Compensatory stream and wetland mitigation in North Carolina: An evaluation of regulatory success

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Abstract

The North Carolina Division of Water Quality (NCDWQ) utilized Wetland Program Development Grant funds from the U.S. Environmental Protection Agency to investigate the regulatory success rates of wetland and stream mitigation projects throughout North Carolina. A probability sampling design was implemented to collect information to facilitate comparison of current statewide mitigation project conditions with regulatory requirements during 2007-2009 using NCDWQ file review (including mitigation plans and mitigation project monitoring report data) and direct observations of site conditions. "Success" for this study was defined as whether the mitigation site met the regulatory requirements for the project that were in place at the time of construction rather than ecological or functional uplift of the mitigation site. Statistical analyses of study data were performed using SUDAAN® software, and results were weighted by both component counts and mitigation size (i.e. acres of wetlands, linear feet of streams). Overall mitigation success rates were estimated at 74.47% (SE=2.94%) for wetlands and 75.01% (SE=4.3%) for streams in NC. Compared to the results of previous studies, the wetland mitigation success rate appears to have increased dramatically since the mid-1990's; two studies documented in 1995 estimated success rates at 20% and 42% (FHWA, 1995; Pfeifer and Kaiser, 1995). Bonferroni corrections were utilized to allow comparison of multiple levels within domains of interest. Domains included mitigation provider (mitigation banks, North Carolina Ecosystem Enhancement Program's design-bid-build and full-delivery programs, North Carolina Department of Transportation and private permittee-responsible mitigation) and method (creation, restoration, enhancement and preservation), as well as project location, age and size. While controlling for the confidence level, differences between success rates for mitigation providers were generally not significant at the 95% confidence level, although permittee-responsible mitigation yielded higher success rates in certain circumstances. In terms of mitigation methods, both wetland and stream preservation showed high rates of success (97.22, SE=2.77 and 100%, respectively), and the stream enhancement success rate (92.42%, SE=5.42%) was significantly higher than that of stream restoration (69.2%, SE=4.88%). Additional comparisons produced statistically significant differences when mitigation size was factored into the analysis: 1.) The Piedmont physiographic region yielded a lower stream mitigation success rate (69%, SE=8%) than other areas of the state (95%, SE=3% in the Coastal Plain, and 98%, SE=1% in the Mountain region), and 2.) Recently-constructed wetland mitigation projects demonstrated a lower success rate (63%, SE=4%) than those built prior to 2002. While improvements in hydrologic modeling and increased understanding of soils issues and stream restoration techniques have contributed to increased mitigation success since the mid-1990's, analysis results showed that no single mitigation provider, mitigation type or geographic region achieved complete success according to the standards approved in mitigation plans. Continued opportunities for improvement exist in the areas of regulatory record-keeping, understanding the relationship between post-construction establishment and long-term ecological trajectories of stream and wetland restoration projects, incorporation of numeric ecological metrics into mitigation monitoring and success criteria, and adaptation of stream mitigation designs to promote greater success in the Piedmont physiographic region.

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Introduction

Purpose of Study

One of the components of stream and wetland permitting is compensatory mitigation. Development projects impacting streams or wetlands in excess of established permitting thresholds often require mitigation activities to offset the impacts. The intent of compensatory mitigation is to replace the functions and values lost due to the impacts, and support the goal of "no net loss" of aquatic resources in the United States.

The purpose of this study was to evaluate compensatory mitigation efforts in North Carolina (NC), in order to determine if mitigation required under Section 404 permits issued by the U.S. Army Corps of Engineers and 401 Water Quality Certifications issued by the NC Division of Water Quality (NCDWQ) met applicable regulatory success criteria in place at the time of project construction.

Funding for Study

This study is the culmination of part of a three-year Wetland Program Development Grant from the U.S. Environmental Protection Agency (USEPA). This grant was awarded to the North Carolina Department of Environment and Natural Resources (NCDENR), Division of Water Quality in 2005, and consisted of two components related to regulatory compliance. The grant funded five NC DWQ staff personnel. Three of these positions (one in each of the NCDWQ Raleigh, Washington and Mooresville Regional Offices) were funded to conduct compliance inspections at sites throughout the state for which 401 Water Quality Certifications were issued for impacts to stream and wetlands. The portion of the grant that inspired this study funded two staff personnel in the NCDWQ Central Office in Raleigh to review compliance with compensatory mitigation requirements associated with 401 Water Quality Certifications.

The mitigation staff developed a computer database for cataloging mitigation projects throughout North Carolina, which provided the population frame for this study. The database was designed to track observations from inspections of mitigation projects, data from monitoring reports and other compliance-related events. Inspection forms were developed and inspections were conducted at stream and wetland mitigation sites throughout the state. A stratified random sampling design was used to collect data through file review and direct field observations of a representative sample of wetland and stream mitigation sites. Data collected reflected the quality of compensatory mitigation and compliance with mitigation requirements in North Carolina. Utilizing a probability-based sample allowed for inferences to be made regarding all wetland and stream mitigation projects listed in the population frame.

Historical and Regulatory Overview

Compensatory mitigation is often required as a condition of permits associated with development impacts to streams and wetlands. In North Carolina, agencies involved in permitting impacts to streams and wetlands include The U.S. Army Corps of Engineers (USACE), the NC Division of Water Quality and the NC Division of Coastal Management (NCDCM). A detailed chronology of federal and state regulatory programs and developments related to wetlands permitting and mitigation prior to 1996 is provided in Pfeifer and Kaiser (1995).

In North Carolina, compensatory mitigation is a component of federal and state administration of Sections 404 and 401 of the Clean Water Act, the State's Coastal Area Management Act (CAMA) and the Dredge and Fill Act. Evaluation of permit applications under all of these acts follows the mitigation sequencing outlined in the 404(b)(1) Guidelines (40 CFR 230), which refers to the avoidance of avoidable impacts, minimization of unavoidable impacts and lastly, compensation for unavoidable impacts. Once impacts have been avoided and minimized to the extent practicable, mitigation actions to compensate for the lost functions and values of the wetlands and/or streams impacted are often required.

North Carolina developed and adopted Water Quality Certification Rules (15A NCAC 2H .0500), which became effective on October 1, 1996. These rules included the mitigation sequencing required under the 404(b)(1) Guidelines, as well as certain other requirements related to compensatory mitigation. Under these rules, compensatory mitigation is required for unavoidable impacts to greater than one acre of wetlands (15A NCAC 02H .0506(h)(2)). Also, mitigation for unavoidable impacts must provide for replacement of wetland acres at a minimum 1:1 ratio through restoration or creation prior to using enhancement or preservation to satisfy mitigation requirements (15A NCAC 02H .0506(h)(6)) when impacts exceed one acre.

The 401 Water Quality Certification Rules implemented in 1996 address activities that have the potential to degrade significant existing uses which are present in wetlands or surface waters. However, in discussing mitigation, the rules refer primarily to wetlands and refer to mitigation of wetland acreage. Similarly, USACE requires applications for fill activities under Section 404 to enumerate impacts in acres. As a result, mitigation in the 1990's generally involved restoration, creation or enhancement of wetland acreage, regardless of whether the impacted resources were wetlands or streams. In 1998, NCDWQ revised the General Water Quality Certifications (GC's) concurrently with the USACE revision and reissuance of the General and Nationwide Permits. The revised GC's included the requirement for compensatory stream mitigation for impacts exceeding 150 linear feet of perennial stream.

Since the reissuance of the GC's, unavoidable impacts to streams and wetlands that required compensatory mitigation (i.e. that exceeded permit thresholds and triggered mitigation requirements) have generally required in-kind mitigation, i.e. mitigation for wetland impacts through restoration, creation, enhancement and/or preservation of wetlands, and mitigation of stream impacts with stream mitigation projects.

Therefore, for the purposes of this study, wetland mitigation projects implemented as early as 1996 were targeted for inclusion in the random sample of sites to be evaluated. Two of the projects sampled were phased such that some of the mitigation was instituted prior to 1996, and these earlier mitigation components were evaluated as part of the study. In general, the earliest stream projects evaluated were designed in 1999 and constructed in 2000 or later.

Performance Standards and Success Criteria

While requirements for compensatory mitigation are referenced in the Clean Water Act Section 404(b)(1) Guidelines, there are no discussions of technical requirements, including performance standards, for compensatory mitigation projects within the Guidelines. Review of mitigation plans as part of this study revealed that while projects often had stated goals (e.g. "replacement of lost functions and values", "restoration of aquatic habitat", "improvement of water quality", etc.), performance standards and success criteria selected for projects generally fell far short of quantifying, or even confirming, that projects were on a trajectory to meet such goals. It should be noted that the demonstration that a project is developing toward the type of goals described above is difficult to quantify, or even to measure directly. The majority of monitoring efforts at mitigation sites utilize surrogates as assumed indicators of restored or improved functions and values. Indeed, even the current regulatory framework for mitigation uses successfully restored wetland area and stream length as a surrogate for compensatory replacement of the functions and values provided by the area of wetland or length of stream impacted.

Some of the earliest wetland projects (early to mid-1990's) required a three-year monitoring period. Many set hydrology success criteria for a minimum duration of saturation or inundation (typically 5% or 12.5% of the growing season) and vegetation criteria of 320 trees per acre (TPA) surviving at the end of three years. In the late 1990's, projects began to require five years of monitoring, vegetation diversity criteria (e.g. minimum six hardwood species) were set for some projects, and some hydrology criteria specified appropriate hydroperiods for wetlands at different landscape positions. Around 2000-2001, hydrology success criteria began to include comparison with a reference ecosystem. Soil criteria have never been the norm, although a few projects in all timeframes required demonstration of hydric soil indicators. In the current study, wetland components were evaluated based on up to four categories of success criteria, depending upon what was specified in the mitigation plans:

- Hydrology – a specified percentage of the growing season during which the project will demonstrate continual saturation within 12 inches of the soil surface or inundation. Criteria usually involve a minimum percentage (generally 5%, 8% or 12.5%) of the growing season based on the targeted wetland type and its expected minimum hydroperiod. Some criteria also establish an upper limit, such as a 75% maximum, to the hydroperiod range for projects in which long-term inundation is a potential concern.
- Vegetation – density and diversity factors. Most criteria for forested wetlands involve a minimum planted woody stem density criterion, such as a requirement that vegetation plot monitoring demonstrate survival of 320 planted TPA at Year 3 post-planting, 290 TPA at Year 4, and 260 TPA at Year 5. Some projects set criteria for woody stem diversity, such as a minimum of five species characteristic of the wetland type. Success criteria for herbaceous wetlands, such as coastal marshes, usually involve a minimum percent cover, which may specify the targeted plant species (e.g. 80 percent cover *Spartina alterniflora* and *S. patens* in appropriate landscape positions).
- Soils – Although this is the third environmental diagnostic in wetland delineation, it is rarely a success criterion for mitigation projects. Soils at restoration projects are

usually disturbed before and/or during construction, and may involve previous agricultural activity or fill material. Development of a soil profile indicative of hydric conditions will not happen instantly, and may take significantly longer than the monitoring period. A small number of projects in the random sample did have a requirement for development of at least one hydric soil indicator (e.g. low chroma matrix, mottles, oroxidized rhizospheres).

- Protection – Mitigation projects are expected to be protected "in perpetuity" and plans must specify some kind of long-term protection mechanism. Most projects today involve a conservation easement that is held by an outside entity (e.g. local land trust, NCDENR's Stewardship Program) other than the landowner. Many older and some newer projects, especially on-site permittee-responsible projects, involve deed restrictions or restrictive covenants which pass with the property title. All protection mechanisms should define limitations on use of the land such that the mitigation project is allowed to continue to develop naturally. Some mechanisms allow for long-term management, especially of vegetation, for specific permittee needs (e.g. airport visibility issues) or larger environmental efforts (e.g. forest management to support endangered species habitats).

Early stream projects (c. 1999) generally had success criteria that included stable channel cross-sections and some percentage of survival of planted vegetation. However, channel stability in some cases was evaluated with a visual inspection and photo points only; quantitative measurements were usually not required. Some of the first specific quantitative stream monitoring requirements were presented in the *Internal Technical Guide for Stream Work in North Carolina* (NCDENR, 2001). The guidance indicated that physical monitoring should include annual measurement of cross-sections at riffles and pools, longitudinal profile surveys and pebble counts. Monitoring of vegetation density was required, with a target success criterion of 320 planted stems per acre at the end of the monitoring period. Additional requirements for macrobenthos monitoring were included for some stream mitigation projects. The monitoring period was expected to be at least five years. However, no specific, measurable performance standards or success criteria beyond vegetative success were provided in the guidance.

In 2003, the *Interagency Stream Mitigation Guidelines* (USACE, et al., 2003) provided the most measurable monitoring criteria for evaluating stream mitigation projects to date. Geomorphic/stability monitoring includes measurement of cross-sections and longitudinal profiles annually for five years. Success criteria are less quantifiable; cross-sections should "…(show) insignificant change from the as-built dimension", and longitudinal profile "…should (show) little change from the as-built longitudinal profile". Additional success criteria include consistency of pool/riffle spacing, minimal aggradation/degradation, and pebble counts should start showing a change in the size of the bed material toward a desired composition. Vegetation monitoring includes evaluation of survival of planted stems. The targeted success criterion is 260 stems per acre after five years of monitoring. An additional requirement included in the 2003 guidelines is the monitoring of bankfull events. An important function of a stream and riparian system is the interaction between these two components during flood flows. The goals of many stream restoration projects include reconnection of the stream with its floodplain (or construction of a newer floodplain at a lower elevation). Therefore, bankfull events must be monitored using a crest or staff gauge during the monitoring period. The success criterion is at least two bankfull events in separate years during the five-year monitoring period.

Review of Historical Mitigation Success

Despite the limitations inherent in evaluating mitigation site success, particularly with the limited guidance available and lack of clarity regarding the goals and objectives of mitigation projects instituted during the 1990s, two reports were identified which attempted to evaluate the status of compensatory mitigation projects in North Carolina (FHWA, 1995; Pfeifer and Kaiser, 1995). Both studies were completed in 1995, and involved evaluation of a variety of wetland mitigation sites throughout North Carolina.

The Federal Highway Administration (FHWA) led a Process Review Team that included the USACE, U.S. Fish and Wildlife Service (USFWS), the NC Department of Environment, Health and Natural Resources (NCDEHNR) and the NC Department of Transportation (NCDOT) to evaluate the effectiveness of compensatory wetland mitigation projects associated with highway construction (FHWA, 1995). The objective of this Process Review was to evaluate compensatory mitigation projects associated with Section 404 permits issued to NCDOT for highway projects during the years 1986 to 1992.

The report of the Process Review Team made a number of observations related to the state of compensatory mitigation at that point in time. It was noted that the older projects did not have clearly stated goals. Of the projects reviewed, only one project utilized target functions in the development of the mitigation plan. None of the projects utilized reference ecosystems in the development of mitigation plans. None of the projects performed hydrologic (water budget) modeling to determine the sources of water or duration of inundation/saturation. In general, the project documentation and reporting was inconsistent or not readily available for review.

The Process Review selected a convenience sample of seven projects for review. The team reviewed permits and plans, and performed on-site inspections. The only available copy of the report located by study personnel included evaluation reports on five of the seven sites. The various data collected were used to answer the following questions, which then were used to determine if the project was successful: 1) Is the site a (jurisdictional) wetland? 2) Is the site the type of wetland designed? The results are presented in Table 1.

Table 1. Inspection Results by Site. – FHWA

Site	Target Wetland Type/ Treatment	Wetland? (Y/N)	Wetland Target Type (Y/N)	Success? Y/N
Sneads Ferry	Marsh/Restoration	Y	Y	Y
Evans Road	BLH[1]/Creation	Y	N	N
Pridgen Flats Bank	Pocosin/Restoration	Partial	N	N
US 52 Bypass	BLH[1]/Rest. & Creat.	Y	NA[2]	N
US 70A	BLH[1]/Restoration	Partial	N	N

[1]BLH = Bottomland Hardwood
[2]The reason for an NA under the Wetland Target Type is unknown
Source: FHWA (1995) Process Review

Of the five projects for which data were available, only one (20%) successfully produced the targeted wetland type. While the sample size was obviously very small, the results of the study highlighted the inadequacies of wetland mitigation planning and implementation in the mid-1990's in NC. The report showed difficulties in attaining correct elevations to support appropriate wetland hydrology, and even when the project resulted in a jurisdictional wetland, the targeted wetland type was usually not achieved.

In *An Evaluation of Wetlands Permitting and Mitigation Practices in North Carolina* (Pfeifer and Kaiser, 1995), 59 permits were reviewed which were issued between January 1, 1991 and December 31, 1993 and required compensatory mitigation. These permits resulted in 82 separate compensatory mitigation "actions". Each "action" having unique characteristics was defined as a separate project. Forty-one of the 82 mitigation projects were visited during the summer of 1994. Table 2 shows the status of these projects at the time of the site visit.

Table 2. Frequency distribution of project status of compensatory mitigation projects

Project Status	No. of Projects
Complete	20
Partially Complete	14
Not Yet Begun	5
Never Implemented	2
Total	41

Source: Pfeifer and Kaiser (1995)

The evaluation method was similar to the FHWA Process Review, and the same evaluation form was used for both studies. Eighteen of the 20 completed projects were successful in creating or restoring jurisdictional wetlands on at least a portion of the site. Eight of the partially completed projects had or most likely would achieve jurisdictional wetland status. Figure 1 illustrates the success data for the completed and partially completed projects.

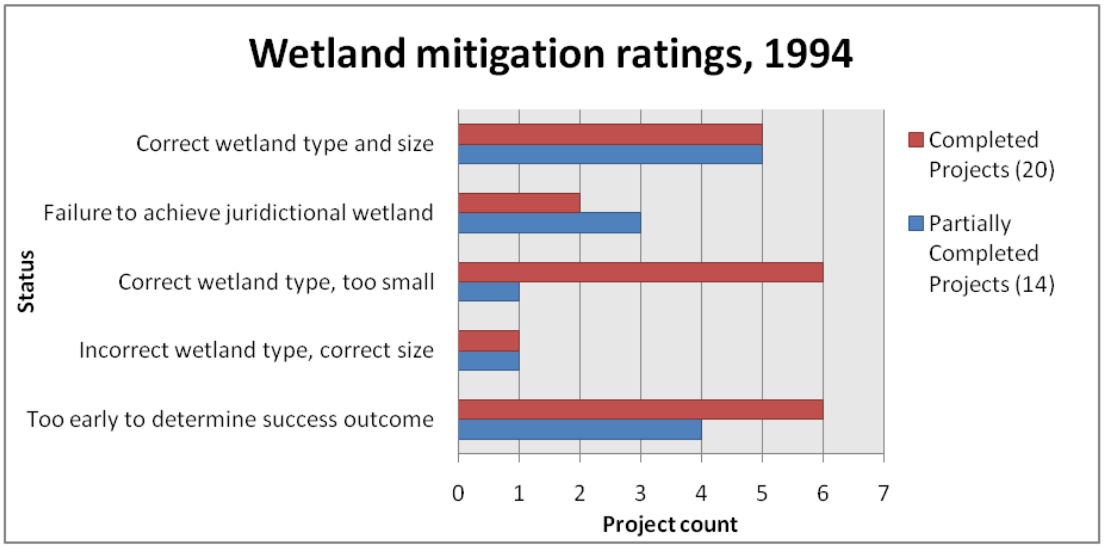


Figure 1. Attainment of target wetland type and size for compensatory mitigation projects evaluated in North Carolina in 1994. Source: Pfeifer and Kaiser (1995).

Of the 24 projects for which current or probable achievement of the correct wetland type and size could be determined, only 10 (42%) were successful. As noted in the FHWA report, failure to achieve hydrology appropriate for the proposed wetland type was the most common factor for lack of success. Incorrect elevation was a contributing factor for seven of the eight completed projects with incorrect hydrology. Vegetative success was not discussed in this report.

Methods

Data Collection

Under the Wetland Program Development Grant (WPDG), the funded NCDWQ staff developed a mitigation tracking database with the goal of cataloging all mitigation projects used to meet conditions of 401 Certifications. The staff searched electronic and paper-based resources available within NCDWQ. NCDWQ's Basinwide Information Management System (BIMS) database was queried for lists of permitted stream and wetland mitigation and restoration projects, and for impact permits requiring mitigation that were issued by NCDWQ from 1990 to the present. Paper files were pulled for each of these 401 Certifications, and the database was populated with information describing each mitigation project: project name and NCDWQ 401 identification number, county, river basin, 8-digit cataloging unit, amount of mitigation present, responsible party contact information, directions to the project, and geographic coordinates (if available). Subforms within the database allowed each mitigation project to be divided into discrete mitigation "components" based on ecosystem type, mitigation type, or other unique characteristics (e.g. "4 acres of riparian wetland enhancement" or "1000 linear feet of perennial stream restoration, priority one"). Thus, a mitigation project could contain one or more components, which may or may not be physically connected. If present in the project's mitigation plan, success criteria were entered with each component.

On-site and project-specific NCDOT mitigation projects were not included in the database. NCDOT already funded NCDWQ staff to track those projects, so utilizing WPDG funds to track the same information would have resulted in redundancy of effort. The effort to populate the mitigation tracking database did include larger off-site NCDOT mitigation projects. Also, because the wetland mitigation threshold is lower for 404 permits issued by USACE (generally 0.1 acre of wetland impact) than for 401 Certifications issued by NCDWQ (1.0 acre of impact), the data searching effort did not capture some of the small on-site permittee-responsible mitigation required by USACE but not by NCDWQ for wetland impacts of less than one acre.

Sample selection

For the purposes of this study, the population of interest was defined as all projects in the mitigation database for which a 401 Certification application (i.e. Pre-Construction Notification) or final mitigation plan had been submitted to NCDWQ from 1996 through 2006. At the time of sample selection, there were 130 wetland projects and 193 stream projects in the population. The population was divided into categories by ecosystem type: wetland and stream. The ecosystem categories were placed into six strata based on mitigation provider: Ecosystem Enhancement Program (EEP) and its predecessor Wetland Restoration Program (WRP) design-bid-build (DBB) program, EEP Full-Delivery program, Mitigation Bank, NCDOT off-site mitigation, Private permittee-responsible mitigation, and Other (generally municipal or Department of Defense projects).

A random sample was selected using a stratified cluster sampling design. USEPA's Environmental Results Program (ERP) Sample Planner[1] with finite population adjustment was used to determine the sample size for each category. ERP Sample Planner selection parameters were set at precision=5%, confidence=95% (α=0.05), and power=80% (β=0.20). With these selection parameters, the ERP Sample Planner indicated a sample size of 98 wetland and 129 stream projects (75% of the wetland and 67% of the stream projects in the population). The sample size was verified by the Yamane formula (Yamane, 1967), which produced the same results as the ERP Sample Planner. The sample size was allocated to each stratum using proportional allocation, such that mitigation provider groups with larger numbers of projects received a larger sample size (Table 3). Projects in each category of the population were numbered sequentially in order of NCDWQ identification number. A random number generator was used to select projects within each stratum, and all components within selected projects were included in the sample.

[1] http://www.epa.gov/erp/toolsandresources.htm

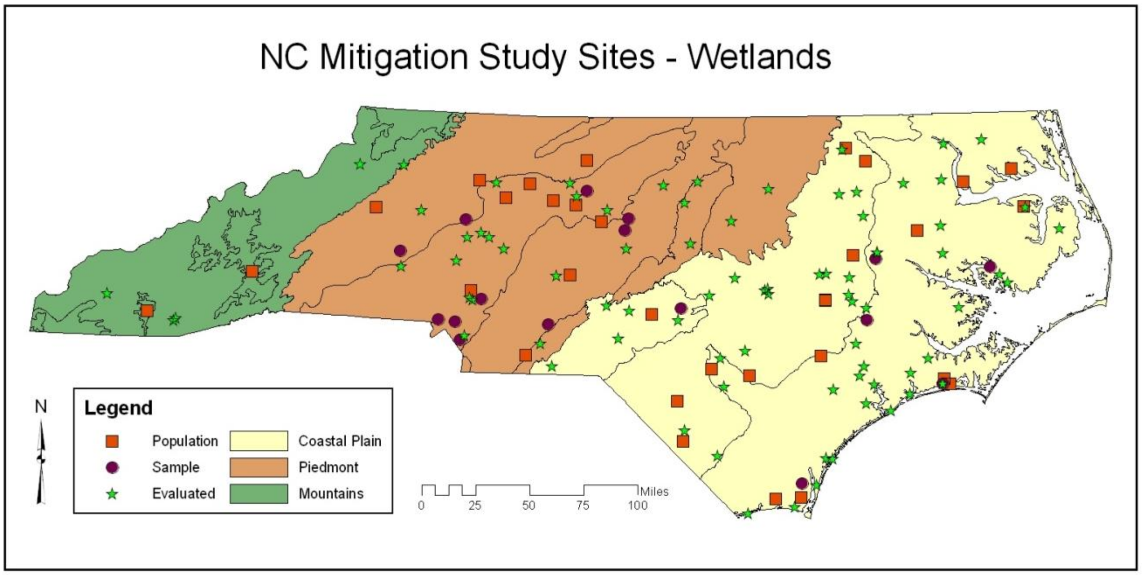
Table 3. Wetland and stream projects in the population frame and random sample.

	Wetlands			Streams		
Provider	**# Projects**		**%**	**# Projects**		**%**
	Population	Sample		Population	Sample	
EEP/WRP	43	32	33%	104	70	54%
Full-Delivery (EEP)	13	10	10%	26	17	13%
Mitigation Bank	11	8	8%	7	5	4%
NCDOT	5	4	4%	4	3	2%
Other	9	7	7%	14	9	7%
Private	49	37	38%	38	25	20%
Total	130	98	100%	193	129	100%

Field and office evaluation protocols

The goal of the stratified random sample study was to estimate population success rates for wetland and stream mitigation projects in North Carolina from a regulatory perspective, and to explore factors that may increase or decrease those success rates. It is important to note that evaluations of mitigation components were performed based on success criteria documented in the project's mitigation plan, rather than on a standardized set of ecological benchmarks. The hope was that the outcomes of this study would highlight practices that were working, as well as opportunities for improvement, and ultimately contribute to greater future success of mitigation within the state.

To facilitate and track project evaluations, data forms were developed for office and field use (Appendix A). The forms were pilot tested on mitigation sites, and circulated among mitigation providers and regulators for comments and suggestions.
Once the forms were finalized, project evaluations began with file reviews for each project in the random sample. Details from the mitigation plan, monitoring reports, previous evaluations and correspondence were recorded on the data forms and/or in the mitigation database. Site visits were conducted for all of the projects that had been constructed. Site visits were coordinated with mitigation providers responsible for the projects, and in almost all cases, providers accompanied NCDWQ staff on the visits. Project evaluation occurred statewide from 2007 to 2009, with the bulk of site visits performed during the 2009 growing season. Each component was evaluated based on available monitoring data and observed site conditions, and given a rating of successful, unsuccessful or NA (for components that could not be evaluated) in the mitigation database.



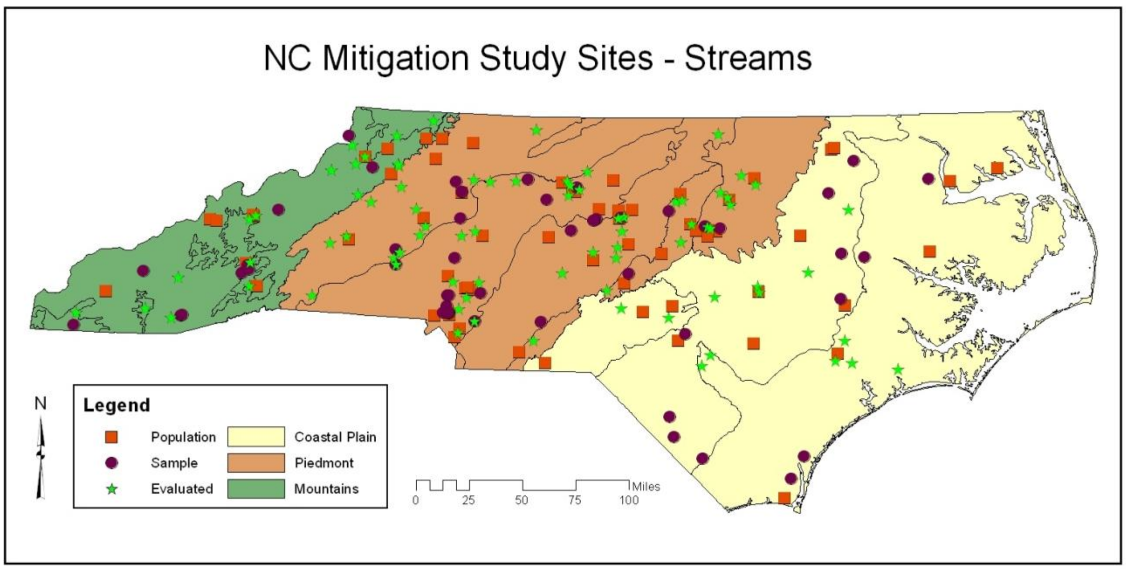


Figure 2. Locations of stream and wetland mitigation project populations (all points), random samples (Sample and Evaluated points) and projects evaluated for the study (Evaluated points).

Figure 2 displays the geographic distribution of mitigation projects in the population, including the relative concentration of wetlands in the Coastal Plain and streams in the Piedmont and Mountain regions. The random sample appeared to have adequately represented the population's distribution. However, Coastal Plain stream mitigation projects in the eastern corners of NC may have been underrepresented in the final dataset of evaluated components because projects in those areas were either not selected in the random sample or were constructed too recently to allow evaluation of success.

During the evaluations, evidence of imperfections in the population frame was detected, and several projects were not evaluated for various reasons.

1. Misclassification: It was determined that the mitigation provider originally assigned to several projects in the mitigation database at times did not accurately reflect the provider currently responsible for the projects. For example, four wetland projects and nine stream projects were classified as EEP/WRP (DBB) or Full-Delivery (EEP) projects because EEP was managing the mitigation credits associated with the projects. However, evaluation activities showed that NCDOT was still taking responsibility for project monitoring and remedial activities at the sites, so these projects were reclassified with NCDOT as the provider type. A total of 15 wetland projects and 18 stream projects were reclassified in terms of mitigation provider, which required adjusting the sampling weights that were used in statistical analysis. Other causes for reclassification included:

    - Projects were planned as mitigation banks, but completed as Full-Delivery (EEP) projects (four wetland, two stream projects).
    - Mitigation banks were thought to be EEP/WRP (DBB) or NCDOT projects because the vast majority of bank credits were utilized to offset NCDOT impacts (six wetland, two stream projects).
    - The provider type was unclear in the mitigation files, so the project was initially classified as Other until the provider type could be clarified (one wetland, two stream projects).

2. Duplicates: One wetland and three stream projects were found to be duplicates of other projects in the database. Each project was evaluated only once as part of the study.

3. Projects that were not elements of the population frame: Two wetland and five stream restoration projects were not conducted for mitigation credit so they were not evaluated as part of the study.

4. Projects for which success could not be evaluated: Twelve wetland and 41 stream projects could not be evaluated because they had not yet been constructed or had been constructed so recently that success could not be determined.

The final number of projects evaluated using the office and field protocol developed for the study was 82 wetland and 79 stream projects (63% of wetland and 41% of stream projects in the population), consisting of 205 wetland and 136 stream individually-evaluated mitigation components, totaling over 20,000 wetland acres and nearly 600,000 linear feet of stream (Appendix B). Sampling weights were adjusted to account for the sampling frame imperfections described above. Post-stratification methods were used to adjust to population totals. Comparisons of the original population frames and the final datasets of evaluated wetland and stream mitigation projects are presented in Figure **3**. Nearly 40% of wetland mitigation projects in both the population and the set of evaluated projects were Private permittee-responsible projects, while EEP/WRP design-bid-build projects made up over one-half of the stream project population, and 42% of the evaluated stream mitigation projects.

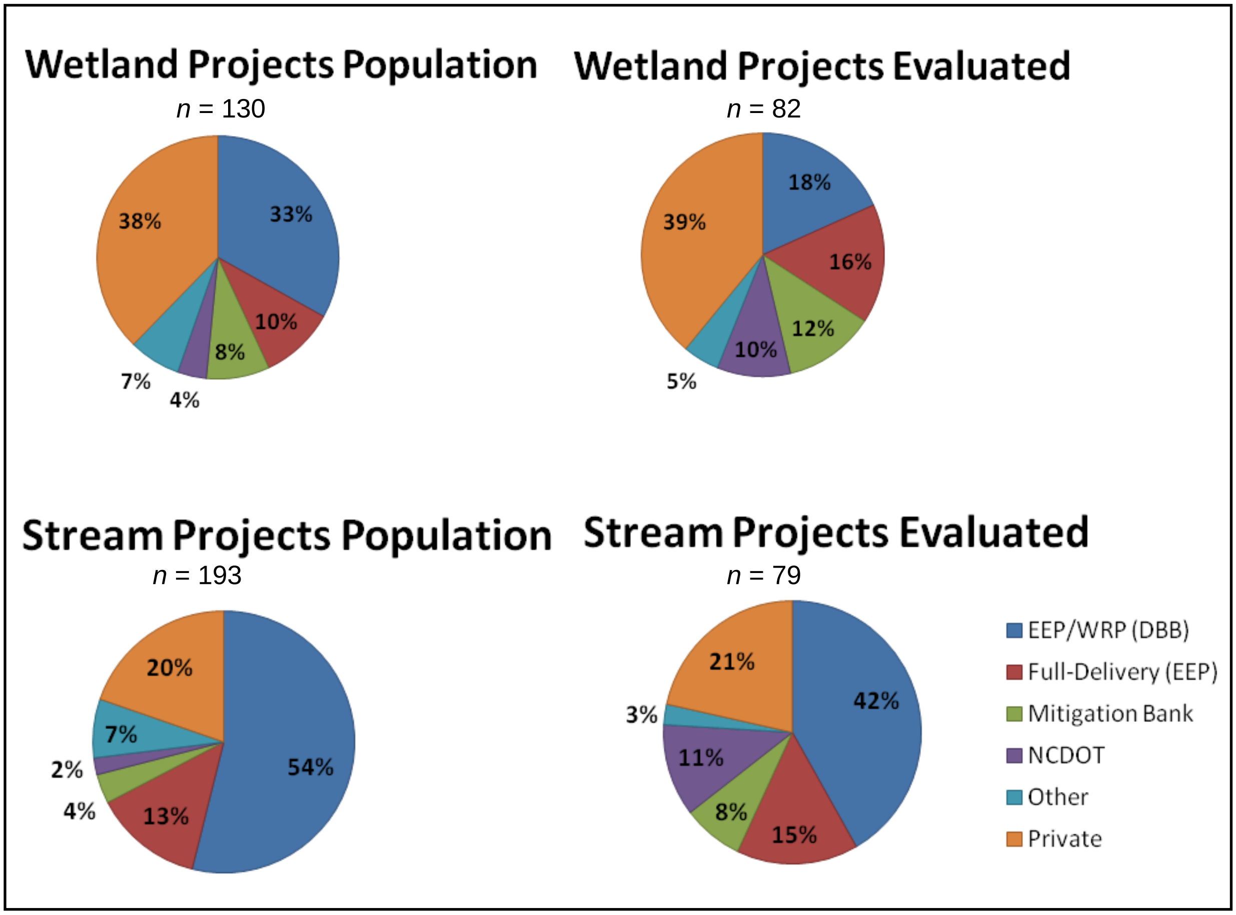


Figure 3. Stratification proportions of initial wetland and stream mitigation project populations, compared with the final datasets of evaluated projects, NCDWQ.

As discussed earlier, regulatory success criteria have changed over time, and they varied from one project to another in the random sample. The present-day environmental conditions of components within each mitigation project were compared to the success criteria set for that specific project at the time of approval or construction. The success ratings described the state of the project at the time of evaluation, but did not predict the future quality of the mitigation. While most projects with "successful" components were expected to continue to meet approved success criteria, an "unsuccessful" rating did not necessarily mean that a component would ultimately fail to provide successful mitigation area or length. For projects with "unsuccessful" components, remediation activities (e.g. supplemental planting, bank stabilization) were recommended with the goal of steering the project onto a trajectory toward long-term success. Project success ratings are included in Appendix C.

Statistical and exploratory data analyses

Statistical data analyses were performed using SUDAAN®, a software package developed at RTI to handle complex study designs, such as the stratified cluster design and weighting present in this study dataset (www.rti.org/sudaan). Using the SUDAAN® outputs as a guide, DWQ staff conducted exploratory data analyses using Microsoft Excel and Access to review evaluation data in an attempt to further investigate factors that may influence mitigation success in NC.

Predictor variables, or domains, of interest included the mitigation provider, the physiographic region of NC in which the mitigation project was located, the mitigation activity, the age and size of the project, and (in the case of wetland mitigation) the ecosystem type. Mitigation providers were the same categories upon which the random sample was stratified: EEP/WRP design-bid-build, Full-Delivery (EEP), Mitigation Bank, NCDOT, Private and Other. The physiographic regions of North Carolina were, from west to east: Mountains, Piedmont and Coastal Plain. Mitigation activities were consolidated into four categories: Restoration, Enhancement, Creation and Preservation, according to the definitions in the *Interagency Stream Mitigation Guidelines* (USACE, et al., 2003) for streams (Creation was substituted for Relocation of a stream outside of its natural valley) and North Carolina's Water Quality Certification Rules (15A NCAC 02H .0506(h)(4)(A-D)) for wetlands. The monitoring start date was utilized as a surrogate for the age of the project, and was categorized into 4-year intervals for wetlands and 3-year intervals for streams to allow analysis consistent with the other categorical variables and provide a roughly equal distribution of component counts within each age class. Project size was categorized similarly into three size classes for wetlands and four size classes for streams at natural breaks in wetland area and stream length. For wetlands, the ecosystem type was also a domain, including the categories Riparian, Non-riparian and Coastal, which consolidated the wetland types defined in the Dichotomous Key in the *N.C. Wetland Assessment Method (NC WAM) User Manual* (NCWFAT, 2008). Riparian included bottomland hardwood forests, riverine swamp forests, headwater wetlands, floodplain pools and non-tidal freshwater marshes located in a geomorphic floodplain. Non-riparian included hardwood and pine flats, pine savannas, pocosins, small basins, and non-tidal freshwater marshes not located in a floodplain. Coastal included salt and brackish marshes.

The response variable for all analyses was the success (Yes or No) of the mitigation components. Success rates were calculated for several sub-domains and statistical testing was used to evaluate significant differences between levels of the domain. Due to the unique characteristics of preservation, there was interest in both analyzing the entire dataset of evaluated components, and removing preservation components from consideration and analyzing the study data for restoration, enhancement and creation components.

Since the domains were categorical, the analyses focused on the association between component success and the categories, or levels, within each domain. The weighted counts of successful and unsuccessful components were produced for the levels within each domain. Successful and unsuccessful rates, as well as their 95% confidence intervals, were calculated for each level. Analyses were conducted in an attempt to determine statistical differences of success rates within levels of each domain. Pair-wise t-tests and their associated probability values were utilized to test null hypotheses of no significant difference in success rates between levels. Because each domain involved multiple comparisons (i.e. each level was compared to every other level within the domain), a sequential Bonferroni correction, Holm's method (Holm, 1979) was utilized to minimize the potential of falsely discovering a difference in the success rate between any two levels. Holm's method involves ordering the p-values (low to high), then dividing the p-value indicative of significance (i.e. $\alpha=0.05$) by the number of pair-wise tests remaining for comparison with each p-value in the sequence (example in Table 4). Analyses were conducted to compare success rates within all levels of each domain with and without the inclusion of preservation components.

Table 4. Hypothesis testing using Bonferroni Corrections (Holm's Method) for success rates of streams in the domain of physiographic regions.

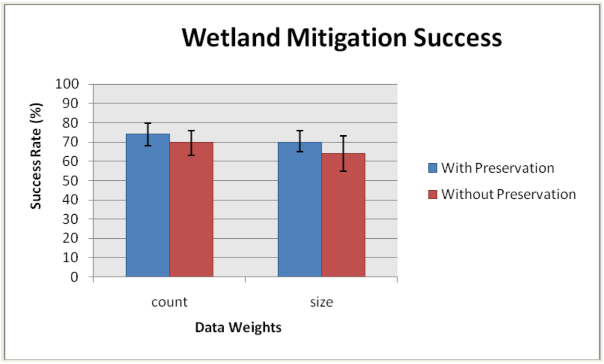
Comparison	Contrast Ratio	p-value	Number of hypotheses	Threshold p-value	Reject null?
Mountains vs. Piedmont	0.29	0.0004	3	0.0167	yes
Coastal Plain vs. Piedmont	0.26	0.0027	2	0.025	yes
Coastal Plain vs. Mountains	-0.03	0.4084	1	0.05	no

In the absence of functional comparisons between impact and mitigation sites, the primary concern of parties interested in stream and wetland mitigation is not the number of mitigation projects or components, but the actual **amount** of mitigation that is successfully offsetting lost linear feet of streams and acres of wetlands. Therefore, it was desirable to examine success based not only on the number of components that were meeting regulatory success criteria, but also based on the size of those components. Analyses were repeated using component size as a way to explore the proportion of successful and unsuccessful acres of wetlands and linear feet of stream in the levels of each domain. Again, analyses were repeated for the data set both with and without the inclusion of preservation components. The results provided an opportunity to examine the amount of mitigation in the state meeting and not meeting regulatory success requirements, and to consider factors that may be related to the amount of successful mitigation. Statistical success rates, contrast p-values and associated Holm's Method values for hypothesis testing are included in Appendix D, based on analysis of both successful and unsuccessful component counts and the size proportions of successful and unsuccessful wetland area and stream length.

Results

Overall Success

For wetland components, the percentage evaluated as successful and unsuccessful was 152:57 (117:56 excluding preservation components), yielding a weighted success rate of 74.47% (SE=2.94%) for all components, and 69.59% (SE=3.32%) when preservation components were excluded. When the proportion of successful wetland mitigation area was considered, the rate of success was slightly lower at 70% (SE=3%) and 64% (SE=4%), with and without preservation, respectively. For stream components, the percentage evaluated as successful and unsuccessful was 102:34 (95:34 excluding preservation components), yielding a weighted success rate of 75.01% (SE=4.30%) for all components, and 73.74% (SE=4.46%) when preservation components were excluded. When the proportion of successful stream mitigation length was considered, the rate of success was estimated at 84% (SE=6%) with preservation components and 75% (SE=6%) when preservation was excluded (Figure 4).



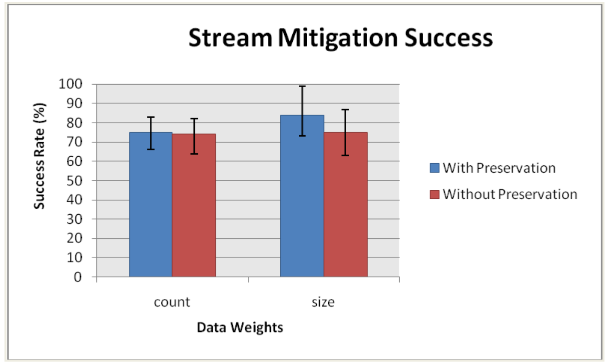


Figure 4. Overall mitigation success rates, based on component counts and mitigation size (acres of wetlands, linear feet of streams). Error bars represent 95% confidence limits.

Mitigation Provider

Due to the small sample size and applicant-provided origin of projects in the Other category, it was combined with Private for this analysis. Analysis of all evaluated wetland components, including preservation, yielded success rates for the categories of mitigation providers ranging from 68.57% (SE=4.55%) to 80.65% (SE=7.51%) when analyzed by component counts, and from 63% (SE=4%) to 79% (SE=9%) when weighted by size. Stream success rates ranged from 68.52% (SE=8.34%) to 83.33% (SE=14.59%) when analyzed by component counts, and 67% (SE=10%) to 98% (SE=1%) when weighted by size. Results for the complete set of evaluated components, including preservation components, are displayed in Figure 5. Preservation-excluded wetland success rates ranged from 59.26% (SE=5.19%) to 77.78% (SE=7.52%) when analyzed by component counts, and from 53% (SE=3%) to 76% (SE=9%) when weighted by size. Preservation-excluded stream success rates ranged from 66.67% (SE=8.5%) to 83.33% (SE=14.59%) when analyzed by component counts, and from 63% (SE=11%) to 86% (SE=8%) when weighted by size.

Using Holm's Method as described previously, contrast analyses of the weighted component success counts of the mitigation provider categories showed that success rates were not statistically significantly different across providers. These results can be observed in the overlapping confidence intervals in the corresponding plots in Figure 5. However, when the proportion of successful size (acres of wetlands, linear feet of streams) was considered, Private/Other permittee-responsible mitigation was found to have greater success rates (75%, SE=1% and 71%, SE=3%) than NCDOT off-site mitigation (63%, SE=4% and 53%, SE=3%); for wetlands only (with and without preservation components, respectively) and EEP/WRP design-bid-build mitigation for streams with preservation component inclusion only (67%, SE=10% for EEP/WRP DBB compared to 98%, SE=1% for Private/Other).

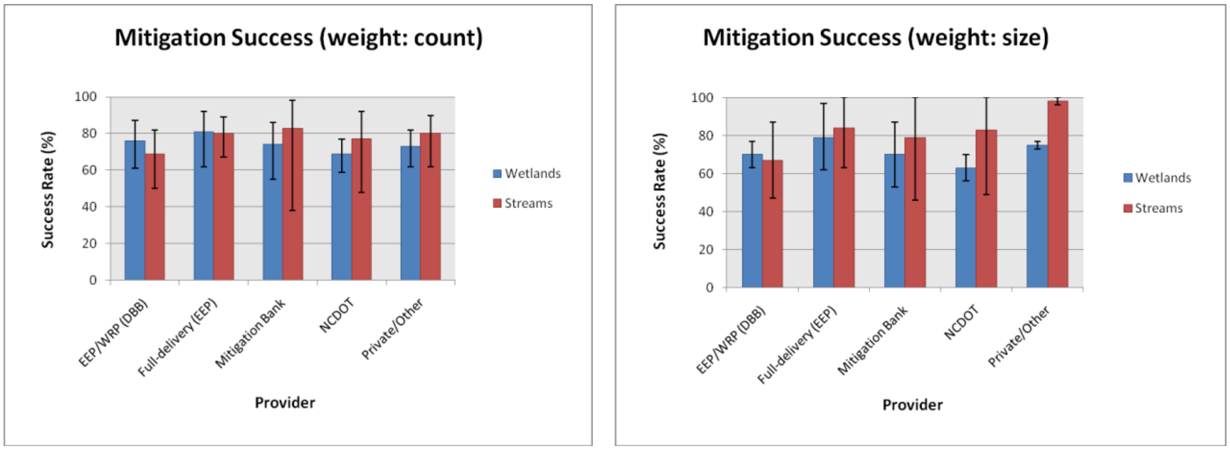


Figure 5. Success rates based on component counts and weighted by wetland area and stream length for the mitigation provider categories. Error bars represent 95% confidence limits.

Physiographic Region

Based on component counts, wetland mitigation showed weighted success rates of 80.52% (SE=13.83%), 77.29% (SE=6.72%) and 73.21% (SE=3.05%) in the Mountains, Piedmont and Coastal Plain, respectively. Contrast analyses indicated that these rates were not statistically significantly different from one another. However, when success ratings factored in size, the values were 53% (SE=4%), 81% (SE=7%) and 70% (SE=3%), respectively (Figure 6), and contrast analyses indicated a statistically significant difference between the Mountains and the other two regions. Results were similar when preservation components were excluded from the analysis. Based on component counts, non-preservation wetland mitigation showed weighted success rates of 77.01% (SE=14.22%), 73.75% (SE=7.27%) and 67.68% (SE=3.53%) in the Mountains, Piedmont and Coastal Plain, respectively. The rates were not statistically significantly different from one another. When success ratings factored in size, the values were 52% (SE=2%), 76% (SE=9%) and 64% (SE=5%), respectively, and demonstrated a statistically significant difference between the Mountains and the other two regions.

Stream results were similar to wetland results in that statistically significant differences were not found based on component counts (81.30%, SE=8.47%; 69.87%, SE=5.78%; and 88.5%, SE=6.75% in the Mountains, Piedmont and Coastal Plain, respectively), but were found when the proportion of successful stream mitigation length was considered. However, it was the Piedmont physiographic region that exhibited a statistically significantly lower success rate (69%, SE=8%) than the other two regions (98%, SE=1% and 95%, SE=3% in the Mountain and Coastal Plain regions, respectively) (Figure 6). When preservation components were excluded from consideration, stream success results were nearly the same when weighted by count: 79.69% (SE=10%), 68.73% (SE=5.8%) and 87.71% (SE=7.15%) in the Mountains, Piedmont and Coastal Plain, respectively. When weighted by stream length, the results displayed a similar, but somewhat less dramatic, trend compared with that shown in Figure 6. Size-weighted success rates were 86% (SE=10%), 67% (SE=8%) and 94% (SE=4%) in the Mountains, Piedmont and Coastal Plain, respectively, and only the Coastal Plain and Piedmont regions were found to have a statistically significant difference in success rates.

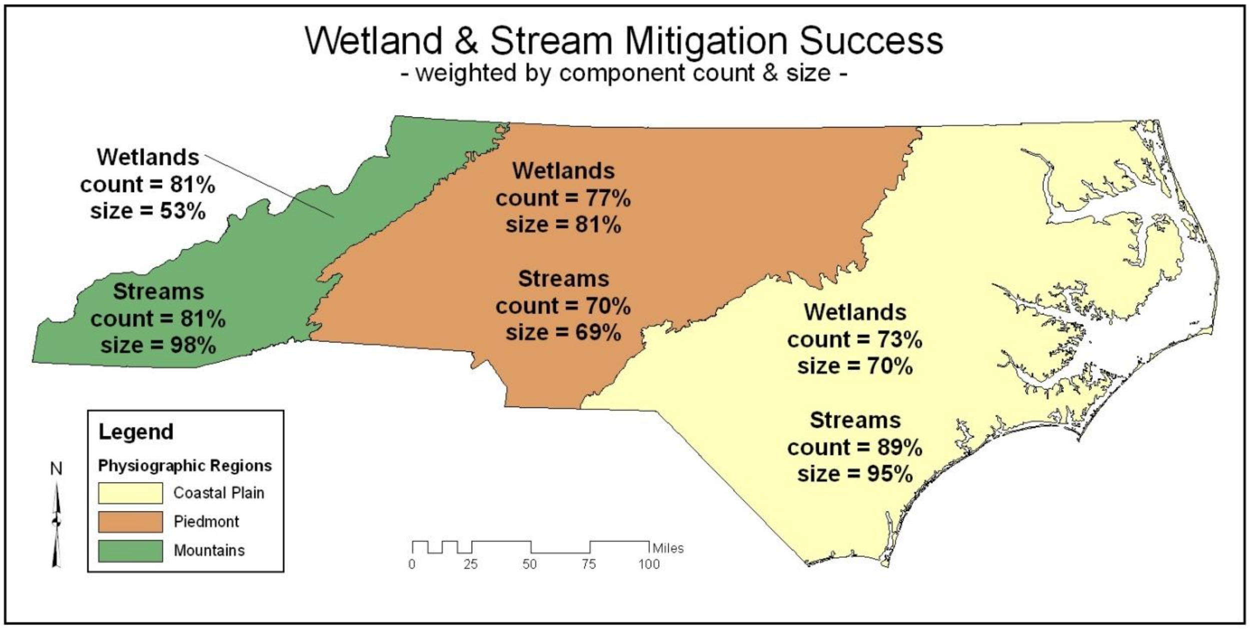
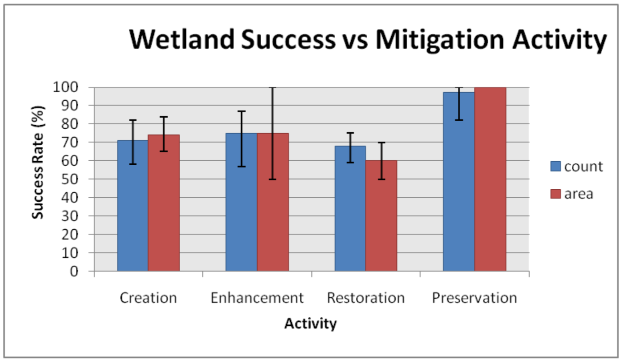


Figure 6. Wetland and stream mitigation success rates in the physiographic regions based on all data (including preservation) and weighted by both component count and size.

Mitigation Activity

Preservation was the most successful mitigation activity for both wetlands and streams, with success rates of 97.22% (SE=2.77%) and 100%, respectively (Figure 7). No statistically significant difference was observed between the success rates of wetland restoration, creation and enhancement at 67.61% (SE=3.91%), 71.42% (SE=6.11%) and 74.78% (SE=7.47%), respectively. Creation accounted for the smallest part of the mitigation area (2% of the non-preservation acreage) in the evaluated sample, restoration accounted for 73% of the area, and enhancement made up the remaining 25% of evaluated non-preservation wetland mitigation area.

The stream restoration success rate (69.2%, SE=4.88% based on component count; 72%, SE=7% when the proportion of successful length was considered) was statistically significantly lower (p=0.0002) than that for stream enhancement (92.42%, SE=5.42% based on count; 99%, SE=1% based on length) as well as preservation (100% in both cases). Stream creation (i.e. relocation) also appeared to have a high rate of success (100%); however, the sample size of two made it difficult to draw conclusions and it was excluded from Figure 7.



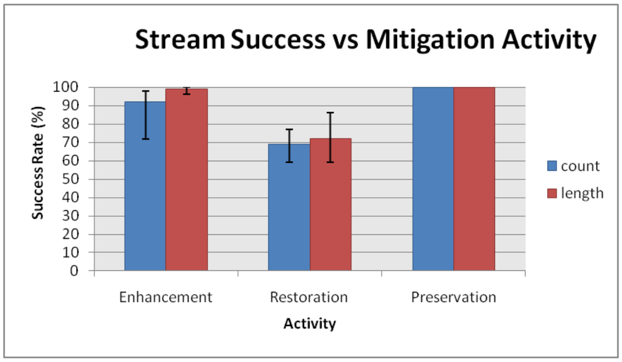


Figure 7. Mitigation activity success rates, based on component counts and size. Error bars represent 95% confidence limits.

Component Age

Stream components were grouped into three age classes based on their monitoring start date: pre-2003, 2003-2005 and 2006-2008. Success rates ranged from 66% (SE=9%) to 89% (SE=8%) across all statistical analyses. No statistically significant differences were found between age classes using Holm's Method. The ages of wetland components spanned a larger range, and were grouped into four age classes: pre-1998, 1998-2001, 2002-2005 and 2006-2009. While component count analyses did not show a relationship between project age and success, consideration of successful wetland area revealed that wetlands that were first monitored prior to 2002 were rated as more successful than newer wetlands, especially those established during the most recent timeframe of 2006-2009 (Figure 8). Preservation-included results were 78% (SE=3%) for pre-1998 projects, 81% (SE=3%) for 1998-2001 projects, and 63% (SE=4%) for 2006-2009 projects. Preservation-excluded results were 76% (SE=1%) for pre-1998 projects, 81% (SE=3%) for 1998-2001 projects, 58% (SE=5%) for 2002-2005 projects and 50% (SE=1%) for 2006-2009 projects.

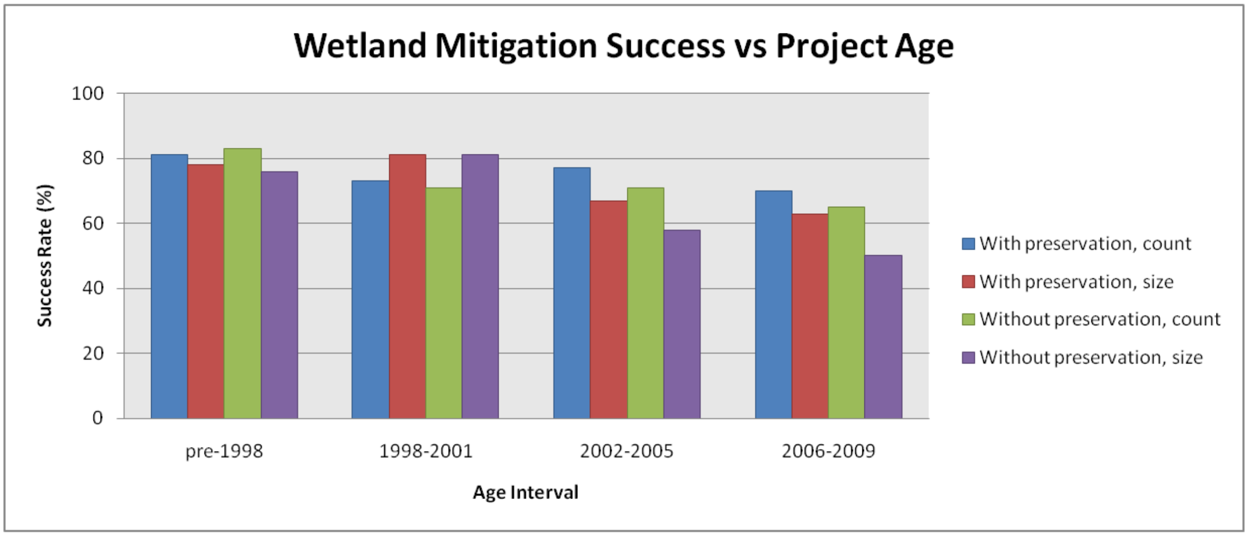


Figure 8. Wetland component success rate by age group, with and without inclusion of preservation components, weighted by count and size. Error bars represent 95% confidence limits.

Project Size

Stream components were grouped into four size classes based on the total stream length of the mitigation project in which they existed: <2,500 linear feet, 2,500-5,000 feet, 5,001-10,000 feet and >10,000 linear feet of stream mitigation. Wetland components were similarly grouped into three project size classes of <20 acres, 20-200 acres and >200 acres of wetland mitigation. No statistically significant differences in success rate were found for either resource type.

Ecosystem Type (Wetlands)

For wetlands, component wetland types were analyzed to explore differences in the mitigation success rates of Coastal, Riparian and Non-riparian wetlands. No statistically significant differences in success rate were found.

Other Variables

Statistical analyses were also conducted for the domains of Basin (i.e. NCDWQ's 17 river basin classifications) and Ecoregion, as defined by the Mitigation Ecoregions in NCDWQ's Guidance on the Use of Compensatory Mitigation in Adjacent Cataloging Units[2]. However, both of these domains contained so many levels that the sample size within several levels was too small to yield conclusive and reliable results.

Discussion

Data Availability

A self-critique, as well as an external criticism (BenDor, et al., 2009), of the regulatory agencies overseeing wetland and stream mitigation in North Carolina involves the absence of an easily-accessible, complete listing of all existing mitigation projects in the state with up-to-date information regarding project location, quality, compliance and credit yield.

The Corps of Engineers, Wilmington District has made great strides in this direction with the recent implementation of the OMBIL (Operations Management Business Information Link) Regulatory Module (ORM-2) with integrated geospatial information systems (GIS) tools for cataloging and analyzing information used in regulatory decision-making, including watershed characteristics, jurisdictional determinations, impact permits and mitigation requirements. USACE, Wilmington District is also working toward tracking mitigation bank activities (e.g. proposals, credit releases, bank debits) with the Regional Internet Bank Information Tracking Systems (RIBITS), and has long provided links to mitigation bank information and mapped locations from the mitigation page on its website[3].

NCDWQ's BIMS database contains mitigation-related information, but was not developed to track mitigation data Developing queries to extract mitigation data has proven to be impossible due to the structure of the database and a lack of staffing and funding resources to implement large-scale changes within it. Through the Wetland Program Development Grant that funded the mitigation compliance project from which this study grew, NCDWQ has designed a database

[2] http://portal.ncdenr.org/web/wq/swp/ws/401/certsandpermits/mitigation/memos
[3] http://www.saw.usace.army.mil/WETLANDS/Mitigation/index.html

to catalog and track all mitigation projects in NC if and when the information for projects can be located and entered. The sample from this study was drawn from the NCDWQ database, which contained an incomplete population of mitigation projects at the time. Populating the database is ongoing, and has grown substantially since the random sample was selected for this study. As personnel have continued to research data sources and enter new projects, the number of projects in the database has nearly doubled, but proportions based on provider types have remained fairly consistent (Figure 9).

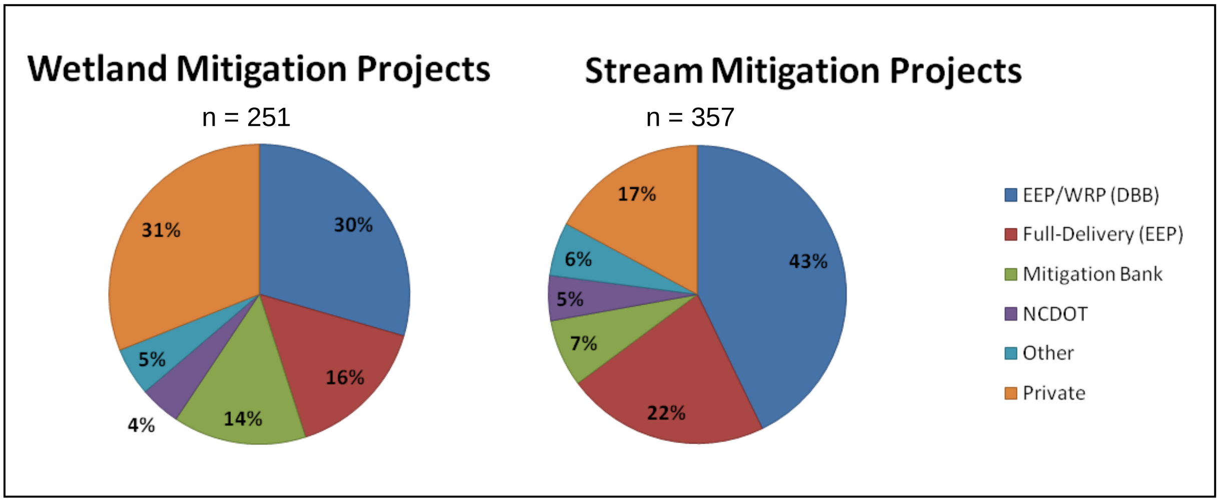


Figure 9. Proportions of mitigation projects by provider type in the NCDWQ mitigation database, as of September 2010.

NCDENR's non-regulatory mitigation provider, EEP, is continually working toward greater transparency, largely through development of data resources on the agency's website, www.nceep.net. Additions during the course of this study included a beta-test version of maps that communicate geographic information about EEP projects and planning areas, and a spreadsheet linking to project documents (e.g. monitoring reports, mitigation plans).

Preservation as Mitigation

Preservation involves the long-term protection of property with high-quality wetlands and streams. As described previously, state wetland rules (15A NCAC 2H.0506(h)(6)) require compensatory mitigation for wetlands to include a minimum 1:1 replacement of impacted acres through restoration or creation prior to utilizing enhancement or preservation. Current DWQ policy does not require this 1:1 replacement for streams.

While preservation does not directly support the goal of "no net loss", preservation is utilized to provide compensatory mitigation, usually in conjunction with other forms of mitigation. In some cases, addition of preservation of existing headwater streams and wetlands located upstream from restoration and enhancement components can have value in capturing a subwatershed and protecting these upstream areas from future impacts which may negatively affect the mitigation areas downstream. However, preservation does not provide added net wetland acreage or stream length that acts to replace lost functions and values. The proposed use of preservation as compensatory mitigation should be evaluated carefully. The 2003 *Stream*

Mitigation Guidelines (USACE, et al., 2003) include criteria that a proposed preservation site must meet to be suitable for use for compensatory mitigation. Preservation of aquatic resources in areas where development potential is minimal, such as preservation of streams in steep, inaccessible valleys, may be of limited value in terms of curtailing potential further losses of aquatic resources in an area.

Only one of the 36 wetland preservation components evaluated was shown to be unsuccessful. Another one was observed to be unsuccessful during the site visit, but the provider took immediate action to address the cause of failure and prevent future issues. Both components were part of private mitigation projects in the Coastal Plain physiographic region which were unsuccessful due to infringement or trespass. All of the seven stream preservation components evaluated were shown to be successful. The high rate of preservation success is attributed to the relatively small risk of failure of these sites. Streams and wetlands being preserved should be in good condition, with fairly high aquatic function. Generally, causes of failure of a preservation site are easement encroachment by adjacent landowners, illegal trespass for recreational purposes (e.g. off-road vehicles), and loss of vegetation due to mowing. These issues can significantly degrade the function of a stream or wetland, thereby reducing its effectiveness as compensatory mitigation. On the other hand, if a solid plan for long-term stewardship is properly implemented by an entity capable of addressing such issues promptly, then preservation appears to provide a viable option for providing protection of existing wetland and stream resources.

Mitigation Activities (other than Preservation)

DWQ staff had expected the data analysis to show that success rates for wetlands would be higher than streams because of the longer experience with wetland mitigation in NC and the lower energy of water movement through the systems. Rather than the lateral, sometimes flashy flow that can cause stability issues at stream restoration projects, water sources returned to previously drained wetland areas primarily interact vertically with soils and vegetation. However, success rates for restoration of the two resource types were similar, and indicated that challenges remain to restoring both. Overlapping confidence intervals for wetland restoration, enhancement and creation results meant that a significant difference was not found for wetland mitigation activities, but enhancement demonstrated greater success than restoration for stream mitigation.

Stream enhancement likely has a higher success rate than stream restoration because enhancement involves work on a stream that is generally in a more stable condition. Enhancement projects generally involve relatively minor adjustments to stream dimension and profile, can be accomplished with less construction equipment activity in the stream channel than restoration projects, and most often include vegetative restoration and livestock exclusion. However it should be noted that stream enhancement does not generally result in an increase in stream length while stream restoration usually results in an increase in stream length. Therefore the reduced success rate with restoration compared to enhancement may be partially offset with a gain in aquatic resources.

Stream restoration (e.g. construction of a new channel) usually begins with a much more degraded stream, often a result of disturbance both along the proposed restoration reach and in the watershed above the project reach. Altered hydrology and/or on-site physical degradation (e.g. loss of streambank vegetation, channelization, hoof shear by livestock with unrestricted access to the stream) have disrupted the natural equilibrium of stream processes (e.g. sediment transport, aquatic life cycles) within the reach, resulting in alterations of the original channel structure and stream functions. The designer is required to use reference reach data and mathematical equations which have been developed to predict channel dimension, slope, radius of curvature of the meanders, and other channel characteristics to design and construct a new channel that will function "naturally" within the existing site and watershed conditions. Errors in the design phase, errors in the construction phase, alterations in the watershed above the restoration reach, and catastrophic natural events (e.g. excessive rain events or drought) are some of the possible reasons for lack of success of stream restoration projects.

Wetland restoration success does appear to have improved substantially since the 1995 FHWA study. To maximize the likelihood of success, care must be taken to provide an appropriate soil environment, surface elevation and water budget for the targeted wetland type. Much of the success of a wetland restoration project depends upon the level of soil manipulation and compaction that has occurred at the site, and the degree to which this can be corrected in order to reestablish the natural connections between surface water, groundwater and plant roots. Methods that are now commonly used on wetland restoration sites include ripping of compacted soils to allow these connections to occur. This practice appears to positively affect the establishment of wetland restoration projects, but must be done thoughtfully with regard to the soils present at the site. Efforts to precisely sculpt ground surface microtopography can have the opposite of the desired effect, and exacerbate compaction issues such that a site will develop a matrix of wetland pockets and upland mounds.

Progress has also been made in some of the other areas found to reduce wetland restoration success in the FHWA (1995) study, especially in the use of hydrologic modeling prior to project implementation. In spite of this, wetland components that were rated "unsuccessful" were usually found to be too dry (i.e. did not achieve saturation or inundation for the targeted hydroperiod duration, as specified in the mitigation plan) or too wet (i.e. long-term inundation was impacting survival of the targeted vegetative community).

It is impractical to assume that every acre of a wetland restoration project or every linear foot of a stream restoration project will become the targeted wetland or stream type during the monitoring period and for all time into the future, given that:

- Wetlands and streams are natural systems that are always in flux and intricately connected with the watersheds around them.
- Hydrologic models and natural channel design principles cannot precisely predict the exact outcomes of restoration work across every point on a site.
- Site conditions will change over time after construction as plant roots stabilize and aerate soil so that it can hold more water; plants grow, take up more groundwater through evapotranspiration, and provide greater shade and organic input; and stream sediment transport and sorting occur.

Creation of both resource types represented a very small portion of the components evaluated for the study. The designs of successful wetland creation components constructed on-site near associated impacts often included consideration and incorporation of post-impact stormwater hydrology in addition to groundwater and precipitation inputs.

Physiographic Regions and Soils

Mitsch and Gosselink (2000) estimated that North Carolina originally contained over 11 million acres of wetlands, including several regionally significant wetland areas in the Coastal Plain, such as Great Dismal Swamp, pocosins and Carolina Bays, and forested wetlands and marshes along the region's large rivers. The vast majority of NC wetlands (unimpacted, impacted and mitigation) are located in the Coastal Plain physiographic region. Of the non-preservation wetland mitigation acreage in the random sample, 97% was located in the Coastal Plain, and included large tracts of pocosin, hardwood flat, pine flat, bottomland and swamp forest ecosystems. The average project size was significantly larger than that in the other physiographic regions. In terms of wetland mitigation success, Coastal Plain projects appeared especially prone to ponding and long-term inundation issues, which in turn impacted the establishment of woody vegetation. Causes included generally high water tables in combination with constructed surface elevations and local weather patterns. An elevation difference of just centimeters can mean the difference between saturation and inundation of a Coastal Plain wetland. Although hydrologic models can calculate optimal elevations, they cannot predict with absolute certainty the amount of water that will be present on the post-construction site. Wetland mitigation projects in this physiographic region may require adjustment of elevation levels during the first years after construction in order to achieve the most favorable hydrologic conditions for wetland development; however, it can be difficult to know when to act to alter site elevations. As vegetation grows and soils loosen over time, a site's hydrology will change accordingly, so it is important to keep a long-term view in mind when considering additional earthwork at a mitigation project. If weather conditions are within normal ranges, but site hydrology is incorrect during the first two years, then it is probably time to consider additional grading activity. After that point, vegetation establishment may reach a point at which is it less desirable to disturb the plants than to adjust the hydrology. A benefit of recently extended monitoring timeframes will be the opportunity to observe hydrology changes, in addition to vegetation growth and survival, over longer periods of time.

Wetlands in the Mountain physiographic region also fill important ecological roles. Many mountain wetlands are unique smaller systems (e.g. mountain bogs) that provide water quality benefits and ecological diversity to local areas and habitat for wetland-dependent organisms, such as bog turtles (i.e. *Clemmys muhlenbergii*) and mountain pitcher plants (e.g. *Sarracenia rubra ssp. jonesii*), some of which are listed as threatened or endangered. The sample size for evaluated components in the Mountains was small (one preservation and six non-preservation components). Most of the non-preservation components involved restoration or creation of small pockets of riparian wetlands that were generally placed in appropriate landscape positions and successfully met regulatory criteria. The one component that did not achieve success had become inundated due to beaver activity in the abutting stream, leading to low survival of woody vegetation. This component was relatively large in size (20 acres) compared to many of the other components, leading to the large shift in success rate when the results were weighted by size. It does not appear that Mountain wetland mitigation is inherently less successful than that in other physiographic regions, and similar issues due to beaver activity were observed in the Coastal Plain and Piedmont, as well.

Stream mitigation success rates in the Coastal Plain and Mountains were higher than in the Piedmont physiographic region. While restoration success is dependent upon the interplay of multiple site condition and design variables, the higher success rate observed in the Coastal Plain is partially attributable to the lower gradient of the streams, which results in lower velocity flows and reduced shear stress on stream banks. A 2005 information paper (USACE and NCDWQ, 2005) on Coastal Plain stream restoration emphasized that Outer Coastal Plain riparian headwater valleys are wetland-stream complexes, and that the two types of aquatic systems are inextricably linked. Therefore, the success of restoring a stream in this setting is dependent upon restoring the connected riparian wetlands. In the Mountains, the higher success rate is likely due, in part, to the relative stability of the materials (i.e. rocks) that make up the surrounding landscape and are appropriate for use in stream restoration projects.

Success rates for stream mitigation were lowest in the Piedmont, likely due in large part to issues stemming from the soil types most frequently encountered in the Piedmont. Soils in this physiographic region generally have higher clay content than soils in other regions, soils and subsoils tend to be highly erodible once they have been disturbed, and establishing vegetation in disturbed clayey soils can be extremely challenging, especially when organic content is low and soils are compacted prior to or during construction. This may be a reflection of historical land use in the Piedmont where massive amounts of soil erosion before modern agricultural erosion control practices filled up many of the Piedmont valleys with deposits of fine sediment (Trimble, 1974; Richter and Markewitz, 2001). The streams have downcut through these sediments and are now often on bedrock or coarse sediment with incised banks of silt and clay which are highly erodible. As a result, Piedmont stream projects often experience difficulties involving erosion at stress points such as around structures and along the outside edges of meander bends. During this study, these issues were particularly evident on sites where a new stream channel was constructed at an elevation lower than the historic floodplain elevation (i.e. Rosgen Priority 2 restoration projects (Rosgen, 1997). In such cases, the stream corridor was excavated down and the channel and floodplain were constructed in subsoil. Once construction was completed and the site was exposed to heat and drought commonly experienced during summer months, the ground surface often resembled pavement, infiltration could be quite low, and survival and growth of planted trees was often impacted. In addition, periods of high flow could result in erosion in these bare areas, causing rills and gullies and transporting loads of eroded fine sediment into the restored stream channels. Lack of deeply rooted vegetation compounded these effects. The same soils issues led to unsuccessful Piedmont wetland restoration components which demonstrated unsuccessful hydrology due to water either running off or perching on top of hardened high-clay soils.

Restoration plans submitted for sites in the Piedmont often include discussions of proposed soil testing and addition of soil amendments, but the frequency at which these activities are actually done as part of the project is unknown. None of the recently-constructed stream projects visited as part of this study showed obvious evidence of the incorporation of soil amendments (e.g. mulch) during construction. Similarly, the plans often recommend “stockpiling and reuse of existing topsoil, where feasible…” which requires a staging area for stockpiled soil, more equipment and manpower time and effort, and thus higher project costs. As above, the frequency at which this practice is utilized is unknown, but these practices would be expected to increase the likelihood of success of Piedmont mitigation projects.

Another contributing factor to lower stream mitigation success rates in the Piedmont may be difficulties in design considerations. While Coastal Plain stream hydrology is largely driven by watershed size and Mountain stream hydrology is related to slope, Piedmont stream hydrology involves differing magnitudes of landscape variables, making the design of stream restoration projects in this region more complicated.

The lower rate of mitigation success in this region is especially troubling because several of the most rapidly developing urban areas (e.g. Charlotte, Greensboro and Raleigh) of NC are located in the Piedmont. Offsetting the impacts related to this urbanization requires successful mitigation projects, so it is important that mitigation attempted in the Piedmont focus on reducing soil compaction and taking other steps to facilitate both hydrologic and vegetative success. The use of soil amendments and inclusion of some larger trees in planting plans has been successful in some cases. The challenges to mitigation success in the Piedmont warrant further experimentation with these and other methods that could boost the establishment of mitigation projects, and continued investigation into appropriate design techniques for stream restoration in this physiographic region.

Vegetation and Hydrology

A review of the wetland components rated unsuccessful during the study showed that failing to meet vegetation success criteria was the most frequent cause for the rating, followed closely by hydrology. Most unsuccessful components were failing to meet multiple success criteria. Wetlands are systems, and if the vegetation was dying, there was usually a related hydrologic or soil issue. The period of drought during the early part of the study inhibited the hydrologic success of many projects, and newly-planted vegetation could not become established under those conditions. However, a nearly equal number of components held too much water, and tree survival was impacted by long-term inundation due to beavers, soil compaction and/or perched water tables. This was especially evident at wetland creation projects where the ground surface was scraped down to subsoils which provided low permeability and fertility, causing issues similar to those at Priority 2 stream restoration projects.

Current wetland restoration practices involve “jump-starting” succession by focusing on planting later successional tree species, such as oaks, rather than pioneer species (e.g. maples and pines) in both wetlands and riparian buffers. Most projects are planted with bare-root seedlings at high densities in hopes that enough trees will survive to meet required densities. During the study site visits, there was discussion about other planting regimes that may provide better results by working in concert with post-construction conditions during the early stages of restoration site development. Ideas included:

- A phased planting approach allowing successional growth immediately after construction, delaying the planting of climax species until Year 3 or later, and then installing a smaller number of larger nursery stock of those species; or

- Intensive management of vegetation during the monitoring period, including removal of not only invasive vegetation, but also opportunistic volunteer tree species in order to reduce competition for planted trees.

Both ideas have merit and could support development of the targeted vegetative communities. Further experimentation and pilot long-term studies, especially in combination with soil amendments, fertilizers, and herbaceous and woody vegetation management techniques are warranted. However, these studies and practices would involve an increase in the cost of mitigation project construction and time commitment by mitigation providers.

Another cause of vegetation failure was competition by aggressive and/or invasive vegetation in all strata (e.g. *Typha spp.*, *Ligustrum sinense*, *Lonicera japonica*, *Liquidambar styraciflua*). Very few mitigation plans included success criteria related to invasive vegetation, although many discussed eradication or reduction of these species as project goals. A few projects tied success to maintaining a maximum stem density or percent cover of invasive species. Control of invasive vegetation can be difficult immediately post-construction as these species take advantage of disturbed conditions and bare soils. Especially when it is present in surrounding areas, removal of invasive vegetation may need to occur often during the early stages of vegetation growth to ensure that it does not gain a foothold and threaten the long-term composition of the vegetative community at the mitigation site.

Mitigation Age

When weighted by size, wetland mitigation projects demonstrated decreasing success rates over time. There are several possible reasons for this trend. First, mitigation success criteria have continued to become more rigorous (specific and measurable) over time. Older projects, especially those in the pre-2002 age groups, generally had less stringent regulatory requirements than those permitted and constructed in the last several years. Secondly, there may be a trend toward greater achievement of success as projects mature. Recently constructed mitigation projects are just that – construction sites. Time is required to allow for vegetation establishment and the development of surface water and groundwater connections through, and interactions with, soil. Wetland functions of chemical transformations and evapotranspiration develop over time, so mitigation projects may become more successful in regard to certain parameters as they age. On the other hand, in some cases unforeseen impacts (e.g. beavers, natural or man-made disturbances) can limit the success of projects. Finally, the most direct cause related to this study could have been the weather during the evaluation phase. 2007 was a year of record-setting drought for the southeastern United States, including the entire state of NC (NCDWR, 2007). Many wetland mitigation projects constructed during or just prior to this time period did not achieve compliance with regulatory success criteria approved in their mitigation plans. Rainfall volume was low, groundwater tables dropped, and newly-planted vegetation had an extremely difficult time surviving and becoming established, making it difficult for newer projects to sustain wetland hydroperiods or attain targeted vegetation densities. Older, already established mitigation wetlands may have been showing greater resilience to temporary shifts in weather patterns due to deeper, more strongly rooted vegetation and more developed soil profiles which allowed for extended storage of groundwater.

After issuance of *Compensatory Mitigation for Losses of Aquatic Resources; Final Rule* (USACE and USEPA, 2008), monitoring has been extended to seven years for forested wetland mitigation ecosystems in NC. The trend observed during this study supports that extension, and indicates that a timeframe greater than the original five-year monitoring period may be necessary to fully apprise the success of a mitigation project and its long-term likelihood to perform the functions that will offset permitted losses of aquatic resources. This phenomenon of wetland mitigation success trajectories over time should be explored under a study utilizing consistent ecological success criteria in order to verify the trend and draw conclusions about its cause(s).

As discussed earlier, stream mitigation success criteria have become more fully developed over time, especially since the development of the *Stream Mitigation Guidelines* (USACE, et al. 2003), so projects constructed since that time were more likely to be evaluated using stricter standards than the pre-2003 projects. To an even greater degree than wetland mitigation, stream mitigation projects (especially restoration) take time to develop, depending largely on the establishment of woody riparian vegetation to provide stability to streambank soils. Younger stream reaches without mature woody vegetation are susceptible to instability issues due to flashy flows, and newly planted vegetation is more susceptible to herbivory and drought impacts. Consideration of longer stream monitoring periods (e.g. 7-10 years) coupled with less intensive monitoring and more frequent visual observation may be warranted to identify problems in the early stages of development.

A preliminary study of riparian buffer age and its effects on stream aquatic function supports the hypothesis that restoration of a functional stream corridor may require significantly longer time periods to display restored ecological functions and values. Orzetti, et al. (2010) collected data on water quality, habitat and macroinvertebrates from 30 Piedmont streams with buffers ranging from zero to greater than 50 years of age in the Chesapeake Bay watershed. Overall, buffer age was positively related to improved stream habitat, water quality, and a suite of macroinvertebrate metrics. The data collected showed marked improvements occurring within 5-10 years post-restoration, with conditions approaching those of long established buffers within 10-15 years post-restoration.

Mitigation Provider

The relative success of area-weighted Private/Other permittee-responsible wetland mitigation was due, at least in part, to the tendency of permittees to attempt more on-site wetland mitigation area than required by the 401 Certification Conditions. For example, as part of the impact permits for a project on Pope Air Force Base, mitigation requirements included 2.0 acres of on-site wetland creation. The area amenable to wetland creation on the site was larger than the requirement, and 2.76 acres of wetland creation were attempted. During a 2009 site visit, USACE-Wilmington and NCDWQ staff determined that although a portion (0.37 ac) of the mitigation area did not meet the approved success criteria, the area that did successfully meet the criteria exceeded the 2.0 acre amount required by the permit. Therefore, for the purposes of this study, the component was evaluated as successful from a regulatory perspective. In the case of all other provider types, the evaluations considered the entire area of wetland mitigation because each acre could end up being used to offset wetland impacts.

Length-weighted stream mitigation results were favorable for Private/Other permittee-responsible mitigation only when preservation components were included. Many stream impact permits require the preservation of on-site streams that are not slated for impact, in order to prevent future losses that could undermine the functionality of on-site mitigation and the remaining local aquatic resources.

Success Criteria

The success criteria used in the evaluations for this study were based on the success criteria proposed in the original restoration plans for each of the projects. These success criteria (primarily channel stability and riparian zone vegetation reestablishment for streams, hydroperiod and vegetation survival for wetlands) are generally regarded as surrogates for improvement of aquatic function. Direct measurements of aquatic function and ecological improvement are difficult to accomplish, and results of such direct measurements (e.g. macrobenthic community monitoring) are greatly affected by climatic variation, especially in the smaller streams that are most often the target of stream mitigation projects. Further, the monitoring timeline of five or seven years makes some analyses (e.g. aquatic chemistry) less useful than they would be for longer-term monitoring. Restored wetlands and streams on subsoils with planted bare-root seedlings will begin developing the functions (e.g. nutrient transformation, shading) of mature vegetative communities and hydric or riparian soils, but full functionality is not generally expected to be achieved in five years. Post-restoration monitoring is utilized to demonstrate that a mitigation project is on a trajectory toward developing the environmental characteristics of the targeted type of ecosystem. Ecological functionality similar to a reference system may begin to develop during the monitoring period, but full functionality will not be achieved until the restored system has had time to mature.

It has been widely discussed within the stream restoration community that there is likely a significant temporal factor involved in the development of a restored stream and riparian zone with regard to the restoration of ecological functions and values. There is agreement among stream restoration practitioners and the regulatory community that the current five-year regulatory monitoring period is, in most cases, too short to see functional improvements in a stream and its associated riparian zone. Very often, the site has not yet achieved a closed canopy over the five-year monitoring period. As of the date of this report, few stream restoration projects exceeding 10 years old are present in North Carolina. Myriad opportunities to test the hypothesis that functional uplift at stream restoration sites cannot be realized until 10-15 years following restoration will be available as projects completed since 1999 reach this age category.

Additional efforts are underway to identify methods of demonstrating functional uplift. The *Interagency Stream Mitigation Guidelines* (USACE, et al., 2003) are currently under revision, and one of the primary goals is the improvement of documenting ~~and~~ success criteria for stream mitigation projects. One direct measurement methodology for measuring stream function that is being considered by the Guidelines revision team is the use of macrobenthos monitoring. The NC Division of Water Quality has been sampling wadeable and non-wadeable waters of North Carolina since 1978. Macroinvertebrates are collected, identified and used to calculate a Biotic Index, which is a summary measure of the tolerance values (numeric descriptors of the tolerance of particular taxa to stressors) found in the sample, relative to the abundance of each taxon. Based on Biotic Index values, NCDWQ assigns a bioclassification (Excellent, Good, Good-Fair, Fair and Poor) to a particular stream reach.

Standard Operating Procedures used by NCDWQ (NCDWQ, Environmental Sciences Section, 2006) have limited the assigning of bioclassifications to streams greater than four meters wide and with a watershed of three square miles or greater. Most stream mitigation projects involve small first and second-order streams with watersheds considerably smaller than three square miles. The Qual-4 methodology can be applied to smaller streams (drainage area of less than three square miles); however, the reliability of the method in these smaller watersheds had not previously been tested.

A total of 122 small streams in 25 counties in the Mountain and Piedmont physiographic regions were sampled annually in 2005, 2006 and 2007 using the Qual-4 methodology (NCDWQ, Environmental Sciences Section, 2009). The mean watershed size for Mountain sites was 1.02 square miles, with a range from 0.30 to 2.70 square miles. The mean watershed for the Piedmont sites was 1.81 square miles, and watershed sizes ranged from 0.3 to 3.0 square miles. The findings of the study supported the use of Biotic Indices for the establishment of bioclassifications for streams with drainage areas less than three square miles, and provide revised bioclassification tables for small Piedmont and Mountain streams. However, it is likely that there is a lower limit to the use of this metric to assess water quality. The Division of Water Quality has recently been awarded a Wetlands Program Development Grant to define the lower limit for small stream biocriteria, expand the index period, and assess the potential application of the use of Biotic Indices to document functional uplift on stream restoration projects. The results from this grant should be available around January 2013.

Data have previously been collected from a subset of EEP stream mitigation projects to document changes in the aquatic community before and after stream restoration (NC State University, Water Quality Group, 2008). A Dominants in Common Index was proposed by the author, David Penrose, to compare the community of the restored reach with an upstream reference area as a measure of stream recovery and improvement following restoration. The data collected has shown that in most cases these restorations do not meet the proposed threshold (75 percent similarity of dominant taxa between restored and reference reach). However, this metric did not consider taxa tolerance values which would reflect the relative tolerance to various pollutants by the various aquatic biota. In addition, this method was not subjected to analysis comparing Dominants in Common (DIC) between similar reference reaches or within the same reach over time.

As part of the *Stream Mitigation Guidelines* review, NCDWQ obtained data collected by Mr. Penrose and calculated Biotic Index values for samples collected from a stream mitigation site located in Catawba County (Lyle Creek). Lyle Creek is located in the Inner Piedmont ecoregion and has a watershed of 0.76 square miles. This project was selected because macrobenthos data were available pre-construction (2001) and post-construction for four years (2003-2006), and other ecological metrics (e.g. DIC, taxa richness) suggested possible ecological uplift. The results of this analysis are shown in Table 5 and Figure 10.

Table 5. Biotic Index Data and Bioclassifications – Lyle Creek

Year	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***
Upstream Ref. BI	4.64		4.42	4.52	4.35	4.00
Restoration Reach BI	6.00	Year of Construction	7.18	5.69	5.59	4.60
Upstream Ref. Bioclass	Good		Good	Good	Good	Excellent
Restored Bioclass	Fair		Poor	Fair	Fair	Fair-Good

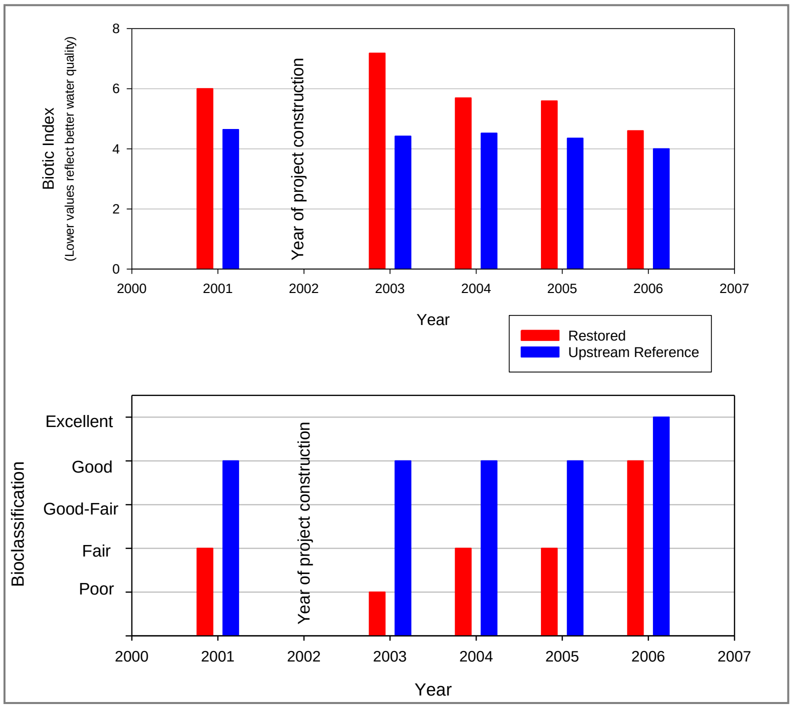


Figure 10. Biotic Index Data and Bioclassifications – Lyle Creek

As shown above, the pre-construction bioclassification was Fair. Usually a stream classified as Fair is reported to USEPA as not meeting its designated uses and is placed on the 303(d) list. As expected, the bioclassification fell to Poor immediately post-construction. However, Biotic Index values improved from 2004 (Fair) to 2006 (Good-Fair), showing improvement of one bioclassification level above pre-construction. Based on these data, it appears that water quality in the restoration reach was improved as a result of the restoration activities. As part of the new Wetland Program Development Grant, NCDWQ has obtained the raw macrobenthos data for additional projects from the NCSU Water Quality Group study in an effort to evaluate the use of Biotic Indices to assess functional uplift for stream mitigation projects under this new EPA grant.

Sediment is one of the most prevalent water pollutants in North Carolina. The USEPA (1992) concluded that siltation and nutrients are the pollutants responsible for most of the nonpoint source impacts to the nation's surface waters. Rivers, lakes, estuaries, and wetlands are all affected primarily by one of these two pollutants. Degraded streams can be a significant source of sediment to downstream receiving waters. Many of the streams targeted for mitigation projects have unstable banks, and mass wasting and erosion result in discharges of sediment downstream.

The *Stream Mitigation Guidelines* revision team is considering demonstration of a reduction of sediment discharge as a possible metric to show functional uplift. One method being considered is the use of Bank Erodibility Hazard Index (BEHI) data to calculate sediment export rates pre-construction and at the end of the monitoring period. While this method can be used to generate quantitative descriptions of sediment loss (e.g. tons of sediment per year), the method can be time-consuming and can also be somewhat subjective, especially if different individuals are collecting the data pre and post-construction.

A methodology recently adopted by EEP for selected projects employs a visual evaluation of the entire stream channel within the proposed conservation easement, and estimates the linear footage of channel with unstable/eroding banks. This same evaluation can then be done post-construction. The visual evaluation can be performed relatively quickly, and unstable areas can be marked on plan sheets and photographed for documentation. While this method is also somewhat subjective and cannot be used to generate sediment export rates, a marked reduction in the total linear footage of unstable/eroding stream channel could reasonably be concluded to represent a reduction in sediment discharge from the restored stream reach.

At DWQ's request, EEP provided streambank stability data for 20 EEP projects (Appendix E) for which there was enough pre-construction data or descriptive information to provide a conservative estimate of pre-construction percentages. Post construction stability data was obtained from the most recent monitoring reports. Before restoration, 20-65% of the stream banks in the restoration were stable. After restoration, 90-95% of stream banks were stable (Figure 11).

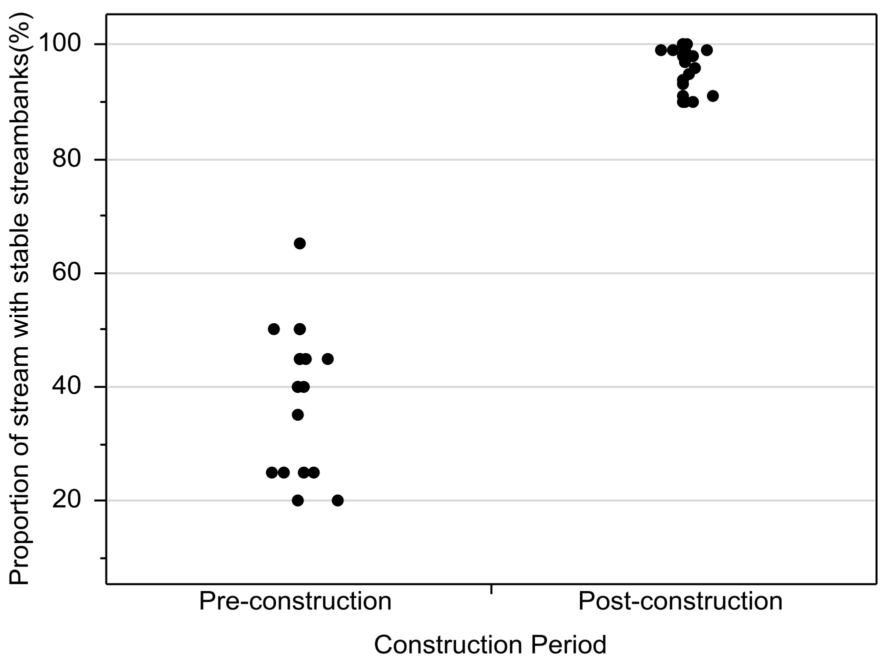
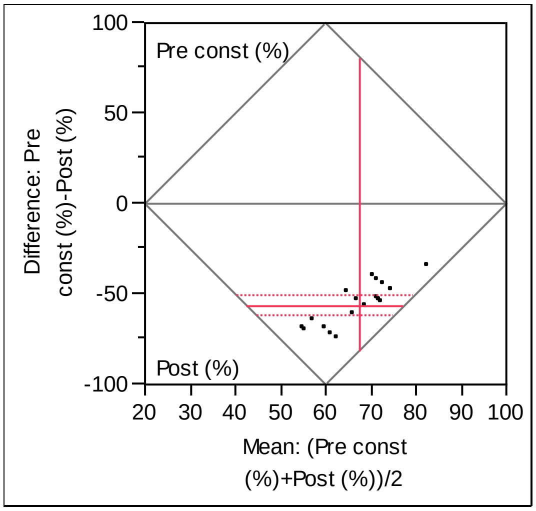


Figure 11. Proportion of stable stream banks before and after restoration.

Since data were included only from projects with before and after data, a matched pairs analysis was appropriate to determine if this increase in stream stability was statistically significant (Figure 12).



Pre const (%)	39.5	t-Ratio	-22.073
Post (%)	95.85	DF	19
Mean Difference	-56.35	Prob > |t|	<.0001
Std Error	2.55289	Prob > t	1.0000
Upper95%	-51.007	Prob < t	<.0001
Lower95%	-61.693		
N	20		
Correlation	0.41436		

Figure 12. Matched Pairs Difference: Pre-construction (%) – Post-construction (%)

Based on the data provided by EEP, the increase in stable banks due to stream restorations was found to be highly statistically significant (p<0.0001), which indicated that there was significantly less sediment entering the restored streams from stream bank erosion than was the case pre-restoration.

DWQ cross-checked site evaluation data collected as part of the grant study with the stability data collected and provided by EEP as discussed above. DWQ concurred with the stability evaluations of 19 of the 20 projects submitted. DWQ observations made through several site visits to the Prestonwood Country Club site suggested that streambank stability at this site was significantly less than the 91 percent reported by EEP. Since 19 of 20 sites showed markedly increased stability after restoration, DWQ believes that the proposed stability evaluation methodology shows promise as a fairly rapid method of documenting improvements in streambank stabilization at stream restoration sites. . This metric, in combination with other metrics currently in use or under consideration by the *Stream Mitigation Guidelines* revision team, may be useful in documenting functional uplift as described in the Federal Mitigation Rule (USACE and USEPA, 2008).

Conclusions

The overall success rate for wetland mitigation in North Carolina found by this study (74%) has greatly improved in comparison with studies conducted in the mid-1990's (FHWA, 1995; Pfeifer and Kaiser, 1995), which estimated success rates much less than 50%. Those studies highlighted the importance of hydrologic modeling in developing the construction plans for wetland mitigation projects. Since that time, the use of hydrologic modeling has become commonplace, and the regular application of this practice appears to have increased the frequency at which mitigation projects achieve hydrology appropriate to the wetland type targeted for restoration or creation. In spite of this, continued obstacles to wetland mitigation success include post-construction soils and ground surface elevations that hold too much or too little water on the site, thereby inhibiting the establishment of the targeted plant community and ecosystem type.

Overall success of stream projects evaluated during this study was approximately 75% based on site conditions at the time of on-site evaluations. Rating of a particular stream component as unsuccessful does not mean that the component will ultimately not generate mitigation credit. In many cases, repairs to stream channels, replanting of riparian buffers and/or nuisance exotic vegetation control efforts will put the project back on track to meet final regulatory success criteria.

North Carolina's aquatic resources are systems, and few mitigation components in the study were rated as unsuccessful for only one reason. The contributing factors of landscape position, hydrologic inputs and outputs, soil permeability and fertility, vegetation survival and vigor, weather conditions and protection from disturbance must work in harmony in order for regulatory or ecological success to be achieved. Natural systems will always display some variability, unpredictable behavior and unexpected results. The regulatory challenge is to decide when that variability translates into failure to successfully replace aquatic resource functions lost through permitted impacts.

Success criteria are continually being refined based on the best available restoration science in an attempt to make that decision. A good deal is understood in regard to wetland soils, hydrology, vegetation and their connections, and stream restoration design methods have developed quickly and robustly over the last twenty years. The study demonstrated that mitigation success has improved substantially since the 1990's, but that further study regarding factors that influence the restoration of aquatic systems is warranted. In North Carolina, specific areas of interest include, but are not limited to:

- Methods to improve the establishment of wetland and riparian vegetation in Piedmont soils;
- Continued development and testing (and eventual incorporation into impact calculations and mitigation success criteria) of functional assessment methods for wetlands and streams with specific, numeric goals;
- Planting regimes to maximize long-term achievement of targeted vegetative climax community diversity, density and health;

- Exploration of hydrology issues (both too wet and too dry) at restored wetland sites to determine specific causes and their likely solutions;
- Study of post-construction ecological development over time at restoration sites, and integration of increased understanding of ecological trajectories into success criteria for mitigation projects; and
- Consideration of longer monitoring periods to better gauge successful development of mitigation projects.

In general, detailed evaluation of mitigation projects or components that are not meeting success criteria should be conducted to address the reasons for the lack of success, rather than simply “treating the symptoms” and replanting or repairing problem areas. Identifying causative factors on problem sites is as important as documenting and highlighting successes in furthering the practices used in performing mitigation activities. Regulatory and non-regulatory agencies comprising the NC Interagency Review Team are working to identify evaluation criteria that can better demonstrate functional uplift of stream and wetland mitigation sites, as required in the federal mitigation rule (USACE and USEPA, 2008).

A significant finding of this study is that the physiographic region in which the project was located had a significant effect on the success of stream restoration. Success rates in the Coastal Plain, Mountains and Piedmont were 89%, 81% and 70%, respectively, with greater differences noted when success results were weighted by length of stream. It is likely the lower success rate in the Piedmont is a result of the soil characteristics prevalent on Piedmont sites, which appear to have an effect on both channel stability and vegetative success. Mitigation providers instituting stream projects in the Piedmont need to put more emphasis on addressing potential problems associated with Piedmont soil characteristics such as erodibility, low permeability/infiltration and low soil nutrient/organic matter. Practices that may require special attention include:

- Soil testing and amendment;
- Application of mulch to retain moisture and increase surface organic matter;
- Final ripping/scarification to address plow pan or compaction caused by equipment;
- Use of larger planting stock;
- Retention and reuse of existing topsoil (especially during “Priority 2” projects); and
- More aggressive streambank matting and livestaking.

Further, the difference in success rates between stream restoration and enhancement indicates that greater emphasis should be placed on developing stream enhancement projects, especially in areas where restoration is a high-risk endeavor.

While efforts continue on several fronts to provide greater transparency and completeness of available data, it is difficult for an interested person to readily glean information related to all aquatic resource impacts and associated mitigation projects in NC. The mitigation community would benefit from a coordinated effort between regulatory and non-regulatory agencies involved in mitigation to develop an easily-accessible data clearinghouse that showed linkages between impact and mitigation sites as well as locations and boundaries, service areas, released and potential credits, plans and other documents, and monitoring data for planned and existing mitigation projects. This type of coordination could benefit the public by increasing availability and accessibility of information, and the agencies by reducing duplication of efforts.

This study examined mitigation projects at one moment in time, based on the available data and environmental conditions of the projects at that moment. To make the results more meaningful, it would be beneficial to conduct a similar study periodically (e.g. every five years) using the most complete inventory of mitigation projects and the most current evaluation techniques available at that time. This repetition would allow for analysis of trends in the quality and compliance of mitigation in North Carolina over time.

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Appendix A: NCDWQ Mitigation Evaluation Forms

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Mitigation Project Evaluations: Information Table

NC Division of Water Quality

Date of Office Review: ___________________ **Evaluator's name(s):** _____________________
Date of Report: ___________________________ **Report for Monitoring Year:** _______________

Date of Field Review: ___________________ **Evaluator's name(s):** _____________________
Other individuals/agencies present: ____
Weather conditions (today & recent): ____
Directions to Site:

I. Office Review Information:

Project Number: **Project Name:** **County(ies):** **Basin & Subbasin:** **Nearest Stream:** **Water Quality Class of Nearest Stream:** **Mitigator Type:** **DOT Status:** **Total Mitigation on Site** **Wetland:** **Stream:** **Buffer:** **Approved mitigation plan available? Yes No** **Monitoring reports available? Yes No** **Problem areas identified in reports? Yes No** **Problem areas addressed on site? Yes No** **Mitigation required on site:** **Associated impacts:**	**Project History:** **Event** **Date** *Add significant project-related events: reports received, construction, planting, repairs, etc.

~ During office review, note success criteria and evaluate each component based on monitoring report results. Record relevant data in Sections II & III.
~ On back of sheet, note other information found during office review or to be obtained during site visit.

II. Summary of Results:

Mitigation Component	Monit Year	Success (report)	Success (field)	Resolved

MITIGATION SUCCESS:
Compared to the mitigation plan, this project is: successful partially successful not successful

List specific reasons for lack of success for this project:

Additional Comments (e.g. DWQ follow-up actions, recommendations, etc.)**:**

[…Page intentionally left blank…]

Wetland Mitigation Project Evaluations: Information Table

NC Division of Water Quality

Component:
Location within project:

III. Success Criteria Evaluation:

HYDROLOGY – Approved Success Criteria:	Wetland Hydrology Indicators:
Monitoring report indicates success? Yes No **Observational field data agrees? Yes No** based on mitigation plan? Yes No based on wetland type Yes No	___ Inundated ___ Saturated in upper 12 inches ___ Drift lines ___ Drainage patterns in wetlands ___ Sediment deposits ___ Water marks
List any remaining hydrology issues to address (e.g. remaining ditches, excessive water, etc.):	

SOILS – Approved Success Criteria:

Are soils hydric or becoming hydric? Yes No
List indicators of hydric soils: ____
List any remaining soil issues to address (e.g. erosion, upland areas, etc.):

VEGETATION – Approved Success Criteria:	Dominant Plant Species ***Species*** ***Story*** ***TPA/% Cover***
Monitoring report indicates success? Yes No Average TPA for entire site (per report):____ **Observational field data agrees? Yes No** based on community composition? Yes No based on TPA and/or % cover? Yes No **Vegetation planted on site? Yes No** **Date of last planting:** **Vegetation growing successfully? Yes No**	

Specific vegetation plots or site locations with little to no vegetation:

Estimated acreage or site percentage of unvegetated areas: __________

Invasive species on site (species, location(s), and % cover):

List any remaining vegetation issues to address (e.g. plant survival, concerns, etc.):

Wetland Mitigation Project Evaluations: Information Table

NC Division of Water Quality

<table>
<tr><td>NCWAM – Approved Success Criteria:

Monitoring report indicates success? Yes No
Observational field data agrees? Yes No

Attach NCWAM analysis results to this report.</td><td>NCWAM Wetland Type on Site:
___ Coastal
___ Riverine
___ Riparian
___ Non-riparian (wetter)
___ Non-riparian (drier)</td></tr>
<tr><td colspan="2">List any remaining NCWAM issues to address (e.g. functionality, developing wetland type, etc.):</td></tr>
</table>

MITIGATION SUCCESS:

Compared to the mitigation plan, this component is: successful partially successful not successful

List specific reasons for lack of success for this component:

Additional Comments (e.g. DWQ follow-up actions, recommendations, etc.)**:**

~ During site visit, document representative conditions and areas of concern. Observe preservation and enhancement areas that may not have specific success criteria. Label and attach photos to this report.
~ Attach maps showing photo locations, areas of concern, and important field observations.
~ Additional notes related to evaluation of this component:

Stream Mitigation Project Evaluations: Information Table

NC Division of Water Quality

Component:
Location within project:

III. Data Reported from Site Visit

STREAMBANK STABILITY – Approved Success Criteria:

Are Streambanks Stable? Yes No
If no, provide description and notes regarding stability issues:

STRUCTURES – Approved Success Criteria:

List all Types of structures present on site:_______________________________________
Are the structures installed correctly? Yes No
Are the structures made of acceptable material?
(Unacceptable materials include: railroad ties, concrete w/rebar, etc.) Yes No
Are the structures located approximately where shown on the plan? Yes No
Are the structures stable (e.g. erosion, deposition, etc.)? Yes No
Provide description and notes regarding problematic structures:

FEATURES – Approved Success Criteria:

Are riffles and pools in approximately the correct locations? Yes No
Is the final sinuosity and gradient designed approximately to plan specifications? Yes No
Any evidence of vegetation growing on the stream bed or in the Thalweg? Yes No
Percentage of the restoration reach that has: Flowing water ________ Ponded areas _________

Describe any stream features that provide evidence of unstable stream reaches (e.g. mid-channel bars, downstream meander migration, chute cutoff formation, etc.):

AQUATIC BIOTA – Approved Mitigation Criteria:

Is aquatic life present in the channel? Yes No

Description of taxa observed, incl. quantities of individuals and general distribution of biota. Include a brief description of the sampling methodology.

List any remaining aquatic biota issues to address (e.g. erosion, discharges or toxicants, etc.).

Stream Mitigation Project Evaluations: Information Table

NC Division of Water Quality

VEGETATION – Approved Success Criteria:	**Dominant Plant Species**
Monitoring report indicates success? Yes No Average TPA for entire site (per report):____ **Observational field data agrees? Yes No** based on community composition? Yes No based on TPA and/or % cover? Yes No **Vegetation planted on site? Yes No** **Date of last planting:** **Vegetation growing successfully? Yes No**	***Species*** ***Story*** ***TPA/% Cover***
General observations on condition of riparian/buffer areas (e.g. buffer width, overall health of vegetation, etc.)	
Specific vegetation plots or site locations with little to no vegetation: Estimated acreage or site percentage of unvegetated areas: _________ Invasive species on site (species, location(s), and % cover): List any remaining vegetation issues to address (e.g. plant survival, concerns, etc.):	

MITIGATION SUCCESS: Compared to the mitigation plan, this component is: successful partially successful not successful List specific reasons for lack of success for this component: **Additional Comments** (e.g. DWQ follow-up actions, recommendations, etc.)**:**

~ Use the definitions in the joint state/federal stream mitigation guidelines to determine the correct type of mitigation used for this project.
~ During site visit, document representative conditions and areas of concern. Observe preservation and enhancement areas that may not have specific success criteria. Label and attach photos to this report.
~ Attach maps showing photo locations, problem areas, and/or important stream features.
~ Additional notes related to evaluation of this component:

Appendix B: Population and Sample Counts

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Table 6. Project and component counts, as well as wetland acreage and stream linear footage, in the population frame, initial stratified cluster random sample, reclassified sample with corrected provider classifications, and final dataset of evaluated wetland and stream mitigation.

(a) Wetlands:

Provider Type	Population			Sample			Sample (Reclassified)			Analyzed		
	Projects	Components	Acres	Projects	Components	Acres	Projects	Components	Acres	Projects	Components	Acres
EEP/WRP	43	102	10878	32	77	10504	25	47	5795	15	34	4491
Full-Delivery (EEP)	13	30	877	10	20	257	13	31	403	13	31	403
Mitigation Bank	11	35	6888	8	26	2981	10	34	3257	10	34	3258
NCDOT	5	20	1480	4	18	1130	8	36	5458	8	35	5458
Other	9	15	889	7	12	67	6	10	64	4	7	56
Private	49	112	7408	37	89	7198	36	84	7160	32	64	6435
Total	130	314	28420	98	242	22137	98	242	22137	82	205	20101

(b) Streams:

Provider	Population			Sample			Sample (Reclassified)			Analyzed		
	Projects	Components	Feet	Projects	Components	Feet	Projects	Components	Feet	Projects	Components	Feet
EEP/WRP	104	158	427079	70	114	298131	62	98	257535	33	54	150249
Full-Delivery (EEP)	26	57	212472	17	34	147995	15	30	113155	12	25	87778
Mitigation Bank	7	8	26244	5	5	16862	9	16	38793	6	12	32438
NCDOT	4	4	748	3	3	0	11	15	66934	9	13	66934
Other	14	17	27834	9	12	19667	10	12	11265	2	2	1860
Private	38	56	318154	25	42	286145	22	39	281118	17	30	260709
Total	193	300	1012531	129	210	768800	129	210	768800	79	136	599968

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Appendix C: Project Ratings

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Stream Ratings (Page 1 of 2)

Table 7. Ratings assigned to evaluated stream mitigation projects.

DWQ ID	Project Name	Rating	Provider Type	PhysRegion
19960470a	Barnhill Mitigation Site (Little Ivy Creek)	Yes	NCDOT	Mountains
19960470d	Fosson Mitigation Site (Paint Fork Creek)	Yes	NCDOT	Mountains
19970330	Grandover/Holden Road	Yes	Private	Piedmont
19970616v1	Bare Mitigation Site (UT to Peak Creek)	Mix	NCDOT	Mountains
19970616v2	Carp Mitigation Site (UT to Laxon Creek)	Yes	NCDOT	Mountains
19970616v3	Miller Mitigation Site (Meat Camp Creek)	Yes	NCDOT	Mountains
19970972	Anson Co. Waste Management Facility	Mix	Private	Piedmont
19980574	Town of Yadkinville Reservoir	Yes	Private	Coastal Plain
19981130	Old Edwards Club (prev Highlands Cove)	Yes	Private	Mountains
19981257	Dowdle Mountain	Yes	Private	Mountains
19990971	Kerner Ridge	Yes	Private	Mountains
19991173	Childress-Klein Properties	Yes	Private	Piedmont
19991453	Edsel Place	Yes	Mitigation Bank	Piedmont
20000447	Red Ramp	Yes	Other	Coastal Plain
20000723	Payne Dairy (Jumping Run)	Yes	EEP/WRP	Piedmont
20001129	Forest Creek Golf Club	Yes	Private	Coastal Plain
20001394	Brush Creek	Yes	EEP/WRP	Mountains
20001434	Jefferson Pilot Stream Restoration	No	EEP/WRP	Piedmont
20010020	Rocky Branch Restoration	Yes	Private	Piedmont
20010382	Villages at Reedy Fork	Mix	Private	Piedmont
20010460	Hernandez Mitigation (Slow Creek)	No	Private	Mountains
20011032	College of Veterinary Medicine	Yes	Other	Piedmont
20011043	Smith & Austin Creeks	Yes	EEP/WRP	Piedmont
20011206	Mount Vernon Springs	Yes	Private	Piedmont
20011690	Pott Creek	No	Mitigation Bank	Piedmont
20011744	Lyle Creek Stream Restoration	Mix	EEP/WRP	Piedmont
20020253	Howell Woods	Yes	EEP/WRP	Coastal Plain
20020257	Brown Branch	Yes	EEP/WRP	Mountains
20020459	Clayhill Farms	Yes	NCDOT	Coastal Plain
20020492	Berger Bank: Homestead	Yes	Full-Delivery (EEP)	Piedmont
20020508	Balsam Mountain Preserve Mitigation	Mix	Private	Mountains
20020771	Givens Estates	Yes	Private	Mountains
20020888b	Benbow Park Stream Restoration	Yes	EEP/WRP	Piedmont
20020906	Suck Creek	Yes	EEP/WRP	Piedmont
20021215	Cato Farms Stream Restoration	Yes	EEP/WRP	Piedmont
20021259	Deep Creek Mitigation Bank	Yes	Mitigation Bank	Piedmont
20021345	Sandy Creek	Yes	EEP/WRP	Piedmont
20021528	Warrior Creek	No	EEP/WRP	Piedmont
20021572	Reedy Branch	Yes	EEP/WRP	Piedmont
20021682	Purlear Creek-Phase 1	No	EEP/WRP	Piedmont
20021742	Carriage Park	Mix	Private	Mountains
20021792	Tributary to South Fork Creek	No	EEP/WRP	Piedmont
20021834	Snow Creek	Yes	EEP/WRP	Piedmont
20021864	Erwin Lowes Project	No	Private	Coastal Plain
20021881	Silas Creek	Yes	EEP/WRP	Piedmont
20021883	Prestonwood Golf Course	No	EEP/WRP	Piedmont

Stream Ratings (Page 2 of 2)

DWQ Project ID	Project Name	Rating	Provider Type	Physiog Region
20021884	Horse Creek	No	EEP/WRP	Piedmont
20030299	Third Fork Creek (Forest Hills)	Yes	EEP/WRP	Piedmont
20030425	Hanging Rock Creek	Yes	EEP/WRP	Mountains
20030503	Little Beaver Creek Stream Restoration	Mix	EEP/WRP	Piedmont
20031001	UT to Billy's Creek Stream Restoration	No	EEP/WRP	Piedmont
20031035	Neu-Con: Marston Site	Yes	Mitigation Bank	Coastal Plain
20031064	UT to Tar River	Yes	EEP/WRP	Piedmont
20031306	Shepherds Tree Mitigation Site	No	NCDOT	Piedmont
20040325	Barra Farms Phase I	No	Mitigation Bank	Coastal Plain
20040500	Back Creek Restoration	Mix	NCDOT	Piedmont
20040667	Purlear Creek-Phase 2	No	EEP/WRP	Piedmont
20040895	Neu-Con: Nahunta Swamp Mitigation	Yes	Mitigation Bank	Coastal Plain
20041198	UT to Barnes Creek	Yes	EEP/WRP	Piedmont
20041235	Privateer Farms	Yes	NCDOT	Coastal Plain
20041292	Pott Creek II	Mix	Full-Delivery (EEP)	Piedmont
20041482	South Fork	Yes	Full-Delivery (EEP)	Piedmont
20041646	Greene Mitigation Site	Yes	EEP/WRP	Piedmont
20042031	Zack's Fork Stream Restoration	Mix	Full-Delivery (EEP)	Piedmont
20050098	Bailey Fork	Mix	Full-Delivery (EEP)	Piedmont
20050409	East Tarboro Canal	Mix	EEP/WRP	Coastal Plain
20050450	Haw Branch Restoration	Yes	Full-Delivery (EEP)	Coastal Plain
20050597	Cox Site Wetland & Stream Restoration	Yes	Full-Delivery (EEP)	Coastal Plain
20050615	South Muddy Creek Tributaries	Mix	Full-Delivery (EEP)	Piedmont
20050732	Harpers Crossroads (Brier Chapel)	Yes	Private	Piedmont
20050733	Cleghorn Creek	Yes	Full-Delivery (EEP)	Piedmont
20051061	UT Rocky River Stream and Buffer	Yes	EEP/WRP	Piedmont
20052147	Gray Farm Stream Restoration	Yes	Full-Delivery (EEP)	Piedmont
20060268	Bold Run Creek	Yes	EEP/WRP	Piedmont
20061346	Lloyd Site	Yes	Full-Delivery (EEP)	Coastal Plain
20061717	Little Grassy Creek	Yes	EEP/WRP	Piedmont
20061760	Stricker Branch	Mix	Full-Delivery (EEP)	Piedmont
20100102	Caviness Mitigation Site	Mix	EEP/WRP	Piedmont
20100296	Starmount Forest Country Club	Yes	EEP/WRP	Piedmont

Note: Yes = all components successful, No = no components successful, Mix = combination of successful and unsuccessful components within the project
Source: NCDWQ mitigation database

Wetland Ratings (Page 1 of 2)

Table 8. Ratings assigned to evaluated wetland mitigation projects.

DWQ Project ID	Project Name	Rating	Provider	Physiog Region
19930273	Mallard Creek	Mix	EEP/WRP	Piedmont
19960353	Beach Walk at Kure Beach	No	Private	Coastal Plain
19960366	Triangle Towne Center	Yes	Private	Piedmont
19960634	Innes Street Market	Yes	Private	Piedmont
19960792	Taylor Farm (Landfall)	Mix	Private	Coastal Plain
19960794	Onslow County Landfill	Yes	Private	Coastal Plain
19960975	Columbus County Airport	No	Private	Coastal Plain
19961136	Senter Sand & Gravel	Yes	Private	Coastal Plain
19961190	Hillsborough Reservoir	No	Private	Piedmont
19970093	Dover Bay (Global Transpark)	Mix	Private	Coastal Plain
19970093a	Stonyton Creek (Global Transpark)	No	Private	Coastal Plain
19970330	Grandover/Holden Road	Yes	Private	Piedmont
19970972	Anson Co. Waste Management Facility	Yes	Private	Piedmont
19980247	McLendon Hills	Mix	Private	Coastal Plain
19980339	Sampson Co. Landfill	Mix	Private	Coastal Plain
19981128	Treyburn	Mix	Private	Piedmont
19981130	Old Edwards Club	Yes	Private	Mountains
19981139	Parker Farms (PCS)	Mix	Private	Coastal Plain
19990231	Nucor Steel	Yes	Private	Coastal Plain
19990872	Town of Fairmont WTP	Mix	Private	Coastal Plain
19990971	Kerner Ridge	Yes	Private	Mountains
19991173	Childress-Klein Properties	Yes	Private	Piedmont
19991423	Tulula Creek Wetlands	Mix	EEP/WRP	Mountains
20000008	Mason Inlet Relocation	Yes	Other	Coastal Plain
20000387	Jumping Run - Carteret	Yes	EEP/WRP	Coastal Plain
20000447	Red Ramp	Yes	Other	Coastal Plain
20000723	Payne Dairy (Jumping Run)	Yes	EEP/WRP	Piedmont
20000846	Horsepen Creek (Fedex - PTAA)	Yes	Private	Piedmont
20000846a	Causey Farm	Yes	Private	Piedmont
20001013	Pitt-Greenville Airport	Yes	Private	Coastal Plain
20001085	Greater Sandy Run	Mix	Mitigation Bank	Coastal Plain
20001129	Forest Creek Golf Club	Yes	Private	Coastal Plain
20010830	Lee Street Mitigation Site	Mix	Private	Coastal Plain
20010904	Mayfaire	Mix	Private	Coastal Plain
20011102	Croatan Mitigation Bank	Mix	NCDOT	Coastal Plain
20011206	Mount Vernon Springs	Mix	Private	Piedmont
20011500	Mildred Woods	Yes	NCDOT	Coastal Plain
20011644	Neu-Con: Casey-King Mitigation	Yes	Mitigation Bank	Coastal Plain
20011690	Pott Creek	Mix	Mitigation Bank	Piedmont
20011750	White Oak Creek	Mix	NCDOT	Coastal Plain
20020241	USMC Marsh Wetland Mitigation	Yes	EEP/WRP	Coastal Plain
20020253	Howell Woods	Mix	EEP/WRP	Coastal Plain
20020459	Clayhill Farms	Mix	NCDOT	Coastal Plain
20020492	Berger Bank: Homestead	Yes	Full-Delivery (EEP)	Piedmont
20020492a	Berger Bank: Second Creek	Yes	Full-Delivery (EEP)	Piedmont
20020569	Neu-Con: Westbrook Lowgrounds	Mix	Mitigation Bank	Coastal Plain

Wetland Ratings (Page 2 of 2)

DWQ Project ID	Project Name	Rating	Provider	Physiog Region
20021143	Rich Fork Creek	Yes	Full-Delivery (EEP)	Piedmont
20021259	Deep Creek Mitigation Bank	Yes	Mitigation Bank	Piedmont
20021345	Sandy Creek	No	EEP/WRP	Piedmont
20021544	Swan Quarter Dike	Mix	Other	Coastal Plain
20021789	Dare County Bomb Range	Yes	Other	Coastal Plain
20021794	Neu-Con: Alexander Wetland Mitigation	Yes	Mitigation Bank	Coastal Plain
20030503	Little Beaver Creek Stream Restoration	Mix	EEP/WRP	Piedmont
20030947	Mountaintop	Yes	Private	Mountains
20030948	Brunswick County Airport	Yes	Private	Coastal Plain
20031003	Daniels Farm	Yes	Full-Delivery (EEP)	Piedmont
20031035	Neu-Con: Marston Site	Yes	Mitigation Bank	Coastal Plain
20031306	Shepherds Tree Mitigation Site	Mix	NCDOT	Piedmont
20040325	Barra Farms Phase I	Yes	Mitigation Bank	Coastal Plain
20040500	Back Creek Stream & Wetland Rest.	Yes	NCDOT	Piedmont
20040667	Purlear Creek-Phase 2	Yes	EEP/WRP	Piedmont
20040895	Neu-Con: Nahunta Swamp Mitigation	Mix	Mitigation Bank	Coastal Plain
20040929	Gregory Site	Mix	Full-Delivery (EEP)	Coastal Plain
20041529	Southern Products and Silica Co.	Mix	Private	Coastal Plain
20041810	Pitt-Greenville Airport	Yes	Private	Coastal Plain
20050635	Jones Creek	Mix	Full-Delivery (EEP)	Coastal Plain
20051680	Roquist Wetland Restoration	Mix	EEP/WRP	Coastal Plain
20060981	Modlin Property Wetland Restoration	Mix	Full-Delivery (EEP)	Coastal Plain
20061241	Reeds Creek Wetland Restoration	Yes	Full-Delivery (EEP)	Piedmont
20061291	Timberlake Farms	Mix	Mitigation Bank	Coastal Plain
20061334	Harrell Site	Yes	Full-Delivery (EEP)	Coastal Plain
20061346	Lloyd Site	Mix	Full-Delivery (EEP)	Coastal Plain
20061780	Floogie Site	Yes	Full-Delivery (EEP)	Coastal Plain
20061905	Mason Property Wetland Restoration	Mix	Full-Delivery (EEP)	Coastal Plain
20081838	Anderson Swamp Wetland Restoration	Mix	Full-Delivery (EEP)	Coastal Plain
20100284	Sturgeon City	Yes	EEP/WRP	Coastal Plain
20100318	ABC Site	Yes	EEP/WRP	Coastal Plain
20100319	Benson Grove	Yes	EEP/WRP	Coastal Plain
20100358	Dowd Dairy	Mix	EEP/WRP	Coastal Plain
20100566	Hammock's Beach	Yes	EEP/WRP	Coastal Plain
TIPR1023WM	Gurley Mitigation Site	Mix	NCDOT	Coastal Plain
TIPR2208WM	Dismal Swamp	Yes	NCDOT	Coastal Plain

Note: Yes = all components successful, No = no components successful, Mix = combination of successful and unsuccessful components within the project.
Source: NCDWQ mitigation database

Appendix D: Statistical Results

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Wetland Success Rates (Page 1 of 2)

Table 9. Wetland mitigation success rates (with 95% confidence intervals) for study domain levels.

		All Data (Incl. Preservation)		No Preservation Data	
Domain	***Level***	***SuccRate-count***	***SuccRate-size***	***SuccRate-count***	***SuccRate-size***
Mitigator	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	EEP/WRP	76 (61-87)	70 (63-77)	73 (57-85)	60 (43-77)
	Full-delivery	81 (62-92)	79 (62-97)	78 (60-89)	76 (58-94)
	Bank	74 (55-86)	70 (53-87)	70 (50-85)	69 (51-87)
	DOT	69 (59-77)	63 (56-70)	59 (49-69)	53 (47-58)
	Other/Private	73 (62-82)	75 (73-77)	67 (54-77)	71 (64-77)
PhysRegion	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	CoastalPlain	73 (67-79)	70 (65-76)	68 (60-74)	64 (55-73)
	Mountains	81 (42-96)	53 (45-62)	77 (40-94)	52 (47-57)
	Piedmont	77 (61-88)	81 (66-95)	74 (57-86)	76 (58-94)
Age Group	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	pre-1998	81 (55-94)	78 (72-84)	83 (66-92)	76 (73-79)
	1998-2001	73 (60-83)	81 (76-86)	71 (58-82)	81 (75-86)
	2002-2005	77 (66-85)	67 (58-77)	71 (59-80)	58 (48-68)
	2006-2009	70 (59-80)	63 (56-70)	65 (53-75)	50 (47-52)
MitigActivity	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	Creation	71 (58-82)	74 (65-84)	71 (58-82)	74 (65-84)
	Preservation	97 (82-100)	100 (99-100)	NA	NA
	Restoration	68 (59-75)	60 (50-70)	68 (59-75)	60 (50-70)
	Enhancement	75 (57-87)	75 (50-100)	75 (57-87)	75 (50-100)
ProjSizeClass	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	<20	74 (59-85)	74 (59-90)	72 (56-84)	72 (55-89)
	20-200	74 (65-82)	70 (60-81)	68 (58-77)	60 (50-71)
	>200	75 (67-81)	70 (64-76)	70 (60-78)	64 (54-74)
EcosysClass	overall	74 (68-80)	70 (63-76)	70 (65-76)	64 (55-73)
	Coastal	84 (42-97)	88 (64-111)	81 (31-98)	82 (49-115)
	Nonriparian	77 (68-85)	71 (65-77)	73 (63-81)	65 (55-75)
	Riparian	72 (63-79)	67 (56-79)	67 (57-75)	59 (46-71)
Ecoregion	overall	74 (68-80)	70 (65-76)	70 (63-76)	64 (55-73)
	CarolinaSlateBelt	49 (8-92)	59 (0-118)	33 (4-85)	42 (-18-101)
	InnerCoastalPlain	65 (55-74)	72 (67-77)	57 (47-67)	63 (57-68)
	InnerPiedmont	100	100	100	100
	Mountains	81 (42-96)	53 (45-62)	77 (40-94)	53 (47-57)
	NorthOuterPied	100	100	100	100
	OuterCoastPlain	78 (70-85)	69 (63-76)	75 (65-83)	64 (52-75)
	SandHills	80 (62-91)	83 (74-91)	75 (60-86)	77 (70-84)
	SouthOuterPied	87 (69-95)	78 (59-97)	85 (66-94)	73 (50-96)
	TriassicBasins	36 (21-55)	32 (35-39)	36 (21-55)	32 (35-39)

Wetland Success Rates (Page 2 of 2)

Basin	overall	75 (69-81)	71 (65-76)	71 (64-78)	64 (55-73)
	Cape Fear	73 (59-83)	81 (77-85)	69 (53-81)	80 (76-84)
	Catawba	90 (71-97)	84 (77-91)	86 (63-96)	80 (70-89)
	Little Tennessee	77 (37-95)	53 (45-62)	72 (37-92)	52 (47-56)
	Neuse	65 (54-74)	64 (57-74)	58 (46-69)	56 (47-65)
	New	100 (1 site)	100	100	100
	Roanoke	67 (51-79)	67 (66-67)	59 (40-75)	50 (50-50)
	Tar-Pamlico	80 (65-90)	77 (72-82)	77 (62-87)	76 (73-79)
	White Oak	85 (63-95)	70 (62-78)	82 (53-95)	52 (48-56)
	Yadkin	86 (66-95)	79 (59-99)	84 (63-94)	74 (50-99)

Note: Analyses were conducted for the entire dataset of evaluated wetland mitigation components, based on successful and unsuccessful component counts and area. Analyses were repeated for the dataset, excluding preservation components.

Source: RTI SUDAAN® outputs

Stream Success Rates (Page 1 of 2)

Table 10. Stream mitigation success rates (with 95% confidence intervals) for study domain levels.

		All Data (incl preserv)		No Preservation Data	
Domain	**Level**	**SuccRate-count**	**SuccRate-size**	**SuccRate-count**	**SuccRate-size**
Mitigator	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	EEP/WRP	69 (50-82)	67 (47-87)	67 (48-81)	63 (42-84)
	Full-delivery	80 (67-89)	84 (63-104)	80 (67-89)	84 (63-104)
	Bank	83 (38-98)	79 (46-112)	83 (38-98)	79 (46-112)
	DOT	77 (48-92)	83 (49-118)	75 (48-91)	83 (47-118)
	Other/Private	80 (62-90)	98 (96-100)	78 (58-90)	86 (70-102)
PhysRegion	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	CoastalPlain	89 (67-97)	95 (89-102)	88 (66-96)	94 (86-102)
	Mountains	81 (59-93)	98 (96-99)	80 (53-93)	86 (66-105)
	Piedmont	70 (57-80)	69 (54-85)	69 (56-79)	67 (51-83)
Age Group	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	pre-2003	85 (60-95)	89 (74-104)	84 (60-95)	88 (73-104)
	2003-2005	76 (61-87)	80 (63-97)	75 (60-86)	78 (60-96)
	2006-2008	69 (55-81)	87 (71-102)	67 (51-79)	66 (48-84)
MitigActivity	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	Creation	100 (2 sites)	100	100	100
	Preservation	100 (7 sites)	100	NA	NA
	Restoration	69 (59-78)	72 (59-86)	69 (59-78)	72 (59-86)
	Enhancement	92 (72-98)	99 (97-101)	92 (72-98)	99 (97-101)
ProjSizeClass	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	<2500	71 (55-84)	78 (61-94)	71 (55-84)	78 (61-94)
	2500-5000	72 (55-85)	80 (65-94)	72 (54-85)	80 (65-94)
	5001-10000	86 (63-96)	82 (62-101)	86 (63-96)	81 (62-101)
	>10000	74 (51-88)	87 (71-103)	70 (45-87)	68 (42-93)

Stream Success Rates (Page 2 of 2)

Ecoregion	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	BroadBasins	81 (47-96)	82 (52-111)	79 (40-96)	79 (44-113)
	CarolinaSlateBelt	86 (59-97)	86 (61-112)	84 (55-96)	80 (46-114)
	InnerCoastalPlain	81 (45-96)	88 (70-105)	81 (45-96)	88 (70-105)
	InnerPiedmont	69 (48-85)	64 (38-89)	69 (47-84)	63 (37-89)
	Mountains	81 (39-97)	99 (98-99)	79 (30-97)	85 (55-114)
	NewRiverPlateau	81 (33-97)	98 (93-102)	81 (33-97)	98 (93-102)
	NorthOuterPied	66 (24-92)	77 (42-111)	66 (24-92)	77 (42-111)
	OuterCoastPlain	91 (51-99)	97 (89-104)	90 (49-99)	97 (89-104)
	SandHills	100 (4 sites)	100	100	100
	SouthOuterPied	67 (46-84)	69 (39-99)	67 (46-84)	69 (39-99)
	TriassicBasins	50 (21-79)	48 (8-89)	50 (21-79)	48 (8-89)
Basin	overall	75 (66-83)	84 (73-96)	74 (64-82)	75 (63-87)
	Broad	100 (2 sites)	100	100	100
	Cape Fear	75 (57-88)	86 (70-101)	75 (56-87)	83 (65-101)
	Catawba	76 (57-88)	79 (55-102)	75 (57-88)	78 (55-102)
	French Broad	85 (54-96)	95 (87-102)	82 (40-97)	93 (81-105)
	Hiwassee	0 (1 site)	0	0	0
	Little Tennessee	78 (28-97)	99 (98-99)	75 (19-97)	66 (10-123)
	Neuse	75 (38-94)	83 (59-106)	75 (38-94)	83 (59-106)
	New	89 (50-98)	98 (95-102)	89 (50-98)	98 (95-102)
	Roanoke	100 (5 sites)	100	100	100
	Tar-Pamlico	50 (19-81)	54 (19-89)	50 (19-81)	54 (19-89)
	Watauga	100 (1 site)	100	100	100
	White Oak	100 (5 sites)	100	100	100
	Yadkin	42 (20-68)	44 (13-75)	58 (32-80)	44 (13-75)

Note: Analyses were conducted for the entire dataset of evaluated wetland mitigation components, based on successful and unsuccessful component counts and area. Analyses were repeated for the dataset, excluding preservation components.
Source: RTI SUDAAN® outputs

Wetland Level Contrasts, All Data Including Preservation (Page 1 of 5)

Table 11. Wetland domain level contrast results for all data (including preservation), weighted by count and size.

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Provider						
	Full-Delivery (EEP) vs NCDOT	0.0050	0.1732	NCDOT vs Other, Private	0.0050	0.0018
	EEP/WRP vs NCDOT	0.0056	0.3203	Full-Delivery (EEP) vs NCDOT	0.0056	0.1
	Full-Delivery (EEP) vs Other, Private	0.0063	0.4203	EEP/WRP vs NCDOT	0.0063	0.1649
	NCDOT vs Other, Private	0.0071	0.4898	EEP/WRP vs Other,Private	0.0071	0.1801
	Full-Delivery (EEP) vs Mitigation Bank	0.0083	0.5143	EEP/WRP vs Full-Delivery (EEP)	0.0083	0.3477
	Mitigation Bank vs NCDOT	0.0100	0.5862	Full-Delivery (EEP) vs Mitigation Bank	0.0100	0.4471
	EEP/WRP vs Full-Delivery (EEP)	0.0125	0.6744	Mitigation Bank vs NCDOT	0.0125	0.4903
	EEP/WRP vs Other,Private	0.0167	0.7005	Mitigation Bank vs Other, Private	0.0167	0.543
	EEP/WRP vs Mitigation Bank	0.0250	0.773	Full-Delivery (EEP) vs Other, Private	0.0250	0.6426
	Mitigation Bank vs Other, Private	0.0500	0.9806	EEP/WRP vs Mitigation Bank	0.0500	0.9616
PhysRegion						
	Coastal Plain vs Piedmont	0.0167	0.5713	Coastal Plain vs Mountains	0.0167	0.0016
	Coastal Plain vs Mountains	0.0250	0.6024	Mountains vs Piedmont	0.0250	0.002
	Mountains vs Piedmont	0.0500	0.8364	Coastal Plain vs Piedmont	0.0500	0.1965
AgeGroup						
	2002-2005 VS 2006-2009	0.0083	0.3794	1998-2001 VS 2006-2009	0.0083	0.0001
	PRE-1998 VS 2006-2009	0.0100	0.3799	PRE-1998 VS 2006-2009	0.0100	0.003
	PRE-1998 VS 1998-2001	0.0125	0.5038	1998-2001 VS 2002-2005	0.0125	0.0134
	1998-2001 VS 2002-2005	0.0167	0.6209	PRE-1998 VS 2002-2005	0.0167	0.048
	1998-2001 VS 2006-2009	0.0250	0.7167	PRE-1998 VS 1998-2001	0.0250	0.4207
	PRE-1998 VS 2002-2005	0.0500	0.7215	2002-2005 VS 2006-2009	0.0500	0.4821
MitigActivity						
	Preservation vs Restoration	0.0083	0	Preservation vs Restoration	0.0083	0
	Creation vs Preservation	0.0100	0.0002	Creation vs Preservation	0.0100	0
	Preservation vs Enhancement	0.0125	0.0067	Creation vs Restoration	0.0125	0.0379
	Restoration vs Enhancement	0.0167	0.3417	Preservation vs Enhancement	0.0167	0.0546
	Creation vs Restoration	0.0250	0.5922	Restoration vs Enhancement	0.0250	0.2471
	Creation vs Enhancement	0.0500	0.7294	Creation vs Enhancement	0.0500	0.9498

Wetland Level Contrasts, All Data Including Preservation (Page 2 of 5)

Domain	*Contrast Levels (Weight = Count)*	*Holm's Test*	*p-value*	*Contrast Levels (Weight = Size)*	*Holm's Test*	*p-value*
ProjSizeClass						
	20-200 acres VS >200 acres	0.0167	0.9766	<20 acres VS VS >200 acres	0.0167	0.6322
	<20 acres VS VS >200 acres	0.0250	0.9776	<20 acres VS 20-200 acres	0.0250	0.6725
	<20 acres VS 20-200 acres	0.0500	0.9955	20-200 acres VS >200 acres	0.0500	0.9953
EcosysClass						
	Nonriparian vs riparian	0.0167	0.3599	Coastal vs Riparian	0.0167	0.1303
	Coastal vs Riparian	0.0250	0.3921	Coastal vs Nonriparian	0.0250	0.1702
	Coastal vs Nonriparian	0.0500	0.6404	Nonriparian vs riparian	0.0500	0.6094
Basin*						
	Cape Fear vs White Oak	0.0014	0	Catawba vs Neuse	0.0014	0
	Catawba vs Neuse	0.0014	0	Cape Fear vs Neuse	0.0014	0
	Broad vs Hiwassee	0.0015	0	Broad vs Hiwassee	0.0015	0
	Broad vs Watauga	0.0015	0.002	Catawba vs New	0.0015	0
	Catawba vs New	0.0016	0.0028	Cape Fear vs White Oak	0.0016	0
	Broad vs Yadkin	0.0016	0.0151	Catawa vs Roanoke	0.0016	0
	Catawba vs Little Tennesse	0.0017	0.0168	Broad vs Little Tennesse	0.0017	0
	Catawa vs Hiwassee	0.0017	0.04	Broad vs Catawba	0.0017	0
	Catawba vs Tar-Pamlico	0.0018	0.0458	Broad vs Tar-Pamlico	0.0018	0
	Broad vs Cape Fear	0.0019	0.0476	Cape Fear vs Roanoke	0.0019	0
	Catawa vs Roanoke	0.0019	0.0541	Broad vs Yadkin	0.0019	0
	Catawba vs Yadkin	0.0020	0.0557	Broad vs White Oak	0.0020	0
	Catawba vs French Broad	0.0021	0.0629	Catawba vs Watauga	0.0021	0.0001
	Broad vs White Oak	0.0022	0.0756	Broad vs French Broad	0.0022	0.0016
	Catawba vs White Oak	0.0023	0.0913	Broad vs Watauga	0.0023	0.0018
	Cape Fear vs Neuse	0.0024	0.1401	Cape Fear vs New	0.0024	0.0024
	Catawba vs Watauga	0.0025	0.1584	Cape Fear vs Tar-Pamlico	0.0025	0.0049
	Broad vs Roanoke	0.0026	0.1641	Cape Fear vs French Broad	0.0026	0.011
	Broad vs New	0.0028	0.221	Broad vs New	0.0028	0.0143
	Cape Fear vs Catawba	0.0029	0.286	Catawba vs French Broad	0.0029	0.0171

Wetland Level Contrasts, All Data Including Preservation (Page 3 of 5)

Domain	*Contrast Levels (Weight = Count)*	*Holm's Test*	*p-value*	*Contrast Levels (Weight = Size)*	*Holm's Test*	*p-value*
Basin*	Broad vs French Broad	0.0031	0.3181	Cape Fear vs Watauga	0.0031	0.0221
	Broad vs Neuse	0.0033	0.3846	Catawba vs Tar-Pamlico	0.0033	0.0399
	Cape Fear vs Little Tennesse	0.0036	0.4439	Cape Fear vs Little Tennesse	0.0036	0.0487
	Broad vs Tar-Pamlico	0.0038	0.4489	French Broad vs Hiwassee	0.0038	0.1079
	Broad vs Little Tennesse	0.0042	0.5216	Cape Fear vs Catawba	0.0042	0.1379
	French Broad vs Little Tennesse	0.0045	0.5408	Catawba vs Yadkin	0.0045	0.2273
	Cape Fear vs New	0.0050	0.544	Catawba vs Little Tennesse	0.0050	0.2368
	Cape Fear vs Watauga	0.0056	0.6017	Broad vs Neuse	0.0056	0.2702
	Cape Fear vs French Broad	0.0063	0.624	Catawba vs White Oak	0.0063	0.3853
	Cape Fear vs Tar-Pamlico	0.0071	0.6491	French Broad vs Neuse	0.0071	0.4242
	French Broad vs Hiwassee	0.0083	0.6666	Broad vs Cape Fear	0.0083	0.4534
	Cape Fear vs Hiwassee	0.0100	0.6931	Catawa vs Hiwassee	0.0100	0.4571
	Broad vs Catawba	0.0125	0.8008	Cape Fear vs Hiwassee	0.0125	0.6552
	Cape Fear vs Yadkin	0.0167	0.8169	Cape Fear vs Yadkin	0.0167	0.7914
	Cape Fear vs Roanoke	0.0250	0.8446	Broad vs Roanoke	0.0250	0.8584
	French Broad vs Neuse	0.0500	0.9073	French Broad vs Little Tennesse	0.0500	0.8721

Wetland Level Contrasts, All Data Including Preservation (Page 4 of 5)

Domain	*Contrast Levels (Weight = Count)*	*Holm's Test*	*p-value*	*Contrast Levels (Weight = Size)*	*Holm's Test*	*p-value*
Ecoregion*						
	Carolina Slate Belt vs Sand Hills	0.0014	.	Carolina Slate Belt vs Sand Hills	0.0014	.
	Inner Coastal Plain vs Mountains	0.0014	0	Inner Coastal Plain vs Mountains	0.0014	0
	Inner Piedmont vs Northern Outer Piedmont	0.0015	0	Inner Piedmont vs Northern Outer Piedmont	0.0015	0
	Broad Basins vs Southern Outer Piedmont	0.0015	0	Broad Basins vs Southern Outer Piedmont	0.0015	0
	Carolina Slate Belt vs Inner Coastal Plain	0.0016	0	Carolina Slate Belt vs Inner Coastal Plain	0.0016	0
	Carolina Slate Belt vs Southern Outer Piedmont	0.0016	0	Carolina Slate Belt vs Outer Coastal Plain	0.0016	0
	Inner Coastal Plain vs Triassic Basins	0.0017	0	Inner Coastal Plain vs New River Plateau	0.0017	0
	Mountains vs Northern Outer Piedmont	0.0017	0	Mountains vs New River Plateau	0.0017	0
	Inner Piedmont vs Southern Outer Piedmont	0.0018	0	Carolina Slate Belt vs Northern Outer Piedmont	0.0018	0
	Mountains vs New River Plateau	0.0019	0.0003	Carolina Slate Belt vs Southern Outer Piedmont	0.0019	0
	Carolina Slate Belt vs Northern Outer Piedmont	0.0019	0.0045	Inner Coastal Plain vs Triassic Basins	0.0019	0
	Carolina Slate Belt vs New River Plateau	0.0020	0.0067	Inner Piedmont vs Southern Outer Piedmont	0.0020	0
	Carolina Slate Belt vs Triassic Basins	0.0021	0.009	Inner Coastal Plain vs Outer Coastal Plain	0.0021	0
	Inner Piedmont vs Mountains	0.0022	0.009	Mountains vs Northern Outer Piedmont	0.0022	0
	Inner Coastal Plain vs Southern Outer Piedmont	0.0023	0.01	Carolina Slate Belt vs Triassic Basins	0.0023	0.0001
	Inner Coastal Plain vs Inner Piedmont	0.0024	0.035	Inner Piedmont vs Mountains	0.0024	0.0001
	Inner Piedmont vs New River Plateau	0.0025	0.035	Inner Coastal Plain vs Southern Outer Piedmont	0.0025	0.0003
	Carolina Slate Belt vs Inner Piedmont	0.0026	0.041	Broad Basins vs Triassic Basins	0.0026	0.0004

Wetland Level Contrasts, All Data Including Preservation (Page 5 of 5)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	Carolina Slate Belt vs Mountains	0.0028	0.0952	Inner Coastal Plain vs Northern Outer Piedmont	0.0028	0.0045
	Broad Basins vs Inner Coastal Plain	0.0029	0.1001	Inner Piedmont vs Outer Coastal Plain	0.0029	0.0162
	Broad Basins vs Mountains	0.0031	0.1001	Inner Coastal Plain vs Sand Hills	0.0031	0.0212
	Carolina Slate Belt vs Outer Coastal Plain	0.0033	0.1633	Inner Coastal Plain vs Inner Piedmont	0.0033	0.0247
	Inner Coastal Plain vs New River Plateau	0.0036	0.1633	Inner Piedmont vs New River Plateau	0.0036	0.0247
	Inner Piedmont vs Sand Hills	0.0038	0.2202	Carolina Slate Belt vs Mountains	0.0038	0.0312
	Broad Basins vs Outer Coastal Plain	0.0042	0.2341	Broad Basins vs Inner Coastal Plain	0.0042	0.1702
	Broad Basins vs Triassic Basins	0.0045	0.2923	Broad Basins vs Mountains	0.0045	0.1702
	Broad Basins vs Northern Outer Piedmont	0.0050	0.3248	Broad Basins vs Sand Hills	0.0050	0.3639
	Broad Basins vs New River Plateau	0.0056	0.3477	Inner Piedmont vs Sand Hills	0.0056	0.4022
	Broad Basins vs Inner Piedmont	0.0063	0.3493	Broad Basins vs Northern Outer Piedmont	0.0063	0.4284
	Inner Piedmont vs Triassic Basins	0.0071	0.4806	Carolina Slate Belt vs New River Plateau	0.0071	0.53
	Broad Basins vs Carolina Slate Belt	0.0083	0.6109	Broad Basins vs Outer Coastal Plain	0.0083	0.5461
	Broad Basins vs Sand Hills	0.0100	0.6734	Carolina Slate Belt vs Inner Piedmont	0.0100	0.5537
	Inner Coastal Plain vs Sand Hills	0.0125	0.68	Inner Piedmont vs Triassic Basins	0.0125	0.6566
	Inner Piedmont vs Outer Coastal Plain	0.0167	0.8126	Broad Basins vs Carolina Slate Belt	0.0167	0.6652
	Inner Coastal Plain vs Northern Outer Piedmont	0.0250	0.8678	Broad Basins vs New River Plateau	0.0250	0.7281
	Inner Coastal Plain vs Outer Coastal Plain	0.0500	0.9808	Broad Basins vs Inner Piedmont	0.0500	0.8521

Notes: Comparisons highlighted in yellow met testing parameters for statistical significance.
***Sample sizes in many Basin and Ecoregion levels were too small to yield statistically-valid results for the domains.**
Source of data: RTI SUDAAN® contrast outputs, including multiple t-test p-values; DWQ comparison of p-values with null hypothesis rejection threshold per Holm's Method

Wetland Level Contrasts, Excluding Preservation Data (Page 1 of 5)

Table 12. Wetland domain level contrast results for data excluding preservation components, weighted by count and size.

Domain	*Contrast Levels (Weight = Count)*	*Holm's Test*	*p-value*	*Contrast Levels (Weight = Size)*	*Holm's Test*	*p-value*
Provider						
	Full-Delivery (EEP) vs NCDOT	0.0050	0.0463	NCDOT vs Other, Private	0.0050	0.0001
	EEP/WRP vs NCDOT	0.0056	0.1101	Full-Delivery (EEP) vs NCDOT	0.0056	0.0164
	Full-Delivery (EEP) vs Other, Private	0.0063	0.255	Mitigation Bank vs NCDOT	0.0063	0.0869
	Mitigation Bank vs NCDOT	0.0071	0.3046	EEP/WRP vs Full-Delivery (EEP)	0.0071	0.2115
	NCDOT vs Other, Private	0.0083	0.3462	EEP/WRP vs Other,Private	0.0083	0.2551
	EEP/WRP vs Other,Private	0.0100	0.4767	EEP/WRP vs NCDOT	0.0100	0.4216
	Full-Delivery (EEP) vs Mitigation Bank	0.0125	0.5093	EEP/WRP vs Mitigation Bank	0.0125	0.4716
	EEP/WRP vs Full-Delivery (EEP)	0.0167	0.6662	Full-Delivery (EEP) vs Other, Private	0.0167	0.5909
	Mitigation Bank vs Other, Private	0.0250	0.7651	Full-Delivery (EEP) vs Mitigation Bank	0.0250	0.603
	EEP/WRP vs Mitigation Bank	0.0500	0.7706	Mitigation Bank vs Other, Private	0.0500	0.8744
PhysRegion						
	Coastal Plain vs Piedmont	0.0167	0.443	Mountains vs Piedmont	0.0167	0.0113
	Coastal Plain vs Mountains	0.0250	0.5175	Coastal Plain vs Mountains	0.0250	0.0248
	Mountains vs Piedmont	0.0500	0.8414	Coastal Plain vs Piedmont	0.0500	0.2349
AgeGroup						
	PRE-1998 VS 2006-2009	0.0083	0.0559	PRE-1998 VS 2006-2009	0.0083	0
	PRE-1998 VS 2002-2005	0.0100	0.1553	1998-2001 VS 2006-2009	0.0100	0
	PRE-1998 VS 1998-2001	0.0125	0.1925	1998-2001 VS 2002-2005	0.0125	0.0002
	1998-2001 VS 2006-2009	0.0167	0.4336	PRE-1998 VS 2002-2005	0.0167	0.0007
	2002-2005 VS 2006-2009	0.0250	0.4679	PRE-1998 VS 1998-2001	0.0250	0.1391
	1998-2001 VS 2002-2005	0.0500	0.9407	2002-2005 VS 2006-2009	0.0500	0.1398
MitigActivity						
	Restoration vs Enhancement	0.0167	0.3417	Creation vs Restoration	0.0167	0.0379
	Creation vs Restoration	0.0250	0.5922	Restoration vs Enhancement	0.0250	0.2471
	Creation vs Enhancement	0.0500	0.7294	Creation vs Enhancement	0.0500	0.9498

Wetland Level Contrasts, Excluding Preservation Data (Page 2 of 5)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
ProjSizeClass						
	<20 acres VS 20-200 acres	0.0167	0.6416	<20 acres VS 20-200 acres	0.0167	0.2502
	20-200 acres VS >200 acres	0.0250	0.7686	<20 acres VS >200 acres	0.0250	0.4059
	<20 acres VS >200 acres	0.0500	0.8057	20-200 acres VS >200 acres	0.0500	0.6331
EcosysClass						
	Nonriparian vs riparian	0.0167	0.3363	Coastal vs Riparian	0.0167	0.1907
	Coastal vs Riparian	0.0250	0.426	Coastal vs Nonriparian	0.0250	0.3049
	Coastal vs Nonriparian	0.0500	0.6576	Nonriparian vs riparian	0.0500	0.4646
Basin*						
	Cape Fear vs White Oak	0.0014	0	Catawba vs Neuse	0.0014	0
	Catawba vs Neuse	0.0014	0	Catawa vs Roanoke	0.0014	0
	Broad vs Hiwassee	0.0015	0	Cape Fear vs Neuse	0.0015	0
	Catawba vs New	0.0015	0.0003	Catawba vs Watauga	0.0015	0
	Broad vs Watauga	0.0016	0.0043	Catawba vs New	0.0016	0
	Catawba vs Little Tennesse	0.0016	0.0089	Broad vs Little Tennesse	0.0016	0
	Broad vs Yadkin	0.0017	0.0281	Broad vs Hiwassee	0.0017	0
	Catawba vs French Broad	0.0017	0.0328	Cape Fear vs White Oak	0.0017	0
	Catawba vs Tar-Pamlico	0.0018	0.0346	Broad vs New	0.0018	0
	Catawba vs Yadkin	0.0019	0.0429	French Broad vs Hiwassee	0.0019	0
	Catawa vs Hiwassee	0.0019	0.0496	Broad vs Catawba	0.0019	0
	Cape Fear vs Neuse	0.0020	0.0656	Cape Fear vs Roanoke	0.0020	0
	Broad vs White Oak	0.0021	0.0733	Broad vs Yadkin	0.0021	0
	Catawa vs Roanoke	0.0022	0.081	Cape Fear vs French Broad	0.0022	0
	Catawba vs White Oak	0.0023	0.0892	Broad vs Tar-Pamlico	0.0023	0
	Broad vs Cape Fear	0.0024	0.0915	Broad vs French Broad	0.0024	0
	Catawba vs Watauga	0.0025	0.1114	Broad vs White Oak	0.0025	0
	Broad vs Roanoke	0.0026	0.1513	Catawba vs French Broad	0.0026	0.0001
	Broad vs French Broad	0.0028	0.2473	Broad vs Watauga	0.0028	0.0007
	Broad vs New	0.0029	0.2742	Catawba vs Tar-Pamlico	0.0029	0.0385

Wetland Level Contrasts, Excluding Preservation Data (Page 3 of 5)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Basin*	Cape Fear vs Catawba	0.0031	0.3334	Catawba vs Yadkin	0.0031	0.0514
	Cape Fear vs Little Tennesse	0.0033	0.3792	Cape Fear vs Watauga	0.0033	0.0745
	Broad vs Neuse	0.0036	0.3872	French Broad vs Neuse	0.0036	0.0794
	Broad vs Tar-Pamlico	0.0038	0.4074	Broad vs Neuse	0.0038	0.1388
	Broad vs Little Tennesse	0.0042	0.4121	Catawba vs Little Tennesse	0.0042	0.1779
	French Broad vs Little Tennesse	0.0045	0.458	Cape Fear vs Yadkin	0.0045	0.2059
	Cape Fear vs New	0.0050	0.4652	Catawba vs White Oak	0.0050	0.4137
	Cape Fear vs Watauga	0.0056	0.4898	Cape Fear vs Little Tennesse	0.0056	0.4198
	Cape Fear vs Tar-Pamlico	0.0063	0.5723	Catawa vs Hiwassee	0.0063	0.4344
	French Broad vs Hiwassee	0.0071	0.6579	Cape Fear vs New	0.0071	0.4732
	Cape Fear vs French Broad	0.0083	0.7458	Cape Fear vs Catawba	0.0083	0.4815
	Cape Fear vs Roanoke	0.0100	0.7786	Broad vs Roanoke	0.0100	0.647
	Cape Fear vs Hiwassee	0.0125	0.8296	Cape Fear vs Hiwassee	0.0125	0.6852
	Broad vs Catawba	0.0167	0.8399	French Broad vs Little Tennesse	0.0167	0.878
	French Broad vs Neuse	0.0250	0.8894	Broad vs Cape Fear	0.0250	0.933
	Cape Fear vs Yadkin	0.0500	0.9258	Cape Fear vs Tar-Pamlico	0.0500	0.9789

Wetland Level Contrasts, Excluding Preservation Data (Page 4 of 5)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*						
	Carolina Slate Belt vs Sand Hills	0.0014	.	Carolina Slate Belt vs Sand Hills	0.0014	.
	Broad Basins vs Southern Outer Piedmont	0.0014	0	Carolina Slate Belt vs Outer Coastal Plain	0.0014	0
	Carolina Slate Belt vs Inner Coastal Plain	0.0015	0	Inner Coastal Plain vs New River Plateau	0.0015	0
	Inner Coastal Plain vs Mountains	0.0015	0	Inner Coastal Plain vs Mountains	0.0015	0
	Inner Piedmont vs Northern Outer Piedmont	0.0016	0	Inner Piedmont vs Northern Outer Piedmont	0.0016	0
	Carolina Slate Belt vs Southern Outer Piedmont	0.0016	0	Broad Basins vs Southern Outer Piedmont	0.0016	0
	Inner Coastal Plain vs Triassic Basins	0.0017	0	Carolina Slate Belt vs Inner Coastal Plain	0.0017	0
	Mountains vs Northern Outer Piedmont	0.0017	0	Mountains vs New River Plateau	0.0017	0
	Inner Piedmont vs Southern Outer Piedmont	0.0018	0.0001	Carolina Slate Belt vs Northern Outer Piedmont	0.0018	0
	Carolina Slate Belt vs Triassic Basins	0.0019	0.0004	Carolina Slate Belt vs Southern Outer Piedmont	0.0019	0
	Inner Piedmont vs Mountains	0.0019	0.0004	Inner Coastal Plain vs Triassic Basins	0.0019	0
	Mountains vs New River Plateau	0.0020	0.0007	Carolina Slate Belt vs Triassic Basins	0.0020	0
	Carolina Slate Belt vs New River Plateau	0.0021	0.0018	Inner Piedmont vs Mountains	0.0021	0
	Carolina Slate Belt vs Inner Piedmont	0.0022	0.0115	Inner Coastal Plain vs Outer Coastal Plain	0.0022	0
	Broad Basins vs Inner Coastal Plain	0.0023	0.0143	Inner Piedmont vs Southern Outer Piedmont	0.0023	0
	Broad Basins vs Mountains	0.0024	0.0143	Inner Coastal Plain vs Southern Outer Piedmont	0.0024	0
	Inner Coastal Plain vs Southern Outer Piedmont	0.0025	0.0194	Mountains vs Northern Outer Piedmont	0.0025	0.0011
	Inner Coastal Plain vs Inner Piedmont	0.0026	0.0301	Carolina Slate Belt vs Mountains	0.0026	0.0029

Wetland Level Contrasts, Excluding Preservation Data (Page 5 of 5)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	Inner Piedmont vs New River Plateau	0.0028	0.0301	Broad Basins vs Triassic Basins	0.0028	0.0047
	Carolina Slate Belt vs Northern Outer Piedmont	0.0029	0.0377	Inner Coastal Plain vs Inner Piedmont	0.0029	0.0226
	Carolina Slate Belt vs Mountains	0.0031	0.0378	Inner Piedmont vs New River Plateau	0.0031	0.0226
	Broad Basins vs Outer Coastal Plain	0.0033	0.0654	Inner Piedmont vs Outer Coastal Plain	0.0033	0.0497
	Carolina Slate Belt vs Outer Coastal Plain	0.0036	0.1102	Broad Basins vs Inner Coastal Plain	0.0036	0.0545
	Inner Coastal Plain vs New River Plateau	0.0038	0.1102	Broad Basins vs Mountains	0.0038	0.0545
	Broad Basins vs New River Plateau	0.0042	0.1226	Inner Coastal Plain vs Northern Outer Piedmont	0.0042	0.0639
	Broad Basins vs Northern Outer Piedmont	0.0045	0.127	Inner Coastal Plain vs Sand Hills	0.0045	0.0794
	Broad Basins vs Inner Piedmont	0.0050	0.1446	Broad Basins vs Northern Outer Piedmont	0.0050	0.2425
	Broad Basins vs Triassic Basins	0.0056	0.1888	Broad Basins vs Outer Coastal Plain	0.0056	0.3393
	Inner Piedmont vs Sand Hills	0.0063	0.213	Carolina Slate Belt vs New River Plateau	0.0063	0.3911
	Inner Piedmont vs Triassic Basins	0.0071	0.3046	Broad Basins vs New River Plateau	0.0071	0.4747
	Broad Basins vs Carolina Slate Belt	0.0083	0.3762	Inner Piedmont vs Sand Hills	0.0083	0.4792
	Inner Coastal Plain vs Sand Hills	0.0100	0.6212	Broad Basins vs Carolina Slate Belt	0.0100	0.487
	Inner Coastal Plain vs Northern Outer Piedmont	0.0125	0.8871	Inner Piedmont vs Triassic Basins	0.0125	0.7356
	Inner Coastal Plain vs Outer Coastal Plain	0.0167	0.9067	Broad Basins vs Inner Piedmont	0.0167	0.7365
	Broad Basins vs Sand Hills	0.0250	0.9079	Broad Basins vs Sand Hills	0.0250	0.7378
	Inner Piedmont vs Outer Coastal Plain	0.0500	0.9772	Carolina Slate Belt vs Inner Piedmont	0.0500	0.8913

Notes: Comparisons highlighted in yellow met testing parameters for statistical significance.
***Sample sizes in many Basin and Ecoregion levels were too small to yield statistically-valid results for the domains.**
Source of data: RTI SUDAAN® contrast outputs, including multiple t-test p-values; DWQ comparison of p-values with null hypothesis rejection threshold per Holm's Method

Stream Level Contrasts, All Data Including Preservation (Page 1 of 7)

Table 13. Stream domain level contrast results for all data (including preservation), weighted by count and size.

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Provider						
	EEP/WRP vs Full-Delivery (EEP)	0.0050	0.2554	EEP/WRP vs Other,Private	0.0050	0.0038
	EEP/WRP vs Other,Private	0.0056	0.3041	Full-Delivery (EEP) vs Other, Private	0.0056	0.1766
	EEP/WRP vs Mitigation Bank	0.0063	0.381	EEP/WRP vs Full-Delivery (EEP)	0.0063	0.2526
	EEP/WRP vs NCDOT	0.0071	0.5514	Mitigation Bank vs Other, Private	0.0071	0.2683
	Mitigation Bank vs NCDOT	0.0083	0.7293	NCDOT vs Other, Private	0.0083	0.4089
	Full-Delivery (EEP) vs NCDOT	0.0100	0.8075	EEP/WRP vs NCDOT	0.0100	0.4241
	NCDOT vs Other, Private	0.0125	0.8277	EEP/WRP vs Mitigation Bank	0.0125	0.531
	Mitigation Bank vs Other, Private	0.0167	0.8297	Full-Delivery (EEP) vs Mitigation Bank	0.0167	0.8197
	Full-Delivery (EEP) vs Mitigation Bank	0.0250	0.8315	Mitigation Bank vs NCDOT	0.0250	0.8684
	Full-Delivery (EEP) vs Other, Private	0.0500	0.9853	Full-Delivery (EEP) vs NCDOT	0.0500	0.9821
PhysRegion						
	Coastal Plain vs Piedmont	0.0167	0.0421	Mountains vs Piedmont	0.0167	0.0004
	Mountains vs Piedmont	0.0250	0.2666	Coastal Plain vs Piedmont	0.0250	0.0027
	Coastal Plain vs Mountains	0.0500	0.5086	Coastal Plain vs Mountains	0.0500	0.4084
AgeGroup						
	pre-2003 vs 2006-2008	0.0167	0.1512	pre-2003 vs 2003-2005	0.0167	0.4396
	pre-2003 vs 2003-2005	0.0250	0.4014	2003-2005 vs 2006-2008	0.0250	0.5563
	2003-2005 vs 2006-2008	0.0500	0.4947	pre-2003 vs 2006-2008	0.0500	0.8535
MitigActivity						
	Creation vs Preservation	0.0083	.	Creation vs Preservation	0.0083	.
	Creation vs Restoration	0.0100	0	Creation vs Restoration	0.0100	0.0001
	Preservation vs Restoration	0.0125	0	Preservation vs Restoration	0.0125	0.0001
	Restoration vs Enhancement	0.0167	0.0011	Restoration vs Enhancement	0.0167	0.0002
	Creation vs Enhancement	0.0250	0.1659	Creation vs Enhancement	0.0250	0.2015
	Preservation vs Enhancement	0.0500	0.1659	Preservation vs Enhancement	0.0500	0.2015

Stream Level Contrasts, All Data Including Preservation (Page 2 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
ProjSizeClass						
	<2500 vs 5001-10000	0.0083	0.1638	<2500 vs >10000	0.0083	0.4194
	2500-5000 vs 5001-10000	0.0100	0.1945	2500-5000 vs >10000	0.0100	0.5089
	5001-10000 vs >10000	0.0125	0.3078	5001-10000 vs >10000	0.0125	0.6829
	<2500 vs >10000	0.0167	0.855	<2500 vs 5001-10000	0.0167	0.7424
	2500-5000 vs >10000	0.0250	0.9196	<2500 vs 2500-5000	0.0250	0.8505
	<2500 vs 2500-5000	0.0500	0.9246	2500-5000 vs 5001-10000	0.0500	0.8647
Basin*						
	Broad vs Hiwassee	0.0006	.	Broad vs Hiwassee	0.0006	.
	Broad vs Roanoke	0.0006	.	Broad vs Roanoke	0.0006	.
	Broad vs Watauga	0.0007	.	Broad vs Watauga	0.0007	.
	Broad vs White Oak	0.0007	.	Broad vs White Oak	0.0007	.
	Hiwassee vs Roanoke	0.0007	.	Hiwassee vs Roanoke	0.0007	.
	Hiwassee vs Watauga	0.0007	.	Hiwassee vs Watauga	0.0007	.
	Hiwassee vs White Oak	0.0007	.	Hiwassee vs White Oak	0.0007	.
	Roanoke Watauga	0.0007	.	Roanoke Watauga	0.0007	.
	Roanoke vs White Oak	0.0007	.	Roanoke vs White Oak	0.0007	.
	Watauga vs White Oak	0.0007	.	Watauga vs White Oak	0.0007	.
	Cape Fear vs Hiwassee	0.0007	0	Hiwassee vs Little Tennesse	0.0007	0
	Catawa vs Hiwassee	0.0007	0	Hiwassee vs New	0.0007	0
	Hiwassee vs New	0.0008	0	Broad vs Little Tennesse	0.0008	0
	French Broad vs Hiwassee	0.0008	0	Little Tennesse vs Roanoke	0.0008	0
	Hiwassee vs Neuse	0.0008	0	Little Tennesse vs Watauga	0.0008	0
	Hiwassee vs Yadkin	0.0008	0	Little Tennesse vs White Oak	0.0008	0
	Hiwassee vs Little Tennesse	0.0008	0.0001	French Broad vs Hiwassee	0.0008	0
	Broad vs Yadkin	0.0008	0.0018	Cape Fear vs Hiwassee	0.0008	0
	Roanoke vs Yadkin	0.0008	0.0018	Hiwassee vs Neuse	0.0008	0
	Watauga vs Yadkin	0.0008	0.0018	Catawa vs Hiwassee	0.0008	0
	White Oak vs Yadkin	0.0009	0.0018	Broad vs Yadkin	0.0009	0.0006
	Broad vs Cape Fear	0.0009	0.0023	Roanoke vs Yadkin	0.0009	0.0006

Stream Level Contrasts, All Data Including Preservation (Page 3 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Basin*	Cape Fear vs Roanoke	0.0009	0.0023	Watauga vs Yadkin	0.0009	0.0006
	Cape Fear vs Watauga	0.0009	0.0023	White Oak vs Yadkin	0.0009	0.0006
	Cape Fear vs White Oak	0.0009	0.0023	Little Tennesse vs Yadkin	0.0009	0.0007
	Broad vs Catawba	0.0009	0.0037	New vs Yadkin	0.0009	0.0009
	Catawa vs Roanoke	0.0010	0.0037	French Broad vs Yadkin	0.0010	0.0021
	Catawba vs Watauga	0.0010	0.0037	Hiwassee vs Tar-Pamlico	0.0010	0.0031
	Catawba vs White Oak	0.0010	0.0037	Hiwassee vs Yadkin	0.0010	0.0066
	Broad vs Tar-Pamlico	0.0010	0.0068	Broad vs Tar-Pamlico	0.0010	0.0107
	Hiwassee vs Tar-Pamlico	0.0010	0.0068	Roanoke vs Tar-Pamlico	0.0010	0.0107
	Roanoke vs Tar-Pamlico	0.0011	0.0068	Tar-Pamlico Watauga	0.0011	0.0107
	Tar-Pamlico Watauga	0.0011	0.0068	Tar-Pamlico vs White Oak	0.0011	0.0107
	Tar-Pamlico vs White Oak	0.0011	0.0068	Little Tennesse vs Tar-Pamlico	0.0011	0.0132
	New vs Tar-Pamlico	0.0011	0.0674	New vs Tar-Pamlico	0.0011	0.0144
	New vs Yadkin	0.0012	0.0712	Cape Fear vs Yadkin	0.0012	0.0186
	French Broad vs Tar-Pamlico	0.0012	0.0981	French Broad vs Tar-Pamlico	0.0012	0.0265
	French Broad vs Yadkin	0.0012	0.1079	Neuse vs Yadkin	0.0012	0.0528
	Broad vs Neuse	0.0013	0.108	Broad vs Cape Fear	0.0013	0.0693
	Neuse vs Roanoke	0.0013	0.108	Cape Fear vs Roanoke	0.0013	0.0693
	Neuse vs Watauga	0.0013	0.108	Cape Fear vs Watauga	0.0013	0.0693
	Neuse vs White Oak	0.0014	0.108	Cape Fear vs White Oak	0.0014	0.0693
	Broad vs French Broad	0.0014	0.1297	Broad vs Catawba	0.0014	0.0693
	French Broad vs Roanoke	0.0014	0.1297	Catawa vs Roanoke	0.0014	0.0693
	French Broad vs Watauga	0.0015	0.1297	Catawba vs Watauga	0.0015	0.0693
	French Broad vs White Oak	0.0015	0.1297	Catawba vs White Oak	0.0015	0.0693
	Catawba vs Tar-Pamlico	0.0016	0.1852	Catawba vs Yadkin	0.0016	0.0739
	Cape Fear vs Tar-Pamlico	0.0016	0.2	Catawba vs Little Tennesse	0.0016	0.0897
	Catawba vs Yadkin	0.0017	0.229	Catawba vs New	0.0017	0.0992

Stream Level Contrasts, All Data Including Preservation (Page 4 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Basin*	Broad vs Little Tennesse	0.0017	0.2471	Cape Fear vs Little Tennesse	0.0017	0.1015
	Little Tennesse vs Roanoke	0.0018	0.2471	Cape Fear vs Tar-Pamlico	0.0018	0.1026
	Little Tennesse vs Watauga	0.0019	0.2471	Cape Fear vs New	0.0019	0.1162
	Little Tennesse vs White Oak	0.0019	0.2471	Broad vs French Broad	0.0019	0.1451
	Cape Fear vs Yadkin	0.0020	0.2514	French Broad vs Roanoke	0.0020	0.1451
	Broad vs New	0.0021	0.2774	French Broad vs Watauga	0.0021	0.1451
	New vs Roanoke	0.0022	0.2774	French Broad vs White Oak	0.0022	0.1451
	New vs Watauga	0.0023	0.2774	Broad vs Neuse	0.0023	0.1525
	New vs White Oak	0.0024	0.2774	Neuse vs Roanoke	0.0024	0.1525
	Neuse vs Tar-Pamlico	0.0025	0.2826	Neuse vs Watauga	0.0025	0.1525
	Little Tennesse vs Tar-Pamlico	0.0026	0.292	Neuse vs White Oak	0.0026	0.1525
	Cape Fear vs New	0.0028	0.3115	Neuse vs Tar-Pamlico	0.0028	0.1761
	Catawba vs New	0.0029	0.3512	Little Tennesse vs Neuse	0.0029	0.1895
	Neuse vs Yadkin	0.0031	0.3843	Catawba vs French Broad	0.0031	0.1929
	Little Tennesse vs Yadkin	0.0033	0.3888	Neuse vs New	0.0033	0.203
	Cape Fear vs French Broad	0.0036	0.4738	Catawba vs Tar-Pamlico	0.0036	0.2445
	Neuse vs New	0.0038	0.4739	French Broad vs Little Tennesse	0.0038	0.2833
	Catawba vs French Broad	0.0042	0.5209	Cape Fear vs French Broad	0.0042	0.3046
	French Broad vs Neuse	0.0045	0.6175	Broad vs New	0.0045	0.3209
	Little Tennesse vs New	0.0050	0.6211	New vs Roanoke	0.0050	0.3209
	Tar-Pamlico vs Yadkin	0.0056	0.7277	New vs Watauga	0.0056	0.3209
	French Broad vs Little Tennesse	0.0063	0.7556	New vs White Oak	0.0063	0.3209
	French Broad vs New	0.0071	0.7783	French Broad vs Neuse	0.0071	0.347
	Cape Fear vs Little Tennesse	0.0083	0.9051	French Broad vs New	0.0083	0.3658
	Little Tennesse vs Neuse	0.0100	0.9225	Cape Fear vs Catawba	0.0100	0.6136
	Cape Fear vs Catawba	0.0125	0.9339	Tar-Pamlico vs Yadkin	0.0125	0.6648
	Catawba vs Little Tennesse	0.0167	0.9409	Catawba vs Neuse	0.0167	0.7956
	Catawba vs Neuse	0.0250	0.9605	Cape Fear vs Neuse	0.0250	0.8439
	Cape Fear vs Neuse	0.0500	0.996	Little Tennesse vs New	0.0500	0.8516

Stream Level Contrasts, All Data Including Preservation (Page 5 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion						
	Sand Hills vs Southern Outer Piedmont	0.0009	0.0017	Mountains vs Sand Hills	0.0009	0
	Inner Piedmont vs Sand Hills	0.0009	0.0022	Inner Piedmont vs Sand Hills	0.0009	0.0063
	Sand Hills vs Triassic Basins	0.0009	0.003	Inner Piedmont vs Mountains	0.0009	0.0085
	Outer Coastal Plain vs Triassic Basins	0.0010	0.0325	Inner Piedmont vs New River Plateau	0.0010	0.0111
	Carolina Slate Belt vs Triassic Basins	0.0010	0.0535	Sand Hills vs Triassic Basins	0.0010	0.014
	Outer Coastal Plain vs Southern Outer Piedmont	0.0010	0.0906	Inner Piedmont vs Outer Coastal Plain	0.0010	0.0162
	Northern Outer Piedmont vs Sand Hills	0.0010	0.0912	Mountains vs Triassic Basins	0.0010	0.0166
	Inner Piedmont vs Outer Coastal Plain	0.0010	0.1141	New River Plateau vs Triassic Basins	0.0010	0.0192
	Carolina Slate Belt vs Sand Hills	0.0011	0.123	Outer Coastal Plain vs Triassic Basins	0.0011	0.0231
	Broad Basins vs Sand Hills	0.0011	0.1255	Sand Hills vs Southern Outer Piedmont	0.0011	0.0441
	Broad Basins vs Triassic Basins	0.0011	0.126	Mountains vs Southern Outer Piedmont	0.0011	0.0541
	Inner Coastal Plain vs Triassic Basins	0.0011	0.1315	New River Plateau vs Southern Outer Piedmont	0.0011	0.0669
	Inner Coastal Plain vs Sand Hills	0.0012	0.1469	Outer Coastal Plain vs Southern Outer Piedmont	0.0012	0.0797
	Carolina Slate Belt vs Southern Outer Piedmont	0.0012	0.1593	Inner Coastal Plain vs Triassic Basins	0.0012	0.0837
	Mountains vs Triassic Basins	0.0012	0.1605	Carolina Slate Belt vs Triassic Basins	0.0012	0.1206
	New River Plateau vs Triassic Basins	0.0013	0.1806	Inner Coastal Plain vs Inner Piedmont	0.0013	0.1392
	Carolina Slate Belt vs Inner Piedmont	0.0013	0.1989	Inner Coastal Plain vs Sand Hills	0.0013	0.1609

Stream Level Contrasts, All Data Including Preservation (Page 6 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	Mountains vs Sand Hills	0.0013	0.2079	Northern Outer Piedmont vs Sand Hills	0.0013	0.1845
	Northern Outer Piedmont vs Outer Coastal Plain	0.0014	0.2563	Broad Basins vs Triassic Basins	0.0014	0.1948
	New River Plateau vs Sand Hills	0.0014	0.2636	Inner Coastal Plain vs Mountains	0.0014	0.2114
	Inner Piedmont vs Triassic Basins	0.0014	0.3094	Mountains vs Northern Outer Piedmont	0.0014	0.2114
	Outer Coastal Plain vs Sand Hills	0.0015	0.3373	Carolina Slate Belt vs Inner Piedmont	0.0015	0.2145
	Carolina Slate Belt vs Northern Outer Piedmont	0.0015	0.3488	Broad Basins vs Sand Hills	0.0015	0.2172
	Southern Outer Piedmont vs Triassic Basins	0.0016	0.3637	New River Plateau vs Northern Outer Piedmont	0.0016	0.2335
	Broad Basins vs Southern Outer Piedmont	0.0016	0.3751	Broad Basins vs Mountains	0.0016	0.2528
	Inner Coastal Plain vs Southern Outer Piedmont	0.0017	0.3801	Inner Coastal Plain vs New River Plateau	0.0017	0.2623
	Mountains vs Southern Outer Piedmont	0.0017	0.44	Northern Outer Piedmont vs Outer Coastal Plain	0.0017	0.2644
	Broad Basins vs Inner Piedmont	0.0018	0.4406	Broad Basins vs New River Plateau	0.0018	0.2819
	Inner Coastal Plain vs Inner Piedmont	0.0019	0.4544	Carolina Slate Belt vs Sand Hills	0.0019	0.2894
	New River Plateau vs Southern Outer Piedmont	0.0019	0.482	Inner Coastal Plain vs Southern Outer Piedmont	0.0019	0.2908
	Broad Basins vs Northern Outer Piedmont	0.0020	0.5037	Northern Outer Piedmont vs Triassic Basins	0.0020	0.2933
	Inner Piedmont vs Mountains	0.0021	0.5048	Broad Basins vs Outer Coastal Plain	0.0021	0.3244
	Inner Coastal Plain vs Northern Outer Piedmont	0.0022	0.507	Inner Coastal Plain vs Outer Coastal Plain	0.0022	0.3271
	Broad Basins vs Outer Coastal Plain	0.0023	0.5307	New River Plateau vs Sand Hills	0.0023	0.3391
	Inner Coastal Plain vs Outer Coastal Plain	0.0024	0.5311	Carolina Slate Belt vs Mountains	0.0024	0.3403
	Inner Piedmont vs New River Plateau	0.0025	0.5312	Outer Coastal Plain vs Sand Hills	0.0025	0.3646
	Mountains vs Northern Outer Piedmont	0.0026	0.5322	Broad Basins vs Inner Piedmont	0.0026	0.3657

Stream Level Contrasts, All Data Including Preservation (Page 7 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	New River Plateau vs Northern Outer Piedmont	0.0028	0.5444	Carolina Slate Belt vs New River Plateau	0.0028	0.3822
	Northern Outer Piedmont vs Triassic Basins	0.0029	0.5472	Carolina Slate Belt vs Southern Outer Piedmont	0.0029	0.3884
	Mountains vs Outer Coastal Plain	0.0031	0.5802	Southern Outer Piedmont vs Triassic Basins	0.0031	0.4134
	New River Plateau vs Outer Coastal Plain	0.0033	0.6109	Carolina Slate Belt vs Outer Coastal Plain	0.0033	0.4389
	Carolina Slate Belt vs Outer Coastal Plain	0.0036	0.718	Inner Piedmont vs Triassic Basins	0.0036	0.535
	Broad Basins vs Carolina Slate Belt	0.0038	0.7393	Inner Piedmont vs Northern Outer Piedmont	0.0038	0.5418
	Carolina Slate Belt vs Inner Coastal Plain	0.0042	0.7527	Broad Basins vs Southern Outer Piedmont	0.0042	0.5624
	Carolina Slate Belt vs Mountains	0.0045	0.766	Inner Coastal Plain vs Northern Outer Piedmont	0.0045	0.5839
	Carolina Slate Belt vs New River Plateau	0.0050	0.7919	Mountains vs Outer Coastal Plain	0.0050	0.5956
	Inner Piedmont vs Northern Outer Piedmont	0.0056	0.867	Carolina Slate Belt vs Northern Outer Piedmont	0.0056	0.6588
	Inner Piedmont vs Southern Outer Piedmont	0.0063	0.8892	Mountains vs New River Plateau	0.0063	0.7133
	Northern Outer Piedmont vs Southern Outer Piedmont	0.0071	0.9352	Broad Basins vs Inner Coastal Plain	0.0071	0.7291
	Inner Coastal Plain vs Mountains	0.0083	0.9894	Northern Outer Piedmont vs Southern Outer Piedmont	0.0083	0.7424
	Mountains vs New River Plateau	0.0100	0.9938	Inner Piedmont vs Southern Outer Piedmont	0.0100	0.7716
	Broad Basins vs Mountains	0.0125	0.9938	New River Plateau vs Outer Coastal Plain	0.0125	0.7989
	Broad Basins vs Inner Coastal Plain	0.0167	0.995	Broad Basins vs Carolina Slate Belt	0.0167	0.8042
	Inner Coastal Plain vs New River Plateau	0.0250	0.9966	Broad Basins vs Northern Outer Piedmont	0.0250	0.8382
	Broad Basins vs New River Plateau	0.0500	1	Carolina Slate Belt vs Inner Coastal Plain	0.0500	0.9415

Notes: Comparisons highlighted in yellow met testing parameters for statistical significance.
***Sample sizes in many Basin and Ecoregion levels were too small to yield statistically-valid results for the domains.**
Source of data: RTI SUDAAN® contrast outputs, including multiple t-test p-values; DWQ comparison of p-values with null hypothesis rejection threshold per Holm's Method

Stream Level Contrasts, Excluding Preservation Data (Page 1 of 7)

Table 14. Stream domain level contrast results for data excluding preservation components, weighted by count and size.

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Provider						
	EEP/WRP vs Full-Delivery (EEP)	0.0050	0.193	EEP/WRP vs Other,Private	0.0050	0.094
	EEP/WRP vs Mitigation Bank	0.0056	0.327	EEP/WRP vs Full-Delivery (EEP)	0.0056	0.1643
	EEP/WRP vs Other,Private	0.0063	0.341	EEP/WRP vs NCDOT	0.0063	0.347
	EEP/WRP vs NCDOT	0.0071	0.5567	EEP/WRP vs Mitigation Bank	0.0071	0.4105
	Mitigation Bank vs NCDOT	0.0083	0.6526	Mitigation Bank vs Other, Private	0.0083	0.7329
	Full-Delivery (EEP) vs NCDOT	0.0100	0.6917	Full-Delivery (EEP) vs Mitigation Bank	0.0100	0.8197
	Mitigation Bank vs Other, Private	0.0125	0.7469	NCDOT vs Other, Private	0.0125	0.8863
	Full-Delivery (EEP) vs Mitigation Bank	0.0167	0.8315	Mitigation Bank vs NCDOT	0.0167	0.8872
	Full-Delivery (EEP) vs Other, Private	0.0250	0.8333	Full-Delivery (EEP) vs Other, Private	0.0250	0.8874
	NCDOT vs Other, Private	0.0500	0.8337	Full-Delivery (EEP) vs NCDOT	0.0500	0.9625
PhysRegion						
	Coastal Plain vs Piedmont	0.0167	0.0462	Coastal Plain vs Piedmont	0.0167	0.003
	Mountains vs Piedmont	0.0250	0.3434	Mountains vs Piedmont	0.0250	0.1327
	Coastal Plain vs Mountains	0.0500	0.5173	Coastal Plain vs Mountains	0.0500	0.4124
AgeGroup						
	pre-2003 vs 2006-2008	0.0167	0.1237	pre-2003 vs 2006-2008	0.0167	0.0655
	2003-2005 vs 2006-2008	0.0250	0.4009	2003-2005 vs 2006-2008	0.0250	0.3589
	pre-2003 vs 2003-2005	0.0500	0.4164	pre-2003 vs 2003-2005	0.0500	0.3878
MitigActivity						
	Creation vs Restoration	0.0167	0	Creation vs Restoration	0.0167	0.0001
	Restoration vs Enhancement	0.0250	0.0011	Restoration vs Enhancement	0.0250	0.0002
	Creation vs Enhancement	0.0500	0.1659	Creation vs Enhancement	0.0500	0.2015

Stream Level Contrasts, Excluding Preservation Data (Page 2 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
ProjSizeClass						
	<2500 vs 5001-10000	0.0083	0.1847	5001-10000 vs >10000	0.0083	0.4041
	2500-5000 vs 5001-10000	0.0100	0.2058	2500-5000 vs >10000	0.0100	0.4259
	5001-10000 vs >10000	0.0125	0.2383	<2500 vs >10000	0.0125	0.5174
	2500-5000 vs >10000	0.0167	0.8651	<2500 vs 5001-10000	0.0167	0.7656
	<2500 vs >10000	0.0250	0.8907	<2500 vs 2500-5000	0.0250	0.8676
	<2500 vs 2500-5000	0.0500	0.9675	2500-5000 vs 5001-10000	0.0500	0.8746
Basin*						
	Broad vs Hiwassee	0.0006	.	Broad vs Hiwassee	0.0006	.
	Broad vs Roanoke	0.0006	.	Broad vs Roanoke	0.0006	.
	Broad vs Watauga	0.0007	.	Broad vs Watauga	0.0007	.
	Broad vs White Oak	0.0007	.	Broad vs White Oak	0.0007	.
	Hiwassee vs Roanoke	0.0007	.	Hiwassee vs Roanoke	0.0007	.
	Hiwassee vs Watauga	0.0007	.	Hiwassee vs Watauga	0.0007	.
	Hiwassee vs White Oak	0.0007	.	Hiwassee vs White Oak	0.0007	.
	Roanoke Watauga	0.0007	.	Roanoke Watauga	0.0007	.
	Roanoke vs White Oak	0.0007	.	Roanoke vs White Oak	0.0007	.
	Watauga vs White Oak	0.0007	.	Watauga vs White Oak	0.0007	.
	Catawa vs Hiwassee	0.0007	0	Hiwassee vs New	0.0007	0
	Cape Fear vs Hiwassee	0.0007	0	French Broad vs Hiwassee	0.0007	0
	Hiwassee vs New	0.0008	0	Cape Fear vs Hiwassee	0.0008	0
	French Broad vs Hiwassee	0.0008	0	Hiwassee vs Neuse	0.0008	0
	Hiwassee vs Neuse	0.0008	0	Catawa vs Hiwassee	0.0008	0
	Hiwassee vs Yadkin	0.0008	0	Broad vs Yadkin	0.0008	0.0006
	Broad vs Cape Fear	0.0008	0.0018	Roanoke vs Yadkin	0.0008	0.0006
	Cape Fear vs Roanoke	0.0008	0.0018	Watauga vs Yadkin	0.0008	0.0006
	Cape Fear vs Watauga	0.0008	0.0018	White Oak vs Yadkin	0.0008	0.0006
	Cape Fear vs White Oak	0.0008	0.0018	New vs Yadkin	0.0008	0.0009
	Broad vs Yadkin	0.0009	0.0018	Hiwassee vs Tar-Pamlico	0.0009	0.0031
	Roanoke vs Yadkin	0.0009	0.0018	French Broad vs Yadkin	0.0009	0.004

Stream Level Contrasts, Excluding Preservation Data (Page 3 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Basin*	Watauga vs Yadkin	0.0009	0.0018	Hiwassee vs Yadkin	0.0009	0.0066
	White Oak vs Yadkin	0.0009	0.0018	Broad vs Tar-Pamlico	0.0009	0.0107
	Broad vs Catawba	0.0009	0.0021	Roanoke vs Tar-Pamlico	0.0009	0.0107
	Catawa vs Roanoke	0.0009	0.0021	Tar-Pamlico Watauga	0.0009	0.0107
	Catawba vs Watauga	0.0010	0.0021	Tar-Pamlico vs White Oak	0.0010	0.0107
	Catawba vs White Oak	0.0010	0.0021	New vs Tar-Pamlico	0.0010	0.0144
	Hiwassee vs Little Tennesse	0.0010	0.0027	Hiwassee vs Little Tennesse	0.0010	0.022
	Broad vs Tar-Pamlico	0.0010	0.0068	Cape Fear vs Yadkin	0.0010	0.0329
	Hiwassee vs Tar-Pamlico	0.0010	0.0068	French Broad vs Tar-Pamlico	0.0010	0.0385
	Roanoke vs Tar-Pamlico	0.0011	0.0068	Neuse vs Yadkin	0.0011	0.0528
	Tar-Pamlico Watauga	0.0011	0.0068	Broad vs Cape Fear	0.0011	0.06
	Tar-Pamlico vs White Oak	0.0011	0.0068	Cape Fear vs Roanoke	0.0011	0.06
	New vs Tar-Pamlico	0.0011	0.0674	Cape Fear vs Watauga	0.0011	0.06
	New vs Yadkin	0.0012	0.0712	Cape Fear vs White Oak	0.0012	0.06
	Broad vs Neuse	0.0012	0.108	Broad vs Catawba	0.0012	0.0674
	Neuse vs Roanoke	0.0012	0.108	Catawa vs Roanoke	0.0012	0.0674
	Neuse vs Watauga	0.0013	0.108	Catawba vs Watauga	0.0013	0.0674
	Neuse vs White Oak	0.0013	0.108	Catawba vs White Oak	0.0013	0.0674
	French Broad vs Tar-Pamlico	0.0013	0.1699	Catawba vs Yadkin	0.0013	0.0784
	Catawba vs Tar-Pamlico	0.0014	0.1979	Cape Fear vs New	0.0014	0.0939
	Broad vs French Broad	0.0014	0.1993	Catawba vs New	0.0014	0.0962
	French Broad vs Roanoke	0.0014	0.1993	Cape Fear vs Tar-Pamlico	0.0014	0.1477
	French Broad vs Watauga	0.0015	0.1993	Broad vs Neuse	0.0015	0.1525
	French Broad vs White Oak	0.0015	0.1993	Neuse vs Roanoke	0.0015	0.1525
	Cape Fear vs Tar-Pamlico	0.0016	0.2151	Neuse vs Watauga	0.0016	0.1525
	French Broad vs Yadkin	0.0016	0.2159	Neuse vs White Oak	0.0016	0.1525
	Catawba vs Yadkin	0.0017	0.248	Neuse vs Tar-Pamlico	0.0017	0.1761

Stream Level Contrasts, Excluding Preservation Data (Page 4 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Basin*	Cape Fear vs Yadkin	0.0017	0.2743	Neuse vs New	0.0017	0.203
	Broad vs New	0.0018	0.2774	Broad vs Little Tennesse	0.0018	0.2359
	New vs Roanoke	0.0019	0.2774	Little Tennesse vs Roanoke	0.0019	0.2359
	New vs Watauga	0.0019	0.2774	Little Tennesse vs Watauga	0.0019	0.2359
	New vs White Oak	0.0020	0.2774	Little Tennesse vs White Oak	0.0020	0.2359
	Neuse vs Tar-Pamlico	0.0021	0.2826	Catawba vs Tar-Pamlico	0.0021	0.2537
	Cape Fear vs New	0.0022	0.2838	Broad vs French Broad	0.0022	0.2543
	Broad vs Little Tennesse	0.0023	0.3031	French Broad vs Roanoke	0.0023	0.2543
	Little Tennesse vs Roanoke	0.0024	0.3031	French Broad vs Watauga	0.0024	0.2543
	Little Tennesse vs Watauga	0.0025	0.3031	French Broad vs White Oak	0.0025	0.2543
	Little Tennesse vs White Oak	0.0026	0.3031	Little Tennesse vs New	0.0026	0.2621
	Catawba vs New	0.0028	0.3149	Catawba vs French Broad	0.0028	0.2633
	Neuse vs Yadkin	0.0029	0.3843	Broad vs New	0.0029	0.3209
	Little Tennesse vs Tar-Pamlico	0.0031	0.4082	New vs Roanoke	0.0031	0.3209
	Neuse vs New	0.0033	0.4739	New vs Watauga	0.0033	0.3209
	Little Tennesse vs Yadkin	0.0036	0.5314	New vs White Oak	0.0036	0.3209
	Little Tennesse vs New	0.0038	0.6073	Cape Fear vs French Broad	0.0038	0.3517
	Cape Fear vs French Broad	0.0042	0.6592	French Broad vs Little Tennesse	0.0042	0.3558
	French Broad vs New	0.0045	0.6925	French Broad vs New	0.0045	0.408
	Catawba vs French Broad	0.0050	0.6976	French Broad vs Neuse	0.0050	0.4444
	Tar-Pamlico vs Yadkin	0.0056	0.7277	Little Tennesse vs Yadkin	0.0056	0.487
	French Broad vs Neuse	0.0063	0.7625	Cape Fear vs Little Tennesse	0.0063	0.5778
	French Broad vs Little Tennesse	0.0071	0.8118	Little Tennesse vs Neuse	0.0071	0.5886
	Cape Fear vs Catawba	0.0083	0.9359	Tar-Pamlico vs Yadkin	0.0083	0.6648
	Cape Fear vs Neuse	0.0100	0.9585	Catawba vs Little Tennesse	0.0100	0.6961
	Cape Fear vs Little Tennesse	0.0125	0.9844	Little Tennesse vs Tar-Pamlico	0.0125	0.7123
	Catawba vs Little Tennesse	0.0167	0.9875	Cape Fear vs Catawba	0.0167	0.7571
	Little Tennesse vs Neuse	0.0250	0.9887	Catawba vs Neuse	0.0250	0.7784
	Catawba vs Neuse	0.0500	1	Cape Fear vs Neuse	0.0500	0.9966

Stream Level Contrasts, Excluding Preservation Data (Page 5 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*						
	Inner Piedmont vs Sand Hills	0.0009	0.0015	Inner Piedmont vs Sand Hills	0.0009	0.0058
	Sand Hills vs Southern Outer Piedmont	0.0009	0.0017	Inner Piedmont vs New River Plateau	0.0009	0.0101
	Sand Hills vs Triassic Basins	0.0009	0.003	Sand Hills vs Triassic Basins	0.0009	0.014
	Outer Coastal Plain vs Triassic Basins	0.0010	0.0394	Inner Piedmont vs Outer Coastal Plain	0.0010	0.0153
	Carolina Slate Belt vs Triassic Basins	0.0010	0.0772	New River Plateau vs Triassic Basins	0.0010	0.0192
	Northern Outer Piedmont vs Sand Hills	0.0010	0.0912	Outer Coastal Plain vs Triassic Basins	0.0010	0.0234
	Carolina Slate Belt vs Sand Hills	0.0010	0.1127	Sand Hills vs Southern Outer Piedmont	0.0010	0.0441
	Outer Coastal Plain vs Southern Outer Piedmont	0.0010	0.1146	New River Plateau vs Southern Outer Piedmont	0.0010	0.0669
	Inner Piedmont vs Outer Coastal Plain	0.0011	0.1245	Outer Coastal Plain vs Southern Outer Piedmont	0.0011	0.0811
	Inner Coastal Plain vs Triassic Basins	0.0011	0.1315	Inner Coastal Plain vs Triassic Basins	0.0011	0.0837
	Inner Coastal Plain vs Sand Hills	0.0011	0.1469	Inner Coastal Plain vs Inner Piedmont	0.0011	0.1322
	Broad Basins vs Sand Hills	0.0011	0.1572	Mountains vs Triassic Basins	0.0011	0.1552
	Broad Basins vs Triassic Basins	0.0012	0.1799	Inner Coastal Plain vs Sand Hills	0.0012	0.1609
	New River Plateau vs Triassic Basins	0.0012	0.1806	Northern Outer Piedmont vs Sand Hills	0.0012	0.1845
	Mountains vs Triassic Basins	0.0012	0.2324	Broad Basins vs Sand Hills	0.0012	0.2239
	Carolina Slate Belt vs Southern Outer Piedmont	0.0013	0.2374	New River Plateau vs Northern Outer Piedmont	0.0013	0.2335
	Mountains vs Sand Hills	0.0013	0.2534	Carolina Slate Belt vs Sand Hills	0.0013	0.2362

Stream Level Contrasts, Excluding Preservation Data (Page 6 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	Carolina Slate Belt vs Inner Piedmont	0.0013	0.2588	Carolina Slate Belt vs Triassic Basins	0.0013	0.2449
	New River Plateau vs Sand Hills	0.0014	0.2636	Inner Coastal Plain vs New River Plat	0.0014	0.2623
	Northern Outer Piedmont vs Outer Coastal Plain	0.0014	0.2777	Broad Basins vs Triassic Basins	0.0014	0.2663
	Inner Piedmont vs Triassic Basins	0.0014	0.3293	Northern Outer Piedmont vs Outer Coastal Plain	0.0014	0.2668
	Outer Coastal Plain vs Sand Hills	0.0015	0.3347	Inner Piedmont vs Mountains	0.0015	0.2762
	Southern Outer Piedmont vs Triassic Basins	0.0015	0.3637	Broad Basins vs New River Plateau	0.0015	0.2785
	Inner Coastal Plain vs Southern Outer Piedmont	0.0016	0.3801	Inner Coastal Plain vs Southern Outer Piedmont	0.0016	0.2908
	Carolina Slate Belt vs Northern Outer Piedmont	0.0016	0.4113	Northern Outer Piedmont vs Triassic Basins	0.0016	0.2933
	Inner Coastal Plain vs Inner Piedmont	0.0017	0.421	Carolina Slate Belt vs New River Plat	0.0017	0.295
	New River Plateau vs Southern Outer Piedmont	0.0017	0.482	Mountains vs Sand Hills	0.0017	0.2994
	Broad Basins vs Southern Outer Piedmont	0.0018	0.4945	Broad Basins vs Outer Coastal Plain	0.0018	0.3163
	Inner Piedmont vs New River Plateau	0.0019	0.5003	Inner Coastal Plain vs Outer Coastal Plain	0.0019	0.3332
	Inner Coastal Plain vs Northern Outer Piedmont	0.0019	0.507	Carolina Slate Belt vs Outer Coastal Plain	0.0019	0.3338
	Broad Basins vs Inner Piedmont	0.0020	0.5291	New River Plateau vs Sand Hills	0.0020	0.3391
	Broad Basins vs Outer Coastal Plain	0.0021	0.5426	Outer Coastal Plain vs Sand Hills	0.0021	0.366
	New River Plateau vs Northern Outer Piedmont	0.0022	0.5444	Mountains vs New River Plateau	0.0022	0.3796
	Northern Outer Piedmont vs Triassic Basins	0.0023	0.5472	Southern Outer Piedmont vs Triassic Basins	0.0023	0.4134
	Mountains vs Southern Outer Piedmont	0.0024	0.5659	Mountains vs Outer Coastal Plain	0.0024	0.4313
	Inner Coastal Plain vs Outer Coastal Plain	0.0025	0.5757	Carolina Slate Belt vs Inner Piedmont	0.0025	0.4408
	Broad Basins vs Northern Outer Piedmont	0.0026	0.5777	Mountains vs Southern Outer Piedmont	0.0026	0.4702

Stream Level Contrasts, Excluding Preservation Data (Page 7 of 7)

Domain	Contrast Levels (Weight = Count)	Holm's Test	p-value	Contrast Levels (Weight = Size)	Holm's Test	p-value
Ecoregion*	Mountains vs Outer Coastal Plain	0.0028	0.5988	Broad Basins vs Inner Piedmont	0.0028	0.479
	Inner Piedmont vs Mountains	0.0029	0.5994	Inner Piedmont vs Northern Outer Piedmont	0.0029	0.5272
	Mountains vs Northern Outer Piedmont	0.0031	0.6132	Inner Piedmont vs Triassic Basins	0.0031	0.5488
	New River Plateau vs Outer Coastal Plain	0.0033	0.6467	Inner Coastal Plain vs Northern Outer Piedmont	0.0033	0.5839
	Carolina Slate Belt vs Outer Coastal Plain	0.0036	0.6696	Carolina Slate Belt vs Southern Outer Piedmont	0.0036	0.6478
	Broad Basins vs Carolina Slate Belt	0.0038	0.7873	Broad Basins vs Inner Coastal Plain	0.0038	0.6489
	Carolina Slate Belt vs Mountains	0.0042	0.8113	Carolina Slate Belt vs Inner Coastal Plain	0.0042	0.6839
	Carolina Slate Belt vs Inner Coastal Plain	0.0045	0.8669	Broad Basins vs Southern Outer Piedmont	0.0045	0.6867
	Carolina Slate Belt vs New River Plateau	0.0050	0.8853	Mountains vs Northern Outer Piedmont	0.0050	0.7356
	Inner Piedmont vs Northern Outer Piedmont	0.0056	0.897	Northern Outer Piedmont vs Southern Outer Piedmont	0.0056	0.7424
	Broad Basins vs Inner Coastal Plain	0.0063	0.9161	Inner Piedmont vs Southern Outer Piedmont	0.0063	0.7526
	Inner Coastal Plain vs Mountains	0.0071	0.9207	New River Plateau vs Outer Coastal Plain	0.0071	0.7883
	Broad Basins vs New River Plateau	0.0083	0.9294	Broad Basins vs Mountains	0.0083	0.7964
	Mountains vs New River Plateau	0.0100	0.9305	Carolina Slate Belt vs Mountains	0.0100	0.83
	Northern Outer Piedmont vs Southern Outer Piedmont	0.0125	0.9352	Inner Coastal Plain vs Mountains	0.0125	0.8624
	Inner Piedmont vs Southern Outer Piedmont	0.0167	0.9379	Carolina Slate Belt vs Northern Outer Piedmont	0.0167	0.9069
	Broad Basins vs Mountains	0.0250	0.9938	Broad Basins vs Northern Outer Piedmont	0.0250	0.9443
	Inner Coastal Plain vs New River Plateau	0.0500	0.9966	Broad Basins vs Carolina Slate Belt	0.0500	0.9631

Notes: Comparisons highlighted in yellow met testing parameters for statistical significance.
***Sample sizes in many Basin and Ecoregion levels were too small to yield statistically-valid results for the domains.**
Source of data: RTI SUDAAN® contrast outputs, including multiple t-test p-values; DWQ comparison of p-values with null hypothesis rejection threshold per Holm's Method

Appendix E: EEP Projects Bank Stability Data

Table 15. EEP projects bank stability data.

DWQ ID	Project Name	County	% Bank Stability	
			Pre-construction	Post-construction
20020888b	Benbow Park Stream Rest.	Guilford	45	99
20020906	Suck Creek	Moore	50	99
20021682	Purlear Creek-Phase 1	Wilkes	25	100
20040667	Purlear Creek-Phase 2	Wilkes	45	98
20050615	South Muddy Creek Tributaries	McDowell	40	98
20021215	Cato Farms Stream Rest.	Mecklenburg	<50	100
20041646	Greene Mitigation Site	Mecklenburg	65	100
20001434	Jefferson Pilot Stream Restoration	Guilford	40	100
20030503	Little Beaver Creek Stream Restoration	Wake	50	100
20000723	Payne Dairy (Jumping Run)	Alexander	<20	>90
20021883	Prestonwood Golf Course	Wake	<20	100
20031001	UT to Billy's Creek Stream Restoration	Franklin	50	100
20031064	UT to Tar River	Franklin	25	100
19970616v1	Bare Mitigation Site (UT to Peak Creek)	Ashe	25	95
20030425	Hanging Rock Creek	Avery	50	93
20021572	Reedy Branch	Alamance	45	99
20011043	Smith & Austin Creeks	Wake	40	na
20021834	Snow Creek	Stokes	45	100
20030299	Third Fork Creek (Forest Hills)	Durham	40	91
20021528	Warrior Creek	Wilkes	35	97