Anthropogenic Influences On Sedimentation In The Chicken Creek Watershed Of South Carolina

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ANTHROPOGENIC INFLUENCES ON SEDIMENTATION IN THE CHICKEN CREEK WATERSHED OF SOUTH CAROLINA

by

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ABSTRACT

Anthropogeomorphic changes in response to destructive agricultural practices followed the arrival of European settlers into the Americas. The southeastern Piedmont physiographic region of the USA was severely affected by erosion and sedimentation following settlement in the 1700s and farming up through the 1930s. Deep floodplain aggradation formed uninterrupted alluvial deposits that extended many km. This research examines anthropogenic impacts of land-use change on valley bottom sedimentation in the Chicken Creek Watershed of South Carolina. Abrupt contacts between pre-settlement floodplain soils and a thick overburden of legacy sediment are common throughout the two-km study reach and provide clear evidence of extensive post-settlement sedimentation. Soil stratigraphic and sedimentologic evidence are presented to contrast pre-settlement and post-settlement sediment characteristics and thicknesses. LiDAR-based spatial analysis is used to examine patterns of legacy sediment delivery, deposition, and floodplain storage and the environments in which this occurred. Legacy sediment 2 to 4 m thick rests on top of exposed pre-settlement soils throughout the stream corridor, with the pre-/post-settlement contact ~1.5 m above the stream channel on average. Linear regression analysis shows that legacy sediment thickness is controlled by valley width and proximity to tributary sediment sources. Thin pre-settlement alluvium over bedrock suggests modest erosion and sedimentation rates prior to European arrival. Pre-settlement geomorphic stability is supported by the presence of a buried Ab soil epipedon on pre-colonial floodplain surfaces. Mean grain-sizes are similar between the pre- and
post-settlement alluvium, but substantial contrasts in the degree of stratification and bulk
density document differences between pre- and post-settlement sedimentation
environments and post-depositional changes. Channel adjustments since the time of
maximum aggradation include incision at least as low as the pre-settlement longitudinal
profile and widening that is on-going.
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CHAPTER 1

INTRODUCTION
Localized sedimentation and erosional processes have been studied extensively over the last century and have contributed to creating a better understanding of geomorphic change on the landscape. In particular, fluvial sedimentation and erosional processes have been examined to determine the impact water plays in shaping the environment. While many of these processes occur over longer temporal scales, periodic changes in system inputs result in rapid changes to rivers and their adjacent floodplains. These changes are often split into two groups; climate and land-use changes. Within the land-use tract of process modification, significant research has been done examining impacts such as agriculture, deforestation, or mining (Dotterweich et al., 2014; Happ, 1940; 1945; Gilbert, 1917; Ireland et al., 1939; James, 1991; 2011; 2013; Knox, 1977; 2006; Trimble 1974; 1983; 1999; Wolman, 1959). Much of this research has focused on the impacts of European settlement in the Americas.

This research focuses on the late-historical anthropogenic influences on fluvial sedimentation and erosional processes in the Piedmont physiographic region. This area was important for agriculture during colonization by Europeans, and, as such, has been heavily impacted by land-use changes since the 1700s. The South Carolina Piedmont in particular was heavily modified, with natural forestland being cleared for cotton and corn production in the post-bellum era. This dramatic modification of the landscape resulted in extensive gullying and subsequent floodplain sedimentation. As upland landscape modification ceased, and forests began to return, sediment inputs began to decrease, thus allowing rivers to begin a process of recovery. Today evidence of this increased
sediment impact and subsequent recover are seen in many floodplains of the South Carolina Piedmont.

The following chapter, presented as a journal manuscript, details these processes and provides details of extensive channel and floodplain alteration and the subsequent processes of recovery in the Chicken Creek watershed in Northwest Fairfield County, South Carolina. This watershed provides a quality example of heavy impacts, and a relatively unaltered recovery process in the years that followed.
CHAPTER 2

ANTHROPOGENIC INFLUENCES ON SEDIMENTATION IN THE CHICKEN CREEK WATERSHED, SOUTH CAROLINA, USA

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2.1 ABSTRACT

Anthropogeomorphic changes in response to destructive agricultural practices followed the arrival of European settlers into the Americas. The southeastern Piedmont physiographic region of the USA was severely affected by erosion and sedimentation following settlement in the 1700s and farming up through the 1930s. Deep floodplain aggradation formed uninterrupted alluvial deposits that extended many km. This research examines anthropogenic impacts of land-use change on valley bottom sedimentation in the Chicken Creek Watershed of South Carolina. Abrupt contacts between pre-settlement floodplain soils and a thick overburden of legacy sediment are common throughout the two-km study reach and provide clear evidence of extensive post-settlement sedimentation. Soil stratigraphic and sedimentologic evidence are presented to contrast pre-settlement and post-settlement sediment characteristics and thicknesses. LiDAR-based spatial analysis is used to examine patterns of legacy sediment delivery, deposition, and floodplain storage and the environments in which this occurred. Legacy sediment 2 to 4 m thick rests on top of exposed pre-settlement soils throughout the stream corridor, with the pre-/post-settlement contact ~1.5 m above the stream channel on average. Linear regression analysis shows that legacy sediment thickness is controlled by valley width and proximity to tributary sediment sources. Thin pre-settlement alluvium over bedrock suggests modest erosion and sedimentation rates prior to European arrival. Pre-settlement geomorphic stability is supported by the presence of a buried Ab soil epipedon on pre-colonial floodplain surfaces. Mean grain-sizes are similar between the pre- and
post-settlement alluvium, but substantial contrasts in the degree of stratification and bulk density document differences between pre- and post-settlement sedimentation environments and post-depositional changes. Channel adjustments since the time of maximum aggradation include incision at least as low as the pre-settlement longitudinal profile and widening that is on-going.

2.2 INTRODUCTION

2.2.1 BACKGROUND

Through the twentieth century, research on localized sedimentation and erosional processes centered around two main themes: process and causality. The process track of research concentrated on sediment delivery and storage and computations of sediment budgets, sediment delivery ratios, or related functions that compare sediment produced in a watershed to the sediment yield (Glymp, 1954; Magilligan, 1985; Meade, 1982; Phillips, 1991; Walling, 1983). One feature of sediment delivery ratios is that only a small fraction of eroded sediment tends to reach the basin outlet, whereas most sediment is stored locally on the hillslopes, swales, floodplains, or in the river channel (Walling, 1983; Trimble, 1983). Although delivery ratios are not constant through time, they are important in understanding the behavior of sediments within a watershed, so the ability to predict sediment storage and sediment yield, which are highly variable between watersheds, is important. The causality track of sedimentation research has focused on the many different drivers of erosion; primarily climate and land-use changes, such as agriculture, deforestation, or mining (Dotterweich et al., 2014; Happ, 1940; 1945; Gilbert, 1917; Ireland et al., 1939; James, 1991; 2011; 2013; Knox, 1977; 2006; Trimble,
1974; 1983; 1999; Wolman, 1959). This causative research was largely born out of the
soil conservation movement in the 1930s and focused extensively on the impacts of
European settlement in the Americas on fluvial systems. The early period of landscape
change promoted scientific inquiry into the impacts of land use on sedimentation.
Many studies have documented late-historical anthropogenic fluvial sedimentation in
Australia (Fryirs and Brierley, 1999), North America (Costa, 1975; Lecce, 1997;
Jacobson and Coleman, 1986), and in Europe (Dotterweich 2005), where anthropogenic
sediment may be much earlier (Macklin and Lewin 2008; Vanwalleghem et al. 2006). In
addition to the initial deposition processes and the characteristics of the sediment,
important questions arise as to the nature of channel responses after the period of
aggradation has come to a close. Typically, channel aggradation in response to
accelerated sediment deliveries is followed by degradation when sediment loads
decrease. The processes and morphological characteristics of the degradation phase can
be highly variable and have been the subject of many studies. The channel evolution
model (CEM) is a well-known conceptual model in which channel responses follow a
prescribed sequence of processes and forms (Schumm et al., 1984; Simon and Hupp,
1986). This model has not only been widely adopted, but also evaluated (Van Dyke,
2013; Cluer and Thorne, 2014; Thompson et al., 2016).

2.2.2 HISTORICAL SEDIMENTATION IN THE PIEDMONT

The Piedmont physiographic province is the region between the low-lying
Atlantic Coastal Plain to the east and the Appalachian Mountains in the west. This was
an important agricultural area during the period of settlement, particularly in the
Southeastern states. Numerous early researchers studied the effects of agriculture on erosional and depositional processes in this region (Eargle, 1940; Happ et al., 1940; Happ, 1945; Ireland et al., 1939) and found a landscape marked by large gullies 3 to 12 m deep and extensive channel and floodplain aggradation. The history of land use is important to understanding these impacts to the South Carolina Piedmont. In contrast to the major trading centers in the Coastal Plain, such as Charleston, the Piedmont of South Carolina was rural during the antebellum period (1700s – 1860). European settlers of the Piedmont arrived from the north along the Appalachian Mountains and from the eastern Coastal Plain (Ireland et al., 1939; Trimble, 1974). Subsistence farms were created among the rolling hills, with cattle free-ranging in the woods and small crops of corn, wheat, and oats grown in valley bottom-lands (Ireland et al., 1939). Due to large distances to market and lack of transportation networks, most of the crops were sold locally. Cotton began to be produced in the region in the early 1800s but faced the same transport challenges (Ireland et al., 1939). Despite an increase in population and production in the late antebellum (1850-60), a lull in agriculture during and immediately following the Civil War resulted in much cultivated land returning to forest. With the introduction of local railways in the late 1860s, the area began an agricultural renaissance in the 1870s, with cotton and corn as the primary crops (Ireland et al., 1939). By the turn of the 20th century, 93.7 x 10^6 ha of cotton were under cultivation in South Carolina (U.S. Bureau of the Census, 1900). Extensive deforestation and a lack of erosion-control led to intense erosion that persisted into the 1930s. Ultimately, crop land in interfluve areas was severely damaged by rill and gully erosion and floodplains were buried by channel aggradation (Happ, 1945). As Trimble (1974) noted:
“Much of the Piedmont has been stripped of the topsoil, and many areas have been dissected and gullied so badly as to render the land unsuitable for agriculture. The debris from this erosion has filled stream channels and valleys to varying degrees, often swamping adjacent bottomlands.” (1974, pg. 1).

Following the 1920s, land degradation, erosion, emergence of the boll weevil (cotton pest), low commodity prices, and new technologies, resulted in a sharp agricultural decline in the Piedmont. Cropland areas decreased more than 50% in nearly every county (1925-1960) in the Southern Piedmont (Trimble, 1974). As cropland was abandoned, secondary ecological succession commenced with ground layer, shrub, understory, and canopy growth (Nicholson and Monk, 1974) that ultimately resulted in the reforested landscapes that dominate the region today. Most of the early work on erosion and sediment in the Southern Piedmont stalled as the United States entered World War II in 1941. Early work regarding legacy sedimentation also occurred in the Coon Creek basin in Wisconsin in the late 1930s and has continued to present, being one of the more important sites in measuring legacy sediment due to a historical data set (Trimble, 1983; 1999). What separated Coon Creek research from that of the South Carolina Piedmont, is that research was restarted post-WWII. The lack of post-WWII research in South Carolina, with the exception of Trimble (1974), presents a challenge and an opportunity for researchers to examine how reforestation and soil-conservation practices have shaped the landscape in the subsequent years.

Details about the timing and severity of erosion and sedimentation vary across the southern Piedmont region and are documented by modern studies in a few locations. Jackson et al. (2005) used stream-bank exposures and floodplain auguring along Murder
Creek, a moderately small watershed (490 km$^2$) in the Georgia Piedmont, to show that legacy sediment thicknesses were nearly uniform at an average of 1.6 m. Jacobson and Coleman (1986) describe the stratigraphy of legacy and underlying sediment from cutbank exposures and cores in seven small watersheds in the Maryland Piedmont. They found that lateral accretion and overbank legacy deposits were thicker than in pre-settlement alluvium due to large increases in sediment supply. They noted that processes later shifted from floodplain vertical accretion by fines to lateral accretion of sand and gravel as channels began to migrate laterally.

2.2.3 LEGACY SEDIMENTS AND FLOODPLAIN MORPHOGENESIS

Many investigations of anthropogenic sedimentation have focused on legacy sediment; i.e., sediment associated with human activities. Early floodplain soils were covered by sediment from interfluves during aggradation episodes. In the Piedmont, early scientists often referred to the legacy sediment as ‘modern sediment’ (Happ et al., 1940; Happ, 1945; Eargle, 1940) and in other regions it has often been described as post-settlement alluvium (PSA) (Knox, 1972; 1977; Magilligan, 1985). These deposits were often described in bank exposures of incised channels and from bore holes revealing the soil stratigraphy that showed historical floodplain sediment lying abruptly on top of dark gray soils (Happ, 1945; Knox, 2006). More recently, the term legacy sediment has been applied to sediment in mill-ponds (Merritts et al., 2011; Walter et al., 2007; Walter and Merritts, 2008) or to anthropogenic sediment in general (James, 2013; 2018). The broader definition allows for the possibility of pre-Columbian legacy sediments; that is,
anthropogenic sediment produced by indigenous people before the arrival of Europeans, such as the Mayan clay (Beach et al., 2006).

This study defines legacy sediment simply as anthropogenically derived sediments and applies the term to relatively young, post-colonial fluvial sediment. A buried Ab soil horizon often provides a distinct stratigraphic marker that can be interpreted as marking the pre-settlement surface due to its dark color, high organic content, and abrupt contact with overlying highly stratified deposits (Donovan et al., 2015, Happ, 1940, Knox, 1977). Sediment above the buried floodplain soils is interpreted as having been generated dominantly by EuroAmerican settlers; i.e., legacy sediment. Sediment below the buried soils are also described and interpreted in light of the possibility that pre-settlement human activity by aboriginals may have produced some degree of accelerated or anthropogenic sediment, although little evidence for this is seen. For the sake of clarity, this study applies the term legacy sediment only to the thick layers above buried floodplain soils that are interpreted as generated by settlers in the historic period.

The premise that sediment overlying buried soils is legacy sediment; i.e., anthropogenic, assumes that natural disturbances such as extreme floods, fires, or climate change were not the primary factor initiating sediment production. While it is not possible to completely eliminate natural processes as factors—especially as factors that may have acted in concert with land-use change—sedimentological and stratigraphic evidence, strongly support the interpretation that agricultural land-use, including forest clearance, was the primary factor that generated these changes. For example, the infrequent occurrence of charcoal in sediment does not support an interpretation based on
fire or landscape desiccation followed by fire. The physical sedimentology of floodplain deposits in bank exposures indicates that aggradation occurred primarily by repeated moderate-magnitude flow events rather than a few extreme discharge events. For example, plane-bedded tabular sets of thin strata (10 to 20 cm)—often with fining upward textures—are common, whereas large-scale cross-bedding or cut-and-fill structures are lacking. Details about sedimentological features are provided later that support these interpretations. Moreover, the occurrence of similar sequences over wide areas of the USA argue against explanations based on localized events such as fire or a large flood (Jacobson and Coleman, 1986).

![Diagram of Aggradation Degradation Episode](image)

**Figure 2.1 – Aggradation Degradation Episode (ADE) from James (2013)**

Many channels that have deposits of legacy sediments have undergone a morphogenesis that can be described as an aggradation-degradation episode (Fig. 2.1). This process describes the morphological changes to a channel system while undergoing aggradation, degradation, and subsequent widening in response to dramatic changes to sediment loads within the system (James, 2018). This process begins with an increase in sediment load that results in aggradation and subsequent overbank sedimentation. During
this aggradation stage, channel form may be modified in response to the changes in stream bed level, texture of bed and bank materials, or slope. Stream systems have been described as changing from a meandering, single-thread channel to a braided or multi-threaded planform during aggradation (Gilbert, 1917). After sediment loads begin to decrease and aggradation peaks, the channel often undergoes a period of degradation back through the aggraded sediments. Overbank sedimentation may decrease or cease altogether due to bed incision and floodplain abandonment as terraces that are colonized by vegetation. During incision, channels may again change planform. As the channel reaches its incised maximum (due to vertical constraint such as bedrock) it may begin to experience an increase in lateral mobility, thus slowly eroding the channel walls and creating a new floodplain within the incision. Lateral migration associated with widening may follow the sequence proscribed by the well-known channel evolution model (CEM) (Schumm et al., 1984; Simon and Hupp, 1986) and may continue until the channel has achieved a stable state in balance with the new loads of water and sediment. While not exclusively tied to anthropogenic driven sedimentation, ADEs represent drastic changes to sediment delivery rates.

2.2.4 OBJECTIVES

The purpose of this study is to examine contrasting sedimentation regimes during the pre- and post- colonial periods and to better understand the factors that control the distribution of legacy sediment on floodplains in the downstream direction. The physical sedimentology of deposits is described to compare legacy sediment with older units underlying buried soils. In addition, legacy sediment thicknesses exposed in incised
channel banks are examined for relationships with slope, valley width, and proximity to sediment sources. It is predicted that the thickness of legacy sediment will be variable throughout the study reaches, illustrating the heterogeneity of the system. Magilligan (1985) found a strong correlation between floodplain width and thickness of legacy sediment (post-settlement alluvium) and presented a theoretical floodplain sedimentation model that compares sediment mean depths to valley width. He suggested that areas with narrow valleys would have the thinnest deposits, and sediment thickness would increase in areas entering or emerging from valley constriction (Fig. 2.2). This model is tested with the legacy sediment thicknesses measured from stream bank exposures within the area of this study. The impacts of bedrock exposures will also be examined throughout the study reaches. These exposures provide a constraint on the depth of pre-settlement alluvium, depth of aggradation, and the magnitude of post-aggradation recovery.

Figure 1.2 - Magilligan (1985) Theoretical Floodplain Sedimentation Model
Figure 2.2 - Chicken Creek Watershed in the lower Piedmont of north central South Carolina, USA. The study reach (circle) is in the lower basin.

2.3 METHODS

2.3.1 STUDY AREA

The Chicken Creek Watershed is a relatively small watershed (15.2 km²) that lies in northwest Fairfield County of South Carolina within the Piedmont physiographic province (Fig.2.3). Evidence of post-colonial agriculture in the region can be dated back to early settlement around 1740 (Ederington, 1901). Agricultural land-use continued up to the late 1920s on much of the land. By the 1930s, however, lands in this area were severely damaged and much had been abandoned for cultivation. Large tracts of private
farmland were purchased in 1936 by the federal government as part of the Weeks Act for inclusion in the newly created Sumter National Forest (Shands, 1992). These tracts of land have since been recolonized by a dense hardwood forest (Fig. 2.4) (Alexander, 1997). This provides a rare opportunity to examine a severely aggraded channel and floodplain system that has had minimal human alterations over the past 80 years. There are no roads, trails, or evidence of logging or channel alterations in the study area, so this paper describes the responses of a deeply aggraded system following a long period of passive restoration. Previous investigations describe 2–3 m of legacy sediment aggraded onto older valley sediments in this basin in the first ½ km downstream of the SC Hwy 215 bridge (Alexander, 1997; James, 2006; 2011). The timing of episodic sedimentation and aggradation was estimated to have occurred between 1870 and 1930, as rapid agricultural expansion occurred after reconstruction (Ireland et al., 1939).

Dendrochronological evidence from Chicken Creek corroborates this estimate by demonstrating stabilization of the high historical terrace in the late 1930s (Alexander, 1997). The stream channel incised deeply at least 2.0 km downstream of the SC HWY 215 bridge, and sediment exposures that are prevalent throughout these reaches provide an opportunity to examine the spatial variability of both pre- and post-colonial floodplain sediments.
2.3.2 IDENTIFICATION OF PRE- AND POST-SETTLEMENT STRATAGRHAPHIC CONTACTS

Buried Ab soil horizons provide a distinct stratigraphic marker at many sites throughout the Chicken Creek study site (Fig.2.5). Additionally, artifacts of a former stable surface prior to aggradation, such as trees rooted in the underlying soil or human artifacts near the contact, can be used to help identify the former floodplain surface (Dotterwich et al., 2014). By identifying the sedimentary contact, pre-settlement floodplain alluvium below the soil can be contrasted with post-settlement alluvium; i.e., legacy sediment, above the soil.
The pre- and post-settlement alluvial sediments—based on this pedo-stratigraphic interpretation—were described and contrasted, and thicknesses of the sediment above the soil was measured with a fiberglass tape.

Figure 2.4 – Abrupt legacy sediment/pre-settlement alluvium contact at surface of Ab soil horizon (arrow).

In some locations, a thin layer up to ~0.5 m thick of sediment immediately above the buried soil is somewhat different than the rest of the sediment and appears to form a transition to the overlying legacy sediment. Several potential explanations for this transitional zone are discussed with the descriptions later. Transition zones, where present, were included in the measurements of legacy sediment thicknesses.
The contact between pre- and post-colonial sediments was determined visually by clearing bank exposures and searching for stratified tan to orange sediments overlaying a dark, organic-rich layer signifying an Ab horizon. Contacts between legacy sediment and older sediment were also identified by the presence of trees rooted on the pre-settlement floodplain surface (Fig. 2.6A, 2.6B). In a few locations (Fig. 2.6C, 2.6D), the underlying soil had a dense, orange to red argillic Bt horizon, indicating more advanced pedogenesis than most of the buried floodplain soils, which were most often weakly developed with an A/C profile.

Figure 2.5 - Soil stratigraphic relations in two stream-bank exposures. (A) 170 cm of legacy sediment over buried Ab horizon (left arrow). (B) close-up of buried tree trunk shown in A. (C) Legacy sediment over a well-developed soil with Ab/E/Bt horizon (D) close-up of soil horizons shown in C
Sediment samples were collected directly above and below the contact between pre- and post-colonial sediments and were analyzed using a combination of field and laboratory analysis. Three sites with clear exposures (i.e. lacking heavy roots or slumping of the channel wall), were selected to collect sediment samples for laboratory analysis. Two sites were sampled at a high resolution (20 cm intervals) and one site at a medium resolution (50 cm intervals) from the top of the high terrace down to bedrock.

Textural analysis of the samples was conducted using hydrometer analysis (Gee and Bauder, 1986) at the biogeomorphology lab at the University of South Carolina to determine percentages of sand, silt, and clay. The grain-size analyses were used to compare and contrast textural properties of sediment above and below the pre-settlement surface and in relation to their depth below the surface of the high terrace that had been the floodplain at the time of maximum aggradation. Additional comparisons were conducted by collecting bulk density samples at these sites with a cylindrical coring device by measuring dry bulk densities in the lab (Blake and Hartge, 1986).

Field analysis centered on measuring thicknesses of both pre- and post-colonial sediments, as well as depth from the high terrace down to bedrock. Most sediment depth or thickness measurements were made with a fiberglass tape from the top of the high terrace. Sites of these measurements were spaced at approximately 100 m longitudinal intervals throughout the study reach, which resulted in 13 study sites. Depth to bedrock was measured by taping distances to rock exposed in banks and depths below sandy bed materials determined by probing with a 2-cm diameter silt probe or with a shovel. Probe depths represent minimum thicknesses of bed material due to the potential for false refusals of the probe.
2.3.3 TOPOGRAPHIC AND SPATIAL MODELING

Light detection and ranging (LiDAR) topographic data were utilized to examine spatial patterns of alluvial sedimentation throughout the study area. LiDAR data for Fairfield County was acquired by Fugro EarthData, Inc. between January 15 and February 10, 2008 with a point cloud mean point spacing of 1.4 m. LiDAR bare-earth returns for the study area were extracted and interpolated using LP360 (QCoherent®) to create a digital elevation model (DEM) with a 1.4-m cell size. The DEM was used for multiple operations, including delineating stream channels and catchment boundaries, extracting longitudinal profiles of the stream channel and high terrace, and calculating floodplain widths and incised channel cross-sections. Delineation of stream channel networks and watershed boundaries was conducted using a combination of tools within the ArcGIS Spatial Analyst, Hydrology toolset (ESRI®) that were operated using Model Builder for repetitive processes. Longitudinal profiles of both the stream channel and the high terrace were created using a stream channel polyline and a polyline running parallel to the stream along the high terrace, respectively. These vectors were split into 25 m point increments and overlaid on the LiDAR DEM to extract elevations. For spatial analysis of legacy sediment thickness, valley widths and proximity to tributaries were measured from the LiDAR data. Floodplain widths were measured perpendicular to the valley using DEM overlays at 25-m intervals and distances from bank exposure sample sites and the apex of tributary fans were measured as a straight-line distance using the measurement tool in ArcMap (ESRI®) and recorded as ‘proximity to tributaries.’

Aerial photography of the study area from 1938 was acquired in order to observe land-use and channel changes. The photography was geo-rectified to the same projected
coordinate system (NAD 1983 State Plane, International Feet) as the 2008 LiDAR-derived DEM. Channels from the 1938 imagery were digitized and used to show lateral changes of the stream channel, corresponding with the approximate time that incision into legacy sediments occurred.

2.4 RESULTS

2.4.1 SOIL STRATIGRAPHY AND THICKNESS OF LEGACY SEDIMENT

Clear, abrupt contacts between the pre- and post-colonial sediment are often exposed in stream banks and high historic terrace scarps throughout the 2.0 km study reach. These contacts generally show a thick layer of stratified sandy sediment over the top of dark Ab-horizons (Fig.2.5). The stratified upper layers of sediment generally have weakly developed soil profiles at the surface with little bioturbation or other pedoturbation of distinct strata and are interpreted as historical deposits derived from accelerated erosion generated by post-colonial agriculture; i.e. legacy sediment. The buried pre-settlement soils typically consist of an Ab/C sequence, which is interpreted as a weakly developed floodplain soil. In some cases, the pre-settlement soil has a well-developed argillic Bt horizon that indicates an older surface interpreted as an alluvial terrace or colluvium on a valley side (Fig.2.7). Many of the buried floodplain soils are gleyed at the base and in some cases grade down to regolith or bedrock.
Figure 2.6 - Thin legacy sediment deposits may occur at bank exposure sites near valley walls where bedrock or pre-settlement terrace surfaces were higher than the pre-settlement floodplain. These sites also may have well-developed buried soils because they were older relict surfaces than the floodplain at the time of burial.

Longitudinal profiles of the channel and high terrace are essentially linear through the study reach regardless of substantial changes in valley width (Fig. 2.8). The high terrace is constantly ~4 m above the channel. Thicknesses of legacy sediment exposed in the terrace scarps are relatively constant and vary from 2.7 to 3.6 m except for three relatively thin exposures at 1200 and near 1600 m where the exposures are near valley walls. Thickness at sites near valley walls can be thin due to the channel having shifted over a higher point in the pre-settlement floodplain (Fig. 2.7). Additional variability in legacy sediment thickness can be attributed to a number of different factors, including valley width and proximity to ephemeral channels and gullies (Fig. 2.9). Field observations show that channels have incised to or near bedrock at several locations (Fig. 2.10), which suggests that vertical incision has largely ceased in the study area. Bedrock outcrops in the channel bed are typically metamorphosed rocks (primarily gneiss) with folia following local patterns of orientation (SW to NE). Locations of
bedrock outcrops define a pattern that appears to be related to reaches where the valley is narrow and are absent in wide floodplains (Fig. 2.8). This pattern suggests scour in valley narrows and pockets of deposition in wide valley sections, in conformance with Magilligan’s (1985) model. Although depths to bedrock between exposures are unknown, the outcrops constrain the minimum elevation of the pre-settlement longitudinal profile and indicate that it was no deeper than present.

Figure 2.7 – Longitudinal profile of Chicken Creek study area. Depths of the legacy sediment and pre-settlement soil contact below the high terrace maintain a relatively constant thickness except at 1200 m where the sample exposure site is against a valley wall.
A statistical regression analysis was conducted to examine potential factors governing legacy sediment thicknesses observed in the terrace scarps. Thicknesses were correlated with floodplain widths and proximity to tributary sediment sources (Fig. 2.9), and those two variables alone explained 18% of the variance in thickness. Three sampling locations within this set were within 5 m from the valley wall and had relatively thin deposits. A third explanatory factor was added to the regression as a dummy variable, which was set to one for the three sites <5 m from the edge of the floodplain and to zero for all other sites. Valley width was also modified from absolute width, to the change in width (dw/dx) to act as a better explanatory variable and to conform with
Magilligan’s floodplain sedimentation model. The floodplain sedimentation model expected that sediment thickness would increase in areas where the valley was either narrowing or widening; therefore, changing over distance as opposed to absolute. The resulting multiple regression resulted in an adjusted $R^2$ of 0.78 with residuals between predicted and observed thickness <0.49 m (Fig. 2.11).

Figure 2.9 - Locations of exposed bedrock in the stream channel
2.4.2 SEDIMENTOLOGY OF LEGACY SEDIMENT

To provide a sedimentological description of the deposits, sediment textures and bulk densities were measured for 40 samples at three sites and the physical sedimentology was described for the historical deposits and underlying sediment. Sediment texture analysis generally shows that pre- and post-colonial regimes at the three sites have similar mean grain sizes (Fig. 2.12). The samples were variable in texture but tended to have high percentages of sand (> 63 μm). Four of the legacy sediment samples at site W1 (Fig. 12B) had >30% clay and <40% sand, whereas the other four legacy
sediment samples at that site had <25% clay and >55% sand. This difference in legacy sediment texture at a single site represents the strong stratification of the deposit with a series of fining upward sequences that each begin with a sand layer and grade up to silts and clays. Overall, pooled sediment textures cannot be used to distinguish between the two sediment regimes, but the legacy sediment on Chicken Creek is much more stratified than pre-settlement sediment (Fig. 2.13) and this resulted in a greater range of mean grain sizes between samples. The samples at site W2 are fairly representative of the visual appearance of many exposed sections, with very sandy stratified legacy sediment overlying a massive unstratified layer of sandy loam and sandy clay loam that has much more sand and silt than the historical sediment. Channel cross-section morphology has been linked to the textures of bank materials. In particular, Schumm (1977) indicated that width/depth was inversely related to the percentage of silt and clay in the banks. Although this, together with the lack of change in mean grain size, could lead to the conclusion that the adjusted channel morphology will ultimately return to a pre-settlement shape, the high degree of stratification of legacy sediment in this area suggests that bank competency is now weaker than in pre-settlement banks.
Figure 2.12 – Soil Textural Analysis – A) Site U1 (samples taken at 20 cm intervals) B) Site W1 (samples taken at 50 cm intervals) C) Site W2 (samples taken at 20 cm intervals) D) All samples from all three sites
Figure 2.13 - Textural Analysis of Sites UC1, and W2
In some locations, the pre-settlement alluvium is buried by a layer of highly stratified sediment, ranging in thickness from 10 to 50 cm, that has higher concentrations of organic matter and other features that may differ from the bulk of the overlying legacy sediment. The slightly higher organics of some of these sediments, indicated by darker material, may represent an initial flush of top soil from a previously stable watershed. Where present, these zones are referred to as a transitional layer that may be interpreted in many ways, including pre-Columbian (indigenous) land-use disturbances, post-Columbian but pre-settlement EuroAmerican changes by itinerant trappers, or early EuroAmerican settlers who established sparse settlements and cleared small plots. Thin tabular plane-bedded sets of strata in the legacy sediment exposures indicate that deposition took place by a series of relatively small sedimentary pulses over a flat channel bed, rather than large bedforms in a deep flow. Repeated fining-upward sequences between sand and fines from 10 to 20 cm thick are common and flame structures in these tabs at one site suggest water escaping between events (Fig. 2.14). This evidence of gradual deposition supports an interpretation that sedimentation occurred in response to elevated sediment loads delivered by a series of moderate flow events over a period of time rather than sudden deposition by a single extreme flood or a few very large floods.
Bulk densities of five samples of legacy sediment (BD\textsubscript{L}) ranged from 1.235 g/cm\textsuperscript{3} to 1.368 g/cm\textsuperscript{3} and averaged 1.304 g/cm\textsuperscript{3}, whereas five samples of pre-settlement alluvium (BD\textsubscript{P}) ranged from 1.403 g/cm\textsuperscript{3} to 1.657 g/cm\textsuperscript{3} and averaged 1.512 g/cm\textsuperscript{3}.

Figure 2.14 - Examples of sedimentary structures with thin strata in legacy sediment. (A) Section with a transition zone ~0.5 m thick. (B) close-up of transition zone (between dashed lines). Pre-settlement sediment is below lower dashed line transit transition ends at upper dashed line with stratified tan silts and sands. (C) Second section with ~3 m legacy sediment. (D) close-up showing flame structures (above arrows labeled “F”).

The highest BD was for a sample from an argillic Bt horizon that was rich in clay and iron, but other BD\textsubscript{P} samples were consistently denser than legacy sediment. The average
BD_p without the sample of the Bt horizon was 1.476 g/cm^3, which is representative of most of the pre-settlement sediment. Samples collected above the pre-settlement alluvial contact showed a consistently lower density than for samples from below the contact (Fig. 2.15). The difference in means was tested for statistical significance using a two-tailed, equal variance t-test. Assumptions for the test were met and a Shapiro-Wilk normalcy test was completed to assure normalcy in the data set. The null hypothesis (H_0: BD_L = BD_P) was tested at the p<0.01 level. Using these parameters, the test generated a result of p = 0.004, therefore, the null hypothesis was rejected. A Wilcoxon rank sum test was also performed, generating very similar results. As might be expected for younger sediment that has not been deeply buried, the legacy sediment tends to have a lower density than the older, underlying pre-settlement alluvium. In addition to the implications of these differences in density regarding the evolution or identification of legacy sediment, bulk density is required to convert sediment volumes to mass, and few measurements have been reported in previous studies.

Figure 2.15 - Bulk Density of Legacy and Pre-Settlement Sediments
2.4.3 POST-AGGRADATION ADJUSTMENTS

Following the model of an aggradation-degradation episode and based on numerous bedrock exposures in the channel bed, these reaches of Chicken Creek have reached their maximum incision and are widening in response to this vertical constraint. Widening can be observed qualitatively in the channel, as numerous trees have fallen into and across the channel. These tree-falls destabilize the bank causing localized sloughing and recruitment of sediment into the active channel system. Additionally, the channel has created a narrow floodplain within the terraced incision, with point-bars, cut-banks, and occasional mid-channel bars. These fluvial features show that the channel is widening into the channel walls.

Comparison of stream channel positions delineated from 1938 aerial imagery and 2008 LiDAR imagery reveals lateral channel change in some locations (Fig.2.16). Of particular interest in this regard is the area along the upper Chicken Creek Branch (the Eastern branch) upstream of the confluence with Storm Branch and downstream of Highway 215. Two lines of evidence indicate that the channel in this reach incised into the valley wall to the south of the original channel location. Figure 2.16 shows the change between channel locations with the 1938 channel delineated in red, and the 2008 LiDAR-derived channel in blue delineated. In addition to the remotely sensed change detection, the stream-bank stratigraphy reveals a well-developed soil with shallow legacy sediment on the south bank that is deeper on the north bank indicating that the channel incised into a colluvial slope. Two sets of culverts under the Highway 215 bridge, which were constructed in 1927, indicate that the north branch was still present, but a lower south branch had formed by that time. Construction plans indicate that an engineered
channel change may have occurred (Fig. 2.17) Additional evidence of the channel having previously been further North than its current location can be seen in LiDAR shaded relief models as a series of small parallel ridges, which also suggests the possibility of a multi-threaded channel at the location the time of maximum aggradation. (Fig.2.18).

Figure 2.16 - Lateral change detection. 1938 stream shown in RED, 2008 LiDAR-delineated stream shown in BLUE
Figure 2.17 – 1927 bridge construction plans of SC State Highway 215 over Chicken Creek. “Make Channel Change” highlighted.

Figure 2.18 - Ridge features representing possible historic channel locations
2.4.4 DISCUSSION

An initial objective of this study was to compare the thicknesses of pre-colonial sediment to the thickness of legacy sediment. The nature of pre-settlement channels in the southeastern Piedmont has long been an open question. Were the channels scoured to bedrock with low riparian wetlands or high forested banks? Were the channels themselves wetlands or beaver ponds? The bank exposures in Chicken Creek allowed a rapid assessment of these conditions. Preliminary measurements of pre-colonial thicknesses above bedrock were insufficient for a complete analysis and there is a bias toward thin observations at valley narrows because thick layers prevented measurement to bedrock by the method used. Nevertheless, the overall signal from these measurements is that the pre-settlement soil ranged from 1.1 m to 2.3 m (mean= 1.5 m) above bedrock, which is 1.25 m less than the mean LS thicknesses. From this it can be concluded that pre-settlement alluvium was substantially thinner than legacy sediment in valley narrows.

The pre-colonial stratigraphy did not provide much clear evidence of forested wetlands. Sediment near the low-flow water level was usually gleyed, but a limited amount of wood was found in the banks, except for a few tree stumps near the present low-water level. The stumps were generally a meter below the pre-colonial soil suggesting a low woodland that was subsequently buried by pre-colonial sediment with enough time for the buried pre-settlement Ab soil to form. One small stump in the channel bed showed evidence of beaver gnawing (Fig.2.19). The silty sediment stratigraphically overlying the stump suggests that pre-colonial sedimentation at that site may have occurred in beaver ponds. In general, however, attempts to characterize the pre-
colonial environment of the Chicken Creek bottoms as wetlands, emergent forest, or bedrock required oversimplifications of the contrasting sedimentation environments that were observable. Apparently, the pre-colonial stream banks varied substantially in the downstream direction between thin marshy alluvium to well-drained banks with dark Ab horizons that indicate non-saturated pedogenic processes.

Figure 2.19 - A stump ~1 m below the legacy sediment/pre-colonial alluvium contact that was apparently gnawed by a beaver (Castor canadensis)

Given the variability of conditions across short distances in this watershed, conceptual generalizations that postulate a uniform environment across multiple watersheds in the Piedmont region seem unrealistic.
2.5 CONCLUSIONS

This study area provides a rare opportunity to examine legacy sediment deposits and the pre-settlement floodplain surfaces below on a reach scale. Not only has the channel incised deeply to expose the sedimentary record, but government purchase of the land and lack of development or public access has allowed the channel and floodplain system to respond to natural recovery processes without further human changes. In essence, this site represents a controlled outdoor experiment where approximately 80 years of recovery from extreme anthropogenic sedimentation can be observed. Legacy sediment deposition and subsequent stream incision and floodplain morphogenesis are highly variable processes that are influenced by a variety of factors. This study examined these processes in a small catchment with a continuous thick deposit of anthropogenic sediment. It is clear from these observations that legacy sediment thickness is not uniform throughout the stream reach but changes in thickness visible in terrace-scarp exposures can be explained by a number of variables. Proximity to sediment sources and valley width control much of the depositional variability. However, superimpositioning the channel onto hillslopes or terraces may result in thin deposits of legacy sediment. Sediment textural comparisons between legacy deposits and the underlying sediment show no significant differences in mean grain size. Both sedimentary regimes have high percentages of sand and some samples have high clay contents, so sample mean grain sizes cannot be used to distinguish legacy sediment from earlier alluvium. The distinguishing feature between the two units is that legacy sediment is often highly stratified with laminae or alternating sand-silt layers representing fining upward sequences during aggradation. Bulk densities of legacy sediment are significantly less
than pre-colonial sediment. This may help to distinguish between sedimentation regimes quantitatively and it certainly makes a difference to conversions of sediment volumes to mass.

Chicken Creek underwent a substantial transformation as a result of tremendous increases in sediment in the late 19th and early 20th centuries. After a period of rapid aggradation, the channel began to incise back toward its original bed level. In some cases, this degradation occurred offset from the original channel location, and these lateral position changes can be seen in both terrace scarp exposures of the former floodplain stratigraphy and in a comparison of 1938 and 2008 delineated channels. After relatively rapid vertical channel incision, qualitative evidence suggests that incision has slowed or ceased, and where bedrock is exposed in the channel bed in some locations incision has ceased. In some areas localized widening is clearly occurring and facilitating the creation of a new lower floodplain surface.

Continued research should further monitor floodplain and channel morphogenesis within the watershed and monitor the long-term responses of the system to anthropogenic changes.
CHAPTER 3
CONCLUSION
The study area in the preceding manuscript provided a rare opportunity to examine legacy sediment deposits and the pre-settlement floodplain surfaces below over nearly 2 km of stream. Not only has the channel in that area incised deeply to expose the sedimentary record, but forest service purchase of the land and a lack of modification or public access has allowed the channel and floodplain system to recover relatively naturally without further human changes. In essence, that site represents a controlled outdoor experiment where approximately 80 years of recovery from extreme anthropogenic sedimentation can be observed.

This research is important in helping to document the drastic impacts that European settlers imposed on the landscape during colonization of the Americas. While this study only represents the impacts of humans on one watershed, many of these impacts have been documented across the southeast and beyond. Undoubtedly many more areas exemplifying rapid geomorphic change remain unstudied and may in the future be important in better understanding the human impact on the landscape.

Continued research should further monitor floodplain and channel morphogenesis within these watersheds and monitor the long-term responses of the system to anthropogenic changes. This will not only help to understand the pre-settlement condition of the floodplains but will also be important for practitioners in restoration activities in the years to come.
REFERENCES


