FINAL REPORT

FEDERAL AID GRANT NO. T-19-P-1

FLUVIAL GEOMORPHOLOGY ANALYSIS OF THE KIAMICHI RIVER, OKLAHOMA

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

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FINAL REPORT

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PROJECT TITLE: Fluvial Geomorphology Analysis of the Kiamichi River, Oklahoma

A. ABSTRACT

A comprehensive geomorphic analysis of the Kiamichi River, Oklahoma was conducted to characterize the current landscape, fluvial geomorphic condition, flow and sediment regimes, and to identify potential impacts from the impoundment of the Jackfork Creek tributary to the morphological form and function of the river. The Kiamichi River channel has changed little over the last 25 years. It was classified as a Rosgen F type stream and had a basin relief ratio of 0.00345. The Kiamichi River Basin is classified as a Rosgen X type valley. Meander wavelength increased significantly in the downstream direction; the average reach meander wavelength ranged from 11 to 60 mean reach bankfull widths. Bankfull width, bankfull area, width:depth ratio, and channel stability increased in the downstream direction. Although there was no significant change in substrate size longitudinally, the percentage of gravel and cobble substrate increased and the percentage of bedrock decreased in the downstream direction. Bankfull discharge increased in the downstream direction, as expected. The majority of sites sampled were classified as Rosgen F4 stream types. The effective discharge (Q_e) at the Big Cedar gaging station was estimated to be 4500 cubic feet per second (cfs) with a threshold discharge (Q_t) of 0.1 cfs. The Antlers gaging station Q_e was estimated to be 25,000 cfs with a Q_t of 3.5 cfs. Deposition bar area below the Jackfork Creek tributary has increased over time. Channel dimensions and particle size immediately downstream of the Jackfork Creek tributary appear to have changed since the creation of Sardis Lake. We recommend further analysis of geomorphic features of the Kiamichi River to delineate references reaches and monitor changes in the channel at monumented cross-sections below the Jackfork Creek confluence. We also recommend releasing water from Sardis Lake that mimics the natural flow regime to aid in stabilizing the Kiamichi River channel.

B. OBJECTIVES:

1. Characterize current landscape, geomorphic, flow regime, and sediment regime conditions of the portions of the Kiamichi River above Lake Hugo.
2. Identify and quantify deviations from the morphologic form and river function in the perturbed portion of the Kiamichi River below Jackfork Creek compared with the unperturbed portion above Jackfork Creek.

C. NEED:

The Kiamichi River contains 30 mussel species (Table 1), which is over half the mussel species known to exist in Oklahoma (Vaughn et al. 1996). This includes seven state-designated imperiled or vulnerable species, two federally endangered species (*Leptodea leptodon* and *Arkansia wheeleri*), and one federally threatened species (*Megalonaias nervosa*). The Kiamichi River contains the only remaining viable population of the Ouachita Rock Pocketbook (*Arkansia wheeleri)* mussel, one of the rarest mussels in North America. The Kiamichi River also has more than 100 fish species (Master et al. 1998). The Kiamichi River mainstem is free flowing for the first 248 kilometers of its length and is impounded by Hugo Lake Dam 29 km upstream from its confluence with the Red River. Sardis Lake, impounded in 1983, is the only other large impoundment directly impacting the river and is located on the Jackfork Creek tributary. This impoundment has altered streamflow below the Jackfork Creek confluence with the Kiamichi River.

During the past 20 years, the lower half of the Kiamichi River has experienced changes in the flow and sediment regime from the construction and operation of Sardis Lake. The Kiamichi River is currently adjusting to these changes, which may impact river system form and function (Rosgen 1996).

D. APPROACH:

Sampling was conducted along 212 km of the Kiamichi River from State Highway 63 Bridge near Big Cedar, Oklahoma to State Highway 3 Bridge south of Antlers, Oklahoma (Figure1). The confluence of the impounded tributary Jackfork Creek (JFC) is at river km 125 near Clayton, Oklahoma. We used the hierarchical approach of Rosgen (1996) to systematically address the project objectives. The study approach combined river morphology analyses at four spatial scales that ranged from a broad geomorphic characterization (Level 1) to a detailed description and assessment (Level 4). The approach made use of fluvial morphological-process relationships that have been established at each of the four levels and, therefore, resulted in detailed quantitative evaluation of river form, function, and deviation from optimal conditions.

<u>Level 1 (Geomorphic Characterization)</u>: A basic site description was compiled using reference literature, USGS topographic maps, and existing geographic information system (GIS) coverages, including some from the Oklahoma Streams Information System (OSIS) (Tejan and Fisher 2001). Geomorphic and channel feature characterization was accomplished with USGS 7.5 minute topographic maps, aerial photographs, and GIS coverages using ArcGIS 9.1 software (ESRI, Redlands, California). Valley morphology and landforms were determined using existing

GIS coverages and 2005 National Agriculture Imagery Program (NAIP) aerial photographs. River dimension, pattern, and profile were determined using USGS topographic maps. USGS topographic maps were also used to develop a longitudinal profile for the Kiamichi River.

Basin relief ratio (R) was calculated from 2005 NAIP aerial photos as,

$$R = \frac{HighElevation - LowElevation}{L_{Max}}$$

where high elevation is the highest point in the watershed, low elevation is the watershed pour point, and L_{max} is the longest distance from the top of the watershed to its pour point.

Gradient and sinuosity were calculated between each elevation contour on USGS topographic maps. Sinuosity (S) was calculated as,

$$S = \frac{StreamLength}{StraightLength},$$

where stream length is the stream distance between elevation contours and straight length is the measured straight-line distance between each river meander apex or the central axis through braided stream sections. Gradient (G) was calculated as,

$$G = \frac{ElevationChange}{StraightLength},$$

where elevation change is the difference between the upstream and downstream elevation contours, 20 ft except one topographic map with 10 ft contours, and straight length is the straight-line distance between each river meander apex or the central axis through braided stream sections. River reaches were designated based on areas of similar channel pattern, gradient, and sinuosity. Due to the intermittentancy of headwater reaches, the first eight reaches were not used in levels two through four, physical sampling. Physical sampling and stream measurements began at State Highway 63 Bridge near Big Cedar, Oklahoma at reach nine.

Meander wavelength and amplitude were measured for each river meander using 2005 NAIP aerial photos in a GIS. Figure 2 shows how measurements were conducted.

Level 2 (Morphological Description): Morphological description and characterization of the river state or condition was accomplished with a longitudinal survey and transect sampling of the Kiamichi River. The longitudinal survey was completed in early spring 2005 when the river was navigable by canoe. Channel units (i.e. pool, riffle, and run) were classified from State Highway 63 Bridge near Big Cedar, Oklahoma to State Highway 3 Bridge near Antlers, Oklahoma. All channel units between pools in a reach were designated as a single sample unit, and 10% of the units ($N = 45$) were sampled (minimum of two per reach), including 10 mussel bed monitoring sites (Vaughn et al. 1996). Channel units can be classified differently depending on water levels (Hilderbrand et al. 1999), so we reassessed channel units at each site at the time of transect sampling, reclassified them if necessary, and placed transects across each distinct channel unit. Transects in riffles, runs, and short pools were centered in the channel unit, and transects in long pools were usually placed at one average bankfull width. Transect placement was adjusted to avoid road crossings and tributaries. At the 10 mussel bed monitoring sites, channel units were assessed for proper classification, reclassified if necessary, and transects were placed across all channel units.

Bankfull width and depth, flood-prone width, water surface slope (gradient), and 50 substrate particle b-axes (Wolman 1954) were measured at each transect. Transects were monumented using a Trimble GeoXT (Trimble Navigation Ltd., Sunnyvale, California) GPS receiver. GPS coordinates for all sites are in Appendix 2. Bankfull stage was defined as the channel maintaining flow (Dunne and Leopold 1978; e.g. highest elevation of deposition features). Bankfull width was measured from left to right bank looking downstream. Bankfull and wetted depth were measured 10 to 20 times per transect. Gradient was measured longitudinally across entire channel units (i.e. riffles, runs, and short pools) or two bankfull widths into long pools. Gradient was given a 0.0000001 value when it could not be detected in the field.

Transect survey data were entered into RiverMorph 3.0 software (Rivermorph LLC, Louisville, Kentucky), which calculates width/depth ratio, entrenchment ratio, bankfull area, wetted perimeter, hydraulic radius, Manning's n, estimated bankfull velocity, estimated bankfull discharge, and sheer stress. Particle counts were conducted along each transect. Sediment particles were measured systematically, with the toe-tip method, from bankfull to bankfull repeatedly until a total of 50 pebbles were measured. For equal representation of the entire channel bed, an effort was made to sample all 50 particles in one pass. A visual estimate of percent substrate class (e.g. bedrock, boulder, cobble, etc.) using the Wentworth scale was also recorded at each transect. Particle counts were entered into RiverMorph software, which calculates D16, D35, D50, D84, D95, D100, and particle class percentages (e.g. bedrock, boulder, etc.) Bank stability was measured for each sample unit using Pfankuch's bank stability rating (Pfankuch 1975).

For each transect many morphological variables were calculated. A width/depth ratio was calculated in RiverMorph using the equation;

$$W / D = W_{bkf} \big/ \overline{D_{bkf}},$$

where W_{bkf} is bankfull width and $\overline{D_{bkf}}$ is average bankfull depth. Entrenchment ratio was calculated in RiverMorph using the equation;

$$E = \frac{W_{fp}}{W_{bkf}},$$

where W_{fp} in flood prone width, measured at two times maximum bankfull depth, and W_{bkf} is bankfull width. Manning's *n* at bankfull was calculated in RiverMorph for each transect using Jarrett's equation;

$$n = (0.39)S^{0.38}R^{0.16},$$

where *S* is water surface slope and *R* is channel hydraulic radius (channel area / channel perimeter). Estimated bankfull velocity (*v*) was calculated in RiverMorph using the equation;

$$v = \frac{1}{n}R^{2/3}S^{1/2},$$

where *n* is Manning's n calculated using Jarrett's equation, *R* is channel hydraulic radius, and *S* is water surface slope. Estimated bankfull discharge (*Q*) was approximated in RiverMorph using the equation;

$$Q = vdw,$$

where *v* is estimated bankfull velocity, *d* is average bankfull depth, and *w* is average bankfull width. Froude number (a measure of tranquil versus rapid flow) at bankfull was calculated for each transect as;

$$F = v/\sqrt{gd},$$

where *v* is estimated water velocity at bankfull, *g* is the gravitational constant, and *d* is bankfull depth of flow. Reynolds number (a measure of laminar versus turbulent flow) was calculated as;

$$\mathrm{Re} = \frac{vR\rho}{\mu},$$

where *v* is estimated water velocity at bankfull, *R* is channel hydraulic radius (channel area / channel perimeter), ρ is water density (~ 1000 kg/m^3), and μ is molecular viscosity (1.002 for water). Sheer stress (τ_0) was calculated in RiverMorph using the equation;

$$\tau_0 = \gamma Rs,$$

where γ is the specific weight of water, R is the channel hydraulic radius, and s is the channel slope.

Linear regression was performed on all measured and calculated geomorphic variables using SAS 9.1 software (SAS Institute Inc., Cary, North Carolina). Variables were regressed against longitudinal distance to determine longitudinal trends in the variables.

Level 3 (Stream State or Condition): Level 3 analysis focused on quantitative description of the current condition or "state" of the river. We described stream condition in relation to stream stability and function. Stream condition was assessed using ten parameters. Broad-level flow regime was described as flow persistence (i.e. subterranean, ephemeral, intermittent, or perennial) and stream flow source (i.e. snowmelt, stormflow, glacial melt, spring-fed, ice flows, tidal influence, regulated flow, and other altered flows). Meander pattern was determined using 2005 NAIP aerial photographs. Stream size was defined as field measured bankfull width. Pfankuch's stability rating, calculated in RiverMorph using field observations, encompasses channel stability, bank erosion potential, aggradation/degradation potential, and riparian vegetation condition. Pfankuch's stability rating was then converted to reach condition using Rosgen (1996) stream class. Depositional features, debris or channel blockage, and channel alteration were recorded per site.

Level 4 (Validation): Level 4 analysis included quantification of flow and sediment regimes and verification of stream stability. Stream flow and sediment data from the Big Cedar and Antlers, Oklahoma USGS gauging stations were used to quantify these regimes. Stream discharge (cubic feet per second, cfs) was used to create a flow-duration curve. Suspended sediment discharge (tons per day, tpd) was used to create a transport-rate curve and defines threshold discharge (Q_t). The calculated product of these curves is a magnitude-frequency curve and defines effective discharge (Q_e). No USGS data were available for bedload sediment. Verification of stream stability is usually determined with long-term monitoring using repeated sampling at monumented reference sites. Monitoring can include comparisons of reference to control reaches and above to below or before to after stream altering impact, e.g. tributary impoundment. Long-term monitoring was not feasible in the project duration of two years. Stream stability verification was attempted using data from field sampling, USGS gauge stations, and aerial photograph interpretation.

Digital image scan aerial photographs from 1979, pre-impoundment of JFC, obtained from the USGS aerial photography field office and 1995, post-impoundment of JFC, DOQQ's (digital-ortho-quarter-quads) downloaded from the University of Oklahoma Geo Information Systems website (http://geo.ou.edu/) were imported into a GIS. The 1979 digital images were georeferenced and then on-screen digitized, creating a shape-file of both banks of Kiamichi River channel in 1979. The 1995 images were on-screen digitized creating a shape-file of both banks of Kiamichi River channel in 1995. These shape files were then compared to determine what changes may have occurred naturally and due to the impoundment of JFC. Deposition bars for both years were digitized, and there area and frequency were compared. Mean deposition bar area before and after and above and below was analyzed using ANOVA. A Student's t-test was used to assess mean sediment bar area below JFC before and after impoundment. Deposition bar frequency before and after and above and below was analyzed using a Chi-square test. A t-test was used to compare all morphological, substrate, and flow variables for the three sites directly above and below JFC confluence.

E. RESULTS AND DISCUSSION:

Level 1 (Geomorphic Characterization): The Kiamichi River is a 6th order stream with irregular meanders originating in the Ouachita Mountains near the Arkansas border. The river flows through the Ouachita Mountains and South Central Plains ecoregions (Woods et al. 2005) of southeastern Oklahoma meandering through Le Flore, Pushmataha, and Choctaw counties. The watershed is 4,700 square kilometers and is 90% forested (USDA 1990). Mixed pine-hardwood forests are dominated by short-leaf pine on south-facing slopes and hardwoods (i.e. oaks and hickories) on the north-facing slopes and bottomlands (Figure 3). The Kiamichi River Basin from the headwaters to Lake Hugo is underlain with folds of Pennsylvanian and Mississippian Era rocks (Heran et al. 2003). The river channel is underlain by the Mississippian formation (Figure 4). The Kiamichi River Basin is underlain by five different soil types; alfisols dominate in riverine areas (Figure 5).

The Kiamichi River flows east out of the Ouachita Mountains and is confined between these and the Kiamichi Mountains, turning south after the confluence with Jackfork Creek near Clayton, Oklahoma in Pushmataha County. Much of the river is contained by a series of narrow valleys with steep, rocky slopes, ranging from 4 to 20 km wide. The Kiamichi River Valley is best described as a Rosgen (1996) type "X" valley. Elevation ranges from 480 m (above mean sea level [MSL]) at the headwaters to 35 m MSL at the confluence with the Red River (Figure 6). The longitudinal profile for the Kiamichi River (Figure 7) shows no obvious knick points indicating no areas aggradation or degradation. The basin relief ratio was 0.00345.

Precipitation is relatively high and uniform in the Kiamichi River Basin, but slightly higher near the headwaters (Figure 8). Average annual precipitation is 119 cm, ranging from 109 to 144 cm, west to east. Most precipitation occurs in late spring (May), with moderate rainfall the remainder of the year (Figure 9). This precipitation pattern results in a varied discharge pattern from upstream to downstream (USGS gauging stations; Big Cedar #07335700, Clayton #07335790, and Antlers #07336200 [Figure 10]).

Few landforms show evidence of channel movement or change, only four oxbow lakes (Figures 11-13) and two areas with meander scars (Figure 14 and Figure 15) were discernable from interpretation of 2005 NAIP aerial photos. Potential channel movement or change occurred in areas of more torturous river meanders and less valley constriction (Figure 16).

Seventeen stream reaches were designated based on areas of similar broad-scale geomorphic characteristics (i.e. stream pattern, gradient, and sinuosity; Figure 17). Reach 14 was split at the JFC tributary confluence making eighteen total reaches. Broad-scale geomorphic characteristics, channel shape characteristics (i.e. channel width, channel depth, and cross-sectional area), and channel form characteristics (i.e. meander wavelength and amplitude) indicate that the Kiamichi River is an "F" type stream. F-type streams are entrenched meandering riffle/pool channels on low gradients with high width/depth ratios. F-type streams can develop high bank erosion rates and have significant bar deposition (Rosgen 1996). High bank erosion potential was observed at most sites. Aerial photographs show significant bar deposition (see Figure 25).

Reach gradient decreased rapidly ($y = 11.475x^{-1.085}$, $R^2 = 0.9585$) from 3.24% in the headwaters to 0.03% downstream (Table 2). Reach sinuosity showed no downstream trend and ranged from 1.09-2.04. This is consistent with Schumm (1968) who found sinuosities ranging from 1 to 2.7 in low gradient streams (0.01% to 0.4%). Meander wavelength per reach increased exponentially downstream ($y = 89.58e^{0.0098x}$, $R^2 = 0.7186$), ranging from 354.89 m to 2751.19 m. Wavelength meanders are generally 10 to14 bankfull widths (Leopold et al. 1964). Average meander wavelength for reaches in the Kiamichi River was 11 to 60 bankfull widths. Meander amplitude per reach also increased exponentially downstream ($y = 65.832e^{0.0111x}$, $R^2 = 0.7788$), ranging from 103.66 m to 978.97 m. No channel shape characteristic had a significant linear trend. Bankfull width per reach ranged from 23.24 m to 50.80 m. Bankfull maximum depth per reach ranged from 1.12 m to 1.78 m. Bankfull cross-sectional area per reach ranged from 15.55 m^2 to 67.62 m^2.

Level 2 (Morphological Description): Stream channel morphological variables (i.e. bankfull width, maximum bankfull depth, bankfull area, width/depth ratio, entrenchment ratio, gradient, Manning's n, and Pfankuch's stability rating) are influenced by flow and sediment regimes, valley morphology, basin relief, and substrate (Rosgen 1996). Manning's n values for the Kiamichi River were comparable to those expected for this stream type based on Rosgen (1996) (Table 3). Bankfull width increased significantly with longitudinal distance downstream ($R^2 = 0.1973$, p=0.0025; Figure 18). Channel width generally increases downstream as the square root of discharge (Leopold et al. 1964). Bankfull area and width/depth ratio also increased significantly with downstream distance ($R^2 = 0.1313$, p=0.0156; $R^2 = 0.2822$, p=0.0002; respectively). Bankfull cross-sectional area is influenced by bankfull magnitude and discharge. Width/depth ratio is influenced by roughness, bank stability, entrenchment, and boundary sheer stress (Rosgen 1996). Stability rating decreased significantly with longitudinal distance ($R^2 = 0.1228$, p=0.0197) indicating an increase in channel stability downstream. We found no significant linear trends in maximum bankfull depth, entrenchment ratio, channel unit gradient, and Manning's n. Channel depth has been shown to vary considerably by reach (Rosgen 1996). Entrenchment ratios are dependent on bankfull depth and valley morphology, both highly variable influences. Channel unit gradient could be expected to change longitudinally but was highly variable and immeasurable in many areas. Manning's n is influenced by gradient, hydraulic radius, and velocity. Channel unit gradient and hydraulic radius were highly variable and showed no linear trends.

Channel gradient decreases in the downstream direction with increasing discharge and generally corresponds to a decrease in sediment size (Rosgen 1996). There was no indication of decreasing sediment size in the Kiamichi River above Lake Hugo (Tables 4 and 5). There was no significant linear relationship between substrate diameter variables (e.g. D50) and longitudinal distance downstream. However, substrate class percentages differed longitudinally. Measured gravel and cobble percentages increased significantly with longitudinal distance downstream ($R^2 = 0.2424$, p=0.0007; $R^2 = 0.0907$, p=0.0470; respectively; Figure 19). Bedrock percentage decreased significantly longitudinally ($R^2 = 0.1384$, p=0.0129). Bedrock was observed sporadically throughout the stream. Particle diameter may be related to longitudinal distance in a nonlinear fashion, but we found no longitudinal difference in particle diameter above to below of JFC (see Level 4). Site statistics and linear regression results for visual estimates of substrate percentage are shown in Appendix 1.

Flow (i.e. estimated bankfull velocity, estimated bankfull discharge, Froude number, Reynolds number, and sheer stress) site statistics are in Table 6. Estimated bankfull discharge increased significantly with longitudinal distance downstream ($R^2 = 0.1562$, $p=0.0079$; Figure 20). Estimated bankfull velocity had a nearly significant ($R^2 = 0.0802$, $p=0.0625$) increase longitudinally. Velocity and discharge would both be expected to increase downstream. Using channel unit gradient to calculate bankfull velocity may be masking downstream velocity trends or the trends may be non-linear.

Level 3 (Stream State or Condition): Sites were categorized using stream condition variables (Rosgen 1996). The majority of sites (68%) were classified as F4 streams (Table 9). Using Rosgen's (1996) definition for perennial streams ("Surface water persists year long"), streamflow in the Kiamichi River is perennial for all sites. Sites in the headwaters, reaches 1-9, have surface water year round with no perceptible surface flow at low water levels. The Kiamichi River streamflow does exhibit seasonal variability indicating a stormflow runoff influenced system (Rosgen classification P:2). Areas of the river may be spring fed; however, this was not determined in the field. The Kiamichi River has irregular meanders (Rosgen classification M-3). Two areas of the river have almost tortuous meanders (see Figure 16). Stream size (bankfull width) ranged from 15 to 71 m, (Rosgen categories S-6 to S-9). As stated above (Level 2 (Morphological Description), bankfull width increased significantly in the downstream direction. Bank erosion potential was high in many areas due to high bank gradients, low bank vegetation density, and small bank material sizes; although overall channel stability was high. Pfankuch stability ratings ranged from 64 to 96. Pfankuch (1975) stability ratings generally range from 38 to 144 with higher numbers indicating poor channel stability. After converting the sites to reach condition by stream type, most sites were rated good to excellent, only two sites rated fair and one poor (see Table 7). There was no indication of bed aggradation or degradation at our sampling sites. At this sampling scale, using Rosgen (1996) categories to classify depositional bars was not feasible. Depositional features did not fit neatly into classes, possibly because sample sites did not encompass entire pools or stream meanders. Point bars were present at some sites with meander curvature. Most sites were straight sections of stream with depositional features that could be, when present, classified as side or mid-channel bars. Side and mid-channel bars occasionally exceeded 2-3 channel widths. There were many areas with mid-channel bars and vegetated islands. One third of sample sites had some type of woody debris present. Most woody debris was categorized as large. Frequently an entire tree would be observed within the channel. Most debris was well embedded in banks and appeared stable. Three sites contained large woody debris jams causing channel erosion.

Thirteen of forty-five sites were subject to some human alteration or disturbance. The Kiamichi River receives high human traffic at accessible areas (i.e., bridge and road crossing) and many areas are used as water for livestock. There are many fords and livestock trails in areas of shallow water (e.g. riffles and low-water runs). There are also several areas that have active disturbance to the channel (e.g. maintained low head dams and channel bulldozing). Rosgen (1996) F4 classified streams are, in general, extremely sensitive to disturbance, have poor recovery potential, a very high sediment supply, very high bank erosion potential, and moderate vegetation control on width/depth ratio stability.

Level 4 (Validation): The Kiamichi River is a hydrologically flashy stream with no flow in dry summer months and extreme flood flows annually (Figure 21). The Big Cedar flow-duration curve (Figure 22) is indicative of the flashy nature of the Kiamichi River and shows that low flows dominate at this headwater location. The Antlers flow-duration curve also shows the flashy nature of the stream at a higher magnitude as is expected at this downstream location. The Big Cedar log-linear transport-rate ($SS=0.0155Q^{1.08}$, $R^2=0.821$, $p<0.00001$) indicates a Q_t of 0.1 cfs. The Antlers log-linear transport-rate ($SS=0.0427Q^{1.18}$, $R^2=0.784$, $p<0.00001$) indicates a Q_t of 3.5 cfs. The Big Cedar magnitude-frequency curve peak indicates a Q_e equal to 4500 cfs, and the Antlers magnitude-frequency curve peak indicates a Q_e equal to 25000 cfs. These effective discharge levels are greater than the Kiamichi River bankfull level. Effective discharge is defined as the flow that does the most work or moves the most sediment. Stream channels not large enough to convey the sediment carried by the effective discharge will deposit that sediment in the stream channel. The expected result of this is channel widening over time and depositional bar growth in frequency and area. There is evidence of an increase in sediment deposition over time in the stream channel (see Figure 24). There is no conclusive evidence of channel widening over time (except at the JFC confluence; see Figure 23). This may be attributable to the suppression of extreme flood flows by Sardis Lake and other impoundments and catchments in the watershed.

When a channel is not changing in dimension, pattern or profile and is neither aggrading nor degrading, it is considered stable. Channel stability is dependent on stream ability to consistently transport its sediment load (Rosgen 1996). There is little apparent change in the Kiamichi River channel shape over time. Aerial photographs were taken at different times of the year, but streamflows were of similar magnitude and therefore comparable between years (Appendix 3). Few areas appear affected, with the exception of the channel at the JFC confluence. Channel change over time is evident at the JFC confluence (Figure 23). Deposition patterns have changed in the Kiamichi River between 1979 and 1995 (Figure 24). Deposition bar before and after, and above and below JFC indicate no statistically significant difference in deposition bars ($df = 2$, $p=0.0671$). However, there is a significant difference (t-test $\alpha=0.05$; $p=0.0487$) in deposition bar area below JFC between years and deposition bar frequencies did deviate from expected values (Chi-square $\alpha=0.05$; $df = 1$, $p<0.0001$).

Dams interrupt and alter most of a river's ecological processes including flow of water, sediment, nutrients, energy, and biota. The three major geomorphic responses to stream impoundment are incision, aggradation, or changes in channel pattern. Changes in streambed substrate, channel width, lateral migration rates, riparian vegetation composition, and bank collapse rates may also occur (Ligon et al. 1995). Changes in flow and sediment regimes will alter stream channel dimensions (Rosgen 1996). A comparison of morphological variables bankfull width, bankfull area, and width/depth ratio indicate that they were higher downstream of JFC than above. These variables changed as expected longitudinally. Entrenchment ratio and Pfankuch's stability rating were higher upstream of JFC. Substrate variables sand and bedrock percentage were higher upstream of JFC. Bedrock was observed sporadically and is influenced by underlying geology. Sand percentage results were contrary to expectations; sand percentages are expected to increase longitudinally. Gravel percentages were higher downstream of JFC. This is expected longitudinally. There was no significant difference in substrate diameter above/below JFC. Flow variables bankfull velocity, bankfull discharge, Froude number, and

Reynolds number were all higher downstream of JFC. These are all expected longitudinal changes.

Our comparison of the six sites closest to JFC indicated that the morphological variables bankfull width, maximum bankfull depth, and bankfull area were higher upstream of JFC. This is contrary to the comparison of all sites and longitudinal expectations. Substrate variables D35, D50, D84, and D95 were all higher downstream of JFC. There are more large size particles downstream of JFC. Particle diameters are expected to decrease longitudinally. Clay and cobble percentages were also higher downstream of JFC. Clay percentage would be expected to increase longitudinally, but cobble percentage is expected to decrease longitudinally. Sand percentage was higher upstream of JFC. This is contrary to longitudinal expectations but similar to results from pair-wise comparison of all sites. Sand percentage is expected to increase longitudinally. No flow variables were significantly different between these sites.

The larger particle sizes below JFC indicate that there is either an outside source of large size sediment particles or a change in flow competency. Reservoirs may act as a sediment sink decreasing suspended sediment load and trapping coarse load (Petts 1982). Flows from JFC, if unable to acquire enough sediment to fill competency potential, may be scouring the stream below the confluence removing smaller sized particles downstream.

The impoundment of Jackfork Creek has had an impact on the geomorphology of the Kiamichi River; however the impact appears localized around the JFC confluence. Although the Kiamichi River was classified as an F4 stream, it exhibits stable stream channel characteristics and does not appear to be adjusting on a large-scale to any disturbance.

We make the following recommendations:

1. Further research is needed to delineate references reaches on the Kiamichi River. There are several segments along the river with similar geomorphic characteristics. Further analysis of the geomorphic data we collected, along with additional data, could be used to delineate these segments and representative reaches within them.
2. The Kiamichi River is currently adjusting to changes in flow regime. Three monumented sites should be monitored for future change: a site immediately below Jackfork Creek, a site in Reach 12 which had the most potential for bank movement and channel adjustment, and a site in Reach 16 which appears stable despite apparent impacts from the impoundment of Jackfork Creek.
3. The impoundment of Jackfork Creek has affected the geomorphology of the Kiamichi River near the confluence of the creek. Channel shape and substrate characteristics are significantly different below the Jackfork Creek confluence. We recommend that Sardis Lakes releases should mimic the natural flow and sediment regimes to aid in maintaining a stable stream channel on the Kiamichi River.

F. SIGNIFICANT DEVIATIONS: None.

G. COSTS: $69,333

H. PREPARED BY:______________________________

Sabrina Rust, Graduate Research Assistant
Oklahoma Cooperative Fish and Wildlife Research Unit
Oklahoma State University, Stillwater, OK 74078

William L. Fisher, Co-Project Leader
Oklahoma Cooperative Fish and Wildlife Research Unit
Oklahoma State University, Stillwater, OK 74078

Richard A. Marston, Co-Project Leader
Department of Geography
Kansas State University, Manhattan, KS 66506

I. DATE: 15 August 2006

J. APPROVED BY:______________________________

Natural Resources Section

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John Stafford, Federal Aid Coordinator
Oklahoma Department of Wildlife Conservation

K. LITERATURE CITED

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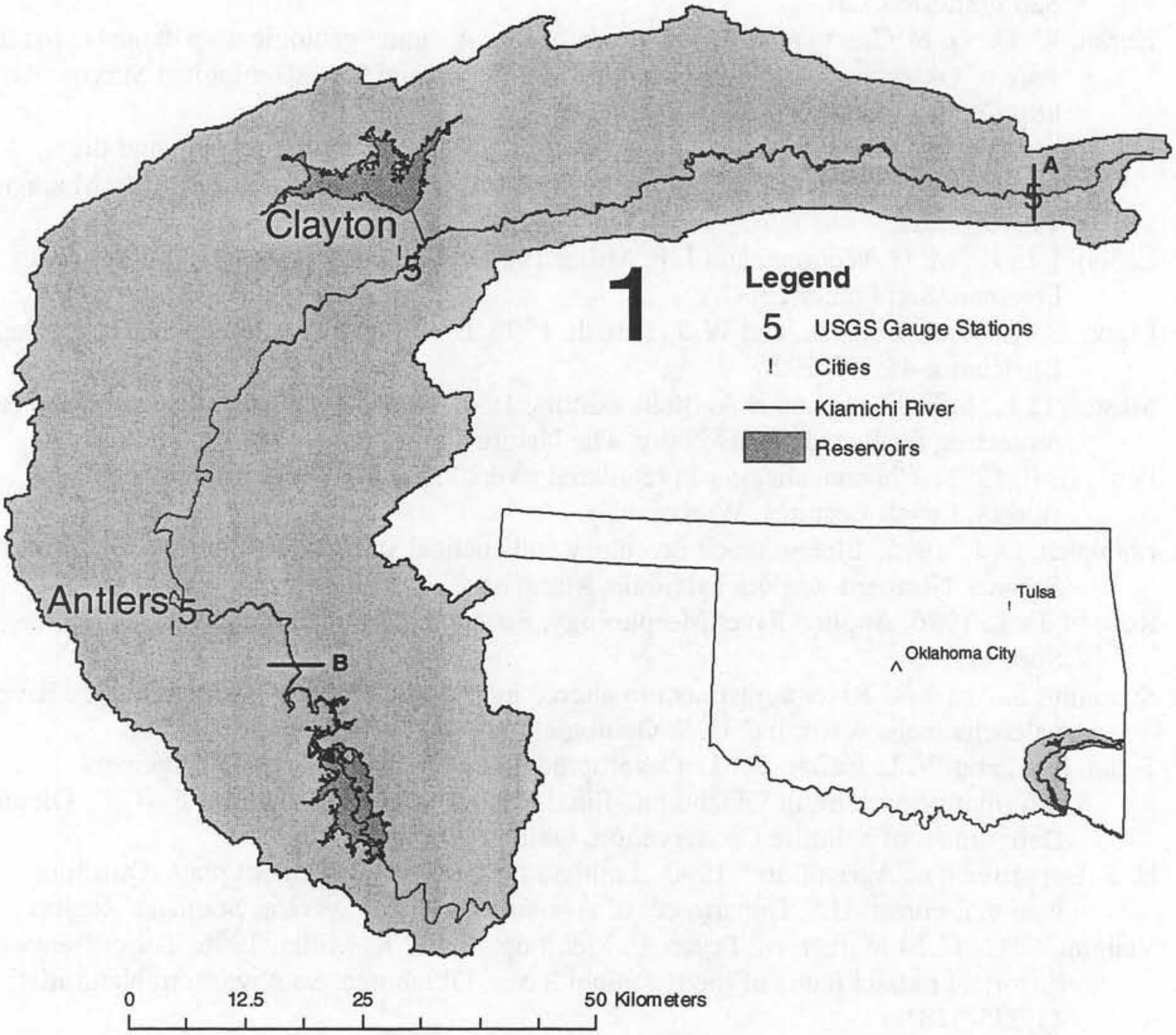


Figure 1. Study area. Kiamichi River watershed, USGS gauge stations, and sample starting (A) and ending (B) points. Inset shows Kiamichi River watershed. Figure information taken from Oklahoma Streams Information Systems (OSIS; Tejan and Fisher 2001).

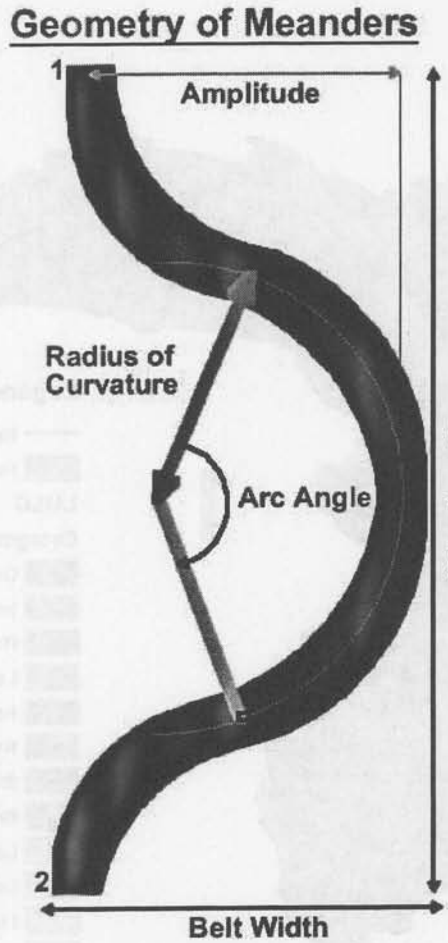


Figure 2. Meander geometry, showing how meander wavelength and amplitude was measured. Taken from State University of New York College of Environmental Science and Forestry (SUNY ESF) fluvial geomorphology website (http://www.fgmorph.com) 19 July 2006.

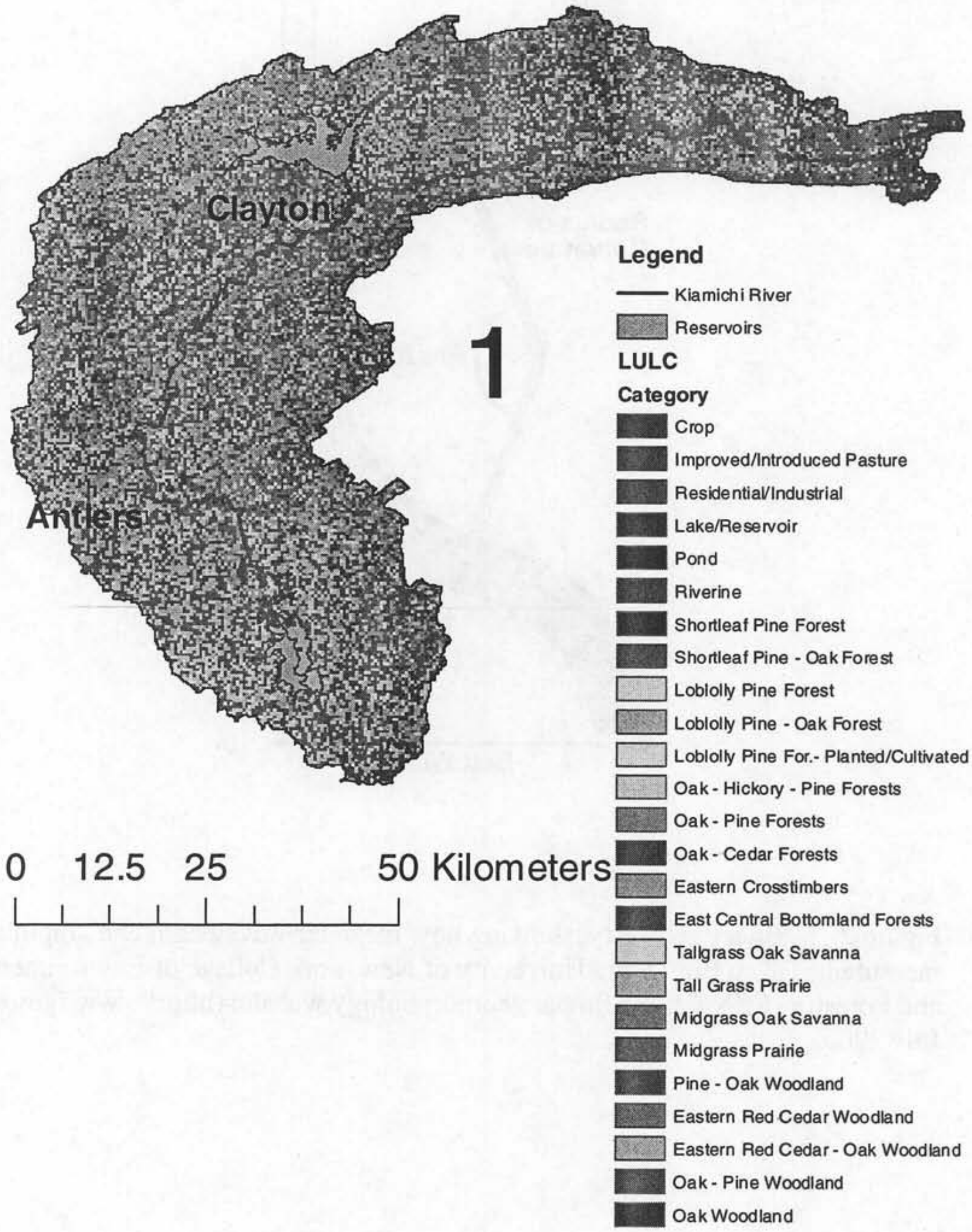


Figure 3. Land cover and usage for the Kiamichi River watershed. Figure information taken from OSIS (Tejan and Fisher 2001).

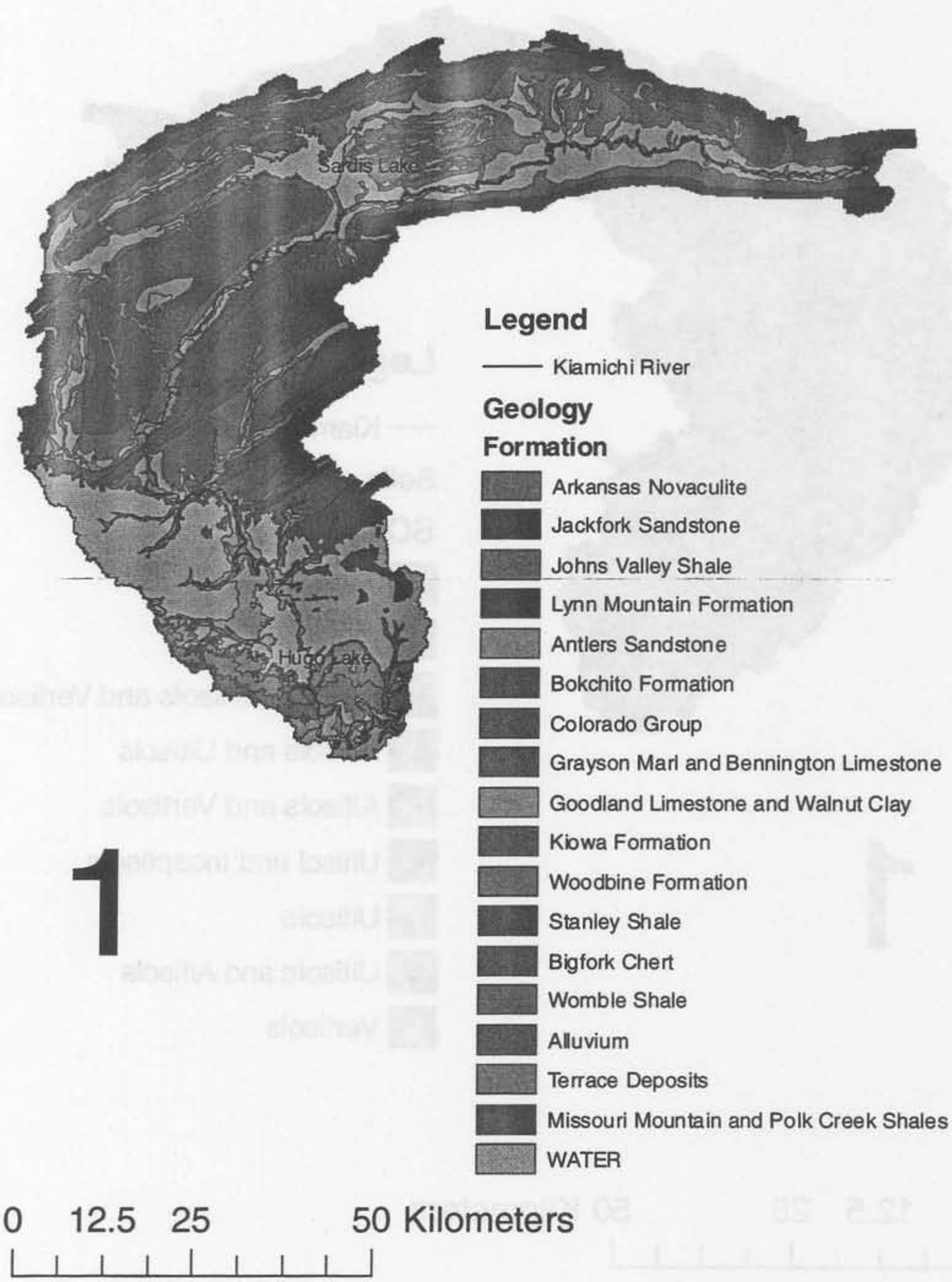


Figure 4. Geology for the Kiamichi River watershed. Figure information taken from Heran et al. 2003.

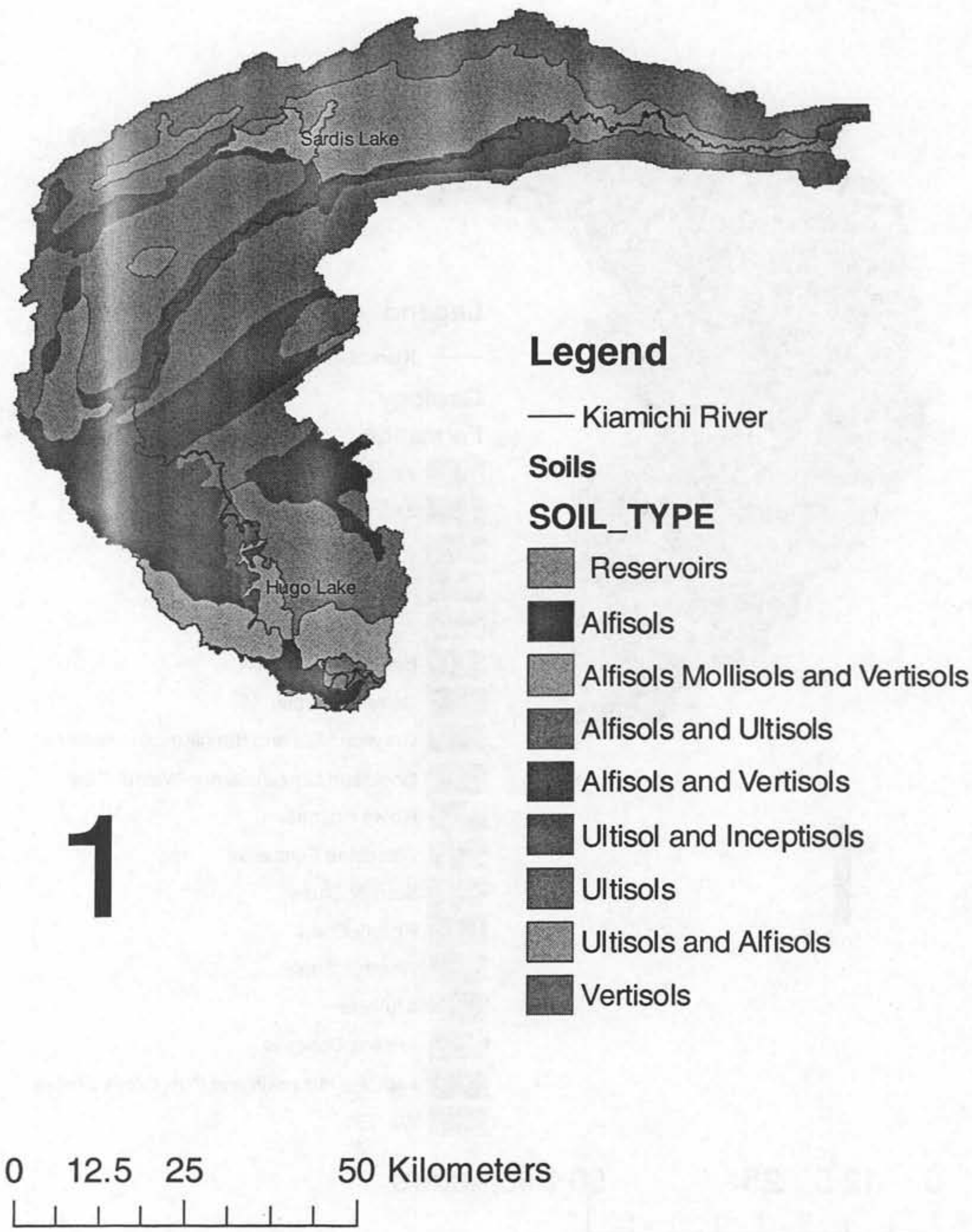


Figure 5. Soils for the Kiamichi River watershed. Figure information taken from OSIS (Tejan and Fisher 2001).

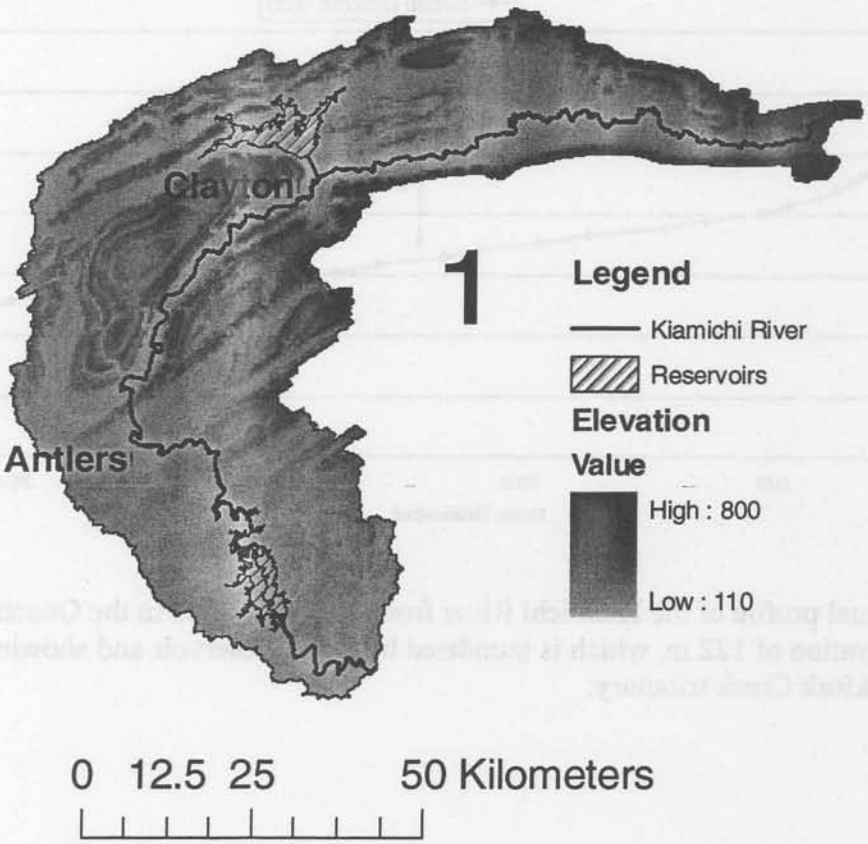


Figure 6. Map of the Kiamichi River watershed showing elevation in meters. Figure information taken from OSIS (Tejan and Fisher 2001).

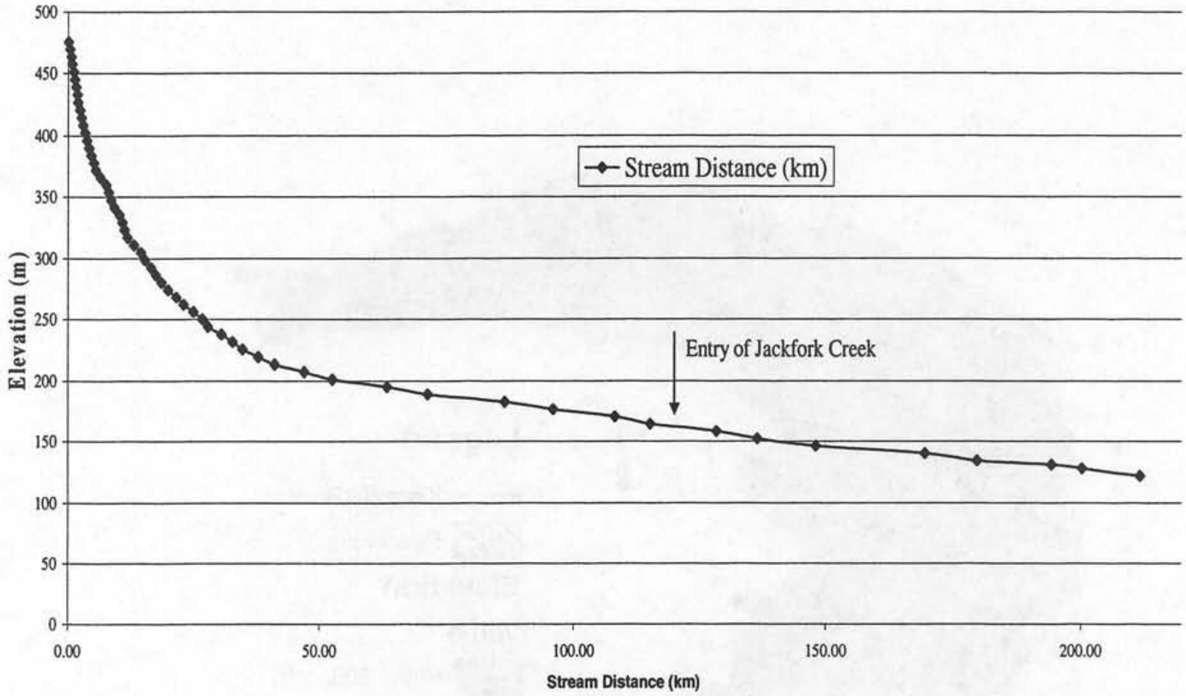


Figure 7. Longitudinal profile of the Kiamichi River from the headwaters in the Ouachita Mountains to an elevation of 122 m, which is inundated by Hugo Reservoir and showing the confluence with Jackfork Creek tributary.

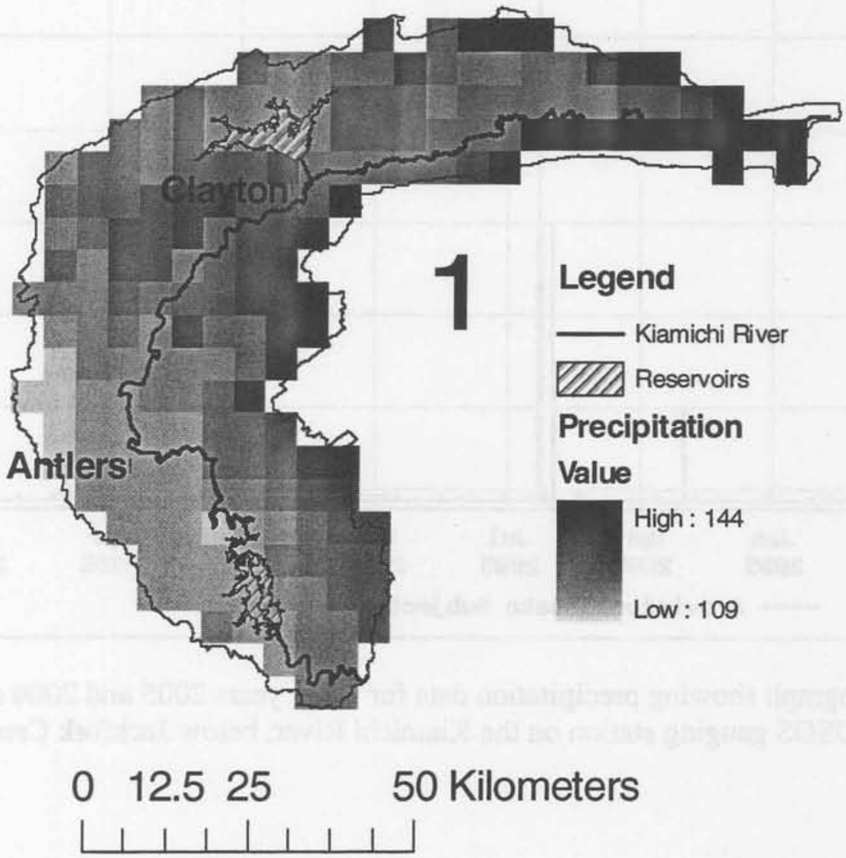


Figure 8. Map of the Kiamichi River watershed showing average yearly precipitation in centimeters. Figure information taken from OSIS (Tejan and Fisher 2001).

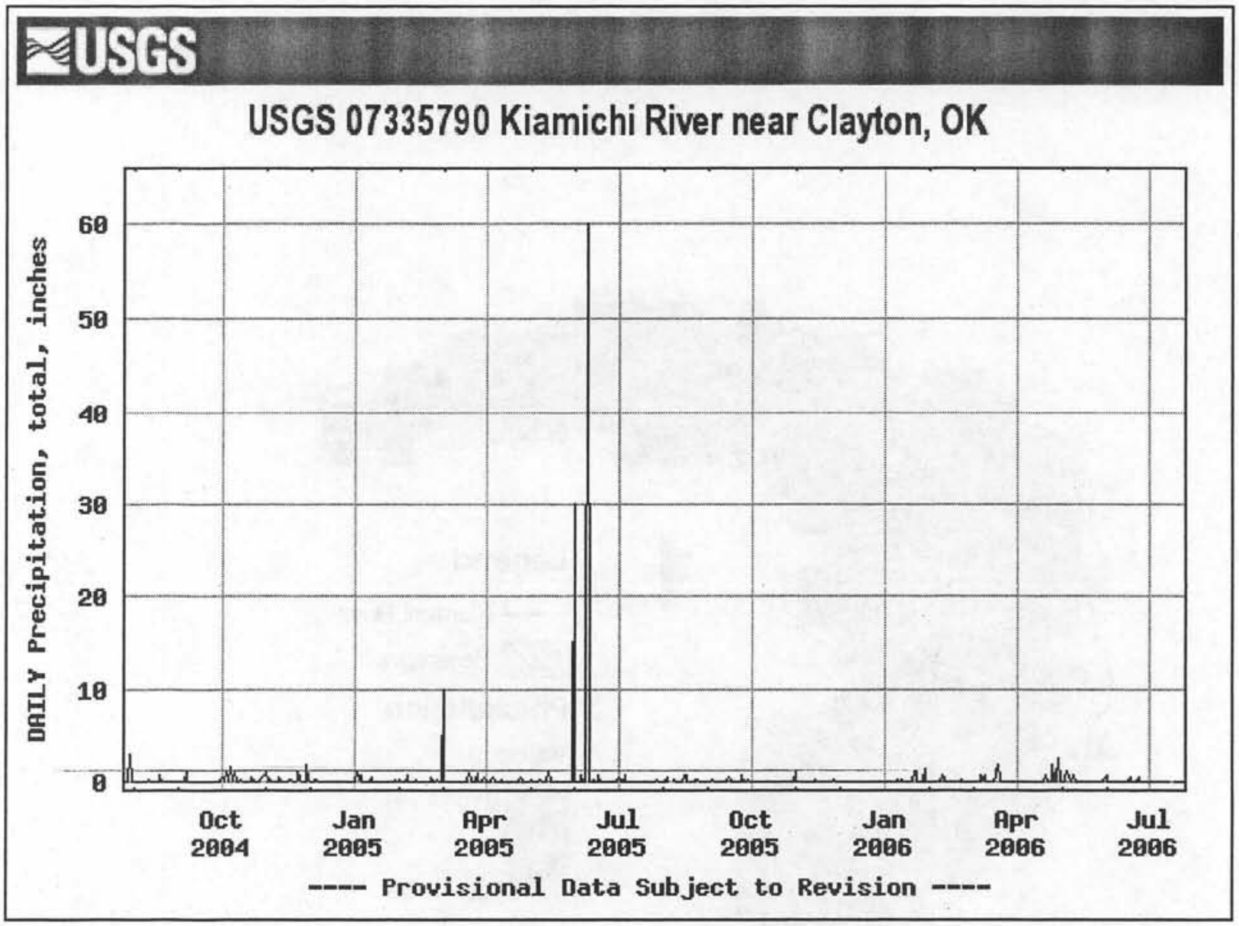


Figure 9. Daily hydrograph showing precipitation data for water years 2005 and 2006 at the Clayton, Oklahoma, USGS gauging station on the Kiamichi River, below Jackfork Creek.

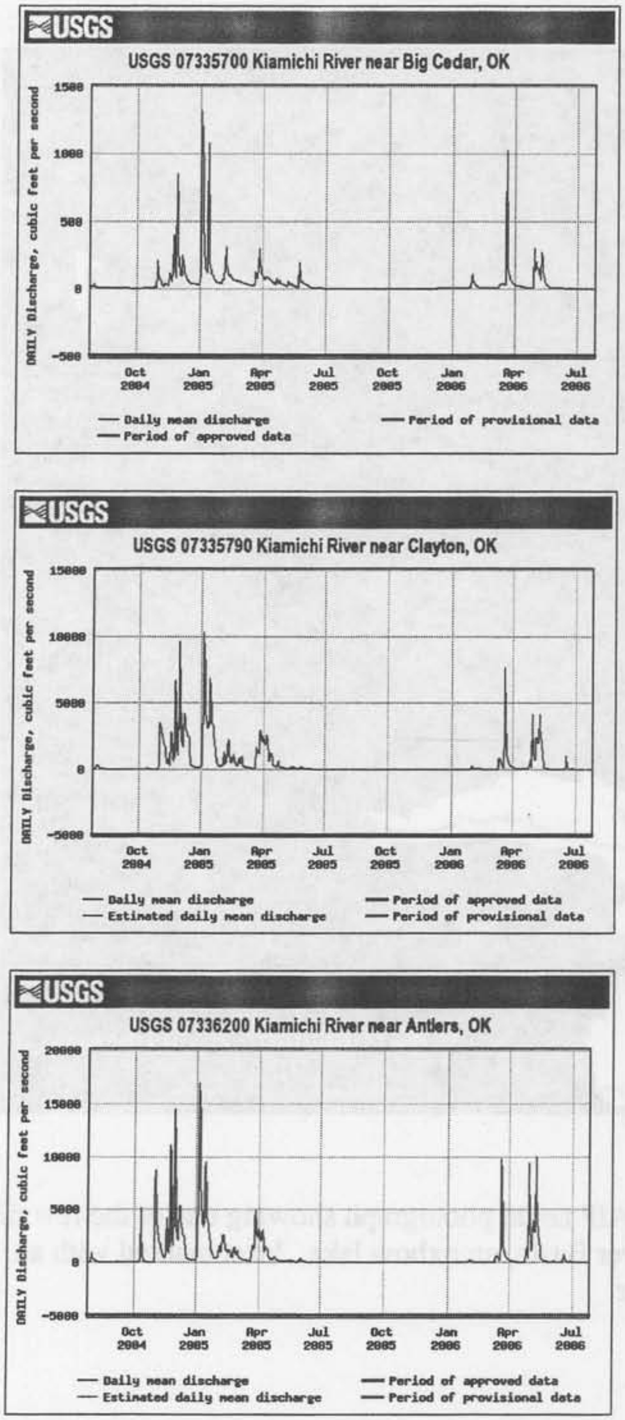


Figure 10. Daily hydrographs showing discharge of the Kiamichi River over water years 2005 and 2006 at the Big Cedar (top), Clayton (middle), and Antlers (bottom) USGS gauging stations, respectively.

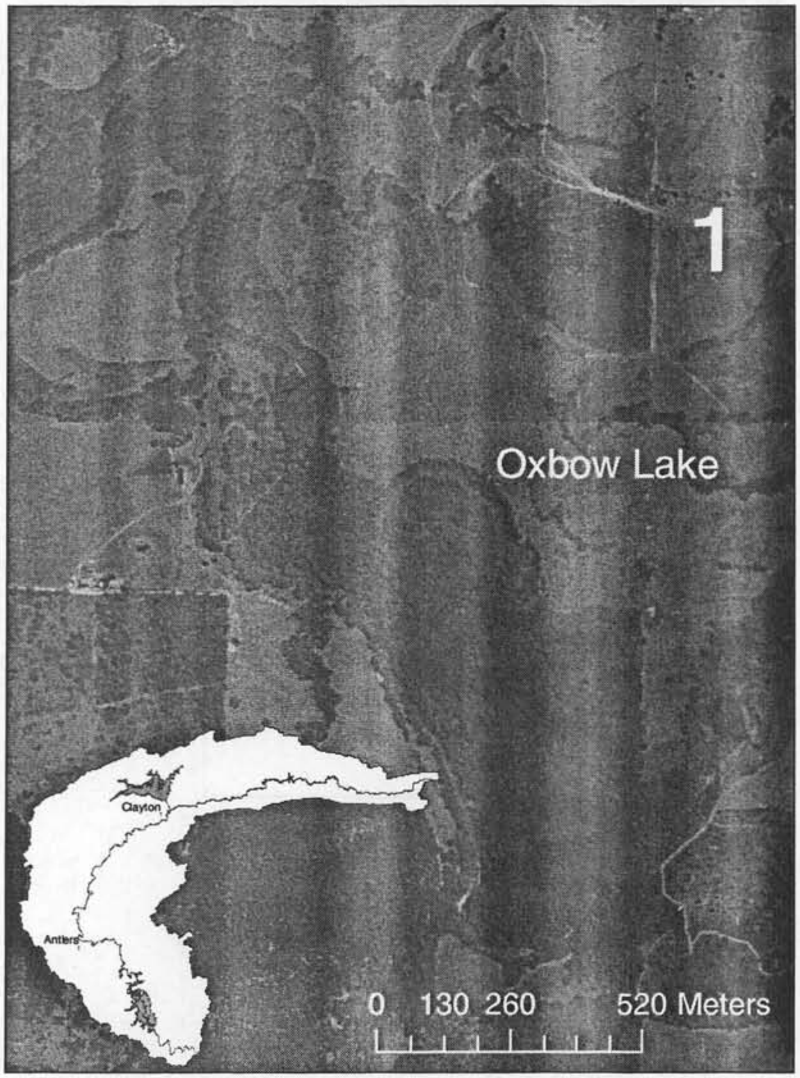


Figure 11. 2005 NAIP aerial photograph showing one of the few discernable landforms in the Kiamichi River Basin, an oxbow lake. Inset marked with an * to indicate landform location on the river.

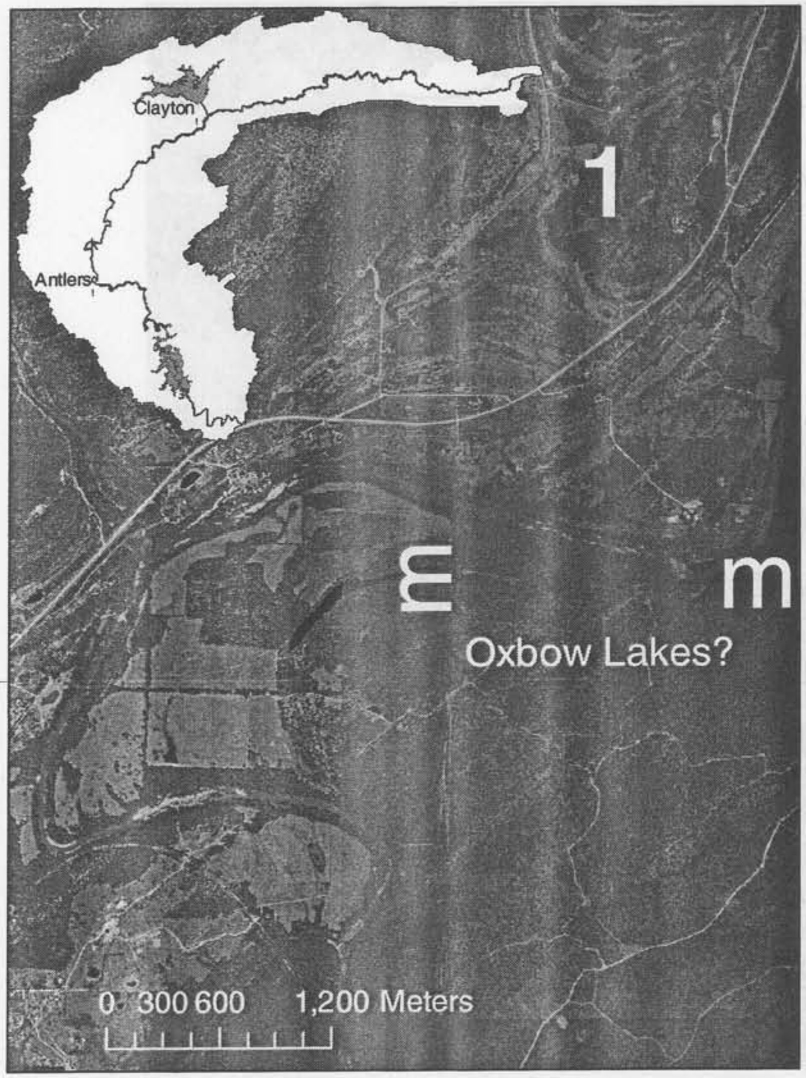


Figure 12. 2005 NAIP aerial photograph showing potential oxbow lakes. Inset marked with an * to indicate landform location on the river.

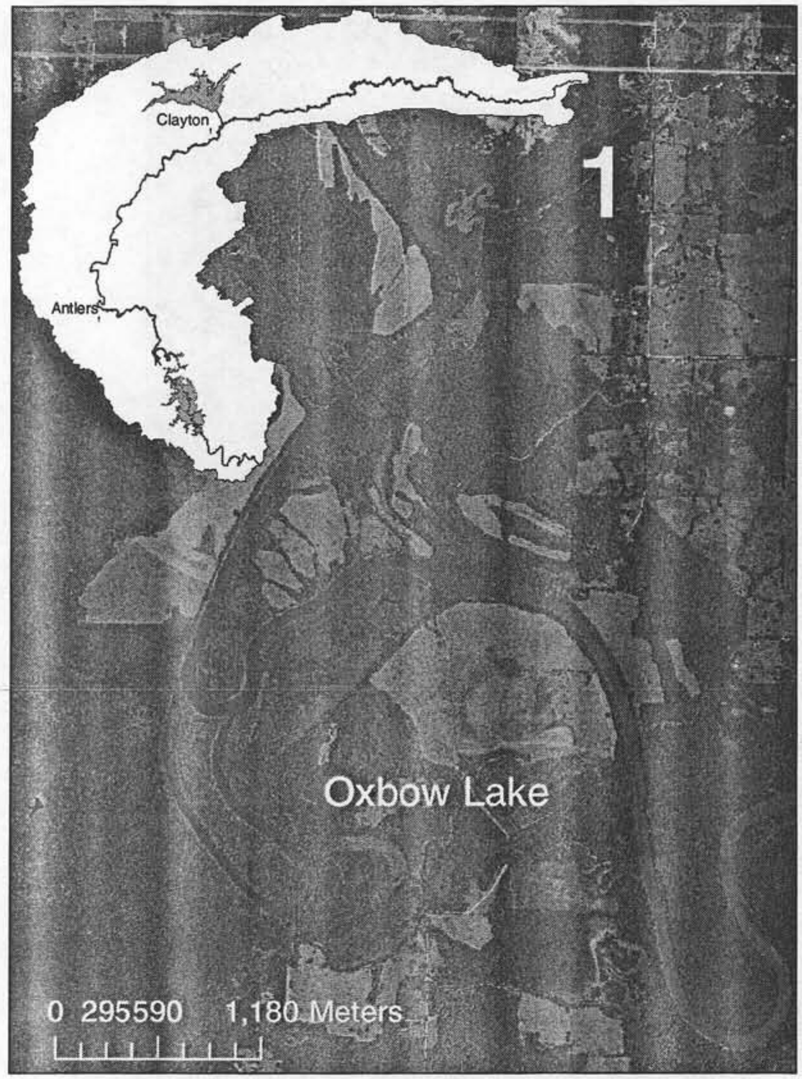


Figure 13. 2005 NAIP aerial photograph showing one of the few discernable landforms in the Kiamichi River Basin, an oxbow lake. Inset marked with an * to indicate landform location on the river.

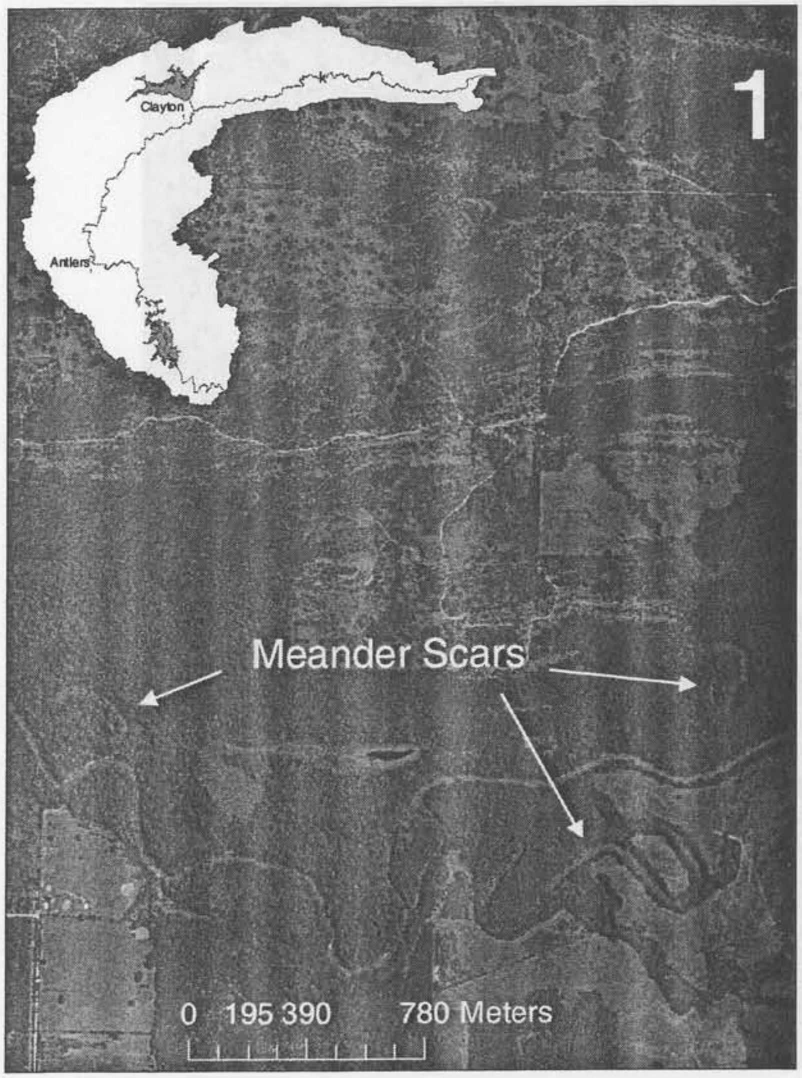


Figure 14. 2005 NAIP aerial photograph showing river meander scars. Inset marked with an * to indicate landform location on the river.

Figure 15. 2005 NAIP aerial photograph showing one of the few discernable landforms in the Kiamichi River Basin, a meander scar. Inset marked with an * to indicate landform location on the river.

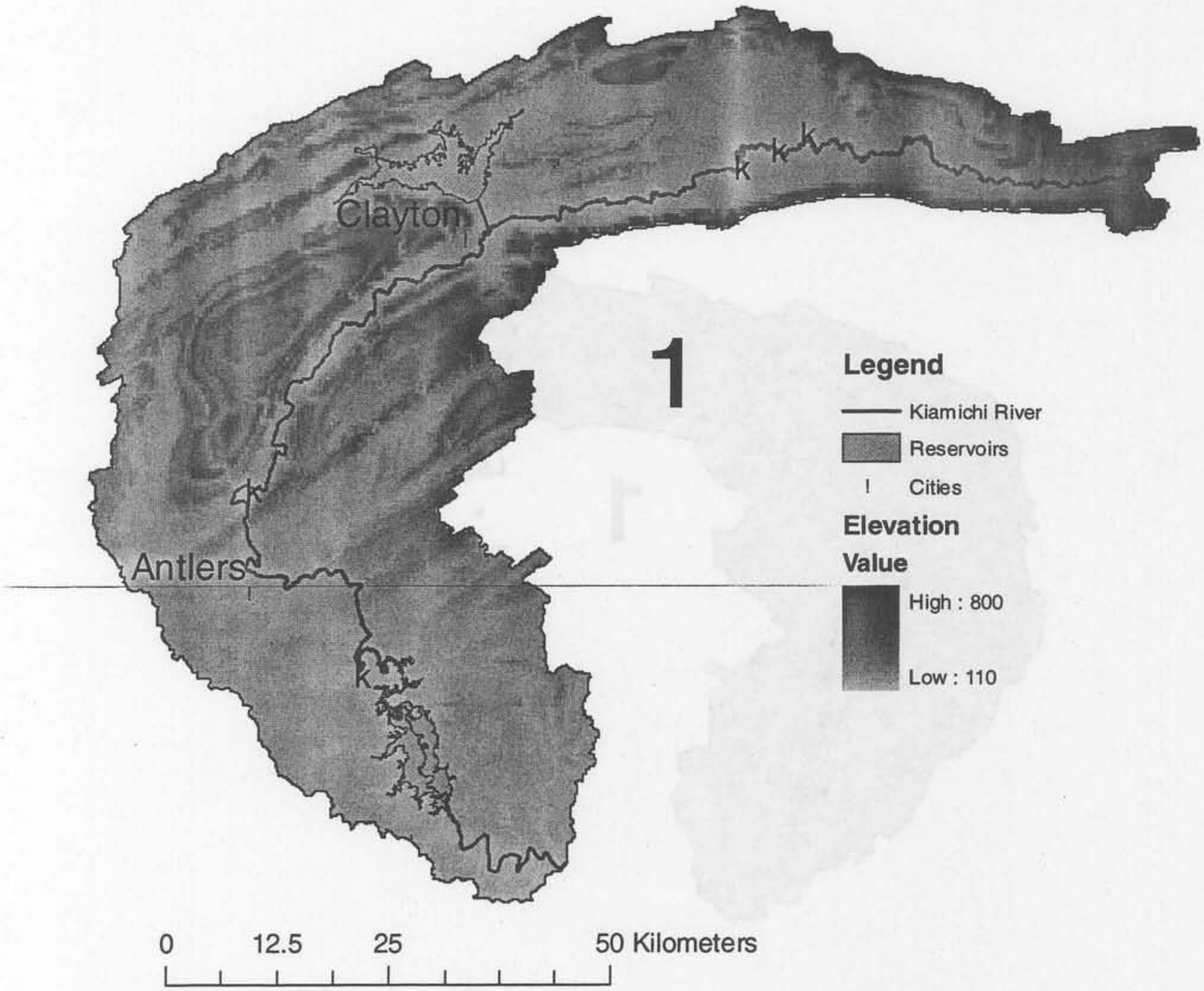


Figure 16. Elevation map showing valley constriction and landforms (*) that are associated with less constricted areas.

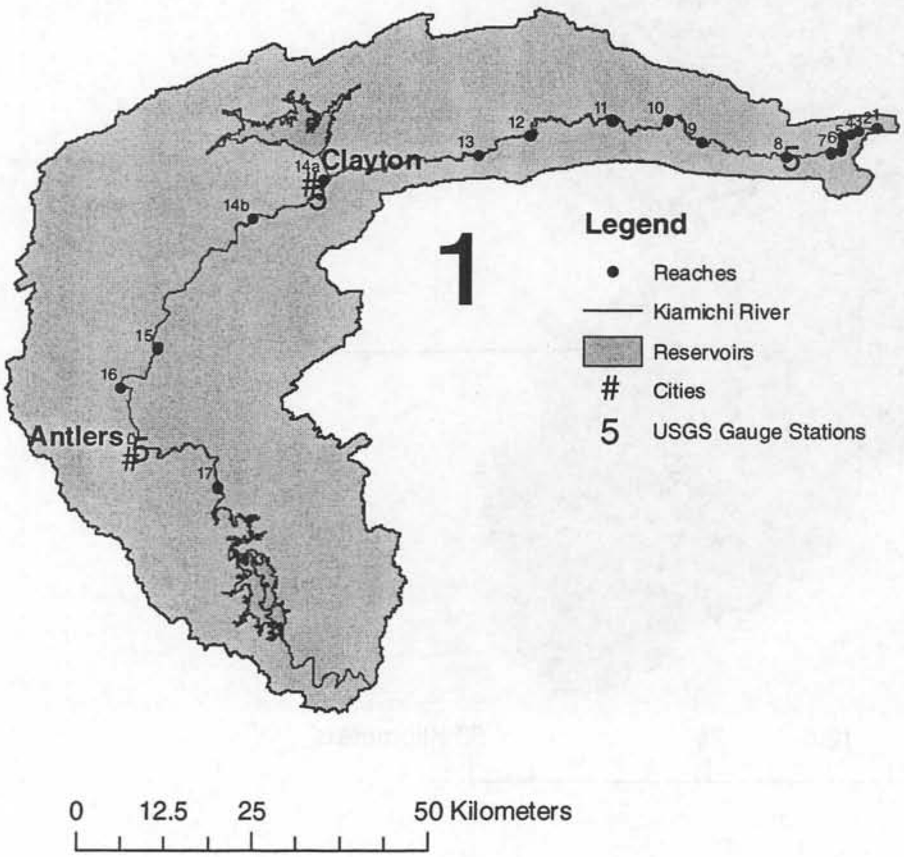


Figure 17. Delineated stream reaches. Circle symbols show the end of specified reach.

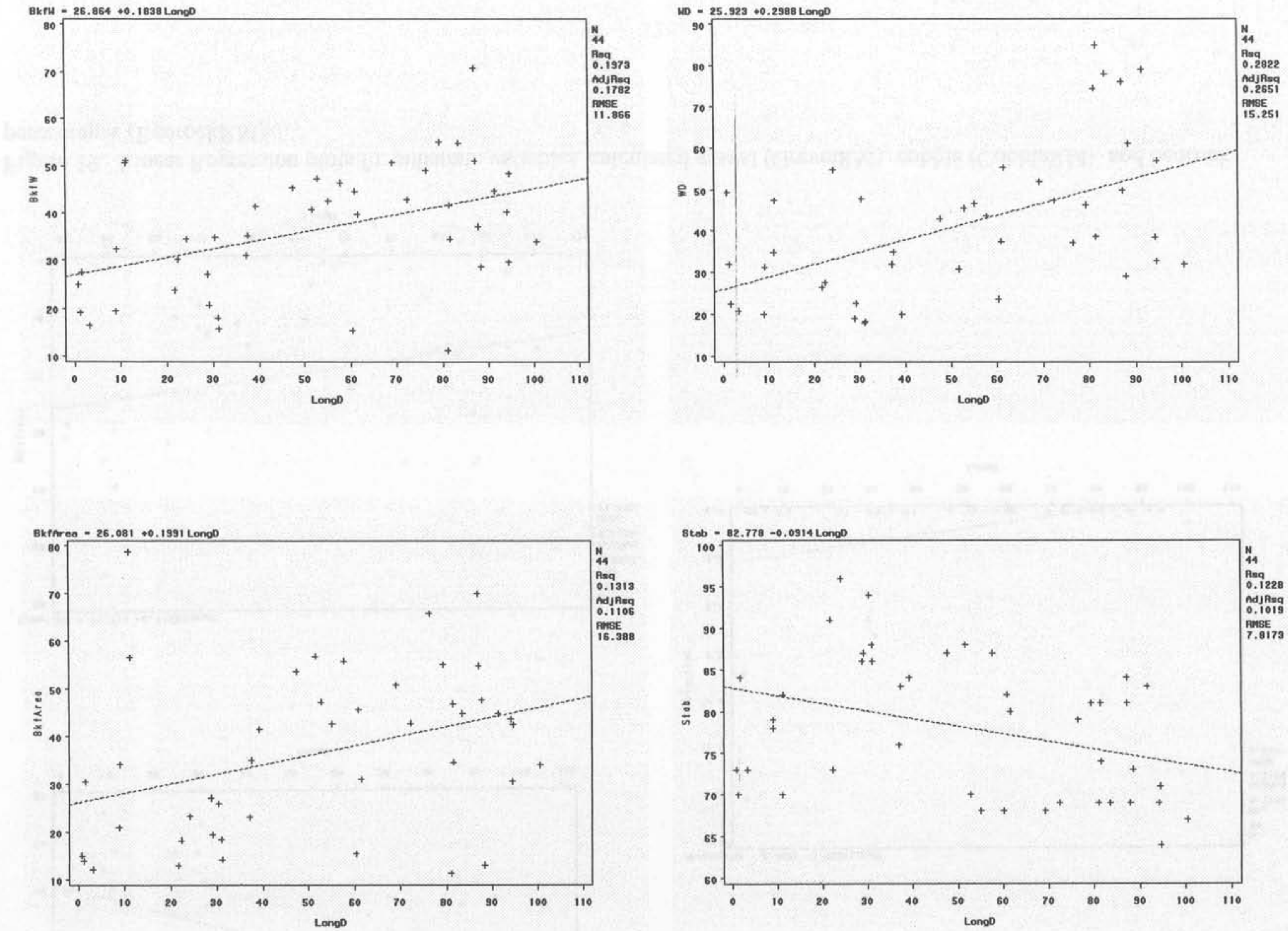


Figure 18. Linear Regression plots for morphological variables, bankfull width (BkfW), bankfull area (BkfArea), width/depth ratio (WD), and Pfankuch's stability rating (Stab).

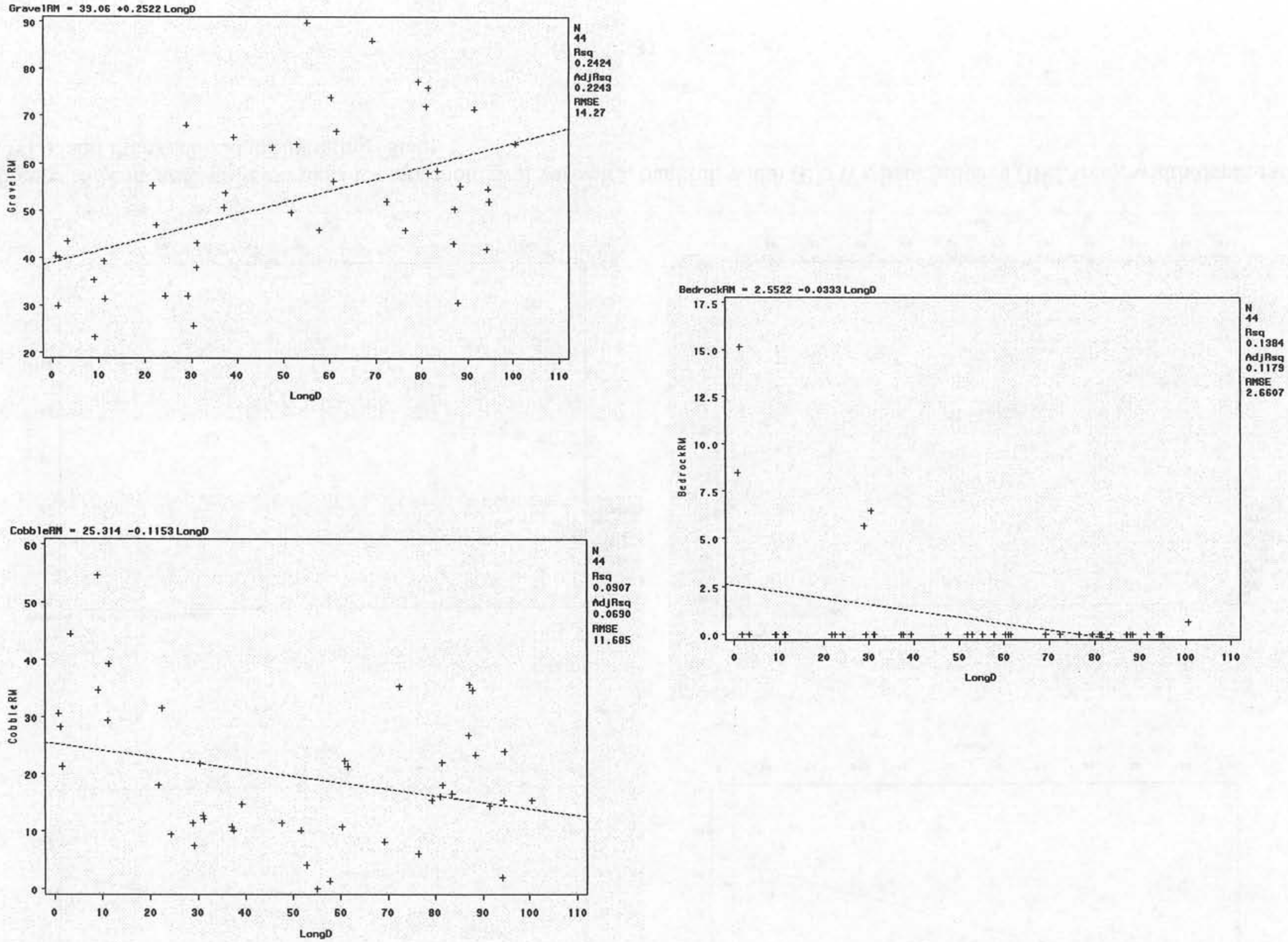


Figure 19. Linear Regression plots for substrate variables, calculated gravel (GravelRM), cobble (CobbleRM), and bedrock percentages (BedrockRM).

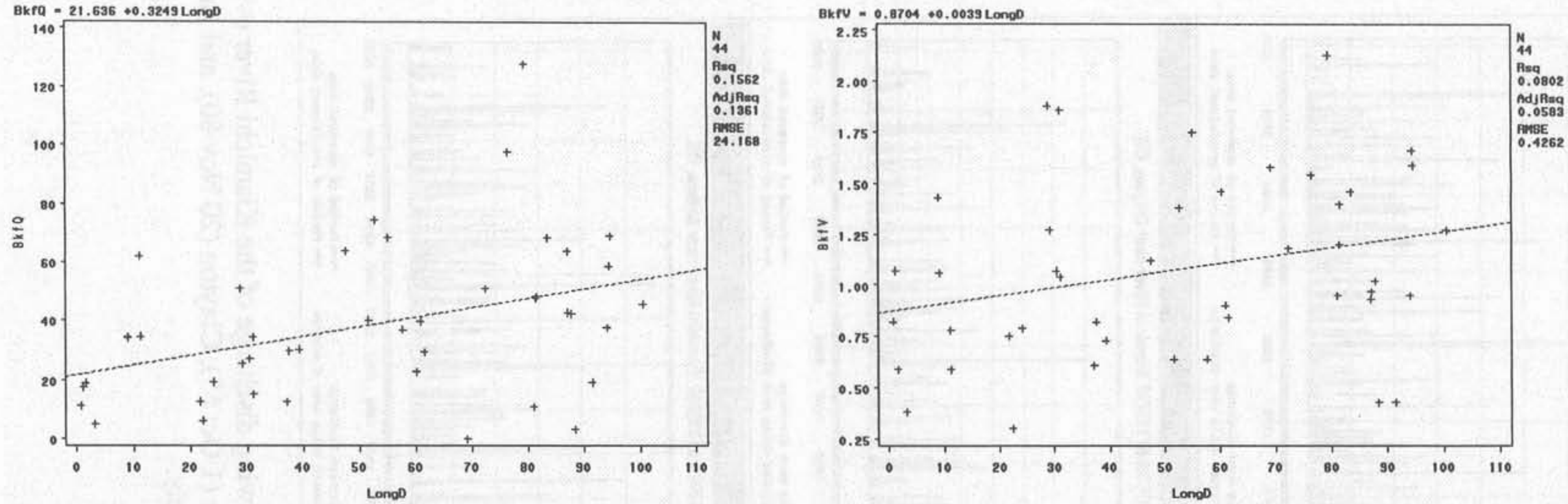


Figure 20. Linear regression plots for flow variables estimated bankfull discharge (BkfQ), and estimated bankfull velocity (BkfV).

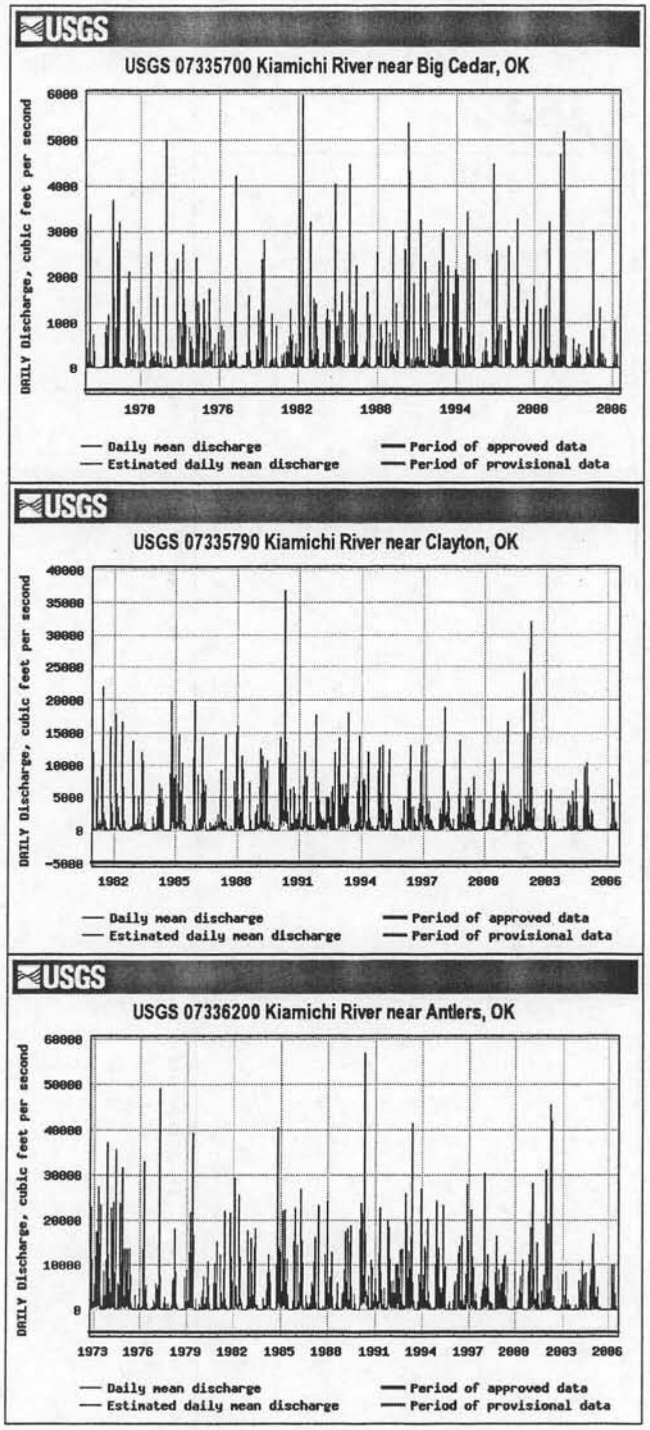


Figure 21. Daily hydrographs showing discharge of the Kiamichi River over the entire period of record (start date) at the Big Cedar (1 Oct 65), Clayton (20 Nov 80), and Antlers (1 Oct 72) USGS gauging stations; respectively.

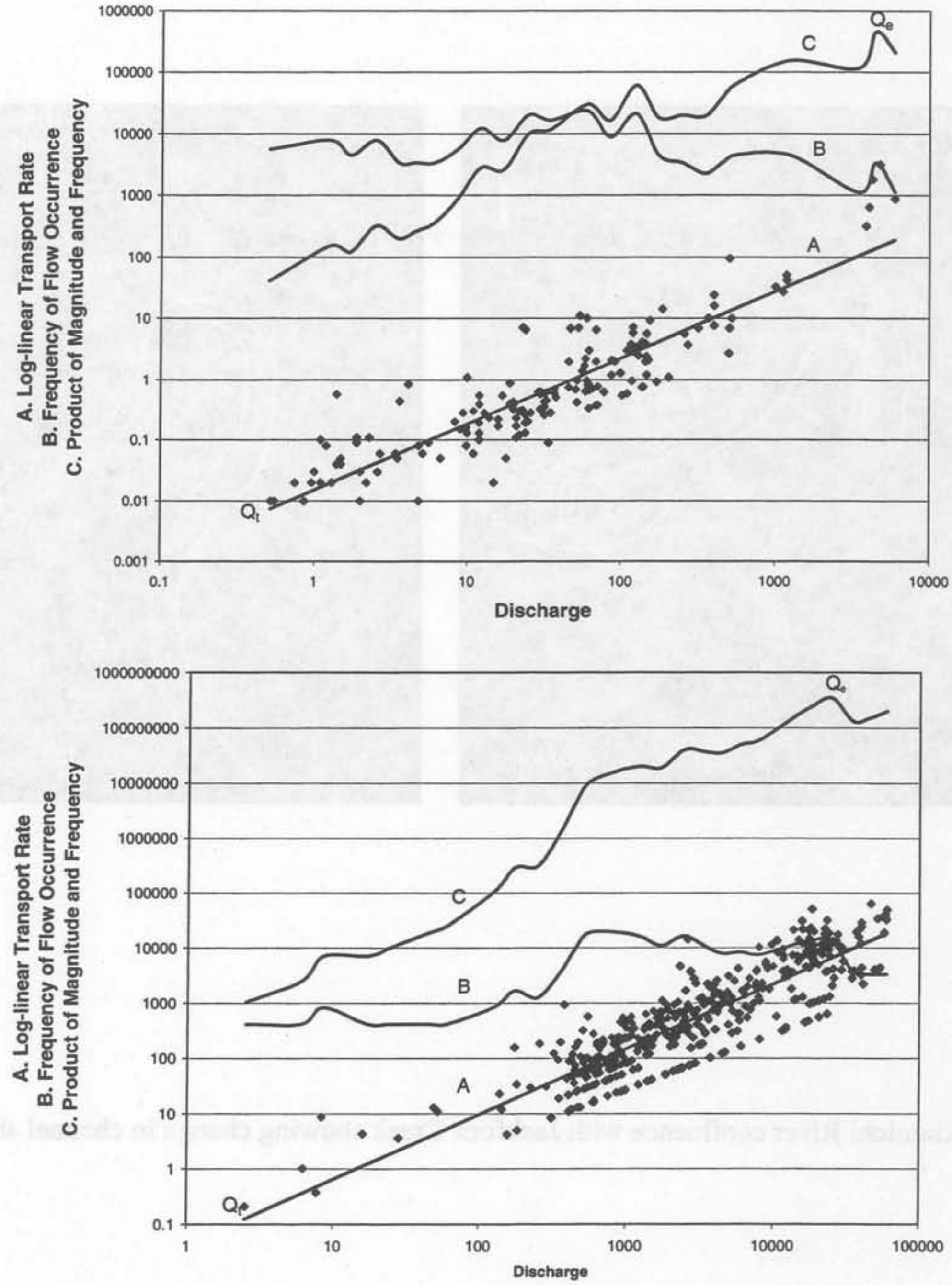


Figure 22. Log-linear Transport-Rate (A), Flow-Frequency (B), and Magnitude-Frequency (C) curves for Big Cedar and Antlers, Oklahoma USGS gauge stations, respectively, showing effective bankfull discharge (Q_e) and threshold discharge (Q_t).

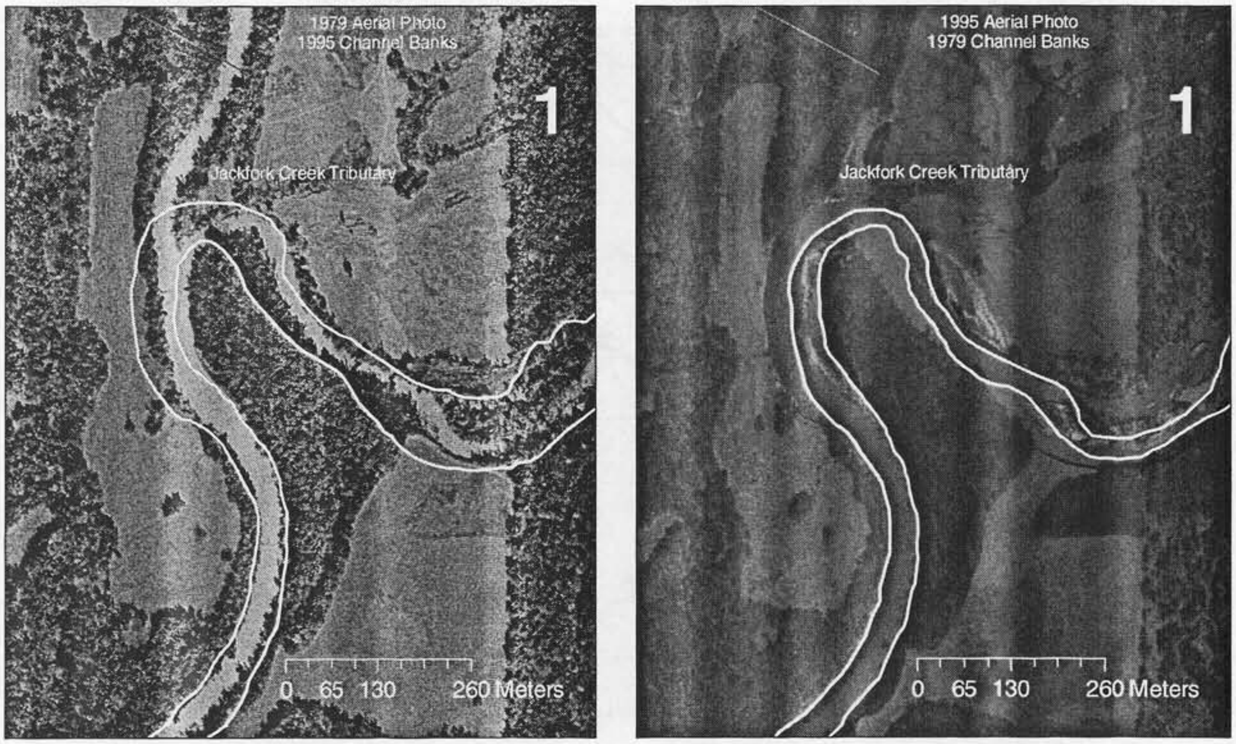


Figure 23. Kiamichi River confluence with Jackfork Creek showing change in channel shape over time.

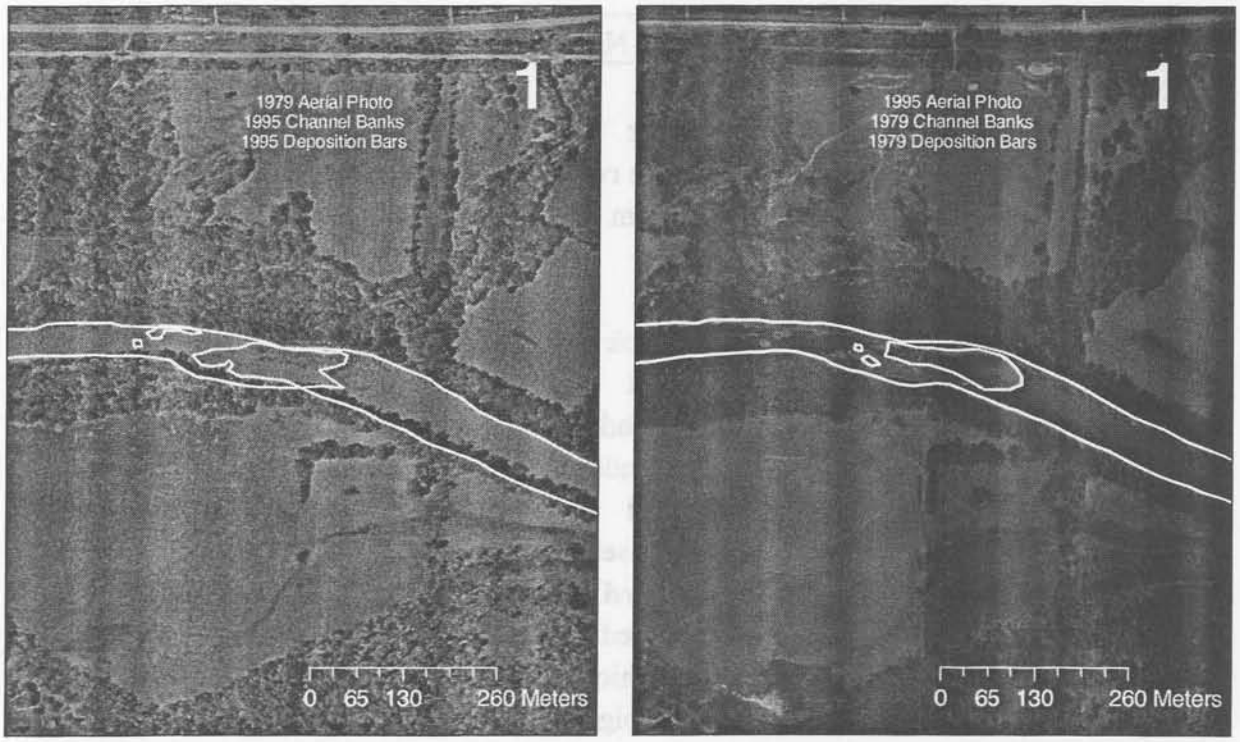


Figure 24. Kiamichi River 13.3 km below the confluence with Jackfork Creek showing changes in sediment deposition over time.

Table 1. Mussels currently known to be present in the Kiamichi River. Adapted from Vaughn et al. (1996).

Species	Common Name	Federal Status
Actinonaias ligamentina	mucket	
Amblema plicata plicata	threeridge	
Arkansia wheeleri	**Ouachita rock-pocketbook**	**Endangered**
Corbicula fluminea	Asian clam	
Ellipsaria lineolata	butterfly	
Fusconaia flava	pigtoe	
Lampsilis cardium	pocketbook	
Lampsilis siliquoidea/hydiana	fatmucket	
Leptodea teres	yellow sandshell	
Leptodea fragilis	fragile sandshell	
Leptodea leptodon	**scaleshell**	**Endangered**
Ligumia subrostrata	pond mussel	
Megalonaias nervosa	**washboard**	**Threatened**
Obliquaria reflexa	threehorned wartyback	
Obovaria jacksoniana	southern hickorynut	
Pleurobema pyramidatum	pyramid pigtoe	
Plectomerus dombeyanus	bankclimber	
Potamilus purpuratus	bleufer	
Pyganodon grandis	stoutfloater	
Ptychobranchus occidentalis	Ouachita kidneyshell	
Quadrula quadrula/apiculata	mapleleaf	
Quadrula pustulosa	pimpleback	
Strophitus undulatus	squawfoot	
Toxolasma parvus	lilliput	
Toxolasma texasensis	Texas lilliput	
Trigogonia verrucosa	pistol grip	
Truncilla truncata	deertoe	
Utterbackia imbecillis	paper pondshell	
Villosa arkansasensis	Ouachita creekshell	
Villosa lienosa	little spectaclecase	

Table 2. Broad-scale geomorphic characteristic by reach. Gradient is a percent, sinuosity is a dimensionless ratio, and all other values are means. See Figure 17 for reach locations.

Reach	Stream Length (km)	Pattern	Gradient (%)	Sinuosity	Wavelength (m)	Amplitude (m)	Width (m)	Depth (m)	Area (m^2)
1	2.40	Meander	3.25	1.19					
2	3.06	Meander	1.64	1.09					
3	2.64	Braided	0.89	2.04					
4	1.08	Meander	1.30	1.07					
5	1.58	Braided	0.79	1.40					
6	1.01	Meander	1.16	1.16					
7	2.64	Braided	0.79	1.59					
8	7.16	Meander	0.55	1.11					
9	16.19	Meander	0.35	1.23	611.47	156.31	23.24	1.41	21.12
10	9.12	Braided	0.19	1.33	562.48	103.66	50.80	1.78	67.62
11	16.42	Braided	0.11	1.49	403.42	111.06	26.95	1.22	15.55
12	23.11	Meander	0.07	1.24	354.89	138.49	25.13	1.12	21.38
13	8.62	Meander	0.05	1.10	614.94	154.53	35.90	1.32	33.20
14a	26.25	Meander	0.05	1.12	1085.13	238.12	44.52	1.63	51.17
14b	14.44	Meander	0.06	1.13	1249.92	247.33	33.30	1.21	30.63
15	33.10	Braided	0.06	1.16	1754.26	524.96	42.52	1.28	43.98
16	10.18	Meander	0.03	1.09	2751.19	978.97	46.50	1.44	46.03
17	31.86	Braided	0.05	1.29	1548.18	444.44	38.08	1.44	37.61

Table 3. Calculated statistics for morphological variables for reaches 9-17. Reaches and sample units (SU) are in longitudinal order. Stability was measured per site.

Reach	SU	Stability	_STAT_	BkfW	MaxD	BkfArea	WD	Eratio	Gradient	Manning's
			N	3	3	3	3	3	3	
			MIN	21.2	1.19	7.77	30.41	5.51	1E-07	0.00
9	3		MAX	29	1.95	20.78	64.36	8.62	0.01524	0.09
		73	MEAN	24.9	1.503333	15.04333	49.40333	7.46	0.005311	0.0404
			STD	3.91535	0.39716	6.63973	17.33123	1.69885	0.008606	0.0476
			N	5	5	5	5	5	5	
			MIN	13.6	0.53	6.86	15.77	20.75	1E-07	0.00
9	4		MAX	25.3	1.6	22.84	66.07	37.79	0.06096	0.15
		70	MEAN	19.04	1.03	13.942	31.886	29.126	0.017022	0.071
			STD	5.455089	0.410792	7.390631	20.28846	8.180485	0.024913	0.0566
			N	3	3	3	3	3	3	
			MIN	20.3	0.98	22.15	17.65	2.07	1E-07	0.00
9	6		MAX	33	1.87	46.58	29.59	2.58	1E-07	0.00
		84	MEAN	27.43333	1.426667	30.49667	22.43667	2.37	1E-07	0.0008
			STD	6.49333	0.445009	13.93191	6.312031	0.266646	0	5.77E-
			N	4	4	4	4	4	4	
			MIN	13.3	1.02	7.7	17.96	1.03	1E-07	0.00
9	12		MAX	19	3.9	15.52	22.99	1.2	0.029779	0.16
		73	MEAN	16.375	1.8025	12.1775	20.8275	1.11	0.007445	0.041
			STD	2.342897	1.400913	3.707599	2.167923	0.082865	0.01489	0.08
			N	3	3	3	3	3	3	
			MIN	16.2	1.04	13.45	16.16	1.09	1E-07	0.00
9	45		MAX	22.6	1.87	32.8	27.05	1.24	0.005563	0.05
		78	MEAN	19.36667	1.386667	20.92	20.00333	1.146667	0.002362	0.
			STD	3.200521	0.431548	10.40152	6.110976	0.081445	0.002874	0.028
			N	3	3	3	3	3	3	
			MIN	29.85	1.17	29.31	24.88	7.88	1E-07	0.00
9	46		MAX	36.8	1.55	38.46	38.82	9.38	0.007468	0.06
		79	MEAN	32.35	1.323333	34.12333	31.28333	8.823333	0.002489	0.0209
			STD	3.863612	0.200333	4.593586	7.038766	0.821361	0.004311	0.0348
			N	3	3	3	3	3	3	
			MIN	45	1.87	70.47	23.33	2.83	1E-07	0.00
10	7		MAX	54.7	2.29	88.78	41.22	5.44	1E-07	0.00
		70	MEAN	50.56667	2.026667	78.77333	34.85333	3.73	1E-07	0.00
			STD	5.006329	0.22942	9.273081	9.997821	1.481587	0	
			N	3	3	3	3	3	3	
			MIN	41.5	1.07	38.09	42.87	2.75	1E-07	0.00
10	8		MAX	57.4	1.89	70.13	55.74	3.61	1E-07	0.00
		82	MEAN	51.03333	1.526667	56.47	47.49333	3.073333	1E-07	0.0008
			STD	8.409717	0.417892	16.53328	7.159304	0.46801	0	5.77E-
			N	3	3	3	3	3	3	
			MIN	21.5	0.87	3.12	23.68	1	1E-07	0.00
11	17		MAX	28	1.2	18.56	28.87	1.25	0.002771	0.04
		91	MEAN	23.66667	1.036667	12.93333	26.37333	1.083333	0.000924	0.0151
			STD	3.752777	0.165025	8.529041	2.600583	0.144338	0.0016	0.0245

Table 3. Continued.

Reach	SU	Stability	_STAT_	BkfW	MaxD	BkfArea	WD	Eratio	Gradient	Manning's n
			N	4	4	4	4	4	4	4
			MIN	28	1.04	10.44	18.13	1.05	1E-07	0.0009
11	19		MAX	33	1.75	29.12	37.99	1.07	1E-07	0.0011
		73	MEAN	30.225	1.3975	18.1675	27.5925	1.0575	1E-07	0.001
			STD	2.341474	0.390246	8.519739	9.378423	0.009574	0	8.16E-05
			N	3	3	3	3	3	3	3
			MIN	33	0.82	20.34	45.46	1	1E-07	0.0009
12	3		MAX	36.7	0.87	25.39	69.47	1	0.005496	0.0566
		96	MEAN	34.46667	0.843333	23.23	54.82	1	0.001832	0.019467
			STD	1.965536	0.025166	2.602941	12.84944	0	0.003173	0.032158
			N	1	1	1	1	1	1	1
			MIN	20.68	1.49	27.1	19	1	0.001081	0.0287
Mussel	1		MAX	20.68	1.49	27.1	19	1	0.001081	0.0287
		86	MEAN	20.68	1.49	27.1	19	1	0.001081	0.0287
			STD							
			N	3	3	3	3	3	3	3
			MIN	17.2	1.16	16.9	18.01	1.04	1E-07	0.0009
12	22		MAX	26	1.25	22.55	30.54	1.1	0.00254	0.0405
		87	MEAN	20.66667	1.19	19.41	22.61667	1.066667	0.001237	0.024067
			STD	4.687572	0.051962	2.877204	6.892056	0.030551	0.001271	0.020641
			N	3	3	3	3	3	3	3
			MIN	29.1	0.87	19.51	43.81	1.13	1E-07	0.0009
12	28		MAX	38.7	0.94	29.72	52.83	1.23	0.005443	0.0567
		94	MEAN	34.76667	0.916667	25.87667	47.84667	1.173333	0.002195	0.0298
			STD	5.029248	0.040415	5.553056	4.58391	0.051316	0.00287	0.027954
			N	3	3	3	3	3	3	3
			MIN	13.7	1.08	14.77	13.1	1	0.000782	0.0261
12	35		MAX	20.5	1.28	20.75	21.67	1	0.009525	0.0665
		88	MEAN	18	1.203333	18.45333	18.02667	1	0.004349	0.044667
			STD	3.740321	0.107858	3.222147	4.426786	0	0.004588	0.020397
			N	5	5	5	5	5	5	5
			MIN	13.8	0.85	10.78	14.77	1.17	1E-07	0.0009
12	38		MAX	17.15	1.46	17.47	23.43	1.45	0.001563	0.0353
		86	MEAN	15.75	1.092	14.198	18.242	1.278	0.000639	0.0172
			STD	1.368393	0.259365	2.775098	3.197182	0.114543	0.000772	0.016558
			N	3	3	3	3	3	3	3
			MIN	25.2	1.11	21.01	25.88	1.02	1E-07	0.0009
13	4		MAX	41	1.16	25.49	41.63	1.12	0.013855	0.0855
		76	MEAN	30.96667	1.126667	23.09	31.99667	1.083333	0.00516	0.050667
			STD	8.72143	0.028868	2.257078	8.44339	0.055076	0.007573	0.044233
			N	4	4	4	4	4	4	4
			MIN	17	1.12	14.4	19.43	1	1E-07	0.0008
13	8		MAX	50.2	1.23	48.69	49.83	2.35	0.001484	0.0331
		83	MEAN	35.25	1.1925	35.0525	34.9125	1.3375	0.000371	0.00892
			STD	13.78417	0.049917	14.58415	12.62156	0.675	0.000742	0.016117

Table 3. Continued.

Reach	SU	Stability	_STAT_	BkfW	MaxD	BkfArea	WD	Eratio	Gradient	Manning
			N	1	1	1	1	1	1	
			MIN	28.44	1.65	41.47	20.01	1.58	1E-07	0.00
Mussel	2		MAX	28.44	1.65	41.47	20.01	1.58	1E-07	0.00
		84	MEAN	28.44	1.65	41.47	20.01	1.58	1E-07	0.00
			STD							
			N	3	3	3	3	3	3	
			MIN	25.2	1.11	25.92	25.02	1.02	1E-07	0.00
14a	13		MAX	66.5	1.95	79.58	78.53	1.39	0.017874	0.08
		87	MEAN	45.4	1.573333	53.53	43.01	1.216667	0.005958	0.0296
			STD	20.6647	0.426654	26.86399	30.76208	0.1861	0.01032	0.0498
			N	5	5	5	5	5	5	
			MIN	16.5	1.46	15.44	15.87	3.72	1E-07	0.00
14a	22		MAX	74	2.01	92.76	60.04	13.43	0.000778	0.03
		88	MEAN	40.8	1.722	56.776	30.868	8.026	0.000156	0.00
			STD	23.40417	0.216379	34.52686	17.80734	4.924645	0.000348	0.0156
			N	3	3	3	3	3	3	
			MIN	43	1.34	37.66	41.93	1.17	1E-07	0.00
14a	25		MAX	55.5	1.71	65.77	48.04	1.28	0.008945	0.06
		70	MEAN	47.33333	1.513333	47.16	45.51	1.236667	0.003058	0.0269
			STD	7.076958	0.1861	16.11791	3.18746	0.058595	0.0051	0.0324
			N	1	1	1	1	1	1	
			MIN	42.58	1.25	42.58	46.67	6.11	0.002901	0.0
Mussel	3		MAX	42.58	1.25	42.58	46.67	6.11	0.002901	0.0
		68	MEAN	42.58	1.25	42.58	46.67	6.11	0.002901	0.0
			STD							
			N	3	3	3	3	3	3	
			MIN	43.4	1.71	41.67	33.53	1.04	1E-07	0.00
14a	35		MAX	49.2	2.35	63.1	60.02	1.08	1E-07	0.00
		87	MEAN	46.46667	2.096667	55.80333	43.66333	1.056667	1E-07	0.0008
			STD	2.914332	0.340196	12.24199	14.29956	0.020817	0	5.77E-
			N	4	4	4	4	4	4	
			MIN	15.54	0.82	13.79	16.28	1.06	0.000893	0.02
Mussel	4		MAX	27.13	1.62	17.95	45.79	1.17	0.018288	0.09
		68	MEAN	21.4425	1.0975	15.4675	34.4825	1.1025	0.00658	0.052
			STD	5.009673	0.364269	1.888145	13.94629	0.047871	0.008171	0.0309
			N	3	3	3	3	3	3	
			MIN	40	1.13	35.06	26.97	1.3	1E-07	0.00
14b	3		MAX	50	1.83	60.76	54.6	1.38	0.007981	0.06
		82	MEAN	44.66667	1.556667	45.53333	37.52667	1.346667	0.002671	0.0252
			STD	5.033223	0.374344	13.49326	14.92328	0.041633	0.004599	0.0341
			N	3	3	3	3	3	3	
			MIN	37.8	0.73	18	35.95	1	1E-07	0.00
14b	8		MAX	42	1.22	37.89	90.81	1	0.001814	0.03
		80	MEAN	39.76667	1.046667	30.90333	55.39333	1	0.000605	0.01
			STD	2.11266	0.274651	11.18741	30.72077	0	0.001047	0.0200

Table 3. Continued.

Reach	SU	Stability	_STAT_	BkfW	MaxD	BkfArea	WD	Eratio	Gradient	Manning's n
			N	1	1	1	1	1	1	[illegible]
			MIN	51.66	1.37	50.7	52.03	1.24	0.000781	0.026
Mussel	5		MAX	51.66	1.37	50.7	52.03	1.24	0.000781	0.026
		68	MEAN	51.66	1.37	50.7	52.03	1.24	0.000781	0.026
			STD							
			N	3	3	3	3	3	3	[illegible]
			MIN	32.4	0.98	21.13	40.29	1.03	1E-07	0.000
15	7		MAX	49.5	2.06	57.22	52.5	1.33	0.001905	0.038
		69	MEAN	42.9	1.383333	42.68667	47.43667	1.18	0.00078	0.01986
			STD	9.192932	0.589604	19.04252	6.366022	0.15	0.000998	0.018
			N	3	3	3	3	3	3	[illegible]
			MIN	45.2	1.65	57.59	32.7	1.04	1E-07	0.000
15	21		MAX	52.2	1.95	76.67	43.36	1.11	0.003033	0.041
		79	MEAN	49.06667	1.78	65.85333	37.27333	1.066667	0.00107	0.01893
			STD	3.557152	0.153948	9.792918	5.488764	0.037859	0.001702	0.02097
			N	3	3	3	3	3	3	[illegible]
			MIN	44.47	1.49	37.27	35.59	4.46	0.000556	0.021
Mussel	6		MAX	56.08	1.95	71.27	86.87	5.51	0.046774	0.117
		81	MEAN	51.95667	1.686667	55.04667	55.37	4.86	0.016458	0.05956
			STD	6.49477	0.237136	17.05314	27.57587	0.567891	0.026265	0.05070
			N	1	1	1	1	1	1	[illegible]
			MIN	28.62	0.67	11.34	74.43	8.73	0.005854	0.064
Mussel	7		MAX	28.62	0.67	11.34	74.43	8.73	0.005854	0.064
		69	MEAN	28.62	0.67	11.34	74.43	8.73	0.005854	0.064
			STD							
			N	3	3	3	3	3	3	[illegible]
			MIN	31	1.26	30.92	30.33	1.01	1E-07	0.000
15	29		MAX	50.6	1.83	57	51.13	1.29	0.018288	0.085
		81	MEAN	41.7	1.6	46.82	38.74667	1.15	0.006096	0.02906
			STD	9.923205	0.3005	13.94921	10.95266	0.14	0.010559	0.04895
			N	1	1	1	1	1	1	[illegible]
			MIN	55.29	0.98	34.58	85.03	1.18	0.006316	0.061
Mussel	8		MAX	55.29	0.98	34.58	85.03	1.18	0.006316	0.061
		74	MEAN	55.29	0.98	34.58	85.03	1.18	0.006316	0.061
			STD							
			N	4	4	4	4	4	4	[illegible]
			MIN	49.5	0.58	26.88	54.25	1.01	0.000218	0.015
15	34		MAX	59.5	1.25	53.02	135.94	1.15	0.00889	0.065
		69	MEAN	54.8	1.0625	44.8175	78.035	1.06	0.002798	0.03572
			STD	5.042486	0.322322	12.17851	39.05272	0.061644	0.004081	0.02110
			N	5	5	5	5	5	5	[illegible]
			MIN	55.5	0.94	62.61	38.47	1.02	1E-07	0.000
16	1		MAX	82	1.83	81.57	107.08	2.27	0.001219	0.031
		84	MEAN	70.8	1.308	69.982	76.126	1.284	0.000427	0.0124
			STD	10.52735	0.397517	7.837147	27.10159	0.551298	0.000594	0.01595

Table 3. Concluded.

Reach	SU	Stability	_STAT_	BkfW	MaxD	BkfArea	WD	Eratio	Gradient	Manning'
			N	3	3	3	3	3	3	
			MIN	34	0.94	22.9	27.07	1.06	1E-07	0.00
16	2		MAX	85.2	2.04	96.17	74.85	2.5	0.010174	0.07
		81	MEAN	51.06667	1.663333	54.77333	49.88667	2.02	0.003392	0.02
			STD	29.56033	0.626605	37.55188	23.96223	0.831384	0.005874	0.0415
			N	3	3	3	3	3	3	
			MIN	25.4	1.52	29.44	14.84	1.06	1E-07	0.00
16	3		MAX	60	2.77	72.97	49.66	1.08	0.000423	0.02
		69	MEAN	37.2	2.09	47.58667	29.19	1.07	0.000141	0.0072
			STD	19.74943	0.632218	22.64933	18.19887	0.01	0.000244	0.0111
			N	3	3	3	3	3	3	
			MIN	19.5	0.49	7.02	43.71	1.16	1E-07	0.0
16	6		MAX	45	0.79	23.51	80.14	2.11	0.005471	0.06
		73	MEAN	28.66667	0.69	13.01333	61.08333	1.516667	0.00206	0.03
			STD	14.18039	0.173205	9.120857	18.27324	0.517333	0.002975	0.0318
			N	1	1	1	1	1	1	
			MIN	59.8	1.46	44.78	79.09	1.05	1E-07	0.00
Mussel	11		MAX	59.8	1.46	44.78	79.09	1.05	1E-07	0.00
		83	MEAN	59.8	1.46	44.78	79.09	1.05	1E-07	0.00
			STD							
			N	3	3	3	3	3	3	
			MIN	33.9	1.52	33.88	27.62	1.02	1E-07	0.00
17	4		MAX	50.6	1.62	51.91	53.48	1.06	0.000991	0.02
		69	MEAN	40.23333	1.553333	43.63	38.64667	1.036667	0.00033	0.0099
			STD	9.051151	0.057735	9.104444	13.34365	0.020817	0.000572	0.0157
			N	3	3	3	3	3	3	
			MIN	26.3	1.01	17.83	16.85	1.29	0.000527	0.02
17	6		MAX	31.85	3.05	54.3	46.44	1.37	0.007298	0.06
		71	MEAN	29.71667	1.72	30.48	32.92333	1.326667	0.003208	0.0411
			STD	2.989286	1.152693	20.64199	14.95976	0.040415	0.003598	0.0226
			N	3	3	3	3	3	3	
			MIN	40.3	0.87	30.06	38.56	1.02	0.000708	0.02
17	7		MAX	56.2	1.28	54.95	74.22	1.14	0.00635	0.05
		64	MEAN	48.43333	1.113333	42.39667	57.02333	1.066667	0.002613	0.03
			STD	7.956339	0.215484	12.44641	17.86371	0.064291	0.003236	0.017
			N	3	3	3	3	3	3	
			MIN	31.94	0.91	14.46	28.91	1.1	1E-07	0.00
Mussel	10		MAX	41.81	1.71	50.12	106.83	5.91	0.016582	0.08
		67	MEAN	38.17333	1.413333	33.93	57.87	2.713333	0.005573	0.0323
			STD	5.423212	0.438216	18.05485	42.63662	2.768435	0.009534	0.0423

Table 4. Calculated statistics for diameter substrate variables by site with N transects. Reaches and sample units (SU) are in longitudinal order.

Reach	SU	_STAT_	D16	D35	D50	D84	D95	D100	D84D16
		N	3	3	3	3	3	3	3
		MIN	1.41	1.91	19.30	119.51	282.50	511.99	8.52
9	3	MAX	27.79	53.93	82.78	236.69	2048.00	2048.00	89.28
		MEAN	12.77	30.09	49.82	170.07	1459.50	1536.00	38.24
		STD	13.57	26.28	31.81	60.22	1019.31	886.82	44.40
		N	5	5	5	5	5	5	5
		MIN	1.36	1.79	16.00	211.92	387.00	512.00	14.74
9	4	MAX	27.21	77.51	180.00	2048.00	2048.00	2048.00	227.30
		MEAN	14.96	45.19	92.39	992.99	1449.67	1740.80	99.91
		STD	11.22	31.77	62.32	965.63	827.58	686.92	90.85
		N	3	3	3	3	3	3	3
		MIN	1.42	1.92	11.30	70.50	121.67	362.00	49.65
9	6	MAX	1.73	19.85	41.75	205.33	418.25	512.00	118.69
		MEAN	1.53	7.91	25.22	121.94	258.97	412.00	76.95
		STD	0.17	10.34	15.39	72.87	149.51	86.60	36.72
		N	4	4	4	4	4	4	4
		MIN	11.30	41.10	61.29	128.00	237.00	362.00	5.23
9	12	MAX	28.87	58.06	95.43	210.40	418.25	512.00	18.62
		MEAN	19.93	46.21	73.28	182.20	321.63	474.50	11.01
		STD	8.14	7.99	15.18	38.87	74.52	75.00	6.40
		N	3	3	3	3	3	3	3
		MIN	9.65	34.17	60.83	136.67	177.11	256.00	4.12
9	45	MAX	35.25	65.30	84.80	154.00	227.50	511.99	14.16
		MEAN	23.75	50.93	73.13	145.33	199.09	376.66	8.04
		STD	13.00	15.70	12.00	8.67	25.80	128.62	5.37
		N	3	3	3	3	3	3	3
		MIN	1.31	1.67	1.96	90.00	173.50	511.99	68.70
9	46	MAX	1.62	29.65	54.50	159.20	282.50	511.99	110.56
		MEAN	1.46	11.10	32.74	132.67	234.17	511.99	90.37
		STD	0.16	16.07	27.41	37.31	55.54	0.00	20.97
		N	3	3	3	3	3	3	3
		MIN	0.03	7.42	29.65	77.00	136.67	180.00	2137.80
10	7	MAX	0.05	33.30	53.14	162.67	437.00	2047.95	5422.33
		MEAN	0.04	17.07	43.65	115.52	263.89	863.32	3375.60
		STD	0.01	14.14	12.38	43.48	155.33	1029.95	1785.44
		N	3	3	3	3	3	3	3
		MIN	0.03	12.48	25.73	109.00	173.50	256.00	1453.40
10	8	MAX	0.05	22.05	60.20	148.80	282.50	511.99	4960.00
		MEAN	0.04	18.49	43.64	134.38	221.50	426.66	3046.13
		STD	0.01	5.24	17.28	22.05	55.65	147.80	1775.22
		N	3	3	3	3	3	3	3
		MIN	1.36	1.80	18.20	45.00	77.00	128.00	7.89
11	17	MAX	5.70	27.30	40.67	115.33	218.00	361.99	84.80
		MEAN	2.93	13.41	32.02	77.67	127.85	223.33	44.90
		STD	2.41	12.90	12.10	35.43	78.28	122.87	38.54

Table 4. Continued.

Reach	SU	_STAT_	D16	D35	D50	D84	D95	D100	D84D16
		N	4	4	4	4	4	4	4
		MIN	1.62	19.30	27.82	61.89	109.00	180.00	6.20
11	19	MAX	18.20	39.58	64.00	118.50	174.80	361.99	68.50
		MEAN	5.81	24.99	40.58	99.87	147.95	316.49	44.14
		STD	8.26	9.75	16.22	25.81	27.76	91.00	28.57
		N	3	3	3	3	3	3	3
		MIN	1.24	1.51	1.74	45.00	70.50	256.00	35.42
12	3	MAX	1.36	1.80	9.65	54.50	167.00	361.99	43.25
		MEAN	1.29	1.62	4.40	49.22	118.67	291.33	38.32
		STD	0.06	0.16	4.55	4.84	48.25	61.19	4.29
		N	1	1	1	1	1	1	1
		MIN	2.32	7.83	19.30	67.37	2048.00	2048.00	29.04
Mussel	1	MAX	2.32	7.83	19.30	67.37	2048.00	2048.00	29.04
		MEAN	2.32	7.83	19.30	67.37	2048.00	2048.00	29.04
		STD							
		N	3	3	3	3	3	3	3
		MIN	1.25	1.55	1.78	40.67	77.00	180.00	32.54
12	22	MAX	1.29	1.63	1.89	45.00	99.50	1023.97	35.43
		MEAN	1.27	1.59	1.83	43.56	86.67	461.32	34.28
		STD	0.02	0.04	0.06	2.50	11.58	487.27	1.53
		N	3	3	3	3	3	3	3
		MIN	1.28	1.60	1.86	60.20	109.00	256.00	47.03
12	28	MAX	1.50	7.31	22.60	2048.00	2048.00	2048.00	1365.33
		MEAN	1.38	3.56	10.82	735.27	774.67	938.66	494.89
		STD	0.11	3.25	10.65	1137.01	1103.12	969.20	753.93
		N	3	3	3	3	3	3	3
		MIN	1.26	1.56	1.81	38.50	96.33	56.00	30.56
12	35	MAX	1.42	1.92	13.65	64.00	141.00	256.00	48.12
		MEAN	1.34	1.74	7.82	53.92	115.44	146.67	40.14
		STD	0.08	0.18	5.92	13.56	23.02	101.30	8.89
		N	5	5	5	5	5	5	5
		MIN	1.21	1.46	1.66	19.30	38.50	64.00	15.95
12	38	MAX	1.80	27.30	38.50	105.20	171.33	361.99	58.44
		MEAN	1.45	8.55	17.27	61.19	100.30	219.20	40.68
		STD	0.23	11.16	15.75	30.69	50.92	136.67	15.50
		N	3	3	3	3	3	3	3
		MIN	1.31	1.67	1.96	52.60	80.25	180.00	37.24
13	4	MAX	1.53	11.64	19.30	61.29	141.00	511.99	40.15
		MEAN	1.45	7.65	12.97	56.58	110.08	316.00	39.15
		STD	0.12	5.28	9.57	4.39	30.39	173.94	1.65
		N	4	4	4	4	4	4	4
		MIN	0.02	0.05	1.93	24.17	54.50	90.00	18.59
13	8	MAX	1.44	8.62	16.00	78.86	113.75	180.00	3943.00
		MEAN	0.70	4.66	10.96	47.89	76.52	131.50	1253.51
		STD	0.77	4.45	6.21	23.44	26.57	36.96	1854.46

Table 4. Continued.

Reach	SU	_STAT_	D16	D35	D50	D84	D95	D100	D84D16
		N	1	1	1	1	1	1	1
		MIN	5.53	12.77	23.78	110.91	2048.00	2048.00	20.06
Mussel	2	MAX	5.53	12.77	23.78	110.91	2048.00	2048.00	20.06
		MEAN	5.53	12.77	23.78	110.91	2048.00	2048.00	20.06
		STD							
		N	3	3	3	3	3	3	3
		MIN	0.03	1.31	9.10	40.67	83.50	128.00	7.70
14a	13	MAX	8.00	17.65	29.65	61.63	96.33	128.00	677.83
		MEAN	3.28	10.01	19.57	52.90	87.78	128.00	238.95
		STD	4.19	8.22	10.28	10.91	7.41	0.00	380.26
		N	5	5	5	5	5	5	5
		MIN	0.03	1.50	1.77	29.65	54.50	90.00	23.72
14a	22	MAX	2.00	12.31	17.65	90.00	154.00	256.00	2250.00
		MEAN	0.90	4.78	11.11	50.98	93.05	166.80	837.06
		STD	0.85	4.79	6.57	24.79	37.63	62.67	1121.16
		N	3	3	3	3	3	3	3
		MIN	1.42	1.92	10.20	38.50	59.25	90.00	25.00
14a	25	MAX	1.67	9.65	16.00	43.14	70.50	511.99	28.76
		MEAN	1.53	6.94	13.62	41.13	63.95	243.33	26.96
		STD	0.13	4.35	3.04	2.38	5.85	233.44	1.88
		N	1	1	1	1	1	1	1
		MIN	4.52	6.69	8.28	32.42	48.48	64.00	7.17
Mussel	3	MAX	4.52	6.69	8.28	32.42	48.48	64.00	7.17
		MEAN	4.52	6.69	8.28	32.42	48.48	64.00	7.17
		STD							
		N	3	3	3	3	3	3	3
		MIN	1.27	1.58	1.83	15.06	30.83	64.00	11.86
14a	35	MAX	1.35	1.76	8.66	26.36	54.50	256.00	20.12
		MEAN	1.31	1.67	4.15	20.97	40.19	128.00	15.97
		STD	0.04	0.09	3.91	5.67	12.59	110.85	4.13
		N	4	4	4	4	4	4	4
		MIN	0.05	7.62	12.15	27.97	40.13	90.00	12.87
Mussel	4	MAX	5.56	11.42	17.10	81.33	154.00	256.00	705.00
		MEAN	2.61	9.69	14.78	54.02	97.13	163.50	190.23
		STD	2.38	1.57	2.21	26.35	56.96	71.86	343.21
		N	3	3	3	3	3	3	3
		MIN	1.22	8.70	14.83	44.31	117.53	180.00	8.57
14b	3	MAX	11.67	37.25	45.79	99.99	139.67	256.00	43.99
		MEAN	4.90	23.57	32.17	74.49	125.58	205.33	29.63
		STD	5.87	14.31	15.81	28.13	12.25	43.88	18.63
		N	3	3	3	3	3	3	3
		MIN	0.05	17.10	29.31	61.29	123.25	256.00	4.91
14b	8	MAX	16.00	36.06	48.45	96.33	192.67	511.99	1592.00
		MEAN	9.51	25.91	36.06	79.07	156.64	376.66	534.31
		STD	8.38	9.55	10.74	17.53	34.79	128.62	915.99

Table 4. Continued.

Reach	SU	_STAT_	D16	D35	D50	D84	D95	D100	D84D16
		N	1	1	1	1	1	1	1
		MIN	6.85	14.59	21.66	51.33	83.50	180.00	7.49
Mussel	5	MAX	6.85	14.59	21.66	51.33	83.50	180.00	7.49
		MEAN	6.85	14.59	21.66	51.33	83.50	180.00	7.49
		STD							
		N	3	3	3	3	3	3	3
		MIN	1.89	20.95	43.56	106.89	141.00	256.00	5.56
15	7	MAX	21.50	38.50	51.91	119.56	218.00	1023.97	56.56
		MEAN	12.35	30.72	48.93	113.08	174.47	547.32	23.46
		STD	9.87	8.94	4.66	6.34	39.47	416.18	28.70
		N	3	3	3	3	3	3	3
		MIN	1.11	1.64	4.85	32.00	99.50	256.00	25.58
15	21	MAX	1.42	1.92	10.64	40.67	309.00	1023.97	36.64
		MEAN	1.26	1.75	7.32	36.33	208.83	597.32	29.34
		STD	0.16	0.15	2.99	4.34	105.05	391.03	6.32
		N	3	3	3	3	3	3	3
		MIN	1.89	6.85	9.98	58.57	121.67	180.00	8.73
Mussel	6	MAX	10.70	18.13	32.93	156.61	2048.00	2048.00	30.99
		MEAN	6.40	12.94	22.62	102.87	1405.89	1425.33	21.13
		STD	4.41	5.69	11.65	49.70	1112.17	1078.49	11.34
		N	1	1	1	1	1	1	1
		MIN	6.27	15.61	20.20	70.50	167.00	361.99	11.24
Mussel	7	MAX	6.27	15.61	20.20	70.50	167.00	361.99	11.24
		MEAN	6.27	15.61	20.20	70.50	167.00	361.99	11.24
		STD							
		N	3	3	3	3	3	3	3
		MIN	1.80	10.06	24.17	78.86	154.00	256.00	16.80
15	29	MAX	10.20	21.94	29.91	171.33	309.00	511.99	43.81
		MEAN	4.63	15.84	27.13	110.51	227.00	376.66	34.55
		STD	4.82	5.95	2.87	52.69	77.89	128.62	15.37
		N	1	1	1	1	1	1	1
		MIN	7.23	25.59	32.00	77.00	167.00	256.00	10.65
Mussel	8	MAX	7.23	25.59	32.00	77.00	167.00	256.00	10.65
		MEAN	7.23	25.59	32.00	77.00	167.00	256.00	10.65
		STD							
		N	4	4	4	4	4	4	4
		MIN	1.62	5.99	13.65	57.67	141.00	256.00	35.60
15	34	MAX	1.89	10.89	22.60	90.00	199.00	361.99	55.56
		MEAN	1.69	8.84	17.97	74.94	166.33	309.00	44.28
		STD	0.14	2.08	4.23	17.48	25.07	61.19	9.11
		N	5	5	5	5	5	5	5
		MIN	0.05	4.28	16.00	62.10	154.00	511.99	90.45
16	1	MAX	1.60	33.30	54.50	174.22	335.50	1023.97	2306.60
		MEAN	0.86	15.26	31.15	123.63	241.60	614.39	771.92
		STD	0.76	10.96	15.55	47.11	69.42	228.96	989.48

Table 4. Concluded.

Reach	SU	_STAT_	D16	D35	D50	D84	D95	D100	D84D16
		N	3	3	3	3	3	3	3
		MIN	4.57	14.83	24.48	109.00	249.67	511.99	7.20
16	2	MAX	32.29	63.06	130.00	232.53	329.12	511.99	23.85
		MEAN	16.45	36.11	68.60	173.84	287.10	511.99	15.16
		STD	14.28	24.61	54.84	61.99	39.92	0.00	8.35
		N	3	3	3	3	3	3	3
		MIN	1.38	1.83	19.30	230.67	354.43	1023.97	7.78
16	3	MAX	29.65	51.79	90.00	437.00	896.00	2047.95	196.48
		MEAN	17.33	32.44	64.99	312.94	581.23	1706.62	75.04
		STD	14.48	26.82	39.63	109.33	281.30	591.20	105.37
		N	3	3	3	3	3	3	3
		MIN	0.04	8.83	20.40	72.67	154.00	180.00	8.23
16	6	MAX	8.83	17.65	32.00	102.67	208.50	256.00	2566.75
		MEAN	3.51	13.38	26.04	86.28	185.06	230.67	874.99
		STD	4.68	4.42	5.81	15.19	28.04	43.88	1465.25
		N	1	1	1	1	1	1	1
		MIN	2.84	7.47	11.56	48.07	112.48	128.00	16.93
Mussel	11	MAX	2.84	7.47	11.56	48.07	112.48	128.00	16.93
		MEAN	2.84	7.47	11.56	48.07	112.48	128.00	16.93
		STD							
		N	3	3	3	3	3	3	3
		MIN	0.04	1.15	1.48	16.00	30.43	90.00	12.80
17	4	MAX	1.64	12.98	17.98	31.15	154.00	511.99	482.50
		MEAN	0.98	5.23	7.08	22.15	79.64	321.33	171.43
		STD	0.83	6.72	9.44	7.97	65.51	213.91	269.41
		N	3	3	3	3	3	3	3
		MIN	0.06	5.27	25.29	60.83	227.50	361.99	47.90
17	6	MAX	1.50	26.13	42.83	199.00	437.00	1023.97	1413.33
		MEAN	0.94	16.46	32.03	114.88	302.61	582.65	531.30
		STD	0.77	10.51	9.45	73.83	116.65	382.19	765.04
		N	3	3	3	3	3	3	3
		MIN	1.60	19.85	30.43	115.33	282.50	511.99	10.26
17	7	MAX	12.48	21.50	45.00	180.00	351.40	1023.99	112.50
		MEAN	6.85	20.71	37.25	141.11	323.13	682.66	46.86
		STD	5.45	0.83	7.33	34.27	36.08	295.60	56.97
		N	3	3	3	3	3	3	3
		MIN	1.64	7.17	14.83	44.49	154.00	362.00	10.77
Mussel	10	MAX	4.13	14.04	19.30	231.59	870.67	2048.00	141.21
		MEAN	3.09	9.97	17.81	118.56	413.79	1486.00	58.24
		STD	1.29	3.61	2.58	99.45	396.91	973.41	72.10

Table 5. Calculated statistics for substrate percentages by site with N transects. Reaches and sample units (SU) are in longitudinal order.

Reach	SU	_STAT_	ClayRM	SandRM	GravelRM	CobbleRM	BoulderRM
		N	3	3	3	3	3
		MIN	0.00	0.00	33.30	15.79	0.00
9	3	MAX	12.00	38.60	52.00	45.91	6.00
		MEAN	4.00	13.96	40.45	30.57	2.55
		STD	6.93	21.40	10.09	15.07	3.10
		N	5	5	5	5	5
		MIN	0.00	3.57	19.23	15.11	6.98
9	4	MAX	0.00	44.23	52.00	39.28	19.65
		MEAN	0.00	14.43	29.84	28.25	12.32
		STD	0.00	17.24	13.15	9.17	5.44
		N	3	3	3	3	3
		MIN	0.00	22.00	36.00	14.00	4.00
9	6	MAX	0.00	38.00	44.00	30.00	12.00
		MEAN	0.00	32.00	40.00	21.33	6.67
		STD	0.00	8.72	4.00	8.08	4.62
		N	4	4	4	4	4
		MIN	0.00	0.00	34.00	38.00	4.00
9	12	MAX	6.00	2.00	50.00	48.00	12.00
		MEAN	2.00	1.00	43.50	44.50	9.00
		STD	2.83	1.15	7.19	4.73	3.46
		N	3	3	3	3	3
		MIN	0.00	4.00	28.00	48.00	0.00
9	45	MAX	0.00	14.00	40.00	62.00	4.00
		MEAN	0.00	8.00	35.33	54.67	2.00
		STD	0.00	5.29	6.43	7.02	2.00
		N	3	3	3	3	3
		MIN	0.00	26.00	16.00	30.00	2.00
9	46	MAX	0.00	52.00	30.00	38.00	6.00
		MEAN	0.00	38.00	23.33	34.67	4.00
		STD	0.00	13.11	7.02	4.16	2.00
		N	3	3	3	3	3
		MIN	20.00	0.00	28.00	16.00	0.00
10	7	MAX	30.00	0.00	50.00	40.00	10.00
		MEAN	26.67	0.00	39.33	29.33	4.67
		STD	5.77	0.00	11.02	12.22	5.03
		N	3	3	3	3	3
		MIN	22.00	0.00	28.00	28.00	0.00
10	8	MAX	32.00	0.00	36.00	48.00	6.00
		MEAN	26.00	0.00	31.33	39.33	3.33
		STD	5.29	0.00	4.16	10.26	3.06
		N	3	3	3	3	3
		MIN	0.00	8.00	28.00	6.00	0.00
11	17	MAX	4.00	44.00	82.00	26.00	2.00
		MEAN	1.33	24.67	55.33	18.00	0.67
		STD	2.31	18.15	27.01	10.58	1.15

Table 5. Continued.

Reach	SU	_STAT_	ClayRM	SandRM	GravelRM	CobbleRM	BoulderRM
		N	4	4	4	4	4
		MIN	0.00	8.00	42.00	14.00	0.00
11	19	MAX	0.00	26.00	60.00	48.00	2.00
		MEAN	0.00	20.00	47.00	31.50	1.50
		STD	0.00	8.16	8.72	13.89	1.00
		N	3	3	3	3	3
		MIN	0.00	44.00	20.00	6.00	0.00
12	3	MAX	0.00	68.00	50.00	12.00	2.00
		MEAN	0.00	58.00	32.00	9.33	0.67
		STD	0.00	12.49	15.87	3.06	1.15
		N	1	1	1	1	1
		MIN	1.89	13.20	67.93	11.32	0.00
Mussel	1	MAX	1.89	13.20	67.93	11.32	0.00
		MEAN	1.89	13.20	67.93	11.32	0.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	56.00	28.00	4.00	0.00
12	22	MAX	0.00	64.00	34.00	10.00	2.00
		MEAN	0.00	60.00	32.00	7.33	0.67
		STD	0.00	4.00	3.46	3.06	1.15
		N	3	3	3	3	3
		MIN	0.00	32.26	20.00	14.00	0.00
12	28	MAX	0.00	58.00	29.03	32.00	2.00
		MEAN	0.00	45.42	25.68	21.79	0.67
		STD	0.00	12.88	4.94	9.24	1.15
		N	3	3	3	3	3
		MIN	0.00	38.00	30.00	8.00	0.00
12	35	MAX	0.00	62.00	48.00	16.00	0.00
		MEAN	0.00	49.33	38.00	12.67	0.00
		STD	0.00	12.06	9.17	4.16	0.00
		N	5	5	5	5	5
		MIN	0.00	20.00	24.00	0.00	0.00
12	38	MAX	0.00	76.00	54.00	24.00	2.00
		MEAN	0.00	44.00	43.20	12.00	0.80
		STD	0.00	21.59	12.30	9.27	1.10
		N	3	3	3	3	3
		MIN	0.00	30.00	38.00	8.00	0.00
13	4	MAX	0.00	52.00	58.00	14.00	2.00
		MEAN	0.00	38.00	50.67	10.67	0.67
		STD	0.00	12.17	11.02	3.06	1.15
		N	4	4	4	4	4
		MIN	0.00	0.00	35.00	4.00	0.00
13	8	MAX	42.00	54.00	70.00	24.00	0.00
		MEAN	17.50	19.00	53.75	10.00	0.00
		STD	18.28	24.58	17.86	9.52	0.00

Table 5. Continued.

Reach	SU	_STAT_	ClayRM	SandRM	GravelRM	CobbleRM	BoulderRM
		N	1	1	1	1	1
		MIN	3.64	7.27	65.45	14.55	0.00
Mussel	2	MAX	3.64	7.27	65.45	14.55	0.00
		MEAN	3.64	7.27	65.45	14.55	0.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	10.00	46.00	8.00	0.00
14a	13	MAX	30.00	20.00	76.00	14.00	0.00
		MEAN	10.00	15.33	63.33	11.33	0.00
		STD	17.32	5.03	15.53	3.06	0.00
		N	5	5	5	5	5
		MIN	2.00	2.00	34.00	2.00	0.00
14a	22	MAX	30.00	60.00	74.00	22.00	0.00
		MEAN	13.60	26.80	49.60	10.00	0.00
		STD	13.30	23.09	16.99	7.48	0.00
		N	3	3	3	3	3
		MIN	0.00	24.00	58.00	4.00	0.00
14a	25	MAX	0.00	38.00	70.00	4.00	2.00
		MEAN	0.00	31.33	64.00	4.00	0.67
		STD	0.00	7.02	6.00	0.00	1.15
		N	1	1	1	1	1
		MIN	8.16	2.04	89.80	0.00	0.00
Mussel	3	MAX	8.16	2.04	89.80	0.00	0.00
		MEAN	8.16	2.04	89.80	0.00	0.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	46.00	40.00	0.00	0.00
14a	35	MAX	0.00	60.00	54.00	4.00	0.00
		MEAN	0.00	52.67	46.00	1.33	0.00
		STD	0.00	7.02	7.21	2.31	0.00
		N	4	4	4	4	4
		MIN	8.16	0.00	68.00	2.00	0.00
Mussel	4	MAX	20.00	8.00	78.00	20.00	0.00
		MEAN	12.54	3.00	73.87	10.59	0.00
		STD	5.21	3.46	4.33	9.94	0.00
		N	3	3	3	3	3
		MIN	1.96	5.89	52.94	11.76	0.00
14b	3	MAX	11.76	19.61	58.82	27.45	0.00
		MEAN	7.19	14.38	56.21	22.22	0.00
		STD	4.93	7.42	3.00	9.06	0.00
		N	3	3	3	3	3
		MIN	0.00	0.00	54.00	14.00	0.00
14b	8	MAX	22.00	2.00	86.00	30.00	2.00
		MEAN	10.00	0.67	66.67	21.33	1.33
		STD	11.14	1.15	17.01	8.08	1.15

Table 5. Continued.

Reach	SU	_STAT_	ClayRM	SandRM	GravelRM	CobbleRM	BoulderRM
		N	1	1	1	1	1
		MIN	0.00	6.00	86.00	8.00	0.00
Mussel	5	MAX	0.00	6.00	86.00	8.00	0.00
		MEAN	0.00	6.00	86.00	8.00	0.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	4.00	40.00	30.00	0.00
15	7	MAX	0.00	18.00	60.00	42.00	2.00
		MEAN	0.00	11.33	52.00	35.33	1.33
		STD	0.00	7.02	10.58	6.11	1.15
		N	3	3	3	3	3
		MIN	0.00	36.00	42.00	4.00	0.00
15	21	MAX	12.00	42.00	52.00	10.00	6.00
		MEAN	6.00	38.67	46.00	6.00	3.33
		STD	6.00	3.06	5.29	3.46	3.06
		N	3	3	3	3	3
		MIN	0.00	0.00	70.00	12.00	0.00
Mussel	6	MAX	0.00	18.00	82.00	18.00	0.00
		MEAN	0.00	7.33	77.33	15.33	0.00
		STD	0.00	9.45	6.43	3.06	0.00
		N	1	1	1	1	1
		MIN	2.00	8.00	72.00	16.00	2.00
Mussel	7	MAX	2.00	8.00	72.00	16.00	2.00
		MEAN	2.00	8.00	72.00	16.00	2.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	4.00	56.00	16.00	0.00
15	29	MAX	4.00	20.00	62.00	26.00	10.00
		MEAN	1.33	14.00	58.00	22.00	4.67
		STD	2.31	8.72	3.46	5.29	5.03
		N	1	1	1	1	1
		MIN	2.00	4.00	76.00	18.00	0.00
Mussel	8	MAX	2.00	4.00	76.00	18.00	0.00
		MEAN	2.00	4.00	76.00	18.00	0.00
		STD					
		N	4	4	4	4	4
		MIN	0.00	18.00	52.00	12.00	0.00
15	34	MAX	0.00	26.00	62.00	20.00	2.00
		MEAN	0.00	24.00	58.50	16.50	1.00
		STD	0.00	4.00	4.43	4.12	1.15
		N	5	5	5	5	5
		MIN	10.00	4.00	34.00	10.00	2.00
16	1	MAX	22.00	20.00	60.00	38.00	8.00
		MEAN	16.00	9.20	43.20	26.80	4.80
		STD	4.90	6.42	10.26	10.64	2.28

Table 5. Concluded.

Reach	SU	_STAT_	ClayRM	SandRM	GravelRM	CobbleRM	BoulderRM
		N	3	3	3	3	3
		MIN	0.00	0.00	35.29	16.00	4.00
16	2	MAX	4.00	8.00	66.00	52.95	11.76
		MEAN	2.67	4.00	50.43	35.65	7.25
		STD	2.31	4.00	15.36	18.59	4.03
		N	3	3	3	3	3
		MIN	0.00	2.00	18.00	22.00	14.00
16	3	MAX	2.00	42.00	38.00	42.00	20.00
		MEAN	0.67	16.67	30.67	34.67	17.33
		STD	1.15	22.03	11.02	11.02	3.06
		N	3	3	3	3	3
		MIN	2.00	8.00	40.00	20.00	0.00
16	6	MAX	24.00	12.00	68.00	28.00	0.00
		MEAN	11.33	10.00	55.33	23.33	0.00
		STD	11.37	2.00	14.19	4.16	0.00
		N	1	1	1	1	1
		MIN	0.00	14.29	71.42	14.29	0.00
Mussel	11	MAX	0.00	14.29	71.42	14.29	0.00
		MEAN	0.00	14.29	71.42	14.29	0.00
		STD					
		N	3	3	3	3	3
		MIN	0.00	22.00	24.00	0.00	0.00
17	4	MAX	28.00	64.00	68.00	4.00	4.00
		MEAN	10.00	44.00	42.00	2.00	2.00
		STD	15.62	21.07	23.07	2.00	2.00
		N	3	3	3	3	3
		MIN	8.00	0.00	52.00	12.00	2.00
17	6	MAX	18.00	22.00	58.00	20.00	10.00
		MEAN	12.00	12.67	54.67	15.33	5.33
		STD	5.29	11.37	3.06	4.16	4.16
		N	3	3	3	3	3
		MIN	0.00	4.00	34.00	22.00	6.00
17	7	MAX	4.00	20.00	62.00	28.00	14.00
		MEAN	2.67	12.00	52.00	24.00	9.33
		STD	2.31	8.00	15.62	3.46	4.16
		N	3	3	3	3	3
		MIN	0.00	0.00	44.00	9.80	0.00
Mussel	10	MAX	7.84	26.00	80.40	18.00	12.00
		MEAN	2.61	12.00	64.13	15.27	5.33
		STD	4.53	13.11	18.51	4.73	6.11

Table 6. Calculated statistics for flow variables by site with N transects. Reaches and sample units (SU) are in longitudinal order.

Reach	SU	_STAT_	BkfV	BkfQ	F	Re	SheerS
		N	3	3	3	3	3
		MIN	0.46	7.77	0.13	359.28	0.0000008
9	3	MAX	1.00	16.58	0.27	568.86	0.0538051
		MEAN	0.82	11.30	0.21	437.92	0.0192260
		STD	0.31	4.66	0.07	114.16	0.0300088
		N	5	5	5	5	5
		MIN	0.12	8.30	0.05	44.31	0.0000011
9	4	MAX	1.87	39.20	0.55	1530.34	0.2211988
		MEAN	1.07	17.63	0.33	795.91	0.0759831
		STD	0.70	12.40	0.22	555.47	0.0863537
		N	3	3	3	3	3
		MIN	0.44	10.01	0.14	338.12	0.0000008
9	6	MAX	0.72	33.54	0.17	977.25	0.0000013
		MEAN	0.59	19.02	0.16	651.53	0.0000010
		STD	0.14	12.70	0.02	319.74	0.0000003
		N	4	4	4	4	4
		MIN	0.23	1.77	0.07	130.84	0.0000006
9	12	MAX	0.48	7.16	0.14	416.77	0.1664660
		MEAN	0.38	4.95	0.10	282.26	0.0416171
		STD	0.11	2.54	0.04	124.54	0.0832326
		N	3	3	3	3	3
		MIN	0.51	8.42	0.15	493.71	0.0000010
9	45	MAX	2.27	74.46	0.53	3103.69	0.0376412
		MEAN	1.43	34.35	0.38	1543.44	0.0193727
		STD	0.88	35.23	0.20	1377.85	0.0188443
		N	3	3	3	3	3
		MIN	0.50	17.30	0.15	464.07	0.0000009
9	46	MAX	2.02	59.21	0.58	1895.01	0.0688407
		MEAN	1.06	34.09	0.30	1058.28	0.0229476
		STD	0.83	22.16	0.24	745.66	0.0397446
		N	3	3	3	3	3
		MIN	0.71	50.03	0.17	935.33	0.0000013
10	7	MAX	0.91	80.79	0.19	1743.71	0.0000019
		MEAN	0.78	62.10	0.18	1218.76	0.0000015
		STD	0.11	16.41	0.01	455.10	0.0000003
		N	3	3	3	3	3
		MIN	0.49	18.66	0.15	440.12	0.0000009
10	8	MAX	0.68	47.69	0.16	855.09	0.0000012
		MEAN	0.59	34.56	0.15	644.81	0.0000010
		STD	0.10	14.71	0.01	207.54	0.0000002
		N	3	3	3	3	3
		MIN	0.29	3.69	0.08	136.03	0.000
11	17	MAX	1.50	25.68	0.51	1137.72	0.021
		MEAN	0.75	12.64	0.24	551.60	0.007
		STD	0.66	11.55	0.23	522.17	0.012

Table 6. Continued.

Reach	SU	_STAT_	BkfV	BkfQ	F	Re	SheerS
		N	4	4	4	4	4
		MIN	0.17	2.82	0.04	40.72	0.0000002
11	19	MAX	0.48	13.98	0.15	416.77	0.0000009
		MEAN	0.3	6.08	0.0875	175.45	4.75E-07
		STD	0.129872	5.2895368	0.046458	165.4227689	2.99E-07
		N	3	3	3	3	3
		MIN	0.35	7.12	0.12	192.12	0.0000005
12	3	MAX	1.6	40.62	0.55	1197.6	0.0404274
		MEAN	0.79	19.266667	0.273333	563.84	0.0134762
		STD	0.702353	18.550863	0.240069	551.5851963	0.0233404
		N	1	1	1	1	1
		MIN	1.88	50.95	0.49	2138.92	0.0120867
Mussel	1	MAX	1.88	50.95	0.49	2138.92	0.0120867
		MEAN	1.88	50.95	0.49	2138.92	0.0120867
		STD					
		N	3	3	3	3	3
		MIN	0.51	8.62	0.15	483.53	0.0000009
12	22	MAX	1.8	33.8	0.53	1724.55	0.0239134
		MEAN	1.266667	25.34	0.373333	1157.35	0.0112288
		STD	0.673375	14.48029	0.198578	627.3424331	0.0120226
		N	3	3	3	3	3
		MIN	0.45	13.37	0.15	354.79	0.0000008
12	28	MAX	1.56	44.3	0.53	1120.96	0.0384325
		MEAN	1.07	27.026667	0.36	755.39	0.0152772
		STD	0.566304	15.778987	0.193132	384.2843256	0.0203914
		N	3	3	3	3	3
		MIN	1.51	27.77	0.46	1386.43	0.007051
12	35	MAX	2.19	45.44	0.63	2207.49	0.0943458
		MEAN	1.86	34.39	0.54	1823.39	0.0427553
		STD	0.340441	9.6320247	0.08544	413.0744674	0.0457643
		N	5	5	5	5	5
		MIN	0.43	4.64	0.14	317.56	0.0000007
12	38	MAX	1.56	24.63	0.48	1421.26	0.0119571
		MEAN	1.044	15.092	0.32	900.24	0.0050515
		STD	0.539889	8.5705612	0.165076	508.9926137	0.0059092
		N	3	3	3	3	3
		MIN	0.06	0.05	0.02	1.2	0.0000008
13	4	MAX	1.3	27.31	0.39	661.68	0.0692943
		MEAN	0.606667	12.61	0.183333	347.9733333	0.0232046
		STD	0.632877	13.755421	0.188768	331.4792768	0.0399151
		N	4	4	4	4	4
		MIN	0.46	6.62	0.13	381.04	0.0000008
13	8	MAX	1.67	63.23	0.48	1583.33	0.0138296
		MEAN	0.815	29.755	0.235	783.4075	0.0034581
		STD	0.573905	23.870356	0.164621	547.4901644	0.0069143

Table 6. Continued.

Reach	SU	_STAT_	BkfV	BkfQ	F	Re	SheerS
Mussel	2	N	1	1	1	1	1
		MIN	0.73	30.27	0.18	998.1	0.0000013
		MAX	0.73	30.27	0.18	998.1	0.0000013
		MEAN	0.73	30.27	0.18	998.1	0.0000013
		STD					
14a	13	N	3	3	3	3	3
		MIN	0.52	13.48	0.13	518.96	0.000001
		MAX	2	110.18	0.61	1636.73	0.1437389
		MEAN	1.123333	63.766667	0.31	1207.75	0.0479139
		STD	0.776938	48.466221	0.261534	602.4768629	0.0829869
14a	22	N	5	5	5	5	5
		MIN	0.29	1.19	0.08	37.62	0.0000011
		MAX	0.82	63.94	0.19	1350.3	0.0009914
		MEAN	0.642	40.2	0.154	829.44	0.0001994
		STD	0.209809	29.574179	0.043359	508.0834702	0.0004428
14a	25	N	3	3	3	3	3
		MIN	0.47	17.7	0.13	403.39	0.0000008
		MAX	2.48	163.11	0.61	2920.56	0.1035162
		MEAN	1.383333	74.586667	0.35	1431.336667	0.035111
		STD	1.017464	77.696049	0.242487	1320.461406	0.0592476
Mussel	3	N	1	1	1	1	1
		MIN	1.75	68.44	0.5	1589.32	0.0258914
		MAX	1.75	68.44	0.5	1589.32	0.0258914
		MEAN	1.75	68.44	0.5	1589.32	0.0258914
		STD					
14a	35	N	3	3	3	3	3
		MIN	0.47	19.58	0.11	394.01	0.0000008
		MAX	0.75	47.33	0.16	1070.36	0.0000014
		MEAN	0.64	36.92	0.14	793.18	1.17E-06
		STD	0.149332	15.117351	0.026458	354.2929589	3.21E-07
Mussel	4	N	4	4	4	4	4
		MIN	1.21	16.69	0.37	789.02	0.0060401
		MAX	1.78	31.95	0.53	1936.33	0.1022303
		MEAN	1.455	22.85	0.4525	1101.545	0.0386783
		STD	0.245017	6.7268021	0.065511	557.0813448	0.0442432
14b	3	N	3	3	3	3	3
		MIN	0.19	1.8	0.04	22.75	0.0000013
		MAX	1.8	73.4	0.54	1455.09	0.0633984
		MEAN	0.903333	39.65	0.253333	818.3633333	0.0211452
		STD	0.820508	35.975651	0.257941	729.268948	0.0365923
14b	8	N	3	3	3	3	3
		MIN	0.27	4.9	0.1	115.87	0.0000004
		MAX	1.74	64.07	0.51	1684.43	0.0172562
		MEAN	0.836667	29.306667	0.25	754.79	0.0057525
		STD	0.790717	30.914683	0.226053	823.7012245	0.0099625

Table 6. Continued.

Reach	SU	_STAT_	BkfV	BkfQ	F	Re	SheerS
		N	1	1	1	1	1
		MIN	1.58	0.0008	0.43	1529.54	0.0074314
Mussel	5	MAX	1.58	0.0008	0.43	1529.54	0.0074314
		MEAN	1.58	0.0008	0.43	1529.54	0.0074314
		STD					
		N	3	3	3	3	3
		MIN	0.52	25.85	0.16	513.77	0.000001
15	7	MAX	1.76	100.71	0.41	2125.35	0.0121435
		MEAN	1.18	51.06	0.32	1152.163333	0.0057704
		STD	0.623859	42.999885	0.138924	856.3658425	0.0060937
		N	3	3	3	3	3
		MIN	0.78	59.8	0.18	1183.23	0.0000015
15	21	MAX	2.19	138.63	0.54	2600.9	0.0353938
		MEAN	1.536667	97.626667	0.373333	1948.803333	0.0125305
		STD	0.710657	39.510893	0.181475	715.6149612	0.0198306
		N	3	3	3	3	3
		MIN	1.28	47.71	0.33	843.11	0.0068654
Mussel	6	MAX	3.23	230.2	0.81	4126.15	0.5871547
		MEAN	2.126667	127.91667	0.523333	2440.253333	0.2024199
		STD	1.000017	93.226522	0.253246	1643.318525	0.3332053
		N	1	1	1	1	1
		MIN	0.95	10.77	0.37	369.76	0.02239
Mussel	7	MAX	0.95	10.77	0.37	369.76	0.02239
		MEAN	0.95	10.77	0.37	369.76	0.02239
		STD					
		N	3	3	3	3	3
		MIN	0.6	31.52	0.15	616.77	0.000001
15	29	MAX	2.31	71.43	0.66	2259.28	0.1757634
		MEAN	1.203333	47.616667	0.326667	1259.083333	0.0585886
		STD	0.959705	21.044292	0.288848	877.7927633	0.1014764
		N	1	1	1	1	1
		MIN	1.4	48.41	0.45	866.27	0.0384022
Mussel	8	MAX	1.4	48.41	0.45	866.27	0.0384022
		MEAN	1.4	48.41	0.45	866.27	0.0384022
		STD					
		N	4	4	4	4	4
		MIN	0.89	23.92	0.37	408.58	0.002135
15	34	MAX	2.08	99.05	0.6	1972.06	0.082825
		MEAN	1.4625	68.475	0.4525	1269.1125	0.0245405
		STD	0.48822	31.846985	0.101448	645.5387411	0.0389291
		N	5	5	5	5	5
		MIN	0.48	31.12	0.14	426.35	0.0000009
16	1	MAX	1.48	98.51	0.49	1240.72	0.0100436
		MEAN	0.93	63.932	0.278	887.046	0.0033725
		STD	0.439261	26.923471	0.16453	322.382664	0.0047554

Table 6. Concluded.

Reach	SU	_STAT_	BkfV	BkfQ	F	Re	SheerS
		N	3	3	3	3	3
		MIN	0.63	31.67	0.14	697.9	0.0000011
16	2	MAX	1.58	60.59	0.52	1056.49	0.0668528
		MEAN	0.97	42.813333	0.273333	889.8533333	0.0222851
		STD	0.529434	15.55932	0.213854	180.6305545	0.0385968
		N	3	3	3	3	3
		MIN	0.67	31.47	0.13	802.4	0.0000012
16	3	MAX	1.6	48.89	0.41	1724.55	0.0044834
		MEAN	1.016667	42.486667	0.24	1239.323333	0.0014954
		STD	0.508167	9.5826006	0.149332	462.9687512	0.0025877
		N	3	3	3	3	3
		MIN	0.22	1.83	0.08	21.96	0.0000004
16	6	MAX	0.81	5.69	0.37	258.68	0.0171687
		MEAN	0.433333	3.2733333	0.183333	132.17	0.0059547
		STD	0.327159	2.1060469	0.161967	119.1988133	0.0097178
		N	1	1	1	1	1
		MIN	0.43	19.26	0.11	317.56	0.0000007
Mussel	11	MAX	0.43	19.26	0.11	317.56	0.0000007
		MEAN	0.43	19.26	0.11	317.56	0.0000007
		STD					
		N	3	3	3	3	3
		MIN	0.53	27.51	0.14	534.23	0.000001
17	4	MAX	1.64	55.56	0.42	1603.99	0.0095263
		MEAN	0.946667	37.763333	0.243333	986.8933333	0.0031762
		STD	0.604511	15.471814	0.153731	553.5118384	0.0054994
		N	3	3	3	3	3
		MIN	1.27	22.64	0.39	826.35	0.0085293
17	6	MAX	2.34	127.06	0.44	3853.29	0.0429429
		MEAN	1.663333	58.783333	0.42	1838.723333	0.021041
		STD	0.588586	59.163312	0.026458	1744.673336	0.0190317
		N	3	3	3	3	3
		MIN	1.08	32.46	0.37	668.26	0.0047518
17	7	MAX	2.12	89.42	0.6	2158.08	0.0635199
		MEAN	1.586667	69.2	0.476667	1445.506667	0.0250013
		STD	0.520513	31.871511	0.115902	747.0126426	0.0333728
		N	3	3	3	3	3
		MIN	0.55	7.95	0.17	192.12	0.0000012
Mussel	10	MAX	2.59	96.37	0.63	2946.71	0.185382
		MEAN	1.266667	45.8	0.326667	1307.553333	0.0619529
		STD	1.147359	45.561748	0.262742	1450.053832	0.106893

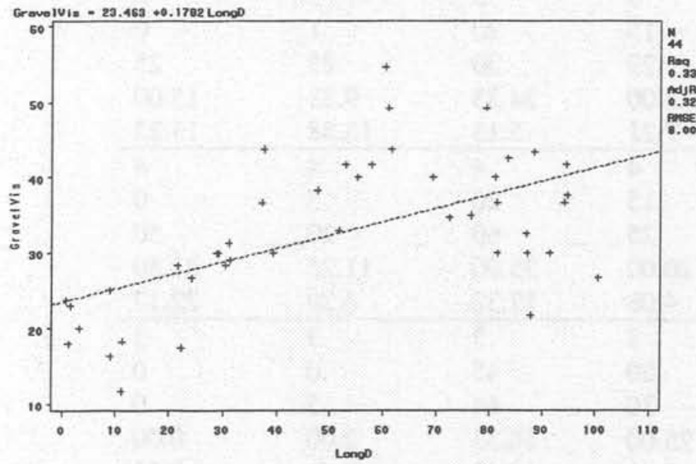
Table 7. Stream condition variables by site with N transects. Reaches and sample units (SU) are in longitudinal order.

Reach	SU	N	Class	Size	Pfankuch	Condition	Debris	Alteration
9	3	3	C4	S-7	73	Good	None	None
9	4	5	C3	S-6	70	Good	None	None
9	6	3	C4c	S-7	84	Good	None	None
9	12	4	F3	S-6	73	Excellent	None	None
9	45	3	F3	S-6	78	Excellent	None	None
9	46	3	C4	S-8	79	Good	None	None
10	7	3	C4c	S-9	70	Good	SWD	Bridge
10	8	3	C4c	S-9	82	Good	SWD	Bridge
11	17	3	F4	S-7	91	Good	None	None
11	19	4	F4	S-7	73	Excellent	None	Grazing, Ford, Bulldozing
12	3	3	F4	S-8	96	Good	LWD	Logging
Mussel	1	1	F4	S-6	86	Good	None	None
12	22	3	F5	S-6	87	Excellent	None	None
12	28	3	F4	S-8	94	Good	LWD	Feral Pigs
12	35	3	F4	S-6	88	Good	None	Feral Pigs
12	38	5	F4	S-6	86	Good	LWD	None
13	4	3	F4	S-8	76	Excellent	None	Grazing
13	8	4	F4	S-8	83	Excellent	None	None
Mussel	2	1	B4c	S-7	84	Fair	LWD	None
14a	13	3	F4	S-8	87	Good	None	None
14a	22	5	C4c	S-8	88	Good	None	None
14a	25	3	F4	S-9	70	Excellent	None	None
Mussel	3	1	C4	S-8	68	Excellent	LWD	Dump Site
14a	35	3	F4	S-9	87	Good	LWDJ	Cleared rip veg
Mussel	4	4	F4	S-6	68	Excellent	None	Ford
14b	3	3	F4	S-8	82	Excellent	None	None
14b	8	3	F4	S-8	80	Excellent	None	None
Mussel	5	1	F4	S-9	68	Excellent	LWD	None
15	7	3	F4	S-8	69	Excellent	LWD	Grazing
15	21	3	F4	S-9	79	Excellent	None	None
Mussel	6	3	C4	S-9	81	Good	None	None
Mussel	7	1	C4	S-7	69	Excellent	LWD	None
15	29	3	F4	S-8	81	Excellent	LWDJ	None
Mussel	8	1	F4	S-9	74	Excellent	LWDJ	None
15	34	4	F4	S-9	69	Excellent	None	Ford
16	1	5	F4	S-9	84	Excellent	None	Feral Pigs
16	2	3	B3c	S-9	81	Poor	None	None
16	3	3	F3	S-8	69	Excellent	None	None
16	6	3	B4c	S-7	73	Fair	None	Low head dam
Mussel	11	1	F4	S-9	83	Excellent	LWD	Bulldozing
17	4	3	F4	S-8	69	Excellent	None	None
17	6	3	F4	S-7	71	Excellent	None	None
17	7	3	F4	S-9	64	Excellent	None	None
Mussel	10	3	C4	S-8	67	Excellent	SWD	Low head dam

Appendix 1

Visual Estimates of Substrate Percentage

Visual estimates could be used to correct pebble count sampling bias. Visually estimated gravel percentages significantly increased in the downstream direction ($R^2 = 0.3368$, $p<0.0001$, top figure). Visually estimated bedrock percentages significantly decreased in the downstream direction ($R^2 = 0.1601$, $p=0.0071$, bottom figure). No other visual substrate variables had significant longitudinal trends. These linear regression results are comparable to the RiverMorph calculated substrate percentage results, except cobble percentage, which was found to significantly decrease downstream in the RiverMorph calculated percentages.



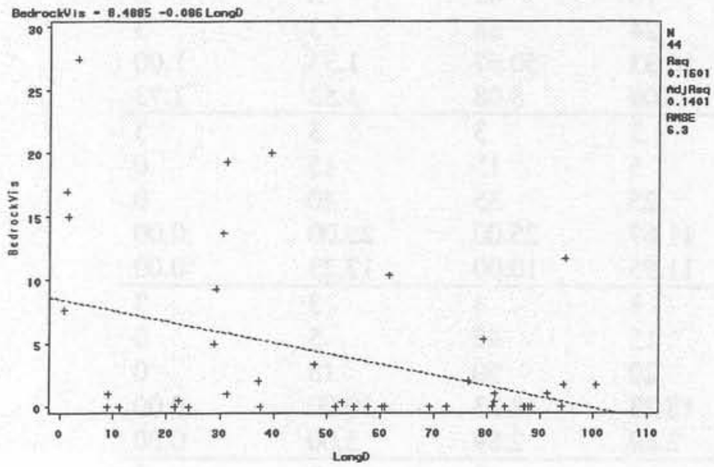


Table A1. Statistics for visually estimated substrate percentages by site with N transects. Reaches and sample units (SU) are in longitudinal order.

Reach	SU	_STAT_	FinesVis	GravelVis	CobbleVis	BoulderVis	BedrockVis
9	3	N	3	3	3	3	3
		MIN	17	16	45	2	0
		MAX	25	30	45	2	20
		MEAN	21.67	23.67	45.00	2.00	7.67
		STD	4.16	7.09	0.00	0.00	10.79
9	4	N	5	5	5	5	5
		MIN	10	10	20	5	0
		MAX	25	25	35	30	40
		MEAN	19	18	29	17	17
		STD	5.48	5.70	6.52	11.51	15.65
9	6	N	3	3	3	3	3
		MIN	20	15	20	1	0
		MAX	40	29	30	25	25
		MEAN	28.33	23.00	24.33	9.33	15.00
		STD	10.41	7.21	5.13	13.58	13.23
9	12	N	4	4	4	4	4
		MIN	5	15	20	5	0
		MAX	10	25	60	20	50
		MEAN	6.25	20.00	35.00	11.25	27.50
		STD	2.50	4.08	17.32	6.29	22.17
9	45	N	3	3	3	3	3
		MIN	15	20	45	0	0
		MAX	20	30	64	5	0
		MEAN	16.67	25.00	56.33	2.00	0.00
		STD	2.89	5.00	10.02	2.65	0.00
9	46	N	3	3	3	3	3
		MIN	15	10	42	0	0
		MAX	42	24	58	3	3
		MEAN	30.67	16.33	50.67	1.33	1.00
		STD	14.01	7.09	8.08	1.53	1.73
10	7	N	3	3	3	3	3
		MIN	35	5	15	15	0
		MAX	40	25	35	40	0
		MEAN	38.33	11.67	25.00	25.00	0.00
		STD	2.89	11.55	10.00	13.23	0.00
10	8	N	3	3	3	3	3
		MIN	20	15	45	5	0
		MAX	25	20	50	15	0
		MEAN	23.33	18.33	48.33	10.00	0.00
		STD	2.89	2.89	2.89	5.00	0.00
11	17	N	3	3	3	3	3
		MIN	20	20	25	0	0
		MAX	50	40	40	5	0
		MEAN	40.00	28.33	30.00	1.67	0.00
		STD	17.32	10.41	8.66	2.89	0.00

Table A1. Continued.

Reach	SU	_STAT_	FinesVis	GravelVis	CobbleVis	BoulderVis	BedrockVis
		N	4	4	4	4	4
		MIN	20	15	40	0	0
11	19	MAX	35	20	60	5	2
		MEAN	31.25	17.50	48.50	2.25	0.50
		STD	7.50	2.89	8.39	2.06	1.00
		N	3	3	3	3	3
		MIN	40	20	20	0	0
12	3	MAX	50	30	30	10	0
		MEAN	46.67	26.67	26.67	3.33	0.00
		STD	5.77	5.77	5.77	5.77	0.00
		N	1	1	1	1	1
		MIN	20	30	15	0	5
Mussel	1	MAX	20	30	15	0	5
		MEAN	20	30	15	0	5
		STD					
		N	3	3	3	3	3
		MIN	37	30	15	0	1
12	22	MAX	40	30	29	1	15
		MEAN	39.00	30.00	21.33	0.33	9.33
		STD	1.73	0.00	7.09	0.58	7.37
		N	3	3	3	3	3
		MIN	20	20	20	0	0
12	28	MAX	40	35	35	0	40
		MEAN	30.00	28.33	28.33	0.00	13.67
		STD	10.00	7.64	7.64	0.00	22.81
		N	3	3	3	3	3
		MIN	20	10	5	0	0
12	35	MAX	30	45	38	0	55
		MEAN	26.67	31.33	22.67	0.00	19.33
		STD	5.77	18.72	16.62	0.00	30.92
		N	5	5	5	5	5
		MIN	35	25	5	0	0
12	38	MAX	70	30	35	0	5
		MEAN	49	29	19	0	1
		STD	15.17	2.24	13.42	0.00	2.24
		N	3	3	3	3	3
		MIN	40	30	15	0	0
13	4	MAX	45	40	22	2	5
		MEAN	43.33	36.67	17.33	0.67	2.00
		STD	2.89	5.77	4.04	1.15	2.65
		N	4	4	4	4	4
		MIN	25	20	2	0	0
13	8	MAX	68	70	35	0	0
		MEAN	40.75	43.75	15.50	0.00	0.00
		STD	20.47	22.87	15.20	0.00	0.00

Table A1. Continued.

Reach	SU	_STAT_	FinesVis	GravelVis	CobbleVis	BoulderVis	BedrockVis
		N	1	1	1	1	1
		MIN	40	30	10	0	20
Mussel	2	MAX	40	30	10	0	20
		MEAN	40	30	10	0	20
		STD					
		N	3	3	3	3	3
		MIN	30	25	10	2	0
14a	13	MAX	45	45	23	10	10
		MEAN	36.67	38.33	17.00	4.67	3.33
		STD	7.64	11.55	6.56	4.62	5.77
		N	5	5	5	5	5
		MIN	20	20	5	0	0
14a	22	MAX	60	50	40	5	0
		MEAN	41	33	24	2	0
		STD	15.17	13.04	12.94	2.74	0.00
		N	3	3	3	3	3
		MIN	35	35	14	0	0
14a	25	MAX	50	45	20	0	1
		MEAN	41.67	41.67	16.33	0.00	0.33
		STD	7.64	5.77	3.21	0.00	0.58
		N	1	1	1	1	1
		MIN	30	40	30	0	0
Mussel	3	MAX	30	40	30	0	0
		MEAN	30	40	30	0	0
		STD					
		N	3	3	3	3	3
		MIN	50	40	0	0	0
14a	35	MAX	60	45	5	0	0
		MEAN	56.00	41.67	2.33	0.00	0.00
		STD	5.29	2.89	2.52	0.00	0.00
		N	4	4	4	4	4
		MIN	2	35	20	0	0
Mussel	4	MAX	10	70	60	2	0
		MEAN	5	54.75	39.75	0.5	0
		STD	3.56	15.92	18.08	1.00	0.00
		N	3	3	3	3	3
		MIN	5	28	15	0	0
14b	3	MAX	40	80	30	5	0
		MEAN	28.33	49.33	20.00	2.33	0.00
		STD	20.21	27.23	8.66	2.52	0.00
		N	3	3	3	3	3
		MIN	1	19	18	1	0
14b	8	MAX	20	64	48	2	30
		MEAN	12.00	43.67	32.00	1.67	10.33
		STD	9.85	22.81	15.10	0.58	17.04

Table A1. Continued.

Reach	SU	_STAT_	FinesVis	GravelVis	CobbleVis	BoulderVis	BedrockVis
Mussel	5	N	1	1	1	1	1
		MIN	40	40	20	0	0
		MAX	40	40	20	0	0
		MEAN	40	40	20	0	0
		STD					
15	7	N	3	3	3	3	3
		MIN	20	30	35	1	0
		MAX	30	40	45	1	0
		MEAN	24.67	34.67	39.67	1.00	0.00
		STD	5.03	5.03	5.03	0.00	0.00
15	21	N	3	3	3	3	3
		MIN	40	30	14	1	0
		MAX	50	40	25	2	5
		MEAN	44.00	35.00	17.67	1.33	2.00
		STD	5.29	5.00	6.35	0.58	2.65
Mussel	6	N	3	3	3	3	3
		MIN	2	40	25	0	1
		MAX	30	58	30	1	10
		MEAN	15.67	49.33	26.67	0.33	5.33
		STD	14.01	9.02	2.89	0.58	4.51
Mussel	7	N	1	1	1	1	1
		MIN	20	40	40	0	0
		MAX	20	40	40	0	0
		MEAN	20	40	40	0	0
		STD					
15	29	N	3	3	3	3	3
		MIN	15	35	30	0	0
		MAX	24	40	45	15	1
		MEAN	19.67	36.67	36.67	6.67	0.33
		STD	4.51	2.89	7.64	7.64	0.58
Mussel	8	N	1	1	1	1	1
		MIN	20	30	50	1	1
		MAX	20	30	50	1	1
		MEAN	20	30	50	1	1
		STD					
15	34	N	4	4	4	4	4
		MIN	15	20	15	0	0
		MAX	20	65	60	10	0
		MEAN	16.25	42.50	37.50	3.75	0.00
		STD	2.50	23.27	23.27	4.79	0.00
16	1	N	5	5	5	5	5
		MIN	15	25	15	2	0
		MAX	45	40	40	10	0
		MEAN	31	32.6	30	6.4	0
		STD	11.94	6.02	10.61	3.51	0.00

Table A1. Concluded.

Reach	SU	_STAT_	FinesVis	GravelVis	CobbleVis	BoulderVis	BedrockVis
		N	3	3	3	3	3
		MIN	10	20	35	10	0
16	2	MAX	15	40	40	30	0
		MEAN	11.67	30.00	38.33	20.00	0.00
		STD	2.89	10.00	2.89	10.00	0.00
		N	3	3	3	3	3
		MIN	10	15	25	20	0
16	3	MAX	15	35	40	50	0
		MEAN	11.67	21.67	33.33	33.33	0.00
		STD	2.89	11.55	7.64	15.28	0.00
		N	3	3	3	3	3
		MIN	20	30	13	0	0
16	6	MAX	40	50	30	5	0
		MEAN	31.67	43.33	22.67	2.33	0.00
		STD	10.41	11.55	8.74	2.52	0.00
		N	1	1	1	1	1
		MIN	60	30	10	0	1
Mussel	11	MAX	60	30	10	0	1
		MEAN	60	30	10	0	1
		STD					
		N	3	3	3	3	3
		MIN	40	20	0	0	0
17	4	MAX	80	50	10	2	0
		MEAN	56.67	36.67	6.00	0.67	0.00
		STD	20.82	15.28	5.29	1.15	0.00
		N	3	3	3	3	3
		MIN	20	40	25	5	0
17	6	MAX	30	45	30	10	5
		MEAN	23.33	41.67	26.67	6.67	1.67
		STD	5.77	2.89	2.89	2.89	2.89
		N	3	3	3	3	3
		MIN	15	30	10	2	0
17	7	MAX	30	45	35	5	35
		MEAN	21.67	37.67	25.00	4.00	11.67
		STD	7.64	7.51	13.23	1.73	20.21
		N	3	3	3	3	3
		MIN	10	25	25	1	0
Mussel	10	MAX	43	30	60	5	3
		MEAN	27.67	26.67	41.67	2.67	1.67
		STD	16.62	2.89	17.56	2.08	1.53

Appendix 2
Monumentation of Sample Sites

Table A2. GPS coordinates for all sample sites (SU; geographic coordinate system: GCS North American 1983; projected geographic coordinate system: NAD 1983 UTM Zone 15 N), channel unit type (CU; PT = pool tail, RU = run, RI = riffle), and number of transects (N). Coordinates are for the farthest upstream transect at each sample site. Sites are in longitudinal order.

SU	Easting (X)	Northing (Y)	CU	N
9-3	350606.14	3834590.34	PT	3
9-4	350595.25	3834502.40	PT	4
9-6	349990.31	3834422.06	PT	3
9-12	348074.60	3834467.91	PT	4
9-45	341183.51	3836176.70	PT	3
9-46	341111.66	3836295.54	PT	3
10-7	337832.51	3836775.05	PT	3
10-8	337786.91	3836759.85	PT	3
11-17	327464.91	3839380.31	PT	3
11-19	326824.22	3839158.98	PT	4
12-3	325051.26	3839592.38	RU	3
Mussel 1	320548.14	3838979.50	RU	1
12-22	320603.69	3838832.81	PT	3
12-28	318693.42	3839532.98	PT	3
12-35	318518.54	3839261.49	PT	3
12-38	318187.29	3839548.58	PT	5
13-4	314299.29	3837015.58	PT	3
13-8	313949.82	3837157.69	PT	3
Mussel 2	311644.29	3836932.53	RU	1
14a-13	300180.79	3833534.88	PT	3
14a-22	294708.12	3832938.45	PT	5
14a-25	293457.03	3832414.25	PT	3
Mussel 3	289254.30	3832643.79	RU	1
14a-35	286537.56	3831151.50	PT	3
Mussel 4	285143.77	3828367.14	PT	4
14b-3	284300.97	3828525.84	PT	3
14b-8	283369.05	3827924.75	PT	3
Mussel 5	273329.78	3824611.81	RU	1
15-7	271771.38	3820853.85	PT	3
15-21	267368.08	3817419.75	PT	3
Mussel 6	263813.50	3814924.48	RU	3
Mussel 7	262835.92	3812551.04	RI	1
15-29	263656.73	3811900.48	PT	3
Mussel 8	263636.48	3811898.70	RI	1
15-34	261879.11	3809878.23	PT	4

Table A2. Concluded.

SU	Easting (X)	Northing (Y)	CU	N
16-1	262433.59	3806483.73	PT	5
16-2	261583.22	3806581.58	PT	3
16-3	261501.68	3806476.74	PT	3
16-6	260865.65	3804950.73	PT	3
Mussel 11	257482.86	3802931.32	RU	1
17-4	257515.42	3801470.03	PT	3
17-6	258223.67	3800782.74	PT	3
17-7	258151.45	3800663.92	PT	3
Mussel 10	258171.74	3793537.81	PT	3

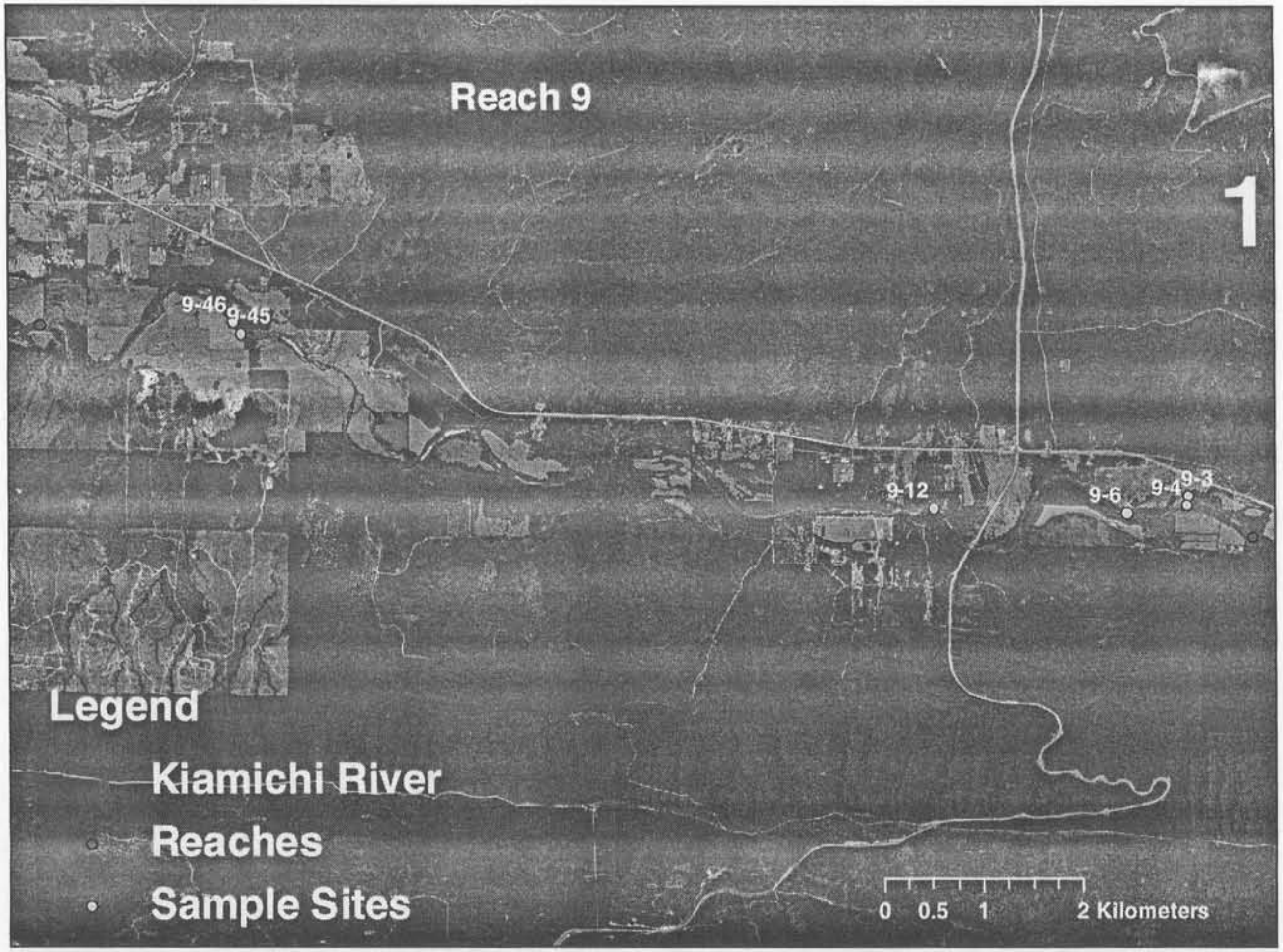


Figure A2-1. Reach 9 sample sites. See Figure 17 for an overview of all reaches.

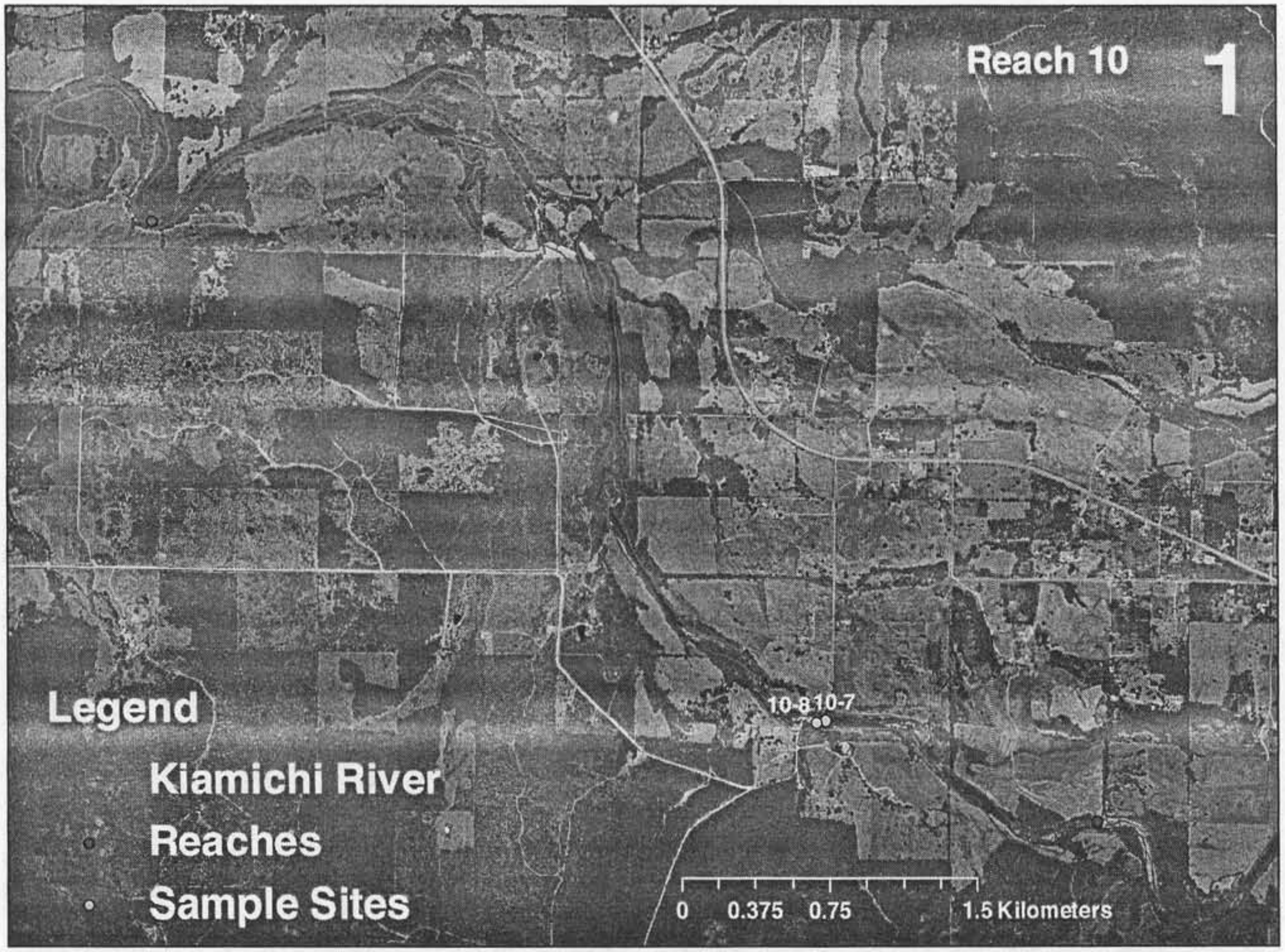


Figure A2-2. Reach 10 sample sites.

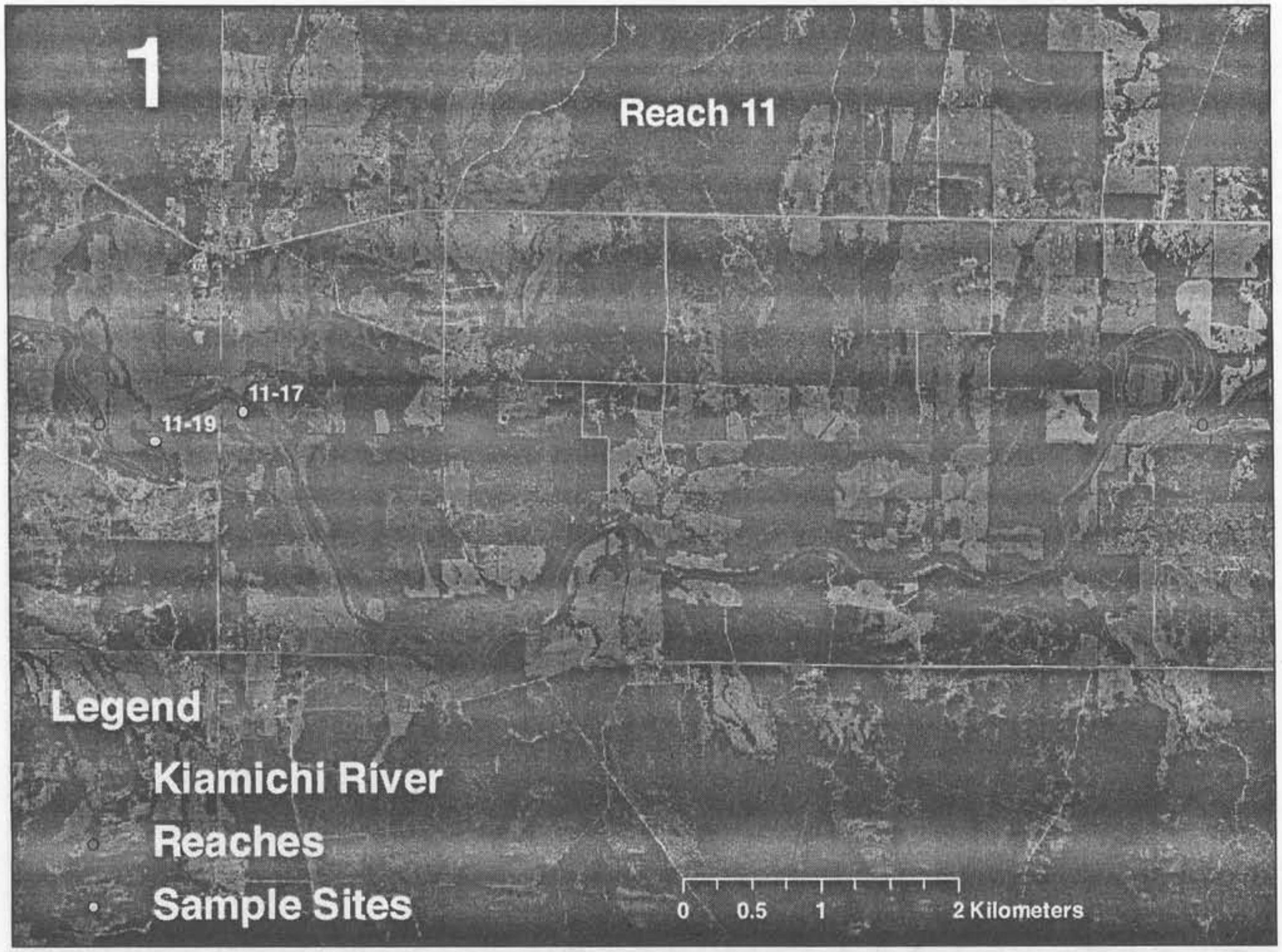


Figure A2-3. Reach 11 sample sites.

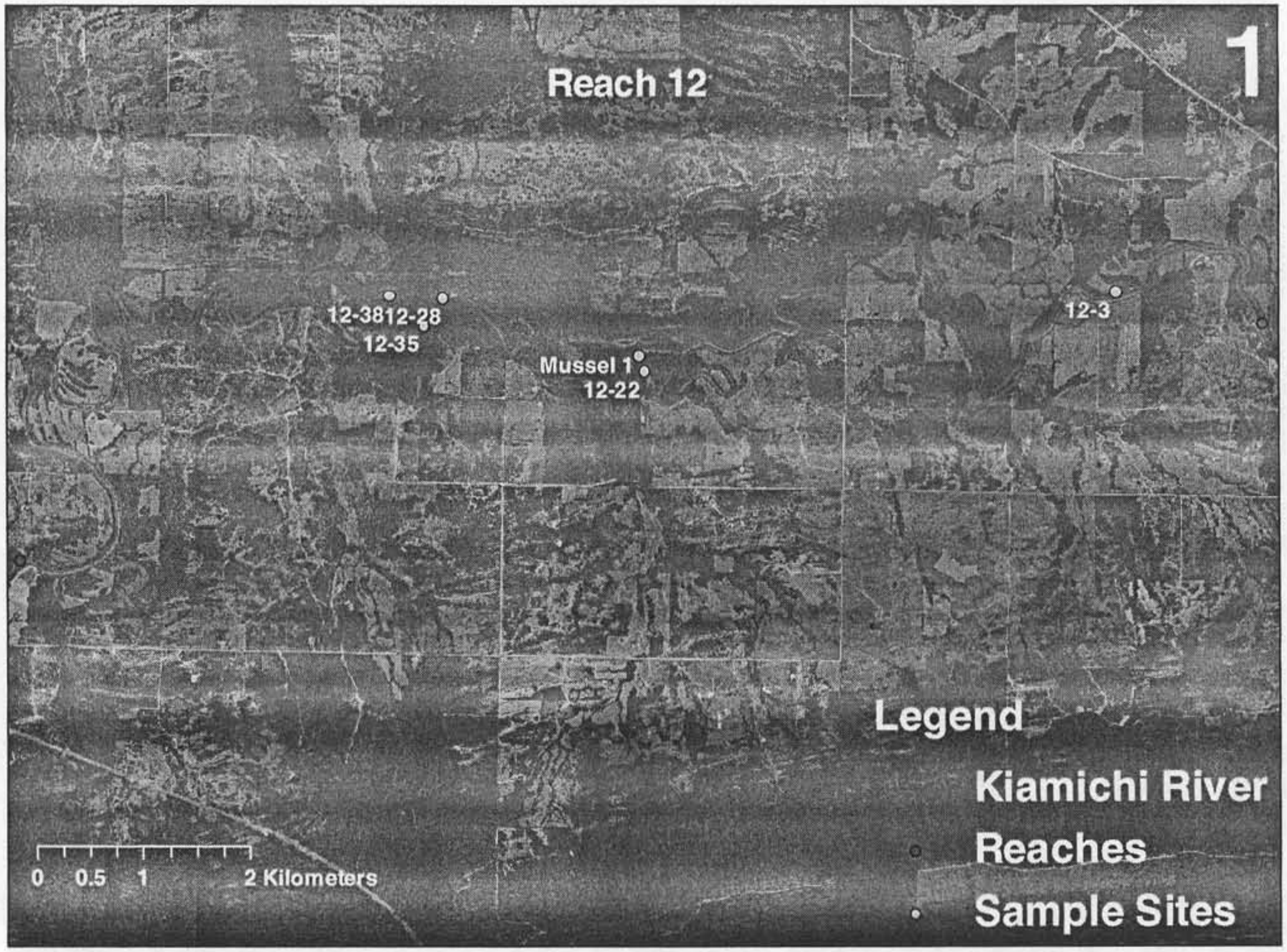


Figure A2-4. Reach 12 sample sites.

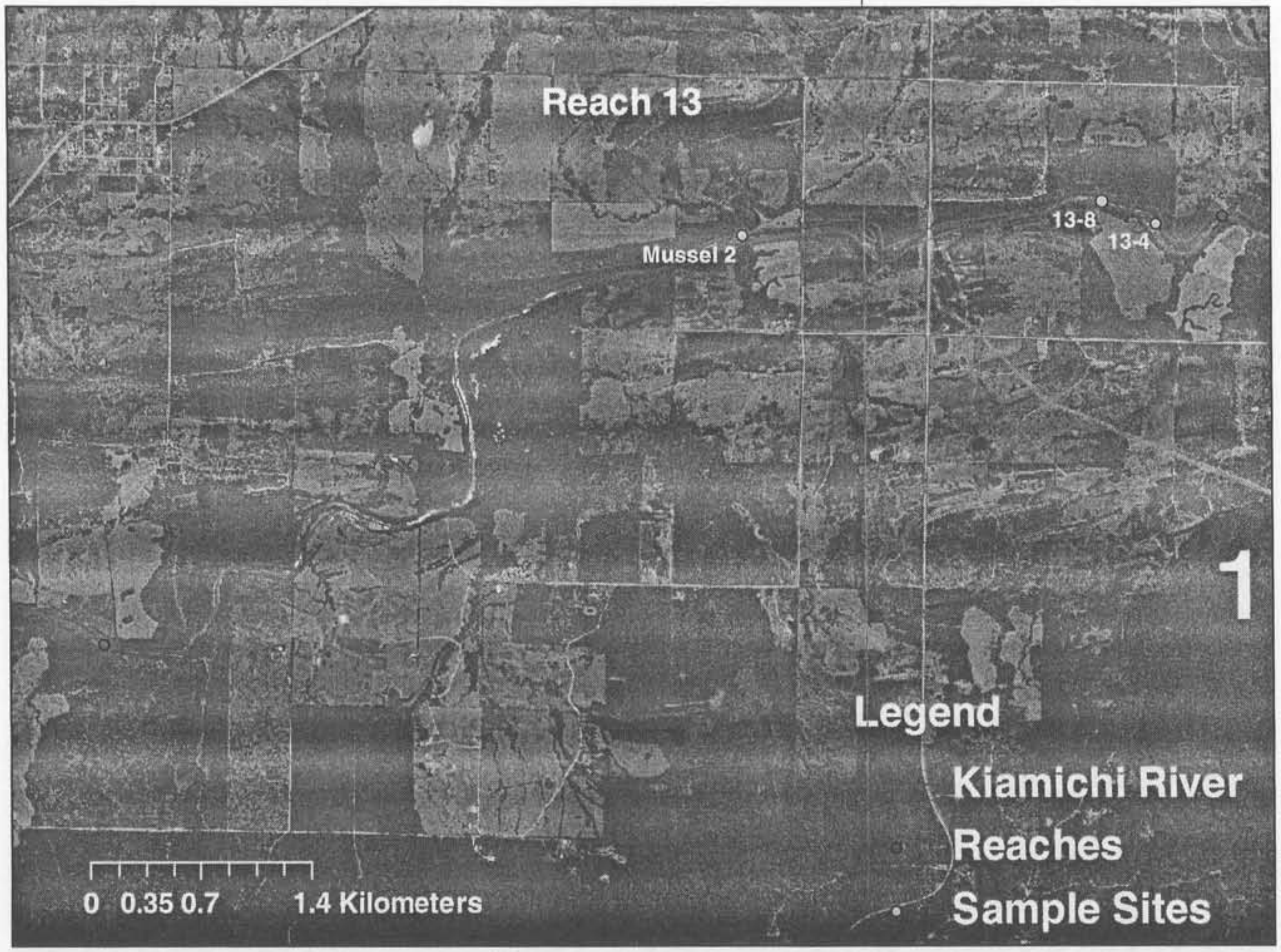


Figure A2-5. Reach 13 sample sites.

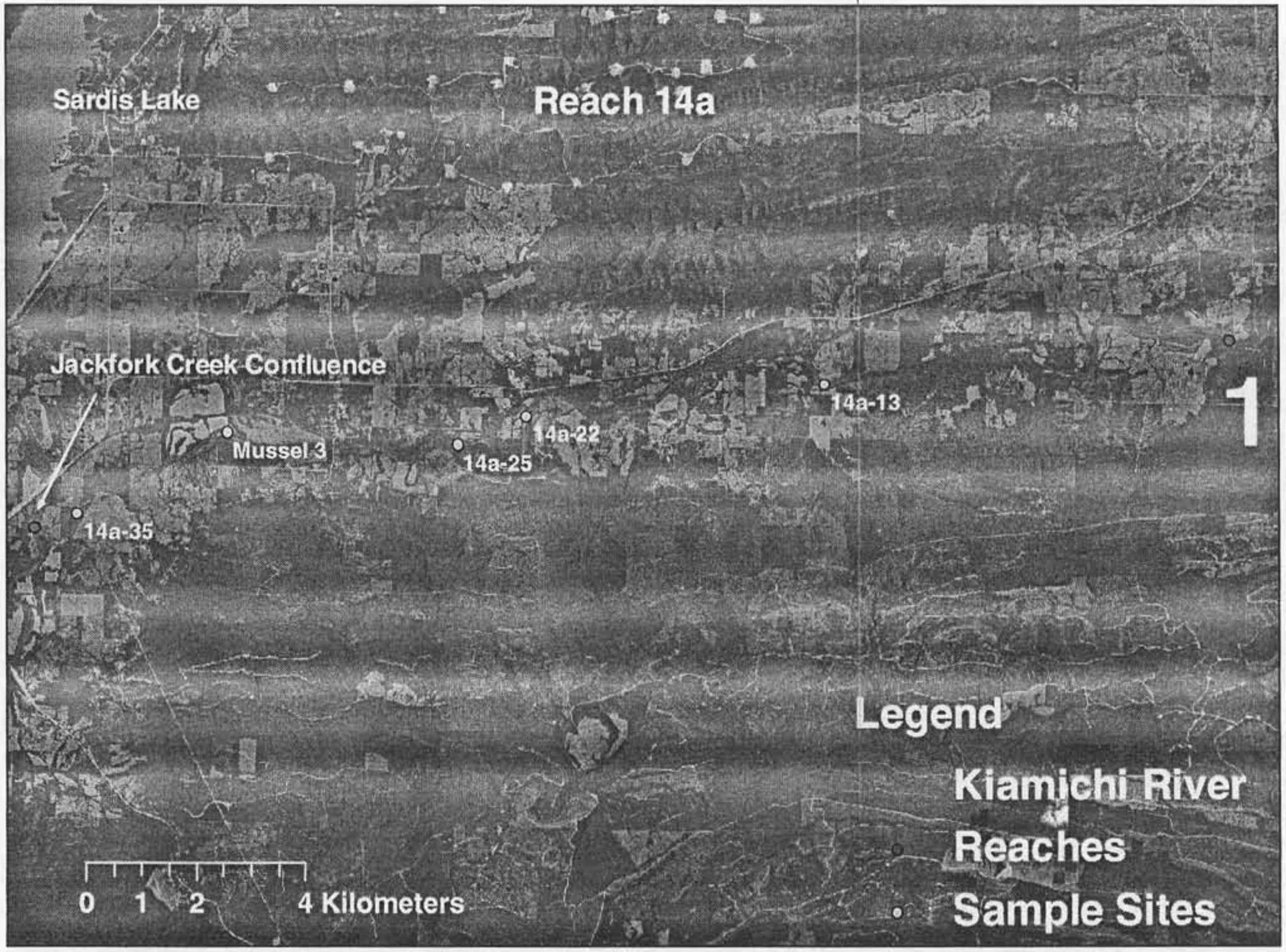


Figure A2-6. Reach 14a sample sites.

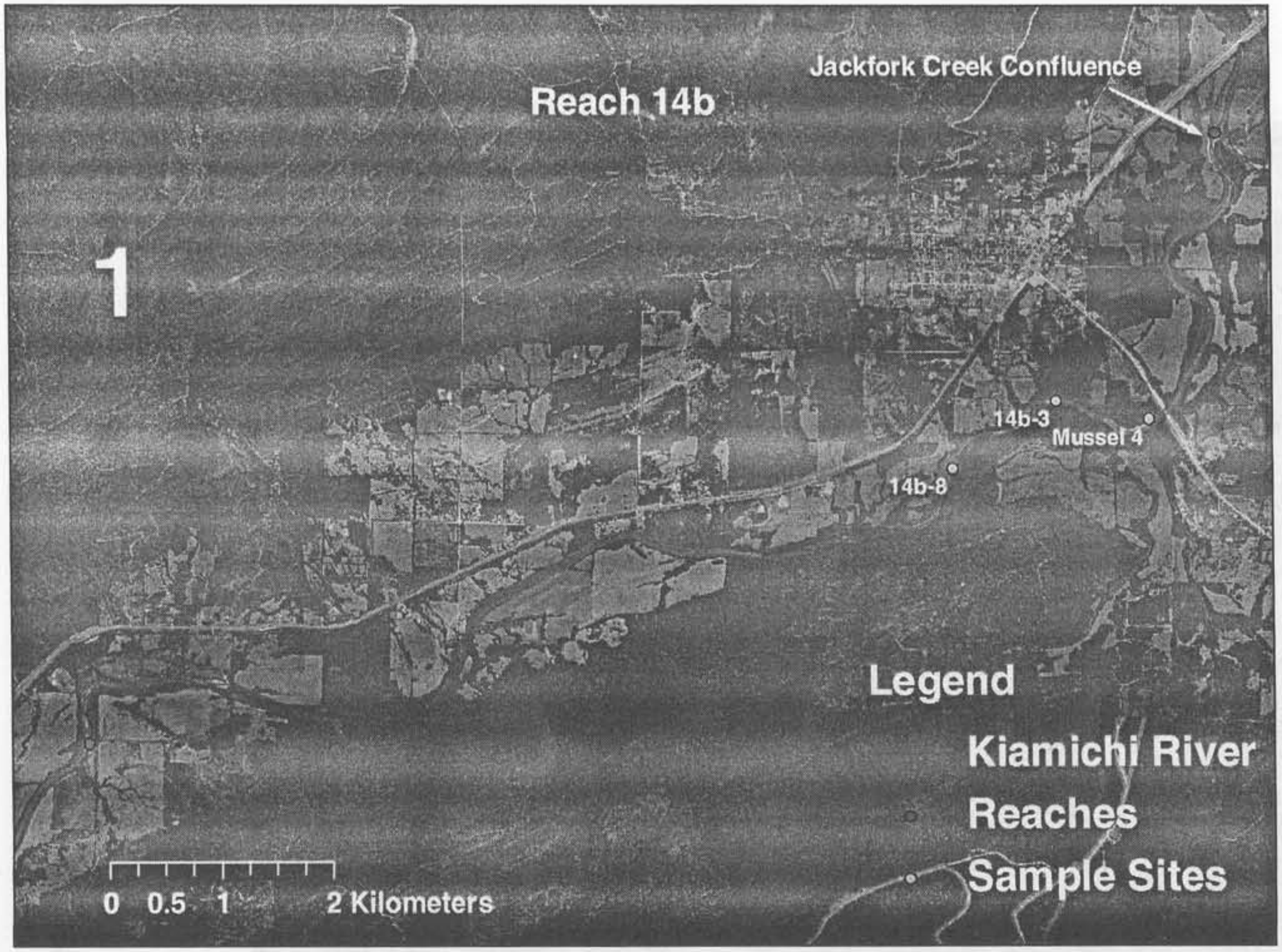


Figure A2-7. Reach 14b sample sites.

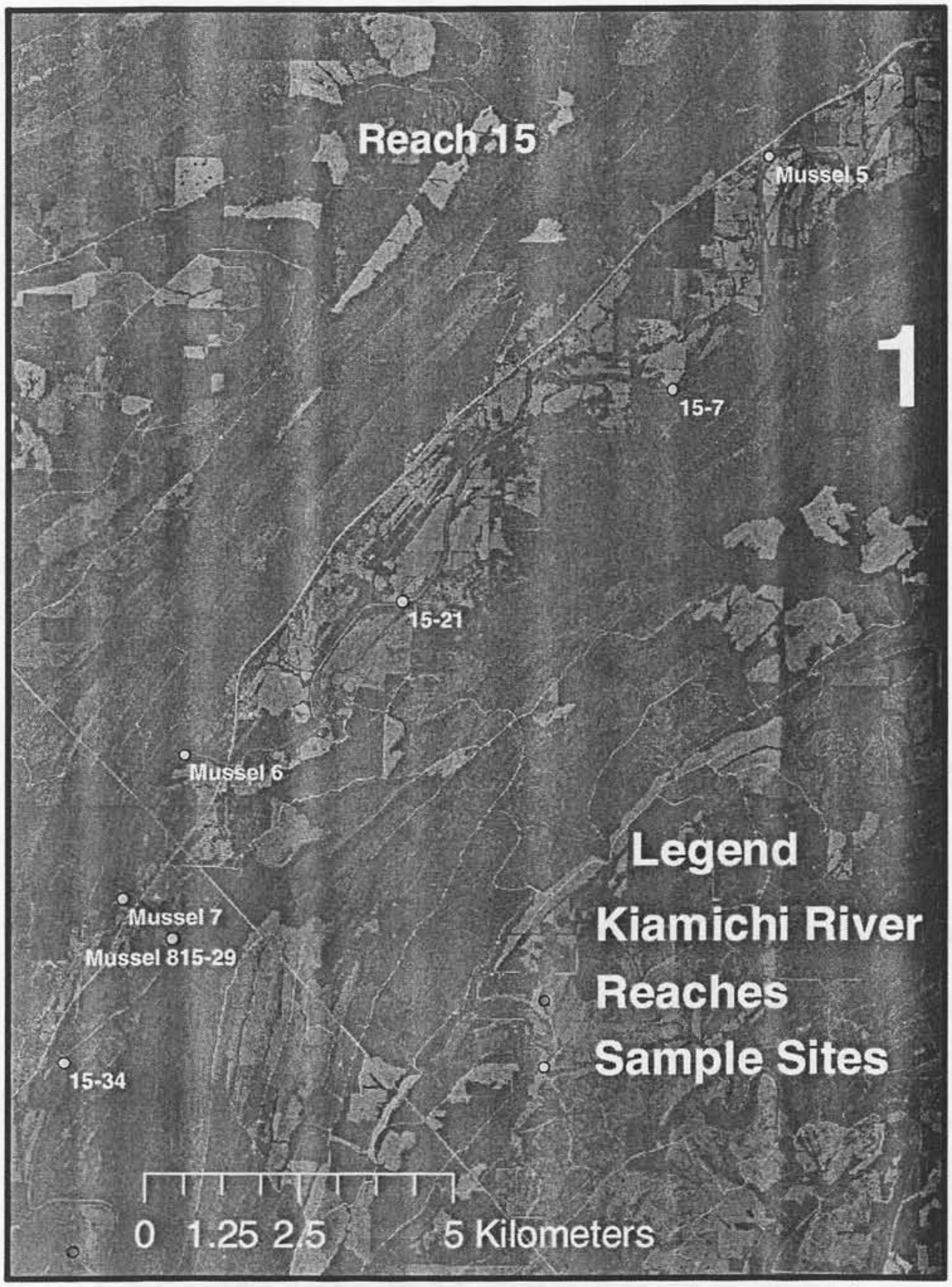


Figure A2-8. Reach 15 sample sites.

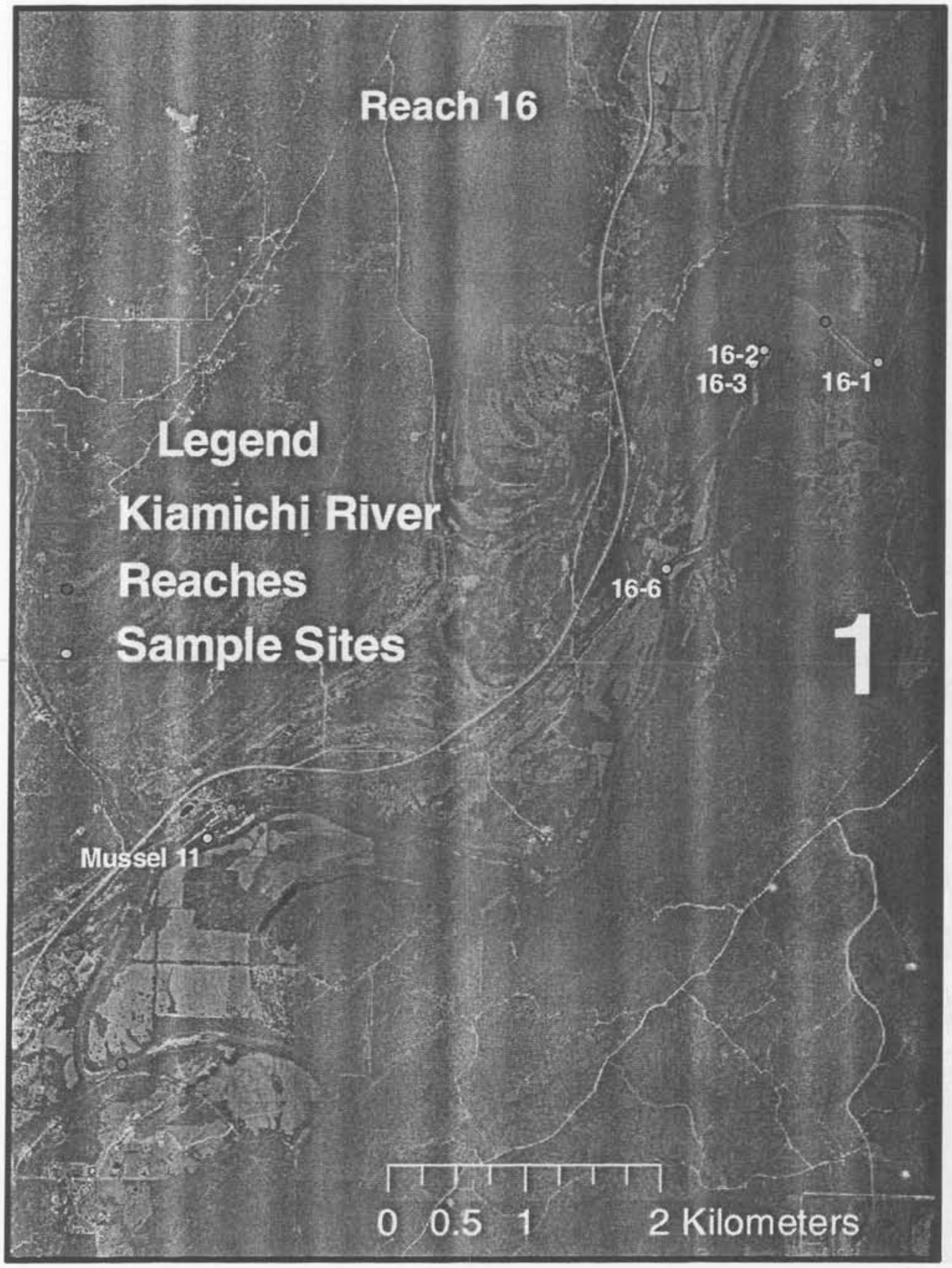


Figure A2-9. Reach 16 sample sites.

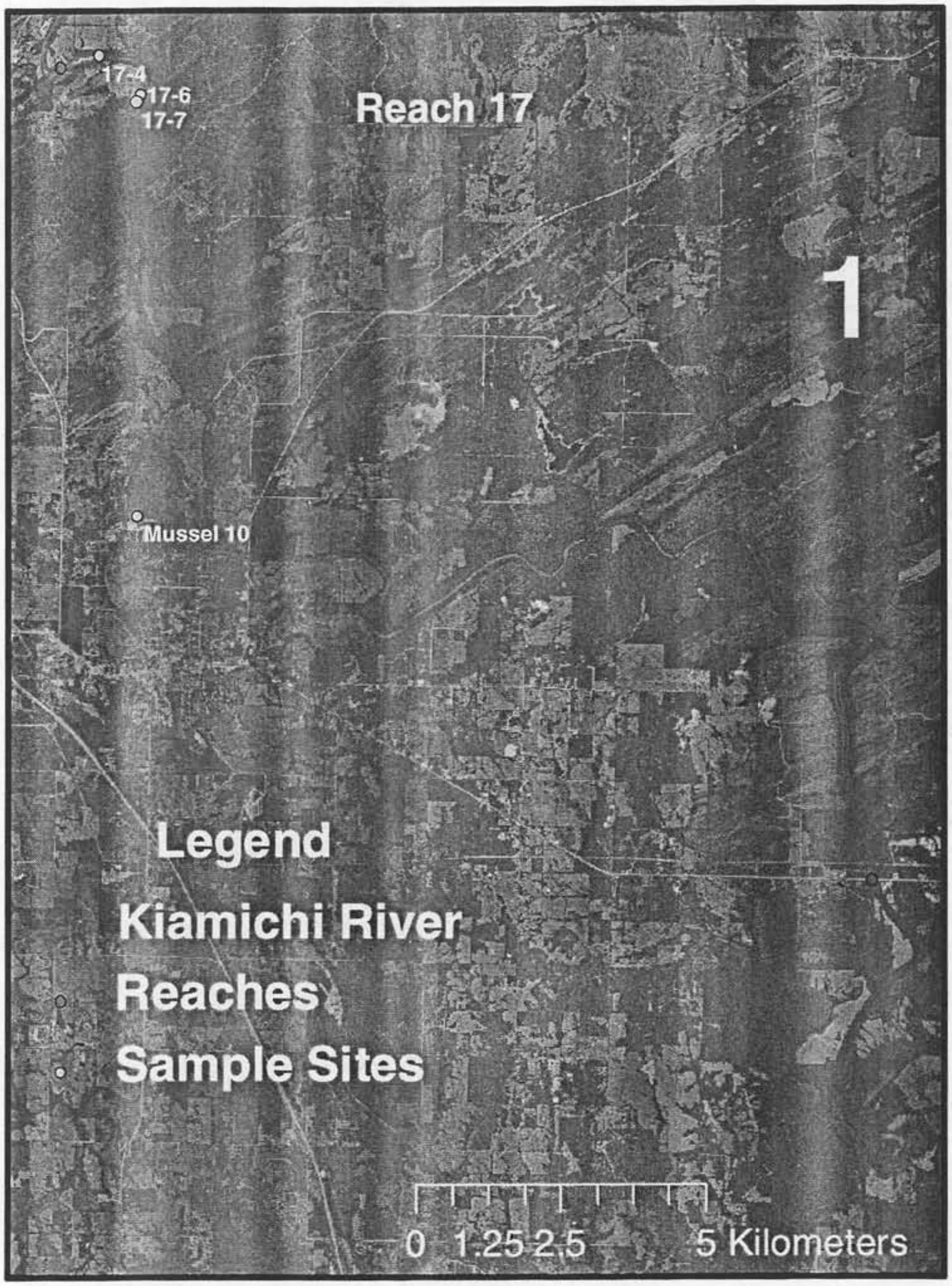


Figure A2-10. Reach 17 sample sites.

Appendix 3

USGS Gauge Station Measured Discharge

Table A3. USGS gauge station discharge for dates when aerial photographs were taken.

Date	Gauge Station	Discharge (cfs)
14-Apr-1979	Big Cedar	140
	Antlers	2900
3-Nov-1979	Big Cedar	23
	Antlers	410
14-Mar-1994	Big Cedar	160
	Clayton	2160
	Antlers	3270
2-Feb-1995	Big Cedar	89
	Clayton	1180
	Antlers	1780
9-Mar-1995	Big Cedar	81
	Clayton	1700
	Antlers	3200
21-Mar-1995	Big Cedar	56
	Clayton	405
	Antlers	850
23-Mar-1995	Big Cedar	47
	Clayton	318
	Antlers	480
12-Apr-1995	Big Cedar	300
	Clayton	2440
	Antlers	3760
16-Mar-1996	Big Cedar	10
	Clayton	39
	Antlers	56