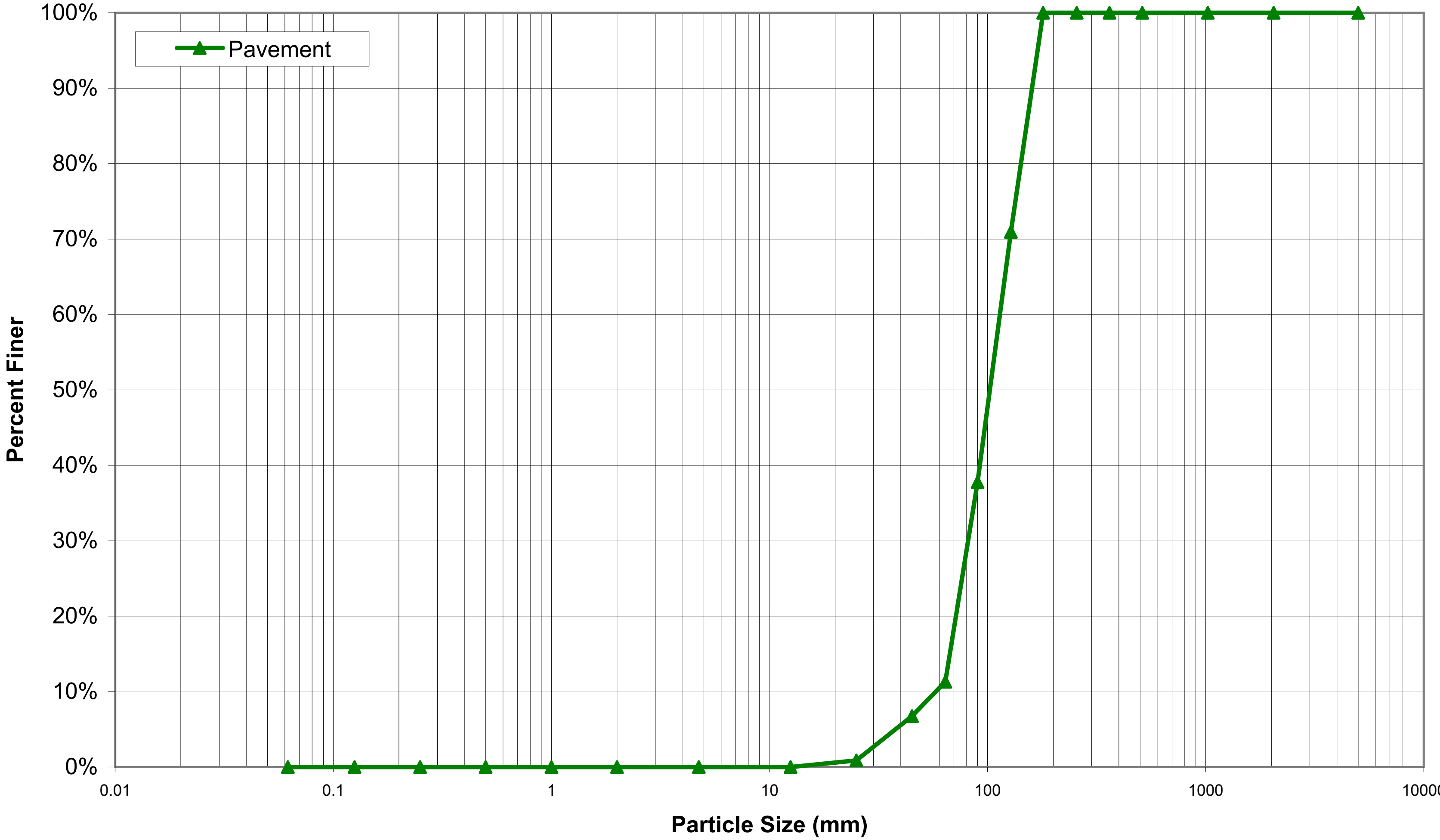
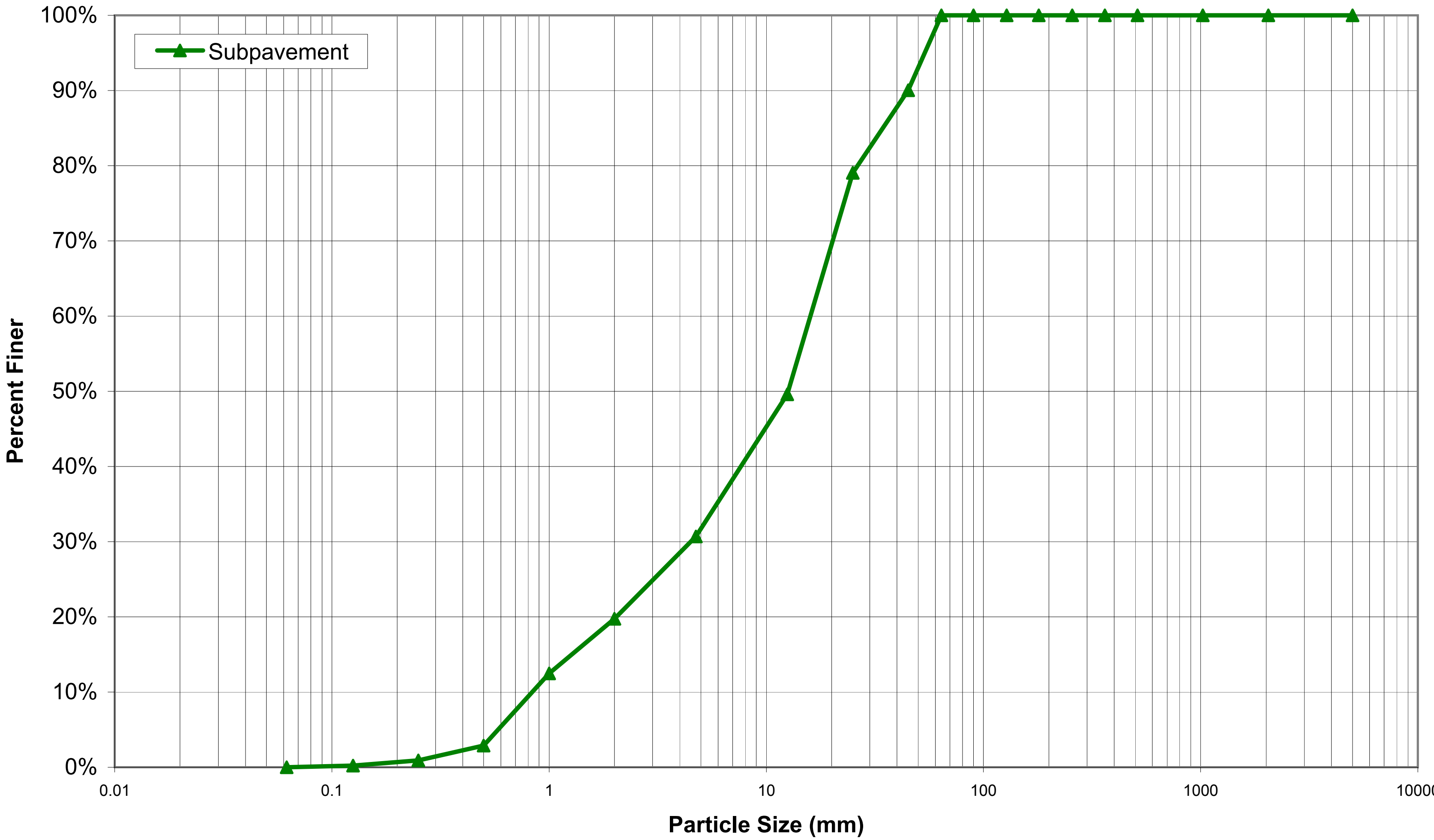
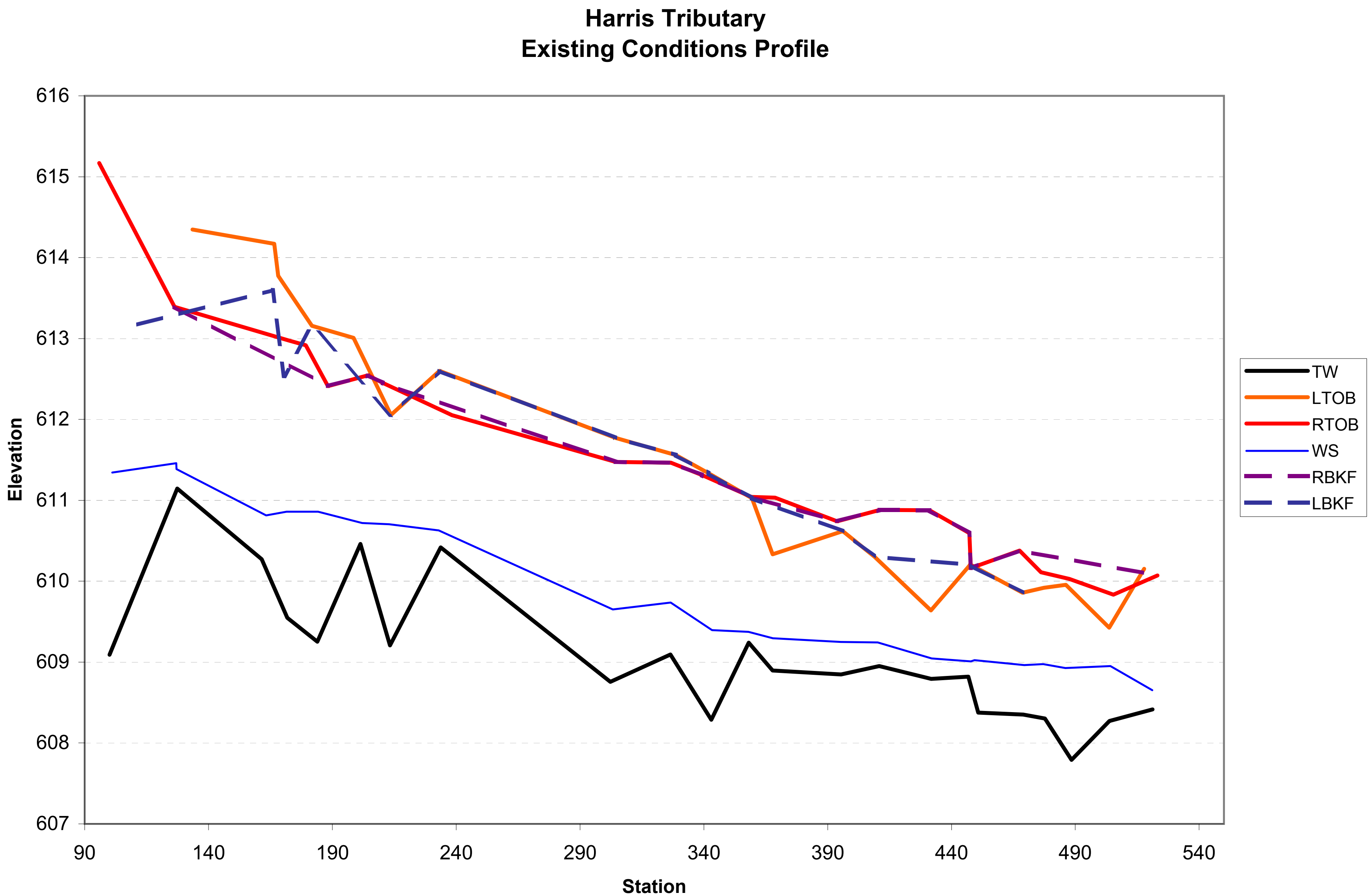
UT to Barnes Creek
Reach 2
Pavement Particle Size Distribution



UT to Barnes Creek
Reach 2
Subpavement Particle Size Distribution

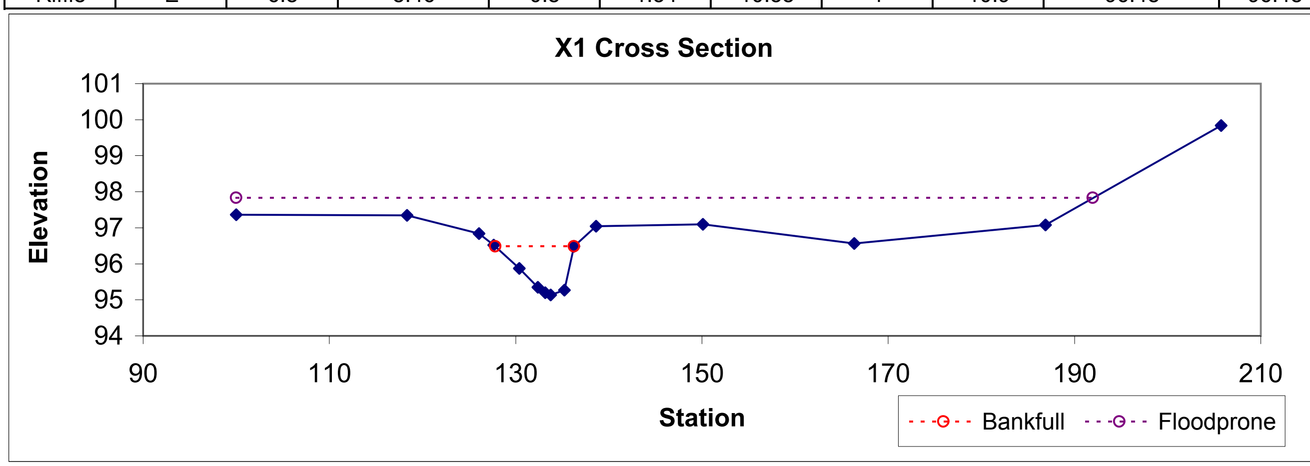




L:\Projects\0172C\Assessment\Exist_Cond\Geomorphic\Tributary.xls, Profile Chart

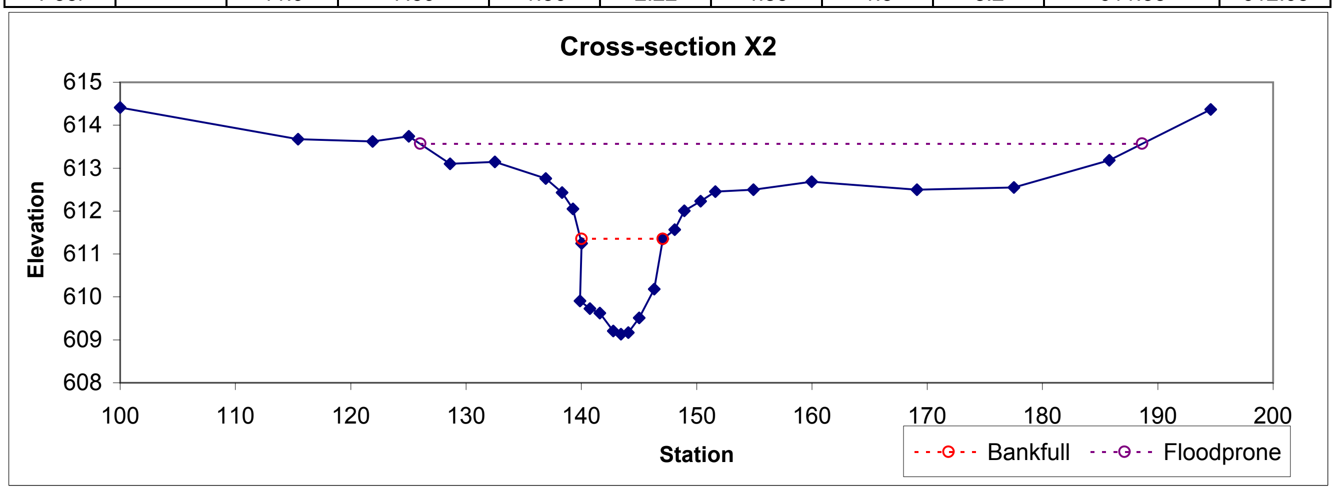
Cross-section Data:

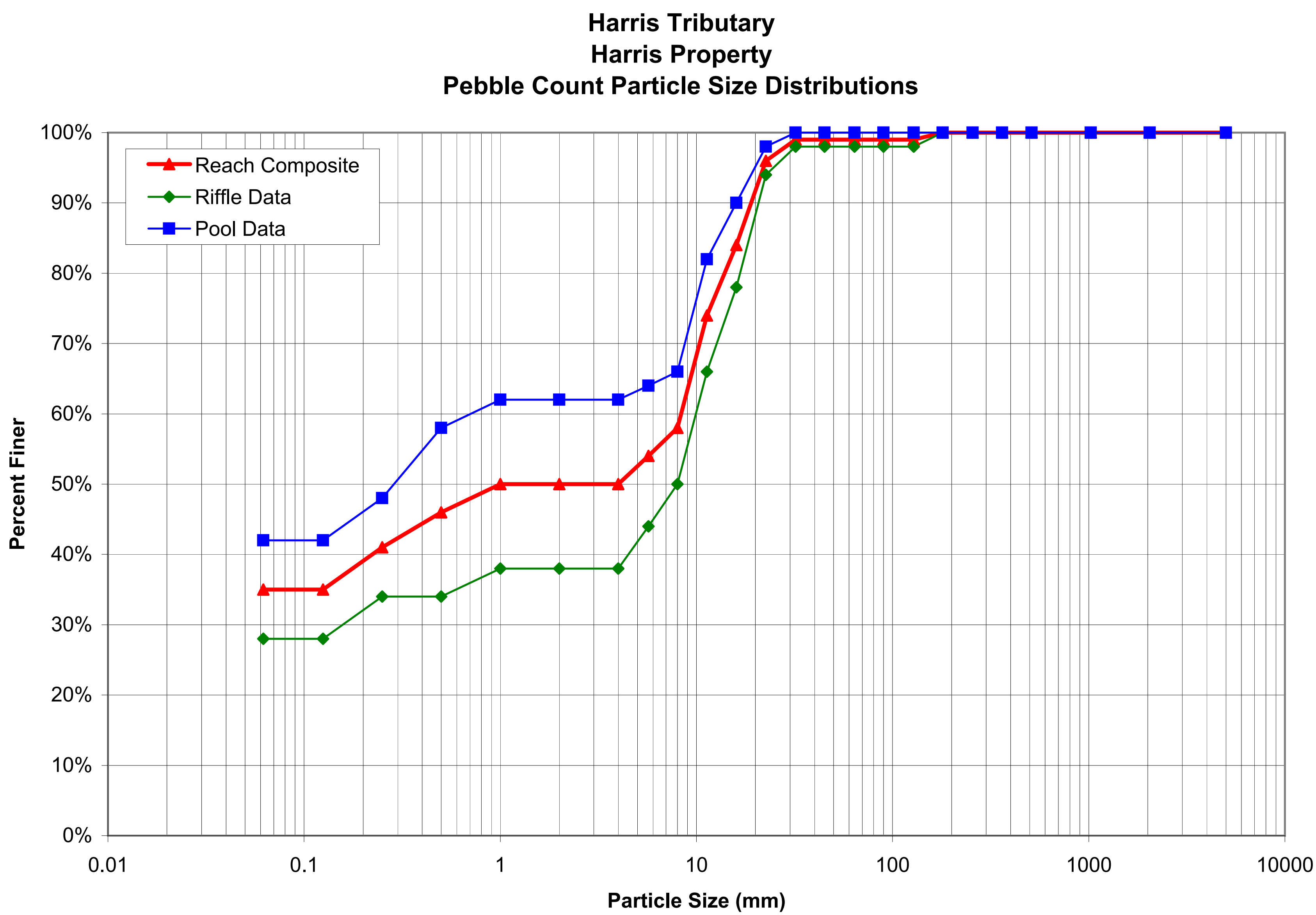
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	6.8	8.46	0.8	1.34	10.58	1	10.9	96.48	96.48



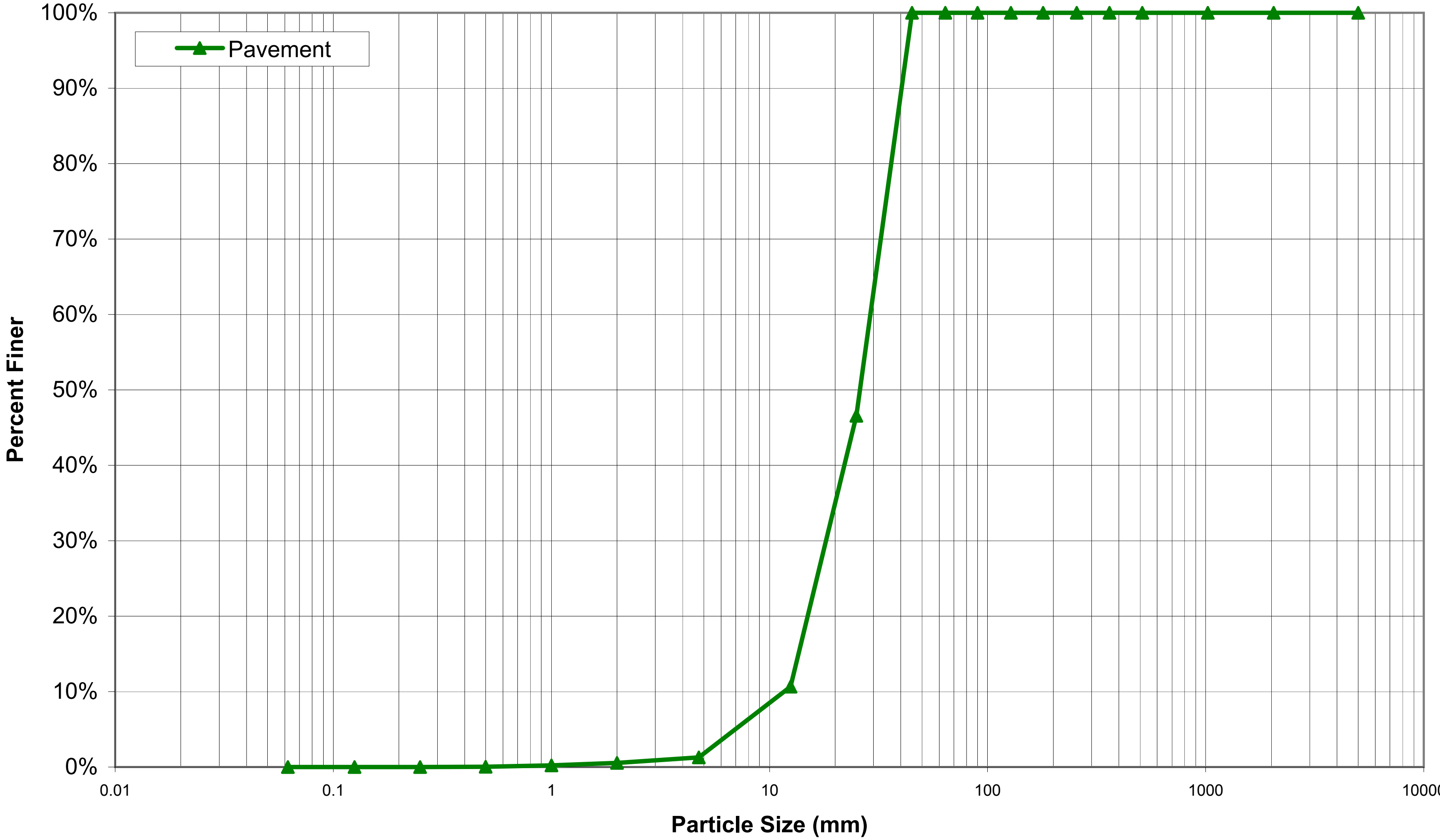
Cross-section Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		11.9	7.59	1.56	2.22	4.85	1.3	8.2	611.35	612.05

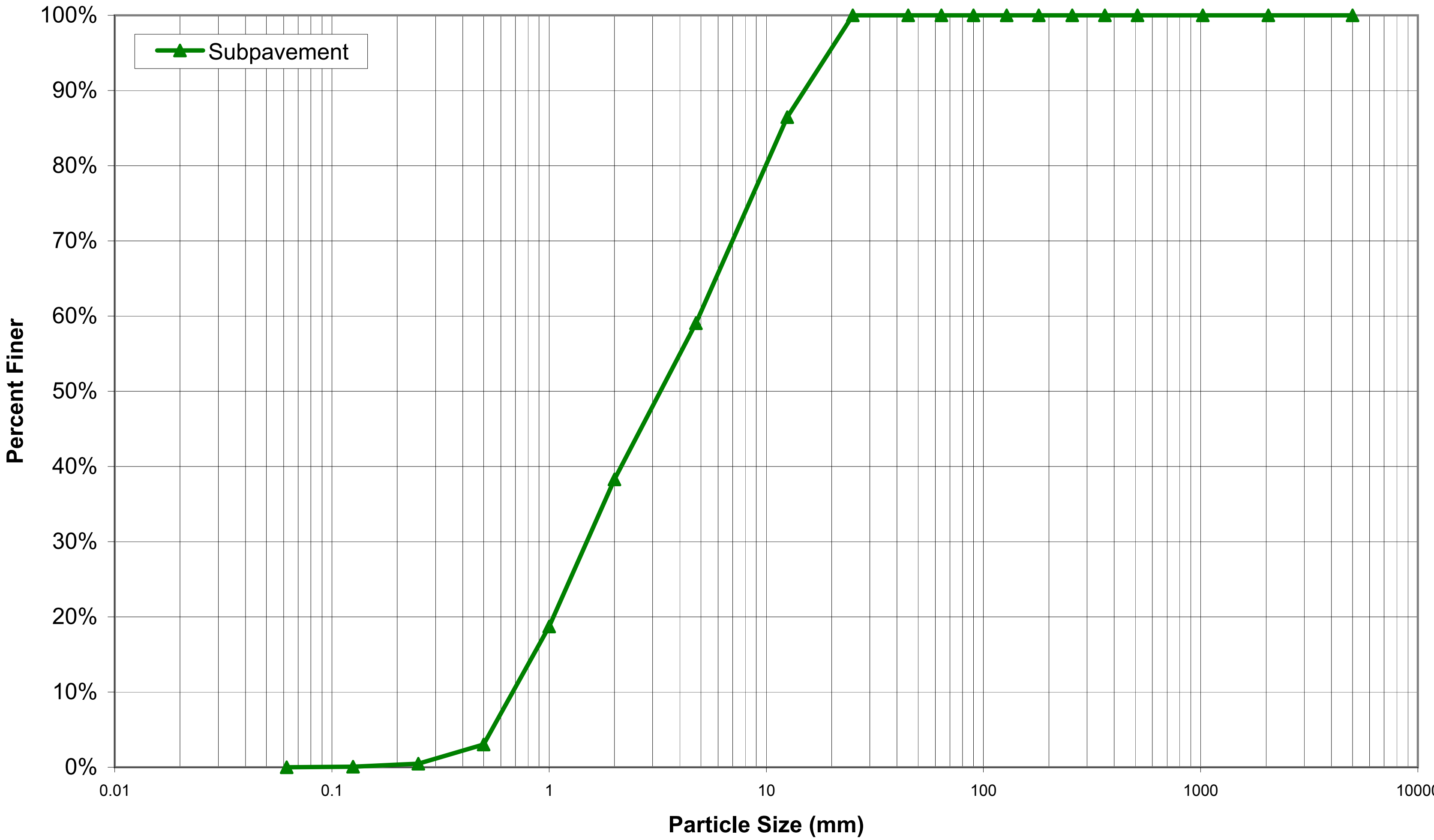



Harris Tributary
Harris Property
Pebble Count Particle Size Distributions
Reach Composite
Riffle Data
Pool Data
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Finer
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)

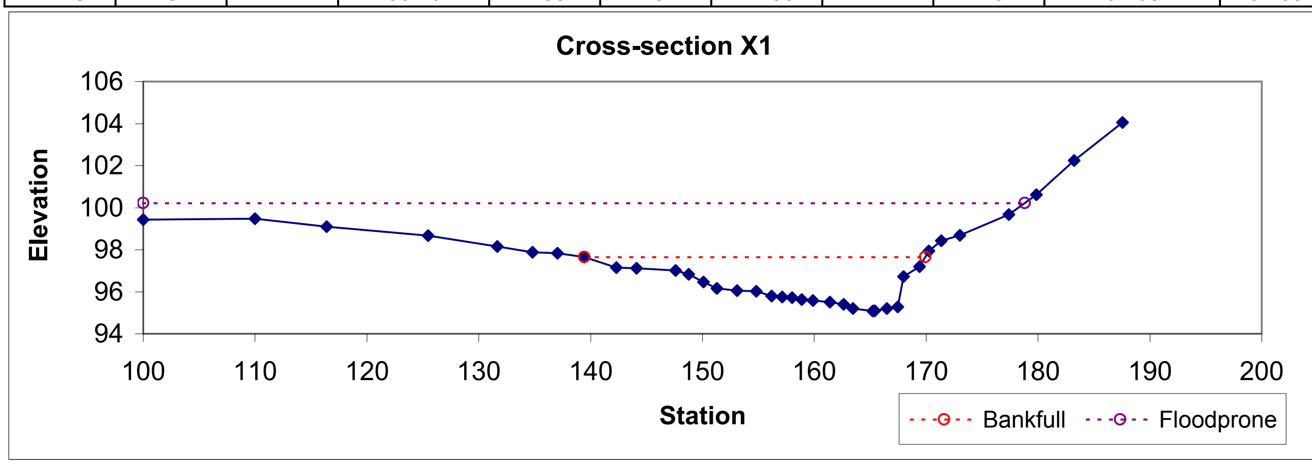
UT to Barnes Creek
Harris Property Tributary
Pavement Particle Size Distribution



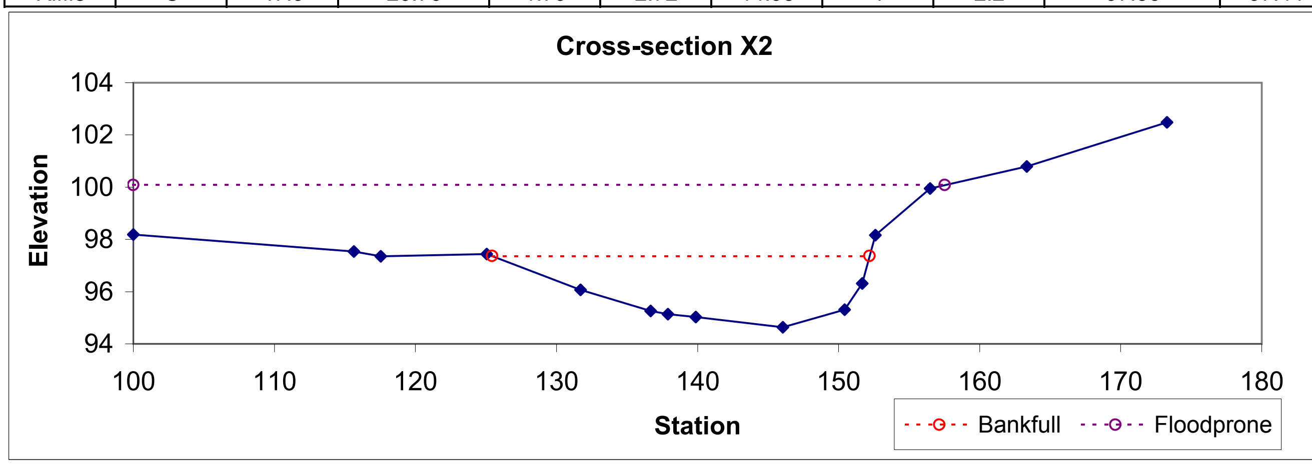
UT to Barnes Creek
Harris Property Tributary
Subpavement Particle Size Distribution



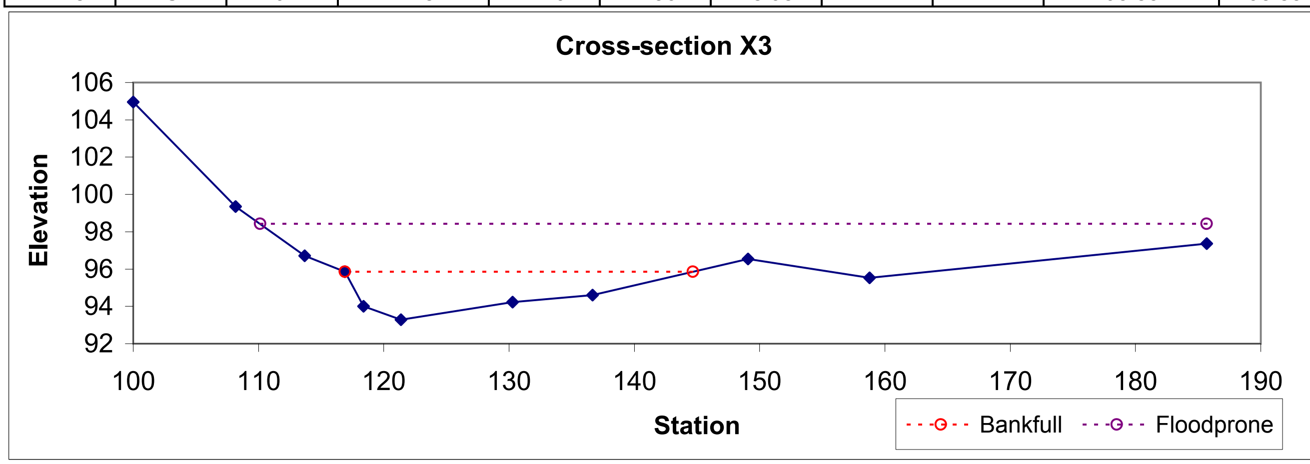
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	42.4	30.46	1.39	2.57	21.86	1	2.6	97.65	97.65



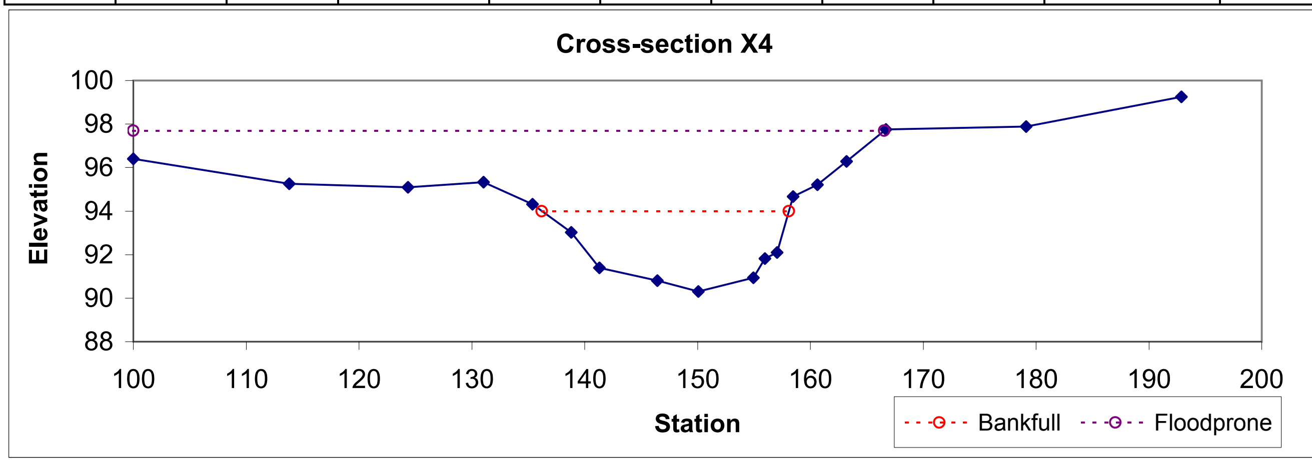
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	47.9	26.76	1.79	2.72	14.95	1	2.2	97.36	97.44



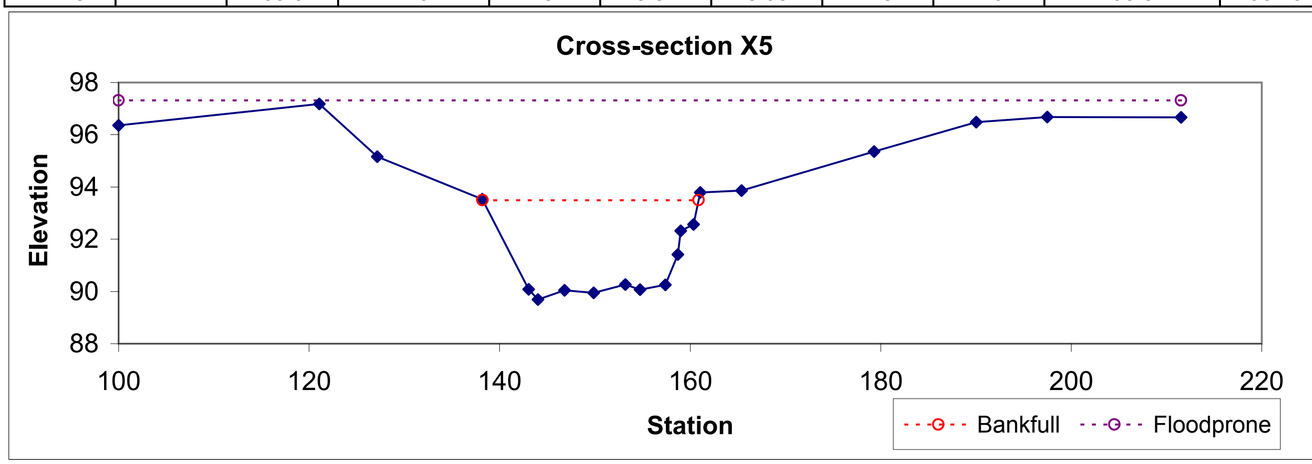
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	40.7	27.8	1.46	2.56	18.98	1	2.7	95.85	95.85



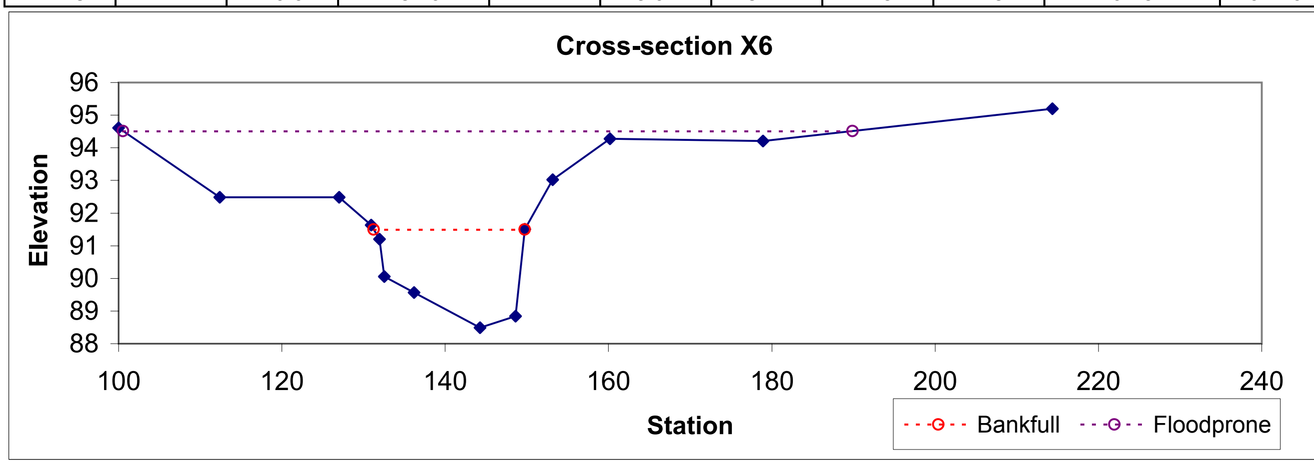
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	55.5	21.89	2.53	3.69	8.64	1.4	3	94	95.33



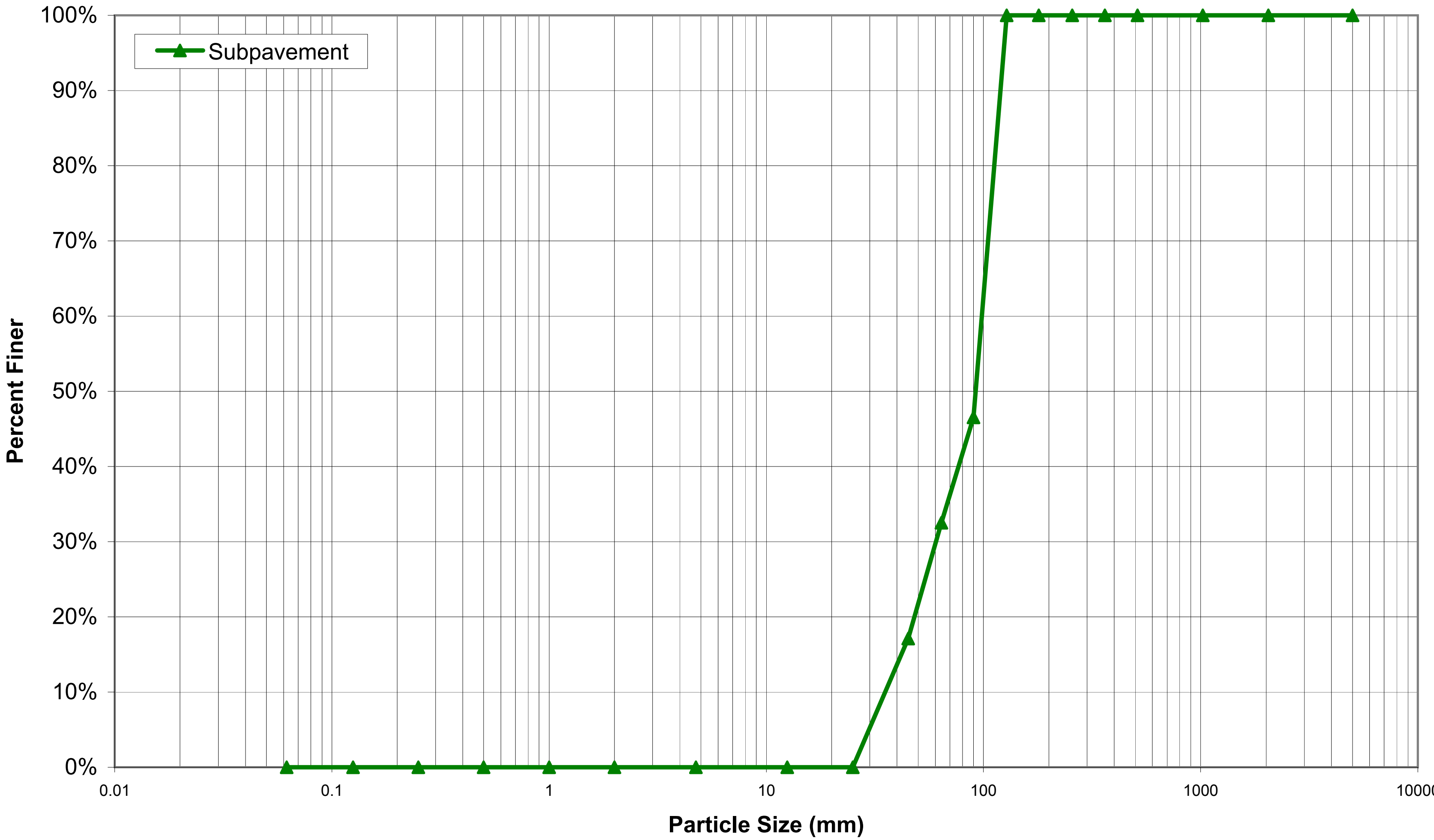
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	63.6	22.67	2.81	3.81	8.08	1.8	4.9	93.5	96.49



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	40.6	18.49	2.2	3.01	8.42	1.3	4.8	91.5	92.49

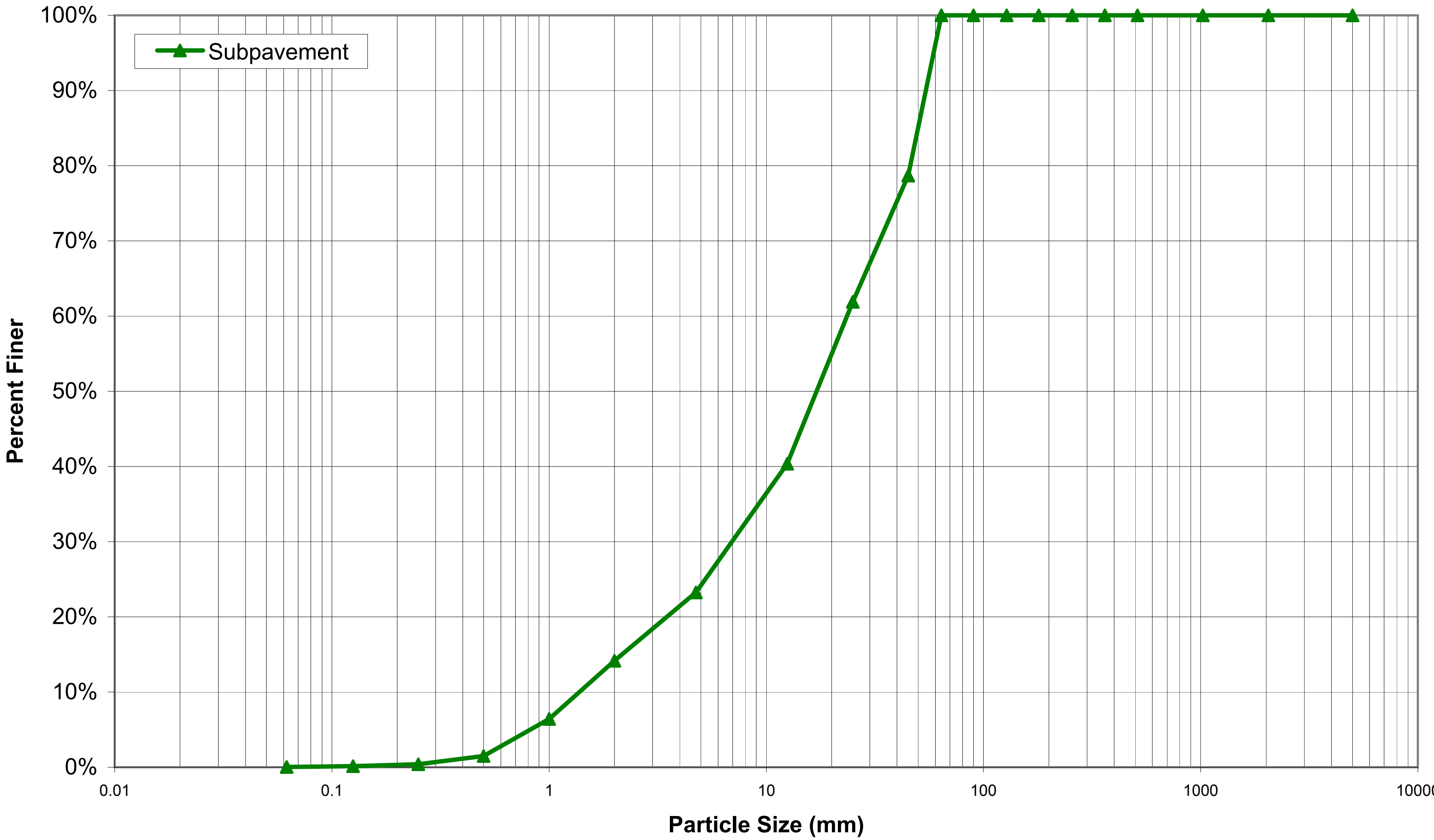


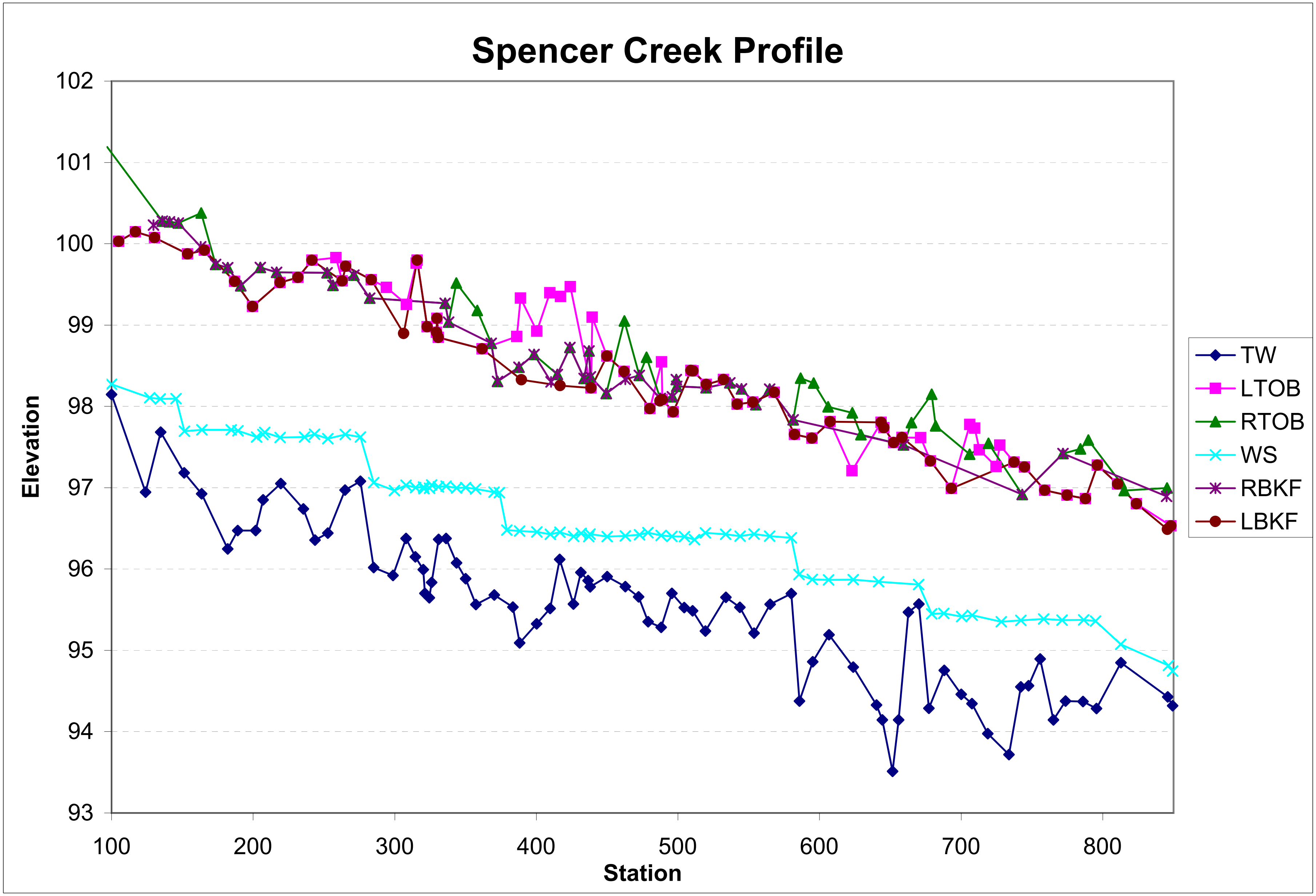
UT to Barnes Creek
Gage Station
Pavement Particle Size Distribution



L:\Projects\0172C\Assessment\Reference Reaches\sediment\gauge station pavement X-1.xls, Distribution Graph 7/6/2004

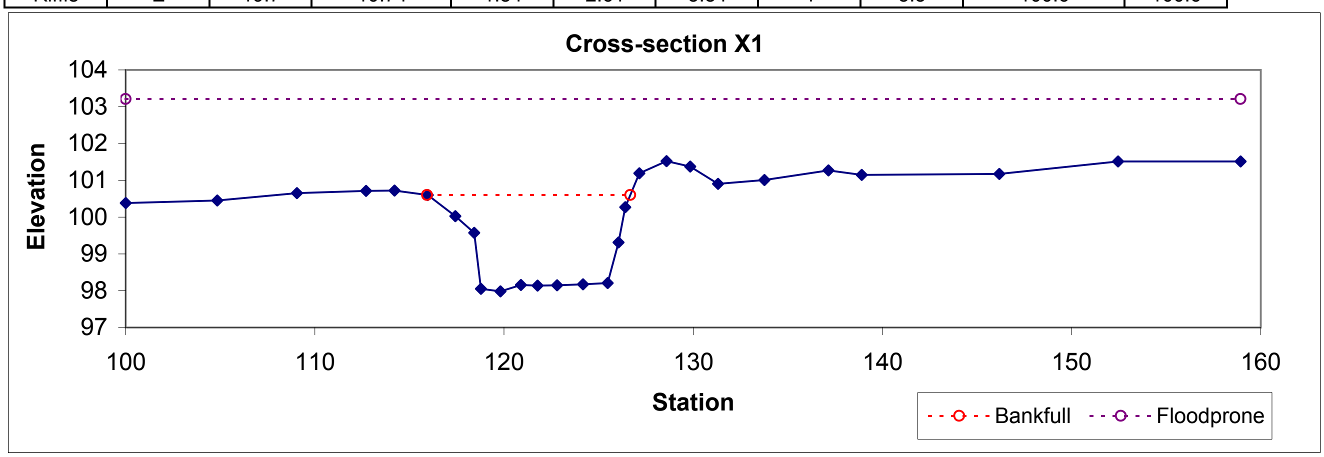
UT to Barnes Creek
Gage Station
Subpavement Particle Size Distribution



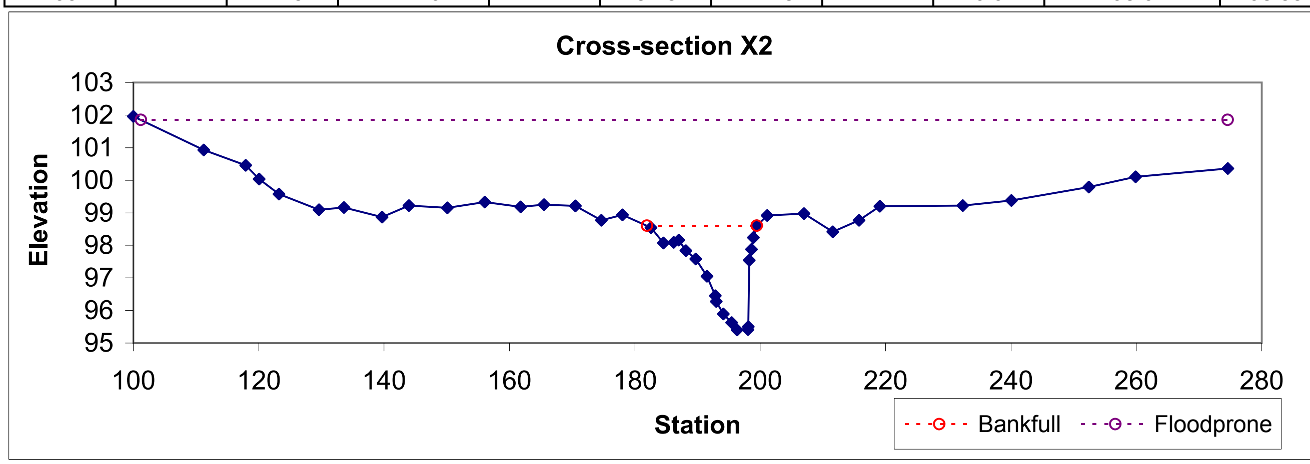


Spencer Creek Profile
Elevation
Station
102
101
100
99
98
97
96
95
94
93
100
200
300
400
500
600
700
800
TW
LTOB
RTOB
WS
RBKF
LBKF

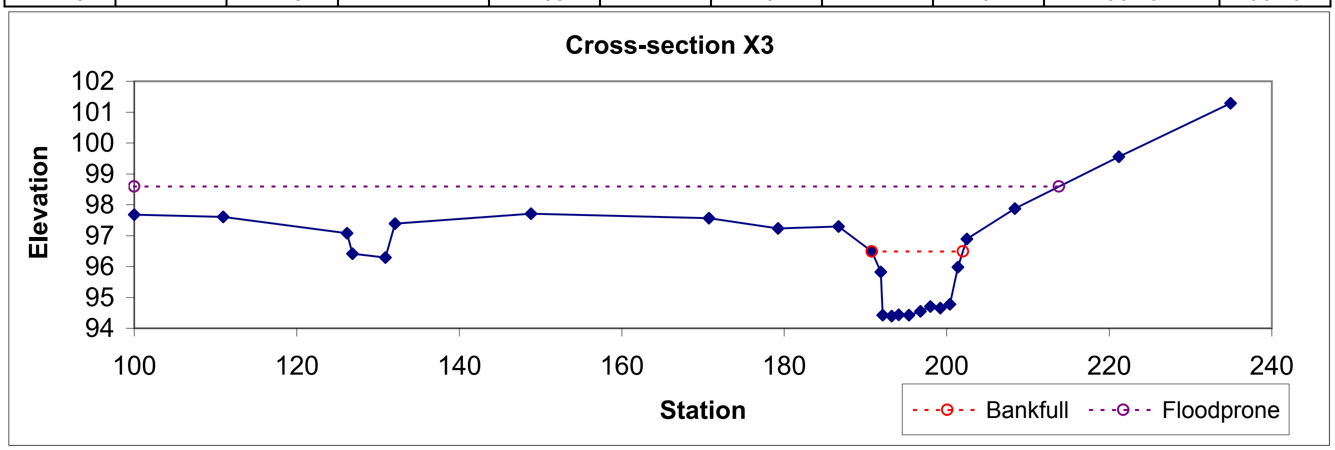
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	19.7	10.74	1.84	2.61	5.84	1	5.5	100.6	100.6

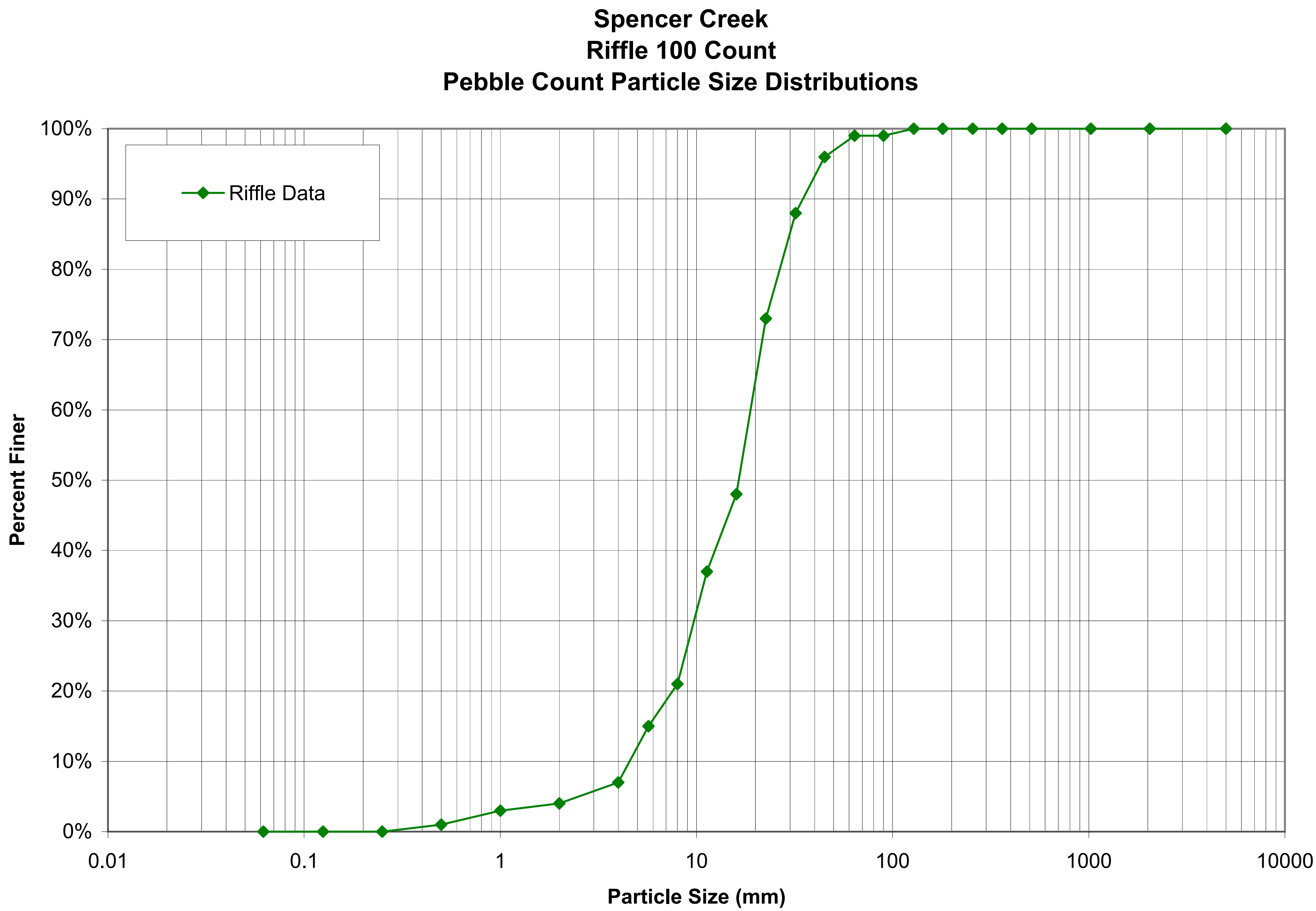


Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		24.5	17.49	1.4	3.25	12.48	1	9.9	98.6	98.55



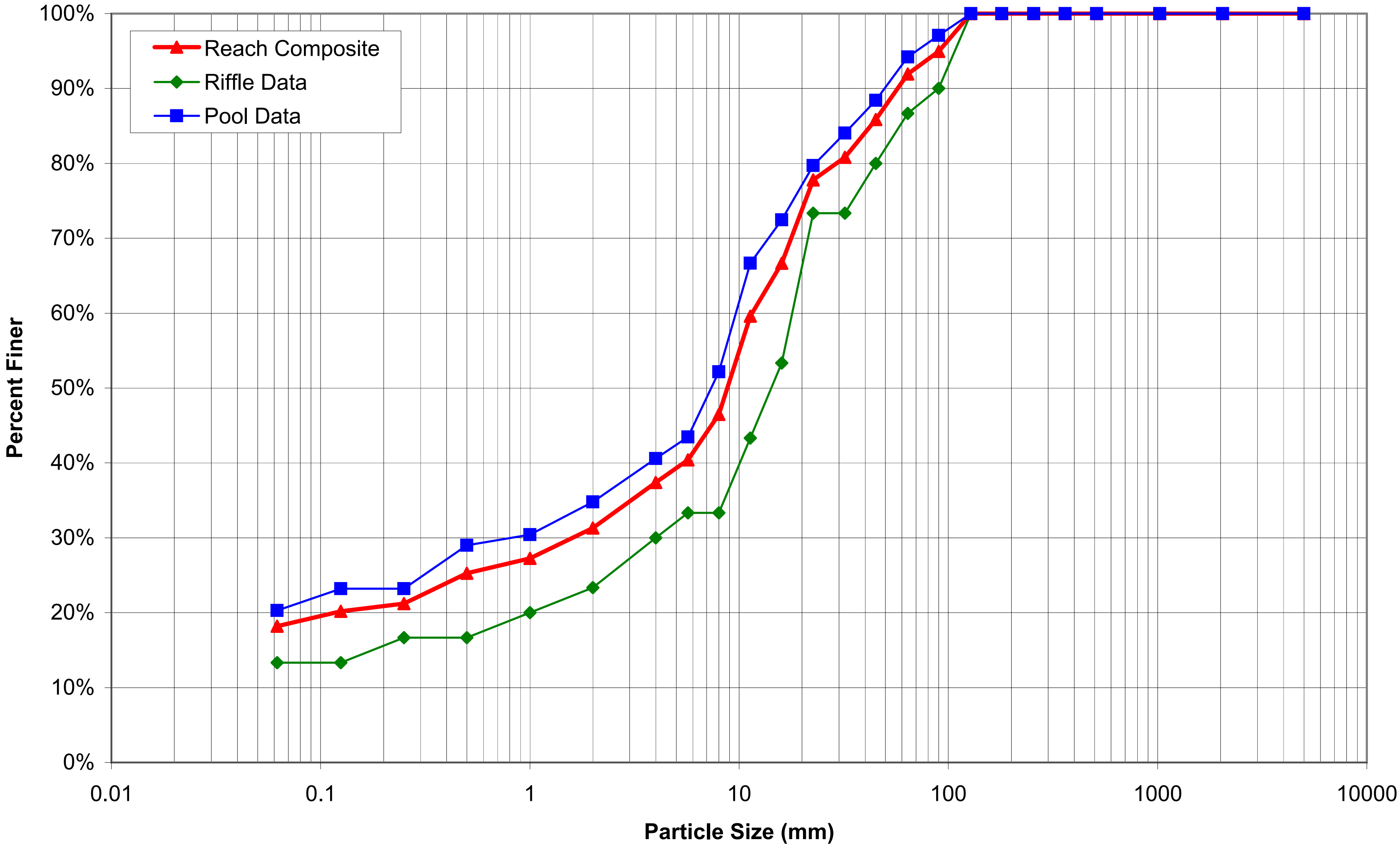
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	17.8	11.21	1.59	2.1	7.07	1	10.2	96.49	96.49



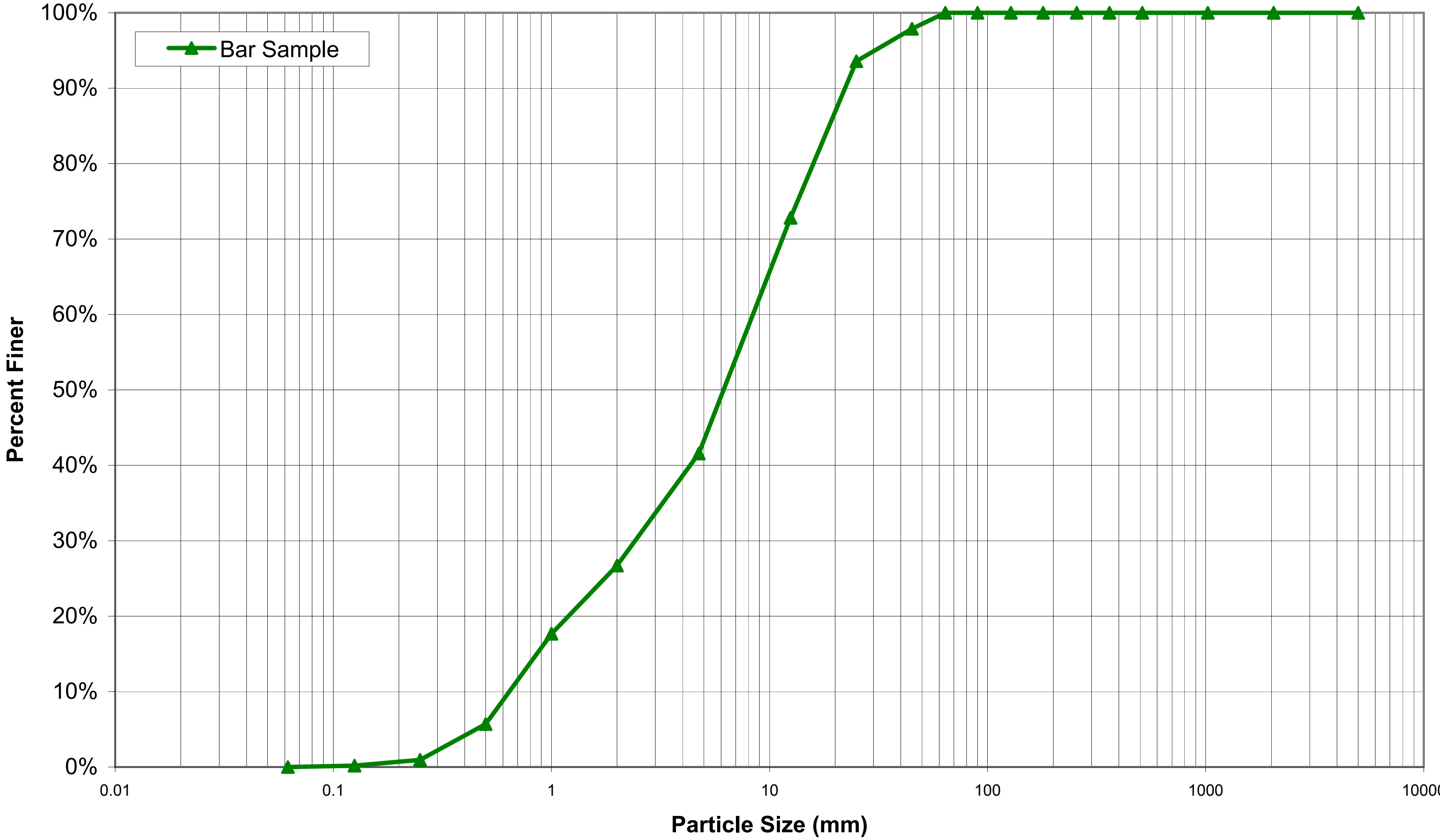

Spencer Creek
Riffle 100 Count
Pebble Count Particle Size Distributions
Riffle Data
Percent Finer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)

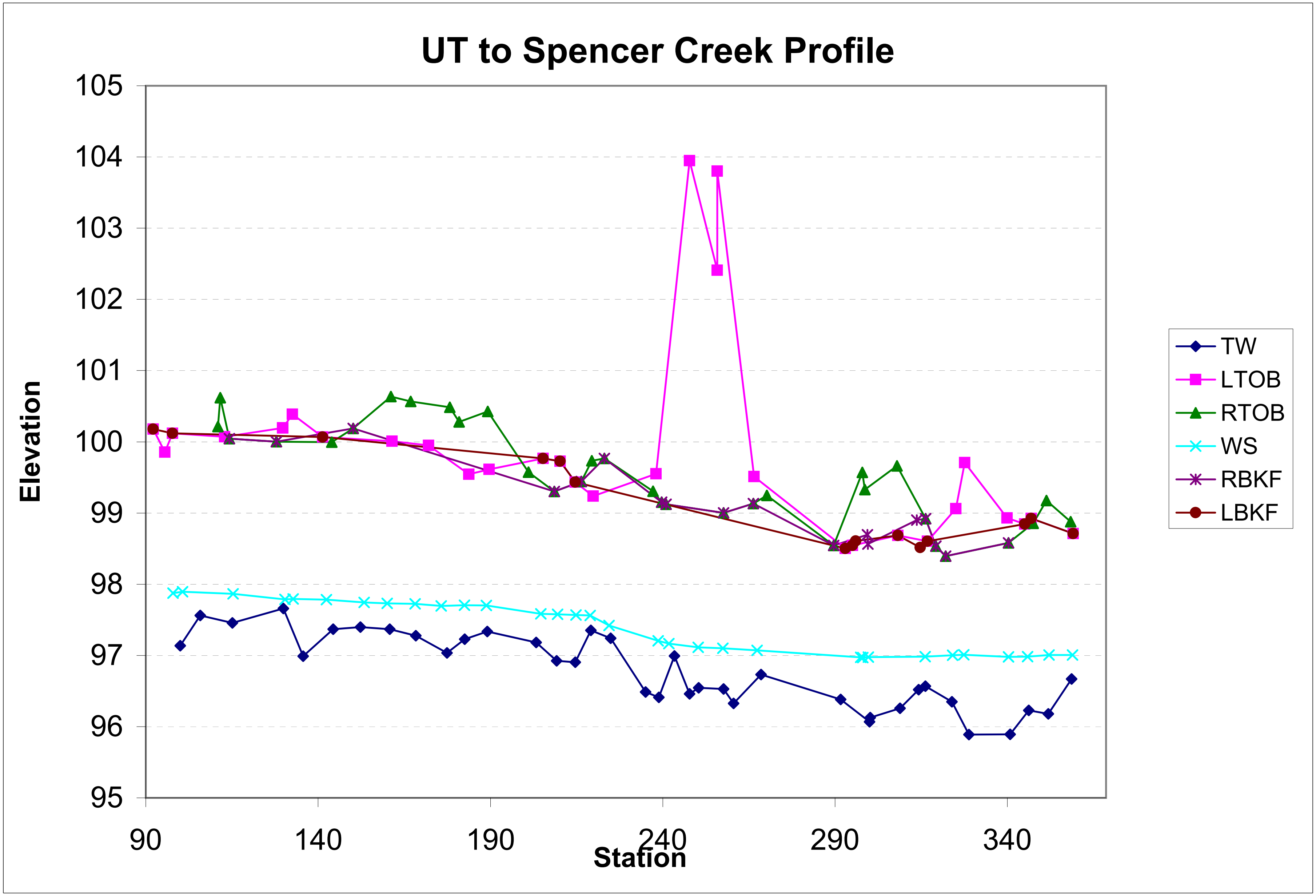
Spencer Creek

Pebble Count Particle Size Distributions



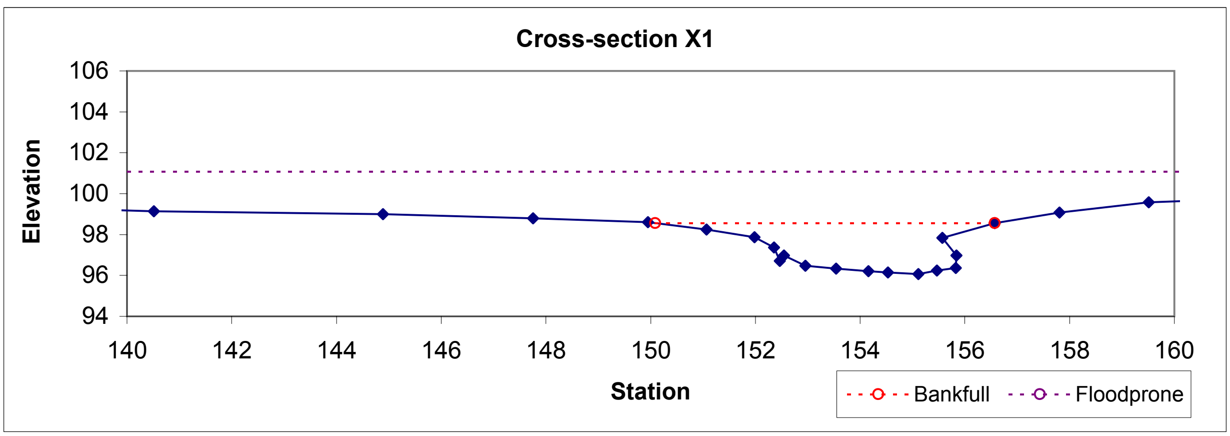
Spencer Creek
Bar Sample
Particle Size Distribution



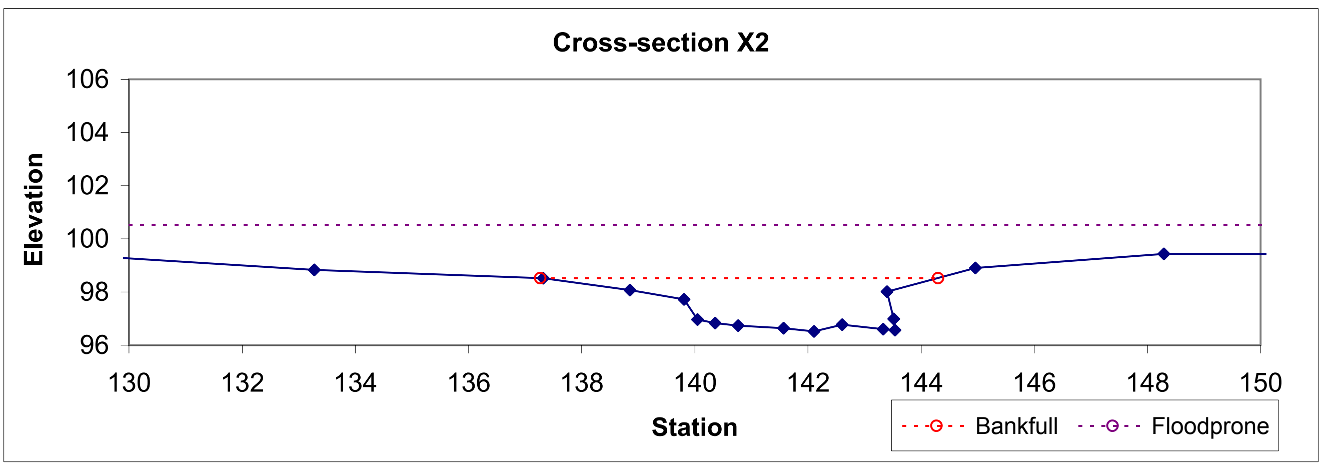


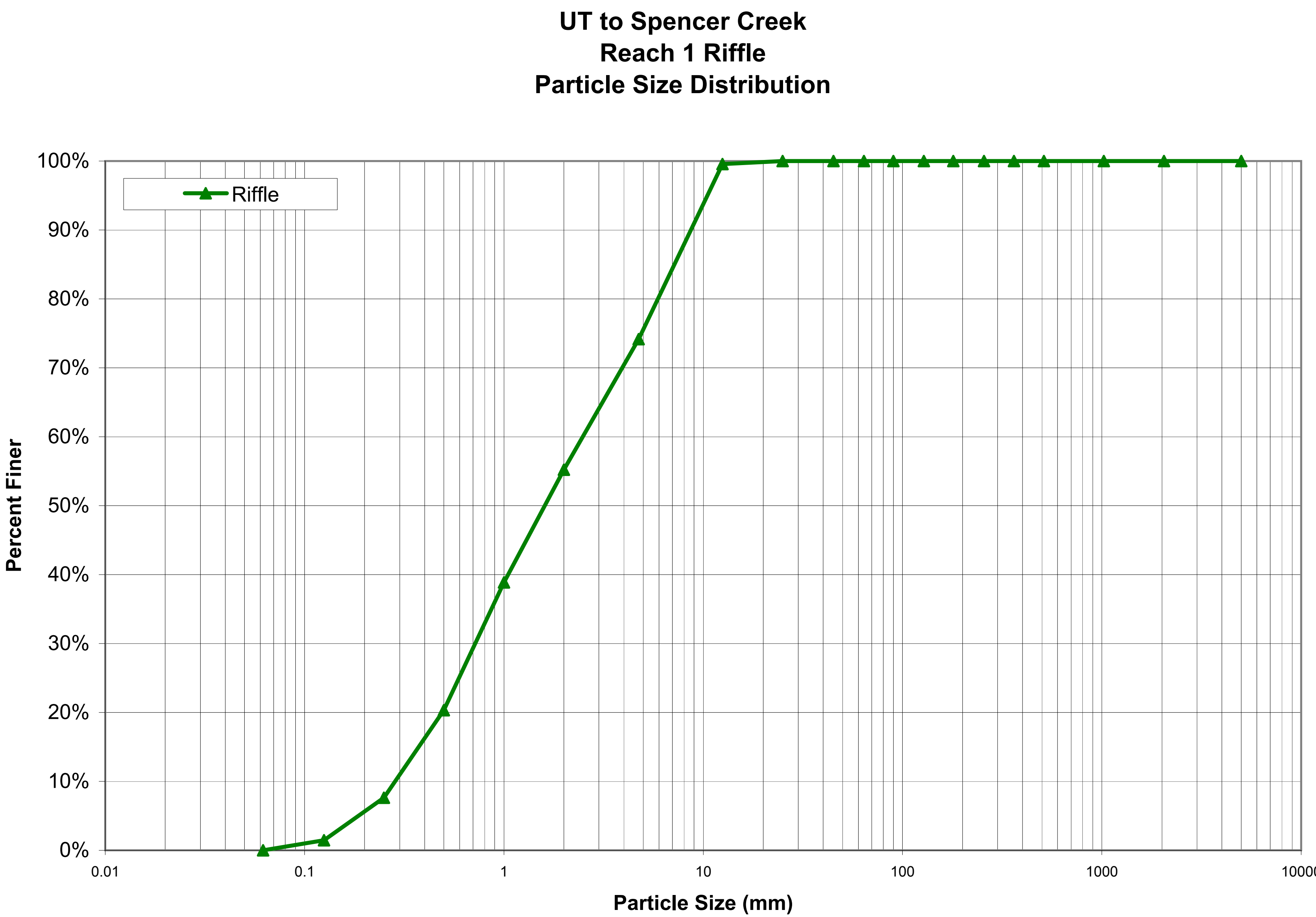
UT to Spencer Creek Profile
Elevation
Station
105
104
103
102
101
100
99
98
97
96
95
90
140
190
240
290
340
TW
LTOB
RTOB
WS
RBKF
LBKF

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		8.8	6.48	1.39	2.5	4.66	1	17.5	98.56	98.61



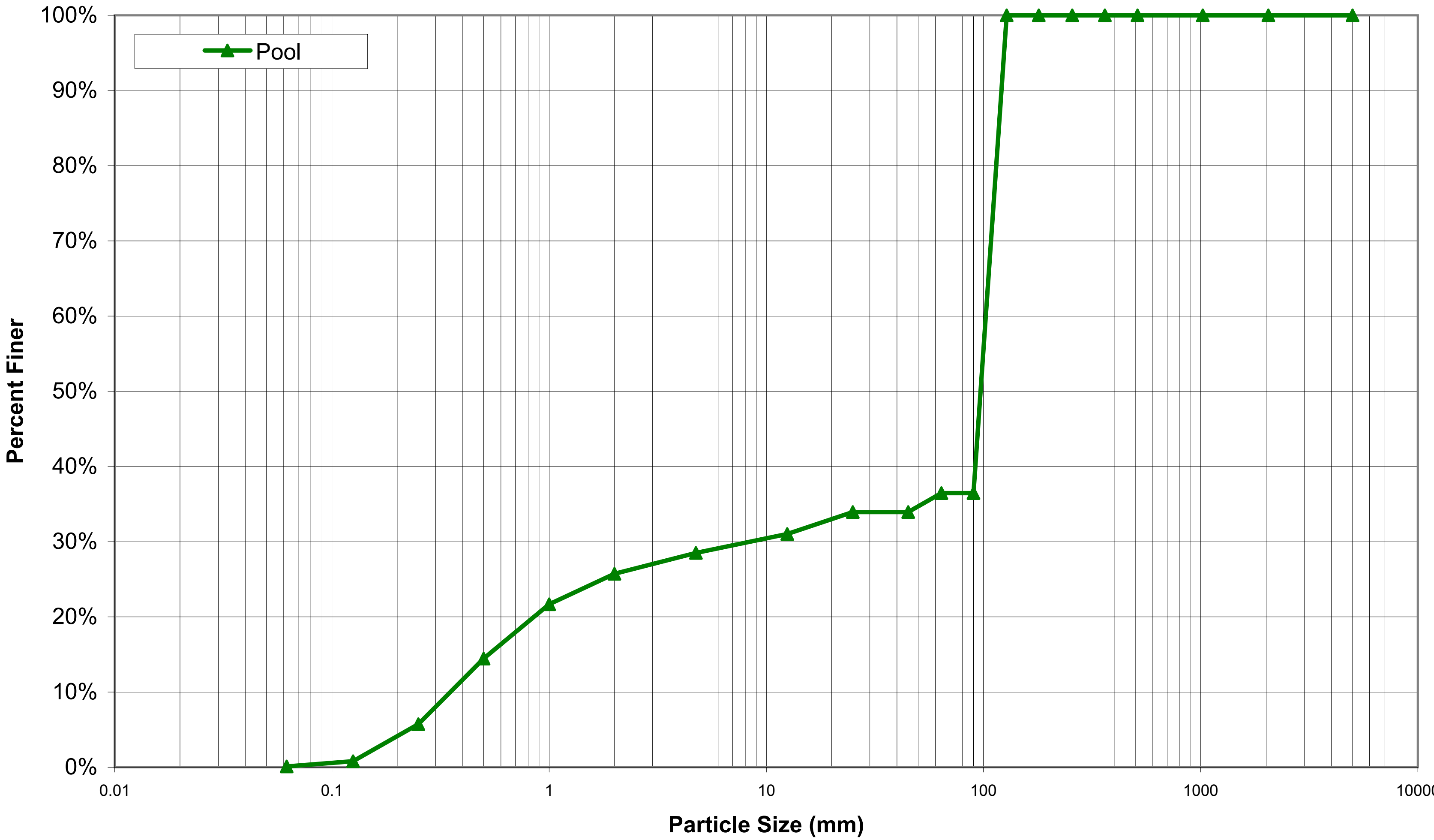
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	7.7	7	1.1	2	6.41	1	11.57	98.52	98.52



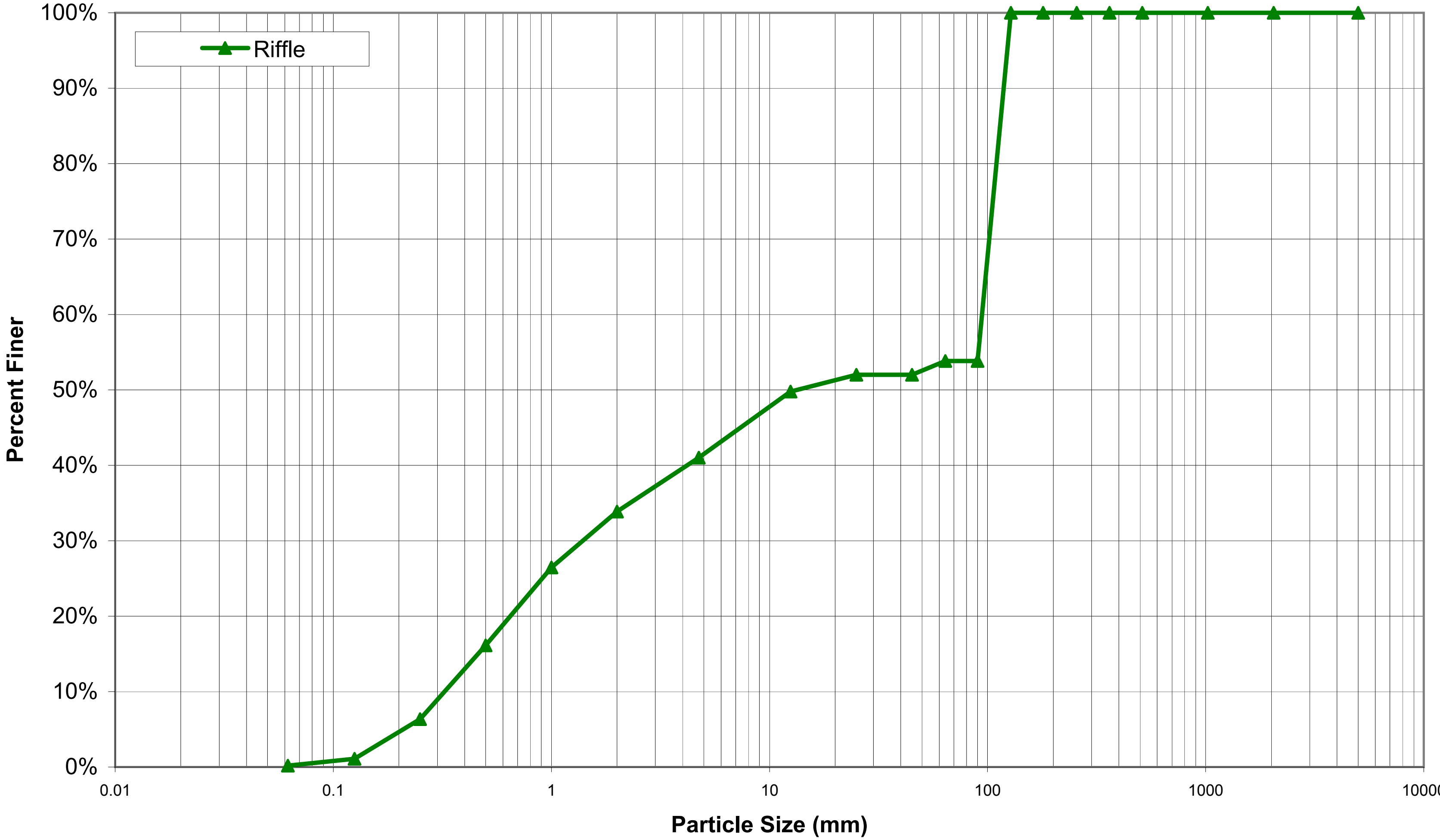


UT to Spencer Creek
Reach 1 Riffle
Particle Size Distribution
Riffle
Percent Finer
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)

UT to Spencer Creek
Reach 1 Pool
Particle Size Distribution



UT to Spencer Creek
Reach 1 Totals
Particle Size Distribution



Appendix D

Site Photographs

Existing UT on the Hurley property.

Existing active wetland area on the Hurley Property

Grazing along the stream corridor on the Hurley property.

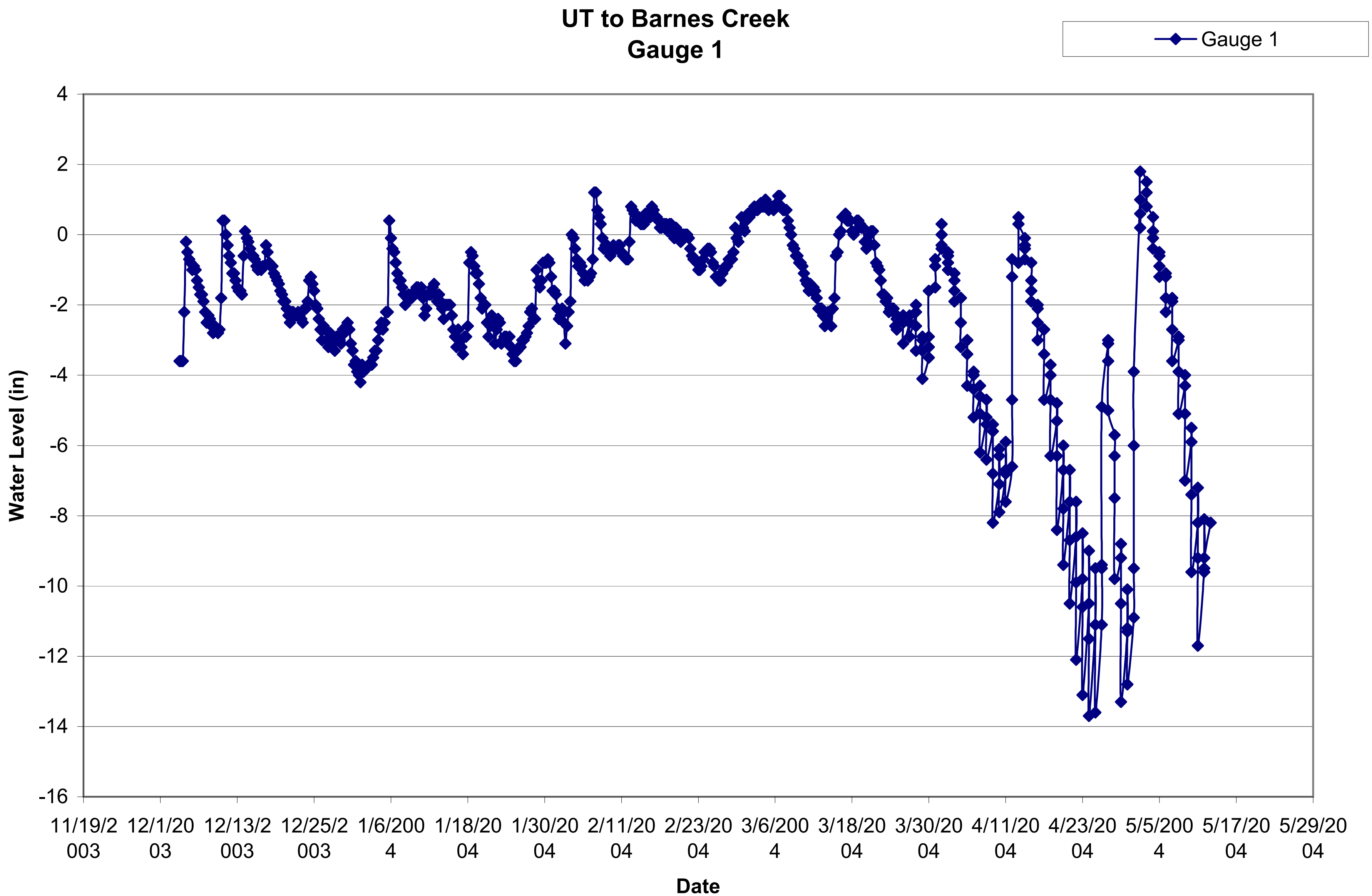
Localized stream overwidening on the Hurley property

The UT on the Harris Property, overgrown with privet.

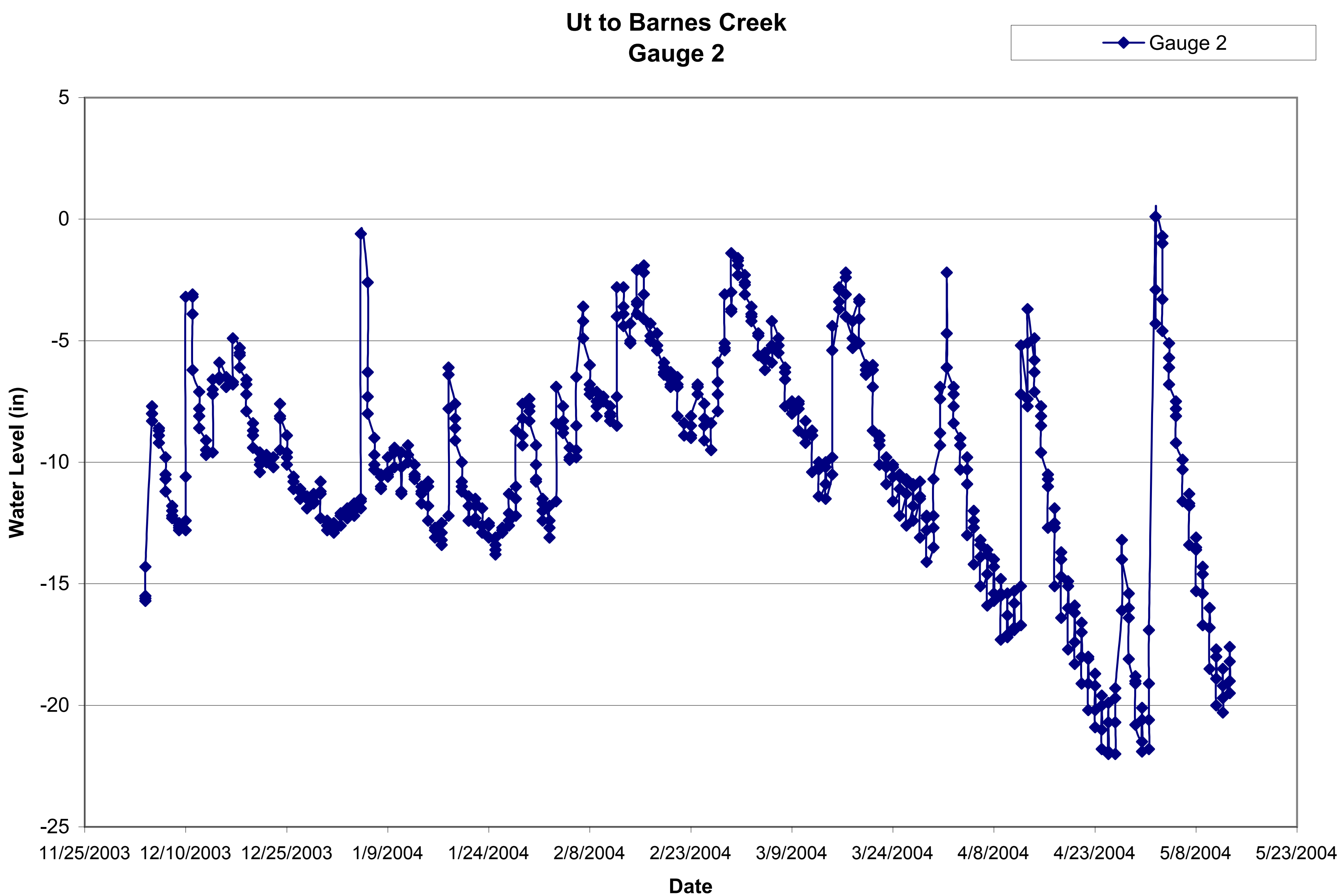
Bank erosion on a small tributary on the Harris property.

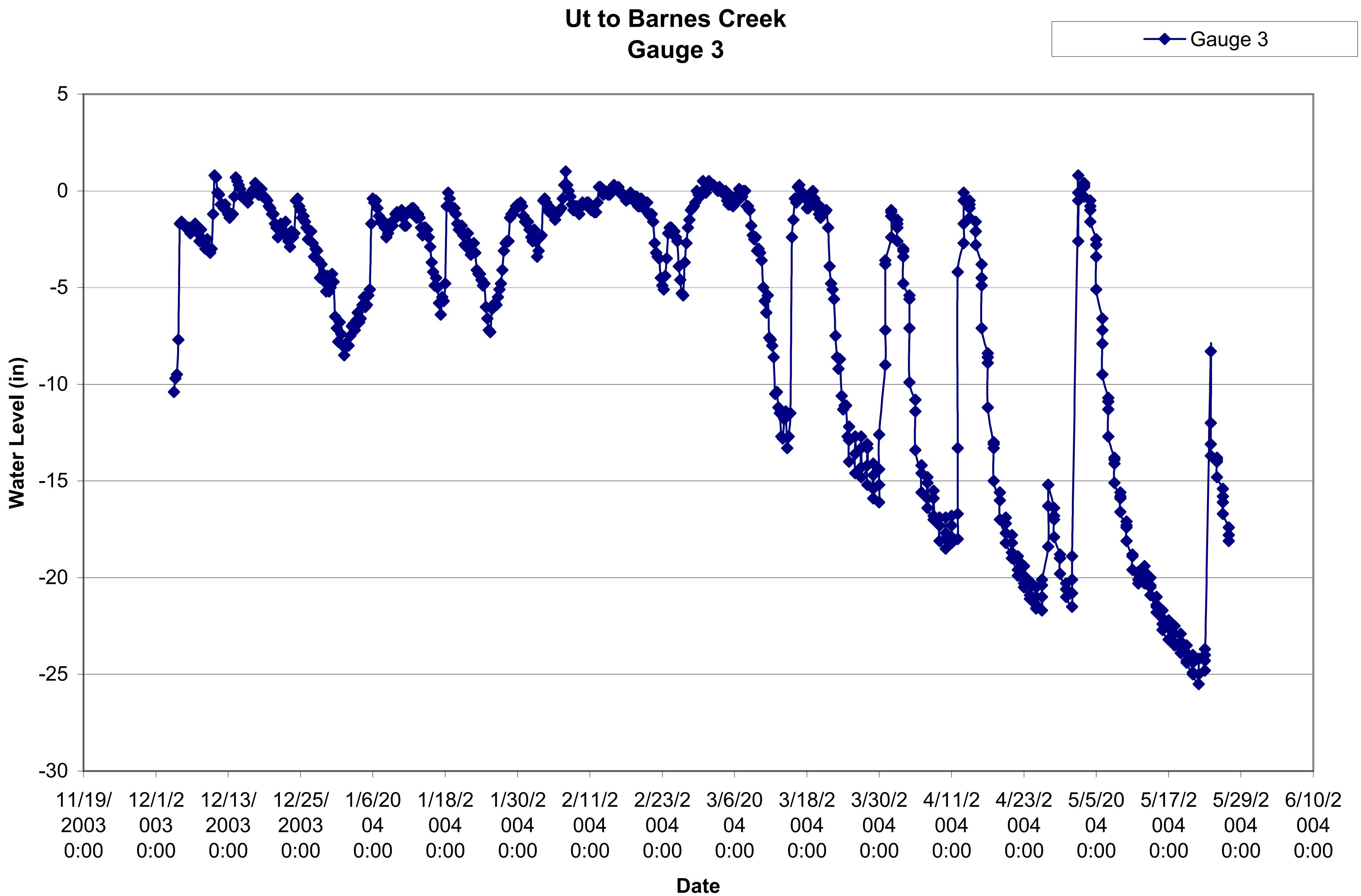
Appendix E

Groundwater Monitoring Well Data

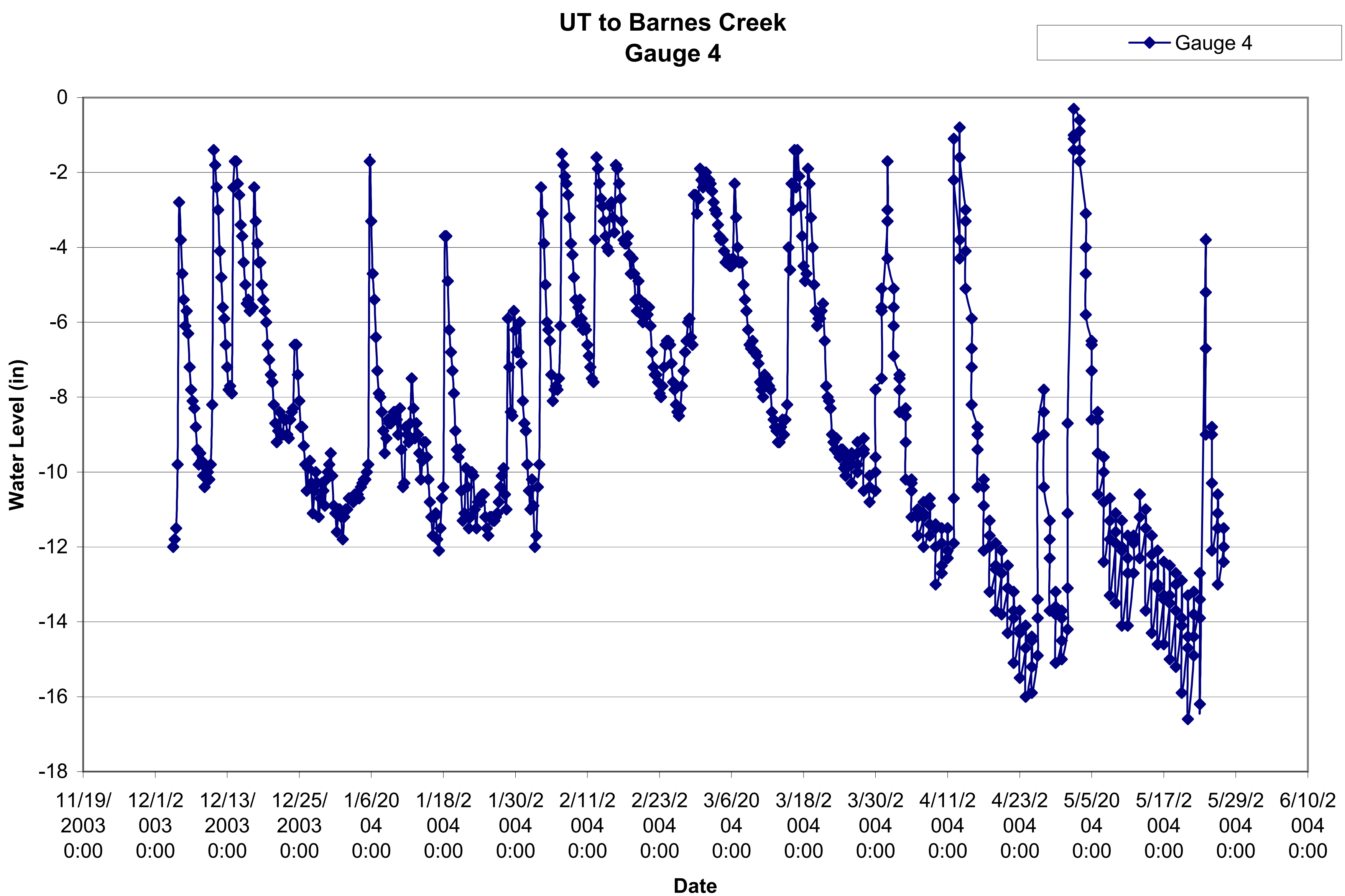


UT to Barnes Creek
Gauge 1
Gauge 1
Water Level (in)
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
11/19/2003
12/1/2003
12/13/2003
12/25/2003
1/6/2004
1/18/2004
1/30/2004
2/11/2004
2/23/2004
3/6/2004
3/18/2004
3/30/2004
4/11/2004
4/23/2004
5/5/2004
5/17/2004
5/29/2004
Date

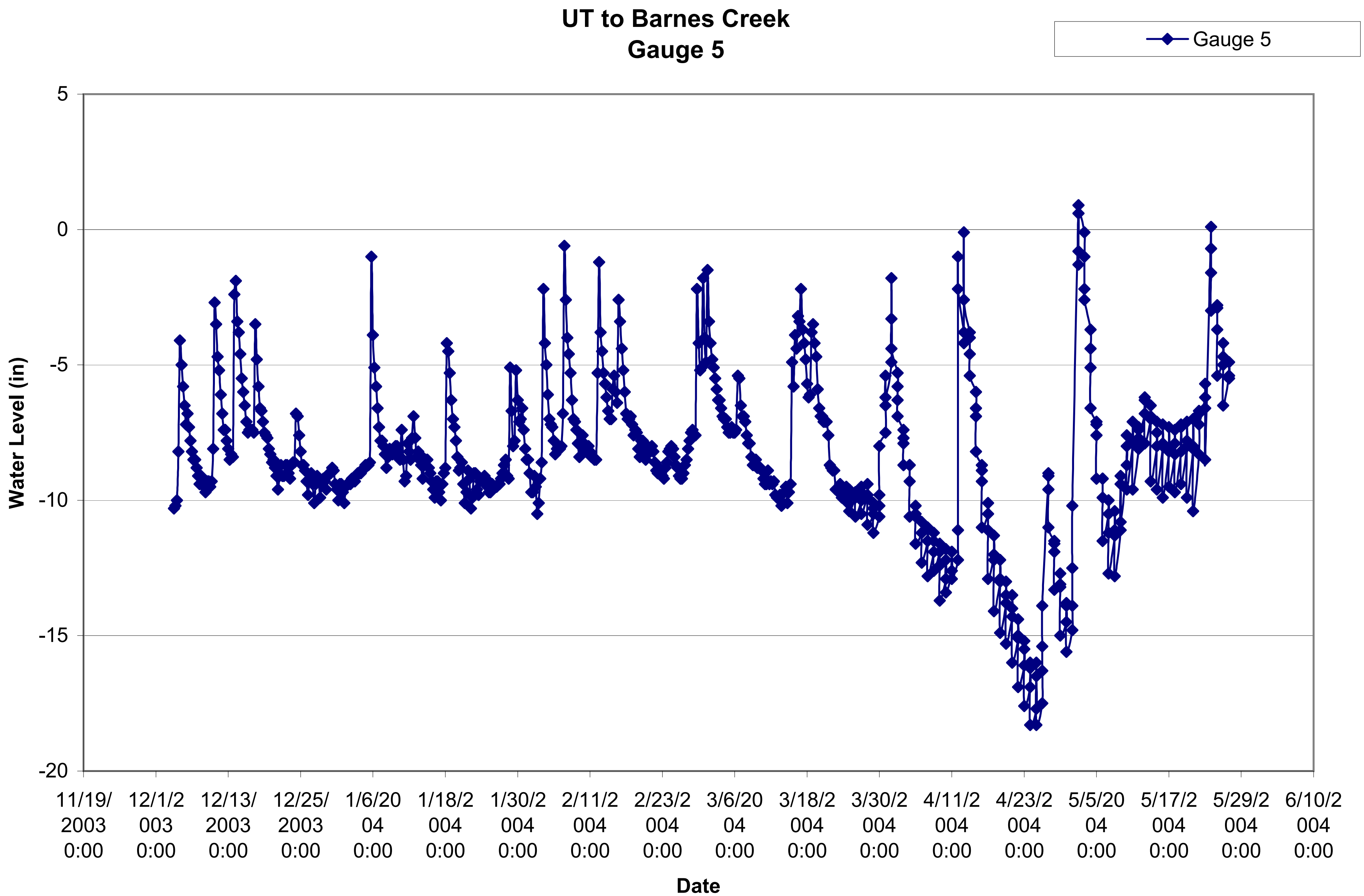

Ut to Barnes Creek
Gauge 2
Gauge 2
Water Level (in)
5
0
-5
-10
-15
-20
-25
11/25/2003
12/10/2003
12/25/2003
1/9/2004
1/24/2004
2/8/2004
2/23/2004
3/9/2004
3/24/2004
4/8/2004
4/23/2004
5/8/2004
5/23/2004
Date

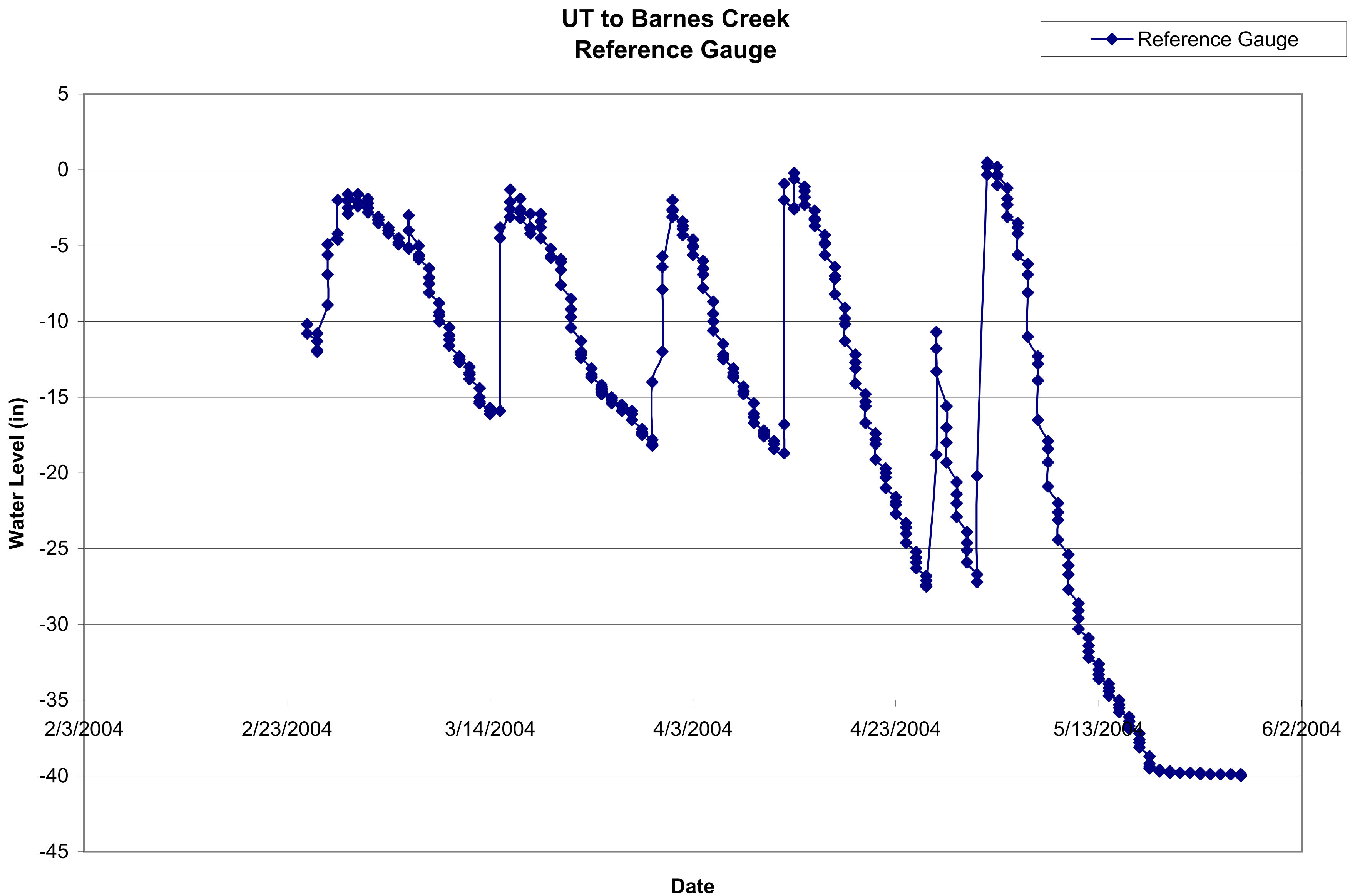


Ut to Barnes Creek
Gauge 3
Gauge 3
Water Level (in)
5
0
-5
-10
-15
-20
-25
-30
11/19/2003 0:00
12/1/2003 0:00
12/13/2003 0:00
12/25/2003 0:00
1/6/2004 0:00
1/18/2004 0:00
1/30/2004 0:00
2/11/2004 0:00
2/23/2004 0:00
3/6/2004 0:00
3/18/2004 0:00
3/30/2004 0:00
4/11/2004 0:00
4/23/2004 0:00
5/5/2004 0:00
5/17/2004 0:00
5/29/2004 0:00
6/10/2004 0:00
Date



UT to Barnes Creek
Gauge 4
Gauge 4
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
Water Level (in)
11/19/2003 0:00
12/1/2003 0:00
12/13/2003 0:00
12/25/2003 0:00
1/6/2004 0:00
1/18/2004 0:00
1/30/2004 0:00
2/11/2004 0:00
2/23/2004 0:00
3/6/2004 0:00
3/18/2004 0:00
3/30/2004 0:00
4/11/2004 0:00
4/23/2004 0:00
5/5/2004 0:00
5/17/2004 0:00
5/29/2004 0:00
6/10/2004 0:00
Date


UT to Barnes Creek
Gauge 5
Gauge 5
Water Level (in)
5
0
-5
-10
-15
-20
11/19/2003 0:00
12/1/2003 0:00
12/13/2003 0:00
12/25/2003 0:00
1/6/2004 0:00
1/18/2004 0:00
1/30/2004 0:00
2/11/2004 0:00
2/23/2004 0:00
3/6/2004 0:00
3/18/2004 0:00
3/30/2004 0:00
4/11/2004 0:00
4/23/2004 0:00
5/5/2004 0:00
5/17/2004 0:00
5/29/2004 0:00
6/10/2004 0:00
Date


UT to Barnes Creek
Reference Gauge
Reference Gauge
Water Level (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
2/3/2004
2/23/2004
3/14/2004
4/3/2004
4/23/2004
5/13/2004
6/2/2004
Date

Appendix F

Benthic Macroinvertebrate Data

Benthos Data for UT to Barnes Creek Collected on December 16, 2003

SPECIES	Tolerance Values*	Feeding Group**	Site 1 Reference	Site 2	Site 3
ANNELIDA					
Oligochaeta		**CG**			
Tubificida					
Naididae		**CG**			
Nais communis	**8.8**	**CG**	8	2	
Tubificidae w.h.c.	**7.1**	**CG**	1		
Hirudinea	***8**	**P**	1		
ARTHROPODA					
Crustacea					
Isopoda					
Asellidae		**SH**			
Caecidotea sp.	**9.1**	**CG**			1
Amphipoda					
Crangonyx sp.	**7.9**	**CG**	12	1	
Insecta		**P**			
Ephemeroptera		**CG**			
Baetidae					
Baetis sp.	***4**	**CG**	3		
Baetis pluto	**4.3**	**CG**		23	
Centroptilum sp.	**6.6**	**SC**	1	12	
Diphetor hageni	**1.6**	**CG**	1		
Ephemerellidae		**SC**	1		
Eurylophella sp.	**4.3**	**SC**		1	2
Heptageniidae		**CG**			
Leucrocuta sp.	**2.4**	**SC**	6	2	1
Stenacron interpunctatum	**6.9**	**SC**	1		
Stenonema modestum	**5.5**	**FC**	61	18	15
Leptophlebiidae					
Leptophlebia sp.	**6.2**	**CG**		16	3
Odonata		**P**			
Aeshnidae		**P**			
Boyeria vinosa	**5.9**	**P**	4		3
Calopterygidae		**P**			
Calopteryx maculata	**7.78**	**P**	2	1	1
Coenagrionidae				1	
Plecoptera		**P**			
Capnidae		**P**			
Allocapnia sp.	**2.5**	**P**	13	5	
Nemouridae	***2**	**SH**	1		
Perlidae		**P**			

SPECIES	Tolerance Values	Feeding Group	Site 1 Reference	Site 2	Site 3
Acroneuria abnormis	**2.1**	**P**	1		
Eccoptura xanthenes	**3.7**	**P**	10		11
Perlodidae					
Diploperla duplicata	**2.7**	**P**	14		
Isoperla sp.		**P**	4	30	2
Taeniopterygidae					
Taeniopteryx sp.	**5.37**	**SH**	10	3	1
Megaloptera					
Corydalidae		**P**			
Nigronia serricornis	**5**	**P**	7		1
Trichoptera					
Calamoceratidae		**SC**			
Anisocentropus pyraloides	**0.9**		3		
Hydropsychidae		**FC**			
Cheumatopsyche sp.	**6.2**	**FC**	26	42	8
Diplectrona modesta	**2.2**	**FC**	5		1
Hydropsyche betteni gp.	**7.8**	**FC**	3	3	9
Leptoceridae					
Ceraclea sp.	**2**	**CG**	1		
Limnephilidae					
Pycnopsyche sp.	**2.5**	**SH**	2		
Philopotamidae		**FC**			
Chimarra aterrima	**2.8**	**SH**	1		1
Dolophilodes sp.	**0.8**	**P**	3		
Psychomyiidae					
Lype diversa	**4.1**	**SC**			1
Rhyacophilidae		**P**			
Rhyacophila carolina	**0**	**P**	2		
Coleoptera					
Elmidae		**SC**			
Dubiraphia vittata	**4.1**	**SC**	1		
Optioservus sp.	**2.4**	**SC**	2		
Psephenidae					
Ectopria sp.	**4**	**SH**	1		
Psephenus herricki	**2.4**	**SC**	3		
Ptilodactylidae					
Anchytarsus bicolor	**3.6**	**SH**	6		
Diptera		**P**			
Chironomidae					
Conchapelopia sp.	**8.4**	**P**	20	4	
Corynoneura sp.	**6**	**CG**	1		
Cricotopus sp.	**7**	**CG**	4		
Diplocladius cultriger	**7.4**	**CG**			1

SPECIES	Tolerance Values	Feeding Group	Site 1 Reference	Site 2	Site 3
Labrundinia sp.	**5.9**	**CG**	2		
Microtendipes pedellus gp.	**5.53**	**P**	7	3	1
Orthocladius sp.	**4**	**CG**	1		
Parachaetocladius sp.	**0**	**CG**	6		
Parametriocnemus sp.	***4**	**CG**	8	15	4
Paratendipes sp.	**5.1**	**CG**	1		
Phaenopsectra punctipes gp.	**6.5**	**SH**	3		
Polypedilum flavum	**4.9**	**CG**	10	1	1
Polypedilum fallax	**6.4**	**CG**	2		
Psectrocladius sp.	**3.6**	**CG**	1		
Rheotanytarsus sp.	**5.9**	**CG**	12	2	3
Stenochironomus sp.	**6.5**	**SH**	1		1
Tanytarsus sp.	**6.8**	**CG**	6	3	
Tribelos sp.	**6.3**	**CG**		4	1
Tvetenia bavarica gp.	**3.7**	**P**	3	10	
Empididae	**7.6**				
Hemerodromia sp.	**6**	**P**			2
Simuliidae		**FC**			
Prosimulium sp.	**6**				3
Simulium sp.	**6**	**CG**	1	10	
Tipulidae					
Dicranota sp.	**0**	**P**		5	
Tipula sp.	**7.3**		13	5	11
TOTAL TAXA RICHNESS			**54**	**26**	**26**
EPT TAXA RICHNESS			**23**	**11**	**12**
BIOTIC INDEX			**4.96**	**5.17**	**5.56**
EPT BIOTIC INDEX			**3.74**	**4.81**	**4.83**
EPT ABUNDANCE			**91**	**71**	**36**

* Tolerance Values ranges from 0 (least tolerant to organic pollution) to 10 (most tolerant to organic pollution).

** Functional Feeding Group: CG = Collector-Gatherer, FC = Filterer-Collector, OM = Omnivore, P = Predator, SC = Scraper, SH = Shredder,