The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

Upper White River Basin Monitoring Program
Geomorphic Channel Assessment
Year 1 (2008-2009)

River Channel Stability and Sediment Characteristics in the Upper White River Basin

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EXECUTIVE SUMMARY

Fluvial geomorphology is the subfield focused on understanding why rivers look as they do--to understand their history and behavior and predict future changes. Geomorphic river monitoring involves the collection and analysis of scientific data describing channel characteristics and riparian conditions to evaluate channel form, sedimentation, and stability to achieve resource management goals. The geomorphic condition of the channel is related to water quality problems in several ways. First, channel assessments quantify the degree of fine-sediment deposition in the channel. Fine-sediment is a major cause of water quality problems and can severely limit some water uses such as recreation and habitat. Second, they can provide a link between watershed source areas and downstream channel instability. Channel and water quality problems can result from both hydrologic disturbances in the upper watershed and local influence of reach instability and sedimentation. Third, channel erosion and sedimentation can itself be a source of water quality impairment. High concentrations of silt and clay in the water column and deposited on the channel bed is a water quality problem. Fourth, aquatic life and habitat condition is related to both water quality (chemistry and level of pollutants) and physical channel structure (bed form and sediment characteristics). Therefore, channel assessments provide information on the physical attributes of streams that improve confidence in biological monitoring interpretations. And, finally, sediment is often involved in the cycling of water contaminants such as metals and nutrients and so sediment itself is a carrier or source of water pollution in some streams.

In summer 2009, geomorphic channel assessments were completed for 10 sites in the Upper White River Basin in support of a long-term water quality monitoring program implemented by the Upper White River Basin Foundation. This report describes the results of these assessments. At each site (see table below), information was collected on slope and pool conditions, channel capacity and sediment transport, degree of bank erosion, occurrence of bar and floodplain features, and sediment size and distribution. The channels examined were generally typical of Ozarks rivers and tend to have narrow valleys and strong bedrock control near the surface. This valley condition tends to limit meandering and excessive bank erosion along many, but not all, river segments.

A variety of stability and sediment indicators were examined to evaluate geomorphic condition and four key metrics are used to evaluate channel stability. Fine sediment on the channel bed (FSD) (as the % of total channel area covered) describes the deposition rate of sand- and silt-sized sediment within the reach. High values indicate a local sediment source or conditions conducive to sedimentation and can increase water temperature, contain absorbed contaminants, and foul aquatic habitats. Relative bed stability (RBS*) describes the degree to which the channel can transport the imposed gravel or cobble load and whether or not there is ample supply of coarse-sediment to create healthy aquatic habitat. The optimum value for this index is 1 with values above and below indicating unstable channel bed conditions. Unstable or unbalanced bed sediment condition can cause bed erosion which can release more sediment to the channel. The riffle stability index (RSI) compares the sediment size distribution of riffle areas to mobile bar deposits. If riffle sediment is similar in texture to bar material, then riffles are considered to be relatively mobile with finer sediment in-filling the pore spaces between cobbles which is poor habitat for aquatic life. The final metric is a composite stream health indicator used by the USEPA to rate streams for biological and physical habitat surveys (rapid assessment tool).

The results of the ratings are shown below (A= good and C= Fair). The overall score is determined as the middle value of the three indicators listed. The RSI was not included in this final scoring since it was relatively high for all sites, and would not have much influence on the scoring. A and B streams are in fairly good condition, but C streams are lacking in one or more areas. At these sites, riffles are affected by the addition of excess fine gravel that fills in pore spaces and increases the mobility of bed substrate. However, channel processes can adequately erode and deposit bed sediment and therefore these channels are conditionally stable. This condition decreases the chances for bank erosion and bed scour in most of these reaches. The C values for RBS* are related to bedrock outcrops in the reach that limit sediment availability and are not caused by excess bed sediment deposition. Fine-sediment deposition (FSD) is a problem at several reaches suggesting that there are upstream sources of sediment in excess of natural loads, possibly coming from bank erosion or tributary inputs. Rapid channel assessment scores show that these reaches range from good to fair and these values generally correlate with FSD and RBS*.

These results suggest that excess fine gravel inputs (high RSI) and fine-grained sediment deposition (high FSD) are the main geomorphic indicators of concern. The bed is relatively stable and bank erosion indexes (discussed in text) indicate only localized problems. However, there are some reaches where bank erosion is obviously a problem, like at the James River-Galena site, and other places not evaluated during this study. It is not clear to what degree bank erosion is affecting fine-sediment loads at present. Fine-grained sediment is a pollutant itself and is a source of phosphorus to streams. Fine-sediment input is a non-point source problem and efforts to control runoff from upstream sediment source areas should be considered including bank stabilization, improved grazing systems, and urban runoff controls. Excess coarse-grained (fine gravel) sediment is also a problem in these reaches. Riffle units are being affected by in-filled pore spaces or embeddedness. This condition decreases the effectiveness of natural water filtering and quality of aquatic habitats for macroinvertebrates. It is likely that some of the biological impairment observed in stream index scores may be the result of local sediment influence as well as upstream watershed sources of disturbance (water quality and hydrology). This coarse-sediment problem stems from a long history of human disturbance in the Ozarks and pulses of gravel released to rivers from hill slope and bank storages as described by studies by the USGS several years ago. Coarse-sediment loads need to be monitored to better understand there transport patterns and effects on channel stability and aquatic life.

	FSD	**RBS***	**Rapid**	**Overall**
Yocum Creek near Oak Grove (AR)	A	A	A-	A
Swan Creek near Swan (MO)	A	B	A	A
James River at Boaz (MO)	A	C	A	A
Flat Creek below Jenkins (MO)	B	A	A-	A-
Finley Creek below Riverdale (MO)	B	A	B+	B+
Kings River near Berryville (AR)	B	A	B+	B+
White River near Fayetteville (AR)	B	B	B+	B
James River at Galena (MO)	D	A	C+	C+
War Eagle Creek near Hindsville (AR)	D	C	B	C
West Fork WR east of Fayetteville (AR)	D	C	C-	C-

Upper White River Basin Monitoring Program
Geomorphic Channel Assessment- Year 1: 2008-09

By: Robert T. Pavlowsky, Ph.D., and Derek J. Martin, M.S.

INTRODUCTION

The Upper White River Basin Foundation (UWRBF) implemented a water quality monitoring program in the Upper White River Basin in 2008 (www.whiteriverbasin.org). The goal of this program is to provide a long-term and consistent source of water quality and stream health information on the major rivers and tributaries draining into the upper portion of the White River including Beaver Lake, AR, Table Rock Lake, MO, and Bull Shoals Lake, MO/AR. It involves several partners including the United States Geological Survey (USGS), University of Arkansas-Fayetteville, Bull Shoals Field Station (BSFS) at Missouri State University-Springfield (MSU), and Ozarks Environmental and Water Resources Institute (OEWRI) at MSU. Annual reports will be published by UWRBF on the status and trend of key water quality indicators throughout the watershed including geology and land use/cover, water quality (chemistry, bacteria, and nutrients), geomorphic or physical channel stability, and aquatic invertebrate communities. The information will be disseminated to the public through a qualitative "A-to-F" rating scale that grades the condition of individual stream segments.

The Ozarks Environmental and Water Resources Institute at Missouri State University (oewri.missouristate.edu) is responsible for protocol development, data collection, and trend analysis to support the geomorphology and watershed source monitoring components of the basin-wide stream monitoring program in the Upper White River Basin in Missouri and Arkansas (Figure 1). The purpose of this report is to familiarize the reader with geomorpholgical assessments and describe the results of the first year of monitoring. The specific objectives are:

1) Provide background information and rationale for geomorphological monitoring;

2) Document the rationale, methods, and analysis used in the Geomorphological River Assessment Protocol (GeoRAP);

3) Develop a GIS database with the watershed characteristics for all monitoring sites;

4) Present the results and trends for Year 1 monitoring for the following:
    (a) Rapid channel assessments
    (b) Geomorphology-based channel monitoring
    (c) Fine-grained sediment monitoring (results reported in future report)

GEOMORPHOLOGICAL ASSESSMENT OF RIVERS

Geomorphology is the scientific study of landforms including their spatial distribution, composition, and processes that formed them. Fluvial geomorphology is the subfield focused on understanding why rivers look as they do: to understand their history and behavior and predict future changes. Fluvial geomorphology is practiced by geologists, geographers, engineers, biologists, and landscape architects. Geomorphic systems define a group of landform components linked by transfers of energy and mass through the landscape under the influence of the forces of gravity, tectonic movement, and solar heating. Geomorphic processes are the physical and chemical interactions between landforms and the natural forces acting on them. In river systems, some important processes are mass-wasting; sediment erosion, transport, and deposition; flooding; bank erosion; and vegetation growth. It is important to recognize that a river system is composed of both channel and floodplain areas that are directly connected during overbank floods.

Geomorphological river monitoring involves the scientific analysis of channel/floodplain characteristics and riparian/aquatic habitat conditions to evaluate physical status and stability of a channel for the purposes of resource management, restoration ecology, and nonpoint pollution source control (MacDonald et al., 1991; Bauer and Ralph, 1999; USEPA, 1999; Parsons et al., 2000; Montgomery and MacDonald, 2002). Sites are generally sampled from a variety of locations based on local conditions, drainage network coverage, or program goals. Long-term monitoring programs typically involve repeat field visits over 1-5 year intervals at 10 to 30+ permanent sampling sites distributed throughout a watershed. The sampling unit is usually a channel reach that is approximately 20 channel widths in length to ensure that most natural variations in channel form and sediment conditions are included in the evaluation. Watershed characteristics of the drainage areas above each sample reach are usually determined using GIS applications. Historical aerial photography is often used to examine the previous condition of the stream and to map riparian vegetation cover and human activities.

Watershed Concept and Influence

Any location along a river is affected by the upstream drainage area that contributes water and sediment to it during runoff periods. The land area that collects and funnels water from surrounding hillsides to a single downstream point along a river is called a watershed. The drainage area of a river is a measure of watershed size as it is bounded by topographic divides on all sides. Watershed characteristics such as geology, soils, climate, relief, vegetation, land use, and hydrology directly affect the form and behavior of a river. Therefore, the geomorphic condition exhibited at any channel location must be considered within the context of its location within the drainage network and the intensity of upstream disturbances (Montgomery et al. 1995).

A hierarchical classification system is typically used to divide the watershed into progressively smaller spatial units called process zones, valley segments, reaches, and channel units (Table 1) (Schumm, 1981; Frissell, et al., 1986; Montgomery and Buffington, 1998). These spatial units are linked by downstream fluxes of water, sediment, and wood which can fluctuate in temporal frequency producing a complex pattern of channel forms and aquatic habitat distributions (Schumm, 1977, 1981; Montgomery and MacDonald, 2002).

Process zones are described based on ability to erode or transport sediment (Schumm, 1977, 1981; Montgomery and Buffington, 1997, 1998). Source zones include high elevation areas in the watershed where runoff and sediment load is generated and delivered to the channel system (Montgomery and

Buffington, 1998). Transport zones occur along intermediate rivers where sediment and water are conveyed downstream. Deposition in floodplain and bar deposits can occur in lower gradient segments. Transport reaches usually contain bedrock, cascade, or step-pool channel types (Montgomery and Buffington, 1998; Figure 2). Response zones are downstream locations where sediment deposition and reworking occurs within floodplains, alluvial plains, and deltas. Excessive sediment deposition can occur on valley floors that are unconfined by bluffs or terraces and/or where base level control by water bodies or resistant bedrock causes reduction in slope. Response reaches usually contain dune-ripple, riffle-pool, or plane-bed channel types (Montgomery and Buffington, 1998; Figure 2).

Process zones are further subdivided into valley segments based on geology, valley width, and bottom soils. Segments range in length from 100 m to 10,000 m and usually begin and end where large tributaries enter the main valley (Montgomery and Buffington, 1998). Valley segments are further divided into channel reaches with similar channel features and typically range in length from 10 m to 1000 m or 20 to 40 channel widths in length (Montgomery and Buffington, 1998). Reaches are classified according to "channel type" as either colluvial, bedrock, alluvial, or forced-alluvial channels (Table 1; Figure 2) (Montgomery and Buffington, 1997, 1998). Different channel types vary in their sensitivity and response to variations in inputs or local conditions. For example, riffle-pool channels are considered extremely sensitive to increased supply of coarse or gravelly sediment, while plane-bed channels are less so (Montgomery and MacDonald, 2002). Channel reaches are finally subdivided into geomorphic channel units (GCUs, after Fitzpatrick et al. 1998) that are up to several channel widths in length (Montgomery and Buffington, 1998). These habitat-scale features are generally classified as riffles, pools, and bars according to topography, sediment characteristics, and effect on flow conditions (e.g. depth and velocity).

Fluvial Process-Response System

Geomorphic assessment requires an understanding of the interconnections among watershed components and how different fluvial processes influence the stability of downstream reaches. Stressor or input variables include the land use/land cover characteristics, natural or anthropogenic disturbance regimes, and management practices that affect runoff processes and soil/sediment mobility on the watershed surface (Table 2). These variables reflect changes in the resistance of the watershed surface that affect runoff rates and sediment supply to the channel system. Vector or transfer variables include inputs of water, sediment, and wood to the channel network due to stressor influence. Input effects are transferred downstream though time and interact with a channel reach as flood discharge, fine- or coarse-grained sediment load, and large woody debris. In undisturbed watersheds, vector variables tend to remain relatively constant and the present channel form is maintained. However, if significant changes in the intensity of vector variables occur, channel behavior may become erratic and unstable.

Response or output variables identify the geomorphic form of the channel or floodplain within the reach due to the interaction of varying vector loads with local valley conditions. Response variables include channel form (i.e. width, depth, and slope) and local erosion/deposition patterns (channel units, bar forms, and floodplain deposits) due to variations or pulses in sediment flux. Condition variables account for the local influence of valley segment geology (confinement, slope) and resistance factors (flow obstructions, bed/bank material, and riparian vegetation) on channel morphology (Table 2). They may act to inhibit or enhance the channel's response to vector inputs. The influence of channel condition variables can be: (i) "permanent" such as in narrow valleys or around bedrock obstructions; (ii) "semi-permanent" such as when a migrating head cut gradually causes bed slope adjustments, and (iii) “temporary” such as when accumulations of large woody debris and log jams shift location over seasonal cycles (Table 2).

Geomorphic indicators usually describe channel and floodplain forms that are responsible for flow energy dissipation (Barbour et al. 1999) and/or capable of adjusting to variations in discharge and sediment loads at timescales of years to decades (Montgomery and MacDonald, 2002) (Table 3). Forms of energy dissipation along a river include: channel meandering, riffle/pool undulations, channel bar deposition, vegetation growth, and presence of low floodplains. All else being equal, a river with a moderate to high frequency of these features will tend to be stable. Bank erosion and instability will occur when higher energy flows can attack bed and banks where sufficient energy dissipation is lacking. Watershed-scale inputs, along with local-scale riparian vegetation and geomorphic processes control the physical structure of a river system and determine the form of the channel such as the degree of meandering, occurrence of pools and riffles, size of bed substrate, height and angle of the banks, and location of large woody debris (Tables 2 & 3).

Channel Equilibrium

An alluvial channel constructs its channel bed and banks with the sediment load that it carries. Through processes of erosion, transportation, and deposition, river form can adjust to the inputs of discharge and sediment delivered to it from the watershed. Geomorphic channel variables that respond to changing inputs include width and depth, sinuosity and pattern, bed sediment size and sorting, bar forms, and hydraulic roughness (Rosgen, 1994). Given relatively constant conditions of discharge and sediment load, the stream channel tends toward a stable channel condition. This balanced condition of the channel is generally referred to as “equilibrium.” Equilibrium refers to the tendency of the channel to maintain a predictable, relatively stable form that transports the imposed sediment load most efficiently downstream. In the equilibrium situation, the amount of sediment entering the reach will equal the amount of sediment leaving the reach, the mass of erosion will equal the mass of deposition, and the sediment budget is assumed to be in balance over periods of years to decades, if not longer. The specific form of an equilibrium channel can vary geographically based on regional geology, climate, and vegetation.

The bankfull channel represents the primary “equilibrium” landform used for geomorphic analysis of fluvial systems (Rosgen, 1996). Alluvial channels in most humid regions that are free to migrate laterally and deposit sediment form a channel cross-section to accommodate the range of flows that most effectively transports the sediment load passing through it (Simon and Castro, 2003). The bankfull channel forms a cross-section area necessary to convey the dominant discharge which is typically represented by a flood with a 1 to 3 year reoccurrence interval (Wolman, 1978, Rosgen, 1996). Bankfull floods transport sediment loads most effectively at the point where the flow begins to widen and spread out over the active floodplain in relatively undisturbed watersheds (Rosgen, 1996; Simon and Castro, 2003).

Bankfull width and depth values typically increase logarithmically downstream due to progressive increases in drainage area and input loads. The ratio of width to depth in a bankfull channel typically increases in bed load-dominated streams to >12. Active floodplains initially form along alluvial rivers at the elevation of the bankfull stage and then accrete vertically over time due to fine-grained overbank deposition (Wolman and Leopold, 1957). The bankfull stage of low-gradient, gravel bed rivers is often identified at the top surface of point or alternate bars at the maximum height of gravel deposition in the channel (Rosgen, 1996, 2006).

There is ample evidence to show that alluvial channels tend toward a form that is in close balance with watershed inputs at timescales of 10 and 50 year periods. Consistent relationships are known to occur between channel morphology and drainage area in many regions, even in watersheds affected by human activities (Rosgen, 1996). Recovery of an unstable reach may occur as its adjusted form comes closer to being in equilibrium with the imposed discharge and sediment regime. If the disturbance is corrected or reduced, the channel may recover to its previous form over time. Recovery periods for rivers can range greatly and it is possible that a river may never reach a "same as before" equilibrium again since recovery periods can range from decades to centuries or more in medium- to large-sized watersheds ($<10{,}000\ km^2$).

Ecological and Water Quality Assessments

Geomorphic processes dictate the physical structure and distribution of stream habitat units. Thus, channel morphology and disturbance regime provide the template for biological communities and occurrence of aquatic species (Montgomery, 1999; Parsons et al., 2000).
Stream habitat indicators are sensitive to important environmental stressors within the watershed including hydrologic alteration, habitat/land use conversion, habitat/vegetation fragmentation, climate change, and sedimentation (MacDonald et al. 1991; Bauer and Ralph, 1999; USEPA, 1999; Young and Sanzone, 2002). Hence, recent plans to provide a framework for ecological assessments by federal agencies incorporate the wide use of geomorphological indicators. The USEPA Science Advisory Board proposed a systematic framework to evaluate ecosystem condition based on six "essential ecological attributes," two of which are directly related to stream geomorphology and aquatic physical habitat assessments (Young and Sanzone, 2002). The "landscape condition" attribute includes indicator variables for channel habitat types, composition, pattern, and structure. The "hydrology and geomorphology" attribute includes indicator variables for (i) channel complexity, channel-floodplain connections, and physical habitat distribution; (ii) channel substrate type, size, and distribution patterns; and (iii) sediment supply and movement (Young and Sanzone, 2002).

Geomorphic indicators are used to support the requirements of the Clean Water (e.g. TMDLs) and the Endangered Species Acts. Useful indicators for this purpose include pool frequency and depth, large woody debris frequency, channel bed and bar substrate, stream bank condition, and riparian zone condition (Bauer and Ralph, 1999). Sediment problems in streams fall under the auspices of the Clean Water Act. Geomorphic indicators relating to bed and bank erosion, bed material size and embeddedness, channel sinuosity and slope, pool frequency and depth, and large woody debris frequency have been used to develop TMDLs for sediment impaired water bodies (USEPA, 1999). Moreover, physical habitat variables derived from geomorphic condition assessments have been used to explain variations in fish and macroinvertebrate communities in natural and disturbed streams (Short et al., 2005; Mazeika et al. 2004, 2006).

In the Ozarks where geologic controls are relatively uniform, local or reach-scale factors rather than basin-wide or large-scale characteristics tend to control aquatic populations. Doisy and Rabeni (2001) found that local slope and velocity factors best explain habitat use in the Jacks Fork River and that within segment variation of fish community composition was greater than for the river system as a whole. Similarly, Rabeni and Jacobson (1993) found that discrete physical spaces with specific hydraulic flow characteristics controlled species distribution and management options in a low gradient Ozark stream. In the Illinois River in Arkansas, Brussock and Brown (1991) found no longitudinal trends in macroinvertebrate species, concluding that a reach-level perspective was best suited for community studies. However, some studies suggest a hierarchal approach where the effects of both longitudinal/watershed factors and local segment factors need to be considered to best understand fish distribution in Ozark streams (Peterson and Rabeni, 2001a, 2001b).

NATURAL AND HUMAN DISTURBANCE IN THE OZARK HIGHLANDS

In order to interpret geomorphic data from a river, the geological setting and land use history of the watershed must be considered.

Geologic Setting and Influence

Ozark river systems are preconditioned by geologic factors to be particularly sensitive to hydrological and geomorphological changes due to riparian zone disturbances, upland and slope runoff, soil erosion, and gravel supply as evidenced by the results of studies of soil distribution and pre-settlement alluvial stratigraphy in the Ozarks (Jacobson, 2004). The Ozark Highlands Physiographic Province is underlain mainly by Paleozoic sedimentary rocks composed mainly of limestone and dolomite with lesser amounts of sandstone and shale. Several important geological aspects of the Ozark landscape that help to understand the response of the hydrology, sediment load, and channel geomorphology to disturbance are described below:

1. Surficial loess deposits. Pleistocene loess deposits cover many, but not all, upland areas of the Missouri Ozarks to a depth of 1 meter or less in most areas where it occurs. The silty material was created by glacial abrasion and transported to the area by wind from the Missouri and Mississippi River valleys. Surface soils or A-horizons formed in loess units are relatively rich in minerals and have good internal drainage properties (Jacobson, 2004).

2. Residual subsoil. Long-term weathering of carbonate rocks forms residual subsoil accumulations that are clay-rich and relatively impermeable. Where the loess topsoil is lacking or has been eroded away, runoff is generated quickly during rain events. In addition, soils formed in residual materials can contain clayey B-horizons and/or dense fragipans that further limit the percolation of overland flow. The infiltration capacity of the residual soil does not recover quickly after periods of soil erosion (Jacobson, 2004).

3. Karst Landscape. Much of the region is underlain by carbonate rocks with extensive karst development. Sink holes and caves are common in this region. Therefore, most headwater streams and upper portions of major tributaries are dry unless spring-fed.

4. Chert gravel source. The chert content of some limestone and dolomite units is relatively high. Thus, residuum accumulations formed by carbonate rock dissolution and weathering often contains large quantities of chert gravel.

5. Chert gravel supply. Colluvial deposits containing cherty gravel are stored in headwater valleys and at the base of valley slopes along larger rivers. These deposits provide an available source of gravel sediment to the river system during periods of channel instability (Jacobson, 2004).

6. Bedrock-controlled rivers. Ozark rivers are frequently located in narrow, confined valleys and are affected by bedrock control. Bed elevations are typically only a few meters above bedrock where aggradation has not occurred.

7. Flashy hydrographs. Tributary runoff can be very flashy in areas with steep relief such as along the bluffs of larger rivers, near the St. Francis Mountains in the eastern Ozarks, and in the Boston Mountains in Arkansas. These steeper areas can transport relatively large sizes of bed sediment, particularly in locations with high relief that drain the Boston Mountains (McKenney and Jacobson, 1996; Nickolotsky, 2005; Nickolotsky and Pavlowsky, 2007).

Anthropogenic Disturbance and Watershed Stressors

Anthropogenic activities have affected all three stressor inputs to the watershed: water, sediment, and wood (Panfil and Jacobson, 2001). Human activities over the past 180 years have changed the channel morphology, riparian vegetation, and gravel sediment load in the Ozark Highlands to varying degrees (Panfil and Jacobson, 2001). Sources of disturbance include historical and present land use including agriculture and urbanization, construction of road and trail networks, horse and all-terrain vehicle use, boat and raft landing access, gravel mining (past and present), bed disruption by swimmers and floaters, and engineered structures (bridges and stabilization measures). Examples of the effects of imposed stressors on channel, habitat, and water conditions in the Ozarks are summarized below:

Storm runoff and increased flows can cause accelerated soil and channel erosion and increase flood magnitude and frequency in the river system. Stream bank and soil erosion are a source of fine sediment and gravel to the stream. Stream bank erosion also leads to stream widening, reduction in channel sinuosity, and loss of canopy cover. This creates shallower, warmer habitats and lowers habitat diversity. The persistence of large floods can change the size and supply of channel bottom and bar substrates and force a change in channel type. Under relatively extreme flood regimes, erosion/scour processes may dominate the channel and also decrease the number and diversity of physical habitats. The release of more gravel to the channel can change habitat structure by filling in pools, covering riffles, and aggrading the channel bed.

Fine sediment inputs to the channel increases embeddedness and reduces pore space between gravel and cobble in riffle and pool units, which are important habitats for invertebrates and small fish. Embeddedness also inhibits flow of oxygenated waters through bed gravels. Fine grained sediment transport and sedimentation also cause water quality concerns related to turbidity, water chemistry, and sediment-borne pollutant transport (USEPA, 1999).

Accelerated gravel deposition in a stream causes the channel to become shallower, fill in pools, and reduce longitudinal roughness. Habitat diversity decreases as more gravel enters the system, glide habitats increase and pool habitats disappear. This reduces living space for pool-dependent species. Shallow streams also may have greater daily and seasonal fluctuations in water temperature. Panfil and Jacobson (2001) demonstrated that the amount of gravel in Ozark streams is positively correlated with cleared riparian buffer zones and with increased cleared land in the drainage basin. When riparian vegetation has been excessively cleared, a chain of disturbances begins that result in modified geomorphology which causes habitat loss and negative impacts to stream biota. In extreme cases, gravel deposition can cover ecologically important floodplain, back swamp, and other wetland areas rendering them unproductive.

Ozarks streams have excess gravel loads and an altered geomorphology due to watershed disturbances related to land clearing of upland and riparian areas more than 100 years ago (Saucier, 1983; Jacobson and Prim, 1994; Jacobson, 1995; Jacobson and Gran, 1999; Panfil and Jacobson, 2001; Jacobson, 2004). Geology reports from the 1800s indicate that excess accumulations of gravel-sized sediment began to occur in the channel bars and deep pools of some tributary and main-stem segments as early as the middle- to late-1800s. However, the major impact of excess gravel accumulation in the larger river valleys probably began in association with a period of extreme flooding between 1895 and 1915 (Jacobson and Primm, 1994). Historical and present-day channel, bar, and floodplain deposits commonly contain more gravel than older, pre-settlement alluvial units (Saucier, 1983; Jacobson, 2004). The reworking of these "legacy" gravel deposits and the additional release of new gravel from tributaries is causing channel instability in some Ozark rivers today. However, recent gravel bar distribution in the Buffalo River reflects the influence of present land use factors such as percent cleared land and road density (Panfil and Jacobson, 2001).

Wood inputs to the channel are important for the maintenance of valuable instream cover habitats and obstruction pools and riffles. An intact riparian vegetation corridor typically offers an ample supply of tree stems and root wads to the channel. Loss of large woody debris inputs into the stream from riparian vegetation means fewer debris jams and snags, which create flow diversity and initiate scour that forms pool habitats. However, accelerated bank erosion can release more wood to a stream than is normal as banks recede into forested area by undercutting and collapse.

Channel instability is caused by relatively rapid changes in sediment load rates and particle size and flood magnitude and frequency. Rapid geomorphic adjustments in unstable streams tend to reduce the number and diversity of micro-habitat features in the channel. Valley bottom reworking is believed to have occurred faster in the last 100 years than over the previous 20,000 years in some Ozark rivers (Saucier, 1983; Albertson et al., 1995). Channel instability is actually a secondary effect of changes in primary watershed stressers (i.e. water, sediment, wood). However, over longer periods of time, channel instability can itself become a source of sediment and wood to the channel as channel erosion releases sediment and undercuts riparian vegetation.

ASSESSMENT METHODS

Sampling Sites

Thirty sampling sites or reaches will be assessed and monitored in the Upper White River Basin (Figure 1). Fifteen "station" sites will be located at or near 15 water quality monitoring stations being operated by the USGS. Water quality data collected at these sites will be compared with geomorphological indicators and sediment geochemistry data generated in this study. In addition, 5 "upstream" sites will be located in each of the three sub-basins (James, Bull Shoals, and Beaver) for a total 15 upstream sites. The plan is to complete biological and geomorphological monitoring at 10 sites per year over a three year period. At the end of the three year cycle, the process will start again as sites are re-visited over time.

Watershed Characteristics

Variations in water quality, sediment geochemistry, macroinvertebrates, and geomorphic indicators need to be evaluated based on the geologic and land use characteristics of the watershed. A GIS database has been developed by OEWRI to organize sampling site information and evaluate watershed conditions.

This data is used for interpreting the long-term trends and databases will be updated to reflect the most current conditions. The database was initially developed by OEWRI for the Upper White River Basin by Ms. Gopala Borchelt for her MS thesis supported by a contract to Pavlowsky from the UWRBF. The Department of Geosciences at University of Arkansas-Fayetteville was also a partner on this earlier project. This database was reorganized and updated by OEWRI staff (see "Projects" at www.oewri.missouristate.edu).

Rapid Assessment: Basin Ranking of Channel Condition

The USEPA's "Rapid Bioassessment Protocol" (RBP) is used in this monitoring program to visually evaluate and rank geomorphic and hydrological conditions at all 30 monitoring sites (Barbour et al., 1999). A copy of the form as used by the Missouri Department of Natural Resources is included in the appendix section of this report (Sarver, 2003). Rapid channel assessment protocols are intended to provide basic, cost-effective channel assessment procedures for screening-level evaluations of aquatic habitat and channel condition. Rapid assessment methodologies describe or rank channel conditions based on simple field measurements, visual estimates, and judgements by workers standing in the channel or on the bank. Typically, few direct measurements are collected during rapid assessments such as tape line distance or level elevation. For reporting purposes, each method produces an index of stream health that can be compared and rated among sites.

A within-reach averaging approach is used to complete rapid assessments. Two different procedures are used based on the annual 10 site rotation schedule of monitoring sites. At the 10 sites where more intensive geomorphic assessments were completed, three glide-riffle sub-reaches were evaluated by three different workers to produce nine separate assessments per monitoring site. Workers were directed to stand in the vicinity of the riffle crest and rate channel conditions within an area of about two bankfull widths upstream and two widths downstream of the crest. The results of all nine evaluations were averaged to obtain one composite score for the reach. At the other 20 sites not selected for in-depth assessment, two workers evaluated one riffle site to yield two completed evaluation forms per site (composite scores for all sites are included in the appendix). In addition, channel width, depth, and bank heights were measured with a tape at each of the same 20 sites.

Sediment Quality: Geochemical Surveys of Fine-grained Sediment

Fine-grained sediment grab-samples are collected from active channel, bank, and bar deposits at all 30 sites. These samples are evaluated for physical properties and geochemical composition. Fine-grained sediment loads through a reach contain the physical and chemical properties of the natural bedrock and soil sources in the watershed. In addition, point and nonpoint sources can elevate the levels of contaminants such as copper, lead, zinc, and phosphorus. Previous work in the basin has shown that sediment geochemistry can be used to detect and track urban, industrial, and agricultural contaminant inputs. Sample collection, sample preparation, and analytical methods are used that have been previously tested in the James River (Fredrick, 2001), Wilson Creek (Rodgers, 2005), and Kings River (White, 2001). Sediment samples were collected from low-water channel edge or low floodplain surfaces. The samples will be air-dried and the <250 um fraction analyzed by X-Ray fluorescence, ICP-AES with hot strong acid extraction, and CNS analyzer to determine organic matter content. Pollutant concentrations will be normalized based on sediment composition and toxicity criteria to yield a relative index of contamination for each pollutant. Presently, these samples are still undergoing laboratory analysis. Hence, **the results of this assessment are reported in an addendum report released in**

January 2010. The sediment quality information derived will be compared with the water quality information reported by the Upper White River Basin Foundation's long-term monitoring program.

Channel Surveys: Geomorphologic River Assessment Protocol (GeoRAP)

The specific procedures used for OEWRI's "Geomorphological River Assessment Protocol" (GeoRAP) have been modified from those published by the USGS (Fitzpatrick et al., 1998; Panfil and Jacobson, 2001), USEPA (Kaufmann et al., 1999), and David Rosgen (Rosgen, 1996, 2006). Field assessment procedures focus on those geomorphic indicators that affect channel behavior at the valley- and reach-scales (Table 4). Field tasks are divided among the following tasks: (i) longitudinal thalweg and water surface profiles, (ii) cross-section surveys above riffle crests, (iii) large woody debris tally, (iv) bed substrate and pebble count assessment, and (v) bed and bar stability evaluation.

Field data at each river site will be collected at the reach- and channel unit-scale. A reach includes 3 to 5 riffle crests and is at least 15, typically 20, bankfull channel widths long where wadeable stream conditions occur. Three sub-reaches are evaluated at each site and composited to determine reach average conditions. Sub-reaches are about 4 to 6 channel widths long and roughly centered at each cross-section site. Permanent monuments are set at each cross-section in association with bio-monitoring locations when possible. It is anticipated that 10 different sampling reaches will be visited every year with an additional two repeat visits for QA/QC purposes to determine precision of metrics. Precision will be evaluated in two ways: (i) within-reach analysis of three sub-reaches sampled on the same day (site variability), and (ii) among-reach analysis of duplicates sampled on different days (method error).

<u>Longitudinal Profile Survey</u>

The longitudinal profile describes the channel bed topography and gradient of the monitoring reach in contrast to transects that cross the channel normal to flow direction (Figure 3). These surveys are used to describe the variations in elevation along the channel bed and to determine important geomorphic metrics such as slope, riffle crest spacing, residual pool area, and sinuosity (Harrelson, et al., 1994; Kaufmann and Robison, 1998; Simon and Castro, 2003). During the survey, rod stationing follows the deepest thread of the channel called the thalweg. While the thalweg may sometimes be located along the centerline of the channel which runs parallel to flow direction equidistant between banks, this is not always the case. The thalweg frequently shifts back and forth across the channel centerline in a periodic or erratic fashion due to forcing by riffle-pool forms, meander bends, depositional bars, and obstacles. For this reason, the length of the thalweg within the sampling reach will always be equal to or greater than the length of the channel centerline.

A total station or laser theodolite is used to survey the channel. Rod elevations are collected along the thalweg at all changes in bed slope (breaks) and channel conditions (channel units and substrate patches) with at least 3 rod measurements every bankfull width interval. The elevation of the water surface at each thalweg point is also collected by the total station. The slope of the low flow water surface is useful for interpreting the channel unit distribution. During longitudinal surveying, survey-grade GPS units are used to set survey datums to determine accurate absolute elevations at each site. All cross-section monuments are also surveyed if possible.

Rod Survey of Channel Conditions. During longitudinal profiling, a visual "rod" survey is used to collect reach information on bed substrate, bar locations, and bank conditions (Panfil and Jacobson, 2001). The worker visually evaluates the channel conditions across the channel at each rod position and this information is recorded into the total station data logger. These indicators are as follows:

1) Bed substrate class within 1 meter of the rod. Six classes are possible: bedrock, boulder (>256 mm), large cobble (128-256 mm), fine cobble+coarse gravel (16-128 mm), fine-gravel+sand (0.1-16 mm, gritty), and fines (<0.1 mm, mud). The dominant class is tallied for each rod location. Indicators are reported in percent of total observations (i.e. rod locations) in each class for the entire reach.

2) Large boulders within 5 meters of the rod. Large boulders offer cover to fish, provide resistance to flow, and often indicate bedrock close by from bed scour or bluff rockfall. There are only two options for data recording: present (observed) or absent (not observed). Indicators are reported as percent large boulders observed at each rod location for the entire reach.

3) Channel unit class. There are 8 possible classes: riffle, run, glide, and middle, side, bluff, scour, and confluence pools. These are described below. Indicators are reported in percent of total observations (i.e. rod locations) in each class for the entire reach.

4) Eroded upper bank. Both banks are tallied separately. Present (observed) is recorded if a relatively steep, raw soil cut bank is observed with little vegetation for a 5 meter distance along the channel. This indicator is reported as percent eroded banks observed on both sides of the channel at each rod location for the entire reach.

5) Bank root protection. Both banks are tallied separately. Woody roots from trees can add stability to banks that are steep and look eroded. Present (observed) is recorded if at least 50% of the bank is covered by woody roots exposed on or very near the bank surface for a 5 meter distance along the channel. This indicator is reported as percent root protected banks observed on both sides of the channel at each rod location for the entire reach.

6) Bar occurrence. Both sides of the channel are tallied separately. Present (observed) is recorded if the lower bank is protected by gravel bar deposits at least 3 meters wide and at least 0.5 bankfull depth in height. This indicator is reported as percent bar occurrence observed on both sides of the channel at each rod location for the entire reach.

Riffle-Pool Terminology. The riffle-pool morphology of the channel is used to determine reach length and provide a template for data collection. This protocol assumes that field workers have a clear understanding of riffle-pool morphology and can identify riffle and pool forms, or other alternative channel forms, in the field. A riffle-pool unit is composed of an sequence of up to five channel units arranged in downstream order as follows: (1) glide, where the bed slopes upward to meet the riffle crest at the tail end of a pool, (2) riffle crest, forms the topographic high of the riffle, (3) riffle slope, dips relatively sharply downward toward the pool below, (4) run (or race), riffle slope breaks slightly and bed material size changes before entering the pool and (5) pool, including the pool trough or deepest point in the channel (Figure 3).
Riffle crests within a reach may not always be of similar height, substrate type, and origin. Riffle crests will commonly appear as obvious breaks in the channel slope with noticeable increases in flow rate, current ripples, and substrate size. However, riffle crests can be more difficult to identify in reaches with low gradients, deep runs, well-sorted bed substrate, dry beds, plane-beds, or bar complexes or other obstructions that "drown" upstream riffle crests due to backwater or ponding effects. Typically, riffle crests are spaced at 5 to 7 bankfull widths along the channel, but shorter or longer spacing may occur in channels with higher slope, coarser substrate, and obstruction influence (Montgomery and Buffington, 1997; Simon and Castro, 2003).

Runs and glides are defined here as transition areas between riffles and pools (McKenney and Jacobson, 1996; Panfil and Jacobson, 2001). However, some workers refer use the term run to describe broader class of channel unit that includes both upper pool zones (races) and lower pool zones (glides) (Panfil and Jacobson, 2001). Runs are located at the downstream end of riffle slopes before the channel enters the main pool trough, often where the slope breaks and the channel takes on a V-shaped form. Glides are located at the downstream margin or tail of a pool where the channel shallows and slope flattens or rises upward toward the riffle crest. Shallow pools with poorly developed troughs and concentrated currents can also be classified as a glide. It is important to locate the point of the topographic low of pool troughs no matter how shallow as long as its elevation is below that of the downstream riffle crest since residual pool metrics rely on complete and accurate bathymetric profiles of the pool thalweg.

Residual Pool Concept. This protocol uses "residual" pool measurements to quantify length and depth of pool channel units in the sampling reach (Lisle, 1987; Kaufman et al., 1999; Panfil and Jacobsen, 2001). Residual pool stage is precisely defined by the expected water surface at the elevation of the channel thalweg as it crosses the downstream riffle crest (Figure 3). It is assumed to indicate the maximum depth to which the pool can fill before it begins to pour over the downstream riffle. Residual pool length is measured along a level horizontal line from the riffle crest back upstream, across the pool, and to the intersection with the bed of the riffle slope or run. Maximum residual pool depth is measured as the difference between the bed elevations at the riffle crest and the deepest point in the upstream pool. Residual pool length and depth are based on topographic surveys of the bed, not just by visual judgements of water flow depth and velocity. Thus, residual pool measurements contain much less error for habitat assessments than hydrological pool stage observations that vary with season, storm occurrence, and worker experience or bias (Kaufman et al. 1999; Bauer and Ralph, 2001; Panfil and Jacobson, 2001).

Glides and different pool types are located within residual pools sub-reaches. In addition, there may be smaller scour or obstruction pools that are located within riffle or run units. In this protocol, we classify the presence of five specific pool types (Panfil and Jacobsen, 2001). Middle pools occur in the center of the channel with the deepest point in the middle third of the channel. Side pools occur along the outside bend of meanders. Bluff pools occur along the outside of channel bends too, but these are found below bedrock bluffs and bedrock is exposed in the side of the pool. Side pools are formed along alluvial or soil banks, not bedrock. Bedrock can be exposed in the bottom of side pools, but to not as great extent as in bluff pools. Scour or obstruction pools form behind obstructions such as boulders, large woody debris, bedrock outcrops, or artificial structures. These are sometimes referred to as "forced" pools and can be relatively small features several meters in diameter. Confluence pools are found in the flow convergence scour zone at tributary confluences and on the downstream end of islands or stable bars.

<u>Cross-section Surveys</u>

Measurements of channel and floodplain morphology are obtained using total station surveys across at least three cross-sections in each reach. Cross-section survey lines are located just upstream of riffle crests in the glide-riffle transition zone. Transect lines extend from low terrace to low terrace (across the entire meander belt) to include the active floodplain, if present (Figure 4). Monuments marking each transect site are located on one or both sides of the channel. At least 10 to 20 elevation points are collected along each cross-section survey. Cross-section information is used to determine metrics for channel morphology, flow hydraulics, and sediment transport.

Large Woody Debris Tally

Woody debris in the channel can increase flow resistance, provide fish habitat, and indicate source inputs due to landslides or bank erosion. Large woody debris are defined as any piece of a tree with a small end diameter of at least 0.1 m (4 in) and a stem length (trunks and branches) of at least 1.5 m (5 ft). This protocol only counts woody debris that is located within the bankfull or active channel cross-section and uses USEPA procedures (Kaufmann and Robison, 1998; Kaufmann et al., 1999). This is to prevent wood on the bank or hanging out over the channel from being counted. But if woody debris is on the channel bed or a bar, with its mass extended upward, only the portion of the wood in the bankfull channel is counted. A worker moves downstream and records measurements of length and mid-point diameter for pieces (stems, trees, branches, root wads). Wood jams are accumulations of at least three pieces of wood in contact with one another in one location. To tally Jams, the width, depth, and height of the jam pile is recorded along with a count of total pieces involved, if possible.

Bed Substrate Assessment

Information on the sediment sizes available for transport on the channel bed is typically used to evaluate channel form, bed roughness, sediment transport, and habitat condition (Kondolf et al., 2003). The diameter of bed and bar substrate is routinely measured using some variation of the Wolman pebble count method (Wolman, 1954). Pebble counts involve measuring the B- or intermediate-axis of 100 to 400 individual bed particles collected from the channel bed by hand using some type of ruler or template (Bunte and Abt, 2001a). Typically, pebble diameter measurements are made in millimeters. Bed substrate classes generally follow those in Rosgen (1996) and Kaufman and Robison (1998) (Table 5).

This protocol uses a "paced-grid" sampling method to determine substrate type and diameter trend in individual glide, riffle, and bar units. Since baseflow depths in the rivers being studied is relatively deep and almost non-wadeable in some places, tapeline transects cannot be used to measure sampling grids in the channel (thus the "lazy" descriptor). Instead, the field worker paces off equal intervals across the channel at about 2 to 5 steps between sampling points, depending on the width of the channel unit to be sampled. This method is similar to using the "zig-zag" traverse method to select substrate samples every few steps or so from within a distinct channel unit or patch (Wolman, 1954; Fitzpatrick et al., 1998; Buffington and Montgomery, 1999; Bunte and Abt, 2001a). Stratification of the reach by channel unit, bedform or "patch" for pebble counting can reduce errors introduced by mixed populations and variable bed form scale (Buffington and Montgomery, 1999; Kondolf et al., 2003).

Pebble counts are distributed among the three cross-sections and channel units in the reach. At each cross-section, glide and riffle units are sampled along four transects spaced 0.5 bankfull widths apart in the upstream (glide) and downstream (riffle) directions. The first transect is 0.5 widths away from the transect line. Ten samples are collected at equal intervals along each transect, making sure to only sample from the targeted channel unit. In addition, the diameters of the five largest mobile clasts found along the riffle crest are also recorded. Mobile clasts are cobbles or boulders showing some evidence for previous movement by flow. Bar deposits are sampled in a similar manner. Thirty five samples are collected from the middle third (longitudinally) of the bar feature at elevations above the baseflow water line and below bankfull stage. Ten largest mobile clasts are also collected from the bar unit. This sampling scheme generates 120 glide, 120 riffle, and 105 bar pebble count samples and 15 riffle crest and 30 bar largest clast samples for a total of 390 substrate measurements per reach.

The "blind-touch" method is used to select samples where the worker steps to a location without looking down and reaches down to grab the first pebble touched with a pointed finger. It is critical that workers do not look down during bed sampling and that the first substrate or particle touched, whatever size or substrate type, is selected for measurement or classification. A gravelometer template is used to measure pebble size (part no. 14-D40 from the Wildlife Supply Company at www.wildco.com). The minimum size of measured sediment using the gravelometer template is 2 mm sieve. The largest size fraction measured by the gravelometer has a sieve diameter range of 128 to 180 mm or large cobbles. Beyond this size, a ruler will be used to measure the B-axis diameter of the larger cobbles and boulders. Some substrate types are non-measureable and so nominal classification is used to tally them during sampling for fines/mud (F), sand (S), bedrock (R), and scoured earth bottom (E).

The substrate sampling strategy used in this protocol aims to reduce measurement and sampling bias by: (i) training workers to use similar and consistent techniques including the unbiased gravelometer template (Marcus et al. 1995; Bunte and Abt, 2001a); (ii) collecting at least 400 samples to estimate the reach-scale substrate size distribution within 10% error (Bunte and Abt, 2001a) (iii) sampling a single geomorphic channel unit or textural patch (Buffington and Montgomery, 1999), and (iv) limiting the number of pebbles collected from each channel unit to between 30 and 100 to reduce the effect of serial correlation on the sample (Hey and Thorne, 1983).

Data Analysis

The following section describes the specific geomorphic indicators and the formulations used to analyze landform characteristics and geomorphic processes (Table 4).

Valley-scale Controls

Valley confinement and slope exert primary control on the planform of a river (Montgomery and MacDonald, 2002). Ozarks streams are commonly characterized by narrow valleys, shallow depth-to-bedrock, and straight or sinuous channels. These effects can be quantified by the measurements of valley slope and width in the vicinity of the sampling reach.

Slope. A measure of the slope or gradient of the channel is required for any kind of hydraulic or geomorphic analyses of fluvial process. Longitudinal profiles of the bed, riffle crests, or water surface using total station data can be used to determine the slope of the channel by rise-over-run calculations in a dimensionless form (m/m). *Thalweg or bed slope* is determined by the mean slope of a regression line through all the thalweg data points. *Riffle slope* is determined by the slope of a regression line plotted through three or more riffle crest elevation points. Data from topographic maps or GIS data bases can be used to determine valley slope.

Sinuosity. Sinuosity represents the degree of meandering exhibited by the channel in the valley and provides a quantitative measure of the planform pattern or channel type. *Thalweg sinuosity* (dimensionless) is calculated as the longitudinal distance along the thalweg from riffle crest 1 to riffle crest 4 divided by the valley center line distance between the same two points on a map. Sinuosity is also ratio of valley slope to thalweg slope. Sinuosity values less than 1.1 indicate straight to sinuous channels while values greater than 1.2 or 1.3 are meandering channels.

Confinement. Valley bottom width (m) is the distance between the valley walls, bedrock bluffs, or high terraces measured perpendicular to the center line of the valley, calculated as the average value of width measurements across the valley at riffle crest control transects (m) using GIS data base, GPS points collected in the field, or valley slope or bluff points collected during the total station surveys. Meander-belt width (m) is calculated as the average distance across the floodplain and active channel area from low terrace bank top to the opposite low terrace bank top from all three transects (total channel width as described in this report). Valley confinement (m/m) is calculated as mean valley bottom width divided by mean riffle bankfull width. Valley confinement values of 10 or more indicate that the channel if relatively “unconfined” and those less than three infer a “very confined” channel. Bank confinement (dimensionless) is calculated as the average meander-belt width divided by mean riffle bankfull width. Confined channels tend to be limited in their ability to migrate laterally and form lower floodplains that can dissipate energy and store excess sediment.

Entrenchment. Channel entrenchment refers to the depth to which the present channel is incised into the valley floor or at least has the appearance of such change. A useful measure of entrenchment is the *bank height ratio (m/m)* which calculated as the top bank height as measured from the toe divided by the bankfull stage height measured from the same toe location. The average value for the reach is calculated by using the lowest high bank height and highest bankfull stage height at each of the four riffle crest control transects and them taking the average value for the reach. Bank height ratio values less than 1.1 indicate a “stable” condition (i.e. active floodplain on both banks) while values greater than 1.5 represent a “deeply incised” condition (Rosgen, 2006). Incised channel tend to be unstable, erode bed and banks, and contain low habitat diversity since deeper, bank-contained flows tend to develop higher shear stress levels than less entrenched channels. Incising channels can also be identified by the degree to which bedrock and scoured earth is exposed in the bed of the channel as can be calculated from pebble count and thalwag survey data.

Riparian Vegetation Control. The influence of vegetation on the channel is described by three indicators: (i) percent forest vegetation within a 100 meter buffer along each side of the channel along the entire reach; (ii) large woody debris tally results indicating the number of jams and pieces and total wood volume/100m found in the reach; and (ii) presence of root protection along the banks determined visually at each longitudinal survey point.

Bedrock Control. Indicators of bedrock control included the following: (i) presence of bedrock at longitudinal survey points in the channel as percent of total survey points; (ii) presence of bedrock at pebble count sampling location as percent of total sample points; and (iii) presence of bluff pools along the thalweg survey line and percent of all pools surveyed.

Overbank Deposition. Indicators for overbank deposition would relate to evidence of active floodplain formation and channel-floodplain connectivity: (i) relatively high sinuosity (> 1.2), (ii) relatively wide meander belts or total channel widths; and (iii) relatively low top bank heights.

<u>Reach-Scale Controls</u>
Reach-scale indicators reflect local conditions and response variables within the constraints imposed by watershed factors and valley controls.

Channel Type. Each reach is classified according to Rosgen’s (1994, 1996) stream type and Montgomery and Buffington’s (1997, 1998) channel type. These comparisons help to identify common patterns of channel morphology among sites.

Channel Dimensions. Channel cross-section surveys are completed by total station for three riffle cross-sections that extend across the entire meander belt. Two channels are considered for analysis: (i) bankfull or active channel near the stage of the new floodplain surface (if present); and (ii) total or meander-belt channel whose top banks are formed by the main valley floor. Channel width, maximum depth, mean depth, area, and w:d ratio are calculated for both channels from cross-sectional data and graphs based on the total station survey data. Width (m) is measured across the channel at the bankfull stage or top of meander-belt or low terrace bank. Maximum depth (m) is the vertical distance from the thalweg where it intersects the transect line to the top channel elevation. Mean depth, velocity, and channel discharge are calculated by hydraulic software (we use Hydraflow Express at www.intelisolve.com). Cross-section area is the product of width and mean depth. The width/depth ratio identifies the shape of the channel. Wide channels have high ratios and tend to transport relatively more bed load, be aggrading, or contain more bars.

Riffle and Pool Characteristics. Longitudinal profile survey data is graphed to show the bed form variations of the thalweg bed and water surface slope. Slope measurements for the reach require calculating the regression slope of key bed and bank slope elevation points. The average riffle crest to riffle crest spacing should normally be from 5 to 7 times the bankfull width. The longitudinal thalweg profile is also used to determine residual pool location, length, and depth. The surface elevation of a residual pool is defined by the pour or overflow point of the riffle below it and residual pool length is the distance from the pour point to its intersection with the bed of the upstream riffle or run. Pool length can be expressed as fraction (0 to 1) or percent (0 to 100) of total reach length (including run and riffle distances) to indicate the relative volume of pool area in a reach. Maximum residual pool depth (RPdmax) is calculated as: (elevation of downstream riffle) – (elevation of deepest pool point). Mean residual pool depth can be expressed as: (i) per pool on thalweg profile = RPdmax/2; (ii) per pool area = RPdmax/4; and (ii) per entire reach area = (RPdmax/4) x pool length fraction of the reach.

Gravel Bars. The presence of gravel bars can be indicated as (i) lower surfaces along the side of the channel on cross-section plots and (ii) percent bar occurrence along the longitudinal profile. Pebble count data yield information on the composition of bar surfaces.

Bank Condition. Three indicators of bank stability are used to develop a qualitative bank stability index for each reach: (i) percent eroded upper bank; (ii) bank height ratio; and (iii) percent bank root protection. The relative bank erosion index used in this protocol is: RBEI= [(0.4 x % bank eroded rating) + (0.25 x bank ht ratio rating) + (0.25 x % root protection rating)]. The scoring for each indicator is as follows: Bank height ratio- <1.2=5, 1.2-1.5=4, 1.5-2=3, 2-3=2, and >3=1; % Bank eroded- <10%=5, 10-25%=4, 25-50%=3, 51-75%=2, and >75%=1; and % Root protection- >50%=5, 30-49%=4, 20-29%=3, 10-19%=2, and <10%=1. Caution must be used in overemphasizing these index values in management decisions since they are subjective and qualitative. However, they do indicate the relative potential for bank erosion among reaches to a reasonable extent given these field observations.

Channel Substrate. Nominal class observations are removed from the measured gravel and larger sample (>2mm) and are reported as percent of total pebble count observations.
The remaining pebble count data from each sampled area are rank-ordered to determine the frequency distribution of important percentiles (i.e. D_{16}, D_{25}, D_{50}, D_{75}, D_{84}, D_{95}) (Rosgen, 1996). Information on the frequency of bed material sizes in different channel units are used to describe transport dynamics, bed form, or size distribution curves for the reach (Kondolf et al., 2003). Besides the frequency analysis, other metrics for sediment analysis are calculated as follows:

(1) Geometric mean (Dgm): average of the $\log_{10}$ values of sediment diameters (not the arithmetic average). The statistic is reported as the anti-log10 of the log-mean value. Since the distribution of sediment sizes on the bed is typically skewed to the coarser sizes, the geometric mean reduces the effect of skew on the mean value by "forcing" a normal distribution on the size data.

(2) Otto sorting coefficient (Sg): This metric is calculated as, $Sg = (D84 / D16)^{0.5}$ (Kondolf et al., 2003). Relatively large values indicate a deposit of mixed sizes. Usually this means that fines have filling in the pore spaces between larger cobble materials which creates poor aquatic habitat and unstable bed.

(3) Fredle Index, or relative sorting coefficient (Fi): This metric is calculated as, Fi= Dgm / Sg. tends to be higher for larger materials with a relatively narrow distribution of sizes in the channel unit. Large Fi values are better than smaller ones for habitat quality and bed condition.

Large Woody Debris

The number and volume of wood pieces and jams indicate the added resistance of wood stored in the channel and the supply of wood from banks and upland to the river system. Typically, large woody debris data are reported as number of pieces (#) or cubic meters of wood per 100 meters of channel length to account for difference reach lengths among sampling sites (Kaufman et al., 1999). For hydraulic calculations, the total volume of wood per reach area (m^2) is used to account for resistance effects on flood flows over the entire channel bed (Kaufman et al, 1999).

Channel discharge and Bed Stability

Channel Hydraulics and Discharge. Channel dimensions, substrate properties, and bedform are used to analyze flow properties, flood conditions, and sediment transport. Discharge is calculated at both bankfull and the channel-full capacity using the continuity equation:

$$Q = A \times V$$

Q = discharge (m^3/s)
A = channel cross-sectional area (m^2), note: A = W x D
V = mean velocity of flow (m/s) (estimated using Manning's Equation)
W = width of water surface in channel (m)
D = mean depth (m)–both W and D are calculated from channel survey data.

Manning's equation is typically used to calculate mean velocity of the flow for use in the continuity equation. Manning's equation requires a roughness coefficient "n" value that is estimated in this protocol using a field based method. Mean channel velocity is calculated as follows:

$$V = (R^{0.66} \times S^{0.5}) / n$$

R = A/Pw = hydraulic radius (m), note: R can be estimated by: (W x D) / (2D + W)
Pw = wetted perimeter (m)
S = channel slope, calculated as rise-over-run either in ft/ft or m/m
n = manning's roughness coefficient (gets larger as roughness increases)

This protocol uses a field-based approach that estimates Mannings "n" using sinuosity, median grain size, and mean residual pool depth to account for channel irregularities due to planform pattern, bed sediment size, and bed form topography (French, 1985, Pizzuto et al, 2000, Martin, 2001). Manning's roughness coefficient (n) is calculated using the following equation:

$$n = F_p (n_g + n_b) + n_g + n_b$$

$F_p = 0.6\ (K\text{-}1)$
$n_g = 0.0395\ (D_{50})^{1/6}$
$n_b = 0.02\ (d_{rp}/\ d_{bf})$, note: $n_b = 0.02$ for values > 0.02)
K = sinuosity (reach length/valley length (m/m))
D_{50} = median grain size of the bed (m)
d_{bf} = mean bankfull depth (m)
d_{rp} = mean residual pool depth of the entire active channel area (m)

Channel form roughness is included in the calculation by F_p , the sinuosity factor with sinuosity (K) determined by dividing reach length along the thalweg by the "straight line" valley length measured from aerial photography or topographic map. Grain or particle roughness is accounted for in the equation by n_g using the median (D_{50}) grain size diameter from pebble count surveys (Chang, 1988). The bed form roughness resistance factor (n_b)is the ratio between the mean residual pool depth (d_{rp}) of the reach and the mean bankfull depth (d_{bf}).

Relative Bed Stability. Relative Bed Stability (RBS, m/m) generally describes the ability of bankfull flows to transport the dominant substrate size found on the bed (after Kaufmann et al., 1999). Ideally, the ratio should equal "1" where the critical sediment size predicted to be mobile under imposed hydraulic forces is equal to the median particle size on the actual channel bed. A high value (>100) may indicate an extremely stable bedrock reach or conditions below a dam, a low number <0.01 indicates a bed where substrates are easily moved. In Ozarks streams, it may be expected that values will decrease in channel affected by excess loads of fine gravel, but RBS values may increase in reaches with exposed bedrock and armored cobble beds. A negative trending RBS with increasing land use intensity can indicate: (i) more sediment is being delivered to the channel network from slope or gully erosion causing bed " fining" or sedimentation; (ii) reduction in riparian buffer function to trap fine sediment and resist bank erosion; and (iii) increased runoff and flood frequency has increased bed shear stress on the bed and reduced channel roughness (Kaufman et al, 2009a).

This protocol calculates the relative bed stability (RBS*) using a method that corrects for the influence of additional flow resistance on sediment transport by large woody debris and riffle-pool forms in the reach (Kaufman et al, 2009a,b). RBS* requires input data on channel slope, flow cross-section, bed material size, large woody debris volume, and residual pool length and depth collected from a reach approximately 20 bankfull widths long. The procedures and equations for calculating RBS* are below:

$$RBS^* = 1.66\ Os\ Dgm\ /\ [\ Rbf\ (Cp\ /\ Ct\ )^{0.333}\ S\ ]$$

Calculate Os as follows:

(1) Determine particle Reynolds Number: $Rep = [\ (\ g\ Rbf\ \ S\ )^{0.5}\ Dgm]\ /\ v$

(2) Then calculate Os based on the Rep value:
(i) For Rep < or = 26: $Os = 0.04\ Rep^{-0.24}$
(ii) For Rep >26: $Os = 0.5\ \{\ 0.22\ Rep^{-0.6} + 0.06\ (10^{-7.7\ Rep^{-0.6}})\ \}$

Cp = reach-scale particle grain resistance at bankfull flow, minimum Cp = 0.002

$= fp/8 = (1/8) [2.03 \text{ Log } (12.2\ d_h / Dgm)]^{-2}$

Ct = reach-scale total hydraulic resistance at bankfull flow

$= 1.21\ dres^{1.08} (d_{res} + W_d)^{0.638}\ d_{th}^{-3.32}$

RBS*= corrected relative bed stability ratio (m/m)
Os = Shields Parameter, dimensionless critical shear stress for incipient motion
Rep = Bankfull particle Reynolds number
v = kinematic viscosity of water = 1.02 x 10^{-6} m^2/s
g= acceleration due to gravity, 9.81 m/s^2
Dgm= geometric mean of bed material from pebble counting (m)
Rbf = bankfull hydraulic radius = 0.65 d_{bfm} (m)
d_{bfm} = maximum bankfull depth (m)
Cp = reach-scale particle grain resistance at bankfull flow (m/m)
d_h= mean depth (m)
Ct= reach-scale total hydraulic resistance at bankfull flow (m/m)
d_{res}= mean thalweg residual depth (m), length-weighted average of $d_{res\text{-}max}$ / 4
W_d = total wood volume (m3) / total active channel planform area (m^2)
d_{th}= thalweg mean depth or mean maximum depth (m) (same as d_{bfm})
S = energy slope, approximated by water surface or riffle crest slope (m/m)
LRBS*= Log10 RBS*

The RBS* value is typically reported in the log form: LRBS* = Log10 [RBS*]. In the log form, a value of 0 indicates the stable condition (i.e. RBS*=1). For the purposes here, LRBS* ratings are as follows: A (excellent)= -0.2 to 0.2; B (good)= -0.5 to 0.5; and C (fair or worse)= <-0.5 to >0.5.

Riffle Stability Index. The riffle stability index (RSI) compares the size distribution of relative mobile bar sediment to the size of pebbles in the riffle (Kasppesser, 2002). Procedures for calculation of the RSI are as follow:

(1) Determine the size distribution of pebble samples collected only from riffle channel units.

(2) Determine the D95 for recent bar sediment from the same monitoring reach as where the riffle samples were collected.

(3) Compare the Bar D95 value to the riffle size distribution to see where it fits in the percentile frequency distribution. The RSI value is the percentile value of the riffle distribution that is equal in size to the D95 of the bar.

If the coarse bar size is generally similar to the D50 of the riffle (D40-D70 range), the channel is relatively stable. If the RSI is > 85, then the riffle is increasingly loaded with excess sediment. If the RSI is <40, there is probably a high bedrock component to the riffle or the channel has been scoured.

Flood Mobility Ratio. The more frequently bankfull discharge occurs, the more frequently potential channel-forming processes will occur in the channel. Doyle et al. (2000) used the return frequency of the bankfull flood to explain the influence of urbanization on channel morphology in Indianapolis, Indiana. Degrading channels had shorter return periods of critical, sediment transporting flows. In this protocol, we introduce the flood mobility index which is calculated as: predicted discharge for the bankfull channel determine from field surveys divided by the predicted 1.5 year flood for Ozark streams. The dominant and bankfull discharge is commonly approximated by 1.5 year return period flood (Rosgen, 1996). Predicted 1.5 year flood discharges are based on regional drainage area-discharge equations published by Simon et al. (2004) in a study of flood and sediment transport characteristics of USA rivers. Relatively low ratio values would indicate that bankfull flows and bed mobility occur more frequently. Frequent bed mobility would indicate more cycles of erosion-deposition and a greater chance to degrade the channel. In addition, this situation would create a more stressful environment for aquatic life.

Database Management and Long-term Data Storage

All GIS data layers and field data are stored at OEWRI in Temple Hall at Missouri State University in Springfield, Missouri. Information about this project can be found at OEWRI's website at www.oewri.missouristate.edu.

RESULTS OF YEAR 1: 2008-09 MONITORING

All thirty sites were visited and sampled by OEWRI workers during the summer of 2009. Ten sites were selected for more intensive assessments for Year 1: 6 in the Beaver Lake sub-basin in Arkansas and 3 in the James River and 1 in the Bull Shoals sub-basins, Missouri (Figure 1). The sites are:

Finley Creek below Riverdale (MO)
Flat Creek below Jenkins (MO) (2x)
James River at Galena (MO)
James River at Boaz (MO)
Swan Creek near Swan (MO) (2x)
Kings River near Berryville (AR)
War Eagle Creek near Hindsville (AR)
West Fork WR east of Fayetteville (AR)
White River near Fayetteville (AR)
Yocum Creek near Oak Grove (AR)

Two sites, Swan and Flat Creeks, were visited twice over the summer for repeat assessments to test the precision of field methods. A complete record of field work at all 30 sites including site maps, GPS coordinates, biological sampling locations, survey points, longitudinal profiles, cross-sections, and photograph log is included in the appendix A of this report. The appendix also contains: (i) B- rapid channel assessment scoring form and sub-reach composite scores (Kaufman and Robison, 1998; Sarver, 2003); (ii) C- description of stream types and classification flowchart (Rosgen, 1996; (iii) D- large woody debris tally results for each site by worker (procedures modified from Kaufman and Robison, 1998); and (iv) E- pebble count data for all sites and channel units with Riffle Stability Index values.

Watershed Characteristics

Watershed characteristics relating to water quality and channel controls were measured and tabulated for all thirty sites using current GIS databases. These data are as follows:

(1) Watershed topography- drainage area, site and divide elevations, and watershed slope (Table 6);

(2) Watershed geology- percentage of four major bedrock lithologies in the region: dolostone/dolomite, limestone, sandstone, and shale (Table 7); and

(3) Watershed Land Use- percentage of eight land use classes: high density urban, low density urban; barren land, cropland, grass, forest, young forest, and water. In addition, the road density in each watershed was calculated as total length of roads (km) divided by the drainage area (km^2) (Table 9).

There are some important differences in geology and land use among the watershed areas of the ten assessment sites investigated (Table 9). Limestone and dolomite (carbonate bedrock) dominate the James River and Finley, Swan, Flat, and Yocum Creeks, while sandstone is the dominant bedrock in War Eagle Creek, West Fork, and White River. The Kings River has a mixed geology. The limestone watersheds have high areas of grazing pasture land and the sandstone areas in the Boston Mountains are relatively forested. Urban land composes from 10% to 17% of the land area above the James River and West Fork sites. At this level of urban cover, a hydrologic and water quality effect might be detectable.

These attributes can generally be used to evaluate water quality and channel stability trends in the basin. However, with only 10 sites evaluated so far it is difficult to test the influence of these watershed characteristics on site condition (sample size is too small). As more sites are assessed next year, statistical testing and modeling using watershed variables will become a more effective analytical tool.

Valley-scale Controls

Valley-scale controls vary among sites to some extent (Table 10). Valley confinement ratios range from 2.2 at Kings River to 9.5 at Yocum Creek. Confinement ratios less than five clearly indicate that natural meandering and floodplain formation is limited. However, narrow valley also limit the potential for extreme lateral erosion of banks. Kings River, James River at Galena, and Flat Creek have confinement ratios less than 4 and Yocum Creek, White River, and Swan Creek have ratios greater than six suggesting that their channels are more free to adjust laterally to stressor inputs. However, the sinuosity values for these sites are relatively low (<1.2) indicating that active meandering is not generally a dominant process at these sites.

All sites exhibit an entrenched form and have relative high banks within which a lower elevation bankfull channel is formed (Table 10). Total channel bank widths are narrow and floodplain features are limited mostly to narrow benches or stabilized high bar surfaces. This limits the ability of these channels to dissipate food energy over floodplains and deposit fine-grained sediment in riparian areas. Bank height ratios range from 1.6 at Finley Creek to 2.9 at War Eagle Creek. Bank ratios > 1.5 indicate a deeply incised condition (Rosgen, 2006).

Bedrock control is an important characteristic of these rivers. More bedrock control decreases the ability of the river to adjust to disturbance, but also makes them more resistant to change—they don't move as much. There are three different groups of sites based on bedrock influence. Flat Creek and the West Fork show the least influence of bedrock and have low percentages of bedrock, large boulders, and bluff pools (Table 10). A group of four sites is affected by a moderate influence of bedrock: James River at Galena, War Eagle Creek, Finley Creek, and Yocum Creek. The channels at these sites have low/moderate bedrock and large boulders exposed in the channel, but have high frequency of bluff pools. At these sites there is enough sediment deposited on the channel bed to cover the bedrock, but the thalweg forms relatively deep pools along the bedrock bluff outcropping along the valley wall. Bluff retreat over long periods of time releases large slabs by rock fall to the margins of the channel and these tend to form boulder lines on the outside of channel bends. The highest influence of bedrock on the channel is found at the remaining sites: White River, James River at Boaz, Kings River, and Swan Creek. At these sites, bedrock exposed in the bed (>30%) and large boulders (>50%) are relatively common, but bluff pools are absent (0% presence at all four sites) (Table 10 & 14). Here the bedrock occurs as a horizontal slab with only a thin veneer of sediment in patches over the top with little opportunity to form bluff pools although the channel is close to bedrock bluffs in most cases.

Riparian forests line the channel at all sites, but the width of the buffer varies (Table 10). The percent forest cover within an area of 100 meters on either side of the study reach ranges from 34% at West Fork to 65% on the White River. There is often different riparian forest cover on opposite sides of the channel suggesting potential for channel instability to expand into less protected banks at the James River sites, War Eagle Creek, and Yocum Creek, for example (Table 11). With the exception of the Boaz site, the other three sites along with Flat Creek and Kings River have relatively low percentages of tree root protection along the upper bank (Table 12). Large woody debris accumulations vary from 9 m^3 or wood per 100 m at Galena to 382 m^3 per 100 m at War Eagle Creek (Table 12 & 13). Wood jams were observed at every site ranging from three at West Fork, Swan Creek, and James River at Galena to 11-13 at White River, War Eagle, and James River at Boaz (Table 13). It is difficult to judge the effect of wood on channel form and stability at this point (i.e. only 10 cases). When evaluated for hydraulic resistance effect, the depth of wood (W_d) averaged over the entire channel area was quite small, typically less than 2 cm (Table 13). Riparian forest buffer is an important aspect of channel behavior, but more samples are needed to identify geomorphic relationships in this monitoring program.

Reach-scale Channel Response

<u>Channel Characteristics</u>

All the sites evaluated are classified as gravel-bed, riffle-pool channels (Montgomery and Buffington, 1997). Some sites have sections that form plane-bed features and others exhibit varying degrees of bedrock-forcing. Longitudinal and alternate bars are fairly common and in some channel excess gravel deposition occurs at riffle crests and on low floodplains. Bar occurrence along the length of the channel reach ranged from 10% or less at White River, West Fork, and James River at Boaz to > 35% at Yocum Creek, Finley Creek, and James River at Galena (Table 14). Some bar forms are beneficial to a healthy and stable stream, but excessive bar sedimentation destabilizes the channel and reduces habitat quality. The bar materials measured in this study may be relatively mobile since Ozark streams have a history of instability related to land use disturbance (Jacobson, 1995; Jacobson and Primm, 1994). Indeed, gravel is the dominant material in bar deposits at all 10 sites (Table 15) and riffle stability index values tend to be >84% suggesting that riffle and bar surface sediments are similar in texture and mobility (Table 15 & pebble count data in appendix).

Pools are long and well expressed in the ten reaches examined. Residual pools compose from 60 to 70 percent of the reach length at Flat and Yocum Creeks to >90% at White River, West Fork, and James River at Boaz (Table 16). Mean residual pool length ranges from 83 m at Yocum Creek to 503 m at Boaz and mean maximum pool depth ranges from <0.8 m at Swan and Flat Creeks to >1.5 m at Boaz and War Eagle Creek (Table 16). Middle or center pools are the most common pool type observed at eight of the study sites typically representing >80% of the linear pool length (Table 17). Side and scour pools are the second most common pool group observed in this assessment. As discussed previously, bluff pools are found in specific reaches where relatively thick bed sediment deposits cover bedrock beds.

The Rosgen Stream Type Classification is a popular system for comparing channel characteristics across regions and under different land use conditions (Rosgen, 1996). Eight of the reaches key out to a Rosgen F4 stream type (Table 18; Rosgen method flowchart in appendix C). These streams are entrenched meandering riffle-pool channels on low gradients. While Rosgen (1996) states that F stream types are laterally unstable with high bank erosion rates, we did not find this relationship. In fact, we needed to force the "sinuosity" value up to make it fit: in our experience, many Ozark streams are too straight to fit the Rosgen classification. The Finley Creek is classified as a C4c stream type because it was only slightly entrenched, possibly due to bedrock control and less overbank storage of sediment over the long-term. Yocum Creek is classified as a Rosgen B4c stream type which is moderately entrenched with irregular pool spacing and stable banks.

<u>Rapid Channel Assessment</u>

Rapid channel assessments were completed for all thirty sites. The scoring system is based on maximum number of 100 points for the composite score (see form in appendix B). The scores for the Upper White River Basin sites typically ranges from 50 to 80 points and the standard deviation among different workers was usually <5 points (Table 19). A normal A-F grading system is used to present the results of this assessment (>89=A; 80 to 89=B, 70 to 79=C, etc).
Ten points are added to each score to correct for reference conditions are typical for Ozark streams. River sites scoring the highest (i.e. B+/A sites) are: Bull Creek, Flat Creek, James River at Boaz, Kings River, Swan Creek, and Yocum Creek and the lowest (D/F) are: Middle Fork of the White River, Richland Creek at Goshen, and War Eagle Creek near Huntsville (Table19; Figure 5). These types of assessments are good for broad comparisons but not for specific management decisions. However, they are routinely used by many state and federal agencies for screening purposes.

River channel width and cross-section area may respond to watershed disturbances. It is often assumed that percent forest cover is analogous to a measure of undisturbed character of a watershed. A preliminary analysis of the relationship among drainage area, channel width and area, and percent forest cover for 30 sites does not show any disturbance relationship (Figure 6). The channel gets larger with drainage area as more water is flowing through the channel, but there is no clear trend with forest cover. The hypothesis is that the low forest cover sites would plot higher than other groups since more runoff and hydrologic disturbance would increase flooding and bed/bank erosion thus creating a larger channel. While the blue triangles (low forest symbols) tend to plot along the upper half of the scatter as hypothesized, only three sites are creating the high trend and more study should be done to elaborate on this observation.

<u>Channel Morphology and Discharge</u>

Field data from the longitudinal profiles and channel cross-sections are used to calculate hydraulic parameters and discharge for the bankfull and total channel at the ten surveyed sites (Tables 20 & 21). An evaluation of the density of topographic survey points shows that the number of rod elevations collected for the longitudinal profile ranged from 35 to 74 or 2 to 4 per unit width (Table 22). The number of points included in cross-section surveys ranged from 11 to 29 points (Table 22).

Bankfull discharge ranged from 16 m^3/s at Yocum Creek to 155 m^3/s at Galena (Table 23). Total channel discharge fills the entire meander belt to higher levels above the bankfull stage. Total channel discharge ranges from 84 m3/s at West Fork to 966 m3/s at King River (Table 23). The return frequency of the bankfull discharge at these ten sites is greater than the regional 1.5 year flood estimate, probably in the 1-year range. Conversely, the return period of the total channel discharge is longer than 1.5 years and probably between 2 and 10 years depending on the site (Table 23). The flood mobility ratio (Qbf/Q1.5) is relatively low for Flat Creek, James River near Boaz, War Eagle Creek, West Fork, and White River suggesting that gravel-sized bed and bar material is mobilized several times a year on average thus causing relatively unstable bed conditions to persist at these sites (Table 23; Figure 7).

Bed and Riffle Stability Indexes

Two channel stability indexes are evaluated in this study. Relative Bed Stability (LRBS*) is the ratio of the actual size of bed material on the bed to the predicted critical size that can be mobilized by imposed conditions (Kaufman, 2009 a,b). Riffle Stability Index (RSI) compares the size distribution of riffle sediment to the coarsest bar sediment fraction assuming that the bar is more mobile than the bed (Kappesser, 2002). LRBS* are near zero indicating that field sediment sizes are in balance with the flow energy during bankfull discharge (Table 24). There are several sites that have relatively high index values of >0.4: James River at Boaz, Swan Creek, War Eagle Creek, West Fork and White River (Figure 8). These site have strong slab bedrock control (limited bed sediment availability or bed coarsening) and relatively low flood mobility ratios (lower bed stress) which would cause the LRBS* value to increase. Nevertheless, these values are not extremely high to warrant major concern. More sampling in the future may help to better understand these subtle mobility trends.

The RSI values are very high (>84) and outside of the upper limit (70) for a stable riffle (appendix E: pebble count data). This result indicates that riffles at all these sites are embedded with fine gravel to a large extent or that the fine gravel supply is excessive in the reaches studied. Interestingly, while the LRBS* values suggest that channel and flow conditions are in balance with present-day sediment loads, the high RSI values suggest that this sediment load is too fine to produce coarse, stable riffles. If one assumes that pre-settlement river beds in the Ozarks were coarser with more cobble than they are now, then the conclusion is that current channel conditions are in quasi-equilibrium with the excess fine gravel loads in these river systems. In effect, fine gravel inputs have remained high for so long that the channel has had time to adjust to them. This means that there is inherent instability in these riffle beds since both bed form and aquatic habitat have a chronic problem with sediment size (too small or embedded) and mobility (too high).

Sediment Size Trends

Following the discussion above, it is important to look at the size of the sediment actually on the bed. Pebble count data for combined riffle and glide units indicate that channel beds contain only <30% cobble or boulder (Figure 9). The coarsest beds are found at Swan and War Eagle Creeks with the D70 in the cobble range. Flat Creek, James River at Galena, West Fork, and Yocum Creek have the finest beds with cobble first being counted in the D95 ranges (i.e. only 5% cobble with 95% gravel) (Figure 9). Fine sediment (mud and sand) deposition relates to both the flow energy and source supply in the reach. The sites with the highest percent fines on the bed are War Eagle Creek (28%) and West Fork (39%) (Figure 10). These sites also had low flood mobility (Table 23) and high LRBS* (Table 24) and so correlate with low energy conditions. However, sites with lowest fines deposition (<2%) include Boaz, also with high LRBS* and low flood mobility, Swan Creek with high LRBS*, and Yocum Creek (Figure 10). Thus, there probably are multiple factors controlling the supply and deposition of fines in these rivers.

Bank Stability
Field and historical experience with stream banks in the Ozarks has helped us understand that some banks can look raw and steep but not migrating laterally much over a 50 year period. Poor bank condition does not always result in high erosion rates. Keeping this in mind, we can try to rate bank stability for this study using bank height, % eroded bank, and % root protection (Table 12). One observation is that at every site, the % of bank protected by roots is greater than the percent of steep, raw, and "eroding" banks (Table 12). Tree root protection allows some banks to remain in a steep condition for a long time by giving support to the soil. The relative bank erosion index (RBEI) indicates that the poorest bank conditions occur at the White River site with the next poorest banks at James River at Galena, Kings River, and Yocum Creek (Table 12; Figure 11). The best bank conditions are at James River at Boaz and Flat Creek (Figure 11). More work needs to be done to understand long-term bank conditions and erosion rates in the Ozarks using historical aerial photograph analysis or repeat surveys.

Precision of Indicators used in this Protocol

Field data comparisons among different sub-reaches within a site show that channel width and depth indicators vary within + or – 20% at the reach-scale (Table 25). The relative standard deviation is used here to evaluate variability. It is calculated as: standard deviation divide by the mean in %. Pebble count data are even more variable at 20 to 80% or more (Table 25). Errors involved with repeat site assessments for channel and sediment indicators are similar to or less than those for sub-reach averages (Table 26). In the case with repeat site analysis, errors are compared using the relative percent difference calculated as one value subtracted from the other divided by the mean of the two values.

Worker error is constrained by the natural variability in the river system. Given the results here, field crews have done a relatively precise job of data collection for these indicators. Worker errors increase for visual judgements such as channel unit classification (Table 27). This occurs because of differences in worker experience, changes in flow condition between visits, and the relative low values of some indicators that increase the relative % error. Repeat sampling errors are relatively low for Swan Creek channel units, but high for pool types with low values of occurrence (Table 27). In addition, crew experience also matters. Flat Creek was the first site visited by the field crew and channel unit classification errors are higher than those for Swan Creek (Table 27). The sampling errors reported are acceptable given the use of the information and consideration for the low indicator values that artificially increase percent errors.

Summary Ratings

It is difficult to give an overall individual rating to each of the 10 sites since there are no sites where all indicators are consistently poor or excellent. In addition, some of the indexes used duplicate information (e.g. LRBS* & FMI) or are not well calibrated (e.g. RBEI). The final rating is based on the middle/median score of three metrics: (i) fine sediment rating; (ii) LRBS*; and (iii) EPA rapid assessment. Each of these indicators has been used previously in published literature and developed independently of one another. The final rankings focus on bed stability, fine sediment deposition, and overall physical condition of the channel including the banks and riparian areas (Table 28). These are as follows:

<u>A-channels</u>	
James River at Boaz (MO)	A
Swan Creek near Swan (MO)	A
Yocum Creek near Oak Grove (AR)	A
Flat Creek below Jenkins (MO)	A-
<u>B-channels</u>	
Finley Creek below Riverdale (MO)	B+
Kings River near Berryville (AR)	B+
White River near Fayetteville (AR)	B
<u>C-channels</u>	
James River at Galena (MO)	C+
War Eagle Creek near Hindsville (AR)	C
West Fork WR east of Fayetteville (AR)	C-

These ratings represent the physical condition of the channel relative to stability and sediment considerations. Physical characteristics form a template for aquatic habitat. However, only a very broad correlation is observed among land use, physical condition, and biological indices (Table 28). Sediment conditions are severe enough to exert a local influence on macroinvertebrate communities. Watershed inputs of excess fine-gravel from both legacy and contemporary sources appear to be a primary factor of stream degradation. Secondary factors include fine-grained deposition in the channel and hydrologic disruption due to dams and urbanization.

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TABLES

Table 1: Hierarchical classification system for watersheds

Classification Level	Spatial Scale (area or length)	Temporal Scale (adjustment time in years)
Geomorphic Province	1,000 km^2	>10,000
Watershed	500 km^2	>10,000
Process Zone: Source zone Transport zone Response zone	<500 km^2	>/= 10,000
Valley Segment: Colluvial segment Bedrock segment Alluvial segment	100 to 10,000 m	1,000 to 10,000
Channel Reach: Colluvial reach Bedrock reach Alluvial, free-formed reach Alluvial, forced reach	10 to 1000 m	1 to 1,000
Channel Unit: "Fast Water" unit (riffle, run) "Slow Water" unit (pool, glide) Bar unit	1 to 10m	<1 to 100

Table 2: River Geomorphology Indicators (after Montgomery and MacDonald, 2002)

Watershed-scale → (Geology and Land Use Stressors)	Valley Bottom-scale → (Local Conditions)	Reach-scale (Geomorphic Response)
Past and present inputs of:	Slope	Channel type and form
Water	Confinement	Bank conditions
Sediment	Entrenchment	Gravel bars
Wood	Flow obstructions	Pool characteristics
(vectors)	Bed and Bank material	Bed material size and sorting
	Riparian vegetation	Instream cover (boulders,
	Overbank deposition	woody debris, microhabitats)

Table 3: Field Indicators for Diagnosing Channel Conditions
(after Barbour et al. 1999; Legassi et al. 2001; Panfil and Jacobson, 2001; Montgomery and MacDonald, 2002; Johnson, 2006)

Field Indicators	Role and Interpretation
	Valley Bottom or Segment-scale
Slope	Primary control on channel type and energy dissipation.
Confinement	Primary control on possible planform channel patterns. Narrow valleys limit the area available for floodplain deposition, flood water detention, and planform adjustment.
Entrenchment	Indicates longer-term balance between runoff and sediment load (sediment budget and erosion/deposition processes). High values indicate a relatively large range in flow stage (flashiness) and potential for deep, turbulent flood flows. Low values indicate a frequent connection of higher flows to and deposition to floodplain areas and allows for more energy dissipation during floods.
Riparian Vegetation	Primary control on channel characteristics. Indicates bank and floodplain resistance and roughness. Provides source of large woody debris to the channel. Responsible for natural bar and bank stabilization. Provides energy dissipation during high flows.
Overbank Deposition	Indicates types and magnitude of recent deposits. May contain subsurface record of past disturbances. Fine-grained deposition may be required for floodplain formation and recovery of eroded or failed banks. Coarse-grained deposition can be caused by the passage of large floods, channel aggradation, excessive bar deposition, and/or transition to a braided channel type.

Table 3: Field Indicators for Diagnosing Channel Conditions (continued)

Field Indicators	Role and Interpretation
	Active Channel or Reach-scale
Channel Pattern or Type	Indicator of sediment availability, transport capacity, and riparian vegetation influence. High sinuosity decreases slope and increases potential energy dissipation in the channel. Directly relates to longitudinal profile and reach slope.
Bank Conditions	Indicator of recent disturbance such as increased flooding or channel aggradation. Indicator of relative channel migration or widening rate. Eroding banks must be considered relative to stream type and channel location.
Gravel Bars	Number, location, and extent related to sediment supply. Interpretation based on channel type, valley configuration, network location, vegetation influence, and historical conditions. Indicator of energy dissipation in the channel.
Channel Dimensions	Indicator of discharge and sediment load. Channel defined by bankfull or dominant stage. Interpretation based on local and watershed conditions. Channel width and depth are typically evaluated.
Pool Characteristics	Indicator of energy dissipation, sediment load, and pool-forcing mechanisms. Fine-grained deposition in pools can indicate upstream source and changes in sediment yields. Pool location, size, and number must be considered relative to stream type, sediment load, and disturbance history. Residual pools are used to determine pool length and depth.
Bed Material Size	Indicator of the relative balance between recent discharge and sediment supply. Changes overtime can indicate upstream changes in supply due to disturbances in the watershed or channel. High embeddedness of gravel/cobble bed with fines is indicator of poor bed condition. Indicator of hydraulic roughness and energy dissipation.

Table 3: Field Indicators for Diagnosing Channel Conditions (continued)

Field Indicators	Role and Interpretation
	Channel Unit or Habitat-scale
Riffle-pool arrangement	Reach-scale variations in channel units reflect a variety of geomorphic processes. Theoretical arrangements can be predicted for channel types and compared to field observations. Locally high quality or diverse channel unit assemblages may yield significant habitat value at the segment-scale.
Bed Material Sorting	Indicator of local variations in flow, sediment supply, hydraulic roughness, and influence of obstructions. Provides for patch-scale variations within channel units.
In-stream habitat cover	Number, diversity, and distribution reflect multiple causes. Examples include obstacles such as boulders and large woody debris jams and micro-habitats including bank cavities, overhanging roots, and aquatic vegetation.

Table 4: Metrics Used in this Protocol

Field Indicators	Protocol Metrics
Valley Bottom or Segment-scale	
Slope:	Valley segment slope and elevation (from GIS) Longitudinal channel or water surface slope
Confinement:	Relative valley width Cross-section survey Relative meander-belt width or total channel width Measures of bedrock influence
Entrenchment:	Bank height ratio (top TC bank/low BF bank) Entrenchment Ratio (Rosgen, 1996)
Riparian Vegetation:	Riparian Forest cover (%) in 100 meter buffer Woody debris tally Root protection and cover on banks
Overbank Deposition	
Active Channel or Reach-scale	
Channel Pattern or Type:	Channel type classification (Rosgen, 1996) Sinuosity Riffle-spacing
Bank Conditions:	Visual erosion indicators: Bank angle (% low angle) Root protection (% protected) Raw upper bank (% eroded) Relative Bank Height (
Gravel Bars:	Bar width (% of BF width) Bar pebble count
Channel Dimensions:	Channel cross-section (width and depth) Bankfull and total channel capacity: Channel roughness Channel discharge Channel power
Pool Characteristics:	Longitudinal profile survey

Residual pool length and depth

Table 4: Metrics Used in this Protocol (continued)

Field Indicators	Protocol Metrics
	Pool classification
Bed Material Size	Visual thalweg survey Pebble count by reach Embeddedness: Total (<16 mm) and fine (<2 mm)
Channel Stability	Visual Rapid Physical Assessment (USEPA) Relative Bed Stability (shear stress corrected) Riffle Stability Index
<u>Channel Unit or Habitat-scale</u>	
Riffle-Pool Arrangement:	Channel unit classification Longitudinal profile survey
Bed Material Sorting:	Pebble count for glides and riffles Sorting value Fredle Index
In-stream flow resistance:	Woody debris tally Boulders by pebble count and visual survey Residual pool analysis

Table 5 : Substrate Classification for Pebble Count Measurements

Minimum Class Diameter (mm)	Substrate Class
Gravelometer Sieve Diameter	
2	Very fine gravel
2.8	Very fine gravel
4	Fine gravel
5.6	Fine gravel
8	Medium gravel
11	Medium gravel
16	Coarse gravel (f)
22.6	Coarse gravel (c)
32	Very coarse gravel (f)
45	Very coarse gravel (c)
64	Small cobble (f)
90	Small cobble (c)
128	Large cobble (f)
180 → 256 ruler	Large cobble (c)
Ruler Measurement of B-axis	
256	Small boulder
512	Medium boulder
1,024	Large boulder
2,048+	X-Large boulder
Nominal Classes (visual judgement)	
F^+	Fines: mud, recent deposits of clay and silt, smooth texture
S	Sand: granular, gritty to the touch
R	Bedrock: smooth or rough
E	Exposed/cut earth: scour into soil material (not recent sediment)
O	Organic material: marl, muck, or debris.
A	Artificial surface: bridge, dam, stabilization structure, etc.
U	Unknown or unable to evaluate

Table 6: **Watershed Topography for all 30 UWRB Assessment Sites**

Site Name	Drainage Area km^2	Site Elevation (m)	Elev. at Top of Basin	Watershed Slope
Bear Creek near Omaha, AR	344.2	217	462	0.0058
Beaver Creek at Bradleyville	772.6	250	493	0.0035
Bull Creek Center St.	96.9	292	419	0.0107
Bull Creek near Walnut Shade	506.9	220	419	0.0043
Crane Creek at Highway AA	399.1	298	433	0.0040
Finley Creek below Riverdale	666.4	317	494	0.0022
Finley Creek near Sparta	425.0	364	494	0.0023
Flat Creek below Jenkins	557.9	348	476	0.0024
James Near Springfield	634.3	350	506	0.0025
James River at Galena	2562.5	285	506	0.0015
James River near Boaz	1191.7	317	506	0.0018
Kings River Hwy 221	788.4	318	694	0.0036
Kings River near Berryville	1363.4	298	694	0.0030
Kings River near Kingston, AR	166.3	399	694	0.0112
Long Creek at Denver	266.0	304	666	0.0086
Middle Fork White River near Fayetteville	196.6	357	733	0.0098
Osage Creek southwest of Berryville	386.7	327	688	0.0051
Pond Creek near Longrun, MO	52.8	237	354	0.0102
Richland Creek at Goshen	361.8	344	588	0.0067
Richland Creek Hwy 303	223.0	378	588	0.0125
Swan Creek near Swan	383.1	243	495	0.0051
Turkey Creek	93.0	218	370	0.0078
Upper Flat Creek at C	411.0	348	475	0.0034
Upper James at B	242.7	385	508	0.0036
War Eagle Creek near Hindsville	683.8	355	644	0.0039
War Eagle Creek near Huntsville	518.0	374	644	0.0049
West Fork White River east of Fayetteville	309.8	353	550	0.0041
White River at Elkins	464.9	363	655	0.0050
White River near Fayetteville	1022.5	349	655	0.0041
Yocum Creek near Oak Grove	136.0	298	476	0.0064

Table 7: Watershed Geology

Site Name	Geology %			
	Dolostone	Limestone	Sandstone	Shale
Bear Creek near Omaha, AR	41	49	10	0
Beaver Creek at Bradleyville	88	5	7	0
Bull Creek Center St.	20	80	0	0
Bull Creek near Walnut Shade	44	56	0	0
Crane Creek at Highway AA	3	92	5	0
Finley Creek below Riverdale	12	88	0	0
Finley Creek near Sparta	19	81	0	0
Flat Creek below Jenkins	9	90	1	0
James Near Springfield	13	87	0	0
James River at Galena	9	90	1	0
James River near Boaz	7	92	1	0
Kings River Hwy 221	9	38	51	2
Kings River near Berryville	21	30	45	4
Kings River near Kingston, AR	0	0	100	0
Long Creek at Denver	0	40	60	0
Mid. Fork White River nr. Fayetteville	0	0	100	0
Osage Creek southwest of Berryville	0	0	100	0
Pond Creek near Longrun, MO	98	2	0	0
Richland Creek at Goshen	0	8	92	0
Richland Creek Hwy 303	0	0	100	0
Swan Creek near Swan	69	31	0	0
Turkey Creek	100	0	0	0
Upper Flat Creek at C	0	99	1	0
Upper James at B	17	83	0	0
War Eagle Creek near Hindsville	0	27	73	0
War Eagle Creek near Huntsville	0	8	92	0
W. Fork White River E. of Fayetteville	0	2	98	0
White River at Elkins	0	1	99	0
White River near Fayetteville	0	2	98	0
Yocum Creek near Oak Grove	7	73	17	2

Table 8: Watershed Landuse

Site Name	Land Use %								Road Density
	HD Urban	LD Urban	Barren	Cropland	Grass	Forest	Young Forest	Water	
Bear Creek near Omaha, AR	0.6	0.6	1.9	0	31.3	59.9	5.6	0	1.10
Beaver Creek at Bradleyville	0.6	0.8	1	0.7	47	43.7	5.8	0.4	1.13
Bull Creek Center St.	0.2	0.5	0.4	0.7	39.3	55.1	3.1	0.5	1.06
Bull Creek near Walnut Shade	1.6	0.3	1	0.2	24	67.7	4.7	0.5	1.06
Crane Creek at Highway AA	0.6	0.6	0.3	2.5	71.9	19.9	4.2	0.1	1.62
Finley Creek below Riverdale	1.8	2.7	1	2.4	61.3	27.2	3.1	0.5	1.90
Finley Creek near Sparta	1	0.7	1	2.7	55.6	35.5	3.1	0.4	1.52
Flat Creek below Jenkins	1.2	1.1	0.8	3.2	61.7	26.4	5.5	0.1	1.43
James Near Springfield	1.8	2.7	1	6.9	52.7	30.6	3.7	0.6	1.87
James River at Galena	3.9	5.6	0.9	3.4	57.5	24.4	3.8	0.7	2.31
James River near Boaz	7	10.1	0.9	4.9	51.3	21.6	3.5	0.8	2.91
Kings River Hwy 221	0	0.1	1.3	0	20.5	73.5	4.5	0	1.10
Kings River near Berryville	0.2	0.5	1.5	0	22	71.1	4.6	0.1	1.15
Kings River near Kingston, AR	0	0	1.1	0	10.7	85.2	2.9	0.1	0.73
Long Creek at Denver	0.1	0.7	1.4	0	31.5	61.9	4.3	0	1.08
Mid. Fork White nr. Fayetteville	0	0.4	1.2	0	19.3	73.5	5.4	0.1	1.22

Osage Creek sw of Berryville	0.1	0.4	1.4	0	22.1	72.3	3.7	0	1.07
Pond Creek near Longrun, MO	0.2	0	4	0.1	34.5	51.8	9.2	0.2	0.98
Richland Creek at Goshen	0	0.4	1.3	0	26.4	65.4	6.4	0.1	1.19
Richland Creek Hwy 303	0	0	0.9	0	18.1	74.7	6.2	0	1.07
Swan Creek near Swan	0.4	0.3	0.8	0.3	23.4	69.5	4.7	0.6	0.93
Turkey Creek	0.6	0.1	0.8	0.1	57.9	35.3	5	0.1	1.03
Upper Flat Creek at C	1.4	1.4	0.8	4.2	67.8	18.7	5.5	0.1	1.62
Upper James at B	1.4	1.3	1.2	9.1	53.6	29.2	3.8	0.5	1.51
War Eagle Creek near Hindsville	0.3	0.8	1.8	0	27.6	63.9	5.7	0	1.12
War Eagle Creek near Huntsville	0.3	0.9	1.4	0	21.8	70.4	5.1	0.1	1.11
W. Fork White E. of Fayetteville	4	6.3	1.3	0	17	65.2	6	0.2	1.95
White River at Elkins	0	0.1	0.6	0	10.1	85.7	3.4	0.1	0.87
White River near Fayetteville	1.3	2.5	1	0	15	75.2	4.7	0.3	1.31
Yocum Creek near Oak Grove	1.3	1.3	2.1	0.2	67.9	22	5.2	0	1.19

Table 9: **Watershed characteristics**

Site	Geology	Landuse	Urban Influence	Relative Disturbance
Finley Creek Below Riverdale	Limestone	Pasture	Mod-Low	Mod
Flat Creek Below Jenkins	Limestone	Pasture	Mod-Low	Mod
James River at Galena	Limestone	Pasture	High	High
James River at Boaz	Limestone	Pasture	High	High
Kings River near Berryville	Mixed	Forest	Low	Low
Swan Creek near Swan	Dolomite	Forest	Very Low	Low
War Eagle Creek near Hindsville	Sandstone	Forest	Low	Low
West Fork East of Fayetteville	Sandstone	Forest	High	Mod-High
White River near Fayetteville	Sandstone	Forest	Mod-Low	Mod
Yocum Creek near Oak Grove	Limestone	Pasture	Low	Mod

Table 10: Valley-Scale Conditions

Site	Reach Length (m)	Rise (m)	Slope Valley (m/m)	W_v (m)	W_{bf} (m)	Valley Conf. Ratio (m/m)	W_{tc} (m)	Meander Belt Conf. (m/m)	d_{bfm} (m)	d_{tcm} (m)	Bank Height Ratio (m/m)	Forest in Riparian Area (%)	LWD Vol./100m (m^3)	Bedrock in Channel (%)	Boulders within 5 m (%)	Bluff Pools of all Pools (%)
Finley Creek Below Riverdale	1,242	3.5	0.0028	246	50.16	4.9	59.91	1.19	1.77	2.77	1.56	45.4	22.6	20	47	18
Flat Creek Below Jenkins	788	0.1	0.0001	143	35.70	4.0	44.76	1.25	1.27	2.38	1.88	57.4	98.6	4	7	0
Flat Creek Duplicate	731	0.1	0.0001	143	36.87	3.9	49.3	1.34	1.41	2.50	1.77	57.4	81.0	2	16	0
James River at Galena	1,225	0.5	0.0004	233	71.02	3.3	90.05	1.27	1.83	3.57	1.95	38.8	9.2	15	47	6
James River at Boaz	1,118	3.0	0.0027	208	47.87	4.3	61.9	1.29	1.77	3.97	2.24	53.4	42.2	30	79	0
Kings River near Berryville	781	1.9	0.0025	146	65.34	2.2	77.13	1.18	1.52	3.82	2.52	47.2	35.8	41	41	0
Swan Creek near Swan	840	0.9	0.0011	253	42.85	5.9	53.57	1.25	1.37	2.90	2.11	46.6	21.3	37	71	0
Swan Creek Duplicate	825	0.9	0.0011	253	41.17	6.1	48.65	1.18	1.28	2.77	2.17	46.6	23.2	26	50	0
War Eagle Creek near Hindsville	624	1.3	0.0020	174	38.42	4.5	52.77	1.37	1.28	3.72	2.90	59.3	381.8	8	31	11
West Fork East of Fayetteville	571	0.6	0.0011	166	29.14	5.7	34.56	1.19	1.49	2.87	1.92	33.9	7.0	10	20	0
White River near Fayetteville	482	1.2	0.0024	316	37.63	8.4	45.24	1.20	1.19	2.54	2.14	65.1	38.6	36	69	0
Yocum Creek near Oak Grove	362	0.4	0.0012	161	16.95	9.5	26.29	1.55	1.13	2.73	2.41	46.8	70.4	3	69	42

Table 11: Riparian Forest Area Analysis

Site Name	Total Reach Length (m)	Total Reach Area (m^2)	Riparian Area Right (m^2)	Riparian Area Left (m^2)	Riparian Area Total (m^2)	Riparian Area % Right (%)	Riparian Area % Left (%)	Riparian Area % Total (%)
Finley Creek below Riverdale	1,242	248,400	42,928	69,957	112,885	35	56	45
Flat Creek below Jenkins	788	157,600	58,104	32,313	90,417	74	41	57
James River at Galena	1,225	245,000	68,441	26,208	95,049	56	21	39
James River near Boaz	1,118	223,600	32,106	87,308	119,414	29	78	53
Kings River near Berryville	781	156,200	34,326	39,371	73,697	44	50	47
Swan Creek near Swan	840	168,000	27,773	50,519	78,292	33	60	47
War Eagle Creek near Hindsville	624	124,800	18,293	55,727	74,020	29	89	59
West Fork White River east of Fayetteville	571	114,200	21,734	17,021	38,755	38	30	34
White River near Fayetteville	482	96,400	28,179	34,590	62,769	58	72	65
Yocum Creek near Oak Grove	362	72,400	5,144	28,747	33,891	14	79	47

Table 12: Bank Conditions

Site	D_{bf} (m)	D_{tc} (m)	Bank Height Ratio (m/m)	Bank Height Index	Bank Eroded (%)	Bank Erosion Index	Root Protected (%)	Root Protection Index	RBEI	RBEI Rating
Finley Creek Below Riverdale	1.77	2.77	1.56	3	42	3	78	5	**3.2**	**B**
Flat Creek Below Jenkins	1.27	2.38	1.88	3	3	5	27	4	**3.8**	**A**
Flat Creek Duplicate	1.41	2.50	1.77	3	6	5	15	2	**3.3**	**B**
James River at Galena	1.83	3.57	1.95	3	17	4	29	3	**3.1**	**B**
James River at Boaz	1.77	3.97	2.24	2	5	5	69	5	**3.8**	**A**
Kings River near Berryville	1.52	3.82	2.52	2	20	4	30	4	**3.1**	**B**
Swan Creek near Swan	1.37	2.90	2.11	2	13	4	42	4	**3.1**	**B**
Swan Creek Duplicate	1.28	2.77	2.17	2	21	4	84	5	**3.4**	**B**
War Eagle Cr. near Hindsville	1.28	3.72	2.90	2	8	5	29	3	**3.3**	**B**
West Fork East of Fayetteville	1.49	2.87	1.92	3	13	4	40	4	**3.4**	**B**
White R. near Fayetteville	1.19	2.54	2.14	2	29	3	44	4	**2.7**	**C**
Yocum Cr. near Oak Grove	1.13	2.73	2.41	2	13	4	31	4	**3.1**	**B**

Table 13: Large Woody Debris Characteristics

Site Name	Channel Reach		Pieces			Jams		Total Volume (m3)		
	Length (m)	Area (m2)	Count (n)	No. per 100 m	Volume (m3)	Count (n)	Volume (m^3)	Volume (m^3)	Volume/ 100m (m^3)	Mean depth (Wd, m)
Finley Creek Below Riverdale	1242	62,348	37	3.0	16.9	8	161.5	178.4	14.4	0.0029
Flat Creek Below Jenkins	788	28,132	45	5.7	12.3	4	684.0	696.3	88.4	0.0248
Flat Creek Duplicate	731	26,974	40	5.5	8.6	6	516.3	524.9	71.8	0.0195
James River at Galena	1225	86,975	58	4.7	23.0	3	19.8	42.8	3.5	0.0005
James River at Boaz	1118	53,552	37	3.3	16.5	13	338.6	355.1	31.8	0.0066
Kings River near Berryville	781	50,999	18	2.3	5.9	7	273.3	279.2	35.8	0.0055
Swan Creek near Swan	840	36,036	15	1.8	5.7	3	141.0	146.7	17.5	0.0041
Swan Creek Duplicate	825	33,990	17	2.1	23.5	3	116.0	139.5	16.9	0.0041
War Eagle Creek near Hindsville	624	23,962	33	5.3	16.3	11	2366.3	2382.6	381.8	0.0994
West Fork East of Fayetteville	571	16,616	19	3.3	2.9	3	37.0	39.9	7.0	0.0024
White River near Fayetteville	482	18,123	33	6.8	11.4	11	174.9	186.2	38.6	0.0103
Yocum Creek near Oak Grove	362	6,154	28	7.7	5.1	6	249.7	254.8	70.4	0.0414

Table 14: Longitudinal Rod Survey of Channel Substrate

Site Name	% Primary Substrate						% With Boulders Present	% Bar Occurrence
	Bedrock	Boulders	Coarse Cobble	Fine Cobble/ Crs. Gravel	Fine Gravel/ Sand	Fines		
Finley Creek Below Riverdale	20	6	33	41	0	0	47	41
Flat Creek Below Jenkins	4	0	30	63	2	0	7	29
Flat Creek Duplicate	2	0	14	84	0	0	16	26
James River at Galena	15	1	16	50	18	0	47	37
James River at Boaz	30	9	39	23	0	0	79	0
Kings River near Berryville	41	0	14	43	2	0	41	22
Swan Creek near Swan	37	6	25	29	2	0	71	14
Swan Creek Duplicate	26	6	0	61	8	0	50	27
War Eagle Creek near Hindsville	8	0	3	61	17	11	31	28
West Fork East of Fayetteville	10	0	24	27	22	17	20	6
White River near Fayetteville	36	8	14	34	3	6	69	10
Yocum Creek near Oak Grove	3	0	37	57	3	0	69	40

Table 15: Bed Material Characteristics by Channel Unit

Site	Location	% of Material Less than 2mm			Grain Size (mm)							Geo Mean	Otto Sorting Coefficient	Fredle Index
		n Total	F+S	R	n >2mm	D5	D16	D50	D84	D95	Max			
Finley Creek below Riverdale	Glide	120	153.0	0.8	112	5.6	14.8	22.6	45.0	53.5	64.0	22.7	1.7	13.0
	Riffle	120	150.5	1.7	115	11.0	16.0	32.0	64.0	64.0	300.0	31.4	2.0	15.7
	Bar	105	139.0	0.0	102	8.0	16.0	22.6	45.0	64.0	90.0	23.6	1.7	14.1
Flat Creek below Jenkins	Glide	120	0.8	7.5	110	2.8	8.0	22.6	32.0	64.0	128.0	17.2	2.0	8.6
	Riffle	120	2.5	5.8	110	4.7	11.0	22.6	45.0	64.0	90.0	20.6	2.0	10.2
	Bar	105	2.9	0.0	102	8.0	8.0	16.0	32.0	45.0	90.0	17.4	2.0	8.7
Flat Creek Duplicate	Glide	120	5.0	5.0	148	4.0	5.6	16.0	32.0	45.0	90.0	15.5	2.4	6.5
	Riffle	120	6.7	7.5	143	4.0	5.6	16.0	45.0	45.0	64.0	15.2	2.8	5.4
	Bar	105	1.0	0.0	139	7.8	11.0	22.6	44.0	45.0	190.0	18.9	2.0	9.4
James River at Galena	Glide	120	10.8	10.0	87	5.6	8.0	22.6	32.0	58.3	300.0	19.1	2.0	9.5
	Riffle	120	10.8	0.0	102	4.1	8.0	16.0	45.0	64.0	300.0	17.8	2.4	7.5
	Bar	105	3.8	0.0	101	8.0	11.0	22.6	32.0	45.0	100.0	22.1	1.7	13.0
James River near Boaz	Glide	120	0.0	22.5	93	11.0	16.0	32.0	50.3	105.2	300.0	32.5	1.8	18.3
	Riffle	120	0.8	8.3	109	11.0	16.0	32.0	64.0	128.0	300.0	34.7	2.0	17.4
	Bar	105	1.9	0.0	68	9.1	14.6	22.6	45.0	64.0	128.0	24.8	1.8	14.1
Kings River near Berryville	Glide	120	6.7	25.0	82	4.0	5.6	16.0	45.0	90.0	650.0	16.3	2.8	5.8
	Riffle	120	2.5	30.8	80	4.0	8.0	22.6	64.0	90.0	128.0	22.2	2.8	7.9
	Bar	105	1.9	0.0	103	4.0	6.4	16.0	64.0	124.2	470.0	19.4	3.2	6.1
Swan Creek near Swan	Glide	120	1.6	11.7	104	6.0	11.0	22.6	64.0	172.2	300.0	26.9	2.4	11.2
	Riffle	120	0.0	0.0	120	7.9	11.2	45.0	228.0	300.0	300.0	47.4	4.5	10.5
	Bar	105	2.9	1.0	86	8.8	16.0	45.0	90.0	292.5	300.0	42.9	2.4	18.1
Swan Creek Duplicate	Glide	120	1.6	16.7	98	7.6	11.0	22.6	90.0	190.0	300.0	29.0	2.9	10.1
	Riffle	120	0.8	1.7	117	5.6	11.0	22.6	90.0	204.0	300.0	29.8	2.9	10.4
	Bar	105	0.0	0.0	60	15.8	22.6	32.0	64.0	300.0	300.0	37.1	1.7	22.0

War Eagle Creek near Hindsville	Glide	120	24.2	21.7	65	8.6	16.0	32.0	90.0	128.0	180.0	31.7	2.4	13.4
	Riffle	120	33.3	3.3	76	5.2	11.0	32.0	90.0	265.0	500.0	32.8	2.9	11.5
	Bar	105	3.9	12.4	86	8.0	11.0	22.6	45.0	83.5	280.0	22.7	2.0	11.2
West Fork east of Fayetteville	Glide	120	24.2	0.0	87	4.0	8.0	22.6	45.0	64.0	64.0	18.6	2.4	7.9
	Riffle	120	17.5	0.0	89	5.6	8.0	16.0	45.0	45.0	64.0	17.5	2.4	7.4
	Bar	105	53.3	0.0	49	5.6	8.0	22.6	45.0	64.0	90.0	19.4	2.4	8.2
White River near Fayetteville	Glide	120	2.5	37.5	65	5.6	8.0	16.0	64.0	120.4	300.0	19.9	2.8	7.0
	Riffle	120	8.3	19.2	87	6.3	11.0	45.0	90.0	180.0	610.0	34.6	2.9	12.1
	Bar	105	1.0	0.0	104	8.0	11.0	22.6	45.0	64.0	90.0	23.3	2.0	11.5
Yocum Creek near Oak Grove	Glide	120	0.0	0.0	118	8.0	11.0	22.6	45.0	64.0	90.0	21.5	2.0	10.6
	Riffle	120	0.0	0.8	119	5.6	11.0	22.6	32.0	64.0	128.0	19.6	1.7	11.5
	Bar	105	2.9	0.0	102	4.1	8.0	16.0	22.6	32.0	128.0	13.8	1.7	8.2

Table 16: Residual Pool Characteristics

Site Name	Reach Length (m)	Percent Residual Pool	Mean Res. Pool Length	Maximum Res. Pool Length (m)	Mean Max Res. Pool Depth (m)	Mean Res. Pool Depth (m)
Finley Creek Below Riverdale	1242	89	366	619	0.9	0.19
Flat Creek Below Jenkins	788	67	176	219	0.8	0.11
Flat Creek Duplicate	731	63	115	229	0.6	0.09
James River at Galena	1225	85	260	927	0.8	0.21
James River at Boaz	1118	90	503	885	1.1	0.31
Kings River near Berryville	781	83	323	392	0.9	0.19
Swan Creek near Swan	840	85	238	333	0.8	0.19
Swan Creek Duplicate	825	87	179	295	0.7	0.19
War Eagle Creek near Hindsville	624	87	273	399	1.6	0.38
West Fork East of Fayetteville	571	98	173	342	1.0	0.28
White River near Fayetteville	482	96	163	237	1.0	0.23
Yocum Creek near Oak Grove	362	69	83	108	0.8	0.15

Table 17: Channel Unit Classification and Pool Type

Site Name	Pool	Glide	Riffle	Run	Middle Pool	Bluff Pool	Scour Pool	Side Pool	Confluence Pool
Finley Creek Below Riverdale	53	22	5	20	65	18	15	3	0
Flat Creek Below Jenkins	20	32	15	34	0	0	44	33	22
Flat Creek Duplicate	38	22	28	12	68	0	21	5	5
James River at Galena	47	11	8	34	94	6	0	0	0
James River at Boaz	51	23	0	26	100	0	0	0	0
Kings River near Berryville	9	2	34	55	50	0	0	50	0
Swan Creek near Swan	35	24	10	31	94	0	0	0	6
Swan Creek Duplicate	27	29	8	36	67	0	6	28	0
War Eagle Creek near Hindsville	50	19	31	0	89	11	0	0	0
West Fork East of Fayetteville	39	37	15	10	81	0	0	19	0
White River near Fayetteville	22	42	11	25	100	0	0	0	0
Yocum Creek near Oak Grove	34	26	14	26	8	42	25	25	0

Table 18: Rosgen Classification System (Rosgen, 1996)

Section #	Site	W_{fpa} (m)	Entrench Ratio (m/m)	w/d Ratio (m/m)	Sinuosity (m/m)	Slope m/m	D_{50} mm	Rosgen Classification
1	Finley Creek Below Riverdale	61.1	1.4	32.6	1.20	0.0008	23	
2	Finley Creek Below Riverdale	>	>2.2	47.6	1.20	0.0005	32	
3	Finley Creek Below Riverdale	>	>2.2	41.7	1.20	0.0013	32	C4c
	Site Mean		>2.2	40.6	1.20	0.0009	29	
	sd			7.5	0.00	0.0004	5.2	
	cv%			19	0	44	18	
1	Flat Creek Below Jenkins	59.2	1.4	63.8	1.07	0.0015	22	
2	Flat Creek Below Jenkins	49.6	1.1	73.1	1.07	0.0015	22	
3	Flat Creek Below Jenkins	>	>2.2	23.8	1.07	0.0015	22	F4
	Site Mean		1.3	53.6	1.07	0.0015	22	
	sd		0.2	26.2	0.00	0.0	0.0	
	cv%		16	49	0	0.0	0.0	
1	Flat Creek Duplicate	60.2	1.5	56.1	1.07	0.0015	18	
2	Flat Creek Duplicate	48.3	1.1	82.1	1.07	0.0015	18	
3	Flat Creek Duplicate	>	>2.2	27.7	1.07	0.0015	18	F4
	Site Mean		1.3	55.3	1.07	0.0015	18	
	sd		0.3	27.2	0.0	0.0000	0.0	
	cv%		23	49	0	0	0.0	
1	James River at Galena	75.2	1.1	62.6	1.11	0.0017	16	
2	James River at Galena	122.2	1.5	67.4	1.11	0.0013	23	
3	James River at Galena	>	>2.2	48.9	1.11	0.0016	19	F4
	Site Mean		1.3	59.6	1.11	0.0015	19	
	sd		0.3	9.6	0.00	0.0002	3.3	
	cv%		24	16	0	15	17	

1	James River at Boaz	51.7	1.1	38.6	1.04	0.0004	32	
2	James River at Boaz	67.5	1.3	36.4	1.04	0.0001	32	
3	James River at Boaz	54.5	1.1	46.4	1.04	0.0007	11	F4
	Site Mean		1.2	40.5	1.04	0.0004	25	
	sd		0.1	5.2	0.00	0.0003	12.1	
	cv%		9	13	0	65	48	
1	Kings River near Berryville	79.8	1.2	83.4	1.05	0.0017	16	
3	Kings River near Berryville	68.5	1.0	65.3	1.05	0.0013	23	
	Site Mean		1.1	74.4	1.05	0.0015	19	F4
	sd		0.1	12.7	0.00	0.0003	4.7	
	cv%		11	17	0	20	24	
1	Swan Creek near Swan	49.7	1.2	43.5	1.05	0.0011	32	
2	Swan Creek near Swan	51.9	1.2	45.2	1.05	0.0011	27	
3	Swan Creek near Swan	>	>2.2	49.0	1.05	0.0012	32	F4
	Site Mean		1.2	45.9	1.05	0.0011	30	
	sd		0.0	2.8	0.00	0.0001	2.7	
	cv%		1	6	0	5	9	
1	Swan Creek Duplicate	44.8	1.1	44.6	1.05	0.0011	23	
2	Swan Creek Duplicate	49.2	1.2	43.7	1.05	0.0011	32	
3	Swan Creek Duplicate	>	>2.2	51.5	1.05	0.0012	32	F4
	Site Mean		1.1	46.6	1.05	0.0011	29	
	sd		0.0	4.3	0.00	0.0001	5.4	
	cv%		2	9	0	5	19	
1	War Eagle Creek near Hindsville	32.6	1.0	35.0	1.07	0.0008	11	
3	War Eagle Creek near Hindsville	58.1	1.3	61.1	1.07	0.0008	32	F4
	Site Mean		1.2	48.0	1.07	0.0008	22	
	sd		0.2	18.4	0.00	0.0000	14.8	
	cv%		16	38	0	0	69	

1	West Fork East of Fayetteville	34.2	1.1	37.9	1.50	0.0006	23	
2	West Fork East of Fayetteville	38.7	1.2	33.8	1.50	0.0003	11	F4
3	West Fork East of Fayetteville	31.2	1.4	24.8	1.50	0.0006	8	
	Site Mean		1.2	32.2	1.50	0.0005	14	
	sd		0.1	6.7	0.00	0.0002	7.7	
	cv%		12	21	0	35	56	
1	White River near Fayetteville	53.8	1.2	59.5	1.14	0.0004	16	
2	White River near Fayetteville	38.2	1.1	41.6	1.14	0.0008	32	
3	White River near Fayetteville	41.5	1.2	50.8	1.14	0.0025	45	F4
	Site Mean		1.2	50.6	1.14	0.0012	31	
	sd		0.1	9.0	0.00	0.0011	14.5	
	cv%		5	18	0	91	47	
1	Yocum Creek near Oak Grove	27.9	1.7	20.1	1.21	0.0014	16	
2	Yocum Creek near Oak Grove	19.9	1.3	36.7	1.21	0.0067	23	B4c
3	Yocum Creek near Oak Grove	27.3	1.5	30.1	1.21	0.0025	32	
	Site Mean		1.5	29.0	1.21	0.0035	24	
	sd		0.2	8.4	0.00	0.0028	8.0	
	cv%		14	29	0	79	34	

Table 19: Rapid Geomorphic Channel Assessment

Site Name	Statistic	Riffle #1	Riffle #2	Riffle #3	All	Overall Grade
Bear Creek near Omaha, AR	Mean	0.74				**B**
	St. Dev.	0.01				
	CV %	1.44				
Beaver Creek at Bradleyville	Mean	0.75				**B**
	St. Dev.	0.05				
	CV %	6.64				
Bull Creek Center St.	Mean	0.81				**A-**
	St. Dev.	0.04				
	CV %	5.27				
Bull Creek near Walnut Shade	Mean	0.79				**B+**
	St. Dev.	0.02				
	CV %	2.23				
Crane Creek at Highway AA	Mean	0.77				**B+**
	St. Dev.	0.07				
	CV %	9.24				
Finley Creek below Riverdale	Mean	0.79	0.85	0.76	0.80	**B+**
	St. Dev.	0.04	0.02	0.03	0.05	
	CV %	0.05	0.02	0.04	0.06	
Finley Creek near Sparta	Mean	0.76				**B**
	St. Dev.	0.02				
	CV %	3.27				
Flat Creek below Jenkins	Mean	0.78	0.80	0.80	0.79	**B+**
	St. Dev.	0.03	0.01	0.02	0.02	
	CV %	0.04	0.02	0.02	0.03	
Flat Creek Duplicate	Mean	0.80	0.85	0.77	0.81	**A-**
	St. Dev.	0.07	0.07	0.15	0.09	
	CV %	0.09	0.08	0.20	0.11	
James River near Springfield	Mean	0.66				**C**
	St. Dev.	0.02				
	CV %	2.69				
James River at Galena	Mean	0.79	0.55	0.70	0.68	**C+**
	St. Dev.	0.05	0.07	0.04	0.12	
	CV %	0.06	0.12	0.06	0.17	
James River near Boaz	Mean	0.85	0.84	0.85	0.84	**A**
	St. Dev.	0.01	0.01	0.03	0.02	
	CV %	0.01	0.02	0.03	0.02	
Kings River Hwy 221	Mean	0.82				**A-**
	St. Dev.	0.02				
	CV %	2.59				

Table 19 Continued: **Rapid Geomorphic Channel Assessment**

Site Name	Statistic	Riffle #1	Riffle #2	Riffle #3	All	Grade
Kings River near Berryville	Mean	0.79	0.76	0.81	0.79	**B+**
	St. Dev.	0.09	0.08	0.05	0.07	
	CV %	0.11	0.11	0.06	0.09	
Kings River near Kingston, AR	Mean	0.81				**A-**
	St. Dev.	0.00				
	CV %	0.44				
Long Creek at Denver	Mean	0.64				**C**
	St. Dev.	0.06				
	CV %	9.35				
Middle Fork of the White River near Fayetteville	Mean	0.27				**F**
	St. Dev.	0.08				
	CV %	29.84				
Osage Creek southwest of Berryville	Mean	0.71				**B-**
	St. Dev.	0.05				
	CV %	7.02				
Pond Creek near Longrun	Mean	0.62				**C-**
	St. Dev.	0.04				
	CV %	5.70				
Richland Creek at Goshen	Mean	0.46				**F**
	St. Dev.	0.15				
	CV %	32.28				
Richland Creek at Highway 303	Mean	0.72				**B-**
	St. Dev.	0.08				
	CV %	11.25				
Swan Creek near Swan	Mean	0.86	0.90	0.81	0.86	**A**
	St. Dev.	0.02	0.02	0.03	0.04	
	CV %	0.02	0.02	0.04	0.05	
Swan Creek Duplicate	Mean	0.80	0.88	0.74	0.80	**A-**
	St. Dev.	0.04	0.07	0.03	0.08	
	CV %	0.06	0.08	0.04	0.09	
Turkey Creek	Mean	0.78				**B+**
	St. Dev.	0.00				
	CV %	0.00				
Upper Flat Creek at C	Mean	0.74				**B**
	St. Dev.	0.00				
	CV %	0.00				
Upper James at B	Mean	0.73				**B**
	St. Dev.	0.05				
	CV %	6.78				

Table 19 Continued: Rapid Geomorphic Channel Assessment

Site Name	Statistic	Riffle #1	Riffle #2	Riffle #3	All	Overall Grade
War Eagle Creek near Hindsville	Mean	0.77	0.71	0.74	0.74	**B**
	St. Dev.	0.07	0.15	0.11	0.10	
	CV %	0.09	0.22	0.15	0.14	
War Eagle Creek near Huntsville	Mean	0.57				**D+**
	St. Dev.	0.04				
	CV %	6.85				
West Fork White River east of Fayetteville	Mean	0.66	0.62	0.53	0.60	**C-**
	St. Dev.	0.03	0.06	0.07	0.08	
	CV %	0.05	0.10	0.12	0.13	
White River near Elkins	Mean	0.65				**C**
	St. Dev.	0.05				
	CV %	7.10				
White River near Fayetteville	Mean	0.72	0.80	0.82	0.78	**B+**
	St. Dev.	0.14	0.07	0.06	0.09	
	CV %	0.19	0.09	0.08	0.12	
Yocum Creek near Oak Grove	Mean	0.75	0.84	0.81	0.80	**A-**
	St. Dev.	0.13	0.07	0.11	0.10	
	CV %	0.17	0.08	0.14	0.12	

Table 20: Bankfull Channel Dimensions, Morphology, and Discharge

Section #	Site	w	d_{bfm}	d_{bf}	R	A	Wp	Slope	Mannings	Mean V	Q
		(m)	(m)	(m)	(m)	(m^2)	(m)	(m/m)	"n"	(m/s)	(m^3/s)
1	Finley Creek Below Riverdale	44.6	1.94	1.4	1.3	61.0	45.3	0.0008	0.026	1.32	80.9
2	Finley Creek Below Riverdale	56.7	1.86	1.2	1.2	67.5	57.0	0.0005	0.025	1.00	67.4
3	Finley Creek Below Riverdale	49.2	1.52	1.2	1.2	58.0	50.1	0.0013	0.025	1.55	89.9
	Site Mean	50.2	1.77	1.2	1.2	62.2	50.8	0.0009	0.025	1.29	79.4
	sd	6.1	0.2	0.1	0.1	4.9	5.9	0.0004	0.001	0.28	11.3
	cv%	12.2	12.4	8.5	8.4	7.9	11.6	43.7	3.2	21.5	14.2
1	Flat Creek Below Jenkins	42.1	1.30	0.7	0.7	27.8	42.6	0.0015	0.023	1.24	34.6
2	Flat Creek Below Jenkins	44.3	1.03	0.6	0.6	26.8	44.8	0.0015	0.024	1.17	31.3
3	Flat Creek Below Jenkins	20.7	1.48	0.9	0.9	18.0	21.1	0.0015	0.023	1.52	27.5
	Site Mean	35.7	1.27	0.7	0.7	24.2	36.2	0.0015	0.023	1.31	31.1
	sd	13.0	0.2	0.1	0.1	5.4	13.1	0.0000	0.0004	0.19	3.6
	cv%	36.5	17.9	19.6	19.1	22.3	36.2	0.0	1.8	14.4	11.4
1	Flat Creek Duplicate	39.9	1.3	0.7	0.7	28.4	40.5	0.0015	0.022	1.4	39.5
2	Flat Creek Duplicate	44.8	1.2	0.5	0.5	24.4	45.3	0.0015	0.022	1.1	27.9
3	Flat Creek Duplicate	25.9	1.7	0.9	0.9	24.2	26.4	0.0015	0.022	1.7	40.9
	Site Mean	36.9	1.4	0.7	0.7	25.7	37.4	0.0015	0.022	1.4	36.1
	sd	9.8	0.3	0.2	0.2	2.4	9.8	0.00	0.0005	0.3	7.1
	cv%	26.6	20.1	26.7	26.4	9.2	26.3	0.0	2.1	19.5	19.8
1	James River at Galena	70.7	1.7	1.1	1.1	79.9	71.3	0.0017	0.023	1.9	151.9
2	James River at Galena	81.2	1.9	1.2	1.2	97.7	82.1	0.0013	0.024	1.6	160.7
3	James River at Galena	61.2	1.8	1.3	1.2	76.6	61.8	0.0016	0.023	2.0	150.8
	Site Mean	71.0	1.8	1.2	1.2	84.7	71.8	0.0015	0.023	1.8	154.5
	sd	10.0	0.1	0.1	0.1	11.4	10.2	0.0002	0.001	0.2	5.4
	cv%	14.0	6.5	5.1	5.0	13.4	14.1	14.9	2.2	9.3	3.5

1	James River at Boaz	45.1	2.0	1.2	1.2	52.6	45.7	0.0004	0.027	0.8	43.1
2	James River at Boaz	50.5	1.9	1.4	1.4	69.9	51.1	0.0001	0.026	0.6	39.4
3	James River at Boaz	48.1	1.4	1.0	1.0	49.8	48.3	0.0007	0.024	1.1	54.9
	Site Mean	47.9	1.8	1.2	1.2	57.5	48.4	0.0004	0.026	0.8	45.8
	sd	2.7	0.3	0.2	0.2	10.9	2.7	0.0003	0.002	0.3	8.1
	cv%	5.7	18.7	14.7	14.4	19.0	5.6	64.6	6.1	32.5	17.6
1	Kings River near Berryville	65.3	1.7	0.8	0.8	51.2	65.5	0.0017	0.024	1.5	74.6
3	Kings River near Berryville	65.4	1.4	1.0	1.0	65.4	66.0	0.0013	0.024	1.5	95.3
	Site Mean	65.3	1.5	0.9	0.9	58.3	65.8	0.0015	0.024	1.5	84.9
	sd	0.1	0.2	0.2	0.1	10.1	0.3	0.0003	0.000	0.0	14.7
	cv%	0.1	15.2	17.2	16.8	17.3	0.5	20.2	1.0	0.0	17.3
1	Swan Creek near Swan	41.8	1.3	1.0	1.0	40.1	42.0	0.0011	0.026	1.2	50.1
2	Swan Creek near Swan	44.4	1.3	1.0	1.0	43.6	44.8	0.0011	0.025	1.3	56.6
3	Swan Creek near Swan	42.4	1.5	0.9	0.9	36.7	43.1	0.0012	0.026	1.2	43.8
	Site Mean	42.9	1.4	0.9	0.9	40.1	43.3	0.0011	0.025	1.2	50.2
	sd	1.4	0.1	0.1	0.1	3.4	1.4	0.0001	0.001	0.1	6.4
	cv%	3.2	10.3	6.6	7.0	8.6	3.3	5.1	2.0	4.2	12.7
1	Swan Creek Duplicate	39.7	1.3	0.9	0.9	35.4	40.2	0.0011	0.025	1.2	43.3
2	Swan Creek Duplicate	42.4	1.3	1.0	1.0	41.2	43.1	0.0011	0.026	1.2	51.3
3	Swan Creek Duplicate	41.4	1.2	0.8	0.8	33.2	41.7	0.0012	0.026	1.1	37.2
	Site Mean	41.2	1.3	0.9	0.9	36.6	41.7	0.0011	0.026	1.2	43.9
	sd	1.4	0.0	0.1	0.1	4.1	1.5	0.0001	0.001	0.1	7.1
	cv%	3.3	3.4	9.4	9.1	11.2	3.5	5.1	3.3	5.6	16.0
1	War Eagle Creek near Hindsville	31.7	1.4	0.9	0.9	28.8	32.5	0.0008	0.026	1.0	28.8
3	War Eagle Creek near Hindsville	45.1	1.2	0.7	0.7	33.3	45.2	0.0008	0.031	0.7	24.6
	Site Mean	38.4	1.3	0.8	0.8	31.0	38.8	0.0008	0.029	0.9	26.7
	sd	9.5	0.1	0.1	0.1	3.2	9.0	0.0000	0.004	0.2	3.0
	cv%	24.6	9.2	14.4	13.0	10.4	23.2	0.0	13.1	21.5	11.3

1	West Fork East of Fayetteville	31.2	1.2	0.8	0.8	25.7	32.2	0.0006	0.028	0.8	19.4
2	West Fork East of Fayetteville	33.4	1.7	1.0	1.0	33.0	34.3	0.0003	0.024	0.7	22.8
3	West Fork East of Fayetteville	22.8	1.5	0.9	0.9	21.0	23.4	0.0006	0.024	1.0	20.0
	Site Mean	29.1	1.5	0.9	0.9	26.6	30.0	0.0005	0.025	0.8	20.8
	sd	5.6	0.2	0.1	0.1	6.0	5.8	0.0002	0.002	0.1	1.8
	cv%	19.1	15.4	9.1	9.3	22.8	19.3	34.6	8.7	17.2	8.7
1	White River near Fayetteville	45.7	1.5	0.8	0.8	35.2	46.6	0.0004	0.026	0.7	23.0
2	White River near Fayetteville	33.8	1.0	0.8	0.8	27.5	34.3	0.0008	0.028	0.9	23.8
3	White River near Fayetteville	33.3	1.1	0.7	0.6	21.8	34.0	0.0025	0.030	1.2	26.8
	Site Mean	37.6	1.2	0.7	0.7	28.2	38.3	0.0012	0.028	0.9	24.5
	sd	7.0	0.2	0.1	0.1	6.7	7.2	0.0011	0.002	0.3	2.0
	cv%	18.7	19.4	10.9	11.2	23.7	18.7	91.1	8.5	31.7	8.1
1	Yocum Creek near Oak Grove	16.6	1.5	0.8	0.8	13.8	17.6	0.0014	0.022	1.4	19.6
2	Yocum Creek near Oak Grove	15.6	1.0	0.4	0.4	6.7	16.5	0.0067	0.026	1.7	11.6
3	Yocum Creek near Oak Grove	18.6	0.9	0.6	0.6	11.5	18.7	0.0025	0.025	1.4	16.2
	Site Mean	17.0	1.1	0.6	0.6	10.6	17.6	0.0035	0.024	1.5	15.8
	sd	1.5	0.3	0.2	0.2	3.6	1.1	0.0028	0.002	0.2	4.0
	cv%	8.8	24.5	32.3	31.6	34.1	6.3	79.2	7.9	12.2	25.4

Table 21: Total Channel Dimensions, Morphology, and Discharge

Cross Section #	Site	W (m)	d_{tcm} (m)	d_{tc} (m)	R (m)	A m^2	P_w (m)	Slope m/m	Mannings "n"	Mean V m/s	Q m^3/s
1	Finley Creek Below Riverdale	60.5	3.6	2.4	2.4	148.0	61.5	0.0008	0.03	2.01	298
2	Finley Creek Below Riverdale	64.2	2.7	1.8	1.8	117.5	64.6	0.0005	0.03	1.23	145
3	Finley Creek Below Riverdale	55.0	2.0	1.5	1.5	84.1	56.2	0.0013	0.03	1.72	145
	Site Mean	**59.9**	**2.8**	**1.9**	**1.9**	**116.5**	**60.8**	**0.0009**	**0.03**	**1.66**	**196**
	sd	**4.6**	**0.8**	**0.5**	**0.5**	**32.0**	**4.3**	**0.0004**	**0.00**	**0.39**	**88**
	cv%	**7.7**	**28.3**	**24.2**	**24.2**	**27.4**	**7.0**	**46.6321**	**4.48**	**23.80**	**45**
1	Flat Creek Below Jenkins	54.5	2.9	2.0	1.9	108.4	55.8	0.0015	0.02	2.66	288
2	Flat Creek Below Jenkins	49.5	2.0	1.5	1.4	72.5	50.8	0.0015	0.02	2.13	155
3	Flat Creek Below Jenkins	30.3	2.2	1.2	1.2	35.8	30.8	0.0015	0.02	1.84	66
	Site Mean	**44.8**	**2.4**	**1.5**	**1.5**	**72.2**	**45.8**	**0.0015**	**0.02**	**2.21**	**170**
	sd	**12.8**	**0.5**	**0.4**	**0.4**	**36.3**	**13.2**	**0.0000**	**0.00**	**0.41**	**112**
	cv%	**28.6**	**21.2**	**26.5**	**26.3**	**50.3**	**28.8**	**0.0000**	**1.25**	**18.60**	**66**
1	Flat Creek Duplicate	56.3	2.9	1.9	1.9	108.0	57.5	0.0015	0.02	2.70	292
2	Flat Creek Duplicate	48.7	2.5	1.7	1.7	84.9	50.0	0.0015	0.02	2.52	214
3	Flat Creek Duplicate	42.9	2.1	0.9	0.9	38.0	43.4	0.0015	0.02	1.58	60
	Site Mean	**49.3**	**2.5**	**1.5**	**1.5**	**77.0**	**50.3**	**0.0015**	**0.02**	**2.27**	**189**
	sd	**6.8**	**0.4**	**0.6**	**0.5**	**35.7**	**7.1**	**0.0000**	**0.00**	**0.60**	**118**
	cv%	**13.7**	**15.2**	**36.4**	**36.0**	**46.3**	**14.0**	**0.0000**	**1.91**	**26.64**	**63**
1	James River at Galena	77.4	4.0	3.2	3.1	248.6	79.5	0.0017	0.02	3.92	974
2	James River at Galena	122.3	3.8	2.3	2.3	283.7	124.7	0.0013	0.02	2.57	730
3	James River at Galena	70.4	2.9	2.1	2.1	147.9	71.7	0.0016	0.02	2.74	405
	Site Mean	**90.1**	**3.6**	**2.5**	**2.5**	**226.7**	**92.0**	**0.0015**	**0.02**	**3.08**	**703**
	sd	**28.2**	**0.6**	**0.6**	**0.6**	**70.5**	**28.6**	**0.0002**	**0.00**	**0.73**	**286**
	cv%	**31.3**	**16.2**	**23.1**	**22.6**	**31.1**	**31.1**	**13.5761**	**3.91**	**23.86**	**41**

1	James River at Boaz	50.2	4.0	2.9	2.7	144.7	53.0	0.0004	0.02	1.57	227
2	James River at Boaz	68.9	3.9	2.8	2.8	193.1	69.9	0.0001	0.02	0.79	152
3	James River at Boaz	66.7	4.0	2.9	2.9	194.0	67.9	0.0007	0.02	2.51	487
	Site Mean	**61.9**	**4.0**	**2.9**	**2.8**	**177.3**	**63.6**	**0.0004**	**0.02**	**1.62**	**289**
	sd	**10.2**	**0.1**	**0.1**	**0.1**	**28.2**	**9.3**	**0.0003**	**0.00**	**0.86**	**176**
	cv%	**16.5**	**1.5**	**2.0**	**2.3**	**15.9**	**14.5**	**75.0000**	**9.22**	**53.28**	**61**
1	Kings River near Berryville	86.5	4.5	3.1	3.1	268.2	87.9	0.0017	0.02	4.02	1078
2	Kings River near Berryville	73.4	3.4	2.9	2.8	211.4	74.8	0.0025	0.02	5.39	1139
3	Kings River near Berryville	71.5	3.5	3.0	2.9	214.1	74.3	0.0013	0.02	3.19	683
	Site Mean	**77.1**	**3.8**	**3.0**	**2.9**	**231.2**	**79.0**	**0.0018**	**0.02**	**4.20**	**966**
	sd	**8.1**	**0.6**	**0.1**	**0.1**	**32.1**	**7.7**	**0.0006**	**0.00**	**1.11**	**247**
	cv%	**10.6**	**16.1**	**3.7**	**4.1**	**13.9**	**9.7**	**33.3278**	**10.60**	**26.43**	**26**
1	Swan Creek near Swan	54.0	3.2	2.5	2.4	133.0	54.9	0.0011	0.02	2.45	326
2	Swan Creek near Swan	55.5	2.9	2.2	2.2	122.3	56.6	0.0011	0.02	2.32	284
3	Swan Creek near Swan	51.1	2.5	1.6	1.6	82.2	52.4	0.0012	0.02	1.87	154
	Site Mean	**53.6**	**2.9**	**2.1**	**2.1**	**112.5**	**54.6**	**0.0011**	**0.02**	**2.21**	**254**
	sd	**2.2**	**0.3**	**0.4**	**0.4**	**26.8**	**2.1**	**0.0001**	**0.00**	**0.31**	**90**
	cv%	**4.2**	**11.4**	**20.9**	**21.3**	**23.8**	**3.9**	**5.0943**	**2.47**	**13.83**	**35**
1	Swan Creek Duplicate	49.5	3.4	2.7	2.6	132.5	51.0	0.0011	0.02	2.70	358
2	Swan Creek Duplicate	49.0	2.5	2.0	1.9	95.5	50.1	0.0011	0.02	2.06	196
3	Swan Creek Duplicate	47.5	2.4	1.7	1.7	82.1	48.3	0.0012	0.02	1.97	162
	Site Mean	**48.6**	**2.8**	**2.1**	**2.1**	**103.4**	**49.8**	**0.0011**	**0.02**	**2.24**	**239**
	sd	**1.1**	**0.6**	**0.5**	**0.5**	**26.1**	**1.4**	**0.0001**	**0.00**	**0.40**	**105**
	cv%	**2.2**	**20.8**	**23.3**	**22.7**	**25.2**	**2.8**	**5.0943**	**4.25**	**17.81**	**44**

1	War Eagle Creek near Hindsville	33.7	3.6	3.0	2.7	102.1	37.8	0.0008	0.02	2.51	256
2	War Eagle Creek near Hindsville	60.7	4.3	2.9	2.8	177.7	62.6	0.0001	0.02	1.30	230
3	War Eagle Creek near Hindsville	63.9	3.2	2.3	2.3	145.9	64.6	0.0008	0.03	1.85	270
	Site Mean	**52.8**	**3.7**	**2.7**	**2.6**	**141.9**	**55.0**	**0.0006**	**0.02**	**1.89**	**252**
	sd	**16.6**	**0.5**	**0.4**	**0.3**	**38.0**	**14.9**	**0.0004**	**0.01**	**0.61**	**20**
	cv%	**31.4**	**14.5**	**14.7**	**11.6**	**26.8**	**27.1**	**71.3197**	**25.83**	**32.30**	**8**
1	West Fork East of Fayetteville	33.5	2.0	1.5	1.5	51.0	35.1	0.0006	0.03	0.97	50
2	West Fork East of Fayetteville	39.1	3.6	2.6	2.4	100.0	41.3	0.0003	0.03	1.15	115
3	West Fork East of Fayetteville	31.1	3.0	2.0	1.9	61.3	32.2	0.0006	0.03	1.40	86
	Site Mean	**34.6**	**2.9**	**2.0**	**1.9**	**70.8**	**36.2**	**0.0005**	**0.03**	**1.18**	**84**
	sd	**4.1**	**0.8**	**0.5**	**0.5**	**25.8**	**4.6**	**0.0002**	**0.00**	**0.22**	**33**
	cv%	**11.8**	**27.0**	**25.7**	**25.2**	**36.5**	**12.7**	**34.6410**	**10.71**	**18.43**	**39**
1	White River near Fayetteville	54.4	3.0	2.1	2.0	111.9	56.1	0.0004	0.02	1.32	148
2	White River near Fayetteville	41.6	2.6	2.1	2.0	85.4	42.9	0.0008	0.03	1.69	144
3	White River near Fayetteville	39.7	2.1	1.5	1.4	58.9	41.4	0.0025	0.03	2.20	129
	Site Mean	**45.2**	**2.5**	**1.9**	**1.8**	**85.4**	**46.8**	**0.0012**	**0.03**	**1.74**	**141**
	sd	**8.0**	**0.5**	**0.3**	**0.3**	**26.5**	**8.1**	**0.0011**	**0.00**	**0.44**	**10**
	cv%	**17.7**	**18.1**	**17.7**	**18.2**	**31.0**	**17.3**	**90.4093**	**9.38**	**25.25**	**7**
1	Yocum Creek near Oak Grove	23.2	2.7	1.6	1.4	38.0	27.4	0.0014	0.02	1.96	74
2	Yocum Creek near Oak Grove	25.0	3.3	2.1	2.0	53.5	27.4	0.0067	0.02	5.14	275
3	Yocum Creek near Oak Grove	30.7	2.2	1.4	1.4	43.5	31.0	0.0025	0.03	2.34	102
	Site Mean	**26.3**	**2.7**	**1.7**	**1.6**	**45.0**	**28.6**	**0.0035**	**0.03**	**3.15**	**150**
	sd	**3.9**	**0.5**	**0.4**	**0.3**	**7.9**	**2.1**	**0.0028**	**0.00**	**1.73**	**109**
	cv%	**14.9**	**19.7**	**21.3**	**20.4**	**17.5**	**7.2**	**79.1610**	**5.97**	**55.14**	**72**

Table 22: Topographic survey point frequency

Site	L_R (m)	L_R/W_{bf} (m)	Pts/W	Pts/ Long. Survey	Pts/Cross Section		
					XS1	XS2	XS3
Finley Creek Below Riverdale	1241	24.7	2.59	64	14	14	15
Flat Creek Below Jenkins	788	22.1	2.08	46	22	12	11
Flat Creek Duplicate	731	19.8	2.52	50	23	14	14
James River at Galena	1225	17.3	4.29	74	25	29	17
James River at Boaz	1118	23.3	2.48	58	17	15	15
Kings River near Berryville	781	12.0	3.68	44	20	15	16
Swan Creek near Swan	840	19.6	2.60	51	11	13	14
Swan Creek Duplicate	825	20.0	3.30	66	23	21	20
War Eagle Creek near Hindsville	623	16.2	2.22	36	18	15	17
West Fork East of Fayetteville	571	19.6	2.14	42	19	17	12
White River near Fayetteville	482	12.8	2.89	37	20	17	17
Yocum Creek near Oak Grove	362	21.3	1.64	35	17	14	12

Table 23: Flood frequency and mobility analysis

Site Name	A_d (km^2)	Simon $Q_{1.5}$ (cms)	Q_{bf}	$Q_{bf}/Q_{1.5}$ Ratio	Flood Mobility Rating	Q_{tc}	$Q_{tc}/Q_{1.5}$ Ratio
Finley Creek below Riverdale	666	93	79	0.85	A	196	2.1
Flat Creek below Jenkins	558	85	31	0.37	C	170	2.0
James River at Galena	2,563	194	155	0.80	A	703	3.6
James River near Boaz	1,192	128	46	0.36	C	289	2.3
Kings River near Berryville	1,363	138	85	0.62	B	966	7.0
Swan Creek near Swan	383	69	50	0.73	A	254	3.7
War Eagle Creek near Hindsville	684	95	27	0.28	C	252	2.7
West Fork White River east of Fayetteville	310	62	21	0.34	C	84	1.4
White River near Fayetteville	1,023	118	25	0.21	C	141	1.2
Yocum Creek near Oak Grove	136	39	16	0.40	B	150	3.8

Table 24: Relative Bed Stability

Site	d_{res} (m)	d_{bfm} (m)	Wd (m)	Ct (m/m)	D_{gm} (m)	d_{bf} (m)	Cp (m/m)	R_{bf} (m)	Slope (m/m)	Reynold's # (REP)	Shields OS	RBS* (m/m)	LRBS* (m/m)
Finley Creek Below Riverdale	0.19	1.77	0.0029	0.0100	0.027	1.25	0.00401	1.23	0.00086	2,697	0.0267	1.53	0.185
Flat Creek Below Jenkins	0.11	1.27	0.0248	0.0149	0.0183	0.71	0.00424	0.70	0.00150	1,822	0.0259	1.14	0.056
Flat Creek Duplicate	0.09	1.41	0.0195	0.0068	0.0151	0.73	0.00395	0.72	0.00150	1,523	0.0255	0.71	-0.149
James River at Galena	0.21	1.83	0.0005	0.0110	0.0178	1.20	0.00357	1.18	0.00151	2,307	0.0264	0.64	-0.197
James River at Boaz	0.31	1.77	0.0066	0.0251	0.0336	1.20	0.00436	1.18	0.00041	2,279	0.0263	5.39	0.732
Kings River near Berryville	0.19	1.52	0.0055	0.0173	0.019	0.89	0.00399	0.89	0.00146	2,097	0.0262	1.04	0.018
Swan Creek near Swan	0.19	1.37	0.0041	0.0239	0.0365	0.94	0.00487	0.93	0.00113	3,630	0.0272	2.66	0.425
Swan Creek Duplicate	0.19	1.28	0.0041	0.0319	0.0294	0.89	0.00460	0.88	0.00113	2,848	0.0268	2.50	0.398
War Eagle Creek near Hindsville	0.38	1.28	0.0994	0.1158	0.031	0.82	0.00481	0.81	0.00080	2,425	0.0265	6.05	0.782
West Fork East of Fayetteville	0.28	1.49	0.0024	0.0371	0.017	0.91	0.00383	0.89	0.00050	1,099	0.0247	3.34	0.524
White River near Fayetteville	0.23	1.19	0.0103	0.0569	0.0273	0.75	0.00477	0.73	0.00123	2,514	0.0265	3.05	0.485
Yocum Creek near Oak Grove	0.15	1.13	0.0414	0.0355	0.0201	0.62	0.00456	0.60	0.00353	2,840	0.0267	0.83	-0.078

Table 25: Sub-reach Variability of Channel and Sediment Data

Site	Bankfull Geometry*				Pebble Counts*				
	w	d_{bfm}	A	w/d	D_{16}	D_{50}	D_{84}	Max G+R	Max B
	(m)	(m)	(m)	(m/m)	mm	mm	mm	mm	mm
Finley Creek Below Riverdale	12.2	12.4	7.9	18.6	34.6	18.8	0	16.5	22.7
Flat Creek Below Jenkins	36.5	17.9	22.3	48.9	45.8	25.8	20.7	24.7	27.3
Flat Creek Duplicate	26.6	20.1	9.2	49.2	26.8	39.3	28	40.3	32.1
James River at Galena	14	6.5	13.4	16.1	84.4	17.1	34.5	39.3	37.5
James River at Boaz	5.7	18.7	19	12.9	20.9	0	64.2	28.2	49.8
Kings River near Berryville	0.1	15.2	17.3	17.1	65.3	58.2	75.8	40	88.6
Swan Creek near Swan	3.2	10.3	8.6	6.1	34.6	8.9	75.8	41.9	31.3
Swan Creek Duplicate	3.3	3.4	11.2	9.2	15.3	21.1	19.3	31.5	6.8
War Eagle Creek near Hindsville	24.6	9.2	10.4	38.4	133.2	107.9	47.4	57.5	82.9
West Fork East of Fayetteville	22.8	1.5	21	20.8	104.8	55.6	24.6	19.9	39.6
White River near Fayetteville	18.7	19.4	23.7	17.7	42.1	46.9	41.9	53.7	57.7
Yocum Creek near Oak Grove	8.8	24.5	34.1	29	34.6	34.2	33.9	35.9	42.2

* Coefficient of Variation Percentage (cv%)

Table 26: Precision for Channel and Sediment Indicators

Site Duplicate	Bankfull Geometry				Pebble Counts				
	Wbf (m)	**dmbf (m)**	**Abf (m)**	**w/d (m/m)**	**D16 mm**	**D50 mm**	**D84 mm**	**Max G+R mm**	**Max B mm**
Mean Swan	42.9	1.4	40.1	45.9	11.7	30.4	160	498.7	360.4
Mean Swan Dup	41.2	1.3	36.6	46.6	12.1	25.7	73.7	260.5	296.3
Difference	1.7	0.1	3.5	0.7	0.4	4.7	86.3	238.2	64.1
RPD %	**4**	**7**	**9.1**	**1.4**	**3.4**	**17**	**74**	**63**	**20**
Mean Flat	35.7	1.27	24.2	53.6	7.7	22	36.3	123.4	111.2
Mean Flat Dup	36.9	1.4	25.7	55.3	5.3	17.6	32.9	142.6	129.9
Difference	1.2	0.1	1.5	1.8	2.4	4.4	3.4	19.2	18.7
RPD %	**3.2**	**10**	**5.8**	**3.2**	**37**	**22**	**10**	**14**	**16**

Table 27: Method Precision for Visual Judgements and LWD

Site Duplicate	Channel Unit Classification								LWD	
	Glide	**Riffle**	**Run**	**Middle Pool**	**Bluff Pool**	**Scour Pool**	**Side Pool**	**Confluence Pool**	**Piece Volume /100m (m^3)**	**Total Volume /100m (m^3)**
Mean Swan	23.5	9.8	31.4	33.3	0.0	0.0	0.0	2.0	11.9	98.6
Mean Swan Dup	28.8	7.6	36.4	18.2	0.0	1.5	7.6	0.0	10.3	81.0
Difference	5.3	2.2	5.0	15.2	0.0	1.5	7.6	2.0	1.5	17.6
RPD %	20	26	15	59	0	200	200	200	14	20
Mean Flat	32	15	34	0	0	8	7	4	5.2	21.3
Mean Flat Dup	22	28	12	26	0	8	2	2	9.1	23.2
Difference	10.0	13.0	22.0	26.0	0.0	0.0	4.5	2.3	3.9	1.9
RPD %	37	60	96	200	0	0	106	74	55	9

Table 28: Summary of Channel and Sediment Rankings

Site	Relative Disturbance	Fine Sediment Rating	Cobble Rating	FMI	LRBS	RBEI	EPA Rapid Assessment	Overall Ranking	SCI Score
Finley Creek Below Riverdale	Mod	B	C-	A	A	B	B+	B+	10 impaired
Flat Creek Below Jenkins	Mod	B	D-	C	A	A	A-	A-	12 impaired
James River at Galena	High	D	D-	A	A	B	C+	C+	12 impaired
James River at Boaz	High	A	C+	C	C	A	A	A-	10 impaired
Kings River near Berryville	Low	B	C+	B	A	B	B+	B+	8 very impaired
Swan Creek near Swan	Low	A	B+	A	B	B	A	A-	14 impaired
War Eagle Creek near Hindsville	Low	D	B+	C	C	B	B	C-	12 impaired
West Fork East of Fayetteville	Mod-High	D	D-	C	C	B	C-	C-	12 impaired
White River near Fayetteville	Mod	B	C+	C	B	C	B+	B+	12 impaired
Yocum Creek near Oak Grove	Mod	A	D	B	A	B	A-	A-	12 impaired

FIGURES

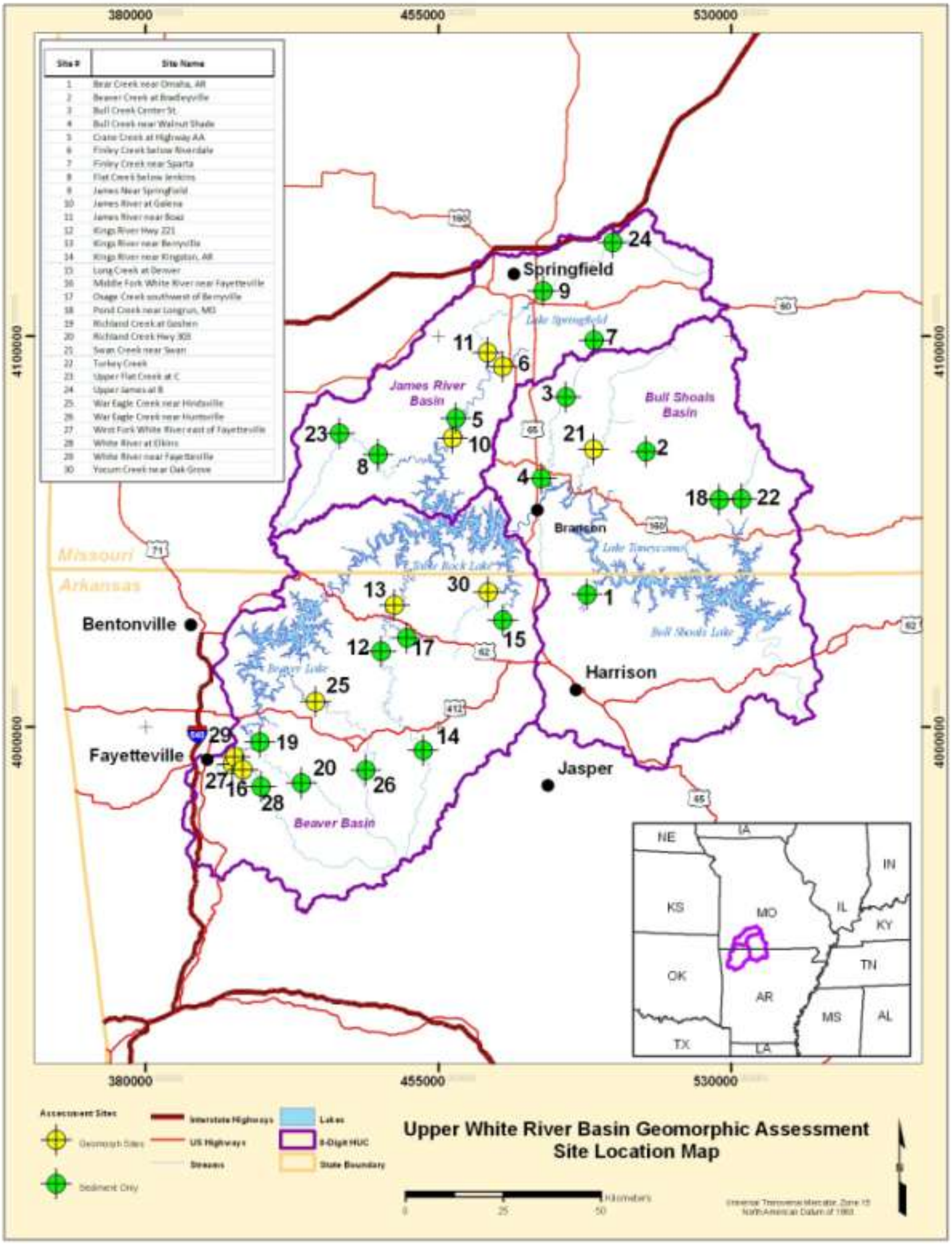


Figure 1: Upper White River Basin monitoring program sites

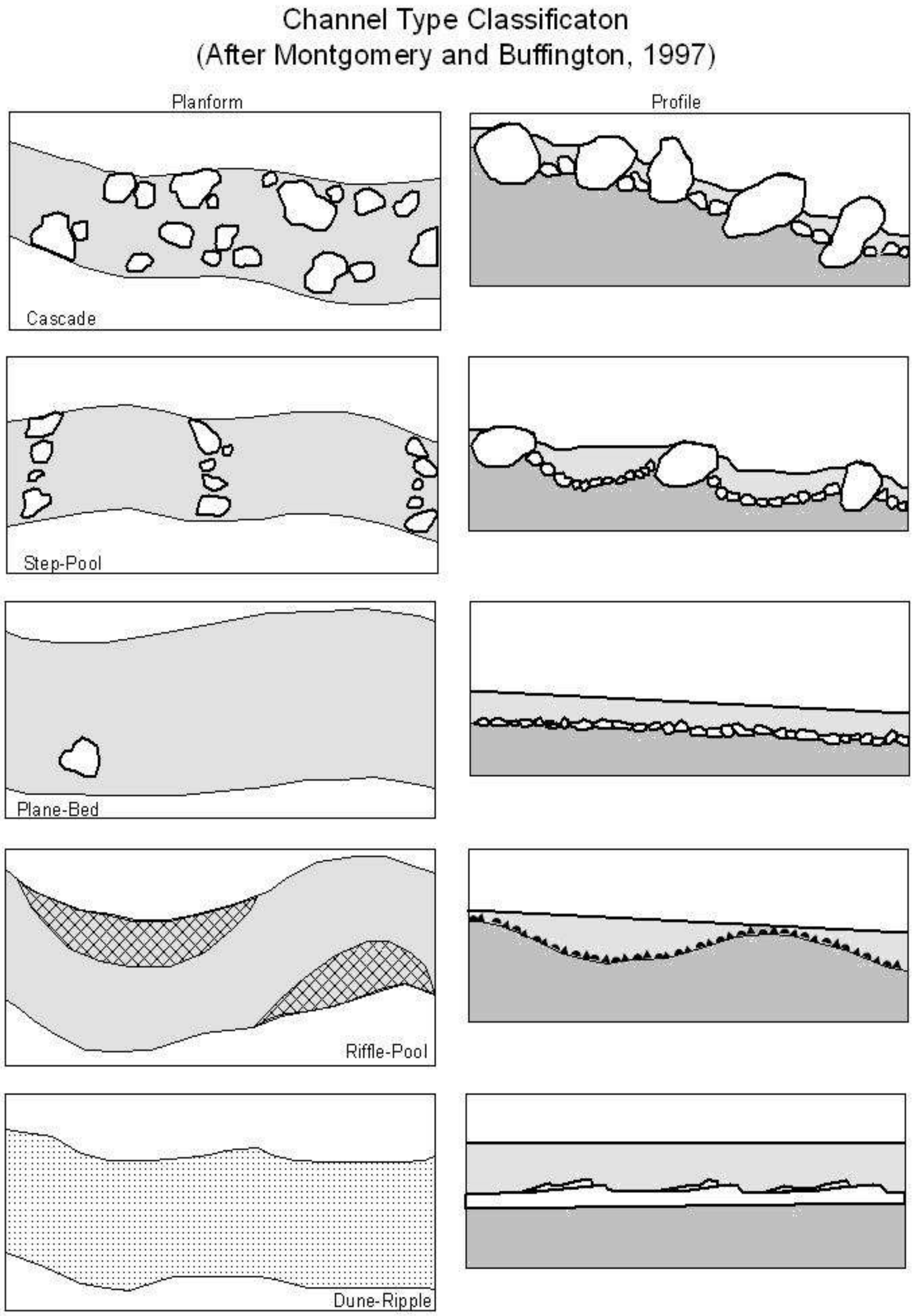


Figure 2: Channel Types (after Montgomery and Buffington 1997, 1998)

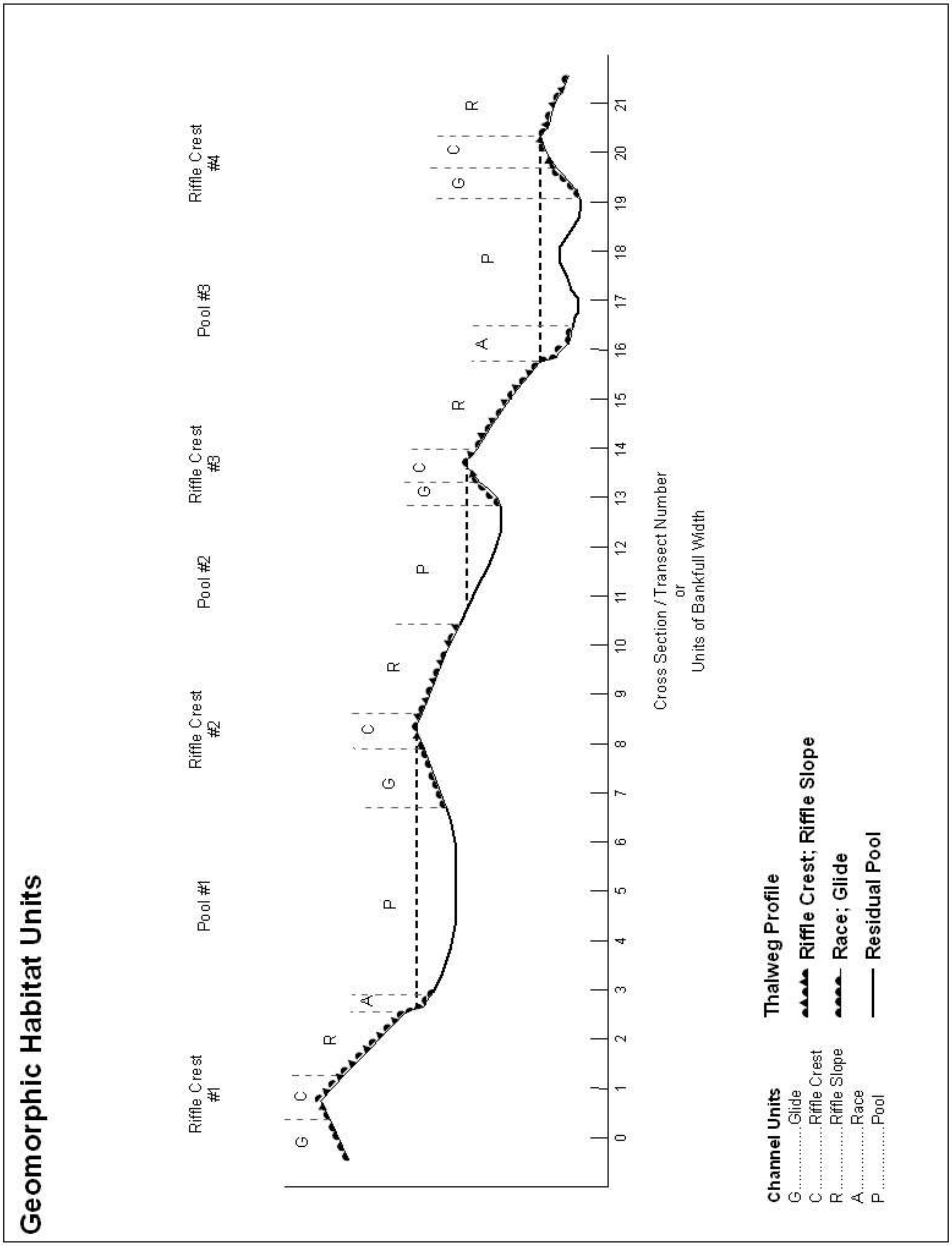


Figure 3: Geomorpic habitat units along a longitudinal profile

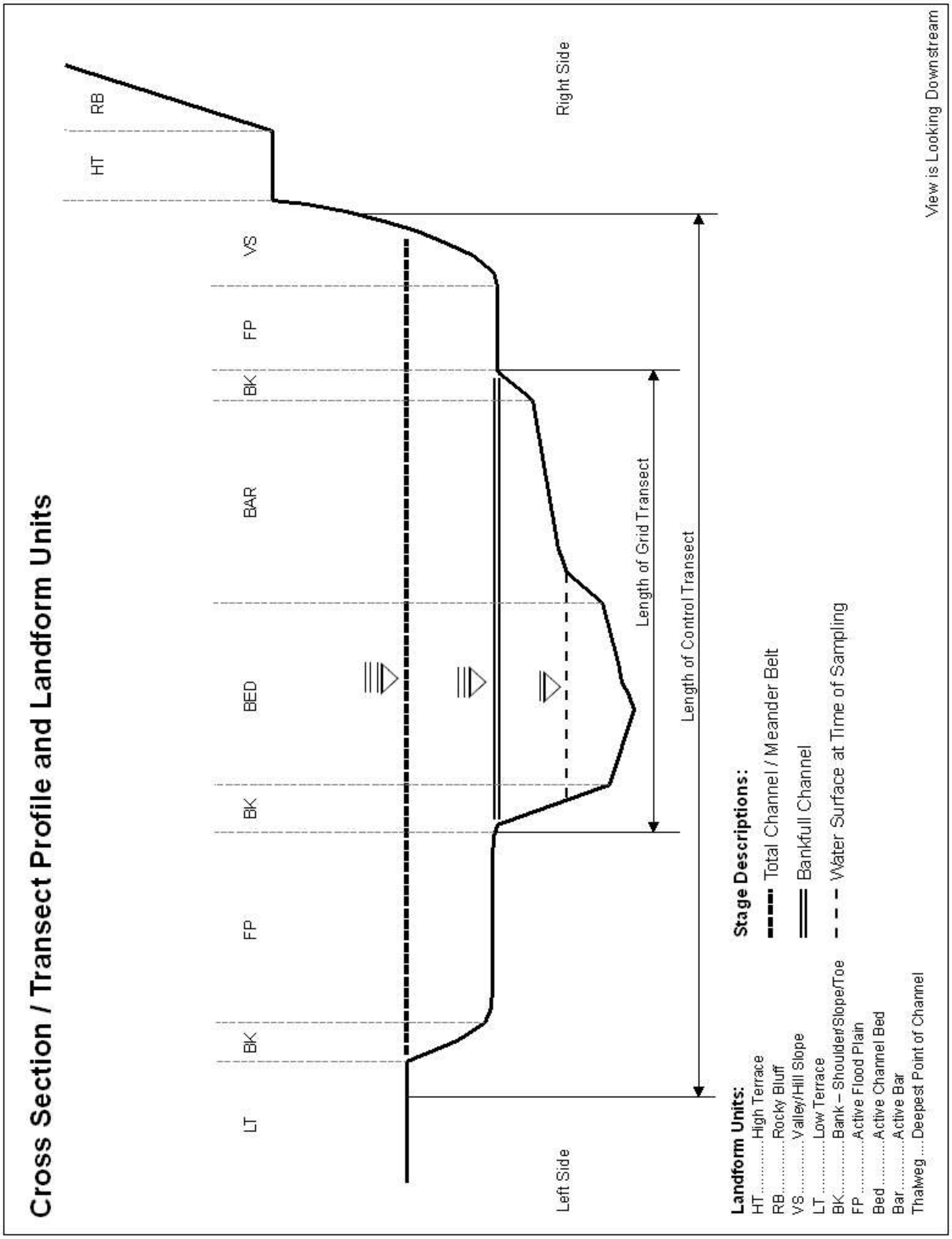


Figure 4: Cross section/transect profile and cross sectional landform units

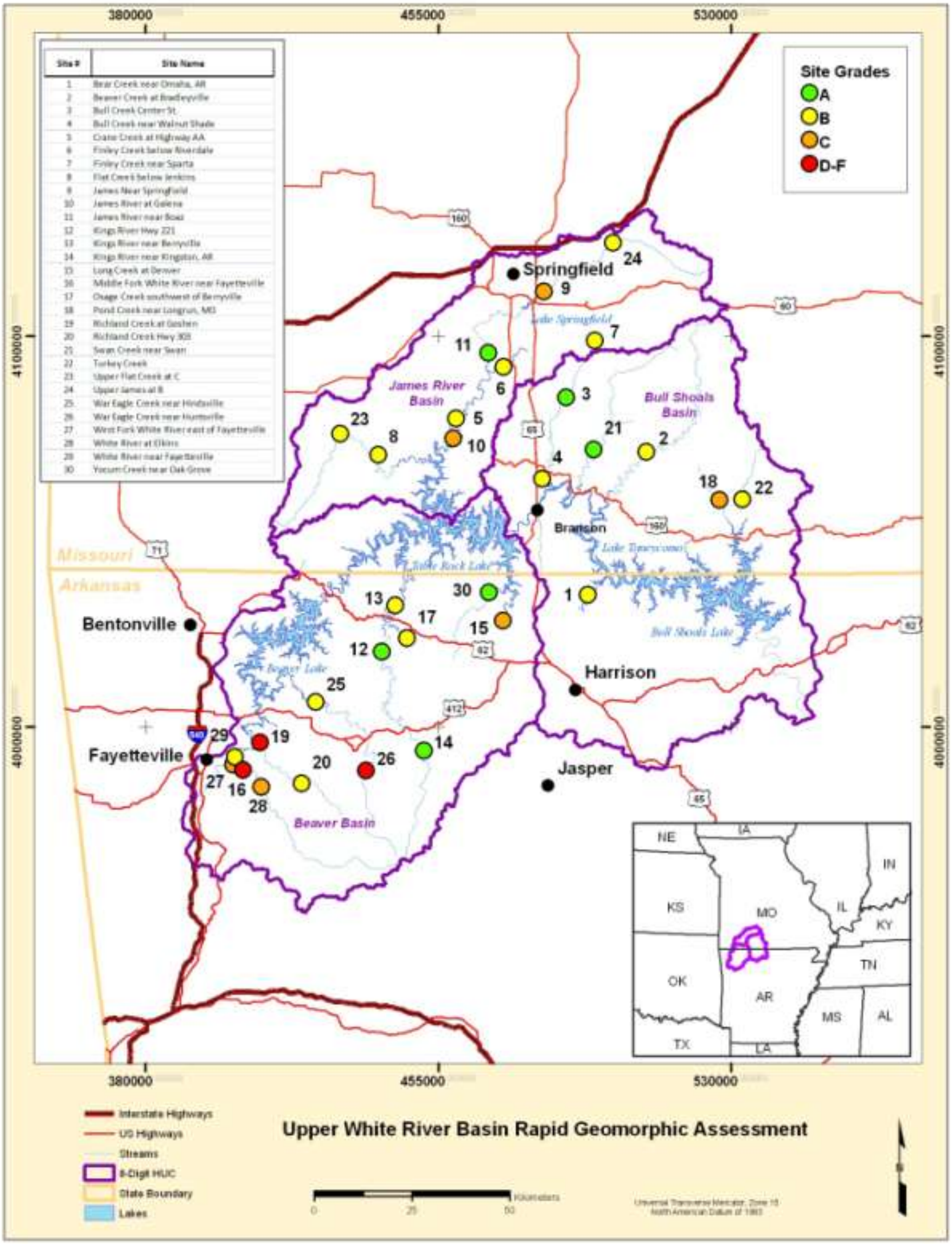


Figure 5: Upper White River Basin assessment site grades based on rapid geomorphic assessment.

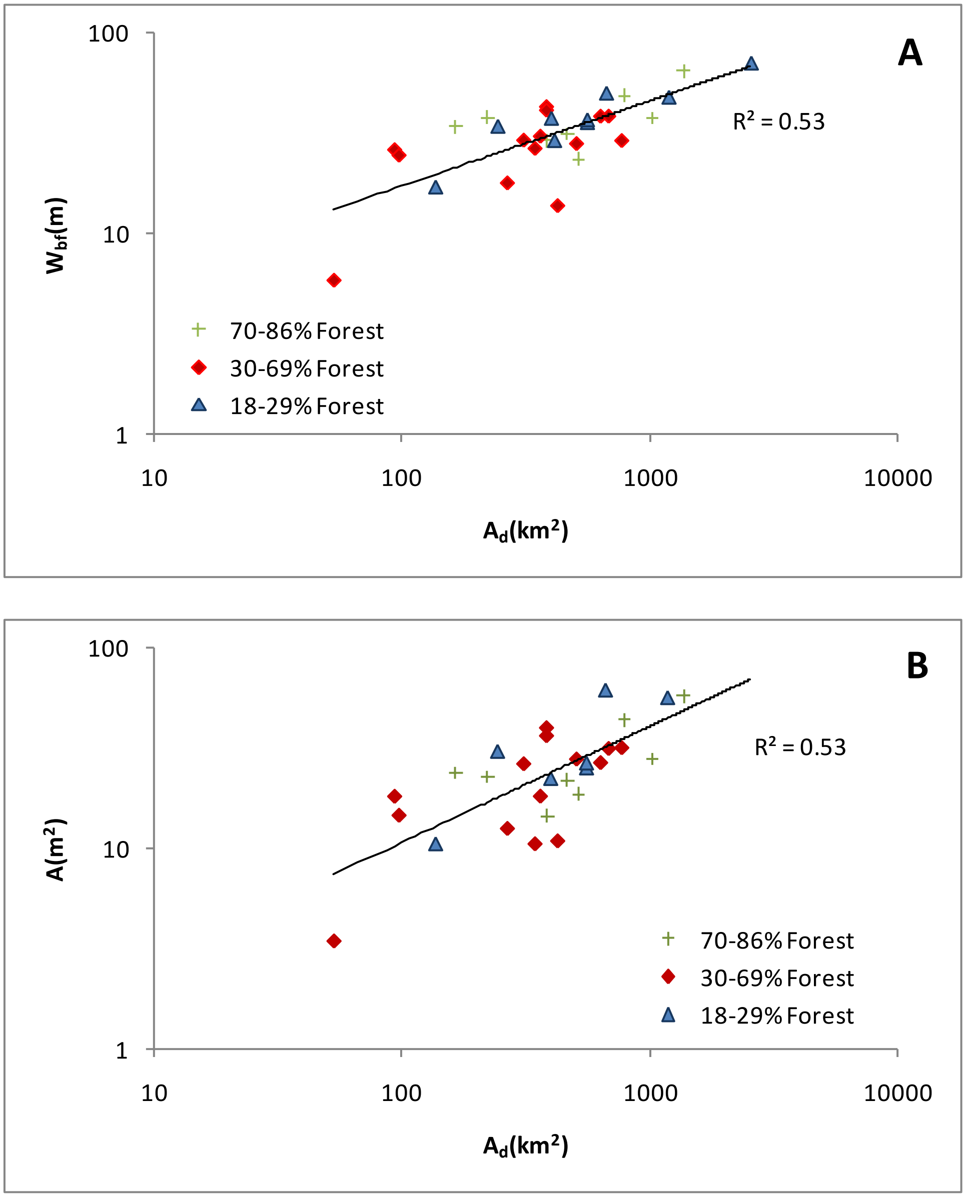


Figure 6: Channel-Drainage Area Relationship stratified by forest cover: A - Bankfull depth, B – Cross-sectional area.

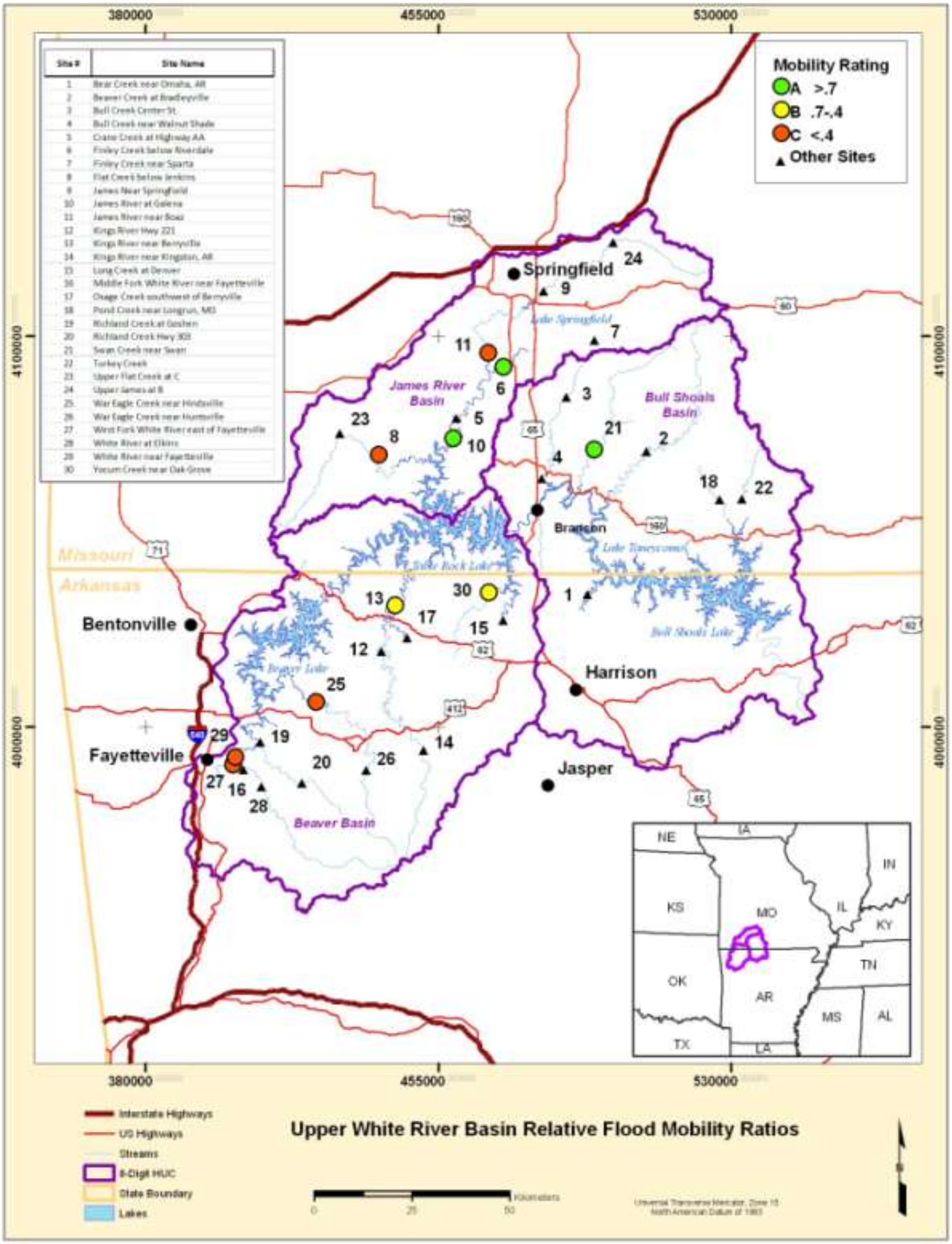


Figure 7: Flood mobility ratings

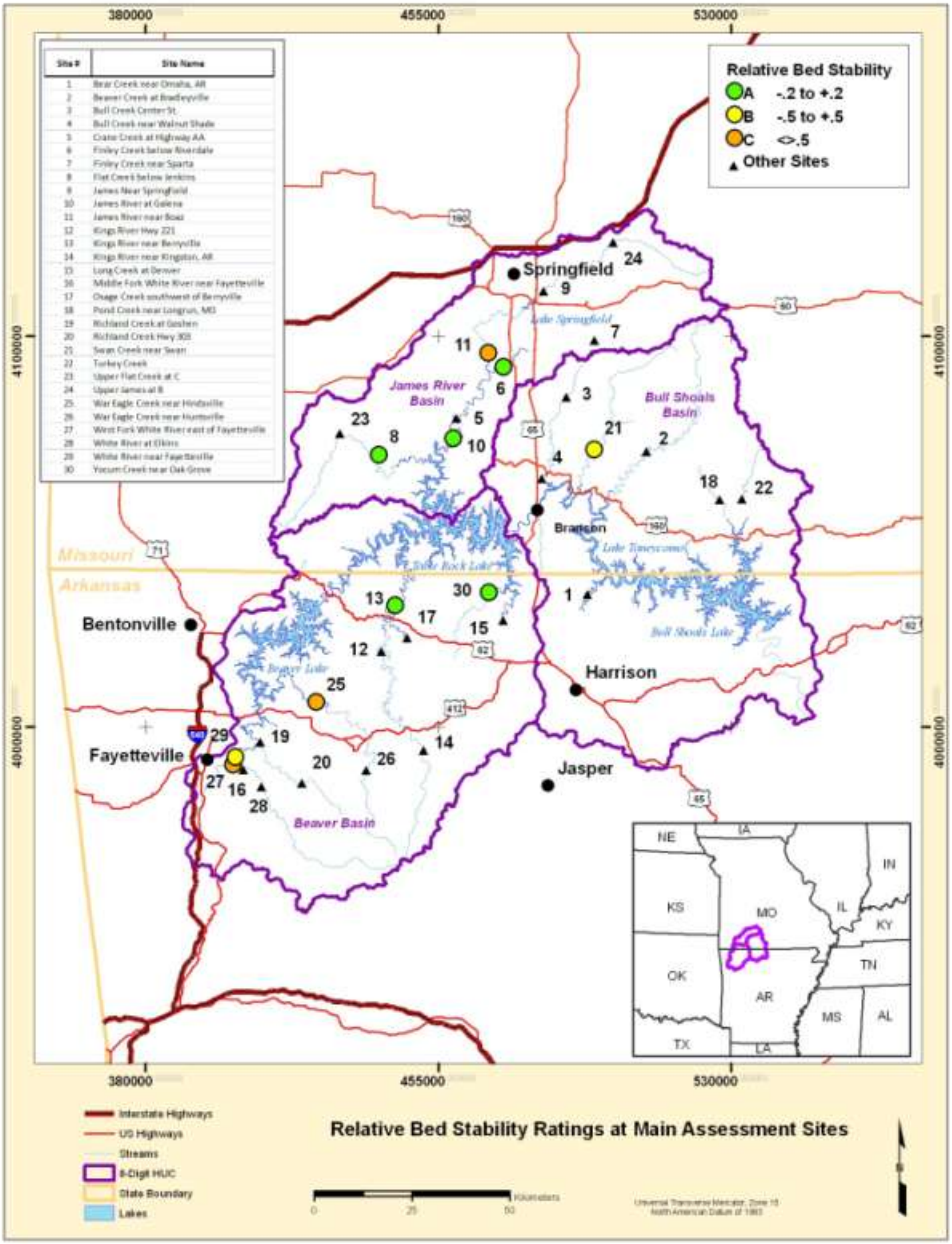


Figure 8: Relative Bed Stability Ratings

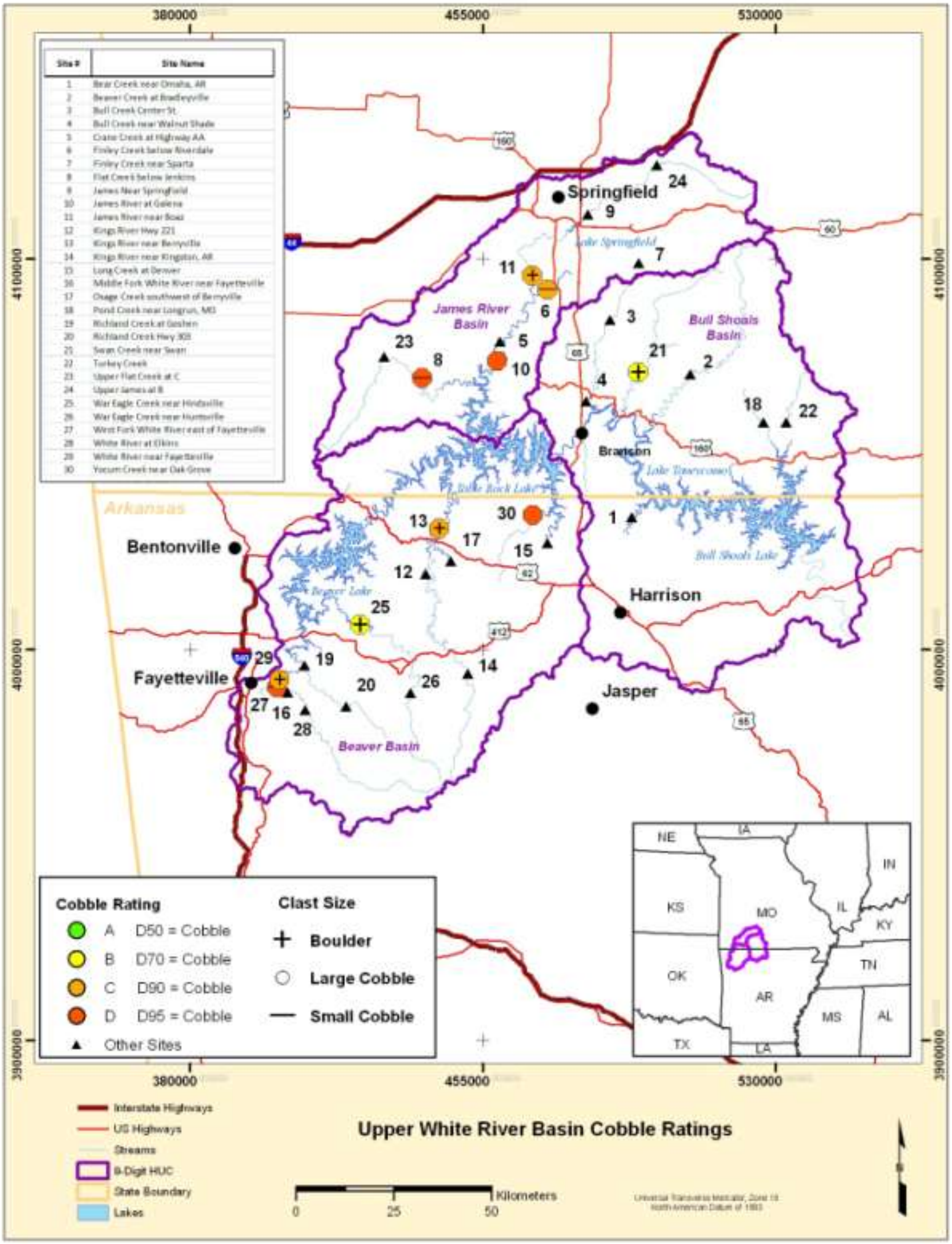


Figure 9: Bed Sediment Size Rating

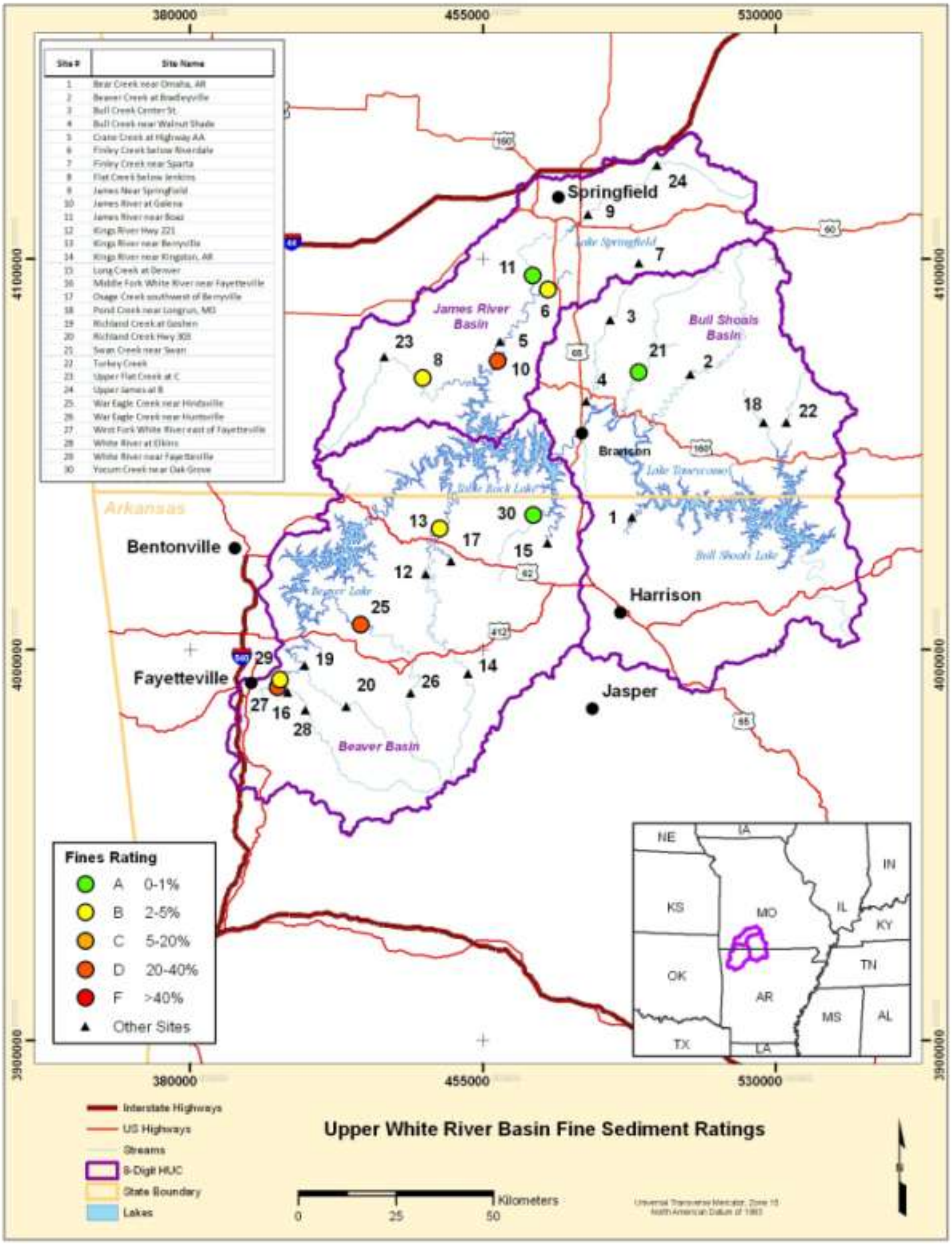


Figure 10: Fine Sediment Rating

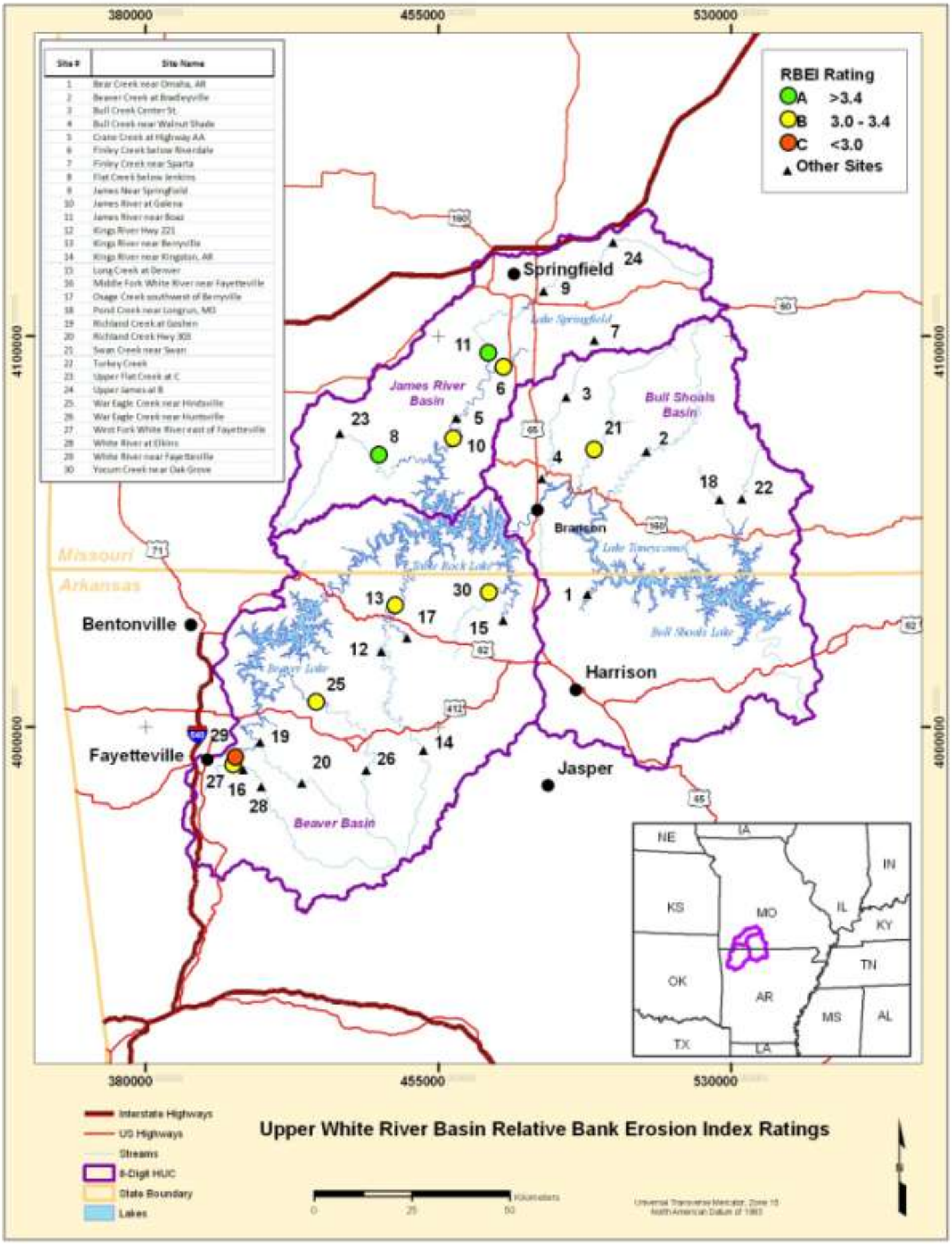
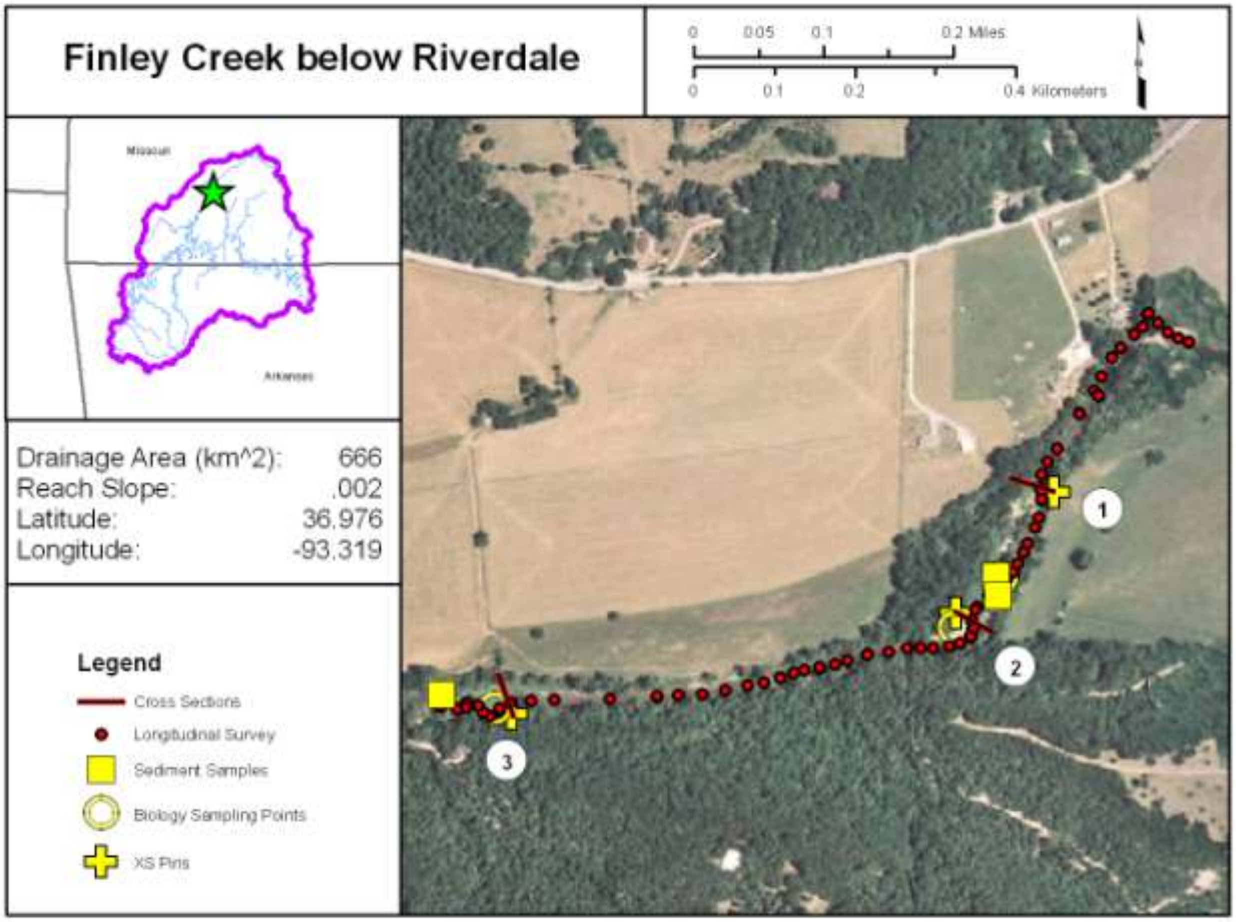


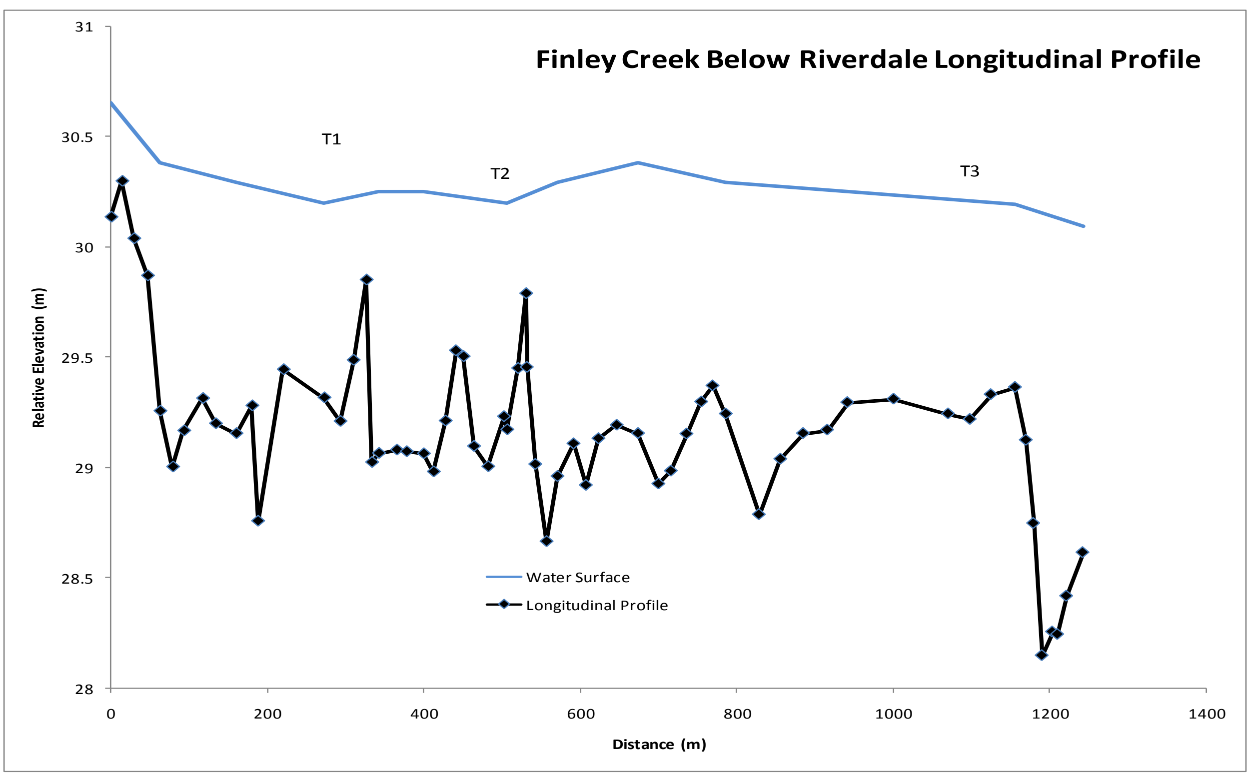
Figure 11: Relative Bank Erosion Rating

Appendix A

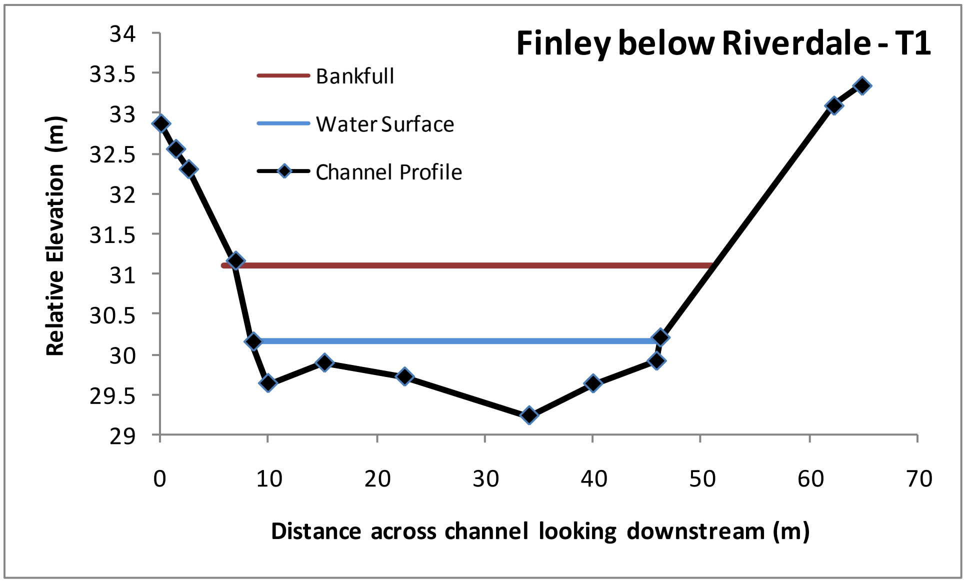
Site Maps and Descriptions



Finley Creek below Riverdale
0 0.05 0.1 0.2 Miles
0 0.1 0.2 0.4 Kilometers
Drainage Area (km^2): 666
Reach Slope: .002
Latitude: 36.976
Longitude: -93.319
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
1
2
3



Finley Creek Below Riverdale Longitudinal Profile
T1
T2
T3
Water Surface
Longitudinal Profile
Relative Elevation (m)
Distance (m)
31
30.5
30
29.5
29
28.5
28
0
200
400
600
800
1000
1200
1400

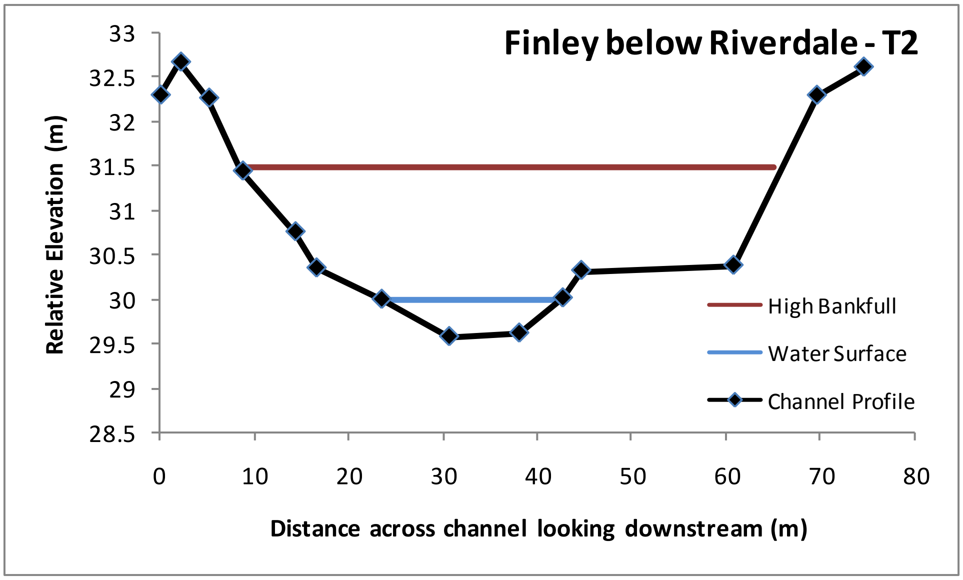

Finley below Riverdale - T1
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
0
10
20
30
40
50
60
70
Distance across channel looking downstream (m)


Up

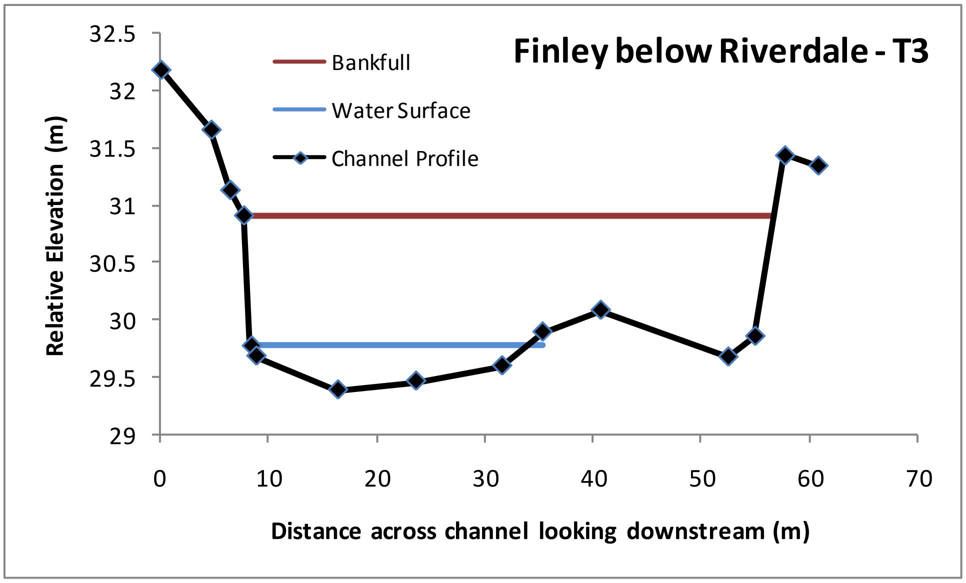

Down


Right


Left


Finley below Riverdale - T2
Relative Elevation (m)
33
32.5
32
31.5
31
30.5
30
29.5
29
28.5
0
10
20
30
40
50
60
70
80
Distance across channel looking downstream (m)
High Bankfull
Water Surface
Channel Profile


Up
Down
Right
Left

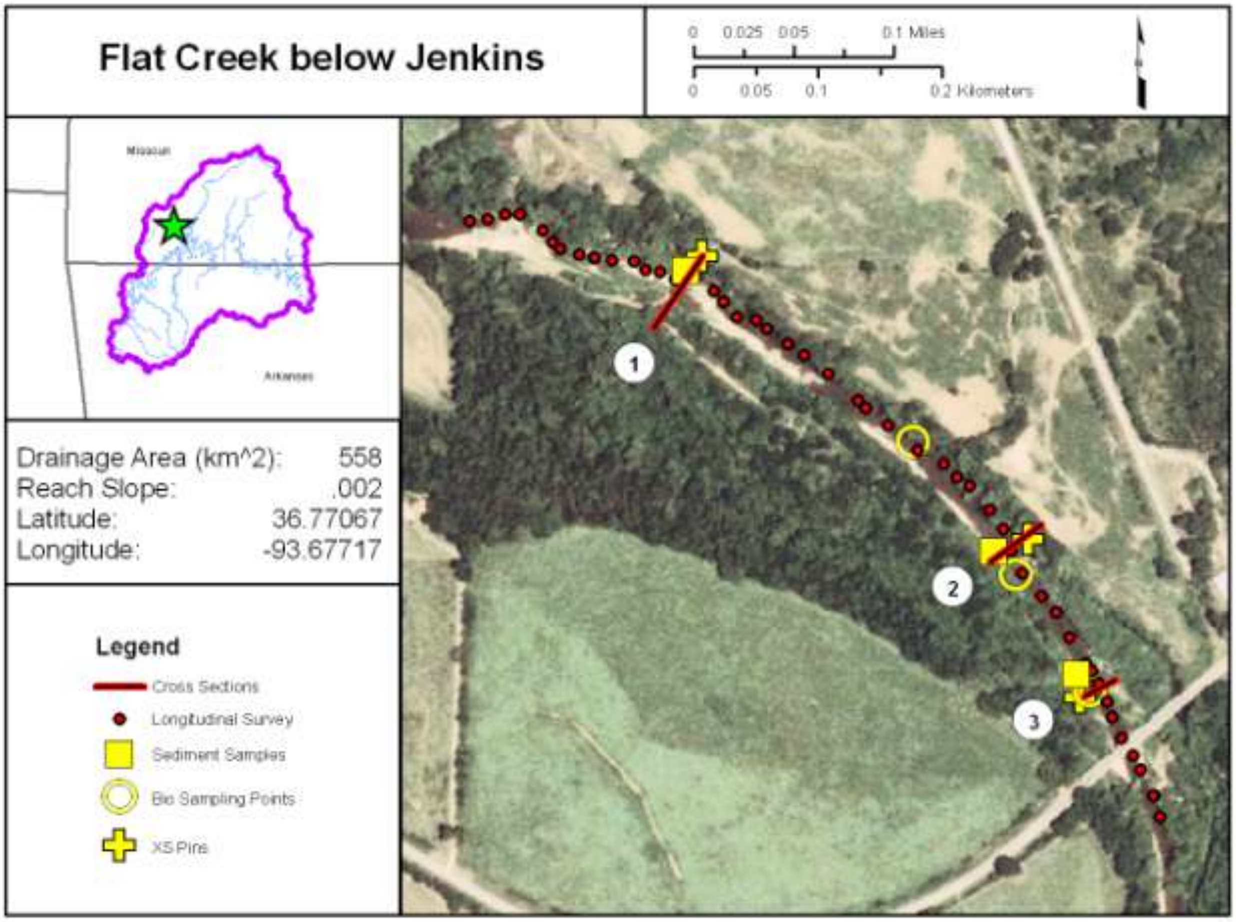

Finley below Riverdale - T3
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
32.5
32
31.5
31
30.5
30
29.5
29
0
10
20
30
40
50
60
70
Distance across channel looking downstream (m)


Up

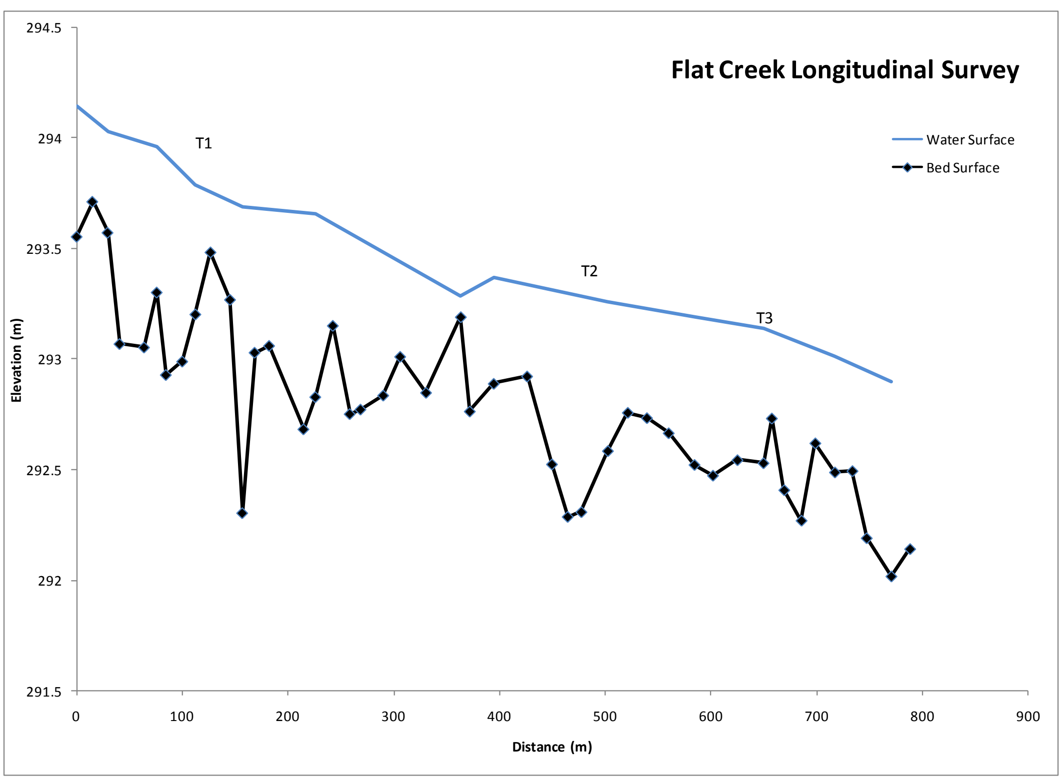

Down


Right

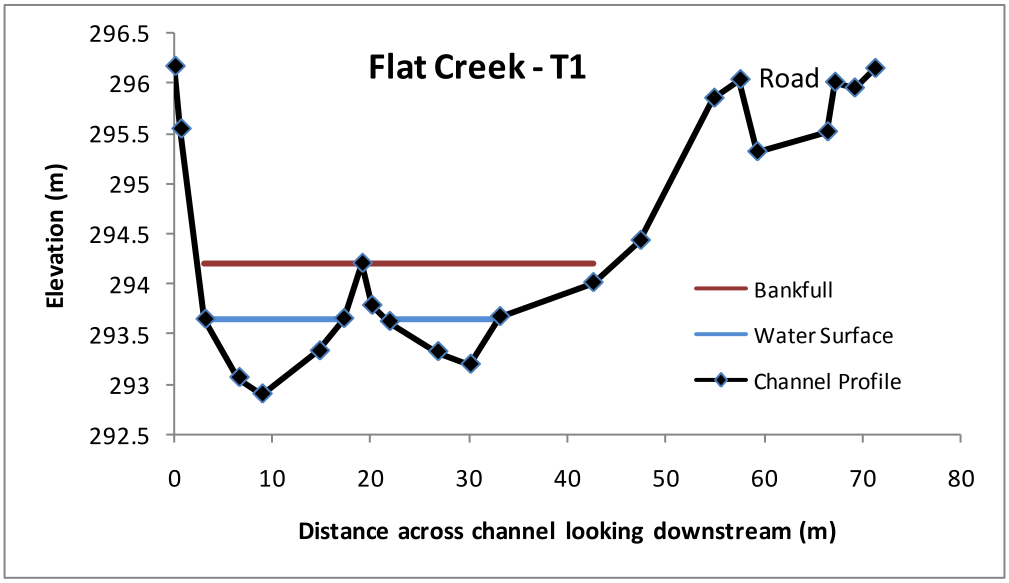

Left



Flat Creek below Jenkins
0
0.025
0.05
0.1 Miles
0
0.05
0.1
0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 558
Reach Slope: .002
Latitude: 36.77067
Longitude: -93.67717
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Bio Sampling Points
XS Pins
1
2
3



Flat Creek Longitudinal Survey
Water Surface
Bed Surface
T1
T2
T3
Elevation (m)
Distance (m)
294.5
294
293.5
293
292.5
292
291.5
0
100
200
300
400
500
600
700
800
900

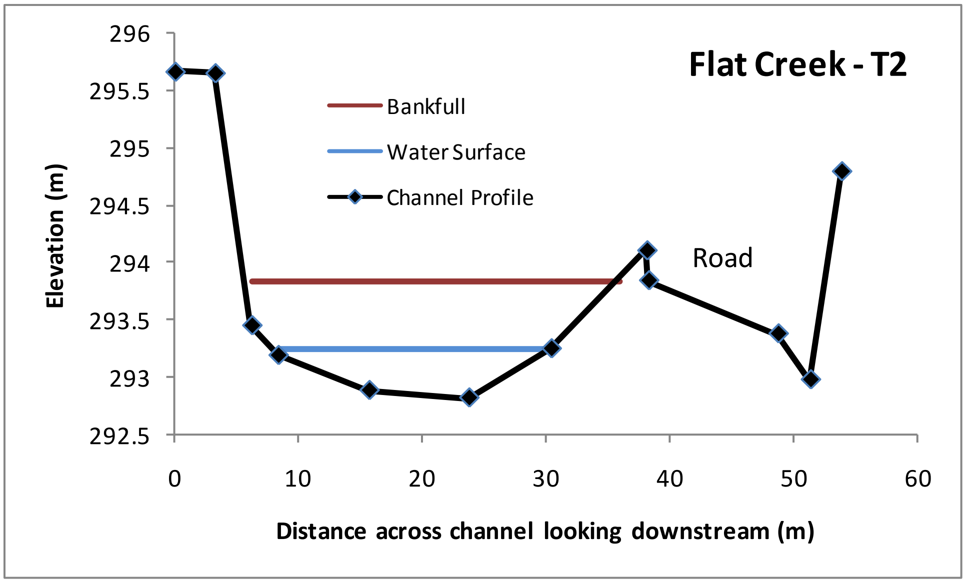

Flat Creek - T1
Road
Bankfull
Water Surface
Channel Profile
Elevation (m)
296.5
296
295.5
295
294.5
294
293.5
293
292.5
0
10
20
30
40
50
60
70
80
Distance across channel looking downstream (m)


Up


Down


Right


Left

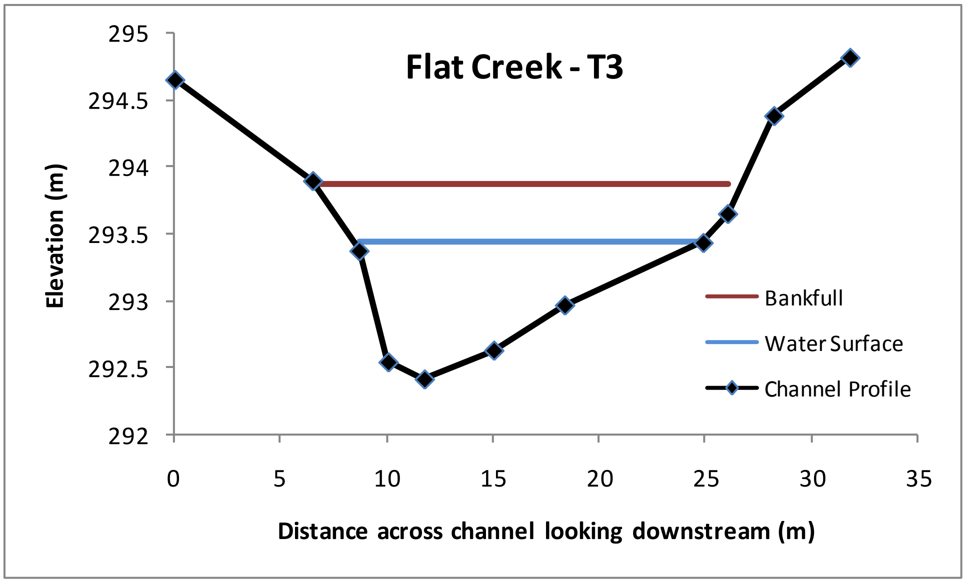

Flat Creek - T2
Bankfull
Water Surface
Channel Profile
Road
Elevation (m)
296
295.5
295
294.5
294
293.5
293
292.5
0
10
20
30
40
50
60
Distance across channel looking downstream (m)


Up


Down


Right


Left



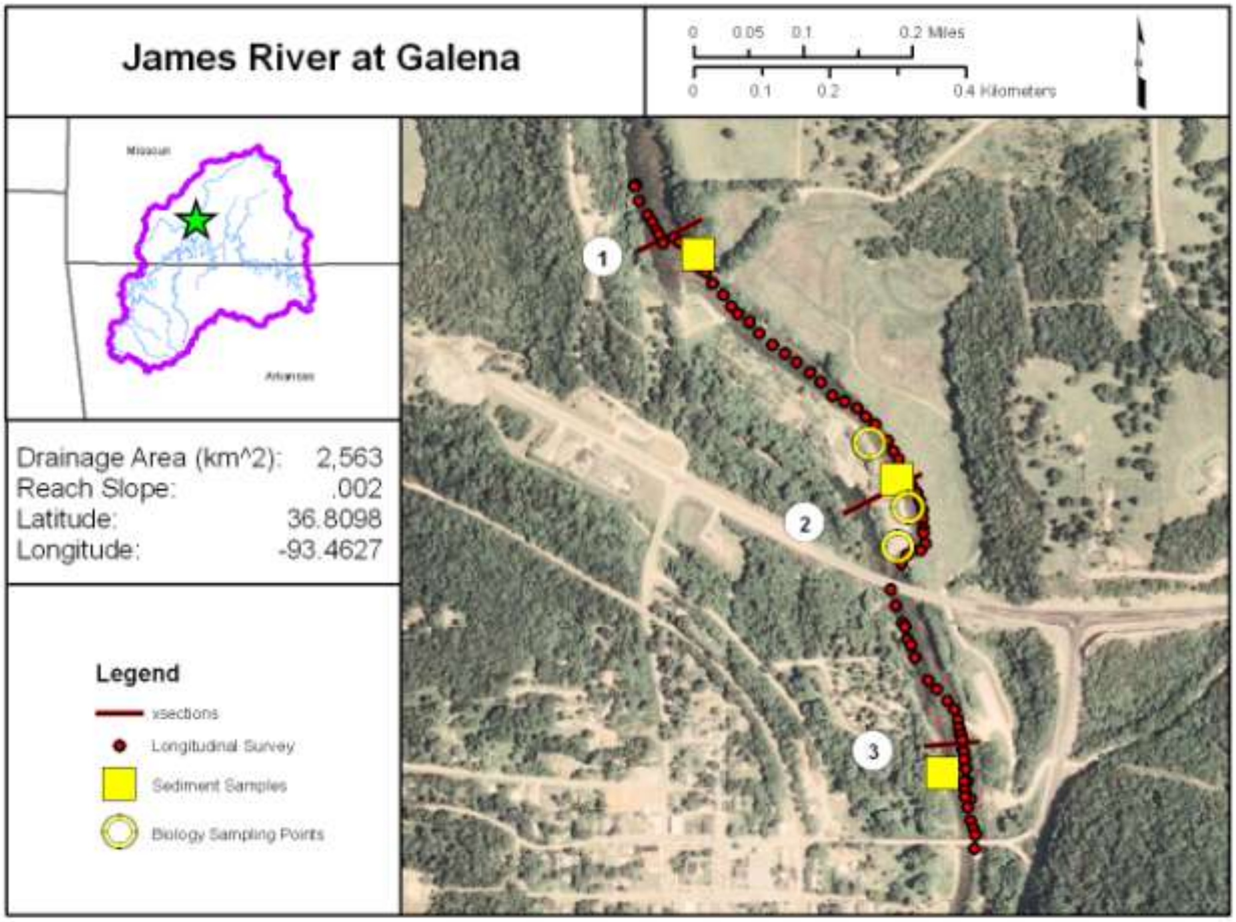
Flat Creek - T3
Elevation (m)
295
294.5
294
293.5
293
292.5
292
0
5
10
15
20
25
30
35
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile

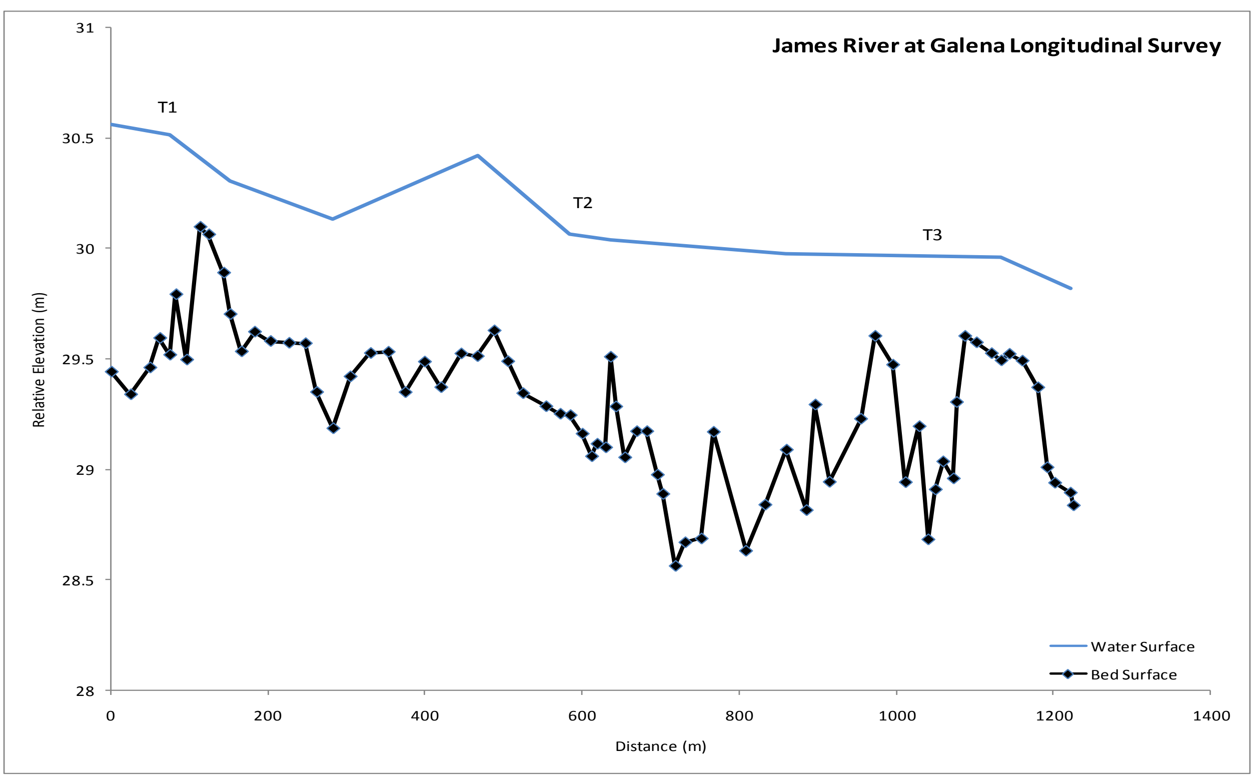
Up

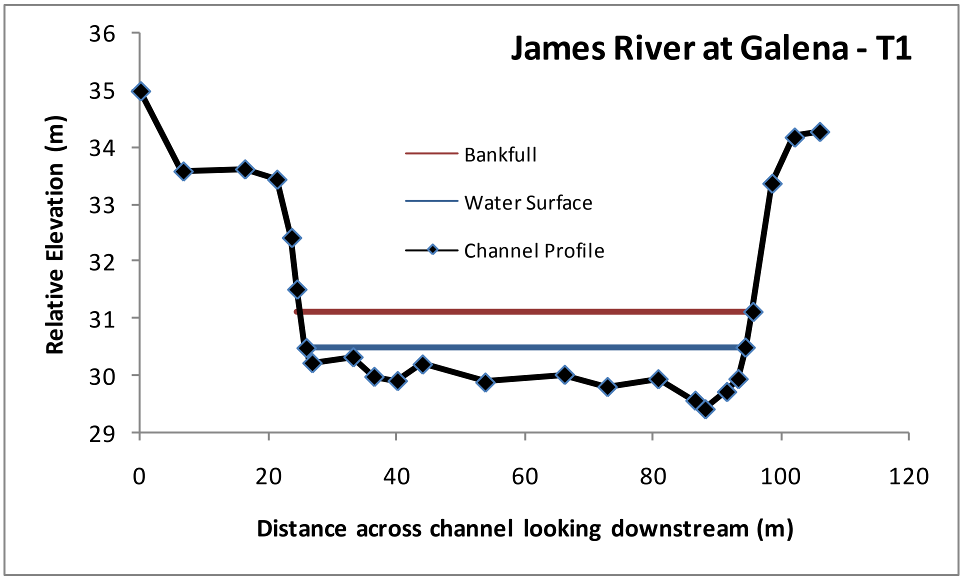
Down

Right

Left


James River at Galena
0 0.05 0.1 0.2 Miles
0 0.1 0.2 0.4 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 2,563
Reach Slope: .002
Latitude: 36.8098
Longitude: -93.4627
Legend
xsections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
1
2
3


James River at Galena Longitudinal Survey
Relative Elevation (m)
Distance (m)
T1
T2
T3
Water Surface
Bed Surface

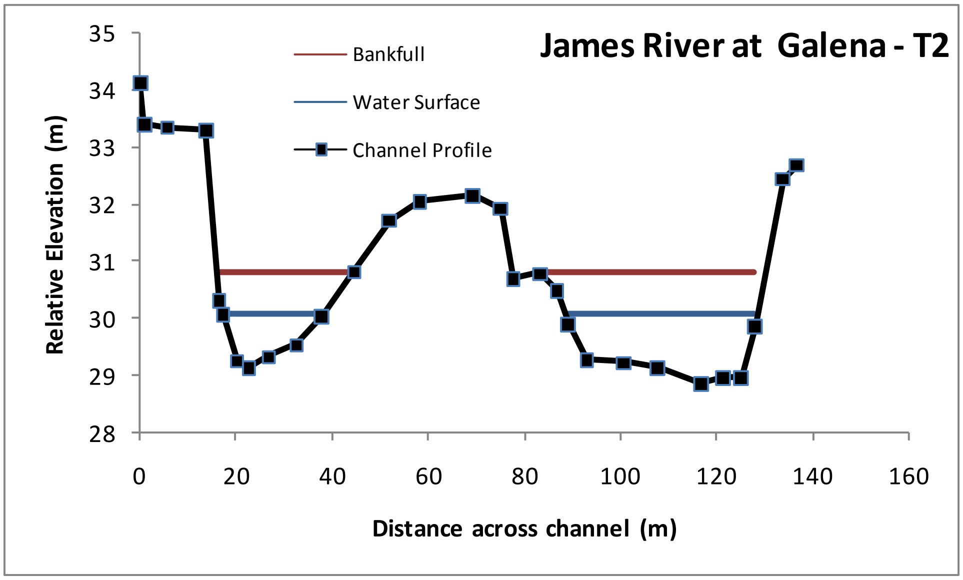

James River at Galena - T1
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
36
35
34
33
32
31
30
29
0
20
40
60
80
100
120
Distance across channel looking downstream (m)


Up


Down


Right


Left

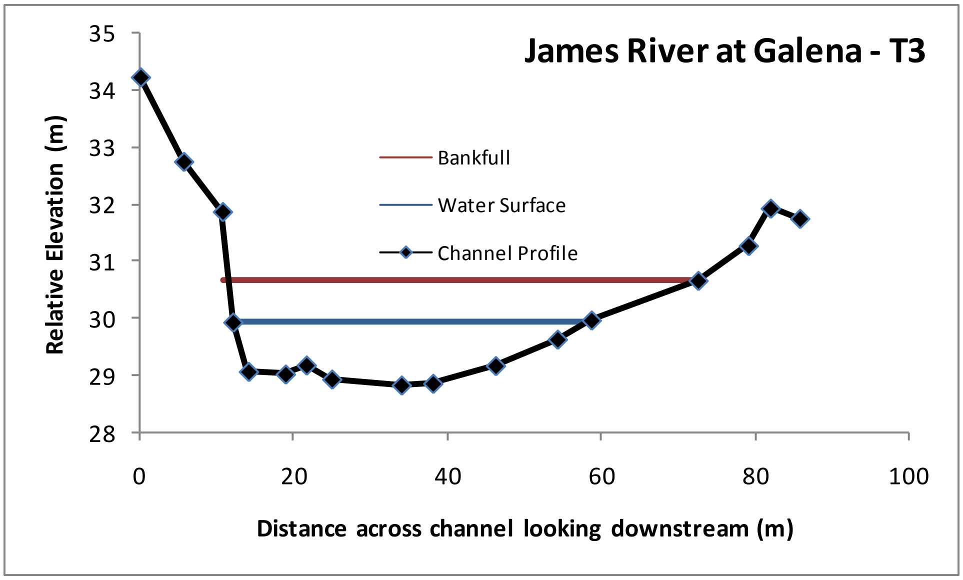

James River at Galena - T2
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
35
34
33
32
31
30
29
28
0
20
40
60
80
100
120
140
160
Distance across channel (m)


Up


Down


Right


Left



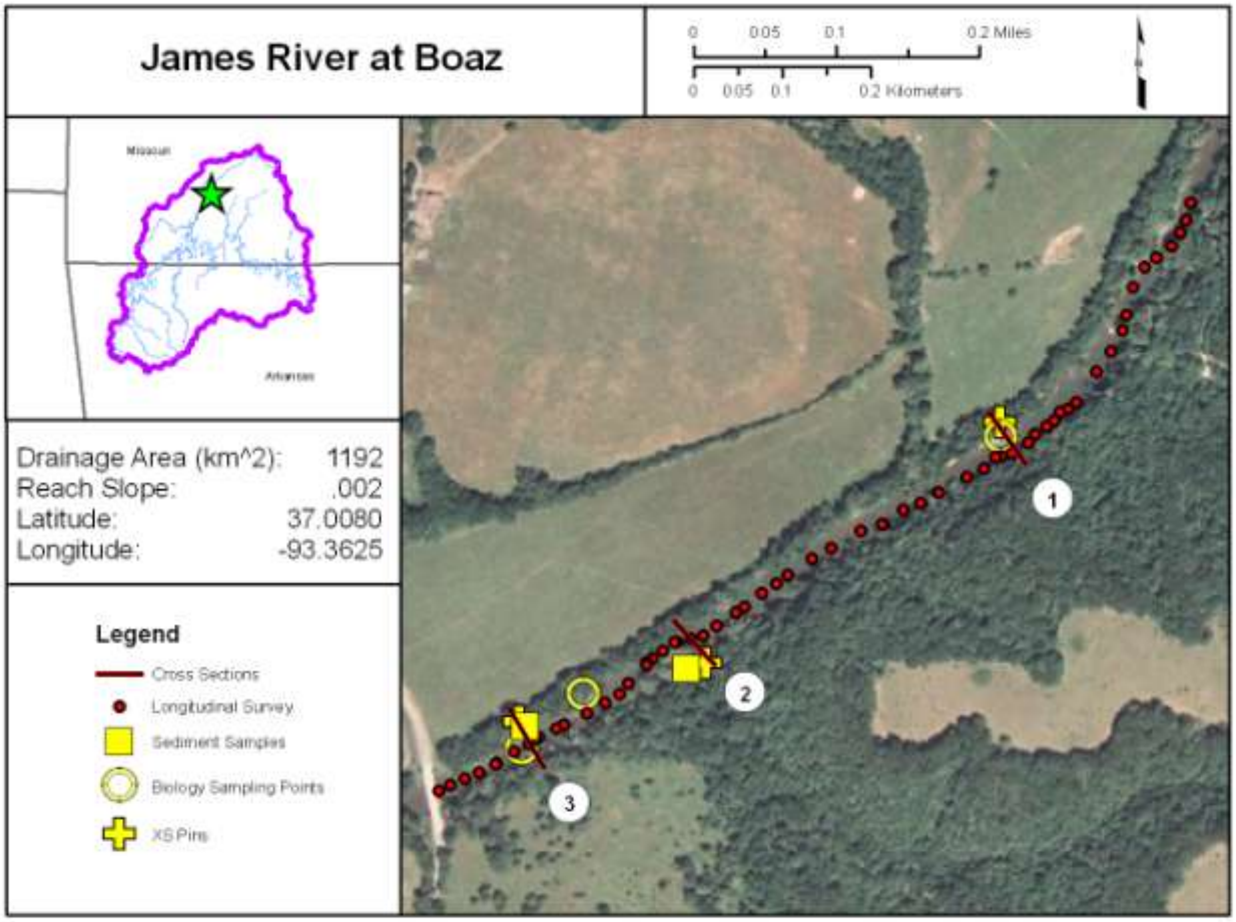
James River at Galena - T3
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
35
34
33
32
31
30
29
28
0
20
40
60
80
100
Distance across channel looking downstream (m)

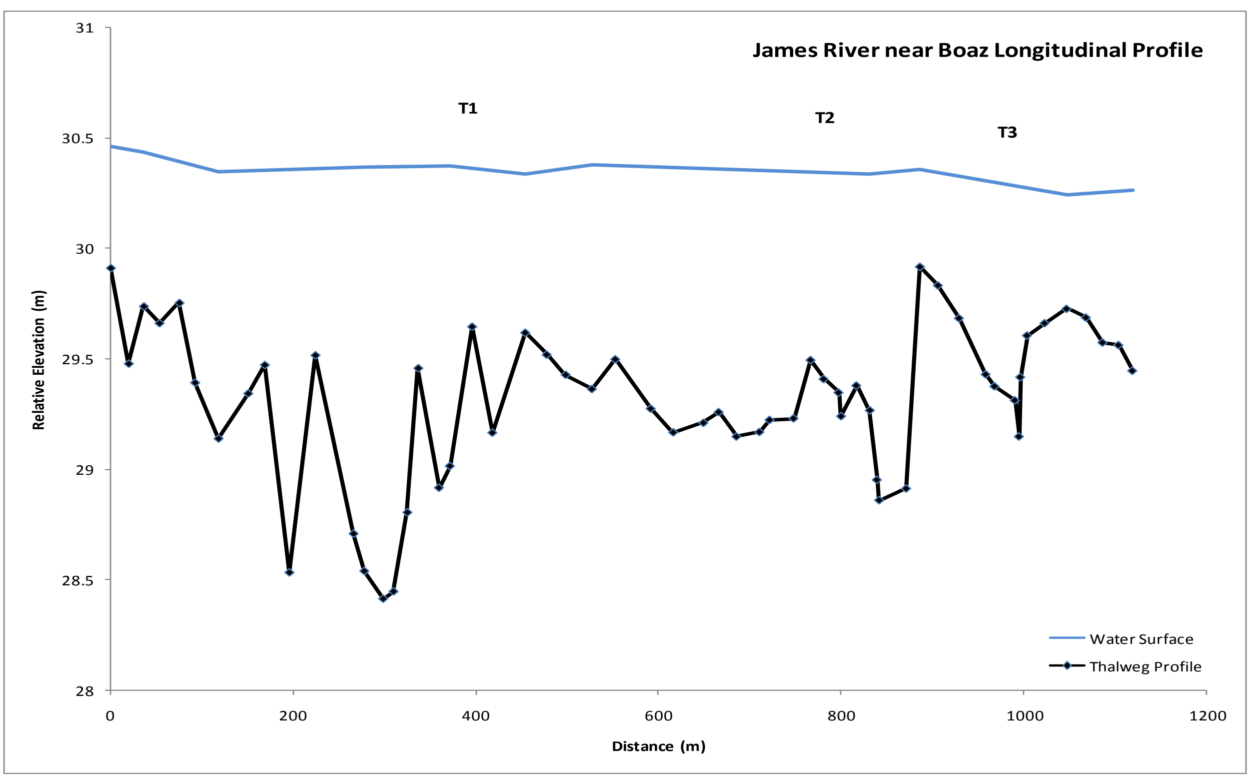
Up

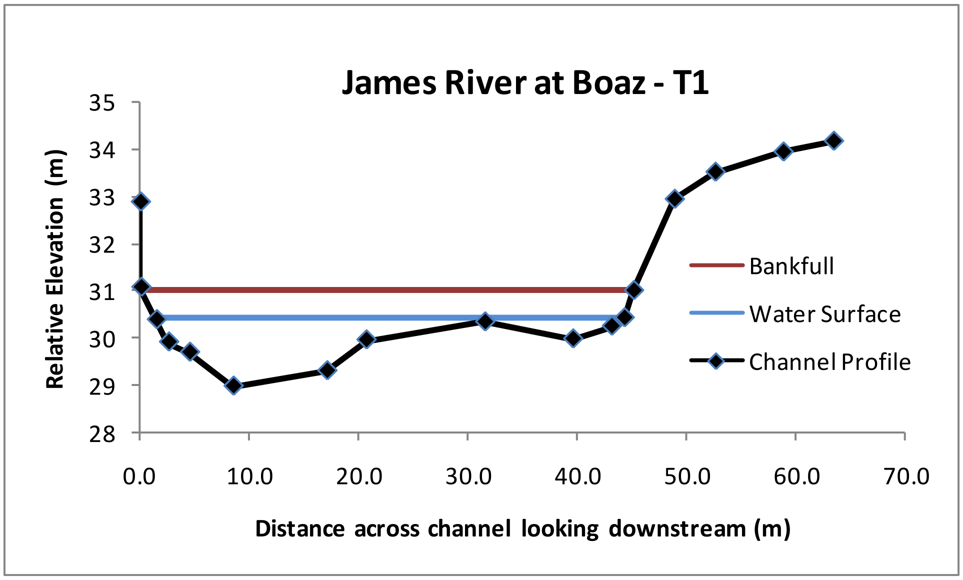
Down

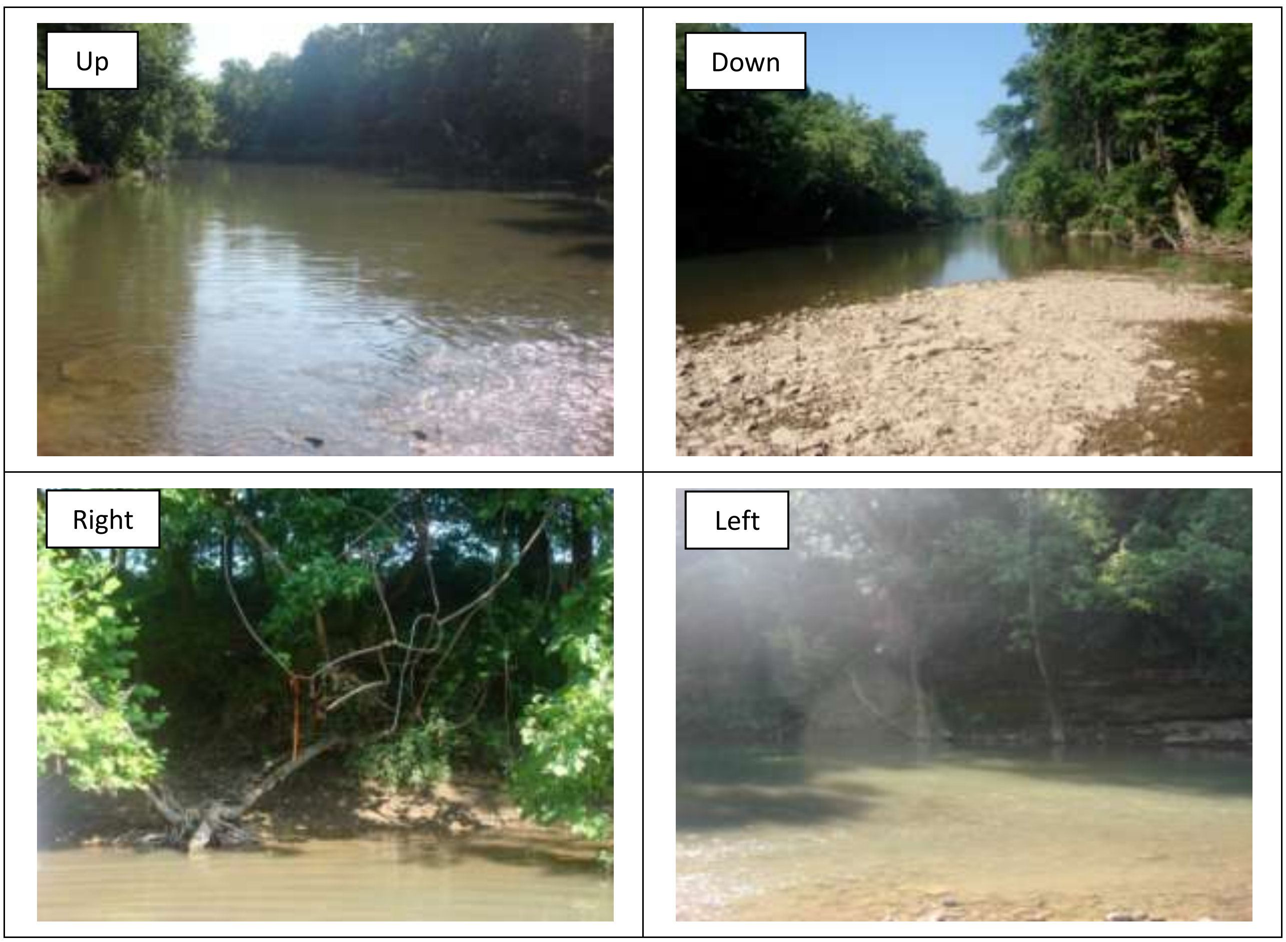
Right

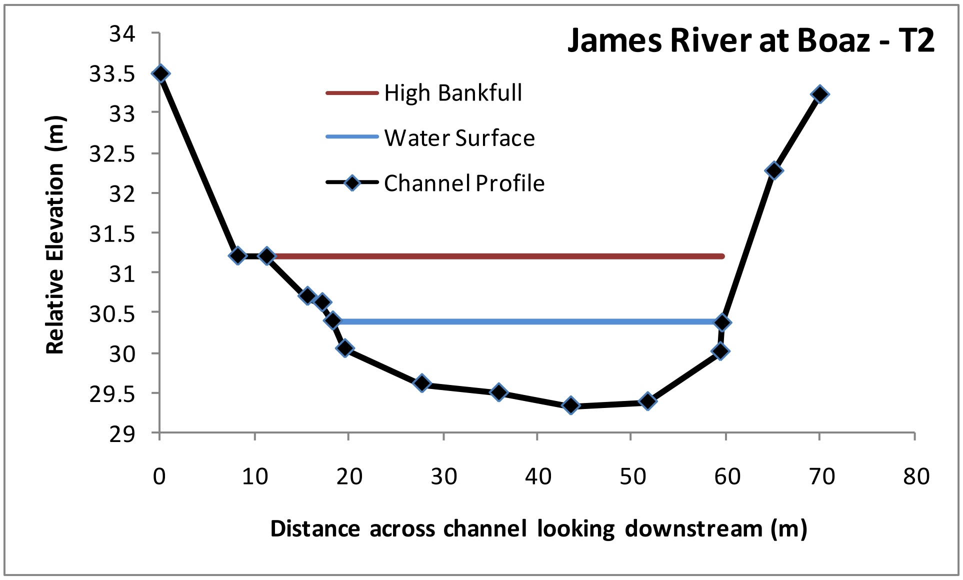
Left

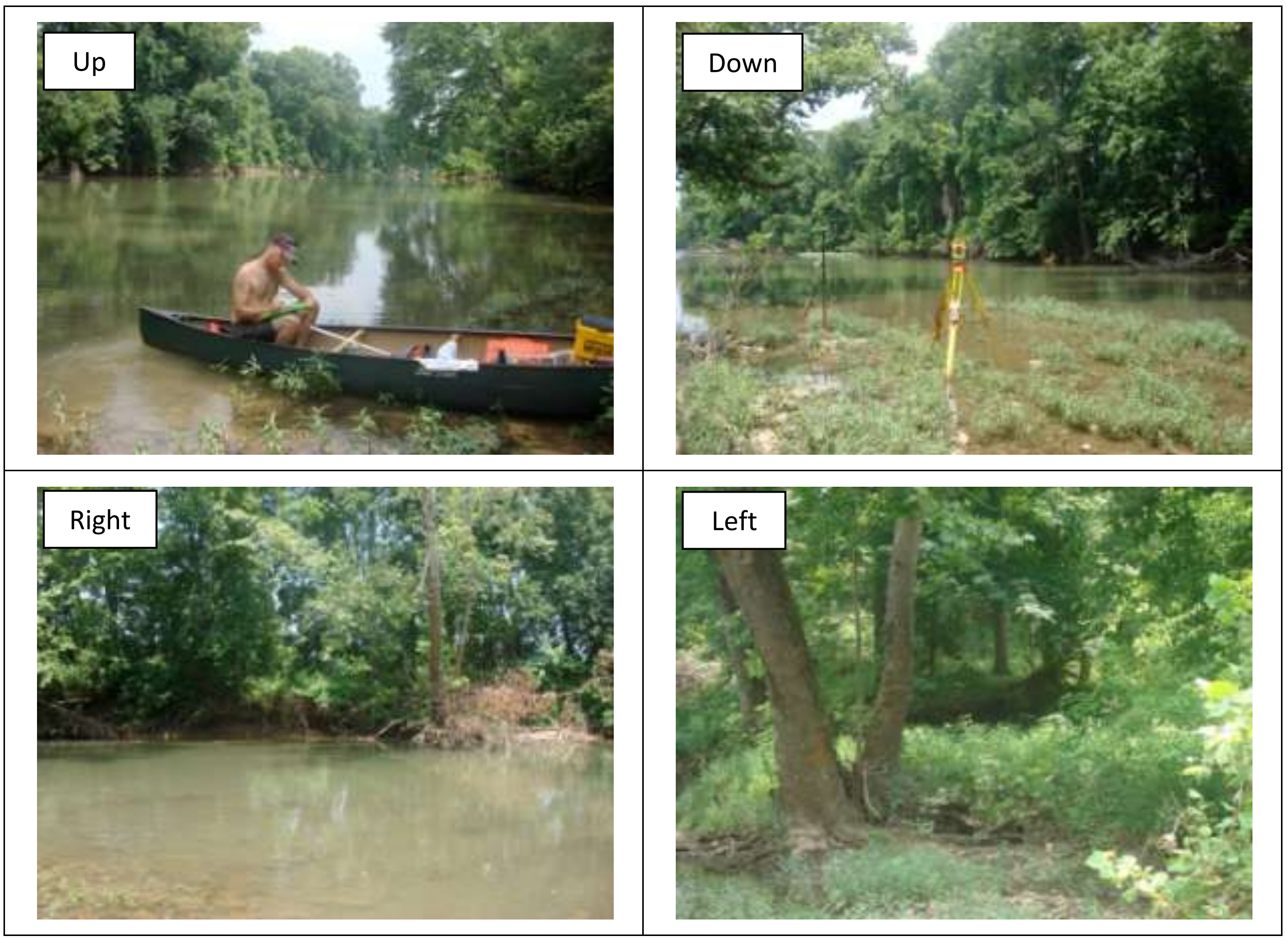

James River at Boaz
0 0.05 0.1 0.2 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 1192
Reach Slope: .002
Latitude: 37.0080
Longitude: -93.3625
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
1
2
3

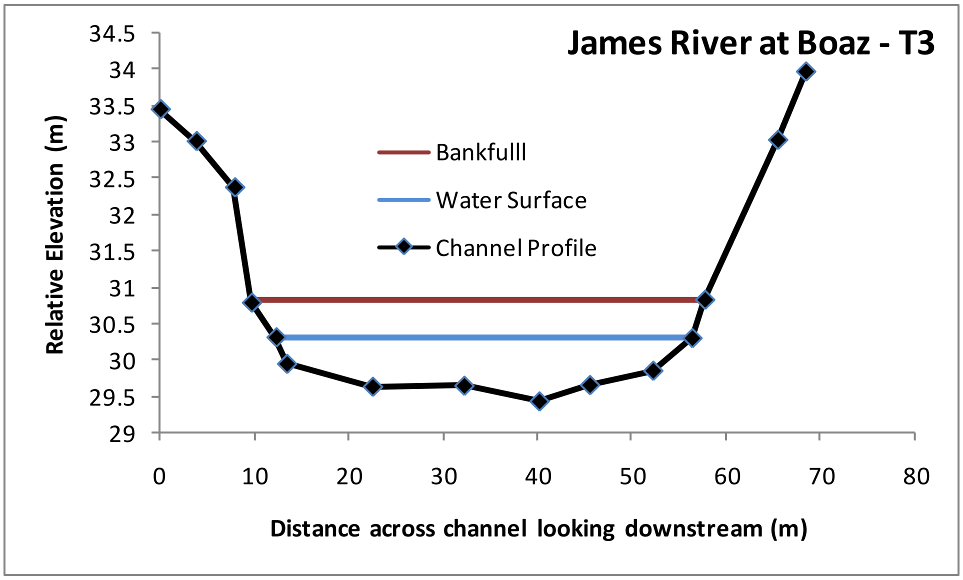

James River near Boaz Longitudinal Profile
T1
T2
T3
Relative Elevation (m)
Distance (m)
Water Surface
Thalweg Profile
31
30.5
30
29.5
29
28.5
28
0
200
400
600
800
1000
1200

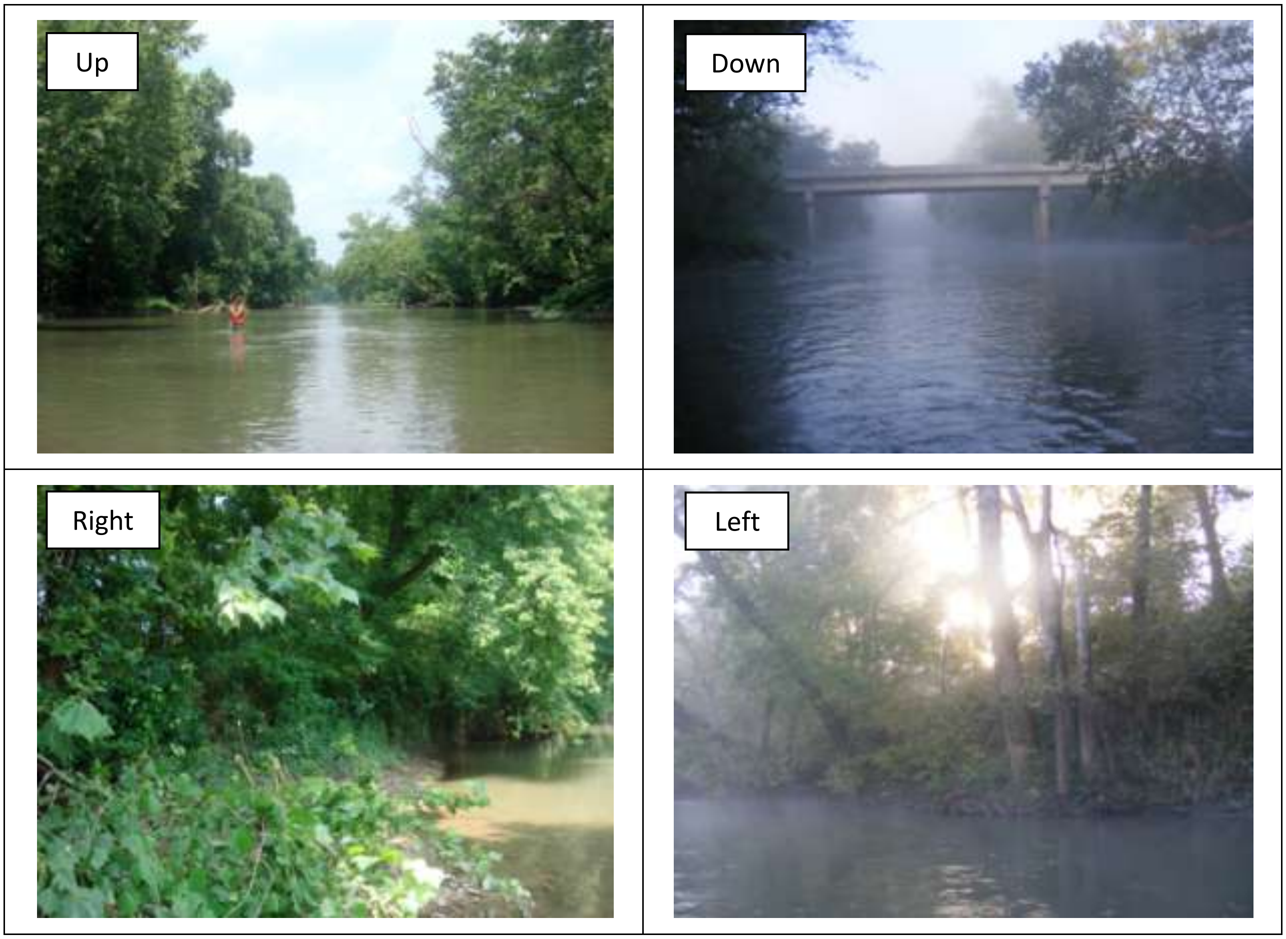

James River at Boaz - T1
Relative Elevation (m)
35
34
33
32
31
30
29
28
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile

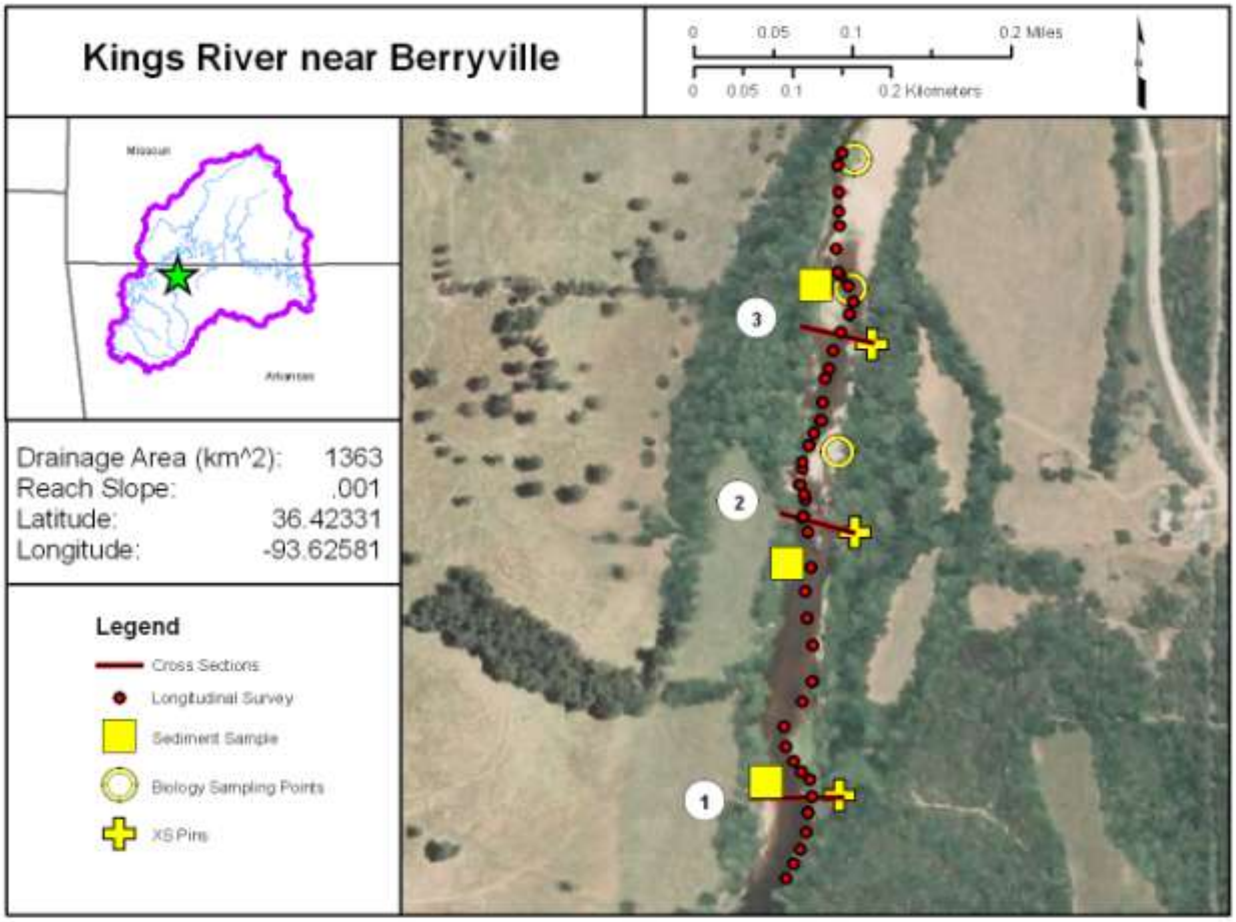

Up
Down
Right
Left

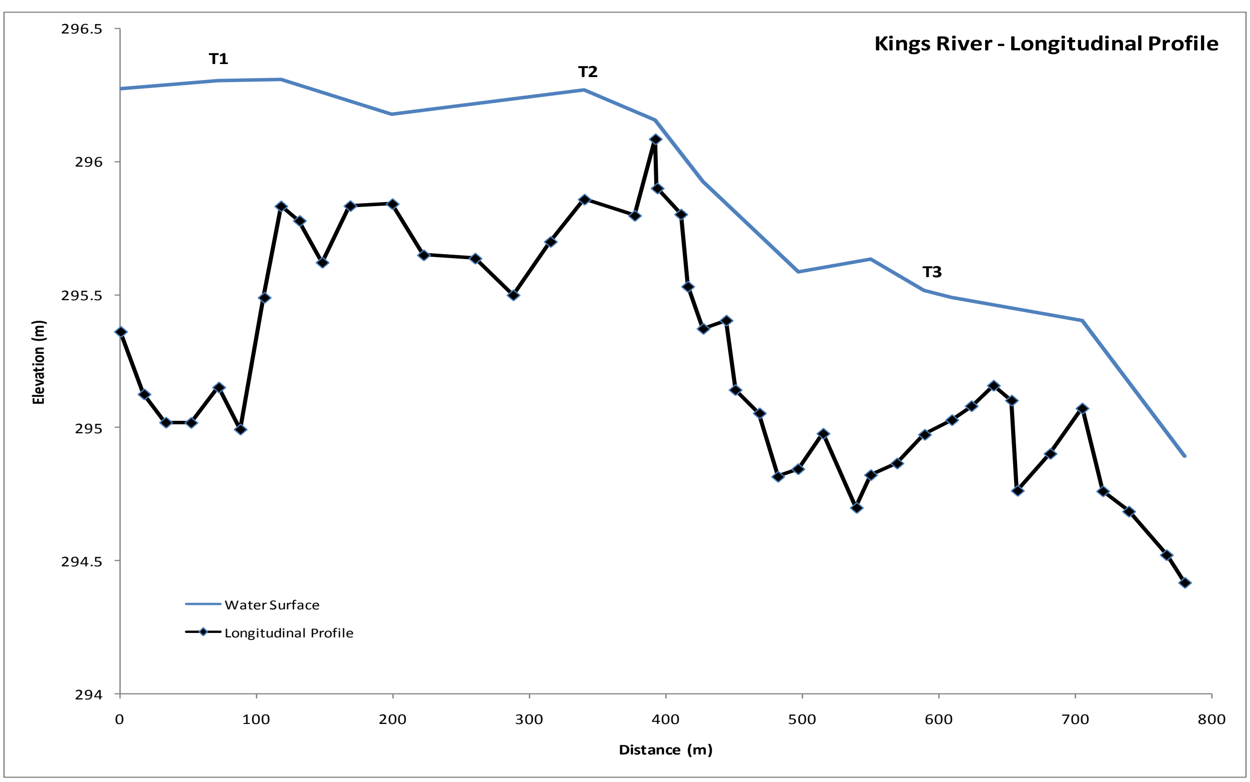

James River at Boaz - T2
High Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
Distance across channel looking downstream (m)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
0
10
20
30
40
50
60
70
80

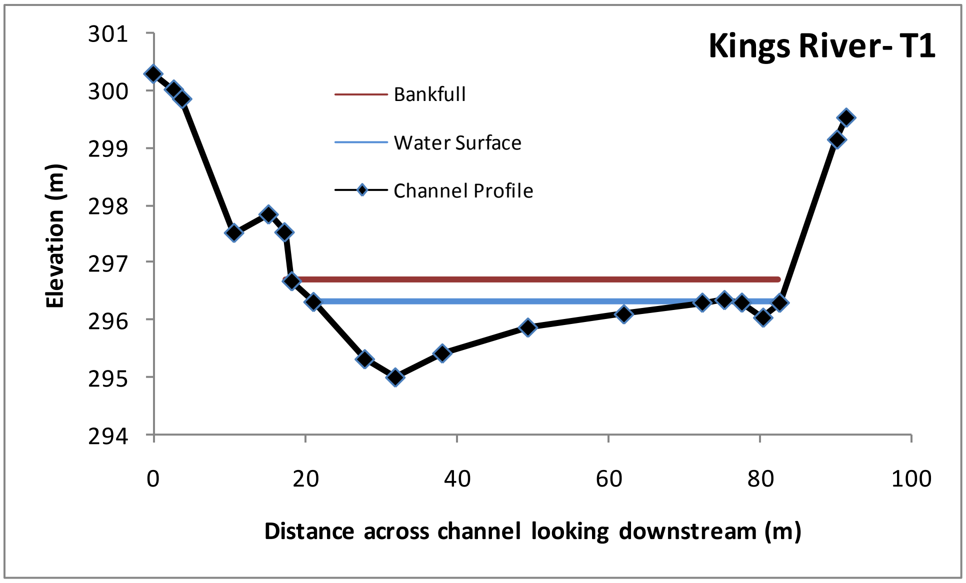

Up
Down
Right
Left

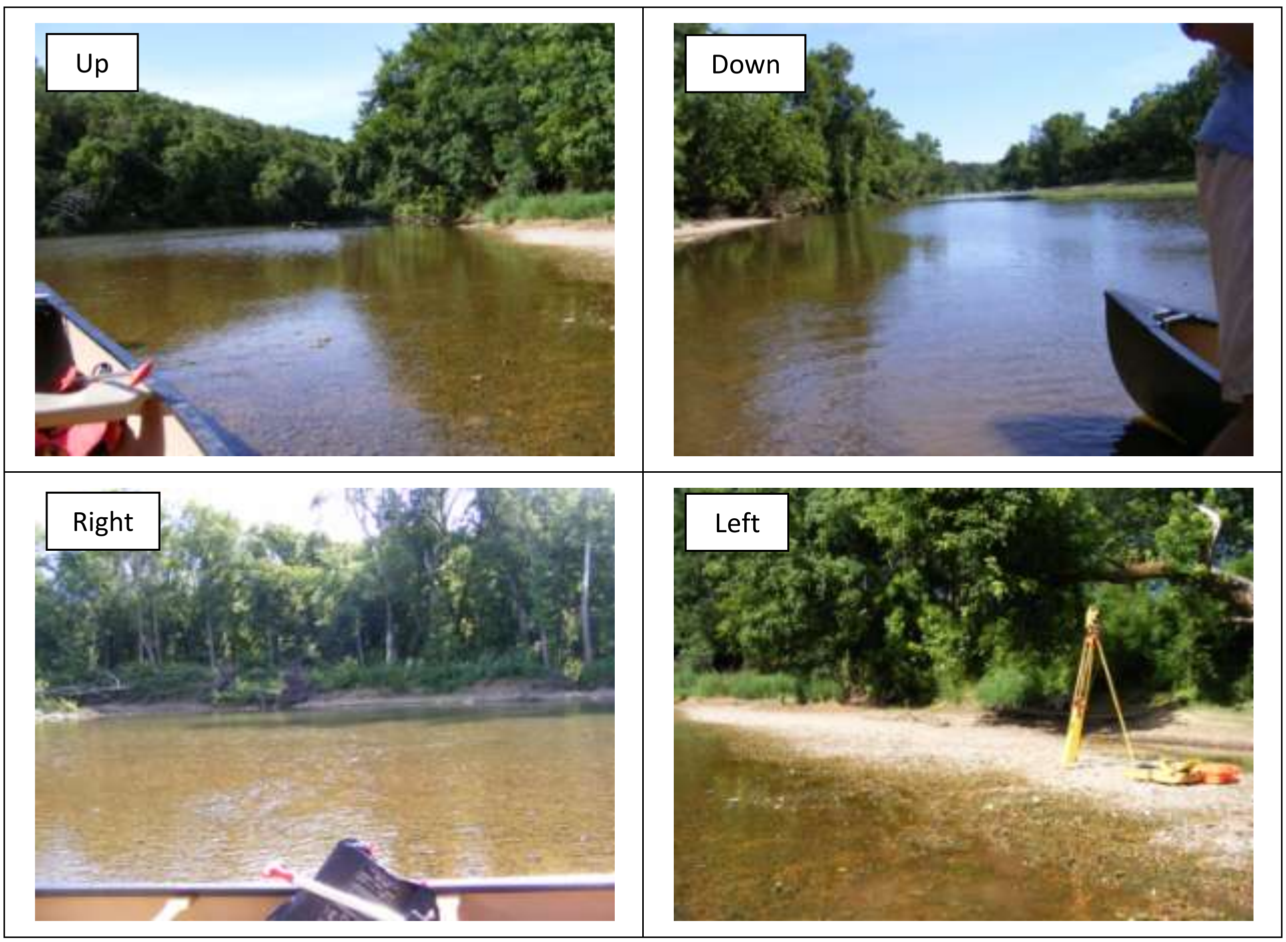

James River at Boaz - T3
Relative Elevation (m)
34.5
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
29
0
10
20
30
40
50
60
70
80
Distance across channel looking downstream (m)
Bankfulll
Water Surface
Channel Profile

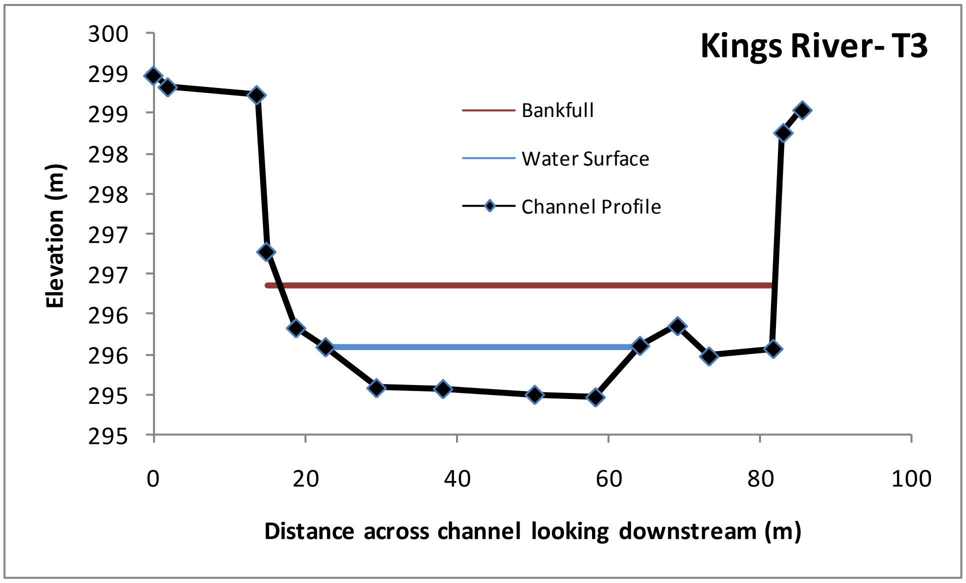

Up
Down
Right
Left


Kings River near Berryville
0
0.05
0.1
0.2 Miles
0
0.05
0.1
0.2 Kilometers
Drainage Area (km^2): 1363
Reach Slope: .001
Latitude: 36.42331
Longitude: -93.62581
Legend
Cross Sections
Longitudinal Survey
Sediment Sample
Biology Sampling Points
XS Pins
1
2
3


Kings River - Longitudinal Profile
T1
T2
T3
Elevation (m)
Distance (m)
296.5
296
295.5
295
294.5
294
0
100
200
300
400
500
600
700
800
Water Surface
Longitudinal Profile


Kings River- T1
Bankfull
Water Surface
Channel Profile
Elevation (m)
301
300
299
298
297
296
295
294
0
20
40
60
80
100
Distance across channel looking downstream (m)


Up
Down
Right
Left

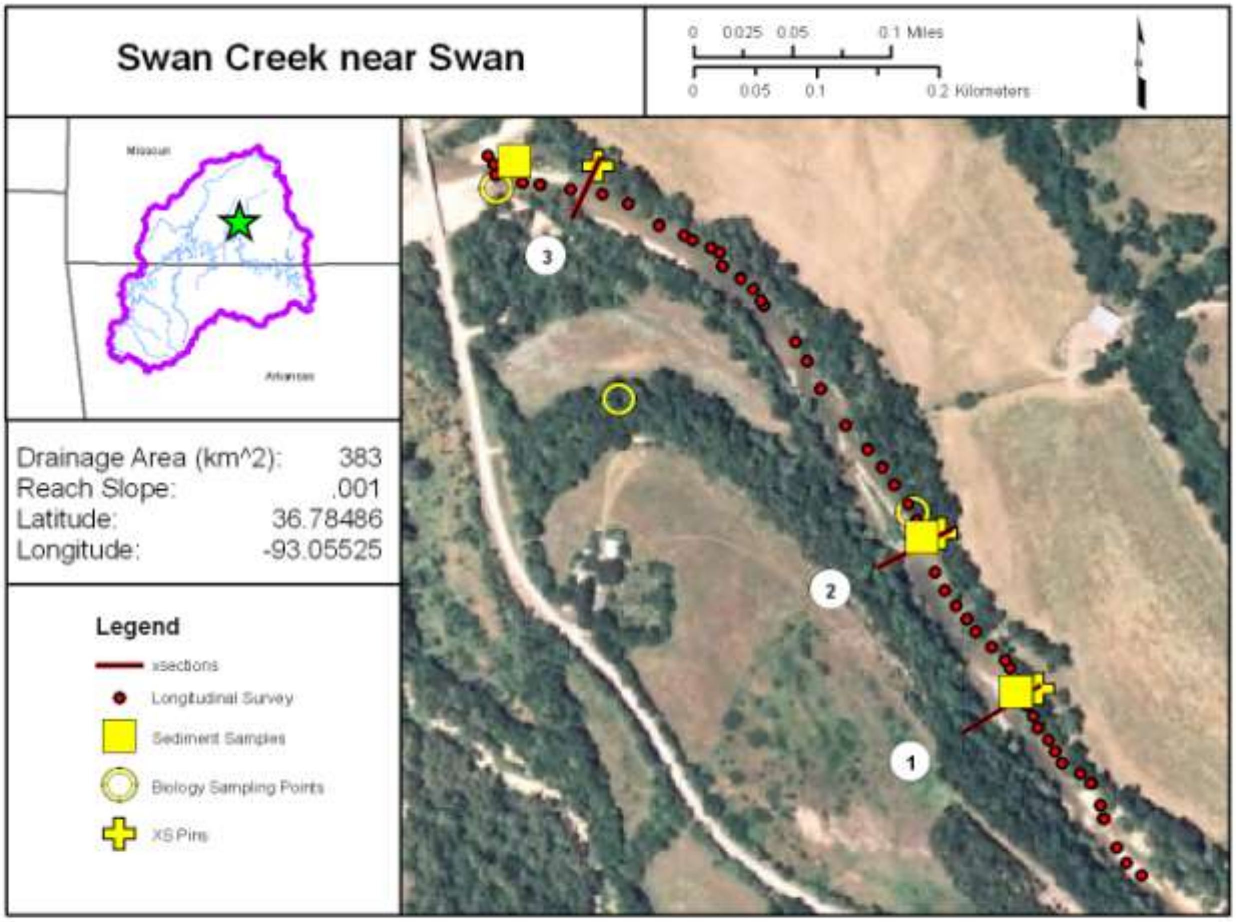

Kings River- T3
Bankfull
Water Surface
Channel Profile
Elevation (m)
300
299
299
298
298
297
297
296
296
295
295
0
20
40
60
80
100
Distance across channel looking downstream (m)

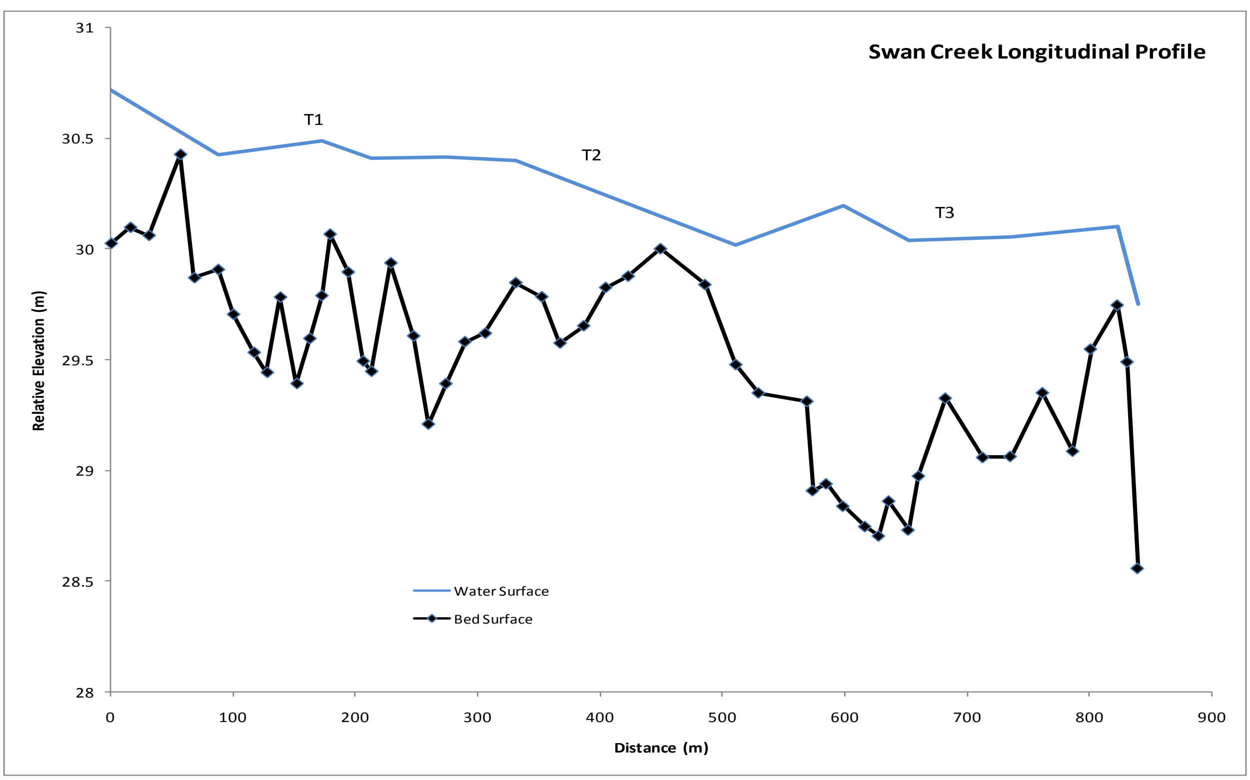

Up

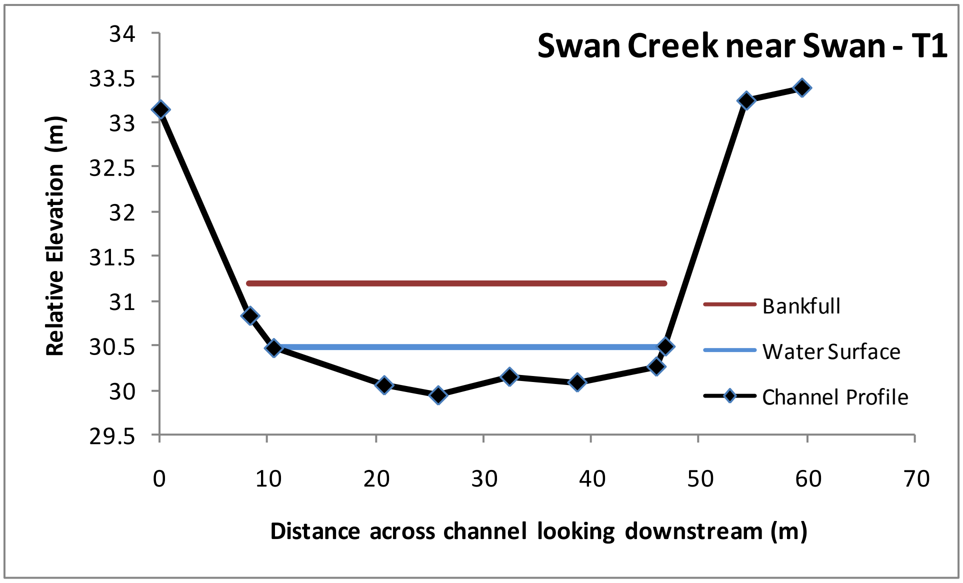

Down


Right


Left


Swan Creek near Swan
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 383
Reach Slope: .001
Latitude: 36.78486
Longitude: -93.05525
Legend
xsections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
3
2
1


Swan Creek Longitudinal Profile
T1
T2
T3
Water Surface
Bed Surface
Relative Elevation (m)
Distance (m)
31
30.5
30
29.5
29
28.5
28
0
100
200
300
400
500
600
700
800
900

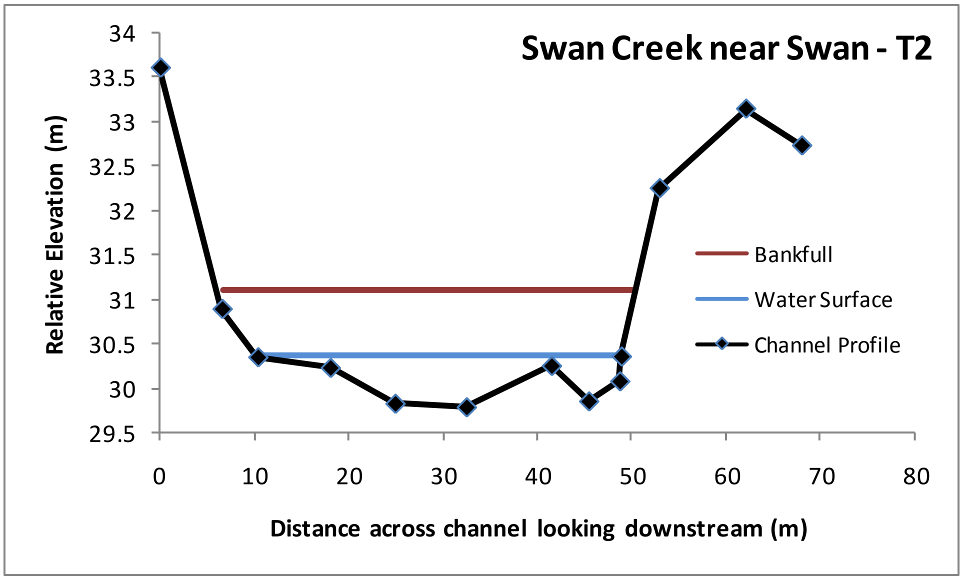

Swan Creek near Swan - T1
Relative Elevation (m)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
0
10
20
30
40
50
60
70
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile

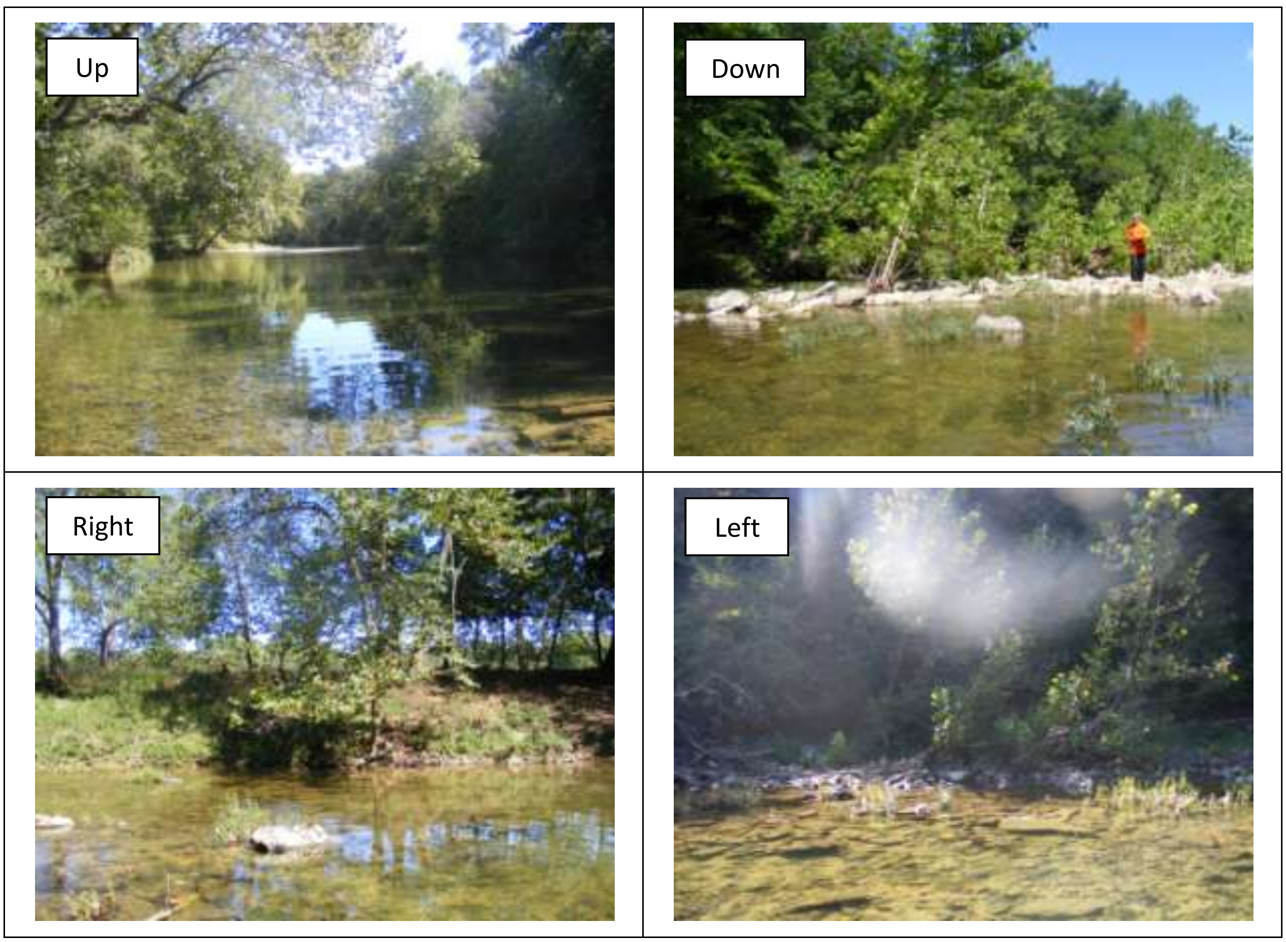

Up

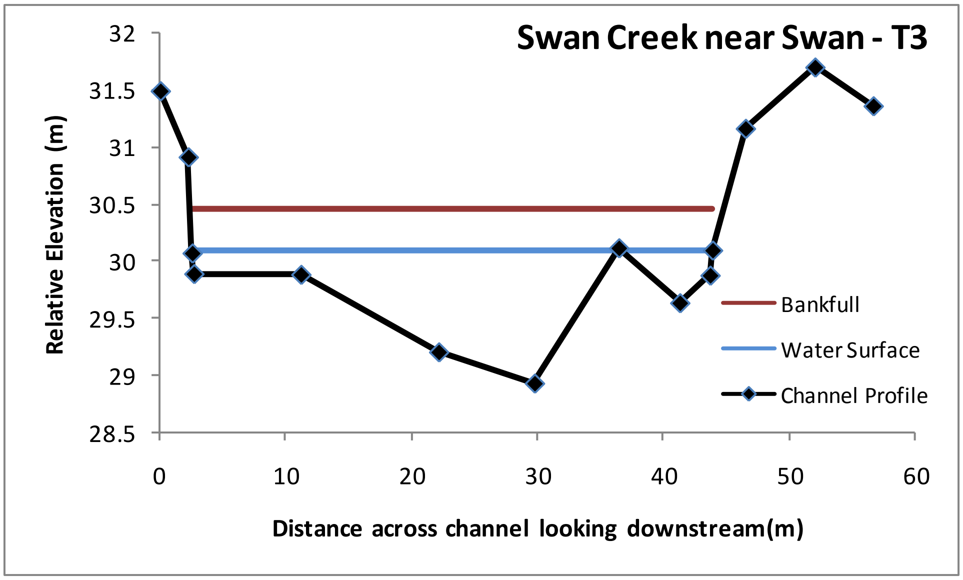

Down


Right


Left


Swan Creek near Swan - T2
Relative Elevation (m)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
0
10
20
30
40
50
60
70
80
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Up
Down
Right
Left



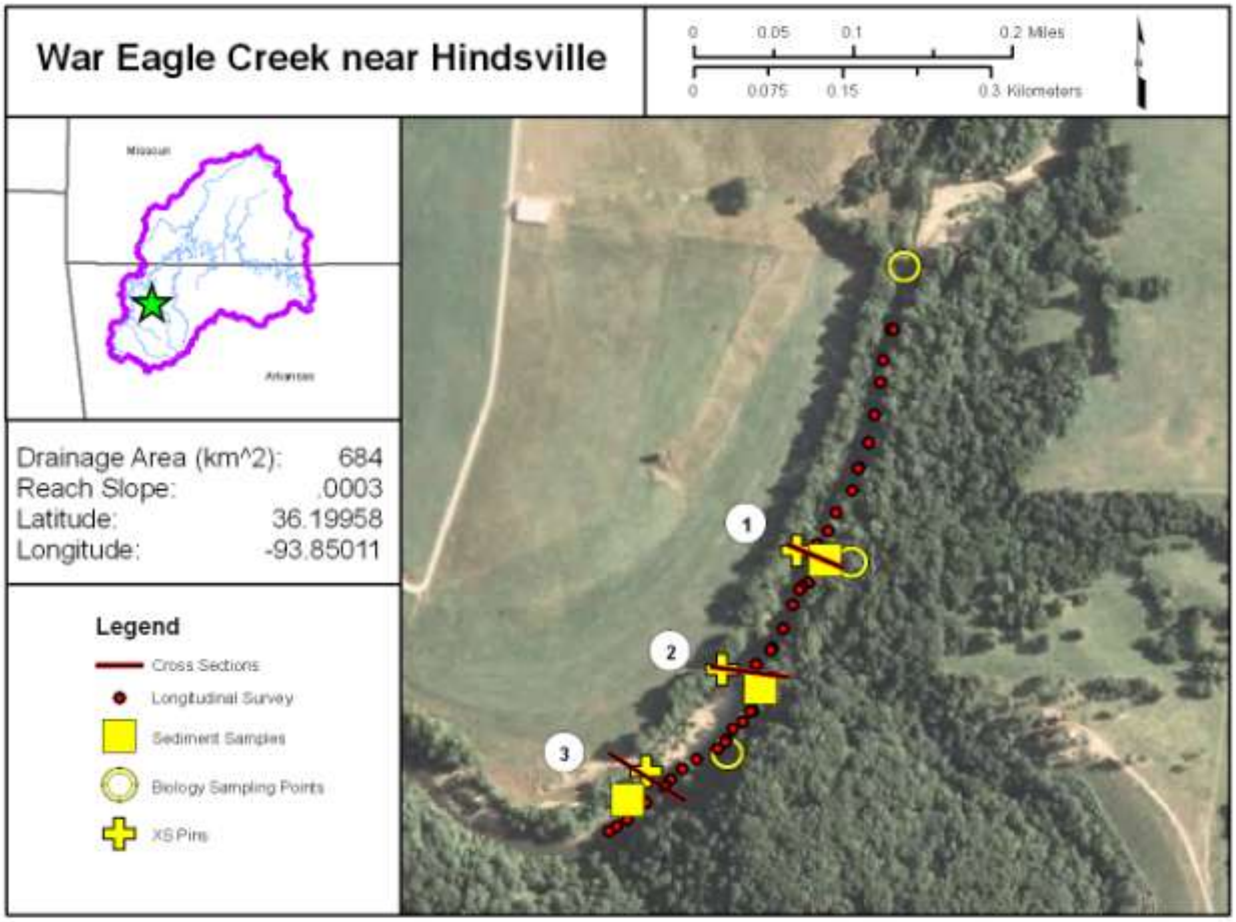
Swan Creek near Swan - T3
Relative Elevation (m)
32
31.5
31
30.5
30
29.5
29
28.5
0
10
20
30
40
50
60
Distance across channel looking downstream(m)
Bankfull
Water Surface
Channel Profile

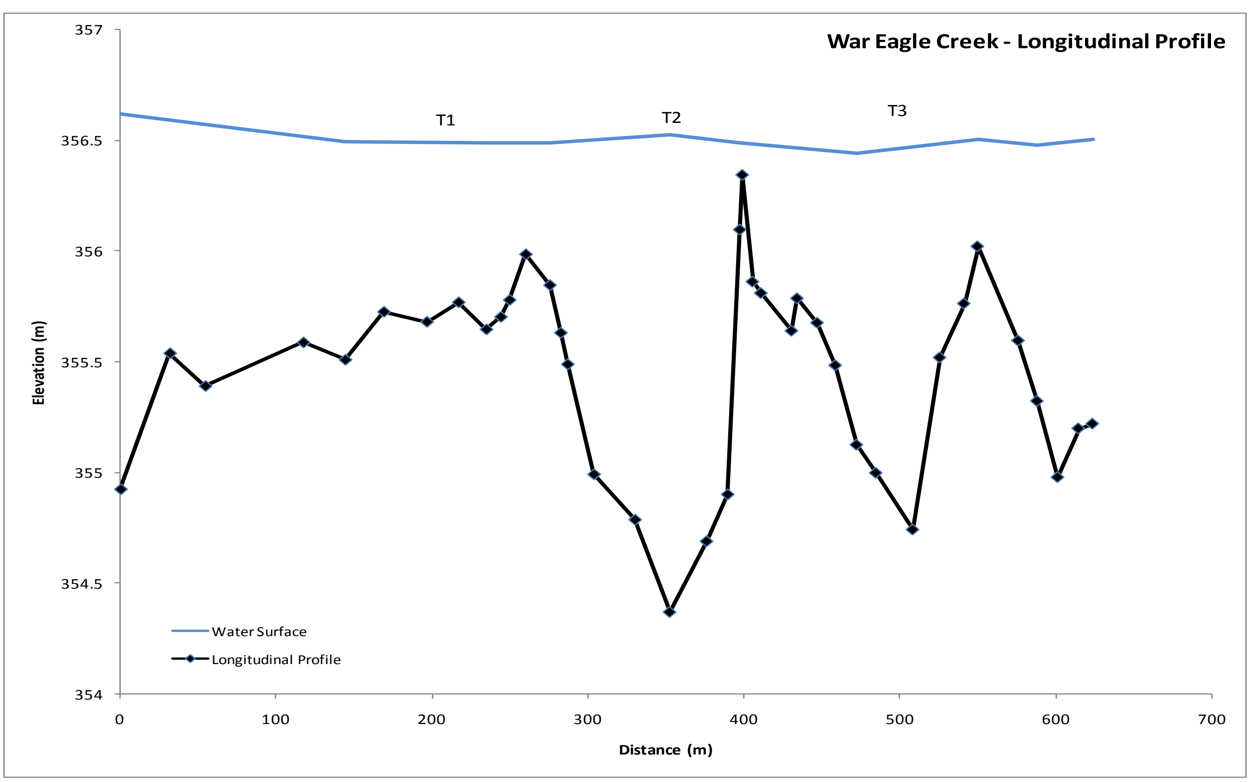
Up

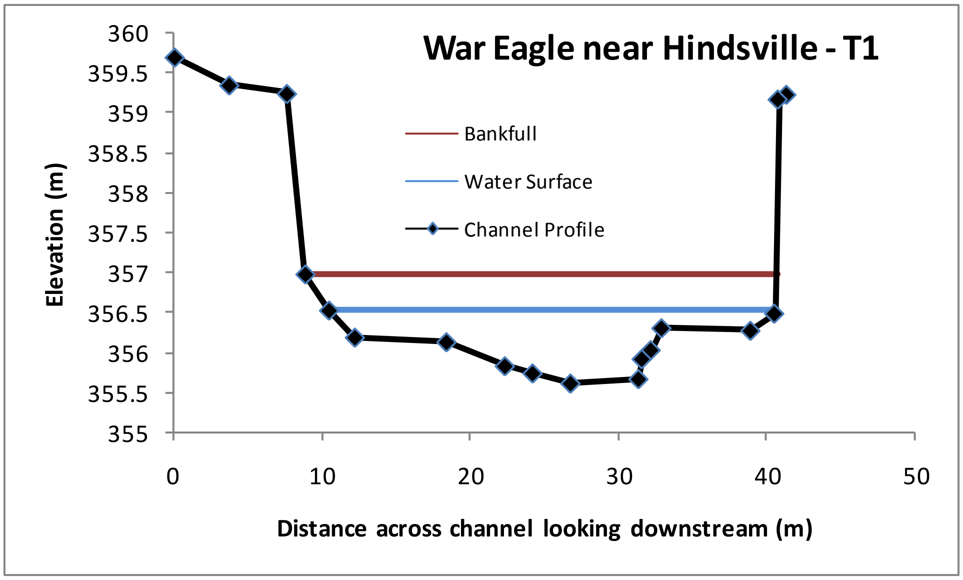
Down

Right

Left


War Eagle Creek near Hindsville
0 0.05 0.1 0.2 Miles
0 0.075 0.15 0.3 Kilometers
Drainage Area (km^2): 684
Reach Slope: .0003
Latitude: 36.19958
Longitude: -93.85011
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
1
2
3


War Eagle Creek - Longitudinal Profile
T1
T2
T3
Elevation (m)
Distance (m)
Water Surface
Longitudinal Profile
357
356.5
356
355.5
355
354.5
354
0
100
200
300
400
500
600
700

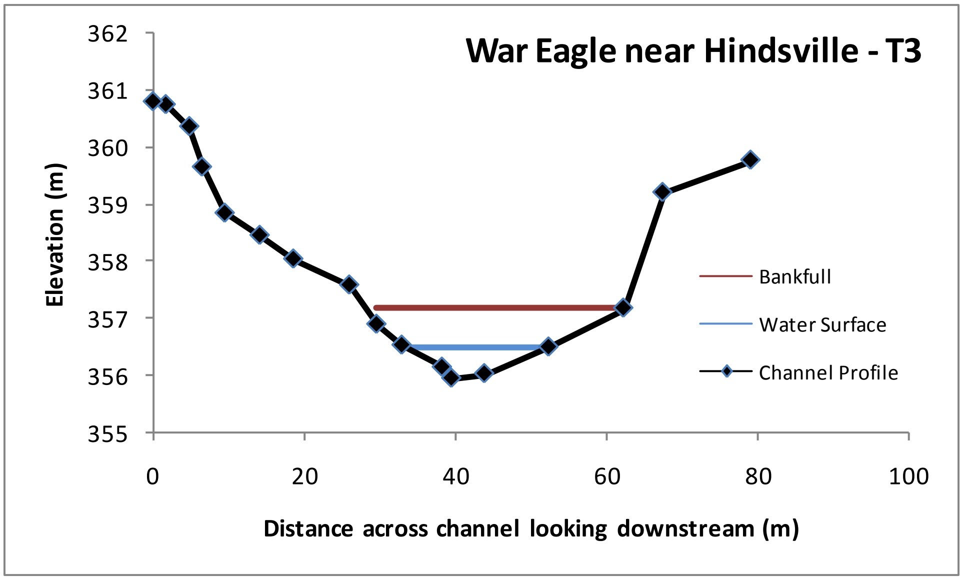

War Eagle near Hindsville - T1
Bankfull
Water Surface
Channel Profile
Elevation (m)
360
359.5
359
358.5
358
357.5
357
356.5
356
355.5
355
0
10
20
30
40
50
Distance across channel looking downstream (m)


Up


Down


Right


Left

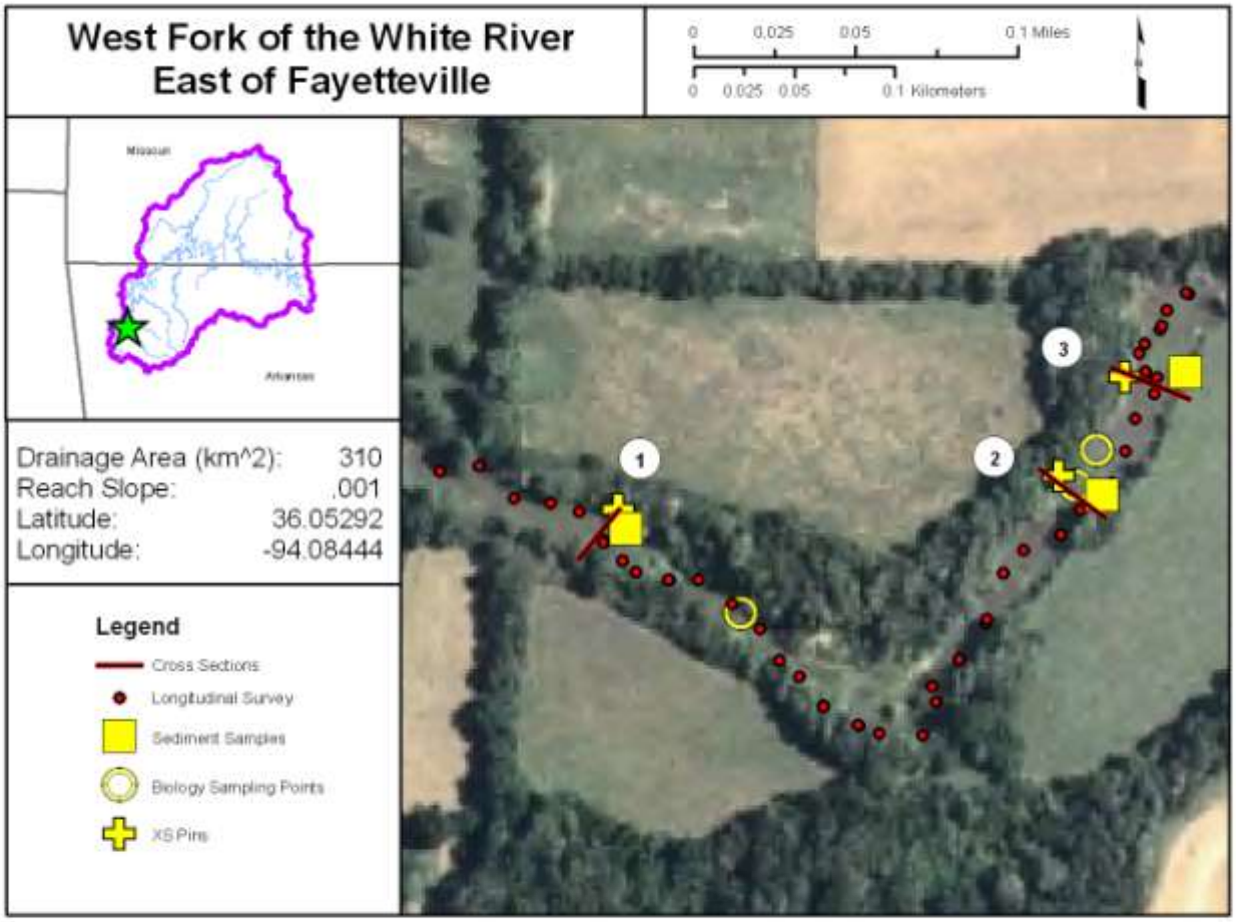

War Eagle near Hindsville - T3
Elevation (m)
362
361
360
359
358
357
356
355
0
20
40
60
80
100
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile

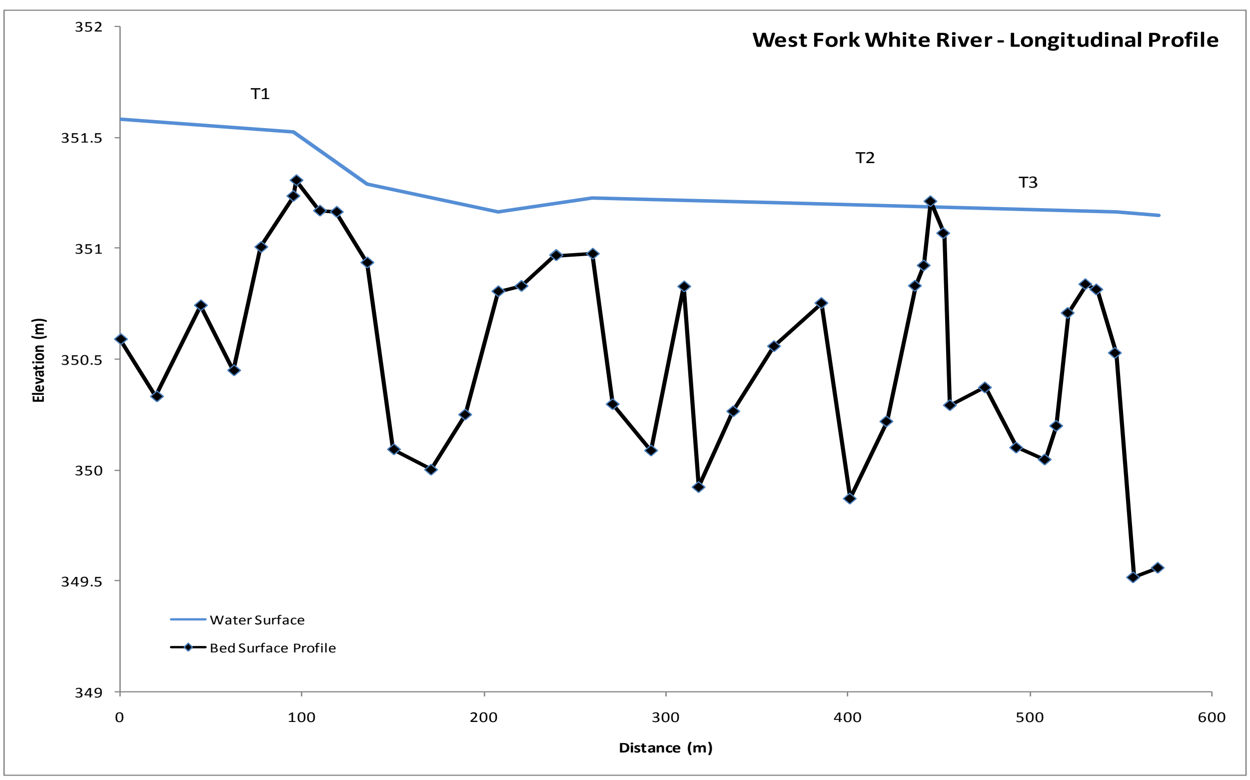

Up

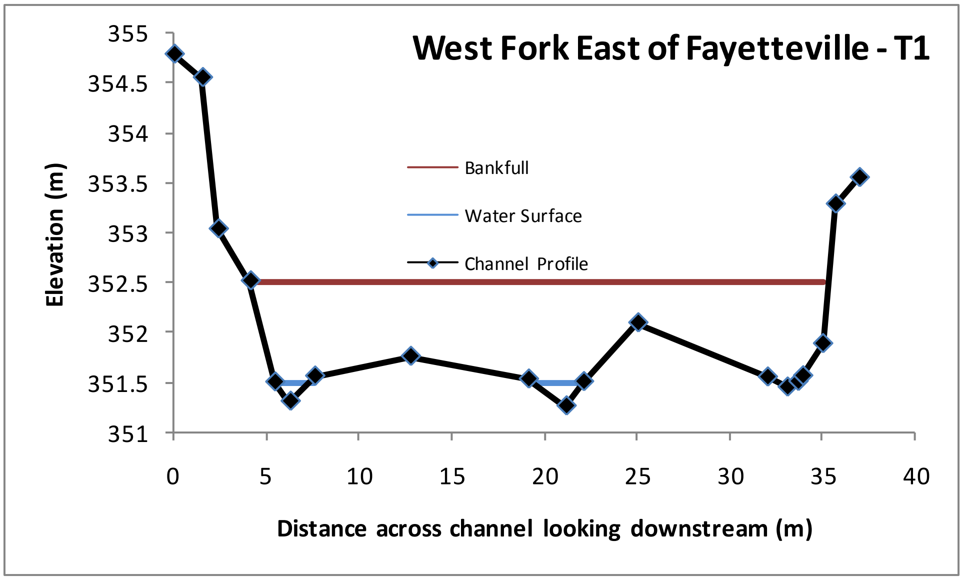

Down


Right


Left


West Fork of the White River
East of Fayetteville
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Drainage Area (km^2): 310
Reach Slope: .001
Latitude: 36.05292
Longitude: -94.08444
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
1
2
3


West Fork White River - Longitudinal Profile
T1
T2
T3
Elevation (m)
Distance (m)
Water Surface
Bed Surface Profile
352
351.5
351
350.5
350
349.5
349
0
100
200
300
400
500
600

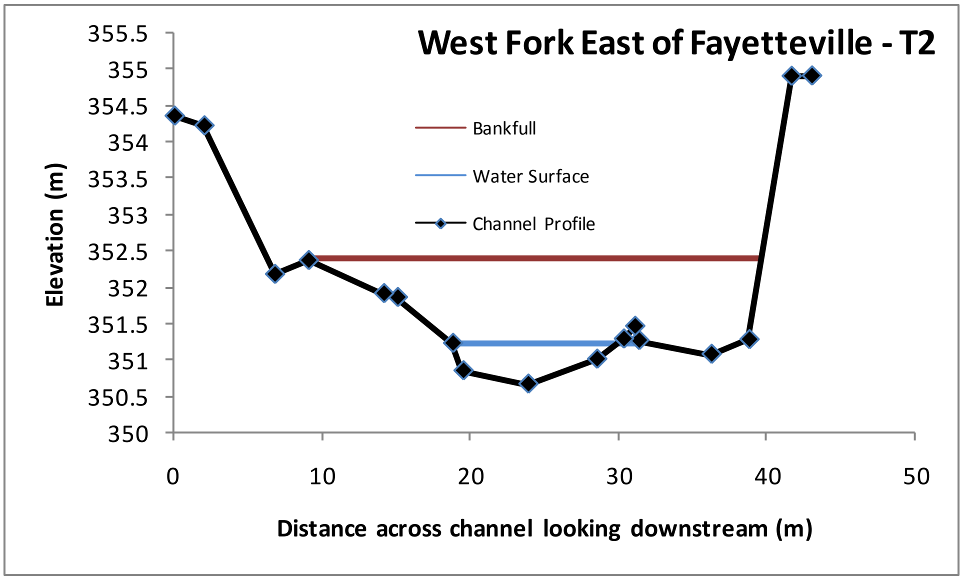

West Fork East of Fayetteville - T1
Elevation (m)
355
354.5
354
353.5
353
352.5
352
351.5
351
0
5
10
15
20
25
30
35
40
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Up


Down

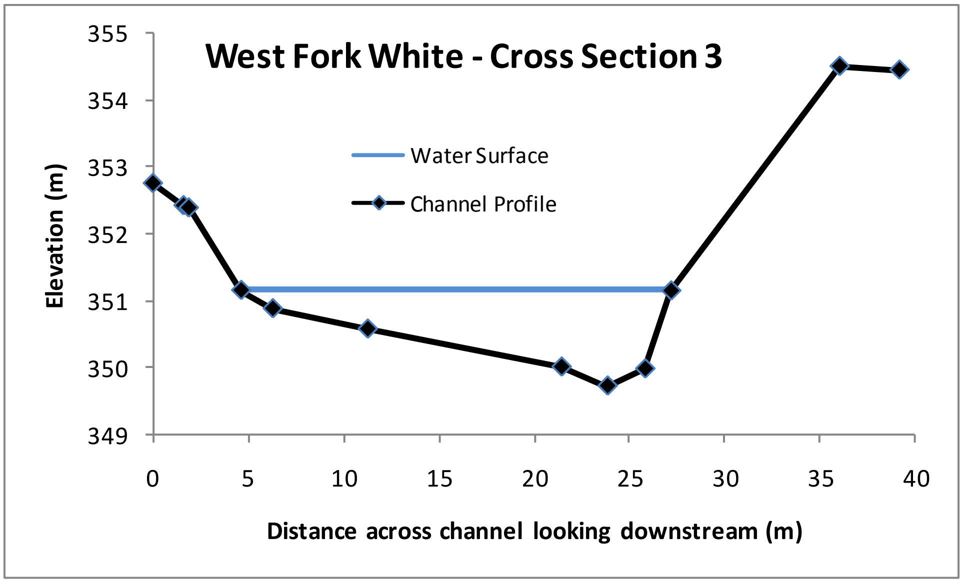

Right


Left



Up	Down
	

Right	Left
	

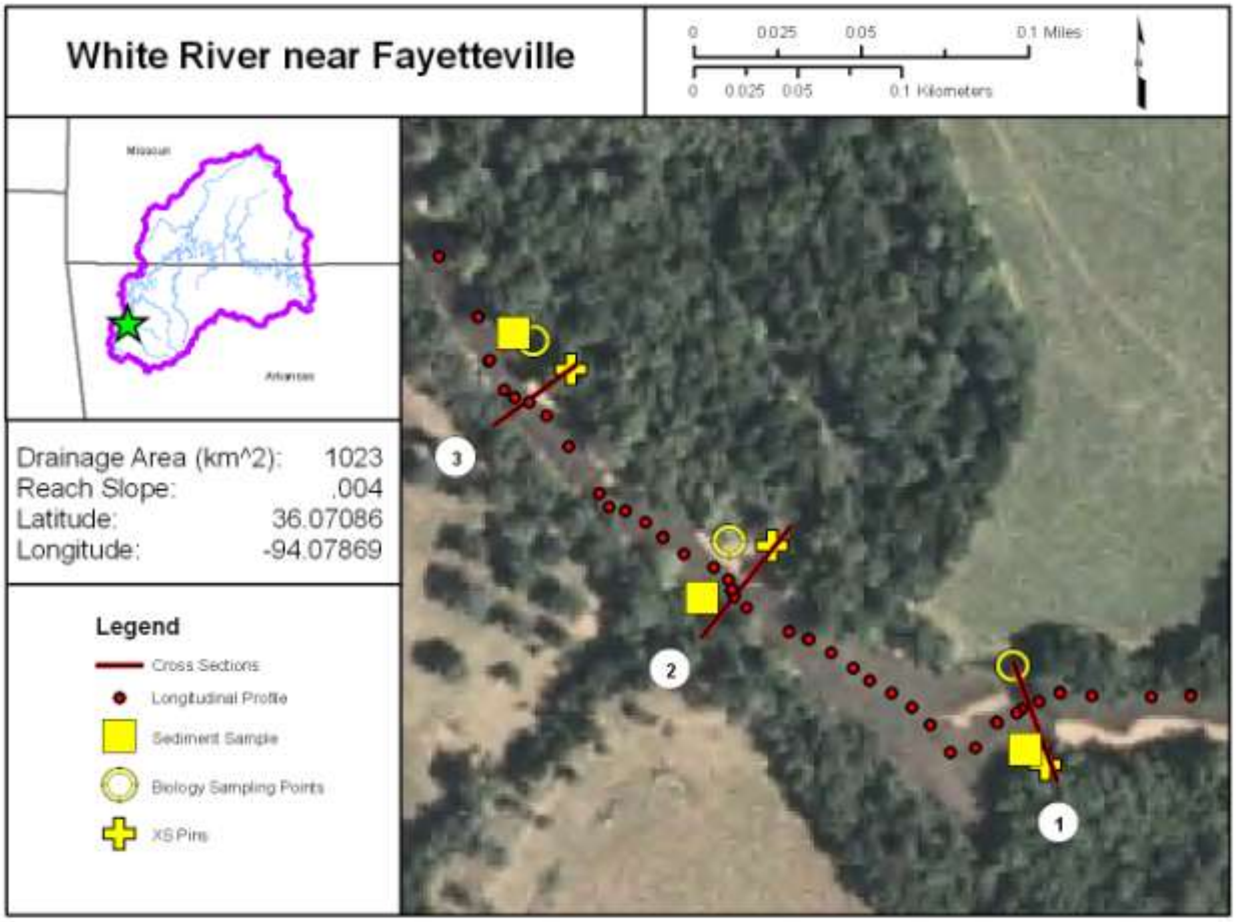

West Fork White - Cross Section 3
Water Surface
Channel Profile
Elevation (m)
355
354
353
352
351
350
349
0
5
10
15
20
25
30
35
40
Distance across channel looking downstream (m)

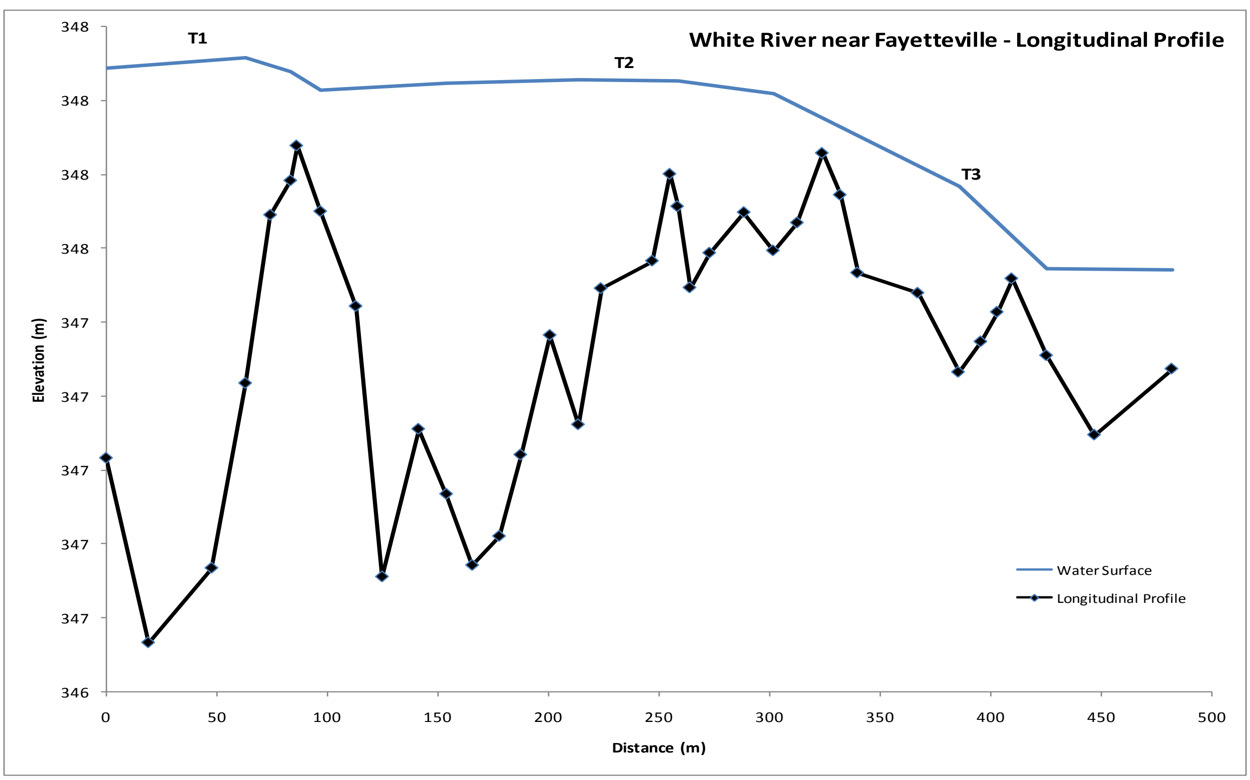

Up

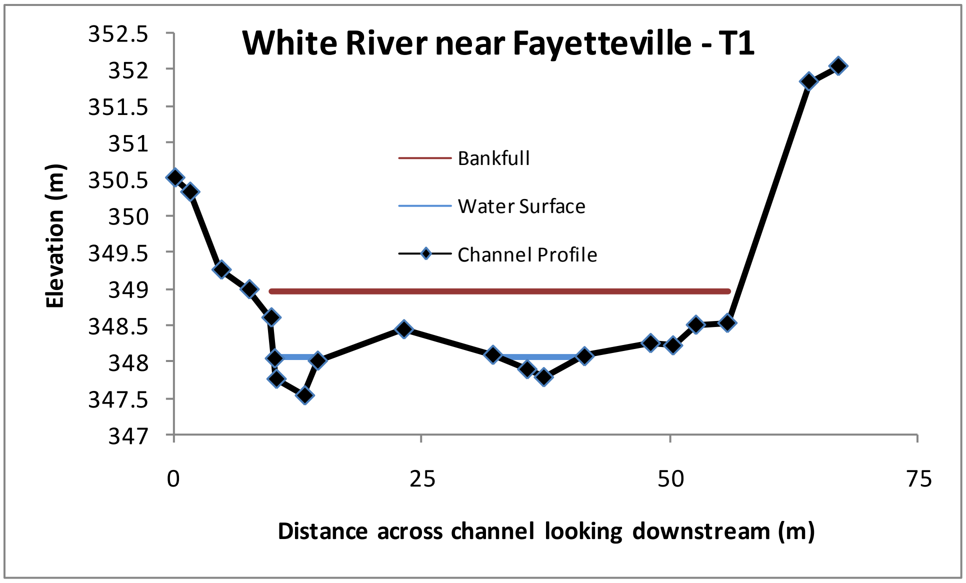

Down


Right

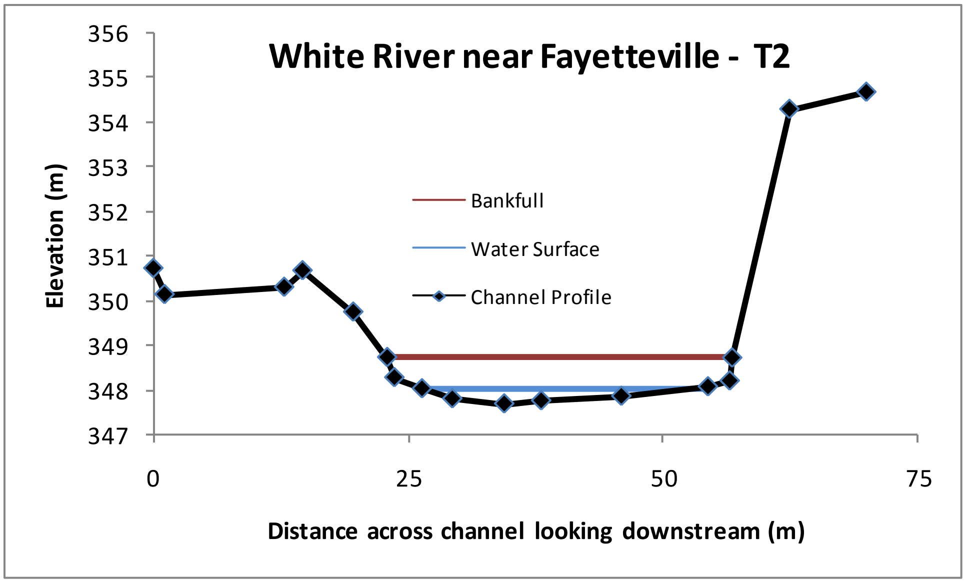

Left

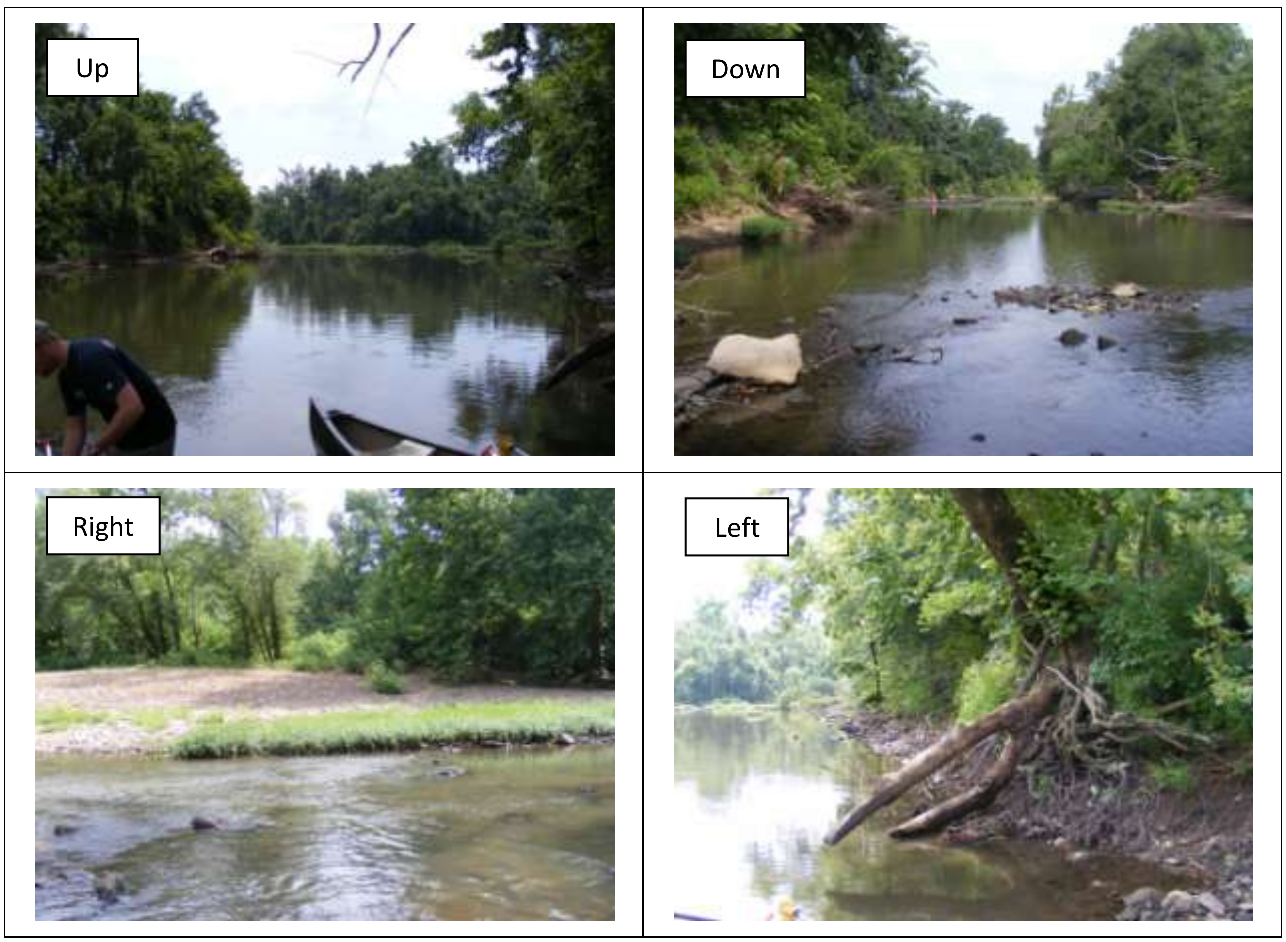

White River near Fayetteville
0 0.025 0.05 0.1 Miles
0 0.025 0.05 0.1 Kilometers
Drainage Area (km^2): 1023
Reach Slope: .004
Latitude: 36.07086
Longitude: -94.07869
Legend
Cross Sections
Longitudinal Profile
Sediment Sample
Biology Sampling Points
XS Pins
3
2
1

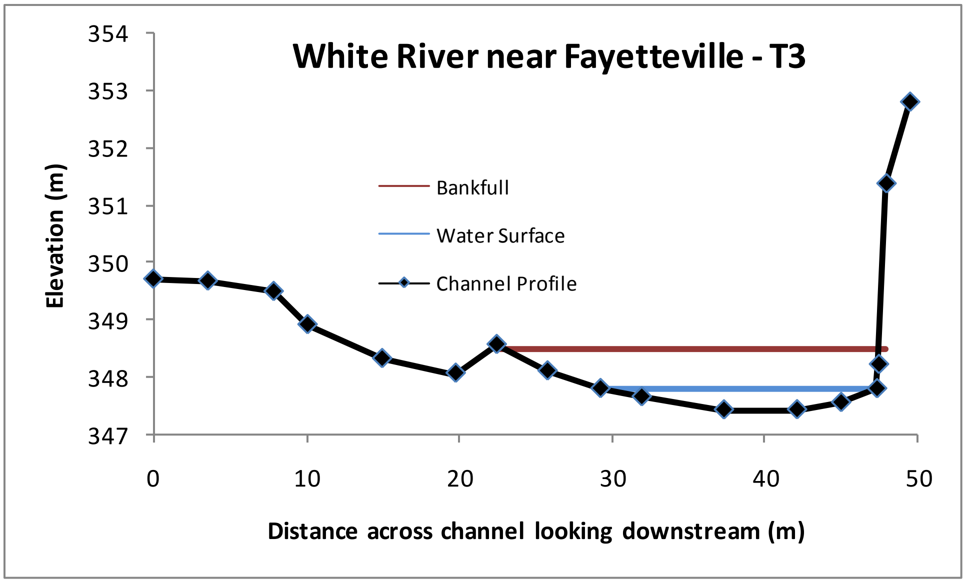

White River near Fayetteville - Longitudinal Profile
T1
T2
T3
Elevation (m)
Distance (m)
348
348
348
348
347
347
347
347
347
346
0
50
100
150
200
250
300
350
400
450
500
Water Surface
Longitudinal Profile


White River near Fayetteville - T1
Bankfull
Water Surface
Channel Profile
Elevation (m)
352.5
352
351.5
351
350.5
350
349.5
349
348.5
348
347.5
347
0
25
50
75
Distance across channel looking downstream (m)


Up
Down
Right
Left


White River near Fayetteville - T2
Elevation (m)
356
355
354
353
352
351
350
349
348
347
0
25
50
75
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Up
Down
Right
Left

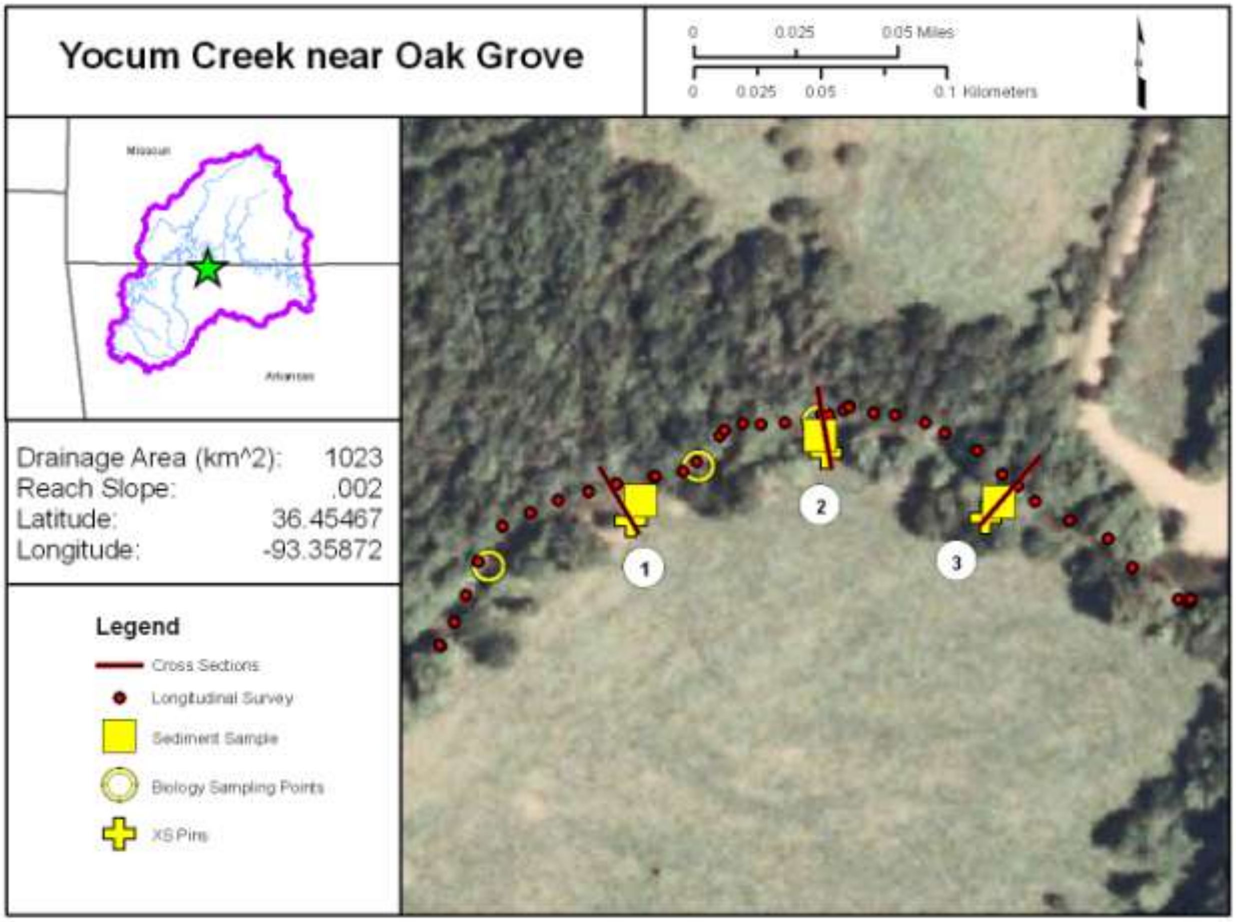

White River near Fayetteville - T3
354
353
352
351
350
349
348
347
Elevation (m)
Bankfull
Water Surface
Channel Profile
0
10
20
30
40
50
Distance across channel looking downstream (m)

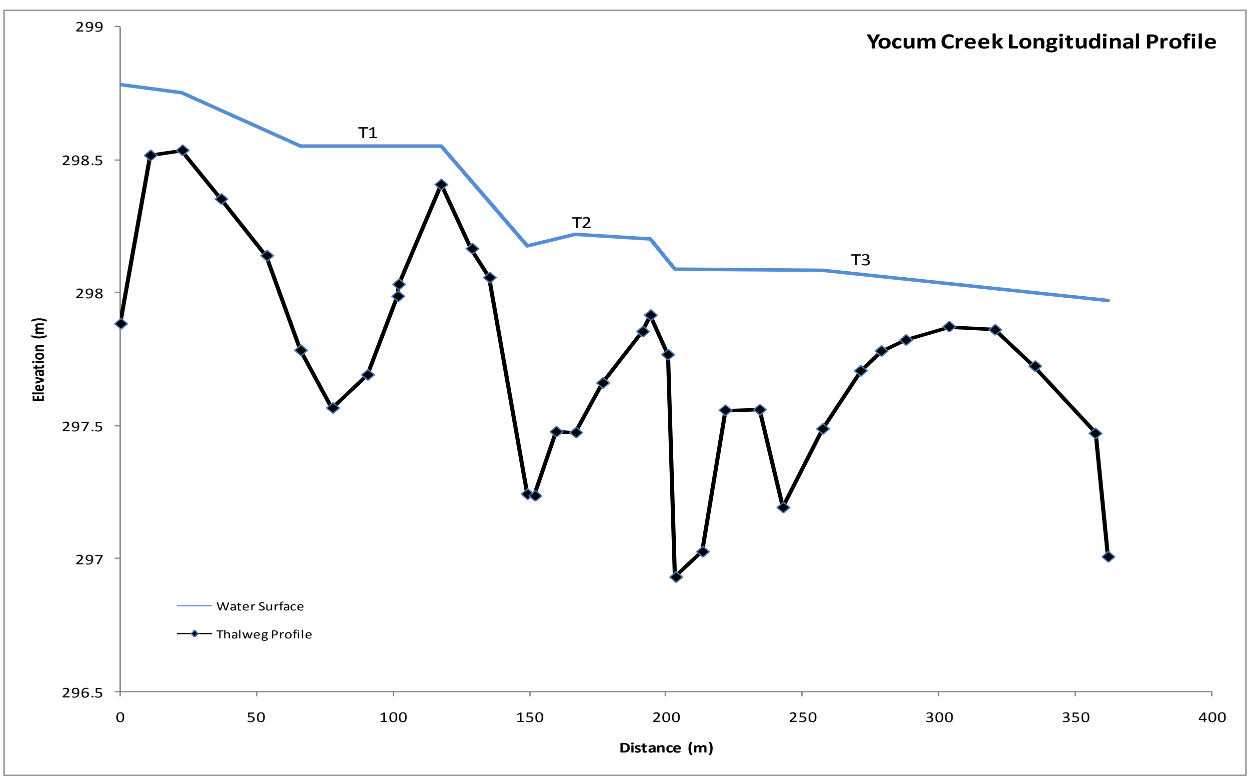

Up

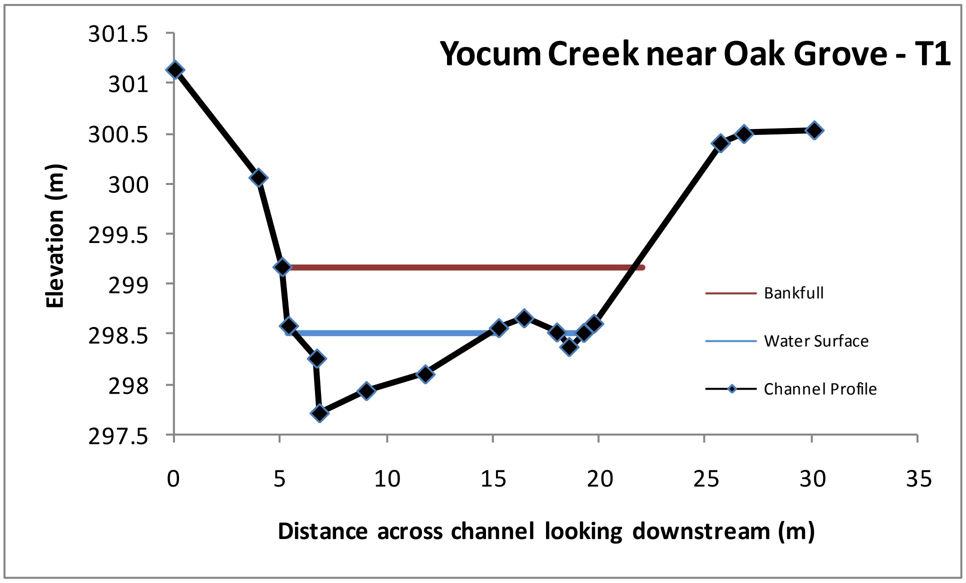

Down


Right


Left


Yocum Creek near Oak Grove
0
0.025
0.05 Miles
0
0.025
0.05
0.1 Kilometers
Drainage Area (km^2): 1023
Reach Slope: .002
Latitude: 36.45467
Longitude: -93.35872
Legend
Cross Sections
Longitudinal Survey
Sediment Sample
Biology Sampling Points
XS Pins
1
2
3


Yocum Creek Longitudinal Profile
Elevation (m)
Distance (m)
299
298.5
298
297.5
297
296.5
0
50
100
150
200
250
300
350
400
T1
T2
T3
Water Surface
Thalweg Profile

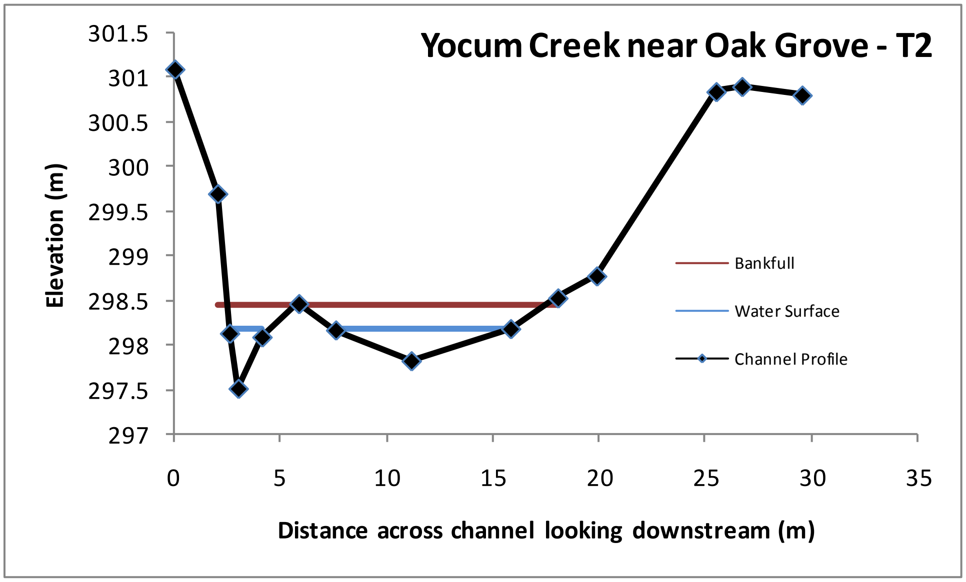

Yocum Creek near Oak Grove - T1
Elevation (m)
301.5
301
300.5
300
299.5
299
298.5
298
297.5
0
5
10
15
20
25
30
35
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Up


Down


Right


Left

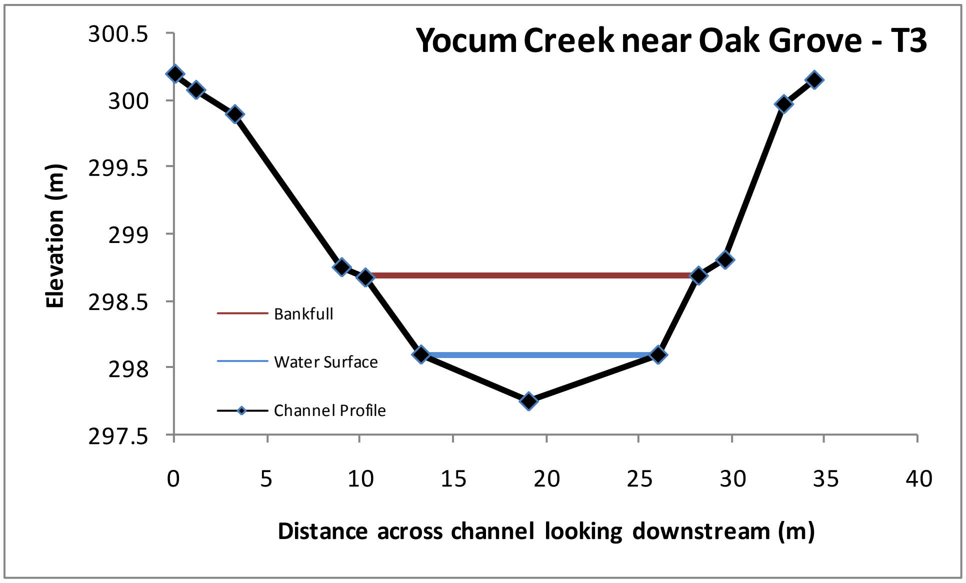

Yocum Creek near Oak Grove - T2
Elevation (m)
301.5
301
300.5
300
299.5
299
298.5
298
297.5
297
0
5
10
15
20
25
30
35
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Up


Down


Right


Left

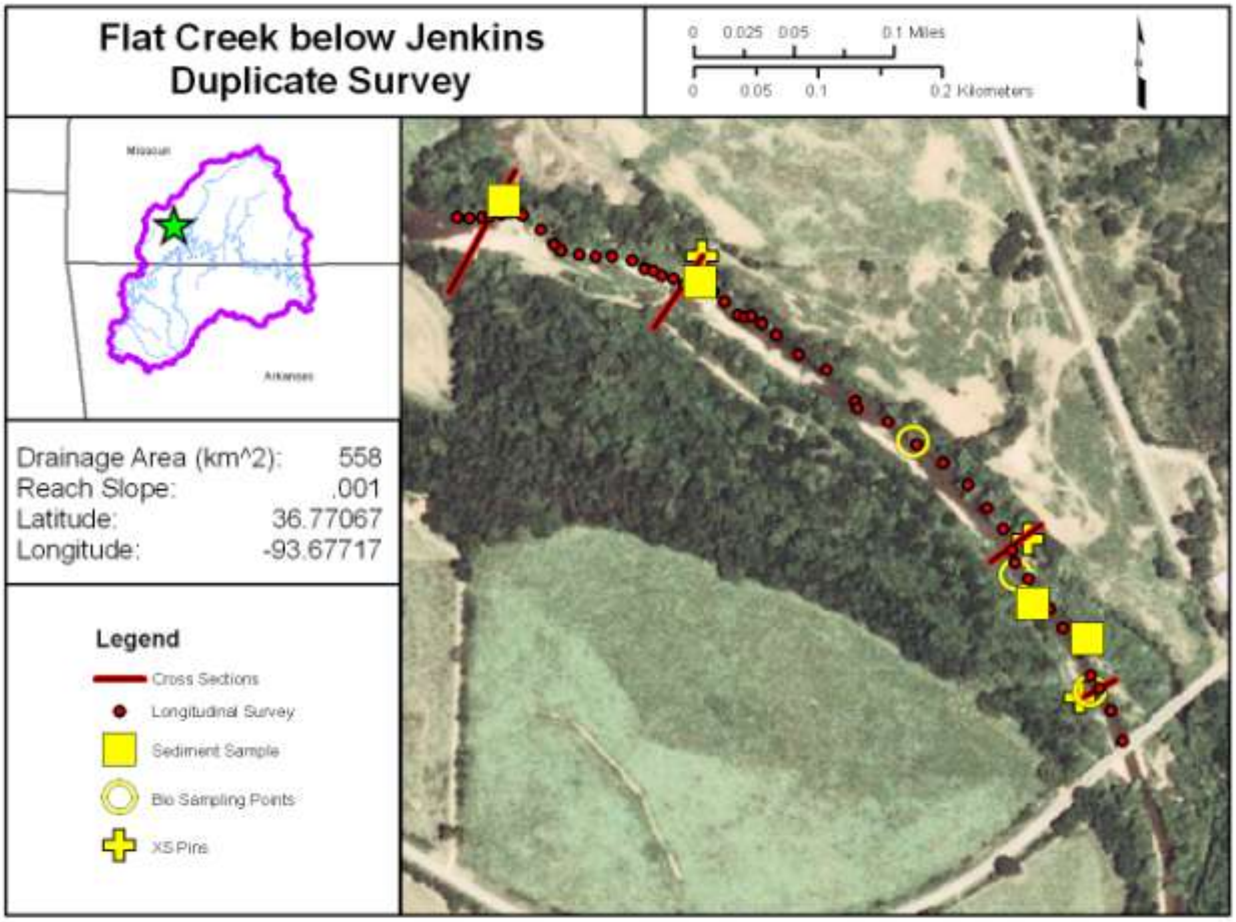

Yocum Creek near Oak Grove - T3
Elevation (m)
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile
300.5
300
299.5
299
298.5
298
297.5
0
5
10
15
20
25
30
35
40

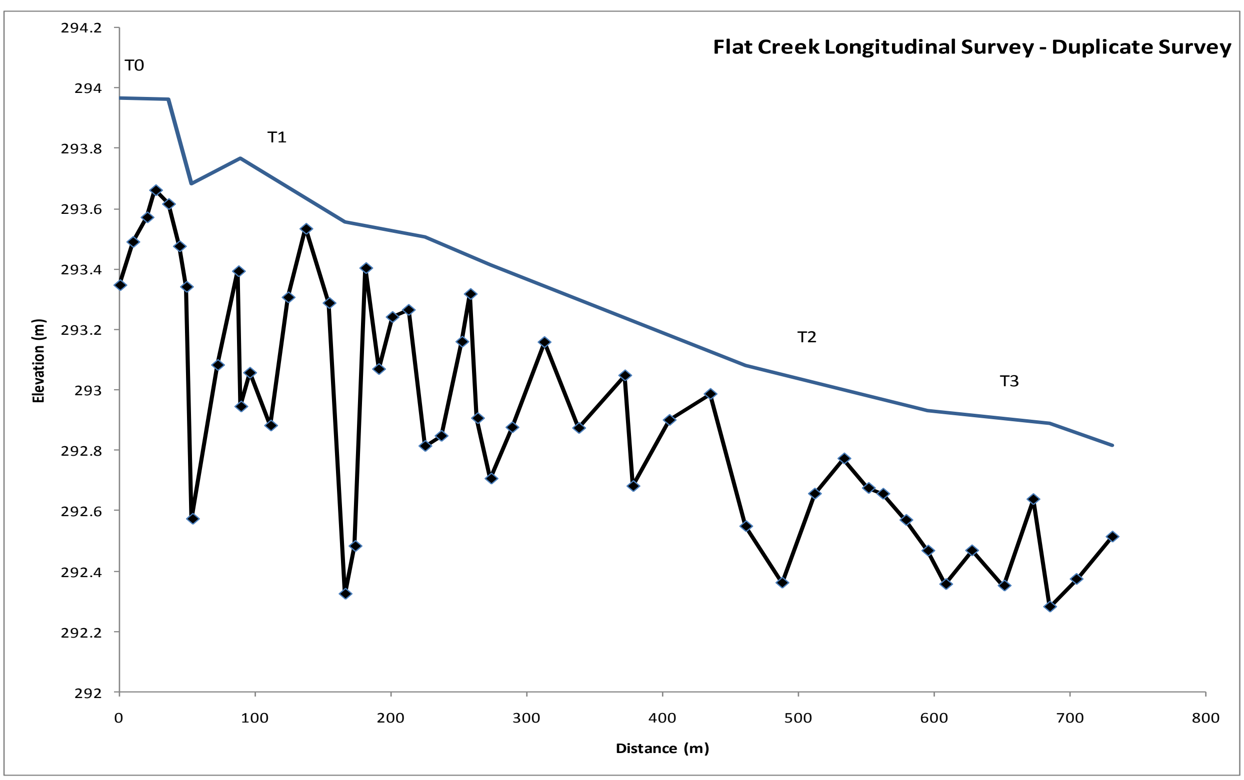

Up

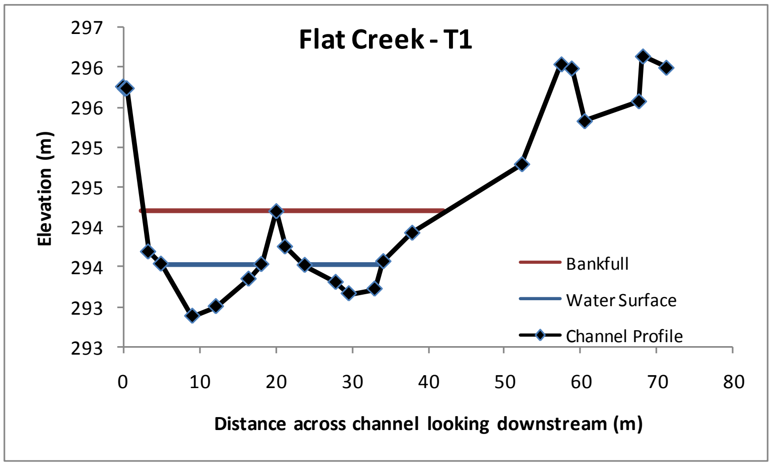

Down


Right

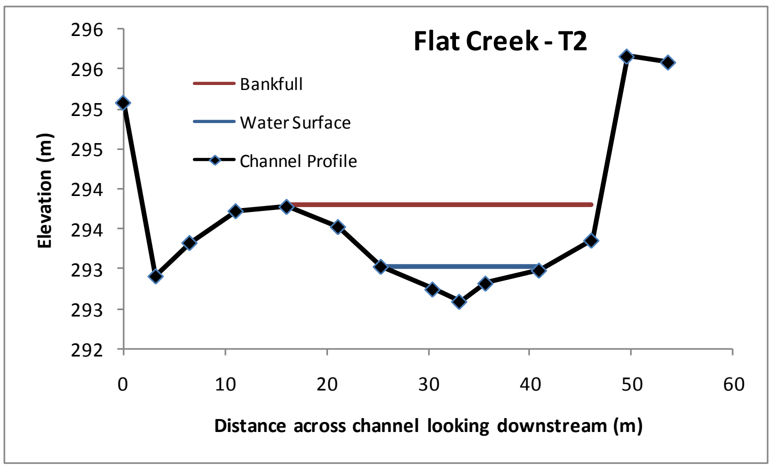

Left


Flat Creek below Jenkins
Duplicate Survey
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Drainage Area (km^2): 558
Reach Slope: .001
Latitude: 36.77067
Longitude: -93.67717
Legend
Cross Sections
Longitudinal Survey
Sediment Sample
Bio Sampling Points
XS Pins

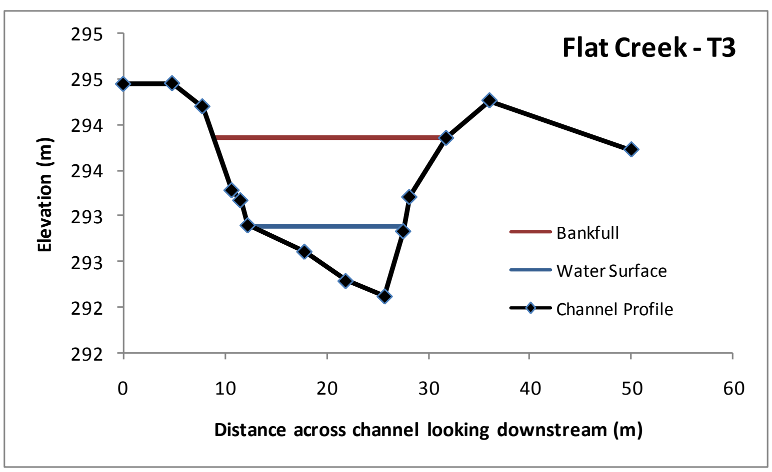

Flat Creek Longitudinal Survey - Duplicate Survey
T0
T1
T2
T3
Elevation (m)
Distance (m)
294.2
294
293.8
293.6
293.4
293.2
293
292.8
292.6
292.4
292.2
292
0
100
200
300
400
500
600
700
800



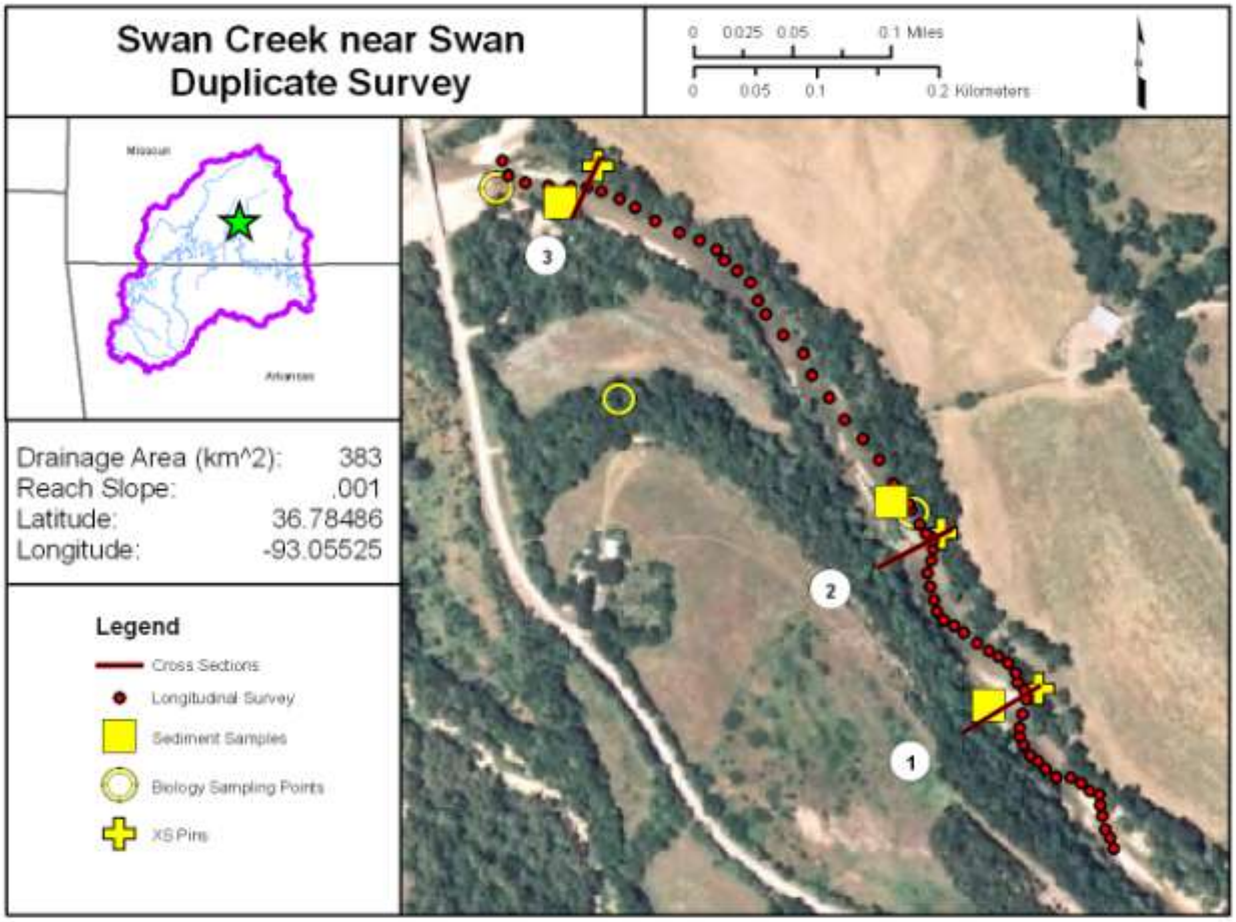
Flat Creek - T1
Elevation (m)
297
296
296
295
295
294
294
293
293
0
10
20
30
40
50
60
70
80
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile

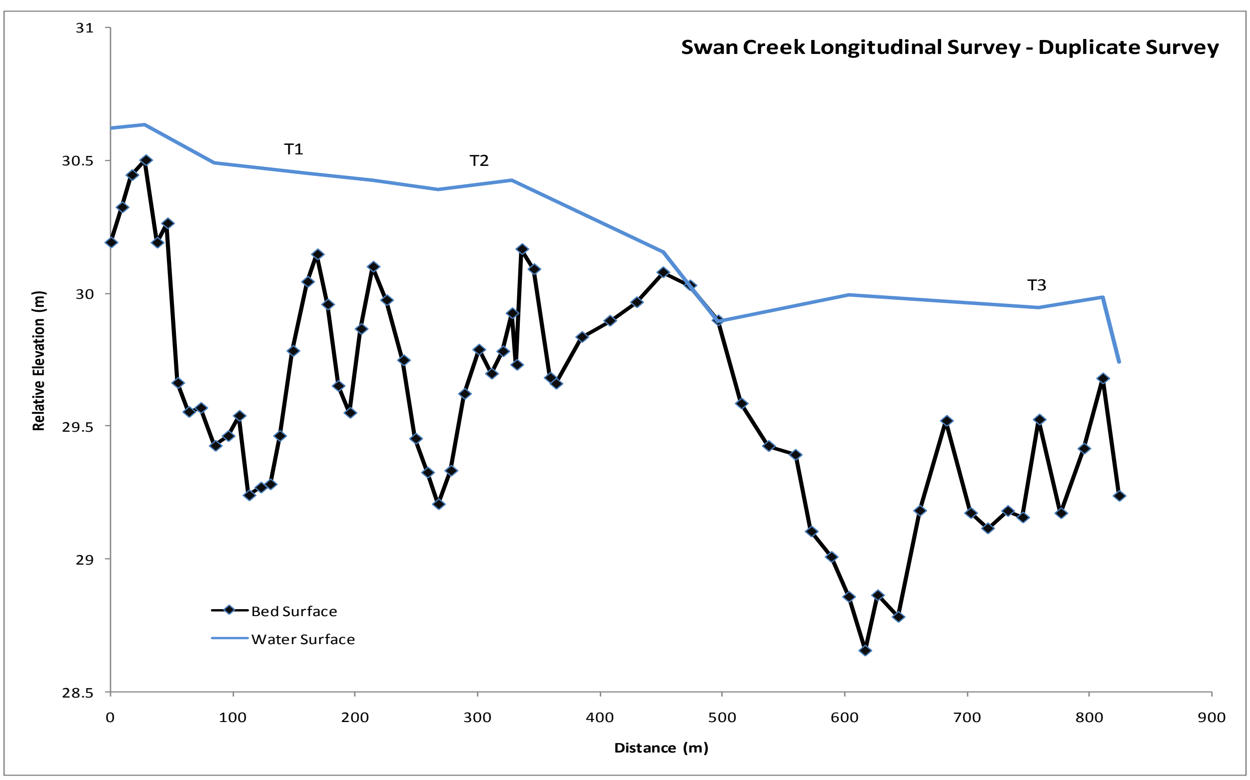


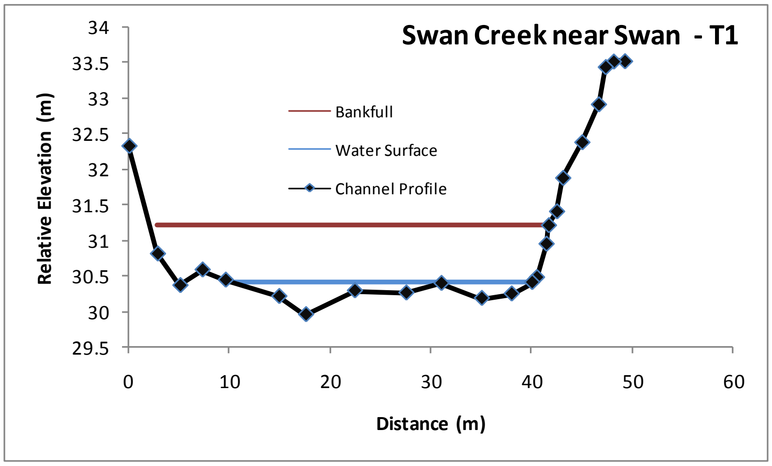
Flat Creek - T2
Elevation (m)
296
296
295
295
294
294
293
293
292
0
10
20
30
40
50
60
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile



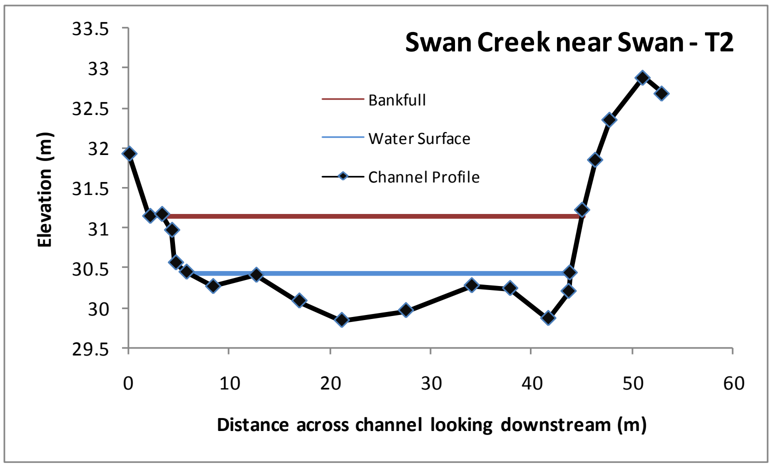
Flat Creek - T3
Elevation (m)
295
295
294
294
293
293
292
292
0
10
20
30
40
50
60
Distance across channel looking downstream (m)
Bankfull
Water Surface
Channel Profile


Swan Creek near Swan
Duplicate Survey
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Drainage Area (km^2): 383
Reach Slope: .001
Latitude: 36.78486
Longitude: -93.05525
Legend
Cross Sections
Longitudinal Survey
Sediment Samples
Biology Sampling Points
XS Pins
3
2
1

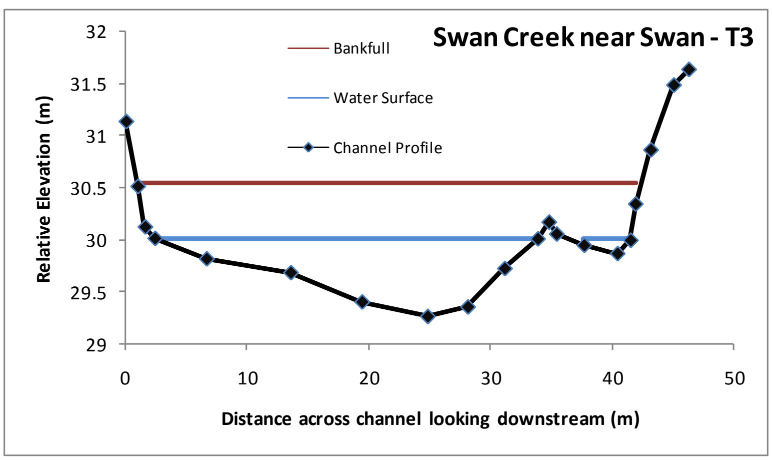

Swan Creek Longitudinal Survey - Duplicate Survey
Relative Elevation (m)
Distance (m)
T1
T2
T3
Bed Surface
Water Surface
31
30.5
30
29.5
29
28.5
0
100
200
300
400
500
600
700
800
900



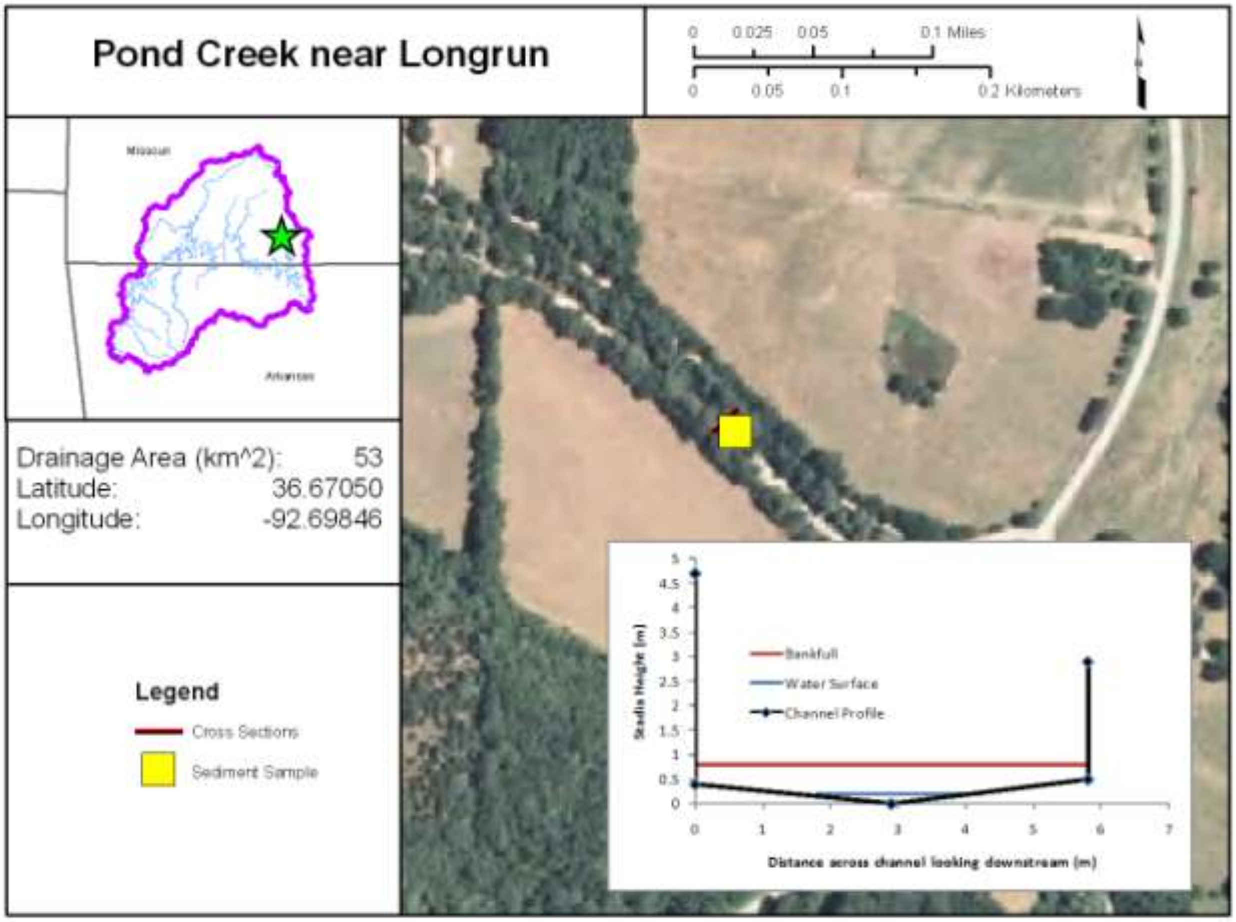
Swan Creek near Swan - T1
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
Distance (m)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
0
10
20
30
40
50
60



Swan Creek near Swan - T2
Bankfull
Water Surface
Channel Profile
Elevation (m)
Distance across channel looking downstream (m)
33.5
33
32.5
32
31.5
31
30.5
30
29.5
0
10
20
30
40
50
60



Swan Creek near Swan - T3
Bankfull
Water Surface
Channel Profile
Relative Elevation (m)
Distance across channel looking downstream (m)
32
31.5
31
30.5
30
29.5
29
0
10
20
30
40
50

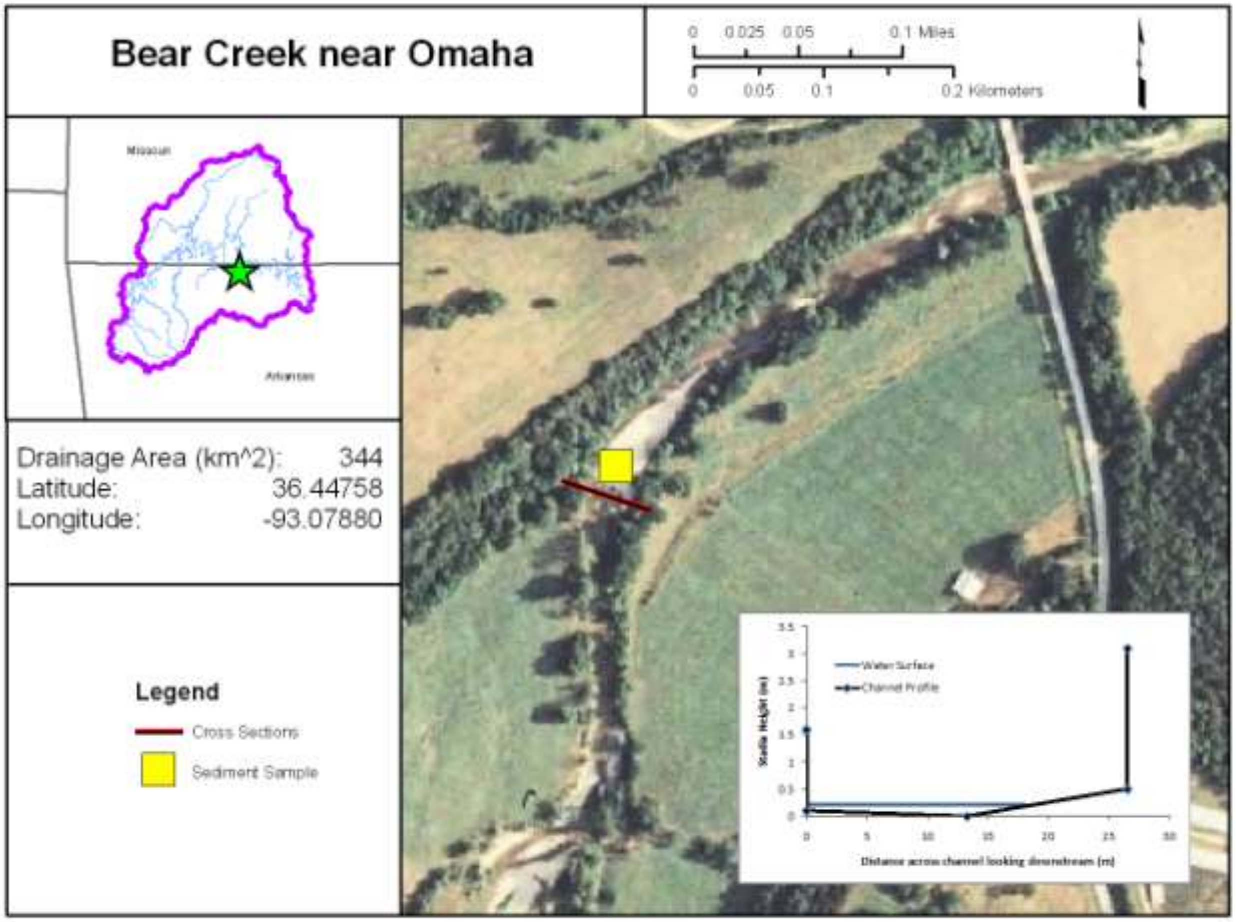

Pond Creek near Longrun
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 53
Latitude: 36.67050
Longitude: -92.69846
Legend
Cross Sections
Sediment Sample
Bankfull
Water Surface
Channel Profile
Stadia Height (m)
Distance across channel looking downstream (m)


Up


Down


Right


Left

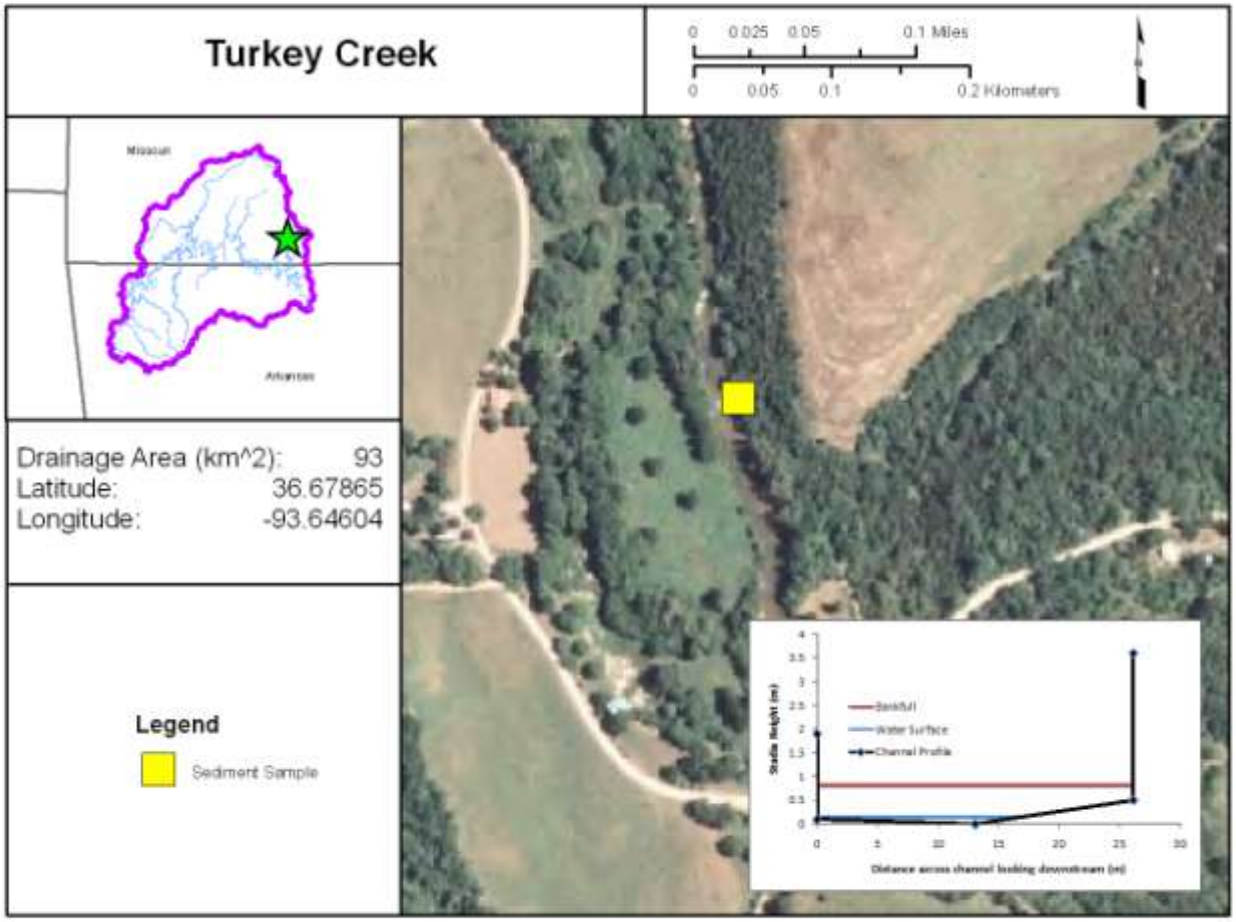


Up

Down

Right

Left

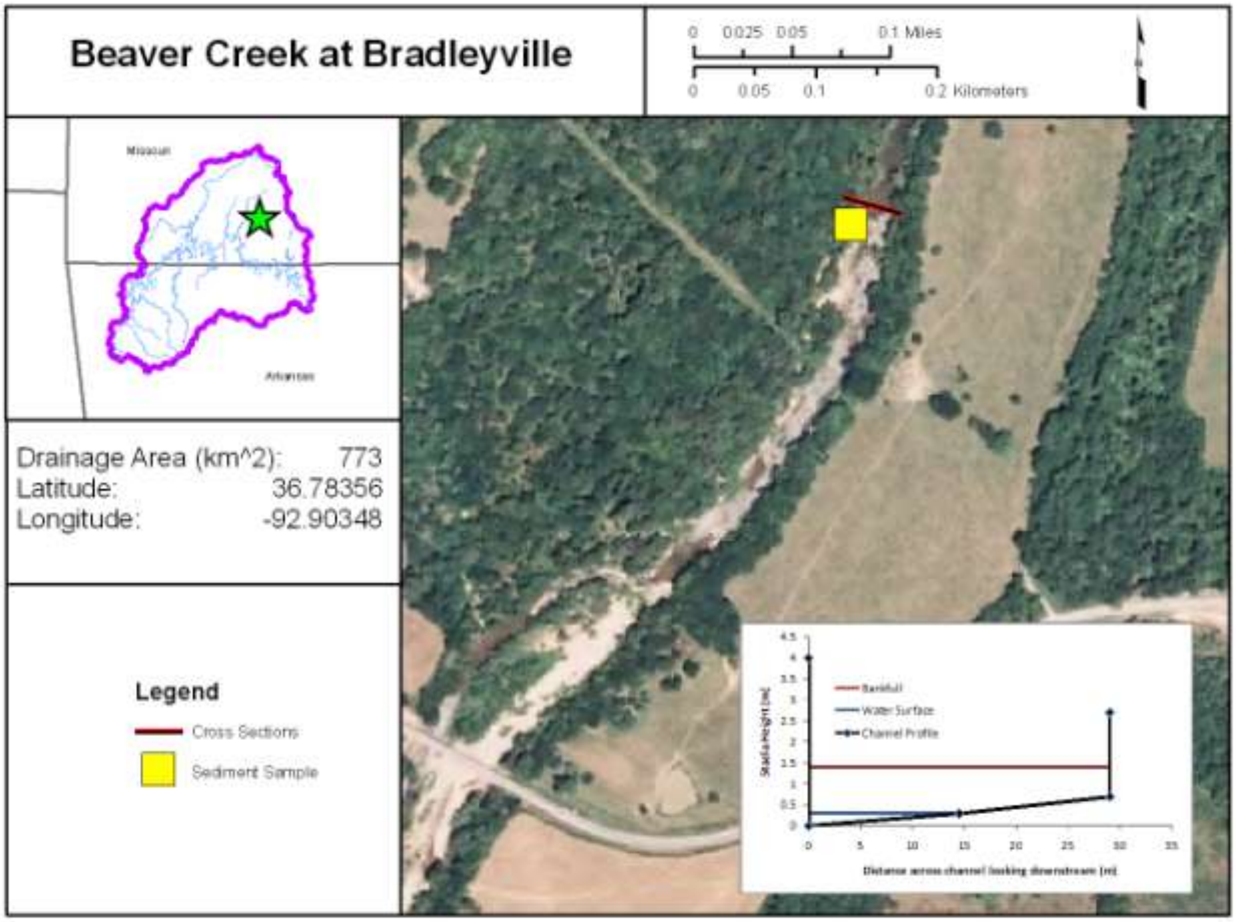


Up

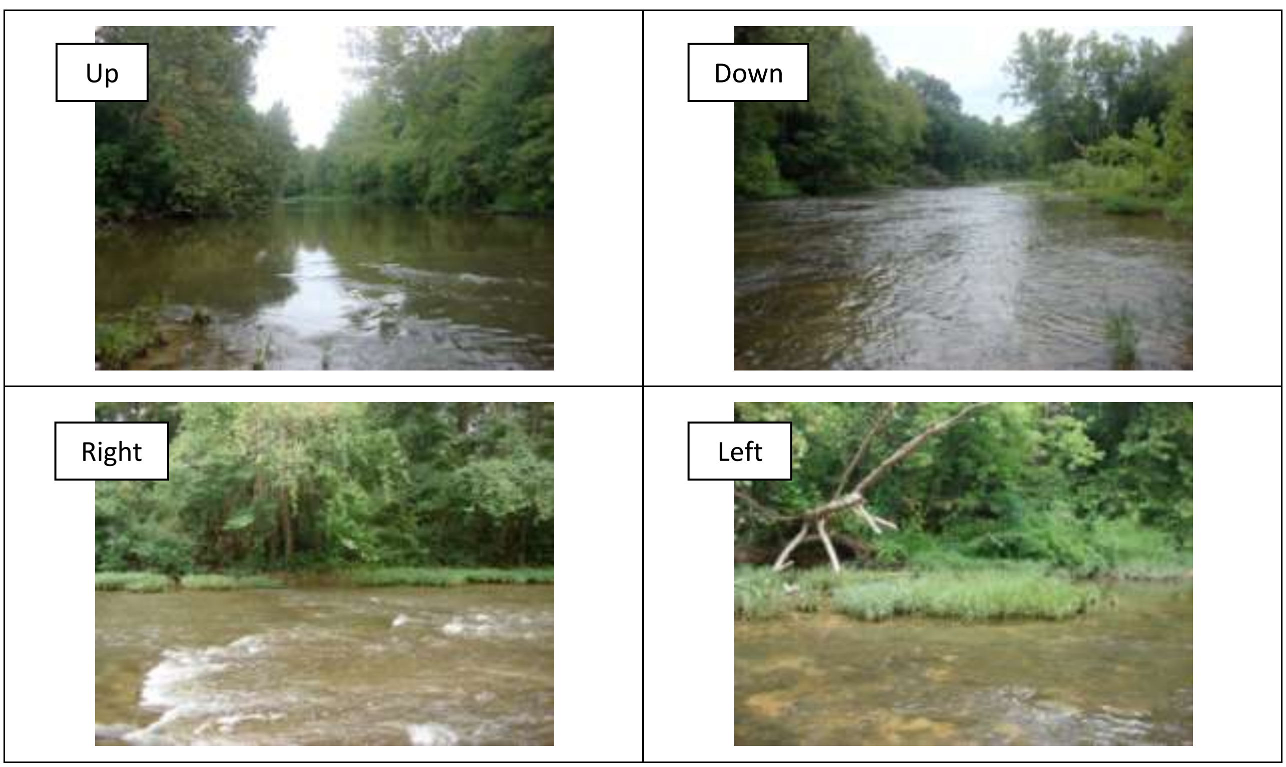
Down

Right

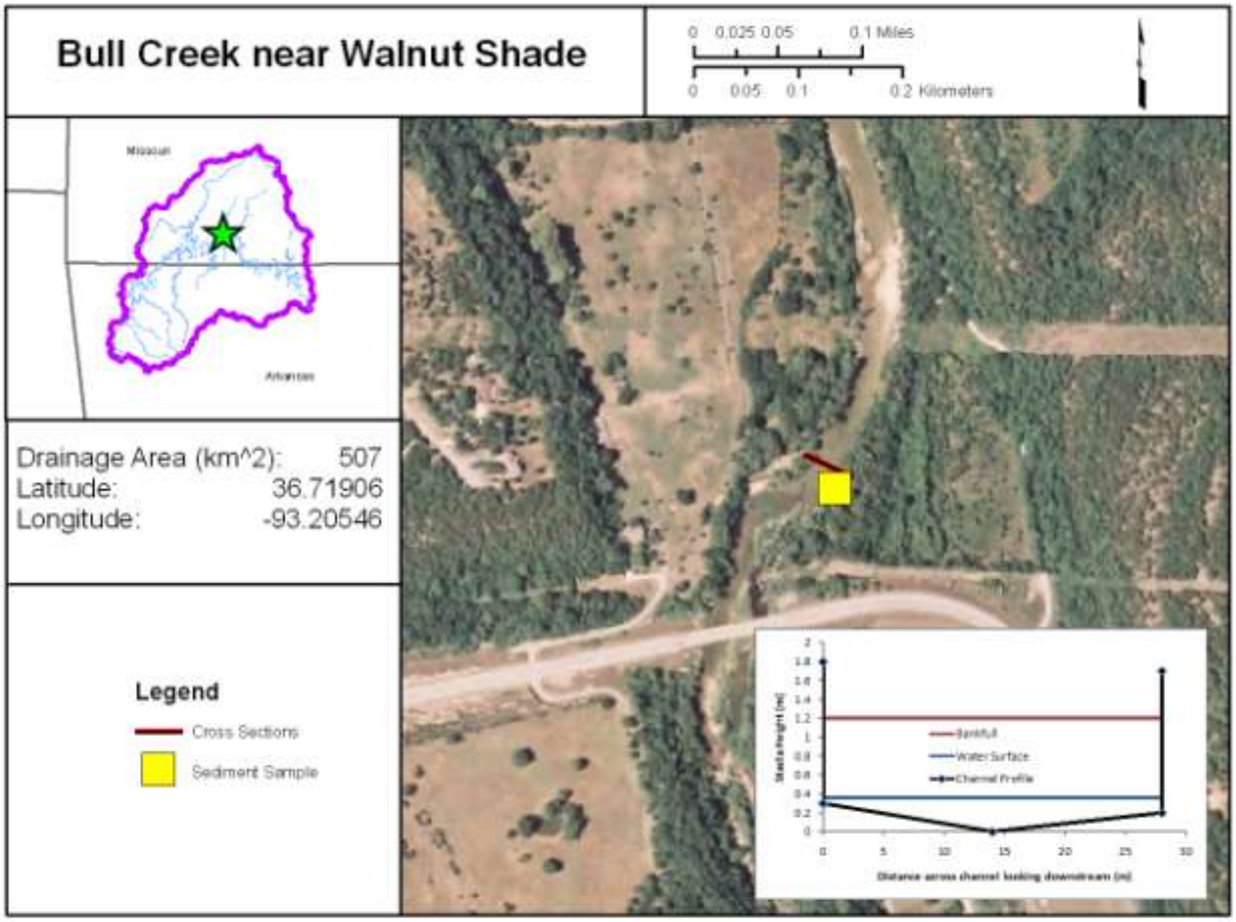
Left



Beaver Creek at Bradleyville
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 773
Latitude: 36.78356
Longitude: -92.90348
Legend
Cross Sections
Sediment Sample
Bankfull
Water Surface
Channel Profile
Stadia Height (m)
Distance across channel looking downstream (m)



Up
Down
Right
Left



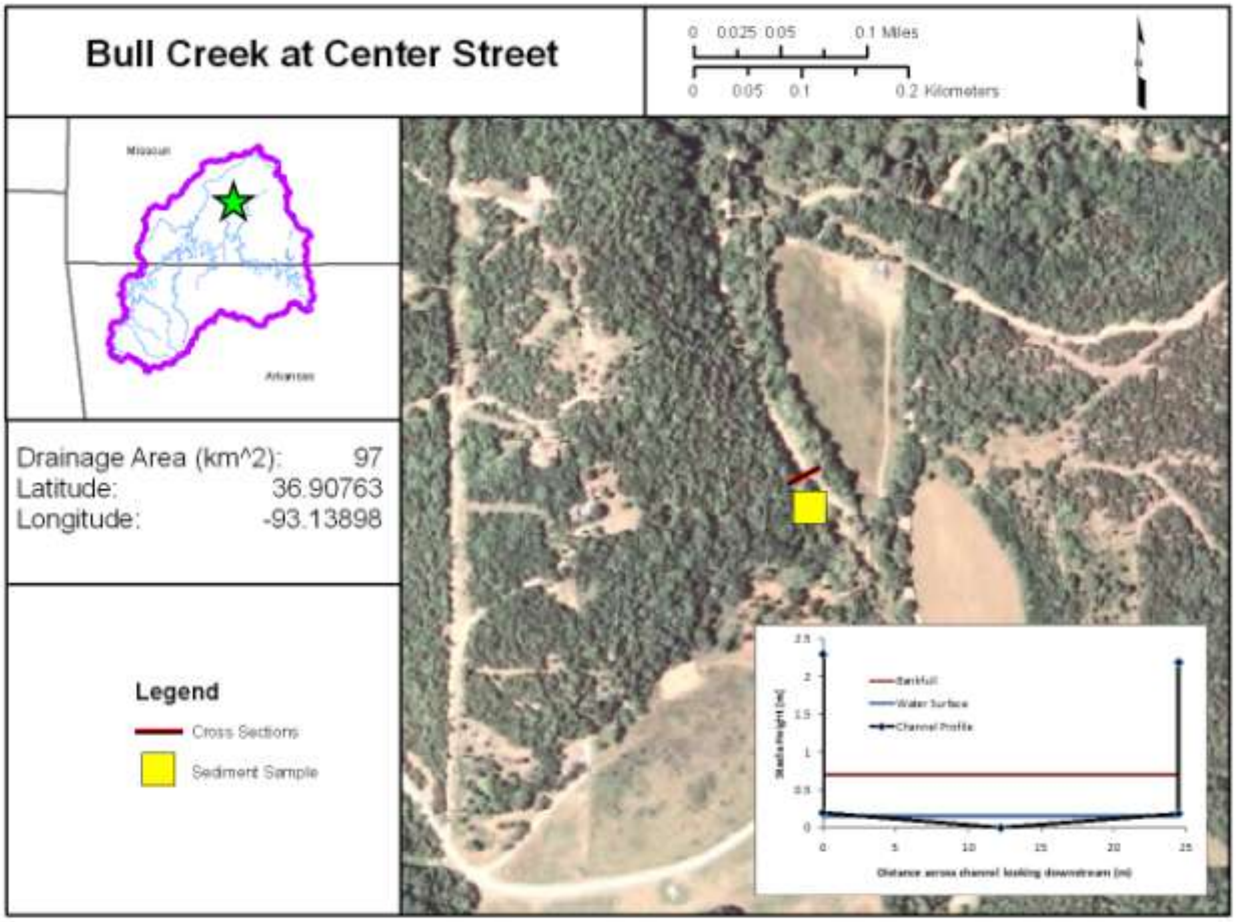
Bull Creek near Walnut Shade
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 507
Latitude: 36.71906
Longitude: -93.20546
Legend
Cross Sections
Sediment Sample
Water Surface
Channel Profile
Distance across channel looking downstream (m)

Up

Down

Right

Left

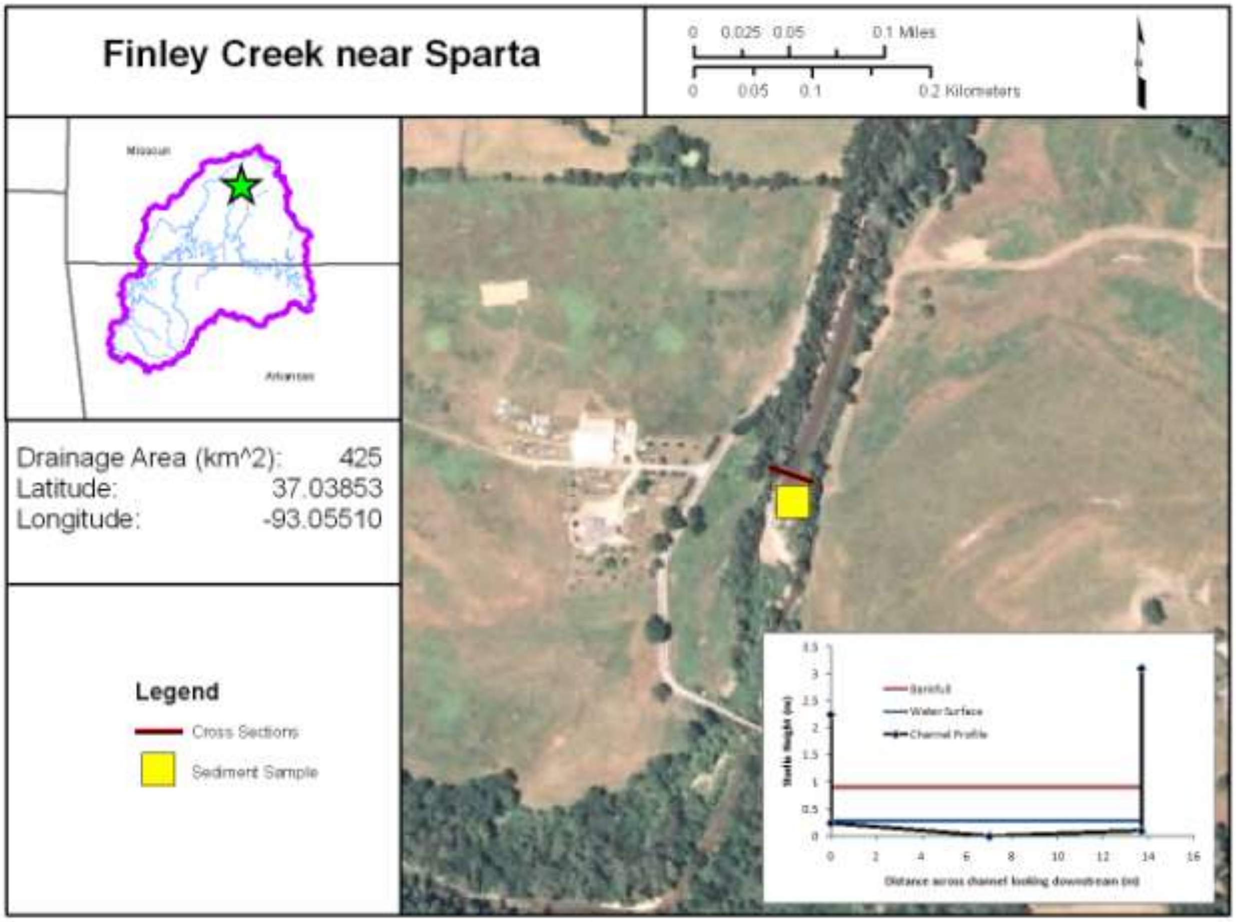


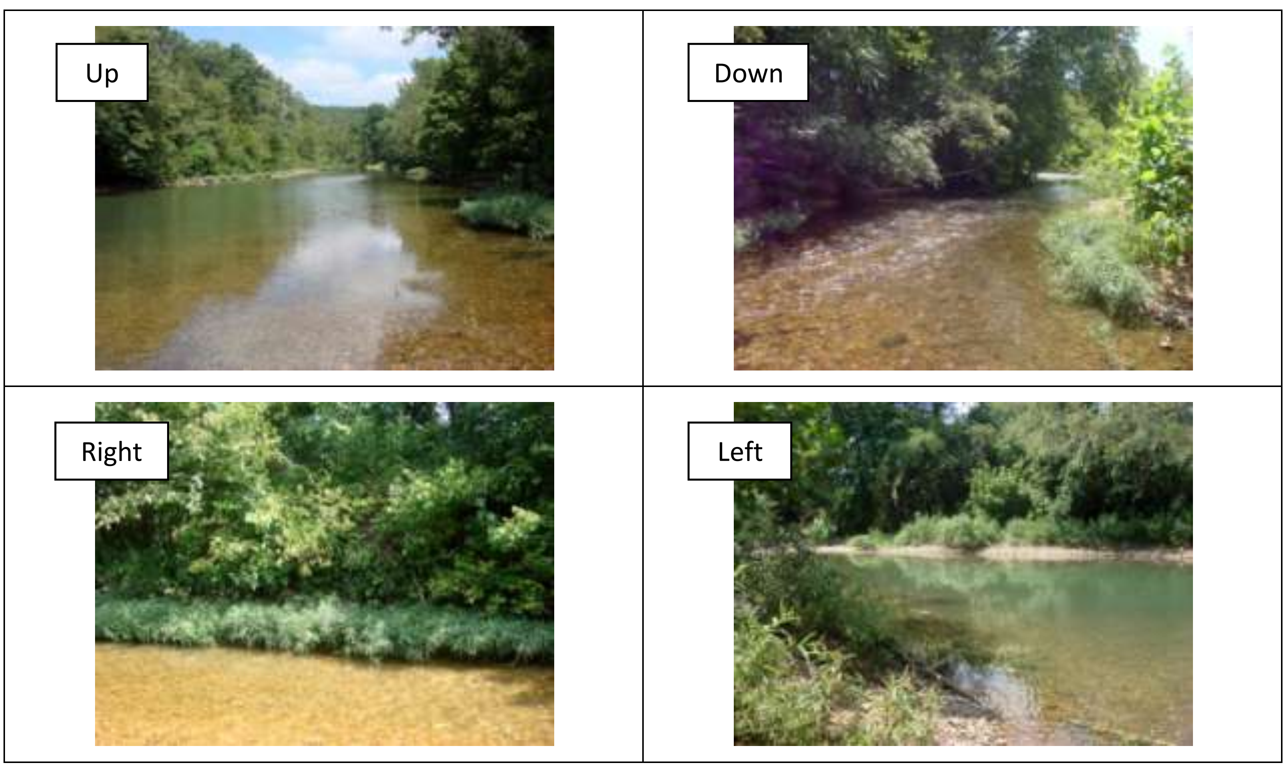
Up

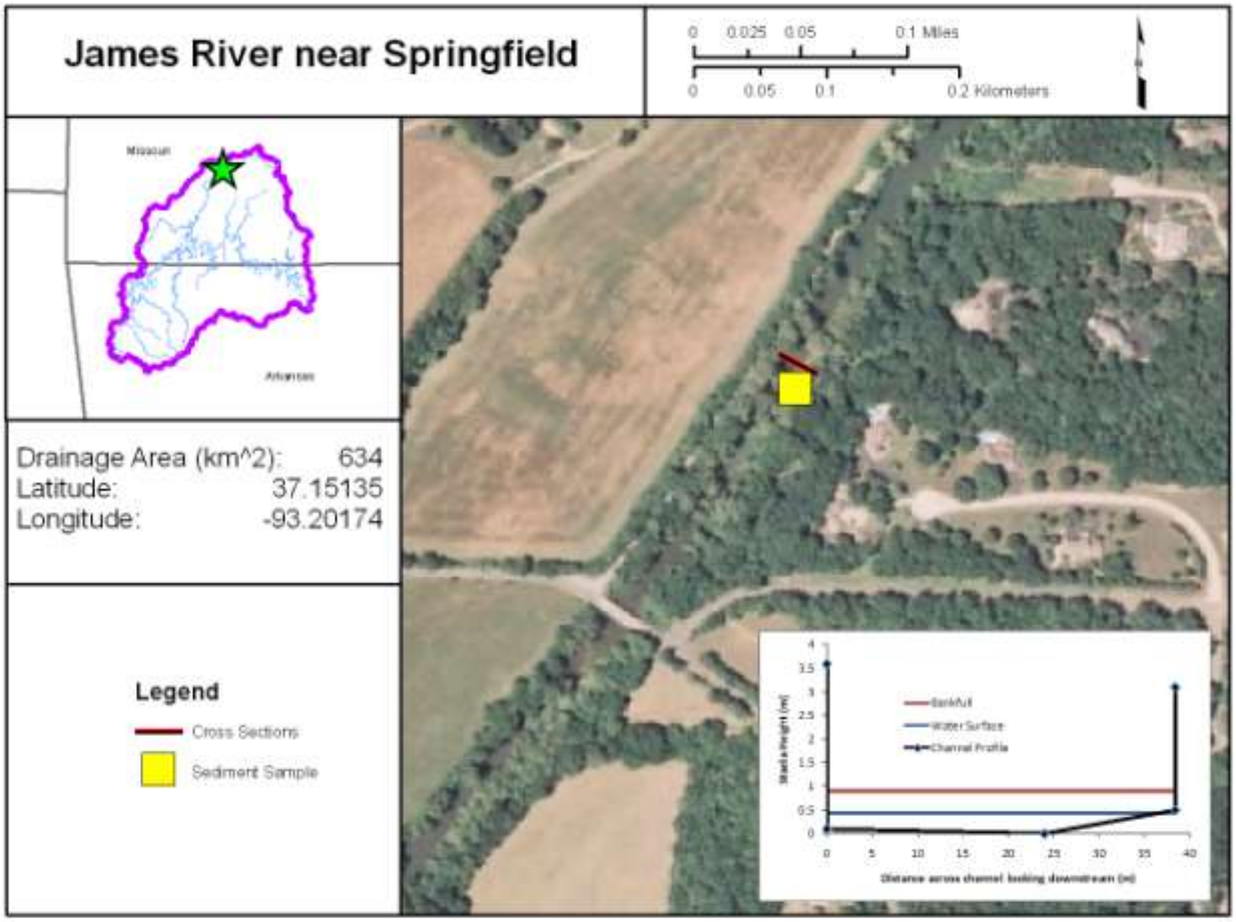
Down

Right

Left


Finley Creek near Sparta
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 425
Latitude: 37.03853
Longitude: -93.05510
Legend
Cross Sections
Sediment Sample
Bankfull
Water Surface
Channel Profile
0 0.5 1 1.5 2 2.5 3 3.5
0 2 4 6 8 10 12 14 16
Distance across channel looking downstream (m)


Up
Down
Right
Left

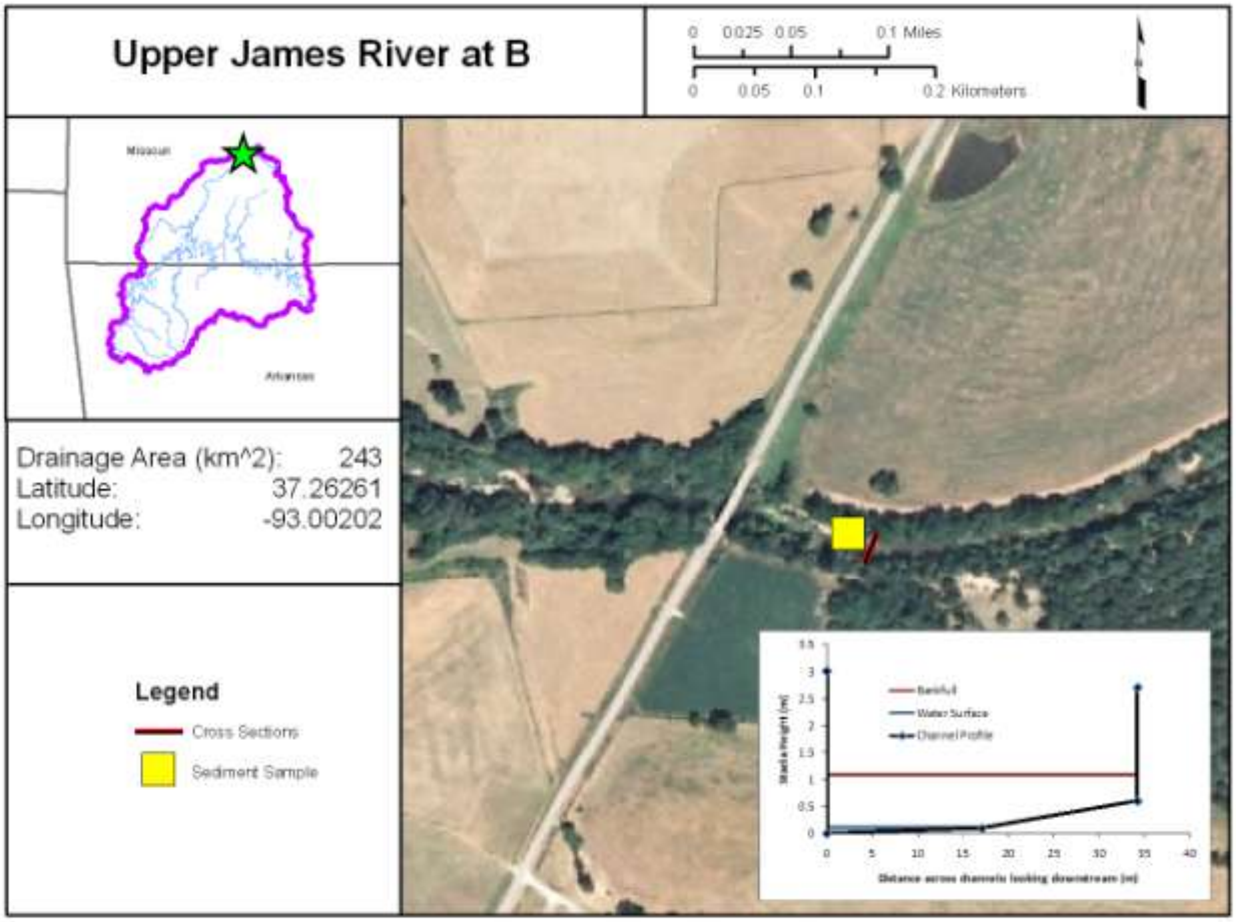


Up

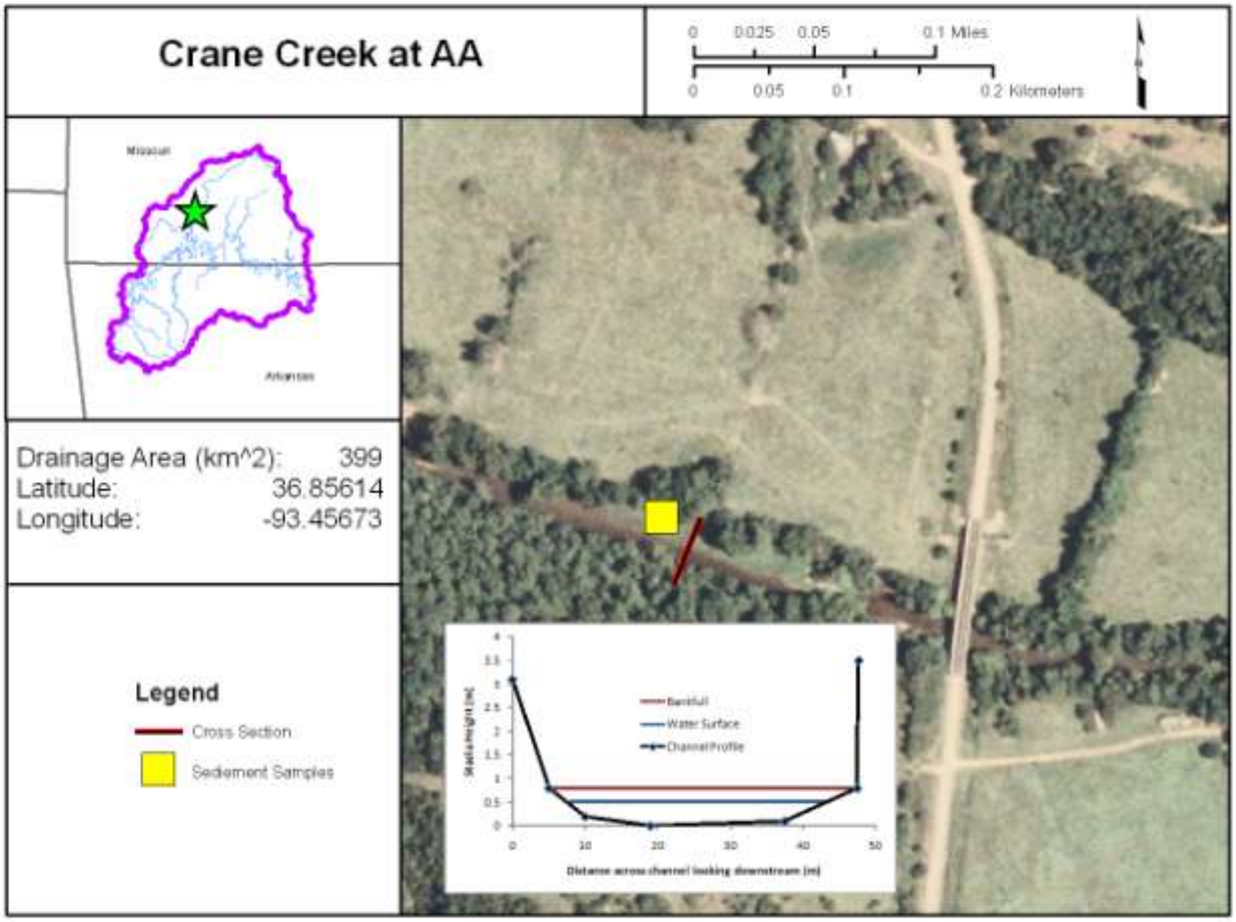
Down

Right

Left



Up 	Down 
Right 	Left 



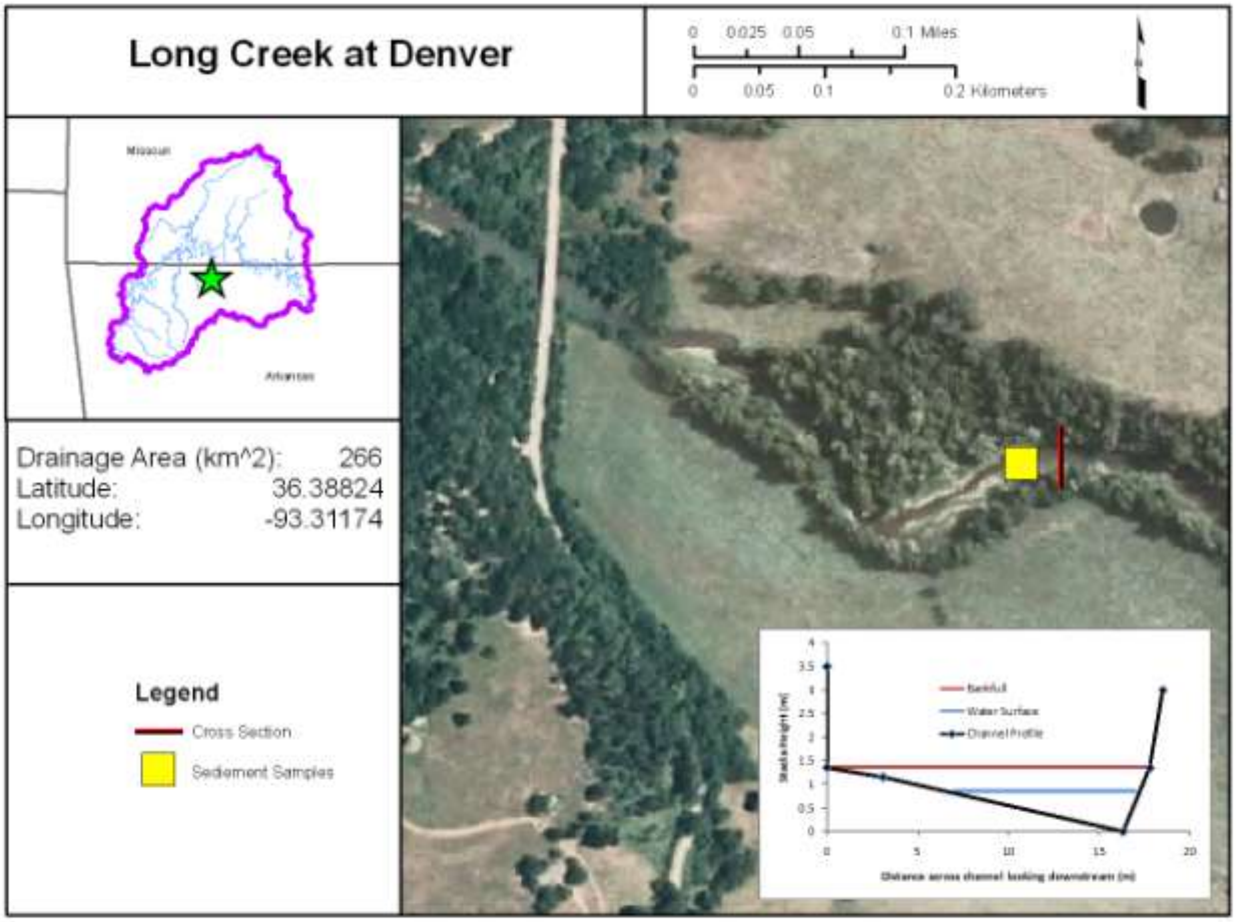
Crane Creek at AA
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 399
Latitude: 36.85614
Longitude: -93.45673
Legend
Cross Section
Sediment Samples
Bankfull
Water Surface
Channel Profile
Distance across channel looking downstream (m)


Up


Down


Right


Left

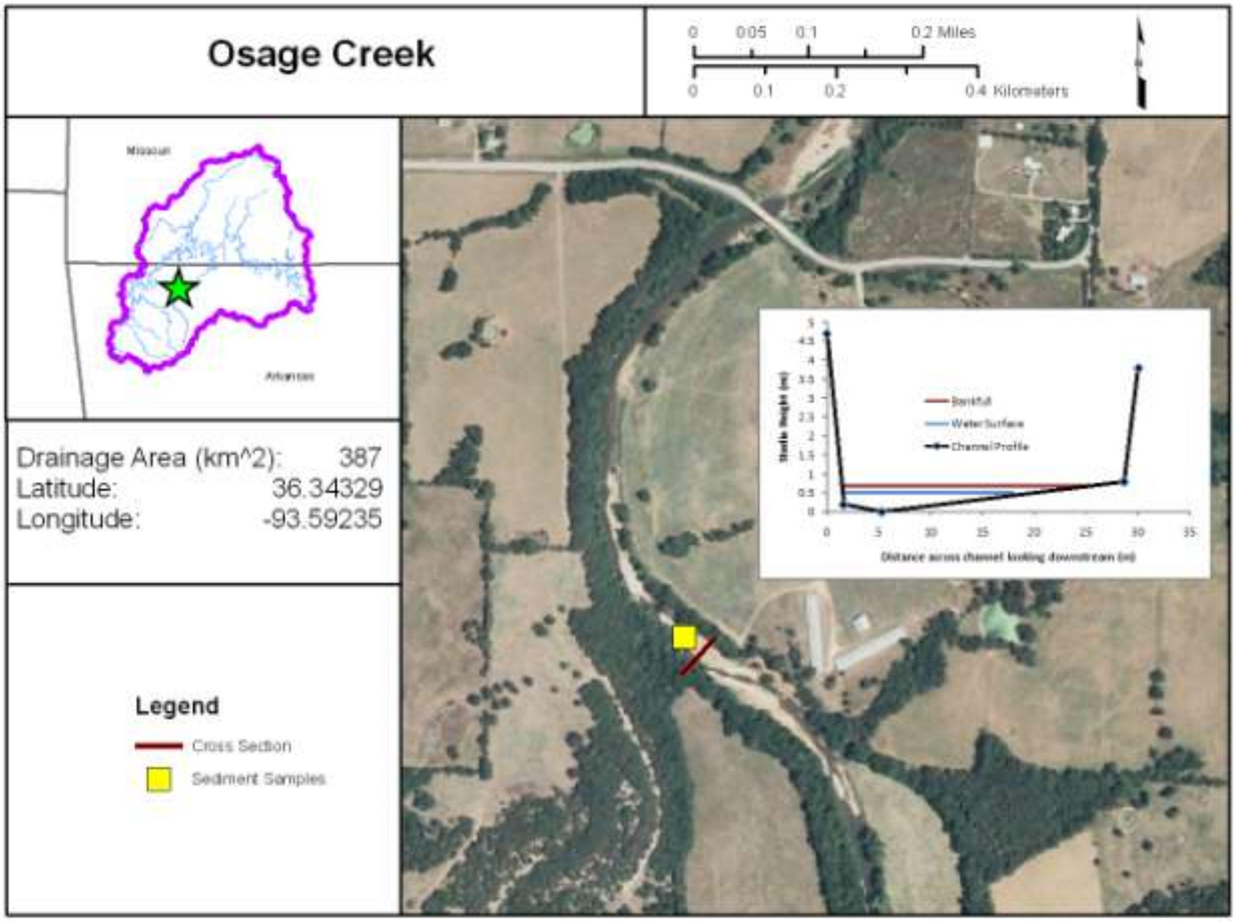


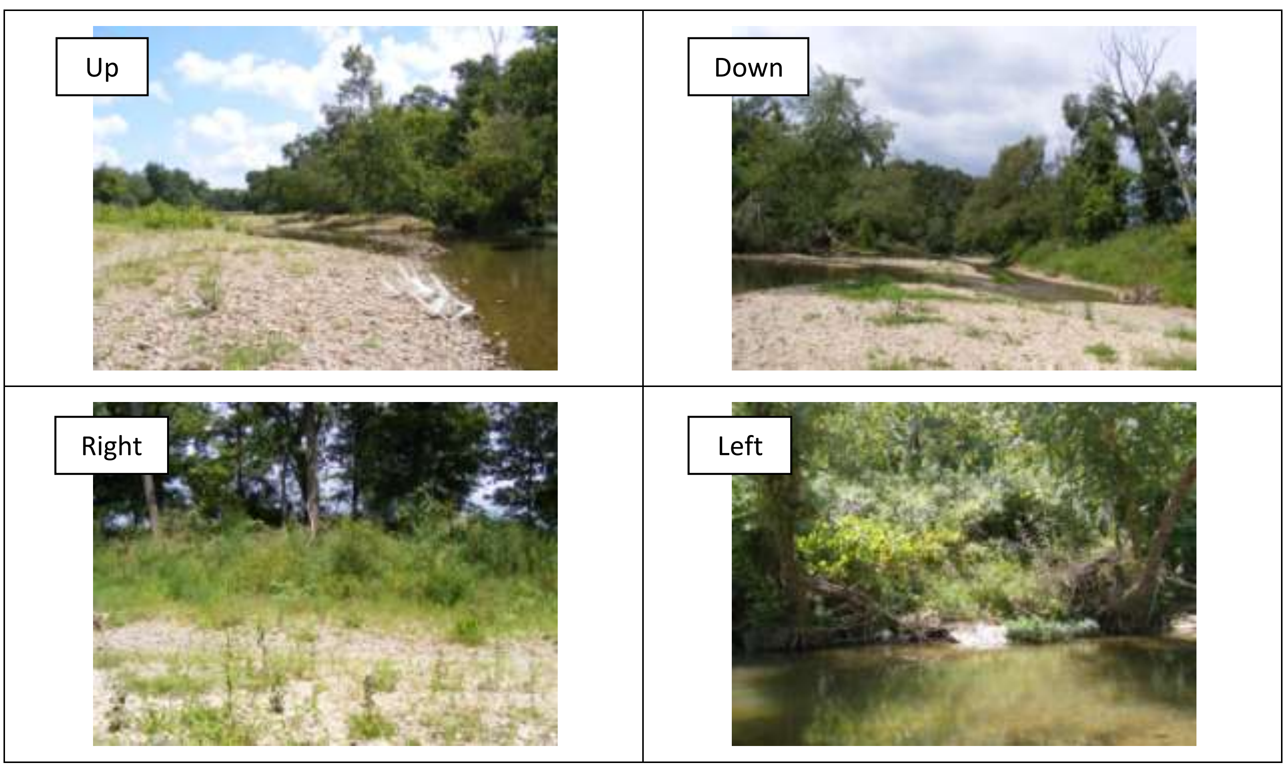

Up

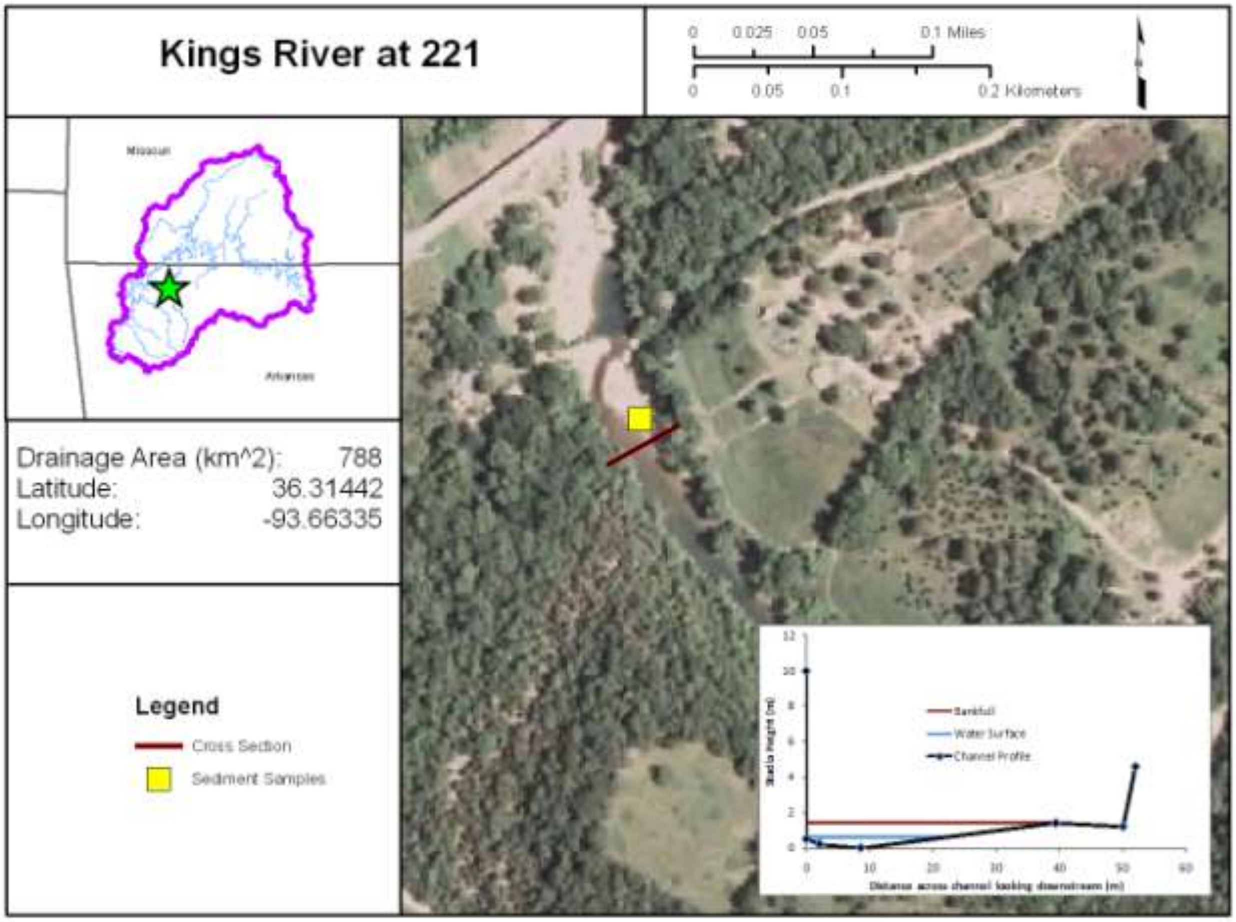

Down


Right

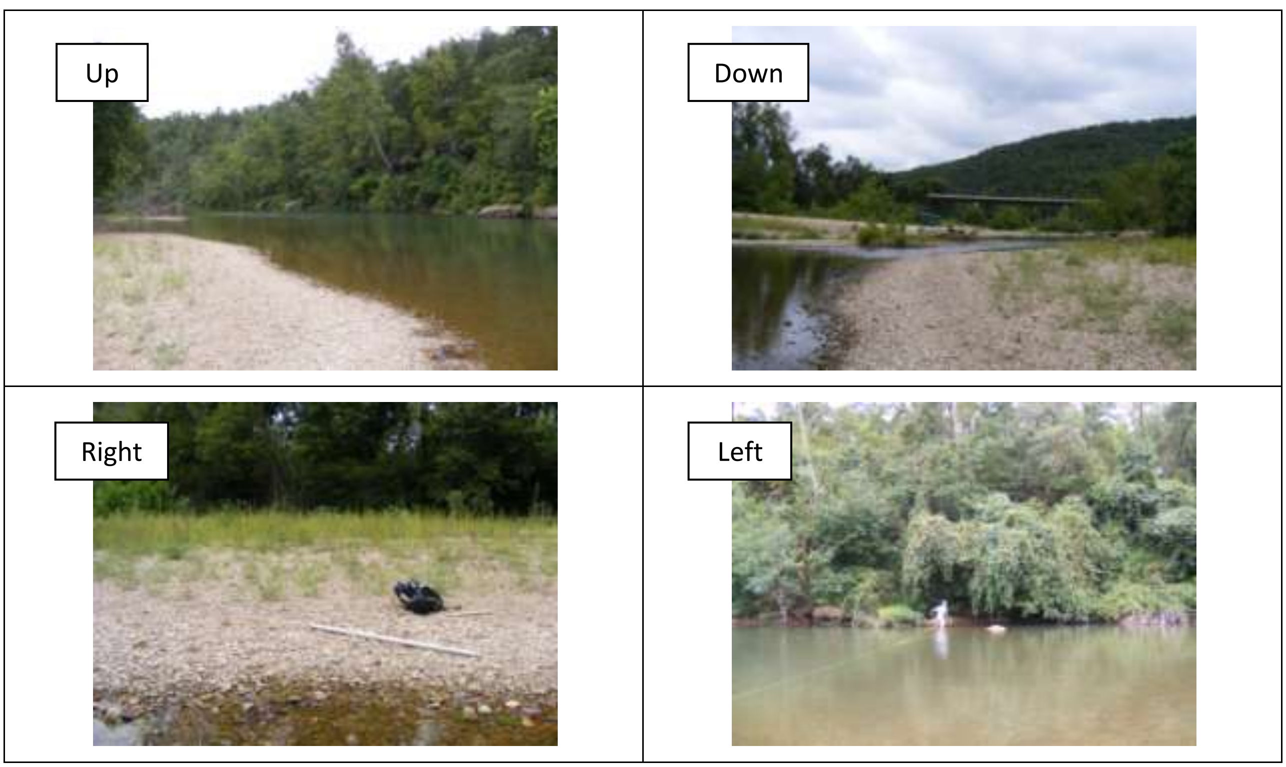

Left


Osage Creek
0
0.05
0.1
0.2 Miles
0
0.1
0.2
0.4 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 387
Latitude: 36.34329
Longitude: -93.59235
Legend
Cross Section
Sediment Samples
Bankfull
Water Surface
Channel Profile
Distance across channel looking downstream (m)

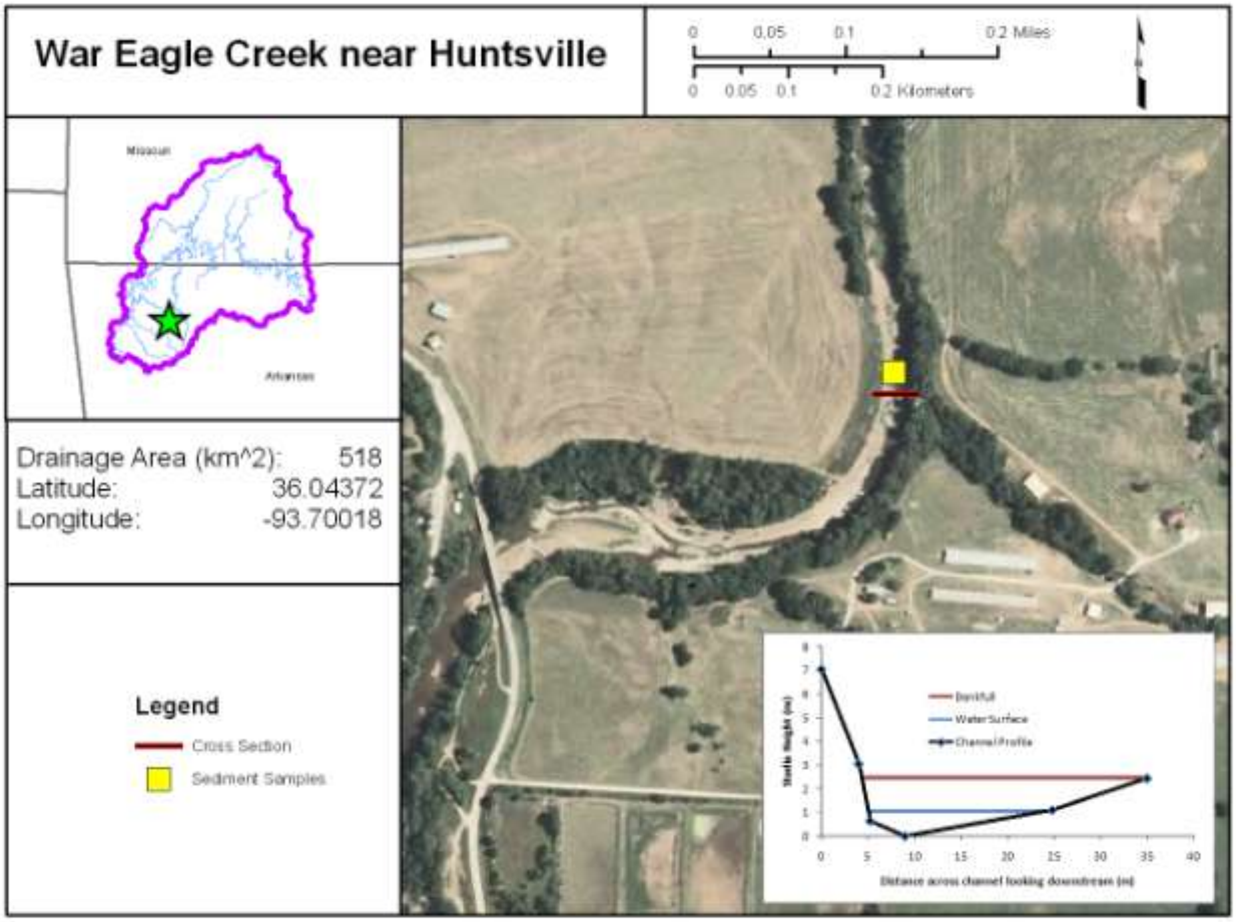

Up
Down
Right
Left



Kings River at 221
0 0.025 0.05 0.1 Miles
0 0.05 0.1 0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 788
Latitude: 36.31442
Longitude: -93.66335
Legend
Cross Section
Sediment Samples
Bankfull
Water Surface
Channel Profile
Stadia Height (m)
Distance across channel looking downstream (m)



Up
Down
Right
Left

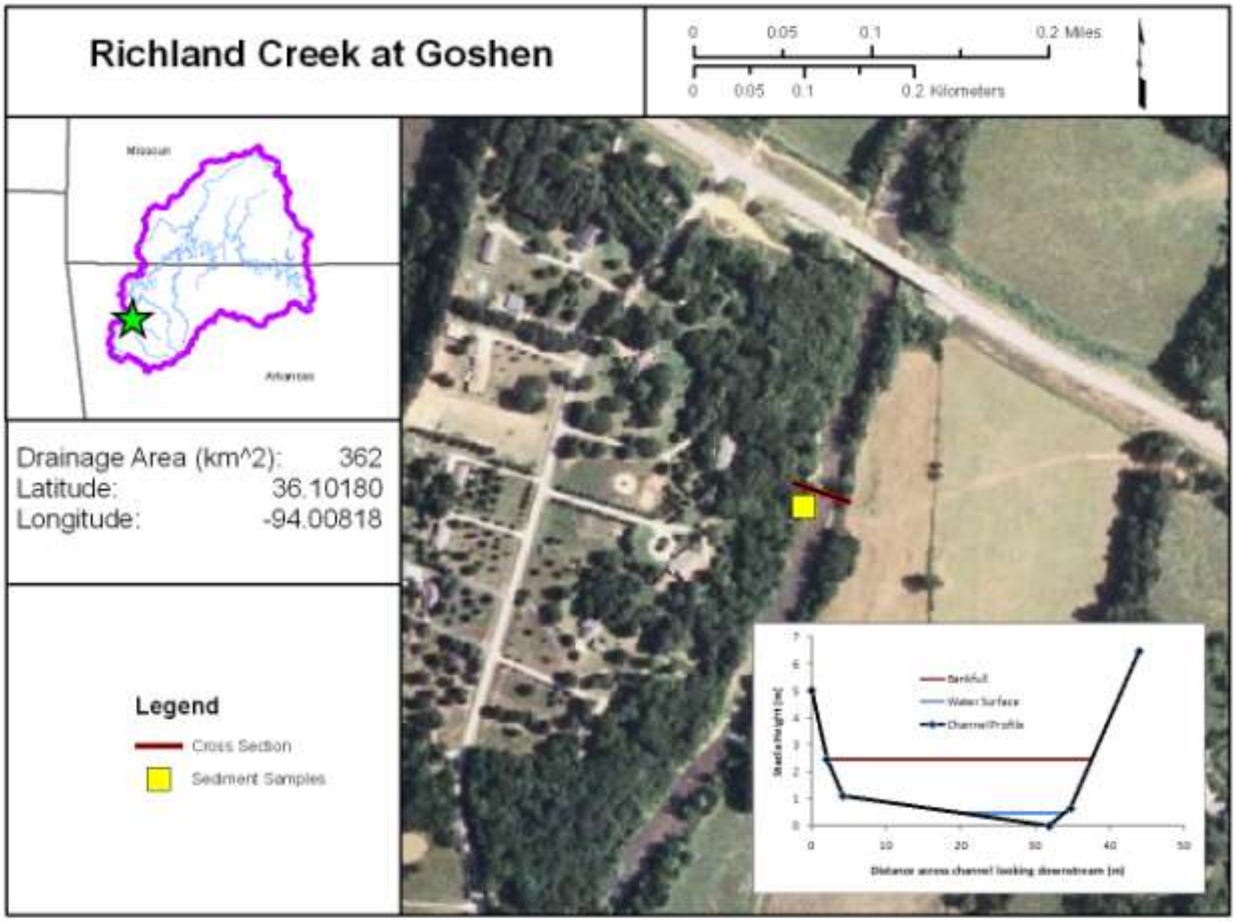


Up

Down

Right

Left

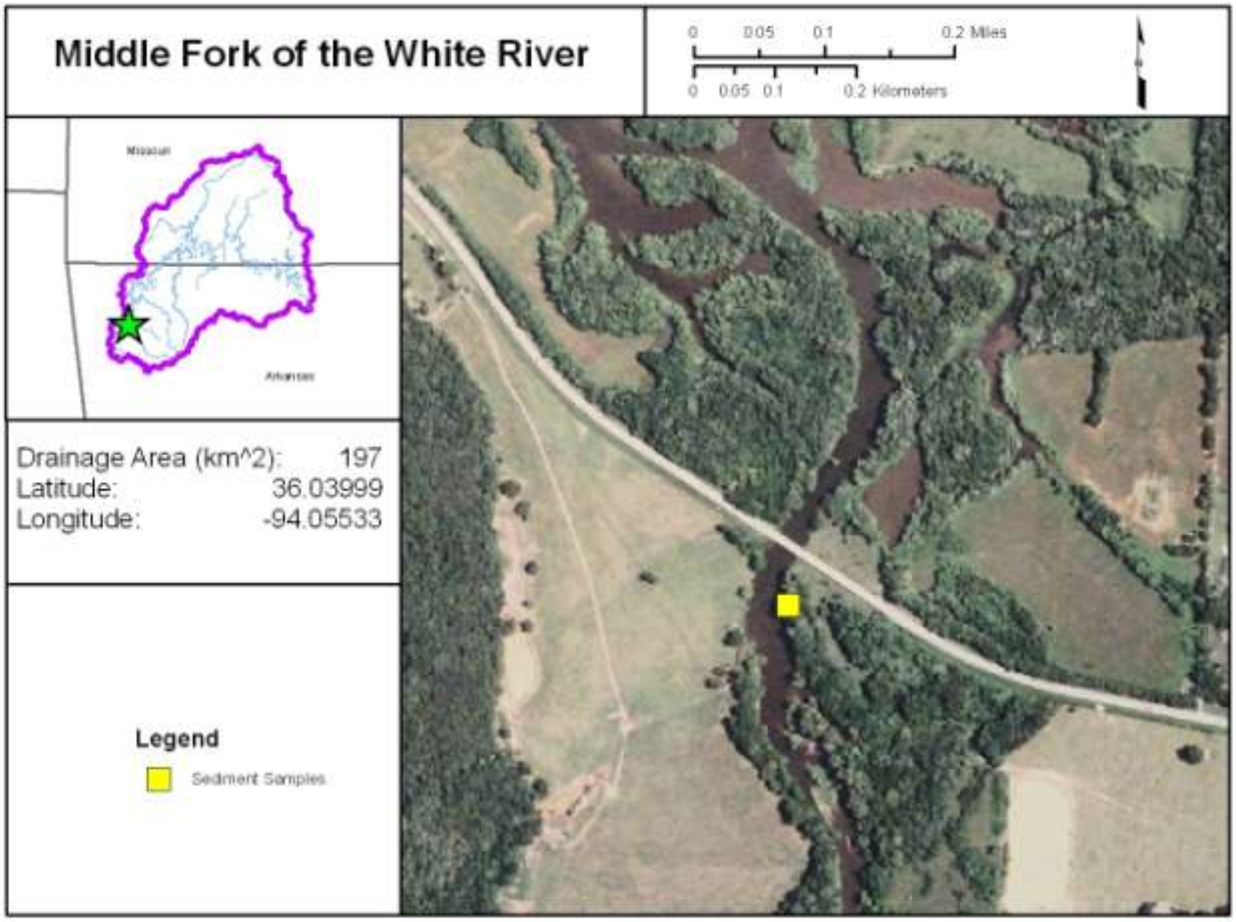

Richland Creek at Goshen
0
0.05
0.1
0.2 Miles
0
0.05
0.1
0.2 Kilometers
Missouri
Arkansas
Drainage Area (km^2): 362
Latitude: 36.10180
Longitude: -94.00818
Legend
Cross Section
Sediment Samples
Bankfull
Water Surface
Channel Profile
Distance across channel looking downstream (m)

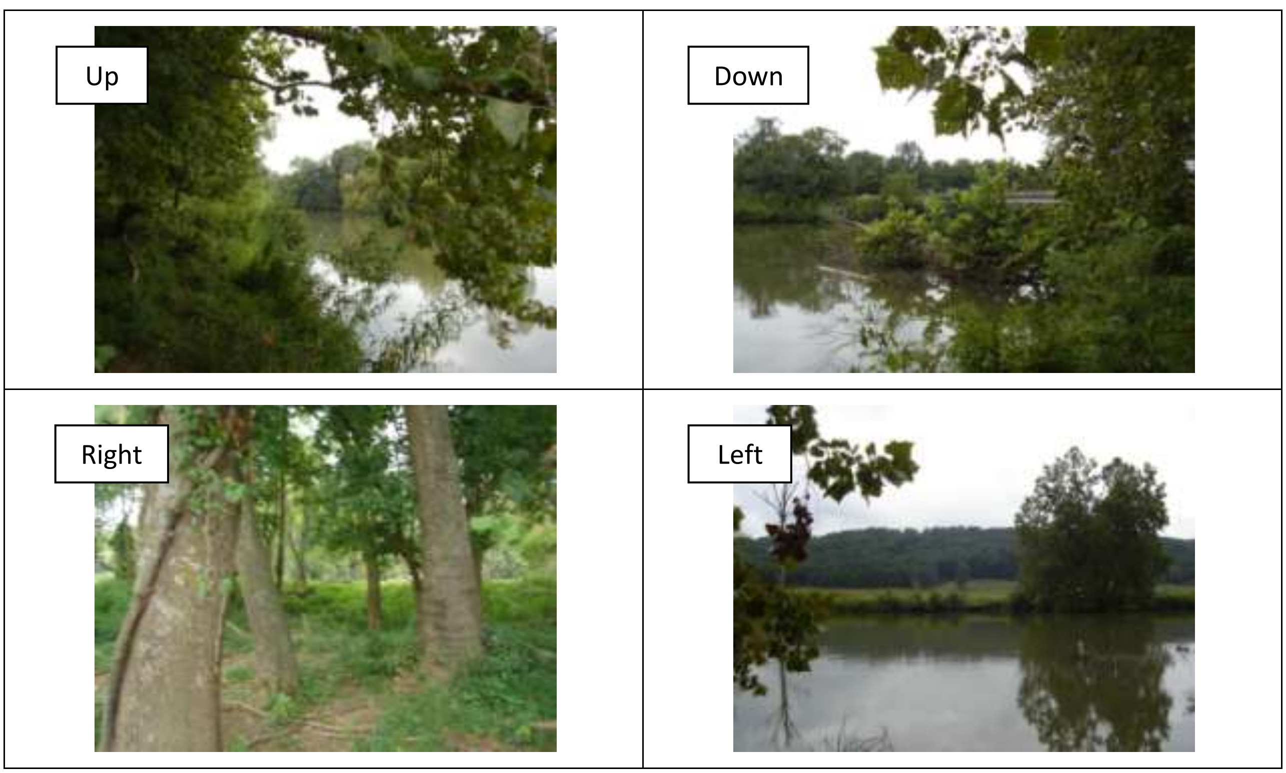

Up


Down


Right


Left

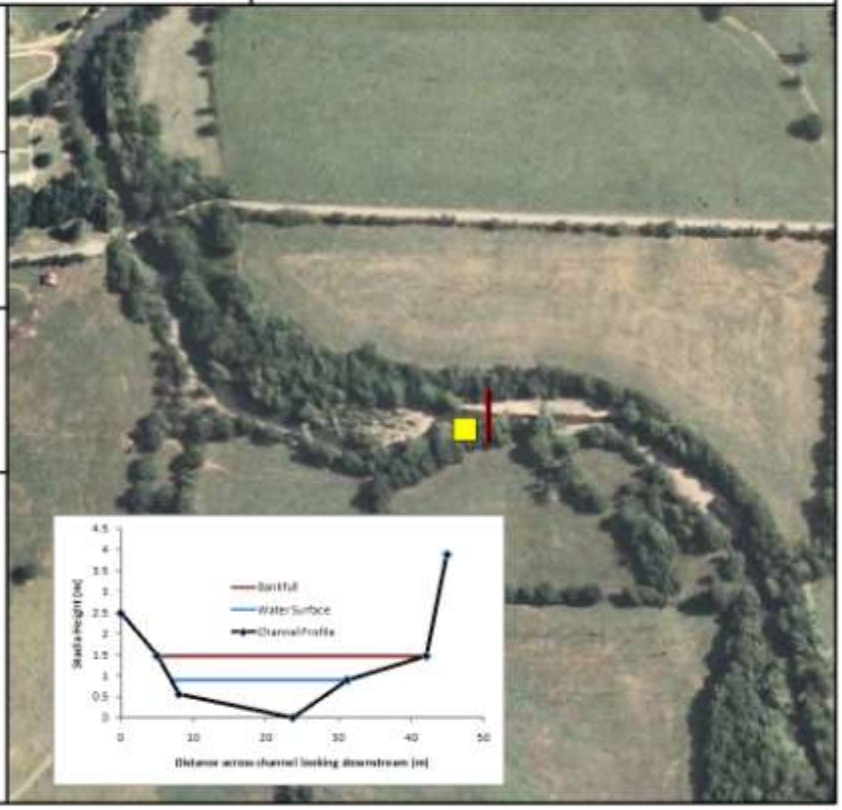

Middle Fork of the White River
0 0.05 0.1 0.2 Miles
0 0.05 0.1 0.2 Kilometers
Drainage Area (km^2): 197
Latitude: 36.03999
Longitude: -94.05533
Legend
Sediment Samples


Up
Down
Right
Left

White River at Elkins

0 0.05 0.1 0.2 Miles

0 0.05 0.1 0.2 Kilometers



Drainage Area (km^2): 465
Latitude: 35.99902
Longitude: -94.00004

Legend

Cross Section

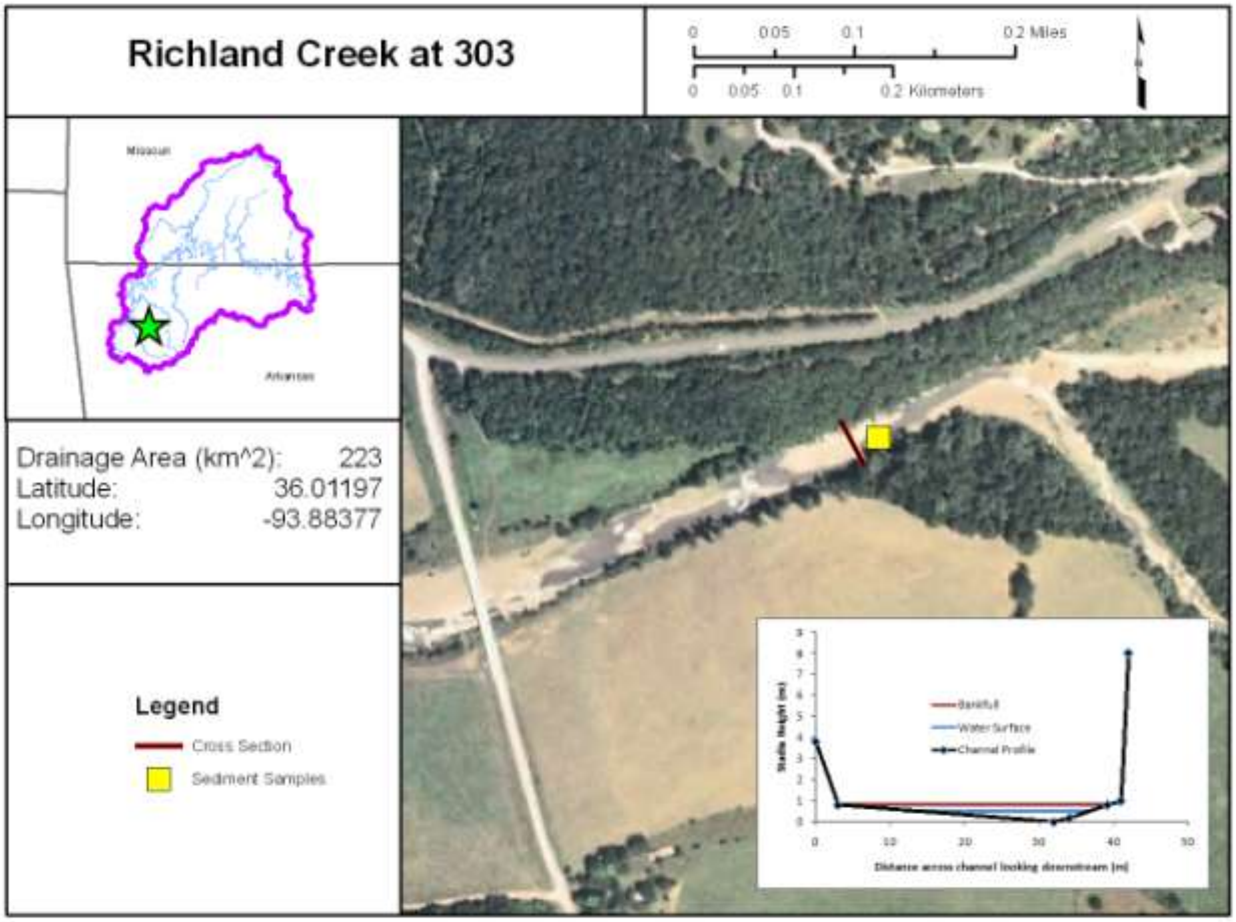
Sediment Samples

Up

Down

Right

Left

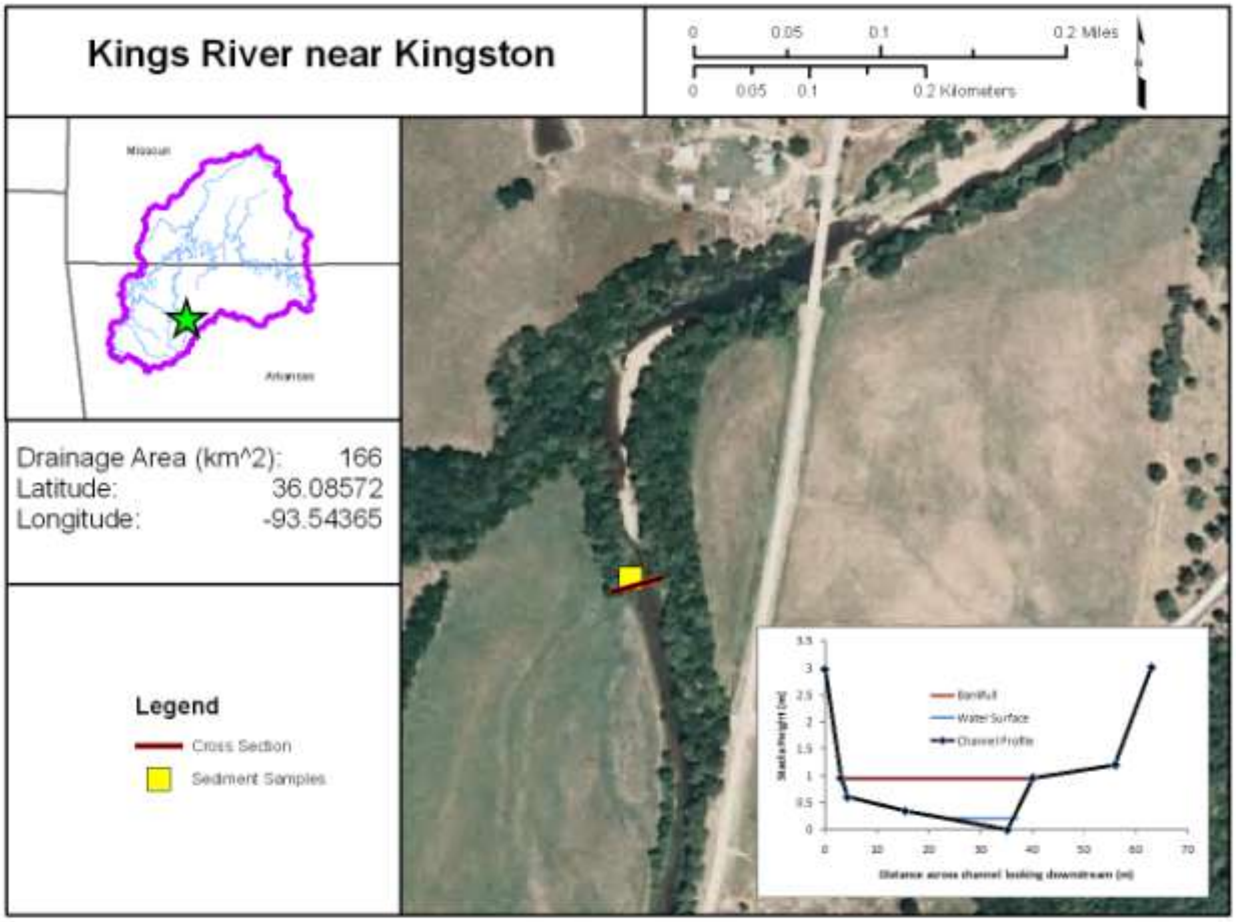


Up

Down

Right

Left



Up

Down

Right

Left

Appendix B

Rapid Channel Assessment Scoring Form and Sub-Reach Composite Scores

Missouri Department of Natural Resources
Stream Habitat Assessment Procedure
Riffle/Pool Habitat Assessment Form

Date:	Analyst:	Station #: Sample #:	Location:

Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
A. Epifaunal substrate/ available cover	Greater than 50% mix of cobble, large gravel, submerged logs, undercut banks, or other stable habitat. 20-16 ______	A 50-30.1% mix of cobble, large gravel, or other stable habitat. Habitat adequate for maintenance of populations. 15-11 ______	A 30-10.1% mix of cobble, large gravel, or other stable habitat. Habitat less than desirable. Substrate frequently disturbed or removed. 10-6 ______	Less than 10% mix of cobble, large gravel, or other stable habitat. Lack of habitat is obvious. Substrate unstable or lacking. 5-0 ______
B. Embeddedness	Gravel, cobble, or boulders are between 0-25% surrounded by fine sediment or sand. 20-16 ______	Gravel, cobble, or boulders are between 25.1-50% surrounded by fine sediment or sand. 15-11 ______	Gravel, cobble, or boulders are between 50.1-75% surrounded by fine sediment or sand. 10-6 ______	Gravel, cobble, or boulders are over 75% surrounded by fine sediment or sand. 5-0 ______
C Velocity/ depth regime	All four velocity/depth regimes present. Slow(< 0.3 m/s) - deep (> 0.5 m) ; slow- shallow (< 0.5 m) ; fast(> 0.3 m/s) - deep ; fast-shallow. 20-16 ______	Only 3 of the 4 regimes present (if fast-shallow is missing score lower than if missing other regimes). 15-11 ______	Only 2 of the 4 regimes present (if fast-shallow or slow-shallow are missing receive lower score). 10-6 ______	Dominated by one velocity/depth regime (usually slow-deep). 5-0 ______
D. Sediment deposition	Little or no enlargement of islands or point bar and less than 5% of bottom affected by sediment deposition. 20-16 ______	Some new increase in bar formation, mostly from coarse gravel, sand or fine sediment From 5-30% of bottom affected by sediment deposits. Slight sediment deposition in pools. 15-11 ______	Moderate deposition of new gravel, sand, or sediment on old and new bars; pools partially filled with silt. From 30.1-50% of bottom affected. Deposits at obstructions, constrictions, and bends. Moderate deposition of pools prevalent 10-6 ______	Heavy deposits of fine material, increased bar development. More than 50% of the bottom changing frequently. Pools almost absent due to substantial deposition. 5-0 ______
E. Channel flow status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed 20-16 ______	Water fills 99.9-75% of the available channel; or <25% of channel substrate exposed. 15-11 ______	Water fills 74.9-25% of the available channel, and/or riffle substrates are mostly exposed 10-6 ______	Very little water in channel (<25%) and mostly present as standing pools 5-0 ______
F. Channel alteration	Channelization or dredging absent or minimal (<5%) stream with normal pattern 20-16 ______	Some channelization present (5-39.9%), usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than 20 years) may be present, but recent channelization is not present. 15-11 ______	Channelization may be extensive; embankments or shoring structures present on both banks; and 40- 80% of stream reach channelizes or disrupted. 10-6 ______	Banks shored with gabion or cement; over 80% of the stream reach channelized or disrupted. Instream habitat greatly altered or removed entirely 5-0 ______

G. Riffle Quality	Well developed riffle and run; riffle is as wide as stream and length extends two times the width of stream; abundance of cobble.	Riffle is as wide as stream but length is less than two times width; abundance of cobble; gravel common.	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or bedrock prevalent; some cobble present.	Riffles or runs virtually nonexistent; bedrock prevalent; cobble lacking.
	20-16 ______	15-11 ______	10-6 ______	5-0 ______
H. Bank stability - Score each bank	Bank stable; evidence of erosion or bank failure absent or minimal; little potential for future problems; <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over; 5-29.9% of bank in reach has areas of erosion.	Moderate unstable; 30-59.9% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "Raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosion scars.
Left Bank	10-9 ______	8-6 ______	5-3 ______	2-0 ______
Right Bank	10-9 ______	8-6 ______	5-3 ______	2-0 ______
I. Vegetative protection – Score each bank	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory, or herbaceous growth; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	90-70% of the streambank surface covered by native vegetation; but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	69.9-50% of the streambank surface covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the stream bank surface covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Left Bank	10-9 ______	8-6 ______	5-3 ______	2-0 ______
Right Bank	10-9 ______	8-6 ______	5-3 ______	2-0 ______
J. Riparian vegetative zonewidth - Score each bank	Width of riparian zones > 18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zones 17.9-12 meters; human activities have impacted zone minimally.	Width of riparian zones 11.9-6 meters; human activities have impacted zone a great deal.	Width of riparian zones <6 meters; little or no riparian vegetation due to human activities.
Left Bank	10-9 ______	8-6 ______	3-5 ______	2-0 ______
Right Bank	10-9 ______	8-6 ______	3-5 ______	2-0 ______

Total ______

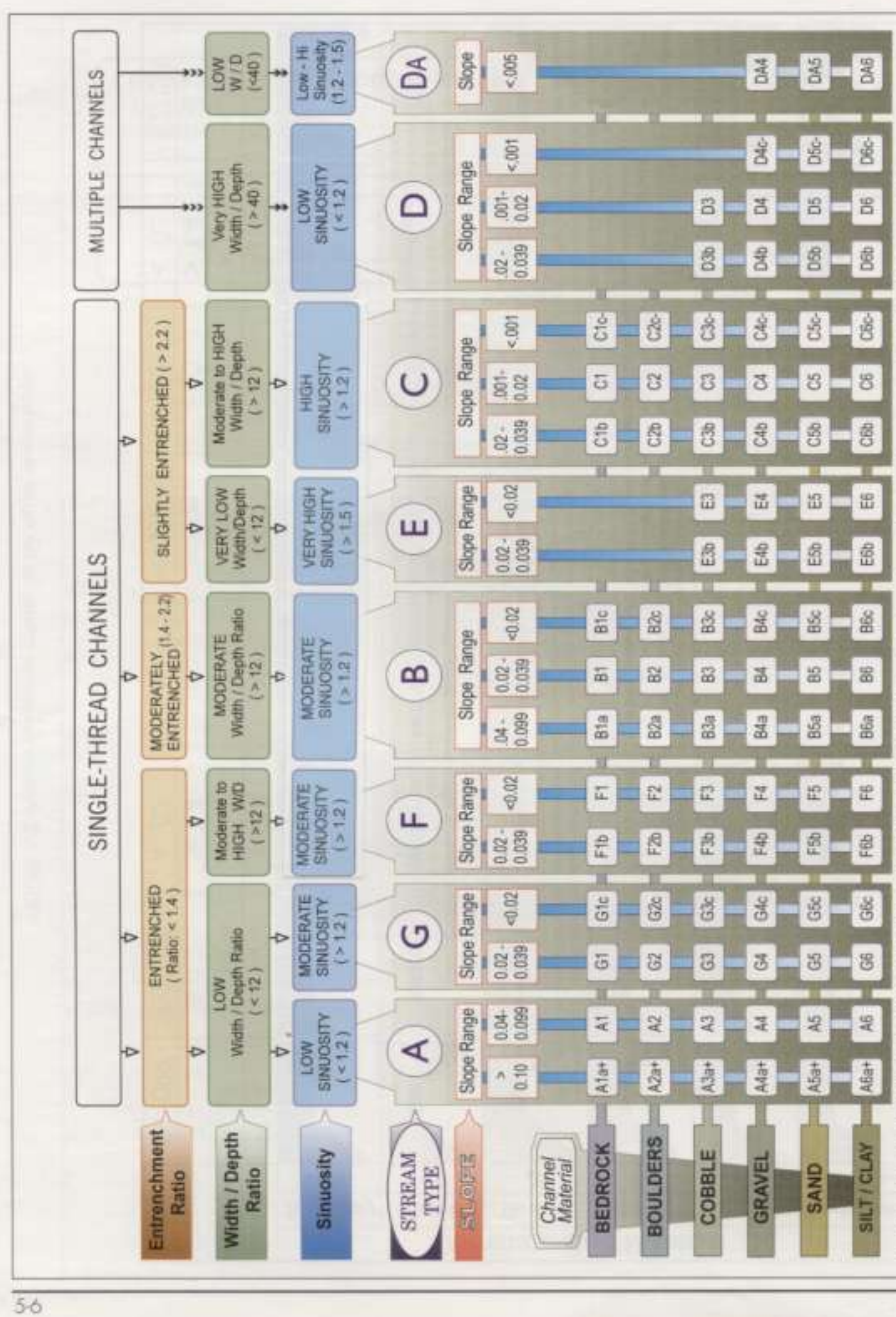
Site Name	Riffle #1	Riffle #2	Riffle #3	Analyst
Bear Creek near Omaha, AR	146			J. Ebert
	149			P. Dryer
Beaver Creek at Bradleyville	142			J. Ebert
	156			P. Dryer
Bull Creek Center St.	155			J. Ebert
	167			P. Dryer
Bull Creek near Walnut Shade	156			J. Ebert
	161			P. Dryer
Crane Creek at Highway AA	163			E. Hutchison
	143			D. Martin
Finley Creek below Riverdale	155	173	144	J. Ebert
	165	167	153	M. Owen
	151	170	157	D. Speer
Finley Creek near Sparta	155			J. Ebert
	148			P. Dryer
Flat Creek below Jenkins	159	159	156	J. Ebert
	160	163	159	M. Owen
	148	158	163	D. Speer
Flat Creek Duplicate	160	168	164	J. Ebert
	145	156	120	M. Owen
	174	183	179	D. Speer
James River near Springfield	129			J. Ebert
	134			P. Dryer
James River at Galena	169	125	148	J. Ebert
	151	102	131	P. Womble
	155	102	139	R. Pavlowsky
James River near Boaz	169	164	174	J. Ebert
	172	169	164	M. Owen
	169	169	170	D. Speer
Kings River Hwy 221	161			E. Hutchison
	167			D. Martin
Kings River near Berryville	161	158	167	J. Ebert
	138	134	151	P. Womble
	172	165	169	D. Speer

Site Name	Riffle #1	Riffle #2	Riffle #3	Analyst
Kings River near Kingston, AR	161			E. Hutchison
	162			D. Martin
Long Creek at Denver	120			E. Hutchison
	137			D. Martin
Middle Fork of the White River near Fayetteville	43			E. Hutchison
	66			D. Martin
Osage Creek southwest of Berryville	134			E. Hutchison
	148			D. Martin
Pond Creek near Longrun	129			E. Hutchison
	119			D. Martin
Richland Creek at Goshen	71			E. Hutchison
	113			D. Martin
Richland Creek at Highway 303	156			E. Hutchison
	133			D. Martin
Swan Creek near Swan	168	178	167	J. Ebert
	175	178	156	M. Owen
	171	184	165	D. Speer
Swan Creek Duplicate	164	192	153	E. Hutchison
	165	168	149	M. Owen
	149	167	141	H. Hoggard
Turkey Creek	156			J. Ebert
	156			P. Dryer
Upper Flat Creek at C	147			J. Ebert
	160			D. Speer
Upper James at B	153			J. Ebert
	139			P. Dryer
War Eagle Creek near Hindsville	160	153	158	J. Ebert
	137	107	122	P. Womble
	164	165	162	D. Speer
War Eagle Creek near Huntsville	108			E. Hutchison
	119			D. Martin

Site Name	Riffle #1	Riffle #2	Riffle #3	Analyst
West Fork White River east of Fayetteville	135	119	94	J. Ebert
	125	114	104	P. Womble
	137	138	120	D. Speer
White River near Elkins	123			E. Hutchison
	136			D. Martin
White River near Fayetteville	144	164	176	J. Ebert
	116	143	151	P. Womble
	170	170	164	D. Speer
Yocum Creek near Oak Grove	151	170	173	J. Ebert
	125	153	136	P. Womble
	176	181	176	D. Speer

Appendix C
Stream Type Description and Classification Flow Charts (Rosgen, 1996)

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/ Soils/Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.4	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.4	<.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gullies, step/pool morphology w/moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.



KEY to the [illegible] CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units; while values for **Width / Depth** ratios can vary by +/- 2.0 units.

Appendix D
Large Woody Debris Tally by Site

Large Woody Debris Tally				
Upper White River Basin Project			Date: 06-17-09	
Site: Flat Creek			Worker: David Speer	

Number (count)	Jam Dimensions or Piece Length (m)	Diameter (m)	Volume (m^3)	Jam Piece Count (#)
Jams				
1	9*2*2	n/a	36	8
2	12*3*2	n/a	72	8
3	16*3*4	n/a	192	10
4	16*4*6	n/a	384	14
TOTAL	***4 jams***		***684***	***40***
Pieces				
1	2.2	0.12	0.02	
2	2.2	0.12	0.02	
3	3.4	0.12	0.04	
4	3.2	0.13	0.04	
5	3	0.14	0.05	
6	2.9	0.15	0.05	
7	2	0.23	0.08	
8	1.7	0.32	0.14	
9	4.5	0.13	0.06	
10	4	0.15	0.07	
11	2	0.31	0.15	
12	3	0.21	0.10	
13	1.8	0.39	0.21	
14	6.4	0.13	0.08	
15	6.2	0.13	0.08	
16	2.5	0.33	0.21	
17	4.5	0.19	0.12	
18	7	0.12	0.08	
19	7.4	0.13	0.09	
20	6.2	0.15	0.11	
21	2.3	0.44	0.35	
22	5	0.22	0.18	
23	6.4	0.17	0.15	
24	6.7	0.17	0.14	
25	4.3	0.26	0.23	
26	7	0.16	0.14	
27	1.5	0.00	0.00	
28	6.5	0.18	0.17	
29	8.5	0.15	0.14	
30	5.1	0.27	0.28	
31	6.2	0.27	0.35	
32	5	0.36	0.49	
33	8.3	0.22	0.30	
34	6	0.31	0.45	
35	8.2	0.23	0.34	
36	7	0.27	0.40	
37	13	0.15	0.23	
38	7.5	0.28	0.45	
39	6.7	0.32	0.54	
40	5.3	0.44	0.81	
41	9	0.27	0.50	
42	8	0.32	0.64	
43	7.7	0.38	0.85	
44	12.2	0.34	1.07	
45	12	0.38	1.32	
TOTAL	***45 pieces***		***12.3***	

Large Woody Debris Tally				
Upper White River Basin Project		Date: 07-23-09		
Site: Flat Creek (Duplicate Survey)		Worker: David Speer		
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	12*2*2.5	n/a	60	9
2	13*3*4	n/a	156	10
3	14*3*5	n/a	210	8
4	2*2*1	n/a	4	?
5	7*2.5*1.5	n/a	26.3	15
6	8*3*2.5	n/a	60	6
TOTAL	***6 jams***		***516.3***	***48***
Pieces				
1	2	0.15	0.04	
2	2.2	0.20	0.07	
3	2.3	0.47	0.40	
4	2.5	0.13	0.03	
5	2.8	0.15	0.05	
6	2.8	0.16	0.05	
7	3	0.13	0.04	
8	3	0.11	0.03	
9	3	0.19	0.09	
10	3.4	0.14	0.05	
11	3.5	0.22	0.13	
12	4	0.12	0.05	
13	4	0.11	0.04	
14	4	0.20	0.13	
15	4.1	0.35	0.39	
16	4.3	0.15	0.08	
17	4.5	0.15	0.08	
18	5	0.23	0.20	
19	5.2	0.21	0.18	
20	5.5	0.44	0.84	
21	5.5	0.15	0.10	
22	5.5	0.30	0.39	
23	5.5	0.21	0.18	
24	6	0.20	0.19	
25	6	0.19	0.16	
26	6	0.25	0.29	
27	6	0.32	0.47	
28	6	0.16	0.12	
29	6.5	0.18	0.17	
30	6.5	0.22	0.25	
31	6.5	0.13	0.09	
32	6.5	0.18	0.16	
33	7.2	0.16	0.14	
34	7.2	0.24	0.33	
35	7.8	0.30	0.53	
36	8	0.14	0.11	
37	9	0.24	0.41	
38	9	0.27	0.50	
39	12	0.18	0.29	
40	16	0.25	0.79	
TOTAL	***40 pieces***		***8.6***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 06-19-09	
Site: Swan Creek			Recorder: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	10*5.1.5	n/a	75	6
2	2*1.5*2	n/a	6	?
3	8*5*1.5	n/a	60	4
TOTAL	***3 jams***		***141.0***	***10***
Pieces				
1	1.5	0.18	0.04	
2	2	0.12	0.02	
3	2.2	0.28	0.13	
4	3	0.21	0.10	
5	3.3	0.17	0.07	
6	3.4	0.14	0.05	
7	3.5	0.12	0.04	
8	4.2	0.12	0.04	
9	4.5	0.31	0.33	
10	4.5	0.12	0.05	
11	5.8	0.16	0.12	
12	6.7	0.25	0.32	
13	9	0.55	2.10	
14	19	0.26	1.01	
15	22	0.28	1.31	
TOTAL	***15 pieces***		***5.7***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 08-05-09	
Site: Swan Creek (Duplicate Survey)			Recorder: Derek Martin	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	3*3*2	n/a	18	15
2	8*2*5	n/a	80	>20
3	3*2*3	n/a	18	>20
TOTAL	***3 jams***		***116.0***	***15***
Pieces				
1	6	0.10	0.05	
2	7	0.05	0.01	
3	5	0.15	0.09	
4	4	0.05	0.01	
5	5	0.10	0.04	
6	2	0.08	0.01	
7	10	0.60	2.83	
8	10	0.10	0.08	
9	8	1.00	6.28	
10	9	0.20	0.28	
11	5	0.30	0.35	
12	13	0.50	2.55	
13	4.5	0.15	0.08	
14	8	0.20	0.25	
15	4	0.40	0.50	
16	20	0.80	10.05	
17	4	0.15	0.07	
TOTAL	***17 pieces***		***23.5***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 06-24-09	
Site: Finley			Recorder: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	10*1.5*1.5	12	22.5	6
2	10.1.5*1	n/a	15	4
3	12*1*2	n/a	24	5
4	12*2*1	n/a	24	5
5	2*1*2	n/a	4	3
6	7*2*1.5	n/a	21	4
7	8*2*1.5	n/a	24	5
8	9*2*1.5	n/a	27	7
TOTAL	***8 jams***		***161.5***	***29***
Pieces				
1	2	0.11	0.02	
2	2	0.17	0.04	
3	3.5	0.25	0.17	
4	3.6	0.11	0.03	
5	3.6	0.11	0.03	
6	4.3	0.17	0.09	
7	4.5	0.13	0.06	
8	5	0.15	0.08	
9	5	0.14	0.07	
10	5.5	0.17	0.12	
11	6	0.15	0.11	
12	6	0.19	0.16	
13	6.2	0.15	0.11	
14	6.5	0.15	0.11	
15	6.7	0.14	0.10	
16	6.7	0.14	0.10	
17	8.5	0.24	0.37	
18	8.5	0.13	0.10	
19	9	0.26	0.48	
20	9.5	0.19	0.27	
21	9.5	0.12	0.11	
22	9.7	0.15	0.16	
23	10	0.24	0.45	
24	10.5	0.21	0.36	
25	10.5	0.14	0.15	
26	11.5	0.63	3.53	
27	12	0.55	2.85	
28	13	0.17	0.28	
29	13.5	0.18	0.34	
30	13.5	0.18	0.34	
31	14	0.14	0.22	
32	15	0.38	1.66	
33	15	0.24	0.68	
34	15.5	0.33	1.29	
35	15.5	0.19	0.42	
36	16	0.15	0.26	
37	28	0.23	1.16	
TOTAL	***37 pieces***		***16.9***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 06-24-09	
Site: James at Boaz			Recorder: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	1*1*1	n/a	1	
2	10*2*1	n/a	20	4
3	10*2*2	n/a	40	4
4	10*2*2	n/a	40	4
5	10*2*3	n/a	60	6
6	15*2*1.5	n/a	45	6
7	2*2*2	n/a	11.3	5
8	20*2*1.5	n/a	60	7
9	4*5*.5	n/a	22	3
10	7*1*1	n/a	7	3
11	9*1*.5	n/a	4.5	4
12	9*1*1.5	n/a	13.5	6
13	9.5*1*1.5	n/a	14.25	3
TOTAL	***13 jams***		***338.6***	***26***
Pieces				
1	2	0.14	0.03	
2	2	0.22	0.07	
3	2.5	0.16	0.05	
4	3	0.18	0.07	
5	3.5	0.24	0.15	
6	3.5	0.25	0.17	
7	4	0.23	0.16	
8	4.5	0.15	0.08	
9	6.5	0.15	0.11	
10	7	0.13	0.09	
11	7	0.16	0.13	
12	7	0.33	0.58	
13	7	0.19	0.19	
14	7.5	0.14	0.12	
15	7.5	0.21	0.26	
16	8	0.18	0.19	
17	8.5	0.15	0.14	
18	8.5	0.23	0.34	
19	8.5	0.39	1.01	
20	9.5	0.18	0.23	
21	9.5	0.24	0.43	
22	10	0.22	0.36	
23	10.5	0.15	0.19	
24	10.5	0.20	0.33	
25	11	0.19	0.30	
26	11.5	0.23	0.46	
27	11.5	0.23	0.48	
28	12	0.35	1.15	
29	12.5	0.16	0.24	
30	13	0.17	0.28	
31	15	0.15	0.26	
32	15	0.18	0.36	
33	15	0.18	0.36	
34	20	0.19	0.57	
35	20	0.31	1.51	
36	25	0.30	1.77	
37	35	0.35	3.27	
TOTAL	***37 pieces***		***16.5***	

Large Woody Debris Tally				
Upper White River Basin Project		Date: 07-01-09		
Site: Kings River		Recorder: David Speer		
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	12*3.5*3.5	n/a	147	8
2	15*1.5*1	n/a	22.5	?
3	2*2*1	n/a	4	?
4	2*8*1	n/a	16	5
5	3*3*1.7	n/a	15.3	?
6	7*2*2	n/a	28	6
7	9*3*1.5	n/a	40.5	7
TOTAL	***7 jams***		***273.3***	***18***
Pieces				
1	2	0.20	0.06	
2	2	0.14	0.03	
3	2	0.48	0.35	
4	2.4	0.25	0.12	
5	3.2	0.17	0.07	
6	3.4	0.18	0.08	
7	5	0.25	0.24	
8	5.5	0.19	0.16	
9	6.5	0.27	0.36	
10	7.1	0.34	0.64	
11	8.2	0.45	1.30	
12	8.5	0.20	0.27	
13	8.7	0.23	0.36	
14	11	0.19	0.30	
15	11.8	0.20	0.37	
16	12	0.14	0.17	
17	13.5	0.16	0.25	
18	14.3	0.27	0.79	
TOTAL	***18 pieces***		***5.9***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 07-02-09	
Site: Yocum Creek			Recorder: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	1.5*1.5*1.5	n/a		
2	3*3*2	n/a	18	
3	4*2.8*7	n/a	78.4	9
4	5*1.5*1.5	n/a	11.25	3
5	5*2.3*4	n/a	46	10
6	8*3*4	n/a	96	7
TOTAL	***6 jams***		***249.7***	***29***
Pieces				
1	2.1	0.19	0.06	
2	2.5	0.31	0.19	
3	3	0.23	0.12	
4	3	0.12	0.03	
5	3	0.15	0.05	
6	3	0.12	0.03	
7	4	0.17	0.09	
8	4.2	0.12	0.04	
9	4.4	0.13	0.06	
10	4.9	0.16	0.09	
11	5	0.20	0.16	
12	5.2	0.21	0.18	
13	5.5	0.12	0.06	
14	6.4	0.16	0.13	
15	6.7	0.06	0.02	
16	8.2	0.14	0.12	
17	8.3	0.15	0.14	
18	8.5	0.18	0.22	
19	9	0.17	0.20	
20	9.7	0.15	0.17	
21	10	0.16	0.19	
22	10.5	0.19	0.28	
23	11	0.20	0.35	
24	11.5	0.19	0.33	
25	11.5	0.17	0.25	
26	12.5	0.20	0.39	
27	14	0.22	0.51	
28	24	0.19	0.65	
TOTAL	***28 pieces***		***5.1***	

Large Woody Debris Tally				
Upper White River Basin Project		Date: 07-08-09		
Site: White River		Recorder: David Speer		
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	1.5*1.5*1.5	n/a	3.4	?
2	1.5*2**1.5	n/a	4.5	?
3	2*2*1	n/a	4	?
4	2*2*1	n/a	4	?
5	2*3*2	n/a	12	?
6	3*3*1	n/a	9	?
7	3*3*1.5	n/a	13.5	?
8	6*1.5*1.5	n/a	13.5	4
9	7*2*1.5	n/a	21	4
10	7*3*3	n/a	63	6
11	9*2*1.5	n/a	27	4
TOTAL	***11 jams***		***174.9***	***18***
Pieces				
1	1.5	0.22	0.06	
2	2	0.14	0.03	
3	2	0.14	0.03	
4	2.2	0.26	0.12	
5	3.1	0.15	0.05	
6	3.2	0.14	0.05	
7	3.4	0.25	0.16	
8	3.5	0.17	0.08	
9	3.5	0.26	0.19	
10	3.8	0.14	0.05	
11	4	0.20	0.13	
12	4	0.11	0.04	
13	4.2	0.06	0.01	
14	4.5	0.15	0.07	
15	4.5	0.26	0.24	
16	5.2	0.15	0.09	
17	5.6	0.14	0.08	
18	6	0.18	0.14	
19	6	0.14	0.09	
20	6.5	0.17	0.15	
21	7	0.18	0.17	
22	7.5	0.20	0.24	
23	7.5	0.42	1.04	
24	8.5	0.14	0.13	
25	8.5	0.20	0.27	
26	9.2	0.18	0.23	
27	10.5	0.16	0.21	
28	11	0.34	1.00	
29	12.5	0.35	1.20	
30	14	0.23	0.58	
31	15	0.48	2.71	
32	15	0.23	0.62	
33	16.5	0.29	1.09	
TOTAL	***33 pieces***		***11.3***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 07-08-09	
Site: West Fork			Recorder: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	2*1*1.5	n/a	3	?
2	3*3*2	n/a	18	4
3	4*2*2	n/a	16	3
TOTAL	***3 jams***		***37.0***	***7***
Pieces				
1	2	0.18	0.048	
2	2	0.11	0.019	
3	2.5	0.13	0.033	
4	3.5	0.13	0.043	
5	4	0.14	0.062	
6	5.4	0.12	0.061	
7	5.4	0.14	0.077	
8	5.5	0.14	0.079	
9	5.5	0.13	0.067	
10	6.3	0.19	0.179	
11	7	0.15	0.116	
12	7	0.19	0.188	
13	7	0.25	0.344	
14	8.5	0.18	0.216	
15	10	0.27	0.552	
16	11.5	0.13	0.141	
17	12	0.14	0.185	
18	12.5	0.14	0.192	
19	13	0.17	0.295	
TOTAL	***19 pieces***		***2.9***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 07-09-09	
Site: War Eagle Creek			Worker: David Speer	
Number (count)	**Jam Dimensions or Piece Length (m)**	**Diameter (m)**	**Volume (m^3)**	**Jam Piece Count (#)**
Jams				
1	14*3*7		294	15
2	2*2*1		4	?
3	2.5*2.5*1		6.25	?
4	3*2*1		6	?
5	3*3*2		18	?
6	38*4*12		1824	25
7	4*2*3		24	?
8	5*2*1		10	3
9	5*6*3		90	3
10	9*2*2		36	5
11	9*2*3		54	3
TOTAL	***11 jams***		***2366.3***	***39***
Pieces				
1	1.5	0.17	0.03	
2	1.5	0.14	0.02	
3	2	0.33	0.17	
4	3.5	0.14	0.05	
5	3.5	0.15	0.06	
6	4	0.24	0.18	
7	5.2	0.12	0.06	
8	5.5	0.18	0.13	
9	5.8	0.19	0.16	
10	6.5	0.18	0.16	
11	7	0.13	0.09	
12	7.5	0.34	0.66	
13	7.5	0.16	0.15	
14	8	0.12	0.09	
15	8.5	0.43	1.21	
16	8.5	0.41	1.12	
17	9.5	0.15	0.17	
18	10	0.23	0.42	
19	10	0.38	1.10	
20	10.2	0.33	0.87	
21	10.5	0.20	0.33	
22	10.5	0.25	0.52	
23	10.8	0.22	0.39	
24	12.5	0.15	0.22	
25	13	0.14	0.20	
26	16	0.24	0.69	
27	17	0.23	0.68	
28	17	0.30	1.20	
29	17	0.23	0.68	
30	19	0.30	1.34	
31	19	0.23	0.79	
32	23	0.14	0.33	
33	25	0.33	2.07	
TOTAL	***33 pieces***		***16.3***	

Large Woody Debris Tally				
Upper White River Basin Project			Date: 07-09-09	
Site: James R @ Galena			Worker: Bob Pavlowsky	

Number (count)	Jam Dimensions or Piece Length (m)	Diameter (m)	Volume (m^3)	Jam Piece Count (#)
Jams				
1	(loose jam- tabulate pieces)		2.3	8
2	(loose jam- tabulate pieces)		2.5	5
3	(loose jam- tabulate pieces)		15.0	11
TOTAL	***3 jams***		***19.8***	***24***
Pieces				
1	2	0.2	0.06	
2	2	0.2	0.06	
3	1.5	0.3	0.11	
4	10	0.3	0.71	
5	8	0.3	0.57	
6	5	0.25	0.25	
7	3	0.25	0.15	
8	11	0.35	1.06	
9	5	0.2	0.16	
10	16	0.45	2.54	
11	2.5	0.3	0.18	
12	8	0.3	0.57	
13	8	0.3	0.57	
14	8	0.2	0.25	
15	3	0.1	0.02	
16	1.5	1	1.18	
17	4	0.2	0.13	
18	5	0.2	0.16	
19	4	0.2	0.13	
20	3	0.3	0.21	
21	5	0.2	0.16	
22	5	0.3	0.35	
23	1.5	0.4	0.19	
24	6	0.65	1.99	
25	3	0.3	0.21	
26	6	0.3	0.42	
27	1.5	0.4	0.19	
28	1.5	0.3	0.11	
29	3	0.3	0.21	
30	5	0.5	0.98	
31	3	0.2	0.09	
32	2	0.2	0.06	
33	2	0.1	0.02	
34	4	0.2	0.13	
35	5	0.2	0.16	
36	2	0.3	0.14	
37	2	0.4	0.25	
38	3	0.2	0.09	
39	10	0.2	0.31	
40	10	0.3	0.71	
41	10	0.4	1.26	
42	10	0.2	0.31	
43	8	0.2	0.25	
44	3	0.3	0.21	
45	3	0.5	0.59	
46	4	0.2	0.13	
47	1.5	0.2	0.05	
48	13	0.4	1.63	
49	2	0.2	0.06	
50	2.5	0.2	0.08	
51	4	0.15	0.07	
52	4	0.15	0.07	
53	5	0.15	0.09	
54	4	0.2	0.13	
55	3	0.15	0.05	
56	3	0.15	0.05	
57	2	1	1.57	
58	4	0.2	0.13	
59	4	0.3	0.28	
60	5	0.2	0.16	
TOTAL	***60 pieces***		***23.0***	

Appendix E
Pebble Count Data

Finley Creek

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	2.5	3.3	0.0	0.8	112	2.0	5.6	8.0	14.8	22.6	22.6	32.0	45.0	45.0	53.5	64.0	22.7		
Riffle	120	1.7	0.8	0.0	1.7	115	8.0	11.0	16.0	16.0	22.6	32.0	45.0	64.0	64.0	64.0	300.0	31.4		
G+R	240	2.1	2.1	0.0	1.3	227	2.0	8.0	11.0	16.0	22.6	32.0	32.0	45.0	64.0	64.0	300.0	27.1		
Crest-max	15					15													108.0	16.5
Bar	105	0.0	1.9	0.0	0.0	102	2.8	8.0	11.0	16.0	16.0	22.6	32.0	45.0	45.0	64.0	90.0	23.6		
Bar-max	30					30													129.7	22.7

Riffle Stability Index	84-95

Flat Creek

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.0	0.8	0.0	7.5	110	2.0	2.8	4.0	8.0	11.0	22.6	32.0	32.0	45.0	64.0	128.0	17.2		
Riffle	120	2.5	0.0	0.0	5.8	110	2.8	4.7	8.0	11.0	16.0	22.6	32.0	45.0	46.9	64.0	90.0	20.6		
G+R	240	1.3	0.4	0.0	6.7	220	2.0	2.8	5.6	8.0	16.0	22.6	32.0	45.0	45.0	64.0	128.0	18.8		
Crest-max	15					15													123.4	24.7
Bar	105	0.0	2.9	0.0	0.0	102	4.0	8.0	8.0	8.0	11.0	16.0	22.6	32.0	43.7	45.0	90.0	17.4		
Bar-max	30					30													111.2	27.3

Riffle Stability Index	84-90

Flat Creek Duplicate

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	5.0	0.0	0.0	5.0	148	2.8	4.0	5.6	5.6	11.0	16.0	22.6	32.0	45.0	45.0	90.0	15.5		
Riffle	120	6.7	0.0	0.0	7.5	143	2.6	4.0	4.3	5.6	8.0	16.0	32.0	45.0	45.0	45.0	64.0	15.2		
G+R	240	5.8	0.0	0.0	6.3	148	2.8	4.0	5.6	5.6	11.0	16.0	22.6	32.0	45.0	45.0	90.0	15.4		
Crest-max	15					20													154.0	23.9
Bar	105	1.0	0.0	0.0	0.0	139	4.0	7.8	8.0	11.0	11.0	22.6	32.0	44.0	45.0	45.0	190.0	18.9		
Bar-max	30					40													111.1	29.0

Riffle Stability Index	84-95

James River at Galena

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	10.8	0.0	6.7	10.0	87	2.8	5.6	5.6	8.0	11.0	22.6	32.0	32.0	45.0	58.3	300.0	19.1		
Riffle	120	10.8	0.0	4.2	0.0	102	2.8	4.1	5.6	8.0	11.0	16.0	32.0	45.0	45.0	64.0	300.0	17.8		
G+R	240	10.8	0.0	5.4	5.0	189	2.8	5.6	5.6	8.0	11.0	22.6	32.0	45.0	45.0	64.0	300.0	18.3		
Crest-max	15					15													240.0	39.3
Bar	105	3.8	0.0	0.0	0.0	101	5.6	8.0	11.0	11.0	16.0	22.6	32.0	32.0	45.0	45.0	100.0	22.1		
Bar-max	30					30													102.5	37.5

Riffle Stability Index	84-90

James River at Boaz

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.0	0.0	0.0	22.5	93	2.0	11.0	16.0	16.0	22.6	32.0	45.0	50.3	90.0	105.2	300.0	32.5		
Riffle	120	0.0	0.8	0.0	8.3	109	2.8	11.0	16.0	16.0	22.6	32.0	45.0	64.0	90.0	128.0	300.0	34.7		
G+R	240	0.0	0.4	0.0	15.4	202	2.0	11.0	16.0	16.0	22.6	32.0	45.0	64.0	90.0	128.0	300.0	33.6		
Crest-max	15					15													497.3	28.2
Bar	105	1.9	0.0	0.0	0.0	68	4.0	9.1	11.0	14.6	16.0	22.6	32.0	45.0	50.7	64.0	128.0	24.8		
Bar-max	30					30													212.0	49.8

Riffle Stability Index	84

Kings River near Berryville

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.0	6.7	0.0	25.0	82	2.0	4.0	5.6	5.6	8.0	16.0	22.6	45.0	64.0	90.0	650.0	16.3		
Riffle	120	0.0	2.5	0.0	30.8	80	2.8	4.0	5.6	8.0	16.0	22.6	45.0	64.0	90.0	90.0	128.0	22.2		
G+R	240	0.0	4.6	0.0	27.9	162	2.0	4.0	5.6	5.6	11.0	16.0	32.0	64.0	90.0	90.0	650.0	19.0		
Crest-max	15					10													311.8	40.0
Bar	105	0.0	1.9	0.0	0.0	103	2.8	4.0	5.6	6.4	11.0	16.0	32.0	64.0	90.0	124.2	470.0	19.4		
Bar-max	30					30													287.2	88.6

Riffle Stability Index	>95

Swan Creek near Swan

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.8	0.8	0.0	11.7	104	2.8	6.0	8.0	11.0	16.0	22.6	32.0	64.0	128.0	172.2	300.0	26.9		
Riffle	120	0.0	0.0	0.0	0.0	120	2.0	7.9	11.0	11.2	22.6	45.0	90.0	228.0	300.0	300.0	300.0	47.4		
G+R	240	0.4	0.4	0.0	5.8	224	2.0	6.0	8.9	11.0	22.6	32.0	64.0	128.0	300.0	300.0	300.0	37.2		
Crest-max	15					15													511.3	40.7
Bar	105	1.9	1.0	0.0	1.0	86	4.0	8.8	13.5	16.0	22.6	45.0	64.0	90.0	128.0	292.5	300.0	42.9		
Bar-max	30					25													360.4	31.3

Riffle Stability Index	>84

Swan Creek Duplicate

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.8	0.8	0.0	16.7	98	5.6	7.6	8.0	11.0	16.0	22.6	45.0	90.0	128.0	190.0	300.0	29.0		
Riffle	120	0.8	0.0	0.0	1.7	117	4.0	5.6	8.0	11.0	22.6	22.6	45.0	90.0	105.2	204.0	300.0	29.8		
G+R	240	0.8	0.4	0.0	9.2	215	4.0	5.6	8.0	11.0	22.6	22.6	45.0	90.0	128.0	190.0	300.0	29.4		
Crest-max	15					15													260.5	31.5
Bar	105	0.0	0.0	0.0	0.0	60	8.0	15.8	16.0	22.6	22.6	32.0	45.0	64.0	66.6	300.0	300.0	37.1		
Bar-max	30					30													296.3	6.8
Riffle Stability Index	>95																			

War Eagle Creek

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	4.2	20.0	0.0	21.7	65	5.6	8.6	11.0	16.0	22.6	32.0	45.0	90.0	128.0	128.0	180.0	31.7		
Riffle	120	3.3	30.0	0.0	3.3	76	2.8	5.2	9.5	11.0	16.0	32.0	64.0	90.0	128.0	265.0	500.0	32.8		
G+R	240	3.8	25.0	0.0	12.5	141	2.8	5.6	11.0	11.0	22.6	32.0	64.0	90.0	128.0	128.0	500.0	32.3		
Crest-max	15					15													341.3	57.5
Bar	105	2.9	1.0	0.0	12.4	86	2.8	8.0	8.0	11.0	16.0	22.6	32.0	45.0	64.0	83.5	280.0	22.7		
Bar-max	30					30													218.9	82.9
Riffle Stability Index	>70																			

West Fork East of Fayetteville

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	7.5	16.7	3.3	0.0	87	4.0	4.0	5.6	8.0	11.0	22.6	32.0	45.0	45.0	64.0	64.0	18.6		
Riffle	120	8.3	9.2	8.3	0.0	89	4.0	5.6	5.6	8.0	11.0	16.0	32.0	45.0	45.0	45.0	64.0	17.5		
G+R	240	7.9	12.9	5.8	0.0	176	4.0	4.0	5.6	8.0	11.0	22.6	32.0	45.0	45.0	64.0	64.0	18.0		
Crest-max	15					15													98.4	19.9
Bar	105	53.3	0.0	0.0	0.0	49	5.6	5.6	5.6	8.0	11.0	22.6	32.0	45.0	64.0	64.0	90.0	19.4		
Bar-max	30					30													92.5	39.6
Riffle Stability Index	99																			

White River near Fayetteville

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	1.7	0.8	5.8	37.5	65	2.8	5.6	5.6	8.0	11.0	16.0	32.0	64.0	79.6	120.4	300.0	19.9		
Riffle	120	5.0	3.3	0.0	19.2	87	2.8	6.3	8.0	11.0	21.3	45.0	64.0	90.0	105.2	180.0	610.0	34.6		
G+R	240	3.3	2.1	2.9	28.3	152	2.8	5.6	8.0	8.0	11.0	32.0	45.0	64.0	90.0	128.0	610.0	27.3		
Crest-max	15					15													320.9	53.7
Bar	105	0.0	1.0	0.0	0.0	104	4.0	8.0	11.0	11.0	16.0	22.6	32.0	45.0	45.0	64.0	90.0	23.3		
Bar-max	30					30													202.4	57.7
Riffle Stability Index	70																			

Yocum Creek at Oak Grove

Location	<2mm					>2mm	Size Distribution (diameter, mm)											GeoMean	Max Clast Size	
	n	F	S	E	R	n	Min	D5	D10	D16	D30	D50	D70	D84	D90	D95	Max		Mean	CV%
Glide	120	0.0	0.0	1.7	0.0	118	2.8	8.0	11.0	11.0	16.0	22.6	32.0	45.0	45.0	64.0	90.0	21.5		
Riffle	120	0.0	0.0	0.0	0.8	119	4.0	5.6	8.0	11.0	16.0	22.6	22.6	32.0	45.0	64.0	128.0	19.6		
G+R	240	0.0	0.0	0.8	0.4	237	2.8	7.5	9.8	11.0	16.0	22.6	32.0	45.0	45.0	64.0	128.0	20.5		
Crest-max	15					15													161.1	35.9
Bar	105	1.0	1.9	0.0	0.0	102	2.8	4.1	5.6	8.0	11.0	16.0	16.0	22.6	32.0	32.0	128.0	13.8		
Bar-max	30					30													105.7	42.2
Riffle Stability Index	84																			