An Evaluation of the Effectiveness of Existing North Carolina Department of Transportation Wetland Mitigation Sites

Phase 1 Report

Prepared for

North Carolina Department of Transportation
and
North Carolina State University on Behalf of the Institute for Transportation Research and Education

by

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16. Abstract

In this study, 49 NCDOT wetland compensatory mitigation sites and 11 reference sites were evaluated on-site in 1999. Seventeen of the larger sites consisted of more than one type of mitigation (restoration, creation and/or preservation). In total, 71 mitigation parcels (approx. 3,000 acres) were evaluated to assess the likelihood that mitigation sites would achieve some level of structure and functioning similar to natural, self-sustaining wetland ecosystems and to provide recommendations for improvements. Ecological success was related to whether or not natural geomorphology had been successfully restored. Sites from which fill was removed were generally successful. Sites in which water impediment structures were constructed showed mixed results for vegetation survival, presumably because it was difficult to determine how wet to make a site. Wetland creations were generally unsuccessful because most all involved excavating soil to reach the underlying saturated zone, thus inhibiting growth of vegetation on sub-soils. Predictions of success were difficult due to the immaturity of sites, but it appeared that many created wetlands would not likely resemble historic, natural ecosystems. Of the 71 compensatory mitigations examined, 26 were judged to be ecologically successful, 19 were preservation sites (automatically judged to be successful), 9 were judged to be unsuccessful, 10 lacked sufficient data (mostly hydrologic data) for judging success, 4 sites were too young to predict the outcome for vegetation survival, and 3 were undergoing construction at the time of our site visit. Alteration of and failure to restore natural geomorphology in compensatory mitigation sites was the major factor associated with the lack of mitigation success, regardless of whether success was defined by permit success criteria or by ecological success. More use of information from reference sites could improve outcomes. Compensatory wetland mitigation involving restoration and creation appears to have gravitated toward relatively narrow sets of conditions for hydrology and vegetation, with little room for flexibility. In contrast, no standards are being used for soil condition. Current success criteria and standards should undergo critical examination to see if they are consistent with no-net-loss wetland policies, and if alternative measures should to be taken.

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EXECUTIVE SUMMARY

Department of Transportation agencies in the U.S. alter more wetlands and undertake more compensatory wetland mitigation than any other entity, yet projects are rarely independently evaluated. In this study, 49 NCDOT wetland compensatory mitigation sites and 11 reference sites were evaluated on-site in 1999. Seventeen of the larger sites consisted of more than one type of mitigation (restoration, creation and/or preservation). In total, 71 mitigation parcels (approx. 3,000 acres) were evaluated to assess the likelihood that mitigation sites would achieve some level of structure and functioning similar to natural, self-sustaining wetland ecosystems and to provide recommendations for improvements.

In the Coastal Plain, 11 of 49 mitigations (22%) were designed to create wetlands, 25 (51%) were designed to restore wetlands, and 13 (27%) were the purchase of wetlands for preservation (no manipulations attempted). In the Piedmont and Blue Ridge Provinces, 6 of 22 (27%) of the mitigations were designed to create wetlands, 9 (41%) were designed to restore wetlands, and 7 (32%) were the preservation of wetlands.

Nine different types of wetlands were used for compensatory mitigation in the Coastal Plain while five wetland-types and one detention basin were used in the Piedmont and Blue Ridge provinces. Wet hardwood flats (n=12) and riverine wetlands (n=16) were the two most common wetland-types slated for compensatory mitigation in the Coastal Plain, constituting 57% of all mitigations. Tidal wetlands of all types accounted for an additional 31% (n=15) of the compensatory mitigations. In the Piedmont and Blue Ridge provinces, riverine wetlands constituted 59% (n=13) of compensatory mitigations, ephemeral ponds accounted for 18% (n=4) of all mitigation sites, while 5 other wetland-types constituted the remaining 23% of compensatory mitigations.

Ecological success was related to whether or not natural geomorphology had been successfully restored. Sites from which fill was removed were generally successful. Sites in which water impediment structures were constructed showed mixed results for vegetation survival, presumably because it was difficult to determine how wet to make a site. Wetland creations were generally unsuccessful because most all involved excavating soil to reach the underlying saturated zone, thus inhibiting growth of vegetation on sub-soils. Predictions of success were difficult due to the immaturity of sites, but it appeared that many created wetlands would not likely resemble historic, natural ecosystems.

Of the 71 compensatory mitigations examined, 26 were judged to be ecologically successful, 19 were preservation sites (automatically judged to be successful), 9 were judged to be unsuccessful, 10 lacked sufficient data (mostly hydrologic data) for judging success, 4 sites were too young to predict the outcome for vegetation survival, and 3 were undergoing construction at the time of our site visit. Alteration of and failure to restore natural geomorphology in compensatory mitigation sites was the major factor associated with the lack of mitigation success, regardless of whether success was defined by permit

success criteria or by ecological success.

The wetland classification system used by NCDOT (and presumably by regulatory agencies as well) was so broad that it was difficult to determine whether wetlands were being restored in the same ratio as those being impacted (i.e., if in-kind compensation was truly being achieved). In addition, terminology used to designate type of mitigation (creation, restoration, etc.) often did not correspond to definitions developed by the scientific community involved in restoration research. Therefore, we often had to revise a site's identity with respect to type of wetland and type of mitigation prior to our analysis of success.

Of the 23 created sites examined, 9 were determined to be ecologically successful, 8 were judged to be ecologically unsuccessful, while there was not enough information on the 6 other sites to reliably gauge success. Of the 23 created sites, soil had been excavated or redistributed in 21 of the sites. Of these 21 sites, only 2 retained soils resembling those in naturally occurring wetlands. Both of these sites were interdune swales created on barrier islands where soils are naturally sandy throughout all horizons. Thus, both sites appeared to be ecologically successful. Also, 9 created sites were successful in spite of massive soil re-distribution (excavation or addition of soil). In 4 of these 9 sites, hydrology was controlled by sea-level fluctuations. Of the remaining 14 created wetlands, 8 were judged to be unsuccessful, while there was not enough information on the 6 other sites to reliably gauge success.

In most cases, compensatory mitigation sites that appeared to be on an ecologically successful trajectory were also judged to meet success criteria required of permits. There were two sites that were judged to be on an ecologically successful trajectory, but which were determined to be inappropriate choices given the geomorphic location of the mitigation sites. These sites may not be sustainable over the long-run.

There were four compensatory mitigations that were appropriate given their geomorphic locations, but which were on an unsuccessful trajectory. Lack of success in these cases were attributed to either failing to grade the surface to an appropriate elevation (sea-level-controlled sites) or producing soil conditions insufficient to support desired vegetation (lack of organic matter).

More use of information from reference sites could improve outcomes. In addition, although preservation of cut-over stream floodplains is a cost-effective approach for improving downstream water quality, it was only rarely undertaken. Compensatory wetland mitigation involving restoration and creation appears to have gravitated toward relatively narrow sets of conditions for hydrology and vegetation, with little room for flexibility. In contrast, no standards are being used for soil condition. Current success criteria and standards should undergo critical examination to see if they are consistent with no-net-loss wetland policies, and if alternative measures should to be taken.

INTRODUCTION

Principles and Assumptions Regarding Wetland Mitigation

This report begins with a review of some of the principles and assumptions that underpin wetland mitigation so that projects conducted by North Carolina Department of Transportation (NCDOT) can be evaluated as objectively as possible. Policies rather than science drive the general direction of wetland mitigation nationwide. Before the Clean Water Act, policies for many years encouraged the alteration and elimination of wetlands in the United States. Less than one-half of the original resource now remains (Tiner 1984). Since earlier policies have been effectively reversed, it is not only essential to understand how policy is currently applied, but it is also important to make a distinction between the policy influencing compensatory wetland mitigation and its scientific or technical components. With an understanding of a given policy framework, technical information can follow as the basis for evaluating opportunities and limitations in the practice of compensatory mitigation.

We begin with a brief description of national and state goals of wetland regulation. Next, the apparent approaches to mitigation are described, followed by a review of some of the changes that have occurred over the past decade. Finally, the current state of wetland mitigation is examined with respect to explicit and implicit assumptions that underlie the direction of NCDOT's program.

Goals of Wetland Regulation

In 1988 a group called the National Wetlands Policy Forum produced a report that was to represent clear and coherent goals for the protection of wetlands in the United States (Conservation Foundation 1988). This report was produced in the spirit of a consensus document from a diverse group that consisted of state governors, corporate executives, environmental and conservation groups, attorneys and consultants, state and local government representatives, agricultural and timber interests, and academicians. The recommendation of the report was that the United States should initiate a policy of no overall net loss of the nation's remaining wetland base. It explicitly mentioned that there should be no net loss of either acreage or functioning. The long-term goal stated by the report was to increase the quantity and quality of the nation's wetland resource base. Details of how to achieve this were provided. Many of those recommendations have since been implemented.

Assuming that unavoidable impacts to wetlands will continue to occur, the only way that no net loss can be achieved is through compensatory mitigation. Mitigation requirements for projects that result in wetland losses are negotiated with the U.S. Army

Corps of Engineers with oversight from the Environmental Protection Agency. States also play a role through the Section 401 water quality certification program. In North Carolina, federal and state agencies also have review roles for permitting programs in the 20 coastal counties through the National Marine Fisheries Service of NOAA and the North Carolina Division of Marine Fisheries. In some cases, regional and local land-use regulation and other statutes may influence wetland policy.

Approaches and Evolution of Mitigation in the U.S.

Mitigation is accomplished in basically two ways: through the reduction of impacts by modification of the original project and through the compensation by creating, restoring, enhancing, or otherwise contributing to wetland area and function. According to the 404(b)(1) guidelines of the Clean Water Act, permit requests undergo a sequencing that consists of avoidance, minimization, and compensation. The avoidance and minimization steps are assumed to be outside of the scope of this study because they are purely administrative in nature. We will assumed that projects requiring a permit have been determined to be unavoidable because they best served the public interest or were "water-dependent." Neither of these components of the 404(b)1 guidelines will be considered further, and are viewed as "givens" for the purpose of this evaluation.

Wetland Mitigation Today: Assumptions and Future Directions

Compensatory mitigation has undergone some very significant changes in the past decade. These changes can be attributed to several factors including (1) improvements due to better decisions and more effective management by agencies and consultants, (2) improved technology and practices such as planting methods, appropriate choices of species and genetic stocks, and better understanding of hydrologic controls, and (3) improvements in evaluating what constitutes a success", including the assessment of wetland functions. This means that decisions made and techniques used in the past are not necessarily relevant and could be quite different from the ones that are currently being used or will be used in the future. Compensatory mitigation is a developing field, and participants are engaged in a learning process. This is the essence of adaptive management where a certain degree of trial and error is necessary for learning and improving management decisions over time. Consequently, past decisions may appear naive or even wrong either because the appropriate technology was unavailable or the technology could not be applied for other reasons.

One of the implicit assumptions of current regulatory programs is the prevalent philosophy of a "hands-off" approach or minimizing the intervention necessary to sustain wetlands credited for compensatory mitigation. In other words, credit is seldom given for enhancements that lead to specific functions and values such as timber production (e.g., pine silviculture), agricultural production (e.g., rice fields), waterfowl enhancement (e.g., duck impoundments), water quality improvement (e.g., stormwater impoundments), and other uses that require alteration from "natural" conditions and recurrent maintenance. In other words, protection through the regulatory program assumes mostly a benign management approach. Even when activities such as silviculture or agriculture continue in wetlands, guidelines are usually developed that restrict activities that would lead to additional drainage or filling.

The recent history and current practices now in place for compensatory mitigation are complex and seldom explicitly described. In general, "in-kind" mitigation typically has been preferred over "out-of-kind", "on-site" mitigation has been preferred over "off-site", and "restoration" has been preferred over "creation." While some of this policy still applies, negotiations to compensate for unavoidable impacts have become much more complex, and usually go beyond the use of simple ratios between the permitted wetland and the one targeted for mitigation. In addition, terminology used in mitigation is very specific and may not coincide with terminology developed in ecological restoration circles. Common terms used in the regulatory arena include:

1. In-kind mitigation is the replacement of a wetland with one of the same type or class. The degree to which in-kind mitigation is achieved depends partially on how rigorously wetland classes are defined.

2. Out-of-kind mitigation is the substitution of one wetland-type with another type, usually one that is considered more 'valuable' than the one impacted by the project. Such action usually requires justification.

3. On-site mitigation is seldom precisely physically possible (esp. in-kind and on-site), but where it occurs, it usually is compensation for a violation and is accomplished by restoring the impacted wetland. On-site has also come to mean mitigation through restoration/creation within a designated "use area", usually identified *a priori* as a geographical region in which mitigation can be practiced. "Off-site" mitigation is more liberal than this, and requires special justification. However, the development of mitigation banks may modify the way "use area" is defined.

4. There is a tendency to favor large mitigation sites that have the advantage of providing functions and values more cost effectively than smaller, individual restoration or creation projects. Usually, a large mitigation area will be designed to compensate for several individual projects. In practice, these are often mitigation banks where the developer buys credits from a restoration site that has demonstrated some level of success.

5. As a general rule, restoration (the conversion of a former wetland site back to wetland status) is preferred over creation (building a wetland where one never existed). This is due, in part, to the fact that many created wetlands did not meet expectations of appropriate hydrologic regime, characteristic vegetation, or position in the landscape that would allow them to function in a manner anticipated from natural wetlands. However, restoring wetland status to a given site is not truly restoration unless the site is restored to its original class with all it inherent structure and functions. Removing excess soil to improve chances of meeting jurisdictional criteria is really creation.

6. Enhancement, as defined in the regulatory arena, is manipulation (management) of a functioning wetland to increase the magnitude of one or more functions. For example, oaks might be planted to increase forage for deer and bear or the hydrologic regime of a low order riverine wetland might be manages for waterfowl (green tree reservoir). The former type of management would in essence be restoration (of a degraded function) if oaks were once a natural component of the ecosystem. Manipulation of water levels would be creating a subclass of wetland that never occurs naturally in that geomorphic position.

7. Reference wetlands are being used more and more as templates and targets for restoration projects, including mitigation banks. The philosophy is consistent with the "hands off" approach discussed above which favors self-maintaining ecosystems. It also more explicitly defines what id “in-kind” and what is needed for restoring structure and functions.

8. Preservation is an option that consists of placing land-use restrictions, in perpetuity, on what is often a wetland site or type that has special ecological or cultural and social significance, especially if it is a habitat for endangered species. Restoration ecologists view preservation as the purchase and protection of sites that fully function as wetlands. Purchases of successional sites, that by definition, are not fully functioning, is not true preservation; however, the maturation of a seral site is a type of restoration, with time being the restoration mechanism. In many cases, time can be shortened (enhanced) by planting late successional species.

9. Mitigation ratios (wetland area offered for mitigation divided by wetland area permitted for destruction) are policy guidelines that provide some predictability to the permitting process.

10. Functional assessment methods are used to provide consistency and apply existing technical information to the permitting process. Functional assessment has been in development since the late 1970s, and is still undergoing development. Assessment

methods so developed attempt to ensure that the mitigation site carries out one or several of the functions normally associated with "desirable" wetlands. Functions normally fall into the categories of hydrologic regime, biogeochemistry, plant community, and animal habitat.

11. Conversions of assessed functions to values (monetary or otherwise) are being developed as an outgrowth of functional assessment. However, cost-benefit analyses have been used for decades in wetlands to evaluate the need for many public work projects.

While this list of terms is not comprehensive, it should be sufficient for the purposes of this discussion.

Most of the generalities made so far are applicable to the state of North Carolina and thus relevant to NCDOT. Because NCDOT is the largest single (individual) modifier of wetlands based on permits issued in North Carolina, any no-net-loss goals at the state level will require a large measure of success by the agency itself. By the same token, NC DOT has an opportunity to take the lead in applying new technical information and approaches for the field of wetland mitigation as a whole. Large projects provide the potential for experimentation in planting techniques, hydrological manipulations, control over species composition, and soil microtopography and fertility, as well as other possibilities.

In order for a given NCDOT compensatory mitigation site to provide mitigation credit, these sites must meet certain Asuccess criteria" previously negotiated with various state and federal agencies that regulate wetlands. Part of this approval process involves multi-year (typically 3 or more) monitoring for compliance with the success criteria. Monitoring usually involves evaluating hydrologic regime to determine if sites meet conditions defining jurisdictional wetlands and vegetation to determine if sites support the composition and quantity (determined by cover, density, and/or composition) of vegetation deemed appropriate. Although soils are sometimes manipulated, there have been no success criteria for soil condition in mitigation sites.

At least one review of NCDOT compensatory mitigation sites had been performed prior to this study. An interdisciplinary team of wetland regulators and NCDOT staff personnel evaluated 7 sites in 1994 (Federal Highways Administration 1995) to determine the effectiveness of mitigation practices and provide recommendations for improvement. Pfeifer (1994) also evaluated wetland permits and mitigation plans (1991-1993), but only a few sites were actually visited. It seems that by 1994 there had only been a few compensatory mitigation sites completed; thus, there were few examples for evaluating the mitigation program.

NCDOT currently has over 150 wetland compensatory mitigation sites that are either proposed, under development, or completed (Dave Schiller, pers. comm.). Of these, approximately 50 sites have been "in the ground" for 1-8 years. Most of these sites have been evaluated by NCDOT at least once. However, there has not yet been any independent evaluation of sites with respect to whether they on a trajectory that might will be ecologically successful, or whether success criteria have been appropriate for the restoring wetlands.

Study Objectives

Objectives of this Phase 1 study were to (1) obtain an overview of the types of NCDOT compensatory mitigation sites completed or under construction and their general condition and (2) evaluate the effectiveness of compensatory mitigation relative to "success criteria" defined by permit conditions and the likelihood that the mitigation sites will achieve some level of structure and functioning similar to natural, self-sustaining wetland ecosystems. This information will be used to determine which sites should be studied in more detail and presented as "case studies" in the second phase of the study.

Without adequate reference data from relatively unaltered wetlands and data on intermediate stages that a site should be expected to attain along a pathway (trajectory) toward success, a judgment about whether any given site will be successful would be difficult to determine with confidence at such an early stage. Therefore, evaluations were not designed to find fault with any particular mitigation, NCDOT’s mitigation program, or regulatory permit requirements; rather, evaluations were meant to help us suggest ways to improve the process and products of compensatory mitigation as now practiced. Bear in mind that the art of compensatory mitigation has continued to advance rapidly and some practices that were applied (and failed) only a few years ago are no longer conducted. However, failures are as instructive than successes, if not more so.

The condition of any given mitigation site is the product of negotiations between NCDOT and other resource agencies, subsequent preparation and construction activities at the site, and any remediation activities performed on the site afterwards (which is also a product of negotiations among agencies). Therefore, the condition of a given site is the product of all the aforementioned activities and cannot be solely attributed to actions of NCDOT. By choosing a subset of sites to study in more detail (case studies, Phase II), we hope to obtain insight into the strengths and weaknesses of past compensatory mitigation efforts and provide a framework for improving both the permit process and the probability of success. These case studies will then be the focus of a workshop involving NCDOT staff and wetland regulatory personnel. Therefore, our goal was to examine an array of sites ranging from ones not yet competed to one that had been in the ground for 8 years. In doing so, we hope to gain insight into the most common practices that appear to relate to strengths and weaknesses of the compensatory mitigation program.

METHODS

The original study plan was to visit all completed or nearly completed NCDOT mitigation sites, any associated wetland reference sites, and the impacted project site(s) for which the mitigation was intended to compensate. However, it was not always possible or practical to locate the reference sites and/or project sites because: (1) some sites had no natural reference condition (e.g., they were not intended to be restored to a natural system), (2) some sites were mature, relatively unaltered preservation sites (i.e., they required no reference site), (3) some sites had no suitable reference sites located in close proximity to the mitigation site, (4) some sites were to compensate for project impacts to a number of wetlands of various types, or (5) we did not have enough information to precisely locate the impacted site(s) for which compensation was required.

In most cases, success criteria negotiated with regulatory agencies required that specific conditions be met (within in a specified time frame) regarding hydrology and vegetation. Soil condition was never required to meet any specific standard. In this preliminary survey of sites, we had to rely most heavily on the condition of vegetation because we did not have access to NCDOT monitoring well data for all sites (summary hydrologic data were only available in NCDOT monitoring reports, published in 1998, which constituted a subset of sites). Further, materials provided to us did not always include the most up-to-date information on well locations, making current evaluation of hydrologic condition impossible. Even so, we sometimes felt confident in making judgments about hydrology, particularly in sea-level controlled sites where vegetation is closely associated with period of flooding and/or salinity and in sites where period of saturation was clearly much wetter or much drier than jurisdictional parameters defining hydrologic conditions in wetlands (i.e., continuous saturation within 12 inches of the surface for > 12.5% of the growing season).

Forty-nine NCDOT wetland compensatory mitigation sites and 11 reference sites were evaluated on-site between July 12 and October 27, 1999 (Tables 1 & 2) Mitigation plans were examined to determine how each compensatory mitigation site had been manipulated. Monitoring reports (prepared in 1998 by NCDOT), available for 22 of the 49 sites, were used to evaluate the most recently recorded status of sites and compare permit success criteria with current conditions. Seventeen of the larger sites consisted of more than one type of mitigation (restoration, creation and/or preservation). At these sites, each mitigation-type was evaluated separately. Thus, we examined 71 compensatory mitigations, 49 mitigations in 33 Coastal Plain sites and 22 mitigations in 16 Piedmont and Blue Ridge sites.

The mitigation sites provided to us by NCDOT constituted a wide variety of wetland types from every physiographic provinces in the state (Tables 1 and 2). In the process of compiling information on sites (from NCDOT files and site reconnaissance), we determined (1) if soils were intact or similar to natural wetlands, (2) if planted vegetation was thriving, (3) if the site was on a trajectory to be ecologically successful, (4) if the site generally met permit conditions for vegetation (we relied on NCDOT well monitoring data to determine hydrologic "success"), and (5) if a mitigation was appropriate assuming that an "in-kind" approach was being taken. If the site did not appear to meet the overall objectives of the mitigation plans or match the geomorphic setting of the impacted site, we commented on what would have been more appropriate. This report also provides information on dominant and/or most conspicuous vegetation occupying each site, general soil conditions, and observations on hydrologic regime.

Table 1. Baseline information on NCDOT mitigation sites located in the Coastal Plain Physiographic Province. Abbreviations: RIV= riverine, WHF= wet hardwood flat, WPF= wet pine flat, TFS= tidal freshwater swamp, TSM= tidal salt marsh, TBM= tidal brackish marsh, LF= lacustrine fringe, TFM= tidal freshwater marsh, TSM= tidal salt marsh, IDS= interdune swale, EP= ephemeral pond, POC= pocosin, UPL= upland, N/A= not applicable or insufficient information available.

Coastal Plain Sites	Wetland-type(s)	1998 Monit. Report available	Type of Compensatory Mitigation[1]	Wetland (Acres)
B-2158 (Midway Park)	TFS	YES	Restoration	0.25
Ballance	WHF, TFM, UPL	NO	Creation, Preservation, UPL restoration	420
Bogue Sound (Sand Shoal)	TSM	YES	Creation	6
Bogue Sound (Weeks Property)	TSM	NO	Creation	4
Bull Farm	WHF, RIV	YES	Restoration, Creation, Enhancement, Preservation	407
Casey	TFM	YES	Creation, UPL preservation	24
Collington West	TSM	YES	Creation	0.5
Collington East	TSM	YES	Restoration	0.5
Cox Farm	TFS	YES	Creation	2
Dismal Swamp	WHF	YES	Restoration, Enhancement, Preservation	612
Dowd Dairy Farm	WHF, RIV	NO	Restoration	658
Finley McMillan	RIV, POC	NO	Preservation, Enhancement	500
Goshen Swamp	RIV	YES	Enhancement	91
Grimesland	RIV	NO	Creation, Preservation	550
Gurley	WHF	NO	Restoration, Enhancement, Preservation	179
Haws Run	WPF, RIV	NO	Restoration, Enhancement, Preservation	600
Huskanaw Swamp	WHF, RIV, UPL	YES	Restoration, Preservation, UPL preservation	114
Kerr Avenue	RIV	NO	Preservation	48
Lengyel	TBM	NO	Creation	12
Little McQueen	RIV	NO	Preservation	880
Long Swamp	RIV, WHF	NO	Restoration, Preservation	240
Manns Harbor	TBM	YES	Creation	2
Mashoes Road	TBM, WHF	NO	Preservation, Restoration	399
Mildred Woods	WHF, UPL	YES	Restoration	618
Pea Island (Interdune)	IDS	YES	Creation	53
Pembroke Creek	TFS	YES	Restoration	10
Pridgen Flats	POC	NO	Restoration	117
Seven Springs	RIV	NO	Restoration	27
Spring Branch	RIV	YES	Creation	11
Thorofare Bay	TBM	YES	Restoration	2
Tucker	WHF, RIV	NO	Restoration, Preservation	37
U-92D	RIV	YES	Restoration	5
USMC Marsh	TSM	NO	Restoration	4
Whalebone Junction	IDS	NO	Restoration, Enhancement	1

[1] As identified by NCDOT

Table 1 (cont.).

Coastal Plain Sites	**Drainage Basin**	**County**	**Latitude (North)**	**Longitude (West)**
B-2158 (Piney Green)	New River	Onslow	N/A	N/A
Ballance	Pasquotank	Currituck	36 28.84	76 05.30
Bogue Sound (Sand Shoal)	White Oak	Carteret	34 42.85	76 45.16
Bogue Sound (Weeks)	White Oak	Carteret	34 40.27	77 06.06
Bull Farm	Cape Fear	Sampson	34 48.61	78 26.69
Casey	Pasquotank	Currituck	36 27.22	76 04.40
Collington West	Pasquotank	Dare	36 00.72	75 41.68
Collington East	Pasquotank	Dare	?	?
Cox Farm	Tar-Pamlico	Beaufort	35 33.43	76 29.88
Dismal Swamp	Pasquotank	Gates/ Perquimmans	36 22.18	76 30.21
Dowd Dairy Farm	Cape Fear	Bladen	34 44.03	78 39.26
Finley McMillan	Cape Fear	Pender	34 32.51	77 38.25
Goshen Swamp	Cape Fear	Duplin	35 09.05	78 07.52
Grimesland	Tar-Pamlico	Pitt	35 35.05	77 09.59
Gurley	Neuse	Greene	35 29.40	77 48.57
Haws Run	Cape Fear	Pender/ Onslow	34 37.30	77 38.21
Huskanaw Swamp	Tar-Pamlico	Martin	35 50.14	77 11.73
Kerr Avenue	Cape Fear	New Hanover	34 16.13	77 52.90
Lengyel	Neuse	Craven	35 05.61	77 02.16
Little McQueen	Lumber	Robeson	34 27.39	78 57.27
Long Swamp	Lumber	Hoke	34 51.39	79 15.81
Manns Harbor	Pasquotank	Dare	35 52.55	75 45.46
Mashoes Road	Pasquotank	Dare	35 55.04	75 46.99
Mildred Woods	Tar-Pamlico	Edgecombe	35 52.06	77 29.19
Pea Island (Interdune)	Pasquotank	Dare	35 38.54	75 28.63
Pembroke Creek	Pasquotank	Chowan	36 03.933	76 39.025
Pridgen Flats	Cape Fear	Sampson	34 38.54	78 17.16
Seven Springs	Neuse	Wayne	35 16.24	77 52.40
Spring Branch	Cape Fear	New Hanover	34 15.23	77 52.22
Thorofare Bay	White Oak	Carteret	34 55.60	76 21.88
Tucker	Pasquotank	Currituck	36 27.13	76 03.68
U-92D	Cape Fear	New Hanover	34 15.23	77 52.44
USMC Marsh	White Oak	Onslow	34 33.58	77 17.70
Whalebone Junction	Pasquotank	Dare	35 54.38	75 35.98

Table 1 (concluded)

Coastal Plain Sites	Planning Staff	Impl./Mon. Staff	Project Status	Consultant	NCDOT Ownership
B-2158 (Piney Green)	N/A	N/A	Completed	?	?
Ballance	Schiller	Lewis	Monitoring in progress	RSE	Own
Bogue Sound (Sand Shoal)	Schiller	Lewis	Monitoring in progress	In-House	Own
Bogue Sound (Weeks)	Todd	Todd	Monitoring in progress	TWC	Own
Bull Farm	Cashin	Cox	Monitoring in progress	In-House	Own
Casey	Schiller	Lewis	Monitoring in progress	RSE	Own
Collington West	Cashin	Cox	Monitoring in progress	In-House	Own
Collington East	Cashin	Cox	Monitoring in progress	In-House	Own
Cox Farm	Schiller	Lewis	Monitoring in progress	In-House	Own
Dismal Swamp	Schiller	Cox	Monitoring in progress	ESI	Own
Dowd Dairy Farm	Schiller	Cox	Monitoring in progress	ESI	Own
Finley McMillan	Schiller	Lewis	Completed	In-House	Own
Goshen Swamp	Schiller	Lewis	Monitoring in progress	In-House	Own
Grimesland	Paugh	Lewis	Mitigation Plan in Progress	HSMM	Own
Gurley	Holland	Smyre	Monitoring in progress	ESI	Own
Haws Run	Paugh	Lewis	Monitoring in progress	Land Mgt.Group	Own
Huskanaw Swamp	Staff	Smyre	Monitoring in progress	ESI	Own
Kerr Avenue	Brady	N/A	Mitigation Plan in Progress	In-House	Being Appraised
Lengyel	Holland	Holland	Monitoring in progress	ESI	Own
Little McQueen	Staff	Smith	Complete	In-House	Own
Long Swamp	Staff	Cox	Monitoring in Progress	ESI	Own
Manns Harbor	Staff	Cox	Monitoring in Progress	In-House	Own
Mashoes Road	Schiller	Cox	Monitoring in Progress	RSE	Own
Mildred Woods	Holland	Holland	Monitoring in Progress	ESI	Own
Pea Island (Interdune)	Staff	Ellis	Monitoring in progress	In-House	Easement
Pembroke Creek	Turner	Rivenbark	Monitoring in progress	In-House	Own
Pridgen Flats	Staff	Lewis	Complete	In-House	Own
Seven Springs	Schiller	Brady	Monitoring in progress	TWC	Easement
Spring Branch	Schiller	Lewis	Monitoring in progress	In-House	Own
Thorofare Bay	Staff	Griffin	Monitoring in progress	In-House	Own
Tucker	Schiller	Lewis	Monitoring in progress	RSE	Own
U-92D	Cashin	Lewis	Awaiting Agency Signoff	In-House	Own
USMC Marsh	Cashin	Cox	Monitoring in Progress	ESI	Own
Whalebone Junction	Staff	Smyre	Monitoring in progress	In-House	Own

Table 2. Baseline information on NCDOT mitigation sites located in the Piedmont and Blue Ridge

Physiographic Provinces. Abbreviations: RIV= riverine, LF= lacustrine fringe, EP= ephemeral pond, FEN= fen, SLP= slope wetland, SDB= stormwater detention basin, UPL= upland, MNC= mitigation not completed, N/A= not applicable or insufficient information available.

Piedmont Sites	**Wetland-type(s)**	**1998 Monit. Report Available**	**Type of Compensatory Mitigation[1]**	**Wetland (Acres)**
Blue	RIV	NO	Preservation	180
Bryan Boulevard (Horsepen Creek)	RIV	NO	Restoration, Creation	11
Bryan Boulevard (Oak Ridge Rd)	RIV	YES	Creation	1
Ephemeral Pond	EP	NO	Preservation	5
Evans Road	LF	NO	Restoration	9
Lake Wheeler	RIV, UPL	YES	Preservation, UPL preservation	114
Little Sugar Creek	SDB	YES	Creation	16
Long Creek	RIV	YES	Restoration	156
Mallard Creek	FEN	YES	Restoration, Creation	9
New Light Creek	RIV, EP	NO	Restoration	20
Phillips	RIV, UPL	NO	Preservation, Enhancement, UPL buffer	59
Ridge Road	EP, UPL	NO	Preservation, UPL preservation	40
South Buffalo Creek	RIV	NO	Restoration, Preservation	32
Wellborn	RIV	NO	Preservation	6

Blue Ridge Sites	**Wetland-type(s)[1]**	**1998 Monit. Report Available**	**Type of Compensatory Mitigation[1]**	**Wetland (Acres)**
Mud Creek	RIV, SLP	YES	Creation, Preservation	34
Tulula Creek	RIV, EP, FEN	NO	Restoration, Creation	67 (9,640 ft reach)

[1] As identified by NCDOT

Table 2 (cont.).

Piedmont Sites	**Drainage Basin**	**County**	**Latitude (North)**	**Longitude (West)**
Blue	Cape Fear	Moore	N/A	N/A
Bryan Boulevard (Horsepen Creek)	Cape Fear	Guilford	36 07.05	79 53.23
Bryan Boulevard (Oak Ridge Rd)	Cape Fear	Guilford	36 07.23	79 55.65
Ephemeral Pond	Lumber	Scotland	34 55.73	79 23.69
Evans Road	Neuse	Wake	35 49.83	78 48.24
Lake Wheeler	Neuse	Wake	35 41.62	78 40.72
Little Sugar Creek	Catawba	Mecklenburg	35 05.31	80 52.83
Long Creek	Catawba	Mecklenburg	35 20.38	80 53.41
Mallard Creek	Catawba	Mecklenburg	35 19.28	80 43.81
New Light Creek	Neuse	Wake	36 01.79	78 35.78
Phillips	Neuse	Wake	35 41.62	78 40.72
Ridge Road	Catawba	Mecklenburg	35 22.15	80 45.02
South Buffalo Creek	Cape Fear	Guilford	36 02.99	79 44.63
Wellborn	Yadkin	Caldwell	36 00.57	81 34.34
Blue Ridge Sites	**Drainage Basin**	**County**	**Latitude (North)**	**Longitude (West)**
Mud Creek	French Broad	Henderson	35 22.27	82 28.47
Tulula Creek	Little Tenn.	Swain	35 16.33	83 42.01

Table 2 (concluded).

Piedmont Sites	**Planning Staff**	**Impl./Mon. Staff**	**Project Status**	**Consultant**	**NCDOT Ownership**
Blue	Smyre	N/A	Completed	RSE	Own
Bryan Boulevard (Horsepen Creek)	Staff	Cox	Monitoring in progress	In-House	Own
Bryan Boulevard (Oak Ridge Rd)	Staff	Cox	Remediation/Monitoring in progress	In-House	Own
Ephemeral Pond	Paugh	Lewis	Completed	In-House	Own
Evans Road	Staff	Smyre	Awaiting Agency Signoff	Earth Tech	Owned by County
Lake Wheeler	Hauser	Griffin	Completed	ESI	Own
Little Sugar Creek	Staff	Smyre	Monitoring in progress	ESI	Own
Long Creek	Staff	Smyre	Monitoring in progress	ESI	Own
Mallard Creek	Staff	Smyre	Monitoring in progress	ESI	Own
New Light Creek	Holland	Holland	Monitoring in progress	Earth Tech	Own
Phillips	Holland	Holland	Completed	Earth Tech	Own
Ridge Road	Holland	Holland	Completed	N/A	Own
South Buffalo Creek	Paugh	Lewis	Monitoring in progress	RSE	Cons. Easement
Wellborn	Gordon	Division 11	Completed	In-House	Own
Blue Ridge Sites	**Planning Staff**	**Impl./Mon. Staff**	**Project Status**	**Consultant**	**NCDOT Ownership**
Mud Creek	Staff	Lewis	Monitoring in progress	RSE	Own
Tulula Creek	Cashin	Cox	Design in Progress	HSMM	Own

RESULTS

NCDOT's repertoire of compensatory mitigation projects included creation, restoration, enhancement, and preservation (Table 3). In the Coastal Plain, 12 of the 55 mitigations (22%) were designed to create wetlands, 19 (35%) were designed to restore wetlands, 7 (13%) were designed to enhance wetlands, 13 (24%) were the purchase of wetlands for preservation (no manipulations attempted), and 4 (7%) were preservation and restoration of uplands (Table 3). In the Piedmont and Blue Ridge Provinces, 7 of 26 (27%) of the mitigations were designed to create wetlands, 7 (27%) were designed to restore wetlands, 8 (31%) were the purchase of wetlands for preservation, and 3 (4%) were upland restoration and preservation. However, in assessing ecological success, we examined compensatory mitigation projects according to scientifically accepted definitions for types of compensatory mitigation. Thus, we defined restoration as any attempt to restore structure and function to degraded wetlands. Thus, some enhancements were counted as restoration if its intent was to return a wetland to its prior, natural condition. Manipulations that included topsoil removal to increase duration of soil saturation were defined as creation (however, removing fill was treated as restoration). The purchase of a fully functioning wetland for protection into perpetuity was considered preservation.

Using the above definitions, 14 of the 49 mitigations (29%) were designed to create wetlands in the Coastal Plain, 21 (43%) were designed to restore wetlands, and 14 (29%) were the purchase of wetlands for preservation (no manipulations attempted) (Table 4). In the Piedmont and Blue Ridge Provinces, 9 of 22 (41%) of the mitigations were designed to create wetlands, 5 (23%) were designed to restore wetlands, and 8 (36%) were the purchase of wetlands for preservation.

Nine different types of wetlands were used for compensatory mitigation in the Coastal Plain while 6 wetland-types and one detention basin were used in the Piedmont and Blue Ridge provinces (Table 4). Wet hardwood flats (n=12) and riverine wetlands (n=16 were the two most common wetland-types slated for compensatory mitigation in the Coastal Plain, constituting 57% of all mitigations. Tidal wetlands of all types accounted for an additional 33% (n=15) of the compensatory mitigations. In the Piedmont and Blue Ridge provinces, riverine wetlands constituted 59% (n=13) of compensatory mitigations, ephemeral ponds accounted for 18% (n=4) of all mitigation sites, while 5 other wetland-types constituted the remaining 23% of compensatory mitigations.

Each of the 71 compensatory mitigations were examined to determine whether they met the required permit conditions and whether they were generally successful from an ecological perspective (Table 5). Ecological success was based on whether a site appeared to be on a trajectory that would allow it to succeed to a condition structurally and functionally similar to a self-sustaining wetland-type that naturally occurs in the region.

Table 3. Summary of NCDOT compensatory mitigations identified by NCDOT.

Mitigation-type	**Coastal Plain**				**TOTAL**	
Creation	12		7		19	
Restoration	19		7		26	
Preservation	13		8		21	
Enhancement	7		0		7	
Stormwater Detention Basin	0		1		1	
TOTAL wetlands	51		23		74	
UPL (Preserv. and Restor.)	4		3		7	

Table 4. Summary of NCDOT compensatory mitigations examined, sorted by mitigation-type and wetland-type. Enhancements were counted as restorations. Upland restorations were excluded.

Mitigation-type	Coastal Plain	Piedmont/Blue Ridge	TOTAL
Creation	14	5	23
Restoration	21	9	26
Preservation	14	8	22
Stormwater Detention Basin	0	1	1
TOTAL	49	22	71

Wetland-type	Coastal Plain	Piedmont/Blue Ridge	TOTAL
Wet Hardwood Flat	12	N/A	12
Wet Pine Flat	2	N/A	2
Riverine	16	13	29
Tidal Freshwater Swamp	2	N/A	2
Tidal Freshwater Marsh	4	N/A	4
Tidal Brackish Marsh	4	N/A	4
Tidal Salt Marsh	5	N/A	5
Interdune Swale	2	N/A	2
Pocosin	2	N/A	2
Lacustrine Fringe	N/A	1	1
Ephemeral Pond	0	4	4
Fen	0	2	2
Slope	0	1	1
Stormwater Detention Basin	0	1	1
TOTAL	49	22	71

Table 5. Condition of NCDOT compensatory mitigation sites. Abbreviations: RIV= riverine, WHF= wet hardwood flat, WPF= wet pine flat, TFS= tidal freshwater swamp, TFM= tidal freshwater marsh, TSM= tidal salt marsh, TBM= tidal brackish marsh, LF= lacustrine fringe, EP= ephemeral pond, POC= pocosin, FEN= fen, SLP= slope wetland, SDB= stormwater detention basin, UPL= upland, N/A= not applicable or insufficient information available, TYTD= too young to determine outcome. Two Coastal Plain sites and one Blue Ridge site had not yet been completed. Wetland-types and mitigation-types were revised based on our classification during fieldwork. All enhancements were counted as restorations.

Coastal Plain Sites	**Wetland - type**	**Type of Mitigation[1]**	**Natural geomorphology**	**Soil intact or soil condition similar to a natural wetland**	**Planted vegetation thriving**	**On trajectory to be similar to a natural wetland-type**	**Negociated success criteria for vegetation met**	**Mitigation Plan appropriate[2] for geomorphic location**
B-2158 (Midway Park)	TFS	Restoration	Restored	YES	YES	YES	YES	YES
Ballance	TFM	Creation	Altered	NO	NO	TYTD	TYTD	NO
Ballance	WHF	Restoration	Not Manipulated	NO	TYTD	TYTD	TYTD	YES
Ballance	TFM	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Bogue Sound (Sand Shoal)	TSM	Creation	Altered	NO	YES	YES	YES	YES
Bogue Sound (Weeks)	TSM	Creation	Altered	NO	NO	NO	NO	NO
Bull Farm	RIV	Creation	Altered[3]	NO	YES	YES	YES	NO
Bull Farm	WHF	Restoration	Not Manipulated	YES	YES	YES	YES	NO
Bull Farm	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Casey	TFM	Creation	Altered	NO	YES	YES	YES	YES
Collington East	TSM	Restoration	Restored	NO	YES	YES	YES	YES
Collington West	TSM	Creation	Altered	NO	NO	NO	NO	YES
Cox Farm	TFS	Creation	Altered	NO	NO	NO	NO	NO
Dismal Swamp	WHF	Restoration	Restored	NO	N/A	N/A	YES	YES
Dismal Swamp	WHF	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Dowd Dairy Farm	WHF	Restoration	Not Manipulated	YES	N/A	TYTD	N/A	TYTD
Dowd Dairy Farm	RIV	Restoration	Not Manipulated	YES	TYTD	TYTD	TYTD	TYTD
Finley McMillan	POC	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Goshen Swamp	RIV	Restoration	Not Manipulated	YES	YES[4]	YES	YES[4]	YES
Grimesland[5]	RIV	Restoration	Restoration planned	N/A	N/A	N/A	N/A	N/A
Grimesland[5]	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Huskanaw Swamp	WHF	Restoration	Not Manipulated	YES	YES[5]	YES	YES	YES

Table 5 (continued).

Coastal Plain Sites	Wetland - type	Type of Mitigation[1]	Natural geomorphology	Soil left intact or soil condition similar to a natural wetland	Planted vegetation thriving	On trajectory to be similar to a natural wetland-type	Negociated success criteria for vegetation met	Mitigation Plan appropriate[2] for geomorphic location
Gurley	RIV	Restoration	Restored	YES	YES	YES	YES	YES
Gurley	WHF	Restoration	Not Manipulated	YES	YES	YES	YES	YES
Gurley	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Haws Run	RIV	Creation	Altered	NO	NO	NO	NO	NO
Haws Run	WPF	Restoration	Not Manipulated	YES	N/A	YES	YES	YES
Huskanaw Swamp	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Kerr Avenue	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Lengyel	TBM	Creation	Altered	NO	N/A	YES	N/A	YES
Lengyel	TBM	Restoration	Altered	NO	N/A	YES	N/A	YES
Little McQueen	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Long Swamp	RIV	Preservation	N/A	YES	N/A	N/A	N/A	N/A
Long Swamp	RIV	Restoration	Not Manipulated	YES	TYTD	TYTD	TYTD	YES
Long Swamp	WHF	Restoration	Not Manipulated	YES	YES	N/A	N/A	NO
Mann's Harbor	TBM	Restoration	Restored	YES	N/A	NO	NO	YES
Mashoes Road[6]	TBM	Restoration	Restoration planned	N/A	N/A	N/A	N/A	N/A
Mashoes Road[6]	WHF	Creation	Altered	NO	NO	NO	NO	YES
Mildred Woods	WHF	Restoration	Not Manipulated	YES	YES	N/A	N/A	YES
Mildred Woods	WHF	Preservation	N/A	N/A	N/A	N/A	TYTD	N/A
Pea Island (Interdune)	IDS	Creation	Altered	YES	YES	YES	N/A	YES[8]
Pembroke Creek	TFS	Restoration	Restored	YES	YES	YES	YES	YES
Pridgen Flats	POC	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Spring Branch	RIV	Creation	Altered	NO	YES	YES	YES	YES
Seven Springs	RIV	Restoration	Not Manipulated	YES	YES	YES	YES	YES
Thorofare Bay	TBM	Restoration	Restored	NO	YES	YES	YES	YES
Tucker	WHF	Creation	Altered	NO	NO	NO	NO	NO
U-92D	RIV	Restoration	Restored	YES	YES	YES	YES	YES
USMC Marsh	TSM	Restoration	Restored	NO	NO	NO	NO	YES
Whalebone Junction	IDS	Creation	Altered	YES	YES	YES	YES	YES

Table 5 (concluded).

Piedmont and Blue Ridge Sites	Wetland - type	Type of Mitigation[1]	Natural geomorphology	Soil left intact or soil condition similar to a natural wetland	Planted vegetation thriving	On trajectory to be similar to a natural wetland-type	Success criteria for vegetation met	Mitigation Plan appropriate[2] for geomorphic location
Blue	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Bryan Boulevard (Horsepen Creek)	RIV	Restoration	Not Manipulated	YES	YES	N/A	N/A	YES
Bryan Boulevard (Oak Ridge Rd)	RIV	Creation	Not Manipulated[9]	YES	YES	YES	YES	YES
Ephemeral Pond	EP	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Evans Road	LF	Creation	Altered	N/A	NO	N/A	NO	YES
Evans Road	RIV	Creation	Altered	N/A	NO	N/A	NO	YES
Lake Wheeler	RIV	Restoration	Not Manipulated	YES	YES	YES	N/A	YES
Little Sugar Creek	SDB	Creation	Altered	NO	NO	N/A	YES	NO
Long Creek	RIV	Restoration	Not Manipulated	YES	YES	YES	YES	YES
Mallard Creek	RIV	Creation	Altered	NO	NO	NO	NO	NO
Mallard Creek	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Mud Creek	RIV	Creation	Altered	NO	NO	NO	YES	NO
Mud Creek	SLP	Preservation	N/A	YES	YES	YES	N/A	N/A
New Light Creek	EP	Creation	Altered	N/A	N/A	N/A	N/A	YES
New Light Creek	RIV	Restoration	Restored	YES	YES	YES	YES	YES
Phillips	RIV	Restoration	Not Manipulated[9]	YES	N/A	YES	N/A	YES
Phillips	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Ridge Road	EP	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
South Buffalo Creek	RIV	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
South Buffalo Creek	RIV	Restoration	Not Manipulated[9]	YES	YES	YES	YES	YES
Tulula Creek	EP	Creation	Altered	NO	N/A	N/A	N/A	NO
Tulula Creek	FEN	Preservation	N/A	N/A	N/A	N/A	N/A	N/A
Tulula Creek[6]	RIV	Restoration	Restoration planned	N/A	N/A	N/A	N/A	N/A
Wellborn	FEN	Preservation	N/A	N/A	N/A	N/A	N/A	N/A

[1] Enhancement identified as restoration if mitigation was designed to restore the site to its historic, natural condition.
[2] Restored or created conditions appropriate for geomorphic location.
[3] One small portion was created for anadromous fish habitat.
[4] Along planted transects only.
[5] Except perhaps in sampled area where vines are dense.
[6] Mitigation had either not been started or not been completed at time of site visit.
[7] Most vegetation dead due to herbicides applied to kill *Phragmites*
[8] Except created area is larger than natural condition.
[9] Impermeable barrier (rock polywall) placed to impede water flow

Success was usually related to whether or not natural geomorphology had been manipulated or successfully restored. Natural geomorphology was almost always altered in restoration by scraping away (removing) an A soil horizon to increase period of saturation. Restoration of natural geomorphology was usually accomplished by removing previously placed soil (fill) on a site. Placing a flashboard riser in a wetland was not treated as a manipulation of natural geomorphology even though saturation period was increased relative to other sites in similar geomorphic settings.

Of the 71 compensatory mitigations examined, 26 were judged to be ecologically successful, 19 were preservation sites (automatically judged to be successful), 910 were judged to be unsuccessful, 10 lacked sufficient data (mostly hydrologic data) for judging success, 4 sites were too young to predict the outcome for vegetation survival, and 3 were undergoing construction at the time of our site visit (Table 6). Alteration of and failure to restore natural geomorphology in compensatory mitigation sites was the major factor associated with the lack of mitigation success, regardless of whether success was defined by permit success criteria or by ecological success.

Of the 22 created sites examined, 9 were determined to be ecologically successful, 8 were judged to be ecologically unsuccessful, while there was not enough information on the 5 other sites to reliably gauge success. Of the 22 created sites, soil had been excavated or redistributed in 20 of the sites. Of these 20 sites, only 2 retained soils resembling those in naturally occurring wetlands. Both of these sites (Pea Island site and Whalebone Junction) were interdune swales created on barrier islands where soils are naturally sandy throughout all horizons. Thus, both sites appeared to be ecologically successful (Table 6). Also, 9 created sites were successful in spite of massive soil re-distribution (excavation or addition of soil). In 3 of these 9 sites, hydrology was controlled by sea-level fluctuations. Of the remaining 13 created wetlands, 8 were judged to be unsuccessful, while there was not enough information on the 5 other sites to reliably gauge success.

In most cases, compensatory mitigation sites that appeared to be on an ecologically successful trajectory were also judged to meet success criteria required of permits. There were two exceptions: portions of Mud Creek and Huskanaw Swamp. Although tree survival in the section we sampled in Huskanaw Swamp will probably meet permit conditions (320 trees/acre) within the time frame of the monitoring period, planted trees appeared to be getting out-competed by vines (primarily *Campsis radicans*). At Mud Creek, reed canary grass (*Phalaris arundinaceae*) was out-competing planted trees in a portion of the site.

There were three compensatory mitigations that were appropriate given their geomorphic locations, but which were on an unsuccessful trajectory: the USMC tidal salt

Table 6. Summary of site conditions sorted by manipulations to natural geomorphology. N/A= data not applicable or insufficient information available, TYTD= too young to determine outcome. Preservation sites (n=19) and sites where compensatory mitigations that have not yet been completed (n=3) are excluded from summary.

Natural Geomorphology not Manipulated		**Soil intact or soil condition similar to a natural wetland**	**Planted vegetation thriving**	**On trajectory to be similar to a natural wetland-type**	**Negociated success criteria for vegetation met**	**Mitigation Plan appropriate for geomorphic location**
Coastal Plain (n=11)	YES	10	7	6	6	8
	NO	1	0	0	0	2
	N/A	0	2	2	3	1
	TYTD	0	2	3	2	0
Piedmont and Blue Ridge (n=6)	YES	6	5	5	3	6
	NO	0	0	0	0	0
	N/A	0	1	1	3	0
	TYTD	0	0	0	0	0

Natural Geomorphology Restored		**Soil intact or soil condition similar to a natural wetland**	**Planted vegetation thriving**	**On trajectory to be similar to a natural wetland-type**	**Negociated success criteria for vegetation met**	**Mitigation plan appropriate for geomorphic location**
Coastal Plain (n=9)	YES	5	6	6	7	9
	NO	4	1	1	2	0
	N/A	0	2	2	0	0
	TYTD	0	0	0	0	0
Piedmont and Blue Ridge (n=1)	YES	1	1	1	1	1
	NO	0	0	0	0	0
	N/A	0	0	0	0	0
	TYTD	0	0	0	0	0

Natural Geomorphology Altered		**Soil intact or soil condition similar to a natural wetland**	**Planted vegetation thriving**	**On trajectory to be similar to a natural wetland-type**	**Negociated success criteria for vegetation met**	**Mitigation Plan appropriate for geomorphic location**
Coastal Plain (n=15)	YES	2	6	8	5	9
	NO	13	7	6	6	6
	N/A	0	2	0	3	0
	TYTD	0	0	1	1	0
Piedmont and Blue Ridge (n=7)	YES	0	0	0	2	3
	NO	4	5	2	3	4
	N/A	3	2	5	2	0
	TYTD	0	0	0	0	0

marsh, the brackish marsh at Mann’s Harbor, and the Wet Hardwood Flat at Mashoes Road. Lack of success in these cases were attributed to either failing to grade the surface to an appropriate elevation (USMC and Mann’s Harbor) or failing to produce soil conditions sufficient for supporting desired vegetation (e.g., lack of organic matter in soil at the Mashoes Road site).

The characterization below was intended to provide the most pertinent information on each site and was not intended to be an exhaustive overview. (Mitigation plans should be consulted for additional information.) Information was used to determine whether compensatory mitigation sites were generally successful, evaluate trends relative to successes and failures, and provide information to help determine which sites would be most appropriate for case studies.

Characterization of Coastal Plain Sites (in alphabetical order)

B-2158 (Midway Park)

County: Onslow
Location: In Jacksonville, on both sides of a bridge crossing Rocky Creek on SR1406.
Size: 0.24 acre
Year started: 1994
Type of mitigation: Riverine restoration (fill removed, vegetation planted).

Description of site and its condition:

This mitigation site was probably a sea-level controlled, fresh water system, especially on the south end of the bridge. The site was planted with hydrophytic trees typical of bottomland hardwood forests. The mitigation seemed successful both ecologically and relative to permit success criteria.

Planted trees present:
Fraxinus sp.
Taxodium distichum
Quercus michauxii
Nyssa biflora
Quercus phellos

Colonizing trees:
Liriodendron tulipifera
Liquidambar styraciflua

Herbs:
Impatiens capensis
Cicuta maculata
Juncus sp.
Rumex sp.
Ptilimnium capillaceum
Polygonum pensylvanicum
Erechtites hieracifolia
Verbena brasiliensi
Typha angustifolia

Ballance

County: Currituck
Location: South of Tulls on east side of SR1232.
Size: 420 acres
Year started: 1998
Type of mitigation: Creation of sea level controlled creeks; and restoration of wet hardwood flats.

Description of site and its condition:

Complex site, mostly consisting of flats and tidal fringe wetlands. A huge spoil pile (7 m high x 50 m long) was located at the eastern end of the site from soil removed to construct tidal (wind-driven) creeks. Some of the excavated material may have been used to fill in a large number of parallel ditches that had been excavated when the site was converted from wet flat to cropland. However, the engineering site plan had called for scraping-off field crowns sufficiently to fill existing ditches. Throughout most of the site, the A horizon was very low in organic matter and the soil appeared to have been compacted, likely a consequence of both long-term agricultural use and scraping during construction of the site. Recovery of the site may take some time, particularly if other stressors (drought, excessive rainfall, etc.) occur.

Two representative plots were examined for survival of planted trees. Densities are based on plot sizes of 2500 $ft.^2$ (50' X 50').

	Plot 1	Plot 2
Fraxinus sp.	5	0
Quercus michauxii	7	3
Quercus falcata	3	0
Quercus lyrata	0	4
Total	15	7
Living (#stems/acre)	261	122
Dead	6	9

Tree survival was found to be fairly low in these plots and appeared to be low throughout in other parts of the site as well. Many tree seedlings still alive did not appear healthy. It appears that the site was planted during drought conditions and would be replanted if success is not met (Randy Wise, pers. comm). Herbaceous plants were abundant on the wet flats. *Solidago* sp., *Aster vimineus* and *Andropogon virginicus* were observed in drier portions of the flats, with *Juncus* sp. and *Polygonum* sp. in wetter areas.

A network of creeks about 1,400 feet in length were constructed, with dimensions of 3.5 to 4.0 feet at their deepest (in the middle of the channels) and at least 400 feet in width. One of the channels connected the constructed network to Tulls Creek, a sea level controlled creek connected to Currituck Sound via the North Landing River. In late October, water level was high in the creeks and standing water was prevalent on flats adjacent to the constructed creeks. Water level had been so high in the relatively recent past, perhaps a consequence of several hurricanes (esp. Floyd), that juvenile fish were observed in shallow, isolated depressions on flats nearby. Adjoining, undisturbed swamps showed evidence of having been subjected to high winds in that new (green) leaves were growing on otherwise leafless *Nyssa biflora* trees.

Panicum virgatum was prevalent along the edges of the constructed creeks (probably seeded to reduce erosion and provide forage). *Setaria* sp. was also common while *Phragmites australis* was patchily distributed, but dense where it occurred. In some places, we observed that *Taxodium distichum* was colonizing the edges of the constructed creeks. We expect that *T. distichum, Nyssa biflora, Acer rubrum*, and *Liquidambar styraciflua* will eventually colonize the edges of the constructed creeks (available seed sources are nearby). It is curious that there was no plan to plant these species along the creek margins to shorten the length of succession.

The constructed creeks also seemed to support fish. We saw juveniles, but adults may be present as well. A large flock of ducks (teals?) were using the creeks also. Although recently created, the constructed creeks seemed to be developing well. At some point, a fish and invertebrate survey would be useful for quantitatively comparing faunal communities with those in Tulls Creek. Although this portion of the site was created from what may have originally been a wet hardwood flat (prior to conversion to cropland), it will likely be successful in eventually approximating functions of tidal (wind driven) wetlands in the area.

Bogue Sound (Sound Shoal)

County: Carteret
Location: Off Morehead City along the Intercoastal Waterway (ICW).
Size: 6 acres
Year started: 1996
Type of mitigation: Tidal marsh creation

Description of site and its condition:

This mitigation site was located on two islands (from dredge spoil?) on the Intercoastal Waterway (ICW), but we could only locate one of the two sites. The site we observed seems to have been the portion designated as Area A (5 acres). Mesh erosion tubes (biologs) were observed in water 30-40 m from shore on the south side of the island. These biologs were placed in the water to accelerate accretion of sediments, and in so doing, raise the general elevation sufficiently to better support *Spartina alterniflora* (Randy Wise, pers. comm.). At this time, it is too early to tell if the strategy is working on the south side. However, sediment accretion appeared to be occurring on the ICW side of the island; some areas had 6 cm of overlying (new) sediment. *Spartina alterniflora* was in flower during our reconnaissance, so it is thriving where present. In addition, large patches of open flats occurred throughout island; infauna was abundant on these flats. Nearby islands appear to be slightly higher in elevation and dominated by *Juncus roemerianus,* with deep peat in their interiors. This makes them inherently a bit more stable than the dredge spoil islands on which mitigation was conducted. It will likely take quite a while for sufficient peat to develop on the mitigation sites to support *Juncus* marsh. Even so, the mitigation site appeared to be successful both ecologically and relative to permit success criteria where *Spartina* was growing.

Bogue Banks (former Weeks Property)

County: Carteret
Location: Spoil island off Main Channel and ICW southeast of Swansboro.
Size: 4 acres
Year started: 1997
Type of mitigation: Tidal marsh creation.

Description of site and its condition:

The mitigation area was located on the south side of a very large spoil island between a *Juncus roemerianus* marsh and massive spoil pile. Sand was excavated from the spoil pile to reduce its elevation to the level of the adjacent *Juncus* marsh. An artificial channel was dug through the center of the area and connected to a nearby tidal creek. The site was then planted with *Spartina alterniflora*. A narrow strip of marsh/upland ecotone was left on the marsh side of the mitigation area. It is unclear why this area of higher elevation was left intact, except that it may have been left intact because it qualified as a jurisdictional wetland already.

The mitigation is doing poorly. There is a very steep slope on the dune bordering the north side with little to prevent transport of windblown sand onto the site except for some sparsely planted stems of *Uniola paniculata* (sea oats), a silt fence, and a shallow trench (at the north end to collect sand). As a consequence, it appears that spoil sand regularly blows onto the created marsh, raising its elevation (the site has received 30 cm of recent sand accretion). It looks like the mitigation site had been re-excavated at least once since the site was first constructed; vegetation (primarily *Distichlis spicata* and *Spartina alterniflora*) showed less than 50% cover over most of the site.

This mitigation did not appear to be sustainable; no muck horizon or dense root/rhizome mat is present in the soils of the created marsh and it may not be possible to prevent accumulation of sand from the adjacent dune over the long-term. Hurricanes and nor'easters may continue to contribute to accelerated erosion of the dune onto the mitigation site.

Bull Farm

County: Sampson
Location: Adjacent to South River, just south a Parkersburg.
Size: 407 acres
Year started: 1995
Type of mitigation: Mixture of riverine preservation and restoration and non-riverine restoration.

Description of site and its condition:

This complex site consisted of wet mineral soil flats, headwater streams, sandy uplands converted to drained pasture, and a mature cypress-tupelo swamp (on the floodplain of the South River). The intact cypress-tupelo swamp was left as a preservation area. Ditches had been plugged and trees planted on the non-riverine portions of the site to retain more water on-site. In one small area, the top soil (A horizon) had been removed to increase duration of soil saturation near the surface and provide habitat for anadromous fish (Randy Wise, pers. comm.).

Soils (including wet areas) across the site were sandy. Judging by the presence of *Aristida stricta* (wiregrass) on one upland knoll that had not been converted to pasture-land and the presence of sandy soils, it is very likely that the whole area was probably once fire-maintained (wiregrass requires frequent fire to regenerate). Therefore, it would have been more appropriate to have restored these wet flats to fire-maintained ecosystems: wet longleaf and cypress savannas. Upland areas could have been restored to longleaf-wiregrass savanna. Instead, the mitigation plan called for converting most of the wet, non-riverine areas to wet hardwood forest. Now that hardwoods have been planted, it would not be reasonable to manage the site with fire.

Planted trees were 3-4 m tall and there was much of standing water over portions of site, particularly in the excavated area (continuous saturation was probably within 12 inches of the surface for >12.5% of the growing season in such areas). Monitoring data from permanent plots did not differentiate tree survivorship by geomorphic location, so it couldn't be determined, for example, if *Taxodium distichum* had been planted in floodplain areas, on flats, or in both geomorphic locations. The 1998 monitoring report stated that different mixtures of tree seedlings had been planted in each of 3 "planting zones", but these zones did not correspond to the 5 tree mixtures outlined in the mitigation plan. Further, survivorship data (by plots) in the annual report did not indicate where the plots had been placed or which seedling mixture had been planted in the permanent plots. Therefore, it was not possible for us to re-construct what had transpired.

This site is an example of a case where density data by size class, particularly trees taller than 2 m, would have been helpful in better assessing the potential for long-term tree survival. In this site, many of the planted trees appear to be surviving and growing tall (3-4 m) in most areas of the site, suggesting good potential for long-term survival of vegetation. In NCDOT's sampling of planted plots, only one plot (#18) appeared to have not met the 320 stems/acre success criteria. Does this mean that the area represented by that plot should receive remedial attention or is this plot's density ignored because the site average is > 320 stems/acre?

The following tree species were observed in these areas.

Planted tree species surviving:

Fraxinus sp.
Quercus michauxii
Quercus phellos
Quercus lyrata
Liriodendron tulipifera
Platanus occidentalis

Colonizing tree species:

Acer rubrum
Liquidambar styraciflua
Salix sp.
Pinus taeda

Monitoring well data collected by NCDOT showed that 10 and 17 of the 22 wells (1997 and 1998 data respectively) met hydrologic success criteria. This is a case where nearby reference sites could have been monitored to determine reasonable success criteria (i.e., do mitigation site wells track reference site wells?). Of course for this to work in practice, reference sites and well locations would have to be agreed upon by both NCDOT and wetland regulatory personnel.

Casey

County: Currituck
Location: In Sligo just east of the junction of SR34 and SR168 on north side of SR168.
Size: 24 acres
Year started: 1997
Type of mitigation: Creation and restoration (freshwater marsh).

Description of site and its condition:

This mitigation site consisted of both wetland and upland areas. As part of the mitigation, fill had been removed from parts of the site that had formerly been wetland and soil was excavated areas that had formerly been upland; thus, this mitigation constituted both restoration and creation. Because the created marsh was surrounded by uplands with only two narrow outlets (to Cowells and Buckskin Creeks), the marsh was protected from potentially erosive wave action. Even so, some sediment accretion had occurred in the marsh (1-2 cm of sediment was observed at base of monitoring wells), perhaps as the gradients were stabilizing.

The following species were observed in the mitigation area (*****= dominants): *Typha angustifolia****,** *Cladium jamaiciense****,** *Hibiscus macheutos*, *Carex* spp., *Rumex* sp., *Eupatorium capillifolium, Lemna* sp. (floating in channel).

There was also a nearby reference site on the north or river-side of the uplands. This reference marsh was a sea-level controlled freshwater marsh and shrub community. The following species were present in the reference area:

Cladium jamaiciense
Phragmites australis (may need to remove to prevent invasion into mitigation area)
Taxodium distichum
Acer rubrum
Liquidambar styraciflua
Pinus taeda
Myrica cerifera
Vaccinium sp.

Water level in the adjacent creeks and the mitigation area was controlled by wind tides. There appears to be a broad range of elevations (and associated flooding conditions) present at the site; thus, planted and colonizing species will probably sort themselves along the hydroperiod gradient once the substrate stabilizes. *Taxodium distichum* seedlings were observed in the reference marsh, although it doesn't appear that cypress was planted in the mitigation area.

There were quite a large number of monitoring wells on the site. Since the site was sea-level controlled, it seems that only one well was really needed (perhaps 2 could be used if a backup is desired). Although there was a monitoring report available, wells had not yet been installed at the time the report was produced. However, it appeared that the site was doing well and would eventually approximate other tidal wetlands nearby in structure and function.

Collington

County: Dare
Location: On SR1217 west of Kill Devil Hills at two tidal creek crossings.
Size: 1 acre (both sites combined)
Year started: 1995
Type of mitigation: Restoration and creation of tidal marshes

Description of site and its condition:

Eastern area: Filled was removed along the roadside to restore a sea level brackish marsh adjacent to Blount Bay off Currituck Sound. Restoration appears successful. *Spartina alterniflora, S. patens,* and *Juncus roemerianus* are growing in the marsh proper. *Baccharis halimifolia* was thriving at the upland edge near the road.

Western area: Rip-rap was placed between the bay and the roadside mitigation area (presumably to inhibit wave erosion). *Phragmites australis* is re-invading the mitigation area (elevation must not be low enough to receive regular tidal influence). Some *Iva frutescens* and *Juncus roemerianus* are present, but sparse. *Scirpus* sp. shows <10% cover on the site. This western site will require re-mediation to fulfill permit conditions.

Cox Farm

County: Beaufort
Location: Just south of Leachville on SR1712, near the Pungo River.
Size: 2 acres
Year started: 1996
Type of mitigation: Creation (geomorphology altered).

Description of site and its condition:

The topsoil (A horizon) of the site was excavated about 0.5 m and the spoil piled at the far end of site. Vegetation was planted in the remaining portion of the site toward the west end. Shrubs observed on the site, located primarily in the center of the site where it was wetter and had not been excavated, included *Myrica cerifera*, *Baccharis halimifolia*, *Iva frutescens*, *Salix* sp., and *Hibiscus macheutos.*

A soybean field was located on the north side of the mitigation area. A ditch ran along the southern edge of the site and a tide gate was observed at a road culvert on the northwest end of the site where the ditch passed under the road. The eastern end of the site was adjacent to estuarine fringe forest and was located about 75-100 m from a freshwater estuarine marsh on the Pungo River. This suggested that water levels are probably subjected to sea level fluctuations and controlled by wind tides.

The ditch adjacent to the site (on the south side) held water at sea level and so was a conduit for water from the Pungo River. The forest on other side of ditch was intact and could have been used as a reference site for restoration, but there was no indication that this was done. Furthest from the river (at west end), the reference site supported a forested canopy of *Quercus pagoda*, *Quercus nigra*, *Pinus taeda*, and *Liquidambar styraciflua*. *Taxodium distichum* was an important canopy constituent in the back (eastern) half of the reference area (nearest the river), suggesting that the cypress area probably floods for a longer period than the western end of the area.

Juncus effusus was fairly evenly distributed across the site; most had been planted. Other colonizing herbs included *Cicuta maculata, Saururus cernuus, Typha angustifolia, Ptilimnium capillaceum*, *Polygonum pensylvanicum*, *Rubus* sp., *Hydrocotyle* sp., and *Rhus radicans*. *Pontedaria cordata* was located in channels near the tidal ditch.

Seedlings of *Taxodium distichum* and *Fraxinus* spp. occurred throughout the site (planted) and *Pinus taeda* was invading. Planted trees were <1 m tall showed high mortality, particularly in the wettest areas. Poor soil quality (lack of A horizon) is probably responsible for the high mortality. Excavation of soil and proximity of the site to sea level controlled hydrology assured that the site would meet hydrologic success criteria, but this had to be obtained by sacrificing natural soil attributes.

Dismal Swamp

County: Gates and Perquimans
Location: Southeastern end of Dismal Swamp near Nicanor, just north of the Perquimans River
Size: 612 acres
Year started: 1996-1997
Type of mitigation: Primarily restoration, but in many areas the geomorphology had been extensively altered to increase hydroperiod.

Description of site and its condition:

This was a large (612 acres), former agricultural site with only a portion of intact wet hardwood forest remaining in the southwest corner of the site. There was a large soil berm located on the northeast corner of the site, originating as dredge spoil from the Perquimans River and then moved from the western end of the site (Dave Schiller, pers. comm.). Additional soil had been excavated from the western end of the site to allow for overbank flow from the channelized upper reaches of the Perquimans River. The mitigation plan also called for grading "portions of the site ... to enhance hydrologic function" (portions other than the western end were not specified in the plan). We observed that the A horizon throughout the site was in very poor condition or absent, possibly due to past agricultural practices and site preparation. Canals bordered the site on all sides, but all interior ditches had been filled and plugged to restore wetland hydrology. There was a sandy upland knoll near the south-central end of site where *Pinus palustris* had been planted.

Eupatorium capillifolium (dog fennel) and *Gnaphalium obtusifolium* (rabbit tobacco) was very dense throughout the site. This made it impossible to efficiently find many permanent plots in the 600+ acre site. Maps to locate plots were not available.

Taxodium distichum seedlings, a species that rarely occurs naturally in flats, had been planted throughout the site although another cypress species, *Taxodium ascendens* (pond cypress), would have naturally occurred at only the wettest end of the wetness gradient on organic-rich soils and in wet pine savanna. Since this mitigation site was a mineral soil flat (very little available organic matter), we would not expect for it to naturally support bald cypress.

A reference wet hardwood flat occurred in the southwest corner of site. Although it was successional (about 50 years old), it provided an indication of what species one would expect to have find on this site prior to its conversion to agriculture. Species observed in the reference site included:

Canopy:
Acer rubrum
Quercus nigra
Chamaecyparis thyoides
Liriodendron tulipifera

Woody Subcanopy:
Ilex opaca
Clethra alnifolia
Asimina triloba
Itea virginica
Symplocus tinctoria
Magnolia virginiana
Persea borbonia
Sassafras albidum

Herbs:
Woodwardia virginica
Osmunda cinnamomea
Thelypteris palustris

Hydrologic data summarized in the NCDOT 1998 monitoring report showed that many wells either failed to meet or marginally met hydrologic success criteria (success related to year of record). However, the period of record occurred during drought conditions, making long-term predictions problematic. Had mutually agreed-upon reference sites been established nearby, hydrology could have been compared with reference sites to guide success criteria. Excessively dry or wet conditions would theoretically affect both reference sites and the mitigation site similarly. Thus, hydrologic success criteria would be more meaningful if tied to reference conditions rather than an absolute benchmark.

Dowd Dairy Farm

County: Bladen
Location: Southeast of White Oak
Size: 658 acres
Year started: 1999
Type of mitigation: Non-riverine restoration

Description of site and its condition:

This mitigation site was a huge (658 acres), complex tract. It was formerly managed as a dairy farm with pasture, hay fields, and cropland. The land had been leveled (graded), plowed, and compacted, probably during conversion to and operation of the dairy farm. Much of the site was a large-scale, low swale running east to west. Many ditches had been dug throughout the site to drain water from the swale.

Restoration involved plugging ditches (except the largest one along Dowd Dairy Farm Road), infilling of selected ditch segments, creating ephemeral pools and stormwater catchments, scarifying soil, and planting vegetation to restore headwater swamp forest, hydric wet hardwood forest, and upland oak-hickory forest. The small area slated for headwater (riverine) restoration could not be located. Most of the area, to be converted to wet hardwood flat, was evaluated as were limited areas slated for upland restoration.

The entire site was covered with fairly dense with old field vegetation (*Ambrosia artemisiifolia*, *Eupatorium capillifolium, Phytolacca americana, Gnaphalium obtusifolium, Leptilon canadense*, *Chenopodium album*). Other successional herbs included *Ptilimnium capillaceum*, *Setaria* sp., *Rumex crispus*, *Polygonum* spp., and *Rubus* sp. In the area south of the ditch plug, where an interior road crossed the site (near well G27), much planted *Fraxinus* sp. and *Taxodium distichum* had been planted. Some *Rubus* spp. occurred to the east of this area, with a sharp vegetation change to more hydric conditions (perhaps at the break from Torhunta to Johnston soils). *Taxodium distichum* and *Fraxinus* sp. had been planted in this area. *Polygonum* sp., *Setaria* sp., *Panicum* sp., and *Lactuca canadensis* occurred there as well.

On a sandy ridge at the east end of the site (near the canal feeding Ellis Creek), planted trees showed unusually high survival relative to the rest of site. Planted species included:

Quercus falcata	1
Carya sp.	2
Quercus lyrata	13
Quercus alba	2
Liriodendron tulipifera	2
Total	20
Living (stems/acre)	348
Dead	4

At the eastern end of the site, there was what appeared to be natural depression in silty clay soil (dominated by *Polygonum* spp. and *Rumex* sp.). Nearby soil was extremely compacted, but mottled below the A horizon. Two monitoring plots were located nearby. Plot A had much *Campsis radicans* vine invading the plot.

Plot A	
Quercus lyrata	9
Quercus michauxii	7
Quercus phellos	3
Total	19
Living (stems/acre)	331
Dead	5

Plot B	
Fraxinus sp.	4
Quercus phellos	7
Quercus pagoda	2
Quercus pagoda	2
Quercus lyrata	11
Total	24
Living (stems/acre)	418
Dead	4

Note: *Nyssa aquatica* and *Quercus michauxii* were observed just outside of plot B.

This site had been too recently constructed to provide any monitoring data at the time of our field visit. Survival of planted vegetation appeared to be patchy across the mitigation site. Some non-hydric or barely hydric areas had been planted with *Taxodium distichum* and *Nyssa aquatica*. However, natural headwater ecosystems are unlikely to harbor these species because such systems are not wet enough for them to withstand competition from less flood-tolerant trees. Additionally, hydric hardwoods probably did not originally occur on wet flats in this area; rather, wet pine savanna likely covered the site originally. This site is best suited for wet pine savanna restoration, but this would have required planting native bunchgrasses and maintaining a long-term fire regime (by prescribed burning)

Finley McMillan

County: Pender
Location: Northwest of Holly Ridge and east of Holly Shelter Game Lands.
Size: 500 acres
Year started: Purchased as preservation site.
Type of mitigation: Preservation of "pocosin" (but at least some of the site may have been on mineral soil).

Description of site and its condition:

This mitigation site was a long, narrow strip of land (identified as "tall pocosin" preserved within an expansive area of elongated sand ridges with wet swales in between, all of which were comprised of mineral soil. The dry, sandy ridges in the surrounding landscape support pocosin vegetation because the area had not burned recently. *Pinus palustris* (longleaf pine) was also observed on the ridges between draws, suggesting that fires were once common in the past. However, fire has been excluded from the local landscape for so long that pocosin vegetation is now very dense. The whole area, including the preservation site, will probably eventually burn in a catastrophic wildfire if the area is not managed with prescribed burns.

We were not sure if we had located the site. Since the site was located on Croatan Muck, it may have been associated with a channelized stream (this could have been why the parcel was straight and narrow). Other very wet sections observed in this tract supported *Taxodium distichum* (bald cypress). However, even these areas must periodically burn when the surrounding mineral soil longleaf areas burn. Proper management would require prescribed burning where feasible. If adjacent lands are a part of the Holly Shelter Game Lands, then the mitigation site could and should be managed with fire in cooperation with the North Carolina Division of Wildlife Management.

Goshen Swamp

County: Dublin
Location: Just west of Calypso, on north side of new connector road from US117 to I-40.
Size: 91 acres
Year started: 1996
Type of mitigation: Riverine enhancement.

Description of site and its condition:

Approximately 20 transects had been cleared in a 30-acre area and planted with hardwood seedlings (Randy Wise, pers. comm.). The remaining, uncut areas of the site were dominated by *Ligustrum sinense* (privet) and were almost impenetrable. Planted species observed along the transects included *Quercus michauxii, Liriodendron tulipifera,* and *Quercus phellos*.

The 1998 monitoring report showed that for three of the transects, an average of 633 trees/acre were calculated. This suggests that the density of trees over the entire site must have been somewhat less than that (because only a portion of the site had been planted). However, the monitoring report did not explain whether success criteria were negotiated for the entire site (at 320 trees/acre) or just for the cleared and planted transects. Planting trees in transects separated by 10-15 m could be a viable option for enhancing succession to hardwood forest (if seedling survival is adequate) because this strategy could produce a closed canopy upon maturity. Success of this site will ultimately depend upon whether privet can be controlled enough to allow the planted seedlings to mature.

Grimesland

County: Beaufort
Location: Just north of Tar River on the east side of SR1565, adjacent to NCDOT borrow pits.
Size: 550 acres (wetland acreage unknown)
Year started: Planning
Type of mitigation: Restoration and creation of riverine swamp and marsh

Description of site and its condition:

This mitigation site contained numerous borrow pits within the former floodplain of Grindle Creek and Tar River. Some remnant pockets of riverine wetland remained, including an intact portion of floodplain along the former floodway of Grindle Creek. The mitigation plan, not yet implemented, called for removing spoil along the edge of the Grindle Creek wetland and lowering the elevation of the adjacent borrow pit to create a continuous wetland from the floodplain to the borrow pit edge.

Water that used to flow through the mitigation area via Grindle Creek was diverted (via a canal) directly to the Tar River several miles upstream where Grindle Creek was channelized. Most of Grindle Creek's upper reaches have been channelized and so water from Grindle Creek's agricultural watershed now gets shunted directly into the Tar River via the diversion canal, thus bypassing the potential for nutrient assimilation and transformation in the Tar River floodplain where Grindle Creek once intersected it.

It might be productive to determine if wetland functioning could be restored to the lower portion of the Grindle Creek floodplain if all or part of the water that now bypasses the Tar River floodplain were re-routed to flow through the old Grindle Creek channel to the NCDOT mitigation site where it could be processed by floodplain wetlands before entering the Tar River. This could likely provide a substantial water quality benefit to the Tar River and the Pamlico River estuary just downstream. An analysis of the flooding regime would have to be performed to determine how much water the restored floodplain and surrounding land could reasonably accommodate and whether the bridge on Grimesland Bridge Road could handle an increased flow of water under it. If not, perhaps as a future mitigation option, Grindle Creek could be diverted over the Tar River floodplain where it now passes through the floodplain via its artificial channel (upstream from Grimesland).

The following vegetation was observed in the old Grindle Creek floodplain, a mature, floodplain forest. This could serve as a reference site for the proposed restoration.

Canopy:
Taxodium distichum
Nyssa aquatica
Quercus phellos
Acer rubrum
Nyssa biflora
Liquidambar styraciflua
Quercus pagoda
Fraxinus sp.
Quercus laurifolia
Quercus nigra
Ulmus sp.

Woody Subcanopy:
Itea virginica
Carpinus caroliniana
Vaccinium sp.
Magnolia virginiana

Herbs:
Woodwardia virginica
Arundinaria tecta
Boehmeria cylindrica
Carex sp.
Saururus cernuus

Vines:
Parthenocissus quinquefolia
Vitis sp.
Decumaria barbara
Campsis radicans

Gurley

County: Greene
Location: Adjacent to Nahunta Swamp southwest of Snow Hill
Size: 179 acres
Year started: 1997
Type of mitigation: Enhancement, mitigation, and restoration of non-riverine wetlands.

Description of site and its condition:

The Gurley mitigation site was a large, complex site adjacent to Nahunta Swamp Creek southwest of Snow Hill. Part of the mitigation plan was to dam ditches entering Nahunta Swamp in order to back water into the mitigation site and encourage nutrient processing prior to entering Nahunta Creek. The ditch plugs appeared to be effective in detaining water on the former floodplain; standing water was evident upgradient of the ditches. Vegetation in these wet areas consisted mostly of *Betula nigra* and *Acer rubrum* saplings and a dense herb and vine cover. The northwest end of the mitigation site (near well GT1) had been farmed prior to restoration. Old field plants were abundant there, including *Eupatorium capillifolium, Aster ericoides, Isopappus divaricatus, Ptilimnium capillaceum, Allium* sp., and *Campsis radicans*. The following tree seedlings were also observed:

Planted trees:
Fraxinus sp.
Taxodium distichum
Quercus falcata
Nyssa biflora
Quercus lyrata

Colonizing trees:
Acer rubrum
Liquidambar styraciflua (much)
Liriodendron tulipifera

The mitigation plan called for planting an area with *Chamaecyparis thyoides*, but we did not locate this area. We did observe a long line of *Taxodium distichum* along an access road at the north end of the site in a place that may not have been a wetland. Presumably, these were left-over seedlings from plantings.

The ditch plugs appear to be allowing water to get processed by wetlands before entering Nahunta Creek. This should partially compensate for the nutrient processing functions that were lost when Nahunta Creek was channelized. Because the creek had been deeply channelized, it no longer overflows its banks. More of this type of mitigation is needed in the Coastal Plain to restore water quality functions of riverine wetlands.

A relatively intact forest occurred on the opposite side of Nahunta Creek. It supported large trees of *Betula nigra, Liquidambar styraciflua, Acer rubrum,* and *Quercus phellos.* Although canopy vegetation was relatively intact there, hydrology had undoubtedly been altered by the deep channelization of Nahunta Creek. Note: The 3rd ditch plug was getting washed out by Nahunta Creek producing a cutbank where the creek made a slight bend.

Haws Run

County: Onslow
Location: Of SR50 south of Maple Hill.
Size: 600 acres
Year started: 1997?
Type of mitigation: Riverine creation and preservation, wet savanna restoration and preservation.

Description of site and its condition:

This site was a large tract of floodplain forest (along Sandy Creek) and former longleaf pine savanna that was converted to a bison pasture in the early 1970s. Conversion to pastureland was accomplished by clear-cutting the longleaf pine, subsoiling, and extensively ditching the site. Mitigation entailed preserving remnant patches of wet and dry savanna, filling ditches to restore wetland hydrology to former wet savannas, preserving the remnant floodplain forests of Sandy Creek, and attempting to create additional floodplain area by excavating soil from a large area adjacent to the historic floodplain of Sandy Creek.

To create additional floodplain area, from 0.5 to 2.0 m of soil was excavated to lower adjacent land to the same elevation as the Sandy Creek floodplain. In doing so, the A horizon was completely removed. The remaining soil was very sandy and devoid of organic matter. The site was then planted with *Taxodium distichum, Nyssa biflora, Quercus lyrata,* and *Quercus michauxii*. (Land that once occupied the excavated area may have once supported Cypress/Pine Savanna along a transition from Bunchgrass/Pine Savanna to riverine floodplain swamp.)

At the time of our visit, trees were not surviving very well in the excavated area. At groundwater discharge points at the edges of the excavated area, banks were sloughing off (eroding) and migrating headward. Attempts had been made to curb this erosion, but were not successful.

The central portion of the mitigation site (west of the levee) was probably Bunchgrass/Pine Savanna before being converted to pasture land. Ditch filling appears to have restored wetland hydrology. Vegetation, which had been burned at least once, supported many wet savanna indicator plants (see list below). The mitigation plans call for restoring native bunchgrasses and presumably managing with prescribed burns over the long-term. Native bunchgrasses (*Muhlenbergia expansa, Ctenium aromaticum, Aristida stricta, Sporobolis* sp.) were planted in ten 100 foot by 100 foot plots at a density of 4,840 plants per acre..

Remnant wet pine savanna, which had been burned recently, occurred at the southern end of the site. This area was to be preserved and managed (presumably with prescribed burns), as wet pine savanna. Although this parcel was described as preservation, it really is ecological restoration because savanna vegetation could not be maintained without being burned. Additional wet savanna could be restored in flats adjacent to the preservation area if also managed with prescribed burns.

Vegetation in the wet savanna undergoing restoration:

Lachnanthes caroliniana (abundant)
Dichromena colorata
Eupatorium luecolepis
Polygala lutea
Aletris farinosa
Xyris sp.
Coreopsis sp.
Eryngium integrifolium
Rhexia sp.
Rhychospora spp.
Andropogon glaucopsis
Bigelowia nudata

Huskanaw Swamp

County: Martin
Location: On south side of new US64 just north of US13.
Size: 114 acres
Year started: 1997
Type of mitigation: Creation of wet hardwood flat and riverine floodplain**.**

Description of site and its condition:

This mitigation site included altered mineral soil flats (wetland and upland) and altered and intact floodplain forests. The mitigation plan called for restoring both wetland and upland forests on the site. Although the mitigation plan did not call for excavating soil from any areas, we observed two square areas (each approximately 1 acre in size) that appeared to be lower than the surrounding land (we stepped down abruptly when entering the area). These areas seemed to lack an A horizon, although no excavations had occurred on the site (Randy Wise, pers. comm.). The lack of A horizon must have been due to past agricultural activities. The steep drop-off may have been associated with the boundaries of a secondary terrace. However, no survey maps were available to us at the detail or scale required for determining terrace boundaries. Nonetheless, we sampled one of these areas, which had monitoring wells and vegetation monitoring plots located within it.

In order to independently determine tree survival and to demonstrate an alternative way to measure survival, we sampled one area rather intensively. Survival of planted trees were recorded for 2 size classes along with the degree (proportion) of ground layer cover which compete with tree seedlings for light.

We compared our data with monitoring vegetation data collected in 1998. However, we could only compare site averages because we did not have "as built" plans or any maps with which we could locate individual plots and match individual monitoring plot counts with densities provided in the monitoring reports. Also, constants used to convert counts of stems in monitoring plots to density differed for each plot. This is because constants were derived from percent survival based on the initial planting density.

In our sampling, ground layer cover was estimated in a series of five 1 m^2 plots placed in a random, discontinuous transect across a series of 5-m radius (78.5 m^2) plots within which seedling and saplings were counted. In total, seven 5-m radius plots and 35 x 1 m^2 plots were sampled (Table 7). In summary, herbaceous vegetation, especially the vine *Campsis radicans*, was found to be vigorously competing with the planted tree seedlings. In fact, 75% of groundcover was composed of *C. radicans*. It had nearly killed most of the planted trees, particularly those less than 1 m tall. Some types of control may be necessary to prevent further tree seedling mortality.

Naturally higher mortality would be expected for stems <1.5 m tall, less so for stems taller than 1.5 to 2 m. Therefore, if survival is to be used as a criterion for mitigation success, then it would probably be better to base survival on the density of taller individuals (taller than 1.5 or 2 m) because of lower natural mortality expected once a stem becomes sapling sized.

To evaluate current age/size structure of tree species, we differentiated between seedlings (stems < 1 m tall), saplings (stems > 1 m tall), and planted vs. colonizing species. We measured 2,241 live woody stems per acre, 507 of which were planted individuals (Table 8). This was more than the 320 stems/acre required by the permit (thus meeting vegetation survival success criteria); however, only 55 of those 507 stems/acre were > 1 m

Table 7. Herbaceous data (% cover) from 1 m^2 plots in the Huskanaw Swamp compensatory mitigation site. Each tree seedling plot had 5 herb plots associated with it.

Tree Seedling Plot	1					2					3					4		
Herb Plot (1 m^2)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3
Campsis radicans	85.0	85.0	85.0	85.0	85.0	67.5	85.0	85.0	67.5	37.5	85.0	85.0	85.0	85.0	85.0	37.5	50.0	37.5
Andropogon sp.		2.5			2.5	2.5			2.5	15.0		2.5	15.0	15.0	15.0	37.5	37.5	50.0
Ambrosia artemisiifolia	2.5		15.0	2.5	15.0	15.0	15.0	2.5	15.0	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5
Eupatorium capillifolium	2.5		2.5	2.5	2.5	2.5	2.5		2.5	15.0				2.5				
Panicum sp.						2.5		2.5		2.5	2.5				2.5			
Aster ericoides	2.5	15.0			2.5		2.5				2.5	2.5						2.5
Acer rubrum	2.5	2.5	2.5	2.5	2.5		2.5							2.5				
Datura stamonium																		2.5
Erechtites hieracifolia														2.5				
Unknown chickweed										2.5						2.5	2.5	
Unknown legume																2.5	2.5	2.5
Unknown herb																		
Seedlings of trees																		
Carya sp.																		
Quercus phellos									15.0									
Liquidambar styraciflua		2.5					2.5											
Nyssa biflora																		
Pinus taeda							2.5											
Quercus michauxii	2.5																	

Table 7 (continued).

Tree Seedling Plot	4		5					6					7					Mean
Herb Plot (1 m2)	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	Cover
Campsis radicans	67.5	85.0	85.0	85.0	97.5	85.0	50.0	37.5	85.0	85.0	85.0	37.5	85.0	85.0	67.5	85.0	97.5	74.9
Andropogon sp.	37.5	15.0	2.5	2.5	2.5	2.5	37.5	37.5	2.5		15.0			2.5				10.1
Ambrosia artemisiifolia		15.0	2.5		2.5		15.0	2.5	15.0	15.0	15.0	37.5	15.0	15.0	15.0	15.0	15.0	8.5
Eupatorium capillifolium		2.5	2.5	2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5			1.9
Panicum sp.								2.5		2.5	25.0	2.5	2.5	2.5		2.5	2.5	1.6
Aster ericoides	2.5			2.5		2.5				2.5		2.5				2.5	2.5	1.4
Acer rubrum	2.5	2.5								2.5						2.5		0.8
Datura stamonium	2.5														2.5	2.5		0.3
Erechtites hieracifolia														2.5				0.1
Unknown chickweed							2.5											0.3
Unknown legume												2.5						0.3
Unknown herb																2.5		0.1
Seedlings of trees																		
Carya sp.		15.0																0.4
Quercus phellos																		0.4
Liquidambar styraciflua																2.5		0.2
Nyssa biflora		2.5																0.1
Pinus taeda																		0.1
Quercus michauxii																		0.1

Table 8. Woody sapling and seedling data from Huskanaw Swamp. Data collected from 5-m radius plots (78.5 m^2).

Saplings (stems >1 m tall)	Counts (stems/plot)							Density (stems/ha)							Mean	Mean
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	density (ha)	density (acre)
Acer rubrum								0	0	0	0	0	0	0	0	0
Carya sp.								0	0	0	0	0	0	0	0	0
Fraxinus sp.		2		1				0	130	0	127	0	0	0	37	15
Hypericum sp.								0	0	0	0	0	0	0	0	0
Liquidambar styraciflua	38							2,417	0	0	0	0	0	0	345	139
Pinus taeda								0	0	0	0	0	0	0	0	0
Quercus falcata	4	2						254	130	0	0	0	0	0	55	22
Quercus michauxii		1						0	65	0	0	0	0	0	9	4
Quercus phellos	4							254	0	0	0	0	0	0	36	15
															483	195

Seedling (stems <1 m tall)	Counts (stems/plot)							Density (stems/ha)							Mean	Mean
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	density (ha)	density (acre)
Acer rubrum	74	30	14		17	6		4,706	7,638	1,782	0	2,164	764	0	2,436	982
Carya sp.	1	1				2		64	65	0	0	0	255	0	55	22
Fraxinus sp.	1	4		5	2	5	3	64	260	0	637	255	637	382	319	129
Hypericum sp.			1					0	0	127	0	0	0	0	18	7
Liquidambar styraciflua	49	8	6			10	24	3,116	2,037	764	0	0	1,273	3,055	1,464	590
Pinus taeda	2		1					127	0	127	0	0	0	0	36	15
Quercus falcata	1	4	3		8	4	1	64	260	382	0	1,018	509	127	337	136
Quercus michauxii	7	3	3	4	3		3	445	195	382	509	382	0	382	328	132
Quercus phellos	1	2	1		2			64	130	127	0	255	0	0	82	33
															5,075	2,047

Density (stems/acre)	Saplings (> 1m tall)	Seedlings (< 1 m tall)	**Total**	
Planted	55	452	**507**	Planted
Volunteers	139	1,595	**1,734**	Volunteers
Total	195	2,047	**2,241**	Grand total

tall. We suspect that most of the stems <1 m tall (452 stems/acre) are unlikely to survive much longer (many are barely alive now), even though they may survive through the required 3-year monitoring period. In contrast, most of the planted saplings (and colonizing species), i.e., those > 1 m tall, will be more likely to out-compete the dense vines (primarily *Campsis radicans*) and survive to become canopy trees.

Hydrologic conditions determined by monitoring well data showed failure in hydrologic success at the time of our sampling. However, this success criterion was based on an absolute benchmark defined by jurisdictional wetland criteria rather than conditions in a nearby reference area. As such, drought conditions could result in failure to meet success criteria even if site conditions are similar to nearby natural wetlands of the same type.

Kerr Avenue

County: New Hanover
Location: Adjacent to sewer line right-of-way, east of Smith Creek, between Reed St. and Faircloth Rd.
Size: 48 acres
Year started: Acquired
Type of mitigation: Tidal swamp preservation

Description of site and its condition:

This site was a preserved tidal freshwater swamp dominated by *Taxodium distichum* and *Nyssa aquatica*. Other woody vegetation included *Fraxinus* sp., *Nyssa biflora, Alnus serrulata,* and *Cyrilla racemiflora*

Lengyel

County: Craven
Location: In New Bern at base of new Neuse River bridge crossing on south side.
Size: 12 acres
Year started: 1998
Type of mitigation: Restoration and creation of tidal fringe and backswamp marsh/swamp complex.

Description of site and its condition:

This mitigation site was located along the Neuse River estuary near New Bern, where salinity is probably slightly brackish (about 1-2 ppt). Hydrology is probably dominated by estuarine wind tides and precipitation. A tidal creek had been constructed (created) to allow water from the estuary to flow into the mitigation site. Many small fish and blue crabs were observed in this tidal creek (they all must have entered through a breach in plug at the creek's mouth). Not much submerged aquatic vegetation (SAV) had colonized the creek yet, but extensive mud flats were present along the creek's margin. It seems likely that this creek and adjacent flats and wetlands will eventually be densely colonized by wetland plants.

Because the constructed creek has no trees to shade, water temperatures in the shallow creek may get quite high in summer. Also there was no coarse woody debris (CWD) in the creek to provide habitat for fauna.

The substrate of the whole site was composed of medium-grained sands low in organic matter. The mitigation plan called for potentially fertilizing the site if the substrate proved to be low in organics and nutrients. The mitigation plan also called for planting *Spartina cynosuroides* and *Juncus roemerianus*. Randy Wise later confirmed that *S. cynosuroides* had been planted and was also naturally colonizing, Randy Wise, pers. comm.). No success criteria for vegetation cover were provided in the plan, but wetland vegetation was observed to be colonizing throughout the site (see list below).

Vegetation located along the constructed creek and depressional margins:

Scirpus americanus
Typha sp.
Ptilimnium capillaceum
Juncus sp.
Leersia sp.
Hydrocotyle sp.
Ludwigia palustris
Spartina cynosuroides
Cyperus sp.

Elsewhere on flats:

Verbena sp.
Baccharis halimifolia
Salix sp.
Iva frutescens
Pluchea camphorata
Hibiscus macheutos
Echinochloa walteri
Rumex crispus
Polygonum sp.

Along storm levee on Neuse River shoreline:

Platanus occidentalis
Carya aquatica
Morus rubra

No monitoring well data were available, but overall, the site appears to be functioning well. A new creek channel is forming from the constructed one, probably by water draining following nor'easters. We observed that high water extends very close to the elevation of the road (this may flood the ramp to the bridge during nor'easters).

We suggest that *Taxodium distichum* and *Nyssa aquatica* be planted along the creek edge to provide shade (cool water) and help stabilize its banks. CWD should also be introduced into the creek. (Nearby unaltered reference sites could supply information on sizes and quantity of CWD needed.)

Little McQueen

County: Robeson
Location: Along the Lumbar River southeast of Proctorville
Size: 880 acres
Year started: Purchased around 1997.
Type of mitigation: Preservation of riverine floodplain

Description of site and its condition:

This mitigation site was a large preservation area of floodplain forest along the Lumbar River. It borders a state park. Observed floodplain vegetation included the following:

Woody Vegetation:
Quercus michauxii
Quercus laurifolia
Liquidambar styraciflua
Acer rubrum
Quercus nigra
Cyrilla racemiflora
Persea borbonia
Ilex verticillata

Long Swamp

County: Hoke
Location: Between SR1105 and SR 1108 southwest of Duffies.
Size: 220 acres
Year started: 1998
Type of mitigation: Restoration and preservation of riverine and non-riverine wetlands.

Description of site and its condition:

This site (100 acres, mostly hydric) was described as the headwater area of Long Swamp Creek. Several Carolina bays (one large one) are located within the site. Upgradient from SR1108, Long Swamp had been ditched and used as agricultural land and as pine plantation. This area formerly consisted of Carolina bays, wet mineral soil pine flats, and headwater areas. It is unlikely that any of the headwater areas north of SR1108 would have had defined channels prior to conversion.

Restoration of the site was to include plugging and filling ditches, constructing flashboard risers, "scarifying" the soil, spreading CWD throughout, and planting trees. The flashboard risers were to be placed on the site so that water levels could be experimentally manipulated to determine the optimal height before replacing them with permanent ditch plugs. Presumably, vegetation would not be planted in areas affected by the risers until after the ideal height had been determined.

The mitigation plan also made use of reference data from nearby sites to direct vegetation restoration, except that *Taxodium distichum* was planted in inappropriate areas (former flats, bays, and headwater areas); rather, *T. ascendens* would have been more appropriate in flats and the Carolina bay.

At the far northern end of the site (a field south of SR1105), weak mottling was present in the soil and herbaceous vegetation consisted mostly of common old field species such as *Eupatorium capillifolium*, *Ambrosia artemisiifolia*, *Desmodium* sp. Planted trees in this flat included *Quercus falcata* and *Quercus michauxii*. In a monitoring nearby plot, the following survival data were recorded:

Quercus michauxii	16
Quercus falcata	7
Quercus lyrata	5
Total	28
Living (stems/acre)	487
Dead	6

A 20 year-old pine plantation occurred in the old Carolina bay north of the power line right-of-way. Several rectangular areas of pines had been clear-cut from the plantation. Soil examined in one of the clear-cut areas (near well PZ-8) was a dark, sandy loam. It didn't appear that much had been planted in these areas, except an occasional *Taxodium distichum.* Other vegetation included:

Woody plants (seedlings):
- *Acer rubrum*
- *Platanus occidentalis*
- *Fraxinus* sp.
- *Liriodendron tulipifera*
- *Magnolia virginiana*

Herbs:

Rhynchospora corniculata
Rhexia sp.
Cicuta maculata
Hypericum sp.
Carex spp.
Erechtites hiercifolium
Rubus sp.
Panicum sp.

In the Carolina bay to the south of the power line, the area had recently burned. (It probably naturally burned historically, before conversion to agriculture.) Vegetation there included:

Canopy (a few surviving trees only):

Nyssa biflora

Woody Subcanopy*:*

Persea borbonia
Gordonia lasianthus
Baccharis halimifolia
Cyrilla racemiflora
Vaccinium sp.
Sorbus arbutifolia

Herbs:

Phytolacca americana
Erechtites hieracifolia
Eupatorium capillifolium

Planted tree seedlings:

Taxodium distichum
Quercus michauxii
Quercus phellos

A relatively intact headwater system was located south of SR1108 where it progressed from an undefined channel to a shallow (30 cm deep), 2-m wide channel. (The floodplain was only 15-20 m wide at this most downstream point.) The vegetation in the intact headwater area included:

Canopy:

Nyssa biflora
Quercus laurifolia (large trees!)

Quercus pagoda
Liquidambar styraciflua
Quercus alba
Liriodendron tulipifera
Acer rubrum

Woody Subcanopy:
Itea virginica
Magnolia virginiana
Clethra alnifolia
Persea borbonia
Ligustrum sinense

Herbs:
Woodwardia virginica
Arundinaria tecta
Boehmeria cylindrica
Smilax rotundifolia
Vitis sp.
Mikania scandens
Pluchea foetida

This site must still be undergoing restoration activities (manipulating flashboard riser heights, etc.). The overall conceptual plan is reasonable, particularly regarding hydrologic restoration. However, wet flats and Carolina bays probably would have been more appropriately restored to fire-maintained pine savanna.

Mann's Harbor

County: Dare
Location: On the west side of SR1105 about 0.25 miles before the end of the road.
Size: 2 acres
Year started: 1995
Type of mitigation: Brackish marsh restoration.

Description of site and its condition:

The substrate was very sandy. Dead *Juncus roemerianus* was everywhere, likely killed by herbicide while trying to eradicate *Phragmites australis* (common reed), an invasive exotic. However, *P. australis* still persisted in great profusion. *Panicum virgatum* (a native plant) was also persisting, but cover was low. Elevation may be 20 cm or so too high, thus giving *P. australis* a competitive advantage over more salt-tolerant native plants. Remediation may be required although success criteria did not specify that *Phragmites* not be included in cover determination.

Mashoes Road

County: Dare
Location: Between Mann's Point and Redstone Point, just north of US64 on Currituck Sound.
Size: 399 acres
Year started: Under construction
Type of mitigation: Brackish marsh restoration and preservation east of road, wet hardwood flat creation west of road.

Description of site and its condition:

This site was an attempt to restore coastal marsh (east side of Mashoes Road) and wet hardwood forest (west of road) from old sand pits. The substrate was very sandy (may have been material used to fill sand pits). Soil does not seem conducive to tree growth due to lack of organic matter and nutrients.

Only the west side of road had been planted at the time of our visit (plantings included *Fraxinus* sp. and *Taxodium distichum). Panicum virgatum* occurred on the east side of the road, but much *Phragmites australis* occurred there as well. *P. australis* may become a problem if not eradicated before vegetation is planted. Organic material and/or fertilizer may be needed to establish and sustain planted vegetation. Site was too recently constructed to provide any hydrologic data.

Mildred Woods

County: Edgecombe
Location: Just southeast of Tarboro, on both sides of the new US64 (a borrow pit occurs on the western end of the site south of US64).
Size: Approximately 618 acres (593 acres of wetlands).
Year started: 1995

Type of mitigation: Restoration, preservation.

Description of site and its condition:

The Mildred Woods mitigation site was very complex. It included a part of a Carolina bay in the southeast portion, a remnant wet hardwood flat in the northwest portion, a sandy ridge in the north-central portion of the site, and degraded flats (both hydric and non-hydric) throughout most of the remainder of the site. Ditches on the site were plugged and filled in 1995 and tree seedlings were planted in 1996 throughout the site. The 1998 monitoring report showed the location of 43 wells on site, but at the time we examined the site, many wells had been removed, others had been placed in new locations, and some had been re-numbered. Thus, in many cases, we couldn't match well data with locations. For example,

Well 33 was labeled MW23;
Well model S3175BO had no number and was not identified on map;
Well 15 was labeled MW19;
Well at north edge of Carolina Bay labeled MW20 (S31F789) was not on map;
Well S3174D4 was labeled MW-19;
Well 27 was labeled MW37;
Wells MW-9 and MW-10 were not at the mapped locations;
Well 42 was labeled MW-14;
Wells at location 39 and 40 had no numbers;
Well 18 was labeled MW20 (S31F789);
Well at well position 7 had no number.

Taxodium distichum and other trees were planted along the edge of the Carolina bay, but only *T. distichum* is surviving there. It would have been more appropriate to plant *T. ascendens* because this species is the one native to flats and depressions (*T. distichum* occurs on floodplains of 3rd order and higher streams and sea-level influenced systems). Planted seedlings observed in the flats included *Quercus phellos*, *Q. pagoda*, *Q. michauxii*, *Liquidambar styraciflua*, and *Fraxinus* sp. *Pinus palustris* was planted on the sandy ridge.

The following canopy species occurred in the remnant wet hardwood flat (preservation area) located at the eastern end of the site, north of US64: *Quercus michauxii*, *Liquidambar styraciflua*, *Liriodendron tulipifera*, and *Acer rubrum.* *Arundinaria tecta* was prevalent in the understory.

We did not have the resources or time to independently verify hydrologic success, but it appeared that planted trees were surviving well. Vegetation plots were not mapped on mitigation plans or the 1998 annual report, so we could not have matched plot counts.

Pea Island (Interdune Swale)

County: Dare
Location: On west side of SR12 on Pea Island NWR north of Rodanthe.
Size: 53 acres
Year started: 1995
Type of mitigation: Creation of interdune swale wetland.

Description of site and its condition:

This mitigation was required for relocating SR12 westward (to avoid future ocean washovers during storms). The mitigation was meant to replicate an interdune swale, but at a scale much larger than that which occurs naturally. A large area (53 acres) was excavated to a lower elevation in order to bring the ground surface elevation closer to the underlying water table.

Soil was a coarse sand with no A horizon. One vegetation plot near the road had < 50% cover. Another plot near well PI-5 had < 50% cover and appeared to regularly flood about 0.5 m deep. Vegetation cover was generally > 50% in the deepest sections of the site.

Abrupt (sharp) elevation gradients occur at wetland/upland boundaries where soil had been excavated. Thus, the present condition is unlikely to persist for long; sand will probably eventually be transported (with storms/wind) into the swale, which in turn will reduce the total wetland area somewhat. Eventually, the site will evolve to a more natural and sustainable condition. Barrier island morphology is inherently unstable and so the created swale is unlikely to persist as a large, contiguous site indefinitely. Sooner or later a storm surge will redistribute sand across the site.

Since success criteria required 50% survival rate for planted vegetation, as indicated in the monitoring report, there was no way to verify survival because planting density was not available. However, cover appeared to be < 50% over most of the site.

Species observed in the constructed swale:

Juncus sp.
Scirpus spp. (*S. americanus, S. robustus*)
Pluchea camphorata (abundant)
Agrostemma glithago

Pembroke Creek

County: Chowan
Location: Just west of Edenton and Pembroke Creek bridge on north side of U.S. 17.
Size: 10 acres
Year started: 1997
Type of mitigation: Restoration of tidal forest (fill removed).

Description of site and its condition:

This site was located adjacent to a floodplain forest along Pembroke Creek, a freshwater, sea-level influenced system. The mitigation plan called for removing fill adjacent to the roadside and planting the site with wetland tree species. A mucky A horizon was intact and variations in microtopography had been created throughout site. Deeper micro-depressions were vegetated with *Typha* spp. and were probably too wet to grow trees, particularly less flood-tolerant oaks. Because the site is sea level-controlled, its hydrologic regime should be sufficient to maintain wetland conditions. The site will probably eventually revert to a Cypress/Tupelo swamp similar to an adjacent reference area (see species list below).

Other (colonizing) species observed in the mitigation area included *Acer rubrum, Ambrosia artemisiifolia, Ptilimnium capillaceum, Cyperus* spp., *Juncus* spp., *Osmunda regalis, Eupatorium capillifolium, Typha* spp., and *Sagittaria* spp..

The adjacent, relatively intact reference forest contained the following species:

Trees:
Acer rubrum
Fraxinus spp.
Nyssa aquatica
Salix sp.
Taxodium distichum

Woody Subcanopy:
Itea virginica
Myrica cerifera
Alnus serrulata

Herbs:
Osmunda regalis
Boehmeria cylindrica
Saururus cernuus
Thelypteris palustris
Hypericum sp.

Hydrologic monitoring had not begun at the time of our site visit, but it appeared that the site was sufficiently wet to meet negotiated success criteria. The site's proximity to sea-level controlled Pembroke Creek will probably insure relatively reliable hydrology.

Pridgen Flats

County: Sampson
Location: South of Kerr between SR1007 SR1105.
Size: 117 acres
Year started: 1992?
Type of mitigation: Pocosin restoration?

Description of site and its condition:

This mitigation site was one of the first mitigation sites developed by NCDOT. It is a portion of a mineral soil Carolina bay that was ditched and clear-cut to grow crops, but was abandoned after crop production failed. An historical reference area was stated to have supported *Pinus palustris, Pinus serotina,* and a dense layer of pocosin shrubs, suggesting that the whole area once burned frequently. The abundance of pocosin vegetation was undoubtedly an artifact of fire-exclusion. The area now superficially resembles a pocosin peatland because pocosin vegetation proliferates following fire-exclusion. Before fire-exclusion, the site probably more resembled a wet pine savanna and burned frequently at a 1-5 year return interval.

Some indicator wet savanna plants still persisted in a relatively open area near SR1105 (*Rhexia* sp., *Eriocaulon* spp., and *Polygala lutea*). Also, *Aristida stricta* (wiregrass) and *Quercus laevis* were observed along sand ridge bordering the bay (both species require periodic fire). Low areas within the Carolina bay proper had about 35 cm of sand overlying a hardpan. Species in these areas included: *Eupatorium luecolepis, Andropogon glaucopsis, Eriocaulon decangulare, Rubus* sp., *Sphagnum* sp., and

Baccharis halimifolia.

To restore the area, flashboard risers were placed in the ditches and the site was sparsely planted with pocosin vegetation. The area is densely vegetated now, making it difficult to tell where pocosin shrubs were planted (pocosin shrubs would have invaded quickly without planting). Vegetation observed in the planted areas included:

Andropogon glaucopsis
Hypericum sp.
Juncus sp.
Dicanthelium sp.
Vaccinium sp.
Cyrilla racemiflora
Diospyros virginiana
Magnolia virginiana
Gordonia lasianthus
Ilex glabra
Persea borbonia
Kalmia angustifolia
Zenobia pulverulenta

The site seemed very dry at the time of our site visit (mid-summer), a time of year one should reasonably expect the site to be dry. However, ditches may have been constructed so deep as to break through the hardpan underlying the site, thus draining the site. This possibility should be explored more thoroughly.

Restoration to wet pine savanna would require planting native bunchgrasses and managing with prescribed burns. If not managed with prescribed burns, the site will eventually burn catastrophically in a wildfire.

Seven Springs

County: Wayne
Location: In Bogue Marsh adjacent and partially within the floodplain of Neuse River northwest of Seven Springs
Size: 27 acres
Year started: 1993
Type of mitigation: Riverine restoration.

Description of site and its condition:

This mitigation site was a former agricultural field on the Neuse River floodplain. The mitigation plan was designed to restore riverine floodplain forest by planting the site with hydric hardwoods.

Juncus sp. and *Solanum* sp. were abundant in a low, wet area toward the southwest corner of the site. A higher elevation area in the middle of site (on west side of access road) was planted with mixed hardwoods (see list below). *Taxodium distichum, Quercus michauxii,* and *Quercus nigra* were planted in the southeast end of the site near the remnant Neuse River floodplain forest. Many *Taxodium distichum* seedlings had been planted in the northeast section. It seemed that *Taxodium distichum* was planted far from the floodplain, further than it seemed it would have naturally occurred.

Trees throughout the site are growing well and are quite tall (> 2 m), especially *Platanus occidentalis*. It appears that vegetation restoration has been successful.

This was the only mitigation site for which seedling height was recorded during vegetation monitoring. Height data are useful because taller (usually older) saplings are more likely to survive over the long-term than smaller seedlings (for which mortality rates are often high).

The following planted species were observed in the site:

On the northwest end, planted trees were fairly tall (2-3 m):

Quercus pagoda
Quercus lyrata
Quercus phellos
Nyssa biflora
Platanus occidentalis (abundant and tall)

Herbs:
Hypericum sp.
Eupatorium capillifolium
Rubus sp.
Rhexia sp.
Boehmeria cylindrica
Juncus sp.
Panicum sp.

No hydrologic data were available to us for this site. However, there did not appear to have been any hydrologic alterations to the site.

Spring Branch Creek

County: New Hanover
Location: Along Spring Branch in Wilmington at the northwest corner of SR132 and Smith Creek Parkway (new connector road).
Size: 11 acres
Year started: 1997
Type of mitigation: Riverine creation.

Description of site and its condition:

Spring Branch was a re-constructed creek section adjacent to a new, 4 lane connector road (Smith Creek Parkway). The re-aligned stream crosses under the parkway and meanders through an excavated floodplain among several constructed depressions. Because massive re-working of soil was necessary to construct this site, soil lacked a well-developed A-horizon.

Depressional areas were dominated by *Typha* spp. and other flood-tolerant herbs (see partial list below). The creek bank and levee (0.5-1.0 m high) was covered with a fibrous mat designed to keep the bank in place while vegetation takes hold. The creek was forming a new channel in places. Several washouts were located in the levee between where the creek exited from under the road and about 30 m downstream. Vegetative growth was dense throughout the site and native vegetation was invading the site, including *Salix* spp. Restoration of vegetation appeared to have been successful. Geomorphology will likely stabilize after the creek reconfigures itself. However, future urbanization upstream, and the proliferation of impervious surfaces, may prevent a stable geomorphology from becoming established.

Species observed in depressions:
- *Typha* sp.
- *Ptilimnium capillaceum*
- *Sparganium* sp.
- *Myriophyllum brasiliense*
- *Sagittaria* sp.

Species observed in other areas on the floodplain:
- *Juncus* sp.
- *Polygonum* spp.
- *Mikania scandens*
- *Ipomoea lacunosa*
- *Verbena* sp.

Planted trees observed on the site(some of which were protected by tubes):
- *Nyssa aquatica*
- *Taxodium distichum*
- *Fraxinus* sp.
- *Quercus lyrata*

Thorofare Bay

County: Carteret
Location: On north and south side of bridge crossing Thorofare Bay on SR12.
Size: 2 acres
Year started: 1995
Type of mitigation: Tidal marsh restoration.

Description of site and its condition:

Roadside spoil was removed to restore wetland hydrology and then the site was planted with *Juncus roemerianus* and *Spartina alterniflora*. The elevation appeared to be correct for long-term stability. The site was well vegetated with *Spartina alterniflora* and *Spartina cynosuroides* at the margins (at ecotone with uplands). Wrack deposition had occurred on site (similar to natural reference sites nearby) and fiddler crabs were abundant. In time, the site will probably revert to a *Juncus roemerianus* dominated marsh.

Phragmites australis occurred in a small area within the western mitigation area; NCDOT may need to monitor this and takes steps to eradicate *Phragmites* should it begin to spread.

Vegetation:
Spartina alterniflora (dense)
Spartina cynosuroides
Spartina patens
Distichlis spicata
Salicornia sp.
Juncus roemerianus
Phragmites australis (at northwest side of bridge)
Baccharis halimifolia
Iva frutescens

Tucker

County: Currituck
Location: Just east of Sligo and Casey mitigation site on south side of SR168
Size: 37 acres
Year started: 1998
Type of mitigation: Creation of primarily wet hardwood flat. Removal of about 40 cm of soil to increase duration of saturation.

Description of site and its condition:

The site appeared to have been geomorphically modified (excavated) about 35-100 cm to create hydrology for a wet hardwood flat. A remnant patch of headwater forest, located at back portion of site, was not modified. Mitigation plans called for filling on-site ditches with material removed from higher elevations on the site.

Deep ruts, due to the use of heavy equipment during wet conditions, were present throughout the site. Soil in the site was very sandy (relatively sterile) with little or no organic matter. Planted trees were not surviving in many locations. Counts of surviving trees planted in five 50' x 50' monitoring plots are provided in Table 9. Counts were also made in random 5-m radius plots throughout the site. Trees in many places appeared stressed with much leave die-back. Only one of the five monitoring plots and three of the six random circular plots met the success criteria of 320 trees/acre after one year. It appears that perhaps as much as half of the site is too wet for trees to survive. Excavated topsoils and proximity to sea level flooding (by fresh water) probably both contribute to the poor survival of planted trees.

Table 9. Density data from monitoring plots and randomly placed 5-m radius circular plots at Tucker site.

	Plot 1 (NW corner)	Plot 2 (North-central)	Plot 3 (NE corner)	Plot 4 (East-central)	Plot 5 (South portion)	
Quercus lyrata	6			5		
Quercus michauxii		1	1	3	1	
Quercus phellos	4	1	6	11		
Quercus sp.			1			
Fraxinus sp.	7	1	8	9	3	
Taxodium distichum	8					
TOTAL survivors	15	3	16	28	4	
	Random 5-m radius plots					
	R1	R2	R3	R4	R5	R6
Quercus lyrata	4	4		1	3	1
Quercus phellos		3	1			
Quercus sp.						
Fraxinus sp.	2	4	2	3	4	2
Taxodium distichum	1	2		1	2	2
TOTAL survivors	7	13	3	5	9	5
TOTAL density/ha	891	1,655	382	637	1,146	637
TOTAL density/acre	359	667	154	257	462	257
Acer rubrum	7	13	1	4		
Salix sp.			1			
TOTAL seedlings	7	13	5	9	9	5
TOTAL density/ha	891	1,655	637	1,146	1,146	637

Colonizing herbs:
Ptilimnium capillaceum
Juncus effusus
Eleocharis sp.
Panicum virgatum
Polygonum sp.

Observed in intact forested wetland (headwater system):
Acer rubrum
Liquidambar styraciflua
Fraxinus sp.
Populus deltoides
Pinus taeda

It is unlikely that this site will meet success criteria for vegetation without fertilization and/or control of flooding.

U-92D

County: New Hanover
Location: At southeast corner of intersection of SR132 and Smith Creek Parkway (new connector) in Wilmington.
Size: 5 acres
Year started: 1996
Type of mitigation: Riverine restoration

Description of site and its condition:

This mitigation site was along the outer edge of the Spring Branch floodplain. Vegetation was dense and doing well. Planted *Fraxinus* sp. was already taller than 2 m. Mostly native plants were present within the site; however, *Sapium sebiferum* was invading the site along the roadside and could invade the mitigation area as well if not eradicated.

Planted trees:
Fraxinus sp. (> 2 m tall)
Liriodendron tulipifera
Pinus taeda
Quercus pagoda
Quercus phellos
Quercus lyrata
Liquidambar styraciflua
Betula nigra

Shrubs:
Baccharis halimifolia
Myrica cerifera

Herbs:
Ptilimnium capillaceum .
Verbena sp.
Carex crinita
Juncus sp.
Cyperus sp

USMC Marsh

County: Onslow
Location: Adjacent to Intercoastal Waterway (ICW) on Camp LeJuene marine base, just north of Salliers Bay.
Size: 4 acres
Year started: 1998?
Type of mitigation: Tidal marsh restoration.

Description of site and its condition:

This mitigation site had been fairly recently constructed. It was formerly a marsh on which fill had been placed to support buildings and a staging area. To restore the site, fill was excavated to lower the elevation to that of an adjacent *Juncus roemerianus* marsh. *Spartina alterniflora* was planted throughout. Also, a "U-shaped" artificial inlet was built to shunt water from the Intercoastal Waterway (ICW) into the created marsh.

Soil throughout the site was pure sand; no organic matter was present. The adjacent *Juncus roemerianus* marsh had a thick peat layer, a condition that would be impossible to restore in the mitigation area within the time frame of monitoring.

It appears that the elevation of the marsh surface had been incorrectly established (too high) because planted vegetation had died en mass. In addition, one edge (bank) of the artificial creek was eroding at its junction with the ICW. Only a few shrubs were surviving in the transition zone (*Baccharis halimifolia, Iva frutescens, Myrica cerifera*) along with some *Echinochloa walteri;* the rest of the area was relatively barren.

Whalebone Junction

County: Dare
Location: In median at junction of US158 and SR12 in Nags Head.
Size: 1 acre
Year started: 199?
Type of mitigation: Creation of an interdune swale wetland.

Description of site and its condition:

The Whalebone Junction site was a small median strip where two roads intersect on the Outer Banks. The soil was very sandy with a 0.5 cm thick A horizon. Vegetative cover was > 80% (see species list below). The mitigation replicated an interdune swale wetland, a type common on barrier islands. Thus, it is a reasonable type of restoration for the location. Restoration appeared successful.

The following species were present in the swale:

Juncus roemerianus
Juncus effusus
Spartina patens
Solidago sp.
Distichlis spicata
Scirpus americanus
Setaria viridis
Borrichia frutescens
Dichromena sp.
Baccharis halimifolia
Myrica pensylvanicum
Iva frutescens
Rhexia sp.
Rumex sp.

Characterization of Piedmont and Blue Ridge Sites (in alphabetical order)

Blue

County: Moore
Location: Along Little River south of Vass and east of US1.
Size: 180 acres
Year started: 1999
Type of mitigation: Riverine preservation.

Description of site and its condition:

Some of this mitigation site had been clear-cut; other areas were intact. The intact area was a slope wetland with much *Chamaecyparis thyoides* (Atlantic white cedar) in places. The area that had been recently clear-cut (during Spring 1999) had little herb re-growth, stump sprouts were numerous, and *Smilax* spp. were just beginning to invade. Soil in the cut-over area was mottled at 12" depth, indicating frequent long-term saturation, typical of slope wetlands. Some *Chamaecyparis* were left standing as was one very large (1.5 to 2.0 m dbh) *Taxodium distichum*. A large *Quercus laurifolia* next to the cypress was also spared.

Uncut area near creek:

Woody species:
- *Fraxinus* sp.
- *Nyssa biflora*
- *Liquidambar styraciflua*
- *Acer rubrum*
- *Quercus laurifolia*
- *Diospyros virginiana*
- *Ilex opaca*
- *Itea virginica*
- *Magnolia virginiana*
- *Cyrilla racemiflora*
- *Viburnum nudum*

Herbs:
- *Panicum* sp.
- *Boehmeria cylindrica*
- *Rhus radicans*
- *Smilax rotundifolia*
- *Eupatorium leucolepis*

Vegetation in clear-cut area:
Woody species (mostly stump sprouts):
Quercus phellos
Acer rubrum
Liquidambar styraciflua
Nyssa biflora
Quercus laurifolia
Ilex opaca

Herbs:
Woodwardia virginica
Carex spp.
Erechtites hieracifolia

Bryan Boulevard Extension (Horsepen Creek)

County: Guilford
Location: Along Horsepen Creek on north side of Byran Boulevard and east of SR 2136.
Size: 11 acres
Year started: 1997
Type of mitigation: Non-riverine restoration and preservation.

Description of site and its condition:

This mitigation site included (1) an area of remnant forested wetland near Horsepen Creek and (2) an area that was excavated to increase period of soil saturation and planted with tree seedlings. No A horizon remained in the excavated area.

Water at the eastern end of the site used to flow directly into Horsepen Creek via a ditch, but was being partially diverted westward into the mitigation site by a constructed drainage-way, presumably to increase water retention time in the site. Another ditch originated from a culvert under Byran Boulevard contributed water to the western end of the site. In addition, the site may occasionally receive water from overbank flow from Horsepen Creek, located on the north of site.

The site varied in elevation and vegetation reflected this variation. In more elevated spots, *Lespedeza* sp. was abundant. In lower (wetter) areas, *Typha* sp., *Leersia* sp., and *Juncus* spp. were more prevalent (see more comprehensive species list below). Trees, many of them with protective tubes, appeared to be surviving well throughout the site, including *Quercus michauxii*, *Q. nigra*, *Q. lyrata*, and *Fraxinus pennsyvanica*.

Vegetation observed in lower (wetter) spots:

Leersia sp.
Juncus sp.
Typha sp.
Cicuta maculata
Impatiens capensis
Tradescantia virginiana
Lobelia cardinalis
Cephalanthus occidentalis

There was a relatively intact forest on north side of the mitigation site, adjacent to Horsepen Creek. Soils had a depleted matrix and were very red-orange in color. The forest also had numerous snags, abundant CWD, and wrack transported by overbank flow from Horsepen Creek. This intact forest was to be preserved as floodplain forest according to the mitigation plan.

Wells labeled 116 and 113 were located in within intact floodplain forest. Neither of these numbers corresponded with the map of wells provided in the 1998 monitoring report for the site. We assumed that these wells are being used to compare hydrology in the intact forest with that in the restored area.

Vegetation in reference area:

Woody species:
Fraxinus sp. (overwhelmingly dominant)
Acer rubrum
Acer negundo
Juglans nigra
Diospyros virginiana

Herbs:
Glyceria striata
Boehmeria cylindrica
Aster sp.
Impatiens capensis
Viola sp.
Cryptotaemia canadensis

There was no monitoring report available for this site, but considering the amount of standing water on-site, it appeared that hydrology would probably meet negotiated success criteria.

Bryan Boulevard Extension (Oak Ridge Road)

County: Guilford
Location: In northwest Greensboro on north side of SR2137 and on west side of Bryan extension.
Size: 1 acre
Year started: 1996
Type of mitigation: Non-riverine creation.

Description of site and its condition:

This mitigation site was located alongside a highway (Oak Ridge) at the bottom of a steep embankment. Runoff from the highway was diverted into the eastern end of the site and now flows westward through the site to eventually enter Brush Creek at the western end (an unnamed creek also enters the site at the eastern end). An earthen sill (low dam) was constructed to hold back water before entering Brush Creek. This sill appeared to extend the duration of soil saturation in the western end of the mitigation area.

A private drive crossed the site at the eastern one third of the site. Before entering Brush Creek, water must pass through a culvert under this drive and flow along a concrete raceway. Site remediation was conducted in 1998 to raise water in the section located to the east side of the private drive because that section apparently was not meeting its required hydrologic success criteria. The remediation consisted of constructing a dam (sill) of rocks in the raceway to back water onto the eastern end of the site.

On the western end of the site, the wetland area was very narrow (about 10 m wide by 150 m long: 0.4 acres). A vegetation monitoring plot located there encompasses most of the western side of the site. Vegetation in the section on western end is doing quite well.

It does not seem that this type of mitigation should be used to obtain compensatory mitigation credit because it is essentially a detention basin for highway runoff. However, this design should represent best management practices (BMP) for collecting roadway runoff because it seemed to work quite effectively in this regard.

Planted trees:
Quercus phellos
Alnus serrulata
Quercus nigra
Quercus lyrata

Colonizing trees:
Pinus virginiana
Liriodendron tulipifera
Salix sp.
Platanus occidentalis
Liquidambar styraciflua
Acer rubrum

Ephemeral Pond

County: Scotland
Location: Northeast of Pinebluff, near the intersection of SR1400 and SR1332 .
Size: 5 acres
Year started: 1999
Type of mitigation: preservation of an ephemeral pond for amphibian habitat.

Description of site and its condition:

This mitigation site was an old sand pit with two deeper, seasonally flooded areas that connect during high water. Vegetation in and around the pond edges was dominated by *Eleocharis* sp. and *Xyris* sp. with much *Utricularia* sp. and *Rhynchospora* spp.

NCDOT bought this 5-acre mitigation site to preserve amphibian breeding habitat. Apparently, the site supported many rare and threatened amphibian species that use the nearby longleaf pine savanna. However, the pond may have been in the process of being degraded by people dumping woody debris into the pond. After acquiring the site, DOT cut pines from around the pond edges and removed submerged woody debris within pond. The cut pines were placed along the pond's banks (above the high water mark) in an attempt to ameliorate erosion into the pond.

Evans Road

County: Wake
Location: Adjacent to Lake Crabtree south of RDU international airport.
Size: 9 acres in 3 areas.
Year started: 1994?
Type of mitigation: Lacustrine creation.

Description of site and its condition:

This wetland area was created by excavating 3-5 feet of soil at several different locations (sections) along the shores of Lake Crabtree. At least one location (Site 8) was used to accept runoff from developed areas. Most of the created wetland areas were too wet to support any but the most flood-tolerant tree species. Thus, most areas were marsh (dominated by herbaceous species). The mitigation may have been effective in increasing water storage capacity in the reservoir (one stated goal of the mitigation).

Section 1A: In this section, mitigation consisted of removing soil (by excavating 4-5 feet) and planting trees. As a result, the remaining soil was highly compacted and most planted trees had died. Some trees (*Salix* sp., *Betula nigra*) had colonized the site, but they were not abundant. However, the herbaceous layer was dense, with *Juncus* sp. and *Boehmeria cylindrica* particularly abundant.

Section 4B: In this section, approximately 4 feet of soil was excavated before trees were planted. Most planted trees had died, except for *Quercus lyrata* and *Fraxinus* sp. Some colonizing trees had established, particularly *Salix* sp. and *Betula nigra*.

Section 4A: This section was a very wet area dominated by *Typha* sp. *Boehmeria cylindrica*, *Eleocharis* sp., and *Cyperus* sp. were also present, but were less abundant than *Typha*. Trees survived at the upland/wetland edge only: *Fraxinus* sp., *Betula nigra,* and *Liquidambar styraciflua*.

Sites 2/5/6/7: This section was mostly covered with colonizing *Salix* sp. and *Acer rubrum*, but a few planted trees had survived, primarily *Quercus phellos*. Marsh vegetation dominated the site closest to the lake margin.

Section 8: This site was formerly upland adjacent to floodplain forest of Crabtree Creek. Topsoil was excavated to increase the duration of soil saturation within 30 inches of the surface. Hardwoods appear to have been planted throughout the site, but only *Fraxinus* sp. and *Salix* sp. (colonizing) appeared to be surviving. Plastic shields were placed around planted trees to inhibit browsing, but mortality appeared to be primarily caused by excessive flooding.

This site was very open and dominated by *Typha* sp. and *Scirpus* sp. (primarily *S. americanus*). *Juncus* sp. and *Polygonum* spp. were also abundant throughout the site. Thus, the site resembled a marsh more than it did the adjacent floodplain swamp, which was a mature forest with a canopy of *Acer rubrum, Liquidambar styraciflua, Pinus taeda, Nyssa biflora, Quercus phellos. Carpinus caroliniana* was prevalent in the understory.

It appeared that a 10 m-wide dirt road had been cut through mature oak-hickory upland forest to allow earth moving equipment to access the mitigation site. Since the access road was approximately 0.5 miles long, almost 2 acres of mature upland forest was sacrificed to create the marsh.

Lake Wheeler

County: Wake
Location: Between US401 and Lake Wheeler south of Raleigh (west side of Swift Creek).
Size: 114 acres
Year started: 1997
Type of mitigation: Non-riverine preservation.

Description of site and its condition:

This mitigation site consisted of approximately 114 acres on the west side of Swift Creek, most of which had been clear-cut prior to being purchased by NCDOT. (The Phillips mitigation site was located on the east side Swift Creek.) The cut-over areas were planted with mast-producing bottomland hardwood species in 1997 and seedling survival was being monitored. No data were available on canopy species composition before the site was clearcut, so we examined the composition of an uncut area below Lake Phillips dam to determine the probable composition of the site prior logging. The uncut site had the following species:

Second bottom:
Acer rubrum
Liriodendron tulipifera
Liquidambar styraciflua
Quercus nigra
Nyssa biflora
Carpinus caroliniana
Styrax americana

First bottom:
Betula nigra
Liriodendron tulipifera
Quercus pagoda
Liquidambar styraciflua
Carpinus caroliniana

Herbs:
Saururus cernuus
Boehmeria cylindrica
Arundinaria tecta
Uniola latifolia
Ludwigia sp.

It is likely that the forest would succeed to a similar condition given sufficient time. However, mitigation included planting additional mast producing species to encourage more rapid succession and enhance wildlife benefits. The following canopy species were planted in the floodplain:

Quercus laurifolia
Quercus pagoda
Quercus lyrata
Quercus michauxii
Fraxinus pennsylvanica
Nyssa sylvatica
Betula nigra

Preservation of such areas (cut-over riparian systems, especially low order floodplains) is-desirable for improving water quality and may be a cost-effective alternative to wetland creation.

Little Sugar Creek

County: Mecklenburg
Location: Adjacent to Little Sugar Creek between I-485 and SR51 in south Charlotte.
Size: 16 acres
Year started: 1997
Type of mitigation: Non-riverine creation

Description of site and its condition:

This mitigation site was adjacent to a business complex and shopping mall. Prior to mitigation, the site was a pasture with several ditches and a small tributary crossing through site to Little Sugar Creek. The site functions as a large detention basin designed to process run-off from surrounding developments before the water enters Little Sugar Creek (there are at least 3 places where water enters the site from surrounding developments). The basin probably rarely, if ever, gets overbank flow from the creek due to the degree of incision within Little Sugar Creek.

Some trees were planted in the detention basin (mostly *Fraxinus* sp.), but many *Betula nigra*, *Platanus occidentalis* (sycamore), and *Populus deltoides* (swamp cottonwoods) are colonizing the site. The basin had much *Eupatorium capillifolium* and *Panicum* spp. growing in it and water conveyance structures in the basin supported abundant *Phalaris arundinaceae* (reed canary grass).

This site is a highly engineered system designed to perform as a detention basin.

Although a great deal was written in the mitigation plan about the use of reference wetlands, there are no naturally occurring reference wetlands for detention basins. The site was supposed to mimic a piedmont bottomland system, but it is not similar with respect to geomorphology, hydrology, or vegetation.

Hydrologic monitoring showed that most of the site was not saturated for > 5% of the growing season; however, since this site was designed to store stormwater runoff, a shorter period of saturation enables the site to store more water during periods of high runoff.

Because this mitigation project was designed to optimize a specific function and primarily benefits private developments, it doesn’t seem to be appropriate compensatory mitigation for highway impacts to wetlands.

Long Creek

County: Mecklenburg
Location: Along Long Creek between SR49 and US21 in northwest Charlotte.
Size: 156 acres
Year started: Proposed
Type of mitigation: Riverine restoration and creation.

Description of site and its condition:

This mitigation site was located in a former pasture along the south side of Long Creek, located just to the north (and in one section, south) of the proposed I-485 outer loop. To augment water input from tributaries that cross through the site, the mitigation plan proposes to modify natural geomorphology (via "minor contour adjustments"), backfill drainage ditches, build water control structures in appropriate locations, and intercept highway run-off.

Bottomland hardwood species have already been planted in the abandoned pasture land, except that *Platanus occidentalis* was specifically excluded from the mix of species planted. Species currently inhabiting the site (near well 16) include:

Trees and shrubs:
- *Liquidambar styraciflua*
- *Fraxinus* sp.
- *Ulmus* sp.
- *Quercus michauxii*
- *Acer rubrum*
- *Quercus pagoda*
- *Cephalanthus occidentalis* (near the creek)

Herbs:

Asclepias sp.
Eupatorium capillifolium
Aster spp.
Rubus spp.
Andropogon virginicus
Phlox sp.
Ambrosia artemisiifolia
Campsis radicans
Vicia sp

It is difficult to for us to predict how the hydrologic modifications will affect vegetation once the highway is built through the site.

Mallard Creek

County: Mecklenburg
Location: on both sides of SR2833, just south of US29 in North Charlotte.
Size: 9 acres
Year started: 1994
Type of mitigation: Non-riverine restoration and creation.

Description of site and its condition:

This mitigation site was adjacent to Mallard Creek on both sides of Mallard Creek Church Road (SR2833). Each section is described separately below.

Both Sections 1 and 2 had undergone remediation by having soil excavated to increase their periods of saturation. Since no monitoring well data were available following remediation, evaluation of hydrology was not possible. Site conditions for each section are discussed below.

Section 1: South side of Mallard Creek Church Road (SR2833)

Section 1 is about 2 acres in size. As part of required remediation in 1997, the section was re-graded (excavated) to increase the period of time over which it will remain saturated. To do this, soils of the A horizon were removed to lower the site’s elevation. The site does not appear to be hydrologically connected to Mallard Creek (on the south side of the site); rather, the site appeared to be precipitation driven, although there may be some groundwater inputs present as well.

At the time of our visit, the site was wet and soggy underfoot. *Cephalanthus occidentalis* was growing along the edge of the site near Mallard Creek Road. Planted *Fraxinus* sp. was abundant throughout the southern portion of the site. All or most of the observed herbaceous vegetation were obligate wetland species, including:

Eleocharis sp.
Cicuta maculata
Leersia sp.
Lysimachia sp.
Scirpus sp.
Cyperus sp.
Lycopus sp.

A fairly mature forest occurred along the streambank of Mallard Creek. Canopy species along the streambank included:

Platanus occidentalis
Ulmus sp.
Acer negundo
Betula nigra

Section 2: North side of Mallard Creek Church Road (about 7 acres)

In Section 2, a UNC boardwalk connected park/playfields with the mitigation area. The boardwalk traversed through remnant floodplain forest along Mallard Creek before traversing the length of the mitigation area proper. This remnant forest contained a mature stand of large trees.

Canopy trees in remnant forest:
Ulmus sp.
Quercus michauxii
Quercus pagoda
Liquidambar styraciflua
Platanus occidentalis
Celtis occidentalis

Subcanopy in remnant forest:
Acer barbatum
Arundinaria tecta

The boardwalk through the mitigation area was very large (at least 10' off the ground, 8' wide and 1,000' long). The end of the boardwalk had been destroyed by flooding from Mallard Creek, showing that the area receives occasional overbank flooding. However, this section also appeared to have been excavated (A horizon removed) in an attempt to increase the duration of saturation. As a result, there appeared to high mortality among planted trees.

Mud Creek

County: Henderson
Location: On south side of I-26 and Mud Creek off SR1454, east of Mountain Home.
Size: 34 acres
Year started: 1997
Type of mitigation: Flats creation, but really a fen.

Description of site and its condition:

This site had been subjected to much soil removal to lower elevation and guarantee longer periods of soil saturation. At least 3 excavated areas were present. One area had at least 2 m of soil excavated. A flashboard riser was installed on a ditch bisecting the site to back water into two other excavated areas. Another area that was not excavated appeared to support groundwater discharge from nearby hills. *Phalaris arundinaceae* (reed canary grass) seems to have overtaken the excavated depressions nearest Mud Creek.

Although designed to be a bottomland forest (riverine), it is unlikely that the Mud Creek would ever overflow into the mitigation site due to a high levee along the creek. However, a sign on SR1454 warns of possible flooding of the roadway and so it is possible that Mud Creek does occasionally overtop its banks (at least it does near the bridge crossing). A more reasonable restoration may have been to create breaks in the levee so the creek could occasionally overflow rather than removing topsoil from the site behind the levee.

Streambank/levee of Mud Creek:
Acer saccharinum
Acer negundo
Viburnum sp.

Excavated area (created depression):

Salix sp.
Acer rubrum
Fraxinus sp. (planted)
Ludwigia sp.
Mimulus ringens
Typha sp.
Sagittaria sp.
Cyperus sp.
Polygonum sp.
Pontederia cordata
Phalaris arundinaceae (much)
Daucus carota
Mikania scandens
Impatiens capensis
Eupatorium capillifolium
Rudbeckia sp.
Asclepias sp.
Trifolium sp. (clover)
Lobelia cardinalis
Diodea virginiana

Upland area (not excavated):

Juglans nigra
Betula nigra
Quercus phellos

It was difficult to evaluate hydrologic parameters because the hydrology on the site was being manipulated with a flashboard riser in order to establish suitable hydrology.

New Light Creek

County: Wake
Location: Off east side of SR1917 north of New Light.
Size: 20 acres
Year started: 1998?
Type of mitigation: Non-riverine restoration.

Description of site and its condition:

This mitigation was identified by NCDOT as "non-riverine" restoration, but it is associated with a channelized section of New Light Creek. The site was formerly a pasture/hay and corn field. There was once a drainage ditch running through the center of the site parallel to New Light Creek (SW to NE) with tile drains connecting the ditch to the creek.

Soil in the site was a silty loam, somewhat blocky, with mottling and concretions throughout. A natural forested drain (referred to as the "wooded area" in site mitigation plan) ran through the eastern end of the property. Banks of the channel were dominated by *Lolium* sp. and *Microstegium vimineum*. Several smaller tributaries also flowed into the site; but the others were treeless.

Restoration involved creating swale depressions, filling ditches, removing tile drains, altering topography to create depressions of various sizes and depths throughout the site, removing a windrow along the New Light Creek, and planting trees throughout the site and along the levee adjacent to the creek. Success criteria for tree seedling survival differed from criteria required by most other mitigation: survival of 240 trees/acre of planted trees had to survive for 5 years.

A reference wetland area in a similar geomorphic setting downstream was used to help design the mitigation, particularly composition of tree seedlings to be planted and design of swale depressions. Canopy vegetation in the reference wetland downstream included:

Fraxinus sp.
Platanus occidentalis
Betula nigra
Liquidambar styraciflua
Liriodendron tulipifera
Ulmus sp.
Nyssa sylvatica

Wells were placed in the reference site and mitigation to compare groundwater fluctuations between the two areas and more accurately determine reasonable hydrologic criteria for success. Swales of various sizes were also constructed throughout the site based on the density and configurations of ephemeral swale depressions in the reference wetland. In following reference conditions, a variety of sizes and depths of swales were constructed, all of which were deeper at one end. A variety of swale configurations meant that each swale remained wet for different lengths of time and each could conceivably accommodate a different suite of species. (A great blue heron was observed searching for prey in swales that still held water). Mud flats predominated where parts of swales that had recently dried with *Polygonum* spp. dominated portions of swales that had been dry for longer.

Several small streams were also re-engineered to shunt water downslope and then through the depressions. Water entering the site from streamlets originated in pasture land on adjacent property and may have contained abundant nutrients (a small dam on one of these streamlets created a small reservoir that was covered with *Lemna* sp., *Hydrocotyl*e sp., and *Sagittaria* sp. (the abundance of *Lemna* suggested nutrient enrichment). In fact, *Microstegium vimineum* was abundant at the ecotone between the field and wooded slope at southern end of site. Other species on the site included:

Herbs:

Rumex sp.
Setaria sp.
Trifolium sp.
Chenopodium album
Lolium sp.
Datura stramonium
Eupatorium capillifolium
Phytolacca americana
Cyperus sp.
Medicago sativa (alfalfa)
Plantago rugelii
Asclepias sp.
Ludwigia sp.
Impatiens capensis

Tree seedlings in field (*=colonizing):
Quercus lyrata
Quercus michauxii
Quercus pagoda
Diospyros virginiana
*Platanus occidentalis**

Levee forest (*=planted):
Quercus lyrata
*Platanus occidentalis**
Juglans nigra

The abundance of coarse woody debris (CWD) in the reference site and the total lack of CWD in the mitigation site was one very noticeable difference (besides the lack of forest in most of the mitigation site). CWD is important for biogeochemical transformations and invertebrate habitat. Restoration could have been enhanced further had CWD been placed in the restored area. However, this site will provide adequate conditions for assimilating and transforming nutrients before they reach New Light Creek. More of these types of sites should be considered for mitigation.

Phillips

County: Wake
Location: Between US401 and Lake Wheeler south of Raleigh (east side of Swift Creek).
Size: 59 acres
Year started: 1996?
Type of mitigation: Non-riverine enhancement and preservation.

Description of site and its condition:

This site consisted of 150 acres along the east side of Swift Creek. Emergent and forested wetlands comprise 114 acres and uplands comprise 36 acres. A permanent plug was placed in a ditch that beavers had dammed (to maintain hydrology over the long-term). Otherwise, the site was considered to be mitigation by preservation. The opposite side of the creek was a clear-cut area purchased for mitigation (see Lake Wheeler site).

The vine *Mikania scandens* was abundant throughout the Phillips site. *Acer rubrum* was colonizing much of the emergent area (dominated by *Cyperus* sp., *Polygonum* spp., and *Juncus* sp.) and may eventually convert the emergent area to hardwood swamp.

Ridge Road

County: Mecklenburg
Location: In north Charlotte at the northern corner of the junction of SR2463 and SR 2601.
Size: 40 acres
Year started: Purchased
Type of mitigation: Preservation of a series of ephemeral ponds.

Description of site and its condition:

This was a site purchased to preserve one to several mafic depressions (ephemeral ponds). Some seepage areas (slope wetlands) also occur on the site. Apparently, such sites are rare; more of such preservation should probably be included in the mix of mitigation alternatives.

Herbs:
- *Carex* spp.
- *Smilacina racemosa*

Trees:
- *Quercus pagoda*
- *Quercus phellos*
- *Quercus lyrata*
- *Ulmus alata*
- *Ulmus americana*
- *Fraxinus* sp.
- *Juniperus virginiana*
- *Carya ovata*
- *Styrax americana*

South Buffalo Creek

County: Guilford
Location: North of I-40 to the west of its intersection with SR6 in Greensboro.
Size: 32 acres
Year started: 1998?
Type of mitigation: Riverine restoration and preservation.

Description of site and its condition:

This mitigation site was a large (58 acre) tract purchased primarily for preservation. From the site feasibility study, it appeared that the original conceptual mitigation plan was to excavate soil from upland areas to increase duration of soil saturation and produce new areas with jurisdictional hydrologic regimes. (We were not provided with a subsequent mitigation plan for the site.) From our site visit, it did not appear that grading had occurred because mature trees were still present. It also appeared that bottomland hardwood mast species were planted along a treeless strip of land paralleling the creek and located about 10 m to the south of South Buffalo Creek. (This strip was cleared to install a poly-wall membrane to impound subsurface flows (Randy Wise, pers. comm.)). Earthen/rip-rap dams were observed at points where small tributaries fed into South Creek, presumably to dam surface water on the site and increase wetland area by raising mean water levels.

The site feasibility study suggested that a water control structure could be built downstream in South Buffalo Creek to raise water levels in the mitigation area, but we did not see any evidence of such a structure had ever been constructed.

Plantings along treeless strip were 3 abreast and included:

Fraxinus sp.
Quercus michauxii
Platanus occidentalis
Quercus lyrata
Quercus pagoda

Canopy trees in preserved mature hardwood forest:

Fraxinus sp.
Quercus phellos
Acer rubrum
Ulmus americana
Celtis occidentalis
Platanus occidentalis
Liquidambar styraciflua

Woody subcanopy in preserved mature hardwood forest:
Lindera benzoin
Acer negundo
Acer barbatum
Ligustrum sinense
Asimina triloba
Carpinus caroliniana

Herbs in preserved mature hardwood forest:
Impatiens capensis
Carex sp.
Cryptotaemia canadensis
Polygonum sp.
Asarum triphyllum
Pilea pumila
Lolium sp. (along dirt road)
Arisaema triphyllum

Vines in preserved mature hardwood forest:
Rhus radicans
Parthenocissus quinquefolia
Bignonia capreolata

Tulula Creek

County: Swain
Location: Along Tulula Creek on north side of SR129 north of Topton.
Size: 67 acres
Year started: To begin in 1999.
Type of mitigation: Riverine restoration and ephemeral pond creation.

Description of site and its condition:

This site was a large, 222-acre site (67 acres of wetlands) located along Tulula Creek, a tributary of the Nantahala River. A portion of the site was identified as a mountain bog, but wet, non-floodplain areas are actually slope wetlands (fens). Historically, the site was managed as a pasture, hay fields, agricultural fields, and for white pine silviculture (one small section). More recent alterations occurred when construction began on a golf course that was later abandoned. Alterations included clearing areas for fairways, constructing 10-12 permanent ponds, channelizing and straightening Tulula Creek to 1.5 m deep x 1.5 m wide, and constructing ditches to drain adjacent fens. Before the resort was completed, NCDOT purchased the site for a wetland mitigation bank.

NCDOT had begun some site remediation with more to follow. Remediation included constructing 10 ephemeral ponds, planting vegetation (mostly *Acer rubrum*, *Prunus* *virginiana*, and *Sambucus canadensis*) in permanent plots, and installing groundwater monitoring wells. Future mitigation plans include partially filling permanent ponds to convert them to ephemeral ponds, restoring Tulula Creek to its original channel dimensions and sinuosity, engineering an artificial pool and riffle complex in the stream, plugging and/or filling ditches, scarifying soil, re-vegetating fairways with native trees, and removing or thinning the white pines in the plantation. Some earth moving (scraping) has been proposed to lower elevations; however, it is unclear whether this is still being seriously considered. It also appears that trees that had recently colonized the site will be removed prior to planting.

The Tulula site was historically referred to as the "Big Meadows Tract" suggesting that at least some portions of it had been treeless. Beaver were building dams on the site and it is likely that the area was used by beavers historically as well. Part of the tract was also grazed by cattle and so those areas could have been kept open by grazing. However, it seems that the Big Meadows designation was used prior to cattle grazing, although wood bison and/or elk may have historically maintained forest clearings on the site. It seems that any discussion of long-term stability and management should address the historic and future impact of beavers by integrating beaver into the mitigation plan and site management.

The wooded portion of the site supported much *Acer rubrum*, an earlier pioneer species in succession from open meadow to forest. We expected to see other typical streamside (cove) trees, such as *Tilia heterophylla*, *Aesculus octandra*, *Magnolia fraseri*, and *Tsuga canadensis*, but only observed a few or none of these species. Observed vegetation is outlined below.

In fens:

- *Sorbus arbutifolia*
- *Viburnum nudum*
- *Acer rubrum*
- *Sarracenia* sp. (probably planted)
- *Sphagnum* sp.
- *Carex* sp.
- *Juncus* sp.
- *Monarda didyma*
- *Phlox* sp.
- *Impatiens pallida*

In mature woods:
Acer rubrum
Quercus rubrum
Pinus strobus
Betula lutea
Lindera benzoin

On abandoned fairways:
Rhexia spp.
Panicum spp.
Solidago spp.
Aster spp.
Lilium canadense
Pteridium aquilinum

Woody species expected to occur at the site, but not observed:
Tsuga canadensis
Aesculus octandra
Tilia heterophylla
Magnolia fraseri
Fagus grandifolia
Acer saccharum
Rhododendron maximum

A more thorough species list is provided in Appendix K in the Tulula Creek Mitigation Bank Plan (North Carolina Department of Transportation 1997).

Wellborn

County: Caldwell
Location: off west side of US321 northwest of Patterson.
Size: 6 acres
Year started: Purchased 1998
Type of mitigation: Riverine preservation.

Description of site and its condition:

This site consisted of a small stream (1.5 m wide) that cut through a wet meadow on its way to the Yadkin River a bit downstream. It was purchased by NCDOT for preservation. One portion of the site had been flooded over a prolonged period (probably by beaver), which killed many *Salix* sp. and *Alnus* sp. A dense line of *Alnus serrulata* occurred at the wetland/upland transition. The site represents an excellent example of preservation because it would be expected to help protect downstream water quality. (Note: There is a barbed wire fence crossing the site that should be removed.)

Vegetation in upland area:

Eupatorium maculatum
Achillea millefolium
Asclepias sp.

Vegetation in wet area:

Setaria geniculata
Rhus copallina
Boehmeria cylindrica
Rubus sp.
Allium sp.
Pluchea camphorata
Erechtites hieracifolium
Pilea pumila
Sambucus canadensis

Vegetation in very wet area (water flooded by road or by beaver):

Leersia virginica
Impatiens pallida
Ludwigia sp.
Mimulus ringens
Polygonum persicaria
Potomogeton sp.
Sagittaria sp.
Salix sp.

DISCUSSION

Early compensatory mitigation projects and associated terminology were developed around the jurisdictional definition of wetlands (U.S. Army Corps of Engineers 1987), which was developed to identify boundary conditions rather than describe ecosystem condition. As a result, wetland terminology associated with types of compensatory wetland mitigation (creation, restoration, preservation, enhancement), does not differentiate natural, self-sustaining wetland ecosystems from degraded ecosystems or artificial systems that require energy subsidies to maintain them.

In wetland mitigation terminology, restoration refers to manipulating hydrology, geomorphology, and/or vegetation to restore jurisdictional wetland status to an area that has been converted to an upland as a result of alteration. The main difference between restoration and wetland enhancement is that enhancements are conducted in sites that already are jurisdictional wetlands while restorations are conducted in sites that were once jurisdictional wetlands, but were later converted to uplands as a result of alterations. As a rule, enhancements receive fewer mitigation credits per unit area (higher mitigation ratio) because enhancement sites are considered to be functioning as jurisdictional wetlands already. This has meant that even if structure, functioning, and hydrologic regime are severely degraded in a jurisdictional wetland, there has been little incentive to return such sites to their historic, natural condition because doing so would tend to accrue fewer compensatory credits than restoring wetland hydrology to altered sites or creating wetland hydrology in places that had been uplands historically. In many cases, this policy seems to have not only discouraged restoration of degraded (poorly functioning) sites, but has encouraged (or at least not discouraged) the removal of soil substrate (A horizon) in order to assure wetland hydrology at the expense of soil integrity. This has in turn led to failure of the vegetation to flourish in some compensatory mitigation wetlands.

Although restorations were often designed to return non-wetlands to their historic condition with respect to hydrologic regime, this was not usually specifically required by NCDOT permit conditions. Instead, the success criterion for hydrology always required that restored sites meet the jurisdictional definition of wetlands. Thus, by failing to use reference, this approach cannot incorporate differences in hydrologic regime we know exist among wetland-types. Further, hydrologic monitoring of wetland-types that typically occur at the wetland/upland boundary (wet flats) may require more long-term monitoring when drought conditions occur during the required monitoring period. These limitations will be developed further in Phase 2 (case studies) for selected mitigation sites.

Hydrologic restoration usually involved removing soil (usually fill), infilling and/or otherwise blocking outflow from previously constructed ditches, or constructing impediments to the free flow of water to increase period of soil saturation. It was assumed that removing fill or removing the effects of ditches would restore historic hydrologic regime. This assumption is probably valid where soil has not been compacted at the time fill is placed on a site or compacted during restoration activities. Sites in which water impediment structures were constructed showed mixed results for vegetation survival, presumably because it was sometimes difficult to accurately predict how wet to make a site. Simply increasing duration of saturation would not, by itself, be recognized as restoration by most restoration ecologists because making a site wetter does not necessarily return a site to historic, natural conditions, the assumed target of restoration. However, since soil is not removed by simply impeding water, such Arestorations" are more likely to resemble natural ecosystems.

Attempts were seldom made to return sites to their historic condition relative to the composition of vegetation. This may have been due to the lack of good historic vegetation data for the site, a desire to enhance the site's habitat for targeted species, lack of structural or functional data from appropriate reference wetlands, and/or lack of appropriate guidance by regulatory agencies. As a result, restorations sometimes failed to resemble the historic, natural ecosystem in tree species composition. For example, *Taxodium distichum* was often planted in wet hardwood flats on mineral soil, although this species never occurs naturally in such places. *Taxodium acendens* naturally occurs only in very wet pine flats and hardwood flats with organic-rich soils.

Wetland creation almost always involved massive re-distributions of soil (often upland excavation) to reach the underlying water table or saturated zone. Relatively high mitigation ratios were required for such creation efforts because the risk of failure was relatively high. Several wetlands were created by excavating up to several meters of soil. (The depth of excavation was adjusted to the depth at which hydric soil indicators occurred.) Although most created wetlands met hydrologic criteria, vegetation failed to thrive in the nutrient-poor subsoils that remained. Exceptions to failure occurred in wetland-types where soil was normally disturbed by natural causes, for example, by erosion and sedimentation in salt marshes and interdune swales. In such areas, success was often achieved where hydrologic regime was restored because plants colonizing such areas has evolved to exploit highly disturbed, geologically young soils.

Preservation, as used in the wetland mitigation arena, refers to long-term protection and management of wetlands, regardless of their degree of alteration. Usually, relatively intact areas were chosen for preservation, but cut-over areas or artificial systems also sometimes qualified (e.g., see Ephemeral Pond and Lake Wheeler mitigation sites). In contrast, restoration ecologists tend to define preservation as long-term protection and management of ecosystems that are intact with respect to structure and functioning. Within this perspective, preserving successional sites would be considered restoration (time and protection from alteration are the restorative mechanisms); additional planting of vegetation to enhance succession would be considered a more active form of restoration, as long as the goal were to restore a site to its historic, natural condition. Purchase of cut-over wetlands or long-term conservation easements, particularly along low order streams, would help restore wetland functioning critical to downstream water quality and could be done successfully and cost-effectively (i.e., large acreages could be purchased and restored cheaply).

A determination of success or failure of mitigation sites was generally consistent between both gauges of success applied to mitigation sites, i.e., success as defined both by permit conditions and relative to naturally occurring ecosystems. However, this agreement between success criteria occurred in spite of differences between the two perspectives for gauging success. This is because vegetation either thrived (in successful sites) or failed to thrive (in unsuccessful sites) regardless of what had been planted or how intensively vegetation had been planted.

Sites in which soil was left undisturbed or where soil had been restored to its original condition (fill removed) were most likely to follow an ecologically successful trajectory in spite of what had been planted. Sites in which the A horizon had been removed were usually ecologically unsuccessful and planted vegetation also usually failed to thrive. This may be due, in part, to the short time period over which success is determined. In areas where topsoil is removed, 3 to 5 years is too short a period to gauge vegetative success and is much to short a period to follow the development of a soil A horizon. Trees planted in such areas may survive the required 3-5 year monitoring period, but we observed that planted trees appeared to be stunted (due to periodic die-backs), some having only a few leaves.

The following summary of general strengths and weaknesses of NCDOT compensatory mitigation projects is provided to help guide future projects. In some case, weaknesses are due to a lack of flexibility in choosing more appropriate restoration options, i.e., regulatory requirements may have dictated mitigation strategies.

Strengths of Mitigation Program

1. Restoration or creation of sea-level controlled wetlands where surface elevation was within range of natural fluctuations and soil substrate did not require high organic matter content.

2. Wet Hardwood Flats where the A-soil horizon was left intact and natural hydrologic regime was restored. However, *Taxodium distichum* (bald cypress) is not native to mineral soil wet hardwood flats and should not be planted there. In flats with soils high in organic matter or very wet fire-maintained wet pine flats on mineral soil

(Cypress/Pine Savanna), *T. ascendens* (pond cypress) would be appropriate because it occurs naturally in such areas. Rheinhardt and Rheinhardt (1998, 1999) and Cazier (1992) could be consulted for determining an appropriate mix of hardwood species for restoration in hardwood flats and Rheinhardt et al. (2000) for Cypress/Pine Savanna.

3. Wet Pine Flats where hydrology and native bunchgrasses are restored and the natural fire regime is maintained over the long-term with a prescribed burning program.

4. Interdune swales on barrier islands. These occur on sandy soils subject to re-distribution by overwash during hurricanes and nor'easters. Mitigation must take into account their inherent instability, i.e., they are not likely to maintain themselves in a given location over the long term.

5. Restoration and re-configuration (creation) of streams and associated floodplains. If gradient and sinuosity are appropriate, they will probably equilibrate with energy of stream. However, in urbanizing landscapes, future stream hydraulics, while predictable, may be difficult to build into one-time restoration efforts.

6. Purchase and long-term preservation of floodplains and adjacent buffers of creeks and rivers, particularly headwater streams. This helps maintain downstream water quality and prevent~~s~~ losses from flood damage.

7. Construction of plugs along tributaries of streams or water conveyance structures that feed deeply incised or channelized creeks. This enables former floodplain to once again process water-from tributaries and upgradient ditches even though overbank flow from the incised streams may be lacking or minimal.

Weaknesses of Mitigation Program

1. Restoration and creation of wetlands in which the A soil horizon is graded, re-distributed, or removed to increase the period of saturation (in order to meet jurisdictional hydrologic criteria). Such alterations are particularly detrimental in wetlands in which organic rich or nutrient-rich soil is part of their natural condition. Trees planted on sites where the A horizon was disturbed, compacted, or otherwise altered appeared to exhibit slow growth rates, and in many case, high mortality. We realize that years of soil redistribution during agriculture and preparation for agriculture tend to alter the A horizon as well and that some modification may be required to try to restore original topography and soil porosity. However, soil structure, bulk density, root structure, organic matter, etc. take decades to centuries to develop. Thus, massive soil re-distribution or removal should be avoided in mitigation whenever possible.

2. Restoration and creation of wetlands where hydrology is naturally controlled by sea-level fluctuations, but where elevation is not restored to within the natural range of fluctuations (usually, elevation is not lowered sufficiently).

3. Planting hydric hardwoods in areas where the historic condition would have supported a fire-maintained Wet Pine Flat (wet savanna on mineral soil). By excluding fire in such areas, a pocosin-like understory eventually develops, providing fuel for wildfires that will destroy hardwoods.

4. Excluding fire or failure to manage a natural, fire-maintained ecosystem with prescribed burning.

5. Creation of stormwater detention basin that are deep and small in area relative to the drainage basin they serve. Such areas are designed to hold a large pulses of water for short periods. They do not mimic any known natural wetland ecosystem and their period of saturation would be unlikely to meet jurisdictional wetland status.

6. Failure to control competition of vines and/or herbaceous plants with planted trees. This was rare: only one case found.

While the above outline provides a general list of strength and weaknesses of the program, they do not address specific problems we encountered in trying find information to evaluate sites. These problems would be encountered by anyone attempting to re-create site histories. Therefore, the following list of recommendations is provided to improve the utility of site data, particularly monitoring data, and the organization of data.

RECOMMENDATIONS

(1) Success criteria for vegetation seemed to require survival of some minimum density after a prescribe period of time for the entire site. If plant survival data are averaged (pooled) across plots within a given site, valuable information on variability may be lost, and may prevent expressing projects as having partial successes or failures. Similarly, when data on intra-site variation are lacking, contingency measures cannot be effectively applied to pertinent portions of a project.

(2) Vegetation monitoring plots were often not stratified by cover-type or geomorphic location. Therefore, one could not tell whether a particular planting mix was appropriate for the geomorphic location of the planting.

(3) Vegetation monitoring plots did not appear to be randomly placed and sometimes did not seem to represent the geomorphic variability within sites. We suggest that a written protocol be established for determining the location and numbers of plots needed to provide an unbiased estimate of survival.

(4) Although permanent plots provide useful information on the survival of planted species and degree of colonization by "volunteer" species, we suggest that they not be used as the sole source of information on survival, particularly since there may be a problem with plots representing variability within sites (see 3 above). If plots are not chosen randomly or according to some established protocol, one could legitimately question whether plots were placed where they were judged to be least likely to fail. An *a priori* procedure for the placement of plots would avoid any appearance of bias.

The above leads to the question of what is done if a plot or set of plots does not meet survival criteria? Does the entire site undergo remediation (likely not necessary if only a portion of the site is not meeting success criteria) or does remediation occur only in the vicinity of the plots in question? If so, how far from the plots does remediation occur? The same questions can be posed for an area or areas that fail to meet hydrologic success criteria. Answers to these questions may reside within “institutional memory” of NCDOT personnel, but it seems that there should be a written protocol to address contingency planning.

(5) We couldn’t find any rationale for the various tree survival success criteria required by the Corps of Engineers. (One of the most commonly used criterion (Appendix B) was 320 trees/acre surviving after 3 years, although this protocol seems to have been revised to 320 stems/acre surviving for 3 years with no more than a 10% reduction per year for a subsequent 2 years.) We realize that specific density criteria was guidance established by the U.S. Army Corps of Engineers and negotiated with the agencies, but the rationale (perhaps provided as a citation) for requiring a given density should be provided in the monitoring reports (assuming the Corps used published information to establish its guidelines). In addition, because mortality of tree seedlings is somewhat inversely related to height, survival criteria for forest restoration would be more useful if based on survival to the sapling stage (perhaps to > 1.5 or 2.0 m in height), rather than length of survival. Otherwise, planted trees might survive for 3-5 years, but not grow larger, a condition that would not be sustainable over the long-term.

Also, some success criteria required that 6 hardwood mast species survive with no more than 20% survival attributed to any one species. Some requirements prohibit more than 10% softwood species as well. These criteria require that all six mast species have to range between 15% and 20% of the total density. It is unlikely that any planting regime could succeed under such stringent conditions.

(6) Monitoring reports did not provide information on plot size. We were further confused by the application among plots of different constants to determine stem density, leading us to assume that plots varied in size. We later learned that these differences were based on survival data which had in turn been based on initial planting densities (Randy Wise, pers. comm.). The point is that there appears to be nothing written about methods employed, including plot size, how densities are derived based on initial starting densities, where each plot in a site was located (with reliable maps to match data from reports with field plots), etc. All data analysis methods should be provided in enough detail, along with "as built" plans, so that sites could be re-constructed and independently evaluated by future researchers. Too much seems to rely on the institutional memory of only a few people at NCDOT.

(7) Wetland-type should be identified less ambiguously. A non-riverine system could be interpreted as a depression, flat, sea-level controlled, or slope wetland system. Each of these types of major classes of wetlands function very differently from one another, particularly with respect to hydrologic regime and elemental cycling characteristics (even though in some cases, vegetation may not be much different, i.e., bottomland hardwood forests of small stream floodplains and wet hardwood flats). Further, as the NCDOT mitigation program is the largest in North Carolina, the agency should consider whether it is altering the geographic distribution and frequency of wetland subclasses at the landscape scale (Gwin et al. 1999). Mitigation plans often incorporated detailed information on site characteristics, but this information had not been synthesized for the mitigation program as a whole, thus making it difficult to judge the success of NCDOT's program in maintaining the natural mix of wetland-types on the landscape.

(8) Relatively unaltered reference sites in the vicinity should be used more often for determining the compensatory mitigation target. More recent restorations tended to incorporate reference information for vegetation. However, monitoring wells are rarely used in reference sites to guide hydrologic restoration or gauge success. Historic aerial photos and other information could also be used more often to determine the original condition of sites considered for restoration.

(9) *Taxodium distichum* (bald cypress) was commonly planted on mineral soil flats and headwater sites, even though this species does not naturally occur in these geomorphic locations (either not wet enough to out-compete less flood-tolerant trees or lacks flowing water). The use of reference wetlands as targets for restoration would help to obviate this problem. The only cypress that occurs in flats is *Taxodium ascendens* (pond cypress), and this only in the wettest pine flats and in hardwood flats on organic soils (e.g., in the Great Dismal Swamp).

(10) NCDOT should consider advantages of purchasing riverine sites and associated buffer zones, especially in headwater reaches. This would help improve downstream water quality and reduce downstream peak discharges.

(11) Many of the mitigation sites were identified as research areas. The mitigation reports did not explicitly describe the nature of the treatments and experimental design. Consequently, it would be difficult for an independent observer to evaluate the sites. Long-term research of sites past the required monitoring period would be useful for improving restoration success for future projects.

(12) It was difficult to locate all pertinent information on a given site prior to our fieldwork. Mitigation plans were not filed with annual reports or with "as built" plans. Some files could not be located. We understand that NCDOT was in the midst of re-organizing the filing system as we started our field reconnaissance, but there is probably room for further improvement. It seems that all files of a given parcel of land (mitigation project) should be located in one file with that file being cross-referenced with its associated construction projects. Correspondences with regulatory personnel, project meetings, maps, etc. should also be filed together by project. A chronological summary of site history would be helpful for conveniently and more thoroughly reviewing a project's history from its inception to completion.

(13) Compensatory wetland mitigation involving restoration and creation appeared to have gravitated toward a relatively narrow set of success criteria (required by regulatory agencies) for hydrology and vegetation, with little room for flexibility. In contrast, no standards were being used for soil condition. These standards (criteria) should undergo critical examination to see if they are consistent with no-net-loss policies, and if alternative measures can be developed.

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APPENDIX A

Species list of plants observed in mitigation sites. Includes dominant and most conspicuous species, organized alphabetically by life-form. Taxonomic nomenclature follows Radford et al. (1968) except that *Quercus falcata* var. *pagodaefolia* Ell. and *Nyssa sylvatica* var. *biflora* (Walter) Sargent are herein referred to as *Quercus pagoda* Raf. and *Nyssa biflora* Walter --S.G., respectively.

CANOPY	
Acer saccharinum	silver maple
Acer rubrum	red maple
Acer saccharum	sugar maple
Acer negundo	box elder
Aesculus octandra	sweet buckeye
Betula nigra	river birch
Betula lenta	sweet birch
Betula lutea	yellow birch
Carya ovata	shagbark hickory
Celtis occidentalis	American hackberry
Chamaecyparis thyoides	Atlantic white cedar
Fraxinus caroliniana	Carolina ash
Gordonia lasianthus	loblolly bay
Juglans nigra	black walnut
Juniperus virginiana	eastern red cedar
Liquidambar styraciflua	sweetgum
Liriodendron tulipifera	tulip poplar, tuliptree, yellow poplar

Magnolia fraseri	Fraser magnolia
Nyssa aquatica	water tupelo
Nyssa biflora	swamp blackgum
Nyssa sylvatica	blackgum
Pinus palustris	longleaf pine
Pinus taeda	loblolly pine
Populus deltoides	swamp cottonwood
Prunus virginiana	choke cherry
Quercus lyrata	overcup oak
Quercus falcata	southern red oak
Quercus laurifolia	laurel oak
Quercus nigra	water oak
Quercus michauxii	swamp chestnut oak
Quercus pagoda	cherrybark oak
Quercus phellos	willow oak
Taxodium distichum	bald cypress
Taxodium ascendens	pond cypress
Tilia heterophylla	white basswood
Tsuga canadensis	hemlock
Ulmus americana	American elm
Ulmus alata	winged elm

SUBCANOPY	
Acer barbatum	southern sugar maple
Acer pensylvanicum	striped maple or moosewood
Alnus sp.	alder
Alnus serrulata	tag alder
Asimina triloba	pawpaw
Baccharis halimifolia	groundsel-tree
Calycanthus floridus	sweet-shrub
Cephalanthus occidentalis	buttonbush
Clethra alnifolia	coast pepperbush
Cyrilla racemiflora	titi
Diospyros virginiana	persimmon
Ilex glabra	low gallberry
Ilex opaca	American holly
Ilex verticillata	common winterberry holly
Itea virginica	sweet-spires
Iva frutescens	marsh elder
Kalmia angustifolia	sheep laurel
Ligustrum sinense	privet
Lindera benzoin	spicebush
Magnolia virginiana	sweetbay
Myrica cerifera	wax myrtle
Myrica pennsyvanica	bayberry

Persea borbonia	redbay
Rhododendron maximum	rosebay
Salix sp.	willow
Sambucus canadensis	elderberry
Sapium sebiferum	Chinese tallow
Sassafras albidum	sassafras
Sorbus arbutifolia	red chokeberry
Styrax americana	American snowbell, storax
Symplocus tinctoria	sweetleaf
Vaccinium sp.	blueberry
Viburnum sp.	viburnum
Viburnum nudum	possum haw
Zenobia pulverulenta	zenobia

HERBS	
Achillea millefolium	yarrow, milfoil
Aletris farinosa	colicroot
Allium sp.	wild onion
Ambrosia artemisiifolia	ragweed
Andropogon virginicus	broomsedge
Andropogon glomeratus	bushy beardgrass
Andropogon glaucopsis	chaulky bluestem
Arisaema triphyllum	jack-in the-pulpit
Aristida stricta	wiregrass
Arundinaria tecta	cane
Asclepias sp.	milkweed
Aster ericoides	heath aster
Bigelowia nudata	rayless goldenrod
Boehmeria cylindrica	false nettle
Carex crinita	sedge
Chenopodium album	lamb=s quarter, pigweed
Cicuta maculata	water hemlock
Coreopsis sp.	coreopsis
Cryptotaenia canadensis	honewort
Cyperus rotundus	nut grass
Cyperus sp.	sedge
Datura stramonium	jimsonweed

Daucus carota	wild carrot
Desmodium sp.	begger's lice
Dicanthelium sp.	Dicanthelium
Diodea virginiana	buttonweed
Echinochloa walteri	coastal cockspur
Erechtites hieracifolia	fireweed
Eriocaulon sp.	hat pins, marsh buttons
Eryngium integrifolium	snakeroot
Eupatorium maculatum	spotted joe-pye weed
Eupatorium leucolepis	white-bracted boneset
Eupatorium capillifolium	dog fennel
Geranium sp.	wild geranium
Gnaphalium obtusifolium	rabbit tobacco, cudweed
Hydrocotyle sp.	pennywort
Hypericum sp.	St. Johnswort
Impatiens pallida	jewelweed
Isopappus divaricatus	yellow aster
Juncus roemerianus	black needlerush
Juncus effusus	needlerush
Juncus sp.	needlerush
Lactuca canadensis	wild lettuce
Leersia sp.	cutgrass
Leersia virginica	Virginia cutgrass

Lemna sp.	duckweed
Leptilon canadense	horseweed
Lespedeza sp.	bush cover
Lilium canadense var. editorium	red Canada lily
Lobelia cardinalis	cardinal flower
Lolium sp.	rye grass
Ludwigia palustris	water purslane
Lycopus sp.	bugleweed
Lysimachia quadrifolia	whorled loosestrife
Medicago sativa	alfalfa
Microstegium vimineum	microstegium
Mimulus ringens	monkey flower
Monarda didyma	oswego tea, bee balm
Osmunda regalis	royal fern
Panicum verrucosum	tall panic grass
Phalaris arundinaceae	reed canary grass
Phragmites australis	common reed
Phytolacca americana	pokeweed
Pilea pumila	clearweed
Plantago rugelii	blackseed plantain
Pluchea camphorata	marsh fleabane
Pluchea foetida	swamp fleabane
Polygala lutea	orange milkwort

Polygonum persicaria	lady’s thumb
Polygonum sp.	knotweed
Pontederia cordata	pickerelweed
Potomogeton sp.	pondweed
Pteridium aquilinum	bracken fern
Ptilimnium capillaceum	mock bishop’s weed
Rhexia sp.	meadow beauty
Rhynchospora corniculata	beak rush
Rubus sp.	blackberry
Rudbeckia sp.	coneflower
Rumex acetosella	sheep sorrel
Rumex crispus	field sorrel
Sagittaria sp.	arrowhead
Salicornia sp.	saltwort
Saururus cernuus	Lizard’s tail
Setaria glauca	yellow foxtail
Setaria sp.	foxtail
Smilacina racemosa	false Solomon’s seal
Solanum caroliniense	horse nettle
Solidago sp.	goldenrod
Solidago fistulosum	red-stemmed goldenrod
Spartina cynosuroides	tall cordgrass
Spartina patens	saltmeadow hay

Spartina alterniflora	saltmarsh cordgrass
Syntherisma sanguinale	crabgrass
Thelypteris palustris	marsh fern
Tradescantia virginiana	spiderwort
Tradescantia virginiana	spiderwort
Trifolium sp.	clover
Typha angustifolia	narrow-leafed cattail
Typha latifolia	common cattail
Uniola latifolia	swamp oats
Uniola paniculata	sea oats
Utricularia subulata	zig-zag bladderwort
Verbena sp.	vervain
Vicia sp.	vetch
Woodwardia virginica	Virginia chain fern
Xyris sp.	yellow-eyed grass

VINES	
Bignonia capreolata	cross vine
Campsis radicans	trumpet creeper
Lonicera japonica	Japanese honeysuckle
Mikania scandens	climbing hempweed
Parthenocissus quinquefolia	Virginia creeper
Rhus radicans	poison ivy
Smilax spp.	greenbriar, catbriar

APPENDIX B (Compensatory Hardwood Mitigation Guidelines)

CORPS OF ENGINEERS - WILMINGTON DISTRICT

COMPENSATORY HARDWOOD MITIGATION GUIDELINES (12/8/93)

I. IMPACT AREA / REFERENCE AREA EVALUATION

A. PHYSICAL CHARACTERISTICS

B. FUNCTIONS AND VALUES

C. IDENTIFY MITIGATION NEEDS IN ACCORDANCE WITH COE MITIGATION POLICY

II. SPECIFIC GOALS/STRUCTURE DESIGN/SUCCESS CRITERIA

A. PHYSICAL CHARACTERISTICS OF SITE
1. SOILS: SUITABLE TO SUPPORT TARGET PLANT SPECIES
a. PHYSICAL
b. CHEMICAL
2. HYDROLOGY: SATURATED WITHIN 12 INCHES OF THE SURFACE, PONDED, OR FLOODED AT LEAST 12.5% OF THE GROWING SEASON UNDE[R] REASONABLY AVERAGE CLIMATIC CONDITIONS
3. GEOMORPHOLOGY: SUITABLE TO MEET HYDROLOGY REQUIREMENT
a. CONTOURS
b. ELEVATION
c. DRAINAGE / CONNECTION WITH SURFACE WATERS

B. BIOLOGICAL/VEGETATIONAL CHARACTERISTICS OF SITE DESIGN
1. SPECIES SELECTION: HARDWOOD SPECIES NATIVE TO AREA
2. NUMBERS OF INDIVIDUAL TREES: A MINIMUM OF 320 TREES/ACRE SURVIVING FOR 3 YEARS
3. UP TO 10% OF SITE SPECIES COMPOSITION MAY BE COMPRISED OF SOFTWOOD SPECIES
4. TREE COMPOSITION: MINIMUM OF 6 HARDWOOD SPECIES WITH NO MORE THAN 20% OF ANY ONE SPECIES

III. SELECTION OF SITE

A. SUITABILITY OF LOCATION: ECOLOGICALLY ACCEPTABLE

B. SUFFICIENT SIZE TO SATISFY MITIGATION NEED

C. PHYSICAL CHARACTERISTICS
1. HYDROLOGY
2. SOILS
3. SLOPE

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IV. SPECIFIC CONSIDERATIONS

A. PHYSICAL SITE PREPARATION REQUIREMENTS
1. HYDROLOGY
2. FERTILIZER NEEDS
3. pH/LIME
4. DRAINAGE
5. ELEVATION
6. EROSION CONTROL MEASURES

B. VEGETATION REQUIREMENTS
1. SPECIES SELECTION: HARDWOOD SPECIES NATIVE TO AREA
2. NUMBERS OF INDIVIDUAL TREES: A MINIMUM OF 320 TREES/ACRE SURVIVING FOR 3 YEARS
3. TYPE OF STOCK
   a. BARE ROOT: PREFERRED
      1) 1 YEAR OLD, 12 TO 18 INCHES HIGH
      2) 1/4 INCH OR GREATER DIAMETER ROOT COLLAR
      3) 4 OR MORE LATERAL ROOTS
      4) HEALTHY
   b. ROOT BALL: ACCEPTABLE
   c. SEED: CONDITIONALLY ACCEPTABLE
4. AVAILABILITY
   a. SEASON
   b. NUMBERS
   c. STOCK ORIGIN/LOGISTICS
5. SOURCES OF STOCK: PREFERRED SOURCE(S) WITHIN 200 MILES NORTH OR SOUTH OF SITE
6. PLANTING REQUIREMENTS
   a. DENSITY OF PLANTINGS: MINIMUM OF 320 TREES/ACRE
   b. SPECIES COMPOSITION: MINIMUM OF 6 HARDWOOD SPECIES WITH NO MORE THAN 20% OF ANY ONE SPECIES
   c. PLANTING TIME: DECEMBER THROUGH MARCH
   d. PLANTING PROCEDURES: SITE SPECIFIC, PROPER SILVICULTURAL TECHNIQUES TO BE EMPLOYED
7. OTHER CONSIDERATIONS: SITE DISTRIBUTION OF SPECIES SHOULD BE BASED ON SPECIES GROWTH RATE AND HYDROGEOMORPHOLOGY OF THE SITE

8. VEGETATION SAMPLE PLOT REQUIREMENTS
   a. 0-3 ACRE MITIGATION SITE: MINIMUM OF TWO 0.05 ACRE SAMPLE PLOTS/ACRE OF MITIGATION SITE
   b. 3-10 ACRE MITIGATION SITE: MINIMUM OF ONE 0.05 ACRE SAMPLE PLOT/ACRE OF MITIGATION SITE
   c. GREATER THAN 10 ACRE MITIGATION SITE: MINIMUM OF ONE 0.05 ACRE SAMPLE PLOT/2 ACRES OF MITIGATION SITE
   d. PLOT DATA MUST BE REPRESENTATIVE OF ENTIRE SITE OR COMMUNITIES OF ENTIRE SITE
   e. SAMPLE PLOT REQUIREMENTS TO BE ULTIMATELY DETERMINED ON A CASE-BY-CASE BASIS

C. MONITORING WELL REQUIREMENTS
   1. NUMBER, LOCATION, AND INSTALLATION TECHNIQUE TO BE DETERMINED BY SITE CONDITIONS
   2. ALTERNATIVE HYDROLOGY MONITORING
      a. OBSERVATION/PHOTO DOCUMENTATION OF SATURATION AND/OR INUNDATION
      b. STREAM GAUGE DATA RELATED TO SITE ELEVATIONS (FLOODING)

V. TRACKING SYSTEM/MONITORING

A. FINAL DESIGN SPECIFICATIONS: SUBMITTED PRIOR TO INITIATION OF CONSTRUCTION
B. AS BUILT REPORT: SUBMITTED WITHIN 30 DAYS OF MITIGATION SITE COMPLETION AND SERVES AS OFFICIAL NOTICE OF COMPLETION OF MITIGATION CONSTRUCTION
   1. FINAL ELEVATIONS
   2. PHOTOGRAPHS
   3. SAMPLE PLOT LOCATIONS
   4. WELL AND GAUGE LOCATIONS (IF APPLICABLE)
   5. PROBLEMS/RESOLUTION
   6. OTHER INFORMATION AS DEEMED APPROPRIATE
   7. PLANTING DESIGN

C. ANNUAL MONITORING
   1. CONDUCTED AUGUST-SEPTEMBER OF EACH YEAR UNTIL VEGETATIVE SUCCESS CRITERIA MET
   2. REPORT SUBMITTED WITHIN 30 DAYS OF SITE MONITORING
      a. PHOTOGRAPHS
      b. SAMPLE PLOT DATA
      c. WELL DATA (IF APPLICABLE)
      d. PROBLEMS/RESOLUTION

VI. REMEDIAL ACTION: DEVIATIONS FROM ACCEPTED MITIGATION PLAN MUST BE COORDINATED WITH/APPROVED BY THE CORPS OF ENGINEERS

A. UNSUCCESSFUL VEGETATION SURVIVAL
   1. REPLANTING
   2. SPECIES MODIFICATIONS

B. HYDROLOGY PROBLEMS
   1. TOO WET
   2. TOO DRY

C. VANDALISM

D. ANIMAL DEPREDATION

E. NUISANCE PLANT SPECIES

VII. PERFORMANCE BOND TO ENSURE COMPLIANCE WITH PERMIT MITIGATION REQUIREMENTS

VIII. FINAL DISPOSITION OF PROPERTY/PERMANENCE OF INTENTIONS

A. CONSERVATION EASEMENT

B. DEED RESTRICTIONS

C. DONATION TO CONSERVATION AGENCIES/ORGANIZATIONS