

Effectiveness of Forestry Best Management Practices for Water Quality Protection in Headwater Catchments in the Falls Lake Watershed

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Background

- 1987 Clean Water Act amendments required states to develop forest management guidelines to reduce nonpoint source pollution.
- 1999 North Carolina Environmental Management Commission adopted protection and mitigation buffer rules.
- 2005 NC BMP implementation survey indicated that NC BMP compliance was 82%, however science-based field data were needed to quantify and document the effectiveness of certain forestry BMPs.
- 2006 NC Forest Service received EPA 319 grant and formed a partnership with US Forest Service.
- 2008 Streamflow and water quality monitoring began.

Objective and Goals

Objective:

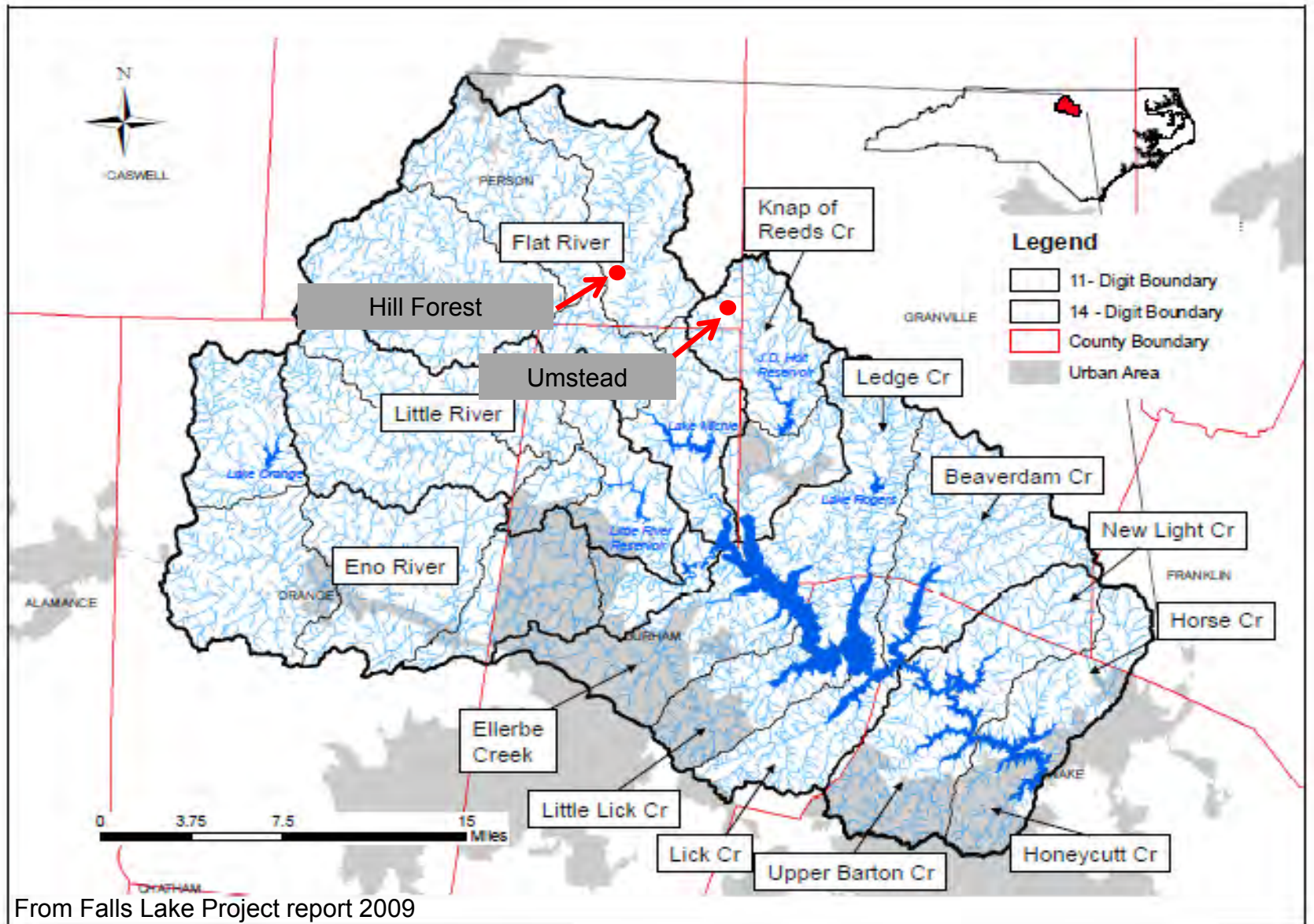
- Evaluate the effectiveness of streamside management zones (SMZs) and stream crossings BMPs on water quality protection in NC piedmont forested watersheds.

Goals:

- **Quantify the effectiveness of forestry BMPs** on a small headwater watershed scale at preventing erosion and sedimentation.
- **Evaluate the Neuse River Basin Riparian Buffer Rule** as it relates to forestry operations.

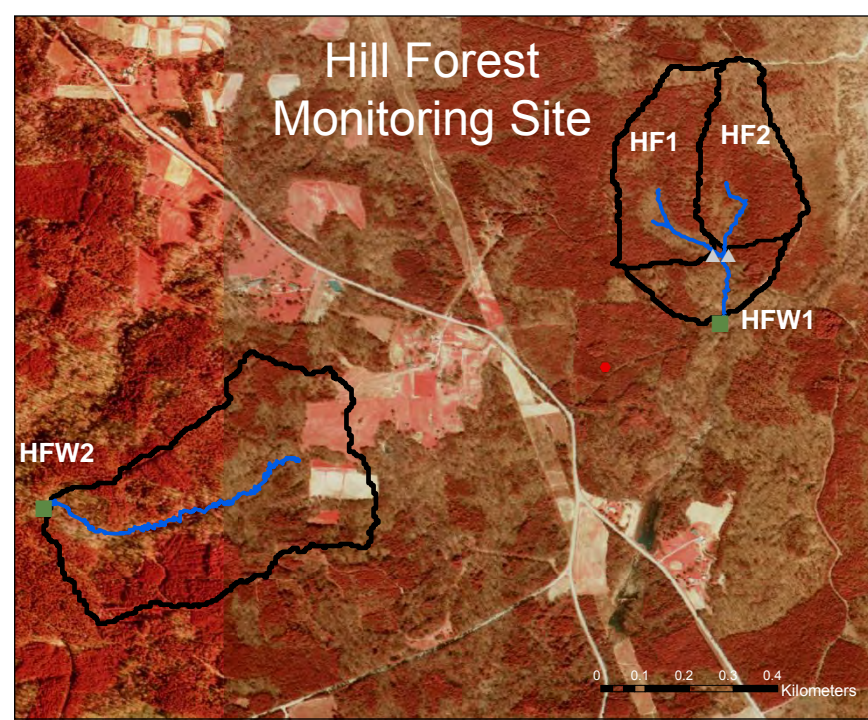
Project Schedule

- Five year study, 2008 – 2013.
- Pre-harvest monitoring, 2008 – 2010.
- Harvest (Treatment), Umstead September 2010 and Hill Forest January 2011.
- Post-Harvest monitoring 2010/2011 – 2013.

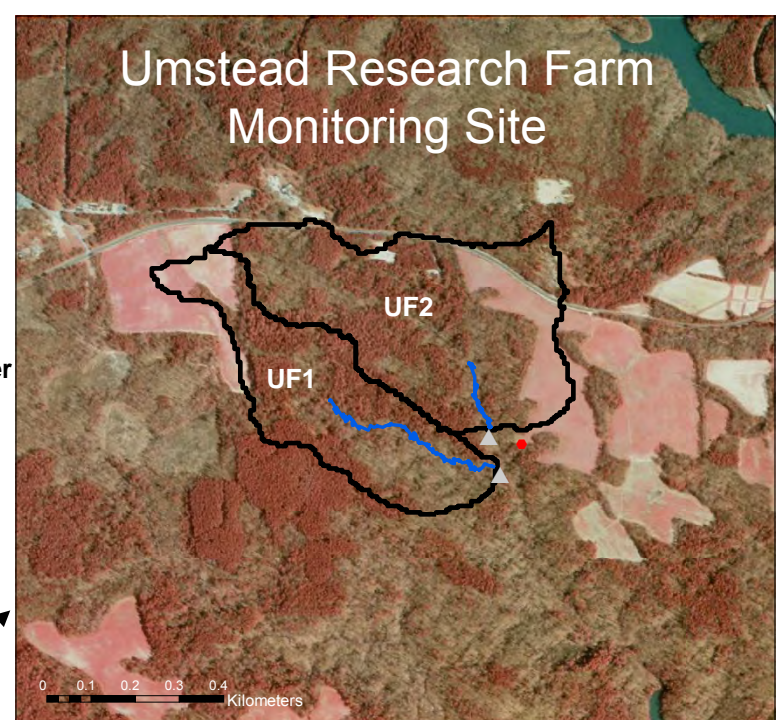


From Falls Lake Project report 2009

Hill Forest Monitoring Site



Umstead Research Farm Monitoring Site

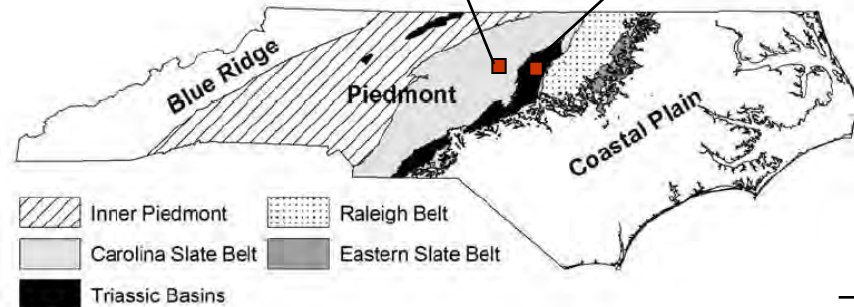


Watershed Characteristics.

	HF1	HF2	UF1	UF2	HFW1	HFW2
Size (ha)	12	12	19	29	29	40
Aspect	South	South	Southeast	Southeast	South	Southwest
Geologic regions	Carolina Slate Belt	Carolina Slate Belt	Triassic Basin	Triassic Basin	Carolina Slate Belt	Carolina Slate Belt

Carolina Slate Belt is more of a rocky region.

Triassic Basins is more of a sandy region where the soil is easily erodible.



Data Category	Parameters	Measurement Frequency	Methods
Meteorology	Rainfall, air temp, relative humidity, total solar radiation, wind speed	Sampled every 4 minutes, logged every hour	Onset micrometeorological station
Stream flow	Water depth, flow rate, flow volume	10 minute intervals	Weirs or flumes and associated water level recorders;
Water Table	Water below ground surface	Twice a month	Global Water pressure transducer
Soil Respiration	Carbon loss	10 minute intervals	EGM
Transpiration	Water use	10 minute intervals	Sapflow (thermal dissipation technique)
Soil Moisture/Temperature	Moisture and Temperature		Onset thermocouples
Vegetation	SMZ overstory, midstory and groundcover survey	Pre and Post harvest	Caroline Vegetation Survey
Land topography	Digital Elevation Model (DEM)	Once	USGS DEM database
Water quality (NCSU)	TSS, NO ₃ , NH ₄ , TP, TKN, TOC at the watershed outlets Stream Temperature Turbidity	During stormflow and baseflow 10 minute intervals 10 minute intervals	Sigma sampler programmed for storm event sampling. Hobo Water Temp Pro V2 Logger Global Water Turbidity Sensor
Stream channels	Channel geomorphology: Cross sections, longitudinal profiles, and stream patterns	Pre-harvest and post-harvest	Total Station
Stream crossing	TSS and Nutrients	Three days with similar flow/rain conditions; from at least 5 harvest sites in piedmont of N.C.	Sigma sampler programmed for storm-based water sampling.
Benthic Macroinvertebrate	Quantity	Sampling periods will be completed during low flow conditions in the winter, spring, and summer.	Protocols according to NCDWQ.

Hill Forest Watershed Carolina Slate Belt



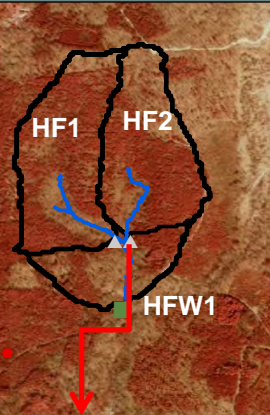
Streams found in Hill Forest are generally shallow, connected to their floodplain and have relatively steep upland slopes.

Umstead Farm Watershed Triassic Basin



Conversely, streams in Umstead have deeper stream channels that are detached from their floodplain with gentle upland slopes.

Hill Forest Monitoring Site

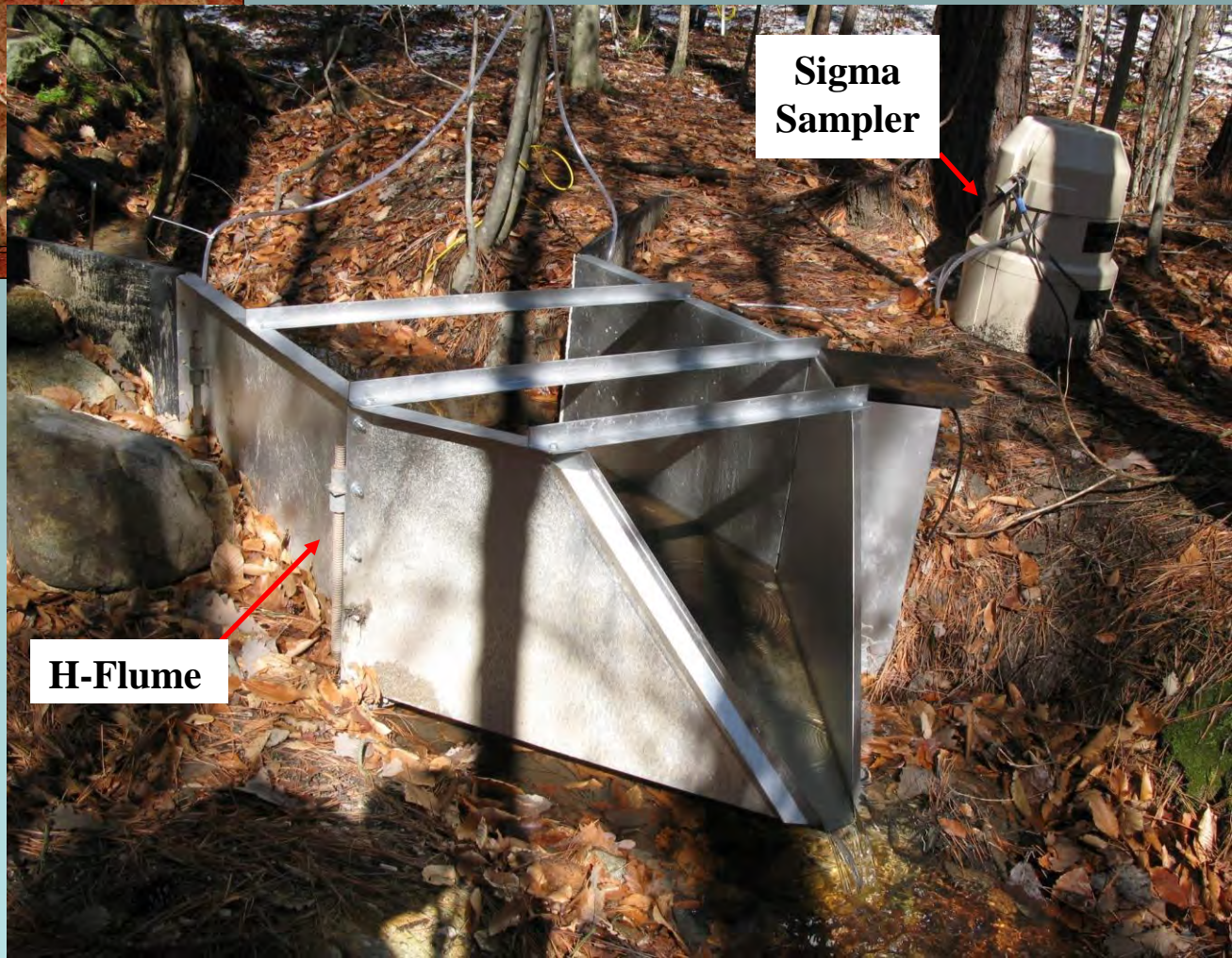


HFW2

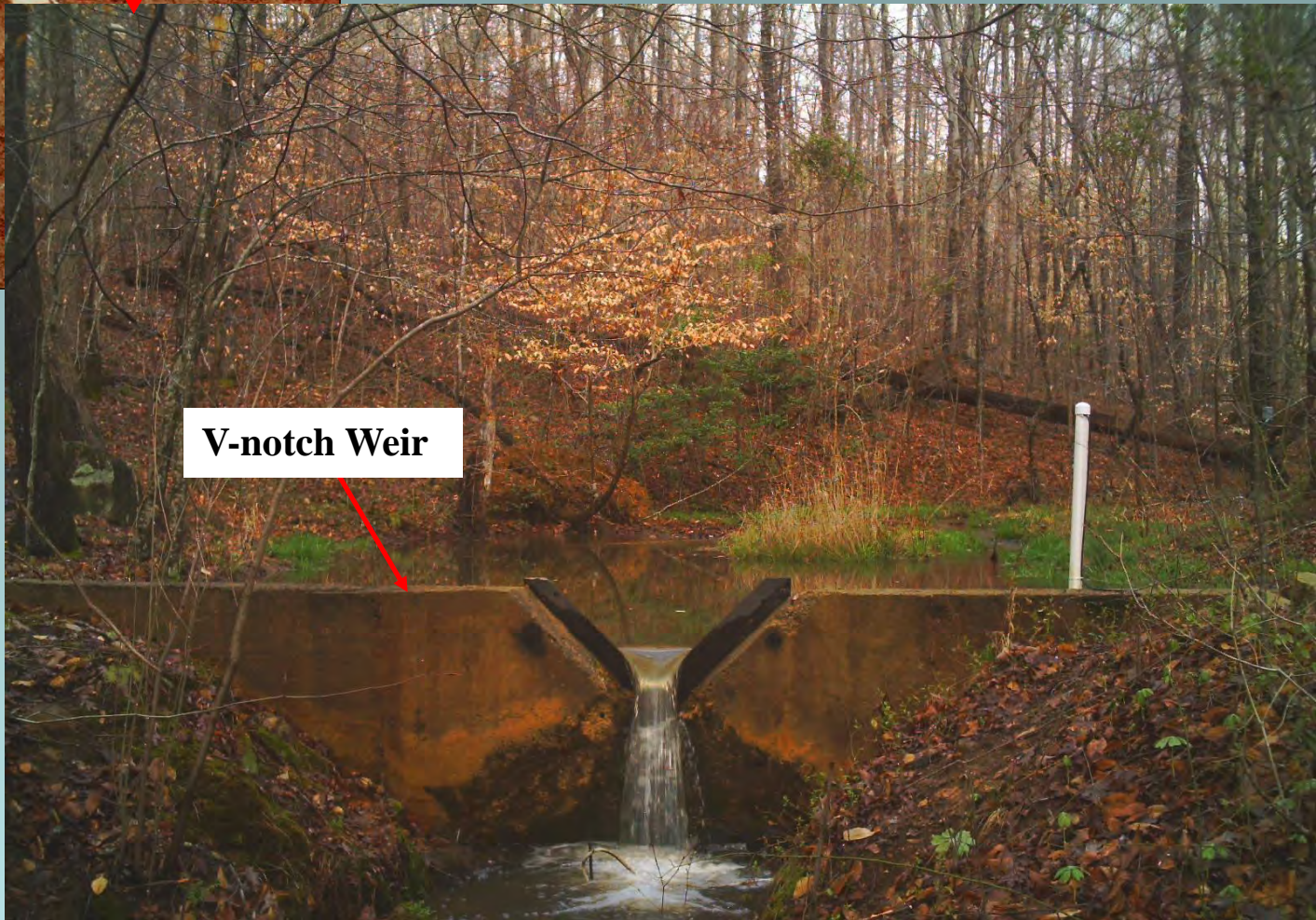
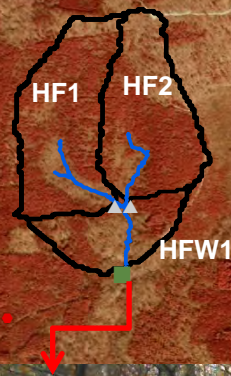


**Sigma
Sampler**

H-Flume



Hill Forest Monitoring Site



V-notch Weir

Paired Watershed Approach

Three Phases

1. Pre-harvest and Calibration monitoring

- Calibrating the paired watersheds is when a quantifiable hydrological and water quality relationship is developed through time between pairs.

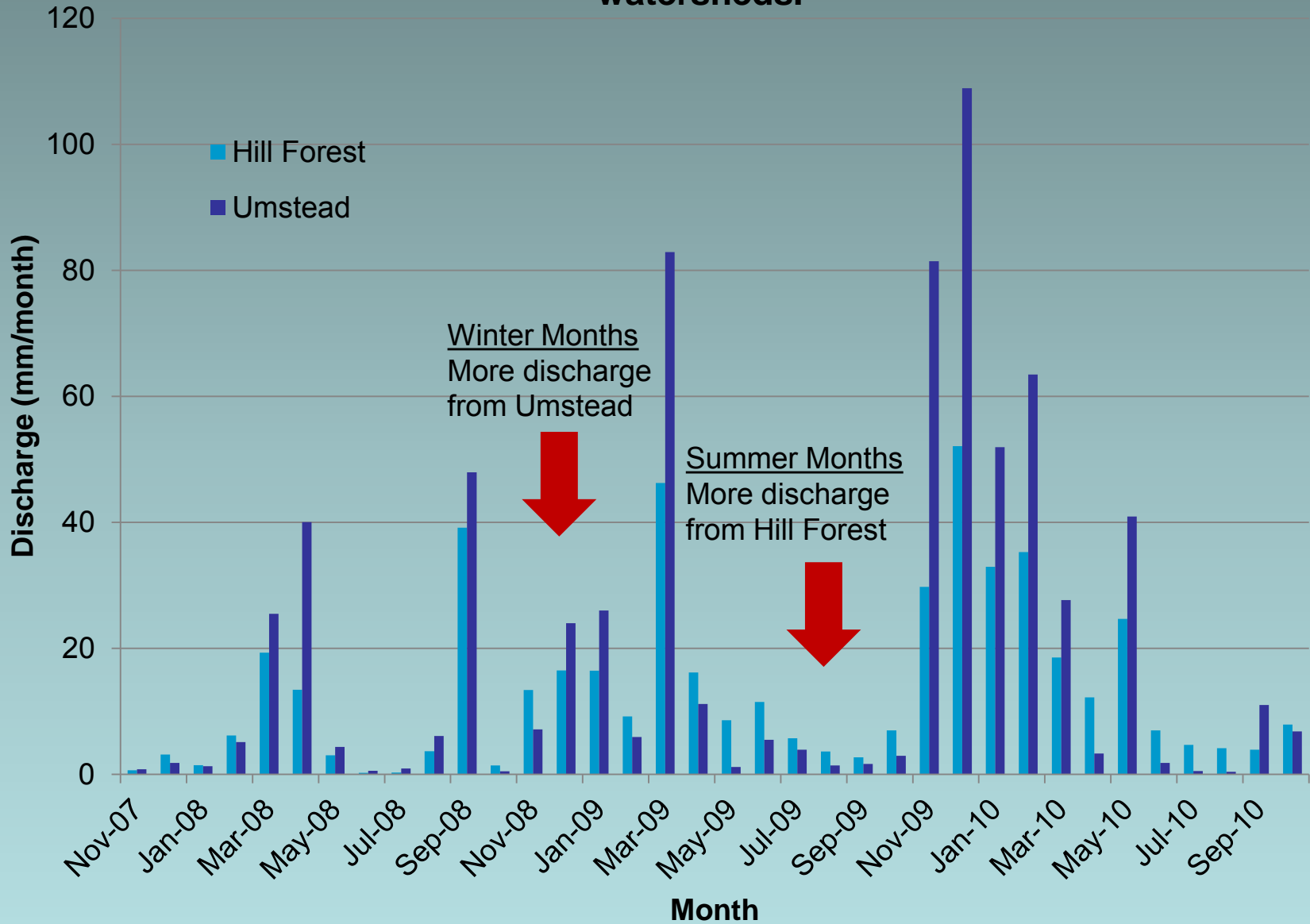
2. Treatment (harvest)

- Clear cut, leaving 50-foot buffer around stream.

3. Post-harvest monitoring

Pre-harvest and Calibration

Pre-Harvest Monthly Discharge from Hill Forest and Umstead watersheds.



Pre-harvest Nutrient and TSS export and discharge in NC Piedmont paired watersheds in 2008.

Watersheds	Geologic Regions	TSS	TN	NH ₄	NO ₃	TP	TOC	Discharge
		kg/ha/yr						
HF1	CSB	21	0.49	0.01	0.01	0.05	8.7	0.5
HF2	CSB	37	0.81	0.00	0.01	0.10	12.3	0.6
HFW1	CSB	22	0.65	0.01	0.03	0.08	9.2	1.4
HFW2	CSB	27	0.96	0.06	0.08	0.19	8.7	1.9
	Mean CSB	27 (7)A	0.73 (0.10)A	0.02 (0.03)A	0.03 (0.03)A	0.10 (0.06)A	9.7 (1.7)A	1.1 (0.7)A
UF1	TB	30	0.84	0.02	0.03	0.09	16.8	0.9
UF2	TB	40	1.53	0.03	0.35	0.08	21.2	1.6
	Mean TB	35 (7)A	1.18 (0.34)A	0.03 (0.00)A	0.19 (0.22)A	0.08 (0.01)A	19.0 (3.1)B	1.2 (0.5)A

Standard deviation is in parenthesis. Total Suspended Sediment (TSS), Total Organic Carbon (TOC), Ammonium (NH₄), Nitrate (NO₃), Total Phosphorus (TP), and Total Kjeldahl Nitrogen (TKN).

Means with the same letters are not significantly different, $p < 0.05$, Tukey test.

Harvest



FORESTRY Leaflets

WQ-1

December 2007

North Carolina Forest Practices Guidelines Related To Water Quality (FPGs): 15A NCAC 011 .0100 - .0209
The FPGs are statewide, mandatory rule requirements that were developed to ensure that forestry activities are conducted in a manner that protects our water quality. These regulations are administered as part of the North Carolina Sedimentation Pollution Control Act of 1973 (SPCA). All sections of the FPGs must be in compliance for your forestry-related, land-disturbing activity if it is to remain exempt from the full requirements of the SPCA. The FPG rule citations are provided in this Forestry Leaflet for your reference. Be sure to read through the General Provisions, as they explain the necessity of the Performance Standards that begin on Page 2. The N.C. Division of Forest Resources encourages you to use suitable Best Management Practices (BMPs) as the primary method of complying with the FPG regulations.

SECTION .0100 - GENERAL PROVISIONS

16A NCAC 011 .0101 INTRODUCTION AND PURPOSE

- (a) Forestry is a major contributor to the economy and quality of the environment in North Carolina. Forestry best management practices allow for the production, harvesting, and utilization of forest resources while maintaining satisfactory water quality. The rules in this Subchapter establish performance standards for the protection of water quality. The intent and purpose of these rules is not to cause or obstruct the lawful, proper and responsible use of forest resources. Persons must adhere to the standards related to land disturbing activities in order to attain the forestry exemption provided in the N.C. Sedimentation Pollution Control Act of 1973 as amended in 1989.
- (b) The Division of Forest Resources is responsible for the protection and development of forest resources in North Carolina, and has been designated by the Secretary of North Carolina Department of Environment, Health, and Natural Resources as the Division within the Department best able to assist the Secretary in the implementation of these rules.
- (c) The Forestry Best Management Practices Manual, published by the Division of Forest Resources in September, 1989, and as amended from time to time, contains specifications for a variety of practices which may be used to meet the performance standards set forth in this Subchapter. Best Management Practices (BMPs) shall be selected to allow for the variation in weather, topography, soil, and vegetation expected for the site and season. Implementation of these rules shall recognize that extreme and unusual weather can cause reasonable and otherwise adequate application of BMPs to fail to control sedimentation. Where installed BMPs fail, additional and more effective BMPs may be required. This manual and the rules in this Subchapter may be obtained by contacting the Director, Division of Forest Resources, Raleigh, North Carolina.

History Note: Authority G.S. 113-4; 113-4; 113A-32(b); 113-4-52.1; 143B-10(e) Eff. January 1, 1990.

16A NCAC 011 .0102 DEFINITIONS

In addition to the terms defined in G.S. 113-44.4 and 113A-52, the following definitions shall apply throughout this Subchapter:

- (1) "Accelerated Erosion" means any increase over the rate of natural erosion, as a result of land-disturbing activities.
- (2) "Access Road" means a temporary or permanent access route.
- (3) "Adverse Impact" as used for pesticides and fertilizers means actions which result in a violation of adopted water quality standards of the Environmental Management Commission Sections 15A NCAC 2B .0200 - Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina, 15A NCAC 2L .0200 - Classifications and Water Quality Standards (related to groundwater) and the N.C. Pesticide Board Rule 2 NCAC 1L .005 - Restricted Areas.
- (4) "Best Management Practice" (BMP) means a practice, or combination of practices, that is determined to be an effective and practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.
- (5) "Channel" means a natural water-carrying trough cut vertically into low areas of the land surface by stream action of concentrated flowing water or a ditch or canal excavated for the flow of water.
- (6) "Colloidal Particles" means fine grained materials, organic or inorganic, that are easily suspended such as clay particles.
- (7) "Ford" means a submerged stream crossing which will bear intended traffic.

- (8) "Ground Cover" means any natural vegetative growth or other natural or manmade material which renders the soil surface stable against accelerated erosion.
- (9) "Land-Disturbing Activity" means any use of the land by any person in residential, industrial, educational, institutional or commercial development, highway and road construction and maintenance that results in a change in the natural cover or topography and that may cause or contribute to sedimentation.
- (10) "Groundwater" means plastic water or subsurface water in the zone of saturation.
- (11) "Log Deck" means a place where logs are gathered in or near the forest for further transport, sometimes called a "landing."
- (12) "Mill Site" means any place where forest products are stored, altered, or processed.
- (13) "Permanently Stabilized" means the site is protected to the state in which no further accelerated erosion is expected to occur from the forestry activities.
- (14) "Pesticides" means a chemical used to kill pests. The term includes insecticides, fungicides, herbicides, and rodenticides.
- (15) "Site Preparation" means a forest activity to prepare the site for reforestation.
- (16) "Skid Trail" means a temporary pathway principally used to drag or transport felled trees or logs or other material to a landing.
- (17) "Stream" means a body of concentrated flowing water at a natural low area of the land surface.
 - (a) "Ephemeral stream" means a stream that flows only during and for short periods following precipitation and flows in low areas that may or may not have a well-defined channel.
 - (b) "Intermittent stream" means a stream that flows only during wet periods of the year (50-90 percent of the time) and flows in a continuous well-defined channel.
 - (c) "Perennial stream" means a stream that flows throughout a majority of the year (greater than 90 percent of the time) and flows in a well-defined channel.
- (18) "Streamside Management Zone (SMZ)" means an area along both sides of intermittent and perennial streams and perennial waterbodies where extra precaution is used in carrying out forest practices in order to protect water quality.
- (19) "Visible Sediment" means solid particulate matter, both mineral and organic, which can be seen with the unaided eye that has been or is being transported by water, air, gravity, or are from its site of origin. This does not normally include colloidal sized particles.
- (20) "Waterbody" means a natural or man-made basin that stores water, not including jurisdictional wetlands or beaver ponds.
- (18) "Working Days" means days exclusive of Saturdays and Sundays during which weather conditions or soil conditions permit land-disturbing activity to be undertaken.

History Note: Authority G.S. 113-44.4; 113-4-52; 113-4-52.1; Eff. January 1, 1990.

SECTION .0200 - PERFORMANCE STANDARDS

15A NCAC 011 .0201 STREAMSIDE MANAGEMENT ZONE

- (a) A streamside management zone (SMZ) shall be established and maintained along the margins of intermittent and perennial streams and perennial waterbodies. The SMZ shall be of sufficient width to confine within the SMZ visible sediment resulting from accelerated erosion.
- (b) Ground cover, or other means, within the SMZ shall be sufficient to restrain accelerated erosion.
- (c) Access roads, skid trails, except as provided in Rule .0203 of this Section, logging decks and mill sites shall be placed outside of SMZs. When barriers such as property lines or limiting land features prohibit the location of any of these outside of SMZs, they can be located within the SMZs. When located within SMZs they shall have effective erosion control and sediment control structures or measures installed to restrain accelerated erosion and prevent visible sediment from entering intermittent or perennial streams or perennial waterbodies.

History Note: Authority G.S. 113-4-52.1; Eff. January 1, 1990.

15A NCAC 011 .0202

PROHIBITION OF DEBRIS ENTERING STREAMS AND WATERBODIES

Stream obstruction and the impediment of stream flow and/or degradation of water quality shall be prevented by keeping debris from construction, harvesting, mill site residue, and site preparation out of intermittent and perennial streams and perennial waterbodies.

History Note: Authority G.S. 77-11; 77-14; 113-4-52.1; Eff. January 1, 1990.

15A NCAC 011 .0203 ACCESS ROAD AND SKID TRAIL STREAM CROSSINGS

Stream crossings shall be avoided when possible. Access roads and skid trails which must cross intermittent or perennial streams or perennial waterbodies shall be constructed so as to minimize the amount of sediment that enters the streams because of the construction. These crossings shall be installed so that

- (1) stream flow will not be obstructed or impeded;
- (2) no stream channel or perennial waterbody shall be used as an access road or skid trail;

Provisions for Selective Harvesting in the Riparian Buffer



Inner Zone 1: (0 to 10 feet)

High Value pine - DBH of 14 inches
High Value hardwood - DBH of 16 inches

Outer Zone 1: (10 to 30 feet)

Maximum of 50 percent of trees greater than 5 inches DBH may be harvested

Zone 2: (30 to 50 feet)

Any tree harvesting is allowed so long as there is sufficient ground cover maintained

Umstead Research Farm

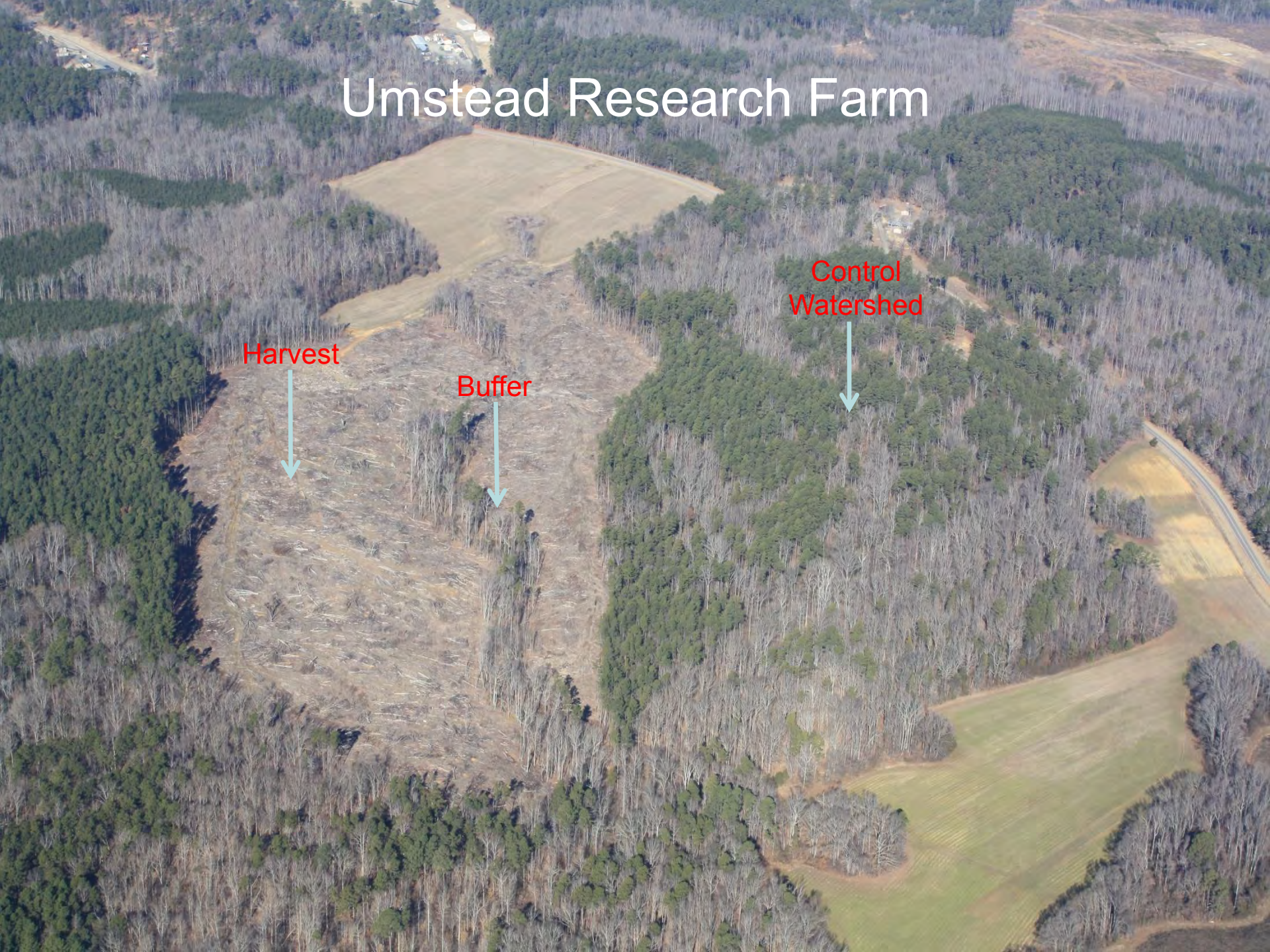
Harvest



Buffer



Control
Watershed



Hill Demonstration Forest

Harvest



Buffer



Control Watershed



Example of tree removed from SMZ



Overstory Trees/ha in SMZ

Umstead

Pre-harvest = 487

Post-harvest = 383

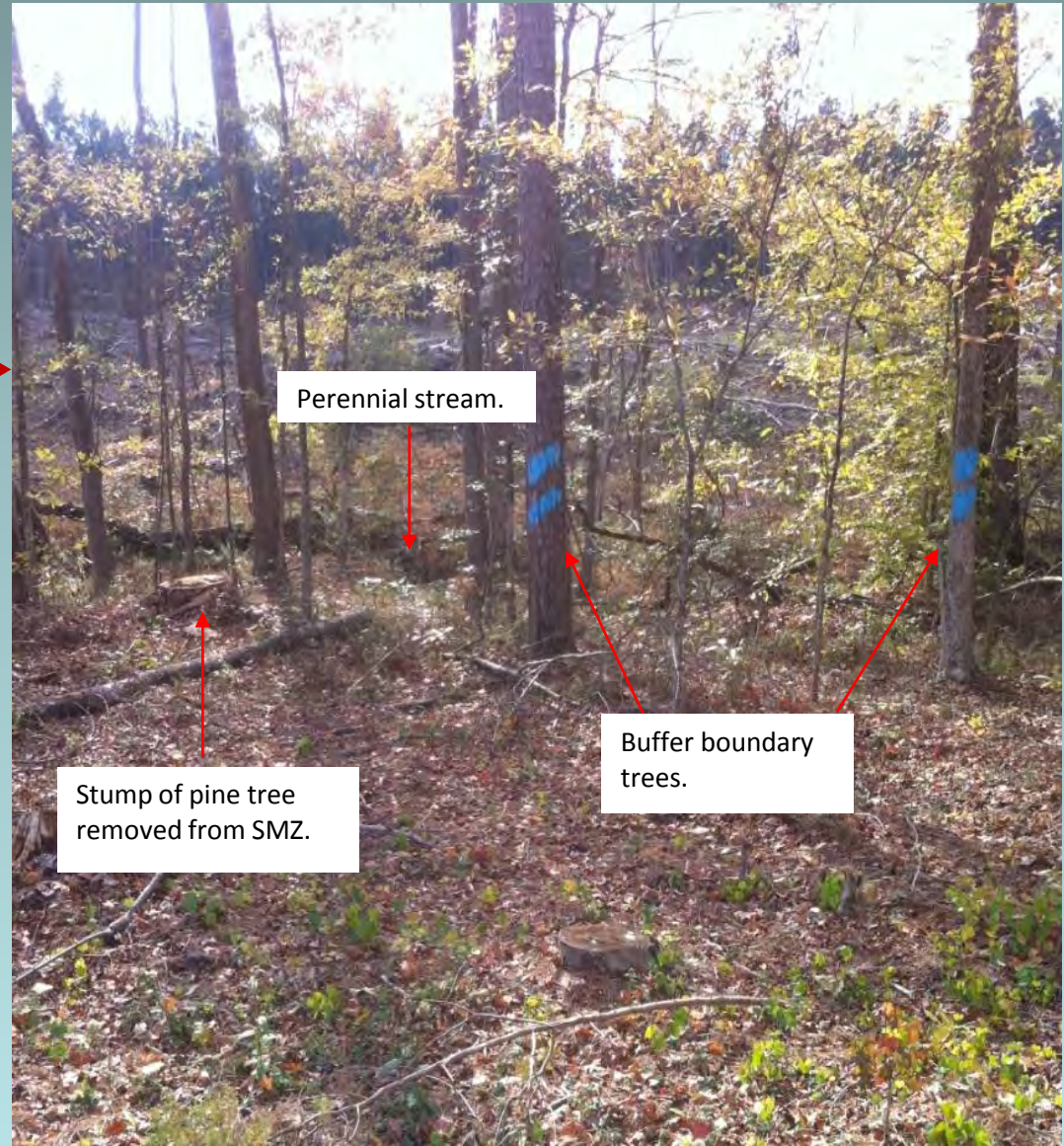
Removed 26% trees/ha

Hill Forest

Pre-harvest = 628

Post-harvest = 476

Removed 32% trees/ha



Reforestation Measures Hill Forest

Recommended Species and stocking:

- Improved Loblolly Pine seedlings of Piedmont origin to be planted at 435 TPA.

Recommended Site Preparation:

- Herbicide at labeled rates to control competition on the site.
- Prescribed fire

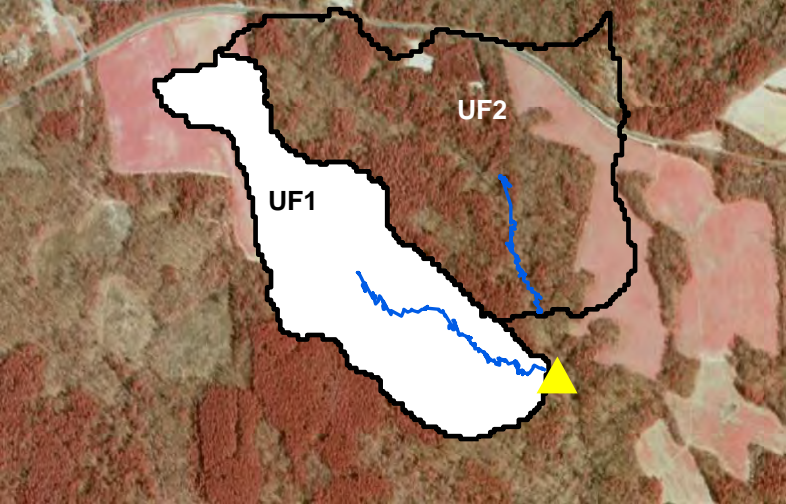
Recommended Reforestation Method:

- Hand plant

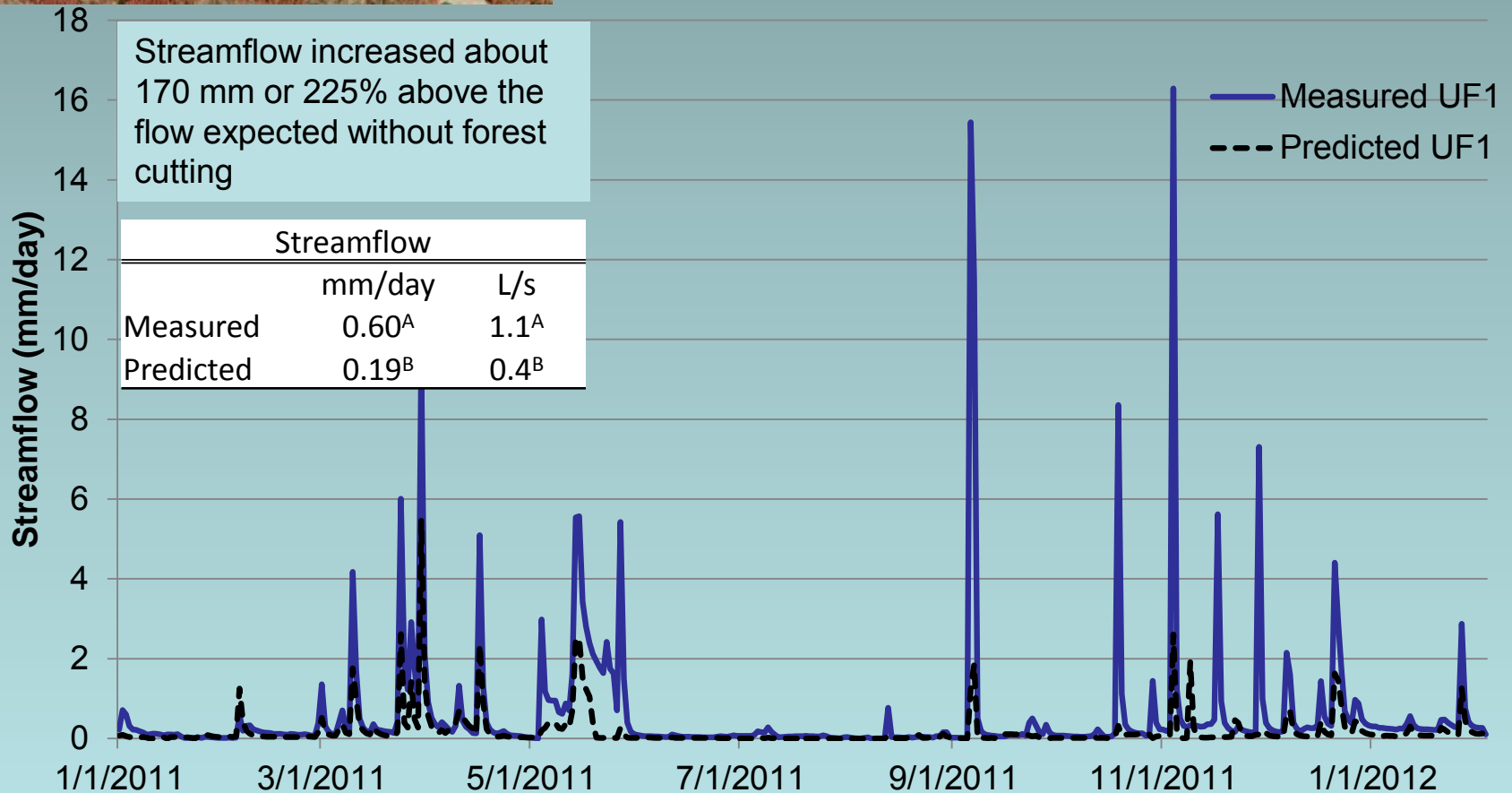
Detail additional anticipated silviculture treatments to get stand to age 5:

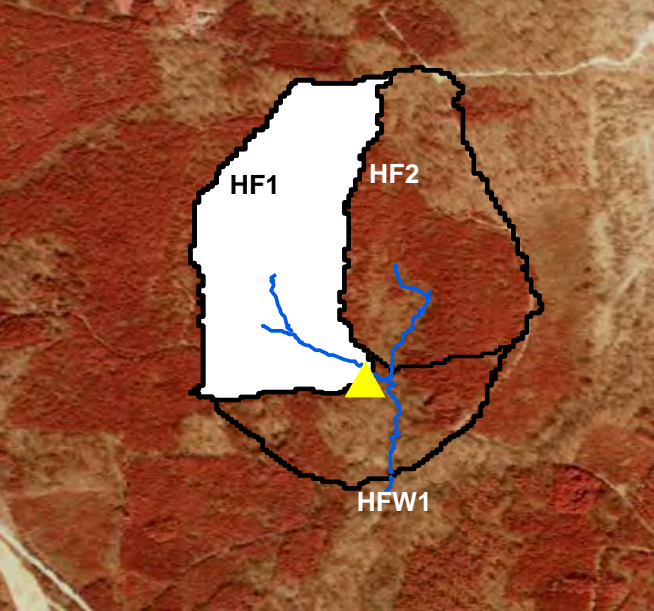
- Herbicide control of HWD competition
- PCT at age 3-4

Post-harvest monitoring

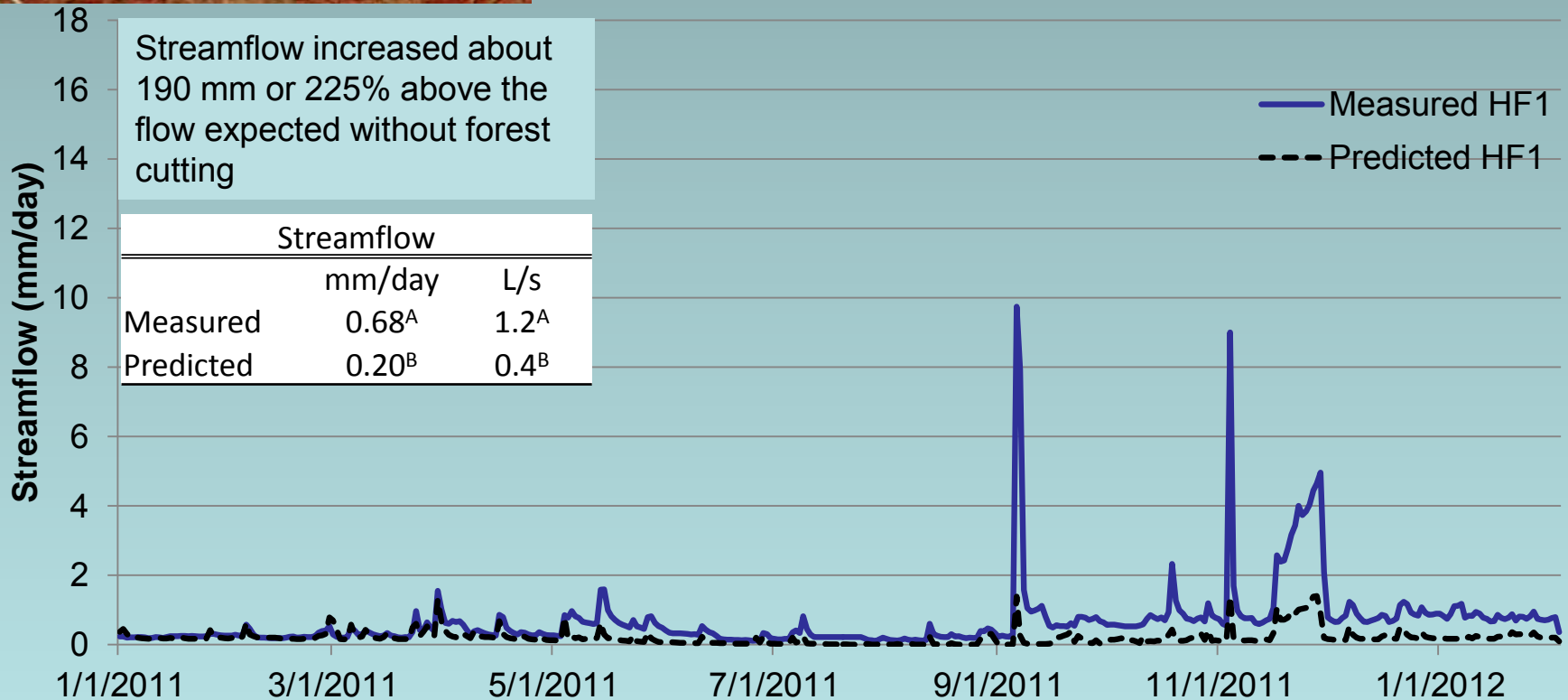


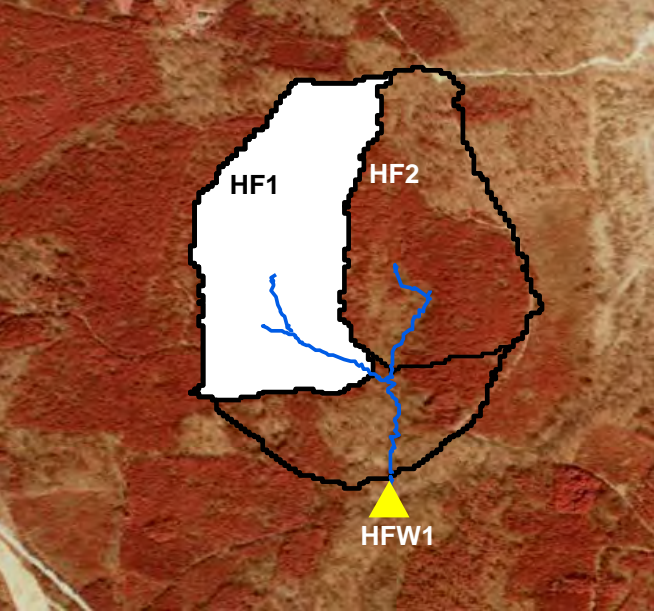
Streamflow Umstead UF1



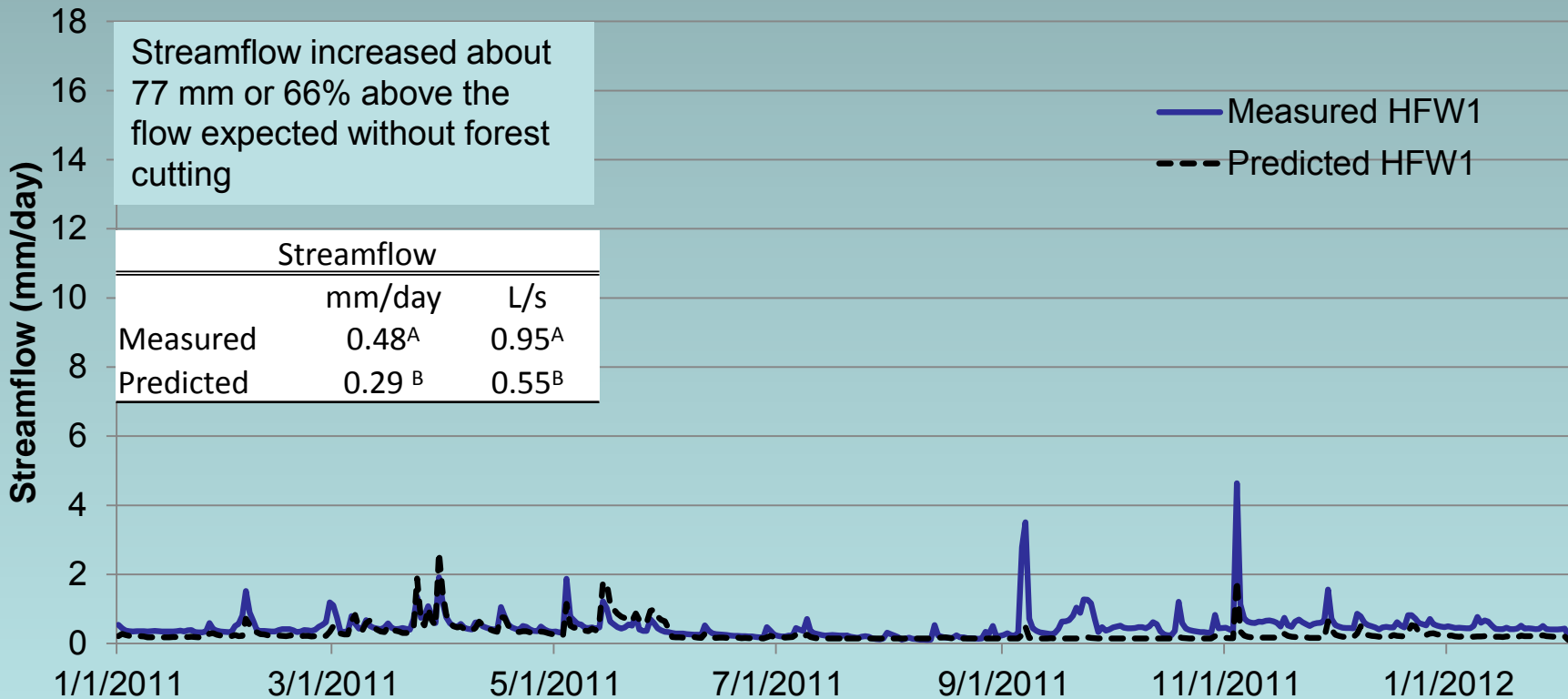


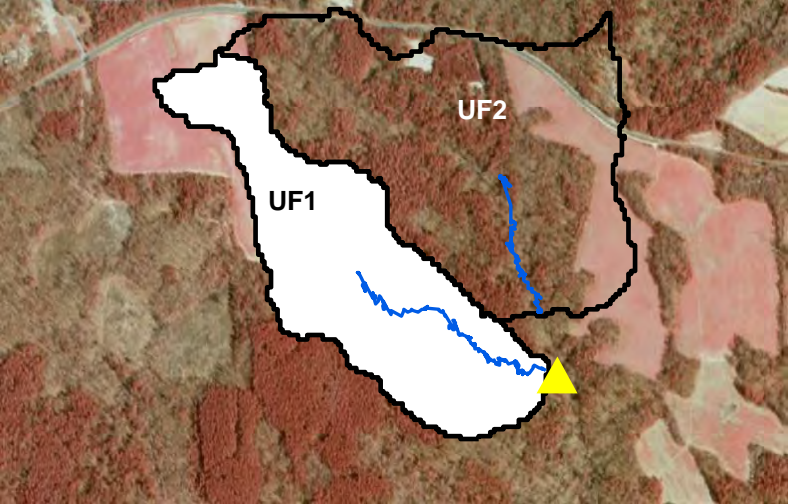
Streamflow Hill Forest HF1



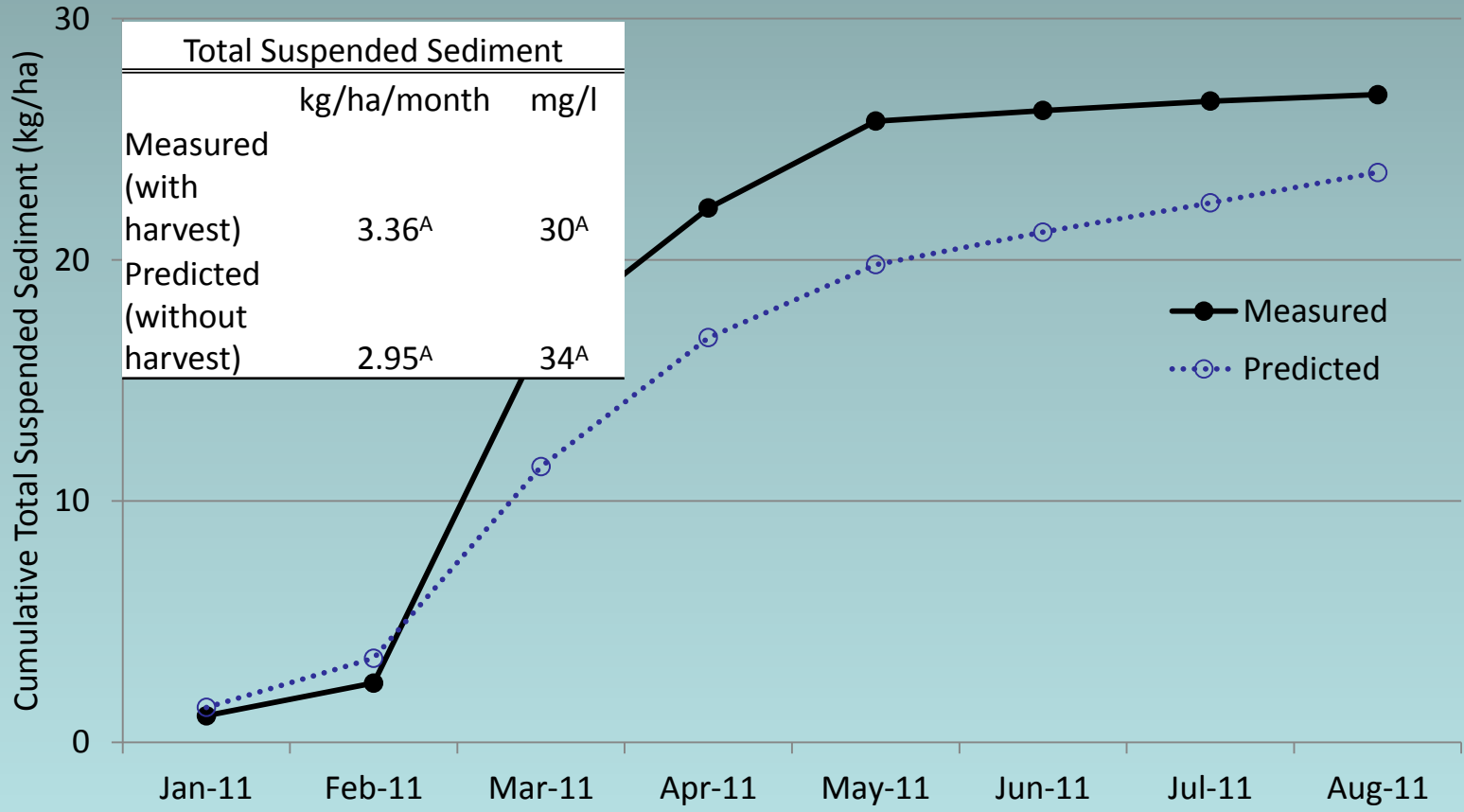


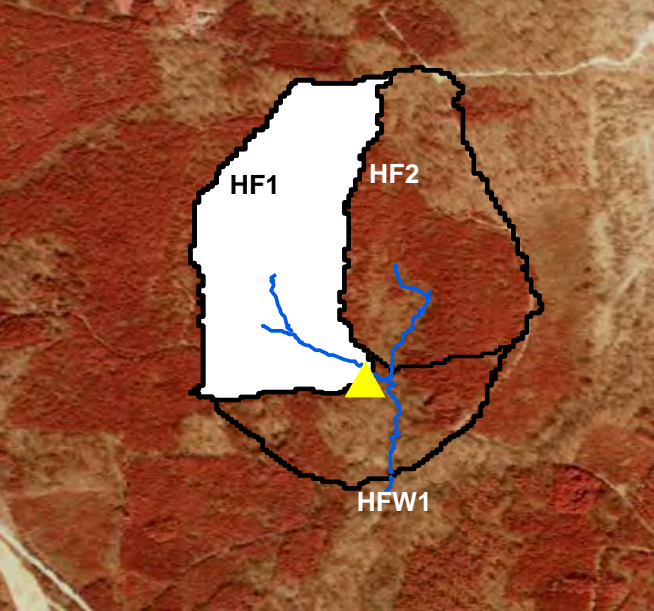
Streamflow Hill Forest HFW1



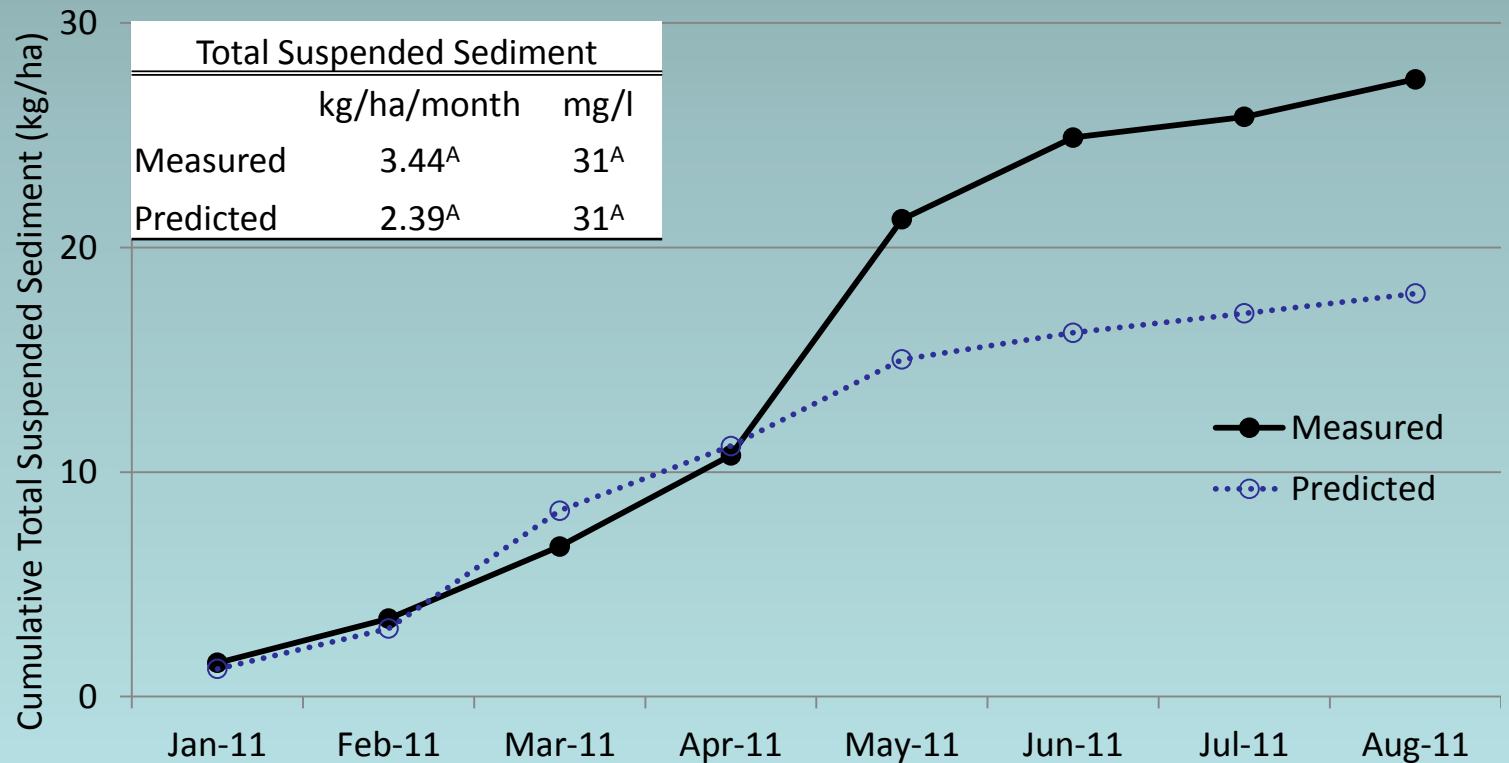


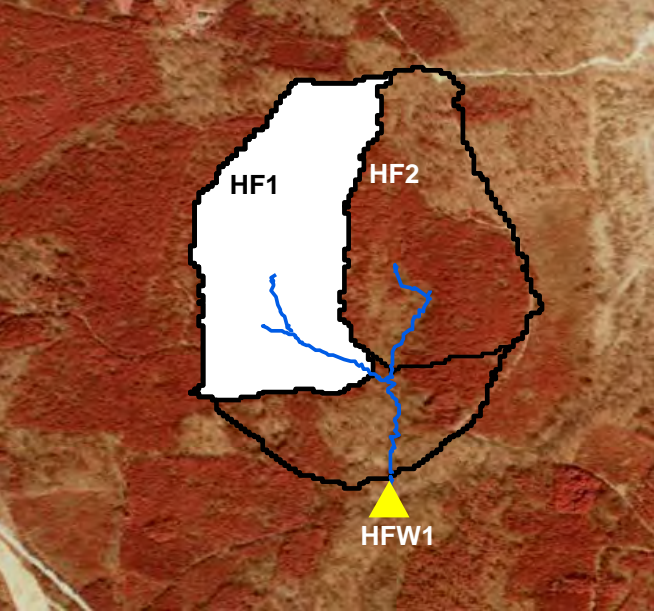
Total Suspended Sediment Load Umstead UF1



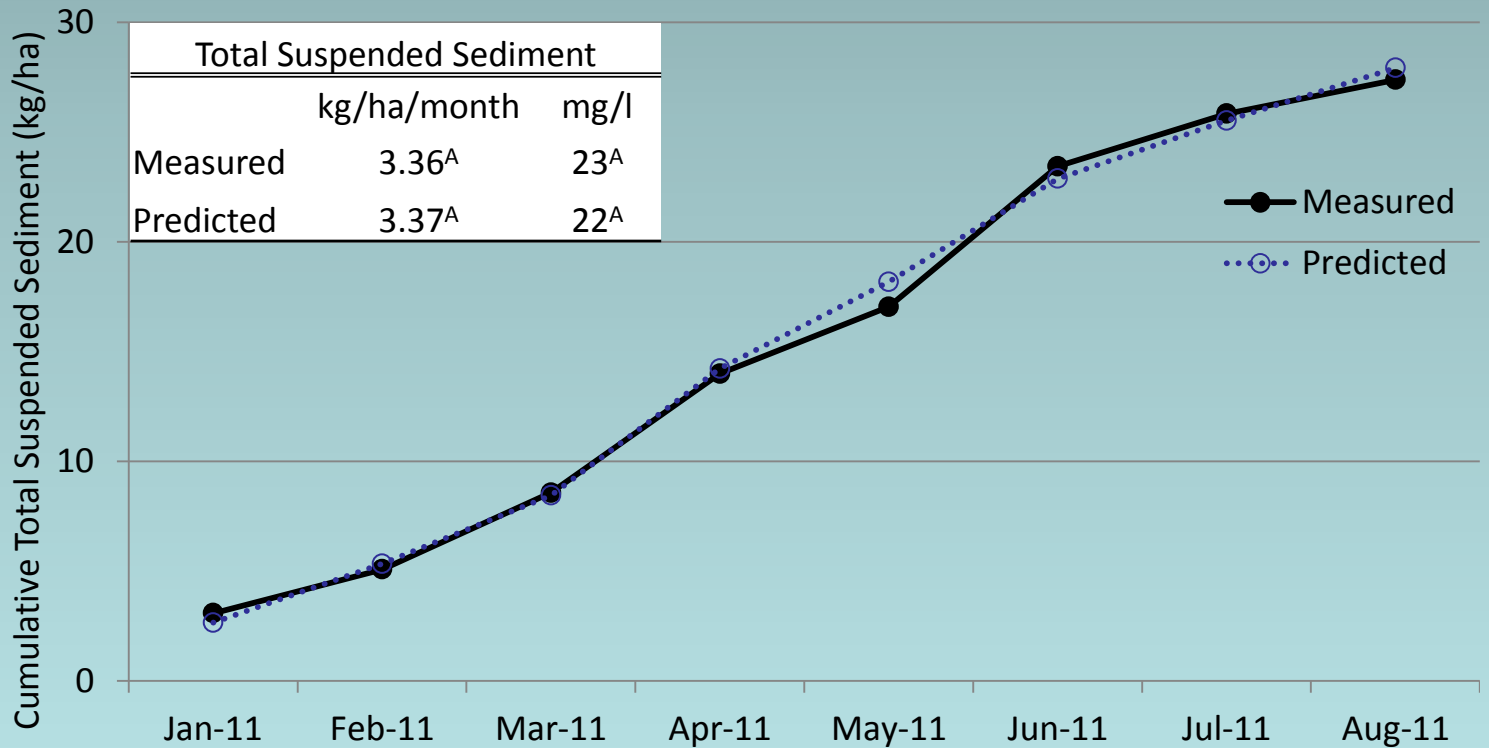


Total Suspended Sediment Hill Forest HF1





Total Suspended Sediment Hill Forest HFW1





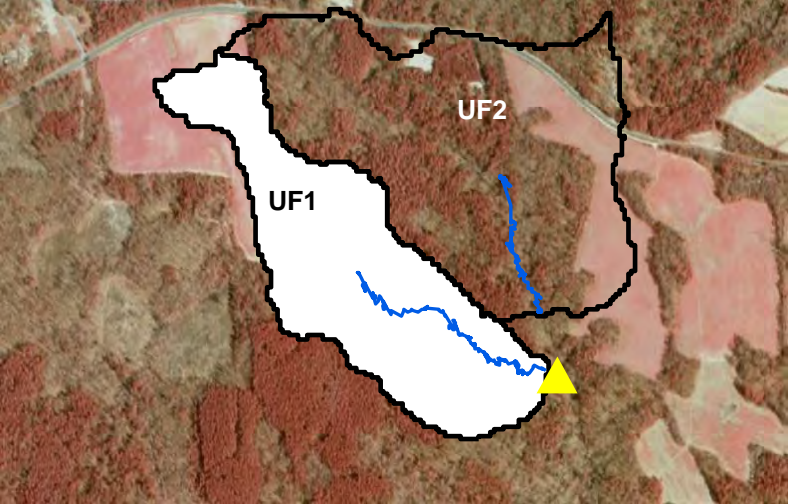
TSS = 30 mg/l



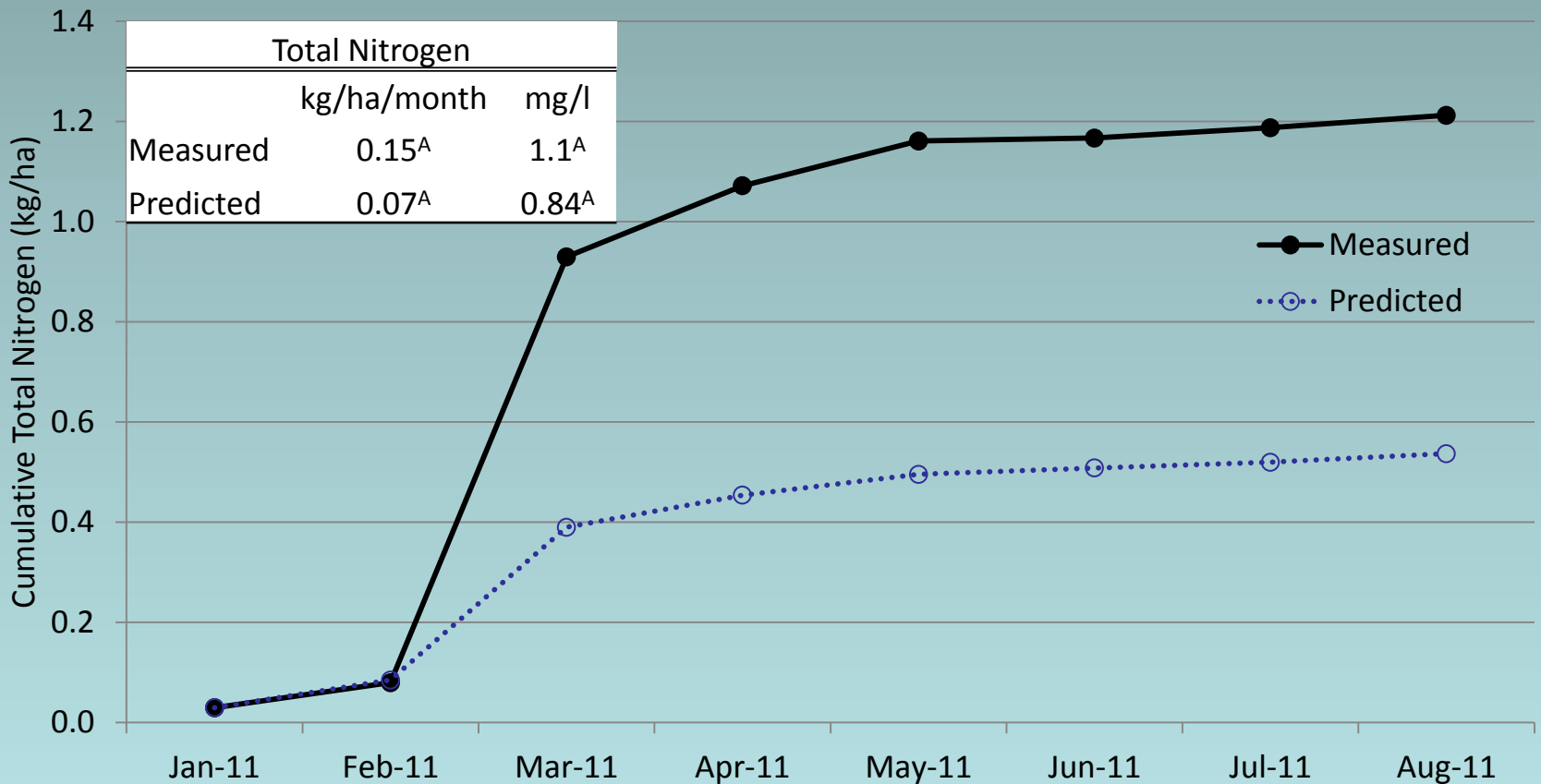
TSS = 60 mg/l

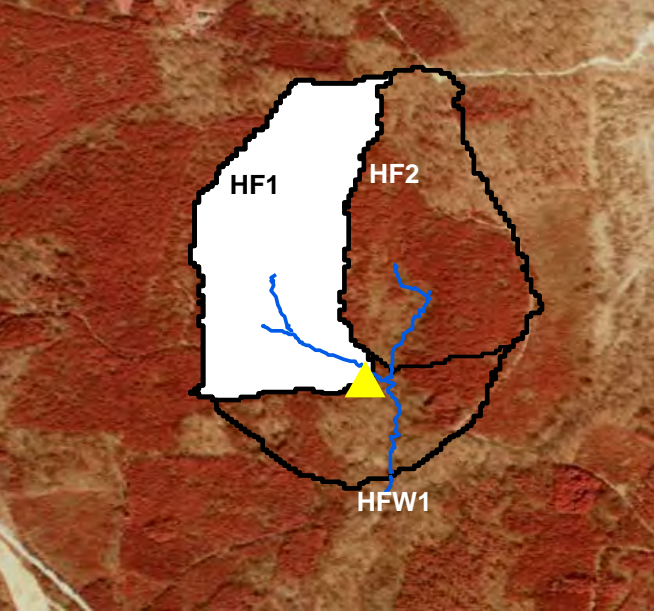


TSS = 160 mg/l

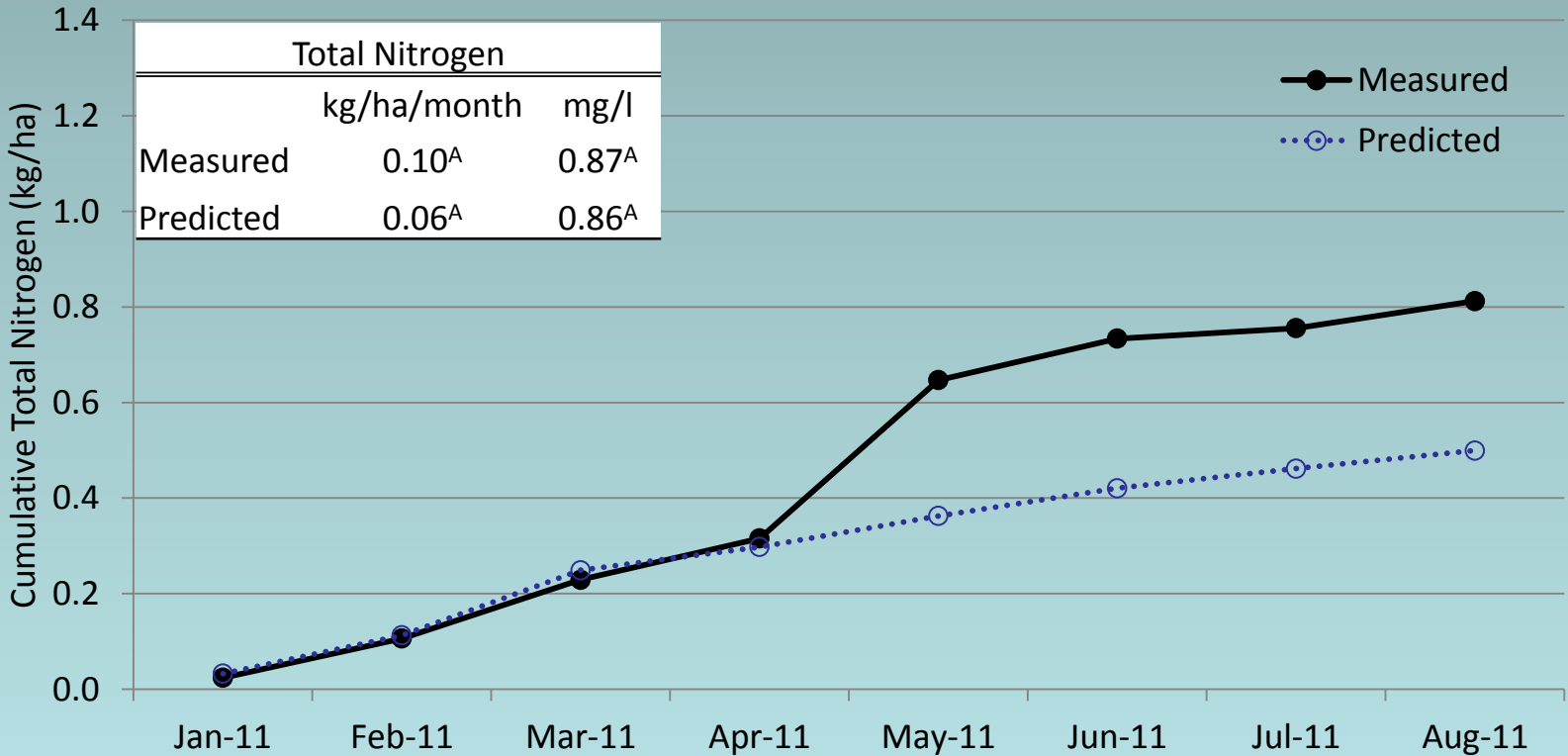


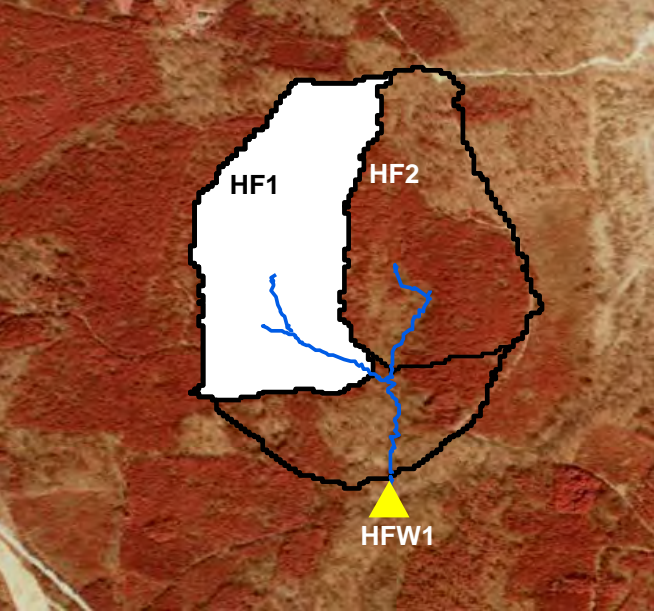
Total Nitrogen Load Umstead UF1



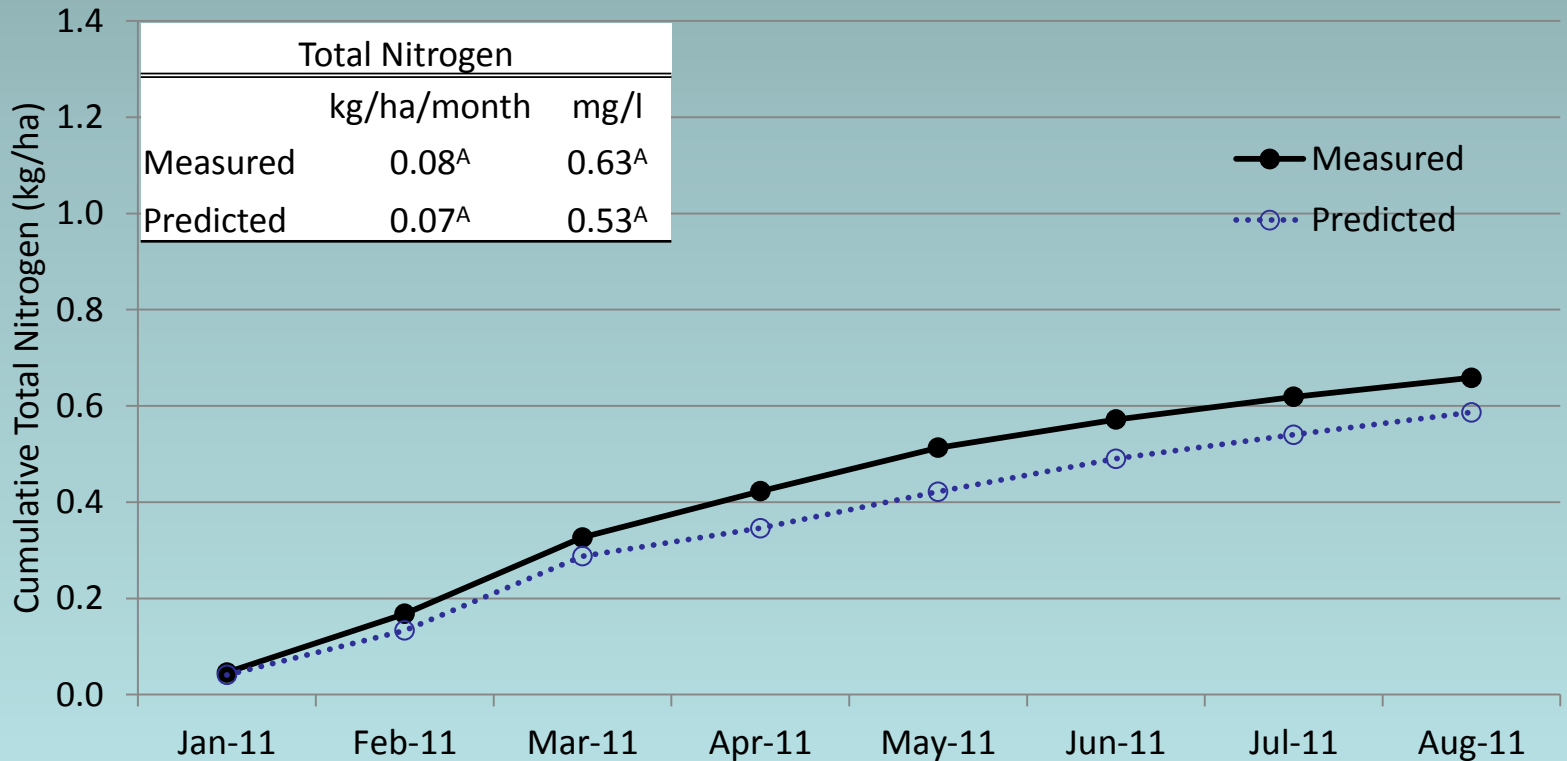


Total Nitrogen Load Hill Forest HF1





Total Nitrogen Load Hill Forest HFW1

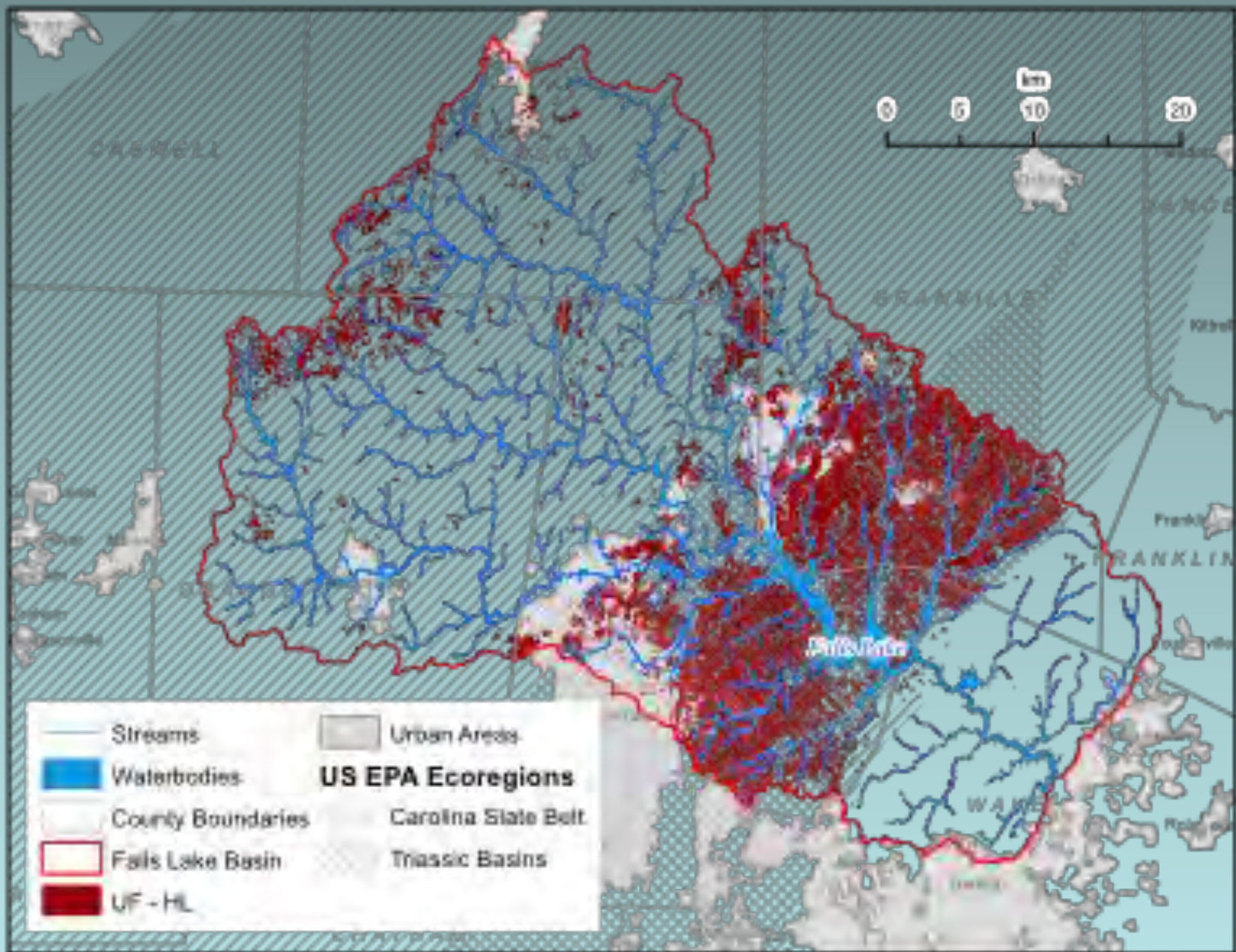


Macroinvertebrate benthic metric results

Watersheds	Geologic Regions	Biotic Index	Stream Quality
Pre-harvest April 2010			
HF1	CSB	3.3	Excellent
HF2	CSB	3.0	Excellent
HFW1	CSB	3.3	Excellent
HFW2	CSB	2.8	Excellent
UF1	TB	4.8	Excellent
UF2	TB	4.0	Excellent
Post-harvest July 2011			
HF1	CSB	4.0	Excellent
HF2	CSB	3.2	Excellent
HFW1	CSB	3.3	Excellent
HFW2	CSB	6.3	Fair
UF1	TB	4.8	Excellent
UF2	TB	6.6	Fair

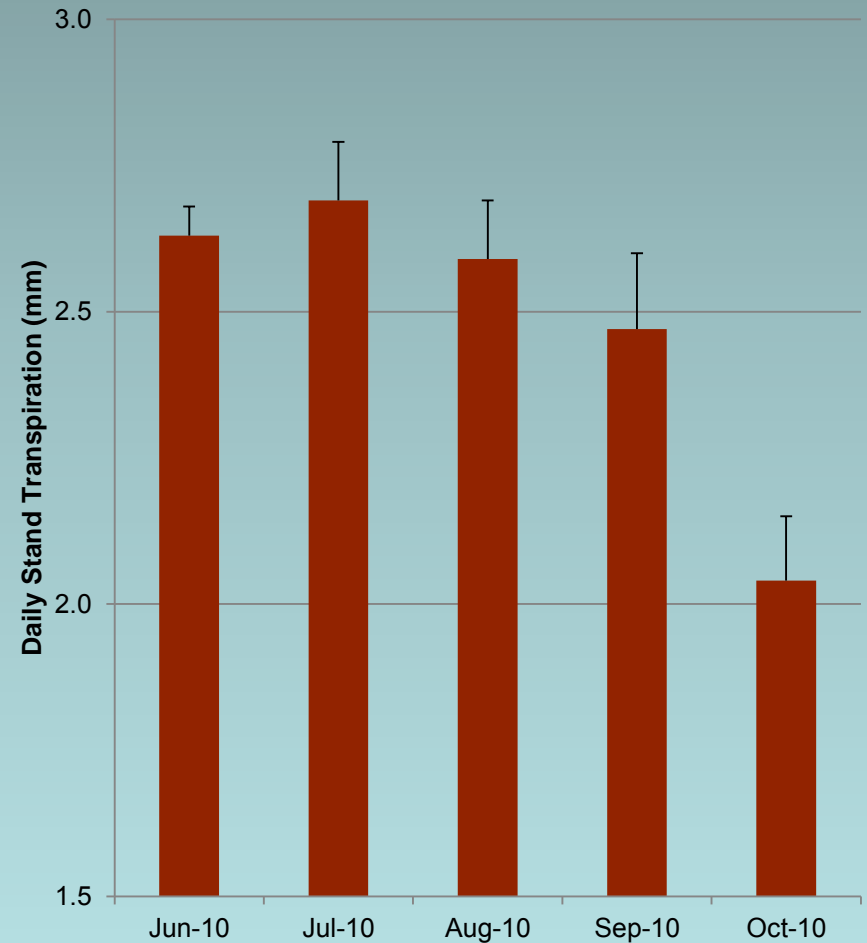
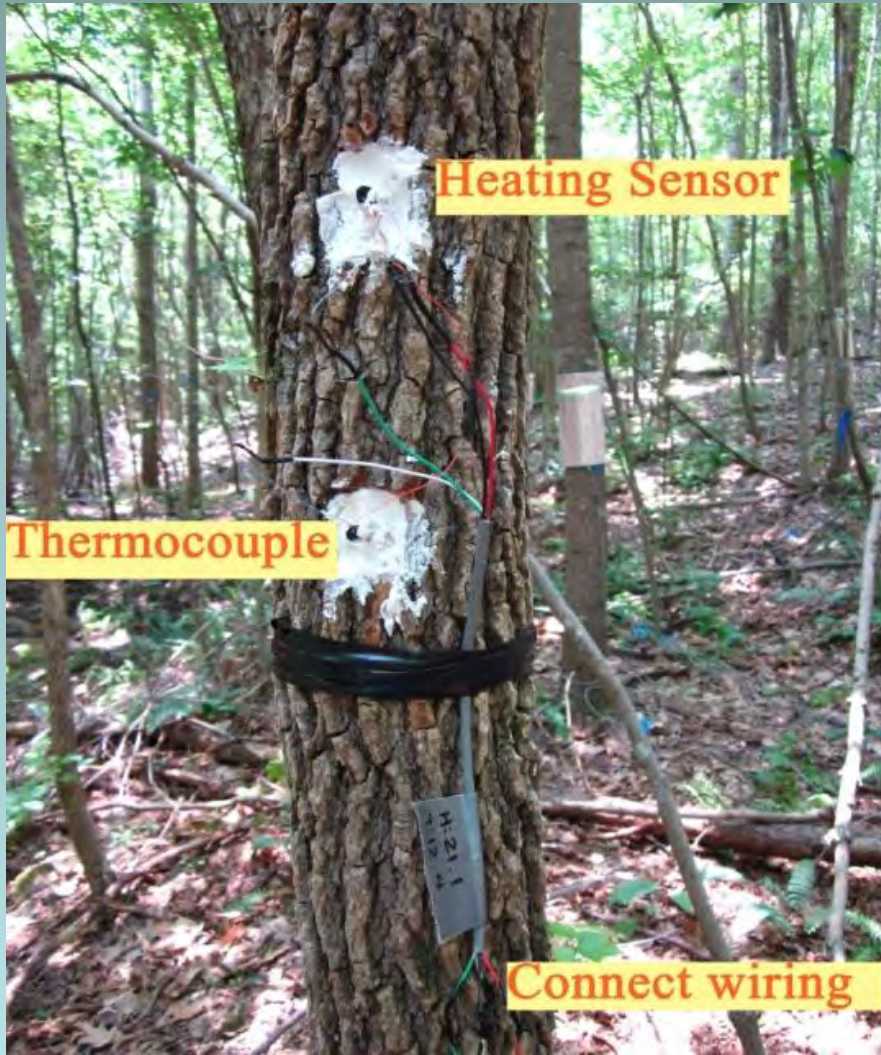
Standard deviation is in parenthesis. Criteria for NC Biotic Index: Excellent < 5.24, Good 5.25 - 5.95, Good-Fair 5.96 - 6.67, Fair 6.68 - 7.70, Poor > 7.71 (Source: Lenat 1993).

EPT = Ephemeroptera, Plecoptera, and Trichoptera.



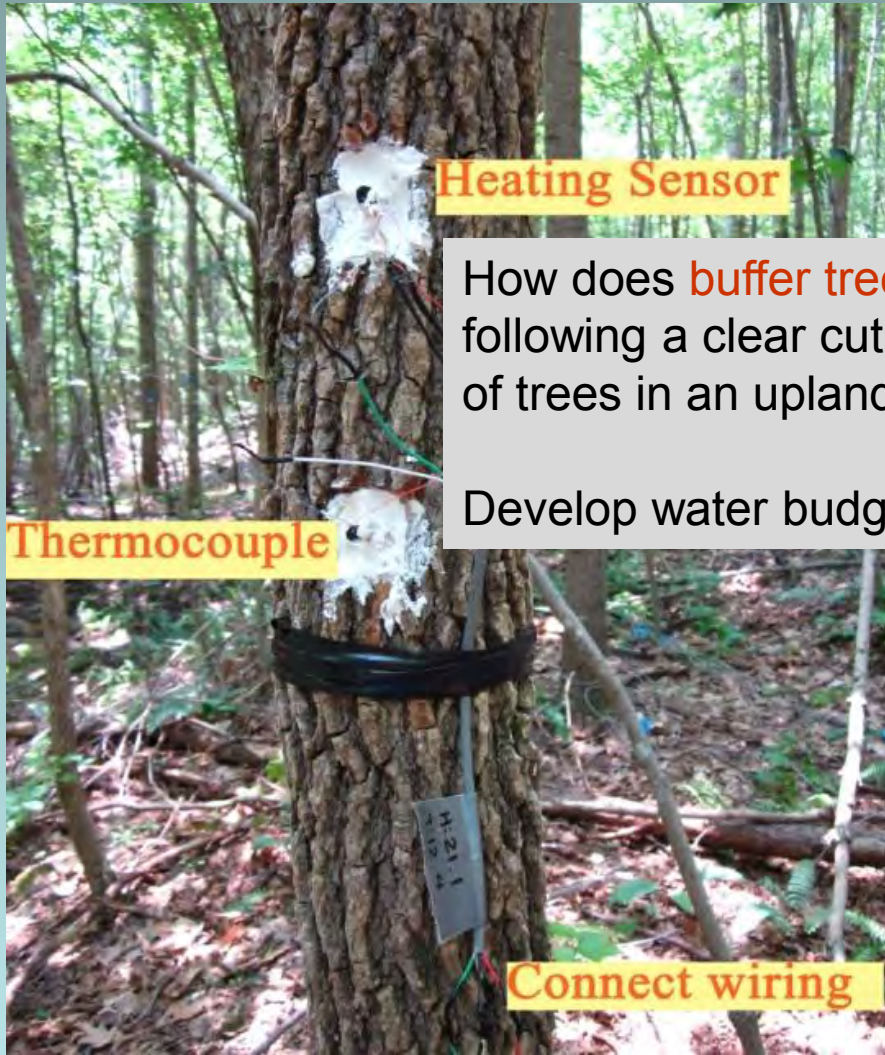
Other Projects

- Stand transpiration, Hill Forest.



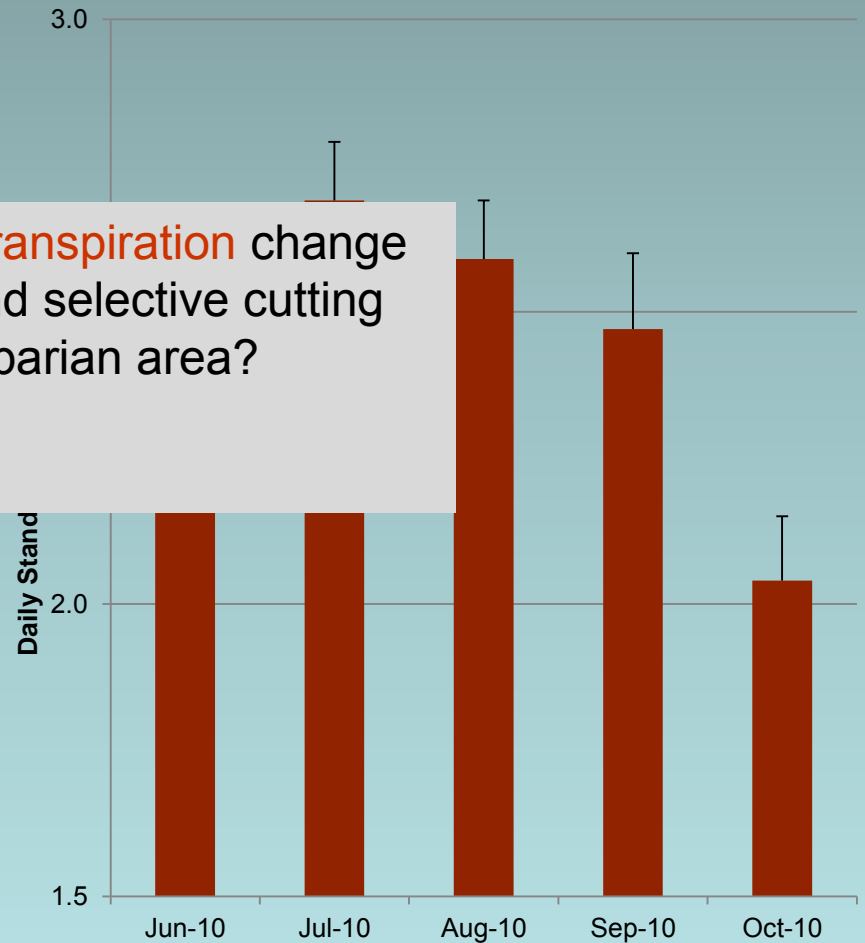
Other Projects

- Stand transpiration, Hill Forest.



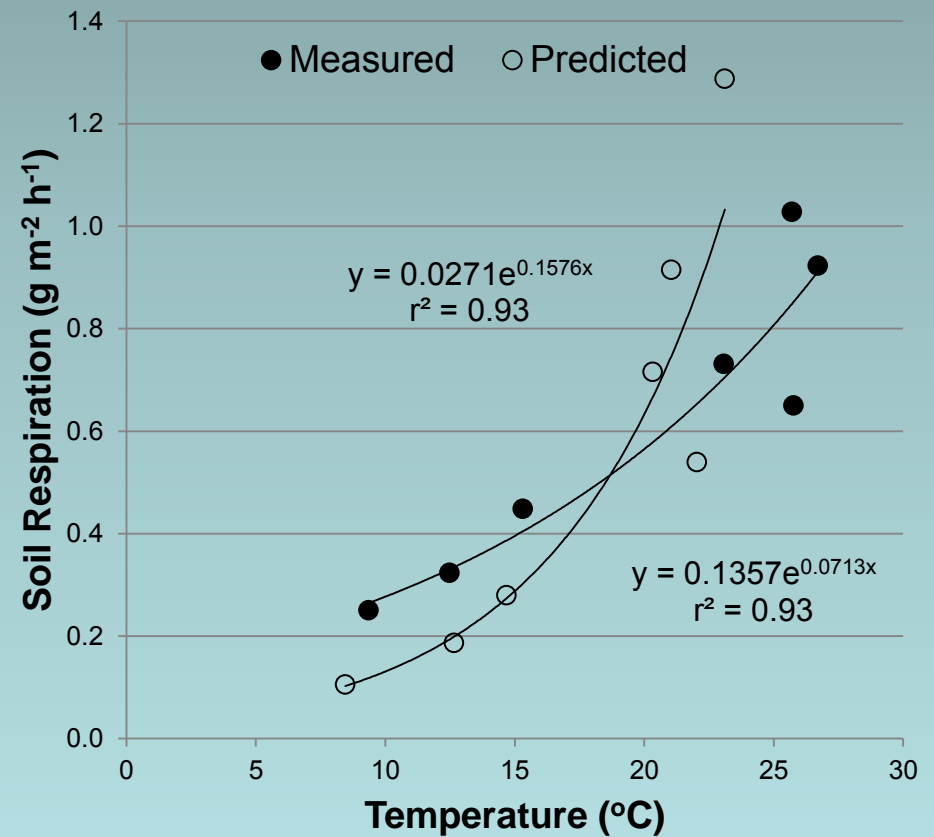
How does **buffer tree transpiration** change following a clear cut and selective cutting of trees in an upland riparian area?

Develop water budget.



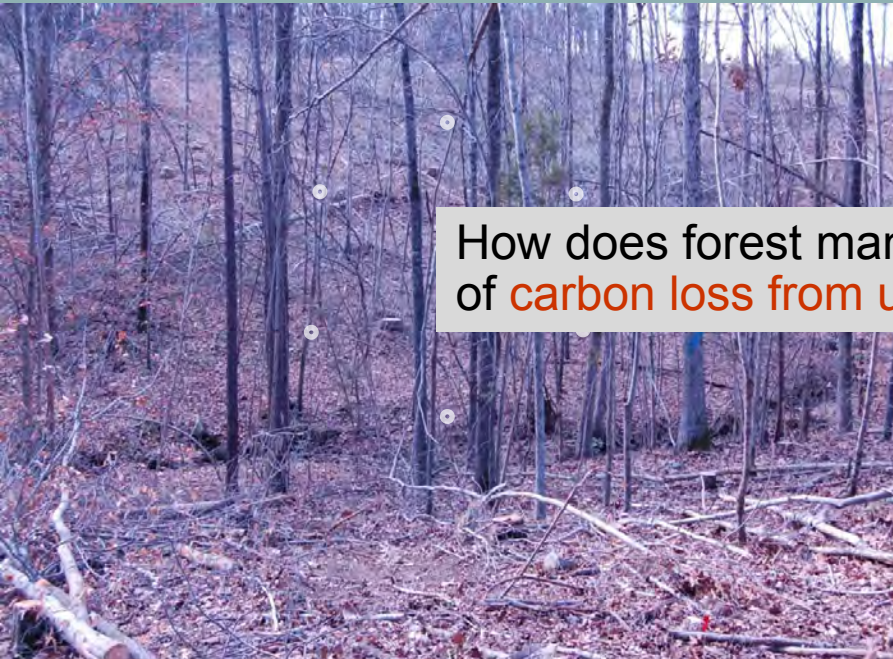
Other Projects

- Soil Respiration, Hill Forest.

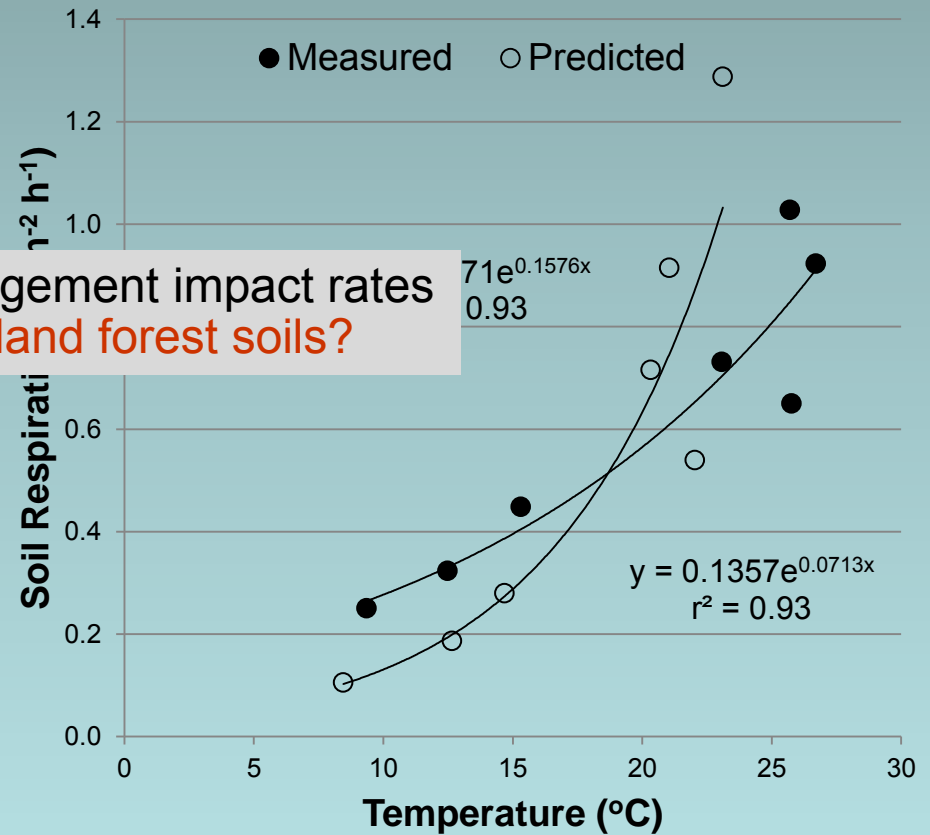


Other Projects

- Soil Respiration, Hill Forest.



How does forest management impact rates of **carbon loss from upland forest soils?**



Summary

- This project is the **first attempt** in the piedmont of NC to **adequately quantify** the effects of a streamside buffer on water quantity and quality post-harvest.
- Both paired watersheds were treated according to the **Neuse River Buffer Rules**, where upland forest land was clear cut and a 50 foot SMZ was left around the stream channel.
- Post-harvest streamflow monitoring indicated that **peakflow and baseflow have increased significantly** at Hill Forest and Umstead.
- Post-harvest water quality monitoring indicated that **TSS and TN exports did not increase significantly** beyond background loads.

Summary

- Effects of tree harvest on the larger nested watershed (control and harvest watersheds combined) at HF was less than the smaller harvested watershed.
- High biotic index (fair stream quality) value found in UF2 during the July 2011 sample is likely due to low flows and not related to water quality conditions.
- Hydrology is driving temporal differences in TSS and TN loads between Hill Forest and Umstead; load spikes were higher in winter months and lower in summer months at Umstead compared to Hill Forest.

Summary

Goals:

- Quantify the effectiveness of forestry BMPs on a small headwater watershed scale at preventing erosion and sedimentation.
 - 50 foot forestry SMZ appears to prevent nutrient export and sedimentation from increasing significantly above baseline levels in piedmont headwater streams.
- Evaluate the Neuse River Basin Riparian Buffer Rule as it relates to forestry operations.
 - Data (so far) suggest Neuse Buffer Rule as it relates to forestry operations is effective.

Thanks

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Questions

TSS = 500 mg/l
Streamflow = 250 L/s

