SEASONAL CHANGE OF

FINE GRAIN SEDIMENT DEPOSITS AT THREE TRIBUTARY CONFLUENCES

IN OAK CREEK, ARIZONA

By Patrick C. Cassidy

A Thesis

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Approved:

Erik Schiefer Ph.D., Chair

Mark Manone, M.A.

Sharon Masek Lopez, M.S.

Abstract

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i. Preface

The purpose of this thesis is to observe and analyze physical properties of the Oak Creek watershed in north central Arizona to determine the seasonal nature of fine-grain fluvial deposits within the active channel of Oak Creek. I have included a research manuscript embedded within this thesis that is intended for submission to the journal Geomorphology. In Chapter 1, I present a review of literature pertaining to the physical characteristics of the study area, bacterial quality of Oak Creek, past research, and methods that I employ in the study. In Chapter 2, I present the manuscript that is being developed for publication. In the manuscript, I present how I conducted a field survey to establish and record seasonal changes to the location, extent, and depth of lateral bar features at three different locations in Oak Creek. I also present how I used core sample extraction and extrusion, density analysis, particle size analysis, LOI, and GIS analysis to produce survey maps, and determine volume and organic content of lateral bar features. Next, I compare changes in sediment volume and particle size of lateral bar features to seasonal flood events recorded by USGS stream gauges in Oak Creek. I then explore how individual flood events could affect lateral bar features by examining the lateral profiles of main stem and tributary channel reaches that are upstream from each field site.

Chapter 3 presents a summary of my findings. Appendices include detailed field work, laboratory, and GIS methodologies, complete data tables, and complete survey maps.

1. Introduction

1.1. Study Area

1.1.1. Setting

The Oak Creek watershed of north central Arizona is located approximately 140 km north of Phoenix. The watershed is a perennial source of streamflow that drains 1205 km^2 where the land transitions from forested highlands at 2580 m a.s.l. and descends 1613 m towards the increasingly arid valleys of the Basin and Range. The highest elevations occur in the northern portion of the watershed, above the Mogollon Rim, a steep rock escarpment that defines a physiographic boundary between the Colorado Plateau to the north and central Arizona's Transition zone to the south (Mayer, 1979). The Colorado Plateau is a relatively flat, elevated block of high semi-arid land in the southwestern United States that includes portions of Utah, Colorado, New Mexico and Arizona. To the south of the Colorado Plateau lies Arizona's Transition Zone. The Transition Zone is a narrow, northwest to southeast trending strip of land where the topography transitions from high northern plateaus, through steep canyons towards the southern valleys of the Basin and Range (Figure 1.1.).

Oak Creek Canyon, a dominant feature within the Oak Creek watershed, is incised into the southern terminus of the Colorado Plateau about 17 km southwest of Flagstaff, AZ. The canyon extends 18 km from north to south and widens from 0.6 km at the head to 1.6 km at the mouth, and has a maximum depth of 450 m. Oak Creek is a perennial stream that originates at the head of Oak Creek Canyon and flows southwest through the watershed to its confluence with the Verde River.

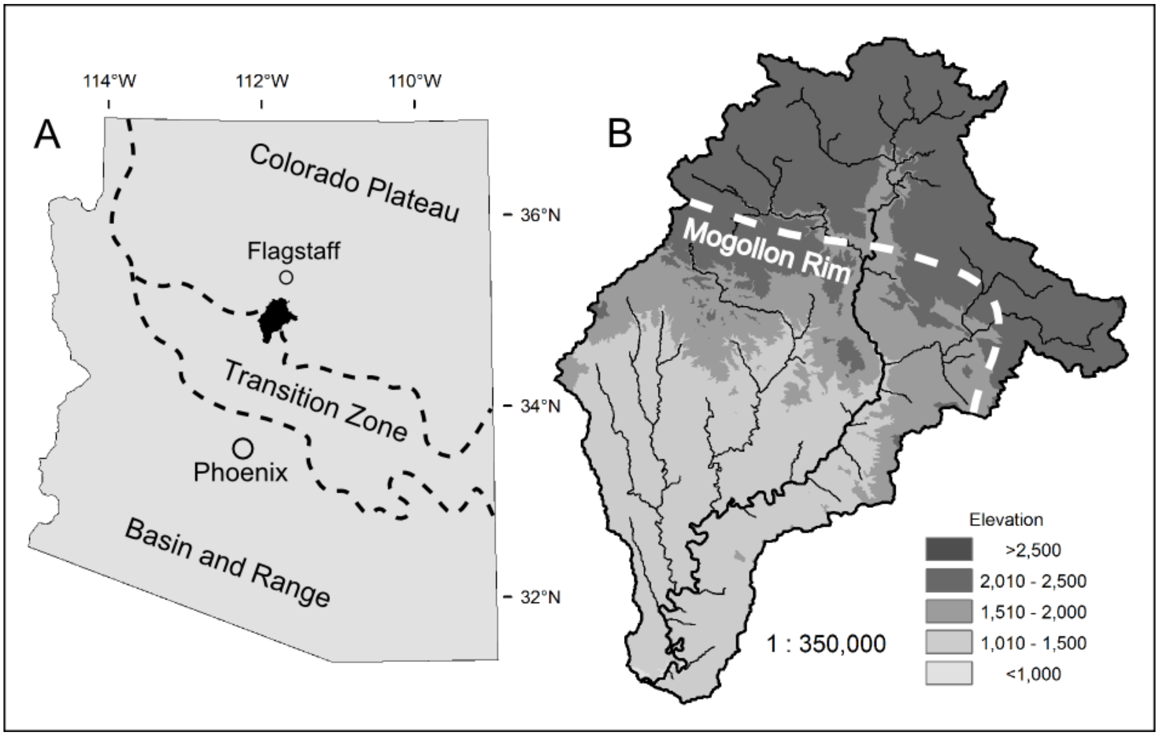


Figure 1.1. Overview and location of the Oak Creek watershed. (A) Location of the Oak Creek watershed within Arizona, the states three physiographic provinces, and the cities of Phoenix and Flagstaff. (B) The Oak Creek watershed with location of the Mogollon Rim, major streams (main stem Oak Creek is bold), and elevations.

1.1.2. Geology

The stratigraphy of Oak Creek Canyon and surrounding area describes the local geology consisting of rock formations ranging from late Paleozoic, to early Mesozoic, and middle Cenozoic age (Blakey, 1990). The Pennsylvanian age Supai Group of shale and siltstone forms the bright red rock formations found in the lower canyons and around the Sedona area. Permian age Hermit formation, Schnebly Hill formation, Coconino sandstone and Kaibab limestone are exposed in canyon walls north of Sedona. Tertiary age gravel deposits are overlain by basalt flows along the upper canyon and the Mogollion Rim. The Verde Formation, made up of Miocene and Pliocene sedimentary rocks occupy the Verde Valley, a structural basin bounded by faults at the southwest and northeast margins (Blakey, 2014).

Oak Creek Canyon, which occurs along the south striking Oak Creek Fault, is an erosional feature resulting from the tectonic activity of the area. The Oak Creek Fault has a long history of displacement that predates uplift of the Colorado Plateau. Cenozoic gravel deposits and basalt flows in Oak Creek Canyon indicate that an ancestral stream once flowed to the north, then reversed direction to the current southern flow arrangement by the late Miocene (Holm and Cloud, 1990).

1.1.3. Soils

The upper Oak Creek watershed above the Mogollion Rim is an elevated plateau with mesas, hills, and incised drainages. Slopes range greatly with local topography and most soils occur on gradients from 0 to 40%. A horizon soils include gravelly fine sandy loam, clay, sandy clay, and very stoney clay from 0 to 15 cm depth (USDA, 2014). B horizon soils are sandy clay loam and sandy clay from 8 to 40 cm depth. C horizon soils range from gravelly fine sandy loam and very gravelly clay loam to clay from 30 to <60 cm depth to bedrock.

The middle watershed around the Sedona area is hilly terrain with slopes of 3 to >60%, where much of the higher slope areas are talus and exposed bedrock. A horizon soils can vary depending on location between loamy fine sand, silty loam, very gravelly loam, and very cobbly silt loam that occur from 0 to 18 cm depth (USDA, 2014). B horizon soils are sandy loams from 10 to 112 cm depth. C horizon soils are clay loam from 18 to 122 cm depth to bedrock.

The lower watershed near Cornville is dominated by terrace and alluvial fan features with typical slopes ranging from 0 to 10%. Fine sandy loam soils make up the A, B, and C horizons of the area with a typical depth of 223 cm from surface to bedrock (USDA, 2014). This soil type is extensive from the Verde River confluence at 967 m elevation to about 1100 m. Stony loam and gravelly sandy loam also occur in the area to a lesser extent.

1.1.4. Vegetation

Vegetation types throughout the Oak Creek watershed experience a great amount of local diversity due to changes in elevation, aspect, and moisture availability. The upper watershed upon the Colorado Plateau is covered by ponderosa pine (*Pinus ponderosa*) forest. Vegetation changes abruptly to oak (*Quercus*) and isolated stands of Douglas fir (*Pseudotsuga Carrière*) and ponderosa pine as the watershed descends through canyons to the south of the Mogollon Rim. Riparian habitats of box elder (*Acer negundo*), Arizona walnut (*Juglans mandshuricaI*), New Mexican alder (*Alnus oblongifolia*), big-tooth maple (*Acer grandidentatum*), and the rare Knowlton's hop hornbeam (*Ostrya Knowltonii*) occur alongside perennial streams of West Fork, Munds, Spring Creek, and Oak Creek Canyons. In the dry lower reaches of the watershed, grassland and chaparral communities of manzanita (*Arctostaphylos manzanita*), mountain mahogany (*Cercocarpus montanus*), live oak (*Quercus turbinella*), prickly pear cacti (*Opuntia chlorotica*), and century plants (*Agave americana*) thrive in arid valleys of the Transition Zone (Mohlenbrock, 1985).

1.1.5. Climate

The city of Sedona, located approximately near the center of the Oak Creek watershed, is near the northern limit of the upper Sonoran desert and has a semiarid climate. Sedona receives 470 mm of precipitation annually, has warm summers and cool winters with annual mean high and low temperatures of 24.6 °C and 8.8 °C, respectively (Figure 1.2.).

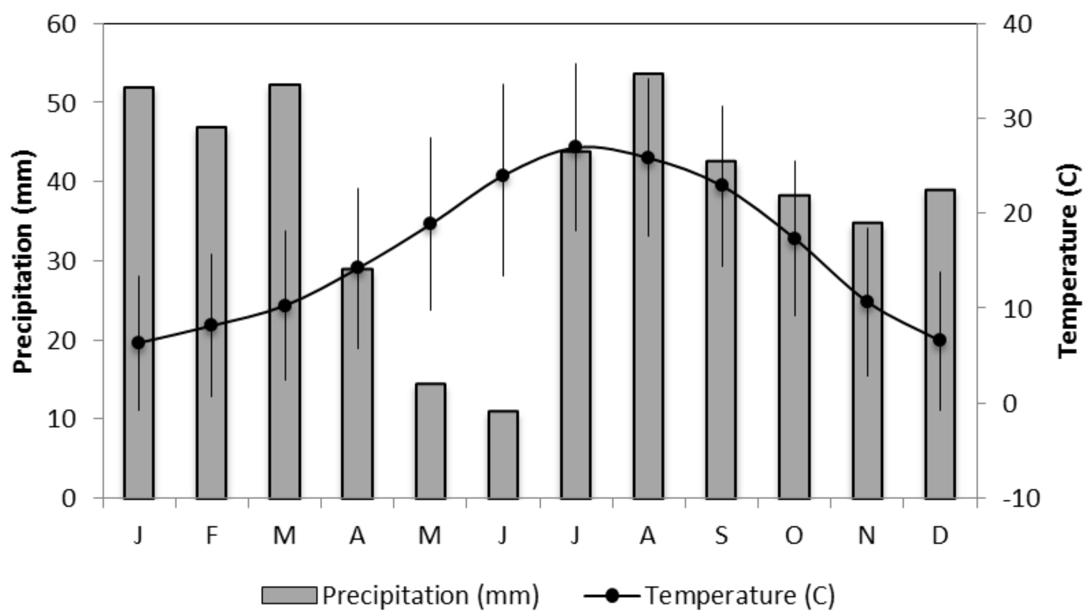


Figure 1.2. Average monthly temperature with minimum and maximum temperatures and precipitation for 34° 52'N, 111° 46'W at 1226 m a.s.l. (WRCC, 2011). Period of record for monthly average climate values from 7/1/1948 to 12/31/2005.

The Oak Creek watershed experiences two distinct periods of precipitation annually. Winter is characterized by low intensity, long duration cyclonic-frontal storms that occur from December to March. Winter storms produce extensive rain throughout the watershed and snow in the higher elevations. Summer precipitation is the result of more localized, high intensity and short duration convective thunderstorms that occur from July to September. Summer thunderstorm events typically occur over a small portion of the watershed but are capable of producing intense rainfall in a short period.

1.1.6. Hydrology

The regional Coconino Aquifer, made up of the Kaibab, Coconino, and Supai formations, feed springs near the top of Oak Creek Canyon that form the headwaters of Oak Creek. The main stem stream of Oak Creek is 83.9 km from source to confluence with a mean gradient of 9.5 m/km. The Oak Creek Fault system is an important influence on the transmission of water between aquifers and to the surface (ADWR, 2014). Baseflow at the headwaters of Oak Creek, a perennial stream, is approximately 6.8 m^3/min., which increases as the stream gains discharge from springs and tributaries while it descends through Oak Creek Canyon and the city of Sedona where baseflow becomes 40.8 m^3/min. (Poff and Tecle, 2002). From Sedona, Oak Creek meanders southwest towards the confluence with the Verde River. The Verde Formation aquifer is an additional groundwater source that feeds springs near Page Springs in the lower watershed. Other perennial tributary streams in the watershed include West Fork Oak Creek, Munds Creek, and Spring Creek.

USGS stream gages record discharge at two locations within Oak Creek. The upper stream gage (09504420) is located near the city of Sedona and the lower gage (09504500) is located downstream near the town of Cornville. Together these gages record discharge data of base flow and floods that occur in Oak Creek (figure 1.3.). Storm events and snowmelt produce seasonal floods within Oak Creek and its tributaries. The largest floods in Oak Creek typically occur during a spring freshet, when late winter precipitation combines with warmer temperatures and snowmelt to produce runoff throughout the watershed.

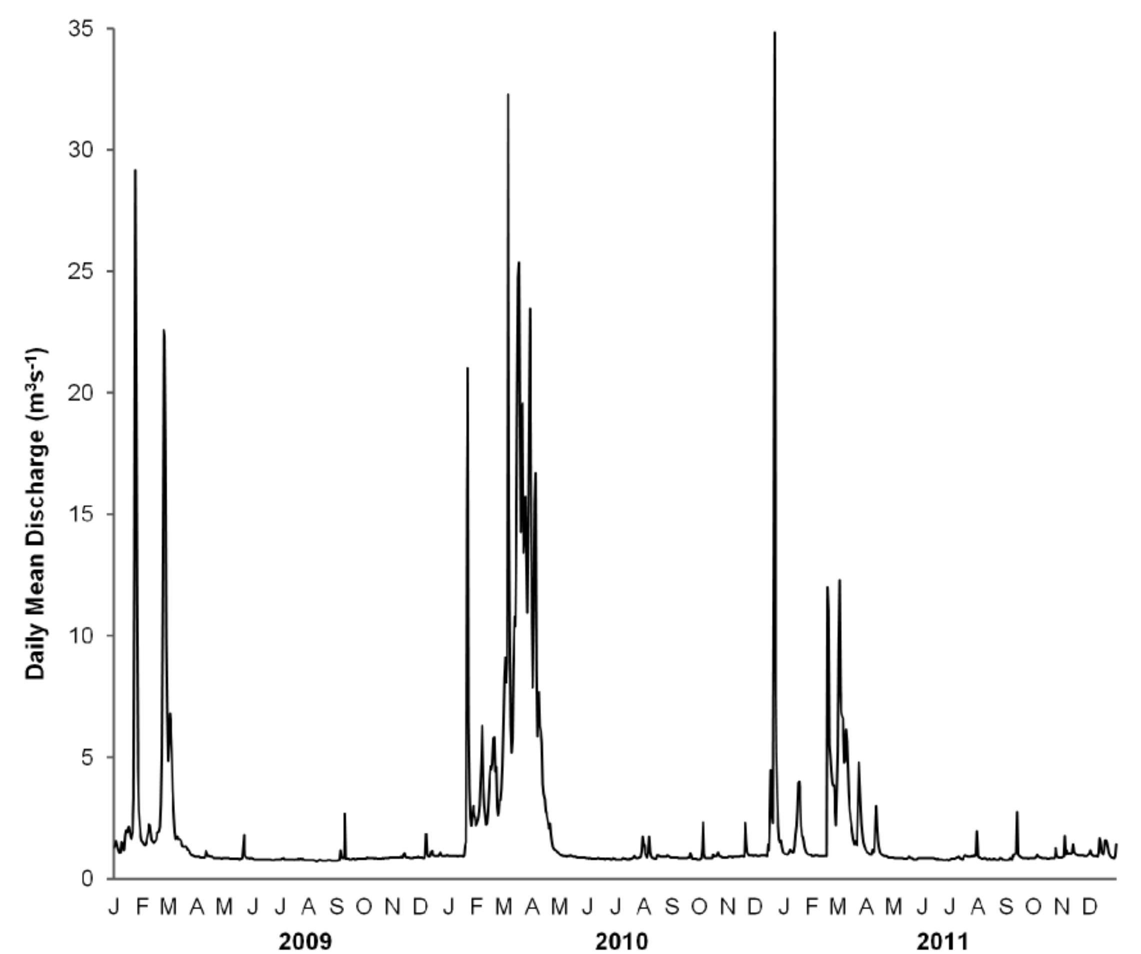


Figure 1.3. Hydrograph of baseflow and floods in Oak Creek from 1/1/2009 to 12/31/2011. Daily mean discharge data from USGS Gauge 09504420 near Sedona, AZ.

1.1.7. Land Use

Seasonal tourism and recreational activities attract many visitors to Oak Creek Canyon and the Sedona area each year. Camping and swimming are popular summer activities that take place along Oak Creek, particularly in Oak Creek Canyon. Much of the land within the Oak Creek watershed is National Forest that accommodates camping and other outdoor activities. Government agencies manage 92% of watershed land and the remaining 8% is privately owned (ADEQ, 2010). Land use within the watershed includes forestry, grazing, recreation, agriculture, residential, and commercial (OCWC, 2012). The city of Sedona, population 10,031 has an incorporated area of 49.7 km^2 and is the largest urban area within the Oak Creek watershed (U.S. Census Bureau, 2010). Other populated communities within the watershed include Mountainaire, Kachina Village, Forest Highlands, Munds Park, Oak Creek Canyon, Page Springs, and Cornville.

1.2. Literature Review

1.2.1. Impaired Waterway

Due to its importance as a natural water resource as well as being a tourist attraction to the area, Oak Creek was designated a Unique Water in 1984, later termed as Outstanding Arizona Water, by the Arizona State Legislature for meeting Arizona Department of Environmental Quality (ADEQ) requirements for outstanding state resource water. These requirements include surface waters that are perennial, in a free-flowing condition without dams or obstructions, water quality that meets or exceeds the applicable water quality standards, and is of exceptional recreational or ecological significance (ADEQ, 2009). This designation has imposed special protection and standards upon Oak Creek that is currently subject to continuous water sample testing for quality in efforts to protect the watershed from sources of pollution and degradation. Despite these protections of Oak Creek, the waters have a history of health risks at popular recreational sites where swimmers are exposed to fecal pathogens that occur in the water on a seasonal basis.

The Oak Creek Watershed Council (OCWC) and Arizona State Parks in association with ADEQ's water quality standards, administer water sample testing to assess water quality at many sites throughout Oak Creek. The OCWC is a nonprofit organization of private citizens, businesses, federal, state, city and county staff and elected officials that are dedicated to protect and preserve the integrity of Oak Creek. One of the main responsibilities of the OCWC is to develop and implement a Watershed Improvement Plan that will reduce the levels of bacterial pollution in the Oak Creek Watershed. Major funding for OCWC activities is furnished by grants from the U.S. Environmental Protection Agency's Clean Water Act and distributed through ADEQ. Water samples are tested for Total Maximum Daily Load of Escherichia coli (*E. coli*.), which is used as an indicator for the presence of recreational water illnesses, including illnesses spread by inhalation, oral or dermal contact with surface waters contaminated by fecal pathogens such as Cryptosporidium, Giardia, Shigella, norovirus and *E. coli* 0517:H7 (ADEQ, 2010). The current Arizona *E. coli*. standard for full body contact is 235 colony forming units (cfu)/100 ml (OCWC, 2012).

The importance of Oak Creek as a natural water resource in the arid southwest region of the U.S. has yielded much scientific interest and research. Water quality studies conducted over the past several decades have found that Oak Creek experiences an annual seasonal decline in bacteriological water quality due to impacts associated with fecal pollution (Segal, 1976; Orb, *et al.,* 1978; Jackson, 1981; Rose *et al.,* 1987; Donald *et al.,* 1998; Crabill *et al.,* 1999; Southam, *et al.,* 2000; Poff and Tecle, 2002).

Early studies of Oak Creek suggested that recreational activities are primarily responsible for seasonal deteriorations in water quality. The first water quality research in Oak Creek found that bacteriological quality of water at Sterling Springs Fish Hatchery and the Page Springs Bridge declines in a pattern consistent with recreational use (Orb *et al.*, 1978). A 1973 study found summer coliform counts exceeded standard bathing limits in the Indian Gardens area of Oak Creek and attributed this to nearby springs that appear to be contaminated by sewage effluent (Segal, 1976). A four year study by Jackson (1981) concluded that the Slide Rock swim area had an obvious effect on water quality based on fecal coliforms found both upstream and downstream of the site. (Rose *et al.*, 1987) found occurrence of human pathogenic enteric viruses in popular recreational areas of Oak Creek and determined the state bacterial standard for bathing water quality of 200 cfu/100 ml was insufficient for preventing transmission of viral disease.

Watershed research (Grimes, 1975, 1980; LaLiberte and Grimes, 1982; Tunnicliff and Brickler, 1984; Doyle *et al.*, 1984, 1992; Buckley *et al.*, 1998) recognizes that natural hydrologic processes within a watershed can transport fecal pollution from human and animal sources to a main stem stream where fecal coliforms are concentrated in sediment reservoirs (sinks). Other studies (Van Donsel *et al.*, 1967; Field and Pitt,1990; Kebabijian, 1994) observe that disturbance of sediments by roiling from floods or recreational activities can negatively impact water quality by releasing fecal coliforms into the water column.

In the 1990s Oak Creek researchers disputed previous findings that maintained a recreational source of fecal pollution by shifting research focus towards identifying other sources of bacterial pollution within the watershed. Donald *et al.*, (1998) and Crabill *et* *al.*, (1999) found that fecal coliforms occur within sediment reservoirs in Oak Creek Canyon. These studies propose that a collection of non-point pollution sources such as wildlife (elk and deer), grazing animals (cattle), domestic animals (dogs), and septic systems within the watershed are responsible for the majority of bacterial pollution in Oak Creek. In addition, these studies confirmed that highly elevated levels of fecal coliforms are caused by roiling of sediment by recreational activities and flood events, which distribute fecal coliforms into the water column.

Following the findings of Donald *et al.*, 1998 and Crabill *et al.*, 1999, a genotype study of bacteriological samples from Oak Creek and several tributary streams determined the sources of fecal pollution impacting water quality in Oak Creek Canyon by genotyping of Escherichia coli isolates from human, natural, and grazing animal populations in the watershed (Southam *et al.*, 2000). This study found that raccoons, humans, skunks, horses, white tail deer, mule deer, elk, cows, beaver, and dogs are the top contributors to fecal pollution in Oak Creek water and sediment.

Confirmation of several non-point sources of fecal pollution in the watershed focused efforts to mitigate bacterial pollution in Oak Creek. Former best management practices (BMPs) aimed to maintain Oak Creek water quality within safe water quality standards by limiting the number of recreational users, which were perceived to be the source of bacterial pollution (Crabill *et al.*, 1999). With more recent research that emphasizes non-point source pollution in the Oak Creek watershed, the OCWC is implementing a watershed improvement plan to reduce bacterial pollution in Oak Creek. The improved BMP strategy is a multidiscipline approach including programs to address community education and outreach, septic systems, stormwater, recreation, and agriculture (OCWC, 2012).

1.2.2. Fluvial Deposition Features

High relief headwater catchments that occur in mountainous regions contain mountain streams that are steep (≥2 m/km) with confined channel segments, have coarse clast and or bedrock substrates, a strong seasonal discharge regime, and spatially limited floodplains (Wohl, 2010). The upper reaches of Oak Creek that run through Oak Creek Canyon are best characterized as a mountain stream with a limited supply of fine grain sediment (finer than gravels), though hillslope instability can periodically deliver fine grain sediments. The gradient of Oak Creek through Oak Creek Canyon, between headwaters and Sedona is 20 m/km. Dominant channel types through Oak Creek Canyon are plane-bed, pool-riffle, and bedrock channel segments (Montgomery and Buffington, 1997) within mostly straight stream reaches. Of the channel types that occur in Oak Creek Canyon only pool-riffle channel reaches are capable of producing fine grain depositional features (bars). Occurrence of fine grain bar features in the canyon is supply dependent and may only occur periodically.

Below Oak Creek Canyon, from Sedona to the Verde River confluence, average stream gradient of Oak Creek becomes 5 m/km, which gradually declines as the stream flows towards the Verde Valley. Channels in lower gradient stream reaches are more conducive depositional environments where fine grain gravel and sand bedforms occur as bar features. The lower stream gradient transforms Oak Creek by increasing sinuosity and channel width to depth ratios to form pool-riffle and dune-ripple channel types. A pool-riffle channel segment has an undulating bed sequence of bars, pools, and riffles where pools are topographic depressions within the channel and bars are high points (Leopold *et al.*, 1964). Riffles are relatively fast and shallow flow with high water surface slope and rough water surface texture (Moirand and Pasternack, 2008). Several studies indicate that an increase in sediment load along a pool-riffle channel will cause preferential filling of the pool, creating a lower reach gradient and flow depth (Lisle, 1982; Wohl *et al.*, 1993; Madej and Ozaki, 1996; Wohl and Cenderelli, 2000; Kasai *et al.*, 2004). Dune-ripple channel bed morphology occurs in low-gradient, sand-bed channels (Montgomery and Buffington, 1997). When a pool-riffle channel reach becomes filled, a dune-ripple channel may temporally exist until the finer grain sediment is eroded, returning the stream reach back to a pool-riffle channel.

Channel bars in the form of lateral bars are dynamic features in pool-riffle stream channel reaches (Montgomery and Buffington, 1997). Moir and Pasternack (2008) describe a lateral bar as a

> *depositional unit that is located at the channel margins and orientated longitudinally to the direction of flow. The feature slopes toward the channel thalweg with an associated increase in both flow depth and velocity. Sediment size tends to be lower than in adjacent sections of the channel.*

Lateral bar morphology, like many other bedforms, is dependent on stream flow and sediment supply. Changes in either of these variable conditions will affect the location, shape, and composition of a lateral bar, making it a highly transient feature.

1.2.3. Sediment Survey and Sample Collection

I conducted a series of modern, fluvial sediment bar surveys at three different locations in Oak Creek near Sedona, AZ (figure 1.4.). The purpose of these surveys is to monitor physical changes to fine grain streambed sediments following seasonal periods of flooding within the Oak Creek watershed. I chose three field sites in Oak Creek where discrete, fine-grain sediment deposits occurred in the streambed. Sediment deposits had to be at least 9 m in length by 1 m in width and 15 cm in depth to facilitate a depth survey and collection of multiple sediment core samples. During field reconnaissance I observed that sediment bar deposits were either adjacent to or in close proximity downstream to a tributary confluence. To diversify the study, I chose sites at or near three different confluences, representing three separate subcatchments in the watershed. The three tributary streams within the study area are all ephemeral in nature, flowing only during times of flow producing precipitation within each subcatchment.

I analyzed stream gage data from two USGS stream gauges in Oak Creek to determine episodes of high and low discharge. Annual hydrographs revealed patterns of seasonal floods that occur during winter cyclonic storms and summer monsoonal (convective) storms (figure 1.3.). To observe the effects of flooding on streambed sediments, I conducted survey and sample collection fieldwork during periods of low flow, following spring and summer floods. A total of six surveys were carried out for each site, beginning in the spring of 2012. I also collected sediment depth measurements and mapped sediment location and extent at each site, for the entire study. These data were used to construct bar deposit maps of each site. Lateral bar features were surveyed using reference point, a point of origin, and a series of transects that extend across the entire width of the stream (figure 1.5.). I collected sediment bar depth data at 0.5 m intervals along each transect using a steel probe.

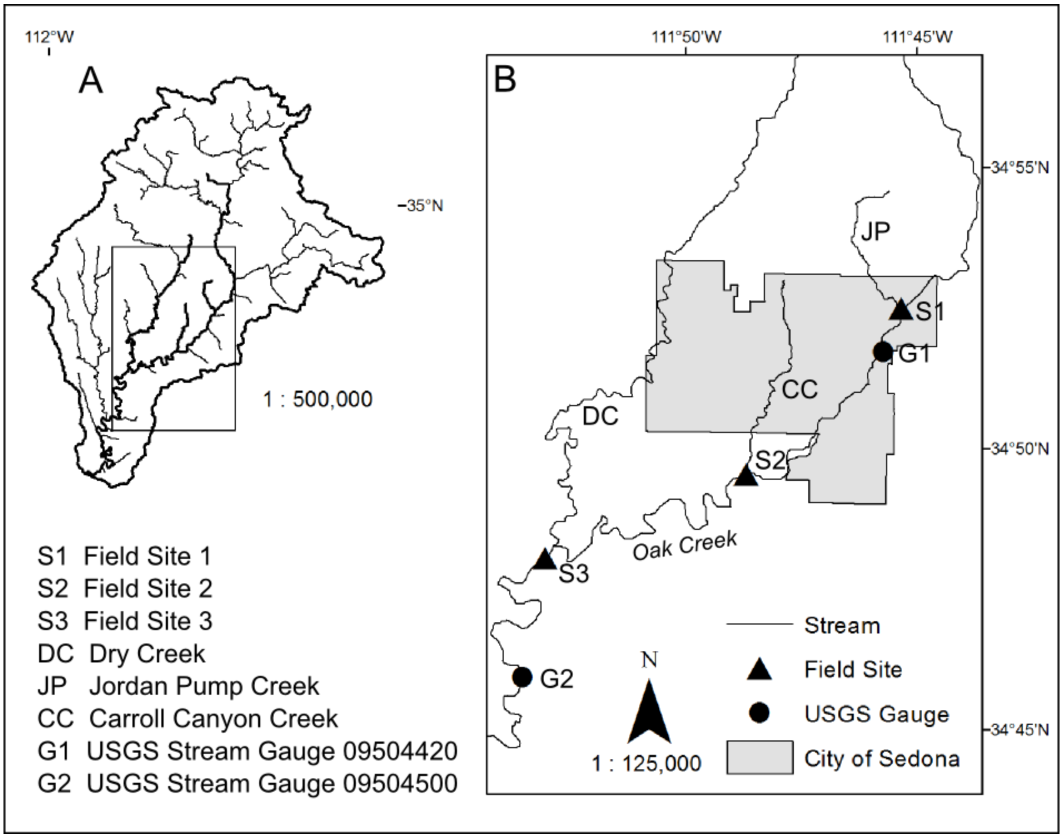


Figure 1.4. Overview of study area within the Oak Creek watershed. (A) The Oak Creek watershed with locations of streams of interest (bold) to the study. (B) Inset detail of study area with locations of streams, field sites, USGS stream gauges, and the city of Sedona.

For the first three surveys, at each site, I collected sediment core samples following the methods of Glew and Smol (2001), and subsampled each core for laboratory analyses of organic content, density, and particle size. For more details on surveys and sample collection see Fieldwork Methods section of the Appendix.

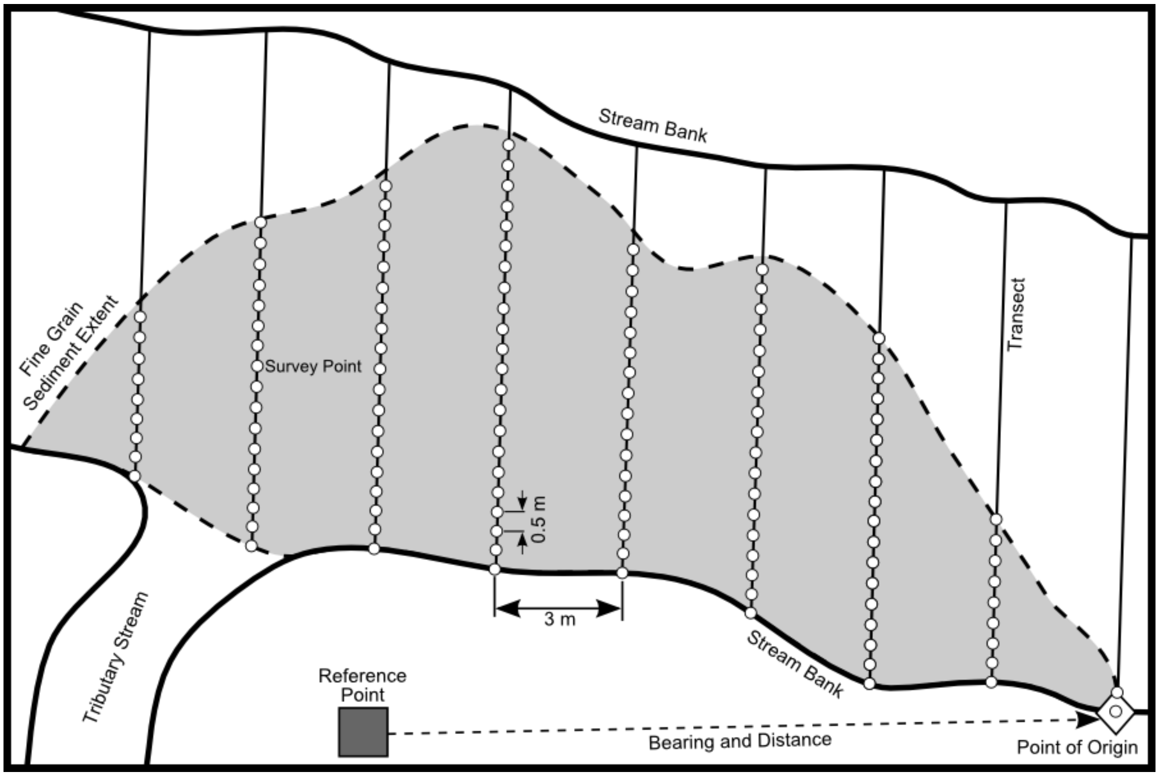


Figure 1.5. Detail sketch of sediment bar survey. Survey features used to map sediment bars include reference point, point of origin, transects, and survey points.

1.2.4. Particle Size, Density, LOI, and GIS Analyses

Two different types of samples were collected from sediment cores that I extracted from Oak Creek. The first type of sample was a 1 cm subsection of a sediment core that I contained in a plastic zip close bag. This type of sample was used for organic content and particle size analysis. The second type of sample was a 1 cm^3 volume of sediment extracted from a 1 cm subsection of a sediment core. I used this type of sample for density analysis and they were contained in a pre-weighed piece of aluminum foil and sealed in a numbered plastic vial.

I analyzed sediment samples collected in the field in the Geography Laboratory at NAU to find several types of physical properties. Lab techniques that I exercised on sediment samples included organic content, density, and particle size analysis. I found organic content of sediment by performing loss on ignition (LOI) analysis on sediment samples. Sediment density was derived by measuring the dry mass of a 1 cm^3 sample. I determined the relative percentages of sand, silt, and clay sized particles by measuring the density of sediment samples, prepared in solution, with a hydrometer. For more details on these analyses see the Laboratory Methods section of the Appendix.

Data that I recorded in the field during site surveys was applied to GIS (Geographic Information System) ArcGIS software to create survey maps. Field data were also analyzed and combined with density data derived from laboratory analysis to generate sediment volume and mass estimates for each field survey. In addition to the sediment analysis, I produced a table of drainage basin characteristics to describe the physical properties of the Oak Creek watershed using a series of raster and vector analysis techniques in ArcMap.

I delineated the Oak Creek watershed from a 30 m digital elevation model (DEM) using the Hydrology Toolset in within the Spatial Analyst extension of ArcMap. I obtained a 30 m DEM that covered the entire Oak Creek watershed from the USGS EarthExplorer website, http://earthexplorer.usgs.gov. A raster mosaic was built, using the Mosaic Dataset Toolset, to combine several grid files that covered the entire watershed area. Once the raster was prepared, I utilized the Hydrology toolset to extract the watershed using a Model Builder sequence for watershed delineation. Subcatchments within the watershed were delineated individually using the watershed extraction model.

I created survey maps of field sites in ArcMap for each field survey. Maps depict key features of field surveys including the reference point, transects, sediment extent, sediment depth, streambanks, and survey points. I used data collected in the field to construct map features as points, lines and polygons. To organize survey spatial data, I created a personal geodatabase was in ArcCatalog to organize map layers into feature datasets according to site and season. The resulting map layers contain survey data that I analyzed to estimate sediment volume and mass for each field survey. To estimate sediment volume, I created a TIN (triangular irregular network) layer to depict the sediment surface. The TIN, which contains sediment depth data, was converted to a raster to graphically display the sediment depth data. Finally, I combined the sediment depth TIN with a sediment area polygon to calculate sediment volume. Density data derived from laboratory analysis was applied to sediment volume to obtain a sediment mass estimate. For more information on GIS analysis techniques see the GIS Methods section of the Appendix.

2. Seasonal change of fine grain sediment deposits at three tributary confluences in Oak Creek, Arizona

2.1. Abstract

2.2. Introduction

The waters of Oak Creek, Arizona along with the impressive rock formations of the Sedona area and Oak Creek Canyon have long been a major recreational destination, especially during the warm seasons. The importance of Oak Creek as a perennial water resource in an arid climate has enacted special Outstanding Water protections and high water quality standards (ADEQ, 2010). Total Maximum Daily Load (TMDL) for *Escherichia coli* is routinely exceeded at recreational sites throughout Oak Creek during the summer months (Segal, 1976; Orb, *et al.,* 1978; Jackson, 1981; Rose *et al.,* 1987; Crabill *et al.,* 1999; Poff and Tecle, 2002), exposing those who come into contact with contaminated portions of the stream to recreational water illnesses. Crabill *et al*., (1999) confirmed that sediment sinks in Oak Creek act as reservoirs for pollutants that originate from various sources throughout the watershed and can distribute high concentrations of fecal pollution into the water column when disturbed by roiling or dredging. A study of sediment deposits in Oak Creek will contribute to the pool of information used to mitigate a solution to *E. coli* TMDL exceedances. The purpose of this study is to locate, identify physical characteristics, and monitor seasonal changes to discrete, predominately fine grain (≤ 2.00 mm) fluvial deposits within the active channel of Oak Creek.

2.3. Study Area and Methods

Oak Creek drains a basin of 1205 km^2 located in north central Arizona, United States, approximately 140 km north of the city of Phoenix (figure 2.1.). The northern third of the watershed occupies forested highlands with an average elevation of 2132 m above mean sea level (asl). The high elevation portion of the watershed is comprised of basalt, limestone and sandstone rock formations, and occurs along and to the north of the Mogollon Rim, a prominent feature that marks the southern terminus of the Colorado Plateau. A series of deeply incised canyons make up the central portion of the watershed, which transitions into a wide alluvial valley to the south. Oak Creek has a mean gradient of 9.5 m/km and travels 83.9 km from source to its confluence with the Verde River. Initially, Oak Creek flows through Oak Creek Canyon, a narrow and steep sided canyon that measures 18 km in length with a maximum depth of 450 m. A break in gradient occurs downstream from Oak Creek Canyon where Oak Creek becomes increasingly wider and sinuous. Two USGS stream gauges (09504500) and (09504420) are located at 26.1 km and 56.1 km respectively, upstream from the Verde River confluence. Baseflow at the headwaters of Oak Creek is 6.8 m^3/min. and becomes 40.8 m^3/min. at the upper USGS stream gauge near the city of Sedona.

Seasonal floods in Oak Creek and its tributaries are caused by two distinct periods of precipitation. The watershed receives an average of 470 mm of precipitation annually. Cyclonic-frontal storms occur from December to March and produce low intensity, long duration rainfall throughout the watershed and snow at higher elevations. In contrast, convective thunderstorms bring more localized, high intensity and short duration precipitation from July to September.

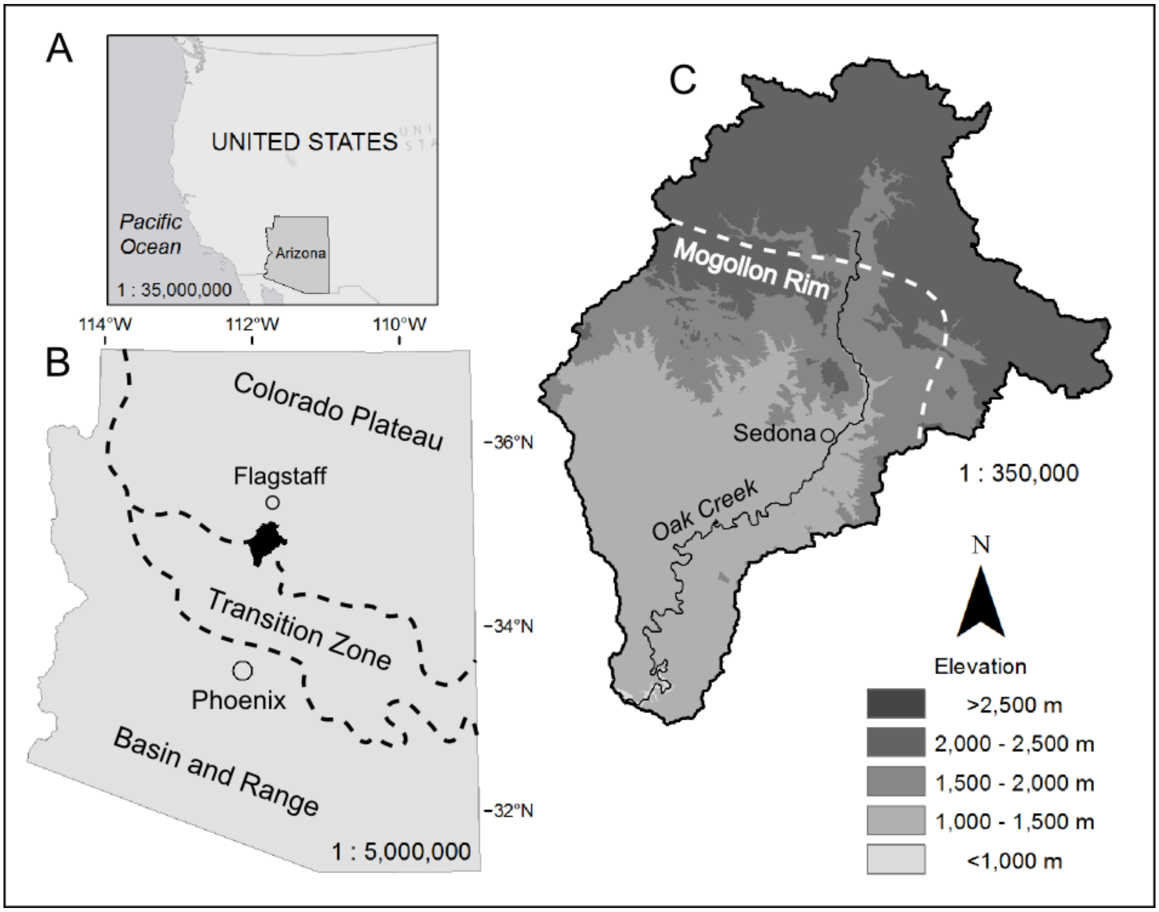


Figure 2.1. Overview and location of the Oak Creek watershed. (A) Location of the state of Arizona within the continental United States. (B) Location of the Oak Creek watershed within the state of Arizona, the states three physiographic provinces, and the cities of Phoenix and Flagstaff. (C) The Oak Creek watershed with elevations, the location of the Mogollon Rim, city of Sedona, and the main stem of Oak Creek.

Three study sites were chosen to sample and monitor fine grain sediment features in Oak Creek (figure 2.2.). Study sites 1 and 2 are located adjacent to the Jordan Pump creek and Carroll Canyon creek tributary confluences, respectively. Study site 3 is 703 m downstream of the Dry Creek confluence. Riffle-pool and plane-bed stream channel morphology types (Montgomery and Buffington, 1997) exist at all three field sites, with a riffle-pool reach arranged between adjacent plane-bed reaches in both the up and downstream directions.

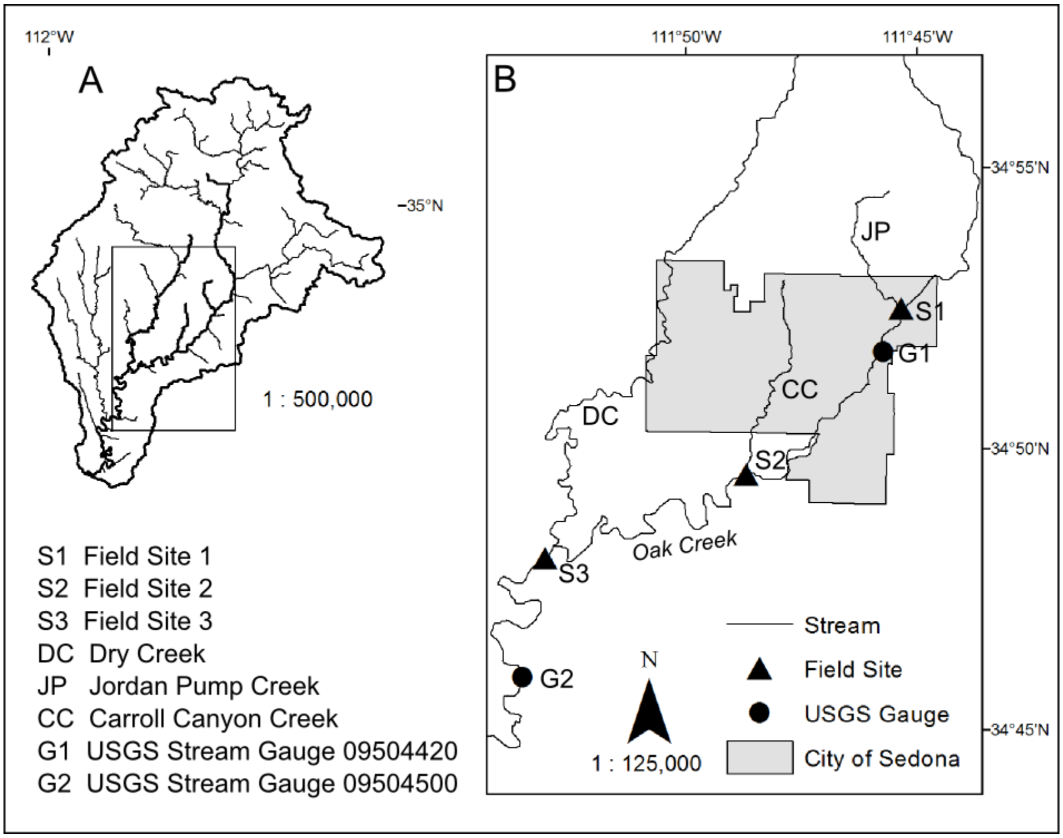


Figure 2.2. Overview of study area within the Oak Creek watershed. (A) The Oak Creek watershed with locations of streams of interest (bold) to the study. (B) Inset detail of study area with locations of streams, field sites, USGS stream gauges, and the city of Sedona.

In the spring of 2012 an initial sediment survey was conducted at each study site after winter floods had receded, during a period of low discharge in Oak Creek. Subsequent surveys were carried out at each site in the fall, following summer floods, when discharge in Oak Creek had returned to base flow levels. The same biannual pattern of sediment surveys were completed for each field site in 2013 and 2014. For each survey, a series of cross-sectional transects were set up at 3 m increments along the lateral axis of a sediment bar feature using a fiberglass tape measure and temporary anchor poles. Sediment depth data were collected at 0.5 m increments along each transect using a steel probe with pierced rubber ball, and metal ruler (figure 2.3.). Measurement error for transects and survey point locations is 3 cm, and sediment thickness measurement error is 5 mm. A permanent reference point was established with GPS above the active channel at each study site from which a bearing and distance determined the starting position for each survey.

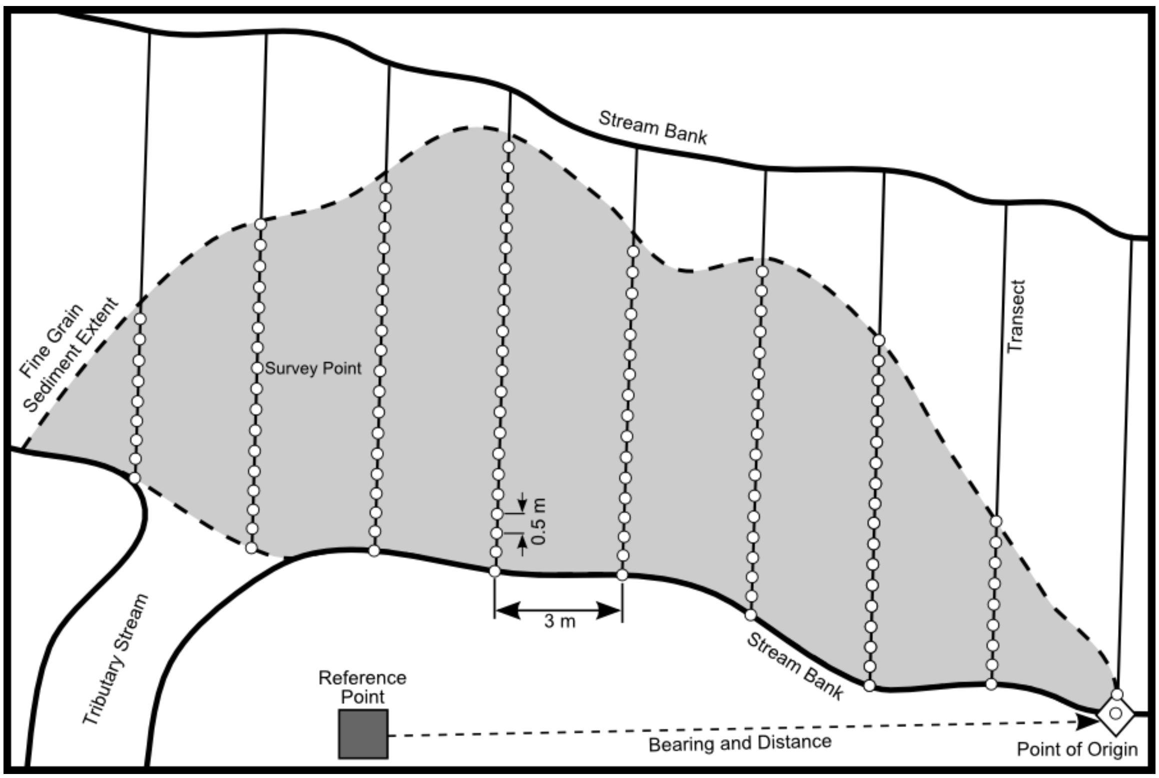


Figure 2.3. Detail sketch of sediment bar survey. Survey features used to map seasonal sediment bars include reference point, point of origin, transects, and survey points.

Sediment cores were collected and extruded (Glew and Smol, 2001) at each field site during the first three surveys. Sediment cores were extruded in the field and subsampled for particle size, density, and organic content analysis. At least one and as many as three sediment cores were collected at each survey transect depending on the extent of the fine grain sediment bar. Sediment density subsamples consisted of a 1 cm^3 volume of sediment. Particle size and organic content subsamples were 1cm thick core extrusions.

Sediment samples were dried at 105º C for a period of 12 h and weighed to determine dry mass (g) or density (g/cm^3). Estimates of organic content were made by performing loss on ignition (LOI) analysis of sediment samples. Dry sediment samples were heated to 550 ºC in a muffle furnace for 120 minutes (Dean, 1974). Organic matter weight percent was calculated by comparing sample dry weight before and after combustion. Relative percentages of sand, silt, and clay sized particles were determined by measuring the suspended density of sediment samples prepared in a 5% solution of sodium hexametaphosphate $(NaPO_3)_6$, using an ATSM 152H model hydrometer (Bouyoucos, 1962). Survey data collected in the field were applied to ArcGIS software to create survey maps. Field data were also analyzed and combined with density data derived from laboratory analysis to generate sediment volume and mass estimates for each field survey.

2.5. Results

2.5.1. Sediment Volume and Mass

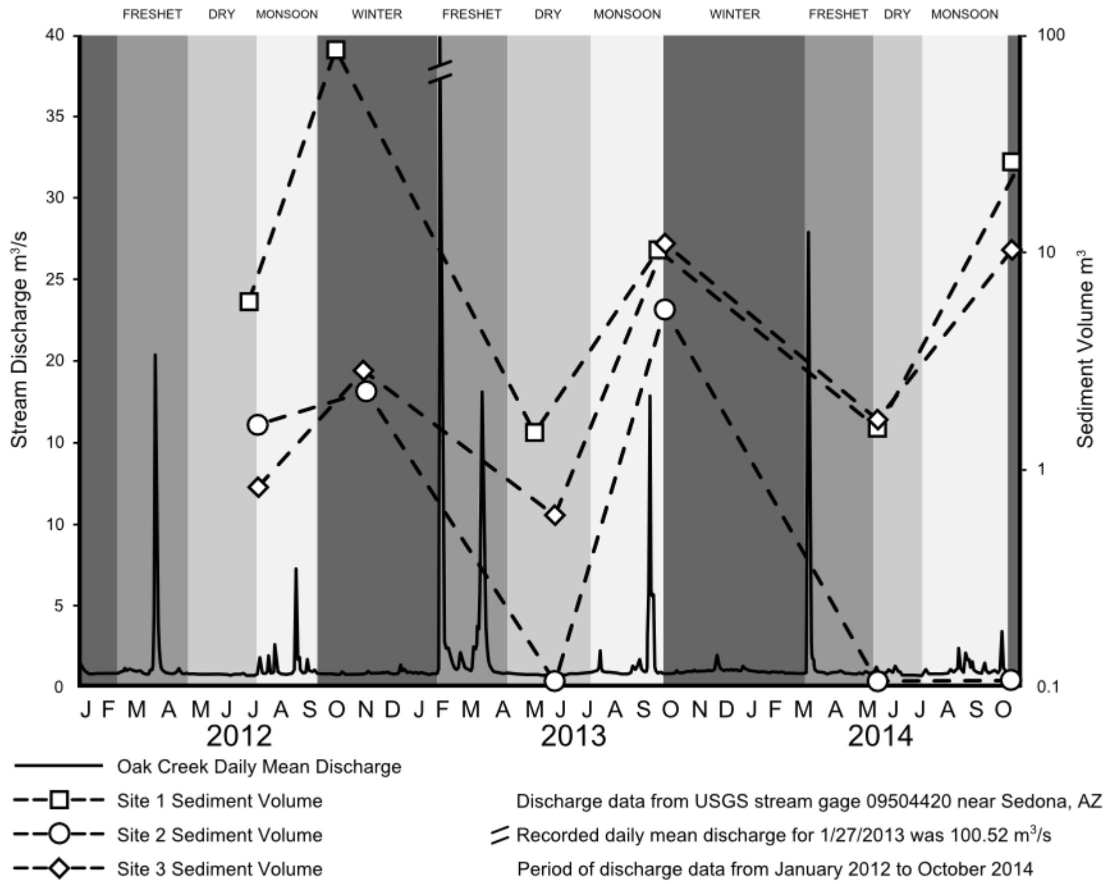
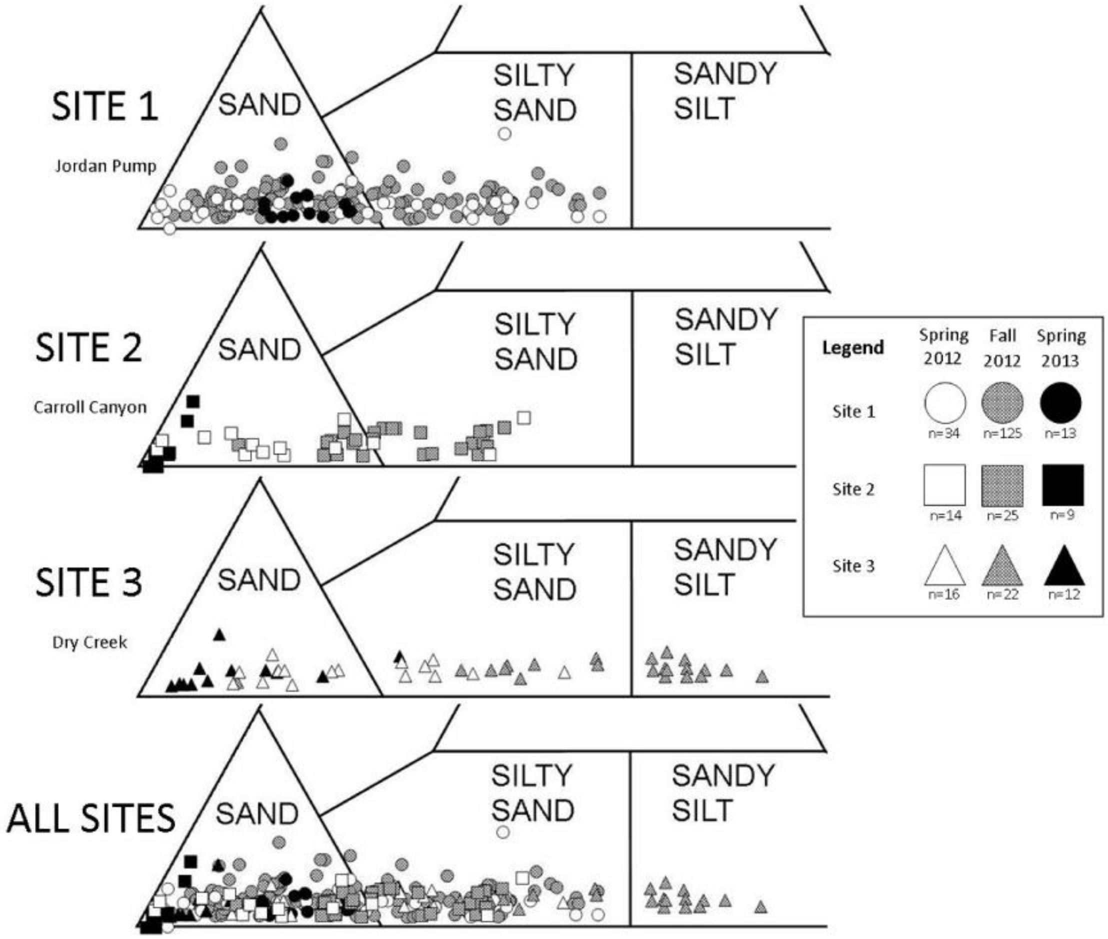


Figure 2.3. Daily mean discharge recorded from USGS stream gauge 09504420 in Oak Creek and fine grain sediment volume estimates for study area field sites. Shaded areas denote seasonal periods of floods and low flow in Oak Creek.

2.5.2. Particle Size


SITE 1
Jordan Pump
SAND
SILTY SAND
SANDY SILT
SITE 2
Carroll Canyon
SAND
SILTY SAND
SANDY SILT
SITE 3
Dry Creek
SAND
SILTY SAND
SANDY SILT
ALL SITES
SAND
SILTY SAND
SANDY SILT
Legend
Spring 2012
Fall 2012
Spring 2013
Site 1
n=34
n=125
n=13
Site 2
n=14
n=25
n=9
Site 3
n=16
n=22
n=12

2.5.3. LOI

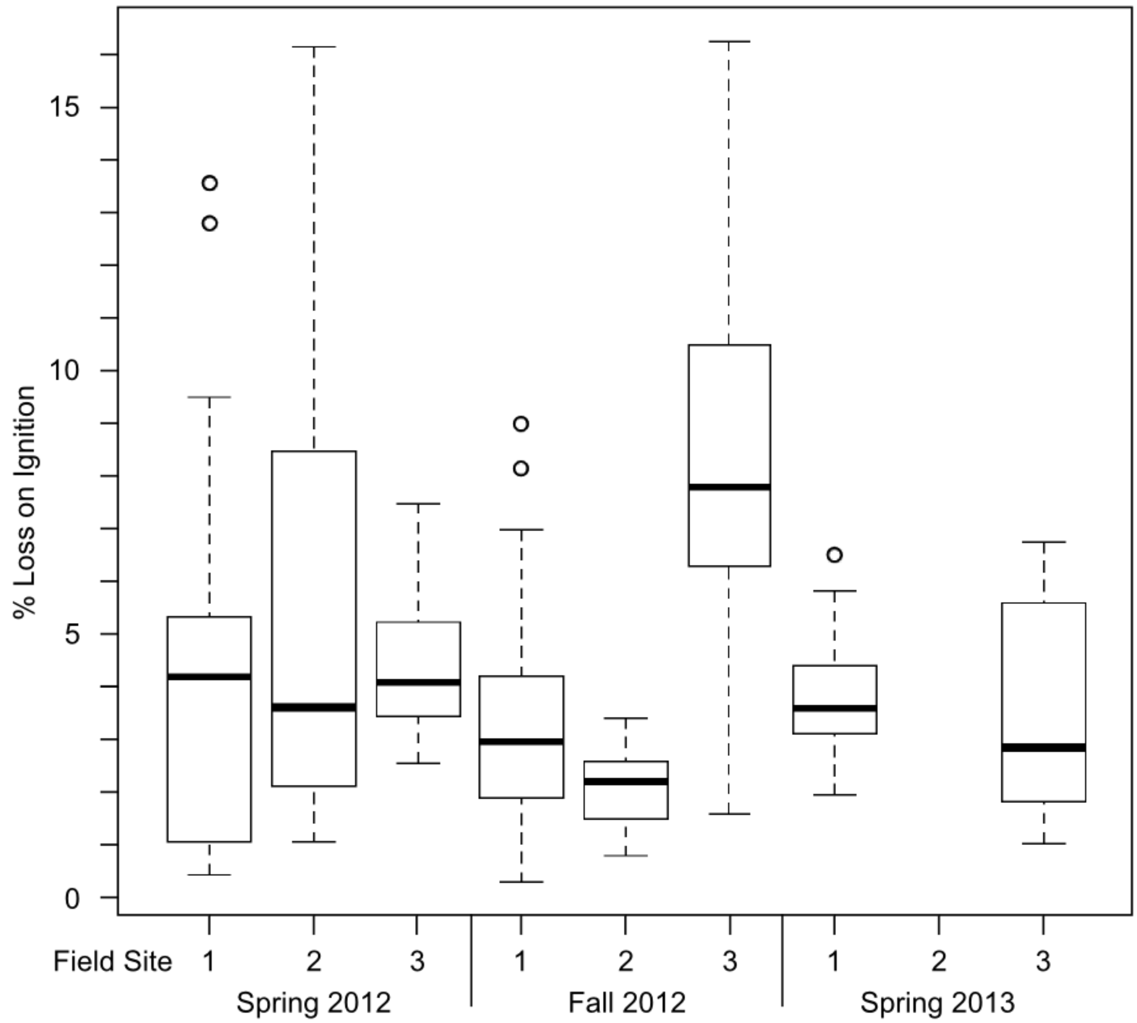
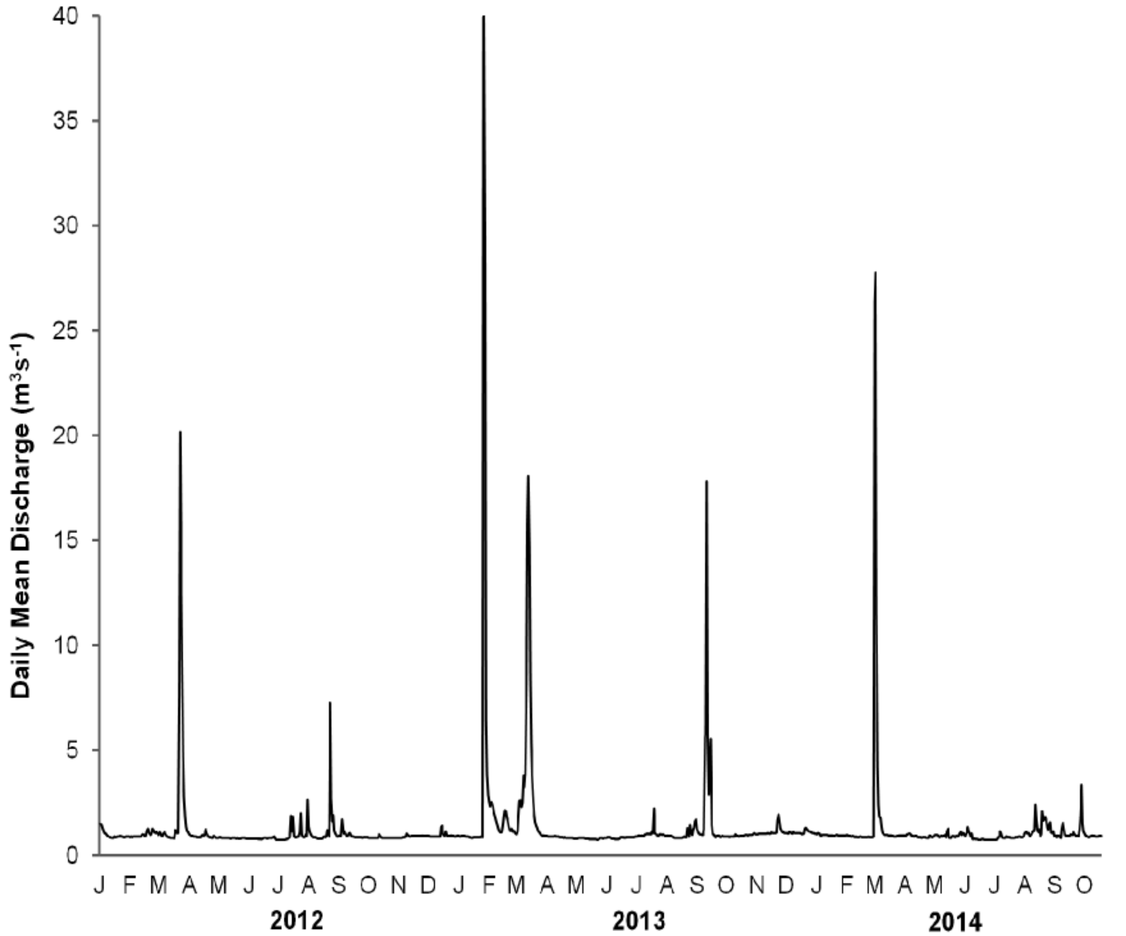


Figure 2.4. Organic content estimates of fine grain sediment samples expressed as percent loss on ignition. No fine grain sediment was observed at field site 2 for spring 2013.

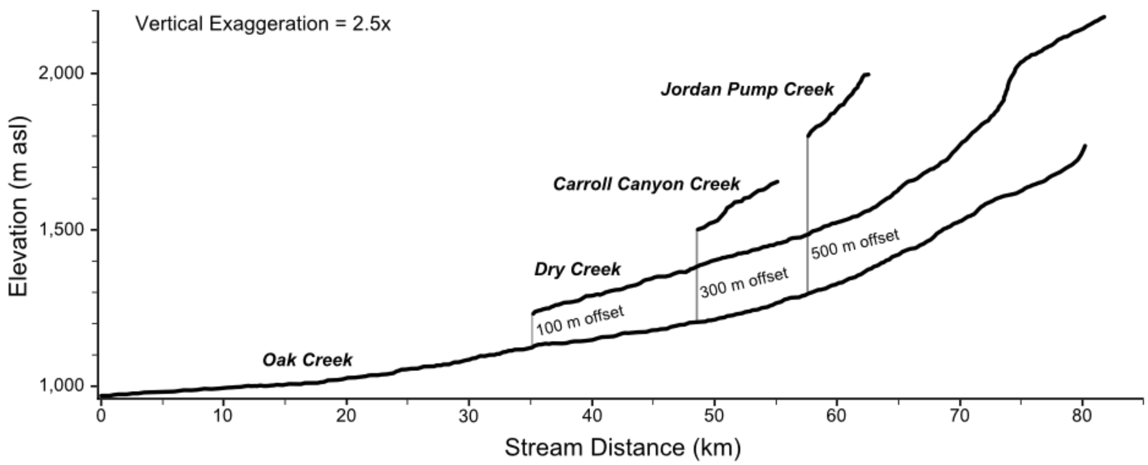
2.5.4. Seasonal Floods



2.6. Discussion

2.6.1. Sediment Volume Change

2.6.1.1. Areal Analysis



	Jordan Pump	**Carroll Canyon**	**Dry Creek**	**Oak Creek**
Area	8.7 km^2	19.0 km^2	184.2 km^2	1204.7 km^2
Perimeter	15.7 km	24.1 km	89.0 km	226.3 km
Peak elevation	2163 m	1937 m	2200 m	2581 m
Relief	192 m	155 m	1077 m	1613 m
Mainstem length	4.8 km	6.4 km	46.6km	83.4 km
Mainstem gradient	40.0 m/km	24.2 m/km	20.3 m/km	9.5 m/km
Average slope	20°	9°	17°	11°
Drainage density	1.14 km/km^2	1.35 km/km^2	1.30 km/km^2	1.31 km/km^2
Stream order[1]	3	3	4	6

Table 2.1. Properties of selected catchments in the Oak Creek watershed. [1]Using Strahler method of stream ordering.

2.6.1.2. Temporal Analysis

2.6.2. Particle Size Changes

2.6.2.1. Areal Analysis

2.6.2.2. Temporal Analysis

2.6.3. Flood Event Analysis

2.7. Conclusions

3. Conclusions

3.1. Main Conclusions

3.1.1. Manuscript Conclusions

3.1.2. Other Conclusions

3.2. Recommendations for Future Work

- Conduct a similar study at different locations of Oak Creek, particularly in Oak Creek Canyon.
- Sample and analyze *E. coli* levels of water and sediment in addition to site survey and sediment analysis.
- Perform a sediment source analysis (i.e. analyze sediment grains to find a match with upstream rock formation sources).

4. Works Cited

Arizona Department of Environmental Quality (ADEQ). 2009. Water Quality Standards for Surface Waters. 18 A.A.C., Chap 11, Art. 1 ADEQ, Phoenix, AZ.

ADEQ. 2010. Oak Creek and Spring Creek Total Maximum Daily Loads for Escherichia coli. OFR 10-01. ADEQ, Phoenix, AZ.

Arizona Department of Water Resources (ADWR). 2014. Groundwater Hydrology in the Verde River Basin. Verde Valley Sub-basin. http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/CentralHighlands/Hydrology/VerdeRiver.htm (accessed 10 December 2014).

Blakey, R. 1990. Stratigraphy and geologic history of Pennsylvanian and Permian rocks, Mogollon Rim region, Central Arizona and vicinity. Geological Society of America Bulletin 102, 1189–1217.

Blakey, R. 2014. Sedona and the Verde Valley Region: A Geologic Guide to the geology of Central Arizona. Geologic Maps and Panel Section, Stratigraphic Column. http://jan.ucc.nau.edu/~rcb7/verde.html (accessed 25 November, 2014).

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal 54, 464–465.

Crabill, C. Donald, R. Snelling, J. Foust, R. and Southam, G. 1999. The impact of sediment fecal coliform reservoirs on seasonal water quality in Oak Creek, Arizona. Water Research 33, 2163–2171.

Dean, W. E. 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition; comparison with other methods. Sedimentary Research 44, 242–248.

Donald, R., Southam, G., Foust, R., Rottarch, R., and Burch, B. D. 1998. The Oak Creek Canyon Section 319(h) National Monitoring Project. U.S. EPA, San Francisco, CA. ADEQ, Phoenix, AZ. Northern Arizona University, Flagstaff, AZ.

Glew, J. R., and Smol, J. P. 2001. Sediment Core Collection and Extrusion. In: Last, W. M. and Smol, J.P. (Eds.), Tracking Environmental Change Using Lake Sediments, Volume 1: Basin Analysis, Coring, and Chronological Techniques. Kluwer Academic Publishers, Dordecht, The Netherlands. pp. 73–105.

Holm, R. F., Cloud, R. A. 1990. Regional significance of recurrent and intercanyon volcanism at Oak Creek Canyon, Southern Colorado Plateau, Arizona. Geology 18, 1014–1017.

Jackson, P. D. 1981. Water quality report, Slide Rock and Grasshopper Point Swim Areas in Oak Creek Canyon, Summer 1980. U.S. Forest Service, Coconino National Forest, AZ.

Kasai, M., Marutani, T., and Brierley, G. 2004. Channel bed adjustments following major aggradation in a steep headwater setting: Findings from Oyabu Creek, Kyushu, Japan. Geomorphology 62, 199–215.

Leopold, L. B.,Wolman, M. G., and Miller, J. P. 1964. Fluvial processes in geomorphology. W. H. Freeman, San Francisco, California.

Lisle, T. E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural channels, northwestern California, Water Resources Research 18, 1643–1651.

Madej, M. A., and Ozaki, V. 1996. Channel response to sediment wave propagation and movement, Redwood Creek, California, USA. Earth Surface Processes and Landforms 21, 911–927.

Mohlenbrock, R. H. 1985. Oak Creek Canyon, Arizona. Natural History 94, 34–36.

Moir, H. J., Pasternack, G. B. 2008. Relationships between mesoscale morphological units, stream hydraulics and Chinook salmon (Onchorhynchus tshawytscha) spawning habitat on the Lower Yuba River, California. Geomorphology 100, 527–548.

Montgomery, D. R., and Buffington, J. M. 1997. Channel-reach morphology in mountain drainage basins. Geologic Society of America Bulletin 109, 596–611.

Oak Creek Watershed Council (OCWC). 2012. Improvement Plan for the Oak Creek Watershed, Arizona. http://oakcreekwatershed.org/ocwc-library/oak-creek-watershed-improvement-plan/ocwip-for-public-review (accessed 10 December. 2014).

Obr J. E., Follett R. H., and Kracht J. K. 1978. Oak Creek water quality report. Arizona Department of Health Services in NACOG-ADHS, Phoenix, Ariz.

Poff, B., Tecle, A. 2002. Bacteriological Water Quality Trend Analysis in Oak Creek Canyon, Arizona. In: Kenny, J. F. (ed.), Proceedings of the American Water Resources Association, Ground Water and Surface Water Interactions Specialty Conference, July 1–3, 2002, Keystone, Colorado, U.S., pp. 431–436.

Rose, J. B., Mullinax, R. L., Singh, S. N., Yates, M. V. and Gerba, C. P. 1987. Occurrence of rotaviruses and enteroviruses in recreational waters of Oak Creek, AZ. Water Research 21, 1375–1381.

Southam, G., Keim, P., Keys, C. 2000. The Oak Creek Canyon Escherichia coli Genotyping Project. ADEQ, Phoenix, AZ. NAU, Flagstaff, AZ.

Mayer, L. 1979. Evolution of the Mogollon Rim in Central Arizona. Tectonophysics 61, 49–62.

U.S. Census Bureau. 2010. State and County Quickfacts: Sedona, Arizona. http://quickfacts.census.gov/qfd/states/04/0465350.html (accessed 3 December 2014).

U.S. Department of Agriculture (USDA). 2014. Natural Resources Conservation Service. Soils. Web Soil Survey. Beaver Creek Area, Arizona (AZ641) and Black Hills – Sedona, Arizona, Parts of Coconino and Yavapai Counties (AZ639). http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx (accessed 10 December 2014).

Western Regional Climatic Center (WRCC). 2011. Sedona Rangers Station, Arizona, National Climate Data Center Monthly Normals. http://www.wrcc.dri.edu/summary/climsmaz.html (accessed 24 November 2014).

Wohl, E. E., Vincent, K. R., and Merritts, D. J. 1993. Pool and riffle characteristics in relation to channel gradient, Geomorphology 6, 99–110.

Wohl, E. E., and Cenderlli, D. A. 2000. Sediment deposition and transport patterns following a reservoir sediment release, Water Resources Research 36, 319–333.

Wohl, E. E. 2010. Mountain Rivers Revisited. American Geophysical Union Press, Washington, DC.

5. Appendices

5.1. Detailed Field and Lab Methodologies

5.1.1. Fieldwork

Site Selection

I chose three field sites in Oak Creek where discrete, fine-grain sediment deposits occurred in the streambed. Sediment deposits had to be large enough to facilitate a depth survey and collection of multiple sediment core samples. During field reconnaissance I observed that sediment bar deposits were either adjacent to or in close proximity downstream to a tributary confluence. To diversify the study, I chose sites at or near three different confluences, representing three separate subcatchments in the watershed. The sites are easily accessible by roads and trails.

Site Locations

Site 1, Oak Creek at the confluence with Jordan Pump (Figure 2)

34.8747000° N, 111.7548500° W

431013 m E, 3859407 m N (UTM Zone 12 N)

1288 m a.s.l.

Directions to site: From Flagstaff drive south on Hwy 89A through Oak Creek canyon. Park at the pull out on the west side of the road at mile marker 376 (this pull out is about 0.2 km from uptown Sedona). Walk down the hill and follow the path through the tunnel that passes under the highway towards Oak Creek.

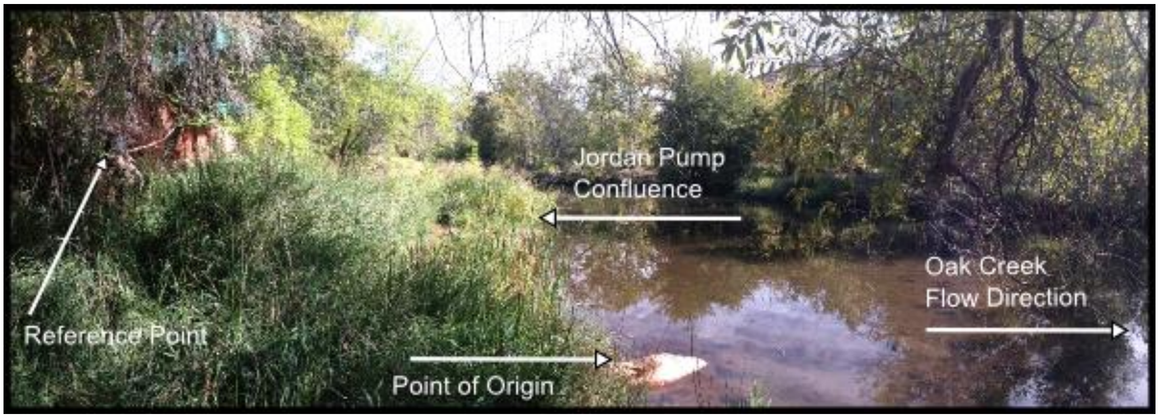


Figure 5.1. Survey features in Oak Creek at the Jordan Pump confluence (field site 1).

Site 2, Oak Creek at the confluence with Carroll Canyon (Figure 3)

34.8250667° N, 111.8101333° W

425916 m E, 3853943 m N (UTM Zone 12 N)

1186 m a.s.l.

Directions to site: From Sedona drive south on Hwy 179 to the Village of Oak Creek. Turn west onto Verde Valley School Rd and drive 7.8 km to USFS parking lot (Fee Area). The paved road eventually turns into a maintained gravel road. From the parking lot walk about 0.4 km down the road until it dead ends above Oak Creek at Red Rock Crossing. Follow the path and walk down stream along Oak Creek until you reach the confluence with Carroll Canyon, about 0.2 km. Alternatively, this site can also be reached from Red Rock Crossing / Crescent Moon Picnic Site (Fee Area) via Upper Red Rock Loop Road and Red Rock Crossing Road from Hwy 89A.

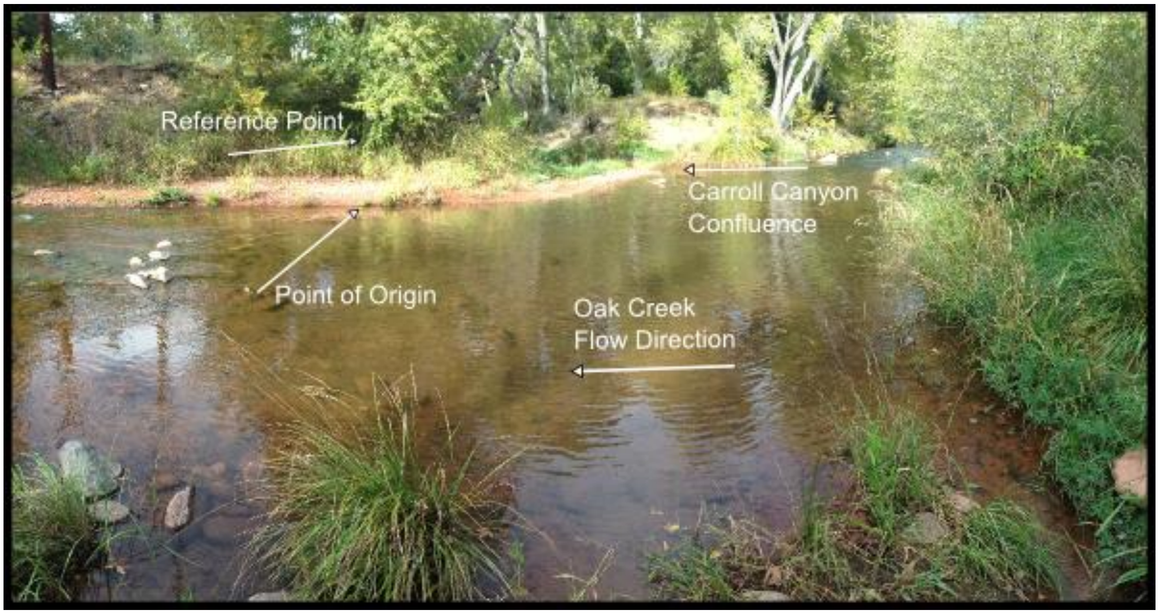


Figure 5.2. Survey features in Oak Creek at the Carroll Canyon confluence (field site 2).

Site 3, Oak Creek at 703 m downstream from the confluence with Dry Creek

34.7998833° N, 111.8823500° W

419287 m E, 3851205 m N (UTM Zone 12 N)

1146 m a.s.l.

Directions to site: From Sedona Drive south on Hwy 89A towards Cottonwood. Turn east onto Forest Road 89B (also called E Deer Pass Rd / Angel Valley Rd), about 1.2 km past mile marker 365. Drive 3.4 km to the USFS campground. Do not take the private road that crosses over Oak Creek towards private property. Use the first pullout on the right as you enter the campground and take the path directly down to Oak Creek.

Figure 5.3. Survey features in Oak Creek near the Dry Creek confluence (field site 3).

Sediment Survey

List of Equipment and Materials:

- Survey poles, steel, 0.5 to 1.0 cm diameter and several lengths of 0.5 m to 1.5 m
- Rubber ball, such as a tennis ball
- Metric tape measure, 50 m length with 0.1 m or finer subdivisions
- Metric ruler, metal with 48 cm length and 1 mm subdivisions
- Flagging tape, bright color
- Hammer or mallet
- Field notebook
- Pencils
- Hand held GPS, for site locations

Magnetic compass, with declination adjustment

Digital camera, to record site characteristics

I conducted a sediment survey at each site to record the extent and depth of fine grain sediment deposits within the active streambed, e.g. bar features composed of sand, silt, and clay sized particles. I performed subsequent surveys for each site following seasonal flood events to measure change in sediment deposits at each site. For survey accuracy, it is important to be able to distinguish fine grain fluvial sediment from other deposits that may occur in the streambed such as bank erosion, coarse gravels, cobbles and boulders. Bank erosion occurs where a steep streambank of alluvial material has been eroded, allowing older alluvial sediments to reenter the stream. Since bank erosion deposits and other coarser materials were not the focus of this study I did not include those deposits in the survey when I could distinguish them from the fine grain streambed sediments of interest.

To prevent unintended sediment erosion, I made sure not cause too much disturbance to the survey sites. Sediment on the surface of a streambed can easily be compacted and or removed simply by walking through the stream. Although it is necessary to walk through the stream to make measurements, I avoided the transect lines that were measured directly to allow survey data to be as accurate as possible.

Point of Origin and Reference Point

I performed sediment surveys using a regular grid system of transects and sampling points beginning at a point of origin. The point of origin established the furthest downstream extent of the sediment deposit, and I marked the point at the streambank. I accurately recorded the point of origin with a compass bearing and distance measurement to a nearby, stationary landmark called the reference point. Throughout the study, I used the reference point landmark to record location changes in sediment deposits. Very detailed notes are necessary to ensure that the reference point and the point of origin can be located for mapping purposes and for subsequent field surveys. Boulders and woody debris that occur along the streambank may seem like good landmarks to use for locating the point of origin but seasonal floods can easily remove these features and change the physical characteristic of the stream. Therefore it is much more reliable to use more stationary features such as buildings, rock formations or large trees above the active stream channel as a reference point. A hand held GPS unit, which has a typical error of ± 3 m in good conditions, is not accurate enough to precisely locate the point of origin, though it is fine for recording the general locations of the reference point feature and the site location.

Transects

I used a system of transects to measure stream width throughout the total extent of the sediment deposit. Beginning at the point of origin, I placed transects every 3 m in the upstream direction, marked along the confluence side of the stream. The distance between transects includes any bends or curves in the streambank. I affixed brightly colored flagging tape to foliage or tied flagging around a stone to temporarily mark the position of each transect. When working without the aid of a field assistant, I used several survey poles to anchor the metric tape measure when setting up transects. The first transect, at the point of origin, extended to the opposite side of the stream, perpendicular to the channel, from one streambank to the other. Every other transect was parallel to the first transect. Along each transect, I recorded stream width to the nearest 0.1 m with a metric tape measure.

Survey Points

I established survey points in 0.5 m increments along each transect, extending across the extent of the sediment feature(s). Survey points began along the confluence side of the streambank. A metric tape measure was stretched across the stream along the transect line and I recorded sediment depth at each survey point.

Sediment Depth Measurement

I made sediment depth measurements using a steel rod of 0.5 cm diameter. The length of a survey pole can vary according to the depth of the sediment deposit. It may be necessary to use survey poles of several lengths, up to 1.5 m. To measure sediment depth, I affixed a tennis ball to the survey pole by making two small holes and piercing the pole through the ball. The ball could be moved in position but remained in place after repositioning. While standing at a survey point in the stream, I drove the survey pole straight down into the sediment until contact was made with bedrock substrate, a boulder, cobble, or coarse gravels that marked the lowest point of the sediment deposit. I was careful to avoid driving the pole down at an angle as this could affect the accuracy of depth measurements. I then positioned the ball by sliding it down until it just made contact with the surface of the sediment without creating a depression. I retrieved the pole and recorded sediment depth to the nearest 0.1 cm. Sediment depth is measured with a metric ruler as the distance from the bottom of the ball to the end of the survey pole.

Azimuths

To draw stream layouts for the survey maps, I recorded azimuths between each transect along the steam bank on both sides of the stream. Additional azimuths were collected for points every 3 m in both the up and downstream directions from the sediment deposits as well as along of the first transect. If a tributary stream confluence occurred at the site then azimuths were also taken up the tributary streambanks to record stream layout. I also took digital photos to record site characteristics including streambank morphology, confluence position, vegetation, sediment deposit features, and reference point location.

Core Samples

List of Equipment and Materials:

Plastic core tubes, 5.1 cm outside diameter, 1.5 mm wall thickness, lengths of 61 cm and 92 cm, AMS Model 425.20 and 406.72

Plastic core tube caps, 5.1 cm diameter, AMS model 418.10

Adjustable rubber bung, 5 cm diameter and hex wrench for adjustment

Petroleum jelly

Wash bottle with nozzle

Core sample extruder

Spatula / Putty Knife: 12.7 cm wide blade

Plastic syringe, modified to extract 1 cc of sediment

Plastic core tube, 7.62 cm section of 5.1 cm diameter, "small cylinder"

Plastic siphon tube, 0.5 cm diameter, 2 m length

Metric Ruler, 1 cm or finer subdivisions for setting extruding length

Plastic vials with caps, numbered for sample identification

Aluminum foil, cylindrical shaped and pre-weighed to contain density samples

Whirl Pak Bags for particle size sample, can substitute plastic zip close bags 16.5 cm by 14.6 cm, or similar size

Permanent marker, to label sample bags

Mobile table and chair, for processing samples in the field

Field notebook

Pencils

Density Sample Vials

Before collecting samples in the field, plastic vials used to hold density samples were cleaned, dried, and prepared with pieces of aluminum foil. Vials were numbered in sequential order with a permanent marker. I fashioned Aluminum foil into a cylinder shape by cutting 5 cm by 5 cm squares and molding the foil around a 1.91 cm diameter wooden dowel. I created a spreadsheet to record the mass of each foil piece to the nearest 0.0001 g along with the number of the plastic vial in which it was placed.

Sample Labels

Samples were labeled accordingly with a unique number or sequence of letters and numbers representing the site location, season, transect number, sediment core, and depth from sediment surface. I wrote labels for particle size samples on the plastic sample bag with a permanent marker. An example of a particle size sample label is JPF2012 T4a-26. This label sequence denotes the sample was collected from the Jordan Pump site in the Fall of 2012 from transect 4, core position a, at a depth of 26 cm below the sediment surface. I recorded core position in the field notebook as a specific distance along transect 4 from the confluence side of the streambank.

I recorded density samples with the corresponding plastic vial number in which they were placed. When recorded in the field notebook, density samples were written directly below particle size samples in columns organized by transect, so sample depth could easily be determined.

Core Sample Extraction

Following completion of the first three sediment surveys, I collected sediment core samples at each field site. At least one core sample was extracted per transect at the sample point with the greatest depth measurement. If the sediment deposit extended three or more meters from the streambank, than I collected two core samples. In this case one sample at or within 0.5 m of the streambank and the other sample at the point of greatest sediment depth. If the sediment deposit covered the entire stream width, than I collected three core samples, two at or near either streambank and the third sample I collected near the middle of the stream channel. When collecting core samples I avoided areas along a transect with vegetation, woody debris, or very coarse sediment visible on the sediment surface.

To extract a sediment core sample I carefully inserted a 5.1 cm diameter plastic core tube into the sediment and pressed downward until it hit coarse gravels or rock substrate, or the full length of the core tube was submerged. At times it was necessary to gently rotate the core tube while pushing down as small woody debris and gravels within the sediment were common and made penetrating the core tube into the sediment more difficult. If a portion of the core tube was standing above the stream water line then I completely filled the core tube with water using a bottle. I tightly capped the core tube with a 5.1 cm diameter plastic tube cap to create suction, which helped contain the sediment core within the tube, and the core was carefully removed from the sediment. Once removed, the core tube contained an intact column of sediment. Before the core tube was lifted out of the water, I quickly inserted an adjustable rubber bung (coated with petroleum jelly) into the bottom of the core tube to contain the sediment column. I found this to be a tricky maneuver because the plastic cap had to be loosened to allow water to escape as the rubber bung was inserted in the bottom of the core tube. I then took the core sample the extruder to process subsamples. I strongly recommended practicing core sample collection methods and using the extruder to become familiar with the process before collecting actual samples for research.

Sample Extrusion

I used sediment cores for two types of laboratory analysis including particle size samples and density samples. To accommodate extraction of two types of samples, I extruded the sediment column in 1 cm increments, alternating between particle size samples and density samples. Prior to sample collection I assembled the extruder, set it to make a 1 cm extrusion of the sediment core with a metric ruler, and I checked it to ensure proper function. The chair and mobile table were also set up with putty knife, numbered plastic vials and caps, plastic sample bags, permanent marker, and field book ready to use.

To begin extrusion of the sediment column, I removed the plastic cap from the sample tube and the water was siphoned out using the siphon tube. A small amount of water was left on top of the sediment to ensure that none of the sediment was siphoned out. Next, I placed the core tube onto the top of the extruder and moved it downward until the sediment was level with the top of the core tube. The sediment column was now ready for a series of 1 cm extrusions.

To extrude a 1cm sample of sediment, I placed the small cylinder directly on top of the sample core tube to contain the sediment sample, and held it in place while the core tube and small cylinder were pressed down. At times it became difficult to move the core tube downward, most often because the rubber bung had been lubricated with an insufficient amount of petroleum jelly. Placing the spatula on top of the small cylinder while pressing down helped the process. Once the 1 cm sample had been extruded, I inserted the spatula between the core tube and small cylinder and the sample was removed with the small cylinder. After the sample was bagged or discarded, I rinsed the small cylinder and spatula so they were clean for the next sample.

Particle Size Samples

The first 1 cm extrusion and every second extrusion thereafter were extracted for particle size analysis. Once the particle size sample was removed, it was carefully placed in a plastic bag. Any sediment left behind on the top side of the spatula or the small cylinder was washed into the sample bag using the wash bottle. The sample bag was then sealed and labeled accordingly. The sample was also recorded in the field book.

Density Samples

The second 1 cm extrusion and every second extrusion thereafter were used for density analysis. Using the plastic syringe, a 1 cc sediment sample was extracted from the sediment column, before the sediment column had been advanced in the extruder. The sample was then contained within a pre-weighed piece aluminum foil and placed in the corresponding numbered plastic vial with cap. Samples were also recorded in the field book with the plastic vial number.

After the 1cc density sample had been extracted and recorded, the sediment column was extruded 1 cm and the remaining sediment cake was discarded. All tools were then rinsed and made ready for the next sample. When sample extraction was completed, all tools and equipment were cleaned and dried before packing out of the field area. All samples collected in the field were stored at 2º C until laboratory analysis began.

5.1.2. Labwork

Density Analysis

List of Materials:

Plastic vials with lids, 2.5 cm diameter and 4.5 cm height

Aluminum foil

Wooden dowel, 1.91 cm diameter and 10 cm length

Cardboard boxes or similar to contain plastic vials in the field

Laboratory oven, Quincy Lab, Inc. model 40 GC

Granular silica Gel and container such as an aluminum pie dish

Aluminum sample tray, 46 cm long by 30 cm wide by 10 cm deep

Analytical Balance, Sartorius model GD-503 NTEP, sensitive to 0.0001 g

Stainless steel tongs or oven glove

Laboratory tweezers or forceps

Before collecting sediment density samples in the field a series of numbered plastic vials had to be prepared for containing samples. First, the vials and lids were thoroughly cleaned, dried and counted. Vials were sequentially numbered with a permanent marker for sample identification. Then, pieces of aluminum foil were cut into approximately 5 cm squares. I shaped the foil squares into a cylinder using a 1.91 cm (0.75”) diameter wooden dowel. Foil cylinders were then measured to record mass to the nearest 0.0001 g. After a foil cylinder’s mass was recorded, it was placed into a numbered plastic vial. Plastic vials were neatly stacked in a box for use in the field. An Excel spreadsheet was created to record both vial numbers and the mass of the foil cylinder that was placed within that vial. Following sample collection field work the same spreadsheet would be used to record the dry mass of samples and calculate sample density. Depending on the volume of sediment that occurs at each field site, several dozen or more plastic vials are needed for each sampling season. To avoid running out of sample vials in the field during sample collection, it is best to prepare as many vials as possible before the start of field work.

When seasonal field work was concluded, density samples were brought into the lab for analysis. To determine sediment density, samples were dried in a lab oven to remove all moisture, about 12 hours, and the sample's dry mass was measured using an analytical balance. The lab oven was allowed to preheat to a temperature of 105º C, and a tray containing silica gel granules was placed on the top most oven rack. The silica gel was used as a desiccant to absorb any moisture in the oven. Small amounts of desiccant granules were also placed in containers within the analytical balance to create a dry environment for measuring sediment mass. To begin density analysis, sample vials were arranged on a counter top according to the field site and core sample from which they were collected. Samples were checked against the data recorded in the field notebook to make sure no samples were missing. Using the lab tweezers, the foil pieces that contained 1 cc sediment samples were removed from their plastic vials and placed onto the sample tray. The top of the foil containers were opened slightly to allow moisture to escape from the sediment sample. Samples were arranged very carefully in the same order and arrangement as the plastic vials on the counter top so that samples could be identified by position, without labels. The oven tray was then carefully placed in the oven and left to dry overnight, or for a period of at least six hours.

After the density samples were fully dried the lab oven was turned off and allowed to cool. The sample tray was removed and placed on a counter top near the analytical balance. Dried samples were then placed in the analytical balance to measure the sample mass. Dry sample mass, which included both the foil mass and the 1 cc sediment sample mass, was recorded to the nearest 0.0001 g for each sample. The excel spreadsheet was updated with dry sample plus foil mass. A final sample density of g/cm3 was calculated by subtracting the initial foil mass from the final dry sample mass. After density analysis was completed all sample vials were cleaned and returned to their storage boxes. All other lab materials were cleaned and sediment samples were discarded.

Organic Content, LOI Analysis

List of Materials:

Laboratory oven, Quincy Lab, Inc. model 40 GC, able to achieve 105º C
Laboratory Furnace, Temco type 1400, model F-1410T-11, able to achieve 550º C
Analytical Balance, Sartorius model GD-503 NTEP, sensitive to 0.0001 g
Standard testing sieve and pan, ATSM No. 10, 2.00 mm grid mesh
Sieve brush
Stainless steel furnace vessels x 4, 150 ml volume and 50 to 65 g, labeled A, B, C, or D
Steel baking dish x 4, 16 cm by 16 cm by 5 cm – sample drying tray
Steel tongs
Stainless steel cooling rack
Wash bottle with nozzle
Oven glove
Masking tape
Plastic storage containers with lids x 4 or more, cylindrical, 6.5 cm diameter by 5 cm
Pen and pencils
Tablet sheets for recording mass data

Sediment samples collected in the field for particle size analysis were first tested for organic content. Sample bags were organized by field site and arranged by transect number in numerical order using sediment depth values. Since sediment core depths varied, samples were amalgamated and processed as groups of 5 or less sample bags. Sample groups represented a range of sediment up to 10 cm of core depth. After organizing samples, the lab oven was preheated to 105 º C and a group of sample bags was selected. The sample bag contents were completely washed into a sample drying tray with distilled water. The sample drying tray was labeled according to the sediment sample range, transect, and site by writing a label code onto a piece of masking tape and affixing the tape to the sample tray. A typical label code looked like the following, JPS2013 T2a 12-20, meaning the samples were collected from the Jordan Pump field site in spring of 2013 from transect 2, position a, at a depth range from 12 to 20 cm below the surface. The sample drying tray was then placed in the lab oven to dry overnight or until all moisture was completely evaporated.

Once organic content samples were completely dried, the sample tray was removed from the oven and allowed to cool on the cooling rack to room temperature. The sediment was then processed through a No. 10, 2.00 mm grid sieve to remove all gravel sized particles from the sample. A sieve brush was used to ensure all fine particles were not lost in the sieve or sieve pan. Once sieved, the sample was returned to the sample tray. The lab furnace was turned on and allowed to reach a temperature of 550º C, with a setting of 22.5 % power. Steel furnace vessels were each labeled with an A, B, C, or D etched into the bottom of the vessel. For each sample, an empty furnace vessel was weighed and the mass was recorded to the nearest 0.0001 g. The empty vessel mass was recorded on a tablet sheet along with the sample range label followed by the vessel identifying letter so that the new label would look like the following, JPS2013 T2a 12-

20a. Since the lab furnace could accommodate two sample vessels, two samples were prepared at a time for LOI analysis. To prepare a sample for LOI, sediment from the drying tray is carefully added to one of the preweighed furnace vessels until the mass of the sediment, not including the vessel mass, is between 20 g and 50 g. To help speed the lab analysis process and make time spent in the lab more efficient, it is best to fill sample vessels with as much sediment as possible. The capacity of the analytical balance and the empty mass of the sample vessels may limit the amount of sediment each vessel can hold to less than 50 g. Because of those possible limitations each vessel should be filled with a quantity of sediment to just under the mass capacity of the balance, or 50 g.

When two furnace vessels are filled with sediment and the masses are recorded, they are carefully placed in the preheated furnace using tongs and protective gloves. The samples are exposed to 550º C for a period of 120 minutes. Within a few moments of placing the samples in the furnace the samples may produce smoke as organic particles are burned off. Make sure the lab space is well ventilated with a fan and open door or window. Some organic rich samples may contain large pieces of woody debris or leaves which will produce excessive smoke within the furnace. If the laboratory space does not contain an enclosed fume hood space, large organic pieces may be removed and discarded after the sample mass is recorded and before the sample is placed into the furnace to avoid excessive smoke. Large organic pieces within a sample should be removed from the sediment carefully leaving behind all sediment particles.

After 120 minutes in the furnace, samples are carefully removed with protective gloves and tongs, and allowed to cool to room temperature on the cooling rack. Once cooled, sample mass was recorded to the nearest 0.0001 g and a LOI mass value was calculated by subtracting the post LOI sediment value from the initial LOI sediment value. The sediment sample was then completely transferred into a plastic container using the sieve brush and sealed with a lid. Using a piece of masking tape, the plastic container was labeled with the same label code that was used to record the sample masses. This label code will be used to identify the sample for particle size analysis.

Particle Size Analysis

Materials:

Glass cylinders, 1000-ml

Glass beaker, 1000-ml

Plunger for mixing solutions

Thermometer, unit increments of one degree Celsius

Hydrometer Bouyoucos, (ATSM 152H) model

Electric mixer, Cuisinart model CSB-79

Stop watch or timer

Digital balance, Sartorius model GD-503-NTEP, sensitive to ± 0.0001

Distilled water, allowed to acclimate to room temperature

Cylinder stopper or plastic sheet and rubber bands to seal cylinders for mixing

Reagent:

Dispersing solution, 5%: Dissolve 50 g of sodium hexametaphosphate, $(NaPO_3)_6$ in distilled water and dilute to 1 liter.

Procedure:

Read carefully through these steps before beginning the procedure so that you fully understand how to complete the lab. Some of the steps must be completed in quick succession in a short amount of time. The worksheet following the lab procedure can be used to record and calculate particle size sample values. All sample values were also recorded in an excel spreadsheet.

1) Set up blank cylinder. Mix 100 ml of the 5% dispersing solution and 880 ml of distilled water in a clean 1000 ml cylinder. This mixture is the blank and it will be used to measure the temperature and density of the dispersing solution. Note that the total volume of the blank solution is 980 ml. The missing 20 ml is to account for the volume occupied by the sediment in the sample cylinder.

2) Set up sample cylinder. Weigh 25-50 g of sediment and record weight to ± 0.001 g. Transfer sediment quantitatively to a clean 1000 ml glass cylinder using distilled water.

3) Add 100 ml of 5% dispersing solution to sediment sample and dilute to about 500 ml with distilled water. The 5% sodium hexametaphosphate solution is used to separate aggregates, or clumps of silt and clay particles that stick to each other.

4) Mix sediment and dispersing solution in the glass cylinder with electric mixer for 60 seconds.

5) Fill sample cylinder to 1000 ml with distilled water.

6) Repeat steps 2 through 6 for each sample.

7) Record blank solution measurements. At the beginning of each set, record the temperature, and the hydrometer reading of the blank solution, using the following procedure.

8) Place the thermometer probe into the blank solution and hold until the gauge needle settles. Record the temperature, rounding up to the nearest half degree Celsius.

9) Carefully mix the blank solution with the plunger to ensure that all of the dispersant is dissolved into the solution. Gently place the hydrometer into the blank solution and allow it to settle. Record the solution density, rounding up to the nearest half gram.

10) Record sample solution measurements. Seal the sample solution cylinder with rubber stopper or plastic sheet and rubber bands. Mix solution by turning the cylinder over from top to bottom and continue turning for 60 seconds. Check to be sure that all of the sediment is mixed into suspension with the solution, i.e. none of the sediment should be resting on the bottom of the cylinder while mixing.

11) When sediment is fully in suspension with the solution, place cylinder on the counter top and carefully place hydrometer into the sample solution while beginning a 40 second timer. If the hydrometer is not carefully placed into the solution it may not completely settle before the 40 second period is up. After 40 seconds record the solution density, rounding up to the nearest half gram. This density measurement is recording the amount of silt and clay left in suspension as all of the sand has fallen out of suspension after 40 seconds.

12) Repeat steps 10 and 11 for each sample and begin a 6 hour, 52 minute timer.

13) After 6 hours, 52 minutes record the hydrometer reading for each sample, rounding up to the nearest half gram. This density measurement is recording the amount of silt left in suspension as all of the silt and sand has fallen out of suspension after 6 hours and 52 minutes.

14) Clean and dry all lab equipment.

Calculations:

Temperature and density corrections:

A Change in temperature affects the density of a solution Since the hydrometer was calibrated to measure the density of a solution at 20º Celsius we must correct any measurements that are recorded at temperatures other than 20º C.

Add 0.3 units to the readings of samples for every 1º C above 20º C

Subtract 0.3 units to the readings of samples for every 1º C below 20º C

Percent Clay:

% Clay = corrected hydrometer reading at 6 hrs, 52 min. x 100 / mass of sample

Percent Silt:

% Silt = corrected hydrometer reading at 40 sec. x 100 / mass of sample - % clay

Percent Sand:

% Sand = 100% - % Silt - % Clay

References

Procedure adapted from the University of Wisconsin-Madison Soil Science Department Particle Size Analysis (Physical Analysis)

Peters, J., (October 2013). Wisconsin Procedures for Soil Testing, Plant Analysis and Feed & Forage Analysis, No.6, Soil Fertility Series. Retrieved from http://uwlab.soils.wisc.edu/lab-procedures/

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54:464-465.

5.1.3. GIS Analysis

Watershed Analysis

ArcGIS Watershed Delineation

The concept of a watershed when applied to a DEM grid in GIS can be described as a specific area of land that will channel all surface flow, from higher to lower elevations, towards a single point. An ArcGIS Model Builder sequence for watershed delineation can be built using the Hydrology toolset in Spatial Analyst extension of ArcMap (Figure 5.4.). For more information on watershed delineation see the ArcGIS Resources Help website and look for Spatial Analyst information under extensions.

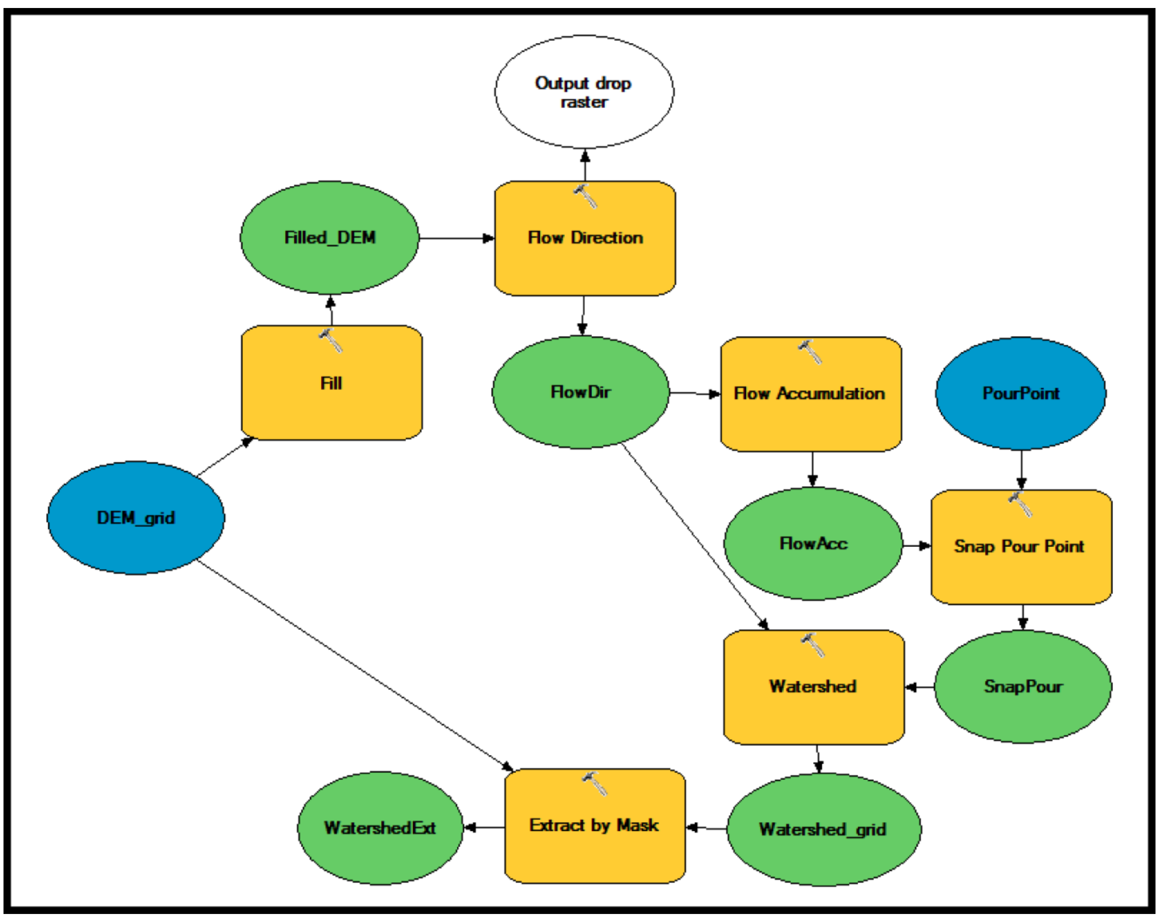


Figure 5.4. Watershed extraction model built in ArcGIS Model Builder.

Drainage Basin Characteristics Table

Once a watershed DEM grid was produced it was analyzed to assemble a table of drainage basin characteristics. Individual subcatchments within the watershed were extracted from the watershed DEM grid using the watershed extraction model. To extract each sub basin, a pour point feature was placed on the tributary stream cell with the highest flow accumulation value just above the confluence with the mainstem stream. The following physical characteristics were found as follows.

Area	Watershed raster was converted to polygon using Raster to Polygon Tool. An area field was added to the polygon attribute table and area geometry was calculated in km2.
Perimeter	A perimeter field was added to the polygon attribute table and perimeter geometry was calculated in km.
Peak elevation	A DEM grid of individual subcatchments was created using the Extract by Mask Tool. The highest elevation value was recorded.
Relief	The lowest elevation value was subtracted from the highest elevation value of subcatchment DEM.
Average slope	A slope raster was created for each subcatchment from the watershed DEM using the Slope Tool in the Spatial Analysis extension. The mean slope value was recorded from statistics in the Source tab of Layer Properties.

Mainstem length	A stream polyline layer was created and digitized for each stream to the furthest 2nd order upstream point. A Length field was added to the attribute table and the field geometry was calculated in km.
Mainstem gradient	Elevation values were recorded from watershed DEM at furthest upstream and furthest downstream points. The change in elevation was calculated for the mainstem stream. Elevation change was then divided by mainstem stream length.
Drainage density	Streams were created from the DEM using the Reclassify tool. Sub basin DEM raster values were reclassified to 0 – 299 = NoData, and 300 – 'highest value' = 1. The raster streams layer was converted to a polyline layer using the Raster to Polyline Tool. A Length_km field was added to the polyline attribute table and length was calculated in km using field geometry. Field statistics were calculated for the Length_km field. The sum value was divided by the total sub basin area.
Stream order	The Stream Order tool was used to convert the sub basin stream raster to a Strahler order raster. The Strahler order raster was converted to polyline using Raster to Polygon Tool.

Field Site Maps and Volume Analysis

A series of GIS exercises and analysis techniques were completed following seasonal survey fieldwork and laboratory analysis to create site maps and estimate sediment volume for each field site. A personal geodatabase was created in ArcCatalog with feature datasets that represented each field site, assembled by the season that surveys were conducted. Data collected in the field and recorded in the lab was tabulated into spreadsheet form then used to create several feature classes for each of the survey feature datasets. Point feature classes were created for reference points, points of origin, and survey points using GPS, azimuth, distance and other data collected in the field. Polyline feature classes were created to represent stream banks and transects, using azimuth and distance data collected in the field. After site maps were created for each field survey, the Sediment Area and Sample Point feature class data were used to estimate sediment volume and mass.

Personal Geodatabase

A personal geodatabase was created to organize a collection of GIS vector layers for each field survey (figure 2). Feature datasets within the personal geodatabase were set up with the same projection of NAD 1983 UTM Zone 12N. One feature dataset was created for each survey that was carried out in the field. Feature dataset names were coded to represent the site name, season, and year in which the survey took place. For example, CarrollCanyonF12 stands for a survey that recorded data at the Carroll Canyon field site in fall of 2012. Each feature dataset contained six feature class layers for site features including point layers for survey points, point of origin, and reference point. Polyline layers were used to draw transects and stream banks, and a polygon layer for sediment area. Feature classes used a naming system similar to the codes used for feature dataset names. Figure 2 illustrates how a personal geodatabase used for this research was organized with feature datasets and feature classes.

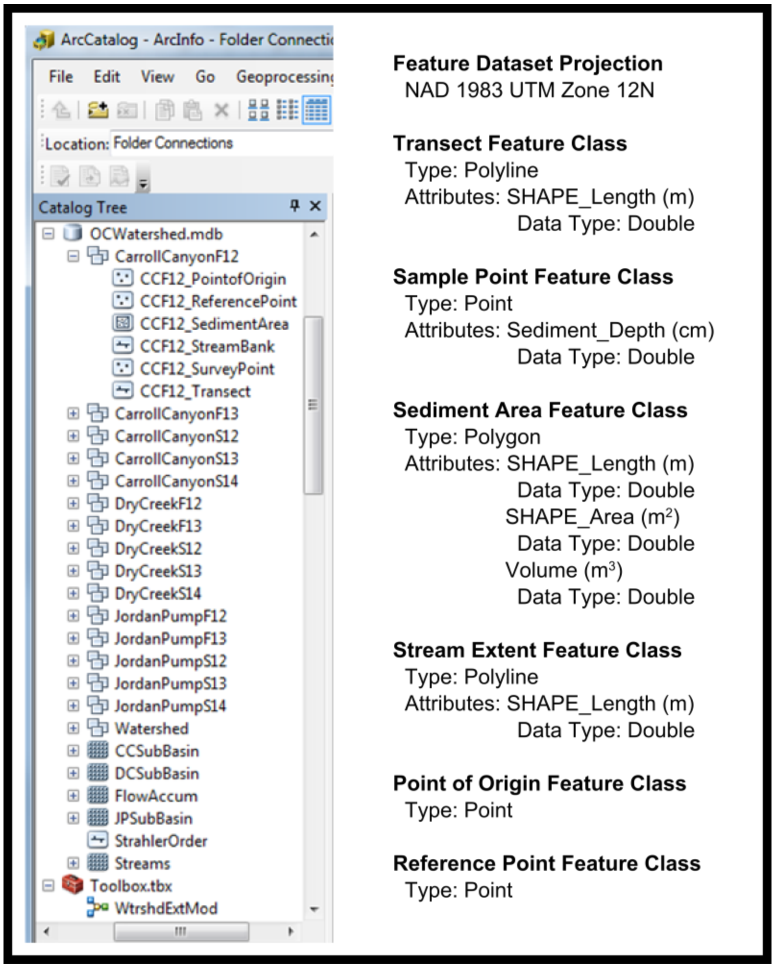


Figure 5.5. Personal geodatabase organization and feature class details.

Site Maps

After the personal geodatabase was set up with feature datasets and feature classes, a site map was created in ArcGIS for each field survey. To create a survey map the Editing Toolbar was used to populate each of the feature classes with attributes using survey data collected in the field. The following procedure details the methods used to create survey map features.

Reference Point

- Add Reference Point feature class to map and start editing the point layer.
- Right click the map and choose Absolute X, Y… to place a point using GPS coordinates.

- Choose the units for Latitude and Longitude according to how the reference point location was recorded in the field, i.e. UTM, decimal degrees, etc.
- Enter coordinates and press enter.
- Save edits and stop editing.

Since the reference point will remain the same for each field site throughout the study, only one reference point needs to be established for each field site location. The point feature class can then be imported and renamed for each of the other field survey feature datasets.

Point of Origin

In order to place the point of origin in the map, a temporary polyline was made using the azimuth and distance from the reference point that was recorded in the field. Note that ESRI uses a different system for azimuth direction than is used for compass direction. In ArcMap, an azimuth has an origin in the due east position and progresses 360º in the counter clockwise direction. In contrast, when recording an azimuth with a compass in the field, the origin is due north and progresses 360º in the clockwise direction. Therefore an azimuth direction must be converted to the ESRI format before it is used in ArcMap.

- Add Point of Origin and StreamBank feature classes to map and start editing.
- Choose the StreamBank polyline layer and begin a polyline by snapping to the Reference Point.
- Before finishing the line, right click and choose Direction/Length.
- Enter the distance in meters to the nearest 0.1 m.
- Enter the converted azimuth in ESRI format and press enter.

Now the Point of Origin can be placed at the end node of the polyline that was just created.

- Choose the Point of Origin point layer and place a point at the end node of the polyline.
- Delete the polyline, then save edits and stop editing.

Transects

The first transect begins at the point of origin and extends across the entire width of the stream. Distance and azimuth measurements recorded in the field are used to draw each transect. Temporary polylines are used to draw the three meter distance and direction between transects, which represents the stream bank. Transects are parallel to each other, so the azimuth direction used to draw the first transect will be the same for all successive transects in a survey map. Transect length will vary according to the stream width recorded at each transect.

- Add Transect feature class to the map and start editing.
- Begin a polyline at the Point of Origin.
- Before finishing the line, right click and choose Direction/Length.
- Enter the stream width recorded in the field for the first transect to the nearest 0.1 m.
- Enter the azimuth direction converted to ESRI format and press enter.

Now that the first transect has been drawn a temporary polyline is needed to establish the placement of the next transect.

- Begin another polyline at the beginning node of the previous transect.
- Before finishing the line, right click and choose Direction/Length.
- Enter the converted azimuth direction between the first two transects that was recorded in the field. The distance is 3.0 m.
- Draw the second transect at the end node of the temporary polyline, then delete the temporary line.
- Repeat this process until all transects have been drawn for the survey map.

Stream Banks

Stream banks are drawn as polylines using distance and azimuth directions recorded in the field. For a more robust survey map, stream banks were recorded past the first transect in the downstream direction and past the last transect in the upstream direction, on both sides of the stream. An azimuth was recorded along either stream bank every 3 m for a total distance of 24 m beyond the survey transects. Using the same method, the banks of a tributary stream were also recorded if one occurred at the field site.

- Edit the Stream Bank feature class to draw stream banks using distance and azimuth data recorded in the field. A temporary line and point may be used to determine the starting location for stream bank polylines.
- Stream bank polylines will be placed along either the beginning nodes or end nodes of the transect lines between the point of origin and the last transect of the survey map.
- If a tributary stream exists in the field area then the stream bank polyline will follow the bank of the tributary in the upstream direction rather than crossing the tributary at the confluence with the mainstem stream.

Survey Points

Survey points were used in the field to record sediment depth every 0.5 m along each transect. To draw survey points in the survey map, temporary polylines are used to mark the distance between survey points. Once survey points are created in the map, a Sediment Depth field is added to the feature class attribute table and sediment depth data recorded in the field is entered for each point to the nearest 0.1 cm.

- Edit the Survey Point feature class to draw survey points at 0.5 m intervals along each transect.
- Turn the Transect layer off and use the Stream Bank polyline layer to draw temporary lines at 0.5 m increments, along the hidden transect line.
- Begin the temporary polylines at the Stream Bank polyline vertices that mark points where transects begin along the stream bank.
- Draw as many temporary line segments needed to accommodate the number of survey points recorded along each transect.
- Add Survey Points at the beginning/end nodes of temporary lines, then delete the lines. Make sure that the number of survey points matches the number recorded in the field for each transect.
- Add Sediment Depth field to the Survey Point layer attribute table.
- Enter sediment depth data that was recorded in the field for each of the survey points to the nearest 0.1 cm.
- Check to be sure that depth data was entered for the correct survey point.

Sediment Area

The sediment area feature class is a polygon that covers the total extent of sediment that was recorded for a field survey. The sediment area polygon was drawn by connecting the outer most survey points, resulting in a perimeter that was established around the sediment area. If streambed sediments extended across the entire width of the stream then the polygon would be drawn along the stream bank on both sides of the mainstem stream.

Sediment Volume and Mass Estimate

Sediment volume was estimated using a series of analysis tools from the 3D Analyst Tool Bar and the 3D Analyst Toolbox. A Survey Point feature class layer was utilized to create a TIN surface of sediment area that was based on sediment depth data. The TIN layer was then converted to a raster grid. The raster was used for displaying sediment depth information in each of the survey maps. The Extract by Mask Tool was used next to ensure the raster area matched the extent of the Sediment Area polygon layer. Finally, the Polygon Volume Tool was used to find sediment volume by combining data from the TIN and Sediment Area layers. This tool appended a volume quantity into the attribute table of the Sediment Area polygon layer.

Sediment mass was calculated using sediment density data and volume estimates for each field survey. A mean sediment density value for each field survey was derived through laboratory analysis. The mean density value was for each field survey was recorded as g/cm^3. The value for estimated sediment volume was recorded as m^3. A conversion of the density value to g/m^3 then multiplying the density value by the volume will yield sediment mass.

Final Survey Maps

After each of the six feature classes was drawn for a particular survey map, the features were checked for accuracy. Layer features were modified in size, shape, and shading was adjusted for visual aesthetics. The sediment depth interpolation raster symbology was reclassified to show sediment depth in appropriate increments. Map elements such as a scale bar and north arrow were added for reference. The survey map was then exported as an image to be used for a final survey figure.

5.2. Complete Data Tables

Table 5.3. Density and LOI data for fine grain sediment samples. Each sample was collected as a 1 cm^3 subsample from sediment cores collected in the field. At least 30% of density subsamples collected from field sites were randomly selected and processed for LOI. A higher percentage of LOI samples were processed for seasonal field sites with fewer than 30 sediment samples collected.

Sample	**Collection Date**	**Field Site**	**Transect**	**Sediment Density (g/cm^3)**	**% LOI**
001	7/3/12	1	1	1.1835	NA
002	7/3/12	1	1	1.2117	NA
003	7/3/12	1	1	1.0097	2.45
004	7/3/12	1	1	0.7741	NA
005	7/3/12	1	1	1.1381	4.18
006	7/3/12	1	2	1.1339	NA
007	7/3/12	1	2	1.1550	NA
008	7/3/12	1	2	1.1009	NA
009	7/3/12	1	2	1.0325	NA
010	7/3/12	1	2	0.9844	4.88
011	7/3/12	1	2	1.1202	NA
012	7/3/12	1	2	1.1326	NA
013	7/3/12	1	3	0.8552	NA
014	7/3/12	1	3	1.2338	NA
015	7/3/12	1	3	1.0180	NA
016	7/3/12	1	3	1.2894	NA
017	7/3/12	1	3	0.9163	NA
018	7/3/12	1	3	0.9481	NA
019	7/3/12	1	4	0.7836	NA
020	7/3/12	1	4	0.9560	NA
021	7/3/12	1	4	1.0316	NA
022	7/3/12	1	4	1.1295	4.92
023	7/3/12	1	4	1.0419	NA
024	7/3/12	1	4	1.0871	5.07
025	7/6/12	1	5	0.8360	NA
026	7/6/12	1	5	0.8473	NA
027	7/6/12	1	5	1.1239	6.39
028	7/6/12	1	5	0.9352	NA
029	7/6/12	1	5	1.3813	NA
030	7/6/12	1	5	0.9180	NA
031	7/6/12	1	5	1.1893	12.81
032	7/6/12	1	5	1.2404	NA
033	7/6/12	1	5	0.8798	5.61
034	7/6/12	1	5	1.1183	7.73

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
035	7/6/12	1	5	1.2316	NA
036	7/6/12	1	5	0.6968	NA
037	7/6/12	1	5	1.4532	NA
038	7/6/12	1	6	1.3793	NA
039	7/6/12	1	6	1.6159	NA
040	7/6/12	1	6	1.5180	0.58
041	7/6/12	1	6	1.5631	NA
042	7/6/12	1	6	1.6412	NA
043	7/6/12	1	6	1.3988	NA
044	7/6/12	1	6	1.5899	0.74
045	7/6/12	1	6	1.3900	NA
046	7/6/12	1	6	1.4150	0.43
047	7/6/12	1	6	1.6278	NA
048	7/6/12	1	6	1.5812	NA
049	7/6/12	1	6	1.3952	0.44
050	7/6/12	1	6	1.4927	0.44
051	7/6/12	1	6	1.5238	NA
052	7/6/12	1	6	1.6611	1.04
053	7/6/12	1	6	1.5140	0.50
054	7/6/12	1	6	1.1316	NA
055	7/6/12	1	6	0.6765	NA
056	7/6/12	1	6	1.5621	0.70
057	7/6/12	1	6	1.4378	NA
058	7/6/12	1	6	1.3478	NA
059	7/12/12	2	1	1.4021	NA
060	7/12/12	2	1	1.2618	NA
061	7/12/12	2	1	1.3356	2.14
062	7/12/12	2	2	1.4402	1.56
063	7/12/12	2	2	1.5260	NA
064	7/12/12	2	2	0.8882	NA
065	7/12/12	2	2	1.0360	NA
066	7/12/12	2	2	1.4584	NA
067	7/12/12	2	2	1.4691	NA
068	7/12/12	2	2	1.3469	NA
069	7/12/12	2	2	1.3007	NA
070	7/12/12	2	2	0.8888	4.79
071	7/12/12	2	2	1.0227	NA
072	7/12/12	2	2	1.2446	2.96
073	7/12/12	2	2	0.8744	NA
074	7/12/12	2	3	1.4914	NA
075	7/12/12	2	3	1.3601	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
076	7/12/12	2	3	1.3046	1.04
077	7/12/12	2	3	1.2896	NA
078	7/12/12	2	3	1.1924	NA
079	7/12/12	2	3	1.3800	NA
080	7/12/12	2	3	0.6661	7.93
081	7/12/12	2	3	0.4736	25.04
082	7/12/12	2	3	0.3973	NA
083	7/12/12	2	4	0.7689	8.49
084	7/12/12	2	4	0.8707	NA
085	7/12/12	2	4	1.0381	NA
086	7/12/12	2	4	1.3102	NA
087	7/12/12	2	4	1.3683	NA
088	7/12/12	2	4	0.7887	8.46
089	7/12/12	2	4	1.3170	NA
090	7/12/12	2	4	1.3782	NA
091	7/12/12	2	4	1.1070	3.60
092	7/13/12	3	1	1.3376	3.03
093	7/13/12	3	1	1.4357	NA
094	7/13/12	3	2	0.9604	5.31
095	7/13/12	3	2	1.1193	3.97
096	7/13/12	3	2	1.1847	NA
097	7/13/12	3	2	1.3003	NA
098	7/13/12	3	2	1.1884	NA
099	7/13/12	3	2	1.2563	3.22
100	7/13/12	3	3	0.9995	NA
101	7/13/12	3	3	1.1156	NA
102	7/13/12	3	3	1.3446	NA
103	7/13/12	3	3	1.0501	NA
104	7/13/12	3	3	1.5425	NA
105	7/13/12	3	3	1.1658	NA
106	7/13/12	3	3	1.5021	NA
107	7/13/12	3	3	0.7232	NA
108	7/13/12	3	3	0.9639	NA
109	7/13/12	3	3	0.9435	5.24
110	7/13/12	3	4	1.1539	2.64
111	7/13/12	3	4	1.1408	NA
112	7/13/12	3	4	1.5172	NA
113	7/13/12	3	4	1.4755	NA
114	7/13/12	3	4	1.1446	NA
115	7/13/12	3	4	1.0364	3.43
116	10/10/12	1	1	0.9970	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
117	10/10/12	1	1	1.5140	0.67
118	10/10/12	1	1	1.4404	NA
119	10/10/12	1	1	1.4048	NA
120	10/10/12	1	1	1.5150	NA
121	10/10/12	1	1	1.2875	NA
122	10/10/12	1	1	1.4955	1.14
123	10/10/12	1	1	1.3823	NA
124	10/10/12	1	1	1.2609	NA
125	10/10/12	1	1	1.1847	2.58
126	10/10/12	1	1	1.3566	NA
127	10/10/12	1	1	1.2852	1.92
128	10/10/12	1	1	1.4822	NA
129	10/10/12	1	1	1.3631	NA
130	10/10/12	1	1	1.0245	4.43
131	10/10/12	1	1	1.1811	4.03
132	10/10/12	1	1	1.0087	NA
133	10/10/12	1	1	1.1359	NA
134	10/10/12	1	2	1.5142	NA
135	10/10/12	1	2	1.2881	NA
136	10/10/12	1	2	1.4988	NA
137	10/10/12	1	2	1.5836	NA
138	10/10/12	1	2	1.3224	NA
139	10/10/12	1	2	1.0447	NA
140	10/10/12	1	2	0.9452	NA
141	10/10/12	1	2	1.3324	1.04
142	10/10/12	1	2	1.2010	NA
143	10/10/12	1	2	1.0956	NA
144	10/10/12	1	2	1.2244	NA
145	10/10/12	1	2	1.2945	NA
146	10/10/12	1	2	1.6300	0.69
147	10/10/12	1	2	1.4147	0.28
148	10/10/12	1	2	1.4440	0.40
149	10/10/12	1	2	1.1338	NA
150	10/10/12	1	2	1.0330	NA
151	10/10/12	1	2	1.1865	NA
152	10/10/12	1	2	1.0482	NA
153	10/10/12	1	2	1.4379	NA
154	10/17/12	1	3	1.2940	NA
155	10/17/12	1	3	1.0992	1.68
156	10/17/12	1	3	1.3378	NA
157	10/17/12	1	3	1.3387	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
158	10/17/12	1	3	1.4350	NA
159	10/17/12	1	3	1.5129	NA
160	10/17/12	1	3	1.5076	NA
161	10/17/12	1	3	1.3647	1.44
162	10/17/12	1	3	1.4860	1.24
163	10/17/12	1	3	1.3124	NA
164	10/17/12	1	3	1.1036	NA
165	10/17/12	1	3	1.3263	1.82
166	10/17/12	1	3	1.4456	NA
167	10/17/12	1	3	1.2630	NA
168	10/17/12	1	3	1.0641	NA
169	10/17/12	1	3	1.1798	2.77
170	10/17/12	1	3	1.2663	NA
171	10/17/12	1	3	1.4798	0.30
172	10/17/12	1	3	1.3417	NA
173	10/17/12	1	3	1.4116	0.28
174	10/17/12	1	3	1.2132	2.23
175	10/17/12	1	3	1.2749	NA
176	10/17/12	1	3	1.2255	NA
177	10/17/12	1	3	1.1506	1.71
178	10/17/12	1	3	1.3247	NA
179	10/17/12	1	3	1.3587	NA
180	10/17/12	1	3	1.3424	NA
181	10/17/12	1	3	0.9924	NA
182	10/17/12	1	3	0.9810	NA
183	10/17/12	1	3	1.0352	NA
184	10/17/12	1	3	1.1510	NA
185	10/17/12	1	3	0.9670	NA
186	10/17/12	1	3	1.0574	3.62
187	10/17/12	1	3	1.1008	NA
188	10/17/12	1	3	0.9650	NA
189	10/17/12	1	3	1.1115	NA
190	10/17/12	1	3	1.0983	NA
191	10/17/12	1	3	0.8386	4.64
192	10/17/12	1	3	0.9432	NA
193	10/17/12	1	3	0.8217	NA
194	10/17/12	1	3	1.0852	NA
195	10/17/12	1	3	1.2675	NA
196	10/24/12	1	4	1.1322	NA
197	10/24/12	1	4	1.2396	1.54
198	10/24/12	1	4	1.2149	1.57

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
199	10/24/12	1	4	1.2988	NA
200	10/24/12	1	4	1.2662	1.88
201	10/24/12	1	4	1.1753	NA
202	10/24/12	1	4	1.1790	NA
203	10/24/12	1	4	0.9114	NA
204	10/24/12	1	4	1.2550	NA
205	10/24/12	1	4	1.3153	1.55
206	10/24/12	1	4	1.2480	NA
207	10/24/12	1	4	1.1637	NA
208	10/24/12	1	4	1.0589	NA
209	10/24/12	1	4	0.9728	6.84
210	10/24/12	1	4	1.0940	NA
211	10/24/12	1	4	0.8636	NA
212	10/24/12	1	4	1.4045	2.56
213	10/24/12	1	4	1.2222	NA
214	10/24/12	1	4	1.2276	1.56
215	10/24/12	1	4	1.2500	1.24
216	10/24/12	1	4	1.2099	NA
217	10/24/12	1	4	1.3148	NA
218	10/24/12	1	4	1.0629	5.10
219	10/24/12	1	4	1.0248	NA
220	10/24/12	1	4	1.2019	4.16
221	10/24/12	1	4	1.4702	0.53
222	10/24/12	1	4	1.4978	NA
223	10/24/12	1	4	1.3937	NA
224	10/24/12	1	4	1.2745	NA
225	10/24/12	1	4	1.3479	NA
226	10/24/12	1	4	1.0508	3.70
227	10/24/12	1	4	1.0929	4.15
228	10/24/12	1	4	1.2541	NA
229	10/24/12	1	4	1.2577	2.13
230	10/24/12	1	4	1.1547	NA
231	10/24/12	1	5	1.1101	2.01
232	10/24/12	1	5	1.0184	NA
233	10/24/12	1	5	0.9202	NA
234	10/24/12	1	5	1.1618	NA
235	10/24/12	1	5	0.9330	5.39
236	10/24/12	1	5	1.0245	NA
237	10/24/12	1	5	1.2863	NA
238	10/24/12	1	5	1.3437	1.78
239	10/24/12	1	5	1.3532	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
240	10/24/12	1	5	0.8782	NA
241	10/24/12	1	5	1.2051	NA
242	10/24/12	1	5	1.2984	NA
243	10/24/12	1	5	1.3187	NA
244	10/24/12	1	5	1.1144	NA
245	10/29/12	1	5	0.9655	4.33
246	10/29/12	1	5	1.2103	3.72
247	10/29/12	1	5	1.3879	1.15
248	10/29/12	1	5	1.4553	NA
249	10/29/12	1	5	1.3686	1.46
250	10/29/12	1	5	1.1145	NA
251	10/29/12	1	5	1.1519	NA
252	10/29/12	1	5	1.1405	NA
253	10/29/12	1	5	1.5331	NA
254	10/29/12	1	5	1.4625	NA
255	10/29/12	1	5	0.8193	NA
256	10/29/12	1	5	0.8253	NA
257	10/29/12	1	5	1.1613	NA
258	10/29/12	1	5	1.4235	NA
259	10/29/12	1	5	1.5343	NA
260	10/29/12	1	5	1.3333	NA
261	10/29/12	1	5	1.1549	3.07
262	10/29/12	1	5	1.1428	NA
263	10/29/12	1	5	1.0918	NA
264	10/29/12	1	5	1.1890	NA
265	10/29/12	1	5	1.2792	2.98
266	10/29/12	1	5	1.0833	NA
267	10/29/12	1	5	0.9268	NA
268	10/29/12	1	6	1.1214	NA
269	10/29/12	1	6	1.3248	NA
270	10/29/12	1	6	1.4679	NA
271	10/29/12	1	6	1.5556	NA
272	10/29/12	1	6	1.5394	NA
273	10/29/12	1	6	1.5337	NA
274	10/29/12	1	6	1.4189	NA
275	10/29/12	1	6	1.4207	NA
276	10/29/12	1	6	1.6222	NA
277	10/29/12	1	6	1.4965	NA
278	10/29/12	1	6	1.4294	1.66
279	10/29/12	1	6	1.4632	0.50
280	10/29/12	1	6	1.4366	0.56

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
281	10/29/12	1	6	1.0845	3.47
282	10/29/12	1	6	0.9939	4.21
283	10/29/12	1	6	1.0856	NA
284	10/29/12	1	6	1.2860	2.35
285	10/29/12	1	6	1.0390	4.06
286	10/29/12	1	6	1.1640	4.02
287	10/29/12	1	6	1.2125	NA
288	10/29/12	1	6	1.1923	NA
289	10/29/12	1	6	1.4952	NA
290	10/29/12	1	6	1.5402	NA
291	10/29/12	1	6	1.1613	3.46
292	10/29/12	1	6	1.1153	NA
293	10/29/12	1	6	1.2610	2.63
294	10/29/12	1	7	1.0669	NA
295	10/29/12	1	7	0.8889	NA
296	10/29/12	1	7	1.3121	NA
297	10/29/12	1	7	1.0317	8.99
298	10/29/12	1	7	1.0722	NA
299	10/29/12	1	7	1.5907	2.00
300	10/29/12	1	7	1.3926	NA
301	10/29/12	1	7	1.3581	NA
302	10/29/12	1	7	1.4660	NA
303	10/29/12	1	7	1.2479	NA
304	10/29/12	1	7	1.3176	NA
305	10/29/12	1	7	1.3538	NA
306	10/29/12	1	7	1.5360	1.95
307	10/29/12	1	7	1.3179	1.94
308	10/29/12	1	7	1.3101	NA
309	10/29/12	1	7	1.3018	NA
310	11/4/12	3	1	1.2002	NA
311	11/4/12	3	1	1.0213	NA
312	11/4/12	3	1	1.4299	NA
313	11/4/12	3	1	1.1525	NA
314	11/4/12	3	1	0.4925	NA
315	11/4/12	3	1	1.7140	NA
316	11/4/12	3	1	1.7924	NA
317	11/4/12	3	1	0.9144	7.05
318	11/4/12	3	1	0.9992	6.35
319	11/4/12	3	1	1.2735	NA
320	11/4/12	3	1	0.7180	21.92
321	11/4/12	3	1	0.4714	25.07

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
322	11/4/12	3	1	1.3683	NA
323	11/4/12	3	1	2.0959	NA
324	11/4/12	3	2	0.8226	NA
325	11/4/12	3	2	0.9572	NA
326	11/4/12	3	2	0.7763	NA
327	11/4/12	3	2	0.7311	NA
328	11/4/12	3	2	1.1093	NA
329	11/4/12	3	2	1.3344	NA
330	11/4/12	3	2	1.0842	NA
331	11/4/12	3	2	1.3204	1.59
332	11/4/12	3	2	1.2384	NA
333	11/4/12	3	2	0.7623	NA
334	11/4/12	3	2	0.9034	NA
335	11/4/12	3	2	0.8800	NA
336	11/4/12	3	2	0.9040	NA
337	11/4/12	3	2	0.6091	NA
338	11/4/12	3	2	0.6499	NA
339	11/4/12	3	3	0.8768	NA
340	11/4/12	3	3	0.8522	6.21
341	11/4/12	3	3	0.9518	NA
342	11/4/12	3	3	0.8818	NA
343	11/4/12	3	3	0.6840	30.64
344	11/4/12	3	3	0.9854	5.41
345	11/4/12	3	3	0.9921	NA
346	11/4/12	3	3	0.8493	5.68
347	11/4/12	3	3	0.9178	7.29
348	11/4/12	3	3	1.0115	6.55
349	11/4/12	3	3	1.1012	NA
350	11/4/12	3	3	1.0151	NA
351	11/4/12	3	3	1.2057	NA
352	11/4/12	3	3	0.9460	NA
353	11/4/12	3	4	0.6482	NA
354	11/4/12	3	4	1.0635	7.79
355	11/4/12	3	4	0.8003	11.01
356	11/4/12	3	4	0.6806	NA
357	11/4/12	3	4	0.4061	34.08
358	11/4/12	3	4	0.9066	NA
359	11/4/12	3	4	1.3429	3.72
360	11/4/12	3	4	1.4678	NA
361	11/4/12	3	4	0.8859	NA
362	11/4/12	3	4	0.9999	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
363	11/4/12	3	4	1.1226	5.77
364	11/4/12	3	4	1.1213	7.23
365	11/4/12	3	4	1.1041	NA
366	11/7/12	2	1	1.2964	NA
367	11/7/12	2	1	1.2597	NA
368	11/7/12	2	1	1.4137	NA
369	11/7/12	2	1	1.5239	0.81
370	11/7/12	2	1	1.6949	NA
371	11/7/12	2	1	1.4235	1.71
372	11/7/12	2	1	1.4363	NA
373	11/7/12	2	1	1.3050	NA
374	11/7/12	2	1	1.1734	NA
375	11/7/12	2	1	1.5242	NA
376	11/7/12	2	1	1.5465	NA
377	11/7/12	2	1	1.6222	0.81
378	11/7/12	2	1	1.5779	NA
379	11/7/12	2	1	1.4491	0.77
380	11/7/12	2	1	1.5735	NA
381	11/7/12	2	1	1.4655	NA
382	11/7/12	2	2	1.1632	3.40
383	11/7/12	2	2	1.3416	NA
384	11/7/12	2	2	1.5073	NA
385	11/7/12	2	2	1.5848	0.81
386	11/7/12	2	2	1.5772	NA
387	11/7/12	2	2	1.5101	NA
388	11/7/12	2	2	1.6292	NA
389	11/7/12	2	2	1.5152	NA
390	11/7/12	2	2	1.3752	NA
391	11/7/12	2	2	1.4174	NA
392	11/7/12	2	2	1.5116	NA
393	11/7/12	2	2	1.2639	NA
394	11/7/12	2	2	1.5819	0.94
395	11/7/12	2	2	1.4358	NA
396	11/7/12	2	2	1.4003	NA
397	11/7/12	2	2	1.2995	NA
398	11/7/12	2	2	1.4120	1.22
399	11/7/12	2	2	1.3362	2.19
400	11/7/12	2	2	1.3584	NA
401	11/7/12	2	3	1.7819	NA
402	11/7/12	2	3	1.4320	NA
403	11/7/12	2	3	1.3860	NA

Sample	Collection Date	Field Site	Transect	Sediment Density (g/cm^3)	% LOI
404	11/7/12	2	3	1.3962	NA
405	11/7/12	2	3	1.3221	NA
406	11/7/12	2	3	1.2003	NA
407	11/7/12	2	3	1.5464	NA
408	11/7/12	2	3	1.2664	2.33
409	11/7/12	2	3	1.2503	2.74
410	11/7/12	2	3	1.5187	1.63
411	5/9/13	1	1	1.2900	NA
412	5/9/13	1	1	1.1060	4.58
413	5/9/13	1	1	1.1519	NA
414	5/9/13	1	2	1.1297	4.16
415	5/9/13	1	2	0.9841	4.39
416	5/9/13	1	2	1.1374	NA
417	5/9/13	1	2	0.9450	5.53
418	5/9/13	1	2	1.2095	2.70
419	5/9/13	1	3	0.9681	NA
420	5/9/13	1	3	1.2196	3.41
421	5/9/13	1	3	1.1819	NA
422	5/9/13	1	3	1.2347	2.95
423	5/9/13	1	3	1.2709	1.94
424	5/9/13	1	3	1.2059	2.50
425	5/9/13	1	3	1.2305	3.58
426	5/9/13	1	4	1.2323	2.60
427	5/9/13	1	4	1.1417	NA
428	5/9/13	1	4	1.2531	NA
429	5/9/13	1	4	0.8408	NA
430	5/9/13	1	4	1.3061	NA
431	5/9/13	1	4	1.2693	NA
432	5/9/13	1	4	1.0365	NA
433	5/31/13	3	1	0.8701	5.84
434	5/31/13	3	1	0.9549	4.75
435	5/31/13	3	1	1.3332	2.92
436	5/31/13	3	1	1.1041	3.74
437	5/31/13	3	3	0.9614	5.40
438	5/31/13	3	3	0.8847	5.80
439	5/31/13	3	3	1.4908	1.03
440	5/31/13	3	3	1.1877	2.36
441	5/31/13	3	4	1.3731	2.16
442	5/31/13	3	4	1.6299	1.07
443	5/31/13	3	4	1.2087	2.84

Table 5.4. Particle size and LOI data for fine grain sediment samples. Samples were collected as 1 cm thick extruded subsamples from sediment cores. In the laboratory samples from a single core were aggregated, dried, portioned, and weighed for LOI and particle size analysis.

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1001	7/3/12	1	1	0	28.8872	4.05	95.5	3.5	1.0
1002	7/3/12	1	1	0	28.1606	4.63	57.4	31.9	10.7
1003	7/3/12	1	1	0	31.4921	4.14	61.9	34.9	3.2
1004	7/3/12	1	1	0	26.0077	4.17	65.4	32.7	1.9
1005	7/3/12	1	1	0.5	46.0699	4.71	60.9	35.8	3.3
1006	7/3/12	1	1	0	38.0924	4.62	64.6	32.8	2.6
1007	7/3/12	1	2	0	28.8474	5.00	75.7	22.6	1.7
1008	7/3/12	1	2	0	28.4040	5.12	75.4	19.3	5.3
1009	7/3/12	1	2	0	36.8286	5.89	52.5	46.1	1.4
1010	7/3/12	1	2	0	37.5088	4.44	54.7	44.0	1.3
1011	7/3/12	1	2	1.0	34.9655	4.71	58.5	38.6	2.9
1012	7/3/12	1	3	1.0	46.1109	4.05	65.3	33.6	1.1
1013	7/3/12	1	3	2.0	34.4394	4.56	84.0	13.1	2.9
1014	7/3/12	1	3	2.0	34.1276	3.67	81.0	16.1	2.9
1015	7/3/12	1	4	1.0	34.2069	6.01	62.0	35.1	2.9
1016	7/3/12	1	4	1.0	45.0972	5.34	61.2	36.6	2.2
1017	7/3/12	1	4	2.5	27.9276	9.50	78.5	19.7	1.8
1018	7/6/12	1	5	1.0	33.9357	6.77	73.5	23.5	3.0
1019	7/6/12	1	5	1.0	44.2262	8.64	68.3	29.4	2.3
1020	7/6/12	1	5	2.0	34.8992	13.57	77.1	18.6	4.3
1021	7/6/12	1	5	2.0	36.8598	6.79	70.2	27.1	2.7
1022	7/6/12	1	6	0	33.0923	8.70	72.8	24.2	3.0
1023	7/6/12	1	6	0	46.4935	0.96	96.8	1.0	2.2
1024	7/6/12	1	6	0	39.0658	1.17	93.6	3.8	2.6
1025	7/6/12	1	6	0	38.5058	1.40	88.3	9.1	2.6
1026	7/6/12	1	6	0	35.7679	1.34	94.4	1.4	4.2

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1027	7/6/12	1	6	0	44.9544	1.26	90.0	6.7	3.3
1028	7/6/12	1	6	0	39.2079	1.05	88.5	8.9	2.6
1029	7/6/12	1	6	0	35.3478	0.86	92.9	5.7	1.4
1030	7/6/12	1	6	0	35.0991	0.68	97.1	1.5	1.4
1031	7/6/12	1	6	2.0	47.3054	0.64	95.8	2.1	2.1
1032	7/6/12	1	6	2.0	37.4209	1.69	96.0	1.3	2.7
1033	7/6/12	1	6	2.0	37.1503	1.49	89.2	8.1	2.7
1034	7/12/12	2	1	0.5	38.0758	3.18	76.4	18.3	5.3
1035	7/12/12	2	2	0	33.8096	15.82	88.2	10.3	1.5
1036	7/12/12	2	2	0	33.0144	10.94	86.4	12.1	1.5
1037	7/12/12	2	2	0	45.2428	2.53	84.5	13.3	2.2
1038	7/12/12	2	2	0	38.4592	2.64	87.0	10.4	2.6
1039	7/12/12	2	3	0.5	35.6680	2.08	95.8	1.4	2.8
1040	7/12/12	2	3	0.5	47.3697	1.47	96.8	1.1	2.1
1041	7/12/12	2	2	1.0	35.5961	10.68	84.5	14.1	1.4
1042	7/12/12	2	3	0.5	29.0502	1.45	91.4	5.2	3.4
1043	7/12/12	2	3	0.5	39.1517	1.42	88.5	7.7	3.8
1044	7/12/12	2	3	1.5	27.4947	16.17	58.2	36.3	5.5
1045	7/12/12	2	4	0	35.7349	9.01	63.6	35.0	1.4
1046	7/12/12	2	4	0	37.9163	3.99	74.9	22.5	2.6
1047	7/12/12	2	4	0.5	44.9600	4.79	78.9	18.9	2.2
1048	7/13/12	3	1	0	38.1490	2.55	88.2	9.2	2.6
1049	7/13/12	3	1	1.0	21.6933	4.09	83.9	11.5	4.6
1050	7/13/12	3	2	0	45.3875	5.21	69.1	27.6	3.3
1051	7/13/12	3	2	0	38.0389	4.07	71.1	25.0	3.9
1052	7/13/12	3	2	0.5	37.7667	4.11	78.8	18.5	2.7
1053	7/13/12	3	2	0.5	34.0466	3.66	78.0	19.1	2.9
1054	7/13/12	3	3	0	45.9038	3.43	71.7	26.1	2.2
1055	7/13/12	3	3	0	36.9173	7.32	55.3	42.0	2.7
1056	7/13/12	3	3	0	37.8806	3.76	89.4	9.3	1.3

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1057	7/13/12	3	3	0	32.8438	2.88	86.3	12.2	1.5
1058	7/13/12	3	3	0.5	42.4497	7.49	64.7	32.9	2.4
1059	7/13/12	3	3	0.5	22.2104	6.02	68.5	29.2	2.3
1060	7/13/12	3	4	0	36.4049	4.60	83.5	15.1	1.4
1061	7/13/12	3	4	0	32.9665	5.07	83.3	13.7	3.0
1062	7/13/12	3	4	0	34.4035	3.58	84.0	13.1	2.9
1063	7/13/12	3	4	0.5	37.4851	5.56	68.0	28.0	4.0
1064	10/10/12	1	1	1.5	26.4732	3.92	77.3	18.9	3.8
1065	10/10/12	1	1	1.5	25.2177	3.31	76.2	19.8	4.0
1066	10/10/12	1	1	1.5	34.6992	2.49	76.9	21.7	1.4
1067	10/10/12	1	1	1.5	27.2192	3.41	72.4	25.8	1.8
1068	10/10/12	1	1	1.5	29.0796	2.38	69.0	29.3	1.7
1069	10/10/12	1	1	1.5	43.2646	3.28	71.1	27.7	1.2
1070	10/10/12	1	1	7.5	36.0162	3.07	76.4	20.8	2.8
1071	10/10/12	1	1	7.5	37.7153	2.54	73.5	22.5	4.0
1072	10/10/12	1	1	7.5	34.5024	1.99	72.5	23.1	4.4
1073	10/10/12	1	1	17.5	31.7481	2.05	71.6	23.7	4.7
1074	10/10/12	1	1	17.5	36.0012	5.42	62.5	33.3	4.2
1075	10/10/12	1	1	17.5	30.7485	4.66	67.5	29.2	3.3
1076	10/10/12	1	1	1.0	27.5256	4.41	65.5	32.7	1.8
1077	10/10/12	1	2	1.0	45.2960	2.99	62.5	36.4	1.1
1078	10/10/12	1	2	1.0	34.6424	2.86	66.8	31.8	1.4
1079	10/10/12	1	2	1.0	34.4071	2.00	62.2	36.5	1.3
1080	10/10/12	1	2	1.0	35.5957	2.83	71.9	25.3	2.8
1081	10/10/12	1	2	7.5	45.9208	2.71	71.7	27.2	1.1
1082	10/10/12	1	2	7.5	38.7530	1.77	91.0	7.7	1.3
1083	10/10/12	1	2	7.5	38.8090	1.16	88.4	9.0	2.6
1084	10/10/12	1	2	16.5	34.9096	1.48	87.1	10.0	2.9
1085	10/10/12	1	2	16.5	31.2734	5.63	61.6	33.6	4.8
1086	10/10/12	1	2	16.5	44.9325	6.01	64.4	33.4	2.2

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1087	10/10/12	1	2	16.5	31.9150	5.07	62.4	34.5	3.1
1088	10/17/12	1	3	0.5	34.5181	3.80	66.7	30.4	2.9
1089	10/17/12	1	3	0.5	37.5864	2.78	92.0	5.3	2.7
1090	10/17/12	1	3	0.5	45.7764	1.87	91.3	6.5	2.2
1091	10/17/12	1	3	0.5	25.9944	4.59	80.8	15.3	3.9
1092	10/17/12	1	3	0.5	38.5732	1.17	89.6	7.8	2.6
1093	10/17/12	1	3	0.5	25.1889	1.96	90.1	5.9	4.0
1094	10/17/12	1	3	0.5	34.6744	1.53	89.9	7.2	2.9
1095	10/17/12	1	3	0.5	31.5101	3.57	92.1	4.7	3.2
1096	10/17/12	1	3	0.5	25.9116	3.21	90.3	5.8	3.9
1097	10/17/12	1	3	0.5	35.2629	2.95	85.8	11.4	2.8
1098	10/17/12	1	3	0.5	23.9032	2.47	83.3	12.5	4.2
1099	10/17/12	1	3	7.5	24.7469	3.11	83.8	12.2	4.0
1100	10/17/12	1	3	7.5	32.1869	2.93	84.5	10.8	4.7
1101	10/17/12	1	3	7.5	40.2460	3.13	92.5	3.8	3.7
1102	10/17/12	1	3	7.5	30.2370	1.31	88.4	8.3	3.3
1103	10/17/12	1	3	7.5	30.5513	1.60	90.2	6.5	3.3
1104	10/17/12	1	3	7.5	36.6397	2.17	80.3	17.0	2.7
1105	10/17/12	1	3	7.5	36.5325	2.12	79.5	17.8	2.7
1106	10/17/12	1	3	7.5	35.7348	1.84	83.2	14.0	2.8
1107	10/17/12	1	3	7.5	22.8456	2.26	69.4	26.2	4.4
1108	10/17/12	1	3	16.0	25.1954	2.03	76.2	19.8	4.0
1109	10/17/12	1	3	16.0	34.7193	8.15	65.4	28.8	5.8
1110	10/17/12	1	3	16.0	34.3299	6.93	62.1	33.3	4.6
1111	10/17/12	1	3	16.0	44.7695	4.24	64.3	32.3	3.4
1112	10/17/12	1	3	16.0	35.5267	3.53	60.6	36.6	2.8
1113	10/17/12	1	3	16.0	23.9678	4.78	56.2	37.5	6.3
1114	10/17/12	1	3	16.0	24.7224	4.80	57.5	38.4	4.1
1115	10/17/12	1	3	16.0	30.3536	5.15	55.5	39.6	4.9
1116	10/17/12	1	3	16.0	26.9582	5.35	74.0	22.3	3.7

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1117	10/24/12	1	4	0	30.9696	5.33	70.9	25.9	3.2
1118	10/24/12	1	4	0	46.7092	2.83	60.4	36.4	3.2
1119	10/24/12	1	4	0	38.4434	3.19	68.8	28.6	2.6
1120	10/24/12	1	4	0	36.7417	3.07	68.7	28.6	2.7
1121	10/24/12	1	4	0	34.6738	2.80	68.9	28.2	2.9
1122	10/24/12	1	4	0	39.9846	3.15	61.2	35.0	3.8
1123	10/24/12	1	4	0	36.3958	6.58	73.9	22.0	4.1
1124	10/24/12	1	4	0	37.1262	4.98	71.7	22.9	5.4
1125	10/24/12	1	4	6.5	27.7291	5.55	69.3	23.5	7.2
1126	10/24/12	1	4	6.5	26.4191	3.63	92.4	5.7	1.9
1127	10/24/12	1	4	6.5	29.0515	3.10	87.9	5.2	6.9
1128	10/24/12	1	4	6.5	26.3536	3.40	77.3	15.1	7.6
1129	10/24/12	1	4	6.5	25.6758	3.42	80.5	9.8	9.7
1130	10/24/12	1	4	6.5	37.7814	4.48	84.1	10.6	5.3
1131	10/24/12	1	4	6.5	21.1998	4.58	85.8	7.1	7.1
1132	10/24/12	1	4	6.5	28.2661	2.67	87.6	7.1	5.3
1133	10/24/12	1	4	6.5	26.6497	3.93	96.2	1.9	1.9
1134	10/24/12	1	4	6.5	37.3841	3.58	83.9	12.1	4.0
1135	10/24/12	1	4	6.5	32.4735	2.89	76.9	15.4	7.7
1136	10/24/12	1	4	6.5	35.6931	3.06	81.8	12.6	5.6
1137	10/24/12	1	4	15.5	25.7170	2.37	78.6	15.6	5.8
1138	10/24/12	1	4	15.5	25.1525	4.38	74.2	17.8	8.0
1139	10/24/12	1	4	15.5	32.2996	4.85	75.2	20.1	4.7
1140	10/24/12	1	4	15.5	28.6479	3.56	82.5	12.3	5.2
1141	10/24/12	1	5	0	40.3078	3.30	81.4	16.1	2.5
1142	10/24/12	1	5	0	33.5956	4.32	82.1	14.9	3.0
1143	10/24/12	1	5	0	44.0599	4.40	88.6	8.0	3.4
1144	10/24/12	1	5	0	28.1065	4.37	78.6	17.8	3.6
1145	10/24/12	1	5	0	29.3186	2.41	84.6	12.0	3.4
1146	10/24/12	1	5	0	28.7833	4.94	89.6	8.7	1.7

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1147	10/24/12	1	5	0	25.3299	3.50	86.2	9.8	4.0
1148	10/24/12	1	5	0	39.4008	4.46	87.3	10.2	2.5
1149	10/24/12	1	5	0	25.2367	2.32	92.1	5.9	2.0
1150	10/29/12	1	5	8.5	25.7249	2.58	92.2	3.9	3.9
1151	10/29/12	1	5	8.5	45.4358	5.11	76.9	18.7	4.4
1152	10/29/12	1	5	8.5	32.7204	4.80	78.6	18.3	3.1
1153	10/29/12	1	5	8.5	37.9440	3.69	74.0	22.0	4.0
1154	10/29/12	1	5	8.5	34.9128	4.04	90.0	5.7	4.3
1155	10/29/12	1	5	8.5	41.6701	2.20	83.2	12.0	4.8
1156	10/29/12	1	5	8.5	38.1614	2.50	85.6	11.8	2.6
1157	10/29/12	1	5	8.5	37.0719	5.35	69.0	28.3	2.7
1158	10/29/12	1	5	8.5	35.0234	4.55	71.4	25.7	2.9
1159	10/29/12	1	5	8.5	45.6776	5.22	63.1	34.7	2.2
1160	10/29/12	1	5	15.5	38.3038	4.10	54.3	43.1	2.6
1161	10/29/12	1	5	15.5	36.7603	4.49	53.7	43.6	2.7
1162	10/29/12	1	5	15.5	29.0762	3.85	53.6	43.0	3.4
1163	10/29/12	1	6	0.5	37.9147	3.77	51.2	44.8	4.0
1164	10/29/12	1	6	0.5	37.6186	1.18	86.7	12.0	1.3
1165	10/29/12	1	6	0.5	37.1599	1.35	86.5	10.8	2.7
1166	10/29/12	1	6	0.5	35.7448	1.29	83.2	14.0	2.8
1167	10/29/12	1	6	0.5	47.2684	1.33	87.3	9.5	3.2
1168	10/29/12	1	6	0.5	39.1749	1.11	89.8	7.6	2.6
1169	10/29/12	1	6	0.5	38.1588	1.24	88.2	9.2	2.6
1170	10/29/12	1	6	0.5	27.6812	1.04	89.1	7.3	3.6
1171	10/29/12	1	6	0.5	40.6560	1.17	88.9	7.4	3.7
1172	10/29/12	1	6	6.5	34.1446	1.71	94.1	4.4	1.5
1173	10/29/12	1	6	6.5	37.4485	3.37	89.3	6.7	4.0
1174	10/29/12	1	6	6.5	36.4449	4.45	90.4	8.2	1.4
1175	10/29/12	1	6	6.5	29.9492	2.52	90.0	8.3	1.7
1176	10/29/12	1	6	6.5	32.6892	2.58	95.4	3.1	1.5

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1177	10/29/12	1	6	15.5	37.2469	4.74	61.1	34.9	4.0
1178	10/29/12	1	6	15.5	34.5148	4.02	55.1	40.5	4.4
1179	10/29/12	1	6	15.5	26.2907	3.96	65.8	30.8	3.4
1180	10/29/12	1	7	2.5	37.1157	5.30	77.1	20.2	2.7
1181	10/29/12	1	7	2.5	29.3104	2.83	81.2	15.4	3.4
1182	10/29/12	1	7	2.5	30.2005	4.68	83.4	11.6	5.0
1183	10/29/12	1	7	2.5	47.1863	1.34	79.9	16.9	3.2
1184	10/29/12	1	7	2.5	39.0426	1.44	79.5	19.2	1.3
1185	10/29/12	1	7	17.0	44.8834	6.98	76.2	21.6	2.2
1186	10/29/12	1	7	17.0	37.3124	2.13	77.2	20.1	2.7
1187	10/29/12	1	7	17.0	37.4691	1.90	70.6	28.1	1.3
1188	10/29/12	1	7	17.0	35.9402	2.19	75.0	23.6	1.4
1189	11/4/12	3	1	0	44.6412	6.90	60.8	35.8	3.4
1190	11/4/12	3	1	0	28.5605	5.45	58.0	38.5	3.5
1191	11/4/12	3	1	0	32.2206	12.98	61.2	35.7	3.1
1192	11/4/12	3	1	1.0	26.3877	9.58	60.2	37.9	1.9
1193	11/4/12	3	1	1.0	41.3633	16.28	51.6	44.8	3.6
1194	11/4/12	3	1	1.0	36.0177	9.44	51.4	44.4	4.2
1195	11/4/12	3	2	0	43.0883	10.39	43.1	54.6	2.3
1196	11/4/12	3	2	0	22.4949	8.16	35.5	62.3	2.2
1197	11/4/12	3	2	0	31.7742	5.05	89.0	9.4	1.6
1198	11/4/12	3	2	0	31.1918	3.22	88.8	9.6	1.6
1199	11/4/12	3	2	1.0	35.1805	12.11	38.9	58.3	2.8
1199	11/4/12	3	2	1.0	33.0445	10.63	41.0	56.0	3.0
1200	11/4/12	3	3	0.5	32.2375	13.33	42.6	54.3	3.1
1201	11/4/12	3	3	0.5	43.6474	9.57	41.6	56.1	2.3
1202	11/4/12	3	3	1.0	36.2748	8.44	62.8	34.4	2.8
1203	11/4/12	3	3	2.0	35.9496	10.68	45.8	50.0	4.2
1204	11/4/12	3	3	2.0	33.8284	7.97	46.2	50.8	3.0
1205	11/4/12	3	4	0	31.7406	12.85	44.9	51.9	3.2

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1206	11/4/12	3	4	0	30.2597	12.32	43.8	51.2	5.0
1207	11/4/12	3	4	0	34.9056	8.99	65.6	31.5	2.9
1208	11/4/12	3	4	1.5	44.8834	6.98	45.4	52.4	2.2
1209	11/4/12	3	4	1.5	37.4105	6.43	42.5	53.5	4.0
1210	11/7/12	2	1	0	38.3259	2.40	73.9	22.2	3.9
1211	11/7/12	2	1	0	35.6403	3.04	71.9	23.9	4.2
1212	11/7/12	2	1	0	46.7934	2.58	72.2	23.5	4.3
1213	11/7/12	2	1	0	39.2489	1.48	69.4	26.8	3.8
1214	11/7/12	2	1	1.5	38.4535	2.46	80.5	18.2	1.3
1215	11/7/12	2	1	0.5	35.7610	2.26	79.0	19.6	1.4
1216	11/7/12	2	1	0.5	47.0560	2.17	76.6	22.3	1.1
1217	11/7/12	2	1	0.5	39.3203	1.42	88.5	9.0	2.5
1218	11/7/12	2	2	0	38.4800	2.12	64.9	33.8	1.3
1219	11/7/12	2	2	0	35.7994	2.23	69.3	29.3	1.4
1220	11/7/12	2	2	0	47.0406	2.06	66.0	31.9	2.1
1221	11/7/12	2	2	0	38.6092	1.91	79.3	18.1	2.6
1222	11/7/12	2	2	0	35.8010	1.94	79.0	18.2	2.8
1223	11/7/12	2	2	0	38.7853	2.40	70.3	28.4	1.3
1224	11/7/12	2	2	0	38.3626	2.44	64.8	32.6	2.6
1225	11/7/12	2	2	0	35.6768	2.63	60.8	35.0	4.2
1226	11/7/12	2	2	0	37.5111	2.71	62.7	33.3	4.0
1227	11/7/12	2	2	1.5	39.2347	1.46	77.1	19.1	3.8
1228	11/7/12	2	2	0.5	38.7609	1.30	76.8	20.6	2.6
1229	11/7/12	2	2	0.5	36.1493	1.57	76.5	20.7	2.8
1230	11/7/12	2	3	0.5	46.5631	2.65	63.5	34.3	2.2
1231	11/7/12	2	3	0	38.4331	2.79	63.6	33.8	2.6
1232	11/7/12	2	3	0	38.2252	2.83	63.4	32.7	3.9
1233	11/7/12	2	3	0	35.1961	3.11	73.0	22.7	4.3
1234	11/7/12	2	3	0	46.9936	2.25	74.5	22.3	3.2
1235	5/9/13	1	1	0	34.8240	3.60	85.6	13.0	1.4

Sample	Collection Date	Field Site	Transect	Core Distance From Stream Bank (m)	Dry Mass (g)	%LOI	%Sand	%Silt	%Clay
1236	5/9/13	1	2	0.5	26.6802	6.50	77.5	20.6	1.9
1237	5/9/13	1	2	0	25.8961	4.48	80.7	15.4	3.9
1238	5/9/13	1	2	0	32.9206	5.81	83.3	15.2	1.5
1239	5/9/13	1	3	0	27.1293	3.09	81.6	16.6	1.8
1240	5/9/13	1	3	0	35.5604	3.75	80.3	18.3	1.4
1241	5/9/13	1	3	0	35.1641	3.38	84.4	14.2	1.4
1242	5/9/13	1	3	0	28.0195	3.25	82.1	14.3	3.6
1243	5/9/13	1	3	0	27.9658	3.28	82.1	12.5	5.4
1244	5/9/13	1	4	0	38.0362	3.14	77.6	19.8	2.6
1245	5/9/13	1	4	0	38.5252	3.69	84.4	14.3	1.3
1246	5/9/13	1	4	0	34.7908	4.28	85.6	11.5	2.9
1247	5/9/13	1	4	0	45.9631	4.40	85.9	11.9	2.2
1248	5/31/13	3	1	0	38.8912	1.48	94.9	3.8	1.3
1249	5/31/13	3	1	0	36.2850	1.34	94.5	4.1	1.4
1250	5/31/13	3	1	0	47.3661	1.62	95.8	3.1	1.1
1251	5/31/13	3	1	0	39.1323	1.80	93.6	5.1	1.3
1252	5/31/13	3	1	0	30.3867	1.79	91.8	6.5	1.7
1253	5/31/13	3	1	0	30.8566	2.06	91.9	4.9	3.2
1254	5/31/13	3	2	0	45.0658	6.75	71.1	24.5	4.4
1255	5/31/13	3	2	0	36.0642	6.24	88.9	8.3	2.8
1256	5/31/13	3	3	0	34.3200	6.45	85.4	11.7	2.9
1257	5/31/13	3	3	0	45.2822	6.21	80.1	17.7	2.2
1258	5/31/13	3	4	0	29.1805	3.34	88.0	5.1	6.9
1259	5/31/13	3	4	0	38.5420	2.40	84.4	13.0	2.6

Table 5.5. Fine grain sediment survey depth data. Depth data reported in cm. Period of data collection from Spring 2012 to Fall 2014. Survey point distance begins on the tributary confluence side (nearest upstream tributary confluence, which happens to be on the west bank of Oak Creek) for all field sites and extends towards the east bank. Transects abbreviated as T1 (e.g. Transect 1).

Field Site	Collection Date	Distance From Stream Bank (m)	T1	T2	T3	T4	T5	T6	T7	T8
1	7/3/12	0.0	8.7	13.4	15.6	8.5	12.5	30.4	NA	NA
1	7/3/12	0.5	8.1	12.6	11.3	13.0	6.6	29.3	NA	NA
1	7/3/12	1.0	5.2	10.8	10.9	14.6	13.1	15.1	NA	NA
1	7/3/12	1.5	0	10.0	3.5	13.1	15.2	17.0	NA	NA
1	7/3/12	2.0	NA	10.6	NA	NA	NA	NA	NA	NA
1	7/3/12	2.5	NA	10.6	NA	NA	NA	NA	NA	NA
1	7/3/12	3.0	NA	3.9	NA	NA	NA	NA	NA	NA
1	7/3/12	3.5	NA	3.7	NA	NA	NA	NA	NA	NA
1	7/3/12	4.0	NA	3.8	NA	NA	NA	NA	NA	NA
1	7/3/12	4.5	NA	1.9	NA	NA	NA	NA	NA	NA
1	7/3/12	5.0	NA	8.6	NA	NA	NA	NA	NA	NA
1	7/3/12	5.5	NA	0	NA	NA	NA	NA	NA	NA
1	7/3/12	6.0	NA	3.7	NA	NA	NA	NA	NA	NA
1	7/3/12	6.5	NA	2.8	NA	NA	NA	NA	NA	NA
1	7/3/12	7.0	NA	0	NA	NA	NA	NA	NA	NA
2	7/12/12	0.0	5.6	22.1	20.6	15.2	NA	NA	NA	NA
2	7/12/12	0.5	4.8	18.4	12.0	9.1	NA	NA	NA	NA
2	7/12/12	1.0	0	13.0	9.8	0	NA	NA	NA	NA
2	7/12/12	1.5	NA	10.6	0	NA	NA	NA	NA	NA
2	7/12/12	2.0	NA	9.9	NA	NA	NA	NA	NA	NA
2	7/12/12	2.5	NA	5.1	NA	NA	NA	NA	NA	NA
2	7/12/12	3.0	NA	0	NA	NA	NA	NA	NA	NA
3	7/13/12	0.0	7.2	17.9	18.8	11.6	NA	NA	NA	NA
3	7/13/12	1.0	6.9	4.5	12.7	8.5	NA	NA	NA	NA
3	7/13/12	1.5	5.9	0	4.4	0	NA	NA	NA	NA
3	7/13/12	2.0	0	NA	0	NA	NA	NA	NA	NA
1	10/5/12	0.0	13.6	22.5	32.6	35.0	35.6	21.7	9.0	NA
1	10/5/12	0.5	7.1	20.3	33.5	36.1	34.2	23.6	8.3	NA
1	10/5/12	1.0	14.9	27.6	28.1	37.3	29.3	35.1	6.7	NA
1	10/5/12	1.5	18.4	18.4	26.6	24.7	28.1	26.7	15.1	NA
1	10/5/12	2.0	21.7	23.7	20.9	20.6	24.4	14.3	7.2	NA
1	10/5/12	2.5	17.0	22.1	27.5	23.9	23.6	31.5	21.1	NA
1	10/5/12	3.0	16.8	21.8	25.0	23.7	27.2	49.0	36.6	NA
1	10/5/12	3.5	12.5	22.0	30.7	31.1	37.1	64.8	62.3	NA
1	10/5/12	4.0	15.0	23.1	29.8	37.3	43.5	70.7	73.5	NA
1	10/5/12	4.5	16.1	18.6	28.0	44.7	48.2	76.2	74.7	NA
1	10/5/12	5.0	9.0	15.7	28.8	47.1	51.6	90.9	82.0	NA
1	10/5/12	5.5	6.6	12.4	33.6	50.0	51.5	102.3	98.1	NA
1	10/5/12	6.0	0	14.9	38.3	51.6	63.2	102.6	102.3	NA
1	10/5/12	6.5	1.6	6.2	34.1	46.2	63.7	106.7	113.0	NA
1	10/5/12	7.0	7.4	14.8	25.7	59.7	70.3	85.0	127.4	NA

Field Site	Collection Date	Distance From Stream Bank (m)	T1	T2	T3	T4	T5	T6	T7	T8
1	10/5/12	7.5	11.4	13.9	24.9	64.2	65.1	93.3	129.5	NA
1	10/5/12	8.0	7.7	14.6	24.8	58.4	62.1	94.6	133.3	NA
1	10/5/12	8.5	0	12.7	22.0	38.6	46.7	83.2	133.5	NA
1	10/5/12	9.0	8.2	10.7	21.3	35.7	56.4	87.1	130.8	NA
1	10/5/12	9.5	6.7	3.4	0	24.6	46.0	76.5	91.1	NA
1	10/5/12	10.0	9.0	0	0	19.8	28.2	75.4	124.0	NA
1	10/5/12	10.5	7.1	0	8.3	18.9	18.7	40.3	119.2	NA
1	10/5/12	11.0	0	0	0	10.6	24.1	57.0	112.5	NA
1	10/5/12	11.5	0	12.4	4.4	2.4	16.1	49.4	99.1	NA
1	10/5/12	12.0	7.6	0	17.5	0	13.0	31.5	96.7	NA
1	10/5/12	12.5	7.1	0	6.3	4.5	16.0	0	66.4	NA
1	10/5/12	13.0	3.8	3.3	3.6	8.9	0	12.8	72.4	NA
1	10/5/12	13.5	9.1	11.8	10.5	0	0	0	56.7	NA
1	10/5/12	14.0	8.6	0	0	0	8.1	6.7	23.5	NA
1	10/5/12	14.5	6.9	8.5	8.0	9.1	0	7.8	0	NA
1	10/5/12	15.0	6.4	0	11.5	10.3	0	13.9	0	NA
1	10/5/12	15.5	1.2	0	9.3	14.0	12.4	19.9	19.2	NA
1	10/5/12	16.0	0	11.1	42.2	40.8	NA	NA	7.8	NA
1	10/5/12	16.5	8.3	18.4	NA	NA	NA	NA	11.5	NA
1	10/5/12	17.0	8.3	11.2	NA	NA	NA	NA	25.4	NA
1	10/5/12	17.5	7.8	NA	NA	NA	NA	NA	NA	NA
1	10/5/12	18.0	13.9	NA	NA	NA	NA	NA	NA	NA
3	11/4/12	0.0	16.9	30.1	33.3	20.5	NA	NA	NA	NA
3	11/4/12	0.5	15.0	14.2	27.5	21.9	NA	NA	NA	NA
3	11/4/12	1.0	15.4	17.9	16.4	5.0	NA	NA	NA	NA
3	11/4/12	1.5	8.2	3.3	2.9	0	NA	NA	NA	NA
3	11/4/12	2.0	0	6.4	9.8	NA	NA	NA	NA	NA
3	11/4/12	2.5	NA	0	0	NA	NA	NA	NA	NA
2	11/7/12	0.0	5.6	22.1	20.6	15.2	NA	NA	NA	NA
2	11/7/12	0.5	4.8	18.4	12.0	9.1	NA	NA	NA	NA
2	11/7/12	1.0	0	13.0	9.8	0	NA	NA	NA	NA
2	11/7/12	1.5	NA	10.6	0	NA	NA	NA	NA	NA
2	11/7/12	2.0	NA	9.9	NA	NA	NA	NA	NA	NA
2	11/7/12	2.5	NA	5.1	NA	NA	NA	NA	NA	NA
2	11/7/12	3.0	NA	0	NA	NA	NA	NA	NA	NA
1	5/9/13	0.0	8.8	17.4	21.6	33.9	7.6	12.1	NA	NA
1	5/9/13	0.5	0	9.7	12.5	11.1	0	0	NA	NA
1	5/9/13	1.0	NA	11.0	4.4	5.1	NA	NA	NA	NA
1	5/9/13	1.5	NA	5.6	0	0	NA	NA	NA	NA
1	5/9/13	2.0	NA	0	NA	NA	NA	NA	NA	NA
3	5/31/13	0.0	21.1	14.0	12.7	NA	NA	NA	NA	NA
3	5/31/13	0.5	0	9.2	3.0	NA	NA	NA	NA	NA
3	5/31/13	1.0	NA	4.6	0	NA	NA	NA	NA	NA
3	5/31/13	1.5	NA	0	NA	NA	NA	NA	NA	NA
1	9/20/13	0.0	17.1	29.7	33.1	33.4	45.3	13.1	NA	NA
1	9/20/13	0.5	13.8	24.4	31.4	20.6	24.2	14.4	NA	NA

Field Site	Collection Date	Distance From Stream Bank (m)	T1	T2	T3	T4	T5	T6	T7	T8
1	9/20/13	1.0	13.2	8.6	20.9	8.8	33.6	21.7	NA	NA
1	9/20/13	1.5	3.4	4.4	3.6	5.7	30.0	14.2	NA	NA
1	9/20/13	2.0	2.2	0	4.5	4.6	22.2	26.7	NA	NA
1	9/20/13	2.5	0	NA	4.8	6.1	13.1	9.2	NA	NA
1	9/20/13	3.0	NA	NA	2.7	8.8	10.3	20.9	NA	NA
1	9/20/13	3.5	NA	NA	3.0	11.3	10.1	16.2	NA	NA
1	9/20/13	4.0	NA	NA	0	9.0	9.2	5.3	NA	NA
1	9/20/13	4.5	NA	NA	NA	15.6	4.5	7.0	NA	NA
1	9/20/13	5.0	NA	NA	NA	14.7	7.1	11.6	NA	NA
1	9/20/13	5.5	NA	NA	NA	14.4	4.6	12.0	NA	NA
1	9/20/13	6.0	NA	NA	NA	8.7	2.5	14.9	NA	NA
1	9/20/13	6.5	NA	NA	NA	10.8	7.0	16.1	NA	NA
1	9/20/13	7.0	NA	NA	NA	6.5	6.9	12.4	NA	NA
1	9/20/13	7.5	NA	NA	NA	0	3.8	0	NA	NA
1	9/20/13	8.0	NA	NA	NA	NA	10.2	NA	NA	NA
1	9/20/13	8.5	NA	NA	NA	NA	0	NA	NA	NA
2	9/27/13	0.0	NA	NA	NA	9.0	40.4	NA	20.8	8.4
2	9/27/13	0.5	NA	NA	NA	23.4	18.2	NA	13.7	11.3
2	9/27/13	1.0	NA	NA	NA	14.7	6.8	NA	0	0
2	9/27/13	1.5	NA	NA	NA	2.0	4.3	NA	NA	NA
2	9/27/13	2.0	NA	NA	NA	0	0	NA	NA	NA
2	9/27/13	2.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	3.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	3.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	4.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	4.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	5.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	5.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	6.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	6.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	7.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	7.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	8.0	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	8.5	NA	NA	NA	NA	NA	NA	NA	NA
2	9/27/13	9.0	0	0	0	NA	NA	NA	NA	NA
2	9/27/13	9.5	9.0	7.0	2.8	NA	NA	NA	NA	NA
2	9/27/13	10.0	17.9	41.8	12.3	NA	NA	NA	NA	NA
2	9/27/13	10.5	16.7	64.6	9.4	NA	NA	NA	NA	NA
2	9/27/13	11.0	46.1	NA	6.1	0	0	0	0	NA
2	9/27/13	11.5	NA	NA	NA	11.9	14.1	18.9	4.3	0
2	9/27/13	12.0	NA	NA	NA	13.5	18.0	25.4	22.7	10.1
3	9/27/13	0.0	30.1	34.6	48.5	27.7	12.0	NA	NA	NA
3	9/27/13	0.5	12.3	29.8	31.0	14.8	9.1	NA	NA	NA
3	9/27/13	1.0	2.7	12.7	14.9	9.6	3.9	NA	NA	NA
3	9/27/13	1.5	0	4.2	14.0	5.8	0	NA	NA	NA
3	9/27/13	2.0	NA	7.9	5.8	0	NA	NA	NA	NA

Field Site	Collection Date	Distance From Stream Bank (m)	T1	T2	T3	T4	T5	T6	T7	T8
3	9/27/13	2.5	NA	12.3	0	2.9	NA	NA	NA	NA
3	9/27/13	3.0	NA	0	0	6.8	NA	NA	NA	NA
3	9/27/13	3.5	NA	11.1	3.0	1.2	NA	NA	NA	NA
3	9/27/13	4.0	NA	14.0	6.1	0	NA	NA	NA	NA
3	9/27/13	4.5	NA	0	0	NA	NA	NA	NA	NA
3	9/27/13	5.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	5.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	6.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	6.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	7.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	7.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	8.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	8.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	9.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	9.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	10.0	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	10.5	NA	NA	NA	NA	NA	NA	NA	NA
3	9/27/13	11.0	NA	NA	NA	0	NA	NA	NA	NA
3	9/27/13	11.5	NA	NA	NA	16.4	0	NA	NA	NA
3	9/27/13	12.0	0	NA	NA	18.8	6.5	NA	NA	NA
3	9/27/13	12.5	5.0	0	NA	0	8.3	NA	NA	NA
3	9/27/13	13.0	5.1	13.6	NA	0	4.9	NA	NA	NA
3	9/27/13	13.5	13.7	17.2	0	0	13.0	NA	NA	NA
3	9/27/13	14.0	12.5	10.1	3.8	29.7	14.1	NA	NA	NA
3	9/27/13	14.5	21.3	15.0	7.4	45.6	44.3	NA	NA	NA
3	9/27/13	15.0	33.5	27.4	23.7	NA	57.0	NA	NA	NA
3	9/27/13	15.5	42.6	21.0	32.0	NA	NA	NA	NA	NA
3	9/27/13	16.0	NA	42.3	NA	NA	NA	NA	NA	NA
1	5/16/14	0.0	21.9	23.8	29.3	11.9	NA	NA	NA	NA
1	5/16/14	0.5	12.0	12.3	5.6	20.1	NA	NA	NA	NA
1	5/16/14	1.0	7.1	4.4	0	3.9	NA	NA	NA	NA
1	5/16/14	1.5	3.0	0	NA	0	NA	NA	NA	NA
1	5/16/14	2.0	3.8	NA	NA	NA	NA	NA	NA	NA
1	5/16/14	2.5	0	NA	NA	NA	NA	NA	NA	NA
3	5/16/14	0.0	18.9	14.3	38.2	18.2	23.6	NA	NA	NA
3	5/16/14	0.5	12.4	11.6	23.7	12.1	5.6	NA	NA	NA
3	5/16/14	1.0	4.6	0	3.8	1.9	0	NA	NA	NA
3	5/16/14	1.5	0	NA	0	0	NA	NA	NA	NA

5.3. Complete Survey Maps

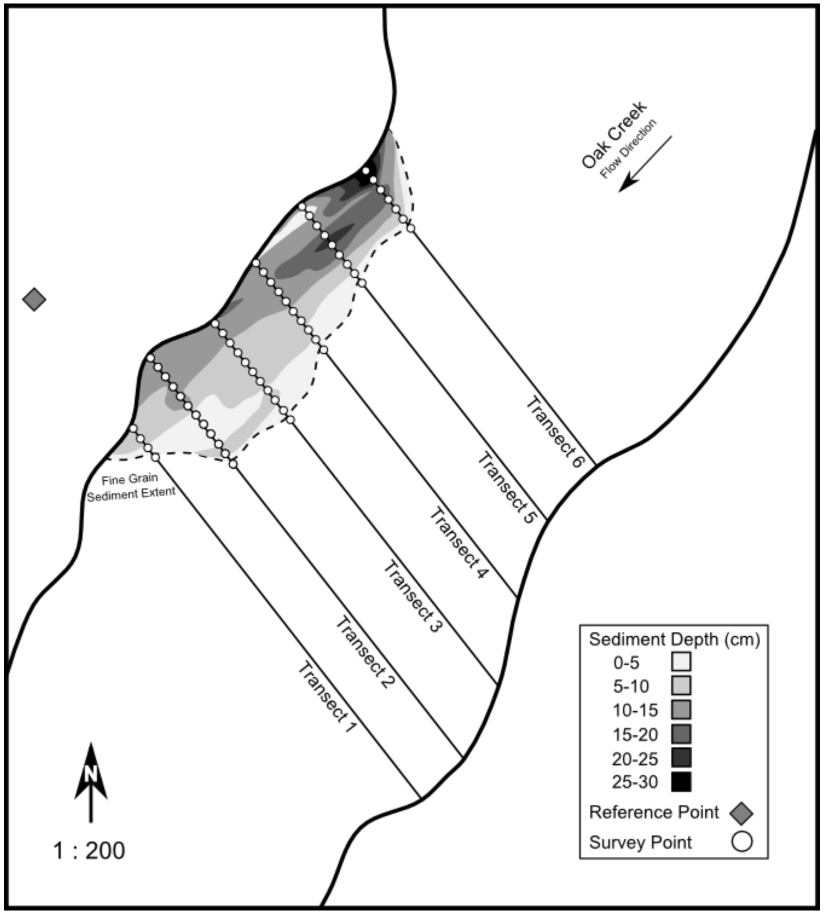


Figure 5.6. Field Site 1 Survey Spring 2012.

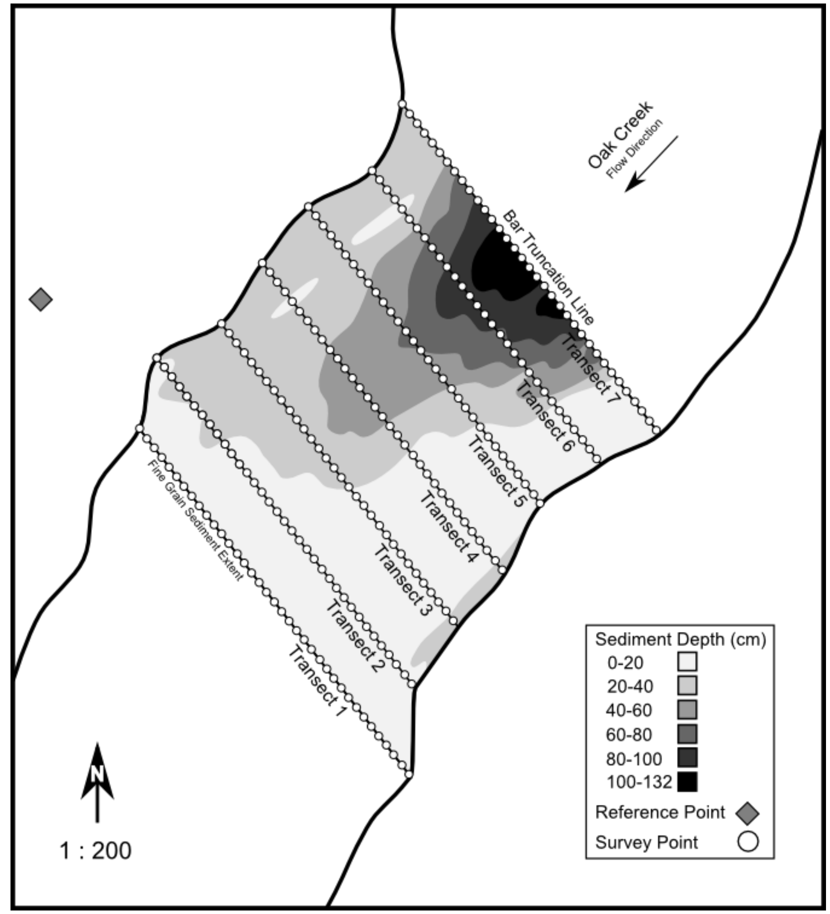


Figure 5.7. Field Site 1 Survey Fall 2012. A very thin layer of fine grain sediment (<1 cm in thickness) existed downstream of Transect 1. Bar extended 17 m upstream of Transect 7.

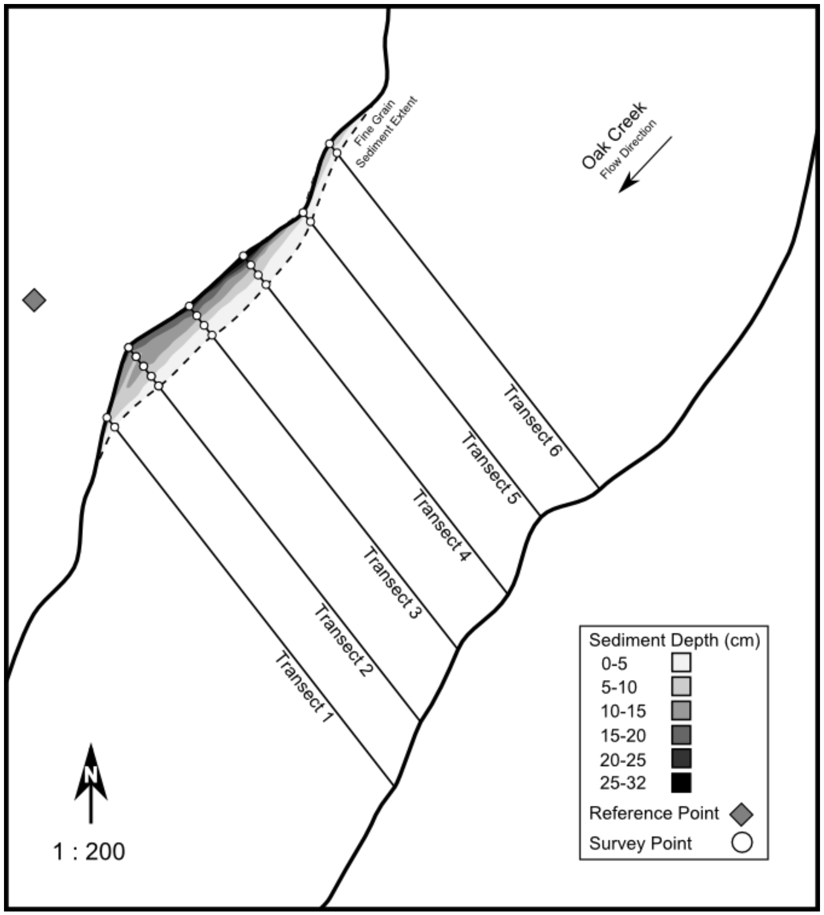


Figure 5.8. Field Site 1 Survey Spring 2013.

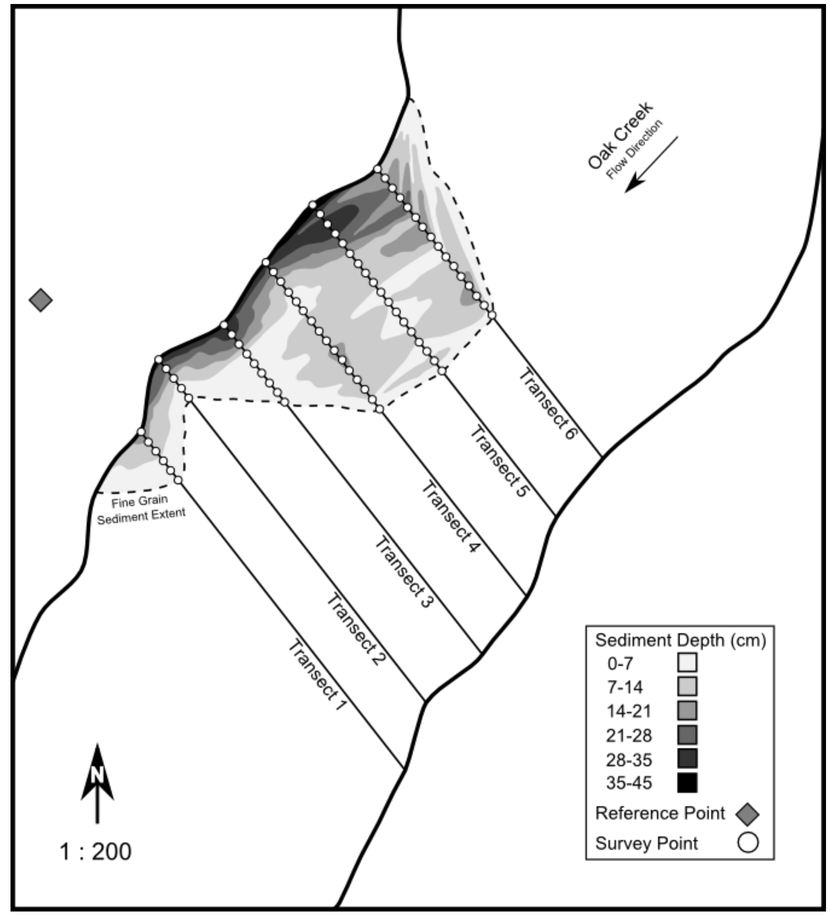


Figure 5.9. Field Site 1 Survey Fall 2013.

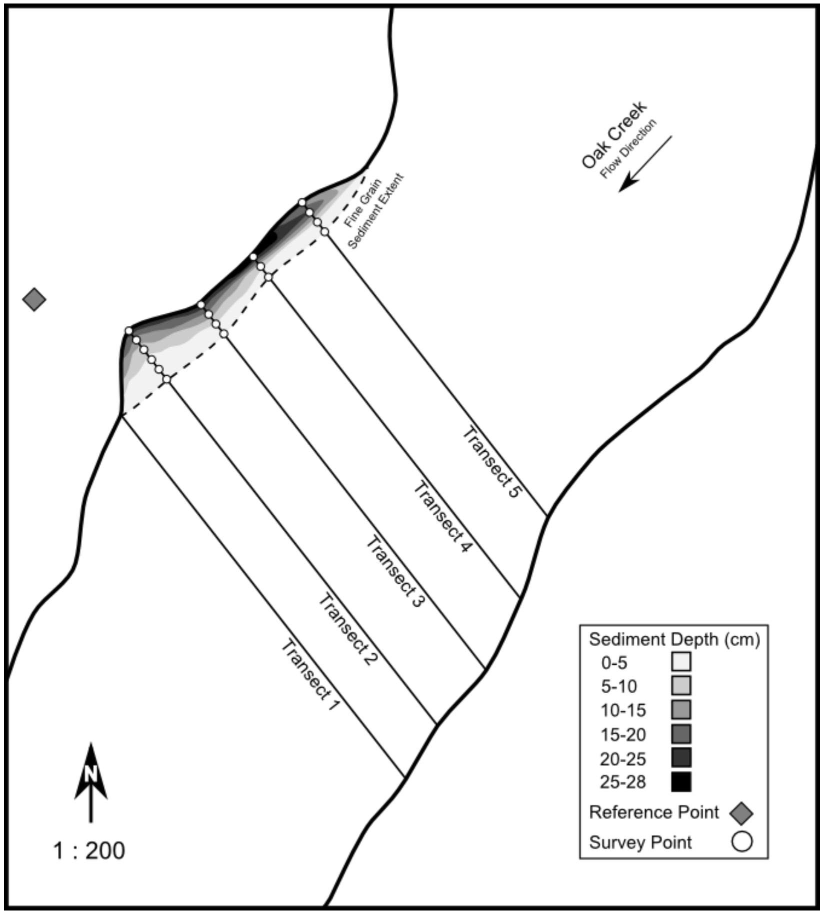


Figure 5.10. Field Site 1 Survey Spring 2014.

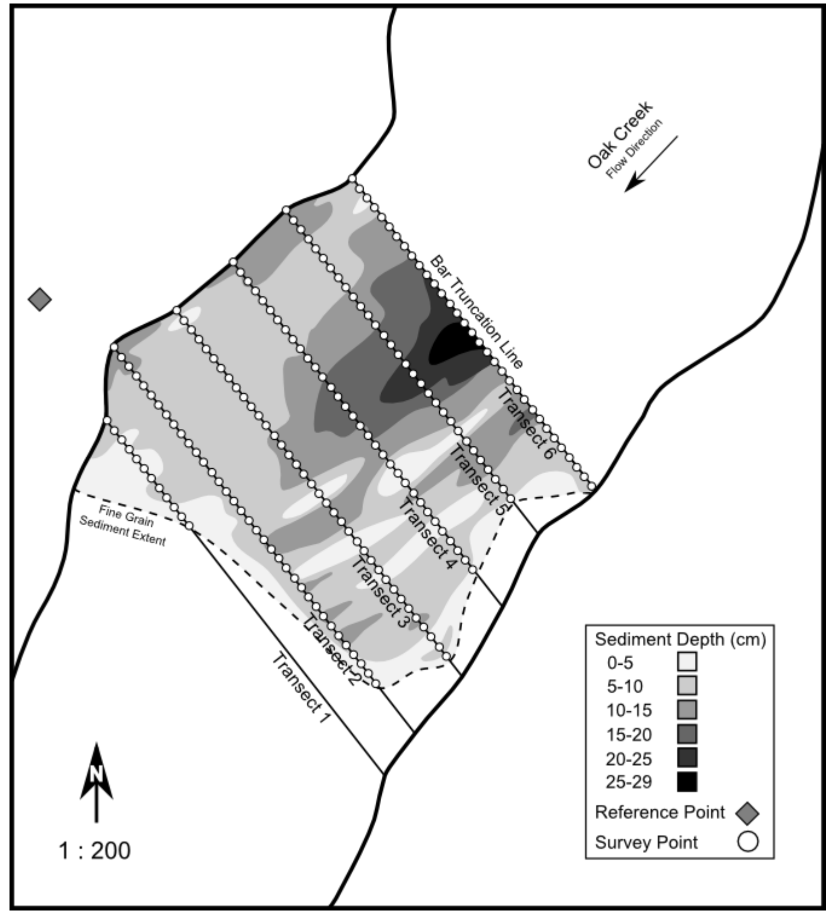


Figure 5.11. Field Site 1 Survey Fall 2014. Bar extended 12 m upstream of Transect 6.

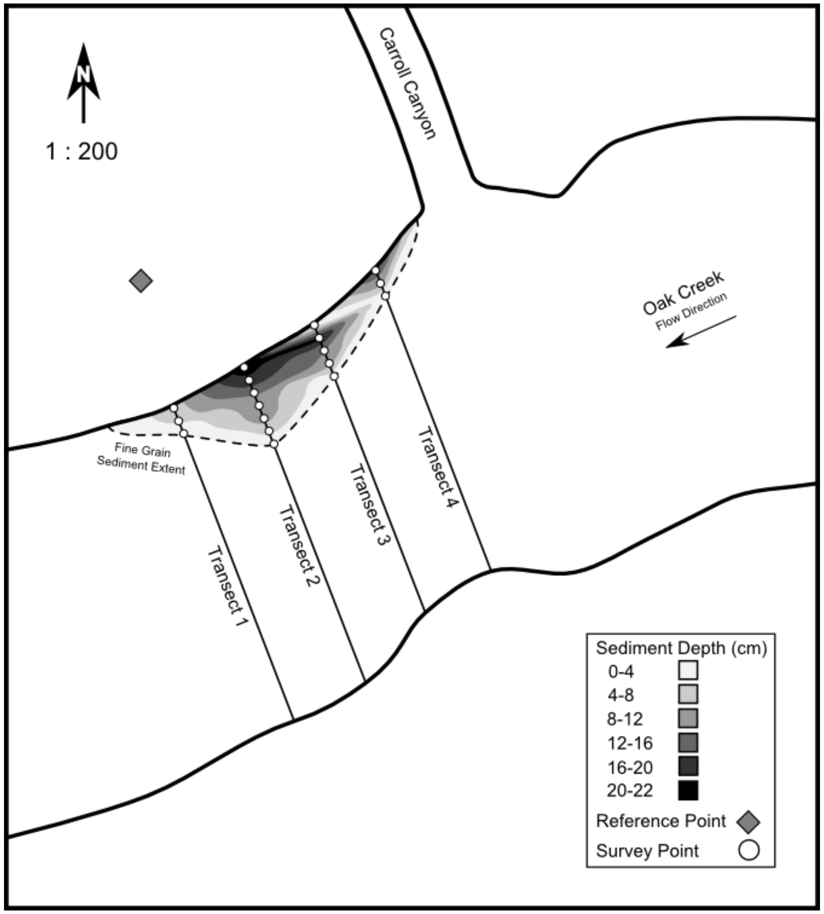


Figure 5.12. Field Site 2 Survey Spring 2012.

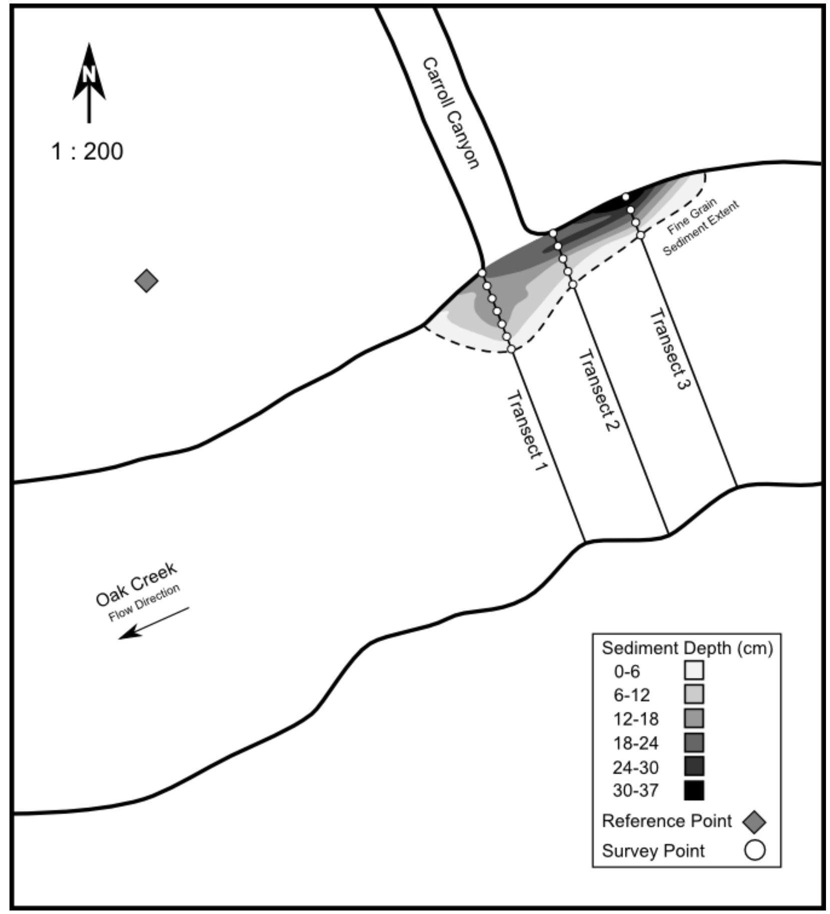


Figure 5.13. Field Site 2 Survey Fall 2012.

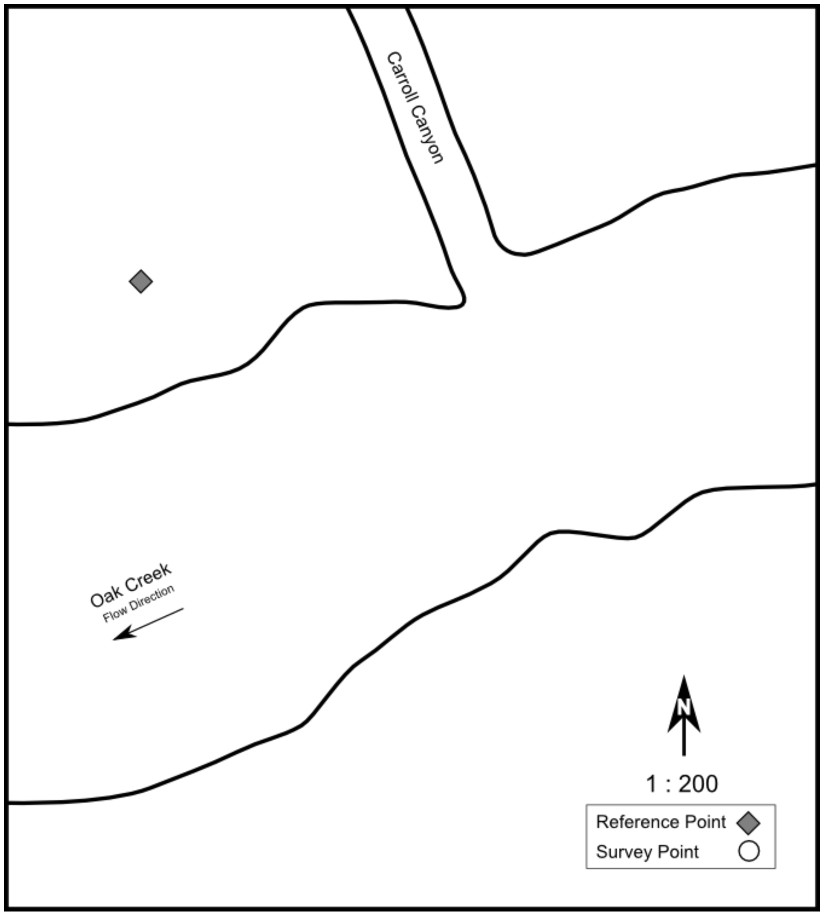


Figure 5.14. Field Site 2 Survey Spring 2013. No fine grain sediment observed.

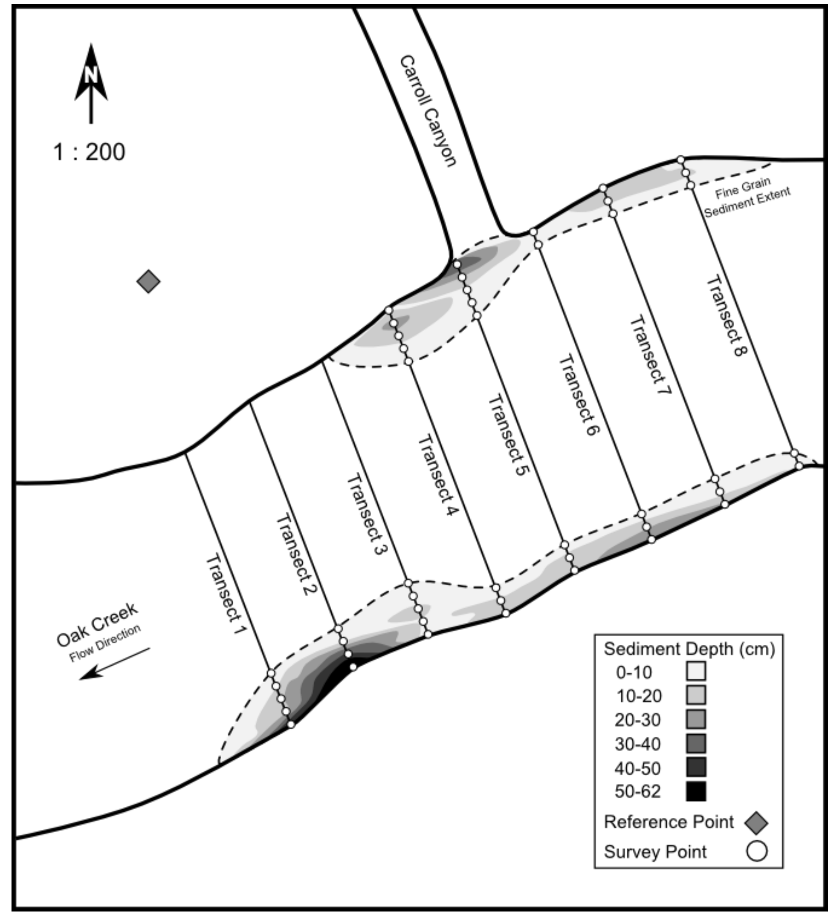


Figure 5.15. Field Site 2 Survey Fall 2013.

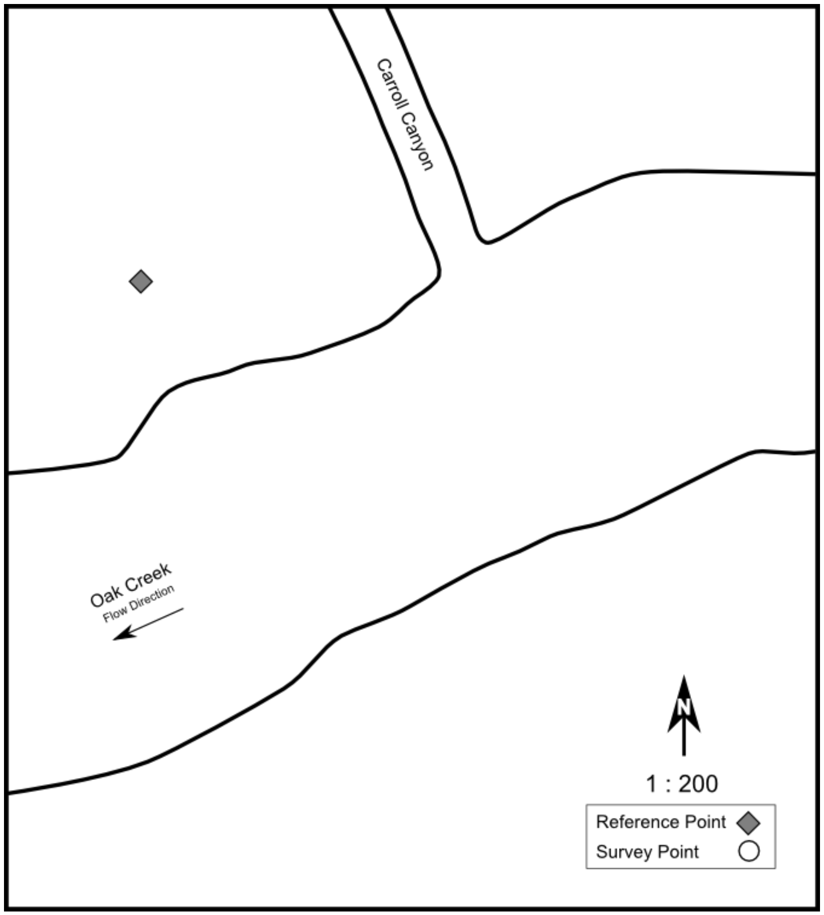


Figure 5.16. Field Site 2 Survey Spring 2014. No fine grain sediment observed.

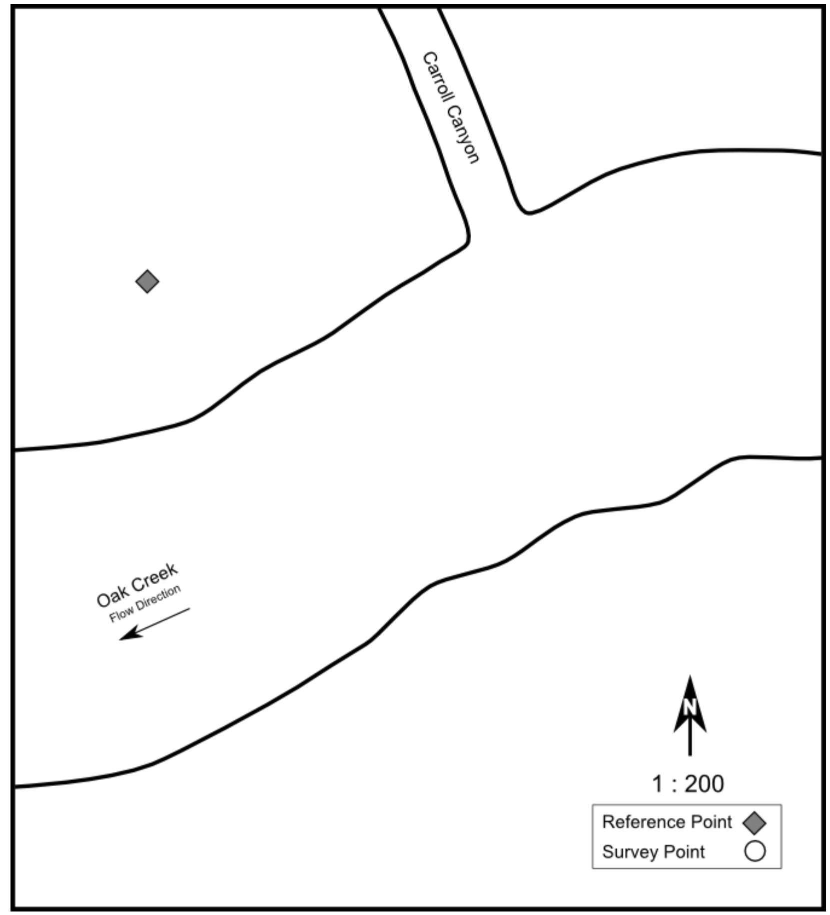


Figure 5.17. Field Site 2 Survey Fall 2014. No fine grain sediment observed.

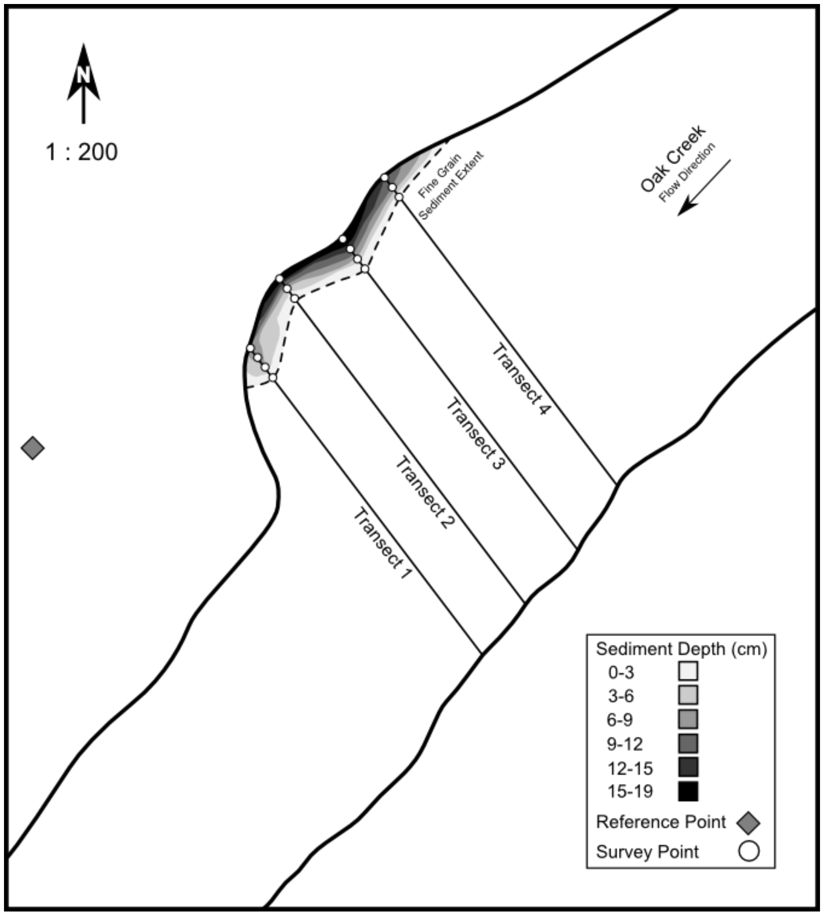


Figure 5.18. Field Site 3 Survey Spring 2012.

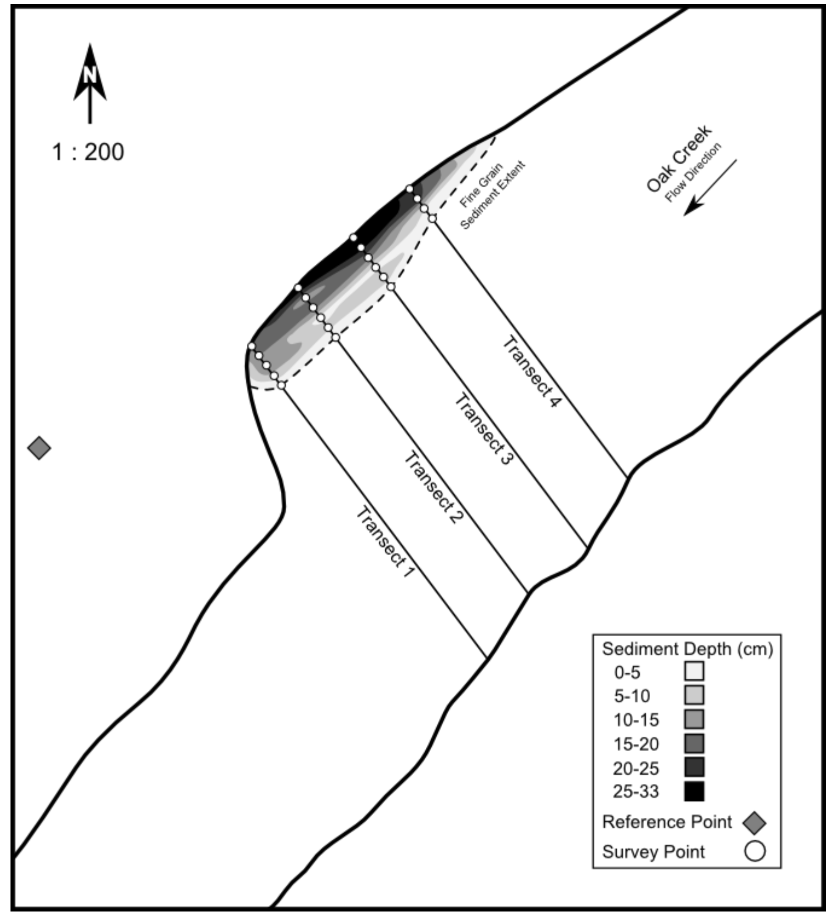


Figure 5.19. Field Site 3 Survey Fall 2012.

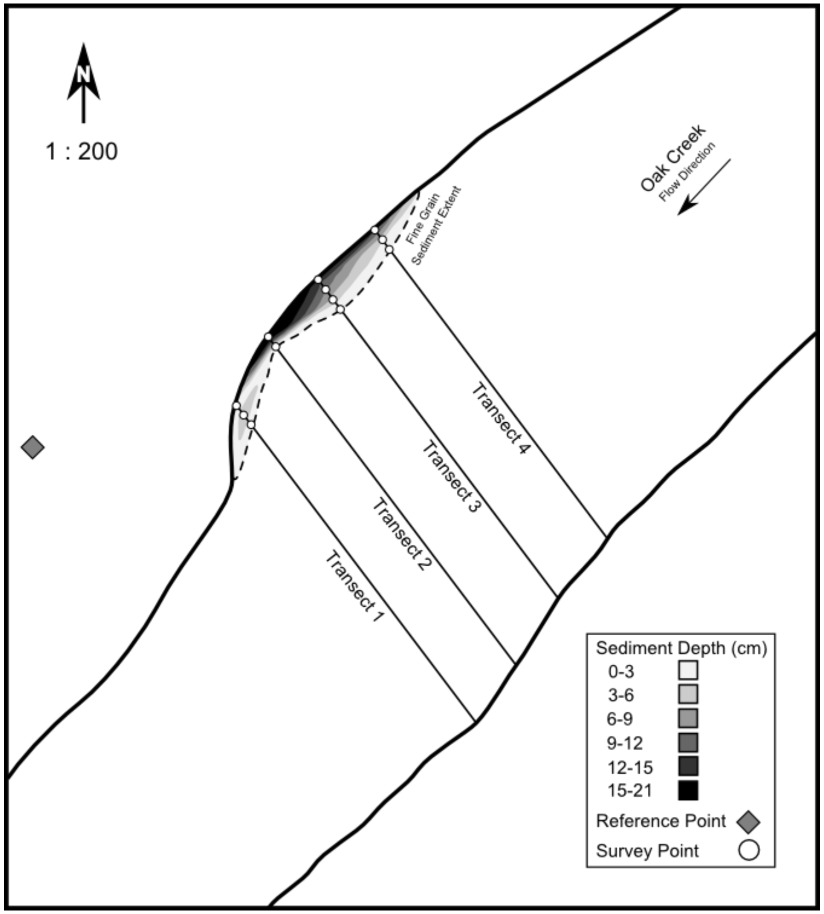


Figure 5.20. Field Site 3 Survey Spring 2013.

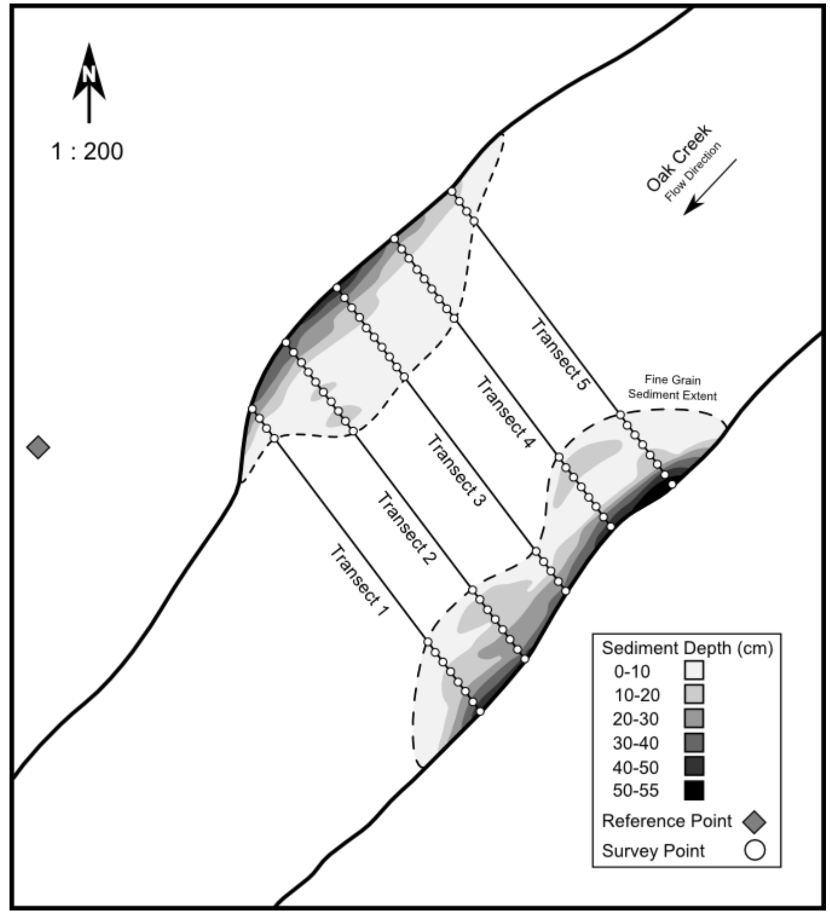


Figure 5.21. Field Site 3 Survey Fall 2013.

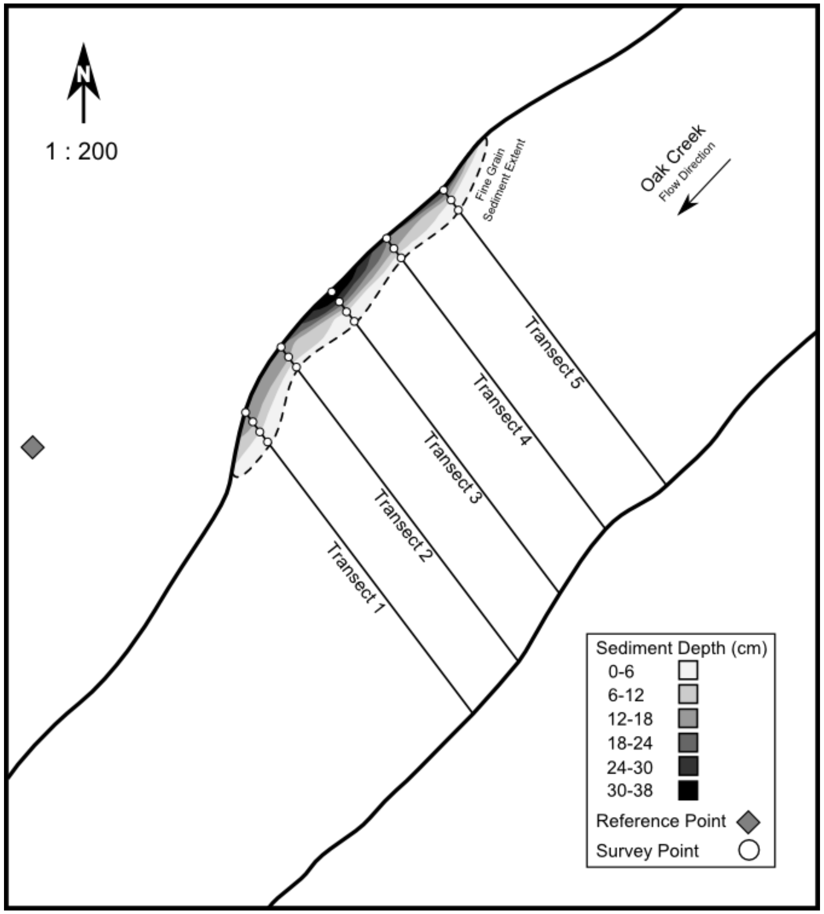


Figure 5.22. Field Site 3 Survey Spring 2014.

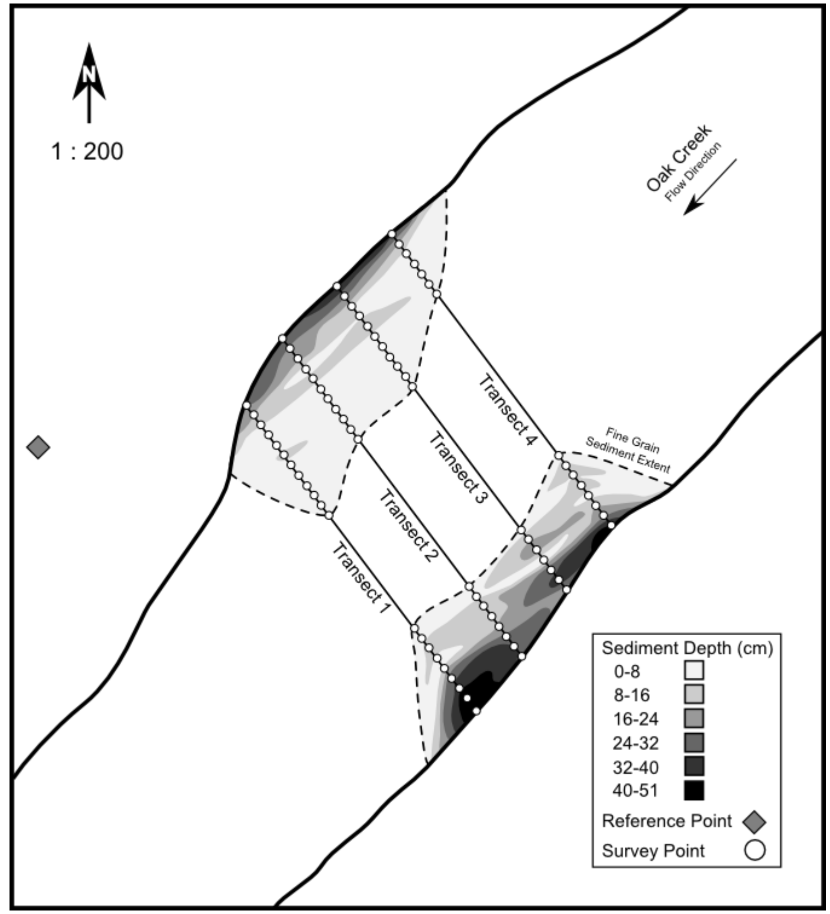


Figure 5.23. Field Site 3 Survey Fall 2014.