

HISTORIC SEDIMENTATION AND ALLOSTRATIGRAPHY OF THE SOUTH  
FORK BROAD RIVER, NORTHEAST GEORGIA

by

KARIN PREST LICHTENSTEIN

(Under the Direction of DAVID S. LEIGH)

ABSTRACT

The arrival of Euro-American agricultural practices (circa A.D. 1820) to the southern Piedmont introduced landuse change that caused rapid floodplain sedimentation in the South Fork Broad River. Stratigraphic sampling of 34 sites indicates that the average thickness of historic sediment stored within the valley bottoms is 0.89 m. A volumetric analysis using GIS indicates that historic (A.D. 1820 - A.D. 2001) sediment yields were greater than 829 tonnes/km<sup>2</sup>/yr. An allostratigraphic framework is applied to the recent floodplain sediment and is based on lithology, unconformable boundaries, landscape morphology, and relative pedogenic development. Accompanying factors such as texture, color, stratigraphic position, radiocarbon dates and organic carbon content are also used for classification. The use of GIS applications and allostratigraphy provides information about pastwere

HISTORIC SEDIMENTATION AND ALLOSTRATIGRAPHY OF THE SOUTH  
FORK BROAD RIVER, NORTHEAST GEORGIA

by

KARIN PREST LICHTENSTEIN

B.S., Union College, 1998

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial  
Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2003

© 2003

Karin Prest Lichtenstein

All Rights Reserved

HISTORIC SEDIMENTATION AND ALLOSTRATIGRAPHY OF THE SOUTH  
FORK BROAD RIVER, NORTHEAST GEORGIA

by

KARIN PREST LICHTENSTEIN

Major Professor: David S. Leigh

Committee: Steven M. Holland  
Larry T. West

Electronic Version Approved:

Maureen Grasso  
Dean of the Graduate School  
The University of Georgia  
May 2003

DEDICATION

Let the downpour roil and toil!  
The worst it can do to me  
Is carry some garden doil  
A little nearer the sea.

*In time of cloudburst*

Robert Frost

## ACKNOWLEDGEMENTS

Many people have supported me with the completion of this project and I would like to thank everyone for their help and encouragement. I would like to thank Earl Hayter and Steve McCutcheon from the US EPA Region 4 and the National Network for Environmental Management Studies (NNEMS) Program (#2001-3016 Environmental Science) for providing me with such a valuable opportunity to work in the South Fork Broad River. I was also privileged to have received support from the UGA Geology Department Wheeler-Watts Fund and I would like to extend my thanks for this aid.

I would also like to thank Frank Stroik, Clay Gross, Becky Cerajewski, Jessica Allen, John Allen, Monica Carroll, Veronica Ciavarella and James Rogers for all their hard work in the field. It is deeply appreciated. Robert Black and Don Norris (US EPA Region 4 ORD) offered their invaluable knowledge of GIS. I would like to acknowledge Patrick Davies and Kim Byne for helping with the carbon analyzer. My friends and family have provided constant encouragement throughout the course of this project and I would like to extend many thanks to them as well.

I would like to sincerely thank my committee members Dr. Larry West and Dr. Steven Holland for their guidance and valuable suggestions during this research process. Yet, I would also like to express my deepest gratitude to my major professor, Dr. David Leigh, for his indispensable advice, support and enthusiasm throughout the course of this project. I especially appreciate the encouragement and guidance he provided in the field, the laboratory, and throughout my studies at UGA.

## TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	v
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
CHAPTER	
1 INTRODUCTION.....	1
Project Objectives.....	1
Research Questions.....	2
Location and Site Description.....	3
2 BACKGROUND AND LITERATURE REVIEW.....	6
Introduction.....	6
Models of Landuse Change.....	8
Stratigraphy.....	10
The EPA and the SFBR TMDL Project.....	12
3 RESEARCH METHODOLOGY.....	16
Introduction.....	16
Field Techniques.....	17
Stratigraphic Delineation and Allostratigraphy.....	23
Particle Size Analysis.....	25
Organic Carbon Analysis.....	26

	Radiocarbon Dating.....	27
	Calculating Sediment Volume and GIS Applications.....	28
	Volume and Sediment Yield Estimates.....	32
4	RESULTS.....	34
	Allostratigraphy.....	34
	GIS, Volume and Sediment Storage.....	53
5	DISCUSSION.....	60
	Allostratigraphy.....	60
	Volume and Sediment Storage.....	62
6	CONCLUSIONS.....	68
	REFERENCES.....	72

## LIST OF TABLES

	Page
Table 1: Parameters used for sample placement within the SFBR.....	18
Table 2: Parameters of each sample location.....	19
Table 3: Typical soil descriptions from the SFBR.....	22
Table 4: Percent Sand for cores SFBR 17.8 and SFBR 19.....	42
Table 5: Percent Organic Carbon for cores SFBR 17.8 and SFBR 19.....	44
Table 6: Statistical results on organic carbon of LOI and carbon analyzer.....	46
Table 7: Radiocarbon Dates.....	48
Table 8: Statistical results on color of allostratigraphic units.....	49
Table 9: Statistical results on field texture of allostratigraphic units.....	50
Table 10: Physical parameters from GIS measurements.....	51
Table 11: Coefficients of determination ( $r^2$ ) on physical parameters.....	52
Table 12: Areal extent of historic alluvium for seven GIS models.....	54
Table 13: Volume estimates for the SFBR.....	55
Table 14: Erosion estimates for the SFBR.....	56
Table 15: Sedimentation rates for the SFBR.....	59

## LIST OF FIGURES

	Page
Figure 1: Location of the South Fork Broad River watershed.....	4
Figure 2: Floodplain development model (Jacobsen and Coleman, 1986).....	11
Figure 3: Ratio of crop land to unimproved land for Madison and Oglethorpe Co.....	14
Figure 4: Gully location map (Eargle et al., 1939) .....	31
Figure 5: Photograph of cutbank, site SFBR 19 .....	38
Figure 6: Schematic cross-section of site SFBR 17.....	39
Figure 7: Schematic cross-section of site SFBR 39.....	40
Figure 8: Cumulative percent sand, silt and clay for sites SFBR 17.8 and SFBR 19.....	43
Figure 9: Percent organic carbon for sites SFBR 17.8 and SFBR 19.....	45

## CHAPTER 1

### INTRODUCTION

#### Project Objectives

Many watersheds in the southern Piedmont have been directly affected by human-induced sedimentation from agricultural practices during early European-American settlement. Such agricultural practices include clearing land for cotton farming as well as the failure to apply soil erosion prevention techniques. This neglect caused large amounts of soil to be removed from unprotected hillslopes and washed directly into streams, leaving the land bare and exposed. Trimble (1974) estimated that between A.D. 1800 and A.D. 1970, the loss of soil accumulated up to six cubic miles of material, or an average depth of 7.5 inches from the surface of the Piedmont in Georgia. This increase in soil erosion in many Georgia watersheds caused numerous stream channels to aggrade and subsequently degrade, directly influencing channel form and morphology (Trimble, 1974).

The impact of accelerated sedimentation during historic times (approximately A.D. 1820 to A.D. 2001) in Georgia has become of recent interest because of the relationship between stored sediment, current sediment concentration, and stream health. Like many other streams throughout Georgia and the Southeast, the South Fork Broad River watershed has appeared in the spotlight because of the increased awareness

of this relationship. Thus, the historical sediment that has been stored in the reaches of the South Fork Broad River has become of great interest to the Athens EPA Office of Research and Development (ORD) in their analysis of present-day sediment pollution of the river.

This project will examine the impact of historic sedimentation in the South Fork Broad River. The first objective of the project is to create a stratigraphic framework for the South Fork Broad River using distinct geomorphic surfaces and soil development to define boundaries of alluvial allostratigraphic units. Secondly, this project aims to aid the Athens EPA (ORD) in their Total Maximum Daily Load (TMDL) analysis of sediment by measuring the thickness and volume of the historical sediment in the South Fork Broad River basin, thus augmenting a sediment budget model for the watershed with historical data. I hypothesize that:

- 1) the floodplain sediment in the South Fork of the Broad River can be defined by the subdivision of alluvial allostratigraphic units, and
- 2) the research will provide a better understanding of the storage and lithology of historic sediment that accumulated because of erosional agricultural practices on hillslopes in the drainage basin.

### Research Questions

The following are research questions that guided the project in the South Fork Broad River:

- How can the historic and pre-historic units be categorized within an allostratigraphic framework?
- How are historical sediments typically distinguished from pre-historic sediments, both in the field and in the laboratory?
- What are the general characteristics of stored historical sediment and how has it shaped the landscape and morphology of the South Fork Broad River?
- What is the approximate volume of historical sediment stored in the floodplains of the South Fork Broad River?
- What are the implications for the assessment of the Total Maximum Daily Load (TMDL) of sediment?

### Location and Site Description

The South Fork Broad River basin forms a dendritic drainage network northeast of Athens, Georgia (Figure 1). It covers approximately 453.25 km<sup>2</sup> (175 mi<sup>2</sup>) within Madison and Oglethorpe counties and drains directly into the Broad River basin (US EPA, 2000). The elevation ranges from 128 m to 287 m above sea level (Stoughton, 2000).

### *Landuse*

Landuse within the South Fork Broad River consists mostly of pasture and forest and the watershed exhibits minimal amounts of cropland and urban growth. Forested lands mostly include a mix of pines and hardwoods. Within the past 50 years, forested lands have increased from 44% in 1944 to 67% in 1993 (Stoughton, 2000).

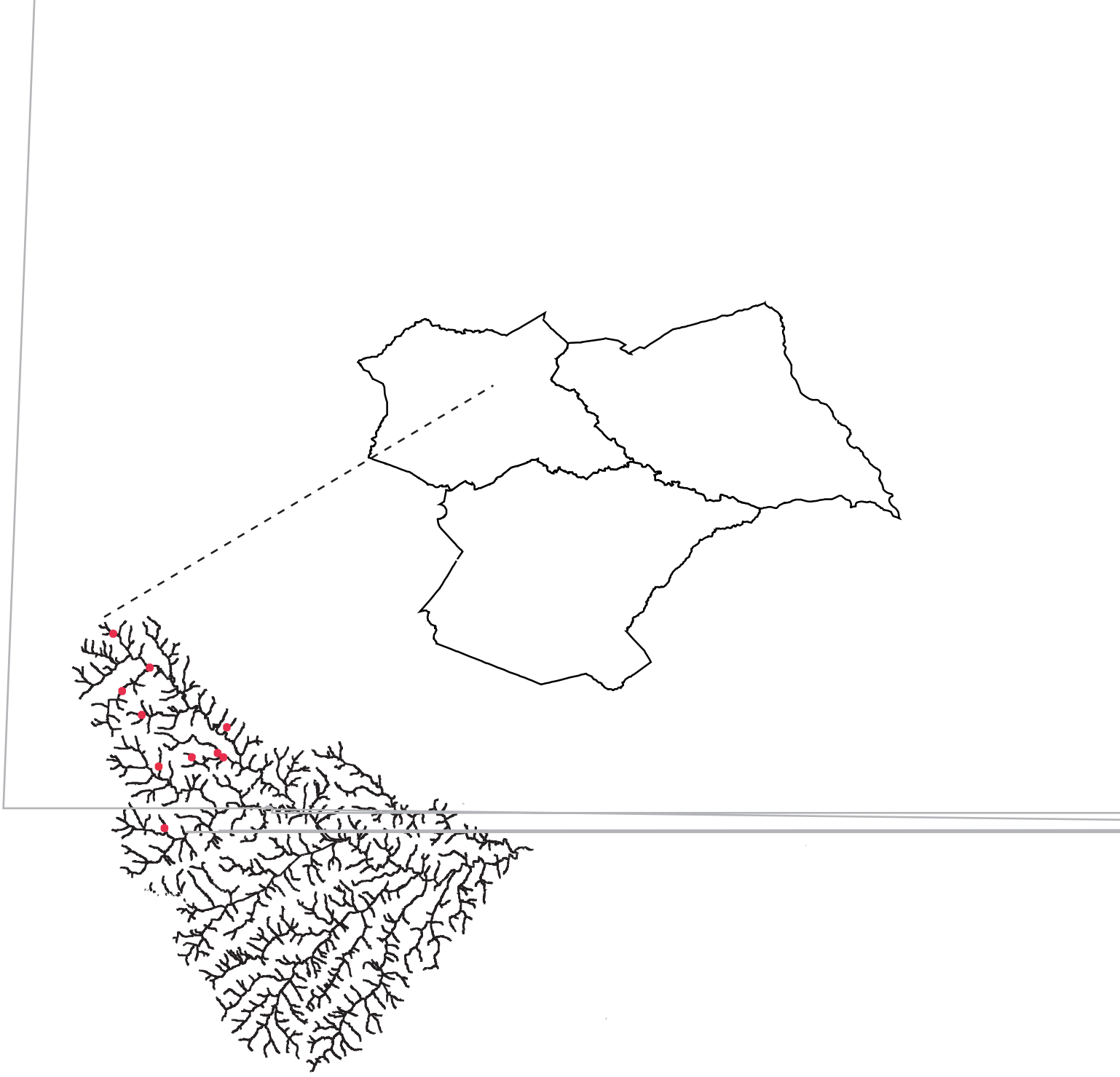


Figure 1.

### *Geology and Soils*

The South Fork Broad River watershed lies within the Piedmont physiographic province. The Piedmont has its western boundary in Alabama where it pinches out between the Valley and Ridge and the Coastal Plain and extends northward to New Jersey. The Piedmont is a region of moderate-to-high-grade metamorphic rocks, such as schists and gneisses as well as igneous rocks like granite (Colquhoun et al., 1991).

Topographically, the Piedmont is comprised of rolling hills and shallow valleys. The soils within the Piedmont are typically Ultisols that are red in color and consist of quartz, the khandite-group clays (kaolinite, halloysite, dickite), and of iron-oxides (Colquhoun et al., 1991). The red color is the result of intense weathering of feldspar-rich igneous and metamorphic rocks. Soils in the floodplains of the South Fork Broad River tend to be loamy alluvial Entisols (Typic Udifluvents) and Inceptisols (Typic Dystrochrepts) and differ from the Ultisols that appear on ridgetops or slopes of the uplands.

### *Climate*

With the Atlantic Ocean 200 miles to the southeast, the Gulf of Mexico 275 miles to the south, and the southern Appalachian Mountains to the north and northwest, the climate of northeast Georgia tends to be fairly mild. Summers are warm and humid with an average temperature of 25.5°C and winters are mild, averaging about 6.8°C. The mean annual precipitation is 126 cm (mostly through April to September) and the mean annual snowfall is 7.11 cm ([www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)).

## CHAPTER 2

### BACKGROUND AND LITERATURE REVIEW

#### Introduction

It has been recognized that the majority of land in the southern Piedmont was covered by forest before early settlers arrived. William Bartram described the land in one of the few accounts about the Georgia Piedmont prior to European-American settlement (circa 1777) as “uneven, by means of ridges or chains of swelling hills and corresponding vales [valleys], with level downs; the soil a loose, grayish brown loamy mound on the hills, but darker and more cohesive and humid in the vales and downs... ”(Harper, 1967). Bartram traveled through present-day Madison County, depicting part of the South Fork Broad River valley as rolling hills covered with dense vegetation (Harper, 1967):

“This branch of Broad River is about twelve yards wide, and has two, three, and four feet depth water, and winds through a fertile vale, almost overshadowed on one side by a ridge of high hills, well timbered with Oak, Hiccory, Liriodendron, Magnolia acuminata, Pavia sylvatica, and on their rocky summits, Fagus castania, Rhododendron ferruginium, Kalmia latifolia, Cornus Florida...”

Bartram described a branch of the Ocmulgee as “a glittering wavy flood passing along actively over a bed of pebbles and gravel” (Harper, 1967). Thus, it has been presumed that the rivers and streams of the southern Piedmont were clear and relatively deprived of suspended sediments prior to the onset of European-American farming, because the forest cover was not conducive to overland flow and erosion. However, the untouched and pristine environment became severely disrupted by the 1820s by extensive row cropping for the cotton and tobacco industries. The invention of the cotton gin (circa 1807) accelerated the production so rapidly that by 1849 cotton had the greatest export value of any agricultural commodity in the United States (USDA, 1900-2001) and large amounts of forested land were converted to cleared agricultural land. The Georgia landscape was directly impacted by this growth in the cotton industry and in many areas the erosion of topsoil left some of the land unsuitable for farming in subsequent years (Trimble, 1974). The erosive farming practices of the cotton and tobacco industries also increased the occurrence of gullies, and therefore significantly contributed to the removal of upland soils. The accelerated erosion from the uplands choked stream channels and lowlands with sand and consequently changed the form of many rivers and tributaries within the Georgia Piedmont by aggrading the stream banks and causing pronounced natural levee and floodplain sedimentation.

A good example of the impact of increased erosion from the introduction of agricultural practices is from the Soap Creek watershed in eastern Georgia, where Oppenheim (1996) found that the historic sedimentation occurred during a brief time period. She was able to divide this accelerated sedimentation into three time intervals: (1) from 1800-1850, when minimum change in sedimentation occurred, (2) from 1850-

1930s, when the peak of cotton agriculture took place and sedimentation rates were found to be close to 2.0 cm/yr, and (3) from the 1930s to the present, when increased recovery of natural vegetation and the implementation of soil conservation practices began. The result of the changes in land use undoubtedly altered many alluvial systems in Georgia.

### Models of Landuse Change

The change in channel form due to accelerated erosion has been modeled extensively throughout the Southeast and the Mississippi Valley. The following section outlines some of the leading research done on erosive land use and their results.

#### *Channel Form*

A model summarized by Trimble (1993) outlined the effect of human-induced accelerated erosion to a fluvial system in southwestern Wisconsin. This sediment budget model implied that a pulse of sediment from increased erosion in the uplands would move through the fluvial system. The eroded sediment would begin residence in the smaller tributaries and move through the upper main valley into the lower main valley, where it would then be stored within the larger floodplains. Thus, the smaller tributaries would experience aggradation before the lower valley reaches at the onset of the erosive practice.

Other models and conceptual ideas have been formed regarding the reaction of stream valleys to accelerated erosion from anthropogenic influences. In Knox's (1987) work in the Lead-Zinc District of the Upper Mississippi Valley, he examined the reaction of tributaries and main channels after a period of accelerated erosion. Using trace metals as relative age indicators, Knox (1987) determined that the tributaries initially aggraded

with the introduction of cropland and experienced incision relatively soon afterwards. Similar work was completed by Miller et al. (1993) in the Drury Creek watershed of southern Illinois. There, it was shown that deforestation and erosive land-use practices caused valley floor aggradation followed by channel entrenchment due to reduced sediment yields.

In Costa's (1975) work in the Maryland and Virginia Piedmont, the author proposed a model of stream response that is initially characterized by stable floodplain conditions during the pre-settlement era, followed by heavy stream aggradation due to forest clearance with the onset of agricultural practices. Owing to decreased sediment loads by the 1900s, scouring and increased incision occurred in many streams following the heavy aggradation. Yet, the author concluded that almost two-thirds of the sediment that had eroded as a result of the introduction of tobacco agriculture might still be stored in the floodplains of many watersheds.

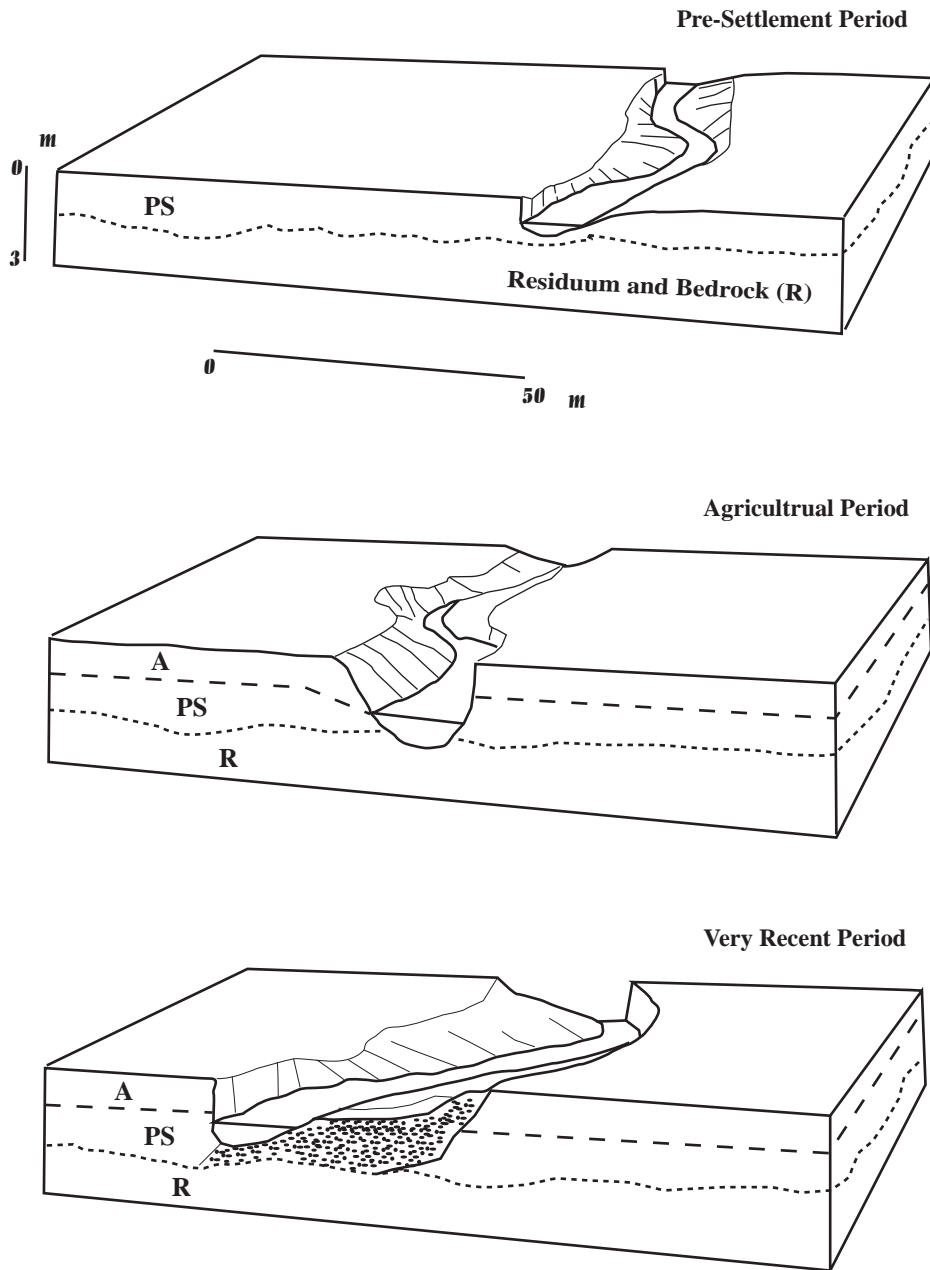
The literature indicates that increased sediment loading from upland erosion can cause an increase in floodplain sedimentation. Once erosive practices begin to decline, incision occurs and leads to a redeposition of sediment downstream. Thus, it is necessary to put this process into perspective, especially with respect to historic agricultural practices in the Southeast. It is important to acknowledge the amount of historic sediment remaining in storage, the relationship of this volume to past sediment yield, and what that relationship implies for current sediment yield analysis.

## Stratigraphy

Stratigraphy can be used to define the impact of pronounced sedimentation on an alluvial system. In fact, several authors have defined alluvial stratigraphic sequences by using “one or more dated proxy records that document change of an external variable that may influence alluviation” (Frederick, 2001). A good example of this external variation is the deforestation that occurred in the southern Piedmont in the mid-1800s.

The stratigraphic model proposed by Jacobson and Coleman (1986) examined floodplains in several reaches of a Maryland Piedmont drainage network in order to characterize three different stages of historic land use (Figure 2). It was determined that the first period of deposition was classified as a pre-European-American settlement unit that consisted of thin, fine, overbank sediments on top of laterally-accreted sand and gravel. The second period was classified as greater land use, increased runoff, and thus more sediment supply. This stratigraphic unit (circa A.D. 1730 to A.D. 1930) shows fine overbank sediment deposits and laterally accreted sands. The final stage of land use (after A.D. 1930) was indicative of farm abandonment and the introduction of soil conservation practices, therefore producing a much lower sediment yield and lower accumulation rates. Jacobsen’s model is one of several that provide a framework for applying stratigraphic sequences to land use change and it may resemble other catchments in the Southeast because of similar landuse and historic agricultural practices.

Like Jacobsen and Coleman (1986), Autin (1992) used stratigraphy to express the evolution of alluvial environments in the middle Amite River in southeastern Louisiana. In this study Autin (1992) designated three separate allostratigraphic units within the drainage basin that were based on “unconformable boundaries, landscape morphology,



**Figure 2.** After Jacobsen and Coleman (1986). Floodplain development model. Pre-settlement (PS), Agricultural Period (A), Very Recent Period (VR).

and relative pedogenic development”. Autin (1992) found that allostratigraphy proved to be an advantageous approach for modeling alluvial landscapes rather than using terraces, facies, morphostratigraphic units, or fluvial associations as indicators. This is because allostratigraphy conforms to a formal classification (North American Commission on Stratigraphic Nomenclature, 1983); it provides a genetic association of stratigraphic units to a specific time interval; it presents a relation between units and a particular fluvial process; and applies the use of a geologic chronology to the units (Autin, 1992). Therefore, allostratigraphy can provide a basis for using three-dimensional sedimentary units to summarize basin evolution and chronology, as well as past channel form.

Thus, the procedures used in Autin’s (1992) study to express floodplain and basin evolution using allostratigraphy may be ideally suited to model the impact of agriculturally induced erosion in the Southern Piedmont. This is because it provides a method that can characterize historic channel form by using geologic units that are genetically associated, but that are separate sedimentary components and are defined by “three-dimensional sediment bodies, [with] a basal unconformity” (Autin, 1992). This basal unconformity may be interpreted, as seen in Jacobsen and Coleman (1986), as the contact between a pre-settlement floodplain unit and a historic floodplain unit.

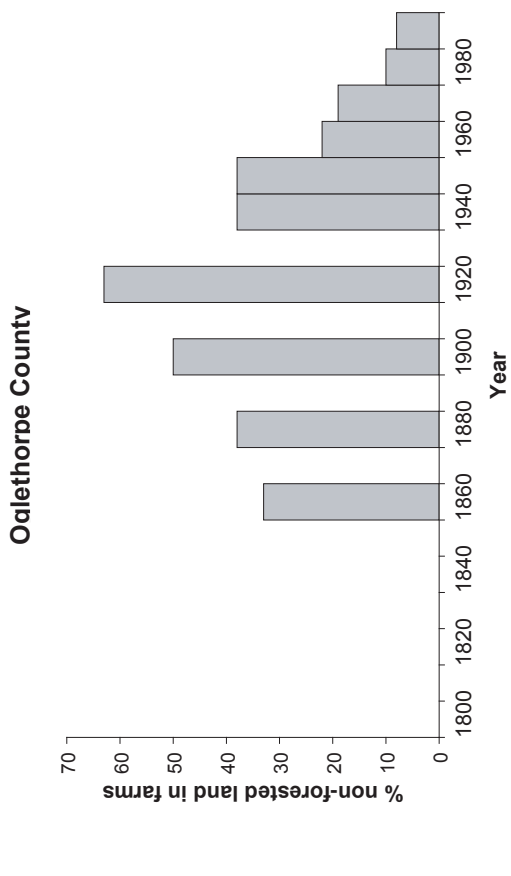
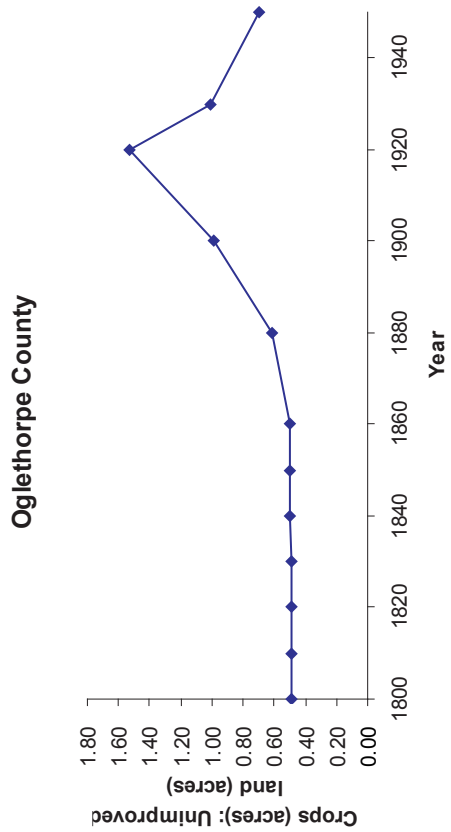
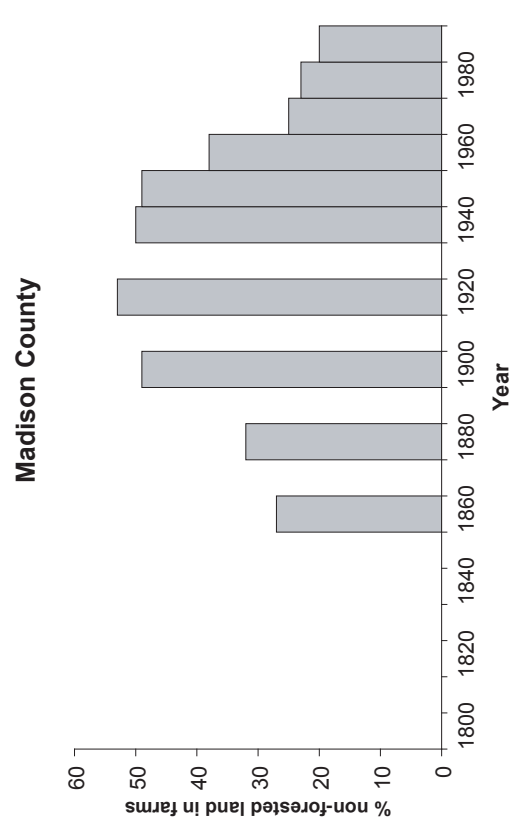
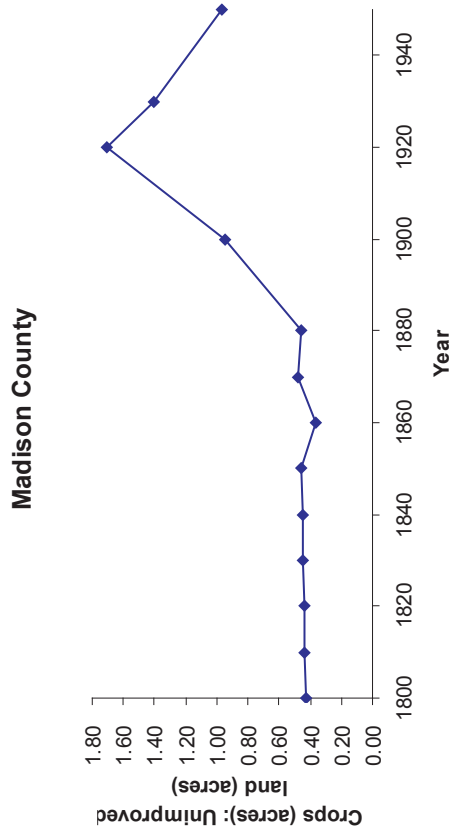
#### The EPA and the SFBR TMDL Project

As a result of human-induced erosion and the subsequent decline of such agricultural practices in the southern Piedmont of Georgia, the South Fork Broad River basin of northeast Georgia has been significantly altered. In Madison and Oglethorpe

Counties, there was a significant increase in population and an increase in the conversion of forested land to cropland in the 1800s (Figure 3) (USDA 1900-2001, <http://fisher.lib.virginia.edu/census/>). This land clearing and erosive practices directly changed channel form and floodplain storage within the channel. The historic sediment that has been stored in the reaches of the South Fork Broad River has become of great interest to the Athens EPA (ORD) in their analysis of present-day sediment pollution of the River.

Sediment has been considered one of the largest sources of non-point source pollution in the Southeast in recent history. According to the “EPA Proposed TMDL Development for Sediment for the South Fork Broad River (US EPA, 2000)”, Section 303(d) of the Clean Water Act (as Amended by the Water Quality Act of 1987), each state is required to identify waters where water quality standards are not being met. In order to maintain water quality, the Total Maximum Daily Load program was introduced for all pollutants causing the violation of water quality standards. From the use of the TMDL program, each state will be able to establish water-based controls so that pollution can be reduced. According to this proposal (US EPA, 2000), the South Fork Broad River was included in Georgia’s TMDL project because of “biological impairment”, but no definite determination was made about the type of pollutant that was contaminating the River. The Athens EPA (ORD) currently believes that sediment may be the cause of the impairment of the South Fork. However, the current sediment loading of the River is not known, owing to the small amount of water quality data that is available.

The TMDL research proposed by the EPA intends to estimate the stream loading capacity, the “relative impact of point source contributions” and an “estimate of some of



**Figure 3.** Ratio of crop land (acres) to unimproved land (acres) and % non-forested land in farms for Oglethorpe and Madison Counties, Georgia. The trend clearly illustrates the increase in agricultural activity beginning in the mid-1800's (USDA, 1999-2001).

the possible non-point sediment sources”. According to the proposal (US EPA, 2000), some unknown sources for the possible exceedence of loading capacity may be erosional processes within the watershed (including unpaved roads and lack of riparian buffer zones) or internal fluvial processes (such as eroding stream banks or down-cutting).

e

## CHAPTER 3

### RESEARCH METHODOLOGY

#### Introduction

The intent of this project in the South Fork Broad River is to determine the volume of historical sediment stored in floodplains, as well as assigning a stratigraphic framework to the alluvial sediment. This procedure involves field, lab and computer techniques. Field and data collection included auger tests, cutbank descriptions, core descriptions, and the overall identification of the historic-prehistoric stratigraphic boundary. Lab techniques involved sediment and particle size analysis, organic matter analysis, and radiocarbon dating. Computer procedures for this project included the use of Geographic Information System (GIS) analyses using ArcView 3.2® and Erdas IMAGINE 8.3®, specifically of determining areal extent and volume of historic sediment stored in the floodplains.

## Field Techniques

### *Sampling Scheme*

A preliminary phase of this project was to assign a sampling strategy to determine cross-section and point sample placement throughout the basin. The stratified random sampling strategy included 34 auger test sites of the main stem and tributaries, one valley cross-section of the main stem, one valley cross-section of a larger tributary, and two well-exposed cutbank sites.

Sample placement was based on drainage area and the two-year flood recurrence interval flood discharge to insure complete sampling of the stream network. This scheme used the two-year recurrence interval flood frequency equation for each drainage area within the South Fork Broad River, and the resulting discharges (cfs) were used to sort the tributaries in a hydrological manner (Table 1). For this region of northeast Georgia, the following equation (Equation 1) (Stamey and Hess, 1993) was used:

$$Q=182A^{0.622} \text{ (where } Q = \text{ discharge (cfs) and } A = \text{ area (km}^2\text{))}. \quad (1)$$

Drainage areas were calculated using the measuring tool in ArcView 3.2® (Table 2). In addition to ranking the streams by discharge or drainage area, the tributaries were also sorted by Shreve stream order. Once this ranking was completed, sample locality was chosen based on the frequency of smaller and larger sized streams within the drainage area and then weighted so that  $n=30$ . This allowed for a full representation of each drainage area and Shreve order within the watershed to be used for sample placements.

In addition to basing sample location on drainage area and stream size, the location of auger sites and cross-sections was also dependent on accessibility to the site (Table 2). The actual placement of auger holes on the floodplain was dependent on

**Table 1** Parameters used to determine the number of sites needed to meet the design load for each of the 22 basins (Q<sub>2</sub> = 622 cfs; km<sup>2</sup>)

Q <sub>2</sub> (cfs)	Largest drainage area (mi <sup>2</sup> ) halved down	Related Shreve order	Shreve order brackets (km <sup>2</sup> )	# of drainage basins in SFBR within brackets	# of sites needed within brackets (weighted to achieve a total of 30 sites)
45	75	435	28 435		
225	57	28	38 28	5	2
25	8.5	38	5 38		
562.5	6.5	5	5 5	6	3
283	2	5	5	59	25

**Table 2.** Sample #, UTM North American Datum 1983 coordinates, Shreve order and location within the SFBR.

Sample #	UTM NAD 83 Coordinates		Shreve #	Road Location
	East	North		
SFBR 1	0285935	3785189	3	McGee Fitzpatrick Rd.
SFBR 2	0290544	3781033	40	Floyd Rd
SFBR 3	0286449	3780568	8	Bray Property
SFBR 5	0292269	3775175	1	Holman Autry Rd.
SFBR 6	0292460	3776721	2	Holman Autry Rd.
SFBR 7	0294490	3779316	1	na
SFBR 8	0289574	3770655	1	Spratlin Mill Rd.
SFBR 10	0309511	3761995	3	na
SFBR 11	0298892	3771716	65	McCarty Dodd Rd
SFBR 12	0289501	3765795	5	Paul Smith Rd.
SFBR 13	0298800	3754409	4	McCurley Lane
SFBR 14	0302921	3762450	86	Chandler Silver Rd
SFBR 15	0305176	3763695	121	RT 22
SFBR 16	0306749	3760957	41	Hughley House Rd
SFBR 18	0313560	3769243	38	RT 78
SFBR 19	0374320	3767154	448	Lexington Rd
SFBR 20	0314060	3766367	3	Turner Hill Rd
SFBR 21	0308734	3766199	128	Watson Mill
SFBR 22	0312197	3756823	4	Tiller Johnson Rd.
SFBR 23	0304584	3773300	4	Paoli Rd.
SFBR 24	0300349	3771340	1	Brickyard Rd.
SFBR 25	0299852	3771351	60	RT 172
SFBR 26	0298944	3757918	5	Meadow Creek Rd.
SFBR 27	0295318	3756585	3	Grove Church Rd
SFBR 28	0297268	3760234	14	Suddeth Rd.
SFBR 29	0298695	3761827	1	Devils Pond Rd
SFBR 31	0302802	3758713	5	Bowen Farm
SFBR 32	0311032	3769803	3	Noble Rd.
SFBR 33	0296043	3776516	5	Strickland Rd
SFBR 34	0306456	3772918	9	New Hope Rd
SFBR 35	0289261	3775098	2	Prospect Rd.
SFBR 36	0287925	3778958	2	Adams Rd
SFBR 37	0288510	3782420	21	Old Ila Rd
SFBR 38	0299514	3768057	5	na
SFBR17.1	0302215	3769890	174	Arnolds Bottom Rd
SFBR17.2	0302200	3769875	174	Arnolds Bottom Rd
SFBR17.3	0302167	3769849	174	Arnolds Bottom Rd
SFBR17.4	0302135	3769819	174	Arnolds Bottom Rd
SFBR17.5	0302103	3769790	174	Arnolds Bottom Rd

SFBR17.6	0302076	3769763	174	Arnolds Bottom Rd
SFBR17.7	0302055	3769748	174	Arnolds Bottom Rd
SFBR17.8	0302047	3769725	174	Arnolds Bottom Rd
SFBR17.9	0302023	3769695	174	Arnolds Bottom Rd
SFBR17.10	0301991	3769663	174	Arnolds Bottom Rd
SFBR17.11	0301964	3769639	174	Arnolds Bottom Rd
SFBR17.12	0301935	3769619	174	Arnolds Bottom Rd
SFBR39.1	0294329	3775857	6	RT 29
SFBR39.2	0294304	3775803	6	RT 29
SFBR39.3	0294286	3775737	6	RT 29
SFBR39.4	0294271	3775690	6	RT 29
SFBR39.5	0294238	3775639	6	RT 29
SFBR39.6	0294224	3775625	6	RT 29
SFBR39.7	0294213	3775599	6	RT 29

minimum valley width, with one hole placed every 50 meters across the floodplain. Average thickness of each alluvial unit was recorded for each site.

### *Field Work*

Two transects of the valley bottom were completed to provide a clear idea of the geometry of the historic sediment stored in the floodplain. One site used a Giddings hydraulic coring device (site SFBR 17, near Colbert, Georgia) and the other used a bucket auger (site SFBR 39, near Danielsville, Georgia). Several intact cores, approximately two meters long were kept from site SFBR 17 and taken to the University of Georgia Geomorphology Laboratory for further analysis. At each sample location (n=34), horizon nomenclature, Munsell color, structure, texture, mottling, concretions (Soil Survey Divisions Staff, 1993), amount of particulate organic matter, and amount of mica were described in the field (Table 3).

It was also necessary to assign the depth of the historic-prehistoric stratigraphic boundary in the field. This boundary was assigned a confidence level ranking based on a scale of 1 to 10, where a value greater than 7 indicates a clear identification of the historic-prehistoric sedimentary unit contact; a value between 3-6 is a gradual boundary; and a value less than 3 is a diffuse or no readily discernable boundary.

The stratigraphic units were delineated in the field on the basis of texture, sedimentary structures, clast composition, color, topographic and stratigraphic position and the occurrence of buried soils (Birkeland, 1999). At several cutbank sites, additional samples were taken in 5 cm intervals for further analysis at the lab. Photographs were also taken at many sites.

**Table 3.** Typical examples of soil descriptions from the SFBR, including examples of confidence level designations. Descriptions follow nomenclature of the USDA Soil Survey Manual (1993).

Sample #	Confidence Level	Depth to Prehistoric Unit (cm)	Type of Boundary	Depth (cm)	Horizon	Moist Munsell Matrix Color	USDA Texture
SFBR 19	10 HIGH	131	CLEAR	0-14	Ap	10YR5/4	loam
				14-35	Bw	7.5YR4/6	sandy loam
				35-48	C1	7.5YR4/6	sandy loam
				48-67	C1	7.5YR4/6	sandy loam
				67-78	C1	7.5YR4/6	sandy loam
				78-82	C1	7.5YR4/6	sand lens
				82-98	3C1	10YR4/3	sandy loam
				98-131	4C1	10YR4/2	silt loam
				131-146	Ab	10YR4/1	silt loam
				146-164	C2	2.5Y5/2 w/5YR4/4	silt loam
SFBR 31	6 MODERATE	110	GRADUAL	164-187	2C2	2.5Y5/2 w/5YR4/4	sandy silt loam
				187+	2C2	2.5Y5/2 w/5YR4/4	sandy silt loam
				0-20	Ap	10YR4/3	loam
				20-40	Bw/C1	10YR5/4 w/ 10YR5/6 mottles	silt loam
				40-60	C1	10YR5/6	loam
				60-80	C1	10YR5/3	silt loam
				80-110	C1	10YR5/4	sandy loam
				110-140	C2	2.5Y6/2	sandy loam
140-160	C2	2.5Y6/2	sandy loam				
160+	C2	2.5Y6/2	sandy loam				
SFBR18	1-2 LOW	30 or 130	DIFFUSE	0-20	C1	10YR6/4	sandy loam
				20-30	Ab?	10YR4/4	loam
				30-80	C1 or C2?	7.5YR4/6	loam
				80-100	C1 or C2?	7.5YR4/6	loam
				100-120	C1 or C2?	5YR4/6	sandy clay loam
				120-130	C1 or C2?	7.5YR4/2	silt loam
				130+	C2	7.5YR4/3	silt loam

Specifically, the identification of historic sediment in the field closely followed the descriptions of Oppenheim (1996) and Happ (1945). According to Happ (1945), the “upper two or three feet of alluvium is usually brown or reddish brown, similar in color to the subsoils of adjacent gullied uplands, and these reddish-brown deposits are generally recognized as the products of accelerated soil erosion”. In the Soap Creek watershed of northeast Georgia, Oppenheim (1996) based the differentiation of historic and pre-historic sediment on bedding, texture, and grain size. Oppenheim (1996) states that historic sediment in the Georgia Piedmont is often coarser, has more distinct bedding structures and laminae, and displays more heterogeneity within graded sequences than prehistoric sediment. Sediment below the prehistoric floodplain surface does not display prominent bedding owing to the amount of time allowed for pedogenesis to destroy these features.

Additional measurements were made at each auger test in the South Fork Broad River watershed. These include bankfull width (m), bankfull depth (m) (as outlined by Harrelson et al. (1994)), as well as valley width (m).

#### Stratigraphic Delineation and Allostratigraphy

The procedure for classifying and naming stratigraphic units in the South Fork Broad River directly followed the North American Stratigraphic Code of the North American Commission on Stratigraphic Nomenclature (1983) (or the NACSN). According to Article 58 of the NACSN (1983), an allostratigraphic unit is “a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities.” Such bounding discontinuities include soils, paleosols, and

geomorphic surfaces and must be laterally traceable. Alloformations are not defined by geologic history or “inferred time spans” and are generally not defined by genetic interpretation. However, according to the NACSN (1983), “genetic interpretation may influence the choice of its boundaries”. Thus, the two allounits designated for the South Fork Broad River basin were delineated on the basis of a bounding discontinuity that separates agriculturally-induced sediment from sediment derived under native forests that existed prior to Euro-American settlement of the region. The allostratigraphic units of the South Fork Broad River are informally referred to as the Ila allostratigraphic unit (related to accelerated erosion) and the pre-Ila allostratigraphic units, after the northern-most town in the South Fork Broad River drainage, Ila.

In addition to distinguishing allostratigraphic units based upon the presence of unconformable boundaries, landscape morphology and relative pedogenic development, other variables such as field texture and Munsell color were used as accompanying classifying factors. Therefore, two non-parametric statistical tests (the Kolmogorov-Smirnov two-sample test and the Mann-Whitney U test) were applied to test the difference between the two allounits based on field texture and color.

Munsell color was recorded for each unit at each sample location in the South Fork Broad River basin and converted to the Buntley-Westin and the Hurst rubification (or redness) indices (Buntley and Westin 1965, Hurst 1977, Birkeland 1999). This conversion was used to change the data from nominal data (Munsell notation) to ordinal data (numerical values). Field texture was also recorded at each locality, based on soil textural classes (Soil Survey Division Staff, 1993). This converted the data from a

nominal scale (soil textural class) to an ordinal scale (percentages) based upon the percent sand for each textural class.

The Kolmogorov-Smirnov (K-S) two-sample test and the Mann-Whitney U test were used on the color indices (both Buntley-Westin and Hurst methods) as well as the textural data because the data had been converted from nominal to ordinal scales. Specifically, the Kolmogorov-Smirnov (K-S) two-sample test was used to test for differences between the two distributions. This test assumed that the data were randomly sampled, which was verified by the use of the stratified random sampling strategy in the selection of sample locations within the drainage basin. The null hypothesis for the K-S test is that the distribution of color and texture of the Ila unit has the same distribution as the pre-Ila units. The Mann-Whitney U tested for the equality of medians between the allounits. This test also assumed that the data were randomly sampled, which again was verified by the original sampling strategy. The null hypothesis is that the median color and median texture of the Ila unit is the same as the median color and median texture of the pre-Ila units. Thus, field texture and color were tested as a means to distinguish between allostratigraphic units in the South Fork Broad River.

#### Particle Size Analysis

In order to classify the allostratigraphic units, particle size analyses were completed for particles finer than 2 mm. The procedure followed the hydrometer method as outlined by Gee and Bauder (1986). Samples for the particle size analysis were taken from two representative cores (SFBR 17.8 and SFBR 19) at 10 cm intervals. These representative cores also provided samples for the total carbon analyses.

The particle size analysis required 40-50 g of sample to be placed into a 200 ml beaker and oven dried for three hours at 105° C. A dispersant of 100 ml of 50 g/L of sodium metaphosphate was then added to the sample. The resulting solution was then shaken on an Eberback mechanical shaker for 8 to 12 hours. The solution was poured into a 1L cylinder and the cylinder was filled to the 1L mark with distilled water. The sample was stirred and allowed to settle for approximately 11 hours. A hydrometer was then used to measure the amount of clay in suspension (g/L). The sample was then passed through a 63µm sieve to remove the sand fraction. This remaining sand was oven dried at 95°C for 4 to 6 hours and at 105°C for 2 hours to remove any remaining water. The particles were then reweighed to determine percent sand for the sample.

#### Organic Carbon Analysis

To provide additional data to distinguish between sedimentary units, the concentration of organic matter was also measured. It has been stated by Knox (1987) that floodplain surfaces that build up rapidly will not accumulate large amounts of organic matter, as compared to sediments that accumulate more slowly. In order to determine organic matter concentration, an automatic carbon analyzer was used (Tabatabai and Bremner, 1970), in addition to the loss on ignition method (Gale and Hoare, 1991). Both methods calculated the total carbon in the soils by evaluating the carbon dioxide that is evolved after the soil is combusted at a high temperature.

The first procedure was run on a Shidazu model. For noncalcareous soils, approximately 0.5 g of < 2 mm soil is placed into small crucibles. The sample is mixed and placed into the instrument. This device then measures total carbon evolved after the

sample has been heated to 900°C for approximately 10 minutes. Total carbon analysis of soils by this method is very simple and can be done quickly and efficiently.

The loss on ignition method, as outlined by Gale and Hoare (1991), measures the loss in mass of plant organic matter resulting from ignition in a high temperature furnace. Approximately 5g of soil are weighed into a labeled crucible. The crucible and its contents are then oven dried at 105° C for 24 hours. The sample is then placed in a desiccator to allow the contents to reach room temperature. Each sample is then placed in the furnace at approximately 430 ° C for 24 hours. The sample is then removed from the furnace, placed into the desiccator once again and cooled to room temperature. The sample is then weighed to 0.001g.

A parametric statistical test was then applied to the loss on ignition (LOI) data and carbon analyzer data in order to test for a statistical difference between the two methods. This test, a pairwise two sample t-Test, tested for a difference of means. The first assumption of this test is that the data were randomly sampled, which is verified by the use of the stratified random sampling strategy in the selection of sample locations within the drainage basin. The second assumption is that the means of the data are normally distributed, which can be verified by the large sample size and the Central Limit Theorem, which states that the means of a sample drawn from a population of any distribution will approach a normal distribution. The null hypothesis for the t-test is that the mean of the LOI data has the same mean as the carbon analyzer data. The significance level was assigned an alpha ( $\alpha$ ) of 0.05. The results from this statistical test indicated that the two methods are statistically similar in core SFBR 19 (n=27, p=0.07) (Table 6), but not in core SFBR 17.8 (n=27, p= 0.01).

### Radiocarbon Dating

Radiocarbon dating is the principal method for determining the age of carbon-bearing materials from approximately 50,000 years ago to the present. By measuring the amount of  $^{14}\text{C}$  in samples of ancient carbon compounds and comparing this with amounts in modern samples, it is possible to evaluate the time of termination of carbon exchange within the atmosphere and thus provide an age determination. For this project, four 30 g samples were sent to the University of Georgia Center for Applied Isotope Studies (CAIS) for accelerated mass spectrometry and conventional dating. Sample preparation and  $^{13}\text{C}$  correction were completed at the CAIS laboratory. The four samples used for  $^{14}\text{C}$  dating were chosen from pre-IIa allostratigraphic units in order to provide a chronology to the allostratigraphic framework. The resulting age determinations were calibrated to calendar years using the University of Washington Quaternary Isotope Lab Radiocarbon Calibration Program (Revised 4.3) (Stuiver et al., 1998).

### Calculating Sediment Volume and GIS Applications

#### *Physical Parameters*

Average depth to the IIa - pre IIa stratigraphic boundary was derived from the auger tests and cutbanks and intact cores taken from transects across the main stem of the River. Once the average depth was determined, comparisons were made between average depth and elevation, slope, Shreve stream order and drainage area. Each variable was initially digitized into ArcView 3.2® for each respective sample site. Cumulative stream length and drainage area were calculated using the measuring tool in ArcView 3.2®,



the South Fork Broad River network. Using the topographic analysis function, slope was derived and put in a grid format. The slope data was then reclassified. Three classes were created, where 0-2.5% slope was categorized as a “1”, 0-3.5% slope was categorized as a “2”, and 0-4.5% slope was categorized as a “3”. This reclassification provided three separate slope categories within the drainage basin.

However, it was necessary to create an elevation buffer in order to remove data that were classified as <4.5% slope in the upland areas of the basin. Two categories were created based on riparian elevations, so that all final data would be within 3 m or 4 m elevation of the existing channel. Therefore, six final categories were obtained from the DEM models. These are data that fell within the 3 m high riparian elevation buffer (<2.5% slope, <3.5% slope, and <4.5% slope), and data that fell within the 4 m high riparian buffer (<2.5% slope, <3.5% slope, and <4.5% slope).

### *Gully Contribution*

In order to provide reasonable volume estimates from the South Fork Broad River basin, calculations were made on the volume of sediment contributed from gully erosion. This aspect of sediment erosion was derived from Trimble's (1974) work in the southern Piedmont and a study completed in Spartanburg County in the southern Piedmont of South Carolina. The study by Eargle et al. (1939) provided detailed data on the areal extent of gully erosion for the county. Erosion estimates were then correlated to the South Fork Broad River drainage area by determining the ratio of gully area to a known circular area (set by using ArcView 3.2®) and using this ratio to the South Fork Broad River drainage (Figure 4). This ratio then provided an approximate areal extent of gullying to

**Figure 4.** Location map of gullies in Eargle et al. (1939). The total areal extents of the gullies from this study were used to infer typical gully coverage in the South Fork Broad River, Georgia. The area of the circle is approximately 225 mi<sup>2</sup> and the areal extent of the gullies is less than 0.01 %. This areal coverage is taken as a minimum in the calculations in the SFBR because new gullies are often not accounted for.

which the depth of historic alluvium was then multiplied. Thus providing an approximate contribution of gully volume to the South Fork Broad River basin. This gully volume is viewed as a minimum estimate, because there probably were more gullies than those identified in Eargle's study.

### Volume and Sediment Yield Estimates

Volume and mass estimates were calculated from the GIS models. These calculations included estimated volume of sediment in storage ( $m^3$ ), mass of sediment in storage (Megagrams), estimated gully volume contribution ( $m^3$ ), the equivalent sediment delivery ratio based on drainage area (USDA, 1983), the equivalent depth of erosion (cm) that occurred throughout the drainage area, the total estimated erosion ( $Mg/km^2$ ), and the equivalent annual sediment yield ( $tonnes/km^2/year$ ).

Typically, sediment budgets use a sediment delivery ratio in the calculation of sediment yields, in order to account for the trapping of sediment owing to size of drainage area. The sediment delivery ratio (SDR) (Equation 2) was calculated for the SFBR basin, which allowed for the estimation of annual discharge from the drainage area. This equation, taken from the National Engineering Handbook by the Soil Science Conservation Service (USDA, 1983), was used in the volume estimate in order to correct for sediment that had escaped the South Fork Broad River watershed.

$$SDR = 0.417762 * (A^{-0.134958}) - 0.127097, \text{ where } A = km^2 \quad (2)$$

Thus, this value was added to the total stored volume to approximate the total erosion from the watershed. The volume was then converted to Megagrams by using the average bulk density of sediment of  $1.50 \text{ g/cm}^3$ .

Erosion estimates were derived from the volume calculations. The final eroded volume was used to calculate the equivalent depth of erosion (cm) that occurred throughout the drainage area. This was done by dividing the total volume of sediment eroded ( $m^3$ ) by the total area of the watershed ( $m^2$ ), excluding the area of the floodplain ( $m^2$ ). In order to determine the total estimated erosion ( $Mg/km^2$ ), the estimated mass in storage (Megagrams) was divided by the total area of the watershed ( $km^2$ ). The equivalent sediment yield from hillslopes ( $tonnes/km^2/year$ ) was then calculated by dividing the total estimated erosion (which had been converted from  $Mg/km^2$  to  $tonnes/km^2$ ) by 181 years (the approximate time period between the arrival of Euro-American agricultural practices and the field season for this project).

## CHAPTER 4

### RESULTS

#### Allostratigraphy

##### *Ila allostratigraphic unit*

An allostratigraphic unit is a “mappable stratiform body of sedimentary rock that is defined on the basis of its bounding discontinuities” (NACSN, 1983). In the case of the South Fork Broad River drainage, allostratigraphy is used to distinguish between “superposed discontinuity-bounded deposits of similar lithology” (NACSN, 1983). In order to classify these allostratigraphic units found in the floodplains of the drainage, the characteristics of each allostratigraphic unit and its boundary had to be measured. These characteristics included color and texture of the sediment (Soil Survey Divisions Staff, 1993), organic content, pedogenic development, bounding surfaces, and facies type.

According to the North American Commission on Stratigraphic Nomenclature (1983), the internal characteristics of allostratigraphic units can vary laterally and vertically throughout the unit. This is true in the case of the youngest allostratigraphic unit, informally named the Ila allounit. The Ila allounit is mapped by the National Resources Conservation Service (NRCS) as an Entisol or an Inceptisol soil order, primarily because of its lack of pedogenic development. The lack of an argillic B-horizon

also indicates a young age for the Ila allounit. This unit typically is graded (fining upward) loam to sandy loam that typically has a reddish color (7.5YR 4/4 to 10YR4/4). The organic content is commonly low and there is little evidence of bioturbation. Sedimentary facies of the Ila unit typically reflect an overbank environment, which was the most common facies encountered on the valley floor. However, the Ila unit also occasionally consisted of lateral accretion deposits, floodplain valley margin colluvial deposits and other hillslope facies. The Ila allostratigraphic unit is commonly bounded by an underlying buried A-horizon, which constitutes a laterally traceable discontinuity. However, the Ila unit can also be bounded laterally by pre-Ila units at the surface (i.e. terraces). The Ila unit is mappable throughout the drainage of the South Fork Broad River. No formal type section has been defined for the Ila allounit.

The Ila allounit is assigned an age of < 181 YBP based on several indicators. The arrival of European-American agricultural practices to the region indicates that the Ila unit is not older than approximately 181 years (USDA, 1900-2001). The age of the unit also is based on sedimentological features, such as the lack of pedogenesis and the appearance of bedding structures and laminae (Oppenheim 1996). Historical artifacts (i.e. cans, glass bottles) can also be found within the allounit. In addition, the age of the unit is derived from historical records that relate to mining activity in the region, which can be directly correlated to metal concentrations in the stratigraphy of the Ila unit (Oppenheim 1996).

### *Allostratigraphic Boundary*

Allostratigraphic units are defined and identified on the basis of the bounding discontinuities. In the South Fork Broad River valley, the boundary between the Ila unit and the pre-Ila units typically can be recognized by differences in lithology and color. The pre-Ila surface typically exhibits a finer texture than the Ila unit. The top of the pre-Ila unit typically is darker than the overlying Ila unit and typically has a higher organic content.

The bounding surface between the Ila unit and the pre-Ila units can exhibit a distinct erosional and discontinuous surface, but typically it is normally graded (fining upwards) from beneath. This erosional boundary is also laterally traceable and can be mapped throughout the region. The confidence level data that was taken in the field in order to characterize the boundary can be also used to illustrate the type of boundary. More than half of the sites were given a ranking of four or above (out of ten), indicating that the boundary between allostratigraphic units mostly ranged from gradual to clear or from 2.5 cm to 12.5 cm thick (Soil Survey Divisions Staff, 1993).

According to the NACSN (1983), genesis is not an appropriate basis for distinguishing allostratigraphic units, but it can influence the choice of its boundaries. In the South Fork Broad River, the boundary can be genetically related to a stable prehistoric floodplain surface that existed prior to the onset of European-American agricultural practices. Therefore, its inferred geologic history can be linked to an historic change in land use.

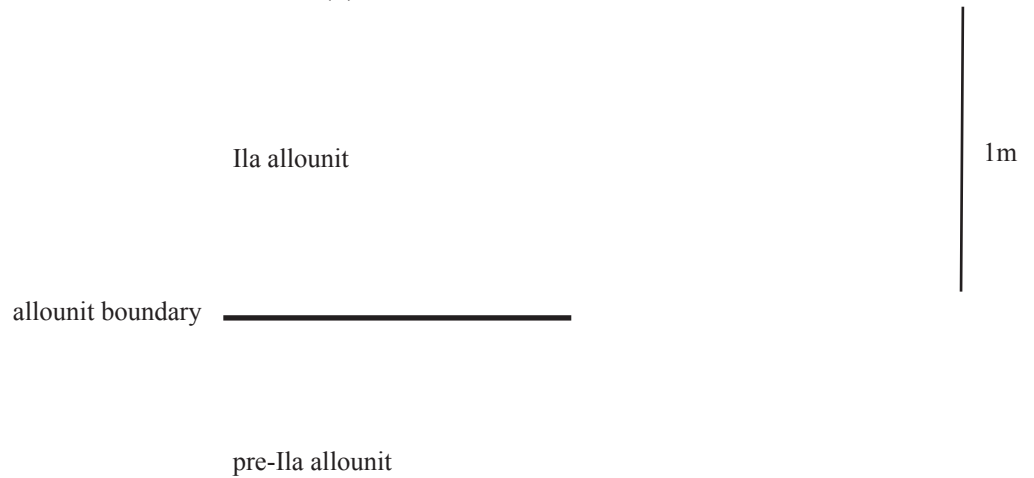
### *Pre-Ila allostratigraphic units*

Pre-Ila allostratigraphic units are the oldest alluvial strata in the framework. The internal characteristics of these units have similar lithology to the Ila allostratigraphic unit, but the pre-Ila units typically are finer and grade to a fine sandy clay loam. The pre-Ila units typically are bounded by basal sands and gravels or channel lag facies. These pre-Ila units also exhibit varied colors and typically are less red than the Ila allostratigraphic unit. Pre-Ila units that underlie the Ila unit typically exhibit redoximorphic features such as gray, low-chroma redox depletions and red redox concentrations (Buol et al., 1997) due to water table fluctuations. Pre-Ila units are typified by overbank facies, but like the Ila allostratigraphic unit, they can also infrequently exhibit a lateral accretion facies, as well as channel fill, channel lag and point bar facies. Occasionally, overbank sands are intermixed within the finer overbank silts and clays, which may indicate large floods. Each of these facies is included in the pre-Ila allostratigraphic units and can be laterally traced and mapped throughout the South Fork Broad River basin. The pre-Ila allostratigraphic units are also occasionally bounded on top by a laterally traceable buried A-horizon. There are no formal type sections for the pre-Ila allostratigraphic units.

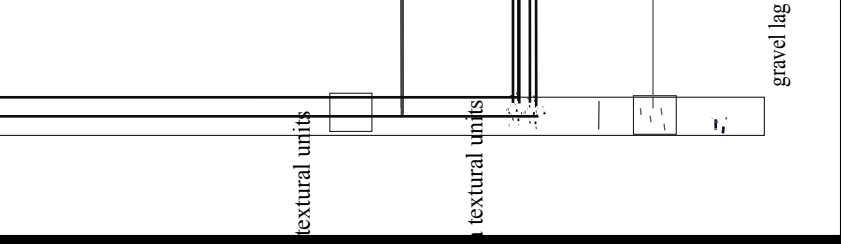
A clear example of this stratigraphic framework can be seen at site SFBR 19, near Lexington, GA (Figure 5). Here, the pre-Ila unit is bounded on top by a gradual, dark buried A-horizon. The Ila allostratigraphic unit lies above this boundary and is visibly redder than the unit beneath it. The stratigraphic framework is also exhibited in the cross-sections completed at site SFBR 17 (near Colbert, GA) and SFBR 39 (near Danielsville, GA) (Figure 6 and Figure 7). At each of these sites, the finer, pre-Ila allostratigraphic

(a)

(b)



**Figure 5.** Photo of cutbank from site SFBR 19 near Carlton, Georgia, near the confluence with the Broad River. These photos clearly show the floodplain aggradation of the Ila allunit (a) and the stratigraphy of the Ila and the pre-Ila allunits (b).

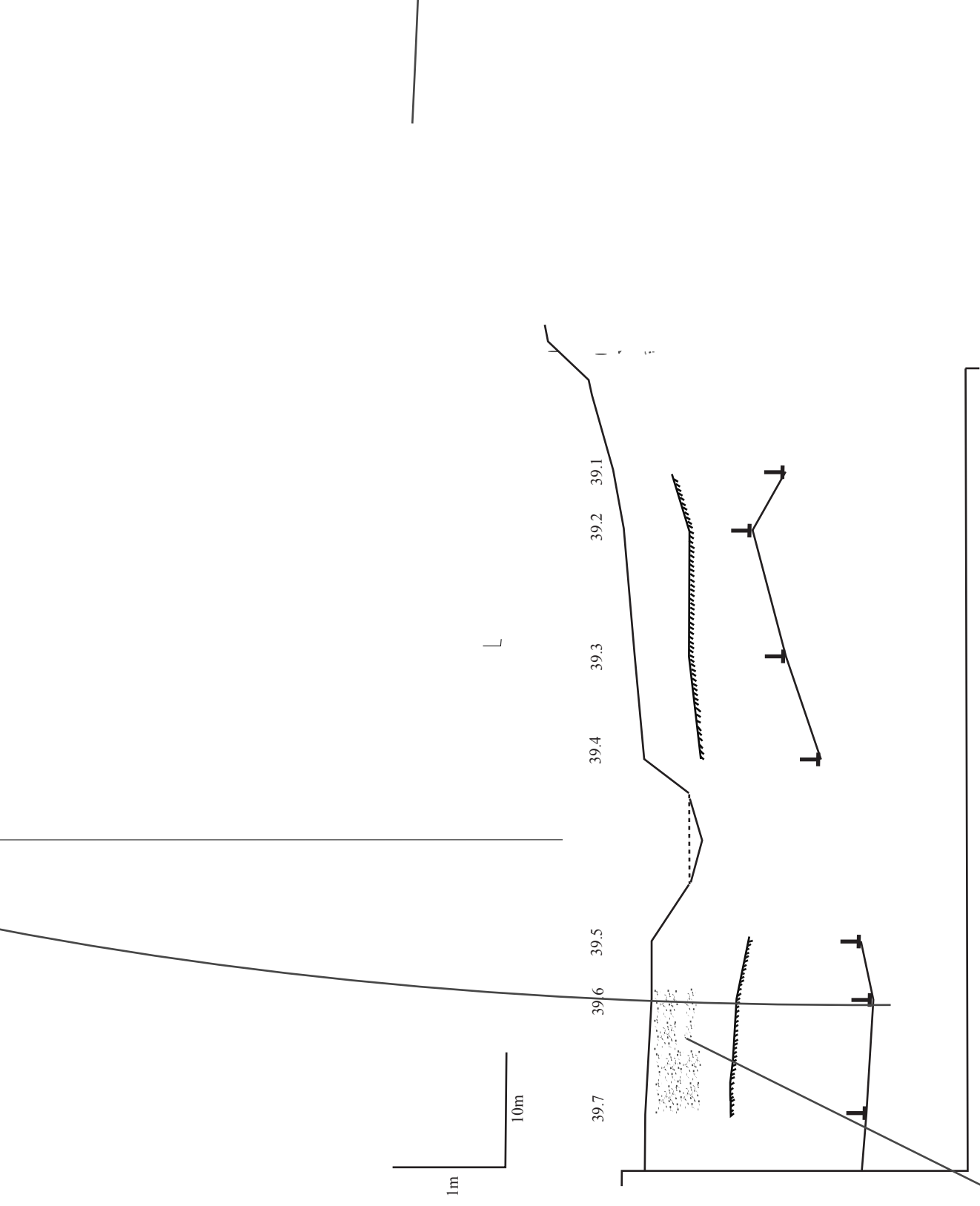


textural units

textural units

gravel lag

n



**Figure 7.** Cross-section of site SFBR 39 of the South Fork Broad River, near Danielsville, Georgia. Ila allostratigraphic unit is shown lying above the pre-Ila allostratigraphic units.

units are clearly overlain by the dark, buried A horizon, while the redder, sandier Ila allostratigraphic unit lies directly above this boundary.

*Additional data*

Additional data were collected in order to supplement the designation of the allostratigraphic units. These include percent sand, silt, clay, organic carbon, and radiocarbon dates from site SFBR 17 (near Colbert, Georgia), and a statistical analyses of field texture and color.

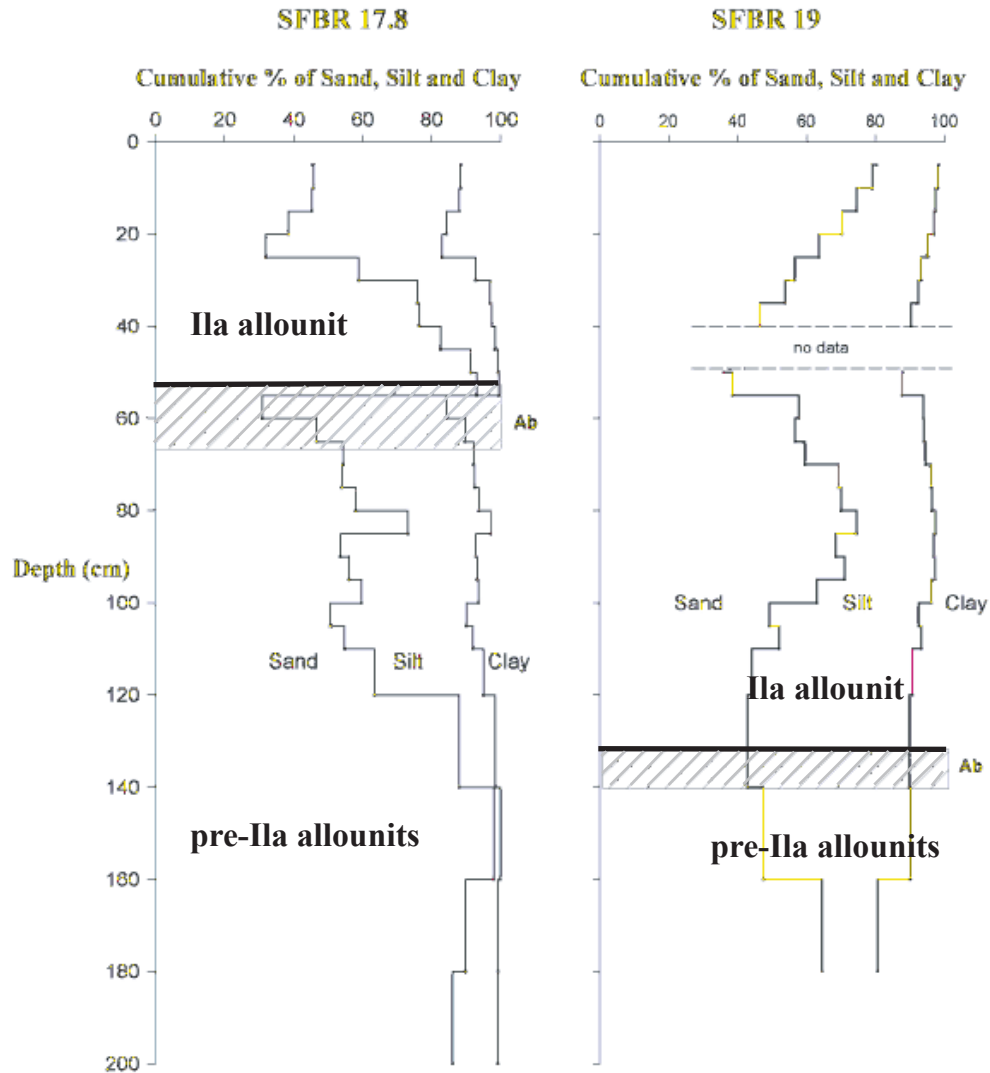
Percent sand, silt, and clay analyses from two sites were completed using the hydrometer method outlined by Gee and Bauder (1986). The results indicate that SFBR 17.8 showed that percent sand increased above the contact with the base of the Ila allostratigraphic unit (Table 4 and Figure 8). However, the increase in percent sand occurred at a shallower depth than site SFBR 19. This result agrees with the field texture designations of each allostratigraphic unit.

Percent organic carbon was also measured in samples from the same sites (SFBR 17.8 and SFBR 19) by using the loss-on-ignition method (Gale and Hoare, 1991) and a carbon analyzer (Tabatabai and Bremner, 1970). The results from both of these analyses indicate that percent organic carbon decreases at the top of the pre- Ila allostratigraphic units (Table 5, Figure 9). This result also agrees with the field texture designations of each allostratigraphic unit.

Two radiocarbon dates were obtained from the pre-Ila allostratigraphic unit, approximately 320 cm below ground surface from site SFBR 17.2, including one wood sample and one seed sample. These results indicate that the pre-Ila unit is at least 2,770

**Table 4.** Percent sand, silt and clay for cores SFBR 17.8 and SFBR 19.

		<b>SFBR 17.8</b>			<b>SFBR 19</b>				
		Sample Interval (cm)	% Sand	% Silt	% Clay	Sample Interval (cm)	% Sand	% Silt	% Clay
<b>Ila allostratigraphic unit</b>		0-5	45.53	43.06	11.41	0-5	80.29	18.05	1.67
		5-10	45.79	42.67	11.55	5-10	79.09	18.96	1.95
		10-15	45.32	42.76	11.92	10-15	74.40	23.01	2.59
		15-20	38.50	45.84	15.66	15-20	70.29	26.58	3.13
		20-25	31.87	51.16	16.97	20-25	63.54	31.54	4.92
		25-30	58.82	33.97	7.21	25-30	56.40	36.72	6.88
		30-35	75.90	21.00	3.10	30-35	53.73	38.60	7.67
		35-40	76.43	21.07	2.50	35-40	46.48	43.85	9.68
		40-45	82.60	15.79	1.60	40-45	n/a	n/a	n/a
<b>pre-Ila allostratigraphic units</b>		45-50	91.37	7.99	0.64	45-50	35.97	51.91	12.12
		50-55	93.11	6.47	0.43	50-55	38.50	49.11	12.39
		55-60	30.89	53.36	15.75	55-60	57.74	36.04	6.22
		60-65	46.69	43.03	10.28	60-65	56.62	37.29	6.09
		65-70	54.41	37.77	7.82	65-70	59.45	34.99	5.56
		70-75	53.94	38.56	7.50	70-75	69.18	26.80	4.01
		75-80	57.97	35.74	6.29	75-80	69.99	26.21	3.80
		80-85	73.16	24.02	2.81	80-85	74.48	22.90	2.62
		85-90	53.59	39.27	7.14	85-90	68.40	28.37	3.23
		90-95	56.04	37.13	6.83	90-95	71.01	26.27	2.72
		95-100	59.64	33.95	6.42	95-100	62.95	33.09	3.96
		100-105	50.60	39.48	9.92	100-105	49.10	43.41	7.49
		105-110	54.80	37.16	8.04	105-110	52.07	41.11	6.83
		110-120	63.49	31.52	4.99	110-120	44.08	46.54	9.39
		120-140	88.02	10.43	1.55	120-140	42.92	46.81	10.27
		140-160	98.03	1.84	0.13	140-160	47.40	42.68	9.92
		160-180	89.89	9.43	0.68	160-180	64.49	16.07	1.68
		180-200	86.09	13.15	0.75				

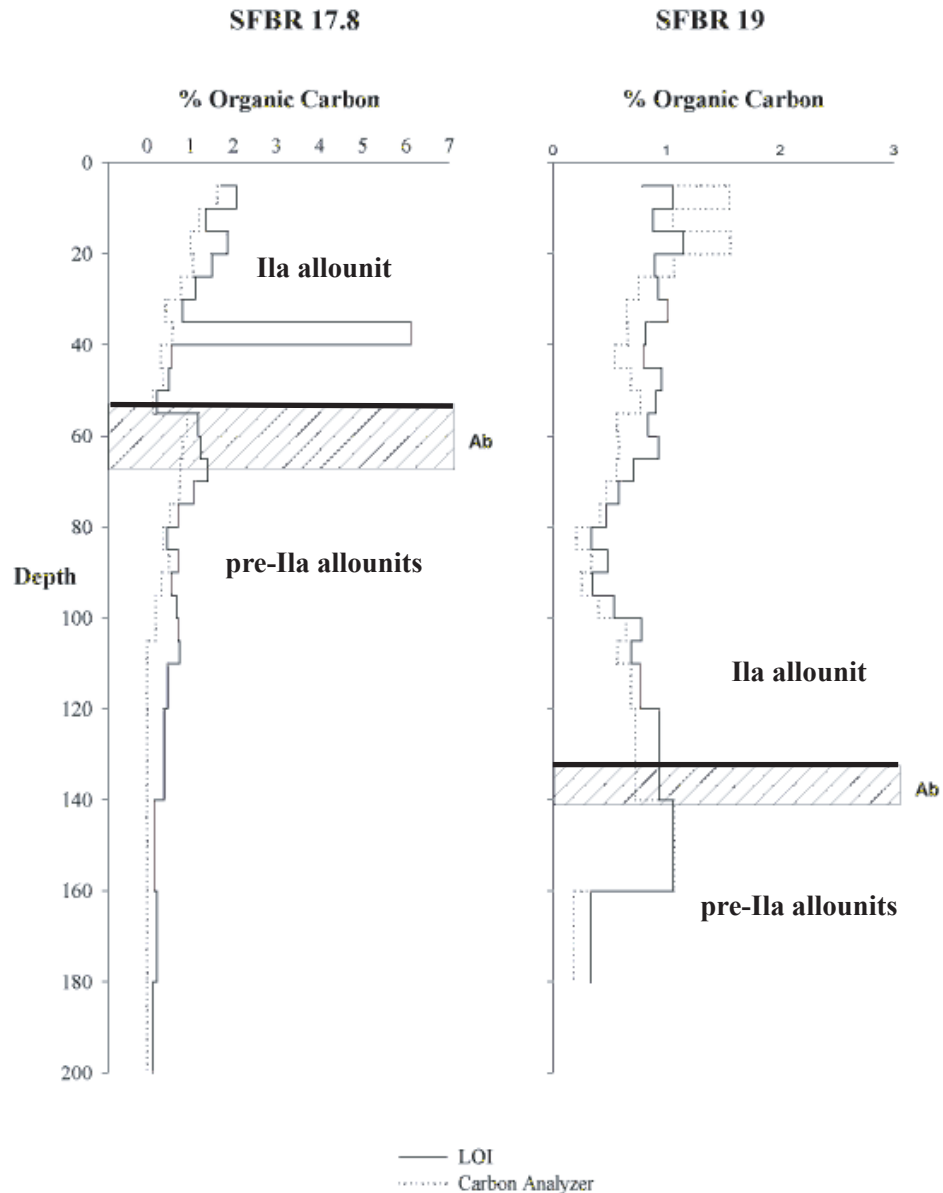


**Figure 8.** Cumulative percent sand, silt and clay for two sites (SFBR 17.8 and SFBR 19) in the South Fork Broad River basin. In both cases, the base of the Ila allostratigraphic unit is located near an increase in percent sand.

**Table 5.** Percent organic carbon for cores SFBR 17.8 and SFBR 19 using loss on ignition and the carbon analyzer.

		SFBR 17.8			SFBR 19		
		Sample Interval (cm)	% C (LOI)	% C (anal.)	Sample Interval (cm)	% C (LOI)	% C (anal.)
<b>Ila allostratigraphic unit</b>		0-5	1.74	1.85	0-5	0.79	1.00
		5-10	2.07	1.63	5-10	1.06	1.55
		10-15	1.35	1.21	10-15	0.88	1.06
		15-20	1.87	1.00	15-20	1.15	1.56
		20-25	1.51	1.05	20-25	0.90	1.07
		25-30	1.12	0.78	25-30	0.92	0.76
		30-35	0.82	0.43	30-35	1.01	0.65
		35-40	6.11	0.58	35-40	0.82	0.66
		40-45	0.57	0.32	40-45	0.80	0.55
<b>pre-Ila allostratigraphic units</b>		45-50	0.50	0.38	45-50	0.96	0.69
		50-55	0.23	0.14	50-55	0.91	0.77
		55-60	1.18	0.92	55-60	0.83	0.56
		60-65	1.24	0.82	60-65	0.93	0.58
		65-70	1.41	0.77	65-70	0.70	0.56
		70-75	1.08	0.75	70-75	0.58	0.47
		75-80	0.73	0.53	75-80	0.47	0.41
		80-85	0.47	0.37	80-85	0.34	0.21
		85-90	0.72	0.51	85-90	0.48	0.34
		90-95	0.56	0.33	90-95	0.35	0.25
		95-100	0.68	0.19	95-100	0.54	0.40
		100-105	0.72	0.19	100-105	0.78	0.65
		105-110	0.76	0.00	105-110	0.69	0.57
		110-120	0.48	0.00	110-120	0.77	0.69
		120-140	0.40	0.00	120-140	0.93	0.72
		140-160	0.17	0.00	140-160	1.06	1.07
		160-180	0.23	0.00	160-180	0.33	0.18
		180-200	0.14	0.00			

**Ila allostratigraphic unit****Pre-Ila allo unit**



**Figure 9.** Percent organic matter used for carbon for two sites (SFBR 17.8 and SFBR 19) within the South Fork Broad River basin. Each plot indicates the two methodological approaches used to determine percent organic carbon (loss on ignition and the carbon analyzer), as well as the location of the allostratigraphic boundary (Ab). The top of the Ab is located near a decrease in percent organic carbon in each case.

**Table 6.** Statistical results from pairwise t-Test. Each test is testing for a methodological difference between Loss-on-Ignition and the Carbon Analyzer. Null Hypothesis ( $H_0$ ): Mean % organic carbon is same for LOI and the Carbon Analyzer.

<b>SFBR 17.8</b>				
	<b>n</b>	<b>mean</b>	<b>stdev</b>	
LOI	27	1.07	1.14	
Carbon Analyzer	27	0.55	0.50	
<b>Statistic</b>	<b>alpha</b>	<b>p-value</b>	<b>Conclusion</b>	
pairwise t-Test	0.05	0.01	Reject $H_0$	

<b>SFBR 19</b>				
	<b>n</b>	<b>mean</b>	<b>stdev</b>	
LOI	26	0.77	0.23	
Carbon Analyzer	26	0.69	0.35	
<b>Statistic</b>	<b>alpha</b>	<b>p-value</b>	<b>Conclusion</b>	
pairwise t-Test	0.05	0.07	Accept $H_0$	

cal YPB near its base (Table 7). Site SFBR 32.1 had a radiocarbon date that indicates that the pre-Ila allostratigraphic unit to be approximately 1,000 cal YBP (Table 7).

Two non-parametric statistical tests were applied to determine if field texture and color could provide significant data to distinguish the Ila and pre-Ila allostratigraphic units. These non-parametric tests, the Kolmogorov-Smirnov (K-S) two-sample test and the Mann Whitney U test, were applied to two color indices and one field texture index.

The results of the Kolmogorov-Smirnov two-sample test and the Mann Whitney U test indicated that the color of the Ila unit is statistically different (more red) than the pre-Ila unit ( $n=34$ ,  $p<0.01$ ) (Table 8). The Kolmogorov-Smirnov two-sample test and the Mann Whitney U test also indicated that the texture of the Ila unit is statistically different (sandier) than the pre-Ila unit ( $n=34$ ,  $0.05<p<0.01$ ) (Table 9).

A Geographic Information System (ArcView 3.2®) was used to measure influencing physical parameters in order to determine if a relationship exists between the mean depth of the Ila unit and valley width (m), drainage area ( $\text{km}^2$ ), cumulative stream length (km), percent slope, and Shreve stream order (Table 10). In order to determine if a relationship existed, a correlation analysis ( $r^2$ ) was calculated between each parameter and the mean depth of the Ila allostratigraphic unit based on its confidence level grouping (Table 11). The correlation tables indicate that no strong relationship exists between the depth of historic alluvium in the South Fork Broad River basin and the physical parameters that were measured with the GIS. These results indicate that the correlation between each parameter and mean depth (m) accepted the null hypothesis ( $H_0$ ) that no linear relationship exists between the parameter and mean depth (m) at a p-value  $>0.01$ .

**Table 7.** Radiocarbon dates from sites SFBR 17 and 32 within the South Fork Broad River basin.

<b>Sample Location</b>	<b>UGA Lab-Code</b>	<b>C14 YBP</b>	<b>1 sigma</b>	<b>Cal YBP</b>	<b>(-) 1 sigma</b>	<b>(+) 1 sigma</b>
SFBR 17.11 224-228cm	10824	210	60	155-282	302	2
SFBR 17.2 320-325cm	10825	2,670	60	2,770	2,749	2,843
SFBR 17.2 320-360cm	10826	2,690	40	2,777	2,754	2,843
SFBR 32.1 251-253cm	10827	1,120	40	992-1051	968	1,061

**Table 8.** Statistical results from the Kolmogorov-Smirnov two sample test and the Mann-Whitney U test. Each is a test for difference in color between the Ila and pre-Ila allostratigraphic units.

K-S Null Hypothesis ( $H_0$ ): Distribution of color of Ila allounit has same distribution of color of pre-Ila units.  
 M-W Null Hypothesis ( $H_0$ ): Median of color of Ila allounit is equal to median of color of pre-Ila allounits.

	Buntley-Weston				Hurst			
	n	mean	stdev	median	n	mean	stdev	median
Ila allounit	33	18.2	6.76	18.0	33	20	9.3	17.5
pre-Ila allounit	29	10.4	7.72	8.0	29	44	27.3	37.6

Method	Statistic	p-value	Conclusion
Buntley-Weston	KS two-sample test	p<0.01	reject $H_0$
Hurst	KS two-sample test	p<0.01	reject $H_0$

Method	Statistic	p-value	Conclusion
Buntley-Weston	Mann-Whitney U-test	p<0.01	reject $H_0$
Hurst	Mann-Whitney U-test	p<0.01	reject $H_0$

**Table 9.** Statistical results from the Kolmogorov-Smirnov two sample test and the Mann-Whitney U test. Each is a test for difference in texture between the Ila and pre-Ila allostratigraphic units. Field texture was converted to an ordinal scale based from 1 (least sandy) to 9 (sandiest).

K-S Null Hypothesis ( $H_0$ ): Distribution of texture of Ila allounit has same distribution of texture of pre-Ila units.

M-W Null Hypothesis ( $H_0$ ): Median of texture of Ila allounit is equal to median of texture of pre-Ila allounits.

	<b>n</b>	<b>mean</b>	<b>stdev</b>	<b>median</b>
Ila allounit	32	6	1.5	6
pre-Ila allounit	29	5	1.6	5

<b>Statistic</b>	<b>p-value</b>	<b>Conclusion</b>
------------------	----------------	-------------------

KS two sample test	p = 0.1	accept $H_0$
--------------------	---------	--------------

<b>Statistic</b>	<b>p-value</b>	<b>Conclusion</b>
------------------	----------------	-------------------

Mann-Whitney U-test	p<0.01	reject $H_0$
---------------------	--------	--------------

**Table 10.** Physical parameters of the South Fork of the Broad River from field work and GIS measurements.

<b>Sample #</b>	<b>Prehistoric Boundary (m)</b>	<b>Shreve #</b>	<b>DA (km<sup>2</sup>)</b>	<b>Cum. Stream Length (km)</b>	<b>Valley width (m)</b>	<b>% slope</b>	<b>Confidence Level of Boundary</b>
SFBR 18	1.30	38	42.42	53.96	16.01	0.01	1
SFBR 25	0.90	60	222.77	335.78	31.66	0.01	2
SFBR 33	0.85	5	5.66	7.30	45.23	0.03	2
SFBR 38	0.85	5	6.30	7.54	177.63	0.02	2
SFBR 1	0.73	3	2.22	2.94	21.58	0.04	3
SFBR 5	0.40	1	0.96	0.74	13.15	0.04	3
SFBR 6	1.10	2	7.37	7.91	36.18	0.01	3
SFBR 7	0.00	1	0.85	1.03	22.72	0.01	3
SFBR 8	0.40	1	1.67	1.19	28.40	0.01	3
SFBR 11	0.70	65	92.15	109.51	34.24	0.01	3
SFBR 20	1.20	3	3.00	4.18	16.44	0.02	3
SFBR 23	0.50	4	5.79	5.58	27.13	0.02	3
SFBR 28	0.50	14	11.45	18.53	127.62	0.01	3
SFBR 35	0.85	2	1.61	1.59	43.24	0.04	3
SFBR 36	0.90	2	2.92	2.61	33.57	0.05	3
SFBR 37	0.95	21	42.44	51.20	28.07	0.01	3
SFBR 10	1.10	3	6.77	7.44	9.25	0.02	4
SFBR 21	1.00	128	122.38	178.45	87.42	0.01	4
SFBR 26	0.80	5	2.87	5.35	63.34	0.04	4
SFBR 29	0.30	1	0.37	0.68	86.01	0.01	4
SFBR 39	1.30	6	12.94	14.52	124.09	0.01	4
SFBR 3	0.78	8	10.28	11.56	66.87	0.02	5
SFBR 16	1.15	41	43.92	61.60	68.38	0.01	5
SFBR 22	1.15	4	3.38	5.62	41.83	0.03	5
SFBR 34	1.05	9	8.19	11.20	33.01	0.05	5
SFBR 13	1.10	4	3.52	4.50	28.58	0.02	6
SFBR 24	0.70	1	1.67	2.31	26.45	0.03	6
SFBR 31	1.10	5	3.89	7.41	21.10	0.02	6
SFBR 12	1.00	5	0.97	0.71	66.89	0.05	7
SFBR 14	1.30	86	82.22	118.15	10.28	0.01	7
SFBR 15	1.30	121	114.42	156.12	23.37	0.00	8
SFBR 17	0.90	174	237.72	355.42	20.56	0.00	9
SFBR 27	0.69	3	3.86	4.29	65.83	0.02	9
SFBR 19	1.31	448	625.70	798.86	26.92	0.00	10

**Table 11.** Mean depth to allostratigraphic boundary (m) and coefficients of determination ( $r^2$ ) of stream channel measurements for all localities and confidence level groupings for the SFBR. Each parameter in each confidence level grouping accepted the null hypothesis ( $H_0$ ) that no linear relationship exists between the parameter and mean depth (m) at a p-value  $>0.01$ .

	n	Mean depth (m)	Standard Deviation (m)	Valley width (m)	Drainage area (km <sup>2</sup> )	$r^2$		
						Stream Length (km)	% Slope	Shreve Stream Order
<b>All localities</b>	34	0.89	0.32	0.01	0.09	0.09	0.01	0.12
<b>Confidence level 7-10</b>	6	1.08	0.26	0.47	0.20	0.19	0.20	0.28
<b>Confidence levels 4-6</b>	12	0.96	0.27	0.01	0.03	0.03	0.01	0.02
<b>Confidence levels 1-3</b>	16	0.76	0.33	0.00	0.04	0.04	0.04	0.06

## GIS, Volume and Sediment Storage

### *Volume, Sediment Yield, and Depth of Erosion*

In order to determine the volume of historic alluvium stored in the floodplains of the South Fork Broad River, the areal extent of the Ila allounit was required. Seven GIS models were created for this purpose using ArcView 3.2® with NRCS soil series maps and Erdas IMAGINE 8.3® with digital elevation models (Table 12).

Total volume of historic alluvium was determined using these models and multiplying the floodplain area (Table 12) by the mean depth of the Ila allostratigraphic unit. These volume estimates (Table 13) ranged from approximately 45 million to 106 million cubic meters based on the seven GIS models. As stated earlier, these volume estimates used a sediment delivery ratio (SDR) (USDA, 1983) for the entire drainage (USDA, 1983) and yielded a value of 4.8% for the whole watershed. The contribution of gully erosion to the stored historic alluvium ( $m^3$ ) in the South Fork Broad River, which had been derived from a study from Spartanburg, SC (Eargle et al., 1939), was estimated to be approximately 27,200  $m^3$  or merely 0.05% of the entire stored volume (Table 13 and 14).

It should be stated, however, an agreement occurs between the NRCS GIS model and the <2.5% and <3.5% slope categories from the DEM models, thus providing volume estimates ranging between 45 million and 75 million cubic meters. The agreement between these three models indicate that estimates derived from the <4.5% slope category of the DEM model may overestimate volume calculations and that the use of

**Table 12.** Areal extent of historic alluvium for each GIS model for the SFBR.

<b>Floodplain area determined using:</b>	<b>Total Watershed Area (km<sup>2</sup>)</b>	<b>Average Depth of Historical Alluvium (m)</b>	<b>Total Area of Historic Alluvium (km<sup>2</sup>)</b>	<b>Total Area excluding floodplain (km<sup>2</sup>)</b>	<b>% Area of Historic Alluvium</b>
<b>NRCS Soil maps</b>	453.25	0.89	62.30	390.95	13.75
<b>Digital Elevation Models (DEMs) within 3m in height of channel</b>					
<2.5% slope	453.25	0.89	48.60	404.65	10.72
<3.5% slope	453.25	0.89	78.89	374.36	17.41
<4.5% slope	453.25	0.89	110.23	343.02	24.32
<b>Digital Elevation Models (DEMs) within 4m in height of channel</b>					
<2.5% slope	453.25	0.89	49.74	403.51	10.97
<3.5% slope	453.25	0.89	81.30	371.95	17.94
<4.5% slope	453.25	0.89	113.80	339.45	25.11

**Table 13.** Estimated volume of sediment in storage ( $m^3$ ) with respect to gully contribution and the Sediment Delivery Ratio (SDR) (4.8%) for the SFBR. Sediment volume was converted to megagrams by using an average bulk density of  $1.50 \text{ g/cm}^3$ .

<b>Floodplain area determined using:</b>	<b>Estimated Volume of Sediment in Storage (<math>m^3</math>)*</b>	<b>Sediment Eroded (<math>m^3</math>) with SDR (%4.8)</b>	<b>Estimated Volume of Eroded Sediment (<math>m^3</math>)</b>	<b>Equivalent Megagrams in Storage</b>	<b>Estimation of Gully volume (<math>m^3</math>) (0.05% of total volume)</b>	<b>Total Estimated Eroded Volume (<math>m^3</math>)</b>
<b>NRCS Soil maps (<math>\times 10^7</math>)</b>	5.54	5.81	5.81	8.71	0.0027	5.81
<b>Digital Elevation Models (DEMs) within 3m in height of channel</b>						
<2.5% slope ( $\times 10^7$ )	4.32	4.53	4.53	6.79	0.0027	4.53
<3.5% slope ( $\times 10^7$ )	7.02	7.35	7.35	11.03	0.0027	7.36
<4.5% slope ( $\times 10^7$ )	9.81	10.28	10.28	15.42	0.0027	10.28
<b>Digital Elevation Models (DEMs) within 4m in height of channel</b>						
<2.5% slope ( $\times 10^7$ )	4.42	4.63	4.63	6.95	0.0027	4.62
<3.5% slope ( $\times 10^7$ )	7.23	7.58	7.58	11.37	0.0027	7.58
<4.5% slope ( $\times 10^7$ )	10.12	10.61	10.61	15.92	0.0027	10.61

*\*does not include sediment lost from the watershed (SDR of %4.8)*

**Table 14.** Erosion estimates based on total volume of eroded sediment in storage ( $m^3$ ) with respect to gully contribution and the Sediment Delivery Ratio (SDR) (4.8%) for the SFBR. Equivalent depth of erosion (cm) is calculated by dividing the total estimated volume of eroded sediment in storage ( $m^3$ ) by the total area of the watershed ( $m^2$ ), excluding the area of the floodplain ( $m^2$ ). Sediment yield is calculated for a 181 year period.

<b>Floodplain area determined using:</b>	<b>Total Estimated Eroded Volume (<math>m^3</math>) (<math>\times 10^7</math>)</b>	<b>Equivalent Depth of Erosion (cm)</b>	<b>Total Estimated Erosion (tonnes/<math>Km^2</math>)</b>	<b>Equivalent Sediment Yield (tonnes/<math>km^2</math>/yr)</b>
<b>NRCS Soil maps</b>	5.81	14.87	192,395	1,063
<b>Digital Elevation Models (DEMs) within 3m of riparian</b>				
<2.5% slope	4.53	11.21	150,107	829
<3.5% slope	7.36	19.66	243,606	1,346
<4.5% slope	10.28	29.98	340,345	1,880
<b>Digital Elevation Models (DEMs) within 4m of riparian</b>				
<2.5% slope	4.62	11.50	153,626	849
<3.5% slope	7.58	20.39	251,045	1,387
<4.5% slope	10.61	31.28	351,365	1,941
<b>Trimble (1974) estimation</b>		19.05		

digital elevation models may be appropriate in the determination of floodplain area in this region of the Southeast.

The equivalent depth of erosion was estimated from the corrected volume, which added back the sediment lost from the basin. These values provided a range of 14.8 cm to 31.2 cm of sediment (Table 14). The total estimated erosion ( $\text{Mg}/\text{km}^2$ ) was calculated from the estimated mass in storage (Megagrams) and provided values ranging from approximately 192,000 ( $\text{Mg}/\text{km}^2$ ) to 351,000 ( $\text{Mg}/\text{km}^2$ ) (Table 14). Equivalent sediment yields ( $\text{tonnes}/\text{km}^2/\text{year}$ ) were derived from the total estimated erosion ( $\text{Mg}/\text{km}^2$ ) by dividing by 181 years and offered values ranging from 829 ( $\text{tonnes}/\text{km}^2/\text{year}$ ) to 1,941 ( $\text{tonnes}/\text{km}^2/\text{year}$ ) (Table 14).

#### *Sedimentation Rates*

In addition to calculating the total volume of historic alluvium in storage in the South Fork Broad River, past and present sedimentation rates have also been computed. These vertical accretion rates were estimated by measuring the thickness of sediment between two known dates. For this particular study, these bounding dates were from the radiocarbon dates on wood and seeds from sites SFBR 17.2 and SFBR 32.1, and from the approximate arrival of agriculture to the area, circa A.D. 1820. The age of the Ila allunit ranged from this onset of agricultural practices (approx. A.D. 1820) to the field season of this project (A.D. 2001), providing an age range of approximately 181 years which was used in the historic sedimentation rate calculations.

In addition, these rates were compared to rates from the Soap Creek basin in Georgia (Oppenheim, 1996), an area that also experienced aggradation due to historic

land use change (Table 15). In general, sedimentation rates are much higher for both the South Fork Broad River basin and the Soap Creek basin during the historic time period. However, it is clear that in the Soap Creek basin that sedimentation rates have sharply decreased with the onset of soil conservation practices.

**Table 15.** Approximated sedimentation rates from sites SFBR 17.2 and SFBR 32 using estimated buried prehistoric surface (circa A.D 1820) and  $^{14}\text{C}$  dates as landmarks, as compared to rates from the Soap Creek basin, GA (Oppenheim, 1996). Average sedimentation rate is derived from average depth to allostratigraphic boundary in SFBR (0.89m)

	<b>Historic (cm/yr)</b>	<b>Prehistoric (cm/yr)</b>
<b>Site SFBR 17.2</b>	0.53	0.09
<b>Site SFBR 32.1</b>	0.83	0.12
<b>Average rate for SFBR</b>	0.49	
	<b>Max. (1850- 1961) (cm/yr)</b>	<b>Min. (1926-1996) (cm/yr)</b>
<b>Soap Creek, GA</b>	1.82	0.43

## CHAPTER 5

### DISCUSSION

Investigations into the impact of historic land use change on alluvial systems have been of interest throughout the past century (Happ, 1945, Trimble, 1969, Trimble, 1974, Costa, 1975, Knox, 1977, Magilligan, 1985, Knox, 1987, Meade, 1990). In particular, several studies have focused upon the morphological aspects of accelerated erosion and the associated alluvial stratigraphy (Jacobsen and Coleman, 1986, Knox, 1987). However, the supplementation of a stratigraphic model with a sediment budget model that relates to the historic sediment in storage is not common. This approach was used for the project in the South Fork Broad River and clearly illustrates the sensitivity of stream response to changes in upland land use.

#### Allostratigraphy

Allostratigraphy has previously been used to define alluvial sequences in the Southeast (Autin, 1992) and in Texas (Blum and Valastro, 1994). In both of these cases, allostratigraphy was applied to relate geomorphic features to external controls such as climate change, sea level fluctuation or human impact on channel stability.

Blum and Valastro (1994) proposed that floodplain morphology was sensitive to changes in base level and that these changes were superimposed on the climatically driven episodes of sediment erosion and deposition in the channel. Autin (1992) also acknowledged the importance of the association between external and internal processes within a drainage basin. He defined alloformations based on channel stability and stated that external geomorphic influences such as human modification on landscapes contributed to channel instability, thus defining the youngest meander belt alloformation in the Amite River channel. This approach of using allostratigraphy to map alluvial sequences caused by external controls such as land use change is comparable to the approach used in the South Fork Broad River.

It is evident that allostratigraphy has proven to be a useful tool in this project in the South Fork Broad River basin. The drainage basin had experienced floodplain accretion due to a historic land use change and allostratigraphy has provided a stratigraphic context for the historic sediment.

The Ila allostratigraphic unit is statistically redder and sandier than the pre-Ila allostratigraphic units, thus the two allounits can be distinguished by color and texture. In addition, the Ila allounit can be distinguished based on a distinct increase in percent sand (close to the base of the unit) and a distinct decrease in percent organic carbon (also at the base of the unit). These allounits can therefore be distinguished by grain size, texture, color, stratigraphic position, and bounding discontinuities.

Despite that these two sedimentary units can be distinguished by their lithology, the use of allostratigraphy in the South Fork Broad River is based primarily upon the occurrence of a bounding surface between the Ila and the pre-Ila allostratigraphic units.

Although the allostratigraphic boundary commonly is vague and very much unlike the distinct, dark buried A-horizons seen in the Midwest, finer texture, occasional darker color, increase in percent organic carbon and decrease in particle size indicate that it is lithologically different than the underlying allostratigraphic units. In addition, this bounding discontinuity can be genetically linked to a period of stability in erosive practices and low sedimentation rates that existed prior to heavy agricultural use in the region. This bounding surface is also mappable and laterally traceable, as the NACSN (1983) requires for allostratigraphic boundaries.

Therefore, allostratigraphy can provide a useful approach to past sediment budget analyses by relating alluvial stratigraphic sequences to external changes that influence alluviation. In this particular project, the stratigraphic framework has provided a means by which a change in historic land use could define an entire alluvial package. Or alternatively, the effect of a land use change can be the single major influence on sediment supply and can provide a distinct floodplain stratigraphy, as reported by Jacobsen and Coleman (1986). Therefore, this stratigraphic approach may be a useful step in non-point source pollution research in similar alluvial systems in the southern Piedmont.

### Volume and Sediment Storage

No strong correlation exists between the average depth of historic alluvium stored in the floodplains of the South Fork Broad River basin and influential physical parameters (drainage area, slope, stream order, cumulative stream length, and valley width). This indicates that the average depth to the allostratigraphic boundary beneath the

Ila allunit (0.89m) may be used in volumetric analysis of historic alluvium within the entire basin.

*Volume, Sediment Yield, and Depth of Erosion*

The use of GIS applications has been valuable in determining the areal extent of the historic alluvium stored in floodplains of the South Fork Broad River basin. One reason for this importance is the accuracy that the application provides in calculating areal extents from maps and Digital Elevation Models. The overlap and agreement of these GIS models (one using ArcView 3.2® and six using Erdas IMAGINE 8.3®) provides important information about which models may be the most accurate in determining floodplain area.

It is important to note the concurrence of the areal calculations made between the National Resource Conservation Service (NRCS) soil series maps (used in ArcView 3.2®) and the DEM models of <2.5% and <3.5% slope categories (used in Erdas IMAGINE 8.3®) (Table 10). This agreement of separate data sources indicates that DEM models using 2.5-3.5 % slope categories may provide a suitable measure of floodplain area where NRCS soil series maps are lacking and the slope categories greater than 4.5% can possibly be dismissed. Thus, this may suggest that a 3% slope within 3-4 m height of the channel is the best proxy for floodplain measurements. This should provide important geomorphic implications for floodplain research and has further important management implications throughout the southern Piedmont because the readily available DEMs provide an efficiency and ease with the use of a GIS, whereas NRCS soil series maps are not often in digital format and are difficult to obtain.

The use of GIS applications in this project also has important implications for sediment yields for the southern Piedmont. These GIS applications provided a sediment storage model for the South Fork Broad River basin that is comparable to other areas that have experienced increased sediment yields due to crop farming. The current volume of historic sediment stored in the floodplains of the river ranges from 45 million cubic meters to 106 million cubic meters (or approximately 45 to 75 million cubic meters if the 3% slope category within 3-4 m in height of the channel is used) and provides an equivalent sediment yield of at least 829 tonnes/km<sup>2</sup>/year from contributing slopes in the basin. This sediment yield estimate agrees with published estimates for regions of heavy agriculture within the southern Piedmont. Such estimates are derived from modern sediment yields corresponding to drainage basins with similar land use and size (Meade et al., 1990). The sediment delivery ratio (approximately 4.8%) used for these calculations also agrees with estimates from the Piedmont of Georgia, South Carolina and North Carolina (Roehl, 1962). This estimate of 4.8% was assumed to be constant, because of the lack of ability to assess changes in delivery over time.

By applying the sediment delivery ratio to the calculated volume in storage, it is possible to approximate the amount of sediment that may have been transported out of the basin. This calculation estimates that approximately 2 million to 4 million cubic meters of sediment could have escaped over this short period of time. In order to determine the maximum volume of sediment that may have been stored, this then can be added back to the initial estimated volume. If it is assumed that the 2.5-3.5% slope models within 3-4 m in height of the channel are indeed correct, then this calculation provides a stored volume between 45 million and 75 million cubic meters of sediment.

This volume then provides an equivalent sediment yield ranging from approximately 829 to 1,387 tonnes/km<sup>2</sup>/year. Although there is no way of precisely describing sediment yields from pre-settlement times, these estimates provide a fairly good idea of post settlement rates of erosion and deposition and how these rates may compare to modern sediment yields.

Gullying was a severe problem for this region of the Piedmont in the early 1900s (Eargle et al., 1939) and was likely to have contributed to floodplain storage of historic sediment. According to Trimble and Lund (1982), gully development should increase sediment delivery and thus directly affect sediment in storage. Therefore, calculations were made on the contribution to the volume of sediment in storage that may have occurred owing to gullying in the drainage basin. The results indicate that gullying may have had little effect on the final volume in storage (only 0.05% of the total volume may have been added due to gullying). However, it is important to keep in mind that storage and movement of sediment is a temporal process and that it is difficult to account for gully erosion that may have occurred, especially if gullies were not carefully monitored and measured over this historic period. Although Eargle et al. (1939) carefully detailed the areal extent and depth of several gullies in Spartanburg County, South Carolina, it is likely that the estimates were low because not all the gullies were documented. Therefore, these gully erosion estimates for the South Fork Broad River basin may be relatively low and indicate that the final volume estimates of historic sediment in storage provided here is a minimum estimate.

It is also essential to note that the erosion estimates from the 2.5-3.5% slope categories within 3-4 m in height of the channel are slightly less than previous

estimations of agriculturally induced erosion for the southern Piedmont (Trimble, 1974). Trimble (1974) estimated that maximum erosion in the Southeast occurred in the southern Piedmont during historic times and that the equivalent of 7.5 inches (or 19.1 cm) of material was eroded from the state of Georgia. The average erosional depth from the 2.5-3.5% slope categories within 3-4 m of the South Fork Broad River channel is 15.5 cm, thus providing a value 18% less than Trimble's (1974) value. Again, this result may be related to the type of applications used to calculate the areal extent of the valley bottom (specifically ArcView 3.2® and Erdas IMAGINE 8.3®), as well as this type of data was not readily available before several years ago. This result could imply that the impact of crop farming in this region may have been less than once thought (Trimble, 1974) and that sediment supply was not quite as high as once estimated. Nevertheless, it is clear that the replacement of natural vegetation by cropland in this area greatly increased the amount of suspended sediment in the South Fork Broad River and significantly altered floodplain morphology and stratigraphy.

### *Sedimentation Rates*

According to rates calculated for the South Fork Broad River basin, floodplain sedimentation increased at the onset of European-American settlement (circa A.D. 1820). In some locations, historic sedimentation rates increased to 0.83 cm/year and far surpassed those of the prehistoric period (< 0.10 cm/year) (Table 15). These estimates are similar to rates in other regions that have experienced heavy aggradation due to land use change. However, it might be hypothesized that sedimentation rates have dramatically

decreased in very recent time (A.D. 1930-present) because of less sediment supply from upland sources.

## CHAPTER 6

### CONCLUSIONS

The alluvial stratigraphy of the South Fork Broad River of northeast Georgia has distinctive allostratigraphic units that represent different periods of land use. The pre-Ila allostratigraphic units include a range of finer grained facies that reflect a period of slow sedimentation and a possible balance between river hydrology and sediment delivery. This period was followed by a period of floodplain stabilization, which occasionally allowed for the accumulation of organic matter at the surface of the prehistoric floodplain. This allostratigraphic boundary is overlain by the coarser overbank and lateral accretion facies of the Ila allostratigraphic unit. This Ila allounit reflects the historic agricultural activity that took place in the uplands of the basin and is revealed by the high sedimentation rates. The development of the entire alluvial package shows a major change in stream hydrology and sediment supply that is indicative of this period (A.D. 1820-A.D. 2001) in the southern Piedmont (Trimble, 1974, Costa, 1975, Jacobsen and Coleman, 1986).

In this particular study, erosion estimates were derived from GIS applications and fieldwork. These estimates were used in association with the allostratigraphic framework, which defined the base of the historic alluvium to create an erosion budget for the period of historic land use based on the amount of sediment in storage and the sediment delivery

ratio for the South Fork Broad River basin. These erosion estimates for the South Fork Broad River agree with published estimates for regions of heavy agriculture within the southern Piedmont (Meade et al., 1990) and indicate that sediment yield was at least 829 tonnes/km<sup>2</sup>/year (the error analysis on 95% confidence limits that was applied to the measurement of the mean depth of the Ila allounit provides a minimum sediment yield of 804 tonnes/km<sup>2</sup>/year). This erosion budget thus has important implications for current sediment reduction strategies in the South Fork Broad River today because with the decline in land use and the implementation of soil conservation practices, sediment yields should not be greater than approximately 800 tonnes/km<sup>2</sup>/year.

With the foundation of soil conservation practices and the subsequent reduced sediment loads, it is possible that streams will continue to rework floodplain sediments, especially if the South Fork Broad River is currently entrenching (Woltemade, 1994) or if the development of meander belts occurs in the headwaters or mid-basin reaches by increasing stream power greater than bankfull (Lecce, 1997). If this is the case, the floodplains could continue to act as non-point source pollution to the current flow of the South Fork Broad River and create concern for the sediment reduction strategies that are being implemented by the EPA.

However, Stoughton (2000) found that the channel morphometry of the South Fork Broad River has experienced little change since the 1940s and that the channel accommodates small flood events (1-2 year recurrence intervals floods). In several other streams within the Georgia and North Carolina Piedmont, it is also clear that only the upper tributaries of these streams currently entraining, transporting and redepositing historic sediment and that little erosion is occurring along the mainstem (Phillips, 1991,

Ntumgia, 2001). In addition, Phillips (1991) found that upland erosion is also taking place in the rivers in the Piedmont of North Carolina and that a great majority of eroded sediment is still being held in storage on hillslopes.

More importantly, Ntumgia (2001) predicted that reduced upland erosion will subsequently increase degradation in the lower reaches of these Georgia Piedmont streams and will depend directly on vegetation development and current land use in the upland region (Maglilligan and Stamp, 1997). Thus, floodplains along the mainstem of the South Fork Broad River may not be acting currently as non-point sources of sediment, but may soon become a focus of sediment reduction strategies when the upper reaches begin to experience more channel stability.

Thus, the combination of allostratigraphy and GIS offers a useful approach that provides a context for past sediment yields that can be used to better understand present-day sediment yield estimates. This approach has important implications for the sediment loading research and the TMDL program that is currently being conducted by the EPA (Region 4) for the South Fork Broad River.

The research implications for the TMDL program focus primarily upon two aspects: 1) the methodological approaches of past sediment budget modeling and 2) the importance of historic sediment as sources of sediment pollution.

First, this study found that the use of Digital Elevation Models (DEM) may be as good as NRCS soil series maps for defining floodplains in a sediment budget analysis, primarily because most of the soil maps have not been digitized and the readily available DEMs provide the same accuracy as the soil maps. With this approach of merging allostratigraphy with a sediment budget model, this project in the South Fork Broad River

has produced reasonable volume estimates which could be used for non-point source pollution analyses.

Therefore, non-point sources such as floodplains consisting of historic sediment should be important to calculations of present-day sediment yields, as they could be a large source of pollution (in addition to point sources like construction sites, impervious surfaces, etc) if the South Fork Broad River were apt to erode its banks. In addition, this research provides useful information about the severity of land use change and the delicate balance of the hydrologic regime of the southern Piedmont. Lastly, this research in the South Fork Broad River has important implications for other regions that have experienced heavy sediment loading due to a land use change in the southern Piedmont, especially in regards to generating past sediment budget analyses for TMDL research, as well as other sediment management issues.

Autin, W.J., 1992, Use of Alloformations for Definition of Holocene Meander Belts in the Middle Amite River, Southeastern Louisiana: Geological Society of America Bulletin, v.104 (2), p. 233-241.

Birkeland, P.W., 1999, Soils and Geomorphology. Oxford University Press, New York, 430 pp.

Blum, M.D., and S. Valastro., 1994, Late Quaternary sedimentation, lower Colorado River, Gulf Coastal Plain of Texas: Geological Society of America Bulletin, v. 106, p.1002-1016

Buntley, G.J. and F.C. Westin, 1965, A comparative study of developmental color in a Chestnut-Chernozem-Brunizem soil climosequence: Soil Science Society of America Proceedings, no. 29, p. 579-582.

Buol, S.W, F.E. Hole, R.J. McCracken, R.J. Southard, 1997, Soil Genesis and Classification. Fourth edition. 572 pp.

<http://fisher.lib.virginia.edu/census/>

Colquhoun, D. et al, 1991, Quaternary geology of the Atlantic Coastal Plain: The Geology of North America, Vol k-2 Quaternary Nonglacial Geology: Conterminous U.S. The Geological Society of America.

Costa, J.E., 1975, Effects of agriculture on erosion and sedimentation in Piedmont province, Maryland: Bulletin of Geological Society of America. v.86, p.1281-1286.

Eargle, D.H., H.H Ireland, S.F.S. Sharpe, 1939, Principles of Gully Erosion in the Piedmont of South Carolina: USDA Technical Bulletin No.633

Fredrick, C.F., 2001, Evaluating causality of landscape change: examples from alluviation. In: P. Goldberg, V.T Holliday, C.R. Ferring, Earth Sciences and Archaeology. Kluwer/Plenum, New York. p.55-76

Gale, S.J. and P.G. Hoare, 1991, Quaternary Sediments: Petrographic Methods for the Study of Unlithified Rocks. New York, Halsted Press. 323 pp.

Gee, G.W. and Bauder, J.W, 1986, Particle-Size Analysis: American Society of Agronomy-Soil Science Society of America.

Happ, S.C., 1945, Sedimentation in South Carolina Piedmont Valleys: American Journal of Science. v. 243 (3), p. 113-126.

Harper, F., 1967, Travels of William Bartram, Naturalist's Edition. New Haven: Yale Univeristy Press

Harrelson, C.C., C. L. Rawlins, and J.P Potyondy, 1994, Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA Forest Service, General Technical Report RM-245.

<http://www4.ncdc.noaa.gov/oa/climate/stationlocator.html> 2002, NCDC Climate-Radar Data Inventories. Athens, GA, United States

Hurst, V.J., 1977, Visual estimation of iron in saprolite: Geological Society of America Bulletin. v.1648, p.19-21.

- Jacobson, R.B. and Coleman, D.J., 1986, Stratigraphy and recent evolution of Maryland Piedmont floodplains: *American Journal of Science*, v. 286, p.617-637.
- Knighton, D., 1998, Channel change and human activity. In: *Fluvial Forms and Processes, A New Perspective*. New York.
- Knox, J.C., 1977, Human impacts on Wisconsin Stream Channels: *Annals of the Association of American Geographers*. v.67 (3), p. 323-342.
- Knox, J.C., 1987, Historical valley floor sedimentation in the Upper Mississippi valley: *Annals of the Association of American Geographers*. v.77 (2), p. 224-244.
- Lecce, S.A., 1997, Spatial patterns of historical overbank sedimentation and floodplain evolution, Blue River, Wisconsin: *Geomorphology*, v. 18, p. 265-277.
- Magilligan, F.J., 1985, Historical floodplain sedimentation in the Galena River Basin, Wisconsin and Illinois: *Annals of the Association of American Geographers*, v.75 (4), p. 583-594.
- Magilligan, F.J. and M.L. Stamp, 1997, Historical Land-Cover Changes and Hydrogeomorphic Adjustment in a Small Georgia Watershed: *Annals of the Association of American Geographers*, v. 87(4), p. 614-635.
- Meade, R.H., Yuzyk, T.R. and Day, T.J., 1990, Movement and Storage of sediment in rivers of the United States and Canada, in Wolman, M.G and Riggs, H.C, eds., *Surface water hydrology*: Boulder, CO, Geological Society of America, *The Geology of North America*, v.O-1.

- Miller, S.O. et al., 1993, Fluvial response to land-use changes and climatic variations within the Drury Creek watershed, southern Illinois: *Geomorphology*. v. 6, p. 309-329.
- North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code: *American Association of Petroleum Geologists Bulletin*, v. 67 no5., p 841-875
- Ntungia, N.G., 2001, Analysis of Channel Change in River of the Georgia Piedmont (1938/42/44-1993/99): Masters of Science. University of Georgia, Athens, GA.
- Oppenheim, J.A., 1996, Sedimentation Rates and Fluvial Response to Land-Use Changes in a Small Georgia Piedmont Watershed: Masters of Science, University of Georgia, Athens, Georgia.
- Phillips, J. D., 1991, Fluvial sediment budgets in the North Carolina Piedmont: *Geomorphology*, v. 4, p. 231-241.
- Roehl, J.W. 1962, Sediment source areas, delivery ratios, and influencing morphological factors: *Symposium of Bari. Internat. Assoc. Sci. Hydrology Pub.* 59, p. 202-213.
- Soil Survey Division Staff, 1993, *Soil Survey Manual: U.S Department of Agriculture Handbook 18*. U.S Government Printing Office, Washington DC, pp. 437.
- Stamey, T.C. and G.W. Hess, 1993, Techniques for estimating magnitude and frequency of floods in rural basins in Georgia: *Geological Survey (U.S) and Georgia Department of Transportation. U.S Geological Survey, Atlanta, GA*, v. 93-4016, pp. 75.

- Stoughton, C.V., 2000, Channel Change in the South Fork Broad River, Georgia (1942-1993): Master of Arts, University of Georgia, Athens, Georgia.
- Stuiver, M. Reimver, P.J, Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormas, F.G., v.d Plicht, J., and Spurk, M. 1998, Radiocarbon 40, p. 1041-1083.
- Tabatabai, M.A. and J.M. Bremner, 1970, Use of the Leco Automatic 70-Second Carbon Analyzer for Total Carbon Analysis of Soils: Soil Science Society of America Proceedings. v. 34, p. 608-610.
- Trimble, S.W., 1969, Culturally accelerated sedimentation in the Middle Georgia Piedmont: Unpublished M.S. thesis, University of Georgia, Athens, Georgia.
- Trimble, S.W., 1974, Man-induced soil erosion on the Southern Piedmont, 1700-1970: Soil Conservation Society of America, pp.180.
- Trimble, S.W. and S.W. Lund, 1982, Soil conservation in the Coon Creek basin, Wisconsin: Journal of Soil and Water Conservation 37, v. 6 (198212), p. 355-356.
- Trimble, S.W., 1993, The distributed sediment budget model and watershed management in the Paleozoic Plateau of the Upper Midwestern United States: Physical Geography, v.14 (3), p. 285-303.
- USDA, Georgia Department of Agriculture, 1900-2001, Georgia Agricultural Facts: National Agricultural Statistics Service, Athens, Georgia.

United States Department of Agriculture, 1983, Sediment Sources, Yields, and Delivery Ratios National Engineering Handbook: Soil Conservation Service, Ch. 6, Section 3.

United States Environmental Protection Agency, 2000, Proposed Total Maximum Daily Load (TMDL) Development for Sediment, South Fork Broad River, Georgia. Athens, Georgia.

Woltemade, C.J., 1994, Form and Process: Fluvial Geomorphology and Flood-Flow Interaction, Grant River, Wisconsin: Annals of the Association of American Geographers. v. 84 (3), p. 462-479.