AN EVALUATION OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION WETLAND MITIGATION SITES: SELECTED CASE STUDIES

Phase 2 Report

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by

Richard D. Rheinhardt
Mark M. Brinson
Biology Department
East Carolina University
Greenville, NC 27858

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16. Abstract

Phase 1 of this study evaluated 50 NCDOT wetland compensatory mitigation sites and 11 reference sites in 1999. The Phase 2 component (this report) examines five of the compensatory mitigation sites to provide a more in-depth analysis. The objective of the two reports is to help NCDOT and wetland regulatory agencies develop a framework to improve NCDOT's compensatory mitigation, to enhance communication between NCDOT and regulatory agencies, and to benefit wetland restoration overall. We encountered problems with various definitions (restoration, preservation, enhancement, etc.) that are not compatible with current scientific understanding of ecosystem functioning. This has led to avoiding the potential for improving the condition of severely altered wetlands because they meet the jurisdictional definition in spite of a highly degraded condition. Elsewhere, socioeconomic limitations may prevent complete restoration. In such cases, partial restorations may be better than none at all. For example, preservation through purchase or conservation easements of headwater streams and their buffers in a partially degraded condition would provide opportunities for improving water quality. Undue reliance on criteria for hydrology over criteria for soil, in extreme cases, has led to soil excavation that reduced survivorship of planted seedlings and lowered recruitment capacity. In general, reference sites have been little utilized to design restorations and to gauge success. Depending on initial conditions, the restoration of wetland structure and function may take many decades to achieve maturity. Presently, all monitoring stops once permit conditions have been met. Institutional memory then rests almost entirely with personnel in the NCDOT organization. To encourage long-term research, regulatory agencies must be willing to provide mitigation credit for establishing reference sites and to conduct long-term research in comparing them with a variety of restoration practices. To avoid unintentional shifting of distribution among one set of hydrogeomorphic classes to others, it will be necessary to track restoration at drainage basin scales according to hydrogeomorphic wetland classes. Many of these suggestions will require acceptance by regulatory agencies and implementation by all parties. Regulatory agencies would have to be willing to accept success criteria based on data from reference wetlands.

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SUMMARY AND RECOMMENDATIONS

Five compensatory mitigation sites were examined in detail to obtain insight into the general strengths and weaknesses of North Carolina’s Department of Transportation (NCDOT) compensatory mitigation program. The overall objective was to provide information that could help NCDOT and wetland regulatory agencies develop a framework to improve NCDOT’s compensatory mitigation program, communication between NCDOT and regulatory agencies, and wetland restoration in general. Suggestions for improvements are provided:

1. Define various types of compensatory mitigation that are compatible with our current scientific understanding of ecosystem functions. Current definitions have led to sites that have been severely altered being overlooked as potential restoration sites because they still meet the jurisdictional definition of a wetland (e.g., some restorations are being viewed as enhancement and thereby excluded from consideration). This will require acceptance by regulatory agencies.

2. Make changes in required success criteria, where appropriate. Jurisdictional criteria used to define wetland boundaries are used to define hydrologic success rather than the hydrologic regime of reference wetlands. This has sometimes led to soil excavation (an attempt to increase period of soil saturation) with the consequent degradation of soil condition, and in turn, the failure of vegetation to thrive.

3. Use data from reference sites to design restorations and determine success. Data on soil, vegetation, and hydrology from reference wetlands has been seldomly used to develop appropriate objectives in restoration. Reference data would not only be useful for directing restoration, but data obtained for one project could be used in designing future mitigation projects. However, regulatory agencies would have to be willing to accept success criteria based on data from reference wetlands.

4. Study some restoration sites for longer periods to obtain information that could be used to improve future restoration projects. The present tendency is to ignore sites for which permit conditions have been met. Institutional memory then rests almost entirely with personnel in the NCDOT organization. To encourage long-term research, regulatory agencies must be willing to provide mitigation credit for establishing reference sites and to conduct long-term research in them.

5. Use innovative means to restore lost functions that can not be recovered through restoration due to socioeconomic limitations. For example, a deeply channelized stream cannot be restored without repercussions upstream. As an alternative to complete restoration, partial restoration of functions could be achieved by dispersing water flowing across a former floodplain, thus allowing longer contact with the floodplain.

6. Track restoration within drainage basins according to hydrogeomorphic wetland classes. Avoid impacting and trying to restore wetland classes that are extremely difficult or impossible to restore (those with high soil organic content).

7. More stream preservation should be attempted. Purchase or permanent conservation easements of headwater streams and their buffers would provide opportunities for improving water quality downstream.

INTRODUCTION

This report is the second part (Phase 2) of a two-phase project examining the effectiveness of compensatory wetland mitigation by the North Carolina Department of Transportation (NCDOT). In Phase 1, we evaluated the condition of 49 compensatory mitigation sites located throughout the Blue Ridge, Piedmont, and Coastal Plain Physiographic Provinces in North Carolina. These mitigation sites comprised a variety of hydrogeomorphic (HGM) classes including tidal salt marshes (estuarine fringe wetlands) along coastal sounds, bogs (slope wetlands) in the Blue Ridge mountains, and ephemeral ponds (depressional wetlands) in the Piedmont.

The primary objective of Phase 1 was to provide an overview of the condition of completed or nearly completed NCDOT compensatory mitigation sites across the state. Although we examined restoration success of sites relative to criteria negotiated between NCDOT and regulatory agencies, emphasis was placed on evaluating sites on the basis of their likelihood of achieving structure and functions resembling natural, self-sustaining ecosystems located in similar landscape positions. This alternative definition of restoration success was based on the application of "reference," i.e., success was judged relative to the condition of reference wetlands in the region of the same wetland-type. Wetland-type was based on the HGM Approach to wetland classification.

This Phase 2 report uses a case study approach to examine five compensatory mitigation projects in detail to obtain additional insight into the strengths and weaknesses of NCDOT's compensatory mitigation program. We hope that insights gained from these case studies will be useful in helping NCDOT and wetland regulatory agencies develop a framework for improving both the permit process and the probability of success for wetland restoration.

Each case study will follow the same general format in that it will provide:

(1) An overview of the natural history of the site prior to alteration, including information on reference ecosystems where available;

(2) An overview of land-use history (past alterations to the site);

(3) The history of compensatory mitigation for the site, including summary of projects for which the site provides compensation and manipulations designed to restore the site. This will include rationale for the manipulations and feedback from regulatory agencies that influenced the outcome;

(4) The present condition of the site, particularly in relation to any available reference information, and our prediction for probable future condition;

(5) Alternative restoration strategies (if any) that might have improved the outcome of the restoration;

(6) Insight into what might be done to remediate problems (if any) with the site or further work that could be done to improve restoration; and

(7) An overview of how improvements or changes might affect regulatory policy.

After a discussion of all the case studies, we will integrate lessons learned to suggest how they could be applied to improve NCDOT's compensatory mitigation program, communication between NCDOT and regulatory agencies, and wetland restoration in general. We also discuss how application of wetland regulatory policy has affected wetland restoration.

METHODS

Five sites were selected to represent the restoration techniques typically used in NCDOT compensatory mitigation projects. The five case study sites were decided upon at a March 24, 2000 meeting with the Technical Advisory Committee for the Center for Transportation and the Environment, North Carolina State University. Sites were chosen to also represent the range of wetland-types to which restoration has been applied across the state and the general level of success realized. We also reviewed the highway projects associated with each site to determine the types of wetlands impacted, their probable condition prior to alteration (if sufficient information was available), and written communications between NCDOT and regulatory agencies that influenced and approved mitigation plans.

Case study sites were visited and sampled during the 2000 field season (May-October). Therefore, our results and recommendations are based on conditions encountered during that period. It is likely that NCDOT has initiated additional work at some or all of the case study sites since our on-site work was conducted.

Case studies differed in type of wetland (HGM subclass), initial starting condition, and specific techniques applied to restore the site. Therefore, we employed slightly different methods in our assessment of each case study site. However, in all sites we determined survival of planted vegetation within some or all NCDOT vegetation monitoring plots. In some sites, we also determined density of stems and/or cover in plots outside established monitoring plots. Because water table measurements over long time periods (years) are required to gain insight into hydrologic regimes, we relied on data from NCDOT's monitoring program in discussing hydrologic regime. Although there have been no success criteria established for soils, we acquired information on soils to draw inferences about soil condition and the effect that soil condition might have on influencing restoration outcomes.

RESULTS: CASE STUDIES

Haws Run

Location: Onslow and Pender Counties south of Maple Hill, North Carolina and west of NC 50 between Sandy Run to the north, Shelter Swamp Creek to the west and south, and an unnamed tributary to Sandy Run on the east.

Size: 595 acres (241 ha)

Natural History

From an evaluation of soils and aerial photos (1949, 1956, 1966, 1972), it appears that Haws Run site once consisted of two wetland classes: a third-order riverine swamp and mineral soil Wet Pine Flats. Although most of the site lies on a flat, inter-stream divide, the northern- and southern-most parts of the site (approximately 171 acres) includes some of the floodplain associated with Sandy Run Swamp Creek and Shelter Swamp Creek, respectively. The mitigation site appears to have remained largely unaltered until sometime after 1972. In the early to mid-1970s, bald cypress was cut from the riverine swamps and the flat was converted to pasture for bison (*Bison bison).* (See details of alterations below.)

Today, the floodplain swamp still retains its historic composition: a canopy dominated by bald cypress (*Taxodium distichum*) and swamp tupelo (*Nyssa biflora*) with a rich understory of shrubs and herbaceous plants. Reference data for similar second and third order cypress swamps are available in Tables 1 and 2. Much of the floodplain was purchased for preservation.

Prior to alteration, the wet flats at Haws Run were part of a much larger area of pine savanna (Fig. 1) maintained by fire at a return interval of 1-5 years. In fact, prior to European colonization most of the coastal plain flats (including wet flats) from eastern North Carolina to eastern Texas were fire-maintained savanna (Ware et al. 1993). Today, less than 2 % of those flats still exist as fire-maintained savanna, and only a few intact sites remain in eastern North Carolina (Schafale 1994).

Haws Run probably once supported at least two types of Wet Pine Flats: Cypress/Pine Savanna and Bunchgrass/Pine Savanna (*sensu* Rheinhardt et al. In Press). Cypress/Pine Savanna occurs on more poorly-drained, clay-rich soils than Bunchgrass/Pine Savanna and typically supports a sparse canopy dominated by pond cypress (*Taxodium ascendens*) and pond pine (*Pinus serotina*) with a luxuriant herb stratum dominated by various sedges (Cyperaceae). Schafale (1994) classifies this sub-type as “Pine Savanna, Very Wet Clay Variant.” Thus, the clayey Torhunta and Grifton soils present at the site (Barnhill 1990, 1992) probably once supported Cypress/Pine Savanna. This supposition is based on (1) our observation of a fire-excluded area of Torhunta soil on the southeast side that still had pond cypress in it and (2) the composition of a nearby Nature Conservancy site (Lanier Quarry) on Grifton soil (Table 3). Darker areas on the 1956 aerial photo (Fig. 1) would likely have been Cypress/Pine Savanna prior to conversion to bison pasture. Woodington soils, covering a small part of the site, would have supported mesic (upland) savanna.

Table 1. Reference data for three woody strata in unaltered riverine cypress-tupelo swamps in NC Coastal Plain. Canopy Importance Values (IV) = (relative basal area + relative density)/2 for trees (> 10-cm dbh); Subcanopy IV = relative density of stems > 1-m tall, < 10-cm dbh; Vine IV = relative density of vines > 1-m tall on trees. P = present on site, but not in plots. Data derived from Rheinhardt et al. (1998).

	Site		
	Bluewater Branch	Big Swamp	Turkey Creek
Strahler stream order	2	3	3
Canopy (basal area: m^2/ha)	70	54	52
Canopy IV			
Taxodium distichum	27.5	2.2	21.1
Nyssa biflora	6.8	72.4	73.4
Acer rubrum	15.4	13.2	1.2
Nyssa aquatica	48.6	-	-
Liquidambar styraciflua	-	12.1	2.1
Liriodendron tulipifera	1.8	-	-
Quercus laurifolia	-	-	1.2
Fraxinus spp.	-	-	1.1
Ulmus rubra	-	P	-
Subcanopy density (stems/ha)	238	3,055	0
Subcanopy IV			
Clethra alnifolia	-	100.0	-
Ilex verticillata	20.0	-	-
Itea virginica	-	-	P
Ilex opaca	53.3	-	-
Cornus stricta	26.7	-	-
Crataegus spp.	-	-	P
Vine density (stems/ha)	1,574	1,447	48
Vine IV			
Rhus radicans	48.5	46.2	-
Parthenocissus quinquefolia	12.1	3.3	-
Smilax rotundifolia	P	31.9	P
Smilax laurifolia	-	P	-
Decumaria barbara	31.3	-	-
Campsis radicans	3.0	-	100.0
Lonicera japonica	P	-	-
Bignonia capreolata	5.1	18.7	-
Berchemia scandens	-	P	-

Table 2. Reference data for the herbaceous stratum of unaltered cypress-tupelo swamps. Data are relative frequency of occurrence in 1-m^2 quadrats. P = species present at site, but not in plots. Reference data derived from Rheinhardt et al. (1998).

	Site		
Herb (Relative Freq.)	Bluewater Branch	Big Swamp	Turkey Creek
Saururus cernuus	26.7	25.0	P
Woodwardia areolata	P	25.0	-
Boehmeria cylindrica	26.7	25.0	25.0
Glyceria striata	10.0	-	-
Hypericum spp.	-	-	12.5
Carex spp.	P	25.0	-
Arisaema triphyllum	3.3	-	-
Lycopus virginicus	P	-	-
Aster spp.	P	-	-
Impatiens capensis	13.3	-	12.5
Eupatorium sp.	P	-	-
Hydrocotyle sp.	3.3	-	-
Peltandra virginica	6.7	-	12.5
Viola blanda	6.7	-	-
Phytolacca americana	3.3	-	-
Polygonum pensylvanicum	P	-	-
Cicuta maculata	P	-	37.5

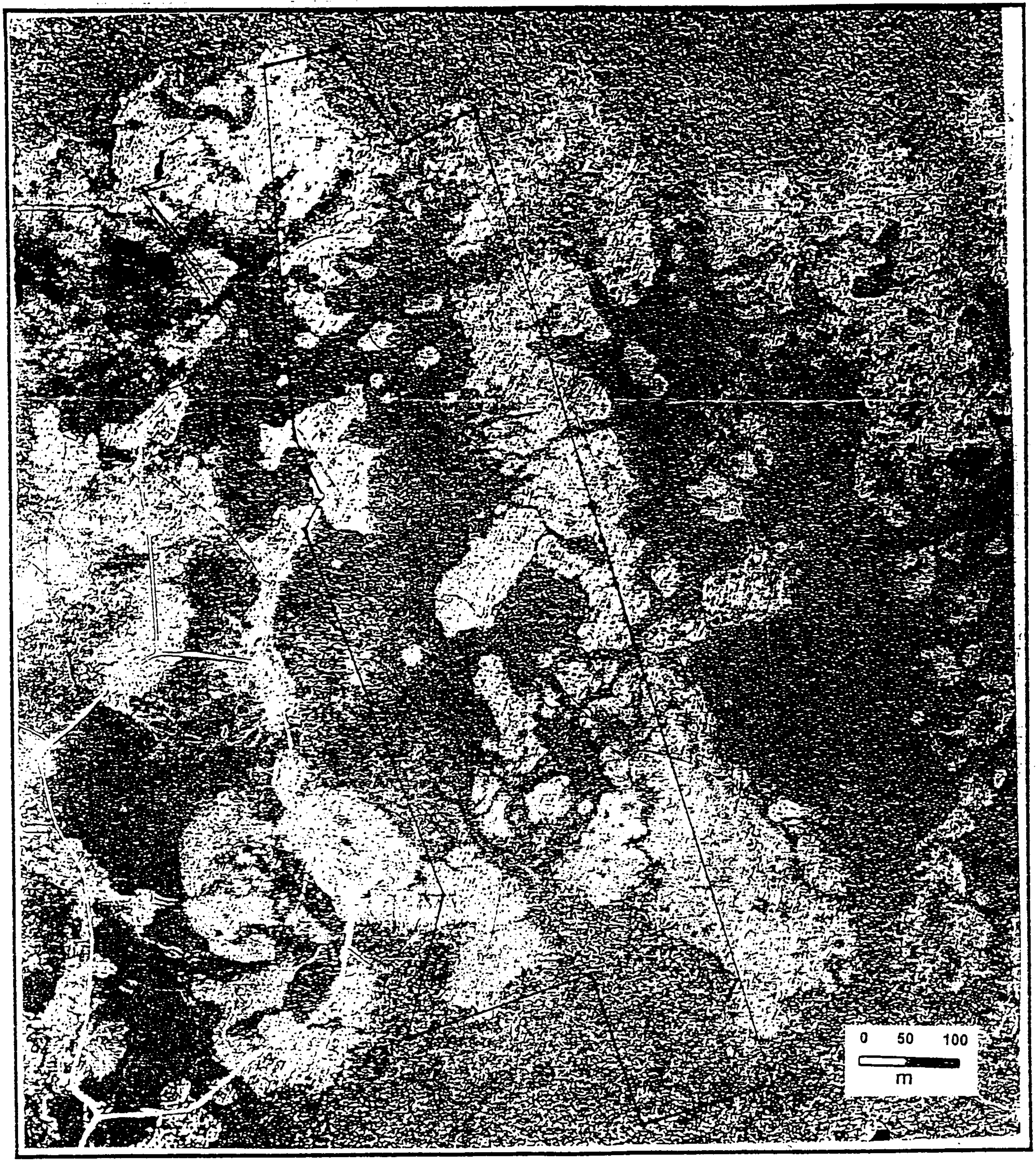

Figure 1. Aerial photo (March 1956) showing location of the Haws Run site (delineated by lines) within a larger matrix of intact, fire-maintained savanna. Darker areas were probably once Cypress/Pine Savanna while light areas were Bunchgrass/Pine Savanna and mesic pine savanna. The floodplain wetlands of Sandy Run are located in the northeast corner of the site.

Table 3. Reference data from relatively unaltered Wet Pine Flats.

Site Name	**Green Swamp Savanna**	**Myrtlehead Savanna**	**Lanier Quarry**	**Friendfield Plantation**
County	Brunswick	Brunswick	Pender	Georgetown
State	NC	NC	NC	SC
Latitude	34 05 14.6	34 08 17.2	34 37 45.9	33 23 10.3
Longitude	78 18 15.5	78 29 58.1	77 40 33.4	79 21 12.1
USGS Quadrangle	Supply, NC	Juniper Creek, NC	Maple Hill, NC	Georgetown N, SC
Sub-class	Bunchgrass/Pine Savanna	Bunchgrass/Pine Savanna	Bunchgrass/Pine Savanna	Bunchgrass/Pine Savanna
Soil Series	Woodington	Woodington	Grifton	Grifton
Soil Taxonomic Group	Typic Paleaquult	Typic Paleaquult	Typic Ochraqualf	Typic Ochraqualf
Horizon 1 (A) depth range	0-7"	0-6"	0-8"	0-7"
Hue Value/chroma	10YR 2/1	10YR 4/1	10YR 2/1	10YR 2/1
Texture	sandy loam	fine sandy loam	loamy fine sand	loamy sand
Horizon 2 depth range	7-15"	6-11"	8-17"	7-11"
Hue Value/chroma	10YR 5/1	10YR 4/1	10YR 2/1	10YR 5/2
Texture	sandy loam	fine sandy loam	loamy fine sand	loamy sand
Horizon 3 depth range	15-19"	11-20"	17-21"	11-24"
Hue Value/chroma	10YR 6/2	10YR 6/2	2.5YR 3/1	10YR 6/1
Texture	sandy clay loam	fine sandy loam	loamy sand	sandy clay
Horizon 4 depth range	19-25"	N/A	N/A	N/A
Hue	10YR 6/1	N/A	N/A	N/A
Texture	sandy clay loam	N/A	N/A	N/A
Depth range of mottles	15-25"	6-20"	17-21"	7-11"
Hue Value/chroma	10YR 6/6	10YR 6/6	10YR 6/8	10YR 5/8
Depth range of mottles	N/A	N/A	N/A	11-24"
Hue Value/chroma	N/A	N/A	N/A	10YR 6/8
Depth to a change in permeability	15"	NA	NA	11"
Bulk Density (g/cm^3)	0.374	0.849	0.686	0.719
% Shrub Cover	0.050	0.300	0.342	0.001
Dead downed wood (m^3/ha)	0.25	10.57	2.09	6.55
Mid-canopy Density (stems/ha)	0	67	133	21
Canopy Density (stems/ha)	170	64	106	64
Canopy Density (stems/acre)	422	158	264	158
Canopy BA (m^2/ha)	8.5	1.5	4.5	7.5
Natural Elevation Range (cm)	3.7	10.7	9.0	9.0
Total # of spp./150 m^2	61	62	77	43

Other less hydric parts of flats at Haws Run would likely have once supported Bunchgrass/Pine Savanna, a type of Wet Pine Flat that typically contains slightly better drained, less clayey soil than Cypress/Pine Savanna. Schafale (1994) classifies this sub-type as “Pine Savanna, Wet Ultisol Variant.” Bunchgrass/Pine Savanna typically has a sparse canopy dominated by longleaf pine (rather than pond cypress) and a herb stratum dominated by one or more hydrophytic native bunchgrass species (*Ctenium aromaticum, Muhlenbergia expansa,* and an as yet unnamed species temporarily called *Sporobolus* sp. 1 by Southeastern botanists). Also, the herb stratum of intact Bunchgrass/Pine Savanna is extremely species rich. In fact, Bunchgrass/Pine Savanna supports the highest small-scale herbaceous species richness in the Western Hemisphere with as many as 40 species occurring in a square meter plot (Walker and Peet 1983). Based on reference data from nearby sites (Table 3), savannas on Grifton and Woodington soils (wetland soils at Haws Run) would likely have originally supported Bunchgrass/Pine Savanna.

In the transition between Bunchgrass/Pine Savanna and less hydric Cypress/Pine Savanna, longleaf pine (*Pinus palustris*) shares the canopy with pond cypress and pond pine. Also, small-scale herbaceous species richness is high and native bunchgrasses are more prevalent than sedges. It would be difficult to determine exactly how much of the Haws Run site would have once occurred in the transitional zone, but any areas now dominated by sedges would likely have been too wet to support much longleaf pine or native bunchgrasses.

In addition to Wet Pine Flats, the Haws Run site would have supported fire-maintained, mesic pine flatwoods, intact examples of which are also rare today. Mesic pine flatwoods usually occur on non-hydric soil series, e.g., Foreston. Schafale (1994) describes mesic pine flatwoods as having a canopy dominated by longleaf pine with an understory of wiregrass (*Aristida stricta*) and sometimes bracken fern (*Pteridium aquilinum*), with a more dense, low shrub layer than wet savannas. On the 1956 aerial photo (Fig. 1), both mesic pine flatwoods and Bunchgrass/Pine Savanna produced the lighter-colored signature.

Land-use History

In examining a series of aerial photos (scale approx. 1:6,000) taken in 1949, 1956, 1966, and 1972, the Haws Run site showed a signature typical for fire-maintained pine savanna. No roads or jeep trails showed up on the 1949 or 1956 photos. The 1966 photo showed one raised jeep trail, probably used by hunters, a powerline right-of-way bisecting the site, and a raised, all-season logging road on the property to the east of Haws Run. By 1972, logging appears to have begun on the adjacent property, but the Haws Run site only showed what appeared to be rutting from off-road vehicles. However, the 1972 photo still showed savanna conditions.

In the early to mid-1970s, the savanna was logged, stumped, ditched, and chisel-plowed to convert the site to pasture for bison. Apparently, 900 tons of lime (approx. 2 tons/acre) was also applied to increase soil pH (Land Management Group 1997). The bison operation became bankrupt and the pasture was abandoned within 10 years of conversion. Title to the land was passed to a bank or insurance company.

Compensatory Mitigation History

In 1996, the NC Natural Heritage Program contacted NCDOT about areas of rare species habitat at the southern portion of the Haws Run mitigation site. Relevant correspondences and chronology of activities are listed in Table 4. (This was not be a mitigation bank *per se* that could be debited using 'credits'; rather, the land was to be credited by a survey that was to identify specific tracts used for offsetting impacts due to specific projects.) Initially, the COE judged the site to be inadequate due to insufficient land-use information, the appearance of it having been scraped and leveled, and the fact that it seemed that little of the drainage could be restored (in particular, the perimeter ditch could not be filled without flooding adjacent lands). However, the COE saw an opportunity for restoring bottomland hardwood (BLH) forest at the north and south ends of the property. A roadway along the continuation of the central ditch was present that connected the north end of the site with NC State Road 50 by crossing Sandy Run at a fairly narrow point along its floodplain. Although BLH restoration appeared to be feasible by removing the roadway throughout the floodplain crossing, doing so would only provided minimal acreage for mitigation purposes.

After a previous owner of the property had relinquished the land to a private firm, the new owner had a consultant install water level monitoring gauges to determine where jurisdictional wetlands occurred. According to monitoring gauge data, some areas adjacent to the large central ditch were still jurisdictional wetlands (due to surface ponding). (Historic aerial photos showed that much of the central area was probably once wet Cypress/Pine Savanna).

In 1997, after further negotiation with the COE, NCDOT bought the land to restore floodplain wetlands on Sandy Run and savanna wetlands on the main portion of the tract. A mitigation plan (Land Management Group, Inc. 1997) was submitted by NCDOT in 1997 and work was begun in 1998. The mitigation plan included 'restoring' 81 acres of wet savanna, 'enhancing' 99 acres of wet savanna, 'enhancing' 113 acres of 'dry' savanna, and 'preserving' 11 acres of savanna. The plan also called for 'restoring' 8 acres of swamp forest by removing fill from road crossings and causeways on Sandy Run, 'enhancing' 25 acres of swamp forest by removing a logging road physically isolating the tract, 'restoring' 22 acres of swamp forest by excavating soils adjacent to the Sandy Run floodplain, and preserving 171 acres of swamp forest. An additional 67 acres would not be manipulated.

Subsequent to the initial mitigation plan, an area of 33 acres adjacent to the floodplain of Sandy Run had been identified as fill. This was provided as justification for excavating the area to the elevation of the adjacent floodplain and planting BLH tree species there. A 1998 Preliminary Report prepared by NCDOT and a coordination letter with the NC Forest Service also stated that the savanna area would be drum chopped by the Forest Service to remove unwanted trees and then burned. The preliminary report also mentioned that grading activities were planned, but no areas were specifically identified. However, NCDOT personnel stated that no grading was performed in the savannas, except to fill ditches and canals north of a power line crossing the site.

The initial mitigation plan was to backfill all ditches on site, but the NC Natural Heritage Program found Cooley's meadowrue (*Thalictrum cooleyi*), an endangered species, and four other Federal Candidate species growing in the ditches at the southern end of the site. (Presumably, Cooley's meadowrue is growing where ground water seeps into the ditches). Therefore, only the

Table 4. Selected correspondences related to Haws Run mitigation site.

Date	From	To	Summary Description
06/15/94	N/A	N/A	Meeting with NC Ports Authority, Soil Conservation Service, and Corps to discuss potential of using the Haws Run site for compensatory mitigation.
06/25/96	DEHNR	NCDOT	Natural Heritage Program identified areas of rare species habitat adjacent to proposed swamp "restoration."
10/23/96	N/A	N/A	Pre-application meeting to elicit feedback for using the Haws Run site for compensatory mitigation.
03/06/97	DENHR	NCDOT	Natural Heritage Program preliminary review of mitigation plan identified critical rare species habitat, remnant pine savanna, and an area with high potential for savanna restoration near the swamp "restoration" area.
03/27/97	USFWS	NCDOT	USFWS indicated that "the Service would be stressing the protection and enhancement of the ecosysytem on which the Fedrally-listed species depend rather than placing great emphasis on the loss of each individual."
04/28/97	NCDOT	COE	Mitigation Plan submitted to COE.
05/12/97	NCDOT	TNC	Permission requested to install monitoring wells at Lanier Quarry.
05/15/97	USEPA	NCDOT	Review of mitigation plan requested that fire-management be part of the written mitigation plan.
05/30/97	NCDOT	COE	Survey of 14.2 acre swamp mitigation area to offset impacts caused by Jacksonville Bypass (U-2107).
07/17/97	COE	NCDOT	Permit meeting in Raleigh: COE stated that no further permits would be issued utilizing flats portion of Haws Run site until success criteria have been met.
10/01/97	DEHNR	NCDOT	DENHR refused to allow the use of Haw's Run for mitigation credits until success criteria had been met.
12/30/97	COE	NCDOT	COE expressed concern using Lanier Quarry as a reference for hydrology because it might prove to not meet the jurisdictional criterion for wetland hydrology.
04/27/98	NCDOT	NCDOT	Internal memo verified a 27.5' excavation elevation for swamp restoration area, placement of spoil to create an access road adjacent to eastern ditch.
7/98	N/A	N/A	1998 Preliminary Report: Indicated that savanna area was "drum-chopped" to remove unwanted trees and then burned.
07/01/98	COE	NCDOT	COE expressed concern about material from excavated area being used to build an access road around the site.

north portion of the central ditch (north of the power line crossing) was back-filled. The intent was to restore hydrologic regime to an 81-acre parcel of wet savanna. In both this area and in a 99-acre parcel of wet savanna previously identified as jurisdictional wetland, NCDOT planned to plant savanna species and initiate a program of prescribed burns. Pond pine, long leaf pine, and pond cypress were to be planted in the wet savanna areas at 40 stems/acre. However, it appears that a vendor could not be found to supply pond cypress in 1999, so initially only pond pine and longleaf pine were planted. Pond cypress was planted in 2000 (North Carolina Department of Transportation 1999b).

The success criterion for tree survival was negotiated at 40 stems/ha (99 stems/acre). Goals for canopy species density were based on Taggart's (1990) definition of longleaf savanna: less than 50% canopy cover with 50-foot diameter crowns. In addition to planting trees, bunchgrasses (*Ctenium aromaticum*, *Sporobolus* spp. 1, *Aristida stricta*, and *Muhlenbergia expansa*) were planted in eleven 100-ft x 100-ft plots at a density of 4,840 plants per acre (1.2 plants/m^2). No success criteria were required for the bunchgrass plots, but it was hoped that bunchgrass would flourish in the plots and spread to other areas of savanna.

The initial mitigation plan called for using reference sites for establishing hydrologic success criteria. Several water level monitoring gauges were established on-site in the savanna and several more at Lanier Quarry (a TNC site) to establish hydrologic success criteria for the savanna portions of the site. Additional gauges were established in the unaltered (preserved) floodplain of Sandy Run to provide success criteria for the restored BLH areas. However, although the COE indicated that the Lanier Quarry site was a jurisdictional wetland based on field indicators, it insisted that if water-level data revealed that this reference site did not meet jurisdictional hydrologic criteria, then hydrologic success for Haws Run should be based on jurisdictional criteria for hydrology (i.e., continuous saturation for 12.5% of the growing season in the upper 12 inches under normal climatic conditions). By January 2001, four projects (49 acres), associated with the Jacksonville Bypass, had used the Haws Run site for compensatory mitigation. The Bypass appears to have impacted riverine and Wet Pine Flats, making Haws Run appear to be an appropriate site for providing compensation for project impacts. However, the COE was initially skeptical about documentation showing that hydrologic restoration of Sandy Run would extend beyond the area from which fill was removed and had misgivings about accepting the flats portion of the site for mitigation credit. Later, after mitigation had been initiated, the COE refused to issue further permits utilizing the flats portion of the Haws Run site until success criteria had been met.

Present Condition of Site

When the 33 acres adjacent to Sandy Run were excavated to restore the riverine floodplain, it became apparent that there was no fill as previously thought, at least not throughout the entire area that was excavated. As a consequence, the excavation not only removed topsoil; it left organic-poor subsoil with sheared-off tap roots of former trees sticking above the surface. (Much of the perimeter road was constructed from fill derived from the excavation.)

We collected two soil samples in late May 2000 and sent them to a private lab for nutrient and mineral analysis (Table 5). One sample was derived from the relatively intact floodplain of Sandy Run; the other was derived from the excavated mitigation area adjacent to the Sandy Run

Table 5. Result of soil nutrient analyses from Haws Run riverine sites. "Sandy Run Floodplain" is from the intact floodplain; the "Created Floodplain" is from area where soil had been excavated.

		Sandy Run Floodplain	Created Floodplain
	Cation exchange capacity	11	12
	pH	6.5	6.5
	% Organic matter	**6.4**	**2.3**
Total mg/kg	Phosphorus	9	35
	Potassium	90	241
	Magnesium	143	516
	Calcium	3,086	2,878

floodplain. Soil from the excavated area contained more phosphorus, potassium, and magnesium than the natural floodplain, likely a result of the higher mineral content. However, as expected, percent organic matter in the excavated area was only one third that of the natural floodplain.

At the edge of the excavated area, the land surface dropped sharply: approximately 2 m (6 feet) from the surface of the wet flat to the bottom of the excavation. Surface and groundwater no longer flow gradually to the floodplain of Sandy Run; instead overland flow down the steep embankment caused severe erosion (Fig. 2). Also, groundwater discharges along the edge of the excavation, further destabilizing the slope-face. Most of the slope face has now been stabilized (Dave Schiller, pers. comm.); one area requires further remediation.

Another unintended consequence of the discharge is that the excavation now functions as a 2-m-deep ditch and so is likely draining the area upgradient from the excavation. Drainage may reduce water levels in the adjacent flat where monitoring gauges 7 and 8 were located and possibly areas as far away as gauges 10 and 11 (NCDOT 1999). NCDOT is monitoring the effect of the excavated area (identified as a transition zone) on the water table of the adjacent flat.

Although rare plant species are still located on portions of the Haws Run site (Fig. 3), past land-use practices had mostly eliminated native bunchgrasses from the Haws Run site and severely reduced the density of the other herbaceous indicators. However, almost all indicator species were still present at the Haws Run site, although not at the small spatial scale typical of intact Wet Pine Flats. Table 6 lists herbaceous indicator species that were observed in the eleven planted-bunchgrass plots and in two other plots we established. Between 5 and 9 indicator species were identified in most of the planted plots (plots 1-10). Fewer indicator species were present in the small (50-ft x 50-ft) bunchgrass plot (#11), a filled ditch (#12), and the very wet Cypress/Pine Savanna (#13). However, species richness is a scale-dependent measure (i.e., plot size affects the number of species), so 1 m^2 plots would likely have many fewer species.

Because unaltered Wet Pine Flats are species-rich at small scales and land-use alterations affect small-scale richness, the condition of plant communities relative to different scales is best assessed using nested plots. This is the approach taken by the regional guidebook for assessing functions in Wet Pine Flats (Rheinhardt et al. In press). The guidebook outlines a procedure for rapidly assessing the condition of a Wet Pine Flat relative to a set of standards. (Standards were determined from field data obtained from relatively unaltered Wet Pine Flats throughout the Atlantic and Gulf coastal plains from North Carolina to Texas). Variables scores derived from field measurements are then used to determine how well an assessed site is maintaining conditions for sustaining selected ecosystem functions. Four functions were modeled in the guidebook: Maintain Characteristic Water Level Regime, Maintain Characteristic Plant Community, Maintain Characteristic Animal Community, and Maintain Characteristic Biogeochemistry.

Table 6. Presence of herb species used to indicate site quality in NCDOT bunchgrass monitoring plots. These indicator plants are used in the HGM regional guidebook for assessing Wet Pine Flats on mineral soil (Rheinhardt et al. In press). Plot 14, an upland mesic savanna, was not assessed.

Herb Indicator Species	1	2	3	4	5	6	7	8	9	10	11 50 m x 50 m	12 Filled Ditch	13 Cypress/ Pine Savanna
Aletris farinosa	x	x	x							x			
Sporobolus spp.									x				
Bigelowia nudata													
Coreopsis spp.	x	x	x	x	x	x	x			x			
Ctenium aromaticum								x	x				
Dichromena spp.			x							x			
Erigeron vernus			x					x		x			
Eriocaulon spp.	x		x	x	x	x	x	x	x	x		x	
Eryngium integrifolium													x
Eupatorium leucolepis	x	x	x	x	x	x	x	x	x	x	x		
Helianthus spp.													x
Lycopodium spp.		x											
Muhlenbergia expansa	x	x				x			x	x			
Rhexia spp.	x	x	x	x	x	x	x		x	x	x		
Sarracenia spp.													x
Xyris spp.	x	x	x	x	x	x	x	x	x	x	x	x	
Total # Indicator spp.	7	7	8	5	5	6	5	5	7	9	3	2	3

Figure 2. Edge of excavated area designed to restore a riverine swamp forest (May 2000). Note sandy, organic poor substrate in swamp "restoration" area.

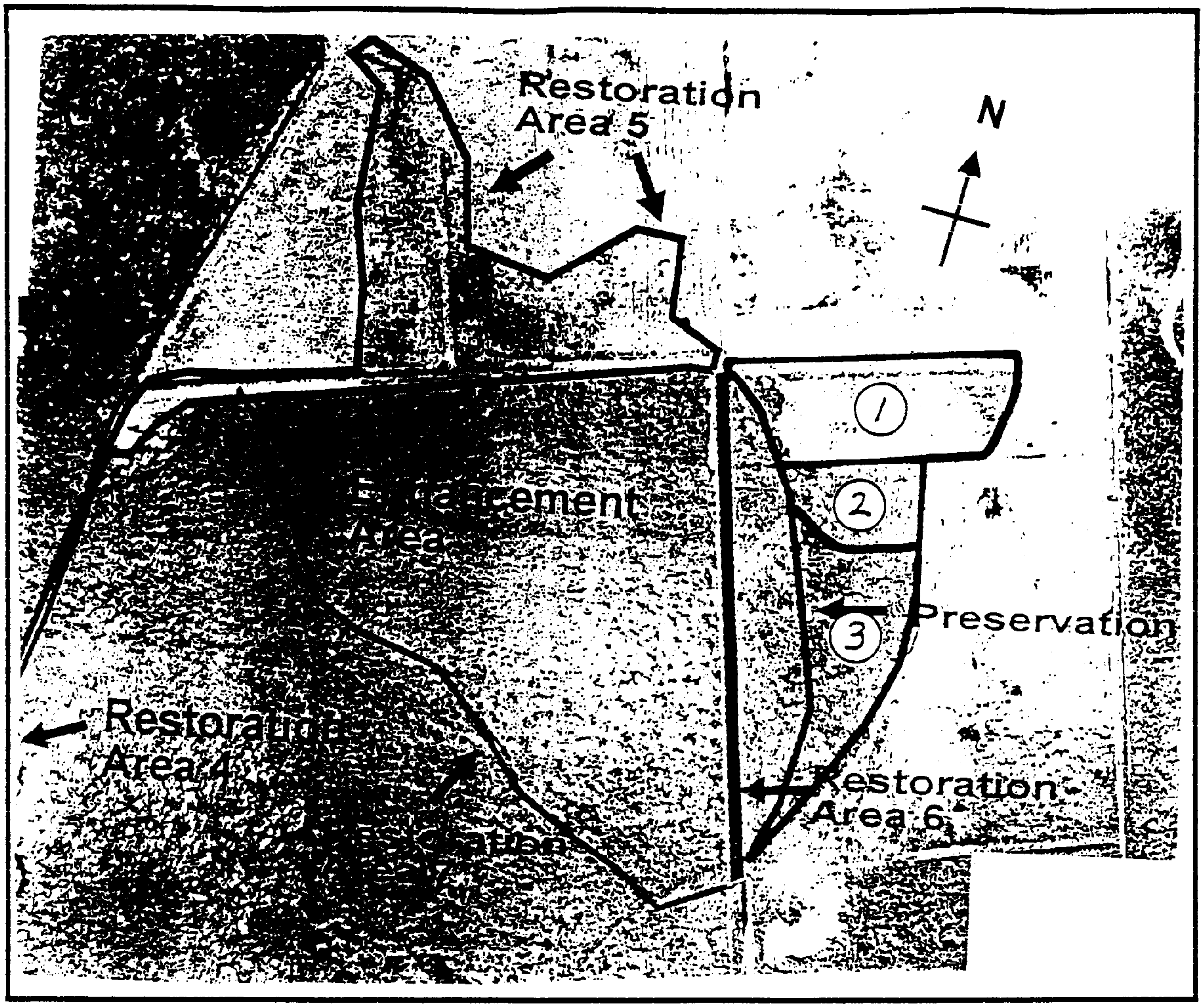

Figure 3. Area of rare species habitat, derived from Richard LeBlond's memo to NCDOT dated March 6, 1997. #1 = rare species habitat, #2 = remnant pine savanna, #3 = area indicated as having "high potential" for restoration.

We used the procedures and standards provided in the regional guidebook to assess the pre-restoration and post-restoration condition of the bunchgrass plots. We assessed all ten of the 100-foot x 100-foot monitoring plots in which bunchgrass had been planted, a section of the filled central ditch, one 50-foot x 50-foot bunchgrass plot, and a very wet area that we assumed had been the wet, sedge-dominated Cypress/Pine Savanna cover type (plot 13) prior to alteration (Fig. 4). For grass plots 1-12, we calculated Functional Capacity Indices (FCIs) assuming that either (1) the plots had been Bunchgrass/Pine Savanna historically or (2) that the plots had originally been the less-wet bunchgrass type of Cypress/Pine Savanna. Because plot 13 was so wet, we assumed that it would have been the wet sedge type of Cypress/Pine Savanna historically and only evaluated it relative to wet Cypress/Pine Savanna standards. Therefore, for all plots except plot 13, four scores were determined:

(a) The FCI of current condition (post-restoration) using Bunchgrass/Pine Savanna standards. This assumed that plots had been Bunchgrass/Pine Savanna historically and that restoration of Bunchgrass/Pine Savanna had been attempted in the mitigation.

(b) The FCI of pre-restoration condition using standards for Bunchgrass/Pine Savanna. This assumed that before restoration, plots had been altered Bunchgrass/Pine Savanna because they had been converted to bison pasture, thus exterminating most native bunchgrasses. We therefore excluded native bunchgrasses, which had been planted as part of the restoration, to assess pre-restoration condition.

(c) The FCI of current condition (Post restoration) using the standards for the bunchgrass sub-type of Cypress/Pine Savanna. This assumed that plots had been Cypress/Pine Savanna historically and that restoration of Cypress/Pine Savanna had been attempted in the mitigation.

(d) The FCI of pre-restoration condition using standards for the bunchgrass sub-type of Cypress/Pine Savanna. This assumed that before restoration, plots had been altered Cypress/Pine Savanna because they had been converted to bison pasture, thus exterminating most native bunchgrasses. We therefore excluded native bunchgrasses, which had been planted as part of the restoration, to assess pre-restoration condition.

Thus, we conducted both pre- and post-mitigation assessments assuming that either Bunchgrass/Pine Savanna or Cypress/Pine Savanna was the historic condition and the condition to which the savannas should be restored. The pre-restoration condition was assumed to be 0.0 for all functions except for the plant community function, which was assumed to be 0.1 for bunchgrass/Pine Savanna. A score of 0.1 was assumed because some herbaceous indicator plants were present prior to restoration. They increased in abundance following removal of woody growth and the initiation of burning.

The difference between a and b (i.e., a minus b) in any plot represents the gain in functioning due to restoration of Bunchgrass/Pine Savanna for that plot (Table 7). Likewise, the difference between c and d (i.e., c minus d) represents the gain in functioning due to restoration of Cypress/Pine Savanna for that plot. For example, if plot # 1 were assessed as a

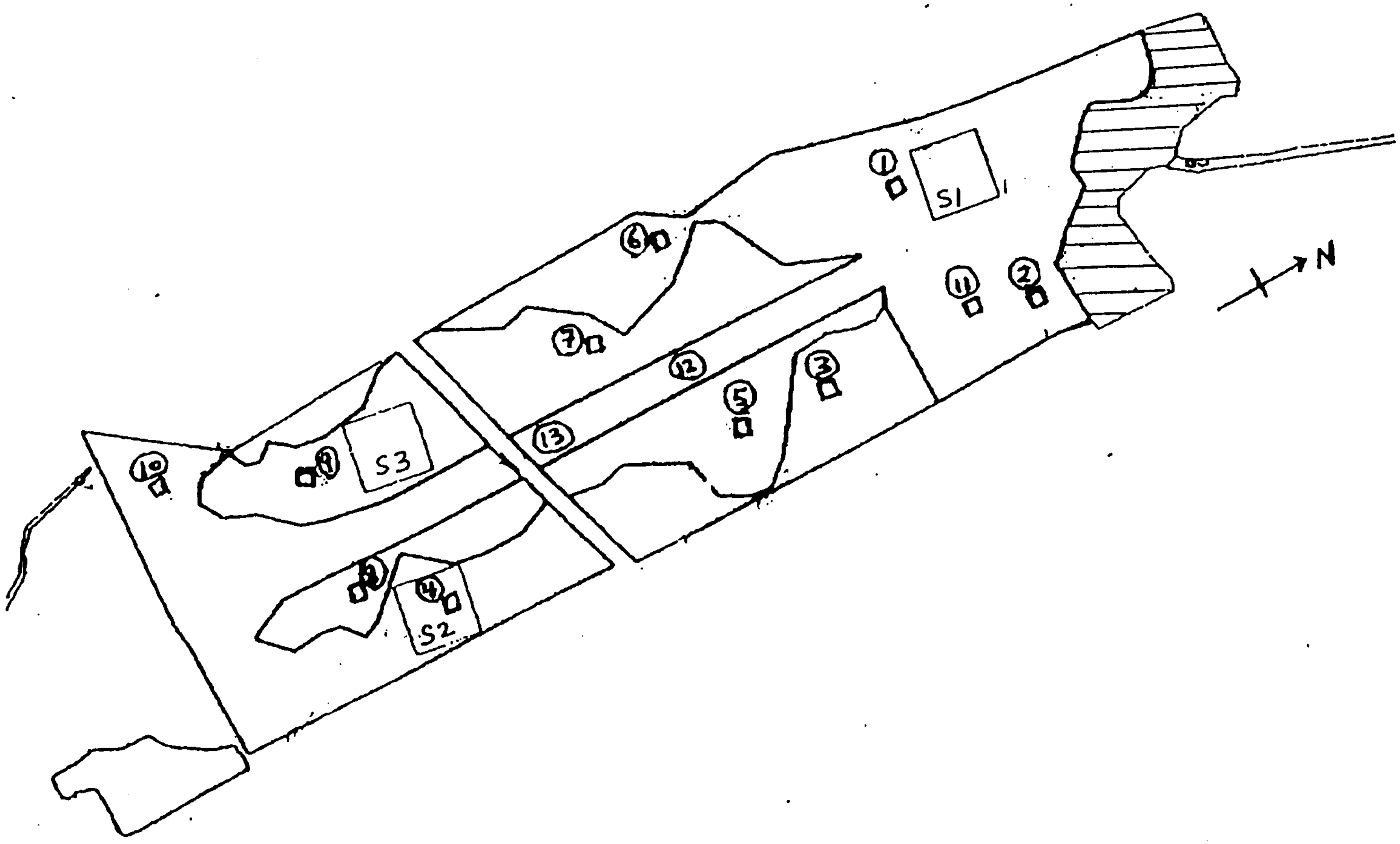

Figure 4. Location of areas assessed at Haws Run using the HGM procedure. Small squares are 100-ft x 100-ft bunchgrass monitoring plots (#1-10), plot #10 is a 50-ft x 50-ft plot, plot #12 is a former ditch (now filled), and plot #13 is a wet depression. Hatched area is location of created bottomland hardwood forest.

Table 7. Functional Capacity Indices (FCIs) for plots sampled at Haws Run. FCIs derived from Regional Guidebook models (Rheinhardt et al. In press) assuming (a) post-restoration Bunchgrass/Pine Savanna (BPS), (b) pre-restoration BPS, (c) post-restoration Cypress/Pine Savanna (CPS), (d) pre-restoration CPS. The highest possible FCI score was 1.0. Plots 1-10 were 100’ x 100’ planted plots, plot # 11 was a 50' x 50' planted plot, and plot 12 was on a filled, former ditch. Plots 1-12 were assumed to have been either BPS or the bunchgrass phase of CPS; plot # 13 was assumed to be the sedge phase of CPS. The expected increase in function per unit area due to restoration is a minus b (for BPS) or c minus d (CPS).

Plant Community FCI	Assuming Subclass	**# 1**	**# 2**	**# 3**	**# 4**	**# 5**	**# 6**	**# 7**	**# 8**	**# 9**	**# 10**	**# 11**	**#12**	**# 13**
a. Post-restoration	BPS	0.50	0.46	0.35	0.54	0.33	0.45	0.43	0.38	0.63	0.40	0.31	0.10	NA
b. Pre-restoration	BPS	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	NA
c. Post-restoration	CPS	0.57	0.52	0.40	0.62	0.38	0.51	0.49	0.43	0.71	0.45	0.36	0.12	0.50
d. Pre-restoration	CPS	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Water Level Regime FCI	Assuming Subclass													
a. Post-restoration	BPS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	NA
b. Pre-restoration	BPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
c. Post-restoration	CPS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
d. Pre-restoration	CPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Animal Community FCI	Assuming Subclass													
a. Post-restoration	BPS	0.71	0.68	0.59	0.73	0.57	0.67	0.66	0.61	0.79	0.63	0.56	0.32	NA
b. Pre-restoration	BPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
c. Post-restoration	CPS	0.76	0.72	0.63	0.79	0.61	0.72	0.70	0.65	0.85	0.67	0.60	0.34	0.71
d. Pre-restoration	CPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biogeochemical FCI	Assuming Subclass													
a. Post-restoration	BPS	0.71	0.68	0.59	0.73	0.57	0.67	0.66	0.61	0.79	0.63	0.56	0.32	NA
b. Pre-restoration	BPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
c. Post-restoration	CPS	0.76	0.72	0.63	0.79	0.61	0.72	0.70	0.65	0.85	0.67	0.60	0.34	0.71
d. Pre-restoration	CPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Bunchgrass/Pine Savanna, the gain in FCI for the plant community function would be 0.40 (0.50 minus 0.1). However, if the plot were assessed as a Cypress/Pine Savanna the gain in FCI for the plant community function would be 0.47 (0.57 minus 0.10). In both cases, the post-restoration FCI score was not 1.0 because indicator species did not occur at the spatial scale required to obtain a 1.0.

In all plots (except plot 13) the Plant Community FCI was lower when assuming the plot was a Bunchgrass/Pine Savanna than when assuming it was Cypress/Pine Savanna. This is because the models and standards for Bunchgrass/Pine and Cypress/Pine Savanna differ; herb indicator plants used to determine FCI scores are generally not as prevalent in Cypress/Pine Savannas as in Bunchgrass/Pine Savannas.

The FCI for the Water Level Regime function was assumed to be 1.0 because all ditches in the vicinity of the plots had been filled. This assumption should be valid if hydrology was returned to its pre-altered condition, i.e., all former wetlands are now wetlands again. This assumption might not be valid within the effective drainage range of the riverine "restoration" area where geomorphology was drastically altered. Also, this assumption is likely not consistent with hydrologic definition of jurisdictional wetlands. This is because the jurisdictional criterion for hydrology is somewhat arbitrary and is not consistent with other wetland indicators. We will discuss problems with using jurisdictional hydrologic criteria for judging restoration success more thoroughly below.

The FCI for the Animal Community function depends partially upon the FCI score for the Plant Community function in that $\mathrm{FCI}_{\mathrm{ANIMAL\ COMMUNITY}} = ((\mathrm{FCI}_{\mathrm{PLANT\ COMMUNITY}} * \text{area (ha)})^{1/2}$ of contiguous fire-maintained landscape $/100\ \text{ha})^{1/2}$. Since most of the Haws Run site is currently being managed with prescribed burns, the contiguous area of fire-maintained landscape is approximately 130 ha (i.e., FCI = 1.0). Therefore, the $\mathrm{FCI}_{\mathrm{ANIMAL\ COMMUNITY}}$ is the square root of $\mathrm{FCI}_{\mathrm{PLANT\ COMMUNITY}}$. Likewise, the FCI for the Biogeochemistry function depends upon both the Water Level Regime FCI and the Plant Community FCI, i.e., $\mathrm{FCI}_{\mathrm{BIOGEOCHEMISTRY}} = (\mathrm{FCI}_{\mathrm{PLANT\ COMMUNITY}} * \mathrm{FCI}_{\mathrm{WATER\ LEVEL\ REGIME}})^{1/2}$.

The functional lift in the $\mathrm{FCI}_{\mathrm{PLANT\ COMMUNITY}}$ ranged between 0.0 (no improvement) to 0.53 assuming Bunchgrass/Pine Savanna and 0.02 to 0.61 assuming Cypress/Pine Savanna. Functioning improved by removing woody vegetation and burning, but little additional improvement was gained by planting native bunchgrasses. This was due to the fact that the planting density did not provide enough cover to significantly increase Plant Community FCI scores. However, functioning would be expected to increase if bunchgrasses are able to increase in cover and density over time. However, the regeneration potential of native bunchgrasses has not been adequately studied to provide any indication on how long this might take.

Maximum improvement occurred in the water level regime function because drainage ditches in the site had been filled as a part of the restoration effort. Significant functional improvements were also realized in the animal community function because prescribed burning was restored over an area greater than 100 ha. Likewise, significant functional improvement was realized for the biogeochemistry function because water level regime had been restored. However, these FCI scores only pertain to the plots we sampled, most of which had been planted with native bunchgrasses. Post-restoration FCI scores for areas outside the plots would likely have been slightly lower (except for the hydrology function) because bunchgrasses were not planted outside of plots 1-11.

Alternative Restoration Strategies

The restoration plan for the savanna at Haws Run primarily focused on restoring savanna tree structure to the site and managing with prescribed burns over the long-term. Structure was defined following Taggart's (1990) definition as > 50% graminoid cover, < 10% shrub cover, and < 50 % canopy cover. However, Taggart did not actually measure percent canopy cover to arrive at his definition; he derived it from the studies of others who did not measure it either. Also, his definition included dry and excluded cypress savannas (both of which tend to be more dense than wet longleaf savannas). To maintain structural and functional integrity of savannas, tree density should be kept low, i.e., rather than try to meet a minimum tree cover threshold, the goal should be to avoid exceeding some maximum tree density threshold. This is a more sparse canopy provides more light to the herbaceous stratum.

Data from intact (unaltered) reference sites is the best way to determine the desired maximum tree density threshold. Reference data from pine savannas in the least-altered condition from Texas to North Carolina showed densities ranging from 8 to 68 stems/acre (Table 8: Rheinhardt et al. In Press). At Haws Run, longleaf pine was planted at 40 stems/acre. NCDOT arrived at this planting density by assuming that approximately 11 mature longleaf pines with 50-ft-diameter crowns (1,962 ft^2) would cover ½ acre. Therefore, assuming 50% mortality, this would provide for 20 trees/acre (D. Schiller, pers. comm.). This expected final density was well within the 8-68 stems/acre found in unaltered wet pine savannas.

While Taggart's definition of savanna (above) is reasonably accurate for wet pine savannas, it is inadequate as a basis for restoration. For one, the appropriate canopy composition varies according to type of savanna desired (pine vs. cypress types). Also, although low canopy and shrub cover are characteristics of intact wet savannas, their most important attribute is that they support high herbaceous species richness at small spatial scales, one of the highest in the world. (Also, a high proportion of federally listed and threatened species occurs in intact wet pine savannas because the ecosystem is globally rare.) Small-scale species richness occurs because native bunchgrasses are keystone species; their life-history traits enable them to perpetuate frequent ground fires (which maintains open canopies and high light conditions) and the tussocks they produce provide the microtopographic complexity required of the myriad of savannas plants that co-occur with them. Thus, although restoring and maintaining the herbaceous component of the ecosystem would lead to the restoration of the woody structure, restoration of the woody structure would not necessarily restore the herbaceous component and its high diversity. Therefore, although restoring the canopy component of Wet Pine Flats would be desirable, it is much less important than restoring the herbaceous stratum.

A truer measure of long-term success would have been the degree to which the herbaceous stratum is restored or the degree to which native bunchgrasses are restored to the density and cover required for carrying frequent ground fires. (Only the wettest areas of the sites would not

Table 8. Tree density data from unaltered wet pine flat reference sites. Density is for trees > 15 cm dbh. Abbr.: BPS = Bunchgrass/Pine Savanna, CPS = Cypress/Pine Savanna, USDA = U.S. Department of Agriculture (National Forest Service), TNC = The Nature Conservancy.

Reference Site	**State**	**Sub-class**	**Density (stems/ha)**	**Density (stems/acre)**
Haws Run	**NC**	**CPS/ BPS?**	**99**	**40**
Apalachicola National Forest (USDA)	FL	BPS	21	8
OKT Plantation (private)	SC	BPS	32	13
Friendfield Plantation (private)	SC	BPS	63	25
North Carolina State Game Land	NC	BPS	64	26
Apalachicola National Forest (USDA)	FL	CPS	64	26
Myrtle Head (TNC)	NC	CPS	64	26
Francis Marion National Forest (USDA)	SC	CPS	74	30
Francis Marion National Forest (USDA)	SC	BPS	85	34
OKT Plantation (private)	SC	CPS	85	34
Lanier Quarry (TNC)	NC	CPS	106	43

have supported native bunchgrasses; native sedges would have dominated the herb stratum of the wettest areas.) Native bunchgrasses are particularly sensitive to degradation by mechanical soil disturbance. The lack of high bunchgrass cover at Haws Run is probably due to extensive soil alterations inflicted upon the site when it was converted to bison pasture, e.g., chisel-plowing and stumping. Although some mechanically altered areas might be induced to recover species if frequent fire were subsequently maintained and further soil alterations were prevented, the regeneration potential of native savanna plants has not been adequately studied to provide any indication on how long recovery might take.

Although bunchgrasses were virtually eliminated by conversion to pasture, many other savanna plant species survived at Haws Run. However, the relative abundance (composition) of savanna plants differed significantly from the historic condition (based on unaltered reference sites). Some savanna plants responded to soil alterations by becoming much more abundant than they normally would have been in the absence of alterations: *Lachnanthes caroliniana, Rhynchospora* spp. (e.g., *R. chapmanii*), *Andropogon* spp. (e.g., *A. glomeratus*), *Dicanthelium* spp. (e.g., *D. strigosum*), *Xyris* spp. (*X. flabelliformis*), and *Helianthus heterophyllus* among many others. Soil alterations have allowed these more weedy savanna plants to displace species sensitive to such alterations, especially the native bunchgrasses.

In order to truly restore the Haws Run ecosystem, native bunchgrasses would have to recover. Planting bunchgrasses at a sufficient density and reinitiating growing-season fires (to allow bunchgrasses to set seed) would probably be necessary to restore a more typical herbaceous composition. Again, most of the typical non-bunchgrass herbaceous plants are present and some would probably recover their historic patterns of distribution relatively rapidly if provided with the proper fire and hydrologic regimes. However, the conventional wisdom is that it would take centuries for bunchgrasses to recover naturally. However, this perception has been based on data from savannas managed with dormant-season fires and savanna grasses almost only set seed following growing-season fires (Streng et al. 1991).

Property to the east of the Haws Run site has recently been purchased by TNC to restore savanna there. Therefore, there may be an opportunity to restore hydrology to the eastern side of the site by removing the perimeter ditch and much of the perimeter road. Cooperation between TNC and the COE in further restoration measures has the potential of greatly enhancing the value of Haws Run as a compensatory mitigation site. Apparently, this is cooperation is on-going (D. Schiller, pers. comm.).

The excavated portion of the riverine restoration along Sandy Run needs to be addressed. The excavation occurred along a section of flat that was probably a transition from pine flat to floodplain forest. As such, the area closest to the floodplain would probably once have been Cypress/Pine Savanna. It is not clear if it would be desirable or possible to restore the geomorphology. In any case, the present abrupt change in slope was unstable (erosion was an on-going problem) and the north end of the site may be draining more rapidly to the excavated area. Changing geomorphology to create wetlands by increasing hydroperiod is commonly practiced in mitigation throughout the country, particularly along floodplains. A recent study of this practice by the Virginia DOT revealed some of the common problems associated with excavations: acidification, hydrology that was either too wet or not wet enough for BLH tree species, and lack of soil fertility (Whittacar and Daniels 1999).

Suggestions for Further Work

In unaltered Bunchgrass/Pine Savanna, bunchgrasses typically grow at a density of 5-12 plants/m^2 (pers. obs.). However, bunchgrasses were planted at a density of only 1.2 plants/m^2 in 11 plots covering 0.0075% of the Haws Run site. Because restoration of the herbaceous stratum is critical for restoring the ecosystem, the restoration effort should be expanded beyond this small-scale experimental regime. We suggest that NCDOT use soil and hydrologic information obtained from reference sites identified in the HGM Wet Pine Flats guidebook to help determine where specific bunchgrasses should be planted. Further, since NCDOT hopes that planted bunchgrasses will spread from planted areas to re-populate the rest of the site, randomly-placed long-term monitoring plots should be established throughout the site to determine if indeed the bunchgrasses increase in cover or abundance in other parts of the savanna. Conducting a long-term study to understand the effects of this restoration experiment would make the mitigation site a true “research site.”

Ditches were not filled in the southern portion of the site and so hydrology was not restored in that section. It seems that if hydrology were restored in that area, more potential critical habitat could be provided for Cooley’s meadowrue (at present, it only persists in along seeps in ditches). One alternative would be to transplant some meadowrue to appropriate areas in the north end of the site to see if they will survive in hydrologically restored areas. If a sufficient proportion of plants were to survive and set seed, there would be justification for filling ditches (therefore restoring hydrology) in the southern portion of the site also. Meadowrue could be transplanted from ditches to appropriate areas on the wet flats. We realize that this is a politically sensitive issue, but it seems that some risk is warranted to restore the larger ecosystem to which Cooley’s meadowrue and other savanna species belong. (Apparently, this plan is being considered by NCDOT and the U.S. Fish and Wildlife Service (D. Schiller, pers. comm.)).

It appears that drum chopping was conducted in the savanna during restoration. This activity disturbs soil and can kill bunchgrasses. Because savanna plants (native bunchgrasses in particular) are extremely sensitive to soil disturbances, most soil disturbances should be severely restricted during restoration.

Apparently, COE personnel were disappointed with the results of the swamp restoration adjacent to the Sandy Run floodplain at the northern end of the Haws Run site. More in-depth attention to the geomorphology of the area adjacent to the swamp might have prevented erroneously concluding that fill material had been placed on the area. However, the excavation is still considered by all parties to be ‘restoration’ rather than ‘creation’ in spite of a change from one wetland class to another and the degree of excavation. Nonetheless, the excavated area needs some remediation. Erosion of the steep slope at the border of the excavation is an on-going problem and is probably inadvertently draining the northern end of the flat. In order to correct the problem, a more gradual gradient will have to be created by excavating more of the flat or filling some of the excavated area. Placing riprap on the slope face may control erosion, but hardening will not alleviate drainage of the upgradient flat unless the hardened structure can impede groundwater discharge. If the slope is hardened, then the effective drainage area (analogous to the impact of a 5-foot-deep ditch) could be determined and the affected area eliminated from mitigation credit.

Overview of Regulatory Implications

There has been an evolution by COE staff regarding the "validity" of using wet flats as compensatory mitigation. More recently, the history of demise and the rarity of intact ecosystems in coastal plain areas have become more apparent, particularly with the review and field testing sessions associated with the Wet Pine Flats guidebook and the emphasis placed on these sites by TNC and the NC Natural Heritage Program. During the early to mid 1990s, fire was not recognized by the regulatory community as a necessary and acceptable management tool for restoration. Nor was there an appreciation of the value of the herbaceous stratum in providing a reservoir for rare and endangered species or the importance of bunchgrass in maintaining high frequency, low intensity fires.

Given the somewhat chaotic state of mitigation practices, the concept of "in kind" has also not been as strict as it could have been. For example, wet hardwood flats have often been classified as Bottomland Hardwood Forest, due to their dominance by hydrophytic trees; however, this classification ignores real differences hydrologic regime resulting from geomorphic differences. Lately, the Schafale and Weakley (1990) 'Natural Communities' classification approach has received more emphasis in identifying sites for in-kind restoration. However, hydrogeomorphic attributes are not always explicit using this classification approach and because the classification was based on attributes of "exemplary" communities, altered sites may be difficult to classify. Classifying by hydrogeomorphic attributes, at least as a first cut, could provide more accurate guidance for meeting goals for true in-kind restoration.

In terms of using reference at Haws Run, an effort was made to use Lanier Quarry as a reference site. Six water-level gauges were monitored at Lanier Quarry from 5/1/98 to 11/13/98. The earliest and potentially wettest part of the growing season was missed (3/23-5/1), which could have affected results. However, Lanier Quarry may have been altered sufficiently by ditching such that it may not have represented an "unaltered" condition. Nonetheless, the site was not considered to be jurisdictional from a hydrologic perspective (i.e., having continuous saturation for 12.5% of the growing season in the upper 12 inches under normal climatic conditions) even though the other two jurisdictional criteria had been met (dominance by hydrophytic plants and hydric soils). This put the COE in a potentially awkward policy position of using hydrologic data from a reference site that could not be proven to be a jurisdictional wetland based on the small amount of data collected. While non-wetland buffers around jurisdictional wetlands are sometimes included as part of mitigation plans, acceptance of large tracts of jurisdictionally marginal wetland would have been unacceptable from a policy perspective. Therefore, the COE felt it could not accept Lanier Quarry as a reference site.

COE personnel do not necessarily object to accepting Wet Pine Flats as a wetland type for mitigation. Instead, they are constrained from accepting them when they do not meet the U.S. Army Corps of Engineers (1987) delineation manual threshold for hydrology. This prevents the COE from holding NCDOT to ecologically meaningful standards for restoration. The hydrologic criterion used by the delineation manual for defining wetlands falls apart at the transitional boundary of wetlands in that it does not correspond to hydric soil indicators and more ecologically relevant characteristics of wetlands. One problem is that the growing season definition used by the COE corresponds to the growing season determined for agricultural crops as defined by county soil surveys and does not address soil temperatures in wetlands. Specifically, they do not adequately incorporate soil conditions that correspond to biological activity and the development of anaerobic conditions. It is these conditions that occur during biologically-active temperatures that select for hydrophytic plant species and in turn promote hydric soil development.

Perhaps the COE could accept a more ecologically relevant definition of growing season, one that would enable it to set standards that are meaningful for restoring Wet Pine Flats. As it now stands, meeting the hydrologic standard in Wet Pine Flats would make them too wet to support Bunchgrass/Pine Savanna and perhaps too wet to support savannas at the least wet end of the Cypress/Pine Savanna gradient. Because Wet Pine Flats are still prevalent in eastern North Carolina, road construction and other activities continue to alter a high number of acres. Restoration of Wet Pine Flats will require a more realistic and meaningful approach to establishing success criteria if this wetland ecosystem-type is to protected and restored.

Precipitation-dominated wet flats are more variable with respect to period of saturation, probably because they lack groundwater inputs that continue to provide water even after rainfall events. Therefore, it appears that to adequately recognize wet flats as wetlands from a jurisdictional perspective, either the period of growing season should be increased (true growing season is practically all year) or the percent of time of continuous saturation during the growing season (as currently defined) should be shortened. If hydrologic criteria cannot be changed for flats, then more emphasis should be directed toward restoring typical vegetation (esp. in the herb stratum), than trying to meet hydrologic criteria based on a scientifically indefensible definition of growing season.

Several studies have found that created wetlands differ from unaltered reference wetlands in soil characteristics such as pH, bulk density, and total nitrogen (Bishel-Machung et al. 1996). Cole et al. (2001) found that soil organic matter in created wetlands was only 10-50% of that found in nearby reference wetlands. Soil organic matter content is particularly important in wetlands in that under anoxic conditions soil microbes use organic matter (and its reduced forms) as an energy source for nitrate reduction and denitrification. At Haws Run, organic matter content in the “restored” swamp was only 36% of that in the adjacent forest.

The attempt to create additional swamp forest by excavating earth from the swamp/flat ecotone might not have occurred had soil standards been in place because amendments of sufficient organic matter might have proven too costly to justify. In any case, performance standards based only on survival of planted vegetation and hydrologic regime miss the importance function of soil condition in the integrity of wetlands. Thus, soil standards would not only be useful for evaluating the success of restoration projects, but would also likely discourage certain types of compensatory mitigation from being proposed in the first place.

Ballance Farm

Location: Currituck County north of Sligo, NC and south of Tull Bay, west of SR 1232 and east of Tull Creek.

Size: Total 403 acres (163 ha): restoration of 236 acres (95 ha) wet hardwood flat, creation of 61 acres (25 ha) of sea-level controlled marsh, preservation of 50 acres (20 ha) of sea-level controlled marsh, preservation of 51 acres (21 ha) of sea-level controlled swamp forest, and preservation of 5.3 acres (2 ha) of upland forest (an additional 26 acres of roads and ditches are also a part of the parcel).

Natural History

The Ballance Farm compensatory mitigation site is located on the outer coastal plain, just south of Tull Bay and the Virginia border (Fig. 5). The terrain is extremely flat and the soils poorly to very poorly drained. Before conversion to row crop agriculture, it appears that Ballance Farm consisted of wet hardwood forest on the interfluvial divide, sea-level-controlled forest in sloughs, and sea-level-controlled fringe marsh along Tull Creek.

Few remnant wet hardwood forests still remain for use as reference in this part of northeastern North Carolina and southeastern Virginia; they are rapidly being logged and converted to short-rotation pine silviculture. NCDOT had obtained access to a reference ecosystem on adjacent land and had installed monitoring gauges there, but the lease had not been renewed and so we were denied permission from the landowner to visit the site and collect vegetation data. However, Tables 9 and 10 provide quantitative data (derived from Rheinhardt and Rheinhardt 1999, 2000) on the vegetation of remnant, relatively unaltered wet hardwood flats located in Currituck County and adjacent counties. The stands are arranged in approximate order of relative wetness with the wettest site on the left (canopy with *Taxodium ascendens*) to the least wet site on the right with high density of *Fagus grandifolia* in the canopy). *Acer rubrum* and *Liquidambar styraciflua* were important in almost all the sampled stands and one or more species of oak (*Quercu*s spp.) occurred in them as well. Much of the central portion of Ballance, with the exception of sloughs and drainage ways traversing the site, was probably once wet hardwood flat.

The slough running east to west through the interior of Ballance Farm is probably affected by water level fluctuations in Tull Creek. When Tull Creek (a sea-level creek) water levels are high, it likely inhibits drainage by acting somewhat as a dam. Maximum flooding probably occurs in winter and early spring when soils on the adjacent flats are most saturated and transpiration is lowest.

We quantitatively sampled vegetation in a relatively unaltered slough forest on the north side of the Ballance Farm to obtain reference data (Table 11). This site could have provided information for guiding restoration in sloughs on the site. *Nyssa biflora, Acer rubrum, Quercus laurifolia*, and *Liquidambar styraciflua* co-dominated the stand, but two other oaks species and *Ulmus rubra* (slippery elm) were also present. The subcanopy was relatively open (only 731 stems/ha) and was dominated by *Carpinus caroliniana* and saplings of *Acer rubrum.* Saplings of

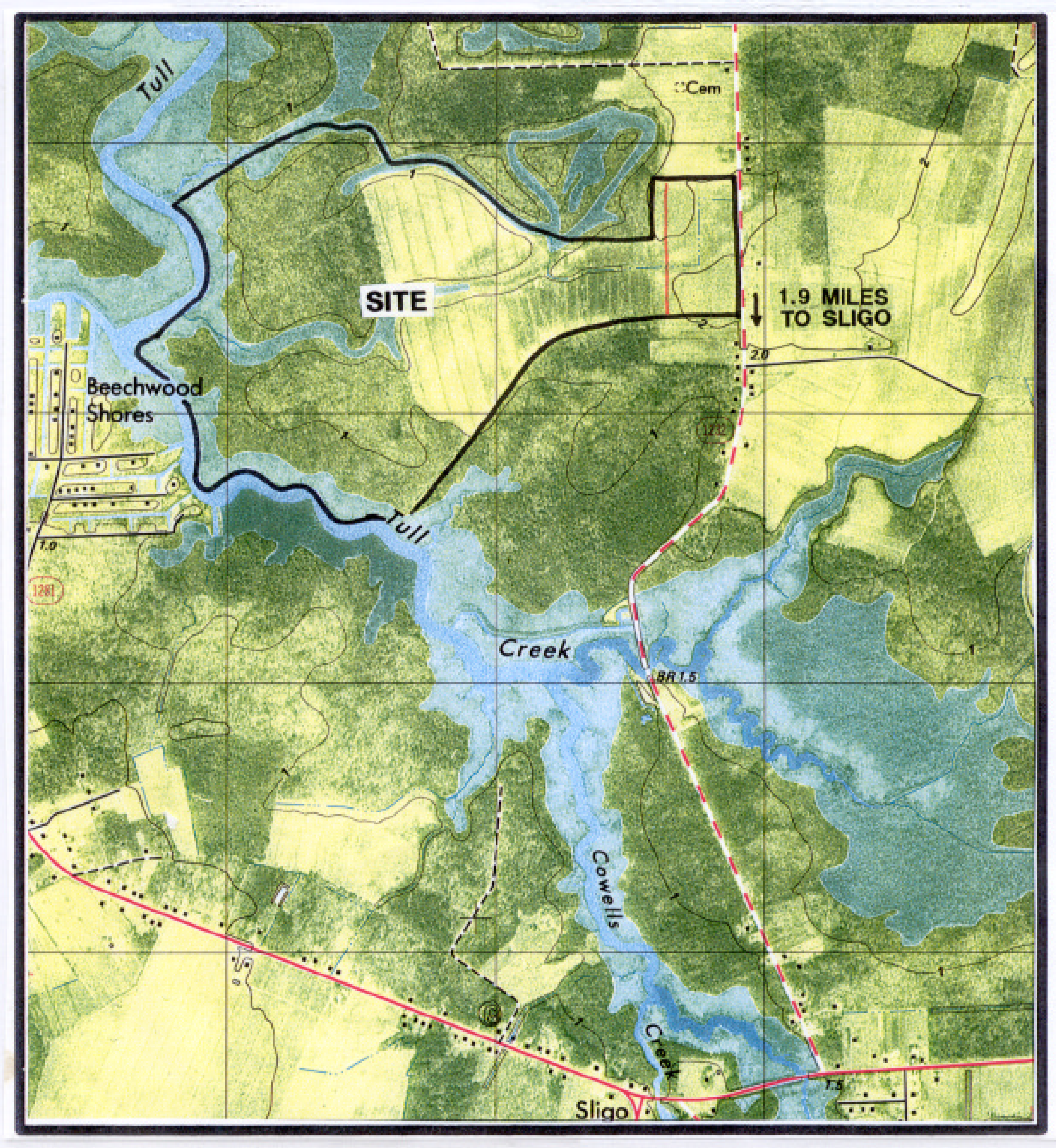

Figure 5. Location of Ballance Farm compensatory mitigation site on a USGS 1:24,000 orthophotoquad. Prior to conversion to agriculture, a slough through the middle of the site probably once connected two portions of Tull Creek.

Table 9. Relative density of canopy vegetation in relatively unaltered wet hardwood flats. Absolute density can be calculated by multiplying total density of a species by its relative density and dividing by 100. Canopy includes trees > 15-cm dbh. Density only for stems between 7.5 and 15 cm dbh. Data derived from Rheinhardt and Rheinhardt (1999).

	Virginia Beach 1	**Currituck County 1**	**Gates County**	**Virginia Beach 2**	**Camden County**	**Perquimans County**	**Currituck County 2**
Total Basal Area (m^2/ha)	31.0	25.5	37.5	27.0	26.0	30.0	26.0
Total Density (stems/ha)	572	302	318	519	342	223	254
Total Density (stems/acre)	231	122	129	210	138	90	103
Relative Density							
Acer rubrum	50.0	26.3	-	12.2	20.9	10.7	15.6
Quercus laurifolia	18.5	7.9	-	-	-	-	-
Liquidambar styraciflua	11.1	18.4	30.0	61.2	39.5	21.4	9.4
Taxodium ascendens	9.3	-	-		-	-	-
Nyssa biflora	5.6	23.7	-		4.7	-	9.4
Ulmus spp.	5.6	-	-	2.0	-	7.1	-
Quercus nigra	-	2.6	5.0	-	-	-	-
Quercus pagoda	-	7.9	-	6.1	11.6	10.7	9.4
Pinus taeda	-	2.6	-	-	-	3.6	12.5
Quercus alba	-	-	-	-	-	-	3.1
Liriodendron tulipifera	-	5.3	35.0	4.1	2.3	14.3	-
Quercus michauxii	-	-	-	2.0	2.3	10.7	6.3
Fagus grandifolia	-	5.3	5.0	-	11.6	14.3	28.1
Nyssa sylvatica	-	-	-	6.1	-	-	-
Fraxinus spp.	-	-	-	6.1	-	-	-
Carya ovata	-	-	-	-	2.3	-	-
Carya sp.	-	-	-	-	2.3	-	-
Ilex opaca	-	-	5.0	-	-	-	3.1
Oxydendron arboreum	-	-	-	-	-	-	3.1
Ostrya virginiana	-	-	20.0	-	-	-	-
Carpinus caroliniana	-	-	-	-	2.3	7.1	-

Table 10. Relative density of woody understory vegetation in unaltered wet hardwood flats. Understory includes all stems > 1-m tall and < 15-cm dbh (X = present, density not determined) absolute density can be calculated by multiplying total density of a species by its relative density and dividing by 100. Density only provided for stems between 7.5- and 15-cm dbh. Data derived from Rheinhardt and Rheinhardt (1999).

	Virginia Beach 1	**Currituck County 1**	**Gates County**	**Virginia Beach 2**	**Camden County**	**Perquimans County**	**Currituck County 2**
Total Density (stems/ha)	212	2,482	1,337	191	902	1,082	1,528
Total Density (stems/acre)	86	1,004	541	77	365	438	618
Relative Density							
Carpinus caroliniana	X	1.3	9.5	5.5	38.0	26.5	-
Persea borbonia		20.5	-	-	-	-	-
Ilex opaca	X	6.4	38.1	-	-	-	2.1
Symplocus tinctoria		1.3	-	-	-	-	-
Vaccinium spp.	X	14.1	-	-	17.0	2.9	25.0
Ostrya virginiana		-	38.1	-	-	-	-
Magnolia virginiana		14.1	-	-	7.0	-	-
Leucothoe axillaris	X	23.1	-	-	-	-	-
Euonymus americanus	-	1.3	-	-	-	2.9	-
Acer rubrum	70.0	3.8	-	72.2	11.0	17.6	22.9
Liquidambar styraciflua	-	9.0	4.8	-	8.0	5.9	20.8
Nyssa biflora	X	-	-	-	-	-	-
Liriodendron tulipifera	5.0	-	-	5.5	-	-	-
Quercus michauxii	X	-	-	5.5	6.0	-	4.2
Quercus alba	-	-	-	-	-	-	4.2
Fagus grandifolia	-	2.6	-	-	13.0	20.6	6.2
Ulmus spp.	25.0	-	4.8	5.5	-	20.6	-
Oxydendron arboreum	-	-	-	-	-	2.9	-
Carya sp.	-	-	-	5.5	-	-	-
Unidentified	-	-	4.8	-	-	-	14.6
Quercus nigra	-	2.6	-	-	-	-	-
Alnus serrulata	X	-	-	-	-	-	-
Leucothoe racemosa	X	-	-	-	-	-	-
Lyonia lucida	X	-	-	-	-	-	-
Lyonia ligustrina	X	-	-	-	-	-	-
Quercus laurifolia	X	-	-	-	-	-	-
Quercus pagoda	X	-	-	X	-	-	-
Cornus florida	-	-	-	X	-	-	-
Cornus stricta	X	-	-	-	-	-	-
Sassafras albidum	-	-	-	X	-	-	-
Euonymus americanus	-	-	-	X	-	-	-
Sorbus arbutifolia	-	-	-	X	-	-	-
Quercus phellos	X	-	-	-	-	-	-
Quercus laurifolia	X	-	-	-	-	-	-

Table 11. Woody vegetation of a relatively unaltered slough. Trees are > 15 cm dbh. Subcanopy is stems > 1-m tall and < 15-cm dbh. Data obtained from three 10-m-radius plots. Basal area of the stand was 26 m^2/ha.

Canopy	Absolute Density (stems/ha)	Absolute Density (stems/acre)	Relative Density (%)
Nyssa biflora	127	51	28.6
Acer rubrum	106	43	23.8
Quercus laurifolia	74	30	16.7
Liquidambar styraciflua	64	26	14.3
Quercus michauxii	21	9	4.8
Quercus pagoda	21	9	4.8
Ulmus rubra	21	9	4.8
Fraxinus spp.	11	4	2.4
No. stems	445	180	100.0

Subcanopy	Absolute Density (stems/ha)	Absolute Density (stems/acre)	Relative Density (%)
Carpinus caroliniana	435	176	59.4
Acer rubrum	265	107	36.2
Quercus michauxii	11	4	1.4
Nyssa biflora	11	4	1.4
Ilex opaca	11	4	1.4
No. stems	731	296	100.0

Quercus michauxii, *Nyssa biflora*, and *Ilex opaca* were also present. Soil in the reference site had roots and organic matter in the top 7-9 cm; the A-horizon was a dark silt (10 YR 2/2).

The western end of the Ballance Farm site lies along Tull Creek, a freshwater, sea-level creek connected to Tull Bay, which in turn is connected to Currituck Sound via the North Landing River. Tull Creek is fresh because the nearest inlet from the Atlantic Ocean is over 90 km (56 miles) away. Fringing marshes and forested wetlands (swamps) line the creek. Flooding is caused primarily by wind-driven tides, i.e., the strength and direction of wind events influence water levels more than do lunar cycles.

The marshes along Tull Creek and other nearby sea-level creeks are typically peat marshes dominated by *Cladium jamaicense* (sawgrass), *Juncus roemerianus* (black needlerush), and *Typha* spp. (cattails). Prior to the closing of the Currituck Bank inlet in 1828, the marshes were probably brackish; hence the continued dominance of *Juncus roemerianus* and the presence of other species more often affiliated with brackish systems. Trees have begun to colonize many marshes (particularly near the transition to upland), but invasion has been slow.

Taxodium distichum (bald cypress) and *Nyssa* spp. dominate forested wetlands (swamps) located at the back edge of marshes; *N. aquatica* typically dominates along creek fringes while *N. biflora* dominates more interior portions (Schafale and Weakley 1990). *Acer rubrum*, and sometimes *Pinus taeda*, are also often important components of canopies in sea-level fringe forests.

Land-use History

Ballance Farm was converted to agricultural use sometime during the 1960s. In order to drain the land, 10-foot-wide ditches (0.50-0.75 m in depth) were constructed along the northern and southern borders of the property and a series of twenty-one 2-3 foot-wide ditches (depths not known) were dug approximately every 77 m (250 feet) in a north/south orientation. Spoil removed when digging the ditches was spread on the fields and used to create a berm at the western end of the field near the marsh to inhibit flooding from Tull Creek (Resource Southeast 1995). Row crops were grown on the land until 1994, when it was cultivated last.

Compensatory Mitigation History

As early as 1992, a mitigation site was sought to compensate for anticipated impacts to wetlands that were to occur from widening Route 168 in Currituck County. Ballance Farm, with approximately 250 acres of prior-converted cropland, was identified as a possible candidate in 1995. Originally, the plan was to fill the ditches to restore hydrology and plant trees to restore the site to wet hardwood flat. However, at an interagency meeting, a consensus developed to also create freshwater tidal wetlands on part of the property.

Approximately 300 acres of Ballance Farm were purchased by NCDOT in 1995. In 1996, a fairly comprehensive hydrologic study was conducted on the property by Resource Southeast, a private consulting firm under contract to NCDOT. Hydrologic modeling showed that ditches were responsible for sufficiently draining the site and that, if ditches were filled, hydrology would be restored so that much of the site would become jurisdictional wetland. Their models also showed that groundwater would flow toward and through a former slough in the middle of the site (Fig. 5). There was some indication that berms located at the interface between Tull Creek and adjacent fields were preventing flooding from the creek during periods of high water, but no mention was made of removing those berms.

The final mitigation plan proposed plugging internal ditches with material scraped from areas between the ditches. (It was believed that when excavating the ditches, spoil had been spread between ditches to create field crowns.) The northern and southern perimeter ditches were to be left in place and a large network of tidal creeks were to be constructed with three connections to Tull Creek. Freshwater marsh species were to be planted along the edges of the created creek system.

Construction at Ballance began in 1998. A long creek with a series of short tributaries was constructed totaling about 1,400 feet in length. Creeks were approximately 400 feet in width and 3.5 to 4.0 feet deep at their deepest (in the middle of their channels). Spoil from the channel excavations was transported to and placed in a large pile at the opposite (eastern) end of the site (Fig. 6). Presumably, some of the spoil was used to construct the earthen berm around the perimeter. At one point, NCDOT requested that material excavated from the created marsh be used to fill the internal field ditches, but the Corps insisted that material from the crowns between the ditches be used instead (Table 12). Therefore, the internal ditches were plugged and filled with material scraped from the inter-ditch areas. A road berm was constructed around the perimeter of the site and several flashboard risers were installed in the perimeter berms to inhibit surface runoff (Resource Southeast 1995).

Herbaceous marsh vegetation was planted along the margins of the constructed creeks in 1998 (a supplemental planting also occurred only a few weeks before our field visit in June 2000). Plants were not in flower or fruit and so they could not be identified to species. However, plant tags left lying along channel margins included some for *Juncus effusus, Scirpus cyperinus, S. fluviatilis, S. americanus,* and *S. olneyi*).

By March 1998, trees had been planted throughout the wet flat and slough portions of the site at a density of 680 stems/acre (275 stems/ha). Tree species planted included *Quercus lyrata, Q. phellos, Q. nigra, Q. laurifolia, Q. pagoda, Q. michauxii, Fraxinus pennsylvanica, Lirodendron tulipifera,* and *Taxodium distichum.* The mixture of species planted in a given area was related to the predicted wetness of the site, with more flood-tolerant species planted in wetter areas.

Fourteen groundwater monitoring gauges and 14 surface gauges were installed throughout the site. A reference ecosystem was located on adjacent property and monitoring gauges were to be installed there as well. However, according to the 1999 NCDOT annual monitoring report, only jurisdictional criterion for hydrology was used to determine hydrologic success (i.e., continuous saturation within 12” of the surface for 12.5% of the growing season: 30 days for Currituck County) rather than hydrologic conditions occurring in the reference site.

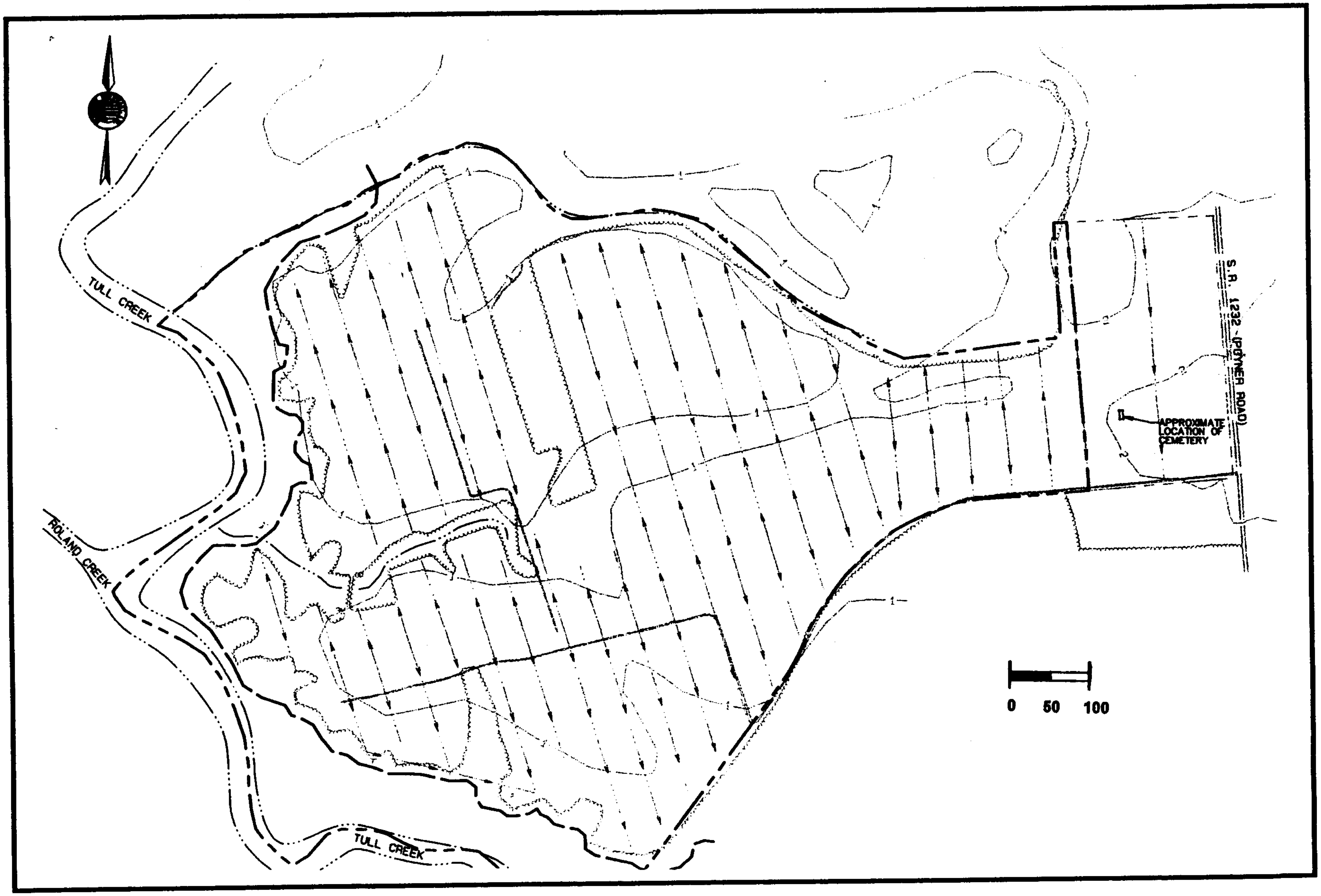

Figure 6. Location of filled ditches (arrows) and elevation transect at Ballance. Spoil from created marsh creeks was placed at the far-eastern end of site.

Table 12. Selected correspondences related to Ballance Farm mitigation site.

Date	From	To	Summary Description
10/20/95	Resource Southeast	NCDOT	Draft feasibility study for using Ballance as a mitigation site. Among other things, Resource Southeast proposed constructing a low berm around perimeter to reduce surface
11/25/95	NCDOT	COE	Response to COE comments on mitigation plan. Discussed creation of a tidal creek/ditch.
04/08/96	NCDOT	COE	Submission of draft mitigation plan for Ballance; includes creation of a tidal creek.
07/05/96	NCDOT	COE	Request for regulatory comments on draft mitigation plan.
07/05/96	Resource Southeast	NCDOT	Identification of four potential reference sites.
08/05/96	NCDOT	COE	Request for regulatory comments on draft mitigation plan.
08/?/96	N/A	N/A	Site visit by NCDOT and regulatory agencies.
08/19/96	COE	NCDOT	Comments on draft mitigation plan. Proposed restoration of a tidal creek in middle of property, establishment of reference wetlands for hydrologic monitoring, installing clay plugs in filled ditches, and providing a planting plan with
09/05/96	NA	NA	Meeting in Elizabeth City with NCDOT and regulatory agencies. Consensus to restore tidal creek into site (to restore swamp/marsh), but some indication that existing slough would have to be deepened to create a sea-level controlled creek to provide "riverine" credits.
09/30/96	NCDOT	NCDOT	Internal memo: NCDOT initiates search for reference sites, but does not want to use HGM or obtain more than 2 reference sites.
10/07/96	NCDOT	COE	Response to comments on mitigation plan. Two reference sites identified, desire to fill ditches with field crown material, contingency plans for vegetation failure.
10/11/96	NCDOT	COE	NCDOT asks for a one-year extension for completion of mitigation due to delays by regulatory agencies and major changes in mitigation plan at request of agencies.
10/24/96	NCDOT	COE	NCDOT asks for changes in permit conditions to allow a one-year extension for completing mitigation.

Table 12 (cont.)

Date	From	To	Summary Description
12/11/96	NCDOT	NCDOT	Internal memo. Response to phone conversation with COE. Apparently swale restoration was envisioned by COE, not tidal creek creation, at least for the interior of the site.
12/11/96	NCDOT	COE	Expressed concern that swale restoration would drain portion of site (possible only if swale not responding to sea-level fluctuations).
12/13/96	NCDOT	COE	Requests that permit be modified to require a swale be restored rather than a tidal creek and to delete requirement of riverine forest restoration (presumably forested swale is what was meant).
10/01/98	NCDOT	COE	NCDOT requests that material excavated to create marsh be used to fill ditches.
10/02/98	NCDOT	COE	Another request to use material excavated to create marsh to fill ditches; soil being stockpiled alongside of ditches until permission provided.
10/?/98	COE	NCDOT	COE does not approve use of stockpiled material to fill field ditches; wants field crowns used instead.
10/20/98	NCDOT	NCDOT	Internal memo: NCDOT decides it would be better to use field crown material to fill internal ditches (original plan) rather than material excavated for marsh creation. Presumably, lowering elevations was expected to increase the chance of hydrologic success.
11/02/98	NCDOT	COE	Summary of October 22 meeting. Field crowns to be scraped and used to fill ditches. Flashboard risers to be installed at several points along perimeter berm (presumably to regulate water levels).

Present Condition of Site

Compensatory wetland mitigation at the Ballance Farm site involved a substantial input of energy. Thousands of cubic yards of earth were excavated and moved to create a system of creeks tied to Tull Creek. Some of the excavated material was used to create a raised berm and road around the mitigation area to provide access for vehicles and inhibit surface water run-off. Flashboard risers were constructed on the perimeter berms. Because they appear to be in working condition, they appear to us to have been designed to block drainage further, if necessary.

The area excavated to create freshwater marsh was planted with marsh species, but many were not surviving well. The excavated area had little or no organic matter, unlike the nearby fringe marsh it was designed to mimic. (The nearby, intact fringe marsh is a peat-based ecosystem, a very different soil substrate than the mineral, organic-poor soil in the created area.) The site was replanted sometime in June 2000 after poor survival was found in the 1999 vegetation monitoring study. Since the supplemental planting had occurred only a few weeks before our field-visit, it was impossible to determine the probability that the newly planted marsh plants will survive over the long term. However, it is unlikely that much soil organic material will be produced during the initial three-year monitoring period.

Four *Scirpus* species were planted in the created marsh; however, one of the planted species (*S. fluviatilis*) is not native to North Carolina. Although this species may not be able to compete well with the other *Scirpus* spp., non-native species should not be intentionally introduced into mitigation sites. In addition, we found a stand of the invasive reed, *Phragmites australis*, near the created marsh. If not removed, it might invade the marsh and out-compete vegetation being planted there.

In excavating soil to create the marsh, hundreds of truckloads of material were transported from one end of the site to the other. This traffic caused considerable soil compaction in some areas. In addition, when the planted marsh vegetation failed to survive the first year, many truckloads of plants were driven across the restoration area, causing further soil compaction along the access road and leaving deep ruts in wetter areas. These compacted areas will likely eventually recover, but initial tree survival in these areas will probably be lower than in the rest of the mitigation area. Compacted soils also reduce infiltration, groundwater movement, and subsurface water storage.

Field ditches in the interfluvial flats were filled using material scraped from adjacent, inter-ditch areas. (It seemed that both NCDOT and regulatory agencies hoped that lowering the elevation of inter-ditch areas would increase the likelihood of making the site wetter.) Even native old-field species appeared to be less dense and less vigorous in the scraped area than in the unscraped areas (Fig. 7). The reduced density of old-field species was probably a consequence of the seed bank being removed during scraping; the lack of vigor of those plants indicates lower soil fertility. The survival of planted trees was also lower in most scraped areas (Table 13), further suggesting reduced fertility. Neither scraped nor unscraped areas had an

Figure 7. Vegetative growth in scraped and unscraped areas at Ballance Farm

***Table 13. Five-meter-radius plots sampled along transects. Transects were perpendicular to the former ditch layout (west-to-east). Odd plot numbers = unscraped areas, even plot numbers = scraped areas. Percent survival assumes that 680 stems/acre were initially planted. N/A = not available*.**

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
Quercus pagoda	5	8	4	3	2	1	1	1
Quercus michauxii	4	2	2	1	5	3	4	4
Quercus lyrata	2	0	0	0	2	2	1	0
Quercus phellos	0	0	1	0	0	0	0	1
Fraxinus spp.	0	0	1	2	1	4	3	0
Total count	11	10	8	6	10	10	9	6
Stems/ha	229	209	167	125	209	209	188	125
Stems/acre	567	515	412	309	515	515	464	309
% Survival	83	76	61	45	76	76	68	45

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
O Horizon depth (cm)	N/A	0	0	0	0	0	0	0
A Horizon depth (cm)	N/A	N/A	N/A	N/A	0-25	0-10	N/A	0-9
A Horizon color	N/A	10 YR 4/1	10 YR 4/1	10 YR 4/1	10 YR 3/1	10 YR 4/1	10 YR 3/1	10 YR 3/1
A Horizon texture	N/A	silty clay loam	silty clay loam	silty clay loam	silt loam	loam	silt loam	silt loam
B Horizon depth (cm)	N/A	N/A	N/A	N/A	25-50	N/A	N/A	9-13

O-horizon or an organic-rich A-horizon, a consequence of tilling activities associated with farming. However, soils from all areas showed low chroma value, suggesting former wetland status.

Relative elevations of the land surface were surveyed perpendicular to the former ditches along a 400-m (1,300-foot) west-to-east transect. All changes from unscraped to scraped areas were surveyed as well as any other irregularities in elevation and the surface elevations of all former ditches. Five former ditches were crossed in the surveyed transect (Fig. 8). The center of each ditch was 10-20 cm lower than the surrounding land, probably due to settling of ditch-fill material over time. In addition, land scraped to fill the ditches was usually located on the west side of the ditches and adjacent to them. Scraped areas ranged from 10 m to 21 m in width (mean = 17 m) and ran parallel with the ditches from north to south across the site (equivalent to 16 acres of scraping across the entire site). If the intention was to use field crowns to fill the ditches, it seems that the center of the inter-ditch areas should have been scraped rather than only areas adjacent to the ditches.

NCDOT planted hydrophytic hardwood trees in most of the former cropland, including the shallow slough running through the center of the site. Density of tree seedlings planted in the slough was determined for the center and edges (transition to wet flat) of the slough. These data were compared with tree density data collected from the nearby, relatively unaltered reference slough (Table 14). Several differences between the reference slough and Ballance Farm slough are apparent. For one, *Quercus lyrata* did not occur in the reference area, but was the most densely planted mitigation species. *Q. lyrata* did not occur in any wet hardwood flats sampled by Rheinhardt and Rheinhardt (1999, 2000). The third most densely planted species was *Taxodium distichum*; it does not occur in mineral soil wet hardwood flats either. *Acer rubrum* and *Liquidambar styraciflua* were not planted, but they (esp. *Acer rubrum*) tend to readily colonize old field sites. *Quercus michauxii* and *Q. pagoda* Raf. *(Q. falcata* var. *pagodaefolia* Ell.) are often a part of NCDOT's planting mix, but these species do not appear to have been planted in the slough. *Ulmus* spp. (elm) used to be and sometimes still is common in wet hardwood flats and riverine ecosystems, but never seems to be planted in mitigation sites. (Perhaps NCDOT should consider including elm in its mix of planted species.) The take-home message here is that a nearby reference could have been used to direct tree plantings in the slough. Using reference to facilitate restoration was talked about quite a bit during the planning phases (see summary of correspondences, Table 12), but in the end, it didn't seem that reference data were ever seriously considered.

Soil profiles were also obtained for both the reference slough and the slough through Ballance (Table 15). Several differences in soils between the three areas were evident. The top 7-9 cm of the soil horizon in the reference slough was composed of organic matter and root material, while the interior of the Ballance slough had no organic horizon, and the edge of the Ballance slough had only 0-3 cm of organic horizon. Also, the A-horizon of the reference slough was darker than soils in the interior and edges of the Ballance slough (chroma 2 for reference area vs. value 4-5 for the Ballance slough). In addition, the soil in at least one of the edge areas of the Ballance slough showed evidence of compaction (tight horizontal layers of soil with roots growing along the horizontal layers rather than vertically) while none of the soil profiles in the reference area exhibited signs of compaction. Lack of organic horizon and lighter-colored soil

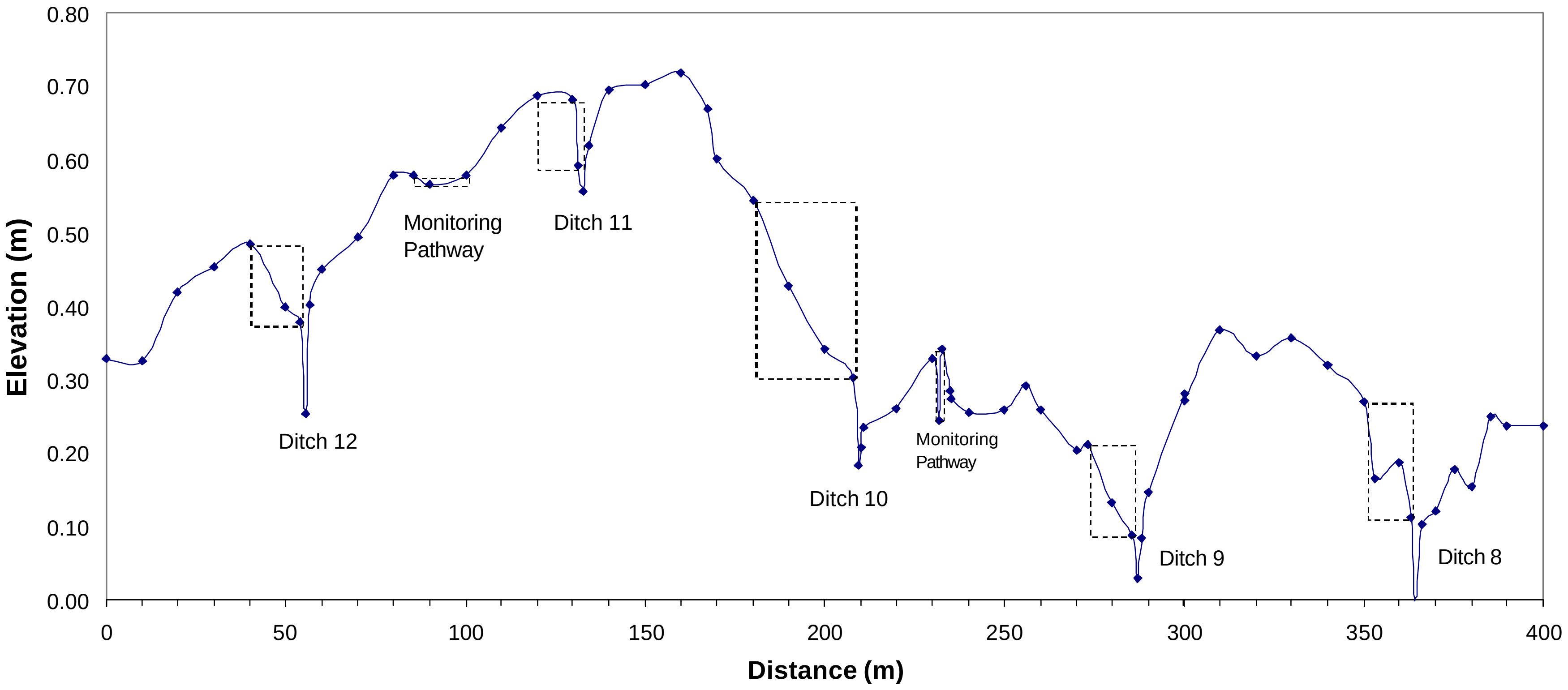

Figure 8. Surveyed cross-section of ground elevations at Ballance site (west to east) relative to the lowest elevation recorded. Ditches are numbered from east to west. Dashed rectangles mark locations of scraped areas. Monitoring pathways are dirt roadways used to access water level monitoring gauges and/or vegetation-monitoring plots. Vertical scale is exaggerated.

Table 14. Density (stems/acre) of trees in a reference slough and tree seedlings surviving in a planted slough at Ballance Farm. Data from the Reference Slough were obtained from three 10-m-radius plots: data from the Planted Slough were from three 5-m-radius plots. Many Acer rubrum ***seedlings < 1-m tall were also present in the Planted Slough, but only planted seedlings were counted.***

	Reference Slough (n = 3)	Planted Slough	
		Interior (n = 3)	Edge (n = 3)
Nyssa biflora	317	119	17
Acer rubrum	264	-	-
Quercus laurifolia	185	34	-
Liquidambar styraciflua	158	-	-
Quercus michauxii	53	-	-
Quercus pagoda	53	-	-
Ulmus rubra	53	-	-
Fraxinus spp.	16	-	102
Quercus lyrata	-	239	136
Taxodium distichum	-	17	51
Quercus phellos	-	-	34
Total (not including *Acer* and *Liquidambar*)	677	409	340

Table 15. Soil characterization of a slough in the Ballance mitigation site and a nearby reference system. Three profiles were examined in each area. Color determined from a Munsell Soil Color Chart (Munsell 1994). N/A = not available.

Soil Profile in Forested Slough in a Reference Site			
Plot	Depth (cm)	Color (Value/Chroma)	Characteristics
1	0-9	N/A	Organic matter and root zone
	9-20+	10YR 2/2	Silt
2	0-7	N/A	Organic matter and root zone
	9-20+	10YR 2/2	Silt
3	0-7	N/A	Organic matter and root zone
	9-20+	10YR 2/2	Silt

Soil Profile in Interior of Slough in Mitigation Area			
Plot	Depth (cm)	Color (Value/Chroma)	Characteristics
1	0	N/A	No organic horizon
	> 0	10YR 4/2	Silty clay loam
2	0-1	N/A	Organic horizon
	> 1	10YR 4/1	Silty clay loam
3	0-3	N/A	Organic horizon
	> 3	10YR 4/2	Silty clay loam

Soil Profile at Edge of Slough in Mitigation Area			
Plot	Depth (cm)	Color (Value/Chroma)	Characteristics
1	0-0.5	N/A	Organic horizon
	> 0.5	10 YR 5/2	Silty clay loam
2	0	N/A	No organic horizon
	> 0	10 YR 4/1	Silty clay loam
3	0-3	N/A	Organic horizon
	> 3	10 YR 5/1	Silty clay loam, compacted

in the A-horizon of tilled soil were due to the oxidation of organic matter during agricultural production.

Hydrophytic hardwood seedlings were also planted throughout hydric flat portion of Ballance Farm. We counted surviving seedlings in five monitoring plots to determine survival (Table 16). Some discrepancies occurred between our counts and those of NCDOT. NCDOT calculated density based on the survival of stems initially planted in each plot and then assumed an initial planting density of 680 stems/acre for all plots, whereas we counted the actual number of stems in each plot without assuming an initial planting density (for plots 2,500 ft^2 in area, each stem represents 17.4 stems/acre). We couldn't apply NCDOT's method to our counts because we couldn't be certain that we had accurately matched our sampled plots with plots identified by NCDOT (plot locations weren't provided nor were they recorded in the 1998 or 1999 NCDOT annual monitoring reports).

Comparing our determinations of density with those determined previously by NCDOT is problematic where our counts of survivors did not match those earlier counts and/or where the initial density in a given plot was much lower than 680 stems/acre (equivalent to 39 stems/plot). Even so, only one of the four plots sampled (#20) showed survival at less than the 320 stems/acre required by regulatory agencies. Mean survival for all four plots was 57% for the year. However, seedlings were all < 1-m tall and some of the counted stems were barely alive (supporting only a few leaves), particularly in Plots 19 and 20.

Table 13 provides density data from eight 5-m-radius plots sampled along a transect across the wet flat. Elevations were also surveyed along this transect (Fig. 8). Assuming an initial planting density of 680 stems/acre, mean survival for the first year was approximately 71% in unscraped areas and 60% in scraped areas.

Alternative Restoration Strategies

The Ballance Farm mitigation site is a large, complex system formerly encompassing a variety of wetland subclasses. In order to restore wetlands to their former status, one would have to know the types of wetland ecosystems that originally occurred at the site and their distribution across the landscape. Alterations caused by ditching and farming make it difficult to reconstruct the original condition without historic information and data from reference sites. If site history could not be documented or reference data obtained, then mitigation plans should have explained this fact and provided rationale for establishing success criteria. However, it didn't appear that historic information was sought, and although an attempt was made to locate reference sites, reference data were not used to guide restoration or establish success criteria. In fact, the one wet hardwood flat that was ultimately chosen as a reference site (water level monitoring gauges were placed there) was inaccessible to us because NCDOT hadn't renewed its lease with the landowner. It also did not appear that any other data (e.g., on vegetation composition or structure) had been collected there for use in establishing success criteria.

Table 16. Survival of trees planted in 1998 for selected plots at Ballance Farm. All stems were < 1.0 m tall. Plot 15 was within a scraped area. DOT = NCDOT's 1999 count; B&R = Brinson's and Rheinhardt's 6/00 count. In Plot 19, 6 plants were barely alive; in Plot 20, 2 plants were only 3 inches tall. Salix sp. (willow) was probably not planted and so was not included in counts of total survival. Survival based on the initial density at planting (in 1998); negotiated success criterion was survival of 320 stems/acre after 3 years.

	Plot 19		Plot 18		Plot 15		Plot 12		Plot 20?	
	DOT	B&R	DOT	B&R	DOT	B&R	DOT	B&R	DOT	B&R
Salix sp.	0	1	0	0	0	0	0	0	0	0
Quercus lyrata	10	13	1	6	0	2	0	6	0	6
Fraxinus pennsylvatica	1	0	6	10	2	0	5	1	0	2
Quercus michauxii	0	0	10	10	9	6	3	4	4	1
Quercus phellos	0	0	3	6	8	9	9	4	3	2
Quercus pagoda	0	0	0	0	8	8	10	8	8	1
Quercus laurifolia	0	0	0	0	0	3	0	1	0	0
Nyssa aquatica	1	0	0	0	0	0	0	0	0	0
Total surviving	12	13	20	32	27	28	27	24	15	12
Number initially planted	23	23	39	39	37	37	42	42	45	45
% Survival	52.2	56.5	51.3	82.1	73.0	75.7	64.3	57.1	33.3	26.7
Surviving (# stems/acre)	355	227	349	558	496	488	437	418	227	209

Aerial photos of the site taken before its conversion to cropland would have been useful in helping determine the types of wetlands present prior to clearing. Geomorphically-similar wetland areas could also have been located for obtaining reference data. Reference data could have been used to both guide vegetation plantings and establish hydrologic standards for different subclasses of wetlands being restored on the site. For example, we located a reference site nearby for the wet swale traversing the site (it was the upgradient continuation of the on-site swale). Density and tree composition data could have been used to guide tree plantings in swales and water level monitoring gauges could have been used to establish hydrologic standards.

Resources used to construct perimeter berms, install flashboard risers, and scrape the site might have been allocated differently had success been based on quantitative data from reference wetlands. Relatively unaltered hardwood flats and sloughs could have been quantitatively sampled within a few day’s time once located (locating appropriate sites often takes longer than sampling them). An added benefit of using reference data is that once reference data are obtained for a subclass in a given area, the data can be used at other mitigation sites for restoring the same subclass. However, regulatory agencies would have to be willing to accept success criteria (standards) based on reference data. Due to wide variations in hydrology exhibited by precipitation-driven wet flats over short period, this might mean that jurisdictional criteria for hydrologic success might have to be abandoned or at least current interpretations of the relationship between hydrology and restoration success might have to be revised.

Reference data could also have been used to establish ecologically meaningful standards for tree seedling survival. Tables 10 and 11 provide composition and density data for the canopy and understory of wet hardwood flats and could have been used to help design restoration approaches. However, those data provide information on mature forests and might not be strictly applicable for establishing short-term success criteria. To develop meaningful short-term success criteria, wet hardwood flats that have been logged within the past 15 years could have been located to obtain data from a chronosequence of tree seedling survival during early seral stages. NCDOT could have then determined the density and composition of seedlings when the stature of seral stands reached a height at which the probability of seedling survival would be high (for example, 1.5 m). Such data could have been used to develop more ecologically meaningful success criterion than the uniform criterion now used: 320 stems/acre surviving after three years.

The concept of reference is not strictly applicable to created wetlands because some wetland types cannot be created. Although it should be relatively easy to create the hydrologic regime of sea-level controlled wetlands at Ballance, organic matter accumulation takes decades to centuries. Thus, the mineral soil of the created marsh had much lower organic matter content than the nearby organic-rich, fringe marshes on which the creation was based. Other wetland-types that also contain high organic matter levels (bogs, fens, etc.) can’t be created within the time frame required for compensatory mitigation under the Clean Water Act regulatory programs (National Research Council 2001).

Because the survival of plant species adapted to organic rich conditions might be very low initially at created wetland sites, such sites are susceptible to invasion by exotic species, such as *Phragmites australis*. At Ballance, *Phragmites* is poised to invade the created marsh area and preventing its invasion and subsequent domination may prove troublesome.

Suggestions for Further Work

The raised roadway (berm) may have been needed to access Ballance in the construction phase and perhaps even during the early monitoring phase. However, road access will probably not be needed once regulatory agencies certify the site’s success. Perhaps perimeter roadways could be removed for additional mitigation credit (as much as 15 acres might be available at Ballance). (In fact, it might be useful to give NCDOT some flexibility in constructing a minimal amount of roads on mitigation sites to efficiently manage the sites and then require that the roads be removed and vegetation restored after success has been assured on the site. Such areas might require considerable soil rehabilitation.) In addition, and if possible, the perimeter ditches could be filled at Ballance Farm if they are part of the property and were excavated by the original landowner. The ditches probably drain water from the eastern end of the site, but likely have little effect on the western portion of the site (nearest the creek) because Tull’s Creek is at sea level.

The mitigation plan also stated that there were berms on the western end of the property between the fringe wetlands of Tull Creek and the former agricultural fields. However, it was not clear to us if these berms were ever removed except where channel breaches were constructed. Removal of the berms should be considered if they haven’t already been removed in creating marsh channels.

Flood-tolerant trees (e.g., *Nyssa aquatica, Taxodium distichum*) could be planted along the upper edges of the created marsh. Although it is likely that both species will eventually recruit naturally, planting them would substantially reduce the time needed to establish a forest. Herbaceous plants adapted to mineral soil conditions (e.g., *Peltandra virginica, Zizania aquatica, Pontedaria cordata*) could also be introduced to the shallow, emergent habitat areas. In addition, the stand of *Phragmites australis* located adjacent to the marsh should be eradicated before it spreads further and compromises the success of the created marsh.

Further effort should be made to establish water level monitoring gauges in reference sites representing appropriate subclasses and use hydrologic data from the reference areas to define hydrologic success, rather than using current jurisdictional definitions. Of course, this would require concurrence with the regulatory agencies.

Overview of Regulatory Implications

The major problem with the Ballance Farm mitigation site was the failure to use reference data in guiding restoration and establishing success criteria (standards). As a result, ‘usual’ restoration practices of the day were employed: (1) a standard suite of hydrophytic trees were planted, including bald cypress, which is not adapted to mineral soil flats, (2) a perimeter berm and flashboard risers were installed to inhibit surface water runoff, and (3) surface soil was scraped in parts of the site to fill field ditches and lower surface elevations. The latter two geomorphic manipulations are commonly applied to mitigation sites. They have evolved in response to jurisdictional hydrologic success criteria that are inappropriately applied to wet flats, i.e., the manipulations were developed to reduce the likelihood of failing to meet hydrologic success criteria based solely on the jurisdictional definition of wetlands.

As was true for the Haws Run mitigation site, reliance on the jurisdictional criteria for wetlands (particularly regarding the definition of growing season) prevents the COE from requiring ecologically meaningful standards in the restoration of wetlands, particularly for wet flats. As a result, geomorphology is manipulated (soil excavated or berms installed) to increase the period of saturation beyond what would be normal for the subclass. In some cases where flats are excavated to assure hydrologic compliance (not at Ballance), vegetation success is low because such sites become so wet and/or soil organic content and fertility is so reduced that many planted trees fail to survive. In other words, there is probably only a very narrow set of conditions under which both the hydrologic and vegetation criteria could be met for hardwood flats. To alleviate this dilemma, either reference conditions should be used to set standards or a more ecologically relevant definition of growing season should be used.

In addition to the above-mentioned problems with hydrologic criteria being based on the jurisdictional definition of wetlands, there were no success criteria required for soils at Ballance Farm. Hydric soils were required, but this is a type of soil and does not address soil quality. In fact, the hydrologic criterion imposed for mitigation sites (particularly for wet flats) often leads to further degradation of soils by encouraging removal of the A-horizon to increase the probability of saturation for the required duration.

Another problem that seems to be common to many compensatory mitigation sites is the degree to which the availability of planting stock drives the on-ground mitigation. Often, plants that are not naturally a component of a wetland subclass being restored are substituted when the desired plant(s) cannot be obtained at the time scheduled for planting. For example, bald cypress is often substituted for pond cypress even though the two species only occur naturally in two very dissimilar wetland subclasses (bottomlands vs. wet flats, respectively). Perhaps NCDOT should consider establishing an in-house nursery to grow the most difficult-to-obtain saplings or contract with growers to grow such species before specific project needs have been identified. Allowing availability to drive planting regime is an indication of a lack of adequate planning, particularly for large, multi-project mitigation activities that are more equivalent to mitigation banks.

Blue

Location: Moore County, along the south side of Little River, south of Vass, NC and east of US Route 1.

Size: 149 acres (60 ha).

Natural History

The Blue compensatory mitigation site is a large wetland area associated with Little River, a tributary of Cape Fear River. It is located in the Sandhills Physiographic Province, an extensive area of sandy soils between the Piedmont and Coastal Plain Provinces. The mitigation site includes the floodplain of a third order portion of Little River (south side of river only), several small, first-order tributary creeks, and an expansive seepage (slope) wetland system (Fig. 9).

The low moisture holding capacity of soils in the Sandhills Region makes forests susceptible to frequent fire, particularly upland areas. Before widespread fire suppression, seepage slopes and bottomlands of river floodplains also occasionally burned, albeit less frequently that the surrounding uplands. They likely burned when upland fires spread into and through wetland areas during drought conditions. Although many sandy, seepage communities occur within the Sandhills Region, communities that still retain a natural fire regime are rare (Schafale and Weakley 1990).

The main stem of Little River is dammed (creating a reservoir) approximately 8 km (5 miles) upstream from the mitigation site, thus probably altering the natural flow regime. Most of Little River and its tributaries originate in the Sandhills Region, and hence, it would be considered a blackwater stream: low in nutrients and sediment, but high in tannins and other dissolved organics. Blackwater swamps are typically dominated by a mixture of bottomland hardwood trees, including various *Quercus* spp. (oaks), *Liquidambar styraciflua* (sweetgum), *Pinus taeda* (loblolly pine), and *Chamaecyparis thyoides* (Atlantic white cedar). *Taxodium distichum* (bald cypress) and *Nyssa biflora* (swamp blackgum) become more important with higher stream order.

Many of the unaltered seepage ecosystems in the Sandhills Region are dominated by *Chamaecyparis thyoides*. Schafale and Weakley (1990) classify seepage slopes dominated by Atlantic white cedar as Streamhead Atlantic White Cedar Forest even though not all are located at streamheads. One or more of the following species tend to co-dominate the canopy of these systems: *Nyssa biflora* (swamp blackgum), *Pinus serotina* (pond pine), *Liriodendron tulipifera* (tulip poplar), and *Acer rubrum* (red maple). A dense shrub understory, primarily dominated by ericaceous species, is also typical of Streamhead Atlantic White Cedar Forests.

Land-use History

Land-use history is not known for most of the site. The site has probably been cut one or more times since European colonization. The presence of Atlantic white cedar indicates that

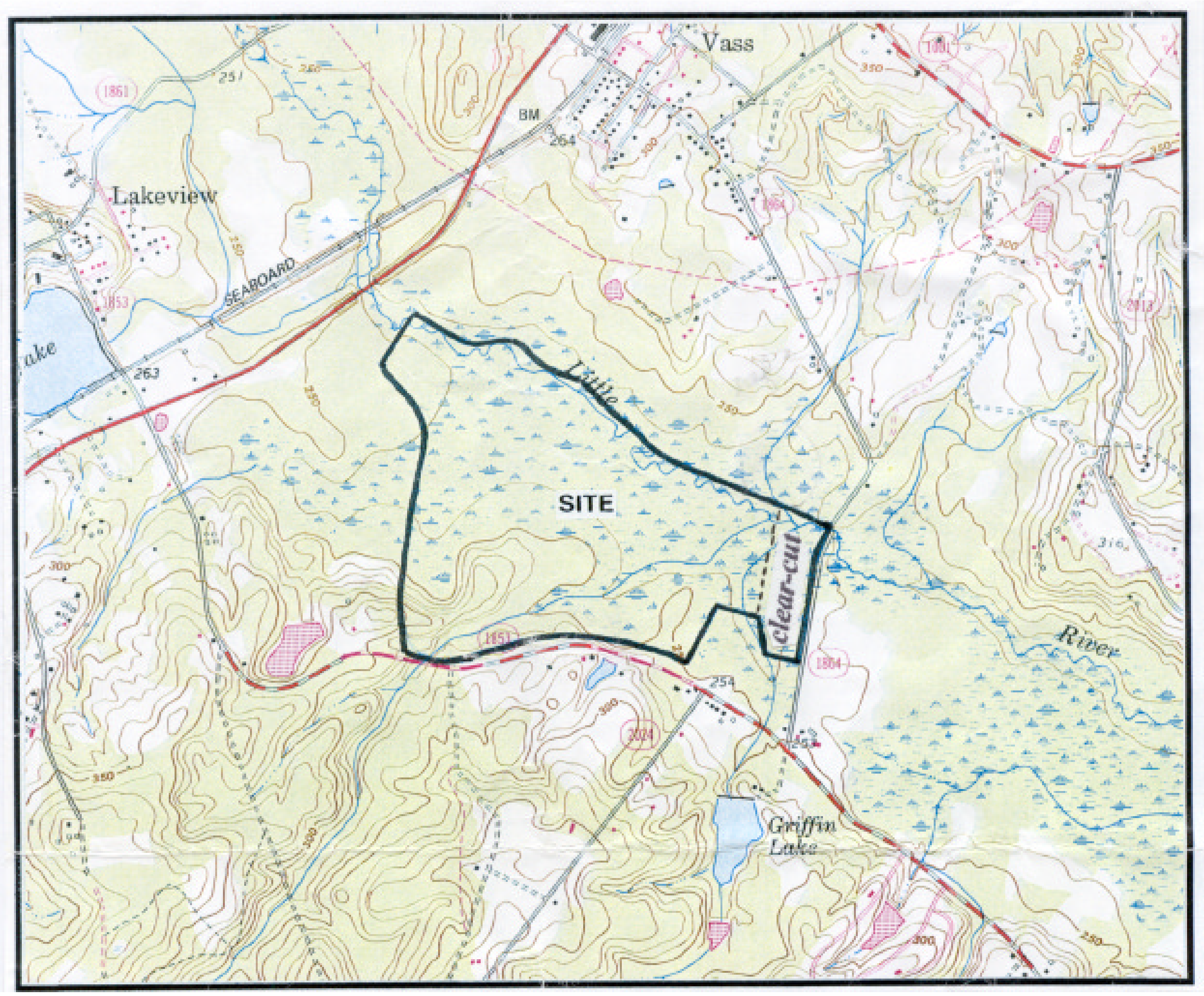

Figure 9. Location of Blue compensatory mitigation site, 1:24,000 USGS topographic quadrangle.

natural fire has likely occurred over some of the site in the recent past, particularly since Atlantic white cedar is so prevalent along the slopes.

One 8.5-ha area on the far-eastern end had been clearcut prior to our site-visit. The site location on topographic maps provided to us by NCDOT made it appear to us that the clear-cut area was a part of NCDOT's holdings, but it was subsequently determined that the area was not owned by NCDOT. Our discussion of Blue in our Phase 1 Report primarily discussed the clearcut area.

A buffer of uncut forest approximately 15-m wide was left between the clear-cut area and the southern bank of the Little River. Clear-cutting must have occurred during the wet season because deep ruts were prevalent throughout the cut-over area. A few large, hollow trees and some Atlantic white cedar had been left uncut. No replanting had occurred on the site. If available for sale, this buffer would be an excellent area for NCDOT to purchase and replant for compensatory mitigation credit.

Compensatory Mitigation History

NCDOT purchased the site in November 1998, primarily to obtain future preservation credit. It was not clear if timber rights were purchased with the property. As of July 2001, the site has been used to supply 11.0 compensatory mitigation credits for one project.

Present Condition of Site

The Blue site harbors an extensive area of relatively mature seepage forest. These seepage areas probably remain continuously wet, except perhaps following long periods of extreme drought. Soils in the seepage wetlands were high in organic matter, reflecting continuously saturated conditions.

Three locations were sampled in the seepage area to provide insight into the variation in composition (Table 17). Site S1 represents a fairly large area dominated in the canopy by *Pinus taeda* (loblolly pine), *Chamaecyparis thyoides*, *Nyssa biflora*, and *Liriodendron tulipifera*. The dense subcanopy was dominated primarily by *Ilex coreacea* and *Lyonia lucida*. This community could be classified as Streamhead Atlantic White Cedar Forest (*sensu* Schafale and Weakley 1990). The other two seepage locations (S2 and S3) were dominated by *Nyssa biflora.* In S3, *Liriodendron tulipifera* co-dominated the canopy with several *Quercus* spp. (oak) present as well. Both S2 and S3 also had a very dense subcanopy and organic-rich soil.

The floodplain portion of the Blue site was dominated by *Nyssa biflora* and *Acer rubrum* (Table 18). Very large diameter *Ilex opaca* (American holly) were also in the site, indicating past logging activity (the holly was probably not cut the last time the site was clearcut). Oaks were also prevalent, including *Quercus laurifolia* and *Q. nigra*. Some *Taxodium distichum* were present, although none occurred in sampled plots. *Fraxinus* sp. (ash), sweetgum, and red maple dominated the subcanopy.

Table 17. Absolute and relative densities of canopy and subcanopy trees for three slope wetlands at Blue. Canopy trees are stems > 15-cm dbh, subcanopy stems are < 1-m tall and < 15-cm dbh. Absolute densities of individual species provided as no. of stems/ha.

	Absolute Density (#/ha)			Relative Density (%)		
Canopy	S1	S2	S3	S1	S2	S3
Nyssa biflora	127	316	126	21.1	90.9	26.6
Chamaecyparis thyoides	127	-	-	21.1	-	-
Pinus taeda	221	-	-	36.8	-	-
Liriodendron tulipifera	95	-	127	15.8	-	26.8
Acer rubrum	32	-	32	5.3	-	6.7
Liquidambar styraciflua	-	-	63	-	-	13.3
Quercus nigra	-	-	63	-	-	13.3
Quercus laurifolia	-	-	32	-	-	6.7
Persea borbonia	-	32	-	-	9.1	-
Ilex opaca	-	-	32	-	-	6.7
Total density (stems/ha)	601	347	474			
Total density (stems/acre)	243	140	192			
Snags/ha	-	32	-			

	Absolute Density (#/ha)			Relative Density (%)		
Subcanopy	S1	S2	S3	S1	S2	S3
Ilex coreacea	127	4074	4,328	1.8	32.7	56.7
Lyonia lucida	1,655	5,347	1,528	23.2	42.9	20.0
Acer rubrum	1,146	255	509	16.1	2.0	6.7
Chamaecyparis thyoides	255	-	-	3.6	-	-
Clethra alnifolia	637	-	-	8.9	-	-
Symplocos tinctoria	764	0	509	10.7	-	6.7
Nyssa biflora	-	-	255	-	-	3.3
Liquidambar styraciflua	-	-	255	-	-	3.3
Ilex ambigua	-	255	255	-	2.0	3.3
Vaccinium corymbosum	637	0	-	8.9	-	-
Quercus laurifolia	382	0	-	5.4	-	-
Magnolia virginiana	382	1273	-	5.4	10.2	-
Ilex opaca	382	1273	-	5.4	10.2	-
Ilex glabra	255	0	-	3.6	-	-
Viburnum nudum	255	0	-	3.6	-	-
Persea borbonia	127	0	-	1.8	-	-
Cyrilla racemosa	127	-	-	1.8	-	-
Total density (stems/ha)	7,129	12,475	7,638			
Total density (stems/acre)	2,885	5,049	3,091			

Table 18. Canopy and subcanopy vegetation at three locations along the floodplain of Little River. Canopy tress were stems > 15-cm dbh, subcanopy stems were stems > 1-m tall and < 15-cm dbh. Mean canopy basal area was 34 m^2/ha (148 ft^2/acre). Absolute density of individual species provided as no. of stems/ha. N/A = not available.

	Absolute Density (#/ha)			Relative Density (%)		
Canopy	FP1	FP2	FP3	FP1	FP2	FP3
Nyssa biflora	445	159	64	63.6	31.2	10.5
Liquidambar styraciflua	32	-	32	4.5	-	5.3
Acer rubrum	95	191	127	13.6	37.5	21.1
Ilex opaca	95	127	191	13.6	25.0	31.6
Quercus nigra	-	-	64	-	-	10.5
Quercus laurifolia	32	32	127	4.5	6.2	21.1
Total density (stems/acre)	700	509	604			
Total density (stems/ha)	283	206	245			
Snags/ha	32	32	-			

	Absolute Density (#/ha)			Relative Density (%)		
Subcanopy	FP1	FP2	FP3	FP1	FP2	FP3
Fraxinus spp.	350	-	-	61.2	-	N/A
Ilex opaca	95	95	-	16.7	75.1	N/A
Liquidambar styraciflua	95	-	-	16.7	-	N/A
Acer rubrum	32	32	-	5.6	25.0	N/A
Total density (stems/ha)	572	127	-			
Total density (stems/acre)	231.6	51.5	-			

The 72-ha section of slope wetlands on the far-eastern end, which had been clearcut within 1.5 year prior to our field-visit, was also sampled before NCDOT was able to tell us that it definitely was not owned by NCDOT. Only a few scattered *Chamaecyparis* had been left uncut, but most of the remaining area had been damaged during logging. The clear-cut area had few interior forest herbs growing in it; the herb cover consisted mainly of sparsely scattered *Carex* spp., *Juncus* spp., and *Iris versicolor*. Stump sprouts were numerous and vines (primarily *Smilax* spp.) were just beginning to colonize. Soil in the cut-over area was mottled at 12" depth, indicating frequent long-term saturation, typical of slope wetlands. Deep ruts occurred throughout the cut-over area, suggesting that the area had been cut during a wet period.

We sampled woody species re-growth in the clearcut section by counting stump sprouts and tree seedlings in three 10-m radius plots (Table 19). Stump sprouts were divided into those taller and shorter than 1-m tall. Only *Acer rubrum* and *Liquidambar styraciflua* were represented as saplings (> 1-m tall). Total density of stump sprouts ranged between 350-986 stems/ha (142-399 stems/acre). All non-conifer (hardwood) trees produced stump sprouts; the only exception was *Liriodendron tulipifera*, which did not occur in any of the sampled plots. This suggests that forest recovery may progress relatively rapidly in this site, at least more rapidly than in former prior-converted cropland mitigation sites where tree seedlings are planted.

Mean density of hardwood canopy tree species regenerating (as both root sprouts and saplings) was 594 stems/ha (240 stems/acre) (Table 20). The most abundant regenerating canopy tree species was *Acer rubrum* (371 stems/ha), followed in abundance by *Liquidambar styraciflua* (96 stems/ha), *Nyssa biflora* (64 stems/ha), *Quercus laurifolia* (32 stems/ha), *Q. nigra* (21 stems/ha), and *Q. phellos* (11 stems/ha).

Alternative Restoration Strategies

The floodplain and slope wetland areas were purchased for preservation credit. This is an excellent site to preserve because it partially protects the floodplain of a low order stream. Purchase of riparian wetlands, particularly along low order streams, is a cost-effective way to maintain water quality downstream in addition to preserving on-site wetland functions.

The purchase also preserved a slope wetland dominated by *Chamaecyparis*. However, no plan had yet been developed for long-term management of the Atlantic White Cedar forest. If the clearcut area were purchased by NCDOT, planting *Chamaecyparis* could become part of the restoration strategy (Phillips et al. 1998). Data from the unlogged slope wetland could be used to determine a management/restoration strategy for the clear-cut area.

Suggestions for Further Work

Most of the Blue site was purchased to provide preservation credit for future highway projects. In addition, an adjacent 8.5 ha area had been clearcut, providing an opportunity to accelerate the restoration of functioning through purchase and active restoration. Hardwoods will likely regenerate in the clearcut without additional management, but *Chamaecyparis*

Table 19. Absolute and relative densities of stump sprouts and tree saplings in a clear-cut area near Blue compensatory mitigation site. Density of individual species provided as sprouts of stems/ha.

	Absolute Density			Relative Density		
Stump sprouts > 1-m tall	**1**	**2**	**3**	**1**	**2**	**3**
Acer rubrum	318	223	-	66.7	58.3	-
Liquidambar styraciflua	32	-	-	6.7	-	-
Nyssa biflora	-	32	95	-	8.3	100.0
Magnolia virginiana	95	64	-	20.0	16.6	-
Cyrilla racemosa	32	-	-	6.7	-	-
Ilex opaca	-	32	-	-	8.3	-
Quercus nigra	-	32	-	-	8.3	-
Total density (sprouts/ha)	477	382	95			
Total density (sprouts/acre)	193	154	39			

	Absolute Density			Relative Density		
Stump sprouts < 1-m tall	**1**	**2**	**3**	**1**	**2**	**3**
Acer rubrum	223	318	-	43.7	52.6	-
Quercus laurifolia	95	-	-	18.7	-	-
Liquidambar styraciflua	64	95	64	12.5	15.8	25.0
Quercus nigra	32	-	-	6.2	-	-
Quercus phellos	32	-	-	6.2	-	-
Nyssa biflora	-	-	64	-	-	25.0
Ilex opaca	32	95	64	6.2	15.8	25.0
Magnolia virginiana	32	95	64	6.2	15.8	25.0
Total density (sprouts/ha)	509	604	254			
Total density (sprouts/acre)	206	245	103			
Total no. of stump sprouts/ha	986	986	350			

	Absolute Density			Relative Density		
Seedlings > 1-m tall	**1**	**2**	**3**	**1**	**2**	**3**
Acer rubrum	32	-	-	100	-	-
Liquidambar styraciflua	-	-	32	-	-	100
Total density (stems/ha)	32	-	32			
Total density (stems/acre)	13	-	13			

Table 20. Mean density of stump sprouts and tree saplings in a clear-cut area near Blue compensatory mitigation site. Root sprouts (RS) provided by size class (> and< 1-m tall). Saplings all > 1-m tall.

	Mean #/acre			**Total**	**Total**
	RS > 1-m	**RS < 1-m**	**Saplings**	**(stems/ha)**	**(stems/acre)**
Acer rubrum	180	180	11	371	150
Liquidambar styraciflua	11	74	11	96	39
Nyssa biflora	42	21	-	64	26
Quercus laurifolia	-	32	-	32	13
Quercus nigra	11	11	-	21	9
Quercus phellos	-	11	-	11	4
Total tree spp. density				**594**	**240**
Ilex opaca	11	64	-	74	30
Magnolia virginiana	53	64	-	117	47
Cyrilla racemosa	11		-	11	4
Total subcanopy spp. density				**202**	**82**

regeneration would be more likely if seedlings are planted (Phillips et al. 1998). Timber rights should be purchased for the uncut area if they haven't been already.

Overview of Regulatory Implications

Wetland preservation has always been one part of the mix of options used to compensate for wetland impacts due to road construction. The number of compensatory mitigation credits accepted for preservation is usually directly related to the area of the preserved site in relation to the area altered by construction. This is usually expressed as a ratio, such as 10 acres of preserved wetland required for each wetland acre altered (i.e., 10:1 ratio). Seldom does the condition of the altered or preserved wetland affect the required ratio, although in practice, the preserved area is usually a mature, relatively unaltered ecosystem. Preservation can be particularly valuable for rare ecosystems or those in imminent danger of degradation.

Purchase and long-term preservation of floodplains and adjacent buffers of streams, particularly headwater streams, could be a particularly valuable part of a regional wetland restoration and protection strategy. Preservation of riparian zones helps maintain downstream water quality and reduces losses from flood damage. Purchasing clear-cut streamside areas (at a minimal expense) could be a potentially more successful alternative than embarking on large-scale hydrogeomorphic manipulations (a usually expensive alternative) that are prone to failure.

Planting poor-seeding species and allowing succession to run its course would be the main restoration tool for clearcut areas. One could use an HGM-type of assessment approach to determine the rate at which functions are expected to accrue through time (M.C. Rheinhardt 1996). The strategy would be to purchase sufficient large areas so that gains in functions could off-set losses within some pre-determined period (e.g., three years). Mitigation ratios would likely be high, but this could be offset by the lower cost of cut-over lands.

Regulatory policy tends to discourage preservation because it does not compensate for lost wetland area, i.e., there is a net loss of wetland acreage caused by projects that provide compensation through preservation. As a result, policy tends to favor restoration projects that manipulate geomorphology over the purchase of wetlands for preservation. Part of this perception arises from the evolution of regulatory definitions of compensatory mitigation. In the present framework, manipulations of geomorphology are considered restoration rather than creation and succession is considered preservation rather than restoration. These concepts will be discussed more fully in the Discussion.

Horsepen Creek (Bryan Boulevard)

Location: Along Horsepen Creek on north side of Byran Boulevard and east of SR 2136 in Greensboro, NC.

Size: 30 acres (12 ha).

Natural History

Horsepen Creek is a 3rd or 4th-order stream located in the Piedmont Physiographic Province, an area of hilly terrain on belted, crystalline rocks (Brown 1985). The compensatory mitigation site is located on the floodplain of Horsepen Creek on the south side of the creek (Fig. 10). A remnant secondary forest occupies the banks of Horsepen Creek. That forest is dominated by *Fraxinus* sp. (ash) and *Acer negundo* (box-elder), with various amounts of *Acer rubrum* (red maple), *Juglans nigra* (black walnut), and *Diospyros virginiana* (persimmon). This species mix is similar to those of Piedmont/Low Mountain Alluvial Forests (Schafale and Weakley 1990).

Vegetation dynamics and composition of alluvial forests are controlled in part by periodic flooding. Flooding both supplies nutrients (in deposited sediments) and creates physical disturbances (which ultimately controls plant composition). Channelization, damming, filling, and other alterations to upgradient drainage basins have altered most small alluvial river floodplains in the Piedmont. Increases in impervious surfaces have also been damaging to floodplains in suburbanizing areas of the Piedmont.

At the mitigation site, a first order tributary once entered Horsepen Creek’s floodplain on the west side and flowed toward the east where it entered Horsepen Creek proper. Wetlands were probably once associated with this tributary and with groundwater seeps along the edges of the floodplain. Few quantitative studies have been conducted on the vegetation of Piedmont streams; therefore, little information is available on reference conditions.

Land-use History

The Horsepen Creek mitigation site is located in northern Greensboro, a rapidly suburbanizing area of the Piedmont. Prior to 1951, the headwaters of Horsepen Creek were largely in pastureland and agriculture. Prior to 1972, the floodplain at the mitigation site was used as pasture and for hay production. In 1972, the eastern end of the floodplain was filled to construct a swim club. In so doing, the second order tributary flowing across the floodplain was ditched and re-routed around the swim club directly to Horsepen Creek at the western end of the site. The other section of the tributary was also channelized and routed to Horsepen Creek on the eastern end of the site.

During the 1970s, much of the catchment of Horsepen Creek began to be converted to housing developments and industrial facilities, greatly increasing the amount of impervious surface in the drainage basin. An airport was built on a large portion of its headwaters. The

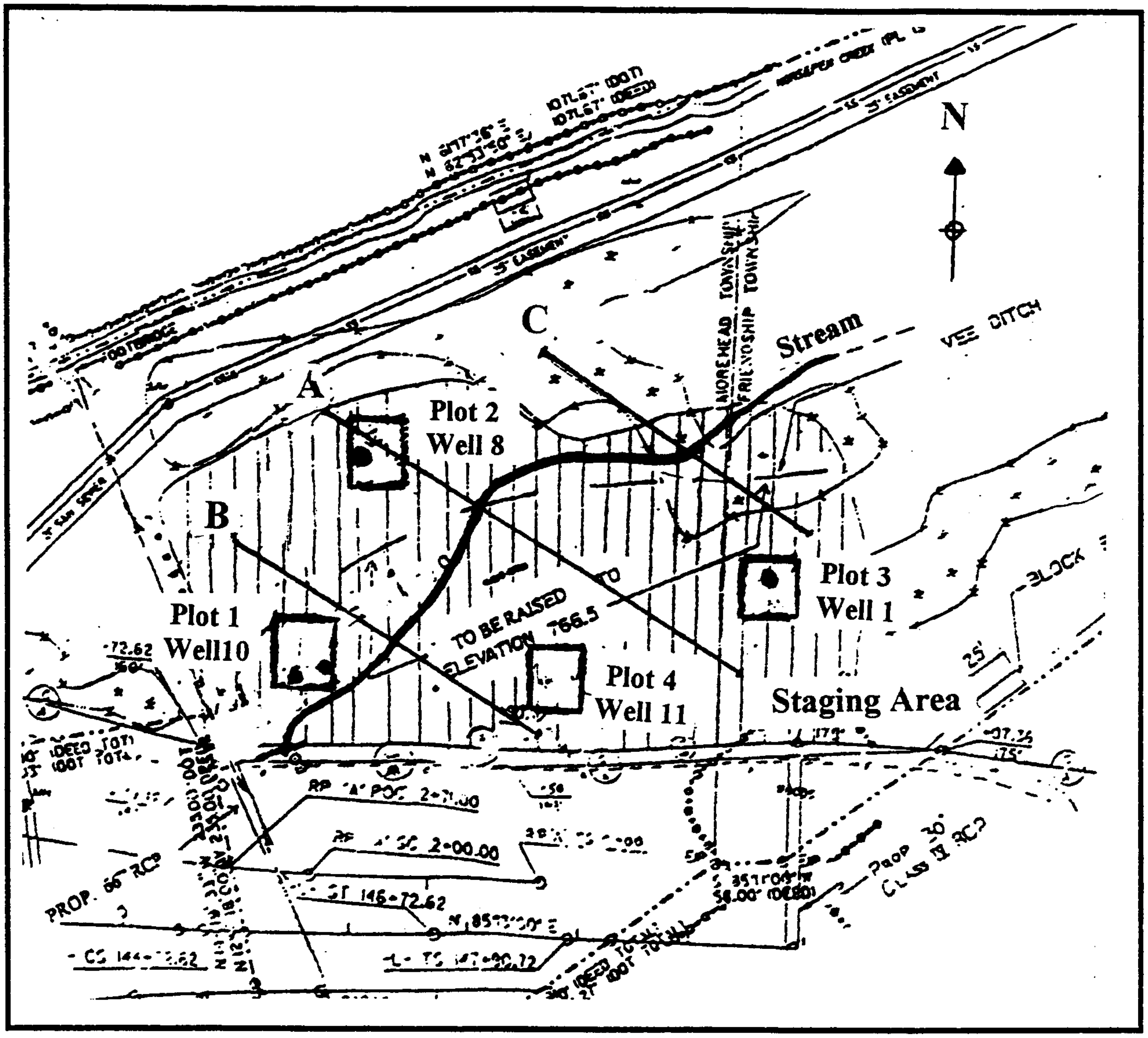

Figure 10. Approximate locations of cross-sectional profiles across Horsepen Creek floodplain with locations of vegetation monitoring plots. Scale is approximately 1:2,000.

larger proportion of impervious surface has probably made flow in Horsepen Creek flashier and may have contributed to a deepening of the channel, both of which have deleteriously affected the timing and volume of flow in Horsepen Creek.

The catchment of the tributary that once flowed through Horsepen Creek's floodplain had also been degraded. Much of it had been converted to housing developments, particularly on the southeastern end, and the stream was impounded in several places upstream. Around 1994, NCDOT built a 4-lane road (Bryan Boulevard) along the southern edge of the floodplain where the tributary Horsepen Creek once flowed.

Compensatory Mitigation History

In early 1993, NCDOT identified the Horsepen Creek site as a potential location for providing compensatory mitigation for the Bryan Boulevard extension, a bypass through northern Greensboro. Construction began in September 1994 and was completed in October 1994 (Table 21). The swim club and associated fill were removed from the site; ditches were plugged and a stream channel was constructed though the floodplain. Soon after construction, a large rainfall event flooded the site and it remained flooded with up to two feet of water for several months. NCDOT concluded that too much fill material had been removed and notified the regulatory agencies of the problem. A consensus was reached that the elevation of the site would have to be raised to prevent the flooding from killing planted trees.

During the period of construction, a housing development was built in a 40-acre drainage basin to the southeast of the site, resulting in an additional 20 acres of impervious surfaces. The developers did not adequately control erosion from the development. We observed that sediment had been washed into the eastern end of the mitigation site.

NCDOT undertook remediation for excessive flooding sometime around June 1995. Material was added to the site to raise its elevation, but some fill material used to build a ramp and a staging area (located along the southern side) was left in place at the conclusion of the remediation effort. NCDOT monitored tree survival and hydrologic regime for four years. At the end of four years, NCDOT requested that vegetation monitoring be discontinued because seedling survival in their four permanent plots were present at a density of more than 320 trees/ha (North Carolina Department of Transportation 1999a). NCDOT continued monitoring water level gauges although only one of eleven monitoring gauges (located in a geomorphically unmanipulated area of forest) failed to meet the negotiated hydrologic success criteria (based on the jurisdictional definition wetland hydrology).

Present Condition of Site

In June 2000, we established three transects across the constructed tributary (Fig. 10) to characterize the floodplain and its associated wetlands. Cross-sectional transects were established parallel to one another approximately 50 m apart. Along each transect, a meter tape was stretched across the floodplain at an orientation of 124° (perceived as being approximately perpendicular to the floodplain). At each 5-m interval along the transects, data

Table 21. Selected correspondences related to the Horsepen Creek mitigation site.

Date	From	To	Summary Description
01/20/93	NCDOT	NCDOT	Potential mitigation site was identified by NCDOT. Wetland mitigation plan was submitted.
09/12/94	N/A	N/A	Removal of fill began, herbaceous seeding completed by October 1994.
02/08/95	NCDOT	NCDOT	NCDOT found that the site was retaining 2-3 feet of water on-site (too wet).
02/13/95	NCDOT	COE	NCDOT requested an extension to raise elevation of site before planting trees (one year delay).
03/27/95	N/A	N/A	Meeting between COE and NCDOT led to an agreement to raise site elevation.
06/95?	N/A	N/A	Fill added to raise elevation, staging area fill was not removed (1.3 acres).

on elevation, vegetation, and soils were collected and together used to characterize the floodplain.

Elevations were recorded using a laser level and tied to a common benchmark. The benchmark was assigned elevation of 0.0-m and all other elevations were tied to this benchmark. The benchmark was the base of the sediment in the stream bottom where the downstream cross-section crossed the stream. This was considered to be the base of the original surface (i.e., before sediment accreted after construction). Cross-sectional profiles of the floodplain and soil characteristics were then used to provide a geomorphological description of the stream and its floodplain.

Herbaceous species were identified and their covers estimated in 1-m^2 plots located at 5-m intervals along three transect cross-sections. Cover was recorded as the following midpoint values (cover classes in parentheses): 0 (no cover), 2.5 (0-5%), 15.0 (5-25%), 37.5 (25-50%), 50 (50%), 62.5 (50-75%), 85.0 (75-95%), 97.5 (95-100%), 100 (100%). Saplings of tree species were also counted and identified in each 5-m-radius plot (centered at points located at 5-m intervals along the transect line) and densities were derived from the plot counts.

A soil pit was dug and the soil profile characterized at each 5-m point. Thickness of sediment (where present) was measured. Soil color, chroma, and hue were identified with a Munsell Color Chart (Munsell Color 1994) and recorded. Soil texture was determined in the field using a texture-by-feel analysis (Thein 1979). Planted saplings surviving in four vegetation-monitoring plots, established by NCDOT, were identified and counted. Saplings >1-m tall that had recruited naturally into the plots were also separately identified and counted. All counts were converted to densities.

The cross-sectional profile (Fig. 11) of the most upstream cross-section showed a gradual rise in the profile on the south side of the stream at between m-65 and m-70. This rise in profile, at approximately 0.9 m above our benchmark elevation, likely indicates the approximate floodplain boundary. This same elevation occurred on the north side of the stream between m-15 and m-20. Recently deposited alluvium (accreted sediment) decreased from the channel (30-cm thick) outward 10-15 m from the channel center, from m-15 to m-75 (Table 22). This indicated that the stream was carrying and reworking the sediment within this zone. Therefore, all areas of active sediment accretion (m-20 to m-65) could be assumed to be within the active floodplain. Based on our cross-sectional profile, it seemed that the floodplain began between approximately m-65 and m-70 on the south side and between m-15 and m-25 on the north side (Fig. 11).

Along the upstream transect, herbaceous vegetation changed from *Solidago*-dominated (upland) assemblages north of m-25 to *Leersia*-dominated (hydrophytic) assemblages between m-25 and m-65 (Table 23). This corresponded to the floodplain boundary inferred from the cross-sectional profile. *Leersia* sp. and *Typha* sp. co-dominated the wettest portion of the floodplain area on both sides of the stream channel, between m-45 and m-55. This near channel area was the portion of the cross-section where the thickest sediment deposition occurred. A mixture of hydrophytic and upland species dominated the transect area south of m-65 (beyond the inferred floodplain boundary).

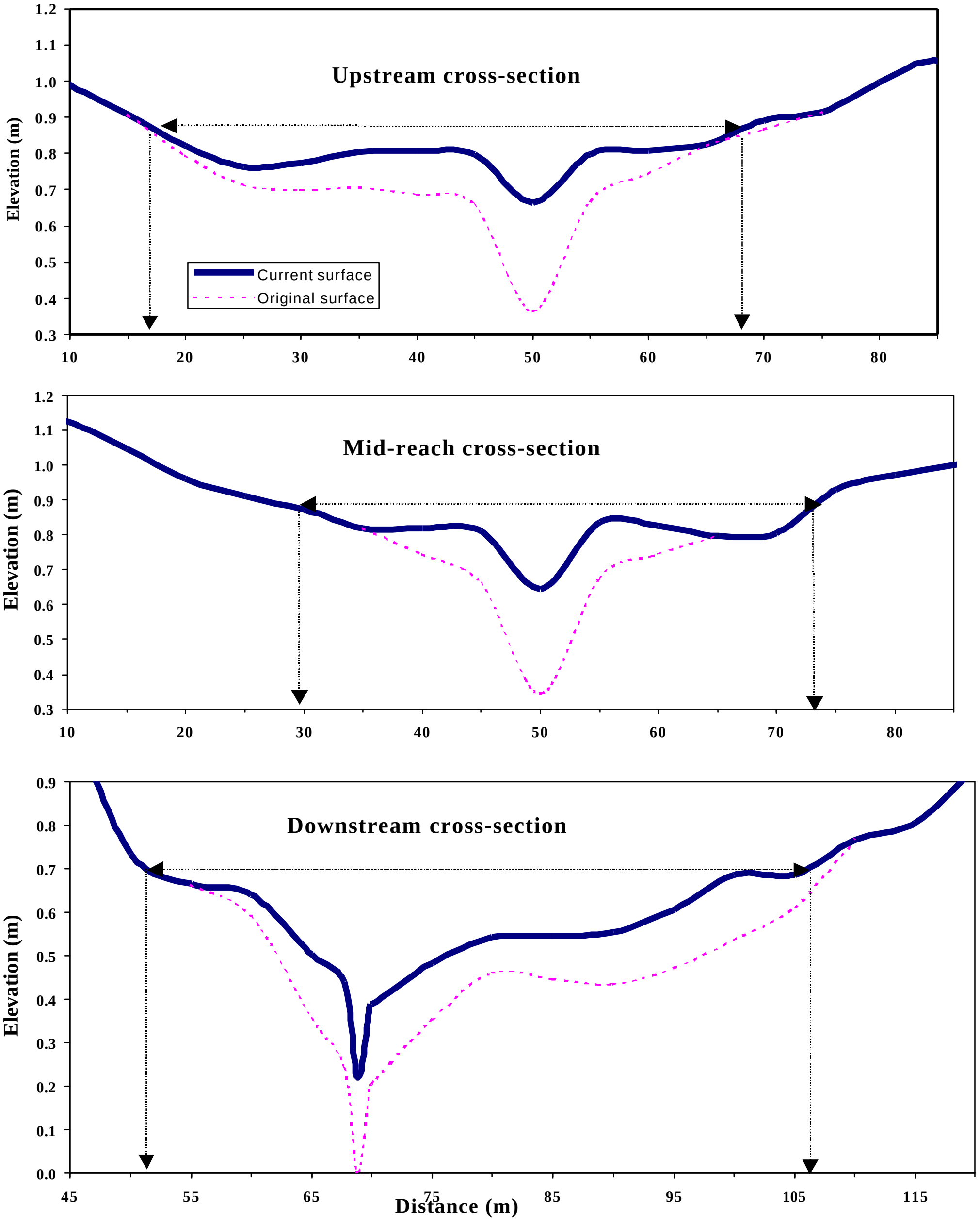

Figure 11. Cross-sectional profiles across Horsepen Creek floodplain. The upstream x-section was the western-most transect. Transects were parallel to one another and approximately 50-m apart.

__Table 22. Soil characteristics along transects at the Horsepen Creek compensatory mitigation site.__

	Distance (m)	Soil matrix (upper 10 cm)	Sediment Thickness	Soil Condition
Upstream cross-section	5	10YR 5/6	0.0	upland soil
	15	5YR 5/6	0.0	upland soil
	25	5YR 4/2	5.0	intermixed litter and silt
	35	10YR 5/4	10.0	inorganic sediment
	45	5YR 4/3	14.0	roots and silt
	50	N/A	30.0	channel center
	55	5YR 4/3	13.0	roots and silt
	65	5YR 5/6	0.5	thin layer of silt
	75	5YR 5/6	0.0	upland soil
	85	5YR 5/6	0.0	upland soil
	95	5YR 5/8	0.0	upland soil
	97.8	N/A	N/A	upland soil
Mid-reach cross-section	5	5YR 5/6	0.0	upland soil
	15	5YR 5/8	0.0	upland soil
	25	5YR 5/6	0.0	upland soil
	35	5YR 5/3	0.0	0.5 cm organic matter at surface, oxidized root channels
	45	10YR 4/2 gley 2.5/5 GY	15.0	buried root and litter in several layers, gravel at 15 cm
	50.0	N/A	30.0	channel center
	55	10YR 3/2	16.0	5 cm root mat, no gleyed layer
	65	5YR 5/6	0.0	3 cm root mat and litter, sharp demarcation
	75	5YR 5/8	0.0	compacted soil, breaks along horizontal bands
	85	5YR5/6	0.0	upland soil
	95	5YR 5/6	0.0	upland soil
	105	5YR 5/6	0.0	upland soil
	115	5YR 5/6	0.0	upland soil
	125	5YR 5/6	0.0	upland soil
Downstream cross-section	50	5YR 4/4	0.0	upland soil
	60	5YR 5/8	5.0	gley 4/5 (chart pg.1) at 15 cm
	67.7	N/A	N/A	edge of channel
	68.8	N/A	22.0	Channel center
	69.8	N/A	N/A	edge of channel
	70	5YR 4/3	18.0	
	80	5YR 5/1	8.0	
	90	4/5 G (gley chart 1)	12.0	gleyed
	100	3/10G (gley chart 1)	15.0	gleyed
	110	5YR 5/6	0.0	upland soil
	120	10YR 5/8	0.0	upland soil
	122?	N/A	N/A	

Table 23. Vegetation of the upstream-most transect along Horsepen Creek floodplain. Transect was oriented at 124 degrees. Center of the creek was located at 49.2 m. The floodplain occurred from approximately m-20 to m-70

	Upstream cross-section									
Distance (m)	**5**	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**95**
Elevation	**0.892**	**0.688**	**0.543**	**0.584**	**0.577**	**0.579**	**0.606**	**0.694**	**0.834**	**0.974**
Herbs (% cover)										
Lespedeza sp.	15.0							2.5	2.5	2.5
Poaceae sp.	37.5	85.0								
Solidago spp.	15.0	62.5						15.0	2.5	2.5
Juncus effusus			62.5		15.0	15.0	62.5		15.0	
Leersia sp.			15.0	85.0	97.5	50.0				
Carex sp.			15.0			2.5	2.5			
Impatiens capensis				15.0			2.5			
Polygonum sagittatum				2.5		15.0				
Typha sp.					15.0	15.0				
Juncus sp.	2.5							37.5		37.5
Galium sp.							2.5	15.0		2.5
Rhynchospora sp.									62.5	
Lycopus americanus										37.5
Datura stramonium		2.5							2.5	
Subcanopy counts (5-m radius)	**5**	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**95**
Acer negundo	9	7								
Fraxinus sp.	2	6	2	1			2			1
Liquidambar styraciflua								1	1	
Quercus lyrata		1							1	1
Quercus michauxii		1					1	3		
Quercus nigra								1		
Salix sp.			1	3						
Total	11	15	3	4	0	0	3	5	2	2
Density (stems/ha)	1,400	1,910	382	509	0	0	382	637	255	255
Density (stems/acre)	567	773	155	206	0	0	155	258	103	103

Sapling density was relatively high (> 560 stems/acre) in the upland area on the north side of the creek, but was much lower (< 260 stems/acre) on both the floodplain proper and on the uplands to the south of the floodplain (Table 23). The poorer survival and recruitment of woody plants on the floodplain may have been due to the very wet conditions there. Soil compaction associated with the staging area constructed on the south side of the creek may have accounted for the poor recruitment of saplings in uplands on the south side of the stream.

In the mid-reach cross-section (Fig. 11), a sharp rise was measured on the south side of the creek about m-72. Recent sediment deposition was measured within the channel (30-cm thick) and 5 m on each side of the channel (16-cm thick). The near-channel area was slightly higher in elevation than the floodplain to the north and south, suggesting that sediment deposition during high flows had formed a slight levee on each side of the channel. In extending the elevation of the highest levee outward across the floodplain, equal elevations occurred at approximately m-29 and m-73. It would therefore seem that active flooding generally occurred within this area. Wetland-soil indicators were also observed in soil profiles south of m-25 and north of m-75, corroborating the estimate of the floodplain area based on geomorphology (Table 22, Fig. 11).

Leersia sp. dominated the floodplain plots located between m-35 and m-65 (Table 24). As in the upstream cross-section, *Solidago* spp. tended to co-dominate the upland plots, particularly those at m-5 and south of m-75. As in the upstream transect, *Juncus effusus* occurred in some upland plots, particularly those closest to the outer edges of the floodplain. The soil at m-35, within the floodplain, did not have particularly low chroma, but did possess other hydric soil indicators such as surface organic matter accumulation and oxidized rhizospheres (Table 22). In relying on wetland indicators for both vegetation and soil, it appeared that the wetland boundaries occurred between m-25 and m-35 on the north side and between m-65 and m-75 on the south side. Therefore, it is reasonable to assume that the floodplain extended from approximately m-30 to m-70, again corroborating results derived from elevational profiles and soil attributes.

As was true for the upstream transect, sapling density along the mid-reach cross-section was relatively high in the upland plots on the north side of the floodplain (> 2,300 stems/acre), but was much lower in the floodplain plots (0 to 103 stems/ha) and in the uplands on the south side of the floodplain (< 520 stems/acre). Soils within the floodplain were probably saturated too long for tree seedlings to survive well, particularly on levees (no seedlings were found there). The density of saplings in plots located at the far southern end of the cross-section may have low due to compacted soil of the staging area.

The downstream cross-sectional profile (Fig. 11) was located approximately 50 m below the midreach cross-section (Fig. 10). Based on a steep rise in the cross-sectional profile on the north of the stream, it appeared that the floodplain extended from between m-50 and m-55 on the north side of the stream to between m-105 and m-110 on the south side. Recent sediment deposits occurred between m-60 and m-100 (Table 22). A low sill with a 15-cm layer of sediment deposit occurred at the edge of the floodplain on the south side, indicating that perhaps sediment eroded from the staging area to that location.

Vegetation along the downstream cross-section also indicated that the floodplain occurred at

Table 24. Vegetation of the mid-reach transect along Horsepen Creek floodplain. Transect was oriented at 124 deg. Center of creek channel was located at 50 m. The floodplain occurred approximately m-30 to m-70.

Distance (m)	**5**	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**95**	**105**	**115**	**125**
Elevation	**0.875**	**0.775**	**0.639**	**0.549**	**0.540**	**0.566**	**0.527**	**0.659**	**0.729**	**0.780**	**0.884**	**0.955**	**1.105**
Herbs (% cover)													
Andropogon virginana											15.0		
Lespedeza sp.								2.5	37.5	15.0	37.5	2.5	37.5
Poaceae sp.													37.5
Juncus effusus	15.0	37.5	37.5	2.5			62.5	37.5	15.0	15.0	2.5		
Solidago spp.	15.0							15.0	37.5	37.5	15.0	62.5	15.0
Carex spp.			15.0					2.5				2.5	
Panicum sp.			15.0	37.5									
Leersia sp.					100.0	50.0	2.5						
Juncus sp.												2.5	37.5
Rhynchospora sp.													15.0
Ambrosia artisiifolia								2.5					
Lycopus americanus							2.5						

Saplin counts (5-m radius)	**5**	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**95**	**105**	**115**	**125**
Acer negundo	15	12							1		3		
Fraxinus sp.	10	56	45					1	2	4		1	
Liquidambar styraciflua	20	2						1		1	1	1	
Liriodendron tulipifera	1												1
Pinus virginiana													
Platanus occidentalis	2									1			
Quercus lyrata	4	1						3			1	1	1
Quercus michauxii	3	1						3	2	2	5		
Quercus nigra												2	
Quercus phellos												1	1
Salix sp.		2		2									
Total	55	74	45	2	0	0	0	8	5	8	10	6	3
Density (stems/ha)	7,002	9,420	5,729	255	0	0	0	1,018	637	1,018	1,273	764	382
Density (stems/acre)	2,833	3,812	2,318	103	0	0	0	412	258	412	515	309	155

between about m-60 and m-100 (Table 25). *Leersia* sp. or *Cyperus* sp. dominated or co-dominated this portion of the cross-section, while *Juncus effusus* or *Solidago* sp. dominated the upland portion. As was true for the upstream and mid-reach cross-sections, sapling density along the downstream cross-section was highest in the upland portion (721 stems/acre) and was much lower (with an exception at m-90) in the floodplain portion. Again, low densities may have been caused by the extremely wet condition of the floodplain. Considering information on cross-sectional profile, soils, and vegetation, it appeared that the floodplain boundary occurred between approximately m-52 and m-106 (Fig. 11).

We assumed that the original surface (i.e., the constructed surface) was the base of the recently accreted sediment (dashed lines in Fig. 10). If so, then a large amount of sediment had been recently deposited. This indicates a low-energy environment, high rates of sediment delivery, or both. For sediment to have accumulated throughout the floodplain, overbank flows must have delivered sediment beyond the channel margins. In addition, the stream and floodplain may not have stabilized following construction of the system and/or it may be that sediment is still be being delivered into the reach from upstream areas of the drainage basin. Actually, both endogenous and exogenous factors may have been at work here.

Whether or not the sediment dynamics have or will soon achieve equilibrium depends upon the relationship between floodplain slope, the rate of sediment supply from upstream sources, and magnitude of high flow events. Equilibrium would be achieved once the channel develops the capacity to reach bank-full stage approximately once every 1-2 years (Leopold 1964). If a high rate of sediment continues to be delivered from upstream, one possible outcome could be movement of depositional zones further downstream into the ash forest below the created wetland. Excessive sediment rates would then cause tree mortality there. On the other hand, if sediment input from upgradient areas does not become a chronic problem, the stream channel and floodplain will eventually equilibrate and sediment deposition will slow. Once the floodplain equilibrates, woody vegetation would likely replace marsh vegetation on the floodplain.

Survival density of planted trees was higher than the negotiated success criterion of 320 stems/acre for all but one (Plot 3) of the permanently monitored plots (Table 26). However, Plot 3 had substantial recruitment of *Fraxinus* spp., a genus also planted throughout the site. All permanent plots appeared to have been established outside the floodplain and so seedling/sapling density in the plots was higher than we measured on the unplanted floodplain along our three transects (Tables 23-25).

Alternative Restoration Strategies

Overall, the Horsepen Creek site was doing quite well considering that there were initially some problems establishing desired elevations and that the site was one of the earliest compensatory mitigation sites designed by NCDOT. The floodplain was so wet that only a few of the most flood-tolerant trees had become established on the floodplain. However, the floodplain was accreting sediment and it will probably accrete enough sediment over time to

Table 25. Vegetation of the downstream transect along Horsepen Creek. The transect was oriented at 124 degrees. Center of creek was located at m-32.8. The floodplain occurred from approximately m-52 to m-106.

	Downstream cross-section							
Distance (m)	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Elevation	**0.515**	**0.422**	**0.168**	**0.322**	**0.335**	**0.467**	**0.542**	**0.714**
Herbs (% cover)								
Juncus effusus	62.5			15.0	15.0	50.0	37.5	
Typha sp.		50.0		2.5		62.5		
Leersia sp.		37.5	85.0	85.0		37.5		
Polygonum saggitatum				15.0			2.5	2.5
Eupatorium capillifolium				15.0				
Cyperus sp.					50.0			
Lespedeza sp.							15.0	62.5
Poacae							15.0	
Solidago sp.							2.5	15.0
Impatiens capensis							2.5	15.0
Galium sp.		2.5						2.5
Carex sp. 1		2.5			2.5			
Carex sp. 2				2.5				
Lycopus sp.			2.5					

Sapling counts (5-m radius)	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Fraxinus penslvanica	8	3			7		1	
Liquidambar styraciflua	3							4
Quercus phellos	1							1
Quercus michauxii	1						2	
Quercus lyrata					1	1	2	
Diosporos virginiana								2
Acer negundo	1							
Alnus serrulata							1	3
Salix sp.			2			1		3
Total	14	3	2	0	8	2	6	13
Density (stems/ha)	1,782	382	255	0	1,018	255	764	1,655
Density (stems/acre)	721	155	103	0	412	103	309	670

Table 26. Counts of tree seedlings, planted species, and recruits in plots at the Horsepen Creek site. Water-level monitoring gauges are located in permanent vegetation monitoring plots.

	Plot 1 at well #10	**Plot 2 at well #8**	**Plot 3 at well #1**	**Plot 4 at well #11**
Planted tree species				
Fraxinus pennsylvanica	11	10	5	6
Liriodendron tulipifera	1	1		2
Quercus lyrata	9	16	3	1
Quercus michauxii	9		3	9
Quercus nigra		5		2
Quercus phellos		3		2
Total	30	35	11	22
# Stems/ha	1,440	1,680	528	1,057
# Stems/acre	583	680	214	428
Recruited saplings (> 1-m tall)				
Acer negundo	4	11		5
Acer saccharinum		1		1
Fraxinus spp.	12	55	16	4
Liquidambar styraciflua		104		2
Platanus occidentalis	2			8
Salix sp.			4	4
Total	18	171	20	24
# stems/ acre	314	2,980	348	418
Total stems/acre (planted + natural recruitment)	896	3,660	562	846

support a forest, if it can become established among the *Leersia* sp. (*Leersia* may not compete as well when floodplain elevation becomes higher). In addition, sediment accretion suggests that the mitigation site is providing water quality benefits to Horsepen Creek proper, i.e., the mitigation site is a sink for sediment generated in its drainage basin.

The practice of creating and/or restoring Piedmont streams and their floodplains is a relatively new and rapidly advancing field. There are no controlled experiments or much use of reference data in stream design. Reference sites could be used to mimic existing, high quality sites in the region. Such reference sites could provide data for appropriate cross-sections, channel and floodplain slopes, sinuosity, and other geomorphic features useful for project designs.

In addition, long-term monitoring of this stream as its channel and floodplain evolve could help restoration engineers design future mitigation sites. Collecting data from cross-sections, as done in this study, would provide more information on the condition of a stream restoration than randomly placed permanent plots. Measurements through time would provide a way to monitor the development of riverine sites by providing information on the dynamics of the system. Since functions of streams and their associated wetlands are related to the unidirectional flow of water downgradient, monitoring designs must take this driving force into account. In summary, our main suggestions for an alternative mitigation strategy are to obtain reference data from high quality ecosystems and continue to study sites already constructed. Designs and success criteria should be adopted that are useful for riverine ecosystems.

Suggestions for Further Work

While water table data may be adequate for characterizing the wet flat system covered in the preceding case studies, riverine wetlands are more complex, requiring more appropriate measures of riverine wetland characteristics. Therefore, standards for evaluating riverine wetlands should differ from those used for hardwood and wet pine flats. Some useful parameters for evaluating riverine wetlands and channel characteristics include bankfull discharge, annual flow, channel cross-section, sinuosity, and floodplain width (Leopold, 1964). Although NCDOT had a series of water level monitoring gauges established throughout the Horsepen Creek site, it didn’t appear that the stream itself had been gauged. At a minimum, flow data (i.e., discharge) would have allowed NCDOT to relate stream dynamics to the condition of the Horsepen Creek site and enable it to gain information that would be useful for planning future stream restorations.

Information from both successes and failures of past restoration efforts could provide information useful for future restorations. Monitoring data could also provide useful information for establishing appropriate milestones as success criteria. The take-home message is that long-term monitoring should not solely be an exercise conducted to prove compliance with negotiated success criteria, but it should also be regarded as a way to acquire information useful for improving future restorations.

We suggest that when establishing a monitoring protocol for future riverine restoration projects, the layout of water level gauges and plots be designed to capture functioning of the ecosystem. A stream gauge would be useful and water level gauges should be established to capture the dynamics of both groundwater discharge from uplands and overbank-flow events. A monitoring approach should be developed to understand whether sediment accretion or scour is taking place and whether the stream channel is stable or moving. Rather than applying a "one-size-fits-all" monitoring strategy to all compensatory mitigation projects, monitoring should be adapted to adequately assess the condition of the specific wetland-type being monitored.

As far as we know, there are no quantitative biotic and abiotic reference data published on low order streams in the Piedmont. (Currently (2001), Water Resources Research Institute is supporting a study classifying intermittent and ephemeral streams. The results of this study may provide useful data on headwater streams in the Piedmont.) Thus, it is impossible to determine how similar or dissimilar the Horsepen Creek site was relative to unaltered low order Piedmont streams. Data from reference ecosystems could provide information critical for restoring these ecosystems. Therefore, we recommend that NCDOT and regulatory agencies obtain reference data for future restorations.

Overview of Regulatory Implications

The Horsepen Creek site was an excellent choice for initiating wetland restoration because the site had become extremely altered from previous filling of wetlands there, ditching of the floodplain, and channelization of the tributary streams traversing the floodplain. In other words, there was ample opportunity to restore functions lost or altered by prior activities. It is therefore likely that removing fill to restore geomorphology is more likely to succeed in producing functioning riverine wetlands than creating additional floodplain wetlands by excavating adjacent toe slopes.

After fill was excavated at the Horsepen Creek mitigation site, it soon became apparent that the site was too wet (several feet of water stood on it) to support riverine floodplain vegetation. NCDOT was able to rapidly assess the problem, alert the regulatory agencies, and eventually remedy most of the problem. Communication between NCDOT and regulatory agencies appears to have been open and frank, leading to a rapid response that enabled NCDOT to take remedial action by the next planting season.

Although the floodplain was still very wet, the restoration appears to be on a successful trajectory. However, it seems that the monitoring strategy negotiated for assessing site condition is probably insufficient for accurately gauging the success of the mitigation through time. Had there been problems, the monitoring strategy may not have caught them. Even if results from the monitoring program had alerted NCDOT to problems, it might not have provided sufficient information to identify a cause or suggest a solution. To alleviate potential problems in future mitigation projects, monitoring protocols should be developed that identify whether the specific wetland-type being restored is functioning as intended. This will require that monitoring protocols be more tailored to the type of wetland being restored. Then, when a mitigation site is successful, quantitative data obtained from the site could be used to derive even more appropriate monitoring protocols.

Whether successful or not, compensatory mitigation sites should be treated a valuable resource for useful information that could help improve design or monitoring protocols in the future. It is likely that past successes and failures have already helped NCDOT improve subsequent mitigation projects, but a more iterative, quantitative approach could provide more insight into potential improvements. Perhaps more input from researchers with expertise in drainage basin hydrology, fluvial geomorphology, and stream ecology would be helpful in designing and revising monitoring protocols.

Gurley

Location: Greene County, northwest of Snow Hill, along the north side of the former floodplain of lower Nahunta Creek, approximately 5 km (3.2 miles) from where Nahunta flows into Contentnea Creek.

Size: 170 acres (68 ha) of restoration on a former floodplain of a riverine wetland

Natural History

The Gurley compensatory mitigation site is located on the north side of Nahunta Swamp Creek, approximately 20 miles (30 km) downstream from its headwaters. At that location, Nahunta is at least a 5th-order stream with a floodplain width of approximately 800 m and a drainage basin of about 208 km^2 (80 $miles^2$). Probably all 5th-order streams in eastern North Carolina have been straightened and/or deeply channelized. Therefore, no unaltered 5th-order streams were available for evaluating Nahunta's condition or determine its condition prior to channelization. However, perhaps some inferences could be made based on the unaltered condition of slightly lower order (midreach) streams.

Table 27 provides data on the composition of four, unaltered midreach (3rd to 4th-order) streams in eastern North Carolina, ranging in drainage basin size from 2.5 km^2 to 10.5 km^2 (Rheinhardt et al. 1998). They all possess relatively wide (175-425 m) floodplains that tended to flood deeply and remain saturated for long periods. Bald cypress (*Taxodium distichum*) and tupelo (*Nyssa* spp.) dominate the canopy.

The 3rd and 4th-order stream channels range in cross-sectional area from 1.6 to 3.2 m^2. A relic section of Nahunta's original channel, located along on the north side of the current channelized creek, was approximately 8 m^2 in cross-section. Therefore, at the Gurley site, Nahunta Creek was quite a bit larger than the midreach sites reported in Table 27 and probably also has a floodplain a least twice as wide as any of the midreach systems studied. Therefore, Nahunta was probably as wet or possibly wetter than midreach streams. If so, then Nahunta may have once supported (prior to channelization) more *Taxodium distichum* and *Nyssa* spp. than it does today.

Former floodplains of most channelized streams fail to function as floodplains and even sometimes lose their wetland status. After channelization, wetlands on former floodplains tend to become restricted to zones of groundwater discharge along former upland boundaries and in depressions of relic channels. However, where beaver (*Castor canadensis*) succeed in damming a channelized stream, the impoundment reconnects the channelized stream with its former floodplain. Although this increases the residence time of water on the former floodplain (Vorosmarty and Sahagain 2000), fluctuations between aerobic and anaerobic conditions differ markedly from floodplains of non-channelized streams without beaver dams.

Table 27. Composition of relatively unaltered 3rd to 4th order floodplains in the North Carolina coastal plain. From Rheinhardt et al. (1998). Composition is provided as importance values (relative density plus relative basal area divided by 2). P = present in stand, but not in plots. N/A = not available.

	Big Swamp	Turkey Creek	Etheridge Swamp	Chicod Creek	Nahunta at Gurley
Watershed Area (ha)	4,211	2,510	5,921	10,620	20,000
Main Channel x-sectional area (m^2)	2.2	1.6	2.1	3.2	8.0
Strahler Order	3	3	4	4	5
Basal Area (m^2/ha)	54	52	57	48	N/A
Nyssa biflora	72.4	73.4	27.6	-	N/A
Nyssa aquatica	-	-	66.4	37.4	N/A
Taxodium distichum	2.2	21.1	0.9	2.2	N/A
Acer rubrum	13.2	1.2	-	25.0	N/A
Liquidambar styraciflua	12.1	2.1	-	11.4	N/A
Carpinus caroliniana	-	-	-	1.2	N/A
Fraxinus spp.	-	1.1	3.1	13.5	N/A
Platanus occidentalis	-	-	-	6.8	N/A
Ulmus americana	-	-	-	2.3	N/A
Quercus laurifolia	-	1.2	-	-	N/A
Ulmus rubra	P	-	1.2	-	N/A
Populus heterophylla	-	-	0.9	P	N/A

Because almost all natural predators of beaver have been eliminated in eastern North Carolina and trapping for pelts is no longer economically viable, beaver populations have exploded during the last 20 years. Beaver have now dammed almost all sections of midreach streams in eastern North Carolina, even those that have been channelized. Higher order streams are less frequently dammed by beaver because their flows are either too energetic for dam construction or their dams blow-out frequently during periods of high flow. (Instead, beaver resort to building bank dens, instead of lodges, along high order streams.)

Without overbank flow, channelized streams flow almost entirely within a narrow zone, thus potentially reducing the opportunity for beaver to successfully establish stable dams. At Gurley, Nahunta Swamp Creek is too deeply channelized for beaver to successfully maintain a dam in the channel. The only way beaver could flood Nahunta's former floodplain would be for them to dam a tributary flowing across the floodplain. In fact, a tributary flowing across Nahunta Swamp is currently dammed by beaver.

Land-use History

The Gurley compensatory mitigation site is on the north side of the former floodplain of Nahunta Creek. Based on tree growth rings of trees in a remnant channel, Nahunta Creek was probably channelized and straightened at least 30 years ago. Before channelization of Nahunta Creek, the floodplain probably flooded quite frequently. Occasional timber removal and hunting were probably the only activities that occurred in the floodplain prior to channelization. After Nahunta was channelized and the former floodplain was ditched to more thoroughly drain the site for crop production and timber removal (NCDOT 1998), the floodplain was converted to cropland. Presumably, farming was eventually abandoned because much of the floodplain still remained too wet to farm, probably a result of groundwater discharge from upland areas and depressional storage of rainwater. Agricultural production had ceased by the time NCDOT purchased the property in 1997.

Compensatory Mitigation History

The Gurley Tract was first identified as a potential compensatory mitigation site sometime prior to November 1995 (Table 28). A draft mitigation plan was submitted in January 1997 and work begun in December 1997. Vegetation was planted and water level monitoring gauges installed between January and May 1998. A study was also conducted in 1998 to locate reference ecosystems that could provide hydrologic success criteria for restoration efforts.

As part of compensatory mitigation activities at the Gurley site, NCDOT plugged ditches on the former floodplain to restrict the export of water (drainage) from the floodplain proper to Nahunta Creek. Notches were also excavated in the levee of Nahunta Creek to encourage overbank flow onto the former floodplain of Nahunta (Environmental Services 1997). The idea was that when Nahunta reached a sufficiently high stage, breaks in the levee would allow rising water to flood the former floodplain and then remain there long enough to mimic the former (natural) duration of floodplain storage. Stone rip-rap was placed at each overflow notch to

Table 28. Selected correspondences related to the Gurley compensatory mitigation site.

Date	From	To	Summary Description
08/09/95	N/A	N/A	Compensatory Mitigation Plan submitted to COE for Wilson by-pass impacts.
09/14/95	NCDOT	NCDOT	Gurley Farm tract purchased for compensatory mitigation work.
11/01/95	COE	NCDOT	COE rejects mitigation plan, requests revision and application for future projects.
08/20/96	N/A	N/A	DRAINMOD used to determine effects of ditches.
10/31/96	COE	NCDOT	COE required additional information to evaluate DRAINMOD results.
12/09/96	N/A	N/A	COE accepts DRAINMOD simulated projections for effects of removing ditches.
01/15/97	NCDOT	COE	Draft mitigation plan for Gurley site sent to COE.
02/12/97	NCDOT	COE	Revised mitigation plan submitted to COE.
04/03/97	N/A	N/A	Meeting in the field with regulatory agencies and NCDOT.
05/20/97	COE	NCDOT	COE provided comments on revised mitigation plan.
03/01/98	NCDOT	NCDOT	Search conducted to locate appropriate reference ecosystems (n=28).
03/12/98	N/A	N/A	Regulatory agencies dropped requirement that hydrologic criteria be tied to conditions in reference wetlands.
05/15/98	NCDOT	COE	Referenced installation of surface well across State Road 1058, but no data were provided in the 1999 Annual Monitoring Report.

prevent erosion when water flowed through the notches in either direction. Computer simulations suggested that the notches would allow flooding to occur at "a natural riverine-influenced flooding regime."

Originally, NCDOT intended to locate reference wetlands to provide hydrologic standards for determining hydrologic success. Although 28 potential sites were identified (North Carolina Department of Transportation 1998), apparently none were deemed suitable for use as reference. Lack of suitability may have been due to the wide degree of variation among sites examined and the fact that none of them truly represented the pre-channelization condition of Nahunta (it is unlikely that any 5th-order streams remain unchannelized in eastern North Carolina). Therefore, the hydrologic success criteria eventually adopted were based on the definition of jurisdictional wetlands: continuous saturation within 12 inches of the surface for 12.5% of the growing season (with growing season defined by the county soil survey). This is the "standard" success criteria imposed the Corps for wetland mitigation projects.

Trees were also planted on the former floodplain at the Gurley site. Planting guidelines were based on data collected from two "reference sites" and a Landscape Ecosystem Classification Procedure that predicts potential vegetation for a given area based on present vegetation, landscape position, and soils. Unfortunately, the two reference sites were inappropriate for the Nahunta site because they were lower order streams. Also, the Landscape Ecosystem Classification Procedure did not incorporate previously identified biogeographic variations among wetland-types, based on present and historic conditions, in context of the larger landscape. For example, a seepage wetland along Nahunta's former floodplain/upland border was identified as an organic precipitation flat because it had soils with a high organic content, the soils were very wet, and it did not receive overbank flow (the assumption was that precipitation was therefore the driving hydrologic force). However, true precipitation flats occur on broad inter-stream divides and not on floodplains.

Present Condition of Site

At the Gurley mitigation site, Nahunta Creek was deeply channelized prior to 1970. This estimated date was based on a count of growth rings on a > 30-year-old red maple (*Acer rubrum*) growing in a relic channel. Channelization lowered the creek bed to about 2 m below the constructed levee. This has restricted overbank flow to those associated with very rare storm events. In fact, Nahunta probably overtopped it banks only during Hurricane Floyd, after mitigation was completed.

Notches were constructed in the levees along Nahunta to allow water to occasionally breach the levee during high flows. To determine the expected frequency of overbank flooding through the notches, we determined how often Nahunta would be expected to reach the elevation of the notches based on historic discharge data compiled by USGS. (USGS has operated a gauging station (#02091000) for 30 years at the SR 1058 bridge.) We used a laser level to obtain levee elevations relative to Nahunta Creek and used the stage/discharge relationship for Nahunta to determine how often the creek reaches the stage of the notches. Elevations are provided in Fig.

12. The lowest and most downstream notch was at 57.2 ft msl, 6.95 ft. above the USGS datum (above the streambed at the bridge).

Using data from the USGS gauge and the stage-discharge curve, it appeared that the discharge required to breach the lowest notch would be 412.3 cfs (cubic feet per second). Nahunta has a discharge of 412 cfs approximately every two years, meaning that flow would be expected to flow through the lowest notch once every two years on average. This predicted flooding frequency is now a bit irrelevant, at least for one portion of the floodplain. Sometime during early 2001, beaver built a dam in 320-350 m upstream from the bridge. The dam is located on a tributary flowing across the floodplain and into Nahunta Swamp Creek. Beavers may have increased the extent of wetlands on the mitigation site, but definitely have increased the depth of flooding.

One area of the mitigation site, labeled as an organic precipitation flat in the 1997 draft mitigation plan (Environmental Services 1997), had dense willow (*Salix* spp.) throughout. Willow had sprouted profusely from stumps, some of which were 6 cm in diameter. It appeared that the willows had been cut in 1998 to plant other tree species. However, the willows had grown back quickly by 2000 and some had grown 3 to 4-m tall within 3 years, towering over the planted trees.

Alternative Restoration Strategies

Apparently, all streams of approximately the same order (5th) as Nahunta Swamp Creek at Gurley have been channelized and so no unaltered reference floodplains remain from which Nahunta's original hydrology can be reconstructed. Therefore, to restore hydrology, some assumptions had to be made concerning Nahunta's original condition. NCDOT assumed that excavating notches in the levee would be sufficient to restore overbank flow, but the complete rationale supporting this assumption was not explicit in the mitigation plan.

Notches excavated from the existing levee were, at their lowest point, designed to be 0.5 m (1.5 ft) above the relic floodplain. This was based on the observation that streams in eastern North Carolina of similar order and drainage basin size have levees about 0.5-m high. However, the streambed of Nahunta is lower than it was prior to channelization, meaning that the former floodplain is now located higher above the streambed than it was before channelization. This also means that the stage at which overbank flow would occur is now higher. As constructed, the Nahunta would have to rise to a stage of 57.2 for water to flow through the lowest notch and onto the former floodplain.

During our initial reconnaissance of Gurley, it appeared to us that the stone rip-rap placed at intervals along the levee of Nahunta were an attempt to block drainages (a creek and ditch) entering Nahunta Creek and prevent erosion of the bank rather than facilitate overbank flow. This seemed like an excellent way to increase the duration of water retention on the former floodplain and enable it to once again process water (albeit, the water would not originate from overbank flow as it did before Nahunta was channelized). However, we later learned that notches were cut in the levee to encourage overbank flow from Nahunta channel to the former floodplain

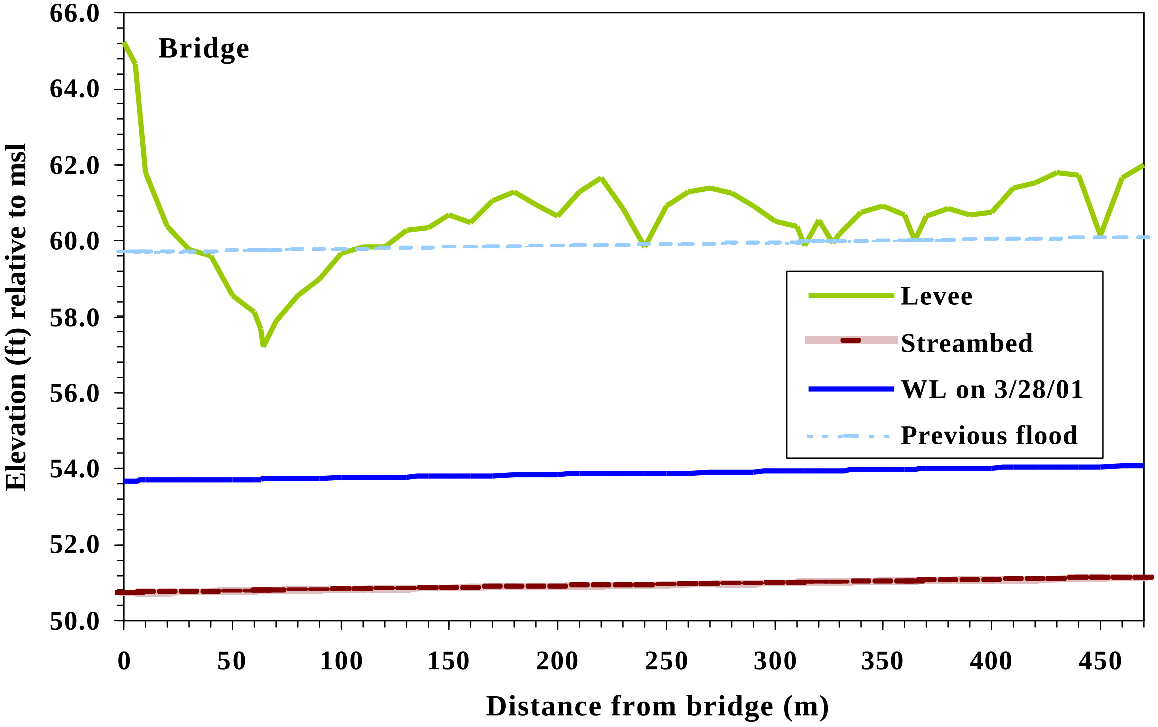

Figure 12. Surveyed elevations at Gurley of Nahunta Swamp Creek upstream from the bridge and the levee located on the north side of the creek.

during periods of high water level and that the rip rap was later placed in the notches to prevent erosion during overflow rather than back up water on the former floodplain.

Due to the large cross-sectional area of the Nahunta channel (enlarged relative to its original, natural channel), overbank flow from Nahunta would be rare. Therefore, a better way to encourage the processing of water on the former floodplain would be to construct a flow-inhibiting dam of rip-rap (or something similar at the point where water flowing across the former floodplain is discharged into Nahunta proper. If a rip-rap plug were designed to restrict surface flow, surface drainage could be slowed and water could be retained on the floodplain for longer (i.e., rip-rap would be leaky enough to allow water to flow through, but slow it sufficiently to cause flooding upstream from the structure). This would allow water on the floodplain to fluctuate in height over time and provide areas that alternate between aerobic and anaerobic conditions. This in turn would create wetlands that more closely mimic conditions in the former floodplain.

Planting guidelines at Gurley were based on the Landscape Ecosystem Classification Procedure that predicts potential vegetation for a given area based on present vegetation, landscape position, and soils. However, because hydrology had been so altered at Gurley due to the channelization of Nahunta, the Landscape Ecosystem Classification Procedure used at Gurley provided information on the kind of species that would be most successful if planted and not what would have naturally occurred there before alteration. For example, a suite of species normally associated interstream flats were planted on portions of Nahunta’s floodplain because precipitation and evapotranspiration were considered to be the main hydrologic forces now driving the hydrologic regime; i.e., overbank flooding was not expected to occur in those areas after channelization. This approach is adequate where site-capacity precludes restoration (e.g., where overbank flow cannot be restored to an area of a former floodplain). However, it should have been more explicitly stated that because there were socio-economic and other constraints prohibiting restoring overbank flow to the site, a hardwood flat was being created on what may have once been a cypress/tupelo floodplain.

In one area of Gurley, a willow forest had been cut prior to planting hardwood trees. Willow stumps had sprouted profusely, creating dense shade. Although it is unknown how the dense willow shading will affect seedling survival, a study by McLeod et al. (2001) showed that 3 of 4 species of tree seedlings planted in a willow forest survived after 3 years. For 2 of the 3 surviving species, growth rates were not impeded by the presence of the willow canopy. (The willow canopy was full-statured and had not been cut prior to planting the container-grown trees.) They therefore concluded “ willow removal is unnecessary for successful outplanting, saving time and money.”

Suggestions for Further Work

The Gurley site should be monitored closely to see how frequently overbank flooding occurs through the constructed notches and whether they restrict drainage from tributary creeks enough to cause flooding during high flow periods in the tributaries. To be effective, the bottom of the rip-rap notches would probably have to be at the same as or lower elevation than the floodplain. It is possible that the ditch plugs (along the levee) dam water on the floodplain during wet periods and that the surface water evaporates completely during drier periods.

Overview of Regulatory Implications

Most if not all 5th and higher order streams have been straightened and deeply channelized in eastern North Carolina. Except following very extreme precipitation events (e.g., Hurricane Floyd), overbank flow no longer occurs onto those floodplains. In most cases, overbank flow cannot be restored to its original condition because the adjacent creeks have been deeply channelized both upstream and downstream. Reversing this situation would not be acceptable from a socio-economic perspective. As a consequence, creative measures must be taken to regain some wetland functions to former floodplains. One way to do this would be to construct of flow-inhibitor dams on the former floodplain where tributary creeks enter the main channel.

Most 3rd order and larger streams in the coastal plain have been deeply channelized and straightened to prevent overbank flow. Because restoring the physical dimensions of such streams to restore overbank flow would be socio-economically infeasible, restoring interaction of former floodplains with water will require some other approach. We propose that one approach to encourage the processing of water on the former floodplain would be to construct a flow-inhibiting dam of rip-rap (or something similar) to impede flow from a tributary creek into a larger channelized stream. Water could be dammed during periods of high flow (thus raising water levels) and accommodate flow during periods of low flow. This would allow water to once again get processed on former floodplains of high order streams. At Gurley, beaver seem to be doing this already. Given the prevalence of beaver, their activities need to be acknowledged as a fundamental variable in riverine mitigation projects.

DISCUSSION: LESSONS LEARNED

There are approximately 50 NCDOT compensatory wetland mitigation sites currently (2001) in the ground across North Carolina and another 150 sites on the drawing board. In this Phase 2 report, five of the 50 sites were chosen to provide additional insight into the general strengths and weaknesses of NCDOT’s compensatory mitigation program and to identify where programmatic improvements could be made. However, mitigation does not occur in a vacuum; regulatory and other sociological constraints, which also often affect outcomes, are embodied in restoration strategies developed by NCDOT.

Wetland restoration is a continually evolving field. Lessons learned from successes and failures of mitigation projects should and have been used to plan and improve the outcome of subsequent projects. However, over the course of the past decade, an adversarial relationship developed between some regulatory agencies and NCDOT. As a consequence, regulatory agencies became increasingly inflexible in their requirements for success and as a result NCDOT become less innovative in what it would try. This hindered progress.

Another problem hindering restoration has been the confusing and sometimes misleading use of several mitigation terms as currently applied by the regulatory community. The term restoration is being applied only to sites where hydrology is restored to former wetlands that no longer meet the jurisdictional definition for wetland hydrology. Mitigation in altered or degraded sites that otherwise meet the jurisdictional definition of wetlands is considered enhancement. However, because enhancement receives fewer mitigation credits per unit area, there has been little incentive to return many altered wetlands to their historic, natural condition as part of compensatory mitigation. This has led to many severely altered (poorly functioning) wetlands being overlooked as potential mitigation sites and has encouraged soil excavations in wetlands (usually precipitation-driven flats) and uplands. In such cases, geomorphology is altered to create wetlands that can meet the jurisdictional definition for wetland hydrology. However, soils in such created wetlands tend to be less productive initially.

A Broader View of Restoration

Restoration and other changes in wetland ecosystems are shown in Fig. 13. Ecosystem condition is the horizontal axis, which ranges from natural (relatively unaltered, or reference standard conditions for wetlands) to altered and finally degraded at the extreme right-hand side. Natural conditions are often the unstated goal of wetland restoration, especially if reference wetlands are used as design templates. Altered ecosystems are managed for goods and services that natural ecosystems cannot provide, such as fast-growing timber and crops. Degraded ecosystems are generally unacceptable to society, and often create an economic burden by posing threats to human health and safety or by not contributing toward overall landscape productivity. Restoration is the totality of moving sites from right to left in the figure. Reclamation is a subset of restoration where degraded sites are managed toward either altered or natural conditions (Brown and Lugo 1994). (The term disturbance is not used except for natural occurrences in order to distinguish disturbance from human-induced activities, or alterations.)

The vertical axis represents changes in hydrogeomorphic state such as the conversion of uplands to wetlands or aquatic sites or wetlands to uplands (Fig. 13). Wetland creation is the process of changing uplands to wetlands, usually accomplished by removing soil to bring land elevation close to the water table elevation. Changes in state occur naturally as well. River meandering can convert upland or floodplain wetland sites to an aquatic ecosystem through cutbank erosion. Rising sea level has the effect of transforming coastal uplands to salt marshes (Brinson et al. 1995). Less extensive geomorphic changes also occur within wetlands. For example, as headward-eroding tidal creeks respond to rising sea level, irregularly flooded portions of high marshes transform into regularly flooded sites dominated by *Spartina* *alterniflora*. None of these cases is considered to be restoration. Rather, state change is the term used to describe processes that occur along the vertical axis (Fig. 13).

Wetland restoration programs seldom make the distinction between state change and restoration. This occurs in spite of the fact that the fundamental goal of most restoration projects is to improve the condition of ecosystems by managing them from a more degraded or altered condition toward one that is more natural and representative of self-sustaining wetland ecosystems. If the distinction is acceptable, then most restorations on prior converted croplands are initially state changes rather than restoration. This is shown as arrow (1) in Fig. 13, where an altered site (in row crop agriculture) is changed vertically (a state change) to a hydrologically functional wetland. An alternative interpretation is that the row crop site is really a degraded wetland and is being managed toward a natural wetland condition. However, the definition of degraded sites is "…when their edaphic conditions and/or biotic richness have been reduced by human activity to such a degree that their ability to satisfy particular uses has declined…. [and may] render the ecosystem useless to people" (Brown and Lugo 1994). Croplands producing corn and soybeans hardly fit the degraded category, and thus are considered altered for the purposes of wetland restoration programs. Consequently, the process of moving an altered upland to an altered wetland by changing hydrology is state change.

After a row crop is converted to a hydrologically functioning wetland, either natural successional processes or plantings can move the site toward more natural conditions (arrow (2) in Fig. 13). This horizontal movement is along the restoration axis. If relatively unaltered sites are used as the target of restoration, appropriate plantings can facilitate successional processes, particularly where seed sources are distant or absent from the soil. This is often the case in prior converted croplands that consist of hundreds of continuous acres at a single site. Other restoration practices, such as the introduction of large pieces of dead wood (logs, stumps, etc.) and the creation of pit-and-mound topography, would speed up other aspects of restoration that contribute to habitat structure and biogeochemical cycles. The extent to which practices are used depends upon the speed at which society wishes restoration to proceed.

The Practice of Restoration

The effectiveness of NCDOT's mitigation program could be improved if the regulatory community adopted a more flexible and scientifically-based view of restoration, like the one proposed recently by the Wetlands Concerns Committee of the Society of Wetland Scientists (Appendix A; http://www.sws.org/wetlandconcerns/restoration.html). This committee defined restoration as "actions taken in a converted or degraded natural wetland that result in the re-establishment of ecological processes, functions, and biotic/abiotic linkages and lead to a persistent, resilient system integrated within its landscape." The definition emphasizes restoration of ecosystem processes and sustainability. By incorporating this definition into the mitigation lexicon, the term "enhancement" would not be considered to be a reasonable option. Rather, mitigations currently defined as "enhancements" would be considered restoration if the manipulation restores structure and functioning to the ecosystem; a manipulation that increased certain functions (usually at the expense of other functions) would not be considered restoration

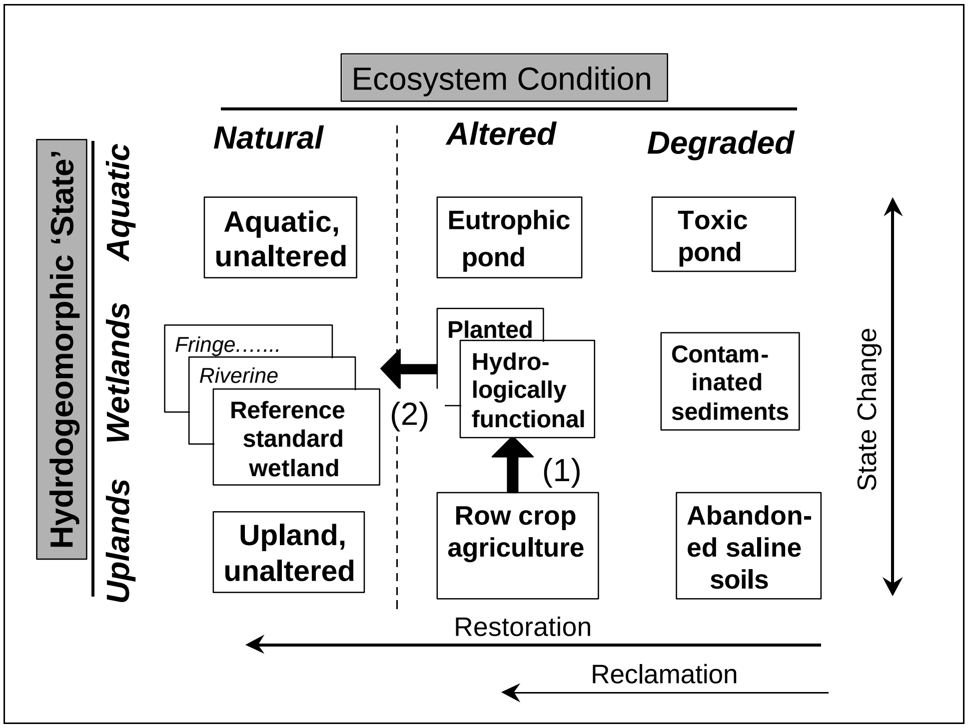

Figure 13. The distinction between restoration and state change. Restoration represents processes that move ecosystems of any type from a degraded or altered condition to the left. Strictly vertical movements are considered state change, and do not necessarily reflect a change in condition. Many wetland restoration projects initially change a former wetland (or upland) to an altered wetland, or from the bottom center box to the center box (arrow 1) as in the case of restoring prior converted croplands. Restoration requires moving sites from the right to the left, e.g., arrow (2).

and thus could be discouraged. Further, a restoration could be judged by how much it improved a function or set of functions relative to a set of standards.

There has been a lot of progress in developing approaches for determining standards (e.g., HGM approach) and some standards, based on the condition of natural, unaltered wetlands, are now available for specific regional subclasses of wetlands (e.g., mineral soil Wet Pine Flats). Heretofore, standards (success criteria) for NCDOT mitigations have not been based on conditions measured in reference sites. More often than not, the same or similar set of rather arbitrary standards have been required for a wide variety of wetland types, e.g., density requirements for trees and jurisdictionally-based hydrologic requirements. Sometimes these requirements have been antithetical to one another (e.g., making flats too wet for trees to grow well). Setting standards based on conditions in reference wetlands would improve the chance of reaching ecologically successful outcomes.

One drawback to basing the effectiveness of restoration on a set of standards from reference sites is that there are no reference standards available for many wetland subclasses. So what could be done in cases where there are no reference standards available? One alternative would be to acquire reference data on a project-by-project basis. Although for a single project it might not be feasible to acquire reference data that incorporates all the variation inherent in the subclass, some data would be better than no data at all. In such cases, an allowance for a wider margin of error would be necessary where few reference sites are used. However, as additional reference data are accumulated through time in conjunction with additional restoration projects, progressively more useful standards could be developed over time. As long as NCDOT continues to build roads, it is inevitable that NCDOT will continue to impact many of the same wetland subclasses in the future. Reference data developed for one project could be used for future projects as well.

Often, NCDOT compensatory mitigation plans state that reference data would be used. However, in most cases, reference data were not obtained and in other cases where reference data were collected, they were not used (e.g., Ballance). This may be because personnel are not quite sure what constitutes appropriate reference sites, what data to collect, or how to use the data once collected. Therefore, establishing protocols for identifying appropriate reference sites and collecting data from those sites might encourage more use of reference for planning and conducting compensatory mitigation. Below, we outline some steps that we feel would be helpful in this regard.

Acquiring and Using Reference Wetland Data

The first step in locating reference wetlands is to accurately identify the appropriate subclass of wetlands for which reference data are required. This is probably the most difficult step, but also the most important one because everything that follows is based on choosing the appropriate sites. Identification of the appropriate subclass should be based on the natural, historic condition of the mitigation site. Its historic geomorphology, vegetation at maturity, and hydrologic regime should be used to determine its wetland class. Historic records, published data, remnant vegetation, and nearby unaltered sites in the same geomorphic setting would be useful in determining the historic condition.

In most cases, the wetland subclass that originally occurred at a mitigation site would be the subclass that should be restored, if at all practical. This default is based on the notion that restoring to the same wetland type and geomorphic setting will be more sustainable than alternative pathways. Exceptions would be cases where site potential would preclude restoration or where wetlands never existed (e.g., a stormwater detention basin). An example of the former case is Gurley, where restoration of a floodplain forest is not feasible because overbank flow can not be restored (for socioeconomic reasons) to its original return frequency. This does not mean that wetland functions can’t be created in areas where site potential precludes restoration; it only means that stakeholders must be willing to accept that the mitigation site will likely never truly represent a natural ecosystem and may require some degree of long-term maintenance. Partially restoring or creating selected functions in such cases might, however, be desirable in landscapes where a subclass that once provided important functions has been largely eliminated and true restoration of the subclass would be untenable from a socioeconomic perspective.

After the appropriate subclass has been identified, differences in condition or attributes between a mitigation site and reference sites could be determined. This would provide supporting data for determining appropriate mitigation credit, developing reasonable success criteria, and even designing restorations. Reference sites that are in the early stages of succession (ones without hydrologic or soil alterations) could be used to set reasonable performance standards for goals to reach within 3-5 years. As indicated above, reference data could also contribute to the build-up of a more complete reference data set over time. Information obtained from long-term reference sites could be used for additional projects within a region and wetland subclass.

The identification of subclasses and reference sites would be aided by first developing an inventory of wetland-types most likely to be impacted in North Carolina, and possibly, a key for identifying them in the field. For each subclass, a narrative could be developed to provide information on what is known about its ecology (vegetation, hydrology, soils, biogeochemistry, and successional attributes) and current or future threats to the subclass. Information could be obtained from historic records, published data, and the North Carolina Natural Heritage Program inventories. Information from hydrogeomorphic (HGM) guidebooks (e.g., Ainslie et al. 1999 for riverine wetlands, Rheinhardt et al. In press for mineral wet pine flats) could be used to provide a foundation for developing a classification, but further sub-classification would likely be necessary.

Standards for Soil

Another problem with success criteria as currently promulgated is that there are no standards for soil condition. Sometimes only the presence of hydric soils are required for certifying success, but this is a morphological attribute for soil-type and does not address soil quality. In fact, the hydrologic criterion imposed for mitigation sites often leads to further alteration of soils by encouraging removal of the A-horizon to increase the probability of soil saturation in the surface horizon. However, a study by Streever (1999) that examined performance standards of compensatory wetland mitigations nationwide found that no performance standards were required for soils.

A study in Virginia comparing soil properties between constructed wetlands, where the A-horizon was removed, and natural wetlands with intact A-horizons, showed that their soils differed significantly in a number of important parameters: degree of microrelief, soil particle size with depth, percent of clay and silt, organic carbon and nitrogen content, and cation exchange capacity (Stolt et al. 2000, Stolt et al. 2001). Therefore, if soil quality standards were developed using soils in reference wetlands, removal of the A-horizon would not be an option, except for creating wetlands. (Excavation of fill to restore a site would not be discouraged by enacting soil standards if the original A-horizon still existed.)

If soil standards were utilized, then what kinds of standards would be appropriate? Reference wetlands would ultimately be needed to provide the necessary information for developing standards, but parameters such as organic matter content, absence of indicators of compaction, friability, bulk density, root mat thickness, etc. would be useful for contrasting altered with unaltered or restored soils.

Standards for Vegetation

Tree seedlings in vegetation-monitoring plots were difficult to locate, and once located, many did not have any identifying labels. This made it difficult for us to compare our stem counts with those provided in NCDOT annual monitoring reports. This was particularly critical because survival was used by NCDOT to calculate density. A lack of detailed maps with plot locations and descriptions also made it difficult evaluate the effectiveness of mitigation at sites.

As currently designed, tree seedling monitoring plots are 50-ft x 50-ft squares placed in a stratified random manner throughout a mitigation site. Soon after trees are planted, NCDOT counts the number of seedlings in the plots, and although all plots are the same size, the initial counts may vary widely depending on the exact position of each plot. This is because seedlings are somewhat uniformly spaced along rows when planted and so any given plot may have more or fewer rows within the plot boundaries, depending on exactly where the plot is established. The procedure also assumes that the density of seedlings actually planted in a site matched the density proposed for planting. However, we did not see any documentation showing whether the required density of seedlings was indeed planted.

A 2,500-ft^2 (50’x 50’) plot would be expected to contain 39 stems if planted at 680 stems/acre. If two sides of a square plot run parallel to the rows, the plot could actually contain more or less than 39 stems (sometimes as much as 40% more or less). For plots in which fewer seedlings are planted initially, the death of any given plant represents a higher rate of mortality than does the death of a seedling in a plot with more stems planted initially. For example, assuming 680 seedlings/acre are planted, then a plot that starts with 23 stems can lose no more than 12 stems before the surviving density falls below 320 stems/acre (11/23 x 680 = 325).

However, a plot that has 45 seedlings initially can lose as many as 23 stems before the surviving density falls below 320 stems/acre (22/45 x 680 = 332). This means that it is not only important to keep track of how many seedlings are initially planted in a plot, but to recognize that that some plots have smaller populations from which to determine survivorship.

Potential discrepancies in percent survival could be alleviated by changing the way monitoring plots are established. One improvement would to orient square plots at 45 degrees to the direction in which seedlings are planted. A better method would be to establish circular monitoring plots, thus eliminating an edge-effect and the need to orient plots. Circular plots are also much easier and faster to establish and sample (if not too large), meaning that more, but smaller plots could be established. Only the center point would have to be marked and a rope or tape of fixed length could be rotated about the center point as stems are counted. A radius of 5-7 m (15-23 ft) would be an efficient size for counting seedlings and even larger saplings. In fact, circular plots have been shown to be the most efficient means for sapling forest vegetation (Lindsey et. al 1958, Levy and Walker 1971). The use of circular plots would also be efficient for verifying initial planting densities.

The above discussion involved how standards are currently measured by NCDOT. However, reference sites are rarely used to develop standards. Reference sites could be used in at least two ways. First, data on the composition of relatively unaltered sites from a given subclass could be used to determine what species to plant and in generally what proportions. Second, information from early successional sites could perhaps be used to establish short-term success criteria (3-5 years). It would be reasonable to assume that a restoration would stand a good chance of being successful if it were similar in composition and stature to natural, early successional sites of the same subclass. Meeting standards based on the condition of such reference sites would also probably be a more realistic (and perhaps less expensive) goal than meeting relatively arbitrary success criteria not based on reference conditions. Finally, the 3-5 year window for evaluating restoration projects *may be* appropriate for herbaceous wetlands, but not forested ones. This time frame is entirely a construct of administrative convenience, and has no proven ecological basis. This is another case of uniform standards being forced to accommodate a broad variety of unlike wetland types.

Standards for Hydrologic Regime

Even when appropriate reference ecosystems are located, regulatory constraints have hindered their use. For example, some mineral soil wet flats (both pine and hardwood) may not meet the jurisdictional definition for hydrology used by the Corps, even when they clearly have hydric soils. The problem is that the jurisdictional definition relies upon the definition of the growing season provided in NRCS soil surveys, which were developed for growth requirements of agricultural crops rather than conditions required for wetland plants. In the Southeastern US, biological activity in wetland soils occurs throughout most of the year in most years. This is why hydric soil indicators and hydrophytic plant species occur in some wetlands (particularly flats) that do not meet the jurisdictional definition of wetland hydrology.

The failure of the jurisdictional definition to adequately define wetland hydrology means that in some wetland-types, particularly wet flats, appropriate reference sites fail to meet the jurisdictional definition. This has led to the excavation of the A-horizon at some compensatory mitigation sites to bring the soil surface closer to the water table and the consequent degradation of soil structure that had taken many years to form (e.g., Tucker, Cox Farm, Mud Creek (Rheinhardt and Brinson 2000)). Where the objective was to restore a mineral soil wetland flat, soil excavation made the sites too wet reduced soil fertility too much to support the subclass.

Attempts to adhere to the jurisdictional wetland criterion have also encouraged the construction of perimeter berms to impede (dam) surface flows from a mitigation site and placement of flashboard risers to manipulate water levels (e.g., Ballance). Wetlands created by such manipulations to geomorphology often fail to resemble anything found in the natural world and some may require long-term manipulation to maintain wetland status. In addition, long-term management is antithetical to the hands-off philosophy that often guides regulatory agencies.

The above-described problems require innovative solutions. One solution would be for regulatory agencies to allow hydrologic conditions in appropriate and agreed-upon reference wetlands to provide hydrologic success criteria regardless of whether they meet the currently interpreted jurisdictional definition for hydrology. Hydrologic success could be defined as the hydrologic regime of the restored wetland following the pattern defined by the reference wetland (with some error allowed). Additional research will be needed to determine differences between the effects of evapotranspiration within natural forested vs. early-successional systems. In the short-term, perhaps early successional forested wetlands would have to provide the reference data for restoration sites. This would require some flexibility on the part of the regulatory community.

Restoration Opportunities

Although using reference conditions for guiding restoration and setting acceptance criteria have been hindered by jurisdictional constraints, it was encouraging to see fire recognized as an important attribute of some wetland ecosystems (e.g., Haws Run). The southeastern coastal plain of North Carolina is full of opportunities to restore fire-maintained ecosystems. The wetland regulatory community also appears to recognize that a long-term program of prescribed burning is required to restore functions to Wet Pine Flats. Perhaps this will translate into providing more value (credit) to restoring fire-maintained ecosystems.

All or almost all mid-reach streams (3rd and 4th order) in eastern North Carolina have been deeply channelized and straightened, thus preventing overbank flow from occurring on former floodplains. Although there are currently no socioeconomic incentives for restoring such floodplains, there are ample opportunities for them to be rehabilitated (by creating wetlands) in ways that could provide some of their former functions. One alternative would be to redirect ditches or tributary streams so that they flow through the former floodplain before discharging into the main channel. This strategy would be particularly productive where roadside ditches flow across a former floodplain directly into a channel.

Another alternative would be to dam ditches and tributaries at the point where they discharge into the channelized stream, and in so doing, spread water across its former floodplain. (At Nahunta, beaver have built an impoundment on one such tributary channel.) Dams would be especially productive if they were designed to slow flow rather than prevent flow (e.g., a rip-rap design might allow water to back up water during periods of high flow). This would allow impounded water to fluctuate in height and create wetlands that alternate between oxic and anoxic conditions.

A third alternative would be to excavate notches in levees along streams (as was done at Gurley) to allow overbank flow at high stages. However, this strategy would only be productive if the stage frequently rises to a height that is above the former floodplain. For many deeply channelized streams, this situation may seldom occur.

There are also opportunities for restoring functions to headwater (1st and 2nd order) streams. In rural eastern North Carolina, roadside ditches make substantial contributions to the water budget and nutrient load of streams located downgradient from roads. Ditches from agricultural fields shunt water directly into roadside ditches and ditches shunt the water directly to streams with little opportunity for removing nutrients or contaminants. Small detention swales with wetland plants designed to intercept water from roadside ditches before entering streams could improve water quality and restore more normal hydrologic regime to headwater streams.

Water quality could also be improved by protecting low order streams and their buffers, particularly in agricultural drainage basins. More incentives should be provided by wetland regulatory agencies for streamside buffer protection through restoration and preservation. Upland buffers are an important component of functioning in riparian systems and so mitigation credit should be provided to encourage more protection of buffer zones.

Peer Review and Research

A limited amount of information can be gained from a three-to-five-year monitoring program that focuses exclusively on whether a site is meeting negotiated success criteria. Longer-term monitoring and research of mitigation sites should be a more integral part of NCDOT's mitigation program. Research could focus on collecting reference data for projects and designing experiments to develop techniques (planting regimes, construction techniques, etc.) that would be both successful in restoring sustainable ecosystems and economical to implement. However, such an integrated research program would require flexibility and support from the regulatory community. That is, the regulatory community would have to allow and provide credit for portions of projects that are experimentally manipulated in ways that might not meet success criteria as currently defined. At the same time, both NCDOT and the regulatory community should become more open and flexible in incorporating advances in restoration science in a timely manner.

In addition, follow-up studies on compensatory mitigation sites should be conducted by outside experts at least once every five years. Studies should be conducted in at least the same level of detail as this Phase 2 study. The review should be designed to provide NCDOT an overview of how their mitigation practices compare with the current state of restoration science and provide suggestions for improvement.

A recent study conducted by the National Research Council (2001) examined the overall effectiveness of compensatory mitigation programs nationwide. Many of the problems we observed in the NCDOT program are common throughout the nation. For example, data required for determining the status of compensatory mitigation projects were generally inadequate to determine if the goal of no-net-loss was being met, proper attention to hydrogeomorphology was lacking, and performance expectations for compliance were unclear and/or inappropriate. Clearly, sufficiently detailed studies of past mitigation approaches will help improve future compensatory wetland mitigations.

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APPENDIX

Society of Wetland Scientists
DRAFT
Position Paper on the Definition of Wetland Restoration

The Society's objective is to increase public understanding of wetland issues and to promote sound public policy through the development and communication of position papers that are based upon the best available scientific information.

POSITION STATEMENT:
Wetland Restoration is defined as: action taken in a converted or degraded natural wetland that result in the reestablishment of ecological processes, functions, and biotic/abiotic linkages and lead to a persistent, resilient system integrated within its landscape.

SCALE OF ISSUE: International

BACKGROUND:
In the last part of the Twentieth Century, a significant amount of money and time was dedicated to re-instating more natural conditions in a variety of ecosystems. Despite an overwhelming sense that such action is critical to the well-being and recovery of many systems, the word 'restoration' is used very loosely in most scientific and political arenas. As the science of restoration is young and we are still learning how it should be applied, the need for a clear definition is critical to identify the framework within which advances will be made.

STATEMENT OF ISSUE:
As a professional organization for many of the scientists currently involved in restoration, it is appropriate for the Society of Wetland Scientists (SWS) to provide guidance as to the meaning of the term "wetland restoration." Current ambiguity in the use of this word has led to a broad range of projects being funded and endorsed under its umbrella. In addition, it has led to difficulty in the communication of ideas within and among academia, the private sector, regulatory agencies, lawmakers, and the public. The advancement of any field depends on clarity and consistency in the use of key terms. A clear, practical definition of restoration is needed to develop a common understanding between all those working toward the restoration of ecosystems.

SCIENTIFIC CONSIDERATIONS:
Many definitions of restoration have been written over the past decade or so. Most indicate that restoration in some way repairs anthropogenic damage to a natural system (Lewis 1989, National Research Council 1992, Jackson et al. 1995, Gersib 1997, Kauffman et al. 1997). The discrepancy between these different definitions lies in the details of what is repaired and the final condition to which it is repaired. Over the past decade, both our scientific and practical understanding of ecological restoration and the number of projects implemented have grown dramatically. In this time, our concept of restoration has evolved to the point that now, in writing a definition, there are a few key elements that need to be conveyed in order to define the term adequately and usefully.

1. Restoration is the reinstatement of driving ecological processes. The fundamental forces that maintain wetland ecosystems are the geomorphic setting, physical processes (e.g., hydrology, fire, sediment movement), biological processes (e.g., competition, decomposition, predation), and biogeochemical processes (e.g., nutrient cycling). These fundamental forces interact to perform the ecological functions and produce the structure that we associate with wetlands. As actively installing the biotic structure of a system may not always be necessary (Mitsch et al. 1998) or adequate to restore the functions of the system (Zedler 1996, Malakoff 1998), restoration needs to address these root forces first. The National Research Council (1992) eloquently summarized this in their approach to restoration of fluvial systems, which favors establishment of the natural sediment and water regime of a river followed by engineering of the natural geometry of the system only if restoring the sediment and water regime alone does not take care of this, and finally introduction of the biotic community only if the previous efforts do not lead to its establishment.

2. Restoration must be integrated with the surrounding landscape. Successful restoration demands that consideration be given to the landscape setting in which the system occurs. It is this landscape that underlies many of the large-scale factors and fundamental forces (e.g., water and sediment movement, geomorphology, fire regimes) that are essential to the formation and long-term maintenance of ecosystems (Brinson 1993, Bedford 1996). Restoration projects that address the effects of alterations that have occurred within the landscape as a result of human development can deal directly with the causes of degradation rather than just the symptoms. As understanding of landscape ecology and its importance to restoration develops, it becomes increasingly clear that the integration of restoration projects with the landscape context is essential to producing ecosystems that function in a dynamic and resilient manner.

3. The goal of wetland restoration is a persistent, resilient system. The concept of a persistent, resilient system is gaining definition through the development of the field of ecological engineering, where a primary objective of designing and building ecosystems is to produce a system that is not static but rather has enough of the physical and biological processes intact that it can respond to disturbances without human intervention (Mitsch 1998). The practical realities of conducting restoration in the modern world often necessitate human involvement to maintain an ecosystem (e.g., prescribed burning or the removal of non-native species). In addition, implementation of adaptive management as we learn how to better conduct restoration requires active management and monitoring of a site. Acknowledging these caveats and limitations in the pursuit of a wholly persistent, resilient system, the ultimate goal of restoration should be a system that is dynamic and that can function without human intervention.

4. Wetland restoration should result in the historic type of wetland but may not always result in the historic biological community and structure. The importance of maintaining the historic diversity of wetlands across a landscape requires that the geomorphology and hydrologic regime of a restored wetland match that present historically. However, this will not always lead to re-instatement of a historic or specific biological structure. While the essence of wetland restoration is ‘putting it back to a former or original state’, a variety of factors (e.g., successional stage, seed bank conditions, disturbance history, etc.) may prevent establishment of the communities and biological structure present prior to human disturbance even when the driving processes have been restored.

5. Restoration planning should include the development of structural and functional objectives and performance standards for measuring achievement of the objectives. This is the foundation of adaptive management. It is critical that we learn from our successes and failures, particularly in the relatively new field of wetland restoration.

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Drafted by Jennifer Brown; reviewed by Kevin Erwin, Mary Kentula, Beth Middleton, Eliska Rejmankova, and Curtis Tanner.