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Assessing Geographically Isolated Wetlands in North and South Carolina – the Southeast Isolated Wetlands Assessment (SEIWA)

Final Report

Prepared for

U.S. Environmental Protection Agency
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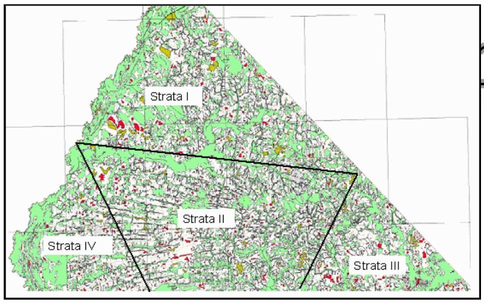

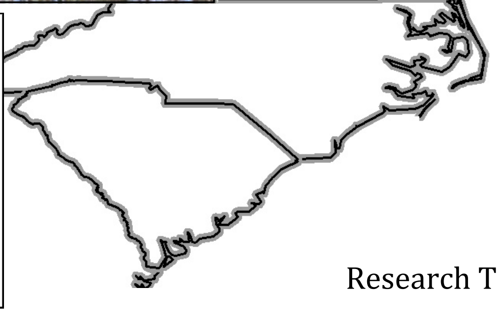

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Disclaimer

This report has not been subject to EPA or peer review and does not represent an official U.S. EPA document.

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Assessing Geographically Isolated Wetlands in North and South Carolina –

Technical Report for the Southeast Isolated Wetlands Assessment (SEIWA)

The use of probabilistic methods to answer questions about the condition and fate of geographically isolated wetlands in southeast coastal plain of Region 4

Project Partners:

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Abstract

Wetlands provide significant benefits to habitats and the surrounding environment. Geographically isolated wetlands (IWs) can provide the same environmental benefits but are subject to being lost due to the encroachment of human infrastructure and agriculture. The Southeast Isolated Wetland Assessment (SEIWA) explored the condition and fate of geographically isolated wetlands (IWs) in an 8-county portion of the coastal plain of North and South Carolina under a grant from the U.S. EPA's Regional Environmental Monitoring and Assessment Program (REMAP). The SEIWA project was conducted by a partnership of wetland scientists and statistician from RTI International (RTI), the North Carolina Center for Geographic Information and Analysis (NC CGIA), the North Carolina Division of Water Quality (NC DWQ), the University of South Carolina (USC), and the South Carolina Department of Health and Environmental Control (SC DEHC). SEIWA employed a phased approach based on three levels of wetland assessment described by EPA (U.S. EPA, 2006): Level 1, which uses geographical information systems (GIS) to identify IWs in the study area; Level 2 to rapidly assess the type and condition of a random sample of the Level 1 sites; and Level 3, detailed assessments to measure the hydrologic, water quality, and habitat functions of selected IW wetland sites.

The SEIWA Level 1 geographical information systems (GIS) approach modeled physical, hydrologic and biological characteristics relevant to the conditions of geographically IWs. The Level 1 method produced polygon datasets that represent the candidate locations of geographically IWs for eight counties along the coast of North and South Carolina. Level 2 field assessments were then done on randomly selected candidate IW sites to determine the accuracy of the maps for depicting wetlands and isolated wetlands, as well as to develop a statistically extensible estimate of the characteristics, condition, and relative level of functioning of the target population. In terms of accuracy, 69% of the candidate IW polygons in the study area were wetlands and 22% were isolated wetlands. These accuracy data, along with field

results from the Level 2 rapid assessments conducted at the randomly sampled IW sites, were used to estimate the number, size, and condition of isolated wetlands in the entire study area. We estimate that there are over 50,000 IWs in the 8-county study area occupying about 30,000 acreas of land, or 2% of the total wetland area. The IWs are mostly forested depressions; we estimate they can hold over 4,000 acre-feet of water in NC, and sequester around 5 million metric tons of carbon in wetland soils. Detailed (Level 3) wetland assessments conducted on two wetland clusters demonstrate assessment methods and techniques and evaluate how IWs in good condition perform in terms of their hydrologic, water quality, and habitat functions in the landscape of the study area.

Problem Statement

It is widely recognized that wetlands provide significant environmental benefits, including assimilation of pollutants, flood water storage, ground water recharge, carbon sequestration, and fish and wildlife habitat. Unfortunately, this recognition has come late. Tiner (1984) and Dahl (1990) estimated that 50% to 55% of the original wetland area in the conterminous United States has been lost since pre-settlement times. This loss has not ceased. In the mid-90's some 15% of current wetlands are estimated to be in a state of transition to other land uses (Moorhead and Cook, 1992). More recent status and trends reports for the United States shows a net gain of wetland acreage although a large portion of that is due to increases in ponds (Dahl. 2006). In addition a more recent study showed that losses of wetlands continue in coastal watersheds of the eastern US (Stedman and Dahl. 2008).

It appears that geographically isolated wetlands[1] can provide the same environmental benefits as wetlands in general, and are particularly vulnerable to losses from urbanization and agriculture precisely because they are geographically isolated and have varying amounts of regulatory protection. However significant gaps in our understanding of key aspects of their occurrence and ecological characteristics make it difficult to manage isolated wetlands in both landscape and regulatory contexts. Although much is known about these systems, recent reviews of the functions and values of isolated wetlands, including those on the U.S. southeastern coastal plain, articulate a clear need for additional research to increase our understanding of these wetlands (e.g., Kirkman et al., 1999; Leibowitz, 2003). This is particularly so in the context of the rapid development and human migration that is transforming the coastal areas of North and South Carolina.

The first requirement for proper assessment of the functions and values of isolated wetlands is a tool to predict their geographic location and extent. Before this project, there was not a dependable method to accurately map isolated wetlands without sending field scientists into the field to perform surveys or requiring that image technicians perform heads-up digitizing from vast archives of aerial photography. Both of these methods would require considerable time and cost for large coastal areas. Existing GIS data and mapping methods also present some challenges to accurately map isolated wetlands for large project areas.

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[1] The term "geographically isolated wetland' refers to those wetlands that have no surface connection to downstream waters. This definition is consistent with that used by the US Army Corps of Engineers for the 404 Permitting Program. This is in contrast to other wetlands identified and regulated by the 404 Permit Program as delineated by the US Army Corps of Engineers Wetland Delineation Manual (Environmental Laboratory, 1987).

- Most satellite imagery used in previous land cover classification projects do not have the resolution needed to capture the small areas covered by isolated wetlands.
- High-resolution imagery, such as aerial photography, contains far too much detail to use traditional land cover classification methods. In addition, remotely sensed imagery is often several years old and may be inaccurate especially in areas with significant development.
- Existing wetland coverages, such as the National Wetland Inventory (NWI) or county soil survey maps, are not reliable and accurate for locating isolated wetlands for several reasons: (1) they are dated (in North Carolina, the NWI maps date from the mid-1980's); (2) they are not sensitive enough to detect small scale features; and (3) they do not separately identify wetlands into isolated and non-isolated categories.

Given the benefits of isolated wetlands, a cost-effective mapping tool was needed to predict their geographic location and extent. The output data generated by a mapping tool should be verified against truth data collected in the field.

The southeast coastal plain has many types of isolated wetlands; forested depression isolated wetlands present particular challenges for resource managers and they occur in large numbers, especially on the outer coastal plain. Forested depression isolated wetlands occur in hydrologic sinks that have small watersheds and are generally hydrologically isolated from surface flows. They may be seasonally or permanently ponded, depending on local conditions. Typically there is a shallow groundwater connection to other wetlands and streams (e.g., Pyzoha et al., 2008). These wetlands can be sinks for nutrients; thus, alterations (e.g., ditching) have negative effects on downstream water quality (Amatya et al., 1998; Blann et al., 2009). Adjacent land use has important implications for both diversity and richness of sensitive taxa such as salamanders and frogs (Russell et al., 2002a; Russell et al., 2002b). Adjacent land management activities, even in rural settings, also have measurable effects on hydrology (Sun et al., 2001). Isolated forested depressions are frequently small (Tiner et al., 2002), making them difficult to detect and inventory, as mentioned above. Problems with detection and less scientific attention focused on these problems contribute to greater vulnerability to degradation and destruction.

The combination of these and related issues have led to inconsistent resource protection strategies in both natural resource management and regulatory agencies. SEIWA is a probability based study designed to provide information that can be used to help regulatory agencies identify and locate isolated wetlands, assess their water quality and hydrologic benefits, and make inferences (e.g. projections of the number and extent) to a region of interest. By applying these tools and techniques, regulatory agencies can quantify the benefits of isolated wetlands, determine their current extent and condition, estimate the rate of loss, and better recognize, protect, and manage these valuable resources.

The Level 2 and Level 3 portions of this study were used to help quantify the environmental benefits of isolated wetlands, both on a landscape scale (Levels 1, 2 and 3) and individually (Levels 2 and 3). Few studies have been done on the condition, relative level of functioning, storage and pollution absorption capacity, and hydrological connection of existing isolated wetlands to groundwater and surface water resources in the coastal plain of the Carolinas. This type of information will be valuable for resource management and policy planning in regards to isolated wetlands in the southeast.

Project Description

The SEIWA project (1) estimated the number and spatial extent of isolated wetlands in a selected study area using GIS mapping tools developed for the project and probability based estimators; (2) developed probability design-based estimates and corresponding standard errors of the number and extent of isolated wetlands and the general level of characteristics and condition in the study area; and (3) estimated the assimilative capacity of selected isolated wetlands for key pollutants, hydrologic connectivity, and biotic communities (amphibians, aquatic macroinvertebrates, and plants). Other outputs of this research included statistic and GIS methodologies and data for developing a GIS isolated wetland–predictive mapping tool and a probability sampling design. These project outputs will lead to the more general environmental outcomes of improved knowledge of and management of these isolated wetland resources within the study area, a blueprint for performing similar analyses in other areas, and an extensive GIS dataset that can be used in future isolated wetland protection and management activities in the study area by the participating regulatory agencies (NC DENR and SC DHEC).

The definition for isolated wetland status were based on the concepts and principles established in the Solid Waste Agency of Northern Cook County vs. United States Army Corps of Engineers (SWANCC) legal decision[2], which are vital to federal regulatory approaches to wetlands and are also of concern to both North Carolina and South Carolina as they pursue their own state-based programs to address isolated wetland issues.

Methodologically, SEIWA employed a phased approach that is consistent with the three levels of wetland assessments recently described by the U.S. Environmental Protection Agency (U.S. EPA, 2006a), as illustrated in **Figure 1**. For **Level 1** assessments, we evaluated existing geospatial and remote sensing imagery and developed GIS mapping tool that defined a population frame of candidate polygons likely to contain, be contained within, or intersect isolated wetlands in the SEIWA study area. Using this population frame, we developed a probability sampling design that was used to select a random set of candidate polygons in the study area for the **Level 2** field work. In Level 2, we conducted rapid assessments to collect data to evaluate the accuracy of the initial population frame (mapping tool) and determine the number, extent, relative level of function, condition, storage capacity (volume), and soil carbon pool of the isolated wetlands in the study area. In the **Level 3** field work, we conducted intensive assessments of selected IWs in the study area. Data from Level 3 include the pollutant absorption capacity, biological characteristics, water quality, hydrologic connectivity, and cumulative hydrologic

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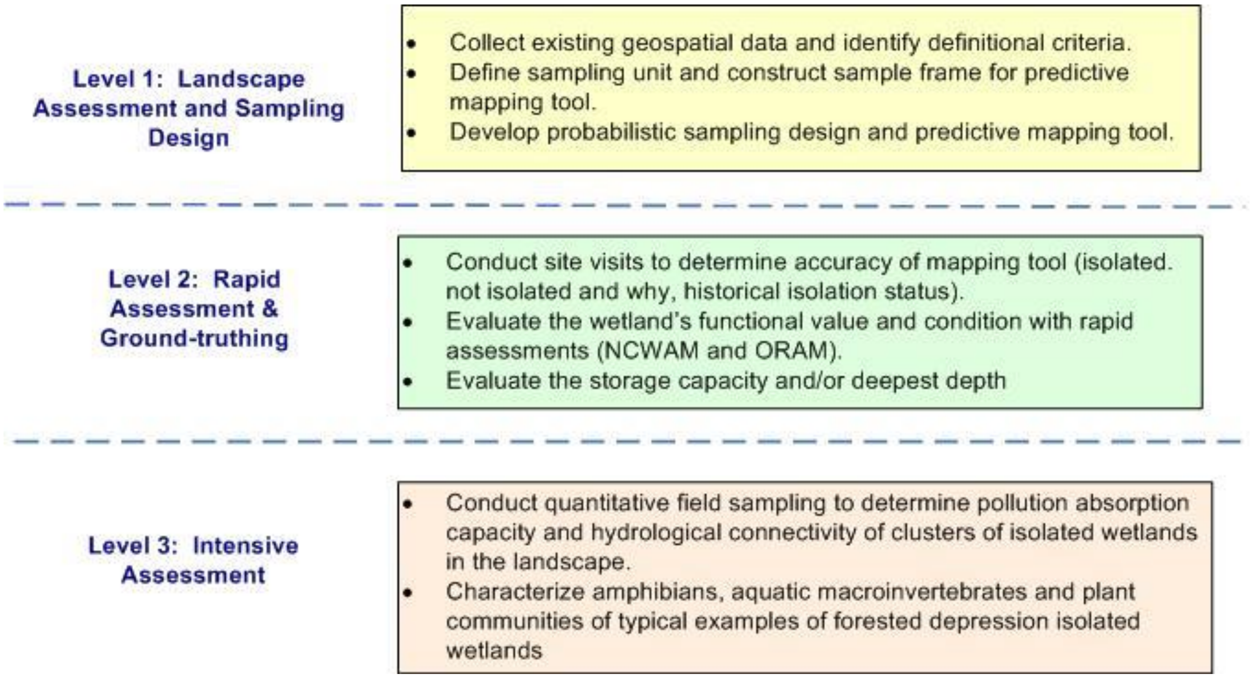
[2] The term “geographically isolated wetland’ are those wetlands that have no surface connection to downstream waters since this definition is consistent with that used by the US Army Corps of Engineers for the 404 Permitting Program. This is in contrast to other wetlands identified and regulated by the 404 Permit Program as delineated by the 1987 US Army Corps of Engineers Wetland Delineation Manual.



Level 1: Landscape Assessment and Sampling Design

- Collect existing geospatial data and identify definitional criteria.
- Define sampling unit and construct sample frame for predictive mapping tool.
- Develop probabilistic sampling design and predictive mapping tool.

Level 2: Rapid Assessment & Ground-truthing

- Conduct site visits to determine accuracy of mapping tool (isolated. not isolated and why, historical isolation status).
- Evaluate the wetland's functional value and condition with rapid assessments (NCWAM and ORAM).
- Evaluate the storage capacity and/or deepest depth

Level 3: Intensive Assessment

- Conduct quantitative field sampling to determine pollution absorption capacity and hydrological connectivity of clusters of isolated wetlands in the landscape.
- Characterize amphibians, aquatic macroinvertebrates and plant communities of typical examples of forested depression isolated wetlands

Figure 1. The SEIWA project employed a three-level wetland assessment approach.

effects of isolated wetland clusters, and create an approach and a base dataset that can be built upon through additional Level 3 investigations in the study area.

The Level 1 assessment began by using digital elevation models (DEMs) and a GIS “sink” algorithm to create candidate polygon sinks representing low spots in the landscape that could be isolated wetlands. These polygons were then overlaid with existing hydrography, soils, floodplains, and land use GIS layers to mask (remove) obviously connected features and soils, wetlands, infrared imagery, and land cover layers to score the remaining features as to their likelihood to be isolated wetlands. These candidate isolated wetland polygon were then randomly selected for the Level 2 assessment.

The Level 2 analysis involves field observations of wetland type and condition in NC and SC using the NC Rapid Assessment Method (NC WAM) (NC Wetland Functional Assessment Team, 2008)) and Ohio Rapid Assessment Method (ORAM) (Ohio EPA, 2001)).The NC WAM ratings allowed a relative determination of hydrology, water quality and habitat functions, and evaluate the various stressors that are present in these wetlands. In addition the Level 2 assessment measured the volume of each isolated wetland in the sample and collected, analyzed, and compared soil samples taken from the wetland and from the surrounding uplands.

For the Level 2 field study, producing estimates with a reasonable precision level required a sample size of around 150 randomly selected sites in the two-state study area. For Level 3, 20 sites would be required statistically. Our selected sample size produced statistically valid results for Level 2 of this project, but budget constraints limited the sample size for Level 3 to two clusters of isolated wetlands.

To ensure the success of the intensive fieldwork, the Level 3 sites were selected based on several criteria that include accessibility (landowner permission), security (safety of deployed equipment), and the occurrence of relatively intact isolated wetlands that are typical of the isolated wetland types of interest. Also, the Level 3 sites were selected to contain clusters of isolated wetlands because initial Level 1 and 2 results suggested that many isolated wetlands occur in close proximity to other isolated wetlands, and studying clusters of wetlands offered the opportunity to see how they function in groups in the coastal plain landscape.

In terms of wetland types for the Level 3 study, the SEIWA team considered focusing on the more common IW types observed in Level 2: flats or forested depression isolated wetlands such as cypress or tupelo ponds. Water levels for these features are normally lowest in autumn and highest in early spring. Some are wet all year; while others fill with water, then dry up, depending on the season. Forested depressions (seasonally or semi-permanently flooded forests of depressional features in broad interstream flats) are smaller isolated wetlands, ranging in size from 0.1 to 10 acres. Both of these types of wetlands are classified as “small basin wetlands” by NC WAM but are very distinct wetlands using the “Third Approximation” (Schafele and Weakley 1990).

Level 3 sampling focused on measuring IW hydrologic and water quality responses and measuring the diversity of the IW biotic communities (amphibians, aquatic macro-invertebrates, plants). The limited number of Level 3 locations was used to develop, test, and define a methodology that can be applied to produce reliable estimates in similar studies when appropriate sample size is available. Part of the project team (USC and NC DWQ) has expanded the Level 3 sample size and analyses, including the Level 3 sites, to investigate longer term and geographically broader results than was possible within the SEIWA project.

Study Area

The SEIWA study area is an eight-county coastal and inter-coastal area (approximately 6,500 mi^2) of North and South Carolina (**Figure 2**). This area was selected because: (1) it has known, significant wetland resources, many of which may be presently unidentified isolated wetlands (Tiner et al., 2002; Comer et al., 2005; Dahl, 2000); (2) the issues expected to be encountered and methodologies used in estimating isolated wetlands in this area should be representative of similar issues/methodologies for the larger Region 4 coastal area as well as elsewhere; (3) because the study area includes subregions of both North and South Carolina, the results will be useful to regulatory programs in both states; (4) the study counties encompass a sharp development gradient: coastal counties with significant growth and development pressure and inland counties with little or no growth; and (5) the study area is large enough to contain a significant number of isolated wetlands, yet small and accessible enough to be doable under the project resources and schedule. The area of interest consists of all regions in these eight counties where the SEIWA wetlands specialists anticipated that isolated wetlands exist.

Table 1 provides basic size and demographic data for the eight selected counties, including area, population density, and population change from 2000 to 2009. The NC counties are very similar in size (around 900 square miles) while the SC counties range in size from 405 to 1,134. The eight counties represent a general development gradient from the coast inland. The two coastal counties (Brunswick,

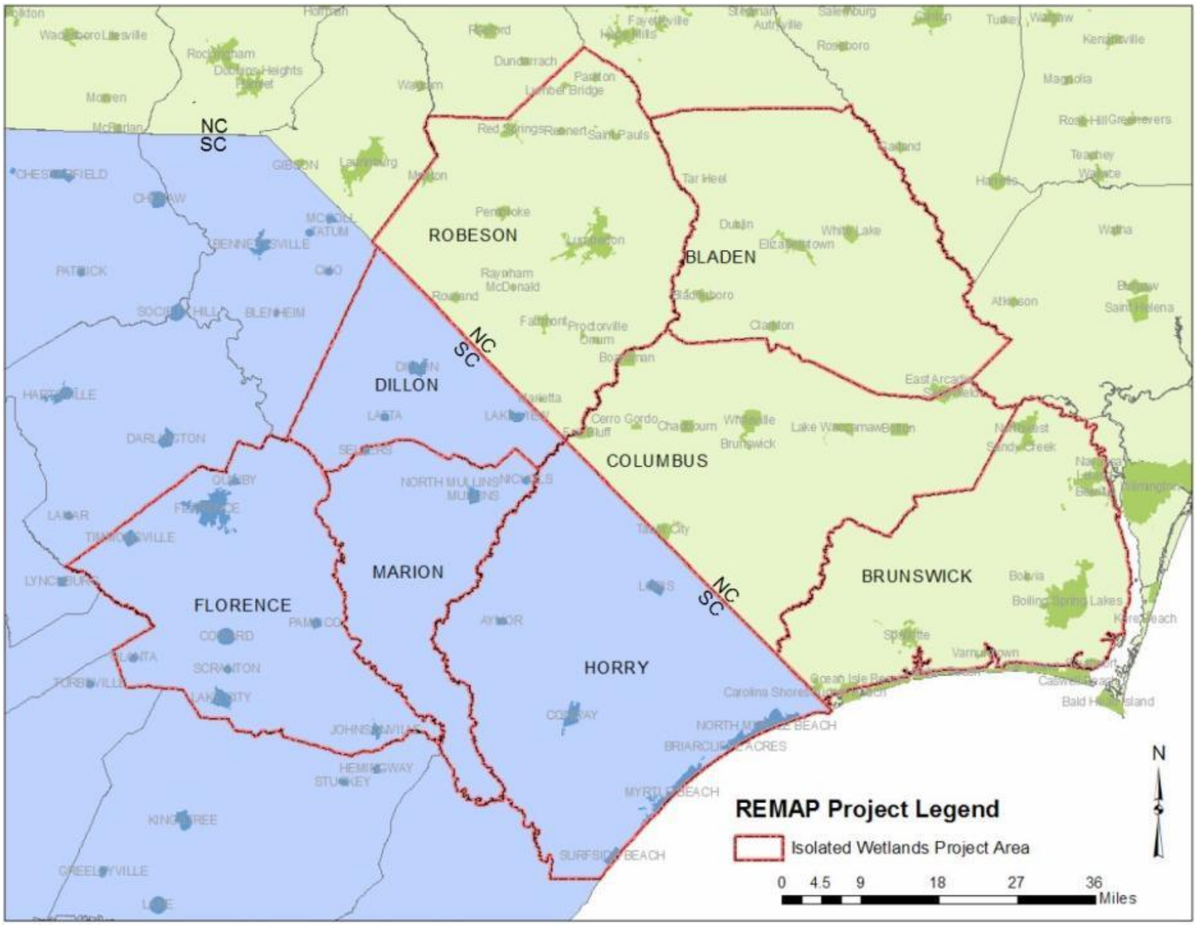


Figure 2. SEIWA study area, showing eight selected counties and population centers.

Table 1. North Carolina and South Carolina Counties Selected for the Southeast Isolated Wetlands Assessment (SEIWA)

County	Area (square miles)	Population (2000)	Population (2009 estimate)	2000 Population Density (per square mile)	2009 Population Density (per square mile)	Percent Change (2000-2009)
North Carolina (165.2 persons per square mile, 16.6% 2000-2009 growth)						
Bladen	874.9	32,280	32,343	37	37	0.2%
Brunswick	854.8	73,107	107,062	86	125	46%
Columbus	936.8	54,751	54,221	58	58	-1.0%
Robeson	948.8	123,241	129,559	130	137	5.1%
South Carolina (133.2 persons per square mile, 13.7% 2000 - 2009 growth)						
Dillon	404.8	30,722	30,912	76	76	0.6%
Florence	799.8	125,761	134,208	157	168	6.7%
Horry	1,133.7	196,660	263,868	174	233	34%
Marion	489.1	35,466	33,468	73	68	-5.6%

Source: U.S. Census State and County Quick Facts (http://quickfacts.census.gov/qfd/index.html; September 2010)

NC, and Horry, SC) have had a very high population growth (46% and 34% respectively), about 2.5 times the state average, which is consistent with the very high rate of coastal development that has occurred over the past decades. The other counties showed small growth (about 1/3 to 1/2 of the state average) only in the counties with population centers (Florence in Florence County and Lumberton in Robeson County). The remaining four rural counties showed no significant growth (Bladen and Dillon) or population loss (Columbus and Marion) over the past decade and have low population densities.

Geologically the SEIWA study area occurs on a feature known as the Cape Fear Arch, an uplifted area of the southeast coastal plain that contains a series of marine terraces with higher elevations as one moves away from the coast. These terraces are composed of marine sediments and limestone that were laid down during former high stands of sea level ranging from Quaternary to Cretaceous in age. The marine terraces have been dissected by river and stream erosion during low sea levels. Within these river valleys alluvial terraces have been formed during subsequent sea level rise in the most recent geologic periods (the Holocene and Pleistocene).

Riggs et al. (2005) observed that historic ditching activities to drain lands for agriculture and forestry have proceeded from the higher (and more easily drained) marine terraces to the lower alluvial terraces, the younger of which have not been drained as extensively as the others. This is significant for isolated wetlands in the study area as ditching has destroyed many wetlands and connected many of the wetland features that would otherwise be isolated.

The basic geomorphic units (GMUs) resulting from the depositional and erosional processes are described in **Appendix A**, moving from lower to higher elevations and generally away from the coast. The marine terrace GMUs are the deposits where most of the isolated wetlands in this study were found, as surface depressions formed mainly by erosional processes during deposition or, in portions of Horry and Brunswick counties, by sinkhole collapse from dissolution of deeper limestone layers. All marine terraces in the area are generally characterized by sandy soils with occasional silts and clays. The alluvial terraces tend to be sands interbedded with silts and clays.

In the Cape Fear Arch region, the surficial Cenozoic alluvial and marine deposits are underlain by Cretaceous aquifers that are used as the primary source of water supply in the area. The uplift along the crest of the Arch (which is aligned to the northwest and centered in the Wilmington, NC, area), has brought these aquifers close enough to the surface that rivers (such as the Waccamaw in Brunswick, Columbus, and Horry counties) have eroded through the overlying Cenozoic system into the Cretaceous aquifers, which discharge groundwater, often at a relatively high pH, into the river systems (Riggs et al., 2005).

As a result, the geologic literature (e.g., Riggs et al., 2005; Harden et al., 2003; Pyzoha et al., 2008) has found that the hydrologic system in the study area (aka "Cape Fear Arch") is a groundwater dominated system. In other words, because of the flat terrain, permeable (sandy) soil, and the underlying upwelling Cretaceous aquifers, surface water and groundwater are intricately and always linked. For example, in Brunswick County, Harden et al. (2003) found that up to 62 percent of the flow in the Waccamaw River is from groundwater seepage, where the stream is incised into underlying Cretaceous aquifers, or from flows from upland banks on more modern flood plains, and the conceptual hydrologic model developed by Pyhoza et al. (2008) showed strong groundwater/surface water connections in a Carolina Bay wetland in the South Carolina coastal plain. Soil descriptions for the hydric soils that are characteristic of isolated wetlands in the study area are consistent with this hypothesis as they indicate that the hydric soils are formed when the water table rises and stays near the surface during the wet months of the year and creates the saturated conditions needed to form hydric soils. In other words, the isolated wetlands we studied in this project are filled both by rainfall falling directly on the wetlands and the small local watersheds they occupy and by water that infiltrates the surrounding land and raises the water table across the landscape, which in turn wets these depressional wetlands from below. In our Level 3 study sites we have sited lines of piezometers within and between wetlands and the nearest downgradient waterbody so we can measure and quantify this interconnectivity.

Project Objectives

To meet the objectives of this project, the Level 1 GIS/remote sensing data, Level 2 rapid assessment data, and Level 3 wetland intensive monitoring data were developed and applied to answer these key project questions.

1. How accurate are existing geospatial datasets in identifying and delineating U.S. Southeastern Coastal Plain isolated wetlands of varying sizes, wetland types, and in differing landscape matrices, and how can that accuracy be improved using existing high resolution remote sensing datasets derived from LIDAR? What is the accurate extent of the isolated wetland resource, what is its condition, and what are its basic characteristics?
2. What is the rate of destruction or extent of modification for these wetland systems? How many and at what rate have these systems been converted, modified, or destroyed?
3. What is the pollutant absorption capacity of isolated wetlands? What are their sizes, condition and relative level of functioning? What is the hydrologic connectivity and function of clusters of isolated wetlands in the coastal plain landscape?
4. What are the characteristic biotic features (amphibians, aquatic macroinvertebrates, and plant communities) of clusters of forested depression isolated wetlands?
5. What tools can be used by regulators and wetland practitioners to reliably locate and assess isolated wetland resources and protect, preserve, and restore these features so they can provide these ecological functions in the study area and other regions where isolated wetlands are a significant portion of the wetland resource?

This report addresses these questions in three Parts describing methods and results for each phase of the SEIWA project: Part 1 for Level 1 (GIS methods), Part 2 for Level 2 (rapid assessment), and Part 3 for Level 3 (intensive assessment). Part 4 summarizes the methods developed, discusses of the overall results, and describes how the study results and methods can be used by wetland regulators and managers in North and South Carolina.

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Appendix A. Geomorphic Units (GMUs) in the SEIWA Study Area

Holocene GMU (Qh, Recent). Alluvial valley deposits in active floodplains confined to major drainageways and small valleys, overlapping older sediments. Deposits are generally incised into or on top of the Wando or Socastee GMUs and are typically interbedded dark clays and light sands (Owens, 1989). For the most part, the Holocene floodplain deposits have not been drained for forestry or agriculture (Riggs et al., 20095)

Wando GMU (Qwa, late Pleistocene). Alluvial valley deposits in older floodplain deposited during last (Wisconsin) glacial maximum. Deposits generally are incised into or on top of Socastee GMU sediments and represent sediment from a larger river system than today. The Wando deposits for a terrace above the Holocene floodplain in the Waccamaw and Pee Dee river valleys, ranging in height from 3 to 34 m above mean sea level (AMSL) in the Pee Dee basin (Owens, 1989) and 6 to 9 m AMSL in the Waccamaw river basin (Riggs et al., 2005). According to Riggs et al. (2005), areas of the Wando terrace in the Waccamaw basin was ditched and drained for forestry operations in the late 1900's, after those on the Penholoway and Socastee terraces. This drainage and silvculture has destroyed many of the wetlands on the terrace.

Socastee GMU (Qs, late Pleistocene). Largely marine deposits deposited by past high sea level stand(s) during previous late-Pleistocene interglacials. The Socastee occurs primarily as a 30 km wide marine terrace in the outer coastal plain within Horry, Columbus, and Brunswick counties as well as alluvial terraces along the Cape Fear River valley in Bladen County and along the Pee Dee river in Marion, Robeson, and Dillon counties. In the outer coastal plain, the Socastee is characterized by a ridge-and-swale topography that represents the remnants of a barrier island system deposited during interglacial high stands of sea level. The surface of the coastal Socastee ranges from 9 m AMSL in the south and east to around 15 m AMSL in the north and west of its range (Owens, 1989; Riggs et al., 2005). The Socastee is composed of interbedded sands and clays. In the Waccamaw basin, wetlands on the Socastee GMU occur between 9 and 15 meters AMSL. As with the Penholoway GMU, the natural hydrology the Socastee terrace was dominated by sheet flow, with wetlands occurring in depressions and in areas of low permeability clay and humic (peat) soils. The Socastee wetlands were drained for agriculture and forestry after the Penholoway wetlands in the mid-1900's (Riggs, 2005).

Penholoway GMU (Qph, early Pleistocene). The Penholoway GMU is a marine terrace composed of barrier and back-barrier deposits and ranging from 15 to 21 m AMSL in the study area (Owens, 1989; Riggs et al., 2005). As with the Socastee GMU, the Penholoway is primarily composed of back-barrier deposits of interbedded sands and clay, with barrier deposits composed of coarser and cleaner sands. The Penholoway was likely formed during a high interglacial sea level stand during the early Pleistocene. According to Riggs (2005), in the Waccamaw basin wetlands occur in depressions on the surface of the Penholway formation and in areas where low permeability clay and humic (peat) soils impeded rainfall infiltration and originally resulted in sheet flow regime across the terrace. The Penholway wetlands were the first wetlands targeted for serious ditching for agriculture, beginning in the 1920’s and continuing into the 1950’s. Many of the wetlands were destroyed by the drainage process.

Waccamaw formation (Qw, early Pleistocene). The Wacccmaw is mainly composed of barrier and back-barrier deposit that form the basal (oldest) Pleistocene unit in the Cape Fear/Long Bay region, with maximum height ranging from 21 to 30 m AMSL (Owens, 1989).

Tb-Bear Bluff formation (late Pliocene). Another largely barrier/back-barrier unit, the Bear Bluff comprises the marine terrace between the Suffolk and Mechanicsville scarps at 30.5 and 41 m, respectively. As described by Owens (1989), the Bear Bluff includes all barrier and back-barrier facies between the Pee Dee and Cape Fear Rivers. In the Pee Dee valley, the Bear Bluff includes interfingered fluvial and back-barrier/barrier deposits (Owens, 1989).

Td-Duplin formation (early Pliocene). The highest marine terrace in the study region is the Duplin formation, from the Mechanicsville scarp to the Orangeburg scarp. The elevation of this broad, highly dissected plain ranges between 41 and 67 m AMSL. Fossil evidence and sedimentary facies suggest a continental shelf depositional environment (Owens, 1989).

Assessing Geographically Isolated Wetlands in North and South Carolina – Part 1: Design and Implementation of a Level 1 GIS Model for Identifying Isolated Wetlands

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1. Assessing Geographically Isolated Wetlands in North and South Carolina – Part 1: Design and Implementation of a Level 1 GIS Model for Identifying Isolated Wetlands

1.1 Introduction and Background

Geographically isolated wetlands (IWs) are wetland features that have no surface water connection to downstream waters. This project set out to define a Level 1, GIS-based method that could be applied in the southeast or in other EPA regions across the United States. The goals of this phase of the project were four-fold: 1.) determine the likely location of IWs; 2.) develop a GIS Model using data that best represent the necessary criteria for determining the probability of a site being an IW; 3.) conduct a field-based accuracy assessment of the GIS model; and 4.) attempt hindcasting to estimate the loss of historic IWs due to development and agricultural activities.

There have been several previous efforts using Geographic Information Systems (GIS) to map likely geographically IWs across the U.S. (Tiner et al. 2002), in Illinois (McCauley and Jenkins, 2005), in North Dakota (Gritzner, 2006), in central Florida (Lane et al., 2008; Reif et al., 2009; Frohn et al., 2009), in Montana (Vance, 2009), and in central Asia (Lane et al., 2007, 2009). The GIS approach developed for SEIWA drew on information from the earlier of these studies as well as the expert knowledge on the study team about local conditions and criteria necessary to map the likelihood of geographically IWs in the project area.

The IWs in the portions of the southeast coastal plain examined during this project are almost always low spots in the landscape with no surface water connectivity. In other words, IWs are depressions in the landscape that are surrounded by uplands. These depressional features are termed “sinks” for this project. The population of sink polygons that were created using the Level 1 GIS model to be randomly selected for the accuracy assessment and for the Level 2 assessment described in Part 2 of this report are termed “candidate IW polygons” for this project.

1.2 Data Sources

Because the IWs in the study area occur as topographic depressions across the landscape, SEIWA employed available ground elevation data (LiDAR [Light Detection And Ranging] and hypsography) and methods adapted from Gritzner (2006) to identify topographic “sink” polygons as the candidate IW study population. Sources of readily-available geospatial information were then identified to characterize the physical, hydrologic, and biological criteria that could be used to score the likelihood that a candidate wetland polygon could be an IW.

Because no single identifier available in geospatial data can map and characterize IWs with much certainty, an approach was developed using multiple GIS data layers and remote sensing imagery. Table 1-1 shows the relevant model criteria for prediction of IWs and the framework of GIS data layers assembled to address each criterion, including a list of federal, state and local GIS resources used to obtain the data.

Table 1-1. Source of Data Layers and Remote Sensing Imagery Used to Develop the SEIWA GIS Model.

Model Criteria	Data layers	Information sources
Baseline Population - Candidate "Sink" Polygons		
Depressions (sinks)	Digital elevation models (DEMs; topography)	LiDAR data: NC Flood Mapping Program (Brunswick, Bladen, Columbus, Robeson); Horry County Government (Horry) Hypsography data: United States Geologic Survey (USGS; Marion, Florence, and Dillon), processed into raster data layers.
Layers used to Score Candidate Polygons		
Wetlands	CREWS (NC wetlands)	CREWS: NC Division of Coastal Management; North Carolina Coastal Region Evaluation of Wetland Significance (NC One Map) http://dcm2.enr.state.nc.us/wetlands/nccrews.htm
	NWI (NC and SC wetlands)	National Wetlands Inventory: US Fish and Wildlife Service; (NC One Map and SC GIS Clearinghouse) http://www.fws.gov/wetlands/Data/DataDownload.html
Hydrologic "blackspots"	Infrared imagery	Color Infrared Digital Ortho Quarter Quad (NC One Map and SC GIS Clearinghouse)
Wetland soils	Soils, Hydric	US Department of Agriculture (USDA) Soil Survey Geographic database (from NC One Map and SC GIS Clearinghouse)
	Soils, Ponded	
Surface water connectivity (streams and floodplains)	Hydrography	USGS National Hydrography Dataset; Derived hydrography from USGS Hypsography and LiDAR bare earth datasets
	Floodplains	USGS National Hydrography Dataset
	Soils, floodplain (riverine soils, e.g., Muckale)	USDA Soil Survey Geographic database (NC One Map and SC GIS Clearinghouse)
Surface water connectivity (ditching)	Land cover	USGS 2001 National Land Cover Dataset (NLCD); http://www.mrlc.gov/nlcd_multizone_map.php
	Roads	NC Department of Transportation (NC One Map) SC Department of Transportation (SC GIS Clearinghouse)
Habitat	EO (element occurrence)	NC and SC Natural Heritage Programs (NC One Map and SC GIS Clearinghouse)

NC One Map - http://www.nconemap.com/
SC GIS Clearinghouse - https://www.dnr.sc.gov/pls/gisdata/download_data.login

The geospatial data obtained included digital elevation models (DEMs), orthophotography, wetland location, soils, surface water connectivity, land cover, and habitat information. Prior to use in the analysis, the data layers were prepared, manipulated, and edited as needed to support the criteria developed to locate IWs. For example, where LiDAR data were not available (for three SC counties), U.S. Geological Survey (USGS) hypsographic contour data were processed to develop the raster coverages needed to develop the candidate IW sink polygons (see Appendix 1-A).

1.3 Methodology

The SEIWA Level 1 GIS methodology was developed to identify and characterize the IWs in the study area using the available GIS spatial data identified and collected for the project (see Section 1.2.1). The SEIWA Level 1 process involved five basic steps:

1) Development of a layer of topographic depressions, or sinks, as the sink polygons that serve as the base layer for SEIWA.

2) Masking of this layer to remove sink polygons with a very low probability of being IWs.

3) Scoring of the remaining candidate IW polygons with the criteria GIS layers described in Section 1.2 to determine the likelihood of each polygon to be an isolated wetland.

4) Field verification to verify that the masking and scoring methods were producing candidate IW polygons that were likely to be IWs and to determine the accuracy level for the map.

5) Compilation of the verified scores for each criterion into the SEIWA Level 1 candidate IW polygon database.

As described in Sections 1.3.4 and 1.4.2, steps 2) through 4) were iterative for groups of the counties assessed, with field results being used to refine the method as the development of the Level 1 methodology progressed.

1.3.1 Developing Depressions or Sinks

The initial layer of sinks was derived from raster elevation data using a fill algorithm (Gritzner, 2006), then converted to vector polygon data and prepared for processing geo-relationships. This step was the starting point for mapping candidate IWs for each county (see Appendix 1-A). Using color infrared (CIR) digital orthophoto quarter-quadrangles (DOQQs) as a background layer, sink polygon data were compared with the location of “wet spots” from Soil Survey Geographic (SSURGO) data and with field verified IW features identified by the SEIWA team (see Section 1.3.4). “Wet spots” are defined in NC county soil surveys as “a somewhat poorly drained to very poorly drained area that is at least two drainage classes wetter than the named soils in the surrounding map unit.” A visual assessment demonstrated that many of the sinks correlated in close proximity with these features (**Figure 1-1**), in addition to revealing the location of other depressional features that may be associated with IWs.

The available datasets used to derive the sinks polygons were different for the counties in North and South Carolina. Elevation data for North Carolina were obtained from North Carolina Floodplain Mapping Program which used LiDAR to map elevation at a 5-meter horizontal spatial

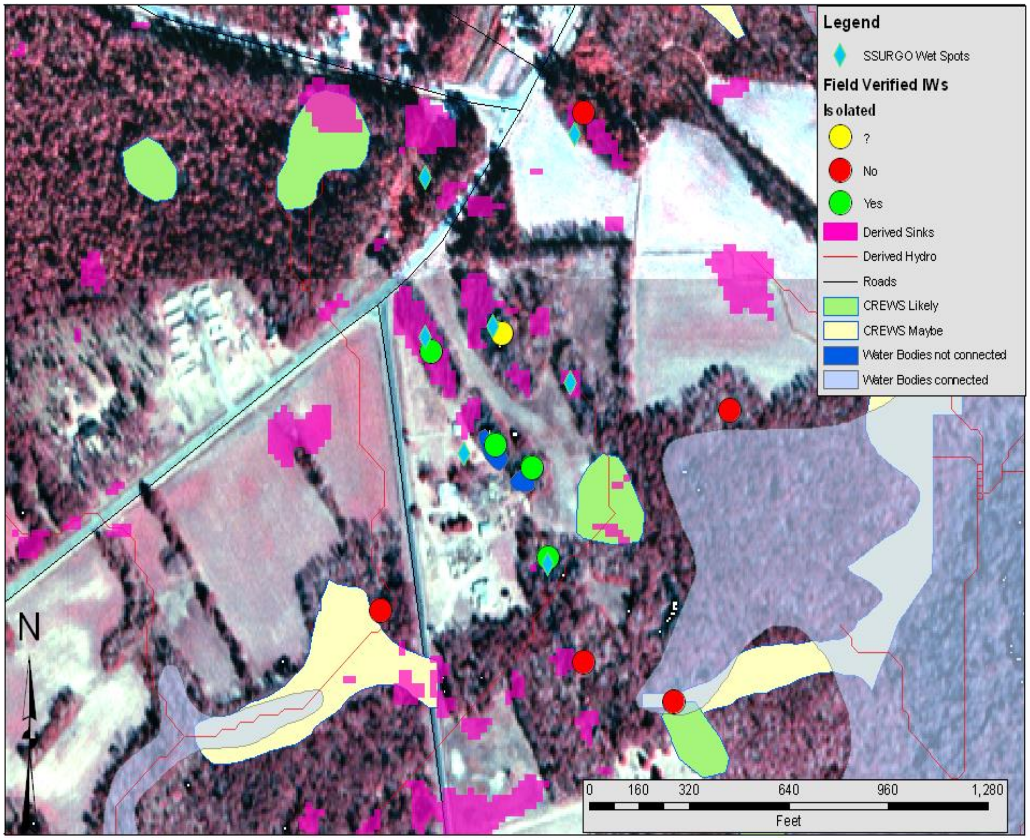

Figure 1-1. **Initial verification of sinks compared to SSURGO wet spots and field verified isolated wetlands.**

resolution. For three of the four South Carolina (SC) counties (Marion, Florence, and Dillon) elevation data were created using the United States Geologic Survey (USGS) hypsography information obtained from the SC Department of Natural Resources GIS Clearinghouse. The hypsography elevation data were created at 30-meter spatial resolution, which is much less detailed than the 5-meter data available for NC. Horry County, SC, had elevation data at 4-meter spatial resolution from a recent LiDAR mapping project conducted by the county government. In terms of vertical resolution, the root mean square error (RMSE) for the North Carolina county LiDAR ranges from 10 to 20 cm[1], and the RMSE for the Horry County LiDAR is 18.5 cm[2]. The vertical resolution for the hypsography data used for Dillon, Florence, and Marion counties is 1.5 m (USGS, 1999).

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[1] LIDAR and Digital Elevation Data, http://www.ncfloodmaps.com/pubdocs/lidar_final_jan03.pdf, January 2003.

[2] LiDAR and Related Data Products, SC Department of Natural Resources, http://www.dnr.sc.gov/GIS/lidar.html

1.3.2 Masking Using GIS Data Layers

The first task was to reduce the number of candidate polygons by deleting sink polygons with a low probability of being geographically isolated. This masking step eliminated unnecessary manipulation, selection, and processing of tens of thousands of candidate polygons that are not likely to be IWs; in other words, polygons were removed from the population of sinks for each county before they were scored for IW likelihood in the following step.

Based on review of the sink layers against CIR DOQQs and other GIS data, and field observation surveys, the SEIWA team established masking criteria specifying that a candidate polygon is not likely to be an IW if it is geographically located on a floodplain, intersects a stream, intersects a connected water body, or is located in a heavily developed area, as defined by the NLCD 2001 High Intensity and Medium Intensity land use classes (Homer et al., 2004). Polygons that were in or intersected with these classes were removed. To ensure the quality of the data during the masking process, the polygon data were overlaid and viewed against the backdrop of color infrared digital (CIR) orthophoto quarter-quadrangles (DOQQs) throughout the project to reduce the removal of sinks that may fit the IW criteria. This masking was especially important in Horry county because the LiDAR data there had a high enough resolution to pick up ditches and other anthropogenic features and mistake them for sinks.

Additional masking, or “filtering”, was implemented for sink polygons according to certain conditions. Filtering sink polygons by size and location are two approaches that were used to remove suspected false polygons. For example, single pixel sink polygons were removed as they are at the LiDAR resolution limit and often do not represent real features. Small sink polygons along roads were removed since they were very unlikely to be isolated. Field visits verified a number of these polygons to be ditches. Polygons that were directly connected to LiDAR-derived drainage and connected water bodies were removed. In counties with significant development such as Horry County, SC, sink polygons were removed in high and medium intensity developed areas represented by NLCD 2001 land cover data. See **Appendix 1B** for more information on the filtering process.

For Horry County, an additional process was used to remove false sink polygons (i.e., sink polygons that could not be IWs). This additional step was necessary because the high-resolution LiDAR data for Horry County created several thousand linear features during the “fill” process to derive sinks. By comparing the sink polygons with the CIR DOQQs, many of these features appeared to be drainage ditches or other linear features along roadways. Feature extraction technology was applied to select and remove these linear polygons from the sink polygons dataset. This reduced the number of false polygons and made the number of sink polygons more manageable.

1.3.3 Scoring Using GIS Data Layers

The next step was to determine the geospatial relationship of each retained candidate IW polygon to the criteria GIS data layers. The data layers obtained and/or derived included wetland data (NC CREWS and NWI wetlands) , hydric soils, streams, derived drainage, connected water bodies, flood plains, riverine soils, agricultural-open field landcover, road ditching, and wetlands species (see Table 1-1). Each of these criteria contributed to the likelihood of whether a candidate IW polygon could be an IW.

The approach was to determine the relationship of the candidate IW polygons with the target relational data layer using the “select-by-location” tool in ArcMap with one of the “intersect”, “have their center within” or “are completely within” options to select all of the candidate IW polygons that meet the geo-relationship criteria. Each candidate IW polygon included in the selection was scored with a value from 0 to 10 for a criterion depending how it contributed to the likelihood of the candidate IW polygon being an IW. If the candidate IW polygon was scored a 0, it was less likely to be an IW. If the candidate IW polygon was scored a 10, it was most likely to be an IW. There were a few criteria that required an intermediate value (i.e., 3, 5, or 7) if there was an intermediate likelihood defined by the geo-relationship of the data layers. These likelihoods were determined by the SEIWA team based on their understanding of and familiarity with the IWs in the study area and the relative importance of these data layers to known IW characteristics. Methods and scoring criteria used for each data layer to score the candidate IW polygons are described in the following sections.

1.3.3.1 Wetland Data

Wetland type is an important characteristic in determining whether a candidate IW polygon is likely to be an IW. A candidate IW polygon must first be considered a wetland before it can be assigned a probability to be an IW. Available wetland coverages used for this project were the North Carolina Coastal Region Evaluation of Wetland Significance (NC CREWS) data from the NC Division of Coastal Management and the National Wetlands Inventory (NWI) data from the US Fish and Wildlife Service.

The NC CREWS data were only available and used for Brunswick, Bladen and Columbus counties. Based on familiarity with the NC CREWS mapping and classification used in the study area, the SEIWA Team categorized the NC CREWS wetland types for this project into 4 classes depending on their likelihood of being isolated: *likely*, *maybe*, *rarely, and not* (see **Table 1-2** and **Figure 1-2**).

Table 1-2. Classification of NC CREWS Wetlands Data Based on IW Likelihood.

NC Crews Wetland Type	
Likely to be isolated	
16, 76	Maritime swamp forest
67f, 7f	Non-riverine swamp forest
May be isolated	
2	Freshwater marsh
4	Pocosin
9	Hardwood flat
10	Pine flat
11	Managed pineland
40	Human impacted
64	Pocosin
69	Hardwood flat
70	Pine flat
71	Managed pineland
Rarely isolated	
22	Drained, freshwater marsh
27	Drained, non-riverine swamp forest
31	Drained, pine flat
36	Drained, maritime swamp forest
Not isolated	
1	Salt/brackish marsh
3	Estuarine scrub-shrub
15	Estuarine forest
17	Headwater swamp
40s	Cleared wetlands
6/7r	Bottomland hardwood / riverine swamp forest
60s	Cutover wetlands

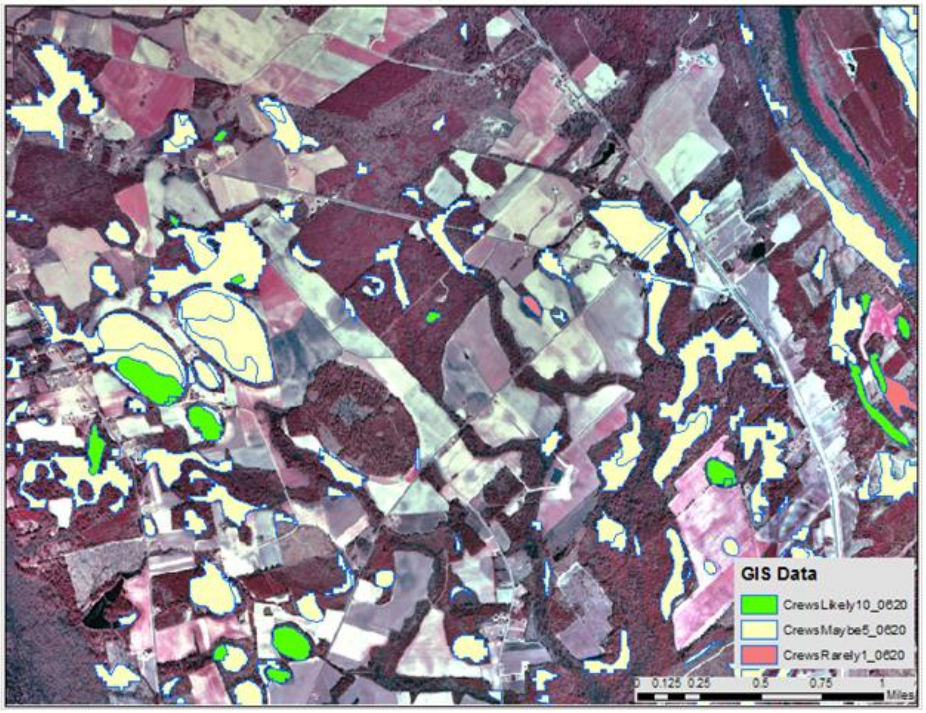


Figure 1-2. **NC CREWS wetland polygons color-coded based on the likelihood they would support isolated wetlands environments.**

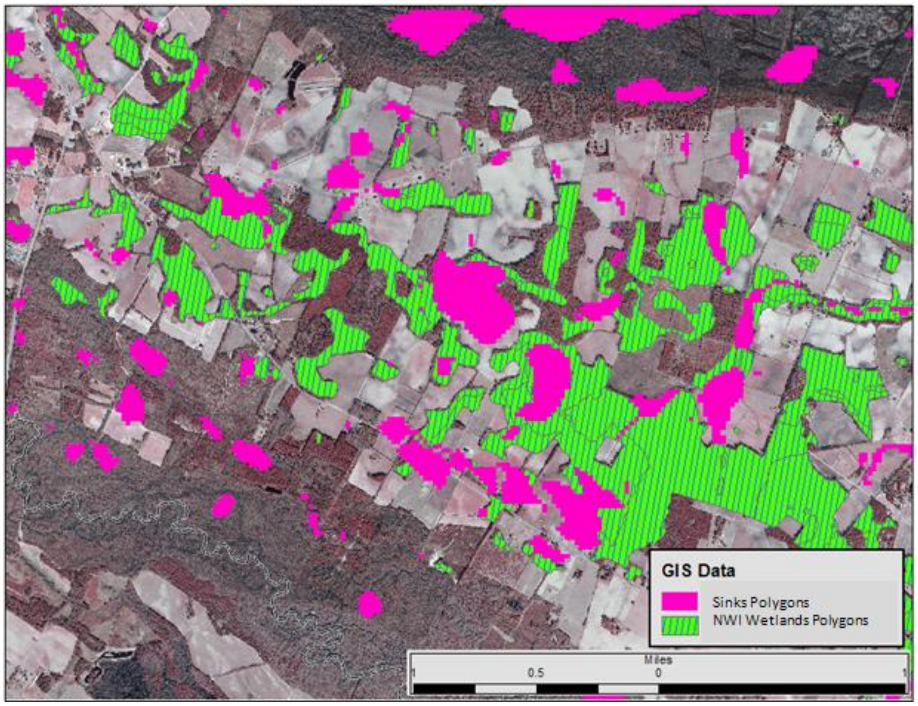


Figure 1-3. **NWI wetlands data viewed along with sinks derived from elevation data.**

Each candidate IW polygon was then scored a value depending on its geographic relationship with the NC CREWS wetland type and the corresponding IW likelihood from a lookup table as follows.

Center of candidate IW polygon intersects with *likely* CREWS classes scored a 10.
- Classes 7f, 27, and 67 (e.g., non-riverine swamp, drained non-riverine swamps, and cutover non-riverine swamp)

Center of candidate IW polygon intersects with *maybe* CREWS classes scored a 5.
- Classes 4, 9, 10, 64, 69, and 70. (e.g., pocosin, hardwood flat, pine flat, managed pineland, and cut-overs)

Center of candidate IW polygon intersects with *rarely* CREWS classes scored a 1.
Center of candidate IW polygon intersects with *not* CREWS classes scored a 0 and were removed from the GIS model.

For Robeson County in NC and all of the SC Counties, NWI data were used because NC CREWS data were not available. Determining IW likelihood for the NWI wetland types is not a straight-forward process and the NWI data are not as reliable as NC CREWS data because (1) NWI was not as extensively ground-truthed as NC CREWS and 2) the NC CREWS data were developed to reflect hydric soils data. Therefore direct cross-correlation similar to what was developed for the NC CREWS data was not attempted. Instead, the SEIWA team decided to first filter the NWI wetlands data by removing NWI wetland polygons that intersected floodplains or water bodies connected to LiDAR-derived drainage. NWI polygons classified as man-made ponds (NWI class PUB) or that intersected with high or medium intensity land use classes (2001 NCLD) also were removed from the dataset as features that are likely to be connected or not likely to be wetlands. Using this filtered NWI dataset, a “select by location” intersection was performed to determine which candidate IW polygons intersected the filtered NWI polygons (**Figure 1-3**). If a candidate IW polygon intersected with a filtered NWI polygon it was scored a 10 (more likely to be an IW) in the attribute table and 1 otherwise (not likely to be an IW).

1.3.3.2 Hydrology - Black Spots

The term “black spots” refer to dark spots visible in CIR imagery that are likely wetland features. Many of these features are coincident with sinks, NC CREWS, NWI, and hydric soils data (**Figure 1-4**). Feature extraction technology was applied to extract these “black spots” from CIR DOQQs into a polygon layer for the entire eight-county project area. The extracted polygons were filtered using surface water connectivity data such as floodplains, streams, and LiDAR-derived drainage. Manual editing was used to remove polygons that were shadow-features and not actually wetlands. Once the “black spot” dataset was finalized, the geospatial relationship with the candidate IW polygons was determined and scored as 10 (more likely to be IW) where it intersected a black spot or as a 1 (not likely to be an IW) where it did not intersect a black spot.

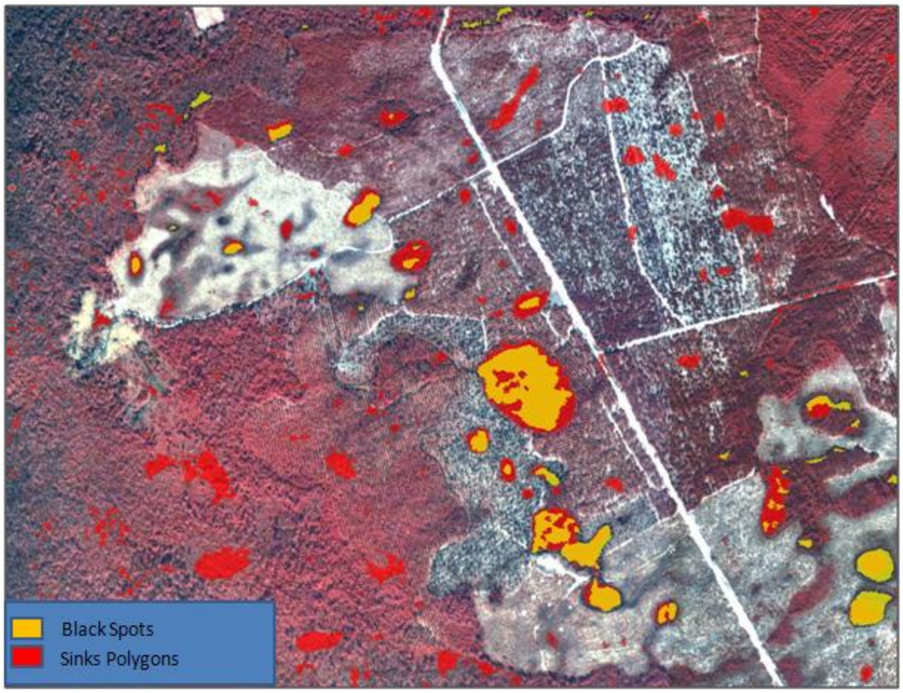


Figure 1-4. **Wetland features extracted from color infrared imagery for inclusion into the wetlands data used to map the likelihood of isolated wetlands.**

1.3.3.3 Hydric Soils

Soil characteristics can be used to help determine whether a candidate IW polygon is likely to be an IW. Wetlands require hydric soils which are generally saturated or have frequent ponding. As was shown in Table 1-1, the U.S. Department of Agriculture's Soil Survey Geographic (SSURGO) database from the National Resources Conservation Service (NRCS) was obtained indirectly for the entire eight-county project area through the NC and SC State GIS data resources.

The SSURGO data were classified for likely IWs based on the hydric soils rating for each map unit and classified into the following: *HydricAll*, *HydricPartial* and *HydricNot* (**Figure 1-5**). The likelihood of a candidate IW polygon being an IW was based on the conditions that an IW is more likely to coincide with *HydricAll* soils and soils that are frequently "ponded" with standing water over a long period of time (usually during the growing season). *HydricAll* soils were scored a value of 10. Candidate sink polygons located on a *HydricPartial* soils were scored a value of 5. Candidate sink polygons not located on either type of hydric (*HydricNot*) soils were scored a value of 1 in the attribute table.

SSURGO data were also used to identify soils with frequent ponding. Candidate IW polygons on soils with frequent ponding were scored a value of 10 and those on all other soils were scored a value of 1 in the attribute table [Ponding]. Hydric soils were a criterion used for all counties, whereas ponding data were only available and used in the NC counties (Brunswick, Bladen, Columbus, and Robeson).

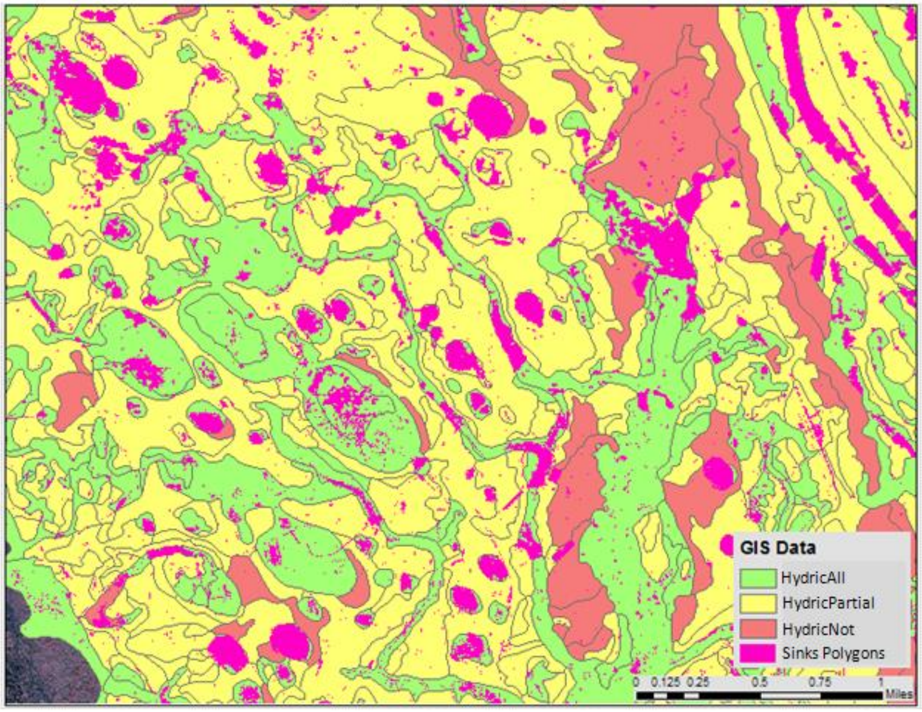


Figure 1-5. Classification of hydric soils viewed along with sink polygons derived from elevation data.

1.3.3.4 Surface Water Connectivity

By definition, IWs are wetland features that have no surface water connection to downstream waters. Several GIS data layers were used to indicate stream connectivity. The SEIWA team obtained data from the United States Geologic Survey (USGS) National Hydrography Dataset (NHD), NC Floodplain Mapping Program, SSURGO, and other state-local government resources such as the SC GIS Data Clearinghouse and NC OneMap.

Drainage data (referred to as *Derived Hydro*) was derived from elevation data (derived from LiDAR or Hypsography for each county) and was created as GIS vector layers to better determine connectivity in upstream areas. The USGS NHD and *Derived Hydro* data layers were used to determine which candidate IW polygons were likely connected to streams and/or flood plains (**Figure 1-6**). Both of these linear features were buffered 5 meters on each side to create a polygon layer to represent a stream channel. We selected a 5 meter buffer to represent the stream channel. Candidate IW polygons that did not intersect these layers [NotConnect] were scored a value of 10 (low likelihood of connectivity) while the candidate IW polygons that did intersect were score a value of 1 (high likelihood of connectivity). Based on comparisons with aerial photographs (see Figure 1-6), the *Derived Hydro* layer was found to be more reliable and more extensive (i.e., better representation of headwater streams) than the standard NHD stream data, however both data sets were used in determining surface water connectivity. The

USGS NHD data were used for Brunswick, Bladen, Columbus, Robeson, and Horry counties whereas *Derived Hydro* was created and used for all counties.

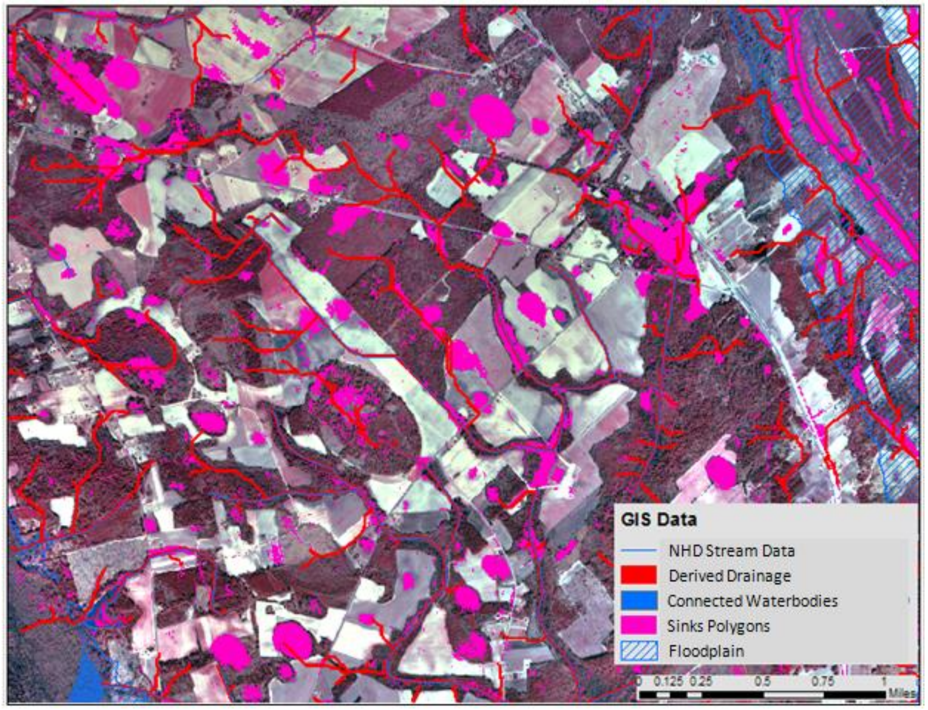


Figure 1-6. Stream and drainage connectivity are shown with sinks derived from elevation data.

USGS NHD floodplain polygon data [NotFloodPl] and NHD Water Body data were also used to determine the probability that a candidate IW polygon would be connected to surface water. NHD floodplain data were available in 6 of the 8 counties (Brunswick, Bladen, Columbus, Robeson, Florence, and Horry). For these 6 counties, candidate IW polygons that were entirely within the floodplain polygon were removed. For Brunswick, Bladen and Columbus counties, candidate IW polygons that did not touch the edges of floodplain data were scored a value of 10 and those that did were scored a value of 0. To reduce the number of false positives in Robeson, Florence and Horry counties, candidate IW polygons that touched the edge a floodplain were masked (i.e., removed) from the dataset. In Marion and Dillon counties where floodplain data were not available, NHD Water Body data were used as a surrogate. Therefore, candidate IW polygons that occurred within or touched the edge of a water body connected to a NHD Stream were masked (removed) from the dataset.

It was also important to determine candidate IW polygons that occur in ditched areas since these would not likely be IWs. Data that directly depict and represent ditches was not available. Therefore, other GIS data layers were used to define areas of possible ditching. Ditches are often geographically associated with agricultural areas and road corridors. Agricultural areas were obtained from the 2001USGS National Land Cover dataset (NLCD) and roadside ditches (**Figure 1-7**) were estimated from road centerline data obtained from NC and SC Department of Transportation coverages (from NC One Map and SC GIS Clearinghouse) that included the respective counties in the SEIWA project area.. This information was used to help define candidate IW polygons that were likely connected to surface waters, and therefore less likely to be an IW.

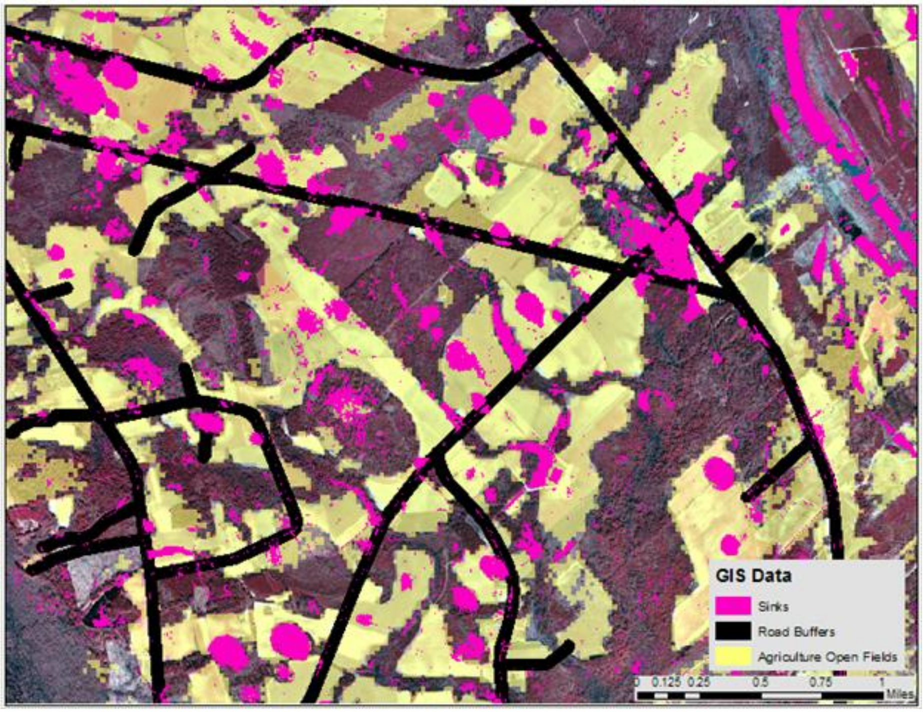


Figure 1-7. Agriculture and open field landcover data was used with road buffers to determine likely areas of ditching. .

Candidate IW polygons that did not intersect agricultural lands (NLCD = agricultural fields and grasslands) were scored a value of 10 and those that did intersect agricultural lands were scored a value of 1 [NotDitchAg] (these polygons could be former IWs that have been connected by drainage and cropping). Similarly, candidate IW polygons that did not intersect roadways were scored a value of 10 and those that did intersect the buffered roadway layer were scored a 1 [NotDitchRd]. To reduce the number of false polygons that were roadway ditches in Robeson County, sink polygons were deleted from the candidate IW polygon layer if they were less than 75 square meters and within the buffered roadway layer. These criteria were developed based on initial field work in Brunswick and Bladen counties which identified several false sinks in the same location as roadside ditches, and were implemented to eliminate contiguous pixels along roadsides that are likely ditches.

1.3.3.5 Riverine Soils

Riverine soil types also were used to help determine surface water connectivity. These soil types were determined from an examination of the soil series in the study area described in the county soil surveys. These soil types are associated with and found on the floodplains and stream channels and are often in narrow stream channels and help delineate upstream drainage areas (**Figure 1-8**). For Dillon and Marion counties floodplain data were not available and riverine soils were used in conjunction with NHD Water body data as surrogate floodplain data. Candidate IW polygons that did not geographically intersect riverine soils were scored a value of 10 for being more likely to be an IW [NotRivSoil or NotRiverin]. Candidate IW polygons that geographically intersect riverine soils were scored a value of 1 for being less likely to be an IW. This criterion was used in Brunswick, Bladen, Columbus, Florence, Horry, and Robeson counties.

Figure 1-8. Riverine soils were used to help define stream channels and connectivity.

1.3.3.6 Habitat

Element Occurrences (EO) data were obtained from NC and SC Natural Heritage Programs. EO data contain geospatial information about rare habitats and species locations that are likely associated with IWs. These data are based on in-field observations over multiple decades. A few counties were entirely covered by an EO polygon. However to maintain consistency, the candidate IW polygons were still scored according to their geospatial relationship to EOs (**Figure**

1-9). Candidate IW polygons located within an EO polygon were scored a 10 and those that did not were scored a 1. These data were available for all eight counties in the study area.

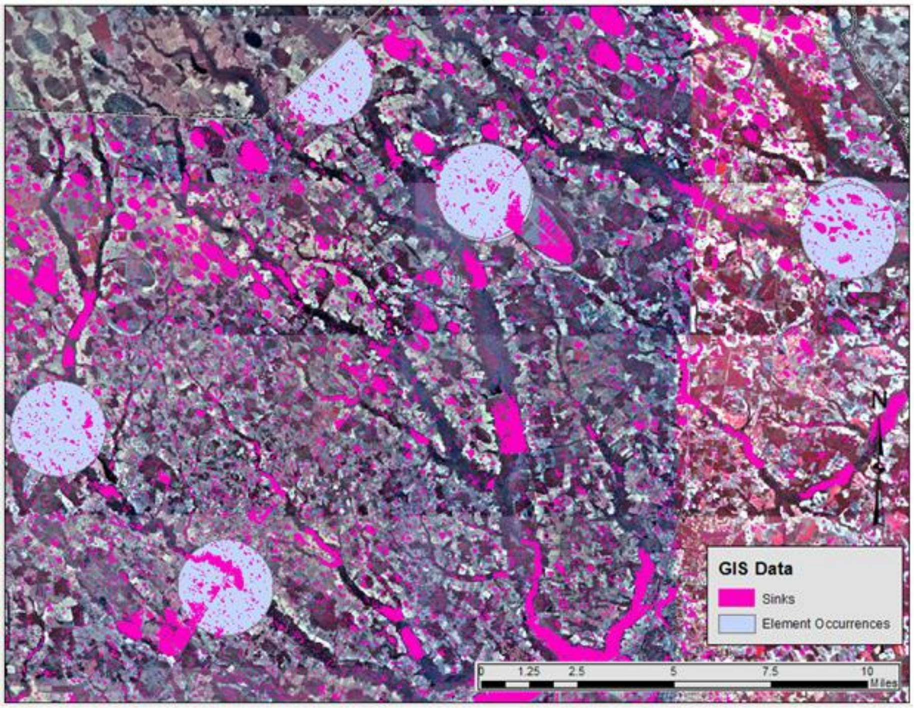


Figure 1-9. Element Occurrences were used to help identify candidate IW polygons located in areas with rare habitats that are often associated with IWs.

1.3.4 Field Observations and Ground-truthing

The team visited about 40 locations of known isolated wetlands in the eight county study area to help calibrate the model. To find and access the randomly selected Level 2 sites, we worked from wetland delineations confirmed by the US Army Corps of Engineers (USACE) as well as county soil surveys (for instance, using the "depression or sink" symbol on the maps), NC-CREWS wetlands data, along with other data sources such as Division of Water Quality (DWQ) permit files and local scientific studies. If the delineated wetland had been explicitly confirmed by the USACE as isolated, then the global positioning satellites (GPS) coordinates of the wetland were sent to NC CGIA for their use in development of the initial GIS model.

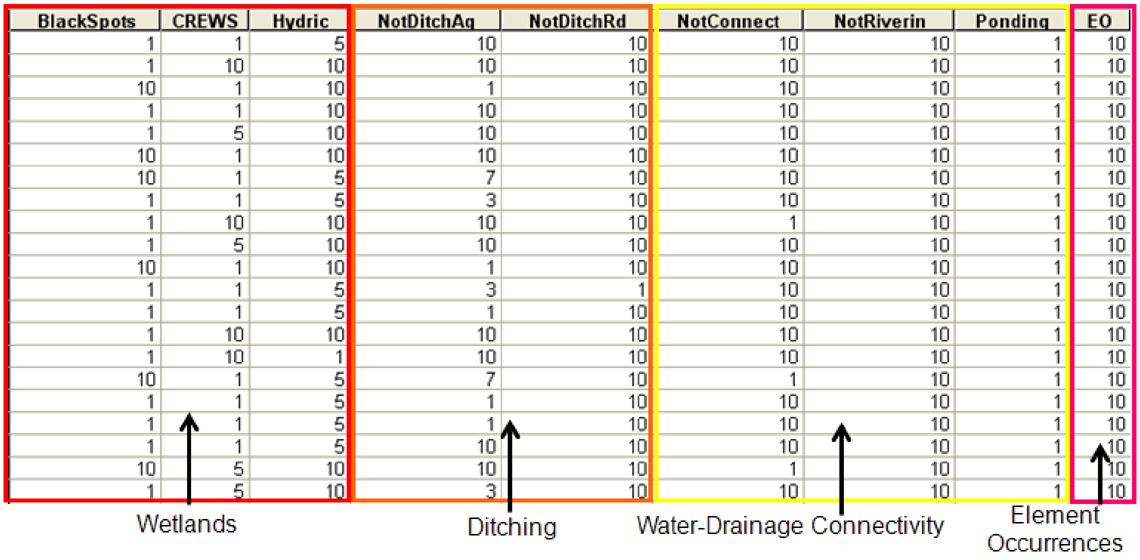
In addition to the locations of known isolated wetlands, team members visited three general locations in Brunswick County that contained isolated wetlands as predicted from an early version of the GIS model. A total of 43 sites were visited to determine if 1) they were jurisdictional wetlands, and 2) if so, if they were isolated wetlands. Overall about 51% (22 of the 43) of the sites that were predicted to be isolated wetlands were indeed isolated wetlands. A similar effort was done in South Carolina to check the refined maps with similar results. The results of these two field beta-testing exercises were then used to further refine the GIS model.

Field observations were used to ground truth the candidate IW polygon layers developed in steps 1) through 3) of the SEIWA Level 1 process. The Level 1 analysis was sequenced by county as follows: 1.) Brunswick, 2.) Bladen, 3.) Columbus, 4.) Marion, 5.) Florence, 6.) Robeson, 7.) Horry, and 8.) Dillon. Because the field observation trips were conducted as the candidate IW polygon layer for each county was produced, the GIS approach to map IWs evolved somewhat as the project progressed from county to county. As a result, the last several counties of the project used the same basic approach as the first set of counties, but some modifications made to the GIS model for the later counties were not used in the earlier counties of the project. The evolution of the process is explained in Section 1.4.3 along with a summary of the approach used in each county including county-to-county methodology differences.

1.3.5 Isolated Wetland Level 1 Database Development

As described in the Section 1.3.3, the primary focus of the SEIWA Level 1 approach was to determine the geo-relationships between each candidate IW polygon and several criteria-supporting GIS data layers. This information was used to calculate the likelihood that a candidate IW polygon was a geographically IW, a non-isolated wetland, or just a depressional non-wetland feature in the landscape. For example, a candidate IW polygon is likely to be an IW if it falls on a wetland (as defined by NC CREWS or NWI), has hydric soil, and has no stream connectivity or ditching. To create the SEIWA Level 1 database, a column was added to the attribute table of the candidate IW polygon data for each criterion GIS data layer described in Section 1.3.3 so that the relationship scores could be added to determine the probability that a polygon was an IW.

In ArcMap, the “select by location” tool was used to select the candidate IW polygons that met the geo-relationship criteria between each polygon and the target GIS data layer. After selection of the candidate IW polygons, the value was populated in the appropriate column of the attribute table. Inverse selection was used to score the candidate IW polygons that were not initially selected. Geo-relationships were defined between all candidate IW polygons and criteria GIS data layers using this approach. Every candidate IW polygon was scored with a valued from 1 to 10 in each column (**Figure 1-10**).



BlackSpots	CREWS	Hydric	NotDitchAq	NotDitchRd	NotConnect	NotRiverin	Ponding	EO
1	1	5	10	10	10	10	1	10
1	10	10	10	10	10	10	1	10
10	1	10	1	10	10	10	1	10
1	1	10	10	10	10	10	1	10
1	5	10	10	10	10	10	1	10
10	1	10	10	10	10	10	1	10
10	1	5	7	10	10	10	1	10
1	1	5	3	10	10	10	1	10
1	10	10	10	10	1	10	1	10
1	5	10	10	10	10	10	1	10
10	1	10	1	10	10	10	1	10
1	1	5	3	1	10	10	1	10
1	1	5	1	10	10	10	1	10
1	10	10	10	10	10	10	1	10
1	10	1	10	10	10	10	1	10
10	1	5	7	10	1	10	1	10
1	1	5	1	10	10	10	1	10
1	1	5	1	10	10	10	1	10
1	1	5	10	10	10	10	1	10
10	5	10	10	10	1	10	1	10
1	5	10	3	10	10	10	1	10

Figure 1-10. Each column in the attribute table represents each data layer used to score the candidate IW polygon dataset.

Note: A value of 1 is less favorable to be an IW. A value of 10 is most favorable to be an IW. There are intermediate values that represent something in between the less likely and most likely conditions.

Each criterion score represented the geo-relationship between the candidate IW polygons and the criterion. A score of 10 represents a geo-relationship where the sink polygon is more likely to be an IW. A score of 1 represents a geo-relationship where the candidate polygon is less likely to be an IW. Scores between 1 and 10, such as 5 or 7, represents an intermediate geo-relationship between the data layers. A summary of the scoring for each criterion based on the geo-relationship (center of sink polygons intersection with polygon in data layer) with different data layers is shown below and a summary by county is provided in **Appendix 1-C**. The criteria were applied to all study counties unless otherwise noted.

Candidate IW polygons scored based on their geo-relationship with CREWS wetlands data (Bladen, Brunswick, Columbus counties):

- Center of candidate IW polygon that intersects with Likely CREWS was scored a 10.
- Center of candidate IW polygon that intersects with Maybe CREWS was scored a 5.
- Center of candidate IW polygon that intersects with Rarely CREWS was scored

Candidate IW polygons scored based on their geo-relationship with NWI wetlands data (Dillon, Florence, Horry, Marion, and Robeson counties):

- Removed NWI class PUB wetland polygons and polygons that intersected floodplains, high or medium intensity land use, and water bodies connected to derived drainage.

- Center of candidate IW polygon intersecting an NWI wetland was scored a 10.
- Center of candidate IW polygon that did not intersect an NWI wetland was scored a 1.

Candidate IW polygons scored based on their geo-relationship with hydric soils data:

- Center of candidate IW polygon that intersects with HydricAll was scored a 10.
- Center of candidate IW polygon that intersects with HydricPartial was scored a 5.
- Center of candidate IW polygon that intersects with HydricNot was scored a 1.

Candidate IW polygons scored based on their geo-relationship with agriculture land cover data (NotDitchAg):

- Center of candidate IW polygon that does not intersect with NotDitchAg was scored a 10.
- Center of candidate IW polygon that intersects with NotDitchAg was scored a 1.

Candidate IW polygon scored based on their geo-relationship with LiDAR-derived drainage (DerivedHydro) with a 10-meter buffer:

- Center of candidate IW polygon that does not intersect with DerivedHydro buffer was scored a 10.
- Center of candidate IW polygon that intersects with DerivedHydro buffer was scored a 1.

Candidate IW polygons scored based on their geo-relationship with 10-meter road buffers:

- Center of candidate IW polygon that does not intersect with RoadBuffer was scored a 10.
- Center of candidate IW polygon that intersects with RoadBuffer was scored a 1.

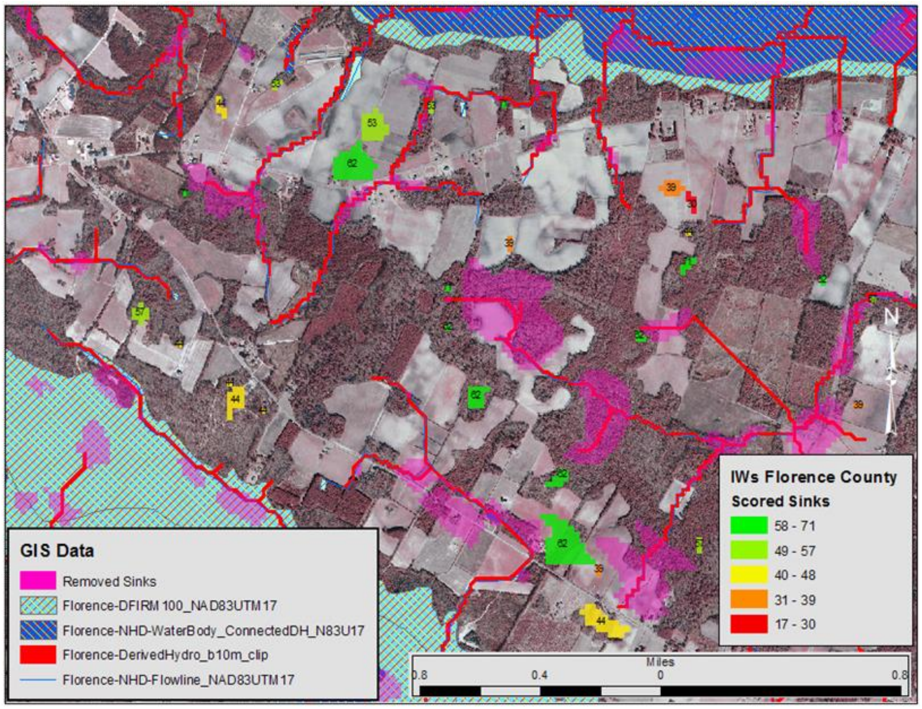
Candidate IW polygons scored based on their geo-relationship with soils ponding (Ponding):

- Center of candidate IW polygon that does intersect with ponding polygon was scored a 10.
- Center of candidate IW polygon that does not intersect with ponding polygon was scored a 1.

Candidate IW polygons scored based on their geo-relationship with Element Occurrences (EO):

- Center of candidate IW polygon that does intersect with Element Occurrence polygons was scored a 10.
- Center candidate IW polygon that does not intersect with Element Occurrence polygons was scored a 1.

The scores were then added together to derive a relative scoring for all the candidate IW polygons in the data set and then color-coded based on that score (**Figures 1-11 and 1-12**). Initially, the relative scoring process was established in an effort to determine probability relative to the GIS approach. However throughout the project, the scoring process was ultimately used to determine geo-relationship instead of probability. Once the SEIWA Level 1 candidate IW polygon database was compiled, probability was determined by the project's statistician in an analytical additional step described elsewhere in this document.



Note: polygons are “connected” to drainage, streams, floodplains.

Figure 1-11. **Color-coded candidate IW polygons based on the scoring of relationships between sinks and target GIS data layers.**

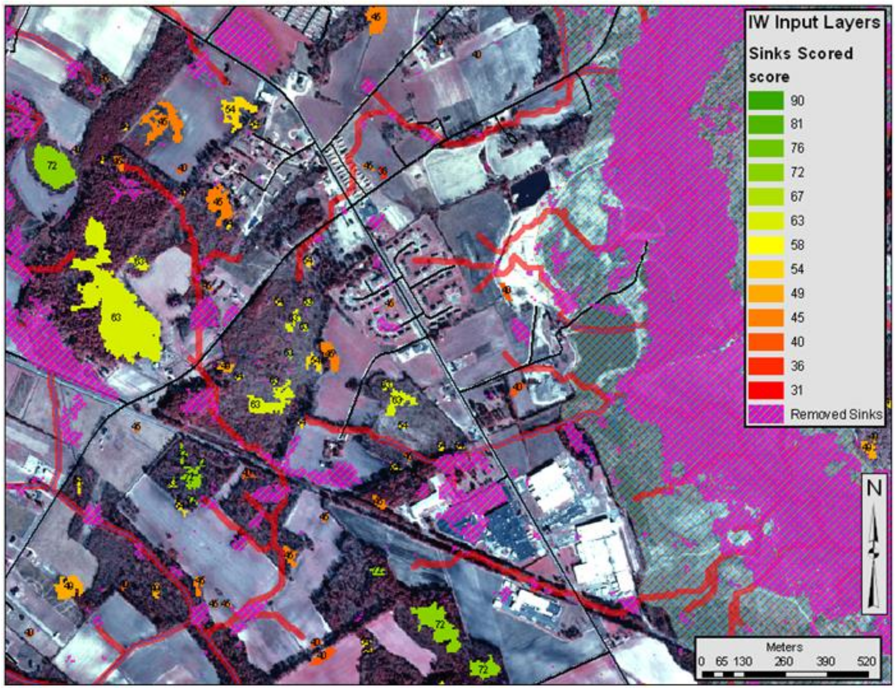


Figure 1-12. **Example of color-coded candidate IW polygons as likely IW locations.**

1.4 Results

This section describes the results of the Level 1 methodology in terms of the accuracy of the method in identifying isolated wetlands using GIS and remote sensing data alone. The GIS approach to map the likelihood of IWs in Level 1 of the SEIWA study was designed to develop a study population that could be combined with a probabilistic sampling approach and Level 2 wetland assessments on the sampled sites to answer questions about the number, size, condition, and function of geographically IWs in the SEIWA study area. This Level 2 assessment and its results are described in Part 2 of this report. For the GIS portion of the project, the primary questions are (1) whether the Level 1 methods contain any biases that should be corrected during the Level 2 analysis and (2) how well the Level 1 methods did in identifying IWs. In addition, Section 1.5 describes the results of a Level 1 hindcasting analysis conducted to provide information on past losses of wetlands and IWs in the study area.

1.4.1 Topographic (Elevation) Data Differences

As described in Section 1.3.1, the Level 1 method began by applying a fill algorithm from Gritzner (2006) to the best available topographic data to create "sinks" or polygons representing depressions in the landscape where isolated wetlands may occur. These candidate IW polygons define the study population to be investigated in this report. **Table 1-3** shows the number of sinks that were initially derived for each county along with the spatial resolution of the data and the number of sinks derived per square mile of county.

The number of sinks generated varied greatly according to the spatial resolution of the source data. Sinks derived from the 4m to 5m resolution LiDAR data in NC and Horry County, SC, were much more numerous than those derived from the 30m USGS elevation (hypsography) data used in Florence, Marion, and Dillon Counties in SC , with over an order of magnitude difference on the per square mile basis. Note that the large number of sinks generated in Horry County using the higher resolution 4m LiDAR data include many anthropogenic features that were later corrected through additional masking as described in Section 1.3.2.

Review of Table 1-3 shows that the 30m hypsography data used for three SC counties produced 22 to 27 sinks per square mile while the 4m – 5m LiDAR data produced from 322 to over 1,500 sinks per square mile. This elevation resolution discrepancy is perhaps the greatest source of potential bias in the study and divides the study population of candidate IW polygons into two distinct domains – LiDAR and non-LiDAR counties. Because of this inherent difference in data sets the results for the Level 2 portion of this report are analyzed according to these two domains: (1) NC (5m LiDAR) counties and Horry County, SC (4m LiDAR), and (2) the SC counties of Dillon, Florence, and Marion with 30 m hypsography data.

Table 1-3. Number of "Sinks" Derived by State and County in the SEIWA Study Area (Prior to Masking) and Elevation Resolution Data from which they were Derived.

State	County	Area (Square Miles)	Number of Derived Sinks	Horizontal Spatial Resolution (meters)	Sinks per Square Mile
NC	Bladen	874.9	526,446	5	602
	Brunswick	854.8	295,481	5	346
	Columbus	936.8	777,961	5	830
	Robeson	948.8	306,000	5	322
SC	Horry	1133.7	1,804,191	4	1,591
	Dillon	404.8	11,036	30	27
	Florence	799.8	18,573	30	23
	Marion	489.1	10,969	30	22

1.4.2 Refinement of SEIWA Level 1 Methodology

As discussed in Section 1.3.4, the SEIWA Level 1 GIS approach evolved as the project progressed from county to county. The first three counties completed included Brunswick, Columbus, and Bladen. The initial process defined at the beginning of the project was used for these counties. Once the field team reported their findings after checking the validity of the wetland assignments, the GIS approach was revised in an effort to increase the success rates. For Robeson, Horry, and Dillon counties, filtering and manipulation of the GIS data layers include masking (removing) the following sink polygons from the candidate IW polygon dataset.

- Sink polygons that intersect agricultural areas that were connected to derived drainage (connected agricultural areas).
- Sink polygons that intersected roads that were connected to derived drainage.
- Sink polygons that intersected with NWI PUB class (man-made ponds).
- Sink polygons that intersect with areas that were neither wetlands nor hydric and also intersect with connected agricultural areas.
- Polygons that intersect with non wetlands/hydric soils and agricultural areas.
- Polygons less than 216 square meters that are located within a 10 meter road buffer.

Sink polygons that "intersected" these areas were removed from the final candidate IW polygon data set in an attempt to reduce the amount of false-positives and increase the success rate of the GIS approach. These refinements were applied to the last three counties processed

(Robeson, Horry, and Dillon counties). After reviewing the results from the last three counties and comparing them to the counties that were processed before, it is not clear how much of a difference these additional steps made (**Table 1-4**), although for Horry county the additional masking was effective at finding "bogus" (non-wetland) sinks and reducing the number of target polygons to numbers similar to those in the NC LiDAR counties.

Table 1-4. Number of "Sinks" Derived by State and County in the SEIWA Study Area (Prior to and After Masking).

State	County	Area (Square Miles)	Number of Derived Sinks	Number of Sinks after Masking	Masked Sinks per Square Mile
NC	Bladen	874.9	526,446	26,623	30
	Brunswick	854.8	295,481	44,038	51
	Columbus	936.8	777,961	85,568	91
	Robeson	948.8	306,000	26,877	28
SC	Horry	1,133.7	1,804,191	25,861	23
	Dillon	404.8	11,036	2,045	5
	Florence	799.8	18,573	2,604	3
	Marion	489.1	10,969	1,903	4

1.4.3 Accuracy of SEIWA Level 1 Assessment

The analysis of accuracy for the SEIWA Level 1 assessment was based on an error matrix, which is also known as an agreement or confusion matrix (Stehman and Czaplewski, 2003). An error matrix is an n-by-n matrix that summarizes the correct classifications and misclassifications, where the rows designate the map levels and the columns the field reference level (or ground-truth levels). The (*i,j*) cell represents the proportion of sampling units classified as map class *i* and reference class *j*. In the presence of a complex sampling design, the standard formulas to estimate the error matrix are no longer valid. Appendix 1-D provides the error matrices for the Level 1 accuracy assessment.

Statistics reported for accuracy assessment include the total accuracy rate (proportion of agreement between the map and the field data), the producer's accuracy (the proportion of agreement for both IW and non-IW), and precision (P), the proportion of W that were correctly identified in the map (Nusser and Klaas, 2003; Foody, 2002). Estimators for the accuracy rate are based on ratio estimators (Levy and Lemeshow, 1999). Ratio estimators are biases estimators that usually have smaller variance than the corresponding Horvitz-Thompson estimators (Sarndal et al., 1992). Measures of variability were computed accounting for the sample design, nonresponse, and type of estimator. Accuracy estimators were obtained using design-based approaches, which incorporate in the calculations the sampling weights for each site after accounting for the sampling design and non-accessibility status of some of the selected sites.

Polygons in the GIS model were classified as having low, medium, and high probability of being isolated wetlands using the scoring system described in Section 1.3.5 of this report. We expected that polygons with low and medium likelihood of being IWs are not actually IWs and that polygons with high likelihood of being IWs are IWs. As shown in the Appendix 1-D error matrices derived for the assessment of the accuracy of these hypotheses, for the entire study area 22% of the polygons predicted as IW by the GIS model were correctly determined and 75% of those that have medium and low likelihood of being isolated wetlands were correctly predicted as non IWs.

With respect to the GIS model for NC, 35% of the polygons predicted as IWs by the GIS model were correctly determined and 75% of those that have medium and low likelihood of being isolated wetlands were correctly predicted as non IWs. For SC, 13% of the polygons predicted as IWs by the GIS model were correctly determined and 69% of those that have medium and low likelihood of being IWs were correctly predicted as non IWs. The significantly lower success rates for SC may reflect the lower resolution topographic data used for three of the four SC counties as described in Section 1.4.1.

These field results show that while the SEIWA Level 1 method can identify wetlands that might be isolated, the high resolution LiDAR data had trouble identifying the small ditches and other drainage structures that can connect an isolated wetland with downstream navigable waters, causing the high false positive rate. Overall, the low true positive and high false positive rates indicate that Level 1 methods applied in this study require field verification on a random selection of sites to be useful in evaluating the IW resource. The higher precision for the true negative rates show that the GIS method is best at identifying the proportions of the sink polygons that are not isolated wetlands. The results suggest that these maps are useful to help predict various attributes of isolated wetlands, and although the relatively low IW accuracy rate requires field confirmation that a particular candidate feature is isolated, the candidate IW polygon layer produced in the Level 1 portion of this project is an available resource to assist nc and SC wetland managers in finding features that are likely to be wetlands, and possibly isolated wetlands in the 8-county SEIWA study area.

Part 2 of this report describes the results of the accuracy assessment in greater detail, along with a quantitative assessment of the impacts of not having LiDAR data in 3 counties: underestimates of the number of IWs and overestimates of the size of individual IWs within the 3 SC counties without the LiDAR data. The stratified statistical design and the field verification effort allowed us to quantify and correct for the inaccuracies (high false positive rates) of the Level 1 method when extending the Level 2 results to the study population. In addition, because of the similar geologic and socio-economic settings in the LiDAR and non-LiDAR counties we were able to extend LiDAR results into the non-LiDAR counties and correct for the size and number biases in the Level 2 estimates of IW characteristics that were likely to be biased by the absence of LiDAR data. As LiDAR data become available for Marion, Florence, and Dillon counties, these corrections can be checked and verified, and the results of this project can be revised as needed.

1.5 Hindcasting

The goal of the Level 1 hindcasting analysis was to map historic IWs to help determine their loss as a result of changes in land cover in the study counties. The approach was to map wetlands and IWs for an earlier time than what the current data represent. We expected that limited geographic data would be available to perform hindcasting, or that much of the required data may not exist at all. However, data were available to support two Level 1 hindcasting approaches to estimate past wetland loss for the SEIWA project: (1) compare the extent of SSURGO hydric soils against more modern wetland coverages (NWI and NC CREWS) to estimate the historic loss of all wetlands in the study area and (2) use NLCD land cover change from 1992 to 2001 to estimate the rate of IW loss in more recent times.

1.5.1 Historic Wetland Loss

Historic wetland loss was estimated by comparing total hydric soils acreage with total wetland acreages assembled from either the NC CREWS wetland coverages (for Bladen, Brunswick, and Columbus counties) or the NWI wetland coverages[3] (for Robeson, Dillon, Florence, Horry, and Marion counties) as estimates of wetland extent in the late 1980s to early 1990s. Hydric soil coverage is used as the baseline of original wetland extent in each county. Hydric soils are generally regarded as the most reliable field measure of past wetland extent because county soil surveys fully extend across the land surface and because the criteria used to distinguish hydric soils can be documented throughout the year and will persist after drainage and loss of wetland vegetation (Moorhead, 1990).

Hydric soil extent was estimated based on county soil survey data in SSURGO, with area data for each soil series containing hydric soils being adjusted by the percent of hydric soil components within the soil series. NC CREWS wetland acreages were totaled for each county with NC CREWS data, and represent wetland extent in the late 1980s to early 1990s. NWI wetland acreages were used for the remaining counties and represent a broader range of dates depending on when the NWI studies were conducted. According to the NWI metadata for North and South Carolina the NWI was conducted across the country from 1977 to the present.

Table 1-5 shows the results of this analysis in terms of historic wetland loss in each of the study area counties. Wetland loss was greatest in Horry County (20% loss) which is partly due to the

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[3] The palustrine unconsolidated bottom (PUB) NWI wetland types were excluded from the totals because they are farm ponds in this area, which were not considered wetlands for the purpose of this analysis. Estuarine and marine wetlands were also excluded from the NWI and CREWS totals for Horry and Brunswick counties.

Table 1-5. Estimates of Historic Wetland Loss in the SEIWA Study Area.

County (Wetland Coverage)	Hydric Status	Acres	Percent Hydric	CREWS or NWI Acreage	CREWS or NWI Percent wetland	Percent Historic Wetland Loss
Bladen (CREWS)	Hydric	268,192	48%	224,056	40%	7.9%
	All soils	560,000				
Brunswick (CREWS)	Hydric	274,533	50%	265,518	49%	1.6%
	All soils	547,200				
Columbus (CREWS)	Hydric	302,942	51%	250,138	42%	8.8%
	All soils	599,680				
Robeson (NWI)	Hydric	264,264	44%	165,099	27%	16.3%
	All soils	607,360				
Dillon (NWI)	Hydric	107,642	41%	90,301	35%	6.7%
	All soils	260,000				
Florence (NWI)	Hydric	177,494	34%	171,701	33%	1.1%
	All soils	515,200				
Horry (NWI)	Hydric	408,365	55%	257,937	35%	20%
	All soils	736,000				
Marion (NWI)	Hydric	149,285	49%	149,223	49%	0.0%
	All soils	307,000				
Study Area	Hydric	1,952,717	47%	1,573,973	38%	9.2%
	All soils	4,132,440				

extensive development around Myrtle Beach, followed by Robeson (16% loss), Columbus (8.8% loss), Bladen (7.9% loss), and Dillon (6.6% loss) which could represent loss due to conversion to agriculture. Brunswick, Marion, and Florence show very little historic wetland loss (less than 2 percent). Overall the study area shows a 9.2% loss of the original wetland acreage as measured by hydric soil extent. Although it is difficult to precisely extend these overall wetland loss estimates to IWs, they do provide an indication of the relative stresses on wetlands in general from county to county and therefore the counties where IWs have been most at risk historically.

1.5.2 Isolated Wetland Hindcasting Using the 1992 and 2001 NLCD

The NLCD 1992/2001 Retrofit Land Cover Change Product obtained from the Multi-Resolution Land Characteristics Consortium (MRLC; http://www.mrlc.gov/multizone.php) was also used for hindcasting in Brunswick and Horry counties, the two study area counties with the most population growth from 1992 to 2001. To serve as a basis for an assessment of land cover changes of the potential IW polygons, this land cover change dataset was analyzed to determine the conversion of forested land to agricultural use and the loss of non-developed (forested) land cover classes to an NLCD developed class from 1992 to 2001. More current landuse change coverages are and will soon be available to extend these estimates to 2005 and 2009[4] to capture more current threats, but these coverages were not available in time for the Level 1 portion of this project.

An attempt was made to identify sink polygons that could have been historical IWs but were affected by land use practices. Throughout the initial GIS process, we noticed that a number of sink polygons fell within agricultural fields. The SEIWA Team suspected that most of these polygons could have been historic IWs based on visual interpretations from orthophotography and field visits (**Figure 1-13**). Candidate IW polygons located in agriculture lands have a high probability of being ditched and therefore connected which results in a low likelihood of being IWs. In contrast, sinks located in forest areas are less likely to be ditched which results in a larger likelihood of IWs. Using the "select by location" tools in ArcMap, a sinks polygon data set was created identifying these polygons as potentially historic IWs.

We also observed that a number of the sinks that were derived from the elevation data were likely there because of development; i.e., they represent anthropogenic depressions rather than natural features. There is likely more uncertainty regarding the hindcasting of these IW polygons. A number of these sinks are apparently associated with ponds and other physical depressions in the ground. Ideally, it would be preferable to have dated elevation data from a time before development occurred to better represent historic sinks. However, these data do not exist and so the sink polygons derived from the LiDAR data are used as the base population for all hindcasting analysis in this report.

Three hindcasting analyses were conducted on the target IW polygons to determine (1) how many polygons forested in 1992 changed to agricultural or developed land cover in 2001, (2) how changes in land use from 1992 to 2001 affected the scoring of the polygons for how likely they are isolated wetland, and (3) an counts of IWs on hydric soils in agricultural areas as an estimate of historic IW loss.

1.5.2.1 Isolated Wetland Polygons and Land Cover Change – Brunswick and Horry Counties.

The 1992/2001 NLCD Retrofit Land Cover dataset was used to determine which sink polygons were affected by a change in land cover between 1992 and 2001. To avoid features such as anthropogenic sinks in developed areas and IWs converted to agricultural use, we focused the hindcasting exercise on target sinks with forested land cover in 1992. In Brunswick County, 47 percent of the target IW polygons were located in forest lands in 1992.

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[4] For example, MDA Federal has created annual correlated land-cover (CLC) change data for the SEIWA study area from 1985 to 2009 (see http://sewwg.rti.org for an overlay with the SEIWA candidate IW polygons), and the NLCD is due to be updated for 2006 in the very near future.

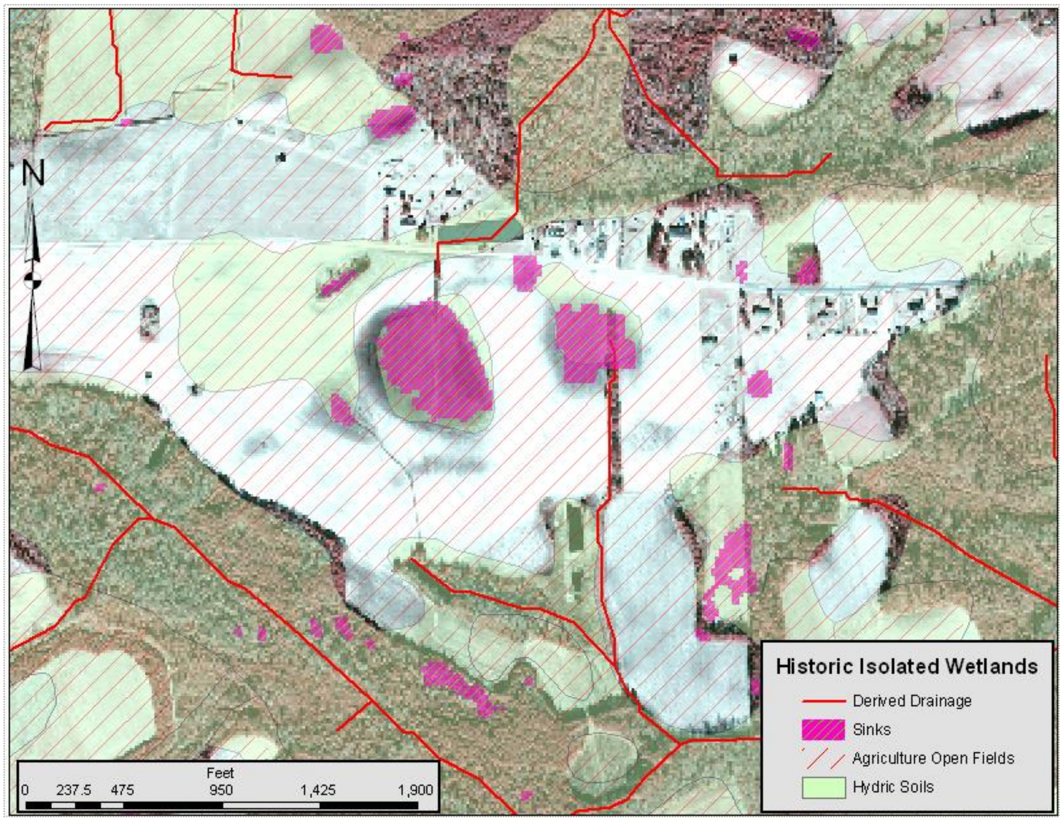

Figure 1-13. Potentially historic IWs located on hydric soils and open agriculture fields. Ditching is visible in the orthophotography to drain the agricultural fields, thus draining the IWs.

Based on the NLCD 1992/2001 Retrofit Change Product, 1.7 percent (759 of 44,038) of these forested polygons changed to developed land cover and 17 percent (7,564 of 44,038) changed to agricultural use. Overall, 19 percent of the forested polygons changed to either agricultural or development from 1992 to 2001. This gives a potential IW loss rate, assuming that development and agricultural land cover change destroys IWs (and all of the forested polygons are IWs), of 2 percent per year or 21 percent every decade for Brunswick County. From 1992 to 2001, the NLCD data suggest that agricultural development was a more significant threat than development to IWs in Brunswick County. However, experience of the project team in the area suggests that the agricultural conversion estimates for Brunswick County may be biased high, perhaps due to counting forest clearcuts as agricultural conversion. We are looking for data to confirm or support this observation.

With respect to Horry County, 2.7 percent (709 of 25,861) of the forested polygons changed to agriculture use and 2 percent (526 of 25,861) changed to developed areas from 1992 to 2001. This results in an overall change rate of 4.8% which suggests a potential IW loss rate, assuming that development and agricultural land cover change destroys IWs (and all of the forested polygons are IWs), of 0.5 percent per year or 5 percent every decade. In Horry County, agricultural land use change was slightly less than change from development from 1992 to 2001 and development pressure was similar to Brunswick County.

1.5.2.2 1992 to 2001 Changes in IW Scoring – Brunswick and Horry Counties

As a measure of how a change in landuse affects the likelihood that the candidate IW polygons are actually IWs, the Brunswick County and Horry County candidate IW polygons were scored using the 1992 NLCD data and these scores were compared to the 2001 NLCD scores used in this study. The procedure to create the 1992 IW data and scores was as follows.

1) Start from original unedited IW Polygons derived from LIDAR Sinks (Section 1.3.1).
2) Remove IW polygons located in the 1992 NLCD Urban class.
3) Maintain the IW polygons and scores located in both 2001 and 1992 NLCD Agriculture class.
4) Rescore IW polygons located in areas where forest, grasslands, wetlands, barren and water were changed to agriculture classes from 1992 to 2001.
5) Remove IW polygons created because of development, e.g., ponds and ditches.
6) Keep IW polygons located in areas where forest, grassland, wetlands, barren and water were changed to developed classes from 1992 to 2001.
7) Maintain scores for wetlands with regard to HydricAll soils.
8) Maintain scores for water connectivity.
9) Recalculate the overall SCORE attribute.

In Brunswick County 26 percent of the candidate IW polygons changed from high likelihood when scored using 1992 NLCD to medium likelihood when scored using 2001 NLCD. In Horry County 35 percent of high likelihood polygons scored with 1992 NLCD changed to medium likelihood when scored using 2001 NLCD. The lower IW likelihood scores in 2002 are due to more wetland polygons being in agricultural areas. As described in Section 1.3.3.4, a change to agricultural land use would change the “NotDitchAg” score from 10 to 1.

1.5.2.3 Presettlement Estimates of IWs using Hydric Soils – Brunswick and Horry Counties

As a measure of historic IW loss in Brunswick and Horry Counties, the polygons were processed as follows.

1) Start from original undedited Isolated Wetlands (IW) Polygons derived from LIDAR Sinks.
2) Keep all IW polygons and remove scores for Agricultural and Developed classes.
3) Maintain scores for HydricAll Soils
4) Remove scores for roads.
5) Maintain Scores for connectivity.
6) Recalculate the overall SCORE attribute.

Applying this method resulted in 22,472 IW polygons in Brunswick County and 6,271 IW polygons in Horry County that are in hydric soils and agriculture/grassland areas for a time prior to 1992 as depicted by the landcover data, showing a significant number of sinks that may have been historically isolated but are now likely to be connected through ditching associated with land cover conversion due to agriculture or development. Whether or not these features are still wetlands was not determined in this analysis but could be subject of future work.

1.6 Summary and Conclusions

Mapping the likelihood of IWs requires multiple sources of geospatial information to model the necessary criteria for IWs to exist. This portion of the SEIWA project defined the critical geospatial information that is needed and implemented an approach that can be adapted to other project areas. Required geospatial information varies in availability, quality and resolution from state to state, county to county, and likely across many regions of the country. Therefore, results will vary as these methods are adapted to other project areas.

Although there were data gaps requiring more recent and reliable datasets, such as up-to-date LiDAR, detailed landcover, wetlands, and other GIS data, the project team utilized the best data with the appropriate geographic coverage that could be gathered from readily available sources to meet the project goal to develop an approach and methodology that could be applied across the United States. The methods developed and information gleaned from this project can be used in other study areas where the approach can be modified and applied depending on the available datasets.

With respect to results, the most significant data gap, the lack of LiDAR data (at the time of this study) for three South Carolina counties (Dillon, Florence, and Marion), provided an opportunity to compare results and accuracy when topographic data of different resolutions are used to develop the candidate sink polygons that are the basis for this method. The use of 30m hypsography resulted in over an order magnitude fewer sinks in these counties, both before and after masking, than were derived in the other counties using 4m or 5m LiDAR. As a result wetland counts are significantly biased low, by over an order of magnitude, for these counties and the “candidate IW polygons” for these counties is an inherently different population than the LiDAR-derived sink polygons in the other counties. Because of this differential, these two populations (the LiDAR and non-LiDAR counties) are analyzed separately in the Level 2 assessment and statistics from the available LiDAR results were used to correct the results for the non-LiDAR counties. The significant undercount of IWs in the non-LiDAR counties leads to the conclusion that 30m DEMs were not adequate to delineate IWs in the study area.

With respect to the accuracy of the Level 1 methods for identifying isolated wetlands in the study area, the following conclusions were reached.

- For the entire study region, 22% of the polygons predicted as IW by the GIS model were correctly determined and 75% of those that have medium and low likelihood of being isolated wetlands were correctly predicted as non IWs.
- For North Carolina, 35% of the polygons predicted as IWs by the GIS model were correctly determined and 75% of those that have medium and low likelihood of being isolated wetlands were also correctly predicted as non IWs.
- For South Carolina, 13% of the polygons predicted as IW by the GIS model were correctly determined and 69% of those that have medium and low likelihood of being IWs were also correctly predicted as non IWs. The lower success rates for South Carolina may be a reflection of the unavailability of LiDAR elevation data for three of the four South Carolina counties.

The results also suggest that these maps are useful in a regional context to help predict various attributes of isolated wetlands, and although the relatively low IW accuracy rate requires confirmation that a particular candidate feature is isolated, the candidate IW polygon layer produced in the Level 1 portion of this project can be a resource to assist wetland managers in finding features that are likely to be wetlands, and possibly isolated wetlands.

This GIS data layer product of this project includes metadata on each candidate polygon's IW likelihood scores (described in Section 1.3.5), and is available as a shape file to NC and SC wetland managers. As an example application, this data layer was posted in a map viewer on the Southeast Wetlands Workgroup (SEWWG) website (http://sewwg.rti.org). The SEWWG map viewer allows users to visit the candidate IW polygons in the 8 county study area and view them against NLCD land cover for 1992 and 2001, land cover change from 1986 to 2009[5], soils, NC CREWS wetlands, NHD hydrography and catchments, and high resolution aerial photography from ESRI. This site (or the independent SEIWA GIS shape files) will enable wetland regulators and managers to review a particular area or watershed of interest see where IWs may be located, their likelihood of being IWs as defined by the Level 1 metrics of this study, and what sort of development pressures are they under, both currently and in the past.

Although this project did find that Level 1 methods alone were not highly accurate in identifying IWs, the statistical design employed in sampling the dataset for the Level 2 field work enabled the SEIWA project to characterize this resource to a known level of accuracy at a regional or state scale (see Part 2 of this report). The Level 1 wetland assessment methods are an important tool to find and conduct a preliminary characterization of a large number of wetland features that may be isolated and with field verification applied in a statistically designed study to confirm the accuracy of the Level 1 methods, can be used to develop estimates, with known accuracy, of IW extent and characteristics for a study area. Verification was especially critical to

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[5] The SEWWG website includes Correlated Landcover Change (CLC) data layers developed by MDA Federal, that show year-to-year changes in land cover based on 1985-2009 LANDSAT imagery. Additional CLC metadata can be found on the website.

identify the small ditches and drainage swales that connected many of the candidate IWs in the study but were too small to be picked up by LiDAR.

Several hindcasting techniques were developed and applied to try and assess the extent and rates of historical wetland and isolated wetland loss in the study area. Although the results are somewhat uncertain because of limitations in the GIS datasets used in the analysis, several general conclusions can be drawn from this exercise.

- Historic overall wetland loss, estimated by comparing hydric soils acreage (as a measure of historic wetlands) with more current wetland acreages from NC CREWS or NWI, was about 9% for the study area, with the ratio between the total hydric soil and total NWI/NC CREWS acreages ranging from 7% to 20% for 5 counties (Horry [20%], Robeson [16%], Columbus [9%], Bladen [8%], and Dillon [7%]). Three counties (Brunswick, Marion, and Florence) showed less than 2% difference between hydric soil and NWI extent.
- For the forested candidate IW polygons in Brunswick and Horry County, analysis using the 1992/2001 NLCD land cover change product indicates that 19% of the forested candidate IW polygons changed to either agricultural or urban/suburban land cover from 1992 to 2001. Assuming that conversion of forested to agriculture or developed land cover threatens IWs, this gives a potential IW "threat" rate from land cover change of about 2 percent per year or 21 percent every decade for the two counties. Most of this change in land cover was from expanded agriculture land cover in Brunswick County; about 2% - 3% of the forested IW polygons changed to urban/suburban development in both counties.
- Comparing the Level 1 scoring of the likelihood of a candidate IW polygon being an actual IW, 26% (Brunswick County) and 35% (Horry County) changed from high likelihood when scored using 1992 NLCD to medium likelihood when scored using 2001 NLCD. This reflects 1992 to 2001 land cover changes from forested to agricultural that would increase the likelihood of ditching.

These hindcasting results should be regarded as preliminary until they can be ground-truthed, for example, with historic aerial photos and field assessments. They also need to be extended to more recent years using newer land cover products becoming available for 2006 – 2009. However the current results do indicate that although wetlands and IWs are extensive in these counties, they are potentially threatened by agricultural and urban development, especially in the coastal counties (Horry and Brunswick).

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Appendix 1A. Workflow to Create Sinks/Depressions and Derived Hydro from Elevation Data

1A.1 Digital Elevation Model (DEM) creation for South Carolina

Methodology

Topographic to Raster function: Interpolate a hydrologically correct surface from point, line, and polygon data. Produce a DEM.

Software

ESRI Spatial Analyst Topo to Raster Tool.

Inputs

24k hypsography. 1:24,000 hypsography downloaded from South Carolina website: http://www.dnr.sc.gov/GIS/gisdownload.html

24k NHD hydrography.

24K lakes and ponds

Output

30-meter DEM

DEM Sink locations (could be true depressions or artifacts of the DEM)

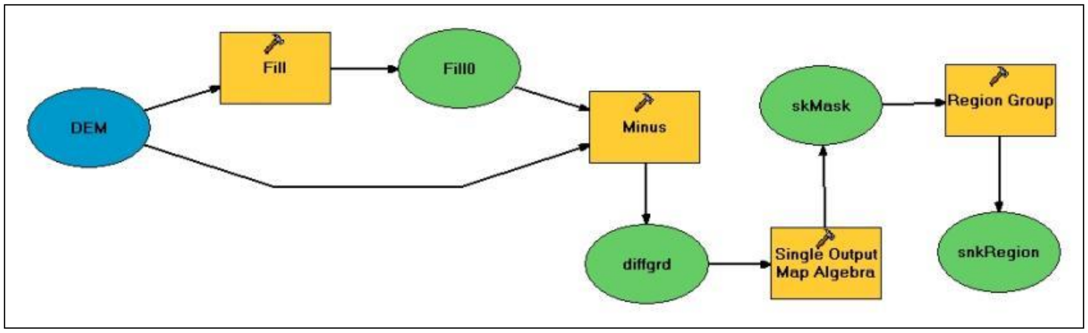
1A.2 Wetland Depressions

Methodology

Gritzner (2006). Identifying Wetland Depressions in Bare-Ground LIDAR for Hydrologic Modeling: http://gis.esri.com/library/userconf/proc06/papers/papers/pap_1225.pdf

- Difference Grid = Filled DEM – Original DEM
- Sink Mask = Con (Difference > 0,1)
- Sink Regions = Region Group (Sink Mask by 8)

- ArcGIS model builder was used to create output.



Software

ArcGIS9.2

Model Builder

Input

DEM (5- and 30-meter)

Output

Candidate “sink” polygons for Level 1 processing

1A.3 Derived Hydrography

Software

ArcHydro

Input

30 meter DEM created from the South Carolina hypsography.

Processes

Agree Stream – NHD Flowline
Filled DEM – From wetland depression processing.
10 acre catchments used for derivation of hydro.

Output

Vector line data depicting channels, location of drainage and the flow of water.

Appendix 1B. Masking Criteria by County

Removed polygons that:	**North Carolina**				**South Carolina**				**Additional Information**
	Brunswick	**Bladen**	**Columbus**	**Robeson**	**Marion**	**Florence**	**Horry**	**Dillon**	
Occurred in flood plain	x	x	x	x		x	x		NHD Flood Plain
Occurred in connected water bodies					x			x	NHD Water body data used as surrogate floodplain data.
Intersect a NHD stream	x	x	x	x	x	x	x	x	
Intersect Derived hydro	x	x	x	x	x	x	x	x	Streams derived from elevation data.
Occurred in Developed Area				x		x	x	x	High and medium intensity from NLCD landcover data
Identified as linear features							x		
Small polygons (single pixel)		x							Less than 75 m^2
Small polygons			x	x					Columbus: <111 m^2; Robeson: <223 m^2
Small polygons and along roads				x			x		Less than 216 m^2 and within 10 meter of road buffer
Man-made ponds				x			x	x	Polygons that intersect with NWI PUB class

Appendix 1C. Scoring Criteria and Number of Polygons by County

Criteria	Scoring	Brunswick	Bladen	Columbus	scoring	Robeson	Marion	Florence	Horry	Dillon	Dillon - re do
NC_CREWS	**0**, 5, 10	**x**	x	x							
NWI					**1**, 10	x	x	x	x	x	x
Blackspot	**0**, 10	**x**	x	x	**1**, 10	x	x	x	x	x	x
Hydric	0, **5, 10**	**x**	x	x	1, **5, 10**	x	x	x	x	x	x
Ponding	**0**, 10	**x**	x	x	**1**, 10	x					
NotConnect	0, **10**	**x**	x	x	1, **10**	x	x	x	x	x	x
NotFloodPl	0, **10**	**x**	x	x					x		
NotDitchAg	0, 3, 7, 10	**x**	x	x	1, **10**	x	x	x	x	x	x
NotDitchRd	0, **10**	**x**	x	x	1, **10**	x	x	x	x	x	x
NotMuckale	0, 5, **10**	**x**									
NotRiverine_SSURGO	0, **10**	**x**	x	x	1, **10**	x					
EO	**0**, 10	**x**	x	x	**1**, 10	x	x	x	x	x	x
NotRivSoil_NCCREWS	0, **10**		x	x				x	x		
Isolated					1, **10**	x			x		
NotDevelop					1, **10**				x		
Wet					**0**, 1				x		
rd_dh					**0**, 1				x		x
AgConnet					**0**, 1				x		
NoWetland					**0**, 1						x
Number of Criteria		11	11	11		10	7	8	14	7	9
Data Processed		6/21/2008	6/27/2008	6/26/2008		9/8/2008	8/15/2008	8/25/2008	9/11/2008	8/18/2008	11/24/2008
Number of Polygons		44,038	26,623	85,568		26,877	1,903	2,604	25,861	2,045	397

Appendix 1D. Error Matrices for Level 1 Accuracy Assessment

Table 1D.1. Error Matrix For SEIWA Study Area

Model: Study Area		
Row Percent/Column Percent FIELD	Isolated Wetland (High)	Non Isolated Wetland or Non-Wetland (Medium, Low)
Isolated Wetland	21.84	25.21
Non Isolated Wetland or Non Wetland	78.16	74.79

Table 1D.2. Error Matrix For North Carolina

Model: North Carolina		
Row Percent/Column Percent FIELD	Isolated Wetland (High)	Non Isolated Wetland or Non-Wetland (Medium, Low)
Isolated Wetland	35.37	24.69
Non Isolated Wetland or Non Wetland	64.63	75.31

Table 1D.3. Error Matrix For South Carolina

Model: South Carolina		
Row Percent/Column Percent FIELD	Isolated Wetland (High)	Non Isolated Wetland or Non-Wetland (Medium, Low)
Isolated Wetland	13.19	30.91
Non Isolated Wetland or Non Wetland	86.81	69.09

Highlighted cells indicate percentages used in report.

Assessing Geographically Isolated Wetlands in North and South Carolina – Part 2: Level 2 Rapid Assessment and Statistical Extension to Study Area

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2. Assessing Geographically Isolated Wetlands in North and South Carolina – Part 2: Level 2 Rapid Assessment and Statistical Extension to Study Area

2.1 Introduction and Background

Geographically isolated wetlands (IWs) can provide the same environmental benefits as wetlands in general, and are particularly vulnerable to losses from urbanization and agriculture precisely because they are geographically isolated and have varying amounts of regulatory protection. Few studies have been conducted on existing IWs in the outer coastal plain of the Carolinas. This project will provided information that will be valuable for resource management and policy planning in managing, protecting, and restoring IWs in the southeast coastal plain.

The second phase of the Southeast Isolated Wetlands Assessment (SEIWA) provided an opportunity to test the Level 1 GIS/remote sensing approaches for identifying IWs developed in the first phase of the project. This was accomplished by selecting a random sample of the Level 1 candidate IW polygons (or 'sinks') and conducting Level 2 rapid wetland field assessments at these sites to confirm the presence and extent of IWs and assess their types, size, soils, condition, and relative level of function. Because the candidate IW polygons were randomly selected for the Level 2 field work, the results of the field work can be extended to the target study population of all IWs in an eight-county area on the Coastal Plain of North and South Carolina.

The definitions for IWs used in the field assessments were based on the concepts and principles established in the SWANCC (Solid Waste Agency of Northern Cook County vs. United States Army Corps of Engineers) legal decision[1], which are vital to federal regulatory approaches to wetlands and are also of concern to both North and South Carolina as they pursue their own state-based programs to protect and preserve IW.

The objectives of the Level 2 SEIWA IW assessment were to use Level 2 field methods to assess the selected Level 1 candidate IW polygons to (1) measure the accuracy of the Level 1 SEIWA assessment in order to estimate the number and spatial extent of IWs in the study area; (2) assess the condition and

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[1] The term "geographically isolated wetland' refers to those wetlands that have no surface connection to downstream waters. This definition is consistent with that used by the US Army Corps of Engineers for the 404 Permitting Program and is in contrast to other wetlands identified and regulated by the 404 Permit Program as delineated by the US Army Corps of Engineers Wetland Delineation Manual (Environmental Laboratory, 1987).

relative function of these IWs using existing rapid assessment methods; (3) estimate certain biological, hydrologic, and chemical characteristics of these wetlands that are important for their ecologic benefits; and (4) extend these results to the study population using probability based estimators. Part 2 of this report summarizes the activities and results associated with this work.

2.2 Methods

In the Level 2 field work, we conducted rapid wetland assessments on randomly selected Level 1 candidate IW polygons to collect data on wetland type, size, condition and relative function, and basic soil chemistry of isolated wetlands in the study area. As described in the Introduction to the SEIWA project report, the SEIWA study area comprises eight counties on the southeast outer coastal plain: four North Carolina (NC) counties - Bladen, Brunswick, Columbus, and Robeson - and four South Carolina (SC) counties - Dillon, Florence, Horry, and Marion.

2.2.1 Sample Design

The population of interest for the SEIWA study consists of a collection of polygons in the Level 1 GIS model representing potential locations of isolated wetlands located in the study area. To create the sampling frame, these “candidate IW polygons” were stratified by county and within each county clustered into 14-digit hydrologic units (HUCs). Counties constitute a natural stratification variable because they capture not only the spatial distribution of the polygons but also among-county variability. The primary sampling units were the 14-digit HUCs, which capture watershed variability within each county and help ensure that the sample points are more evenly distributed across each county.

A two-stage cluster stratified sampling design incorporating the spatial distribution of the polygons in the study area and the watershed-specific variability was used to select the random sample of polygons. In the first sampling stage, HUCs were selected at random using sequential probability proportional to the size (where size was defined as the number of polygons in each HUC) independently within each county. Polygons within selected HUCs were randomly selected for the Level 2 assessment based on a stratified sample design with the number of samples depending on the likelihood (high, medium, or low) of a polygon being an isolated wetland (as defined in the Level 1 method), with high, IW likelihood sites being more likely to be selected.

2.2.2 Sample Size

The selected sample size was the minimum sample size needed to achieve a specified uncertainty level for the main estimators in this project, with a 95% confidence level and 80% power. The minimum sample size (number of sampling units) needed was estimated by first calculating the sample size that would be needed with a simple random sampling (SRS) design. That sample size was then multiplied by an adjustment factor, called the design effect, to produce the minimum sample size needed under the proposed sampling design (see Section 4.1.1 of Cochran, 1977).

The sample size calculation was determined by specifying a desired uncertainty in the key project variables. One of the key variables was the overall accuracy of the GIS model created in the Level 1 assessment (as described in Part 1, Section 1.4.3). The overall IW detection accuracy rate was defined as the proportion of polygons in the study area correctly classified by the GIS model as IWs or non-IWs, with the non-IWs including both wetlands that were not isolated and non-wetland features (e.g., ponds, excavations, ditches). The detection rate for wetlands, isolated or not, was also determined in the analysis.

To determine the minimum sample size needed to estimate the overall accuracy under SRS, we assumed a conservative preliminary estimate of the true overall accuracy (population proportion). In the absence of prior information, we used 50% as the preliminary estimate as this assumption results in the largest sample size and is the most conservative.

Table 2-1 shows the sample size by state required for different values of the true overall accuracy rate, p, assuming a SRS design with a 95% confidence level and for different precision levels.

Table 2-1. State Sample Size by Precision Level and Proportion for 95% Confidence Level

Accuracy Rate, *p*	Precision										
	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30
0.30	81	56	41	32	25	20	17	14	12	10	9
0.35	87	61	45	34	27	22	18	15	13	11	10
0.40	92	64	47	36	28	23	19	16	14	12	10
0.45	95	66	49	37	29	24	20	17	14	12	11
0.50	96	67	49	38	30	24	20	17	14	12	11
0.55	95	66	49	37	29	24	20	17	14	12	11
0.60	92	64	47	36	28	23	19	16	14	12	10
0.65	87	61	45	34	27	22	18	15	13	11	10
0.70	81	56	41	32	25	20	17	14	12	10	9
0.75	72	50	37	28	22	18	15	13	11	9	8
0.80	61	43	31	24	19	15	13	11	9	8	7
0.85	49	34	25	19	15	12	10	9	7	6	5
0.90	35	24	18	14	11	9	7	6	5	4	4
0.95	18	13	9	7	6	5	4	3	3	2	2

Because the SEIWA survey design is not an SRS, but includes stratification and clustering to account for the spatial distribution of the isolated wetlands in the study area, the actual precision estimates are expected to be better (smaller confidence intervals) than those in Table 2-1. Observe that as the precision level decreases (i.e., smaller confidence intervals), the sample size increases. In the case of maximum variability, *p* = 0.5, a sample of 96 sites in each state will produce estimates with ±10% precision level.

After evaluating the time and costs involved in the collection of Level 2 data at one selected site, the SEIWA team concluded that a sample size of 90 would provide estimates with enough precision to address the research questions. To get an estimate of the expected precision with the proposed complex design, we calculated an estimate of the design effect (Deff) using estimates of the total area of hydric soils (**Table 2-2**) as an estimate of overall wetland extent in the study counties.

Design effects are very often used in the design and planning of complex surveys, and are defined as the ratio between the variance of the estimator based on the complex sampling design and the variance of the estimator based on a SRS design (Kish, 1965). First, we allocated the sample size to each county within each state proportional to the area of hydric soils, which we assumed is highly correlated with the expected number of IWs. Then, we calculated the Deff using the approach developed by Liu et al. (2002). The estimated Deff of 2.69 suggested that a stratified sampling design as the one proposed with a same sample size of 90 sites per state would provide estimates with a third of the precision (more precise) expected with a SRS design with the same sample size. In other words, if the expected precision with a SRS design with 90 sites was 0.1, then we expect a precision of 0.04 with the proposed sampling design.

Table 2-2. Area and Hydric Soil Extent by County

County	Area of county (acres)	Hydric soil in county[1] (acres)	Percent of county in hydric soils	Sample size	Additional Sites
North Carolina					
Brunswick	547,200	274,533	50	22	2
Columbus	599,680	302,942	51	25	3
Bladen	560,000	268,192	48	22	2
Robeson	607,360	264,264	44	21	2
Total		1,109,931		90	9
South Carolina					
Dillon	260,000	107,642	41	11	1
Marion	307,000	149,285	49	16	2
Florence	515,200	177,494	34	19	2
Horry	736,000	408,365	55	44	5
Total		842,786		90	10

[1] Data from NRCS list of hydric soils by county multiplied by the acreage of the soil series in that county from the County soil survey, adjusted by hydric soil component percentages. Prepared by John Dorney, DWQ July 14, 2008 and August 19, 2008

Table 2-2 also shows the number of sites and additional sites determined for a sample size of 90, assuming a 10% rate of non-accessibility, and the percent of county area that corresponds to hydric soils. Note that because of the proportional allocation within states, counties with larger amounts of hydric soils had larger sample sizes. Proportional allocation across the states considering hydric soil extent will allow state comparisons while allowing state estimates with similar precision, and better estimates at the study area level.

Table 2-3 shows the total number of candidate IW polygons and number of HUCs in each county, the average number of candidate IW polygons per HUC within each county, the number of selected HUCs within each county, and the number of candidate IW polygons selected as sites for the Level 2 study.

Approximately 3 polygons were selected per HUC, with a total of 90 candidate IW polygons selected for each state.

Table 2-3. Total Counts and Sample Size of HUCs and Candidate IW Polygons

County	Candidate IW Polygons	HUCs per County	HUC Sample Size	Average Polygons per HUC	Polygon Sample Size
North Carolina					
Brunswick	24,479	23	8	1,423	22
Columbus	28,930	31	8	1,221	25
Bladen	40,439	33	7	1,890	22
Robeson	24,294	36	8	966	21
Total	*118,142*	*123*	*31*		*90*
South Carolina					
Dillon	2,092	24	4	103	11
Marion	1,940	25	5	96	16
Florence	2,673	37	8	78	19
Horry	13,580	51	13	321	44
Total	*20,285*	*137*	*30*		*90*

2.2.3 Field Assessment

The SEIWA Level 2 wetland assessments were field surveys to verify the accuracy of Level 1 assessments and to rapidly assess the characteristics, condition, and relative functioning of each IW identified in the field portion of this study. Level 2 outputs include the accuracy of the mapping tool predictions (reported in Section 1.4 in Part 1 of this report) and a determination of the volume, condition, and relative function of the IWs that were assessed. Indices from the output of these assessments include metrics based on water quality, hydrology, and vegetation from the North Carolina Wetland Assessment Method version 4.0 (NC WAM; NC Wetland Functional Assessment Team, 2008) and the Ohio Rapid Assessment Method version 5.0 (ORAM; Ohio EPA, 2001). These data help fulfill the goal to evaluate the ecological benefits of isolated wetlands and allow characterization and description of the population of IWs in the eight-county SEIWA study area.

The Level 2 field work involved locating all randomly selected candidate IW polygons in the study area and conducting a field verification of whether or not they were a wetland and their isolated status. For the IWs, we then conducted wetland delineation, rapid assessment using ORAM and NC WAM, measurement of area and depth (either maximum depth or a survey of cross sectional area), and collection and analysis of upland and wetland soils. This work was carried out by staff from NC Department of Environment and Natural Resources' Division of Water Quality (NC DWQ), and the University of South Carolina (USC), with field assistance from the SC Department of Health and Environmental Control (DHEC) and the US Army Corps of Engineers. The Level 2 field work was conducted at randomly selected candidate IW polygons created during the Level 1 analysis by the NC

Center for Geographic Information Analysis (NC CGIA), using a statistical study design by RTI International (RTI).

2.2.3.1 . Field Method Overview

The following is a summary of the field process and methods that were used in this work. This work was done in teams of at least two wetland ecologists under the direction of John Dorney (NC DWQ) and Dan Tufford (USC).

1. Site Selection and Access. Each site was selected at random by the team statistician (see Section 2.2.1 Sample Design). If the landowner refused access or if the site was determined to be inaccessible in the field, then an alternative site of similar likelihood of being an IW was selected by the team statistician and visited by the field team. We visited 83 sites in NC and 87 sites in SC and made the following determinations.

2. Is the site a wetland according to the 1987 USACE manual? A soil auger, Munsell soil chart and the 1987 US Army Corps of Engineers (USACE) manual (USACE, 1987) were used to make this determination[2].

3. If the site is a wetland, then is it isolated? In order to make this determination, the boundary of the site was walked in order to see if there was any surface hydrologic connection via a ditch, pipe or overland flow.

4. What is the extent of the wetland? If the site was a wetland and if it was isolated, then the boundary of the wetland was delineated using the 1987 USACE manual and the boundary was recorded using a Trimble GPS unit. Plastic flagging was installed at the upland-wetland boundary of the IW.

5. What is the hydrologic volume of the IW? The volume of the wetland available for water storage was determined from the area and average depth of each IW. The average depth was determined from surveyed transects for a subset of the Level 2 sites.

6. What is the type of the IW? Each IW's type was determined using the NC *Third Approximation of Natural Communities* (Schafale and Weakley 1990) and/or *The Natural Communities of SC: Initial Classification and Description* (Nelson, 1986).

7. What is the condition and relative functioning provided by the IW? Rapid site evaluations were done for all IWs in the sample using both NC WAM (NC WFAT, 2008) and ORAM (Mack, 2001; metrics 1, 2, 3, 4, and 6).

8. What are the soil characteristics of the IW? Soil samples were taken in the center and midddle of each IW as well as on two upland sites adjacent to each IW. Soil samples were analyzed for

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[2] The Coastal Plain Supplement to the USACE manual was not available at the time the Level 2 assessments were conducted.

nutrients, texture, cation exchange capacity, and carbon. In addition, matrix color and field texture were recorded for the top soil horizon for the two wetland and two upland soil samples.

Digital photos of each IW were taken to document its condition. Any animals observed were noted on an appropriate field form along with dominant plant species found by strata (canopy, understory, etc.) and overall strata coverage.

Methods for each major element of the Level 2 field investigations are described below. Field forms used in the Level 2 analysis are located in **Appendix 2A**.

2.2.3.2 Access and Location of Candidate Polygons for Field Visits

Prior to visiting the site in the field, the boundaries of the selected candidate IW polygons were loaded into a GPS for navigation to the site in the field. In addition, available maps, including 1:24,000 USGS topographic maps, aerial photos, and county soil survey maps, were assembled to help the field team find each selected candidate IW polygon.

The selected candidate IW polygon sites were relatively accessible since the study area has a large number of roads that are accessible via four wheel drive. A few of the sites were not accessible due to locked gates, lack of roads, landowners denying access, or impenetrable vegetation. In those cases, an alternative candidate IW polygon with the same Level 1 likelihood to be an IW as the original selection (High, Medium, or Low) was taken from the oversample list to ensure that a representative sample was achieved.

Once in the field, the team members used the GPS-loaded locations and maps to locate the prospective IW. If an IW was present within 100 feet of the predicted location, then data from that IW was collected. If a non-isolated wetland was present within 100 feet of the predicted location, then the site was listed as a wetland that is not isolated. If no wetlands were present within 100 feet, the site was listed as not being wetland. The results of this assessment can be found in Part 1 of this report.

2.2.3.3 Delineation of Wetland Features

Upon arriving at the site of the candidate IW polygon, the team first determined if the site was a wetland by taking a series of soil cores and assessing the hydrology and presence of wetland vegetation within the polygon and up to 100 feet away. The boundary of the wetland was walked to determine if there was a surface hydrologic connection such as a ditch, pipe, or overland flow. If evidence of a surface connection was not found, then the wetland was determined to be isolated and the GPS coordinates were recorded. Sites that were determined to be an IW were delineated with a soil auger, Munsell soil chart and the 1987 USACE Wetland delineation manual (USACE, 1987) and the delineation was recorded on the GPS. For wetlands that were not isolated, the cause of the wetland’s lack of isolation (man-made or natural) was noted and later used along with hydric soil maps to determine whether the site was historically isolated or not. In addition, if the site was not isolated (i.e., hydrologically connected through a ditch, pipe, or overland flow), then the GPS coordinates of the site were recorded as a non-isolated wetland.

2.2.3.4 Wetland Depth and Volume

Average wetland depth, where available, was used along with area from the delineation to calculate wetland volume (volume = area × average depth). For 29 of the 47 sampled wetlands, average wetland depth was determined from the relative relief across the wetland with the use of two or more transects that were laid out to capture the contours of the wetland basin. In general, a transect was located along the longest axis of the wetland and then at least one additional transect was placed perpendicular to the original transect. Additionally, a measurement of the deepest depth was taken at all sites by taking a measurement of the lowest point and comparing it to a measurement taken in the surrounding upland.

Along each transect, depth was measured using a stadia rod and simple level. Average depth was calculated one of two ways, depending on whether the level and spotter remained in the same position for all readings along the transect or were moved due to an obstruction in the line of sight.

1. Average depth for transects with one location for level and spotter. The relative depth of each individual measurement along a transect was calculated by comparing it to the deeper of the two measurements taken at either end of the transect. Relative depth was calculated by subtracting the deepest of the two transect end measurements from each individual measurement taken along the transect. Any relative depth measurements that had a negative value were converted to zero. Stadia rod measurements taken at either end of the transect also had a zero relative depth value. The relative depth measurements taken from all transects were averaged to determine the relative average depth which was then used to calculate volume.

2. Average depth for transects with two or more locations for the level and spotter. The relative depth of each individual measurement along the transect was calculated by comparing it to the measurement taken at the same end of the transect that was surveyed by that level and spotter location. For example, for an 80m transect, if the first spotter location surveyed the stadia rod measurement at 0 m, 10 m, 20m, 30m and 40m and the second spotter location surveyed the stadia rod at 50m, 60m, 70m and 80m, then the readings for 10m, 20m, 30m and 40m would be compared to 0m and the readings for 50m, 60m, and 70m would be compared to the reading for 80m. Relative depths were calculated by subtracting correct transect end measurement from each individual measurement taken along the transect with that spotter location. Any relative depth measurement that had a negative value was converted to zero. Stadia rod measurements taken at either end of the transect also had a zero relative depth value. The relative depth measurements taken from all transects were averaged to determine the relative average depth which was then used to calculate volume.

In summary, wetland volume was determined by multiplying the average depth, where available, by the wetland area from the delineation. For the 18 IWs without an average depth, wetland volume was regarded as missing in the statistical data analysis, as discussed in Section 2.2.5.1.

2.2.3.5 Wetland Type

The type of each IW assessed in the study area was determined based on the different wetlands classification systems in use in North and South Carolina, including the Third Approximation in use in NC (Shafale and Weakley, 1990) and the Natural Communities of South Carolina (Nelson, 1986). **Table 2-4** compares and crosswalks these different wetlands classification systems for the IWs in the SEIWA study area, along with the classification systems used for NC Coastal Region Evaluation of Wetland Significance (NC CREWS; Sutter et al., 1999), and the NC Wetlands Assessment Method (NC WAM; NC Wetland Functional Assessment Team, 2008). Table 2-4 also shows the likelihood of each type being an isolated wetland, as determined by the NC and SC wetland scientists on the SEIWA team based on criteria (e.g., hydric soils, hydrologic isolation, wetland types, and USACE technical criteria) that operationally define a wetland as isolated. Although many of the wetland types in Table 2-4 may have common characteristics (e.g., hydric soils, forested cover), other characteristics, including vegetation and typical spatial extent, may be quite different.

Table 2-4. Isolated Wetland Types and Classifications for SEIWA Study Area

North Carolina Wetlands (Schafale and Weakley, 1990)	South Carolina Wetlands (Nelson, 1986)	NC CREWS (Sutter et al., 1999)	NCWAM	Potential to be Isolated[1]
Nonriverine Wet Hardwood Forest	Non-Alluvial Swamp Forest	Hardwood Flat	Basin Wetland	2
Nonriverine Swamp Forest	Non-Alluvial Swamp Forest	Pine Flat	Basin Wetland	2
Small Depression Pocosin (1)	Pocosin	Pocosin	Pocosin	2
Small Depression Pocosin (1)	Swale Pocosin (2)	Pocosin	Pocosin	2
Wet Pine Flatwoods	Pine Flatwoods (3)	Pine Flat	Basin Wetland	2
Cypress Savannah	Pond Cypress Savannah	Freshwater Marsh	Basin Wetland	3
Small Depression Pond (4)	Limestone Sink	Not Identified[2]	Basin Wetland	3
Small Depression Pond	Pond Cypress Pond	Depressional Swamp Forest	Basin Wetland	1
Pond Pine Woodland	Pond Pine Woodland	Pocosin	Pocosin	2
Vernal Pool	Swamp Tupelo Pond	Depressional Swamp Forest	Basin Wetland	1

[1] "1" is most likely to be isolated, "2" may be isolated, and "3" may be isolated rarely

[2] Not Identified Wetlands - wetland types that NC - Crews did not identify, or due to small size

(1) Small Depression Pocosins - Typically most pocosin vegetated IWs are small depression pocosins

(2) Swale Pocosins occur along the fall-line between parallel sand ridges, and are irregularly shaped.

(3) The SC "Pine Flat" is the closest SC crosswalk although this SC community was considered to be terrestrial uplands.

(4) Small Depression Ponds in NC are permanently flooded in the center and can be limesinks.

2.2.3.6 Rapid Wetlands Assessment

The Level 2 analysis involved field observations of wetland type, condition, and relative function in NC and SC using NC WAM (NC Wetland Functional Assessment Team, 2008) and the Ohio Rapid Assessment Method (ORAM; Mack, 2001).These rapid assessment ratings allowed us to make a general determination of the relative functioning of the wetland (as determined by NC WAM in terms of hydrology, water quality and habitat) and its condition (as determined by ORAM) through evaluation of various stressors in or around each wetland.

NC WAM is a rapid wetlands assessment method recently developed over a 5-year period by a wide range of cooperating wetland agencies, including the NC DWQ, USACE, U.S. EPA, the North Carolina Natural Heritage Program, the North Carolina Department of Transportation (NCDOT), the NC Division of Coastal Management (NC DCM), the North Carolina Ecosystem Enhancement Program, the North Carolina Wildlife Resources Commission, and the US Fish and Wildlife Service. NC WAM is an observationally based, qualitative method that uses comparisons to reference wetlands (where appropriate) to evaluate the relative functioning of each of 16 major types of wetlands in the state as either high, medium, or low for hydrology, water quality, and habitat, and then for overall function. NC WAM generates functional ratings for each assessed wetland through comparison with reference examples of the same wetland type only (in-kind functional assessment). This can give an indication of the level of function of an individual wetland based on and relative to its landscape position and level of disturbance. NC WAM has begun to be calibrated using intensive data collected on 34 headwater wetlands across the piedmont and coastal plain under the auspices of Wetland Program Development Grants issued by EPA to the NC Division of Water Quality. In addition, Level 3 data from a previous study, this study, and another study will be used to calibrate the method with respect measuring to the functions NC WAM is intended to represent.

Because NC WAM has been designed to be used for the evaluation of any wetland site, we used this method on all isolated wetland sites that were visited for this project and in order to collect enough data to characterize the functions of all types of isolated wetlands in North and South Carolina including the two most common isolated wetland types –basin wetlands and pocosins (as defined by NCWAM). Using the NC WAM method, each isolated wetland was then evaluated according to its NC WAM scores of hydrology, water quality, and habitat functions relative to reference wetlands.

In addition to NC WAM, the Level 2 wetland sites were assessed using ORAM for Wetlands (Mack, 2001) for comparative purposes. ORAM metrics 1, 2, 3, 4, and 6 were used because these metrics are applicable to NC wetlands (metric 5 was not used because it is specific to wetland types that are not found in the SEIWA study area). The goal of the ORAM rapid assessment was to obtain as much information about the condition of the IWs as possible in a relatively short time.

2.2.3.7 Soil Sampling

Soil quality, similarly to water quality, has been known to exhibit extensive variability between wetlands located in natural and urbanizing areas (Azous and Horner, 2001). Soil samples were taken in two locations in each isolated wetland (generally in the center and midway between the center and the boundary of the wetland) and in two other locations in the surrounding upland (usually on opposite edges of the wetland).

Soil samples were analyzed for nutrients, metals, sodium, pH, soil class, cation exchange capacity (CEC), and percent base saturation and humic matter after analysis by the State of North Carolina soil laboratory. In addition, soils were analyzed for total organic matter using a loss on ignition method by USC.

At each sampling location, a ~30 cm deep soil core was excavated with a 6-cm-diameter stainless steel auger. A soil descriptions was made for the A horizon. The horizon location (wetland or upland), matrix and mottle color, mottle (%) abundance, and texture was recorded. The Munsell Soil Color Charts (Munsell Color Company, 2000) were used to determine Hue, Value, and Chroma, and the “Soil Texture by Feel Flow Chart” (Brookings Institution, 2000) was used to determine texture. Information on hydric soil indicators was also noted. Natural Resource Conservation Service (NRCS) soil maps were used to determine soil map unit names, taxonomy, and drainage class. Approximately 0.5 kg of soil was collected from the A horizon (at approximately 10 cm depth). Samples were placed in labeled ziplock bags in the field. The North Carolina Agronomic Division, Soil Testing Section analyzed soil samples for the following parameters:

- Levels of major plant nutrients, including nitrogen, phosphorus, potassium, calcium, and magnesium
- Levels of plant micronutrients, including copper, manganese, sulfur, and zinc
- Levels of sodium
- pH and exchangeable acidity
- Soil class
- Percent base saturation
- Percent humic matter
- Cation exchange capacity and weight-to-volume ratio (bulk density).

See http://www.agr.state.nc.us/agronomi/stmethod.htm for further details on NC Agronomic Division lab analyses methods, including soil test methodologies and performance quantitation. The NC Soil Testing Lab follows performance standards listed in the National Soil Survey Handbook (http://soils.usda.gov/technical/handbook/).

In addition to these measurements, loss on ignition (LOI) analyses were conducted to measure soil organic matter by the University of South Carolina (USC) using a method similar to Konen et al. (2002) and Schulte and Hopkins (1996) except that samples were pre-dried at 58°C for at least 24 hours (instead of 105°C overnight) and combusted at 320°C for 8 hours (instead of 360°C for 2 hours). Soil samples were also analyzed by USC for phosphorus adsorption capacity. This analysis was done using methods described by Axt and Walbridge (1999). Briefly, adsorption isotherms were developed by equilibrating soil in solutions containing added KH_2PO_4. After centrifugation the supernatant was analyzed colorimetrically for soluble orthophosphate. Samples were also analyzed for oxalate-extractable iron and aluminum. These analyses were done at the University of South Carolina, but results were not available in time for this report.

Chain of Custody of Soil Samples

Soil samples for basic soil analysis. Soil samples were collected in the field and placed in zip lock bags labeled with the wetland site name and sample number. Samples were later transferred to sampling boxes labeled with contact information, site name and sample numbers. There is no hold time for soil samples. The soil sample boxes were then delivered to the Agronomic Division, Soil Testing Section in Raleigh, NC. The procedures followed the Soil Testing Section Lab's "Sample collection and packaging guidelines" specified in at http://www.agr.state.nc.us/agronomi/uyrst.htm.

Soil samples for phosphorus adsorption capacity. Soil samples were collected in the field and placed in zip lock bags labeled with the wetland site name and sample number. There is no holding time for soil samples. The soil samples were delivered to USC for analysis using collection and handling procedures similar to those found in the North Carolina Soil Testing Section Lab's "Sample collection and packaging guidelines" specified in at http://www.agr.state.nc.us/agronomi/uyrst.htm.

2.2.3.8 Biological Data

The dominant plant species in the canopy and understory, shrub and sapling, and herb strata were recorded for each site. The overall coverage for each vegetation stratum was also recorded. Any visual or auditory observations of wildlife or signs of wildlife such as tracks or scat were also noted. Wildlife observations included mammals, birds, reptiles, and amphibians.

2.2.3.9 Timing of Field Work

All field work was completed in the summer and fall of 2008 with some limited additional assessment done in the summers of 2009 and 2010. The following schedule was followed for the Level 2 data collection:

- North Carolina
  - Bladen County – August 21- 22, 2008; September 16 -19, 2008;
  - Brunswick County- July 21 – 25, 2008; December 11 and 16, 2008;
  - Columbus County – August 7 – 8, 2008; August 18 – 20, 2008; August 29, 2008
  - Robeson County – October 13 – 17, 2008;
- South Carolina
  - Dillon County – December 8 – 10, 2008;
  - Florence County – September 8 – 12, 2008; September 15, 2008; September 18, 2008;
  - Horry County – October 28-31, 2008; November 3-7, 2008;
  - Marion County- August 25- 28, 2008.

2.2.4 Data Management and Quality Control

Quality control for the Level 2 field assessments was based on the expertise of the field team leaders, training of field staff, and review of field data forms for completeness, accuracy, and consistency. The Principal Investigators for this project (Mr. John Dorney and Dr. Dan Tufford) coordinated joint site visits and shared methods in order to harmonize the field data collection methods prior to beginning field work. Each wetland delineation and assessment was reviewed by a wetlands expert for reasonableness and accuracy. All field work was done in teams of at least two scientists always including either John Dorney, Dan Tufford, Rick Savage, or Virginia Baker. This ensured that an experienced wetland field ecologist supervised each Level 2 assessment. Decisions in the field were by consensus of the supervisor(s) and trained field team. All NC WAM evaluations were made by individuals who had completed the four day NC WAM class.

All original field datasheets were maintained, scanned, and archived in the electronic and hard copy project records. As QA coordinator for the SEIWA project, Kim Matthews at RTI was responsible for assuring that all data transfers and analyses were accurately done. Transfer of all field information to project data systems and reports was checked for correct entry. Any changes to original data entry were documented. In addition, all data were checked by a different team member after data entry and any discrepancies were reconciled by referring to the original field sheets.

2.2.5 Statistical Data Analysis

This section describes the statistical methods used to analyze the Level 2 data and produce the estimates of IW occurrence and ecological characteristics for the SEIWA study area.

2.2.5.1 Sampling weights

Sampling weights were used to estimate statistics from sampled units (i.e., candidate IW polygons) with respect to the population targeted in this project. The ***study population*** is the collection (list) of candidate IW polygons identified in the ***GIS model map*** generated in Level 1 (see Part 1 of this report).

Non-response issues were present in this study. Bias in sample selection from frame coverage issues (e.g. multiple IWs found in one site, non-wetland features instead of a wetland) and non-responses (i.e., inaccessible sites) were observed during the field verification, so the sampling weights were adjusted for bias and non-response in the sample selection.

The process of creating analysis weights generally consisted of three steps: calculation of design weights, adjustments for non-response, and adjustments for coverage bias. The final analysis weights were the product of the design weights and any adjustment factors. Adjustment for coverage bias, through post-stratification adjustments or “raking”, forced the marginal distributions of sampling units weighted by non-response adjusted weights to match some known distribution totals. For example, the sum of the analysis weights of sites in a given county was constrained to be equal to the total number of polygons in that county.

Frame imperfections were uncovered by the field work included instances where the population frame (GIS model map) did not include all the polygons that represent IWs (undercoverage) at a site (i.e., several IWs were found in one polygon), and cases where candidate IW polygons were not IW (overcoverage, e.g., where a polygon was a pond). Inaccessible sites were not excluded from the calculation of marginal distributions when adjusting for frame imperfections, but ineligibles (e.g., ponds instead of IWs) were excluded.

Non-response adjustment of sample weights

The procedure of adjusting sample weights for missing data (e.g., inaccessibility) is a common practice in most surveys. Essentially, the adjustment transfers the base weights of all eligible non-responding sampled units (e.g. inaccessible sites) to the responding units (e.g. accessible sites), and is implemented in the following steps:

- Calculate the initial sampling weights, w_{1i}, as the product of the probability of selecting a HUC within a county times the probability of selecting a candidate IW polygon within each of the stratum (high, medium, and low likelihood of being IWs).
- Partition the sample into subgroups (e.g. counties) and compute weighted response rates, r_i , for each subgroup.
- Use the reciprocal of the subgroup response rates for non-response adjustments (i.e., $w_{2i} = \frac{1}{r_i}$).
- Calculate the non-response adjusted weight for the i-th sampling unit as: $w_i = w_{1i} \times w_{2i}$ where w_{1i} is the initial weight and, w_{2i} is the non-response adjustment weight.

Definitions used in weight adjustment for non response include:

n = sample size
n_{op} = number of selected candidate IW polygons that were accessed
n_{rp} = number of replacement candidate IW polygons that were accessed
n_{nr} = number of non accessed (non response) candidate IW polygons (neither the originally selected candidate IW polygons nor their replacements were accessed)

Note that the following equation holds: $n = n_{op} + n_{rp} + n_{nr}$.

The candidate IW polygons final sampling weights were calculated for sampled sites originally selected and replacement sites that were visited.

Non response (NR) adjustment was calculated as:

$$NR = \frac{n}{n_{op} + n_{rp}} = w_{2i}$$

Post-stratification forcing to maintain the total number of HUCs and candidate IW polygons.

The probabilities of selecting a HUC within each county were adjusted so the corresponding weights added to the total number of HUCs in each county, and the total number of HUCs in each state. The final adjusted total weights were summed up to the total of candidate IW polygons in each county. In addition, the final total weights by county were also adjusted to the total population of candidate IW polygons at the state level.

2.2.5.2 SAS and SUDAAN analysis

Data management, manipulation, and statistical analysis were performed using SAS ® and SUDAAN®. Designed and developed at RTI International, SUDAAN® is an internationally recognized statistical software package that specializes in providing efficient and accurate analysis of data from complex studies. SUDAAN is ideal for the proper analysis of data from surveys and experimental studies, since SUDAAN procedures properly account for complex design features, such as correlated observations, clustering, weighting, and stratification.

2.2.5.3 Accuracy Assessment

The methods for determining the accuracy of the SEIWA Level 1 assessment are described in Section 1.4.3 of Part 1 of this report; error matrices are provided in Appendix 1D of Part 1. The estimates for the accuracy rates used in this analysis are as follows.

- For the entire study region, 22% of the candidate IW polygons from the GIS model were correctly determined as IWs and 75% of those that had medium and low likelihood of being IWs were correctly predicted as non IWs. 69% of the candidate IW polygons were determined to be wetlands (isolated or not).
- For North Carolina, 35% of the candidate IW polygons from the GIS model were correctly determined and 75% of those that had medium and low likelihood of being isolated wetlands were also correctly predicted as non IWs.
- For South Carolina, 13% of the candidate IW polygons from the GIS model were correctly determined and 69% of those that had medium and low likelihood of being IWs were also correctly predicted as non IWs.

These error rates were used to adjust the results described in the following sections.

2.3 Results

The Level 2 assessment was designed to provide a better understanding of IW occurrence and relative significance in the landscape of the study area. By extending the Level 2 results to the population of isolated wetlands, the statistical methods used in the SEIWA analysis provide valuable information about the IW resource in the outer coastal plain of North and South Carolina, in terms of their numbers, acreage, water storage volume, soil characteristics, ORAM condition, and NC WAM relative function individually and in the landscape. This information should be of practical use to wetland regulators and resource managers in NC and SC by providing a better understanding of the resource that they are managing.

As discussed in Part 1 and in Section 2.2.5.3, the Level 1 methodology had a 22% accuracy in determining the whether a candidate IW polygon was actually an IW. This resulted in 44 IW sites that were evaluated using the Level 2 methods described in Section 2.2 to generate the results described in this section. **Attachment A** to this report tabulates these sites and some of their basic characteristics, and includes a map of each IW showing the original candidate IW polygon and the field wetland delineation (as recorded using field GPS) over a recent aerial photograph taken from Google Earth.

Table 2-5 lists the Level 2 IW sites, their basic wetland land cover and adjacent landcover (as observed in the aerial photographs), and areas as measured by GIS and in the field delineations. Almost all (95%) of the Level 2 SEIWA IWs are forested, most are adjacent to forested and agricultural lands and about 40% are surrounded by active silviculture (as evidenced by trees planted in rows). A few are near major roads and residential areas. Level 2 IW site counts in the study area counties are: Bladen (4), Brunswick (8), Columbus (6), Dillon (1), Florence (3), Horry (10), Marion (3), and Robeson (7), roughly reflecting the sample proportions previously shown in Table 2-3. The percent difference between the GIS areas of the IW polygons and the areas measured in the Level 2 field delineations ranged from 10 to 196 percent, with the Level 1 sink polygons generated using GIS underestimating actual IW acreage at most sites.

Table 2-5. Land Cover and GIS and Field Acreages for SEIWA Isolated Wetlands Sample

ID	Wetland Land Cover[1]	Adjacent Land Cover[1]	Field Acres	GIS Acres	Area Percent Difference[2]
Bladen County, NC					
BL-05	Forest	Forest	0.19	0.54	100
BL-13	Forest	Silviculture	0.46	0.39	19 (-)
BL-15	Forest	Silviculture	20.9	0.23	196 (-)
BL-22	Forest	Forest, agriculture	1.4	0.56	86 (-)
Brunswick County, NC					
BR-04	Clearcut	Silviculture	0.49	0.20	83 (-)
BR-05	Forest, pocosin	Forest, agriculture	1.78	0.37	132 (-)
BR-07	Forest	Forest, agriculture	0.83	0.06	87 (-)
BR-09	Forest	Silviculture	1.22	0.61	67 (-)
BR-10	Forest	Silviculture	0.02	0.12	143
BR-17	Forest	Forest, residential	0.1	0.12	18
BR-19	Forest	Silviculture	0.6	0.23	89 (-)
BR-26	Forest	Silviculture	0.45	0.59	27
Columbus County, NC					
CO-01	Forest	Forest, agriculture	0.13	0.06	68 (-)
CO-04	Forest	Silviculture	1.27	0.06	181 (-)
CO-11	Forest	Silviculture	0.03	0.06	73
CO-20	Forest	Silviculture	0.25	0.09	93 (-)
CO-24	Forest	Forest, agriculture	5.51	0.07	195 (-)
CO-26	Forest	Forest, agriculture	0.445	0.06	150 (-)

ID	Wetland Land Cover[1]	Adjacent Land Cover[1]	Field Acres	GIS Acres	Area Percent Difference[2]
Dillon County, SC					
DI-09	Forest, clearcut	Forest, clearcut	0.48	0.67	33
Florence County, SC					
FL-12	Forest	Forest	5.43	3.11	54 (-)
FL-14	Forest (cyprus)	Forest, agriculture	10.18	0.22	191 (-)
FL-18	Forest	Forest, agriculture	3.31	0.44	153 (-)
Horry County, SC					
HO-04	Forest	Forest, agriculture	0.55	0.63	14
HO-18	Forest	Forest, agriculture	1.58	1.16	31 (-)
HO-19	Forest	Forest, silviculture	0.95	0.13	151 (-)
HO-22	Forest	Forest, agriculture	0.5	0.08	145 (-)
HO-28	Forest	Sewage treatment plant	0.17	0.34	66
HO-29	Forest	Forest, road	0.029	0.43	175
HO-32	Forest	Forest, residential	0.29	0.23	23 (-)
HO-35	Forest	Forest, residential, golf	0.76	0.41	60 (-)
HO-41	Forest	Commercial	0.81	0.13	143 (-)
Marion County, SC					
MA-02	Forest	Silviculture	2.33	-	-
MA-03	Forest	Silviculture	0.0365	-	-
MA-07	Forest	Silviculture	1.85	-	-
Robeson County, NC					
RO-01	Forest	Silviculture, agriculture	2.94	1.07	94 (-)
RO-04	Forest	Silviculture	2.79	1.36	69 (-)
RO-07	Forest	Forest, agriculture	3.76	2.98	23 (-)
RO-10	Forest	Clearcut, agriculture	0.27	0.74	93
RO-13	Forest	Forest, agriculture	1.28	1.02	23 (-)
RO-19	Forest (vernal pool)	Forest, agriculture	0.39	0.43	10
RO-22	Forest	Forest, agriculture	0.45	0.77	53

[1] As observed on air photos (see Attachment 2-A).

[2] (-) indicates IWs where the GIS acreage estimates is less than the delineated field acreage.

2.3.1 Wetland Type and Hydrogeomorphic Setting

As noted in Section 2.2.3.5, NC and SC use different classification systems for natural communities. A crosswalk was developed between these systems (see Table 2-4) to allow comparison of wetland types across the study area. As can be seen in the population estimates in **Table 2-6**, for the NC Third Approximation types, five types make up 94% of the total IWs: small depression ponds (29% + 1% = 30%), wet pine flatwoods (24%), nonriverine wet hardwood forest (19%), small depression pocosins (14%), and nonriverine swamp forest (7%). Using the SC Natural Communities types, four types made up 93% of the total IWs: pond cypress ponds (23%), pine flatwoods (19%), non alluvial swamp forest (14% +

6.7% = 21%), and pocosins (8%). NC and SC showed similar distributions in wetland types although the SC sites showed a greater number of vernal pools (11%) and cypress savannahs (4%). Overall most IWs were forested ecosystems and many were relatively small depressional features in the study area landscape. Section 2.3.5 provides additional discussion of the IW types in the SEIWA study and the vegetative communities and habitats they support.

Table 2-6. SEIWA Isolated Wetland Types and Proportions (numbers) In the Study Area

Area Domain	Third Approximation (NC)	Natural Communities SC	Percent of IWs	SE Percent of IWs
Study Area	Small Depression Pond	Pond Cypress Pond	29	23
Study Area	Wet Pine Flatwoods	Pine Flatwoods	24	19
Study Area	Nonriverine Wet Hardwood Forest	Non Alluvial Swamp Forest	19	14
Study Area	Small Depression Pocosin	Pocosin	14	8.0
Study Area	Nonriverine Swamp Forest	Non Alluvial Swamp Forest	6.7	6.7
Study Area	Vernal Pool	Swamp Tupelo Pond	3.4	1.7
Study Area	Small Depression Pocosin	Swale Pocosin	1.4	1.5
Study Area	Small Depression Pond	Limestone Sink	0.94	0.97
Study Area	Cypress Savannah	Pond Cypress Savannah	0.67	0.57
Study Area	Pond Pine Woodland	Pond Pine Woodland	0.33	0.29
NC	Small Depression Pond	Pond Cypress Pond	32	26
NC	Wet Pine Flatwoods	Pine Flatwoods	23	21
NC	Nonriverine Wet Hardwood Forest	Non Alluvial Swamp Forest	18	16
NC	Small Depression Pocosin	Pocosin	15	9.1
NC	Nonriverine Swamp Forest	Non Alluvial Swamp Forest	7.7	7.8
NC	Vernal Pool	Swamp Tupelo Pond	2.3	1.5
NC	Small Depression Pocosin	Swale Pocosin	1.6	1.7
NC	Pond Pine Woodland	Pond Pine Woodland	0.38	0.34
NC	Cypress Savannah	Pond Cypress Savannah	0.17	0.18
SC	Wet Pine Flatwoods	Pine Flatwoods	28	12
SC	Nonriverine Wet Hardwood Forest	Non Alluvial Swamp Forest	25	11
SC	Small Depression Pond	Pond Cypress Pond	14	11
SC	Small Depression Pocosin	Pocosin	11	8.2
SC	Vernal Pool	Swamp Tupelo Pond	11	8.0
SC	Small Depression Pond	Limestone Sink	7.2	7.3
SC	Cypress Savannah	Pond Cypress Savannah	4.0	3.9

SE = standard error

IW hydrogeomorphic setting was measured in terms of the geomorphic units (GMUs) that characterize the SEIWA study area. As can be seen in the population estimates in **Table 2-7**, almost all (99%) of the IWs in the SEIWA study area occur on the marine terraces that define the basic geomorphology and hydrogeology of the SEIWA study area. Moving away from the coast, and from youngest to oldest, these are the late Pleistocene Socastee GMU (Qs, 28% of IWs), the middle Pleistocene Penholoway GMU (Qph, 22%), the early Pleistocene Waccamaw GMU (Qw, 9%), the late Pliocene Bear Bluff GMU (Tb, 22%), and the early Pliocene Duplin GMU (Td, 19%). Much smaller numbers of IWs were found on the Holocene floodplain GMU (Qh, 0.31%) and the late Pleistocene Wando floodplain GMY (Qwa, 0.22%), as would be expected as floodplain wetlands are most likely to be hydrologically connected and not isolated. Regardless of type the IWs in the study area have a very consistent hydrogeologic setting as depressional features on the marine terraces that make up the southeast coastal plain.

Table 2-7. Hydrogeomorphic Settings for the SEIWA Isolated Wetlands

Geomorphic Unit	Symbol	Deposit Age/Period	Percent	SE Percent
Pleistocene/Pliocene Marine Terraces				
Socastee	Qs	Late Pleistocene	28	8.6
Penholoway	Qph	Mid-Pleistocene	22	7.9
Waccamaw	Qw	Early Pleistocene	9	5.1
Bear Bluff	Tb	Late Pliocene	22	7.3
Duplin	Td	Early Pliocene	19	7.7
Late-Quaternary Floodplains				
Holocene	Qh	Holocene	0.31	0.24
Wando	Qwa	Late Pleistocene	0.22	0.22

SE = standard error

2.3.2 Wetland Occurrence, Size, and Extent

This section describes the numbers, size (area), and geographic extent of IWs in the study region. As described in Part 1, the most significant bias in the Level 1 analysis was from the unavailability of LiDAR data for Dillon, Florence, and Marion counties in SC. To see the effects of this bias we present the results in two ways, (1) by state and the overall study area and (2) by the LiDAR and non-LiDAR county domains.

Because of the significant undercount in the non-LiDAR counties, the estimates for the LiDAR and NC county domains provides the best unbiased estimates available at this time for many of the variables described in this report. Estimates for SC and the eight-county study area are likely biased low, in terms of wetland numbers and high in terms of wetland size (because the 30m hypsography data cannot detect the smaller IWs), and are presented in shaded italics in the tabulated estimates below. We are considering ways of correcting for this error to allow for more accurate estimators of IW characteristics in SC and the entire study area (for example, LiDAR data has recently become available for Marion County[3]). In lieu of that, we have extended the estimates for the LiDAR counties to the entire study area by applying simple ratios based on county area. This is defensible as IWs in the study have very similar geomorphic, biological, and cultural characteristics across the entire study region.

About half of the candidate IW polygons in the field sample were found to be wetlands that were not isolated because of ditches or other drainage swales that connect the wetlands to downgradient water bodies. The field team looked at each of these sites in terms of whether they were historically isolated, and in most cases they were. Although they were not fully assessed, we do include estimates of this

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[3] http://www.csc.noaa.gov/crs/tcm/ldartdat/metatemplate/sc2008_marion_template.html

portion of the study population where we can as they appear to be similar in form, occurrence, and biota to IWs, and should perform similarly to true IWs in terms of ecological benefits.

Table 2-8 shows the estimate of the number and density (wetlands/mi^2) and of IWs and non-IWs for the study area. (Non-IWs represent candidate IW polygon features that were not wetlands – which ponds, pits, ditches, and other depressions in landscape that were not wetland features.) For NC and SC the IW estimates are almost 30,000 and 4,400 respectively, reflecting the previously discussed bias for the SC non-LiDAR counties. This bias is more apparent in the LiDAR and non-LiDAR estimates (33,000 versus 1,800). This bias is also evident in wetland density, with 8.3 wetlands per square mile in NC, 6.8 wetlands per square mile for the LiDAR counties, but only 1.1 wetlands per square mile in the non-LiDAR counties.

Table 2-8. Estimated Number and Area Density of Isolated Wetlands in SEIWA Study Region

SEIWA Area Domain	Candidate IW Polygons	Isolated Wetlands	Non-Isolated Wetlands	Non-Wetlands
Number				
North Carolina	118,142	29,849	34,965	53,328
South Carolina	*20,285*	*4,464*	*11,669*	*4,152*
LiDAR Counties[1]	131,722	32,507	43,615	55,601
Non-LiDAR Counties[2]	*6,705*	*1,806*	*3,020*	*1,879*
South Carolina (est.)[3]	92,747	21,884	34,662	
Study Area (est.)[4]	210,889	51,733	69,627	
Percent				
Study Area	100	25	34	42
North Carolina	100	25	30	45
South Carolina	100	22	58	20
LiDAR Counties[1]	100	25	33	42
Non-LiDAR Counties[2]	100	27	45	28
Area Density (feature/mi^2)				
North Carolina	33	8.3	9.7	
South Carolina	*7.2*	*1.6*	*4.1*	
LiDAR Counties[1]	28	6.8	9.2	
Non-LiDAR Counties[2]	*4.0*	*1.1*	*1.8*	

[1] Bladen, Brunswick, Columbus, Robeson (NC); Horry (SC)
[2] Dillon, Florence, Marion (SC)
[3] Estimated using adjusted counts using LiDAR wetland/polygon densities for non-LiDAR counties
[4] North Carolina + estimated South Carolina[3]
Italics and shading indicate estimates based on non-LiDAR topographic data (probable low bias)

To correct for this bias we estimated the number of IWs in the non-LiDAR SC counties using the IW density from the LiDAR counties multiplied by the area of each non-LiDAR county. This gives an estimate of almost 22,000 IWs in SC, about 30,000 IWs in NC and almost 52,000 in the eight-county study area. For the non-IWs, the counts are over 34,000 in SC, 36,000 in NC and almost 70,000 for the study area. It is clear from these data that IWs are numerous in the SEIWA study area, and that small wetlands, isolated or not, are more numerous.

Isolated wetlands in the study area were relatively small (**Table 2-9**) with a mean size of 0.77 acres for the study area and 0.68 acres in NC and 1.4 acres in SC, and median sizes of 0.41 acres (study area), 0.40 acres (NC), and 0.52 acres (SC). The higher values in SC may be a result of the lack of LiDAR data as discussed earlier; for all LiDAR counties the mean and median sizes were 0.68 and 0.41 acres while the mean and median acreages were 2.4 and 0.48 for the non-LiDAR counties. Therefore the most likely mean size for isolated wetlands in the study area is probably 0.68 acres (median of 0.41 acres). IW sizes for the LiDAR data ranges from 0.002 acres to 21 acres. Generally as the size of a wetland polygon increases, it becomes more likely that the wetland is no longer isolated due to relict or active ditching.

Table 2-9. Average, Median, and Range of Individual IW Area (acres) by SEIWA Area Domain

SEIWA Area Domain	Min	Max	Mean	Median
Original Study Area				
Study Area (all counties)	*0.002*	*21*	*0.77*	*0.41*
NC (Bladen, Brunswick, Columbus, Horry)	0.019	21	0.68	0.40
SC (Dillon, Florence, Horry, Marion; inland)	*0.002*	*10*	*1.4*	*0.52*
LiDAR and Non-LiDAR Counties				
LiDAR Counties (Bladen, Brunswick, Columbus, Horry, Robeson)	0.002	21	0.68	0.41
Non-LiDAR Counties (Dillon, Florence, Marion)	*0.029*	*10*	*2.4*	*0.48*
Coastal and Inland Counties (LiDAR only)				
Coastal (Brunswick, Horry)	0.002	1.8	0.38	0.32
Inland (Bladen, Columbus, Robeson)	0.032	21	1.5	0.24

Area estimates with non-LiDAR results, shown in italics, are likely biased high.

In addition, there appears to be a real difference in isolated wetland size between coastal counties (mean size of 0.38 acres) and inland counties (mean size of 1.5 acres) using the LiDAR data.

Data from the non-LiDAR counties show a significantly lower total IW acreage than the LiDAR counties (**Table 2-10a**), reflecting the previously discussed underestimate of the percentage of wetlands in the study area that are isolated. For the LiDAR counties there were 4.7 IW acreage per square mile, compared to 2.6 IW acreage per square mile for the non-LiDAR counties. For the LiDAR counties, coastal IW acreage per square mile was 4.5 versus 4.8 for inland counties. The latter value was used to correct the non-LiDAR county (which are all inland) IW acreage, for an estimate of about 30,000 acres of IW, compared to 26,000 acres using the non-LiDAR data.

IWs made up a very small percentage of the estimated total freshwater wetlands in the study area and in each state (**Table 2-10b**). Estimates of total wetland acreage were determined by using the NC CREWS data (Sutter et al., 1999) in Bladen, Brunswick, and Columbus Counties in NC and the National Wetland Inventory (NWI) data (U.S. FWS, 2008) in the remaining counties. The estuarine wetlands were excluded from these totals as were ponds (PUB) from the NWI data in order to estimate the acreage of freshwater wetlands in the study area. Overall (based on LiDAR data), about 1.9% of the total freshwater wetlands were found to be isolated. There was little difference between coastal counties (average 1.7%) and non-coastal counties (2.1%) using LiDAR data. This overall low percentage of isolated wetlands is consistent with the permitting data from the NC Division of Water Quality whose BIMS (Basinwide Information Management System) data from 2002 to 2010 show that 1 to 2 % of the total permits were issued to isolated wetlands as compared to non-isolated wetlands (John Dorney, NC Division of Water Quality, personal communication, November 22, 2010).

Table 2-10a. Total IW Acreages and IW Acreage per Square Mile

Area Domain	Total Area (sq miles)	IW acreage	IW acres/ sq. mile
LiDAR Counties	4,749	22,111	4.66
Non-LiDAR Counties	1,694	*4,373*	*2.58*
Coastal Counties (LiDAR)	1,989	8,864	4.46
Non-coastal LiDAR Counties	2,761	13,247	4.80
Non-LiDAR Counties (estimated)	1,694	8,128	4.80
Study Area (w/non-LiDAR data)	6,443	*26,484*	*4.11*
Study Area (estimated)	6,443	30,239	4.69

IW area estimates with non-LiDAR results, shown in italics, are likely biased low.
Estimated study area IW acreage using wetland area density from LiDAR counties.

Table 2-10b. Total IW Acreage and Percent IWs in Several SEIWA Area Domains

SEIWA Area Domain	Total IW Acres	Standard Error	Total Wetland Acres^1	Percent IWs
Original Study Area				
Study Area (all counties)	*26,484*	*11,646*	*1,573,973*	*1.7%*
NC (Bladen, Brunswick, Columbus, Robeson)	20,331	11,260	904,811	2.2%
SC (Dillon, Florence, Horry, Marion)	*6,153*	*2,974*	*669,162*	*0.9%*
LiDAR/Non-LiDAR Counties				
LiDAR (Bladen, Brunswick, Columbus, Horry, Robeson)	22,111	11,306	1,162,748	1.9%
Non-LiDAR (Dillon, Florence and Marion)	*4,373*	*2,793*	*411,225*	*1.1%*
Coastal/Inland Counties (LiDAR only)				
Coastal Counties (Brunswick, Horry)	8,864	4,504	523,455	1.7%
Inland Counties (Bladen, Columbus, Robeson)	13,247	10,370	639,293	2.1%

Total area estimates with non-LiDAR results, shown in italics, are likely biased low.

[1] Wetland acreage derived by totaling NC CREWS (Bladen, Brunswick, Columbus) acreage minus estuarine and marine wetlands or by totaling NWI (Robeson and SC counties) acreage minus estuarine and ponds (PUB).

2.3.3 Wetland Depth, Volume, and Water Storage

IWs can potentially store surface water in the study area mainly because of their bowl-shaped configurations. As described in Section 2.2.3.4, maximum surface water storage was calculated as a function of IW area and average IW depth, with average depth being measured on a transect or estimated from maximum depth using an empirical relationship derived from the IW sites where both measurements were available. The IW depth estimates (**Table 2-11**) show that the IWs are relatively shallow features, with average IW depths (i.e., mean depth across the wetland) ranging from 0.03 to 2 feet across the study area and an overall average depth of 0.4 meters. The IWs ranged from 0.4 to 7 feet deep at their deepest point, with an average maximum depth of about 2 feet.

Table 2-11. Average IW Depth in SEIWA Study Area

SEIWA Area Domain	Min	Max	Mean	StdErr
Average Depth per Isolated Wetland (feet)				
Study Area	0.03	1.9	0.41	0.19
NC	0.03	0.92	0.41	0.21
SC	0.07	1.9	0.42	0.04
Maximum Depth per Isolated Wetland (feet)				
Study Area	0.37	6.9	2.0	0.33
NC	0.43	3.0	2.0	0.38
SC	0.37	6.9	1.8	0.26

With respect to storage volume (**Tables 2-12** and **2-13**), the LiDAR and non-LiDAR counties showed great differences which (as before) reflects the greater resolution of IWs in the LiDAR counties. In the five LiDAR counties, this study estimated that these wetlands could store a total of almost 3,900 acre-feet of water. The two coastal counties with LiDAR data (Brunswick and Horry) are estimated to be able to store a great deal more water (3,100 acre-feet) than the non-coastal counties with LiDAR data (720 acre-feet). This reflects the greater depth an larger storage volume per IW in the coastal counties (mean storage of 0.25 acre-feet per IW) than in the non-coastal LiDAR counties (mean of 0.11 acre-feet of storage per IW).

Because data on water storage for other wetlands in the study area are not available, it is not possible to directly compare the water storage of these IWs with other wetlands in the landscape of our study area. However it is clear that these IWs do store surface water on the landscape and if they were allowed to be filled in or drained this storage would not be available. Based on prior studies of the regional hydrogeology and groundwater-surface water interactions in the study area (e.g., Riggs et al., 2005; Harden et al., 2003; Pyzoha et al., 2008), the most likely contribution of the water stored in IWs in the study area is to recharge local groundwater which in turn provides stream flow to down-gradient wetlands and other waterbodies that intersect the water table. This function of IWs is the main focus of the Level 3 study of clusters of IWs as well as the other long-term monitoring of IWs being studied under another EPA wetland grant. Preliminary results of that work will be discussed in the Part 3 of this report.

Table 2-12. Average, Median, and Range of IW Storage Volume in Acre-feet for Several SEIWA Area Domains

	Storage Volume per IW (acre-feet)			
SEIWA Area Domain	**Min**	**Max**	**Mean**	**Median**
Original Study Area				
Study Area	0.003	3.4	0.20	0.15
NC	0.003	3.4	0.19	0.15
SC	0.014	1.4	0.26	0.20
LiDAR/Non-LiDAR Counties				
Bladen, Columbus, Robeson, Brunswick, Horry	0.003	3.4	0.20	0.15
Dillon, Florence, and Marion	0.014	0.48	0.19	0.09
Coastal and Inland Counties (LiDAR only)				
Coastal Counties (Brunswick, Horry)	0.011	1.4	0.25	0.33
Inland Counties (Bladen, Columbus, Robeson)	0.003	3.4	0.11	0.04

Table 2-13. Total Volume of Water (acre-feet) Stored by IWs in Several SEIWA Area Domains

	Total Volume Stored by IWs	
SIEWA Area Domain	**Total (acre-feet)**	**Standard Error**
Original Study Area		
Study Area	*4,126*	*2,572*
NC	3,596	2,563
SC	*530*	*220*
LiDAR and Non-LiDAR Counties		
LiDAR Counties (Bladen, Brunswick, Columbus, Horry, Robeson)	3,897	2,569
Non-LiDAR Counties (Dillon, Florence and Marion)	*229*	*137*
Coastal and Inland Counties (LiDAR only)		
Coastal Counties (Brunswick, Horry)	3,108	2,539
Inland Counties (Bladen, Columbus, Robeson)	790	392

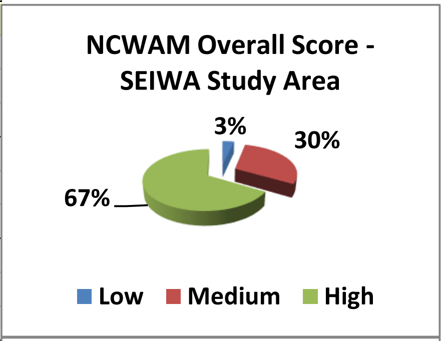
Total storage volume estimates with non-LiDAR results, shown in italics, are likely biased low.

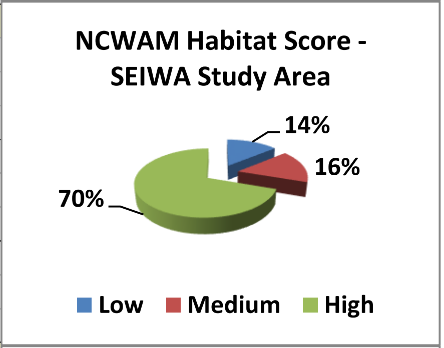
2.3.4 Wetland Rapid Assessment Results: Relative Function and Condition

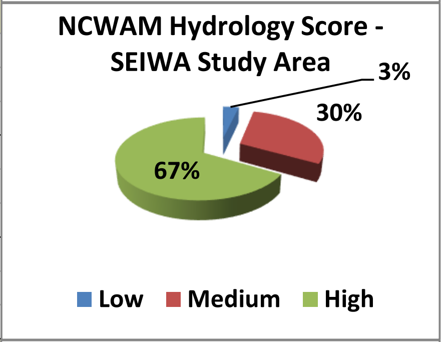
Table 2-14 provides the NC WAM scores for the IW hydrology, water quality and habitat in the study area. In terms of overall NC WAM score, only 3.6% of the wetlands were rated low, 30% were rated medium, and 67% were rated high. With respect to the individual NC WAM scores, habitat had the lowest scores with a low rating for 14% of the sites, followed by water quality at 12%. The ORAM condition scores did not correlate well with the NC WAM scores (Chi square test = 0.79, p value = 0.58). For the ORAM scores, 14% were in the lowest third of the ratings, 81 % were in the middle tier and 4.4% were in the highest tier (**Table 2-15**). Therefore in general, it appears that at least 90% of the IWs in the study area are in fairly good condition and are have high to medium NC WAM scores for hydrology, water quality and habitat.

Table 2-14. NCWAM Scores by Study Area and State

SEIWA Area Domain	NCWAM Score	Percent	SE Percent
NCWAM Overall Score			
Study Area	Low	3.6	3.6
Study Area	Medium	30	16
Study Area	High	67	16
NC	Low	4.2	4.2
NC	Medium	26	18
NC	High	69	18
SC	Low	0	0
SC	Medium	51	11
SC	High	49	11
NCWAM Habitat Score			
Study Area	Low	14	8
Study Area	Medium	16	13
Study Area	High	70	16
NC	Low	13	9
NC	Medium	16	15
NC	High	71	18
SC	Low	20	12
SC	Medium	19	8.73
SC	High	62	14
NCWAM Hydrology Score			
Study Area	Low	3.6	3.6
Study Area	Medium	30	16
Study Area	High	67	16
NC	Low	4.2	4.2
NC	Medium	26	18
NC	High	69	18
SC	Low	0	0
SC	Medium	51	12
SC	High	49	12
NCWAM Water Quality Score			
Study Area	Low	12	8.0
Study Area	Medium	37	21
Study Area	High	51	20
NC	Low	13	9.4
NC	Medium	36	24
NC	High	50	23
SC	Low	0	0
SC	Medium	42	13
SC	High	58	13







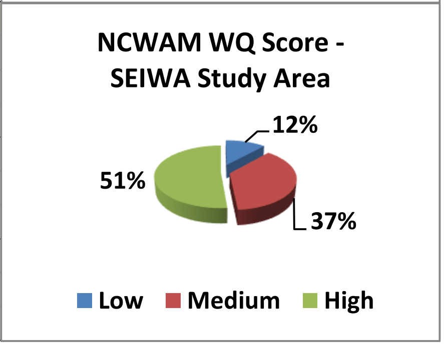
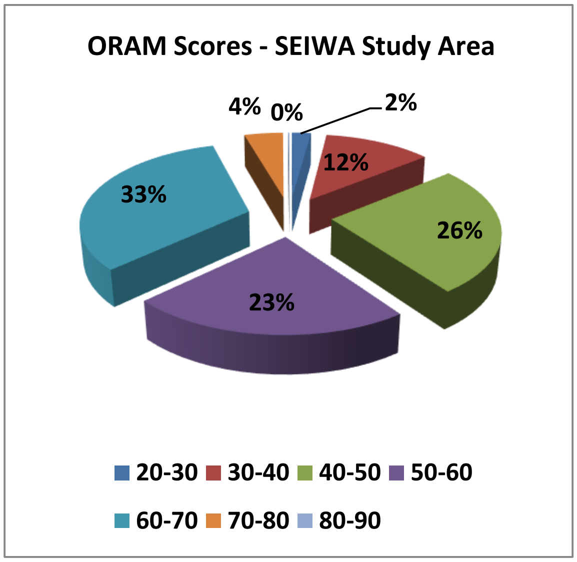


Table 2-15. ORAM Scores by Study Area and State

SEIWA Area Domain	ORAM Score	Percent	SE Percent
Study Area	20-30	2.1	1.7
Study Area	30-40	12	8.1
Study Area	40-50	26	15
Study Area	50-60	23	18
Study Area	60-70	33	22
Study Area	70-80	4.3	2.4
Study Area	80-90	0.14	0.15
NC	20-30	0	0
NC	30-40	13	9.4
NC	40-50	27	17
NC	50-60	23	20
NC	60-70	34	24
NC	70-80	2.0	1.7
NC	80-90	0	0
SC	20-30	16	10
SC	30-40	4.9	5.1
SC	40-50	17	11
SC	50-60	20	11
SC	60-70	21	9.7
SC	70-80	19	12
SC	80-90	1.1	1.2



2.3.5 Wetland Habitats

During the Level 2 survey qualitative observations of wildlife were made and recorded on field sheets. These were random observations with many variables including time spent at the site, type of IW, condition of the IW, investigator, and weather, time of day, and month of survey. Some of the more commonly observed reptiles and amphibians included eastern box turtles (*Terrapene carolina Carolina*), black racers (*Coluber constrictor constrictor*), Carolina anoles (*Anolis carolinensis*), skinks (*Eumeces spp.*), southern toads (*Bufo terrestris*), and southern cricket frogs (*Acris gryllus*). A rattlesnake (*Crotalus sp.*) was also observed at a Marion county site. Deer (*Odocoileus virginianus*) were the most commonly observed mammal. Other mammal observations included raccoon (*Procyon lotor*) and black bear (*Ursus americanus*). Various song birds as well as quail (*Coturnix coturnix*) were also observed at the sites.

The dominant types of vegetation that occurred at the Level 2 sites are reflected in the wetland type classifications for each of the 47 IWs assessed in the 44 Level 2 sample sites. These classificatoins were based on a cross-walk developed between Schafale and Weakley's (1990) *Classification of the Natural Communities of North Carolina, Third Approximation*, Nelson's (1986) *The Natural Communities of South Carolina*, and NC CREWS wetland types (Sutter et al., 1999) (see Section 2.2.3.5 and Table 2-4) .

As shown in **Table 2-16** forested flats were the most common IW community types, accounting for 50% of the IWs in the study area. About 25% of the IWs were Non-Alluvial Swamp Forest wetlands according to the SC wetland classification system, with 14% identified as Nonriverine Wet Hardwood Forest and 7% as Nonriverine Swamp Forest under the NC classification system. Wet Pine Flatwoods (NC) or Pine Flatwoods (SC) accounted for 24% of the IWs in the study area. Forested ponds comprised 33% of the study area IWs, with Small Depression Ponds (NC) or Pond Cypress Ponds (SC) as the most common forested pond community type, accounting for 29% of the IWs in the study area. About 16% of the IWs were small pocosins with 15% classified in NC as Small Depression Pocosins, with 14% defined as Pocosins and 1% defined as a Swale Pocosin in the SC classification system. These three sets of NC/SC wetland types (forested flats, forested ponds, and small pocosins) account for almost all of the IWs in the study area.

In terms of the more minor wetland types, about 1% of the IWs are NC-defined Small Depression Ponds or SC Limestone Sinks. SC Swamp Tupelo Ponds or NC Vernal Pools comprised about 3% of the SEIWA IWs. The NC and SC Pond Pine Woodland classification, which is very similar to pocosins, comprised less than 0.5% of the wetlands in the study area and NC defined Cypress Savannahs or SC defined Pond Cypress Savannahs comprised less than 0.5%. Combining the small pond/pool features, over 99% of the IWs could be described as small forested ponds (34%), wet forested flats (50%), or small basin pocosins (16%),

Table 2-16. SEIWA Isolated Wetland Types and Proportions (by counts) In the Study Area

Third Approximation (NC)	Natural Communities SC	NC CREWS	Percent of IW	SE
Forested Flats				
Wet Pine Flatwoods	Pine Flatwoods	Pine Flat	24	19
Nonriverine Swamp Forest	Non Alluvial Swamp Forest	Pine Flat	6.7	6.7
Nonriverine Wet Hardwood Forest	Non Alluvial Swamp Forest	Hardwood Flat	19	14
		Total ForestedFlats	*50*	
Forested Ponds				
Small Depression Pond	Pond Cypress Pond	Depressional Swamp Forest	29	23
Vernal Pool	Swamp Tupelo Pond	Depressional Swamp Forest	3.4	1.7
Small Depression Pond	Limestone Sink	Not identified in NC CREWS	0.94	0.97
		Total Forested Ponds	*33*	
Small Pocosins				
Small Depression Pocosin	Pocosin	Pocosin	14	8.0
Small Depression Pocosin	Swale Pocosin	Pocosin	1.4	1.5
Pond Pine Woodland	Pond Pine Woodland	Pocosin	0.33	0.29
		Total Small Pocosins	*16*	
Other				
Cypress Savannah	Pond Cypress Savannah	Freshwater Marsh	0.67	0.57

SE = standard error

Forested Flats

The *Wet Pine Flatwoods (NC) or Pine Flatwoods (SC)* IW communities are dominated with loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*) with a canopy cover that generally ranged from 70-100 percent for those sites that had not recently been logged. Species in the shrub and herb stratum included gallberry (*Ilex glabra*), high bush blueberry (*Vaccinium fuscatum*), cat briar (*Smilax sp.*), muscadine grape (*Vitis rotundifolia*), titi (*Cyrilla racemiflora*), wax myrtle (*Morella cerifera*), broomsedge (*Andropogon sp.*), bracken fern (*Pteridium aquilinum*), Virginia chain fern (*Woodwardia virginiana*), and rushes (*Juncus sp.*). Herb cover was generally less than 20 percent while shrub cover was quite variable, ranging from 20-100%. The variable herb and shrub cover appeared to be related to how recently the site had been burned or clear cut.

The *SC Non-Alluvial Swamp Forests or NC Nonriverine Wet Hardwood Forests and Nonriverine Swamp Forest* IW communities had a higher predominance of hardwoods then the pine flatwood IW sites, including sweet gum, red maple, black gum (*Nyssa sylvatica*), oaks (*Quercus laurifolia* and *Quercus nigra*), and sweetbay (*Magnolia virginiana*) with a canopy cover that generally ranged from 60-95 percent. Shrub cover also was generally higher than the pine flatwood IWs (greater than 60 percent) and was comprised of red bay (*Persea palustris*), titi, poison ivy (*Toxicodendron radicans*), cat briar, high bush blueberry, fetter bush (*Lyonia lucida*), wax myrtle, gall berry, and yellow Jessamine (*Gelsemium sempervirens*). The herb stratum was generally around 10% but ranged up to 30% with species such as switchcane (*Arundinaria gigantea*), chain fern (*Woodwardia areolata*), royal fern (*Osmunda regalis*), mosses, cinnamon fern (*Osmunda cinnamomea*), and various grasses present.

Forested Ponds

The *NC Small Depression Ponds* that were defined as *Pond Cypress Ponds by the SC* classification system had a more open canopy with 50-60 percent cover of pond cypress (*Taxodium ascendens*), swamp tupelo (*Nyssa biflora*), sweet gum and red maple. Shrub cover was 15-40% with myrtle holly (*Ilex myrtifolia*), wax myrtle, high bush blueberry, titi, and pondspice (*Litsea aestivalis*) occurring. The herb cover ranged from 3-20% and was not very diverse with species of *Carex sp.*, Virginia chain fern, and Carolina redroot (*Lachnanthes caroliniana*), and broomsedge occurring. The four small *Limestone Sink* wetlands (≤ 0.02 acre) located at a site in Horry County had very little vegetation and appear to have recently formed.

The *SC defined Swamp Tupelo Ponds and NC defined Vernal Pools* typically had a canopy cover of 80-100 percent that was composed of swamp tupelo, red maple, sweet gum, and sometimes loblolly pine, and sweet bay. The shrub cover ranged from 15-60% and was composed of variable species depending on the site such as titi, fetterbush, redbay, wax myrtle, cat briar, sweet pepperbush (*Clethra alnifolia*), bay-gall holly (*Ilex coriacea*) and sweet bay. The herb cover had a wide range (3-100%) and was composed of Virginia chain fern, chain fern, switchcane, various grass and sedge species, and sphagnum moss.

Small Pocosins

The *NC-defined Small Depression Pocosin or SC-defined Pocosin or Swale Pocosin* typically had a more open canopy (40-50 percent, sometimes higher) and was composed of loblolly pine, red maple, and sweetbay. The shrub stratum was usually very dense (>90 percent) with species such as fetterbush, titi, highbush blueberry, wax myrtle, gall berry, and zenobia (*Zenobia pulverulenta*). Herb cover was variable (usually <50%) with cinnamon fern and Virginia chain fern often occurring. *Pond pine woodlands (NC and SC)* were similar to the pocosin IWs, however these communities had pond pine (*Pinus serotina*) and more loblolly pine occurring in the canopy.

Other

The *NC-defined Cypress Savannahs and SC-defined Pond Cypress Savannahs* generally had a more open canopy (25-30%), were more shallow, and had a denser herb cover then the NC Small Depression Ponds or SC Pond Cypress Pond IW communities. The canopy was composed of loblolly pine, red maple, and pond cypress while the shrub cover (20-50%) was composed of fetterbush, highbush blueberry and red bay. The dense herb stratum (~ 90%) was composed of Virginia chain fern, *Carex sp.*, other sedges and grasses, and broomsedge.

2.3.6 Wetland Soils

As described in Section 2.2.3.7, two upland and two wetland soil samples were collected for each IW investigated in the Level 2 analysis. The upland and wetland sample pairs were averaged and analyzed to determine whether there were differences between the upland and wetland samples for the measured soil parameters. In addition, loss on ignition (LOI) measurements for the wetland soils were used to estimate the amount of soil organic matter (OM) and soil organic carbon (OC) stored in each Level 2 IW and for IWs in the study area as a whole.

2.3.6.1 Comparison of Upland and Wetland Soils

To determine the differences between upland and wetland soils, the t-test for paired samples was used to evaluate the hypothesis that there are no differences between upland and wetland soil averages. **Table 2-17** summarizes the results of this analysis for the study area, showing for each soil parameter comparison the mean, standard error of the mean, the upper and lower 95% confidence limits, and the p-value that was used to compare the wetland and upland means for each soil parameter. The p-value results show whether there were any statistical differences across the eight counties for each soil parameter average, as well as any differences within each of the eight counties, with p-values less than 0.05 generally indicating a significant difference. **Appendix 2B** provides the full statistical results of the analysis, including the contrast mean and its standard error and the t-statistic, for the study area and for each county, along with summary of the results by parameter.

Soil pH results showed that the IW soils are generally acid, with pH values ranging from 3.5 to 4.9 and an overall mean pH of 4 for both upland and wetland soils. No significant differences in upland and wetland pH were found in the study area (p-value=0.6523) and most of the counties. Only Florence County (p-value=0.001) showed significantly more acidity in the wetland soils. Upland and wetland soil cation exchange capacity (CEC) were not significantly different in the study area (p-value=0.07), but showed a strong linear correlation with exchangeable acidity (AC; $R^2 = 0.94$; **Figure 2-1**), which is expected because higher CEC values correspond to higher exchangeable acidity.

There were statistically significant differences in soil chemistry between upland and wetland soils for potassium and manganese, with levels in the wetland being statistically higher than in the upland across

Table 2-17. Soil Analysis Summary – SEIWA Level 2 Upland and Wetland Soils

Soil Parameter	U-W	Min	Max	Mean	SE mean	Lower 95% CL	Upper 95% CL	p-value
pH	Upland	3.70	4.6	4.09	0.05	3.99	4.2	0.6523
	Wetland	3.45	4.9	4.02	0.15	3.72	4.31	
Dry bulk density (W/V, kg/L)	Upland	0.785	1.54	1.22	0.07	1.08	1.36	0.1254
	Wetland	0.210	1.55	1.01	0.16	0.69	1.33	
% Loss on ignition (% organic matter)	Upland	0.700	14.2	3.91	0.87	2.17	5.65	0.1203
	Wetland	0.600	93.8	11.44	4.61	2.18	20.7	
% Humic matter	Upland	0.585	6.57	1.93	0.24	1.45	2.4	0.0809
	Wetland	0.685	10.0	4.69	1.72	1.25	8.14	
Cation exchange capacity (CEC, meq/100cc)	Upland	2.49	11.1	5.15	0.64	3.86	6.44	0.0713
	Wetland	2.43	13.8	7.11	1.46	4.18	10.04	
Exhangeable acidity (AC, meq/100cc)	Upland	2	8.2	4.10	0.49	3.11	5.09	0.1632
	Wetland	1.9	11.9	5.69	1.3	3.08	8.29	
Base saturation (%)	Upland	9.56	34.6	20.95	0.81	19.32	22.57	0.6996
	Wetland	6.75	48.5	19.18	4.96	9.22	29.14	
Potassium (meq/100cc)	*Upland*	0.016	0.146	*0.05*	*0.01*	*0.03*	*0.07*	*0.0490*
	Wetland	0.019	0.198	*0.07*	*0.02*	*0.03*	*0.12*	
Sodium (meq/100cc)	Upland	0.028	0.152	0.07	0.01	0.05	0.09	0.1181
	Wetland	0.030	0.241	0.09	0.02	0.05	0.13	
Calcium (meq/100cc)	Upland	0.347	3.31	0.74	0.11	0.52	0.97	0.4953
	Wetland	0.322	4.35	1.02	0.49	0.04	2	
Magnesium (meq/100cc)	Upland	0.127	0.690	0.26	0.04	0.17	0.34	0.3873
	Wetland	0.136	1.05	0.32	0.11	0.1	0.55	
Nitrate as N (mg/dm^3)	Upland	0	13.8	2.06	0.73	0.59	3.54	0.2342
	Wetland	0	17.0	0.94	0.27	0.4	1.49	
Phosphorous (mq/dm^3)	Upland	1.55	156	17.14	4.08	8.94	25.34	0.8695
	Wetland	2.2	119	17.53	4.01	9.48	25.57	
Sulfur (mq/dm^3)	Upland	0.10	1.25	0.38	0.06	0.26	0.5	0.9428
	Wetland	0.10	7.85	0.39	0.09	0.22	0.56	
Copper (mq/dm^3)	Upland	0.10	1.25	0.38	0.06	0.26	0.5	0.9428
	Wetland	0.10	7.85	0.39	0.09	0.22	0.56	
Manganese (mq/dm^3)	*Upland*	0.55	10.9	*1.2*	*0.17*	*0.85*	*1.55*	*0.0108*
	Wetland	0.50	10.7	*0.94*	*0.13*	*0.69*	*1.2*	
Zinc (mq/dm^3)	Upland	0.25	14.3	0.99	0.35	0.29	1.69	0.8160
	Wetland	0.30	27.3	1.09	0.43	0.24	1.95	

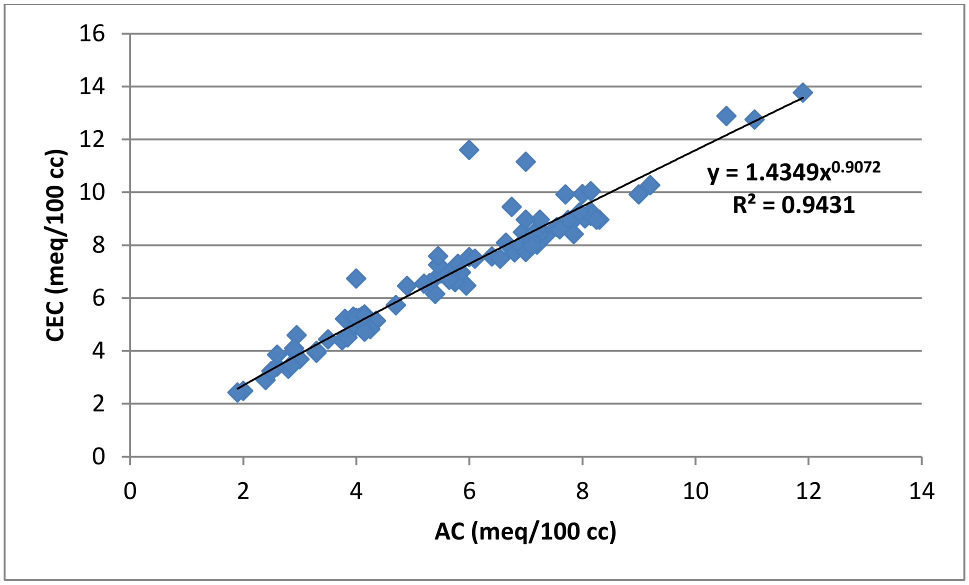


Figure 2-1. Correlation between cation exchange capacity (CEC) and exchangable acidity (AC) in the SEIWA Level 2 dataset.

the entire study area. For all other constituents (exchangeable acidity, percent base saturation, cation exchange capacity, calcium, copper, humic matter, magnesium, nitrogen, sodium, phosphorus, sulfur, weight per volume, zinc, pH, and loss on ignition) there was no difference between the upland and wetland soils in the study area, although differences were observed in some counties. For example, of the 17 parameters for soil chemistry, 9 showed a statistically significant difference for Bladen County and 8 showed a statistically significant difference for Horry County. In general, there was little difference between upland soil chemistry and wetland soil chemistry except for those limited instances noted above.

Columbus County showed a statistically significant difference for 10 of the 17 soil parameters but most of those differences were in the opposite direction from the other counties. Further examination of the Columbus soil data is warranted to understand this reverse trend.

2.3.6.2 Soil Organic Carbon

One important ecological service provided by wetlands is as a natural sink for sequestering carbon. The saturated, reducing conditions prevalent in wetland soils tend to slow the decay of fallen organic matter (OM) resulting in higher organic carbon (OC) concentrations in wetland versus upland soils. This condition was apparent in most of the loss on ignition measurements of soil OM (**Figure 2-2**), with 34 of 44 soil OM measurements being higher in wetland soil samples than in the corresponding upland soil samples, especially for the wetland soils with the higher OM levels. Soil OM in the upper foot (30 cm) of wetland soil ranged from 1% to 94% for the Level 2 IW sites, with a weighted mean of 11%, compared to a range of 1% to 14% and a mean of 4% for upland soils. Organic soils (soils with OM greater than 30%) only occurred in three IW soils in in Horry County and one IW soil in Brunswick County.

Methodology

The soil loss on ignition (LOI) measurements were used to estimate the total carbon sequestered in IW soils by first assuming that the percent LOI represents the percent OM in soils. The use of soil LOI measurements for estimating wetland soil OM is generally accepted as long as soil clay content is relatively low (e.g., see Craft et al., 1991; Konen et al., 2002; Howard and Howard, 1990), as is the case for the SEIWA IW soils.

The second step was to estimate the percent OM with depth, which was done by assuming that the organic matter percentage drops off exponentially with depth. The natural log of the OM was reduced by 1 for each foot of depth in the soil profile. Although more sophisticated analyses of soil OM with depth are available for other regions (e.g., see Jobbagy and Jackson, 2000; Heiderer, 2009), this simple relationship produced a reasonable soil OM depth profile that could be improved with a more detailed study of actual IW soil OM profiles for the SEIWA study area. The amount of soil OM for each foot (30 cm) of depth over a square meter of wetland surface was then computed using the following equation:

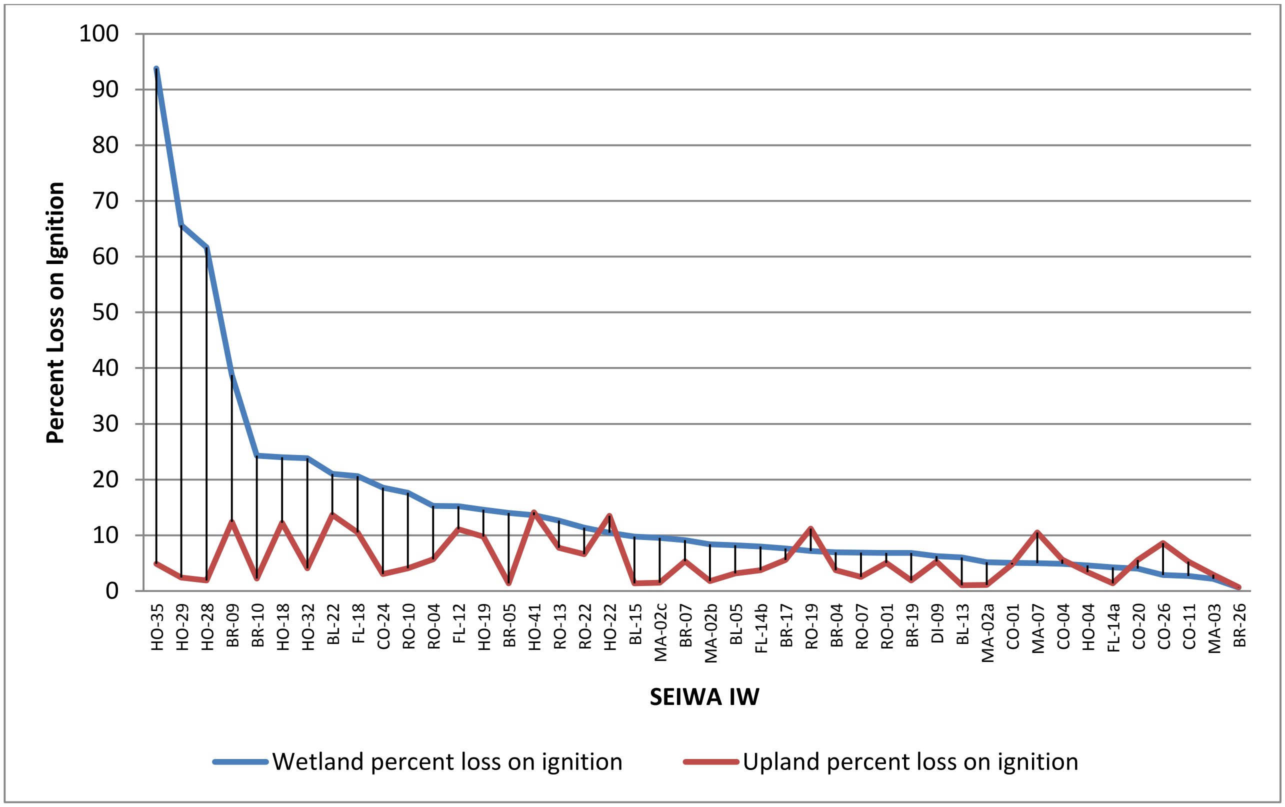


Figure 2-2. Comparison of isolated wetland and upland % soil organic matter (as % loss on ignition).

$$\text{OM per foot (kg/m}^2\text{)} = [(\text{Soil OM (\%)} \times \text{Soil Bulk Density (kg/L)})/100] \times 0.30\text{ m x } 1{,}000\text{ L/m}^3$$

Soil bulk density was adjusted for the decrease in OM content with depth using the strong correlation ($R^2 = 0.93$) shown in **Figure 2-3** derived from the bulk density and LOI measurements in the Level 2 IW soils. A maximum bulk density of 1.6 kg/L was assumed for the mineral soils at depth (the maximum bulk density measured for the Level 2 soils was 1.55 kg/L for a soil with 0.6% LOI/OM).

Figure 2-4 shows a typical per foot soil OM profile from the analysis for IW site HO-32, which had 24 percent OM in the top foot (30 cm) of soil. The OM per foot per square meter estimates were totaled for each soil profile to get a total OM estimate for each square meter of each IW. This total was multiplied by the area of each IW to get a total OM per wetland in metric tons. Note that as shown in Figure 2-4, most of the soil organic carbon is assumed to be in the upper three to four feet of the IW soil profile.

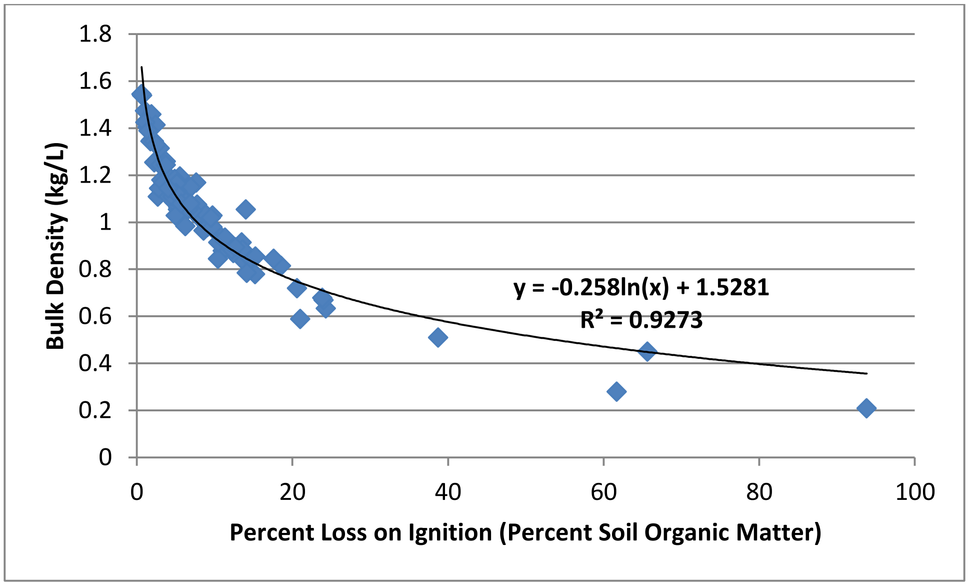


Figure 2-3. Relationship of dry bulk density and percent loss on ignition for SEIWA IW soils.

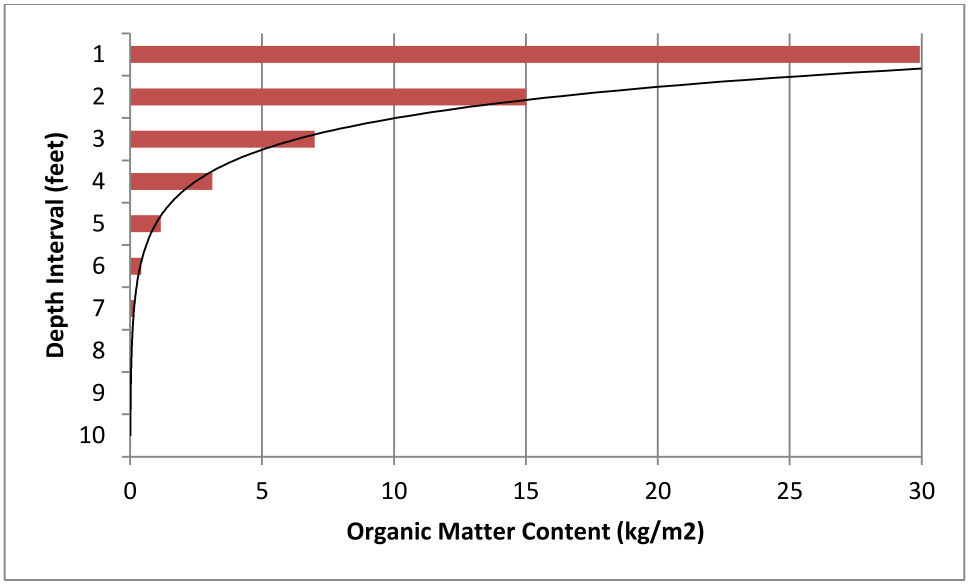


Figure 2-4. Example exponential soil organic matter profile assumed for SEIWA IWs (site HO-32)

The final step in the analysis was to convert the total wetland OM estimates to total soil OC. This was accomplished using the widely used assumption that soil OM is 58% OC (Nelson and Sommers, 1996). Although there has been considerable research showing that this relationship is not extremely accurate in some situations, and that the relationship is complex, varying with soil type, condition, and geography (e.g., see Howard and Howard, 1990; Schulte and Hopkins, 1996; Cambardella et al., 2001), the soils in the study area have not been studied in this regard and this widely used assumption was deemed the best available for the purposes of this analysis.

Results and Uncertainties – Soil Organic Carbon in SEIWA Study Area IWs

Table 2-18 shows the results of the total soil OC estimates for the IWs in the SEIWA study area. The IWs in the SEIWA study area are estimated to contain about 5 million metric tons (Mg) of carbon in their wetland soils, with greater amounts in NC than in SC.

Examination of the results by non-LiDAR and LiDAR counties shows that the LiDAR counties account for 85% of the total soil OC estimate for the study area soils, suggesting a significant low bias for the non-LiDAR counties, similar to the one observed for the wetland occurrence, area, and volume estimates described in Section 2.3.2. A high bias was also observed for the mean OC content of the individual IWs in the non-LiDAR counties, which could reflect the larger size of the IW polygons that were developed using the 30m hypsography elevation data (see Table 2-9).

To try and correct for these biases, we used the mean IW soil OC content for the LiDAR counties (62 Mg) and an adjusted estimate of the number of IWs in the Non-LiDAR counties (described in Section 2.3.2) to calculate an adjusted estimate of total IW soil OC in the non-LiDAR counties. This procedure resulted in an adjusted total IW soil OC estimate for the study area of 5.2 million metric tons, compared to the unadjusted estimate of 4.7 million metric tons. This difference represents an uncertainty in the analysis depending on the actual number and OC content of the IWs in the non-LiDAR counties. The mean and total soil OC content of the IWs in the non-LiDAR counties could be different (higher or lower) than that observed in the LiDAR counties.

Table 2-18. Organic Carbon Content of SEIWA Isolated Wetland Soils

SEIWA Area Domain	Total Soil Organic Carbon per IW (Mg)				Total Soil Organic Carbon per Area Domain (Mg)	
	Min	**Max**	**Mean**	**Mean StdErr**	**Total**	**Total StdErr**
Original Study Area						
Study Area	*1.2*	*2,466*	*69*	*38*	*4,719,401*	*2,389,598*
Study Area (est.)[1]					5,212,855	
NC (Bladen, Brunswick, Columbus, Robeson)	1.2	2,466	56	42	3,359,073	2,351,382
SC (Dillon, Florence, Horry, Marion)	*1.3*	*901*	*152*	*42*	*1,360,327*	*425,654*
SC (Dillon, Florence, Horry, Marion) (est.)[1]	-	-	-	-	1,853,782	
LiDAR and Non-LiDAR Counties						
LiDAR (Bladen, Brunswick, Columbus, Horry, Robeson)	1.2	2,466	62	39	4,020,843	2,383,186
Non-LiDAR (Dillon, Florence, Marion)	*1.3*	*901*	*193*	*78*	*698,557*	*174,938*
Non-LiDAR (Dillon, Florence, Marion) (est.)[1]	-	-	62	-	1,192,012	

Estimates with non-LiDAR results, shown in italics, are likely biased low for total soil OC in the area domains and biased high for total OC per IW.

[1] Adjusted estimates using the mean soil OC per IW for the LiDAR counties multiplied by the adjusted estimates for the number of IWs in the non-LiDAR counties discussed in Section 2.3.2.

Other uncertainties in this analysis center around two primary assumptions: (1) soil OM contains 58% organic carbon and (2) the exponential decrease of soil organic matter content with depth. The latter is probably much more significant than the OM/OC relationship; for example, Howard (1966) reports that LOI:C factors ranged from 1.77 to 2.07 in British soils. Although this suggests that the 1.724 ratio may be low, the level of variability is only 17% from 1.724 to 2.07. This uncertainty could be investigated by measuring carbon directly in a sample of the SEIWA IW soils to establish an SEIWA-specific relationship between soil organic carbon (OC) and soil OM in the study area.

The assumption of exponential decrease in soil OC with depth is another potential source of bias in the IW soil OC estimates – some of the higher OM sites may have greater thicknesses of organic soils (e.g., peat deposits) than that predicted by the relationship used in this analysis, which would underestimate soil organic carbon. This uncertainty can be assessed by deeper soil cores in the Level 2 IWs, continuously sampled for soil LOI measurements to a depth of 5 to 10 feet.

Based on the total estimate acreage of IWs in the study area (30,000 acres), IW soils have an average soil carbon content of over 190 tons per acre. This is slightly above the upper end of the range of soil carbon content of 175 tons per acre reported by Neely (2008) for North Carolina natural wetlands, well above the range (58 – 89 tons per acre) for U.S. wetland soils (Gleysols) reported by Bridgham et al.

(2006), and well below the typical value for U.S. peatlands (670 tons per acre) used in Bridgham et al. (2006). Given that some of the IWs had peat deposits (with up to 90 percent organic matter as measured by LOI) this level is at the upper end of the range that would expected based on literature values. However it should be recognized that many soil organic carbon estimates in the published literature do not consider soil layers below the top layers of soils sampled for organic matter analysis as done in this study, and they may, as a result underestimate soil carbon per acre. Regardless, the SEIWA soil carbon analysis shows that IWs are significant sinks for carbon and contain levels comparable to other wetlands in the southeast and elsewhere in the U.S.

Soil Organic Matter and Cation Exchange Capacity

Figure 2-5 shows the relationship of soil OM to cation exchange capacity (CEC). Soil OM correlated fairly strongly with CEC ($R^2 = 0.78$) and with exchangeable acidity (AC; $R^2 = 0.80$). These relationships are consistent with similar data reported for forested wetlands by Fissore et al. (2009) and suggest that much of the CEC (and AC) in the IW soils is controlled by the organic matter in the soil rather than clay content (the other important CEC/AC source in soil). The positive correlation between CEC and OM suggests that the soil OM sequestered in the SEIWA IWs also serves a role in pollutant and nutrient absorption capacity as measured by CEC.

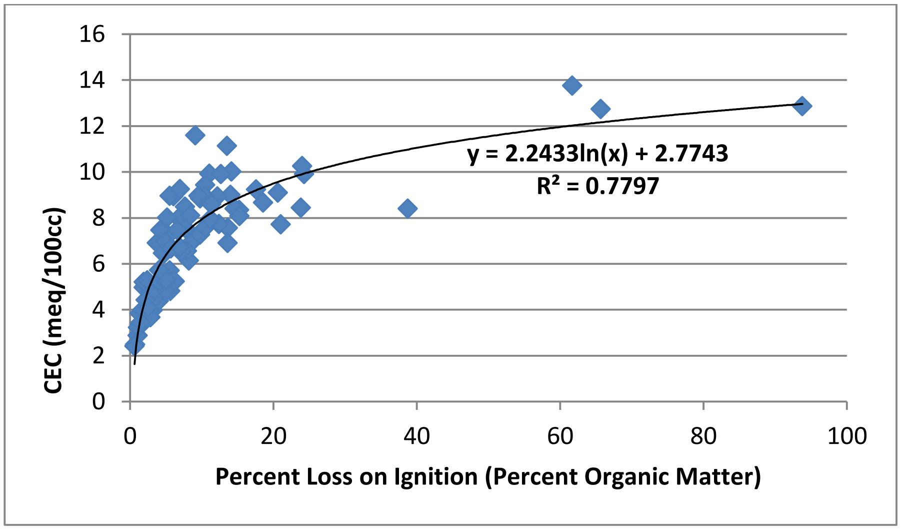


Figure 2-5. Correlation between CEC and soil OM in SIEWA wetland and upland soils.

2.4 Summary and Conclusions

In general, IWs in our study area are numerous (estimate of 22,000 IWs in the four SC counties and 30,000 in the four NC counties), relatively small (mean size of 0.68 acres), and occupy a small percentage of overall wetlands (about 1.9% of the total wetland area). Overall most IWs in the study area were forested ecosystems of three general types (forested flats [50%], forested ponds [33%], and small pocosins [16%]) that occur in relatively small depressions on the uplifted marine terraces that form this portion of the southeastern coastal plain.

The IWs in the SEIWA study area are relatively shallow (average depth of 0.4 feet), as well as being small (average area of 0.68 acres), and store about 3,900 acre-feet of water in the five LiDAR counties in the study area. The hydrological significance of IWs within the SEIWA study area will be discussed in more detail with the Level 3 results in Part 3 of this report, but IWs do appear to play a potential role in slowing the percolation of water into the landscape after the precipitation and high water table events that periodically fill the IW features during wet times of the year.

The IWs in the study area are generally in fairly good condition, with 81% having moderate ORAM condition scores. With respect to overall NC WAM scores, 67% rated high and 30% rated medium, with similar values for the individual habitat, hydrology, and water quality NC WAM subscores. In addition, IW soils store about 5 million metric tons of carbon in the study area. Because some of the IWs contain peat deposits, they have on soil carbon content per acre between typical forested wetland soils and peatlands.

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3 Assessing Geographically Isolated Wetlands in North and South Carolina –Part 3: Level 3 Intensive Assessment

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3. Assessing Geographically Isolated Wetlands in North and South Carolina – Part 3: Level 3 Intensive Assessment

3.1 Introduction

The goal of the Level 3 portion of the Southeast Isolated Wetlands Assessment (SEIWA) was to quantify the environmental benefits of isolated wetlands (IWs), both individually and on a landscape scale. Few studies have been done on the biological composition, water storage and pollution adsorption capacity, and hydrological connection of existing IWs in the coastal plain of the Carolinas. The Level 3 report includes the methods developed to make these measurements, as well as results to date as of the end of the project.

The sites described in this section are part of a larger study of sites developed for a landscape analysis of wetland functions and services that is being continued under a separate grant, described below, which will expand the results presented in this report with additional work on these sites and several additional sites. This additional work should be completed in 2012 and will be reported to EPA at that time.

3.2 Project Description

Level 3 assessments are intensive field surveys to collect quantitative data on clusters of IWs and their hydrologic, water quality, and ecological (habitat) effects on the landscape. The objective of the Level 3 assessment develop and demonstrate a sampling and monitoring design for quantifying the benefits provided by geographically isolated wetlands for sustaining stream flow, water quality, and habitats for amphibians, macroinvertebrates, and plants. This intensive assessment included the following features.

- <u>Site selection.</u> Sites were selected to maximize success of the demonstration by ensuring site access, security, and good condition. ORAM and NC WAM scoring to identify least altered sites to best analyze relationships between wetlands and benefits.

- <u>Measurement of ecological condition</u>. Vegetation, amphibian, and macro-invertebrate sampling was conducted to assess the biological quality of each site. Standard protocols were selected to allow data to be used in other projects. Metrics were assembled to establish reference condition.

- <u>Analysis of pollutant adsorption capacity</u>. Soil sampling was conducted to calibrate a phosphorous adsorption index (PSI). The PSI is a dimensionless index that ranks soils by their potential to adsorb and thus immobilize phosphorus, an essential plant nutrient but also a pollutant when present in excess quantities in aquatic systems.

- <u>Analyze water quality impacts</u>. Surface and groundwater sampling was conducted to establish baseline water quality conditions for IWs and to determine how the wetland functions with respect to pollution absorption capacity. Also, NC WAM was evaluated as a possible way of extrapolating intensive site-specific results across the broader study area.

- Analyze hydrologic regime and connectivity. Surficial and groundwater sampling was conducted to (a) account for hydrology in determining pollutant absorption capacity (hydraulic loading rate); (b) determine hydrological connectivity between the wetlands and groundwater; (c) determine connectivity of wetlands in a cluster; (d) establish groundwater connectivity to downgradient streams and connected wetlands. Also, NC WAM was evaluated as a possible way of extrapolating intensive site-specific results across the broader study area.
- Analyze plant and animal composition. Surveys were conducted to quantify species composition and habitat use for plants, amphibians, and macroinvertebrates. Also, NC WAM was evaluated as a possible way of extrapolating intensive site-specific results across the broader study area.

The SEIWA Level 3 locations were used to develop, test, and define a methodology that can be applied to produce reliable estimates in similar studies when the additional sites needed for an appropriate sample size are available. The Level 3 analysis will be expanded in the "Hydrologic Connectivity, Water Quality Function, and Biocriteria of Coastal Plain Geographically Isolated Wetlands" EPA funded grant (DC 95415809) which will continue to assess the sites described in this study along with Level 3 hydrologic, water quality, and biological assessments at 10-12 additional sites.

3.3 Site Selection

Although a random sample of a number of the candidate isolated wetland sites selected under Level 2 would have provided a statistical means of extending the Level 3 results to the study population, project resources did not allow Level 3 analyses to be conducted at the number of sites (9 or more) that would have been required for a valid random sample. Instead, two sites were selected according to selection criteria that (1) that used judgment to select sites representative of isolated wetland functions in the study area and (2) maximized the probability of success for the Level 3 data collection efforts. This approach provided a way of testing and demonstrating the field methodologies developed for this phase of the project, and also provided the opportunity to collect preliminary measurements of how wetlands in good condition function in the landscape to provide hydrological and habitat services within the ecosystems in which they occur.

Initial results of the Level 2 assessment suggested some of these isolated wetlands occur in close proximity to other isolated wetlands in the same catchment area. Two of these clusters were selected for the Level 3 assessment to enable assessment of multiple IWs with a single site mobilization and to see how IWs function in clusters across the landscape. Additional selection criteria included: (1) accessibility, which includes landowner permission and drivable to within reasonable walking distance; (2) security, the likelihood that deployed field equipment will be subject to theft or vandalism, and (3) extent of anthropogenic alteration of the wetlands and the surrounding landscape. Wetlands in good condition were preferred to provide the best chance of having measurable ecological benefits.

We attempted to select Level 3 sites from among those that were visited during Level 2 (to further utilize those data) in both states, but were not able to find enough usable sites for one of the Level 2 site clusters. The reconnaissance work conducted for Level 3 is summarized in **Table 3-1**. In order to meet the requirements of the study for the Level 3 work we selected other candidate sites by examining the Level 1 polygons or nearby aerial signatures using digital orthophotographs of the study area. The candidate Level 1 site polygons or nearby map signatures were visited to confirm the occurrence of isolated wetlands and to assess the relative anthropogenic impact. Level 2 results suggest that a large percentage of isolated wetlands have been altered (e.g. logging, ditching). The alterations exist across magnitude (minor/major) and age (recent/distant past) gradients that may make it impossible to find clusters of completely unaltered isolated wetlands. The study sites that were least altered, and therefore in the best condition, were selected for the study.

Table 3-1. Site Reconnaissance Results

Site	Wetland Type (NC WAM)	Suitability for Level 3
May 18-19, 2009		
Robeson 85.19	Basin wetland	Unsuitable, Level 2 site close to different stream/channel than others
Robeson 72.1	Basin wetland	Potentially suitable, but deep in dense, young forest
Marion 137.0	Basin wetland	Potentially suitable, selected
Horry 109.22	Basin wetland	Unsuitable, three small IW but large retention pond in close proximity
Columbus 25.1	Basin wetland	Unsuitable, Level 2 site is very small, other wetland in agricultural field
Brunswick 10.10	Basin wetland	Potentially suitable, pending change of ownership so no permission
Brunswick 9.9	Basin wetland	Unsuitable, Level 2 site is fine but nearby polygon is not IW
Bladen 54.5	Basin wetland	Unsuitable, heavily degraded
July 14-15, 2009		
Green Swamp, Site 1	5 Basin Wetlands	*Bruns L3 was selected.*
Green Swamp, Site 2	7 Basin Wetlands	*Selected for Isolated wetland connectivity grant*
Green Swamp, Site 4	3 Upland Sites	*Non wetlands*
Seawatch, Site 4	1 Basin Wetland	*Isolated wetland with maidencane*
Bladen County, Site 25	1 Pocosin	*Not isolated*

3.4 Field Assessment Methods

The Level 3 field assessment was an intensive assessment of the selected clusters of isolated wetlands using the following specific metrics.

- *Condition and relative function assessment*. The entire wetland was inspected for signs of physical alteration, such as ditches, roads, clearing, filling, or excavation. NCWAM and ORAM forms were completed if not previously done.

- *Soil characteristics*. Soil samples from the interior of the wetland and surrounding upland were analyzed for nutrients, metals, sodium, pH, soil class, CEC, and percent base saturation, humic matter, and total organic matter (through loss on ignition).

- *Pore water characteristics*. About 6 shallow wells were placed in a grid across the wetland cluster and conditioned using methods developed by Sprecher (2000). The wells were deep enough to intercept the water table. At later site visits water was collected for analysis of nitrogen and phosphorus fractions and dissolved organic carbon (DOC). A YSI Environmental multiparameter meter was be used to measure temperature, specific conductance, pH, dissolved oxygen concentration, and oxidation-reduction potential. This was done four times during the study period.

- *Water table dynamics*. Continuous water level recorders were placed in the wells. These data were analyzed for information about direction of movement, response to precipitation, and seasonality. When analyzed along with the soil and water quality (surface and pore water) data, profiles of effect of the wetlands on pollutant dynamics were estimated.

- *Surface water characteristics*. When there was standing water in the wetland, we collected a sample for analysis of nitrogen and phosphorus fractions and DOC.

- *Fauna*. Amphibians and aquatic macroinvertebrates were surveyed and compared to survey work previously completed in Brunswick County. Although one of the Level 3 study sites was not in Brunswick County, the site in Marion County is similar from an ecoregional perspective to the Brunswick County site. Shannon's diversity index (Brower and Zar, 1977) was derived for aquatic macroinvertebrates.

- *Flora*. Dominant woody, shrub, and herb species were surveyed and compared to survey work previously completed in Brunswick County. Shannon's diversity index (Brower and Zar, 1977) was derived for each site, along with floristic quality, wetness, and other floral indices.

3.4.1 Pollutant Adsorption Capacity

The Level 3 assessment was intended to address the question of how to determine the pollutant adsorption capacity of isolated wetlands of various types, sizes, and conditions, and the effect of isolated wetlands on downstream receiving waters. To accomplish this objective, the Level 3 site assessment included a wetland condition assessment (see Part 2) and water quality gradient analysis across each site using an array of up to six wells into the shallow aquifer.

Well sites were selected to provide data on the movement of water within the cluster and from the cluster toward the nearest downgradient waterbody. Well depth ranged from 5-10 feet. Well holes were drilled using a 3-inch diameter hand auger, and soil descriptions by depth (i.e., boring logs) were recorded based on the soil excavated during well installation. Well installation followed the methods described by Sprecher (2000) and all well locations were surveyed.

Water was collected from the wells using bailers and analyzed to measure the metrics described below during site visits. This was done four times at each site over the course of a 14-month sampling period. Sampling events occurred quarterly, October 2009, February 2010, May 2010, and August 2010. We also placed an automated water level recorder in each well to provide hourly measurements of water table depth below the ground surface.

The analytical results for the undisturbed wetlands in the undisturbed catchments were used as reference conditions. In combination with the condition assessment described above, these data allowed us to rank sites according to size, condition, and pollutant adsorption capability.

3.4.2 Water Quality Monitoring

Both groundwater and surface water quality were assessed in and around the isolated wetland clusters. Groundwater samples were collected from monitoring wells and surface water samples were collected from within the individual wetlands on a quarterly basis. Each IW had one wetland surface water station and at least three monitoring well stations located along a transect that radiated away from the wetland toward the connected wetland or stream, with the closest well to the wetland located in the wetland near the wetland surface water sample station (see Figure 3-15 and 3-16, in Section 3.5.1, Site Description, for maps of the wetland and monitoring well stations). The Marion County sites had one additional well station, Marion 2b/c located between the Marion 2b and Marion 2c sites.

It was not possible to collect water samples at all of the stations during each sample event. Lower water tables prevented the collection of water quality samples at the upland well stations and within the wetland at the Marion 2b and Marion 2c sites. At the Brunswick sites, flooding during winter and spring prevented the collection of water at the Brunswick wetland well station (Brunswick L3.1 well “a” and Brunswick L3.2 well “a”) when the wells were flooded with wetland surface water through the well pipe vent holes.

Physical parameters (pH, dissolved oxygen [DO], specific conductivity, and temperature) were measured in the field with YSI meters. Water quality samples were collected for chemical analysis of nutrient fractions and DOC. The NC DWQ Laboratory Section conducted the chemical analysis of collected samples. All water samples were collected, preserved, and transported in accordance with the NC DWQ Laboratory Section Sample Submission Guidance Document (NC DWQ, 2009) and the NC DWQ Laboratory Section Standard Operating Procedures (NC DWQ, 2004a).

Groundwater samples were collected using bailers from each of the shallow monitoring wells located in the wetland cluster. Monitoring wells were purged with a bailer prior to measuring water quality field parameters or the collection of water samples for chemical analysis of ammonia, orthophosphate, and dissolved organic carbon. Surface water samples were taken in the same single location in each wetland. Samples were collected where there was standing water.

A unique station number that reflected the site name, sample location, and time of sample (month and year) was assigned for each sample event. Station locations were photographed with a digital camera each time the station was sampled to make a visual record of the hydrology of the sample station (**Figures 3-1** and **3-2**). Meters were calibrated daily by NC DWQ and/or USC staff. Additional QA measures taken during the laboratory analysis are explained in NC DWQ's *The Quality Assurance Manual for the NC DWQ Laboratory Section* (NC DWQ, 2004b). Examples of water quality field and lab sheets are shown in Appendix 3-A.

Figure 3-1. Marion 2a wetland WQ station, May 2010.

Figure 3-2. Marion 2c Wetland WQ station, Aug. 2010.

3.4.3 Soil Monitoring

Soil quality, similar to water quality, has been known to exhibit extensive variability between wetlands located in natural and urbanizing areas (Azous and Horner, 2001). Soil samples were taken at the two clusters of wetland sites, one time, within the wetland and in the surrounding upland and at the location of upland groundwater monitoring wells installed for this study. Typically six wetland samples and two upland samples were collected at each site. A reduced number of soils, one wetland and one upland, were described in the field and collected at the Marion 2a site due to its small size (0.3 acres). **Figure 3-3** shows the sampling design for soils collected in wetlands and uplands. The sampling locations for soils in a wetland and surrounding upland were based on the vegetation sampling design (see Section 3.4.4).

At each sampling location, a 45–50 cm deep soil core was excavated with a 6-cm-diameter stainless steel auger. Soil descriptions were made for each core sample horizon. The horizon depth, location (top layer = A, second layer=B, etc.), matrix and mottle color, mottle (percent) abundance, and texture were

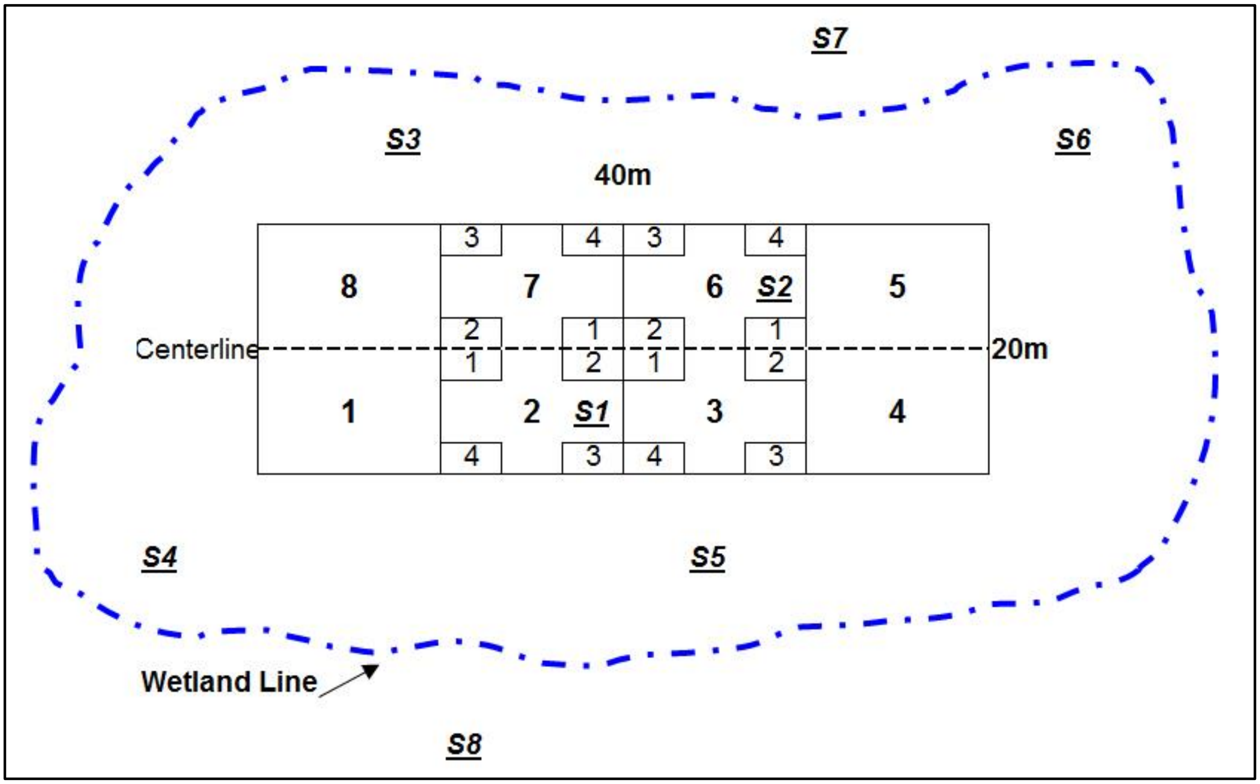

Figure 3-3. Soil sampling design for isolated wetlands.
S1 – S8 show wetland (S2-S6) and upland (S7 and S8) soil sampling locations in relation to vegetation sampling grid and locations (1-8).

recorded for each horizon. The *Munsell Soil Color Charts* (Munsell Color Company, 2000) were used to determine Munsell hue, value, and chroma, and the *Soil Texture by Feel Flow Chart* (Brookings Institution, 2000) was used to determine texture. Information on hydric soil indicators was also recorded. Examples of soil field sheets are shown in Appendix 3A.

Approximately 0.5 kg of soil was collected from each horizon to a depth of 45 cm. Samples were placed in labeled ziplock bags in the field. The North Carolina Agronomic Division, Soil Testing Section, analyzed soil samples for the following parameters:

- Levels of major plant nutrients, including phosphorus, potassium, calcium, and magnesium
- Levels of plant micronutrients, including copper, manganese, sulfur, and zinc
- Aluminum and iron content
- Sodium levels
- pH and acidity
- Soil class

- Percent base saturation
- Percent humic matter
- Cation exchange capacity and weight-to-volume ratio.

See http://www.agr.state.nc.us/agronomi/stmethod.htm (Mehlich, 1953) for further details on NC Agronomic Division lab analyses methods.

Soil samples were also analyzed for phosphorus adsorption capacity using methods described by Axt and Walbridge (1999). Briefly, adsorption isotherms were developed by equilibrating soil in solutions containing added KH_2PO_4. After centrifugation the supernatant was analyzed colorimetrically for soluble orthophosphate. Samples were also analyzed for extractable calcium and oxalate-extractable iron and aluminum. These analyses were done at the University of South Carolina.

3.4.4 Vegetation Monitoring

Wetland plant communities are a useful indicator of human disturbance. Intact wetland plant communities are important for maintaining water quality (U.S. EPA, 2006) and providing habitat to wildlife. Quantitative monitoring of isolated wetland vegetation will enable us to better understand the community characteristics of these systems. All plants that were observed during the survey were identified to the lowest taxonomic level possible. Voucher specimens were obtained for identification, and were processed, labeled, and kept for future reference.

Floras of the Carolinas, Virginia, Georgia, and Surrounding Areas (Weakley, Draft January 2007), and the US Department of Agriculture, Natural Resource Conservation Service (USDA NRCS**)** National Plant Database (plants.usda.gov) were used for genus species nomenclature for all survey-related field research or databases used for this project. Other identification books included: *Trees, Shrubs, and Woody Vines of North Florida and Adjacent Georgia and Alabama* (Godfrey, 1988), *The Manual of Vascular Flora of the Carolinas* (Radford et al. 1968), and *Aquatic and Wetland Plants of the United States* (Godfrey and Wooten, 1979 and 1981). The US Fish and Wildlife (USFWS) wetland indicator status and whether the plant was native or exotic was also determined with the USDA NRCS National Plant Database (plants.usda.gov) and *The National List of Plant Species that Occur in Wetlands, Region 2 – Southeast* (Resource Management Group, Inc. Environmental Planners and Consultants, 1999).

Plant community monitoring methods were devised from the *North Carolina Vegetation Survey Protocol: A Flexible, Multipurpose Method for Recording Vegetation Composition and Structure* (Peet et al., 1998) which will be referred to as the CVS (Carolina Vegetation Survey) protocol in this report. The CVS protocol was developed by experienced North Carolina botanists for the purpose of providing a quantitative description of the vegetation in a variety of Carolina habitats. This method has proved to be flexible in design and highly accurate in the 23 field seasons it has been used.

The CVS protocol normally consists of 10 m x 10 m modules laid out in a 5 x 2 array or 50 m x 20 m plot. The exact layout and size of the modules can be altered according to the area chosen for the survey. For this project, eight modules in a 4 x 2 array or 40 m x 20 m plots were used at three of the selected wetland sites, Brunswick L3.1, Marion 2B, and Marion 2C (**Figure 3-4**). The best location and orientation for the 40m by 20m vegetation plot were determined in the field based on the contours of the wetland site boundary and variability of the vegetative community.

The CVS protocol was used to collect data on three types of plant community characteristics: vegetation presence, cover, and woody stem size class. Modules were numbered counter clockwise from "1" to "8" with corners also numbered clockwise from "1" to "4". The four modules located in the center of the plot, 2, 3, 6, and 7, are "intensive modules" and were surveyed for vegetation presence, cover and woody stem size class. The other modules, located at either end of the plot, 1, 4, 5, and 8, are "residual modules" and were just surveyed for woody stem size class (Figure 3-4).

Information on vegetation presence, cover, and woody species diameter at breast height (DBH) was recorded on field sheets using methods described in the CVS protocol (see Appendix 3-A). At Brunswick L3.2, eight modules were also surveyed, four intensive and four residual. The eight modules at the Brunswick L3.2 were oriented differently due to deep standing water in the middle of the site that was too wide for the regular 4 x 2 array of modules. The modules were placed around the standing water, at Brunswick L3.2, in a U-shaped formation. At the Marion 2A site, just one single intensive module (10 x 10 m) was surveyed. Marion 2A, which has a narrow band of upland separating it from the very similar Marion 2B site, is only 0.03 acres, too small for a complete eight module survey.

As previously discussed, the intensive modules, modules 2, 3, 6, and 7 were surveyed for vegetation presence and cover. Species presence was determined at one chosen corner within each intensive module first and then cover classes were assigned to each species present within the module. One corner was chosen in the field for each intensive module to be surveyed for presence. Adjacent corners of adjacent modules such as module-2, corner-1 and module-7, corner 2 (Figure 3-4) or corners with

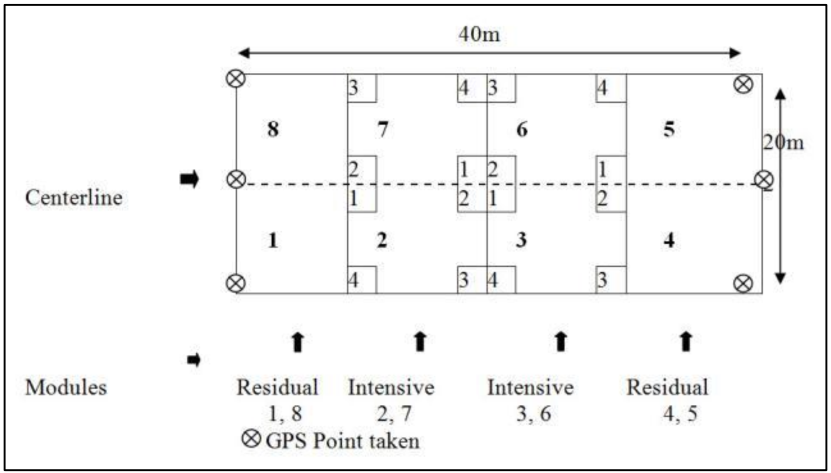

Figure 3-4. Vegetation plot diagram for isolated wetlands.

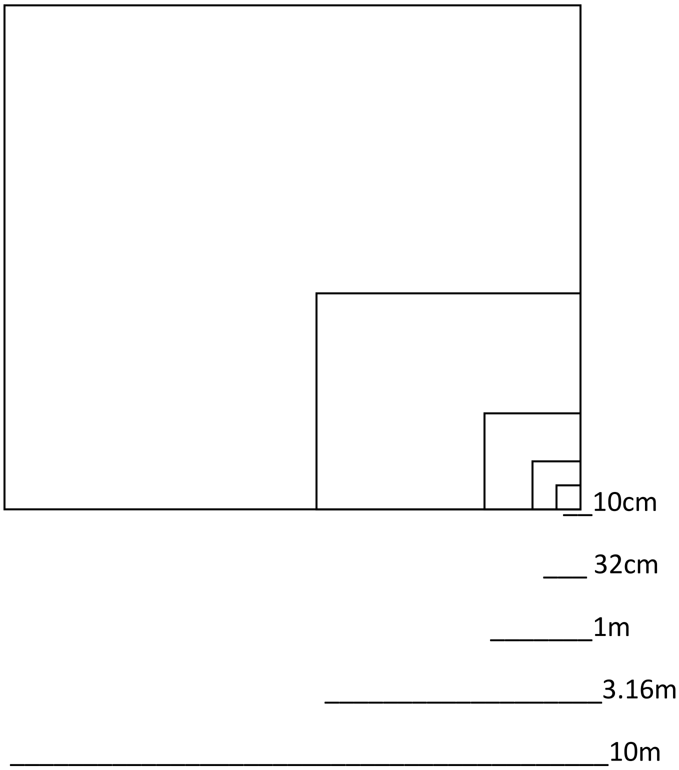

Figure 3-5. Nested quadrat diagram.

localized disturbance, such as a downed tree, were not chosen to survey for presence. Vegetation presence was determined with a series of four nested quadrants (10 cm x 10 cm, 32 cm x 32 cm, 1 m x 1 m, and 3.16 m x 3.16 m; **Figure 3-5**) within each 10 m x 10 m module.

Presence in the CVS protocol is defined as "the occurrence of a species within a quadrat, where the species must be 'rooted in the quadrat.'" Species occurring within the module were given a presence class number for the smallest nested quadrat in which they occurred: "5" for the smallest nested quadrat—10 cm x 10 cm; "4" for 32 cm x 32 cm; "3" for 1 m x 1 m; "2" for 3.16 m x 3.16 m; and "1" for the entire module. Species overhanging the intensive module but not rooted in the module were assigned a presence value of "0".

Cover was collected for all species rooted in or overhanging the module, which included herbs, shrubs, vines, and trees, and was defined as "the percentage of ground surface obscured by the vertical projection of all above ground parts of a given species onto that surface." The CVS protocol was used to divide cover into cover classes based on what the human eye can detect. The cover classes were based roughly on doubling percents: trace (1–2 individuals only), 0–1% (1 m^2), 1–2% (1 m x 2 m), 2–5% (1 m x 5 m), 5–10% (1 m x 10 m), 10–25% (5 m^2), 25–50% (5 m x 10 m), 50–75% (8.7 m^2), 75–95% (9.7 m^2), and 95–100% (10 m^2). Species not rooted or overhanging the intensive modules but located in the residual module, were also recorded. A cover value was also assigned for the overall herb, shrub and sapling, and canopy strata for each of the intensive modules.

Woody stem data were recorded for every woody plant, shrub, vine or tree rooted within the module that reached breast height (BH = 1.37 m above the ground). Woody stems were divided into diameter at breast height (DBH) size classes for ease of measuring and recording in the field: 0–1 cm, 1–2.5 cm, 2.5–5 cm, 5–10 cm, 10–15 cm, 15–20 cm, 20–25 cm, 25–30 cm, 30–35 cm, and ≥ 40, but the exact size was also recorded. A separate tally was kept for each intensive module and a combined tally was kept for the residual modules. All stems were surveyed for bifurcated saplings or shrubs that split below 1 m while only the largest stem was surveyed for bifurcated saplings or shrubs that split above 1 m. Snags that reached a 5 cm DBH were also included in this survey.

3.4.5 Amphibian Monitoring

Many amphibian species are sensitive to environmental disturbances and act as indicators of the quality of their surroundings (EPA, 2002a). North Carolina has 91 species of amphibians and is known for its diverse population of salamanders, boasting more than any other U.S. state at 61 (Braswell, 2006). Deforestation and the increase of acidic conditions and pollutants such as nitrogen and heavy metals can affect these environmentally sensitive species (EPA, 2002a; Smith et al., 1994). Most amphibians spend part of their life in water and part on land or even in subterranean habitats, which makes surveying especially difficult except during the yearly breeding season. Some species of amphibians can reproduce in farm ponds, lakes, ditches, puddles, or rivers, while other species have more specialized requirements, needing mature forested wetland areas that have good water quality and lack predatory fish. These conditions can occur in isolated wetlands or headwater wetlands. In North Carolina, 52 species of amphibians are known to use these types of habitats during their breeding season, 30 of which, or nearly one-third of the amphibian species in North Carolina, require these conditions to reproduce (Braswell, 2006). Of those species, 3 are considered to be of Federal special concern and 2 are State threatened; 4 are of State special concern and 8 are significantly rare (North Carolina Natural Heritage Program, 2008). Continued loss of these critical habitats in North Carolina has the potential to affect population diversity and survival of these unique and sensitive species.

A qualitative and quantitative survey for amphibians was performed at each wetland in conjunction with the aquatic macroinvertebrate survey (see Section 3. 4.6) in late March and then again in late May during the 2010 field season. For the qualitative survey, approximately 2 to 2.5 man-hours of survey work were completed for each site during the March and May sampling events. Surveyors systematically walked the study sites looking for amphibians. D-shaped sweep nets were used to search for amphibians (frogs, tadpoles, egg masses, and larval salamanders) in larger pools of water that were at least 4–5 feet deep. Pools of water were also carefully walked to search for egg masses floating at the surface of the water. Other areas of the wetland site, including upland areas near the delineation line that had more shallow water, or saturated or dry soil, were also searched using potato rakes. Logs or woody debris located in the wetland or adjacent upland were carefully turned over and replaced to look for salamanders or toads. Leaves were lightly scraped adjacent to or over wet and moist areas to search for salamanders. Any auditory calls were recorded and identified if possible.

Marion 2A, which had no standing water, was time surveyed as part of the buffer for Marion 2B. A quantitative survey was performed with funnel traps and coverboards. Funnel traps were deployed for approximately 22 hours in March at both sites and in May at just the Brunswick sites due to lack of standing water at the Marion sites in May. **Table 3-2** shows the number and type of trap that was deployed at each site during the March and May sampling events. Fewer funnel traps were deployed at the Marion 2C site in March due to lack of standing water. Three types of funnel traps were used in the study: plastic, galvanized, and mesh traps made from window screening (**Figure 3-6**). The traps were deployed in 5-inch or deeper water to cover the funnel entrance. Coverboards made out of 2’ x 2’ plywood were deployed in January 2010 at both the Brunswick and Marion sites but due to flooding none of the Brunswick and only some of the Marion site coverboards were checked (**Figure 3-7**). In May,

Table 3-2. Amphibian Survey Summary (Number of Traps Deployed)

	March	May	March	May	March	May
Sites	**Mesh**		**Galvanized**		**Plastic**	
Traps						
Brunswick L3.1	16	10	16	10	0	10
Brunswick L3.2	16	10	16	10	0	10
Marion 2B	17	0	15	0	0	0
Marion 2C	15	0	0	0	0	0
Coverboards						
Brunswick L3.1	0	25	-	-	-	-
Brunswick L3.2	0	23	-	-	-	-
Marion 2B	37	61	-	-	-	-
Marion 2C	68	54	-	-	-	-
Time Survey Traps						
Brunswick L3.1	2	2	-	-	-	-
Brunswick L3.2	2	2	-	-	-	-
Marion 2B	2.5	2	-	-	-	-
Marion 2C	2.5	2	-	-	-	-

coverboards were checked at both the Brunswick and Marion sites (Table 3.3.4.2-1). Fewer coverboards (25) were deployed at the Brunswick sites due to the smaller size of these wetlands in comparison with the Marion sites and two of the boards disappeared in the flood at the Brunswick L3.2 site. At the Marion sites 61 and 54 boards were retrieved in May for Marion 2B and 2c respectively (see Table 3-2). **Figures 3-8** to 3-**10** show the funnel traps deployed at the Marion and Brunswick sites.

Field data sheets (see Appendix 3-A) were kept for each amphibian sampling event. Information on the field data sheets included site name, county, observers, date, start and stop time, water quality parameters, air temperature, wind speed, percent cloud cover, rain in last 48 hours, comments on the hydrology of the site, hours deployed for funnel traps only and a table with records for each separate

Figure 3-6. Funnel Traps

Figure 3-7. Amphibian Coverboards

Figure 3-8. Marion 2B, March 2010 Survey

Figure 3-9. Brunswick L3.2 May 2010 Survey

Figure 3-10. Brunswick L3.1 March 2010 Survey

Figure 3-11. Measuring Amphibians

observation. Each record included species, survey method, life-stage, the number observed, specimen number, photo number, and comments on microhabitat, behavior, malformations, auditory or visual observation, identification information and size (head to tail for salamanders and head to anus for frogs and toads, **Figure 3-11**).

Air and water temperature and water pH, conductivity, and DO were also taken and recorded. The previous 48-hour precipitation and temperature minimum and maximum levels were obtained from the nearest weather stations and recorded on field sheets. Surveys were not done if temperatures were below 40^o F the previous night or below 60^o F during the survey. Herpetologists at the North Carolina State Museum of Natural Sciences assisted with the identification of photos. The Distribution of Amphibians in North Carolina draft document written by the Museum (North Carolina State Museum of Natural Sciences, 2003) was used for genus species nomenclature.

3.4.6 Aquatic Macroinvertebrate Monitoring

Macroinvertebrate samples were collected with D-shaped sweep nets at each wetland on March 23rd (Brunswick county sites) and March 25th (Marion county sites) during the 2010 field season in conjunction with the amphibian surveys. Samples were not taken at Marion 2A, which did not have standing water. The sweep nets were used to sample a variety of microhabitats within each wetland in order to obtain taxa representative of each site (**Figure 3-12**). Details for each sweep net sampling station were recorded on field sheets (see Appendix 3-A). Five to six one-meter sweeps were taken at each wetland sampling station. Additonally, larger mobile taxa such as crayfish, Coleoptera, and Hemiptera were caught in funnel traps (**Figures 3-13** and Figures 3-6 to 3-10) used for amphibian surveys and were combined into one funnel trap sample per site. As discussed in the Amphibian Monitoring Section, Section 3.3.4.5, an equal number of traps was not deployed at each site due to the lack of standing water at the Marion 2C site (see Table 3-1). Therefore, sampling effort with the use of funnel traps was not equal between sites.

Samples were placed in 1000 mL containers and preserved with 70% ethanol, stored at room temperature and later picked for identification and enumeration in the lab. Sample contents were mixed and deposited evenly and then sorted randomly on a 14 x 17 inch picking tray with 12 grid cells under a light (**Figure 3-14**). All macroinvertebrates that were greater than 1 cm were picked from the sample first to ensure that predators were included in the processed sample. Grid cells were randomly chosen for picking after the greater than 1 cm taxa were removed from the sample. Each grid cell was entirely picked prior to starting the next randomly chosen grid cell. A total of 200 individuals or the entire sample (if less than 200 individuals were found) was picked for each sweep-net sample. The entire funnel trap sample was picked. Trained DWQ entomologists did the picking, identification, and enumeration of each sample. *Aquatic Insects and Oligochaetes of North and South Carolina* (Brigham et al., 1982) and *Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina* (Epler, 2001) were used for genus and species nomenclature.

Figure 3-12. Sweep net samples

Figure 3-13. Funnel Trap Samples

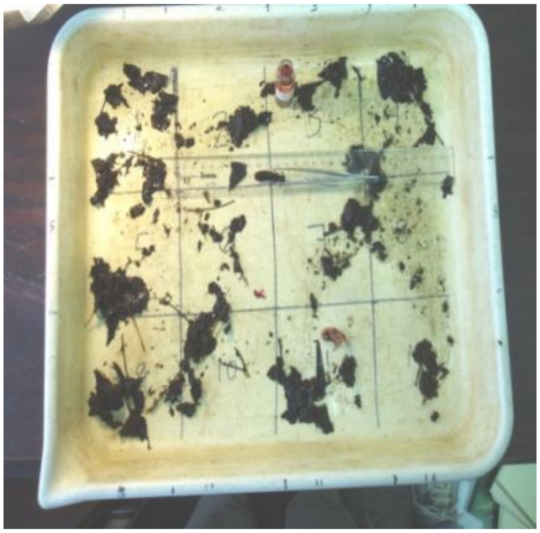

Figure 3-14. Gridded Picking Tray

3.4.7 Chain of Custody

Samples collected for the Level 3 field work included water quality samples, soil samples, plant vouchers, amphibian specimens, and aquatic macroinvertebrate samples. Sample handling and custody is described below.

Water Quality Samples - Handling and custody of water quality samples included sample labeling, sample transport, temporary storage, temperature control, and delivery to the Division of Water Quality laboratory in Raleigh NC. Samples were transported to the laboratory in <6°C iced containers within the holding time limitations for each chemical analysis. Water sample handling followed the DWQ Sample Submission Guidelines (http://h2o.enr.state.nc.us/lab/qa/ sampsubguide.htm). The process of collecting samples in the field, submitting them to the lab, receiving results, and transferring results to an electronic database was tracked with a Water Quality Sample Tracking Sheet. See the GPS section for handling of GPS information.

Soil samples for basic soil analysis - Soil samples were collected in the field and placed in zip lock bags labeled with the wetland site name and sample number. Samples were later transferred to lab soil sampling boxes labeled with contact information, site name and sample numbers. There is no hold time for soil samples. The soil sample boxes were then delivered to the Agronomic Division, Soil Testing Section in Raleigh, NC. The procedures followed the Soil Testing Section Lab's "Sample collection and packaging guidelines" specified at http://www.agr.state.nc.us/agronomi/uyrst.htm.

Soil samples for phosphorus adsorption capacity - Soil samples were collected in the field and placed in zip lock bags labeled with the wetland site name, sample number, and horizon. There is no hold time for soil samples. The soil samples were delivered to the University of South Carolina for analysis. Soil collection and handling procedures were similar to those found in the North Carolina Soil Testing Section Lab's "Sample collection and packaging guidelines" specified in at http://www.agr.state.nc.us/agronomi/uyrst.htm.

Aquatic Macroinvertebrate Samples - Samples collected in the field were stored in 1000 ml Nalgene containers with 70% ethanol at room temperature and labeled with site name and sample number. Samples were processed and transferred to glass vials with 70% ethanol with the same labeling. Sampling vials remained stored at room temperature until they were identified and enumerated. There was no hold time for aquatic macroinvertebrate samples. Samples were processed, identified and enumerated by trained NCDWQ aquatic entomologists.

Amphibian Samples - No amphibian specimens were collected for this project. Rather, photographs were taken and taxa were identified by the NC Museum of Natural History (see Amphibian Monitoring Results Section 3.5.6).

Plant Samples - Voucher specimens were collected and flagged for identification in the field. All samples were recorded on the field sheet with a descriptive name that reflects the genus or family or diagnostic characteristics such as leaf size or shape (e.g. mint – pubescent leaves or triangular-leaved forb). Flagging was labeled with the same descriptive name and Site plot numbers. Samples were kept in refrigerated zip lock bags labeled with the wetland site number and collecting date prior to identification. All voucher specimens were identified to the lowest taxonomic category possible. Voucher specimens were then pressed and labeled with name, wetland site name, and collecting date.

3.4.8 Data Management and Quality Control

Quality control for the Level 3 field work relied on the expertise of the field team leaders, training of field staff, and review of field data forms for completeness, accuracy, and consistency. The lead investigators for this phase of the project (Dr. Dan Tufford and Ms. Virginia Baker) coordinated site visits, shared methods, and harmonized their methods prior to beginning field work. All wetland site preparations, equipment installation, surveys, and assessments were reviewed by a wetlands expert for reasonableness and accuracy. All field work was done in teams of at least two scientists always including either Dan Tufford, Virginia Baker, Rick Savage, or Warren Hankinson. This ensured that an experienced wetland field ecologist supervised all Level 3 activity. Decisions in the field were by consensus of the supervisor(s) and trained field team.

Similarly to the Level 2 work, all field datasheets were maintained and archived in project records and any changes to the original data entry were recorded and archived.

3.5 Results

3.5.1 Site Description

The Marion County, SC, number 2 Level 2 site met the selection criteria as a Level 2 site with a cluster of isolated wetlands that were accessible and secure, had minimal anthropomorphic alterations, and were close to a stream or connected wetland (see Section 3.3, Site Selection). The Marion 2 site included three IWs (Marion 2a, Marion 2b, and Marion 2c) and is located in the southern part of Marion County in the Woodbury Wildlife Management Area (see **Figure 3-15**). A cluster of Level 2 IWs that met the study criteria was not found in NC, so Level 1 candidate IW polygons and aerial photos were reviewed to identify candidates that were then field checked for usability. A suitable cluster of two IWs, the Brunswick L3.1 and L3.2 sites, was found in Brunswick County, NC, east of State Hwy 211 in the Green Swamp Preserve owned by The Nature Conservancy (see **Figure 3-16**).

Table 3-3 summarizes the Level 2 field location, depth, volume, size, and historical isolation results for the two Level 3 sites. **Table 3-4** provides the ecological wetland community type, NCWAM type, NCWAM Functions, and overall NCWAM results. **Table 3-5** summarizes the ORAM metrics and overall ORAM results. The individual IWs within the clusters range in size from 0.03 acres (the Marion 2a site) to 1.82 acres (the Marion 2c site), have maximum depths that range from 0.97 ft (the Marion 2a site) to nearly 10 ft (the BrunswickL3.1 site), and were all ranked high overall by the NCWAM and ranged from 53 (the Marion 2a site) to 78 (the Brunswick L3.1 site) for the ORAM. All sites were defined as Basin Wetlands by NCWAM. The Marion 2a site was only 0.03 acres in size and is separated from an ecologically similar site, the Marion 2b site, by a narrow band of sandy upland. Marion 2a was not surveyed for depth therefore volume was not calculated.

The Level 2 and Level 3 surveys were limited due to the small size of the Marion 2a site, proximity and similarity to the Marion 2b site, and lack of standing water. For the Level 2 survey, only maximum depth was collected at this site (see Part 2, Section 2.2.3.4, Wetland Depth and Volume). The average depth for the other sites ranged from 0.2 feet (Marion 2c) to 3.7 feet (Brunswick L3.2) and the volume ranged from 5,492 cubic feet (Marion 2b) to 41,963 cubic feet (Brunswick L3.2). For the Level 3 survey, water quality samples, macroinvertebrate samples, and hydrological data were not collected, and only a time survey for amphibians was conducted, at the Marion 2a site. The Marion 2a site was searched for amphibians during the Marion 2b site survey since this site was located in the buffer of the Marion 2b site. Also a reduced vegetation and soils survey was completed at the Marion 2a site.

As noted earlier, the Marion 2a and Marion 2b sites were similar ecologically and considered to be Pond Cypress Savannahs by the Nelson (1986) "Classification of Natural Communities of SC" and "Cypress Savannahs" by Schafale and Weakley (1990) "Classification of Natural Communities of North Carolina, Third Approximation". Both the Marion 2a and Marion 2b sites have an open canopy, however the Marion 2a site was more diverse and had a less dense shrub layer (20% cover) than the Marion 2b site (50% cover, see **Figures 3-17 and 3-18**). Vegetation at the Marion 2a site included loblolly pine (*Pinus taeda*) in the canopy stratum, fetter bush (*Lyonia lucida*), highbush blueberry (*Vaccinium fuscatum*) and red maple (Acer rubrum) in the shrub stratum and broomsedge (*Andropogon sp.*) and Virginia chain fern

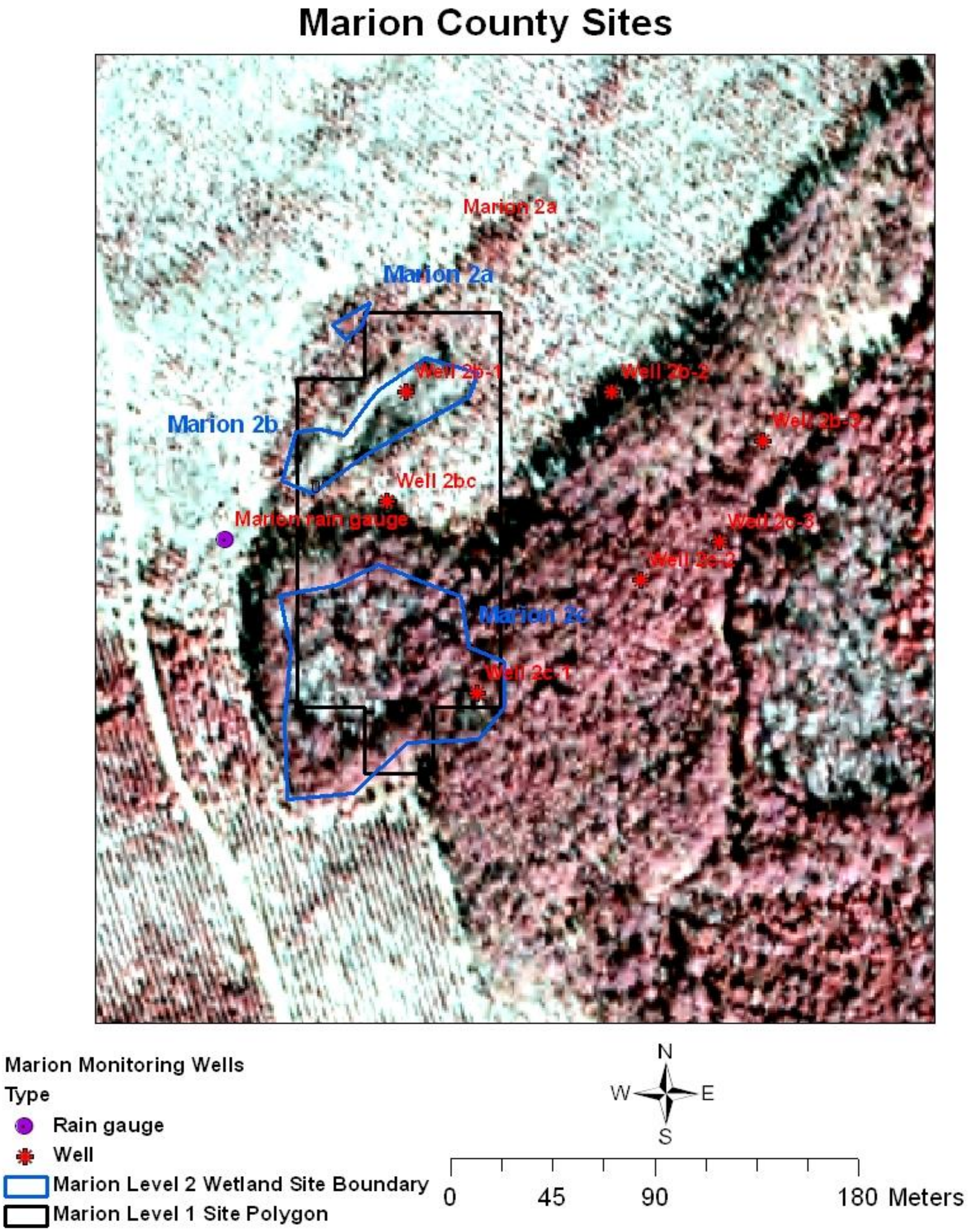

Figure 3-15. Marion County Level 3 IW sites.

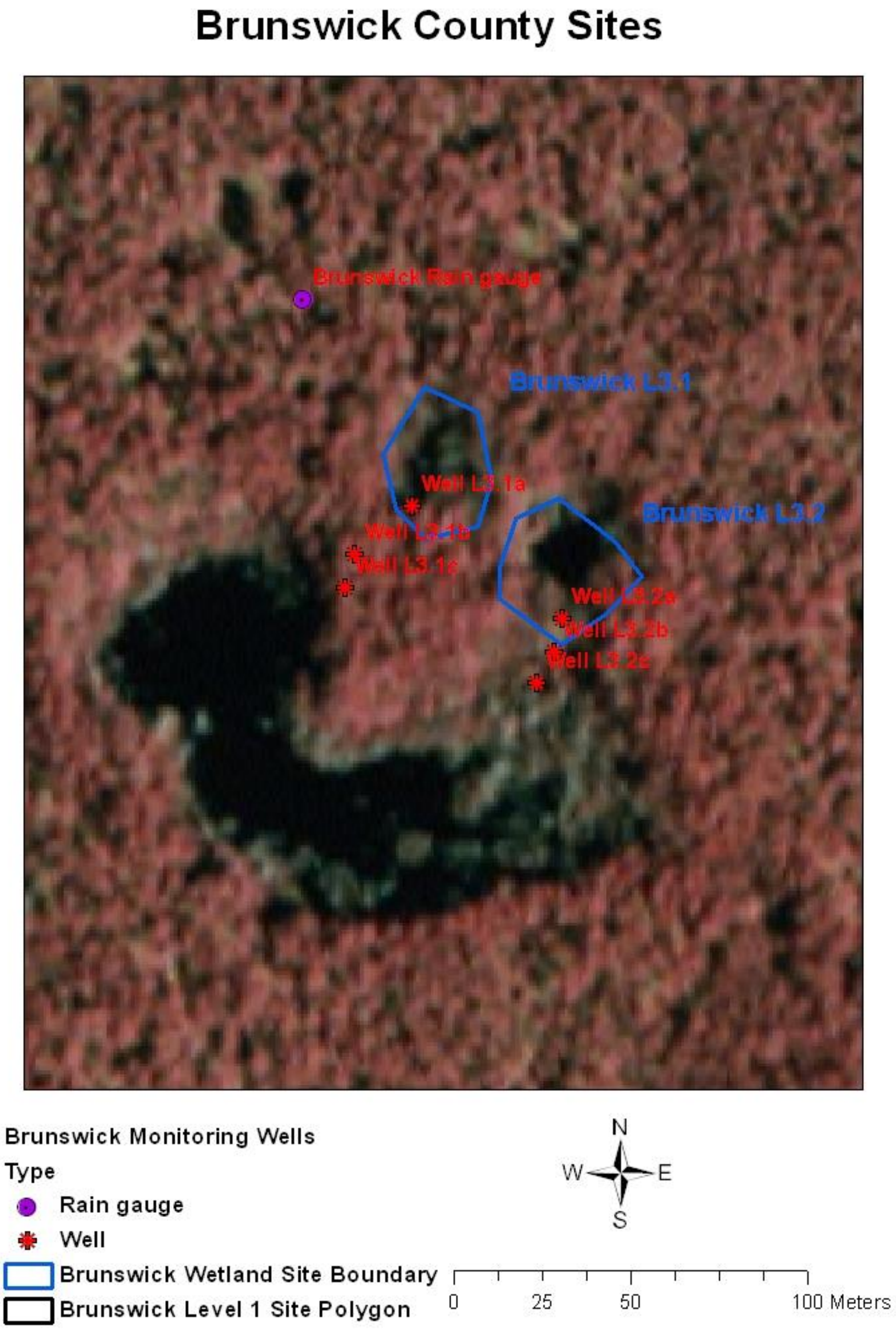

Figure 3-16. Brunswick County Level 3 IW Sites.

Table 3-3. SEIWA Level 3 Site Description - Location, Depth, Volume, Size, Historical Isolation

Lat	Long	Relative Average Depth (ft)	Maximum Depth (ft)	Surface Area		Volume (cubic ft)	Historically Isolated?
				(sq ft)	(acres)		
Marion 2a (SC)							
33.7687	79.2834	N/A	1.0	1,263	0.03	--[1]	Yes
Marion 2b (SC)							
33.7687	79.2834	0.3	0.8	19,950	0.46	5,492	Yes
Marion 2b (SC)							
33.7687	79.2834	0.2	0.7	79,279	1.82	16,423	Yes
Brunswick L3.1 (NC)							
34.0541	78.2714	2.3	9.9	10,063	0.23	23,280	Yes
Brunswick L3.2 (NC)							
34.0539	78.2765	3.7	8.8	11,201	0.26	41,963	Yes

[1] *Marion 2a was not surveyed for depth resulting in no calculation for volume.*

Table 3-4. SEIWA Level 3 Site Description -Community Type, NCWAM Type, and NCWAM Results

Site	3rd Approximation (NC)	Natural Communities (SC)	NCWAM Wetland Type	Hydrology Function Score	Water Quality Function Score	Habitat Function Score	Overall NCWAM Score
Marion 2a	Cypress Savannah	Pond Cypress Savannah	Basin Wetland	High	Medium	High	High
Marion 2b	Cypress Savannah	Pond Cypress Savannah	Basin Wetland	High	High	High	High
Marion 2c	Small Depression Pocosin	Pocosin	Basin Wetland	High	High	High	High
Brunswick L3.1	Small Depression Pond	Pond Cypress Pond	Basin Wetland	High	High	High	High
Brunswick L3.2	Small Depression Pond	Pond Cypress Pond	Basin Wetland	High	High	High	High

Table 3-5. SEIWA Level 3 Site Description -ORAM Metric Scores and Overall results

Site	Overall NCWAM Score	ORAM Scores					
		Metric 1-Wetland Area	Metric 2-Buffers / Land-use	Metric 3-Hydrology	Metric 4-Habitat Alteration	Metric 6-Plant Community	Overall ORAM Score
Marion 2a	High	1	13	18	11	10	53
Marion 2b	High	2	13	23	14.5	17	69.5
Marion 2c	High	3	13	26.5	20	13	75.5
Brunswick L3.1	High	2	14	25	20	17	78
Brunswick L3.2	High	1	14	25	20	17	77

(*Woodwardia virginiana*) in the herb stratum. Similar species occurred at the Marion 2b site along with red maple and sweet gum (*Liquidambar stryraciflua*) in the canopy stratum, myrtle holly (*Ilex myrtifolia*), red bay (*Persea palustris*), and federally endangered southern spice bush (*Lindera melissifolia*) in the shrub stratum, and various species of Carex and other sedge species in the herb stratum.

The Marion 2c site, located 40 meters to the south of the Marion 2b site (see **Figure 3-19**) is very different ecologically than the Marion 2a and 2b sites. A slough that connects to a perennial stream is east of the Marion 2 isolated wetlands - 150 meters from the Marion 2b site and 140 meters from the Marion 2c site. The Marion 2c site was defined as a "Pocosin" by Nelson (1986) and a "Small Depression Pocosin" by Schafale and Weakley (1990). The Marion 2c site had a dense shrub and canopy cover composed of loblolly pine, red maple, pond cypress (*Taxodium ascendens*), swamp tupelo (*Nyssa biflora*), fetterbush, and highbush blueberry, with a nearly non-existent herb stratum.

Figure 3-17. Marion 2a, July 2008.

Figure 3-18. Marion 2b, February 2010.

Figure 3-19. Marion 2c, July 2008.

All three sites were fairly shallow with average depth values for the all the Marion sites equaling less than a third of a foot. The large size of the Marion 2c site (1.82 acres) caused the volume of this site to be more than three times (16,423 cu ft) the volume of the Marion 2b site (5,492 cu ft). Hydrological data recorded by monitoring wells outfitted with transducers indicated water levels ranged up and down by 3.68 feet at the Marion 2b site and 3.87 feet at the Marion 2c site. The surrounding sandy upland soils enabled rapid drainage to these sites, especially the Marion 2a and 2b sites, during rain events. Most of the soil samples examined at the three Marion sites during the Level 3 survey were sand or loamy sand, a few were also sandy loam. The Marion 2a and Marion 2b sites are surrounded with planted 15-year old loblolly pine. The soils at the Marion County sites are mapped as Leon sand which is considered to be a poorly drained upland soil. The Marion 2c site has the 15-year old planted loblolly pine to the south, 20-30 m of mature forest to the north and west, and mature forest to the east beyond 1000 m.

The Brunswick County sites are ecologically more similar to each other than the Marion county sites. Both the Brunswick L3.1 and L3.2 sites are small (approximately quarter acre), steep-sided and deep lime sinks with an open water section in the middle (**Figures 3-20** and **3-21**). According to Schafale and Weakly (1990) the Brunswick sites are considered to be "Small Depression Ponds" and according to Nelson (1986) they are considered to be "Pond Cypress Ponds".

Figure 3-20. Brunswick L3.1, July 2009.

Figure 3-21. Brunswick L3.2, February 2010.

The vegetation is similar at the two Brunswick sites with a concentric zone of pond cypress, swamp tupelo and titi (*Cyrilla racemiflora*) surrounding the deep open water middle sections and another zone of loblolly, fetter bush, highbush blueberry, and sweet pepper bush (*Clethera alnifolia*) occurring around the outer edge of the two lime sinks. The IWs are surrounded by mature and intact flatwoods. The two Brunswick sites are approximately 10 meters apart. Brunswick L3.1 is 25 meters from the nearby connected wetland and Brunswick L3.2 is 10 meters away from the same wetland.

Both Brunswick sites, although small in size, have a much larger volume than the Marion sites. The maximum depth for the Brunswick L3.1 and Brunswick L3.2 sites are 9.9 ft and 8.8 ft respectively, the average depths are 2.3 ft and 3.7 ft respectively, and the volumes are 23,280 cu ft and 41,963 cu ft respectively. Hydrological data collected at these sites indicated the water levels varied significantly during the year, by 5.54 feet in Brunswick L3.1 and 5.94 feet in Brunswick L3.2. The Green Swamp Preserve land managers commented that these two sinkholes had more flooding this past winter than they could recall in previous years. The Brunswick L3.1 and L3.2 sites are mapped in Hydric B soil types known to have hydric inclusions. The mapping unit is an upland soil, Kureb fine sand. However soils observed in the interior of the IWs were clearly wetland soils with muck and sandy muck textures. Soils observed around the edge of the IWs were sandy in texture and may have washed into the wetland from the adjacent upland.

As shown in Table 3-3, NCWAM scores for the hydrology, water quality, and habitat functions were rated as high for all of the sites except the Marion 2a site in which the water quality function was rated medium. The lower score for the Marion 2a site was likely due to the small size of this site. The Marion 2a site also had the lowest ORAM score, 53, while the Marion 2b site rated 69.5 and the Marion 2c site rated 75.5 (see Table 3-4). The two larger Marion sites, Marion 2b and Marion 2c, both scored higher for the ORAM Metric 3- Hydrology and Metric 4-Habitat Alteration. The Marion 2a and Marion 2b sites had ground disturbance from past logging operations. The Brunswick sites were very similar in regards to the ORAM results, scoring 78 and 77 overall for the Brunswick L3.1 and Brunswick L3.2 sites respectively.

3.5.2 Water Quality Monitoring Results

Water quality results indicated there was variability between both wetland and well stations and variability between season (October 2009 and February, May, and August 2010). Summary results were calculated for stations within each individual IW and for combined stations within the clusters of wetlands.

3.5.2.1 Water Quality Results by Individual IW

Individual IW results for each parameter, including the mean, median, range, and number of samples collected for each wetland and well station, are shown in **Table 3-6** for the Brunswick County IWs and in **Table 3-7** for the Marion County IWs. Tables 3-6 and 3-7 also include the station name, station type (wetland or well), and the order of the water quality monitoring station along its sampling transect. For station order, the wetland monitoring station was assigned a "1", the well station located within the wetland (Brunswick "well a"; Marion "well 1") was assigned a "2", the closest upland well to the wetland was assigned a "3" (Brunswick "well b"; Marion "well 2"), and the upland well furthest from the wetland was assigned a "4" (Brunswick "well c"; Marion "well 3"); Figures 3-15 and 3-16 in Section 3.5.1 show a map view of the Brunswick and Marion sampling transects. Marion well 2b/c, which is located in the upland between Marion 2b and Marion 2c, was not along a transect and was assigned a station order of "5". Note that well c at Brunswick L.3-2 site was located at the edge of the connected wetland located 10m southeast of the Brunswick L3.2 IW site (see Figure 3-16).

Table 3-6 shows that the Brunswick L3 cluster of IWs had an average **pH** ranging from a low of 3.49 at the Brunswick L3.1 well a station to a high of 4.31 at the Brunswick L3.1 well b station. Average temperature ranged about 5°C at the Brunswick L3 sites, from 16°C at Brunswick L3.2 well c to 22°C at Brunswick L3.2 well a. Average **dissolved oxygen (DO)** levels in the Brunswick wetland and wells were also low, with the Brunswick L3.2 well a station having the lowest levels of DO with 1.35 mg/L (15.6% saturation) and the Brunswick L3.1 well c station having the highest levels of DO with 5.38 mg/L (55.5% saturation). **Dissolved organic carbon (DOC)** averages at the Brunswick L3 sites were more variable with the Brunswick L3.1 well b station having the lowest average of 4.25 mg/L DOC and the Brunswick L3.2 well c station having the highest average of 54.4 mg/L. The other Brunswick wetland wells had an

Table 3-6. Summary of Water Quality Results by Individual Brunswick County Level 3 Isolated Wetland

IW	Station	Station Order	Parameter	Mean	Median	Range	N
L3.1	wetland	1	pH	3.58	3.57	0.16	4
L3.1	well a	2	pH	3.49	3.49	0.18	2
L3.1	well b	3	pH	4.31	4.26	0.48	4
L3.1	well c	4	pH	4.33	4.27	0.43	4
L3.2	wetland	1	pH	3.9	4	0.76	4
L3.2	well a	2	pH	3.86	3.86	0.11	2
L3.2	well b	3	pH	3.99	3.87	0.76	4
L3.2	well c	4	pH	3.46	3.36	0.69	4
L3.1	wetland	1	Water Temperature (C°)	17.0	17.05	15.2	4
L3.1	well a	2	Water Temperature (C°)	21.7	21.7	5.2	2
L3.1	well b	3	Water Temperature (C°)	17.8	18.25	7	4
L3.1	well c	4	Water Temperature (C°)	18.2	18.55	9.4	4
L3.2	wetland	1	Water Temperature (C°)	16.00	15.25	13.8	4
L3.2	well a	2	Water Temperature (C°)	22.0	21.95	4.5	2
L3.2	well b	3	Water Temperature (C°)	16.9	17.75	11.9	4
L3.2	well c	4	Water Temperature (C°)	16.4	17	13.6	4
L3.1	wetland	1	DO (mg/L)	3.36	2.87	4.1	4
L3.1	well a	2	DO (mg/L)	2.05	2.05	2.5	2
L3.1	well b	3	DO (mg/L)	2.5	2.55	0.3	4
L3.1	well c	4	DO (mg/L)	5.38	5.75	2.6	4
L3.2	wetland	1	DO (mg/L)	3.74	3.47	4.6	4
L3.2	well a	2	DO (mg/L)	1.35	1.35	1.3	2
L3.2	well b	3	DO (mg/L)	2.03	2.6	2.1	3
L3.2	well c	4	DO (mg/L)	3.27	2.6	3	3
L3.1	wetland	1	DO (% saturation)	32	31.25	29	4
L3.1	well a	2	DO (% saturation)	24	24.1	31.8	2
L3.1	well b	3	DO (% saturation)	26	27	5.5	4
L3.1	well c	4	DO (% saturation)	56	58.4	25.3	4
L3.2	wetland	1	DO (% saturation)	36	29.85	45.3	4
L3.2	well a	2	DO (% saturation)	16	15.6	16.8	2
L3.2	well b	3	DO (% saturation)	21	24.2	22.5	3
L3.2	well c	4	DO (% saturation)	32	28	20.1	3
L3.1	wetland	1	DOC (mg/L)	21.1	22	11.5	4
L3.1	well a	2	DOC (mg/L)	45.5	45.5	13	2
L3.1	well b	3	DOC (mg/L)	4.25	4.35	4.3	4
L3.1	well c	4	DOC (mg/L)	4.35	2.7	8	4
L3.2	wetland	1	DOC (mg/L)	16.6	14.6	11	4
L3.2	well a	2	DOC (mg/L)	30	30	6	2
L3.2	well b	3	DOC (mg/L)	7.25	7.05	5.1	4
L3.2	well c	4	DOC (mg/L)	54.4	53.85	54	4
L3.1	wetland	1	Specific Conductivity (µs)	75.4	69.45	43.7	4
L3.1	well a	2	Specific Conductivity (µs)	123	122.5	96.2	2
L3.1	well b	3	Specific Conductivity (µs)	51.2	50	19.8	4
L3.1	well c	4	Specific Conductivity (µs)	68.4	63.65	35.8	4

IW	Station	Station Order	Parameter	Mean	Median	Range	N
L3.2	wetland	1	Specific Conductivity (µs)	65.8	65.95	25.8	4
L3.2	well a	2	Specific Conductivity (µs)	96.9	96.9	0	1
L3.2	well b	3	Specific Conductivity (µs)	97	97.35	14.3	4
L3.2	well c	4	Specific Conductivity (µs)	130	128.9	29.6	4
L3.1	wetland	1	Ammonia (mg/L)	0.09	0.09	0.14	4
L3.1	well a	2	Ammonia (mg/L)	0.08	0.08	0.04	2
L3.1	well b	3	Ammonia (mg/L)	0.05	0.04	0.09	4
L3.1	well c	4	Ammonia (mg/L)	0.05	0.04	0.07	4
L3.2	wetland	1	Ammonia (mg/L)	0.06	0.02	0.14	4
L3.2	well a	2	Ammonia (mg/L)	0.05	0.05	0.06	2
L3.2	well b	3	Ammonia (mg/L)	0.02	0.02	0.01	4
L3.2	well c	4	Ammonia (mg/L)	0.09	0.08	0.15	4
L3.1	wetland	1	NO2+NO3 (mg/L)	0.03	0.02	0.03	4
L3.1	well a	2	NO2+NO3 (mg/L)	0.02	0.02	0	2
L3.1	well b	3	NO2+NO3 (mg/L)	0.02	0.02	0	4
L3.1	well c	4	NO2+NO3 (mg/L)	0.02	0.02	0	4
L3.2	wetland	1	NO2+NO3 (mg/L)	0.02	0.02	0.01	4
L3.2	well a	2	NO2+NO3 (mg/L)	0.02	0.02	0	2
L3.2	well b	3	NO2+NO3 (mg/L)	0.02	0.02	0	4
L3.2	well c	4	NO2+NO3 (mg/L)	0.02	0.02	0	4
L3.1	wetland	1	TKN (mg/L)	0.77	0.83	0.58	4
L3.1	well a	2	TKN (mg/L)	2.15	2.15	2.1	2
L3.1	well b	3	TKN (mg/L)	1.88	2.15	1.98	4
L3.1	well c	4	TKN (mg/L)	2.27	2	3.73	4
L3.2	wetland	1	TKN (mg/L)	0.63	0.66	0.34	4
L3.2	well a	2	TKN (mg/L)	5.25	5.25	1.1	2
L3.2	well b	3	TKN (mg/L)	1.39	1.3	1.46	4
L3.2	well c	4	TKN (mg/L)	3.93	3.1	4.1	4
L3.1	wetland	1	Phosphorus (mg/L)	0.04	0.04	0.04	4
L3.1	well a	2	Phosphorus (mg/L)	0.23	0.23	0.02	2
L3.1	well b	3	Phosphorus (mg/L)	0.41	0.41	0.37	4
L3.1	well c	4	Phosphorus (mg/L)	0.63	0.63	0.56	4
L3.2	wetland	1	Phosphorus (mg/L)	0.04	0.03	0.08	4
L3.2	well a	2	Phosphorus (mg/L)	0.23	0.23	0.09	2
L3.2	well b	3	Phosphorus (mg/L)	0.32	0.29	0.38	4
L3.2	well c	4	Phosphorus (mg/L)	0.49	0.36	0.76	4

average DOC of 45.5 mg/L and 30 mg/L for the Brunswick L3.1 and Brunswick L3.2 well a stations. Average **specific conductivity** ranged from a low of 51.2 µs at Brunswick L3.1 well b station to a high of 130 µs at the Brunswick L3.2 well c station.

Average **ammonia** levels were low at all Brunswick stations, with the Brunswick L3.2 well b station being lowest at 0.02 mg/L and the Brunswick L3.1 wetland station being highest at 0.09 mg/L. The average **total Kjeldahl nitrogen (TKN)** results ranged from 0.63 mg/L at the Brunswick L3.2 wetland station to

5.25 mg/L at the Brunswick L3.2 well a station. Brunswick average **nitrate/nitrite (NO2+NO3)** levels were also all very low, typically 0.02, which is the DWQ water quality practical quantitation limit.

Average **phosphorous** levels varied from an average of 0.04 mg/L at both wetland stations for the Brunswick L3 sites to 0.63 mg/L at the Brunswick L3.1 well c station.

The Marion 2 IW cluster was similar and dissimilar to the Brunswick IW cluster in terms of average water quality station results (**Table 3-7**). Average **pH** results were lower at the wetland stations for the Marion IW cluster than for the wetland stations for the Brunswick IW cluster with average results of 3.08 and 3.46 occurring respectively at the Marion 2c wetland and the Marion 2b wetland stations. However, pH average results for the wells at the Marion IW cluster wells tended to be higher than the Brunswick IW cluster with the highest average pH (4.33) recorded at Marion 2b well.

Table 3-7. Summary of Water Quality Results by Individual Marion County Level 3 Isolated Wetlands

Site	Station	Station Order	Parameter	Mean	Median	Range	N
2b	wetland	1	pH	3.46	3.46	0.31	2
2b	well 1	2	pH	4.13	4.29	0.69	3
2b	well 2	3	pH	4.33	4.33	0.65	2
2b	well 3	4	pH	4.31	4.31	0	2
2c	wetland	1	pH	3.08	3.08	0.3	2
2c	well 1	2	pH	3.92	3.89	0.92	3
2c	well 2	3	pH	4.25	4.25	0.4	2
2c	well 3	4	pH	4.3	4.3	0.08	2
2b/2c	well 2b/c	5	pH	4.25	4.13	0.42	3
2b	wetland	1	Water Temperature (C°)	27	27	0	1
2b	well 1	2	Water Temperature (C°)	16.87	19.5	8.9	3
2b	well 2	3	Water Temperature (C°)	18.55	18.55	11.9	2
2b	well 3	4	Water Temperature (C°)	18.35	18.35	10.3	2
2c	wetland	1	Water Temperature (C°)	16.3	16.3	14.6	2
2c	well 1	2	Water Temperature (C°)	16.5	18.7	9.2	3
2c	well 2	3	Water Temperature (C°)	17.9	17.9	12.4	2
2c	well 3	4	Water Temperature (C°)	18.05	18.05	10.9	2
2b/2c	well 2b/c	5	Water Temperature (C°)	19.57	21.3	14.2	3
2b	wetland	1	DO (mg/L)	3.75	3.75	4.7	2
2b	well 1	2	DO (mg/L)	2.17	2.6	2.5	3
2b	well 2	3	DO (mg/L)	5.15	5.15	4.5	2
2b	well 3	4	DO (mg/L)	8.8	8.8	0.4	2
2c	wetland	1	DO (mg/L)	3.4	3.4	5.8	2
2c	well 1	2	DO (mg/L)	1.87	1.8	2	3
2c	well 2	3	DO (mg/L)	8.2	8.2	2.6	2
2c	well 3	4	DO (mg/L)	7.1	7.1	2.6	2
2b/2c	well 2b/c	5	DO (mg/L)	7.13	6.6	1.6	3
2b	wetland	1	DO (% saturation)	35.5	35.5	33	2
2b	well 1	2	DO (% saturation)	21.5	27.7	21.2	3
2b	well 2	3	DO (% saturation)	51.75	51.75	33.9	2
2b	well 3	4	DO (% saturation)	93.1	93.1	16.2	2

Site	Station	Station Order	Parameter	Mean	Median	Range	N
2c	wetland	1	DO (% saturation)	30	30	48	2
2c	well 1	2	DO (% saturation)	18.47	19.2	16.4	3
2c	well 2	3	DO (% saturation)	85.15	85.15	6.3	2
2c	well 3	4	DO (% saturation)	73.85	73.85	10.7	2
2b/2c	well 2b/c	5	DO (% saturation)	76.83	75.1	7.6	3
2b	wetland	1	DOC (mg/L)	56	56	40	2
2b	well 1	2	DOC (mg/L)	23.03	9.7	40.6	3
2b	well 2	3	DOC (mg/L)	4.45	4.45	4.9	2
2b	well 3	4	DOC (mg/L)	2.4	2.4	0.8	2
2c	wetland	1	DOC (mg/L)	117.5	117.5	65	2
2c	well 1	2	DOC (mg/L)	37.1	20.7	73.4	3
2c	well 2	3	DOC (mg/L)	5.3	5.3	3.8	2
2c	well 3	4	DOC (mg/L)	2.65	2.65	0.3	2
2b/2c	well 2b/c	5	DOC (mg/L)	2.27	2	0.8	3
2b	wetland	1	Specific Conductivity (µs)	84.4	84.4	14.6	2
2b	well 1	2	Specific Conductivity (µs)	40.1	34.8	16.9	3
2b	well 2	3	Specific Conductivity (µs)	28.2	28.2	9.6	2
2b	well 3	4	Specific Conductivity (µs)	28.3	28.3	0.6	2
2c	wetland	1	Specific Conductivity (µs)	202.65	202.65	69.7	2
2c	well 1	2	Specific Conductivity (µs)	70.5	56.2	68.1	3
2c	well 2	3	Specific Conductivity (µs)	32.35	32.35	8.9	2
2c	well 3	4	Specific Conductivity (µs)	31.35	31.35	4.5	2
2b/2c	well 2b/c	5	Specific Conductivity (µs)	36.13	34.5	19.1	3
2b	wetland	1	Ammonia (mg/L)	0.02	0.02	0	2
2b	well 1	2	Ammonia (mg/L)	0.07	0.06	0.06	3
2b	well 2	3	Ammonia (mg/L)	0.03	0.03	0.02	2
2b	well 3	4	Ammonia (mg/L)	0.06	0.06	0.07	2
2c	wetland	1	Ammonia (mg/L)	0.07	0.07	0.05	2
2c	well 1	2	Ammonia (mg/L)	0.09	0.09	0.15	3
2c	well 2	3	Ammonia (mg/L)	0.12	0.12	0.17	2
2c	well 3	4	Ammonia (mg/L)	0.05	0.05	0.05	2
2b/2c	well 2b/c	5	Ammonia (mg/L)	0.12	0.13	0.02	3
2b	wetland	1	NO2+NO3 (mg/L)	0.02	0.02	0	2
2b	well 1	2	NO2+NO3 (mg/L)	0.02	0.02	0	3
2b	well 2	3	NO2+NO3 (mg/L)	0.02	0.02	0	2
2b	well 3	4	NO2+NO3 (mg/L)	0.04	0.04	0.01	2
2c	wetland	1	NO2+NO3 (mg/L)	0.02	0.02	0	2
2c	well 1	2	NO2+NO3 (mg/L)	0.02	0.02	0	3
2c	well 2	3	NO2+NO3 (mg/L)	0.03	0.03	0.01	2
2c	well 3	4	NO2+NO3 (mg/L)	0.02	0.02	0	2
2b/2c	well 2b/c	5	NO2+NO3 (mg/L)	0.04	0.03	0.02	3
2b	wetland	1	TKN (mg/L)	1.31	1.31	0.78	2
2b	well 1	2	TKN (mg/L)	2.17	1.9	1.4	3
2b	well 2	3	TKN (mg/L)	0.71	0.71	0.54	2
2b	well 3	4	TKN (mg/L)	1.33	1.33	0.75	2
2c	wetland	1	TKN (mg/L)	2.53	2.53	1.45	2
2c	well 1	2	TKN (mg/L)	3.2	3.4	0.8	3

Site	Station	Station Order	Parameter	Mean	Median	Range	N
2c	well 2	3	TKN (mg/L)	0.59	0.59	0.17	2
2c	well 3	4	TKN (mg/L)	0.9	0.9	0.41	2
2b/2c	well 2b/c	5	TKN (mg/L)	1.83	1.6	2.31	3
2b	wetland	1	Phosphorus (mg/L)	0.07	0.07	0.05	2
2b	well 1	2	Phosphorus (mg/L)	0.31	0.26	0.24	3
2b	well 2	3	Phosphorus (mg/L)	0.47	0.47	0.57	2
2b	well 3	4	Phosphorus (mg/L)	3.15	3.15	0.9	2
2c	wetland	1	Phosphorus (mg/L)	0.06	0.06	0.05	2
2c	well 1	2	Phosphorus (mg/L)	0.31	0.32	0.44	3
2c	well 2	3	Phosphorus (mg/L)	1.01	1.01	0.78	2
2c	well 3	4	Phosphorus (mg/L)	1.95	1.95	1.3	2
2b/2c	well 2b/c	5	Phosphorus (mg/L)	3.5	4.2	3.3	3

Most of the average **water temperatures** recorded were within three °C of each other, 16.3° C (the Marion 2c wetland station) to 19.57° C (the Marion 2 well 2b/c station) except for the Marion 2b wetland station which had a much higher average temperature, 27 °C, than all other water quality stations at either IW cluster. Average **DO** levels were a little higher at the Marion 2 IW cluster than the Brunswick L3 cluster of IWs, ranging from 1.87 mg/L (21.5% saturation) at the Marion 2b well 1 station to 8.8 mg/L (93.1 percent saturation) at the Marion 2b well 3 station. The Marion 2c wetland station had a very high average result for **DOC**, 117.5 mg/L, with the Marion 2b wetland station being second highest with an average result of 56 mg/L. The lowest average result for DOC at the Marion 2 IW cluster was recorded at the Marion 2 well b/c station, 2.27 mg/L. An extremely high average result for **specific conductivity**, 202.65 µs, was recorded at the Marion 2c wetland station, with the next highest average value of 70.5 µs recorded at the Marion 2c well 1 station. The lowest average result for specific conductivity at the Marion IW cluster was, 28.2 µs which occurred at the Marion 2b well 2 station.

As in Brunswick, average **ammonia** levels were very low, ranging from 0.02 mg/L at the Marion 2b wetland station to 0.12 mg/L at the Marion 2c well 2 and Marion b/c well stations. Also similar to the Brunswick IW cluster, **NO2+NO3** had very low average results recorded at all the stations (0.02-0.04 mg/L) and **TKN** average results were also low with lowest average TKN result, 0.71 mg/L, occurring at the Marion 2b well 2 station and the highest average TKN result, 3.2 mg/L occurring at the Marion 2c well 1 station. **Phosphorus** average values were higher at the Marion IW cluster then at the Brunswick IW cluster with 3.15 mg/L average phosphorous recorded at the Marion 2 well b/c station. The lowest average phosphorous result at the Marion 2 sites, 0.06 mg/L, occurred at the Marion 2c wetland station.

3.5.2.2 Water Quality Results by IW Clusters

The sites within both clusters, the Marion 2 and Brunswick L3 cluster of IWs, were similar enough in terms of soils, depth, size, and distance of wells along the transect to combine the water quality station results for each wetland cluster. **Table 3-8** summarizes water quality results for the wetland and well stations combined across the Brunswick County L3 and Marion 2 IW clusters, including the mean,

Table 3-8. Water Quality Results for the Wetland and Well Stations Combined

Wetland Cluster	Station Type	Station Order	Parameter	Mean	Median	Range	N
Brunswick L.3	Wetland	1	pH	3.74	3.64	0.76	8
Brunswick L.3	Well	2	pH	3.67	3.69	0.51	4
Brunswick L.3	Well	3	pH	4.15	4.17	0.86	8
Brunswick L.3	Well	4	pH	3.89	4.04	1.39	8
Marion 2	*Wetland*	*1*	*pH*	*3.27*	*3.27*	*0.68*	*4*
Marion 2	*Well*	*2*	*pH*	*4.03*	*4.09*	*0.92*	*6*
Marion 2	*Well*	*3*	*pH*	*4.29*	*4.25*	*0.65*	*4*
Marion 2	*Well*	*4*	*pH*	*4.31*	*4.31*	*0.08*	*4*
Marion 2	*Well*	*5*	*pH*	*4.25*	*4.13*	*0.42*	*3*
Brunswick L.3	Wetland	1	Water, Temperature (C°)	16.5	15.25	15.2	8
Brunswick L.3	Well	2	Water, Temperature (C°)	21.83	21.95	5.2	4
Brunswick L.3	Well	3	Water, Temperature (C°)	17.34	18.25	11.9	8
Brunswick L.3	Well	4	Water, Temperature (C°)	17.31	18.5	13.6	8
Marion 2	*Wetland*	*1*	*Water, Temperature (C°)*	*19.87*	*23.6*	*18*	*3*
Marion 2	*Well*	*2*	*Water, Temperature (C°)*	*16.68*	*19.1*	*9.2*	*6*
Marion 2	*Well*	*3*	*Water, Temperature (C°)*	*18.23*	*18.35*	*12.8*	*4*
Marion 2	*Well*	*4*	*Water, Temperature (C°)*	*18.2*	*18.35*	*10.9*	*4*
Marion 2	*Well*	*5*	*Water, Temperature (C°)*	*19.57*	*21.3*	*14.2*	*3*
Brunswick L.3	Wetland	1	DO (mg/L)	3.55	3.09	4.6	8
Brunswick L.3	Well	2	DO (mg/L)	1.7	1.4	2.6	4
Brunswick L.3	Well	3	DO (mg/L)	2.3	2.6	2.1	7
Brunswick L.3	Well	4	DO (mg/L)	4.47	5.1	4.2	7
Marion 2	*Wetland*	*1*	DO (mg/L)	*3.58*	*3.75*	*5.8*	*4*
Marion 2	*Well*	*2*	DO (mg/L)	*2.02*	*2.2*	*2.5*	*6*
Marion 2	*Well*	*3*	DO (mg/L)	*6.68*	*7.15*	*6.6*	*4*
Marion 2	*Well*	*4*	DO (mg/L)	*7.95*	*8.5*	*3.2*	*4*
Marion 2	*Well*	*5*	DO (mg/L)	*7.13*	*6.6*	*1.6*	*3*
Brunswick L.3	Wetland	1	DO (mg/L)	34.04	29.85	47.4	8
Brunswick L.3	Well	2	DO (mg/L)	19.85	16.1	32.8	4
Brunswick L.3	Well	3	DO (mg/L)	23.8	26.5	22.5	7
Brunswick L.3	Well	4	DO (mg/L)	45.46	44.1	41.3	7
Marion 2	*Wetland*	*1*	*DO (mg/L)*	*32.75*	*35.5*	*48*	*4*
Marion 2	*Well*	*2*	*DO (mg/L)*	*19.98*	*22.75*	*21.2*	*6*
Marion 2	*Well*	*3*	*DO (mg/L)*	*68.45*	*75.35*	*53.5*	*4*
Marion 2	*Well*	*4*	*DO (mg/L)*	*83.48*	*82.1*	*32.7*	*4*
Marion 2	*Well*	*5*	*DO (mg/L)*	*76.83*	*75.1*	*7.6*	*3*
Brunswick L.3	Wetland	1	DOC (mg/L)	18.84	17.5	13	8

Wetland Cluster	Station Type	Station Order	Parameter	Mean	Median	Range	N
Brunswick L.3	Well	2	DOC (mg/L)	37.75	36	25	4
Brunswick L.3	Well	3	DOC (mg/L)	5.75	5.9	8	8
Brunswick L.3	Well	4	DOC (mg/L)	29.39	19	80	8
Marion 2	*Wetland*	*1*	*DOC (mg/L)*	*86.75*	*80.5*	*114*	*4*
Marion 2	*Well*	*2*	*DOC (mg/L)*	*30.07*	*15.2*	*73.4*	*6*
Marion 2	*Well*	*3*	*DOC (mg/L)*	*4.88*	*5.15*	*5.2*	*4*
Marion 2	*Well*	*4*	*DOC (mg/L)*	*2.53*	*2.65*	*0.8*	*4*
Marion 2	*Well*	*5*	*DOC (mg/L)*	*2.27*	*2*	*0.8*	*3*
Brunswick L.3	Wetland	1	Specific Conductivity (µs)	70.59	65.95	50.5	8
Brunswick L.3	Well	2	Specific Conductivity (µs)	113.97	96.9	96.2	3
Brunswick L.3	Well	3	Specific Conductivity (µs)	74.1	75.9	61.3	8
Brunswick L.3	Well	4	Specific Conductivity (µs)	98.91	103.1	89.6	8
Marion 2	*Wetland*	*1*	*Specific Conductivity (µs)*	*143.53*	*129.75*	*160.4*	*4*
Marion 2	*Well*	*2*	*Specific Conductivity (µs)*	*55.3*	*47.4*	*77.4*	*6*
Marion 2	*Well*	*3*	*Specific Conductivity (µs)*	*30.28*	*30.45*	*13.4*	*4*
Marion 2	*Well*	*4*	*Specific Conductivity (µs)*	*29.83*	*28.85*	*5.6*	*4*
Marion 2	*Well*	*5*	*Specific Conductivity (µs)*	*36.13*	*34.5*	*19.1*	*3*
Brunswick L.3	Wetland	1	Ammonia (mg/L)	0.07	0.02	0.14	8
Brunswick L.3	Well	2	Ammonia (mg/L)	0.07	0.07	0.08	4
Brunswick L.3	Well	3	Ammonia (mg/L)	0.04	0.03	0.09	8
Brunswick L.3	Well	4	Ammonia (mg/L)	0.07	0.06	0.15	8
Marion 2	*Wetland*	*1*	*Ammonia (mg/L)*	*0.04*	*0.03*	*0.07*	*4*
Marion 2	*Well*	*2*	*Ammonia (mg/L)*	*0.08*	*0.08*	*0.15*	*6*
Marion 2	*Well*	*3*	*Ammonia (mg/L)*	*0.07*	*0.04*	*0.18*	*4*
Marion 2	*Well*	*4*	*Ammonia (mg/L)*	*0.05*	*0.05*	*0.07*	*4*
Marion 2	*Well*	*5*	*Ammonia (mg/L)*	*0.12*	*0.13*	*0.02*	*3*
Brunswick L.3	Wetland	1	NO2+NO3 (mg/L)	0.03	0.02	0.03	8
Brunswick L.3	Well	2	NO2+NO3 (mg/L)	0.02	0.02	0	4
Brunswick L.3	Well	3	NO2+NO3 (mg/L)	0.02	0.02	0	8
Brunswick L.3	Well	4	NO2+NO3 (mg/L)	0.02	0.02	0	8
Marion 2	*Wetland*	*1*	*NO2+NO3 (mg/L)*	*0.02*	*0.02*	*0*	*4*
Marion 2	*Well*	*2*	*NO2+NO3 (mg/L)*	*0.02*	*0.02*	*0*	*6*
Marion 2	*Well*	*3*	*NO2+NO3 (mg/L)*	*0.02*	*0.02*	*0.01*	*4*
Marion 2	*Well*	*4*	*NO2+NO3 (mg/L)*	*0.03*	*0.03*	*0.02*	*4*
Marion 2	*Well*	*5*	*NO2+NO3 (mg/L)*	*0.04*	*0.03*	*0.02*	*3*
Brunswick L.3	Wetland	1	TKN (mg/L)	0.7	0.74	0.58	8
Brunswick L.3	Well	2	TKN (mg/L)	3.7	3.95	4.7	4
Brunswick L.3	Well	3	TKN (mg/L)	1.63	1.65	1.98	8
Brunswick L.3	Well	4	TKN (mg/L)	3.1	2.85	6.13	8

Wetland Cluster	Station Type	Station Order	Parameter	Mean	Median	Range	N
Marion 2	*Wetland*	*1*	*TKN (mg/L)*	*1.92*	*1.75*	*2.33*	*4*
Marion 2	*Well*	*2*	*TKN (mg/L)*	*2.68*	*2.85*	*1.9*	*6*
Marion 2	*Well*	*3*	*TKN (mg/L)*	*0.65*	*0.59*	*0.54*	*4*
Marion 2	*Well*	*4*	*TKN (mg/L)*	*1.11*	*1.03*	*1.01*	*4*
Marion 2	*Well*	*5*	*TKN (mg/L)*	*1.83*	*1.6*	*2.31*	*3*
Brunswick L.3	Wetland	1	Phosphorus (mg/L)	0.04	0.03	0.08	8
Brunswick L.3	Well	2	Phosphorus (mg/L)	0.23	0.23	0.09	4
Brunswick L.3	Well	3	Phosphorus (mg/L)	0.36	0.34	0.43	8
Brunswick L.3	Well	4	Phosphorus (mg/L)	0.56	0.49	0.76	8
Marion 2	*Wetland*	*1*	*Phosphorus (mg/L)*	*0.06*	*0.06*	*0.06*	*4*
Marion 2	*Well*	*2*	*Phosphorus (mg/L)*	*0.31*	*0.29*	*0.44*	*6*
Marion 2	*Well*	*3*	*Phosphorus (mg/L)*	*0.74*	*0.69*	*1.22*	*4*
Marion 2	*Well*	*4*	*Phosphorus (mg/L)*	*2.55*	*2.65*	*2.3*	*4*
Marion 2	*Well*	*5*	*Phosphorus (mg/L)*	*3.5*	*4.2*	*3.3*	*3*

median, range, and number of samples collected for each parameter in each cluster along with station type (wetland or well) and station order (1-5) discussed earlier in this section.

The average **pH** levels were similar in the Brunswick and Marion clusters, with the Brunswick L3 IW cluster ranging from 3.67 for the order 1 “a” wells to 4.15 for the order 3 “b” wells, and the Marion 2 IW cluster average pH ranging from 3.27 at the order 1 wetland stations to 4.31 in the order 4 “3” wells. Average **water temperatures** for the combined stations at the IW clusters were also comparable, ranging from 16.5°C at the order 1 wetland stations to 21.83°C at the order 2 “b” wells for the Brunswick IW cluster and from 16.7°C at the order 2 “1”wells to 19.9°C at the order 1 wetland stations in the Marion IW cluster.

The average **DO** levels at the Brunswick IW sites ranged from 1.70 mg/L (20% saturated) at the order 3 “a” wells to 4.47 mg/L (45 % saturated) at the order 4 “c” wells. The Marion IW sites showed higher average levels of DO, ranging from 2.02 mg/L (20% saturated) at the order 2 “1” wells to 7.95 mg/L (83% saturated) at the order 4 “3” wells. Average DOC levels were also higher at the combined stations at the Marion sites, ranging from 2.27 mg/L at the well between the wetlands (station order 5, well 2b/c) to 86.75 mg/L within the wetland (station order 1). At the Brunswick L3 sites the average **DOC** level ranged from 5.75 mg/L at the order 3 “b” wells to 37.75 mg/L at the order 2 “a” wells within the wetland. **Specific conductivity** average results at the Brunswick L3 sites were highest (113.97 µs) at the order 2 “a” wells and lowest (70.59 µs) at the order 1 wetland stations. In comparison to the Brunswick IW cluster, the combined stations at the Marion sites exhibited a greater range of average specific conductivity levels with an average high result of 143.53 µs occurring at the order 1 wetland stations and an average low result of 30.28 µs occurring at the order 3 “2” wells.

At the Brunswick L3 IW cluster the wetland stations and wells at station order 2 and 4 (wells a and c) were highest for average **ammonia** levels, 0.07 mg/L, while wells at station order 3 (wells b) were lowest with 0.04 mg/L for average ammonia levels. At the Marion 2 IW cluster, the highest average ammonia level (0.12 mg/L) was recorded at the station between the wetlands (well 2b/c), with the lowest average ammonia level (0.04 mg/L) recorded at the wetland stations. **TKN** average results for combined stations ranged from a low of 0.70 mg/L at the order 1 wetland stations to a high of 3.70 mg/L at the order 2 wetland wells at the Brunswick L3 sites from a low of 0.65 mg/L at the order 3 "2" wells to a high of 2.68 mg/L at the order 2 "1" wells 1 at the Marion 2 sites. The average levels for **NO2+NO3** at the combined stations were very low at both IW clusters, typically 0.02 mg/L.

3.5.2.3 Seasonal Trends

The average water quality results for each site by parameter were graphed to see if there were any notable changes in water quality parameters during the months of October 2009, February 2010, May 2010, and July 2010. As would be expected, **water temperature** averages were highest in August, lowest in February, and fairly similar in May and October at all of the sites. The colder water temperatures also resulted in higher **DO** levels during that February sampling event. The only other water quality parameter to have a seasonal trend was **pH** which was lowest in February 2010, highest in October 2009 and similar in May and August 2010 at all of the IW sites.

3.5.2.4 Trends along Sampling Transects

In order to determine if any trends existed along the water quality sampling transects, both the station (wetland and well stations) results within each individual IW and the combined station results for each cluster of wetlands were graphed with box and whisker plots provided in **Appendix 3-B**. These figures show observable trends for pH, DOC, DO, phosphorous, and specific conductivity for both the individual IW transects and IW cluster combined station transects. Trends along transect lines were not as apparent for the reduced nitrogen species (ammonia and TKN) for either individual IWs or IW clusters, although higher nitrate and nitrite levels in the upland wells farthest from the wetlands suggest an increase as one moves away from the wetland.

pH

Water pH levels were low (generally < 4.5) and were typically lower in the wetland and wetland well stations than upland well stations.

Dissolved Organic Carbon (DOC)

DOC levels were higher in the wetland stations and wells located in wetlands than in the upland well stations.

Dissolved Oxygen (DO)

The DO levels had similar trends at the four individual IW sites and at the IW clusters. DO levels were at a medium level for the surface wetland stations, station order 1, dropped to the lowest level for the well within the wetland, then showed an upward trend along the transect to the upland wells.

Phosphorous

Phosphorous had a clear upward trend from the wetland stations to the well stations located furthest from the wetland at all of the IW sites. Phosphorous levels were particularly high (up to almost 5 mg/L) at the upland Marion 2 sites.

Specific Conductivity

Specific conductivity showed a downward trend from the wetland to the well at the Marion sites but inconsistent trends at the Brunswick sites.

3.5.3 Hydrology Monitoring Results

Both surface and water table hydrology are strongly influenced by surface topography, especially in locations with relatively little anthropogenic disturbance. The two study sites had very different topographies (**Figures 3-22, 3-23, 3-24**). Two longitudinal transects and one lateral transect were developed at each site to aid in understanding surface elevation gradients (**Figures 3-24, 3-25, 3-26**).

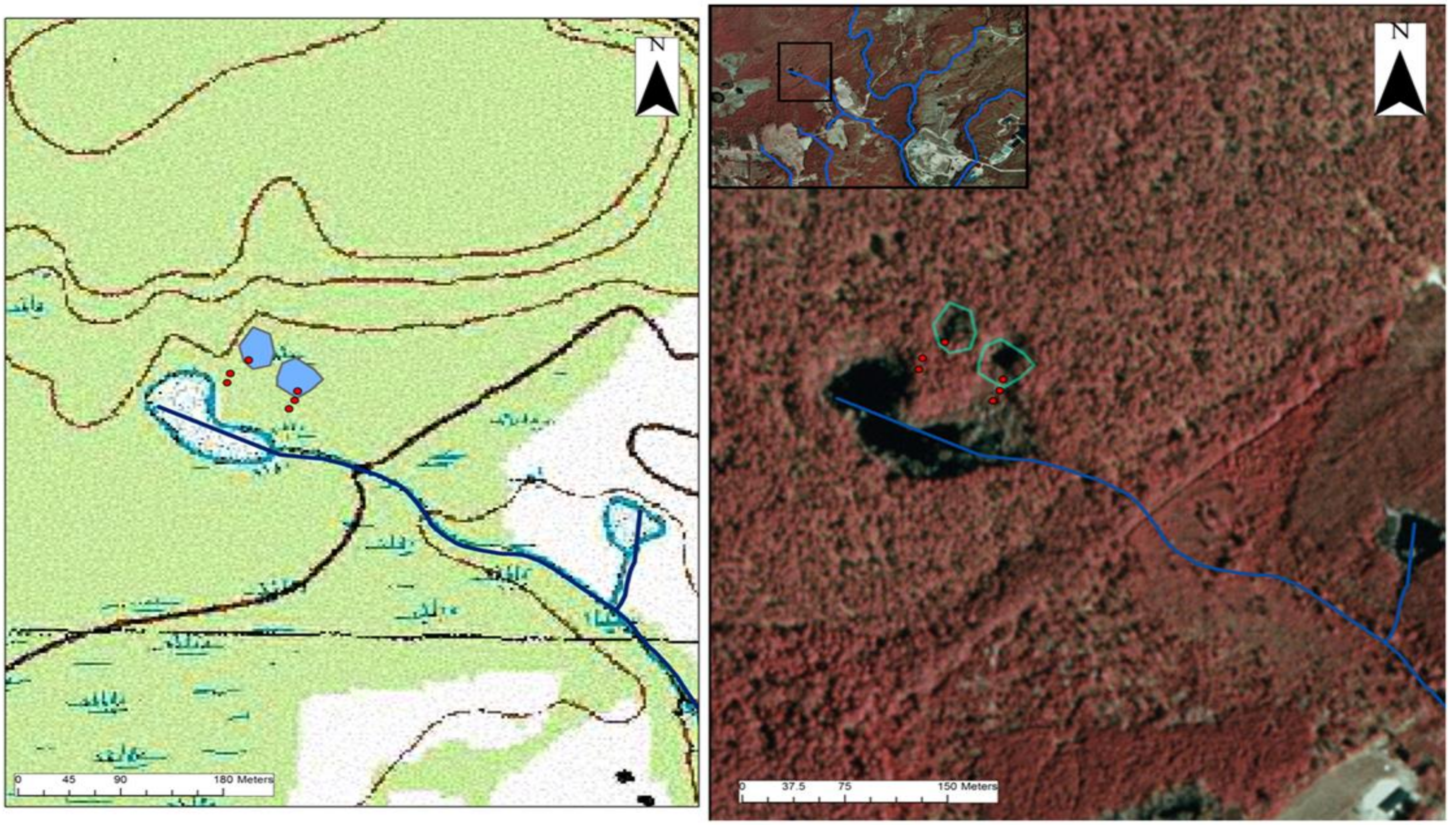

Fig. 3-22. Landscape perspectives of the Brunswick County study site using topographic (left) and DOQQ (right) images as the base map.

(Shown are the IWs, well transects (red dots), adjacent connected wetland, and stream (blue line). The DOQQ image includes an inset with a larger perspective. Note the horizontal scales are not the same in the two images.)

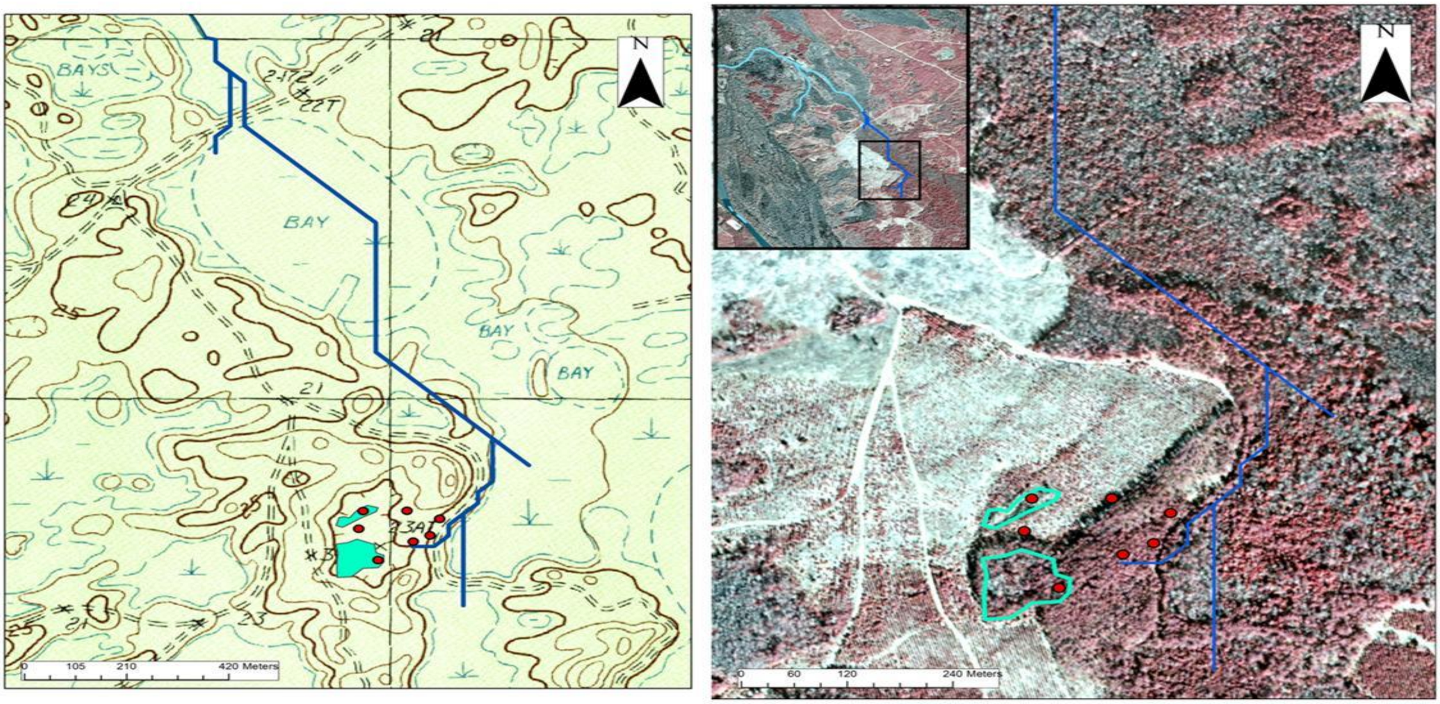

Fig. 3-23. Landscape perspectives of the Marion County study site using topographic (left) and DOQQ (right) images as the base map.

Shown are the IWs, well transects (red dots), adjacent connected slough, and stream. The DOQQ image includes an inset with a larger perspective. Note the horizontal scales are not the same in the two images.

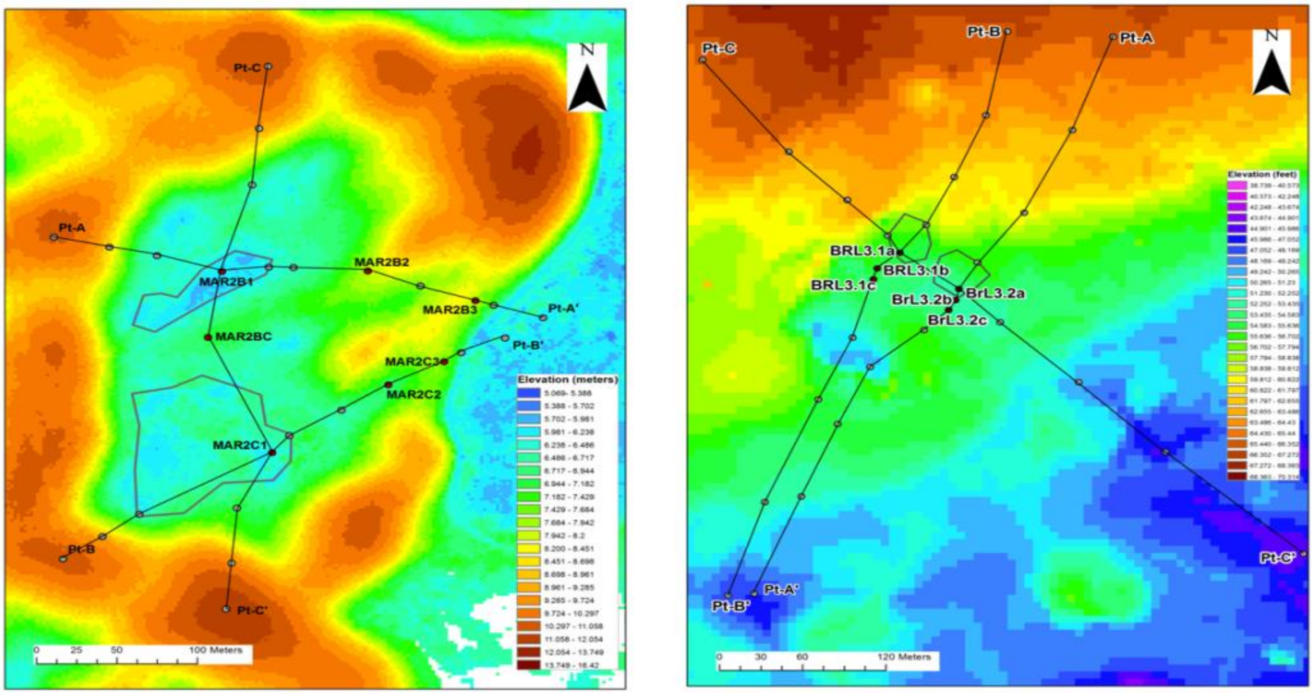

Fig. 3-24. Relief maps of the Marion County (left) and Brunswick County (right) study sites.

Elevation transects are also shown; vertical images of the transects are shown in Figs. 3-31 and 3-32. Both images use the same color palette to aid visual understanding, but the elevations are not the same. Also note the horizontal scales are not the same.

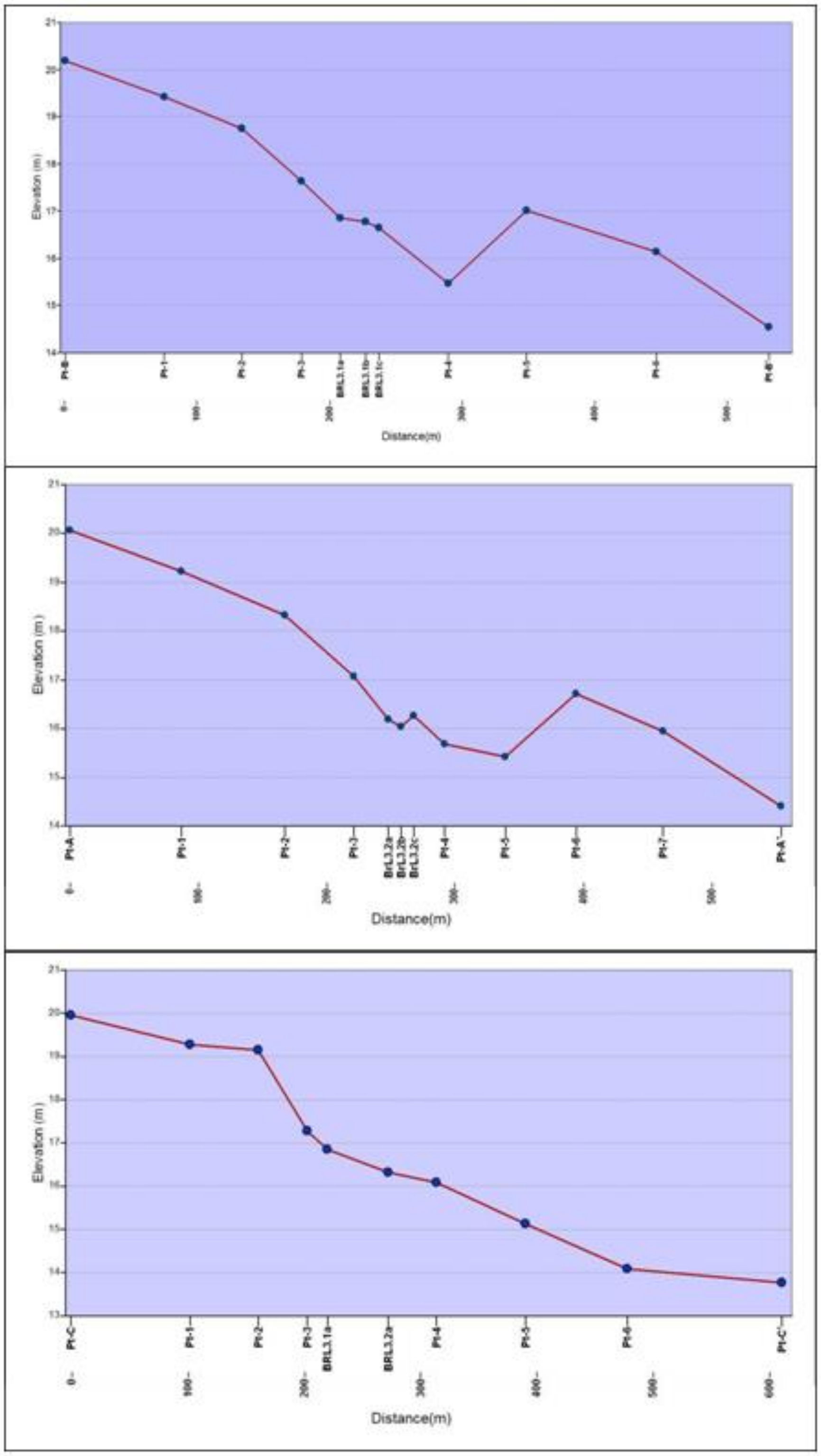

Figure 3-25. Elevation transects at the Brunswick County study site. See Fig. 3-30 for locations. The vertical exaggeration is approximately 35x.

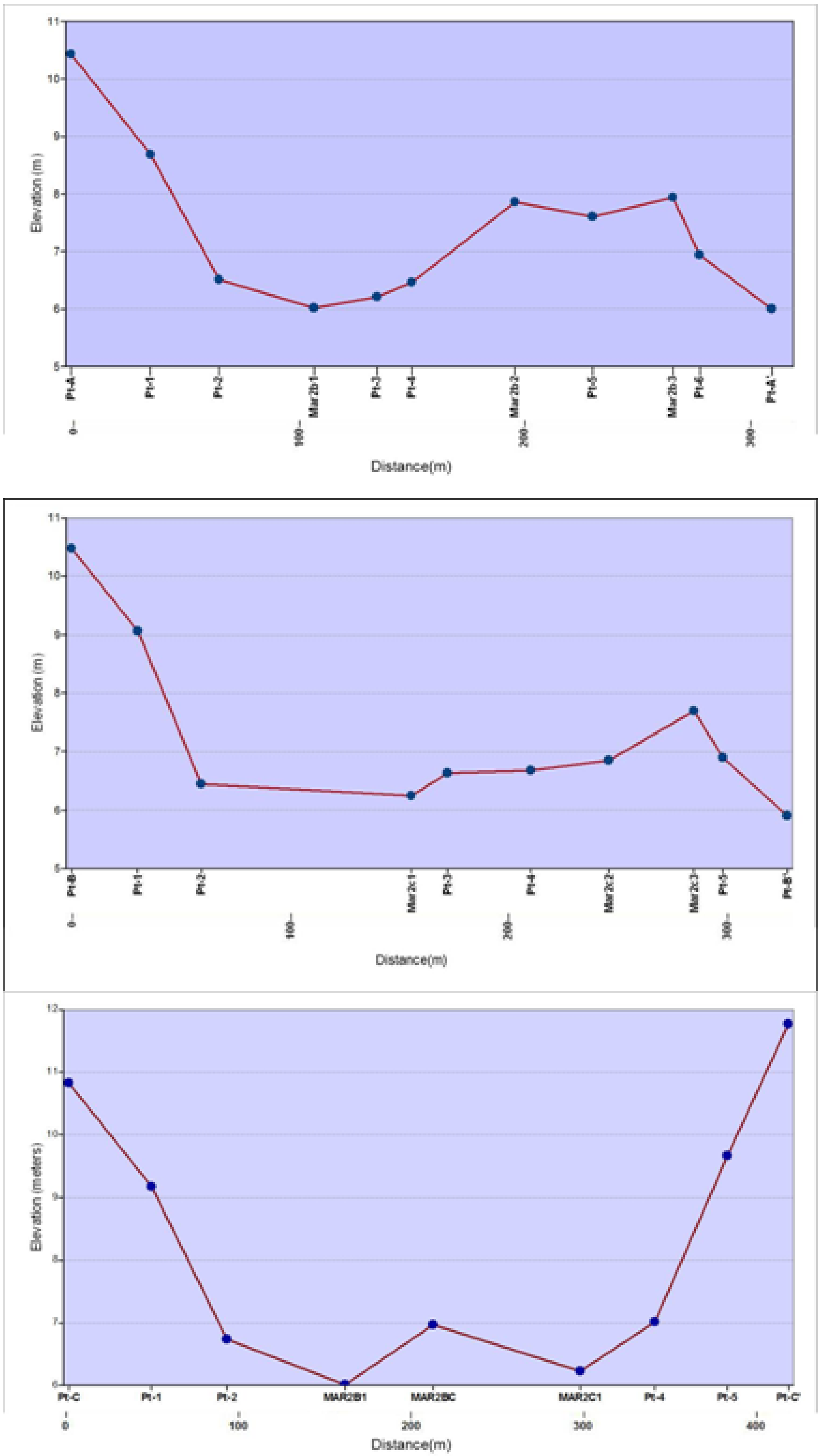

Figure 3-26. Elevation transects at the Marion County, SC study site. See Figure 3-30 for locations. The vertical exaggeration is approximately 35x.

Transect points are associated with the wells and representative elevation breaks. LiDAR DEMs were used to develop the transects and point elevations. The Brunswick County site shows a relatively clear elevation gradient from upland to the connected wetland directly southwest of the study wetlands. The study wetlands are depressions in a landscape that broadly trends to lower elevations along its entire southern extent. The Marion County site, in contrast, is completely surrounded by higher elevations except for a break due east of the study wetlands. This was the expected direction of lateral groundwater flow. At both sites the two study wetlands are separated by a moderate rise in elevation.

The drill logs for the Marion County wells indicate the soils are all sand except in the wetlands where there is a sandy clay layer (**Table 3-9**). The soil stratigraphy at the Brunswick County site is characterized by greater heterogeneity with a significant clay layer that served as the bottom of the wells (**Table 3-10**). Clay was found at depth in BRL3.2a, unlike BRL3.1a, although it is likely that if drilling had continued in BRL3.1a clay would have been reached. The geometry of all wells is provided in **Table 3-10**.

Table 3-9. Drill logs for the monitoring wells in Marion County, SC.

Transect #1						Transect #2				
Well/drill date	Depth (ft)	Munsell	Texture	Notes		Well/drill date	Depth (ft)	Munsell	Texture	Notes
MA2B1	0.00	2.5YR 2.5/2	Sandy	Moist		MA2C1	0.00	2.5YR 2.5/1	Sandy	Moist
20010609	0.58	2.5YR 2.5/2	Sandy	Wet		20010609	1.25	2.5YR 2.5/2	Sandy Clay	Wet
	1.00	2.5YR 2.5/2	Sandy Clay	Wet			2.00	2.5YR 3/4	Sandy	Wet
	2.00	2.5YR 3/5	Sandy	Wet			3.17	2.5YR 6/2	Sandy	Wet
	4.00	2.5YR 4/4	Sandy	Wet			4.75	2.5YR 6/2	Sandy	Bottom
	4.83	2.5YR 4/4	Sandy	Bottom						
						MA2C2	0.00	2.5YR 3/3	Sandy	Dry
MA2B2	0.00	2.5YR 4/2	Sandy	Dry		20010608	1.83	2.5YR 5/2	Sandy	Dry
20010609	1.17	2.5YR 5/6	Sandy	Dry			2.83	2.5YR 7/2	Sandy	Dry
	6	2.5YR 7/4	Sandy	Dry			3.25	2.5YR 7/2	Sandy	Moist
	6.42	2.5YR 5.4	Sandy	Moist			4.00	2.5YR 7/2	Sandy	Wet
	7.75	2.5YR 6/4	Sandy	Moist			7.32	2.5YR 7/2	Sandy	Bottom
	8.17	2.5YR 6/5	Sandy	Wet						
	8.58	2.5YR 6/5	Sandy	Bottom						
						MA2C3	0.00	2.5YR 6/6	Sandy	Dry
						20010609	5.08	2.5YR 6/6	Sandy	Moist
MA2B3	0.00		Oganic	Litter			6.58	2.5YR 6/8	Sandy	Wet
20010609	0.17	2.5YR 5/6	Sandy	Dry			7.33	2.5YR 6/8	Sandy	Bottom
	2.08	2.5YR 5/8	Sandy	Dry						
	5.33	2.5YR 5/8	Sandy	Moist						
	6.42	2.5YR 6/8	Sandy	Wet		Between wetlands				
	7.67	2.5YR 6/8	Sandy	Bottom		Well/drill date	Depth (ft)	Munsell	Texture	Notes
						MA2BC	0.00	10YR 4/2	sand	
						20090818	0.98	10YR 6/4	sand	
							1.97	10YR 6/6	sand	
							4.13	10YR 6/3	sand	moisture @ 4.76
							6.69	10YR 6/4	sand	Bottom

Table 3-10. Drill logs for the monitoring wells in Brunswick County, NC

Transect #1						Transect #2				
Well/drill date	Depth (ft)	Munsell	Texture	Notes		Well/drill date	Depth (ft)	Munsell	Texture	Notes
BRL3.1A	0.00	10YR 2/1	silty clay			BR2A	0.00	10YR 2/1	loam	
20090819	1.17	10YR 5/1	sand saturated @1.5 ft			20090820	1.83	10YR 2/1	sandy loam	
	2.67	10YR 4/1	sand wet				2.17	10YR 4/1	sand	
	4.25	10YR 4/2	sand wet	Bottom			2.33	10YR 3/1	sand wet	
							4.75	10YR 2/1	sandy loam	
							5.75	10YR 2/2	clay w/many rocks <5mm	
BRL3.1B	0.00	10YR 5/1	sand				6.08	10YR 2/3	clay w/many rocks <5mm	Bottom
20090819	0.62	10YR 6/1	sand							
	1.08	10YR 5/3	sand, small rocks							
	1.58	10YR 6/4	sand			BR2B	0.00	10 YR 2/1	loamy sand, salt&pepper	between wetlands
	2.33	10YR 7/3 & 6/4	comatrix, sand			20090820	0.92	10 YR 4/1	sand	2in litter at surface
	3.25	10YR 4/2	loamy sand				1.42	10 YR 2/1	loamy sand	
	3.50	10YR 2/2	loamy sand				2.58	10 YR 5/2, 5/6	mottles clay	
	5.42	10YR 2/2	loamy sand				3.17	10 YR 2/1	loamy sand	
	6.08	10YR 4/2	weathered shale & sandy loam				4.58	10 YR 3/2	loamy sand	
	6.50	5YR 3/3	loamy sand				5.67	10 YR 5/2, 5/6	clay	8' depth to h2o
	6.67	10YR 4/2, 6/3	sand comatrix				9.42	10 YR 5/2, 5/6	clay	Bottom
	7.08	10YR 6/3	sand							
	7.58	10YR 4/3	sand							
	8.25	10YR 7/1	sand saturated			BR2C	0.00		organic root mat	
	10.00	10YR 5/2	sandy clay			20090929	0.33	10YR 2/1	loam	
	13.17	10YR 5/2	wet clay				1.08	10YR 3/1	sand	
	14.42	10YR 5/2	wet sandy clay	Bottom			2.25	10YR 3/1, 5/1	comatrix sand moist	
							2.92	10YR 2/1	sandy loam	
							3.25	5YR 3/3	sandy clay loam and gravel	
BR1C	0.00	10YR 6/2	sand				3.50	10YR 2/1	sandy loam	
20090819	0.83	10YR 7/3, 5/4	sand comatrix				3.92	10YR 3/3	sandy clay loam w/sm rocks	
	1.17	10YR 6/4	sand				5.08	7.5YR 3/3	sand wet with water	
	3.33	10YR 4/2	loamy sand				6.17	7.5YR 3/3	wet sandy loam, gravel	
	3.50	10YR 3/1	loamy sand				7.17	7.5YR 3/2	wet sandy loam, gravel	
	4.17	10YR 2/1	loamy sand red mottles				7.83	10YR 4/1, 5/2	clay comatrix	
	6.00	10YR 4/2	weathered shale				9.00	10YR 5/2	wet clay	
	6.58	5YR 4/4	sand				9.50	10YR 5/1	wetclay	Bottom
	7.08	7.5YR 4/4	sand							
	8.00	10YR 6/3	sand saturated							
	8.58	10YR 7/2	sand wet							
	9.08	10YR 5/3	clay wet							
	10.00	10YR 5/2	clay wet							
	13.42	10YR 5/3	clay wet	Bottom						

Table 3-11. Dimensions and Elevations (meters) of the Wells at the Level 3 Study Sites.

Marion	Elevation	Depth	Ground to top of casing	Length of WLR
2B1	5.973	1.47	0.72	1.95
2B2	7.900	2.61	0.55	2.83
2B3	----	2.34	0.22	2.12
2B3 redeploy	7.670	2.84	0.70	2.74
2BC	6.962	2.04	0.65	1.94
2BC redeploy	6.962	2.04	0.65	2.53
2C1	6.115	1.45	0.80	2.10
2C2	6.914	1.63	0.73	2.10
2C3	7.548	2.23	0.42	2.00
Brunswick				
31A	16.072	1.29	1.46	2.33
31A redeploy		1.29	1.26	2.33
31B	17.706	4.40	0.38	4.65
31C	17.736	4.10	0.70	4.31
32A	15.786	1.86	1.43	3.10
32B	16.791	2.87	0.35	3.12
32C	16.087	2.90	0.23	3.05

Note: Marion 2B3 was redrilled before elevation measurements were made so it is not known with certainty. The data are not used for this analysis. The redeployment of Marion 2BC was a longer cable on the WLR to ensure it was always submerged. Earlier data from that well are not used in this analysis.

At the Brunswick County site two longitudinal transects of wells from the IWs to the nearby connected wetland were installed and water level loggers were deployed on September 17, 2009 (September 29 for BRL3.2c). There is a continuous record of data except in well BRL3.1a (the well in the wetland). Tampering occurred that resulted in a 2-month gap in the data. For that reason, this report will show elevation charts for the second wetland transect. The overall form of the data are essentially the same in both transects. The data from all wells will be used to develop water table maps in the future. A tipping bucket recording rain gauge was also installed at each study site.

At the Marion County site, all wells were installed and loggers were deployed on June 9 and 10, 2009 (August 18 for MA2BC). There are two transects that extend from each IW to the nearby slough and one well was placed in the upland between the two IWs. MA2B3 was redrilled 0.5 m deeper on August 17 which resulted in a deeper logger deployment. Data from only one well transect is presented here since the second transect is similar in form to the first. Data from the lateral transect is also presented in this report. The data from all wells will be used to develop water table maps in the future.

The Level 3 wells were deployed in the summer during drought conditions. Water table elevations were low and continued lower but began to recover during late fall 2009 and winter 2010. At the Brunswick County site (**Figure 3-27**), water table elevations steadily increased, with step increases following each significant rain event. During this period there was a consistent water elevation gradient along the transect, with water elevations in the IW (BR1C) higher than the two upland wells. The upland well closest to the connected wetland (BR2C) had the lowest elevation.

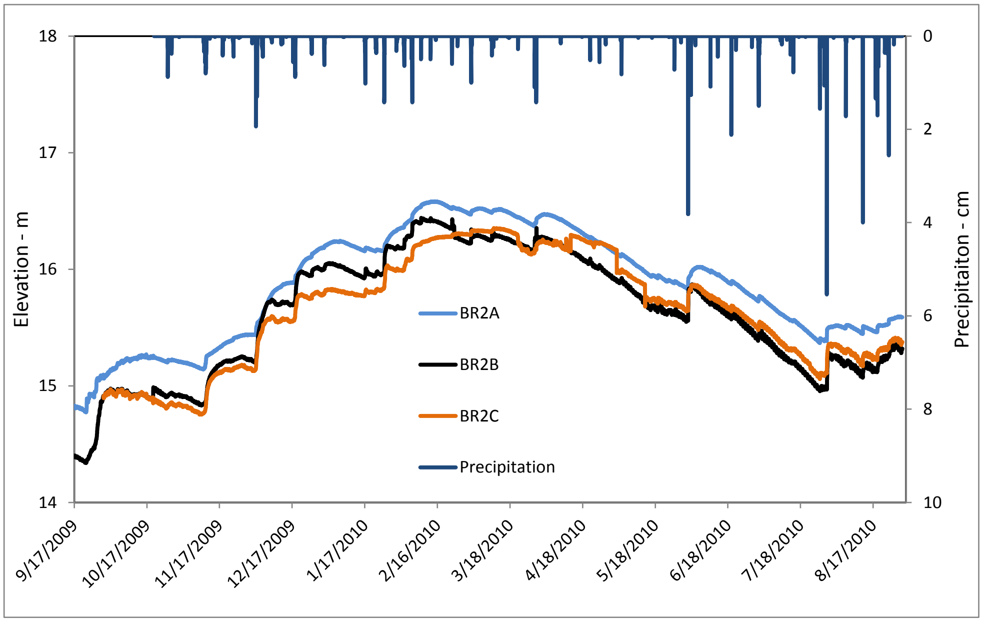

Figure 3-27. Hourly water table elevation and rain gauge data from one of the well transects at the Brunswick County study site.

(BR2A is in the IW, BR2C is closest to the nearby connected wetland, and BR2B is in between.)

As late winter transitioned into spring and summer the elevations began a seasonal decline, commonly seen as a result of increased evapotranspiration. There is also a reversal of elevation differential among BRL3.2b and BRL3.2c. This suggests the water elevation decline in the nearby connected wetland occurred at a slower rate than in the IW, resulting in hydraulic head resistance to water movement toward the connected wetland. We did not have a water level recorder in the connected wetland and so we cannot be certain about the elevation dynamics at that location.

Abrupt elevation changes occurred in well BRL3.2c during spring 2010. Abrupt elevation rises occurred in all wells in response to large precipitation events but abrupt drops only occurred in BRL3.2c and only during mid-April to mid-May. The cause for this is not immediately clear. It was during a time of relative large declines in water elevation in the other two wells also but none as abrupt as seen in this well. BRL3.2c is furthest from the study IW and is in a wetland fringe of the adjacent connected wetland. Its elevation may be influenced by elevation dynamics in the larger wetland, but if so and how cannot be determined from this analysis.

The soils at the Marion County site are all sand at least to the depth of the wells except for those in the isolated wetlands. This manifested itself in very low water tables during dry periods of summer 2009 and early summer 2010 (**Figure 3-28**). The water table elevation gradient is from upland wells into the wetland except during the period of water table recovery in fall 2009 and mid-summer 2010. Whether the water elevation in the wetland is above that in the uplands during the dry periods is undetermined from these data but it is possible that it is, especially after significant precipitation events. The adjacent

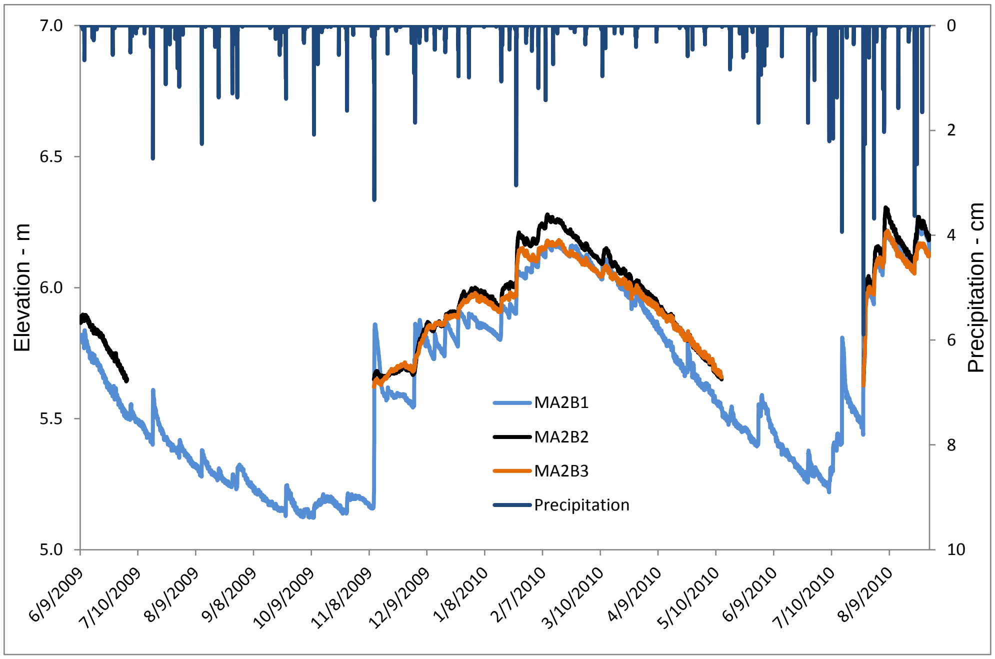

Figure 3-28. Hourly water table elevation and rain gauge data from one of the well transects at the Marion County study site.

(MA2B1 is in the IW, MA2B3 is closest to the nearby slough, and MA2B2 is in between. Gaps in the time series for MA2B2 and MA2B3 represent periods when the water table was below the level of the water level recorder.)

slough is down gradient from the IW but the intervening higher ground appears to prevent lateral water movement from the IW into the slough except when certain conditions develop.

There are indications (e.g., clays from the boring logs) these wetlands may be perched water tables on top of clay (or sandy clay) lenses. If so, the maximum elevation decline in the wetland is constrained by the permeability of the clay lens. An additional indication of this limit is the rapid water elevation increase in the wetland during November 2009. This was preceded by a significant water table drawdown, due in part to dry conditions and evapotranspiration. The rapid increase in elevation may be the result of plant senescense, lower air temperatures, and wetter conditions that combined to cause the permeability of the clay lens to decrease, thus increasing the volume and elevation of the water table above the lens. Also note that the upland wells intersected the water table at that time, indicating overall local groundwater elevation was increasing.

A well was placed in the upland area between the two IWs to detect the potential for groundwater movement between them. During most of the study interval there is a distinct elevation gradient from wetland MA2C to MA2B (**Figure 3-29**). This suggests MA2B is a local sink for water in most circumstances. The exception to this is during water table drawdown in spring 2010, which appears to be relatively uniform across the mesoscale landscape in which the two IWs occur.

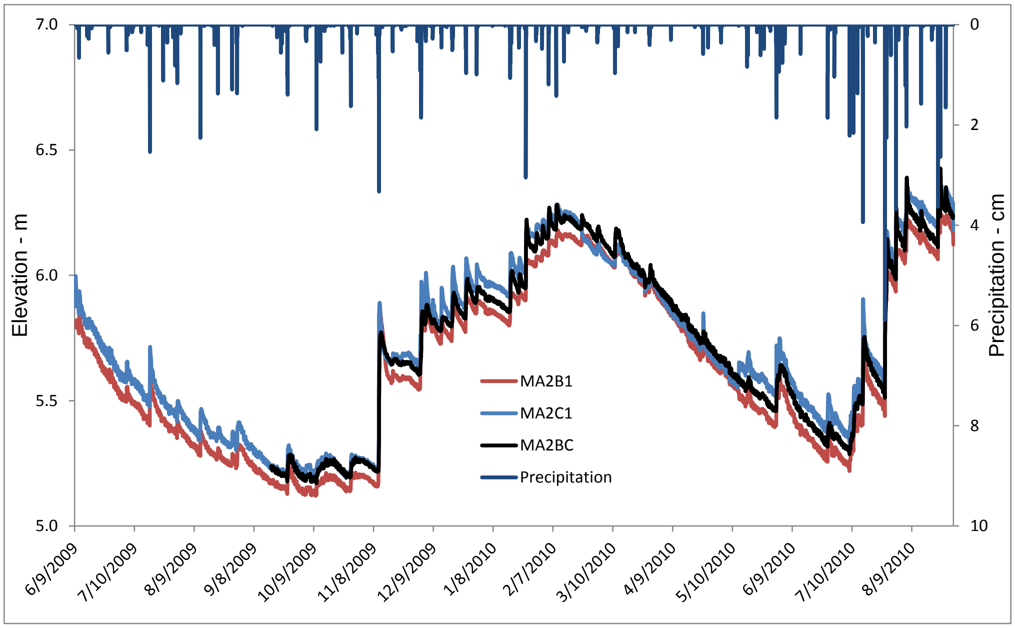

Figure 3-29. Hourly water table elevation and rain gauge data from lateral well transect at the Marion County study site.

(MA2B1 and MA2C1 are in the IW and MA2BC is in between.)

This figure also highlights the abrupt elevation increase that occurred in all three wells in mid-November 2009. The occurrence in the upland well reinforces the suggestion of a sudden change in the hydraulic properties of the soil. The same thing appears to have occurred in a less dramatic magnitude in late July 2010.

In summary, the groundwater data at the Brunswick County site suggest the potential for substantial groundwater movement for much of the year between the IW and adjacent connected wetland. In contrast, at the Marion County site any groundwater movement from the IW into the nearby slough probably occurs only when certain conditions develop, both in terms of water table elevation and precipitation. Planned groundwater mapping will provide a better perspective on this difference for both sites; simulation modeling would bring greater clarity to this issue.

3.5.4 Soil Sampling Results

Most of the Level 3 soil samples and a large subset of the Level 2 soil samples were analyzed for oxalate extractable aluminum (Al) and iron (Fe). A phosphorus adsorption index (PSI) was also developed using single-point phosphorus adsorption isotherms (Axt and Walbridge, 1999). What follows is a brief summary and preliminary analysis of these data. The percent loss on ignition was also determined as described in Part 2 of this report. These results were combined with the analyses performed by the NC Agricultural lab, also described in Part 2.

The PSI is a dimensionless index that ranks soils by their potential to adsorb and thus immobilize phosphorus, an essential plant nutrient but also a pollutant when present in excess quantities in aquatic systems. In this study PSI values ranged from 0 - 47.2 in upland soils and 0 - 64.7 in wetland soils (**Table 3-12**). The median in upland soils was 5.5 and in wetland soils it was 16.0. The PSI tended to be larger in wetland soils but variability was larger also.

Table 3-12. Summary Statistics for Phosphorus Adsorption Index (PSI) Values.

Statistic	Upland	Wetland
Mean	10.2	17.5
Standard Error	1.48	1.63
Median	5.5	16.0
Standard Deviation	11.63	14.81
Minimum	0	0
Maximum	47.2	64.7

Correlation matrices were developed with several parameters that commonly play a role in soil biogeochemistry (**Table 3-13**). There was a strong correlation between PSI and Al concentration in both upland and wetland soils, a common finding (e.g. Walbridge and Struthers 1993; Hogan, Jordan et al. 2004; D'Angelo 2005; Novak and Watts 2006). There appears to be a difference in the binding characteristics of soils from the two general locations, upland versus wetland (**Figure 3-30**), suggesting the presence of oxalate extractable Al is a principal factor but one among others in phosphorus sorption. Percent LOI has no correlation with phosphorus adsorption in wetland soils but significant correlation in upland soils (**Figure 3-31**). Bulk density is negatively correlated with phosphorous adsorption but there also appears to be a difference in the magnitude of effect between upland and wetland soils (Table 3-12). Other parameters have a significant correlation but the relationship is less strong.

Table 3-13. Correlation Matrices (ρ and p-value) for PSI and other Soil Parameters .

Parameter	PSI	% LOI	Al - ppm	Fe - ppm	% humic matter
Upland					
% LOI	0.717	1			
p-value	<.0001				
Al - ppm	0.909	0.631	1		
p-value	<.0001	<.0001			
Fe - ppm	0.574	0.379	0.473	1	
p-value	<.0001	0.005	0.0003		
% humic matter	0.620	0.832	0.617	0.325	1
p-value	<.0001	<.0001	<.0001	0.016	
Bulk density	-0.748	-0.908	-0.613	-0.474	-0.785
p-value	<.0001	<.0001	<.0001	0.0003	<.0001
Wetland					
% LOI	0.147	1			
p-value	0.186				
Al - ppm	0.897	0.290	1		
p-value	<.0001	0.007			
Fe - ppm	0.230	0.073	0.147	1	
p-value	0.048	0.535	0.212		
% humic matter	0.266	0.405	0.341	-0.058	1
p-value	0.015	<.0001	0.001	0.623	
Bulk density	-0.430	-0.830	-0.502	-0.207	-0.599
p-value	<.0001	<.0001	<.0001	0.077	<.0001

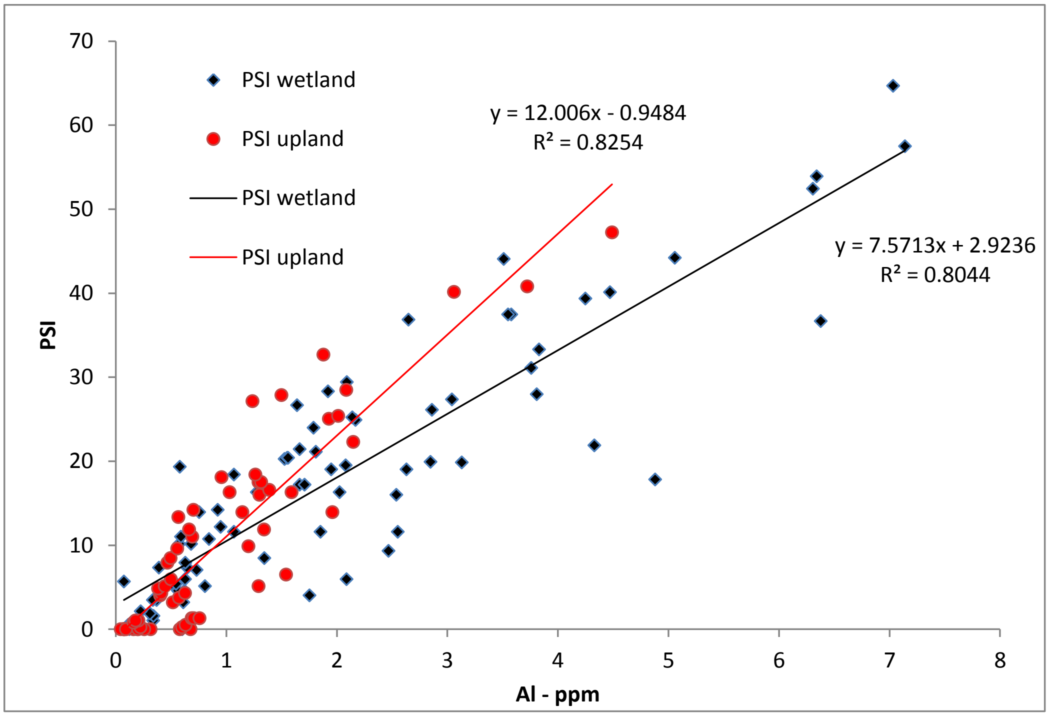

Figure 3-30. Relationship between Al concentration and PSI in wetland and upland soils.

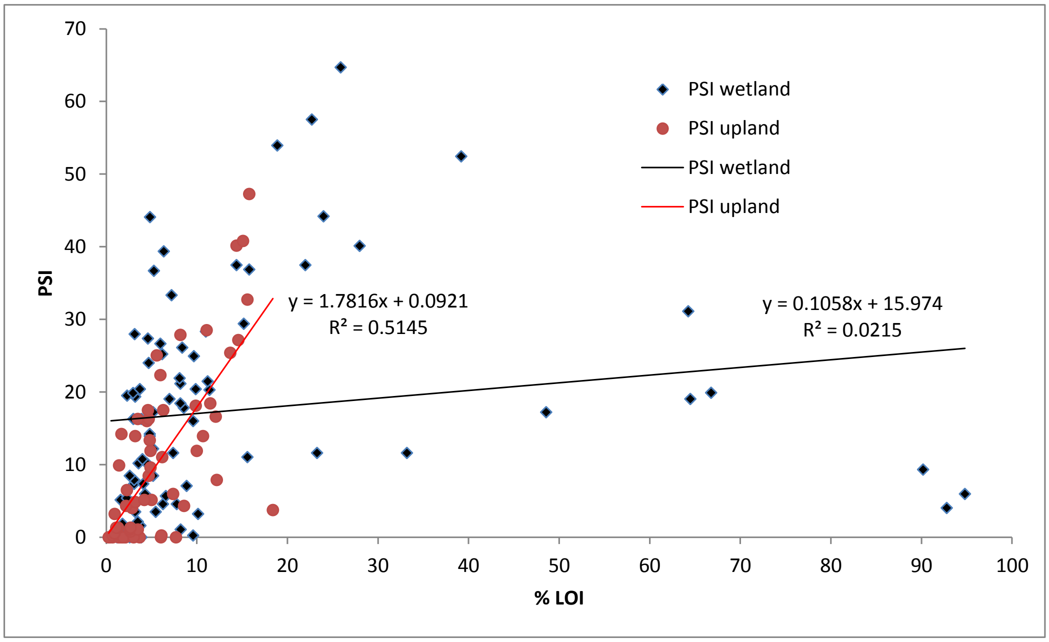

Figure 3-31. Relationship between LOI and PSI in wetland and upland soils.

This brief preliminary analysis suggests that these data reinforce prior work on phosphorous sorption in soil. It also shows significant differences between upland and wetland soils that is suggests additional analysis based on other soil characteristics may reveal spatial patterns at small and large scales. The soil samples collected during the Level 2 surveys were entirely near-surface soil. During the Level 3 sampling soil from up to three horizons was collected, opening the possibility to analyze vertical differences in phosphorous adsorption. All these analyses are still to be completed and reported in the final report for the EPA Isolated Wetland connectivity grant discussed earlier.

3.5.5 Vegetation Monitoring Results

The vegetation survey of the Level 3 sites in August of 2009 showed that these are diverse wetlands with intact vegetative communities in which 57 types of native plants were identified comprised of 48 species, 39 genera, and 30 families including the Federally Endangered southern pond spice (*Lindera melissifolia*) found at the Marion 2B site. As discussed in Section 3.5.1 (Site Description), the Brunswick sites are very similarly ecologically with comparable vegetation. Schafale and Weakley's *Classification of the Natural Communities of North Carolina, Third Approximation* (1990) considers these sites to be Small Depression Ponds characterized by permanent flooding, concentric zone of shrubs such as titi (*Cyrilla racemosa*) and fetterbush (*Lyonia lucida*) around the exterior and scattered pond cypress (*Taxodium ascendens*) and swamp tupelo (*Nyssa biflora*). The same community type in Nelson's *The Natural Communities of South Carolina* (1986) would be Pond Cypress Ponds characterized by year round standing water, pond cypress, swamp tupelo, and titi.

Marion 2B (and Marion 2A which is similar to Marion 2B but only 0.03 acres and more shrubby) is closest to the Schafale and Weakley's (1990) Cypress Savannah description and Nelson's (1986) Pond Cypress Savannah, characterized by the flat nature of the site and open to sparse canopy of pond cypress, loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*), the presence of shrubs such as fetterbush and variable herb species. The Marion 2A site has sandy soils that are similar to the Marion 2B site and is very likely connected hydrologically through groundwater across a narrow band of upland separating the two sites. Marion 2C is a pocosin dominated with Ericaceae shrub species such as fetterbush and highbush blueberry (*Vaccinium fuscatum*) and a canopy of red maple, swamp bay (*Persea palustris*), and sweet bay (*Magnolia Virginia*). Schafale and Weakley (1990) would categorize Marion 2c is a Small Depression Pocosin because of its isolated nature while Nelson (1986) would classify it as a Pocosin.

The plant survey results from the CVS protocol were used to characterize the plant communities associated with the Level 3 isolated wetlands by calculating biological attributes or candidate metrics used in previous studies completed by the NC Division of Water Quality (Baker et al., 2008; Savage et al., 2010). These previous studies focused on using candidate metrics to develop of Indices of Biotic Integrity (IBIs) for wetland plant communities. Although IBIs are not the goal of this study, these biological attributes or candidate metrics can be used to characterize the diversity, the floristic quality, the wetness, the ecological guilds, and the structure of these vegetative communities associated with isolated wetlands.

A total of 37 candidate metrics or biological attributes were calculated for this study. These metrics, described further in this section, were categorized into five types of vegetative parameters or types of metrics: community balance metrics, floristic quality metrics, wetness metrics, functional group metrics, or community structure metrics. Metrics and IBIs can be used as a measuring tool to determine the condition of a wetland by comparing that wetland to a known reference site. The EPA defines reference wetlands as “minimally impaired wetlands that are representative of the expected conditions of a wetland of a particular region” (U.S. EPA, 1998). IBIs are a more robust representative of wetland condition than single metrics, however, studies have shown that some metrics such as the Floristic Quality Assessment metric (FQAI) are a powerful representative of wetland condition (Mack, 2004; Herman et al., 2006; Bernthal, 2003; Cohen et al., 2004).

Table L3B-1 in **Appendix 3-C** was developed to calculate these candidate metrics (described in detail in Appendix 3-C), and includes the list of plant species identified in the Level 3 plant survey. Table L3B-1 contains fields for a species code (first four letters of the genus and first four letters of the species), genus, species, common name, family, NWI Region 2 Wetland Indicator Status (Resource Management Group, Inc., 1999), physiognomic form (fern, forb, grass, moss, sedge, shrub, small tree, tree, and vine), habit (annual, perennial, cryptogram, woody species), group (monocot or dicot), shade tolerance (shade species, light species, partial light species, or adventive) and coefficient of conservatism value (C of C). Three botanists (Dr. Alan Weakley, Dr. Peter White, and Dr. Johnny Randall) from the University of North Carolina, Chapel Hill, were contracted to evaluate each plant species and assign C of C values based on Taft et al. (1997), which is summarized in Table L3B-2 (in Appendix 3C). An average value of the C of C ratings of the three botanists was calculated for Table L3B-1. Information from the field sheets recorded in the field (see Appendix 3A) was used to summarize the overall coverage for each species, number of species identified at each site, and number of individuals tallied in each woody diameter size class. The median cover value was used for calculating vegetation coverage since cover class or size range was recorded in the field.

The results of the calculated plant metrics (or biological attributes) are shown for each site in **Table 3-14**. Table 3-14 also indicates which metrics would potentially have a positive, negative, or no association with higher quality wetland sites. It should be noted here again that the Marion 2A site, which has a narrow band of upland between it and the Marion 2B site and is very similar, was surveyed for just one intensive module. Therefore, one quarter the size area for plant coverage metrics was surveyed and one eighth the size area for richness metrics and metrics derived from the woody species data was surveyed in comparison with the four other sites.

3.5.5.1 Community Balance Metrics

For the community balance metrics the results between the sites were fairly comparable. The Simpson’ Diversity Index ranged from 0.65 (the Brunswick L3.1 site) to 0.78 (the Marion 2C site) and Evenness ranged from 0.66 (the Brunswick L3.1 site) to 0.85 (the Brunswick L3.2 site). Species Richness was 33 at both Brunswick sites, 27 and 28 and the Marion 2B and 2C sites respectively, and 19 at the Marion 2A site. Species Genera was also highest at the Brunswick sites, 28 at Brunswick L3.1 and 29 and Brunswick L3.2. Dominance (relative cover of the most dominant three species) was highest at the Brunswick L3.1 site (0.87) and lowest at the Brunswick L3.2 site (0.60) while Herb and Shrub Dominance (Relative cover in the herb and shrub stratum of the most dominant herb and shrub species) was also highest at the Brunswick L3.1 site (0.98) and lowest at the Marion 2A site (0.84).

3.5.5.2 Floristic Quality Metrics

The floristic quality results were more variable than the Community Balance results. The FQAI Cover value was very similar for the Brunswick L3.1, Brunswick L3.2 and Marion 2C sites at 32, 29.5, and 28.8 respectively, while the Marion 2A and Marion 2B sites were both 16.3 and 16.2 respectively. Average C of C scores ranged from 5.2 at the Brunswick L3.1 site to 6.3 at the Marion 2C site. None of the sites had a very high percentage of tolerant (C of C scores ≤2) species with the Marion 2A and Brunswick L3.1 sites

Table 3-14. Vegetation Metrics for SEIWA REMAP

Plant Metric	Brunswick L3.1	Brunswick L3.2	Marion 2A	Marion 2B	Marion 2C	Indication of Site Quality
Community Balance						
Simpson's diversity index	0.65	0.82	0.68	0.68	0.78	Yes
Evenness	0.66	0.85	0.71	0.71	0.81	Yes
Species richness	33	33	19	27	28	Yes
Genera richness	28	29	16	22	21	Yes
Dominance	0.87	0.60	0.72	0.84	0.76	No
Herb and shrub dominance	0.98	0.94	0.84	0.95	0.97	No
Floristic Quality						
FQAI Cover	32.03	29.47	16.32	16.17	28.80	Yes
Average C of C	5.2	5.4	5.9	5.7	6.3	Yes
Percent tolerant	2.0	12.1	12.1	7.1	3.7	No
Percent sensitive	90.4	68.7	75.9	21.8	50.6	Yes
Wetness Characteristics						
FAQWet	5.57	7.12	6.68	8.72	8.8	Yes
Wetland plant species richness	2	2	1	2	1	Yes
Relative % wetland plant cover	60.7	40.0	41.1	2.2	58.1	Yes
Relative % wetland shrub cover richness	5	7	5	5	8	Yes
Wetland shrub cover	98.0	95.2	90.1	34.6	73.3	Yes
Functional Guild						
Herb richness	6	4	3	7	1	Yes
Total herb cover	4.5	2.3	16.5	309.8	9.0	Yes
Forb richness	3	0	1	1	1	N/A
Relative percent forb cover	3.6	0.0	1.4	0.2	0.0	N/A
Cryptogram richness	1	2	1	1	1	Yes
Relative percent cryptogram cover	7.1	33.3	41.1	2.1	58.1	Yes
Annual:perennial	0.17	0.00	0.00	0.00	0.00	No
Relative percent bryophyte cover	35.7	40.0	8.2	1.3	41.9	Yes
Carex richness	0	0	0	2	0	Yes

Plant Metric	Brunswick L3.1	Brunswick L3.2	Marion 2A	Marion 2B	Marion 2C	Indication of Site Quality
Relative percent carex cover	0.0	0.0	0.0	94.5	0.0	Yes
Cyperaceae, poaceae, juncaceae richness	2	2	2	5	0	Yes
Relative percent cyperaceae, poaceae, juncaceae cover	53.6	26.7	49.3	96.5	0.0	Yes
Dicot richness	24	23	12	16	20	Yes
Relative percent dicot cover	62.5	75.3	71.6	45.4	92.2	Yes
Community Structure						
Total cover	515.5	644.3	114.3	618.3	686.5	N/A
Shade	11	12	3	7	8	Yes
Sapling density	0.32	0.55	0.55	0.88	0.82	No
Large tree density	0.27	0.12	0.00	0.00	0.04	Yes
Pole timber density	0.41	0.32	0.45	0.12	0.14	No
Canopy importance	0.53	0.31	2.3	0.48	0.35	Yes
Average importance shrub	0.18	0.17	0.25	0.35	0.26	Yes
Standing snag importance	0.25	0.20	0.00	0.36	0.19	Yes

Indication of Site Quality - Yes = Higher values potentially associated with higher wetland quality.
Indication of Site Quality - No = Lower values potentially associated with lower wetland quality.

being the highest at 12.1percent and the Brunswick L3.1 site being the lowest at two percent. The Brunswick L3.1 site had the highest percentage of sensitive (C of C scores ≥ 7) with 90.4 percent, the Marion 2A, Marion 2C, and Brunswick L3.2 sites ranged from about 50-75 percent, while the Marion 2B site only had 21.8 percent sensitive plant species coverage.

The floristic quality assessment index (FQAI) has been found in other studies to be an indicator of wetland quality (Mack, 2004; Herman et al., 2006; Bernthal, 2003; Cohen et al., 2004). NC DWQ found that FQAI metric significantly correlated with disturbance criteria when developing IBIs for basin and headwater forest wetlands (Savage et al., 2010, and Baker et al., 2008). The 12 basin wetlands that were surveyed in Brunswick and Granville Counties in NC during the 2007 field season ranged from 7.72 to 30.9 for FQAI, with only two sites over 30 and the rest under 22. One of the sites ranked over 30 is a very large pristine bay that is considered to be a state natural heritage site by the NC Natural Heritage Program. Brunswick L3.1 had a slightly higher FQAI score of 32.03 while Brunswick L3.2 had a slightly lower score of 29.47. Comparison of the scores with the results of the previous NC DWQ study strongly suggests that the Brunswick sites are both reference sites in terms of vegetation. The Marion 2C site also had a score of 28.8 which suggests this site is reference or close to reference. Marion 2a and Marion 2b had lower scores, 16.32 and 16.17, which are just below the average (20.35) and median (18.55) for the combined 2007 basin study and this IW study.

3.5.5.3 Wetness Metric

The FAQWet equation (see Appendix 3b) indicated that the Marion 2B and Marion 2C sites had the predominance of wetter species with scores of 8.72 and 8.8 respectively, while the Brunswick L3.1 site had the least predominance of wet species with a FAQWet score of 5.57. Wetland plants (only plants in the herb stratum) were not very diverse at any of the sites with just one or two obligate or facultative wet species recorded. Relative percent wetland plant cover, the percent of wetland plants (herbs) with an obligate or facultative wet status, ranged from 40 percent at the Brunswick L3.2 site to 58.1 percent at the Marion 2C site but was only 2.2 percent at the Marion 2B site. Wetland shrubs (obligate and facultative wet shrubs) were a little more diverse with five species surveyed at the Brunswick L3.1, Marion 2A and Marion 2B sites, seven species surveyed at the Brunswick L3.2 site and eight species surveyed at the Marion 2C site. Relative percent wetland shrub cover was over 90 percent at both the Brunswick sites (98 percent for the Brunswick L3.1 site and 95.2 percent for the Brunswick L3.2 site) and the Marion 2A site (90.1 percent), 73.3 percent for the Marion 2C site, but only 34.6 percent for the Marion 2B site.

Ervin et al. (2006) developed the Floristic Assessment Quotient for Wetlands (FAQWet) as an alternative to using FQAI since most regions have not developed coefficient of conservatism ratings for wetland plant species. Ervin's study of 53 fringe, riverine, and depression wetlands found that FAQWet scores were comparable with FQAI scores and could therefore be used as an indicator of wetland quality. The NC DWQ 2007 study of riverine (n=7), bottomland forest (n=6), and basin (n=12), and the 2008 headwater wetland study (n=23) found that FAQWet scores correlated with disturbance criteria for riverine swamps only (Savage et al., 2010, and Baker et al., 2008) not basin wetlands. During the 2007 study, the wetland shrub metric better correlated with disturbance criteria than the FAQWet metric for basin wetlands. The 2007 shrub richness results ranged from 0-8 with an average of 3.36 and median of three. Combining the 2007 and the 2008 study shows the same range, 0-8, with an average of 4.18 and median of 4.5. Only one site in the 2007 study had a wetland shrub richness of eight which would indicate eight is a high score for wetland shrub richness.

The Marion 2c site also had eight species of wetland shrubs, while Brunswick L3.2 had seven species, and the other sites had five species. Our results at this time do not indicate the wetness metrics are as good an indicator of reference condition as FQAI, however, this may be a function of study size. Nevertheless, the FAQWet scores for the Level 3 sites in this study are in the upper end of the scale measured in previous two studies conducted by NC DWQ.

3.5.5.4 Functional Group Metrics

The functional guild metric analysis showed that the herb stratum was most notable at the Marion 2B site and that the herb stratum was primarily composed of species in the cryptogram (fern), Cyperaceae, Poaceae, and Juncaceae (sedges, grasses, and rushes), and bryophyte (moss) guilds. Forb species richness and relative percent cover was low or zero at all of the sites. The overall herb cover at most of the sites was low (≤16.5 m^2) except for the Marion 2B site which was notably higher with 309.8 m^2 surveyed in the intensive modules. Herb species richness, which was not diverse at any of the sites, was also highest at the Marion 2B site with seven and lowest at the Marion 2C site with one. The results showed that cryptograms (ferns) and species in the Cyperaceae, Poaceae, and Juncaceae (sedges, grasses, and reeds) were not very diverse, usually one or two species of each except at the Marion 2B site which had five species of sedges, grasses, and reeds. However, these two groups in combination with bryophytes were the dominant plant type in the herb stratum at three of the sites, both of the Brunswick sites and the Marion 2A site.

Ferns and bryophytes were dominant in the Marion 2C herb stratum, and sole species in the sedge, grass, and reed guild were dominant at the Marion 2B site. Ferns made up 58.1 percent of the herb stratum at the Marion 2C site, 41.1 percent at Marion 2A site, 33.3 percent at the Brunswick L3.2 site, 7.1 percent at the Brunswick L3.1 site, but only 2.1 percent at the Marion 2B site.

The percentage of the herb cover that was a sedge, grass, or reed species was very high at the Marion 2B site, 96.5 percent, with 94.5 percent being in the *Carex* genus, none of the other sites had species in the *Carex* genera. Relative percent cover of the sedges, grasses, and reeds was 53.6 percent at the Brunswick L3.1 site, 49.3 percent at the Marion 2A site, and 26.7 percent at the Brunswick L3.2 site, however the Marion 2C site had zero percent.

Relative bryophyte cover in the herb stratum was 35.7 percent at the Brunswick L3.1 site, 40 percent at the Brunswick L3.2 site, 41.9 percent at the Marion 2C site, and just 8.2 percent the Marion 2B site and 1.3 percent at the Marion 2A site. There were very few annuals or bi-annuals surveyed at any of the sites as the Annual to Perennial ratio for the herb stratum was zero at all the sites except the Brunswick L3.1 site which had 0.17. Dicot richness was lowest at the Marion 2A site with 12 species being surveyed while at the other sites this metric ranged from 16 (the Marion 2B site) to 24 (the Brunswick L3.1 site). Dicot cover was lowest at the Marion 2B site with 45.4 percent coverage and highest at the Marion 2C site with 92.2 percent coverage.

3.5.5.5 Community Structure Metrics

The community structure metrics also had variable results between the Level 3 sites. Total cover for the four sites that had a full survey was lowest at the Brunswick L3.1 site, with 515.5, while it was 644.3 at the Brunswick L3.2 site, 618.3 at the Marion 2B site, and highest with 686.5 at the Marion 2C site. The total cover was 114.3 at the Marion 2A site which would be 457.2 if multiplied by four.

Shade species richness were similar in number at the Brunswick sites and two of the Marion sites with 11 and 12 shade species at the Brunswick L3.1 and Brunswick L3.2 sites respectively and seven and eight shade species at the Marion 2B and Marion 2C sites respectively. The Marion 2A site only had three shade species.

Sapling density was highest at the Marion 2B site, 0.88, followed by 0.82 at the Marion 2C site. The Marion 2A and Brunswick L3.2 sites both had a sapling density (trees and small trees ≤10) of 0.55 and the Brunswick L3.1site had the lowest sapling density of 0.32. The Brunswick L3.1 site also had the highest large tree density (trees > 25 cm DBH) with 0.27, the Brunswick L3.2 site had 0.12 for large tree density, the Marion 2C site had 0.04 for large tree density, and the other sites had zero for this metric. The Pole Timber Density Metric (trees 10-15 cm DBH) was only 0.12 and 0.14 at the Marion 2B and

Marion 2C sites respectively, and was higher at the other three sites, 0.41 at the Brunswick L2.1 site, 0.32 at the Brunswick L3.2 site and 0.45 at the Marion 2A site.

Canopy importance was highest at the Brunswick L3.1 site with 0.53 and second highest at the Marion 2B site with 0.48, while Canopy Importance was only 2.3 at the Marion 2A site. Canopy importance was similar at the other two sites 0.31 and 0.35 at the Brunswick L3.1 site and Marion 2C site respectively. The Average Importance Shrub Metric (shade and partial shade native shrubs) was highest at the Marion 2B site with 0.35 and similar at the Marion 2A (0.25) and Marion 2C (0.26) sites and also similar at the Brunswick L3.1 (0.18) and Brunswick L3.2 (0.17) sites. The standing snag importance was highest at the Marion 2B site with 0.36, while the Marion 2C, Brunswick L3.1 and Brunswick L3.1 sites ranged from 0.19 to 0.25, and the Marion 2A site was zero.

3.5.6 Amphibian Monitoring Results

The intensive surveys of the Level 3 sites for Amphibians in March and May of 2010 resulted in the observation of 12 types of amphibians comprised of 11 identified to species and one identified to genus. Of those 11 amphibian species, there were nine frog species, one newt species, one siren species, but no toad or salamander species. Only adults and a few juvenile amphibians were found in this study, no egg sacs or larvae were observed. Examples of some of the amphibians observed in this study are shown in **Figures 3-32** through **3-37**. Previous work completed by the NC Division of Water Quality on amphibians and wetland usage focused on the development of Indices of Biotic Integrity (IBIs) for amphibians in wetlands (Baker et al**.**, 2008; Savage et al., 2010**)**. The goal of this study was to characterize amphibian assemblages in isolated wetlands. In order to do this characterization some of the candidate metrics or biological attributes that were used in these previous studies by NC DWQ as well as by other state wetland programs (Micacchion, 2004) were used to summarize the Level 3 site survey results. The metrics that were determined for each site include Species Richness, Site Abundance, an Amphibian Quality Assessment Index (AQAI), Percent Sensitive, Percent Tolerant, Percent Caudata (salamanders, newts, sirens), Percent Anura (frogs and toads), and the Percent of Isolated Wetland-Ephemeral Wetland-Seepage and Headwater Wetland (IW-EW-SEEP-HW).

Figure 3-32. Notophthalmus viridescens dorsalis.

Figure 3-33. Notophthalmus virdescens dorsalis.

Figure 3-34. Siren intermedia.

Figure 3-35. Rana clamitans.

Figure 3-36. Juvenile *Rana clamitans.*

Figure 3-37. Rana sphenocephala

NCDWQ worked with Alvin Braswell of the NC Museum of Natural History to develop Coefficient of Conservatism (C of C) scores and for each species of amphibian observed in this study (Pers. Comm., Braswell 2010). Scores were assigned from 1-10 with "1" being species that were considered to be generalist with the least specific habitat requirements and "10" being species that had the most specific habitat requirement and sensitivity to stress. NCDWQ also worked with Mr. Braswell to determine which amphibian species required the fish free habitat associated with ephemeral, seepage, headwater, and isolated wetlands (EW-SEEP-HW-IW) (Braswell 2010). **Table 3-15** shows the scientific and common names for the amphibian species, C of C scores, tolerant species (C of C score $\leq$3), sensitive species (C of C $\geq$6), Caudata (salamanders, newts, and sirens) species, Anura (frogs and toads) species, and species associated with IW-EW-SEEP-HW, that were observed in this study.

Table 3-15. SEIWA REMAP Amphibian Ratings Table.

Species	Common Name	C of C	Tolerant ≤ 3	Sensitive ≥ 6	Caudata	Anura	IW-EW-SEEP-HW	Comments
Acris gryllus	Coastal Plain Cricket Frog	2	Yes			Yes		Generalist-grassy margins of ponds, streams or ditches
Hyla chrysoscelis	Cope's Gray Tree Frog	5				Yes	Yes	Site specific to ephemeral ponds or deeper water headwater wetlands, adults rarely found -
Hyla femoralis	Pine Woods Tree Frog	5				Yes		High tree climber, found in pine flatwoods or in or near cypress swamps.
Hyla gratiosa	Barking Treefrog	7		Yes		Yes	Yes	Climber and burrower plus other habitats.
Hyla squirella	Squirrel Treefrog	6		Yes		Yes		Will use ephemeral wetlands deeper water headwater wetlands can also use ditches and other areas, found in urban settings
Notophthalmus viridescens dorsalis	Broken Striped Newt	1	Yes		Yes			Found in pools, ponds, ditches, slow moving pools in streams.
Pseudacris nigrita	Southern Chorus Frog	6				Yes		Pine flatwoods, wet meadows, roadside ditches and moist woodlands.
Pseudacris ocularis	Little Grass Frog	6		Yes		Yes	Yes	Site specific to ephemeral ponds or deeper water headwater wetlands, Limnaedus ocularis synonym
Rana clamitans	Northern Green Frog	2	Yes			Yes		Generalist can persist in environments with fish.
Rana sp.	Frog species	1	Yes			Yes		Consider generalist if not identified to species
Rana sphenocephala	Southern Leopard Frog	3	Yes			Yes		Ephemeral pond or other areas, ponds, ditches and swamps, lake and stream margins
Siren intermedia	Lesser Siren	6		Yes	Yes			Requires standing water year round, otherwise will estivate, will not use metal traps. Burrows in mud during day.

C of C = Coefficient of Conservatism (Braswell pers comm. 2010)

IW-EW-SEEP-HW=Amphibian requiring Isolated, Ephemeral, Seepage, or Headwater wetland conditions (Braswell pers. Comm 2006, 2010).

Peterson Field Guide - Reptiles and Amphibans, Conant and Collins 1991

The AQAI was developed by the Ohio Environmental Protection Agency (Micacchion, 2004) and was used in this study with the NC C of C scores (see Table 3-14 and AQAI equation shown below). A higher AQAI score indicates there is a higher abundance of sensitive species or a high number C of C species at the site.

$$AQAI = \frac{\sum S_i * S_{i\ \text{c of c}}}{N}$$

Where:

S_i = Adult number of species i
$S_{i\ \text{c of c}}$ = C of C value for species i
N = Total number of adults.

3.5.6.1 Amphibian Results by Survey Method

Table 3-16 compares the results by survey method, trap (galvanized, plastic, and homemade mesh), coverboard, and time. The time survey had the highest abundance at 299 observations and species richness at 10, while the total for the traps was 29 for abundance and five for species richness. Although the abundance was higher overall for the time survey, the trap method was better for capturing Caudata species (broken striped newts [*Notophthalmus viredescens dorsalis*]) and the lesser siren [*Siren intermedia*]) with 23 (22 broken striped newts and one lesser siren) being caught by the traps while 13 striped newts were netted or observed swimming during the time survey. The time survey was far better at recording Anura species which were either heard or observed, often around the edge of the wetland sites. For the trap methods, the mesh traps had the highest abundance, 17, while the galvanized traps had the highest species richness, four. The plastic traps did catch the one Lesser Siren recorded in the study. The coverboard method proved to be ineffective for this study with no observations recorded.

Table 3-16. Summary Results by Amphibian Survey Method

Method	No. / Hours	Abundance	Diversity	Number Anura	Number Claudata
Trap – Galvanized	67	6	4	3	3
Trap – Plastic	20	20	2	0	3
Trap – Mesh	84	3	3	3	17
Coverboard	268	0	0	0	0
Time	17	299	9	286	13

3.5.6.2 Amphibian Results by Survey Time

Table 3-17 summarizes amphibian results by site and survey month. The abundance and species richness were higher at the Brunswick sites than at the Marion sites during both months. The Brunswick L3.1 and L3.2 sites had an abundance of 95 and 46 in March and 69 and 77 in May, while the species richness was 4 and 2 in March and 7 and 8 May. The Marion 2B site had 27 for abundance in March but only 2 observations were made in May while the Marion 2C site had an abundance of 12 in March and 5 observations in May. Southern Cricket frogs (*Acris gryllus*) were the most abundant species at all sites.

The species richness for the Marion sites was comparable in March to the Brunswick sites but less so in May; Marion 2B and 2C had 4 and 2 species observed in March and 1 and 3 species observed in May. There was also some variability between the survey month and species that was observed or heard calling. Southern cricket frogs and *Rana* sp. frogs were observed during the March survey at both sites and during the May survey at the Brunswick site. Broken striped newts were also observed during both sampling months at the Brunswick site. The southern cricket frog was notably more abundant in March than in May at the Brunswick site and had a higher abundance at Brunswick L3.1 overall. At the Marion sites in March, the southern chorus frog (*Pseudacris nigrita*) was heard calling and in May the squirrel tree frog (*Hyla squirella*) and little grass frog (*Pseudacris ocularis*) were heard calling. In May at the Brunswick sites the little grass frog, pine wood tree frog (*Hyla femoralis*), Cope's gray tree frog (*Hyla chrysoscelis*), and barking tree frog (*Hyla gratiosa*) were heard and the lesser siren was caught at Brunswick L3.2.

Table 3-17. Amphibian Summary Results by Survey Time

	March		May	
Site	Abundance	Diversity	Abundance	Diversity
Brunswick L3.1	95	4	69	7
Brunswick L3.2	46	2	77	8
Marion 2B	27	4	2	1
Marion 2C	12	2	5	3

Table 3-18 summarizes the candidate metric or biological attributes for each intensively surveyed isolated wetland as well as the March and May results combined for the four isolated wetlands surveyed for amphibians during the Level 3 phase of the study.

Table 3-18. Amphibian Candidate Metric Results.

Site Name	Species Richness	Site Abundance	AQAI	Percent Tolerant	Percent Sensitive	Percent Caudata	Percent Anura	Percent IW-EW-SEEP-HW
BrunwicksL3.1	9	164	2.5	83.8	4.0	11.0	89.0	7.0
BrunswickL3.2	8	123	2.6	77.6	6.1	14.7	85.3	9.4
Marion 2b	5	29	3.3	66.7	7.0	0.0	100.0	7.0
Marion 2c	4	17	3.3	66.7	18.2	0.0	100.0	12.1
Total	12	333	2.6	79.2	5.7	10.9	89.1	8.2

AQAI=Amphibian Quality Assessment Index

IW-EW-SEEP-HW=Amphibian requiring Isolated, Ephemeral, Seepage, or Headwater wetland conditions

As previously discussed, species richness and abundance were higher at the Brunswick sites than the Marion sites. The Brunswick L3.1 site had higher values for species richness (9) and abundance (164) than the Brunswick L3.2 site which had eight for species richness and 123 for abundance. The Marion 2B site also had higher species richness (5) and abundance (29) than the Marion 2C site which had 4 for species richness and 17 for abundance. The Marion sites proved to have a lower percentage of tolerant species and a higher percentage sensitive species which resulted in slightly higher AQAI scores. The Marion 2B and 2C sites had the lowest percentage of tolerant species (66.7 percent tolerant for both sites) and highest AQAI score (3.3 for both sites). The Marion 2C site had the highest percentage of sensitive species, 18.2 percent sensitive. Brunswick L3.1 had the highest percentage of tolerant species (83.8 percent tolerant), lowest percentage of sensitive (4.0 percent sensitive) and lowest AQAI score (2.5). At the Brunswick L3.1 site 11 percent of the observations were Caudata species and at the Brunswick L3.2 site 14.7 percent of the observations were Caudata species (primarily broken striped newts) while at the Marion sites 100 percent of the observations were Anurans. The percentage of IW-EW-SEEP-HW species were comparable between the two counties and four sites with Marion 2C having the highest percentage 12.1 percent, and Marion 2B having the lowest percentage, seven percent. Combining the four sites resulted in a species richness of 10, an abundance of 333, an AQAI score of 2.6, 79.2 percent tolerance, 5.7 percent sensitive, 10.9 percent Caudata, 89.1 percent Anuran, and 8.2 percent IW-EW-SEEP-HW (see Table 3-17).

3.5.7. Aquatic Macroinvertebrate Monitoring Results.

The intensive surveys of the Level 3 sites for aquatic macroinvertebrates in March 2010 yielded 43 taxa comprised of 12 species, 29 genera, 23 families, 15 orders, five classes and two phyla (**Table 3-19**). Table 3-19 also shows the taxon's Functional Feeding Guild (FFG – collector-gatherer, shredder, predator), Habit Guild (burrower, climber, sprawler, swimmer), three aquatic macroinvertebrate index values - Merritt and Cummins (Merritt et al. 2008), a national index for aquatic macroinvertebrate tolerance in streams, the NC DWQ biotic index (Lenat 1990), a regional index for aquatic macroinvertebrate tolerance in streams, and lastly, a combined index value.

The FFG analysis in this study revealed the collection of 18 predator, 8 collector-gatherer, and 1 shredder taxa, while for Habit there were 14 swimmers, 5 burrowers, 4 sprawlers, and 1 climber taxa collected. Of the 44 taxa observed, 13 had a DWQ assigned index value and 17 had a Merritt and Cummins assigned value. The combined index values use the scores from both the Merritt and Cummins and DWQ indices. For species that had both a Merritt and Cummins and DWQ index score (eight taxa) the DWQ index score was used because this a regional rating and therefore assumed to be a more accurate assessment of the taxon's tolerance. The aquatic macroinvertebrate tolerance index value rates species from 1-10 with the higher score indicating the taxon has the capacity to be more tolerant to organic pollutants and the low dissolved oxygen levels associated with those pollutants and therefore poor site conditions. In this study, the index scores ranged from 3.6 to 9.7, with 55% of the rated taxa being greater than 9. Note that the tolerance index scores for aquatic macroinvertebrates differ from the C of C scores

Table 3-19. SEIWA REMAP Aquatic Macroinvertebrate Observed Taxa.

Phylum	Class	Order	Family	Taxon	Function Feeding Groups	Habit	Merritt & Cummins Index	DWQ Biotic Index	Combined Index Values
Annelida	Clitellata			Clitellata			NG	NG	NG
Annelida	Clitellata	Haplotaxida	Enchytraeidae	Enchytraeidae			NG	9.8	9.8
Arthropoda	Insecta	Coleoptera	Dytiscidae	Liodessus sp.	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dyticidae	Thermonectus basillaris	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dyticidae	Thermonectus ornaticollis	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dytiscidae	Acilius fraternus fraternus	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dytiscidae	Acilius sp.	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dytiscidae	Agabetes acuductus			NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dytiscidae	Copelatus sp.	predator	swimmer	9.1	NG	9.1
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscidae	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscus sp.	predator	swimmer	5	NG	5
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hoperius sp.	predator	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Hydrochara sorror	collector/gatherer	swimmer	NG	NG	NG
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Tropisternus sp.			NG	9.3	9.3
Arthropoda	Insecta	Collembola		Collembola			NG	NG	NG
Arthropoda	Insecta	Diplostraca	Daphniidae	Daphniidae		swimmer	NG	NG	NG
Arthropoda	Insecta	Diptera	Ceratopogonidae	Dasyhelea sp.	collector/gatherer	swimmer	NG	NG	NG
Arthropoda	Insecta	Diptera	Chaoboridae	Chaoborus punctipennis	predator	sprawler	8.5	NG	8.5
Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae	collector/gatherer	burrower	NG	NG	NG
Arthropoda	Insecta	Diptera	Chironomidae	Chironomus sp.	collector/gatherer	burrower	9.8	9.6	9.6
Arthropoda	Insecta	Diptera	Chironomidae	Gymnometriocnemus		sprawler	7	NG	7
Arthropoda	Insecta	Diptera	Chironomidae	Limnophyes	collector/gatherer	sprawler	8	7.4	7.4

Table 3-19. SEIWA REMAP Aquatic Macroinvertebrate Observed Taxa.

Phylum	Class	Order	Family	Taxon	Function Feeding Groups	Habit	Merritt & Cummins Index	DWQ Biotic Index	Combined Index Values
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum tritum	shredder	climber	6.7	9.5	9.5
Arthropoda	Insecta	Diptera	Chironomidae	Psectrocladius Psilopterus Gr.	collector/gatherer	sprawler	3.8	3.6	3.6
Arthropoda	Insecta	Diptera	Chironomidae	Smittia sp.	collector/gatherer	burrower	NG	NG	NG
Arthropoda	Insecta	Diptera	Chironomidae	Zavrelimyia	predator	sprawler	9.1	9.1	9.1
Arthropoda	Insecta	Diptera	Culicidae	Aedes	collector/gatherer	swimmer	8	NG	8
Arthropoda	Insecta	Diptera	Dolichopodidae	Dolichopodidae	predator	burrower	9.7	NG	9.7
Arthropoda	Insecta	Diptera	Muscidae	Limnophora sp.	predator		8.4	NG	8.4
Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae			NG	9	9
Arthropoda	Insecta	Hemiptera	Corixidae	Hesperocorixa sp.			NG	9	9
Arthropoda	Insecta	Hemiptera	Notonectidae	Buenoa	predator		NG	NG	NG
Arthropoda	Insecta	Hemiptera	Notonectidae	Notonecta sp.	predator		8.7	NG	8.7
Arthropoda	Insecta	Lepidoptera	Noctuidae	Noctuidae			NG	NG	NG
Arthropoda	Insecta	Lepidoptera	Pyralidae	Pyralidae			NG	NG	NG
Arthropoda	Insecta	Odonata	Aeshnidae	Aeshna umbrosa	predator		NG	NG	NG
Arthropoda	Insecta	Odonata	Libellulidae	Libellula	predator		9.6	9.4	9.4
Arthropoda	Insecta	Odonata	Libellulidae	Pachydiplax longipennis	predator		9.9	9.6	9.6
Arthropoda	Malacostraca	Amphipoda	Gammaridae	Crangonyx serratus		swimmer	7.9	7.9	7.9
Arthropoda	Malacostraca	Decapoda	Cambaridae	Procambarus acutus			7	NG	7
Arthropoda	Malacostraca	Isopoda	Asellidae	Asellus			NG	9.1	9.1
Arthropoda	Maxillopoda	Copepoda		Copepoda			NG	NG	NG
Arthropoda	Ostracoda			Podocopida			NG	NG	NG

NG = Not Given

for amphibians and plants, in which a higher C of C score indicates the species is more sensitive to poor sites conditions and a lower score indicates the species has high tolerance to poor site conditions.

Summary results for species richness and abundance by station are shown in **Table 3-20** and by method (sweep or funnel trap) in **Table 3-21**. Species richness was comparable between the stations and sites, ranging from 1-10 with an average of 4.6 and median of four (**Table 3-20**). The funnel trap method collected 19 species and the sweep method collected 36 species. More of the mobile species such as adult Coleoptera and Hemiptera were collected in the funnel traps as well as crayfish (*Procambus acutus*, see **Figure 3-38**), while some of the benthic species such as Diptera and Odonata were collected in the sweep nets. Mosquito larvae (Dipterans) were captured in the funnel traps, but these were not picked out of the traps due to time constraints. The abundance values were notably higher for the sweep stations at the Marion sites than at the Brunswick sites with six of the 10 Marion sites having a 200+ count. Funnel traps also collected more individuals at the Marion sites (Marion 2B, 66, and Marion 2C, 35), than at the Brunswick sites (Brunswick L3.1, 27 and Brunswick L3.2, 28).

Table 3-20. SEIWA REMAP Aquatic Macroinvertebrate Richness and Abundance by Station

Station	Method	Species Richness	Abundance
Brunswick L3.1 SW1	sweep	5	11
Brunswick L3.1 SW2	sweep	4	12
Brunswick L3.1 SW3	sweep	2	7
Brunswick L3.1 SW4	sweep	2	7
Brunswick L3.1 SW5	sweep	5	6
Brunswick L3.1 funnel	funnel	9	27
Brunswick L3.2 SW1	sweep	1	2
Brunswick L3.2 SW2	sweep	2	2
Brunswick L3.2 SW3	sweep	7	16
Brunswick L3.2 SW4	sweep	3	4
Brunswick L3.2 SW5	sweep	5	12
Brunswick L3.2 funnel	funnel	3	28
Marion 2B funnel	funnel	10	66
Marion 2B SW1	sweep	4	209
Marion 2B SW2	sweep	6	85
Marion 2B SW3	sweep	7	200
Marion 2B SW4	sweep	5	200
Marion 2B SW5	sweep	9	200
Marion 2C SW1	sweep	4	200
Marion 2C SW2	sweep	4	103
Marion 2C SW3	sweep	1	210
Marion 2C SW4	sweep	3	156
Marion 2C SW5	sweep	6	131
Marion 2C funnel	funnel	4	35

Table 3-21. SEIWA REMAP Aquatic Macroinvertebrate Richness and Abundance by Site.

Method	Species Richness	Abundance
funnel	19	156
sweep	36	1773

Figure 3-38. Crayfish from funnel trap.

The average and median abundance values at the Marion stations were 150 and 178 respectively while the average and median abundance values at the Brunswick stations were 11.2 and 9 respectively.

Previous work completed by the NC Division of Water Quality on aquatic macroinvertebrates and wetland usage focused on the development of Indices of Biotic Integrity (IBIs) for aquatic macroinvertebrates in wetlands. The goal of this study is simply to characterize the composition of aquatic macroinvertebrate communities in isolated wetlands. To accomplish this goal, candidate metrics or biological attributes that were used in previous studies by NCDWQ and other programs (Baker et al., 2008, Savage et al., 2010, Rader et al., 2001, Ohio EPA, 2004, U.S. EPA, 2002b, Reiss and Brown, 2005, Chirhart, 2003, and Stribling et al., 1998) were used to summarize the Level 3 site survey results.

The metrics results by site are organized in **Table 3-22** by metric type: Functional Feeding Guild (FFG), Habit, Site Composition (e.g. percent Chironomidae [midge], percent Coleoptera [beetle]), Site Richness (e.g. Chironomidae species richness, Coleoptera species richness), and Site Sensitivity / Tolerance. Combined aquatic macroinvertebrate index scores of ≤ 4 were considered sensitive and ≥ 8 were considered tolerant. Species that did not have a combined index score were excluded from the percent sensitive and percent tolerant calculation. Similarly to the percent sensitive and tolerant metrics, taxa without tolerance values were excluded from the biotic index calculation.

The biotic index for aquatic macroinvertebrates uses a method created by David Lenat for the NC DWQ for use in southeastern streams (Lenat, 1990). The Aquatic Macroinvertebrate Biotic Index for the DWQ, Merritt and Cummins, and the combined tolerance values were calculated with the following equation:

$$BI = \frac{\sum TV_i N_i}{N}$$

where:

BI = Biotic Index
TV*i* = tolerance value of *i*th taxon
N*i* = abundance of *i*th taxon
N = total number of individuals in taxa.

Table 3-21 also indicates which metrics would potentially have a positive, negative, or no association with higher quality wetland sites (Pers. Comm. Eaton, 2010).

For the FFG results, predators were the most dominant FFG at the Brunswick sites with 38.6 percent (Brunswick L3.1) and 62.5 percent (Brunswick L3.2) occurrence and 9 (Brunswick L3.1) and 7 (Brunswick L3.2) taxa of predator species. At the Marion sites, collector-gatherers were more dominant with 24.6 percent (Marion 2B) and 94.5 percent (Marion 2C) abundance and 6 (Marion 2B) and 3 (Marion 2C) taxon of collector-gatherer species. For Habit guild results, swimmers were the dominant type of taxa with 65.7, 57.8, 93.8, and 98.2 percent occurrence at the Brunswick L3.1, Brunswick L3.2, Marion 2B, and Marion 2C sites respectively. Species richness for the swimmer taxon ranged from 5 (Brunswick L3.2) to 9 (Marion 2B).

Table 3-22. SEIWA REMAP Aquatic Macroinvertebrate Survey Site Results.

Metric	Brunswick L3.1	Brunswick L3.2	Marion 2b	Marion 2c	Indication of Site Quality?
Functional Feeding Guild					
Percent Collector-Gatherer	2.9	1.6	24.6	94.5	N/A
Percent Predator	38.6	62.5	5.3	4.1	positive
Percent Shredder	10.0	0.0	0.2	1.2	N/A
Richness-Collector-Gatherer	1	1	6	3	N/A
Richness-Predator	9	7	8	6	positive
Richness-Shredder	1	0	1	1	N/A
Habit Guild					
Percent Burrower	0.0	1.6	0.5	0.2	N/A
Percent Climber	10.0	0.0	0.2	1.2	N/A
Percent Sprawler	2.9	7.8	0.2	0.2	N/A
Percent Swimmer	65.7	57.8	93.8	98.2	N/A
Richness-Burrower	0	1	2	2	N/A
Richness-Climber	1	0	1	1	N/A
Richness-Sprawler	2	1	2	2	N/A
Richness-Swimmer	6	5	9	6	N/A
Site Composition					
Percent Chironomidae (Midges)	11.4	1.6	0.9	1.6	N/A
Percent Coleoptera (Beetles)	25.7	42.2	8.3	4.0	N/A
Percent Corixidae	2.9	15.6	0.2	0.0	N/A
Percent Corixidae+Coleoptera (Beetles)	20.0	42.2	1.7	0.1	N/A
Percent Crustaceae	41.4	18.8	69.4	0.0	N/A
Percent Decapoda	41.4	15.6	0.0	0.0	N/A
Percent Diptera (Flies)	18.6	9.4	21.6	95.9	N/A
Percent Dytiscidae	25.7	42.2	5.0	4.0	N/A
Percent Hemiptera (True Bugs)	8.6	21.9	0.5	0.0	N/A
Percent Hirundinea (Leech)	0.0	0.0	0.0	0.0	N/A
Percent Micro-crustaceae	0.0	1.6	69.4	0.0	N/A
Percent Mollusk	0.0	0.0	0.0	0.0	N/A
Percent Oligochaetes (Segmented Worms)	2.9	0.0	0.1	0.0	N/A
Percent Orthocladiinae	1.4	0.0	0.5	0.2	N/A
Percent Terrestrial	0.0	1.6	0.1	0.1	N/A
Percent Trichoptera (Caddisflies)	0.0	0.0	0.0	0.0	N/A
Percent Trombidiformes (Water Mites)	0.0	0.0	0.0	0.0	N/A
Percent Insecta	55.7	82.8	95.5	100.0	N/A
Site abundance	70.0	64.0	960.0	835.0	N/A
Evenness	1.0	0.9	0.9	0.9	positive
Simpson's Diversity Index	0.9	0.9	0.9	0.8	positive

Metric	Brunswick L3.1	Brunswick L3.2	Marion 2b	Marion 2c	Indication of Site Quality?
Site Richness					
Richness-Chironomidae (Midges)	2	1	5	4	N/A
Richness-Coleoptera (Beetles)	4	3	9	5	N/A
Richness-Corixidae	1	1	2	0	N/A
Richness-Corixidae + Coleoptera (Beetles)	2	2	5	1	N/A
Richness-Crustaceae	3	4	2	0	N/A
Richness-Decapoda	3	2	0	0	N/A
Richness-Diptera (Flies)	5	2	6	6	N/A
Richness-Dytiscidae	4	3	7	5	N/A
Richness-Hemiptera (True Bugs)	2	2	3	0	N/A
Richness-Hirudinea (Leeches)	0	0	0	0	N/A
Richness-Micro-crustaceae	0	1	2	0	N/A
Richness-Mollusk	0	0	0	0	N/A
Richness-Oligochaetes (Segmented Worms)	1	0	1	0	N/A
Richness-Orthocladiinae	1	0	3	2	N/A
Richness-Terrestrial	0	1	1	1	N/A
Richness-Trichoptera (Caddisflies)	0	0	0	0	N/A
Richness-Trombidiformes (Water Mites)	0	0	0	0	N/A
Family Richness	14	10	9	5	positive
Genus Richness	14	9	15	8	positive
Species Richness	17	14	22	12	positive
Site Sensitivity / Tolerance					
Percent EOT	2.9	6.3	0.0	0.0	positive
Percent EPT	0.0	0.0	0.0	0.0	positive
Percent POET	2.9	6.3	0.0	0.0	positive
Richness-EOT	2	2	0	0	positive
Richness-EPT	0	0	0	0	positive
Richness-POET	2	2	0	0	positive
Percent Sensitive	0.0	0.0	0.4	0.0	positive
Percent Tolerant	42.9	65.5	90.8	97.1	Negative
Richness-Sensitive	0	0	1	0	positive
Richness-Tolerant	8	4	7	5	Negative
DWQ and Merritt and Cummins Combined Biotic Index	8.39	8.58	7.78	7.94	Negative
DWQ Biotic Index	8.42	8.58	8.55	9.29	Negative
Merritt and Cummins Biotic Index	7.81	8.42	7.74	7.91	Negative

EPT=Ephemeroptera (Mayflies), Plecoptera (Stoneflies), Trichoptera (Caddisflies)
OET=Odonata (Dragonflies), Ephemeroptera (Mayflies), Trichoptera (Caddisflies)
POET=Plecoptera (Stoneflies), Odonata (Dragonflies), Ephemeroptera (Mayflies), Trichoptera (Caddisflies)
DWQ Biotic Index - NC DENR Division of Water Quality - Lenat, 1993

Merritt and Cummins Biotic Index-Merrit, R.W., K.W. Cummins and M.B. Berg. 2008. An Introduction to the Aquatic Insects of North America, Fourth Edition. Kendall/Hung Publishing Company, Dubuque, IA
Indication of Site Quality - Positive = Higher values potentially associated with higher wetland site quality.

Metric	Brunswick L3.1	Brunswick L3.2	Marion 2b	Marion 2c	Indication of Site Quality?

Indication of Site Quality - Negative = Lower values potentially associated with lower wetland site quality.

The site composition was comparable for some of the summary composition metrics like the Simpson's Diversity Index, which ranged from 0.82 to 0.94, and Evenness, which ranged from 0.89 to 0.98. Other metrics were quite variable; abundance varied greatly between the Brunswick and Marion sites, with total abundance of 70 and 64 for the Brunswick L3.1 and Brunswick L3.2 sites respectively, while the Marion 2B and 2C sites had abundance of 960 and 835.

Most of the other aquatic macroinvertebrate composition metrics are based on systematic level categories (phyla, sub-phylum, class, sub-class, order, and family). There was one metric at the phylum level, percent Mollusk, which had zero percent occurrence at all of the sites. The one metric at the sub-phyla level, percent Crustaceae, had more notable differences at three of the sites, 41.4 percent at the Brunswick L3.1 site, 18.8 at the Brunswick L3.2 site, and 69.4 at the Marion 2B site, but only zero percent at the Marion 2C site. Metrics at the class level (percent Insecta) and sub-class levels (percent Hirudinea [leech] and percent Oligochaetes [segmented worms]) showed higher percentages of Insecta at the Marion sites (95.5 percent at Marion 2B and 100 percent at Marion 2C) and somewhat lower percentages at the Brunswick sites (55.7 percent at Brunswick L3.1 and 82.8 percent at Brunswick L3.2). Percent Hirundinea was zero percent at all sites. Percent Oligochaetes was 0 at Brunswick L3.2 and Marion 2C, 0.1 percent at Marion 2B, and 2.9 percent at Brunswick L3.1.

For metrics at the order level (Coleoptera [beetles], Diptera [flies], Hemiptera [true bugs], Trichoptera [caddisflies], Trombidiformes [water mites]), Coleoptera were the most prevalent at the Brunswick sites (25.7 percent for the Brunswick L3.1 site and 42.2 percent for the Brunswick L3.2 site) while the Diptera were most prevalent at the Marion sites (21.6 percent for the Marion 2B site and 95.9 percent for the Marion 2C site). The Trichoptera and Trombidiformes orders had zero percent occurrence at all of the sites while Hemipteran taxon occurred at the Brunswick sites (8.6 percent for the Brunswick L3.1 site and 21.9 percent for the Brunswick L3.2 site) but was nearly non-existent at the Marion sites (0.5 percent at Marion 2B site and zero percent at the Marion 2C site).

For family level metrics (Chironomidae [midges], Orthocladiinae and Dytiscidae) the percent Dytiscidae were notably high at the Brunswick sites (25.7 percent the Brunswick L3.1 site and 42.2 percent at the Brunswick L3.2 site), the percent Corixidae was 15.6 percent at the Brunswick L3.2 site, and the percent Chironomidae was 11.4 percent at the Brunswick L3.1 site. The other family percentage metric results were less notable, ranging from zero to five percent.

For the other metrics that are not at the phylum, class, order, or family level (percent Corixidae+Coleoptera, percent Micro-crustacean, percent Decapoda, and percent Terrestrial) there were notable results for percent Corixidae+Coleoptera at the Brunswick sites (20 percent at the Brunswick L3.1 site and 42.2 percent at the Brunswick L3.2 site), and for the percent micro-crustaceae at the

Marion 2B site there was 69.4. Lastly, percent Decapoda was 41.4 at the Brunswick L3.1 site and 15.6 percent at the Brunswick L3.2 site. None of the sites had a high percentage of terrestrial species as would be expected in a wetland survey.

Metric types based on species richness or diversity were also variable between the two locations and four sites. At the order level, the number of coleoptera, 9, at Marion 2B was notable as was the number of Diptera species, 6, at the same site. Additionally, at the family level, the number of Chironomidae, 5, and Dystiscidae, 7, at the Marion 2B site, was also notable. Marion 2B had the highest species richness, 22, and genera richness, 15, while Brunswick L3.1 had the highest family richness, 14.

In most cases, the Sensitivity and Tolerance Metrics were fairly comparable between the two locations and four sites. There were three species of Odonata (dragonflies) with low counts that were collected at the Brunswick sites (two species at each site) but were absent in the Marion sites. There were no Ephemeroptera (mayflies), Trichoptera (caddisflies) or Plecoptera (stoneflies) collected at any of the sites. This resulted in 2.9 percent and 6.3 percent for percent EOT (Ephemeroptera-Odonata-Trichoptera) and percent POET (Plecoptera- Ephemeroptera-Odonata-Trichoptera) at the Brunswick L3.1 site and Brunswick L3.2 site respectively and zero percent at both Marion sites. The percent sensitive metric (percent of taxa with a combined aquatic macroinvertebrate tolerance rating of ≤ 4) was 0.4 percent at the Marion 2B site due to the single observation of *Psectrocladius psiloterus* gr., that had a combined tolerance rating of 3.8. All other sites had a percent sensitive rating of zero percent. The percent tolerant metric (percent of taxon with a combined aquatic macroinvertebrate tolerance rating of ≥8) had more variable results. At the Brunswick sites there was 42.9 percent and 65.5 percent tolerance with 12 and six tolerant species present for the Brunswick L3.1 and Brunswick L3.2 sites respectively while there was 90.8 percent and 97.1 percent tolerance Marion 2B and 2C respectively with ten tolerant species present at both Marion sites. Although the percent tolerance metric results were somewhat variable, the aquatic macroinvertebrate index scores for the three indices, NC DWQ, Merritt and Cummins, and the combined index were similar. The DWQ biotic index ranged from 8.4 (Brunswick L3.1) to 9.3 (Marion 2C), the Merritt and Cummins biotic index ranged from 7.7 (Marion 2C) to 8.4 (Brunswick L3.2) and the combined index, which should be the most representative result, ranged from 7.8 (Marion 2B) to 8.6 (Brunswick L3.2).

3.6 Discussion

The Level 3 portion of the Southeast Isolated Wetlands Assesment was successful in demonstrating intensive field methods that could be used to characterize the physical and biological features of southeast isolated wetlands and provide information on how well they are functioning with respect to the hydrology of the landscape, local water quality conditions, and habitat for plant and animal species. The Level 3 methods included measurement methods for the following general categories of wetland characteristics:

- Water quality measurements (well and wetland samples) for nine variables including pH, temperature, specific conductivity, dissolved oxygen, dissolved organic carbon.

- Hydrologic measurements using monitoring well transects and data recorders to capture trends over time.

- Soil measurements including a phosphorous adsorption index

- Vegetation measurements including natural community classification, species identification, and metrics relevant to biological integrity for community balance, floristic quality, wetness, functional group, and community structure.

- Amphibian measurements including traps and observations of species numbers as well as metrics of species richness, site abundance, an amphibian quality assessment index (AQAI), percent sensitive, percent tolerant, percent Caudata (salamanders, newts, sirens), percent Anura (frogs and toads), and the percent of isolated wetland-ephemeral wetland-seepage and headwater wetland (IW-EW-SEEP-HW).

- Aquatic macroinvertebrate measurements including species counts and prevalence and metrics reflecting functional feeding guild (FFG; collector-gatherer, shredder, and predator), habit guild (burrower, climber, sprawler, and swimmer), and three aquatic macroinvertebrate index values and a combined index value.

These methods were applied to two clusters of isolated wetlands in the SEIWA study area, two forested cypress ponds in Brunswick County, NC, (the L3 site) and a cluster of cypress savannah and small pocosin wetlands in Marion, SC. Results from these studies are discussed below.

3.6.1 Water Quality Discussion

Isolated wetlands in this study maintain their wetland characteristics through the input of rain water, shallow groundwater flow from beneath when the water table is high, and some overland flow during rain events. The acidity of the local groundwater, and limited overland flow due to small local watersheds, causes the high acidity levels observed in the wetlands and well stations and low nutrient levels in comparison to other wetland types like alluvial swamps that are connected and receive regular surface and groundwater inputs that are more alkaline and rich in nutrients.

Phosphorous adheres to wetland soils, and nitrogen is reduced to ammonia and organic forms, which may explain why the water quality samples had an upward trend in phosphorous and nitrite/nitrate moving away from the wetland. Typically the wetland samples collected from upland wells were very turbid and full of sediment which may have contributed to the higher levels of phosphorous detected at these stations. Agitation of the water sample while bailing water quality samples may also have had some affect on the DO levels, thus increasing the DO levels at well stations. The higher DO levels recorded in the wells did not seem to correlate with cool temperatures which would be another explanation for increased DO levels. The warmer temperatures observed at the Marion 2b site were likely due to the fact this Marion 2b is a shallow wetland located in open sunlight unlike the other three IW wetland stations that were located in the shade. The higher levels of DOC found in the wetland and wells located in wetland stations were not surprising as wetlands are known to be high in organic carbon.

3.6.2 Soils Discussion

The phosphorus adsorption capacity of these isolated wetlands was estimated using a phosphorus adsorption index (PSI) from the soil samples collected in the Level 2 part of the study. PSI is a dimensionless index that rank soils based on their ability to adsorb and immobilize phosphorus. Overall the PSI was much higher in the wetland soils (median value of 16.0) than in the upland soils (median value of 5.5), with a higher variability in the wetland soils. Therefore it appears that these isolated wetlands have significant potential to immobilize phosphorus introduced into the wetland via surface water. There was a strong, positive correlation between PSI and aluminum concentrations in the soil which has been observed in both upland and wetland soils during other studies. Additional study is in progress to see how PSI changes with depth.

3.6.3 Hydrology Discussion

The hydrologic system in the study area is a groundwater dominated system; because of the flat terrain and permeable (sandy) soil, surface water and groundwater are linked. For example, up to 62 percent of the flow in the Waccamaw River is from groundwater seepage (Harden et al., 2003). SSURGO Soil descriptions for the hydric soils that are characteristic of IWs in the study area indicate that the hydric soils are formed when the water table rises and stays near the surface during the wet months of the year. In addition, Pyszhoa et al. (2008) verified this groundwater connectivity for a forested Carolina bay in the coastal plain of South Carolina and developing a conceptual hydrologic model that is consistent with the observations in this study.

In other words, the isolated wetlands we studied in this project are filled both by rainfall falling directly on the wetlands and by water that infiltrates the surrounding land, raises the water table across the landscape, and wets the depressional wetlands from below. In our Level 3 study sites we have sited lines of piezometers within and between wetlands and the nearest downgradient waterbody so we can measure and quantify this interconnectivity.

Groundwater monitoring wells were installed in and adjacent to two clusters of isolated wetlands in Brunswick and Marion Counties. Long term monitoring was conducted and will continue for the next several years, but the wells were installed and measured in time to record the recovery of groundwater levels from drought conditions in early to mid-2009 to more wet conditions in 2010.

These preliminary data allowed some conclusions to be made about the Level 3 wetland clusters. First, similar to the wetland in Pyzoha et al. (2008), these wetlands appear to be perched water tables on top of clay (Brunswick) or sandy clay (Marion) lenses. This situation constrains downward movement of water to deeper aquifers and also retains water in the wetland during droughts or dry periods of the year (mainly the growing season). Water gradients from the wetland to the upland in Brunswick County show that there the clay layer is particularly effective in retaining water in these wetland features, and that the wetlands have the potential to feed the surrounding surficial aquifer for most of the year.

Pyzoha et al. (2008) confirmed this for the Carolina bay in that study, showing that as groundwater levels dropped during dry seasons, water flows from the wetland to the underlying aquifer.

Second, the water levels in the wetlands respond quickly and consistently to significant precipitation events. Each rainfall event is reflected in an immediate increase in groundwater levels at all wells at each site, with well-to-well water levels generally mirroring each other in adjacent wells. Furthermore, the wells in the wetlands showed a general recovery from dry, low water conditions during a record drought to more normal conditions at the current time.

Third, there appears to be the potential for substantial groundwater movement between the isolated wetlands and the adjacent connected wetland at the Brunswick County site. In contrast at the Marion County site, any groundwater movement from the isolated wetlands to downstream waters appears to occur only during limited hydrologic conditions (i.e., the IWs appear to be a water "sink"). Additional monitoring and simulation modeling will be pursued with another EPA grant to examine more precisely the connectivity of these isolated wetlands to connected wetlands and streams.

3.6.4 Vegetation Monitoring Discussion

Wetland plants exist for their entire life and often over long periods of time in the same location and are thus a notable indicator of human-derived disturbance. The presence of wetland vegetation can have a positive effect on water quality by removing pollutants from the water column and underlying sediments (EPA, 2006c). However, urban and agricultural runoff containing larger quantities of heavy metal toxins such as copper or other pollutants can alter the plant species type and distribution over time (Rader et al., 2001). Other disturbances to isolated wetlands plant communities originate from disturbances to the adjacent upland buffer such silviculture, agriculture, and development that has the potential to introduce invasive exotics that outcompete native species. Understanding the vegetative characteristics of quality reference isolated wetlands, like the ones surveyed in this study, provide useful information that can be applied toward wetland management and mitigation requirements.

The results of the vegetation monitoring indicate the Level 3 wetlands are three examples of quality isolated wetland communities as defined by Schafale and Weakley (1990) and Nelson (1986). The types of isolated wetland communities at the Level 3 sites were defined as Small Depression Ponds/Pond Cypress Ponds (Brunswick L3.1 and L3.2), Cypress Savannah/Pond Cypress Savannah (Marion 2A and 2B), and Small Depression Pocosin/Pocosin (Marion 2C). As was noted earlier, one of the indications of quality was the presence of a population of the federally endangered southern spice bush (*Lindera melissifolia*).

The Brunswick sites are steep-sided lime sinks that rapidly transition from deep standing water to flatwood upland. The layout of the modules at the Brunswick sites captured both the standing water with no vegetation, concentric zone of wetland shrubs, and the wetland-upland ecotone with the surrounding pine flatwoods. The Marion 2B and Marion 2C sites, were large enough (0.47 and 1.82 acres respectively) to avoid capturing an upland/wetland ecotone. These sites were not nearly as wet and deep standing water void of vegetation did not occur there. Marion 2B site and to a lesser degree, the

Marion 2A site, had a prominent herb layer associated with a Cypress Savannah/Pond Cypress Savannah, while Marion 2C had an extensive shrub cover associated with Small Depression Pocosin/Pocosin systems. The Marion 2A site was surveyed for just one module and therefore was not as diverse as the other four sites. Additionally, 8-10 modules are needed to really capture the species diversity and structure of the canopy stratum which was not the case at the Marion 2A site, an open canopied, small, 0.03-acre isolated wetland.

The Simpson's Diversity, Evenness, and Species and Genera Richness results for the Level 3 sites indicate that these sites are diverse and heterogeneous in nature. The higher species richness results at the Brunswick sites may be partly due to the fact that the upper edge of the vegetation plot at both sites encompassed a narrow ecotone areas between the surrounding upland and isolated wetland resulting in the survey of additional upland species. Although these were diverse sites, the dominance results did indicate that the top three dominant species comprised more than fifty percent of the overall coverage. At both Brunswick sites, titi (250 m^2) followed by pond cypress (175 m^2) were the most dominant with fetterbush (26 m^2) also being dominant at the Brunswick L3.1 site and water oak (*Quercus nigra,* 70 m^2) also being dominant at the Brunswick L3.2 site. Fetterbush (62.5 m^2) was by far the most dominant species at the Marion 2A site followed by loblolly pine (12.5 m^2) and broomsedge (*Andropogon* spp.) and Virginia chain fern (*Woodwardia virginiana*) tying for third most dominant (7.5 m^2) at the Marion 2A site. An unidentified *Carex* spp. was the most dominant species at the more open and herbaceous Marion 2B site with a coverage of 295 m^2, other dominant species at this site were red maple (180 m^2) and red bay (44 m^2). Fetter bush (225 m^2) and red maple (200 m^2) were also the most dominant species at the Marion 2C site followed by highbush blueberry (96 m^2).

The results of the Floristic Quality metrics indicate that all of the sites are high quality, although the FQAI scores at Marion 2A and 2B were approximately half the value of the other three sites. In addition there was only about 20% sensitive species coverage at the Marion 2B site. The Marion 2B site did have an unidentified *Carex* spp which was not included in the equation; it is likely the percent tolerant and possibly the FQAI score and percent sensitive metric results would have changed if this *Carex* was identified. Also, none of the 28 *Carex* species that have been assigned C of C scores by the UNC method had a tolerant species C of C score of ≤2; therefore the percent tolerance species would have been lower than 3.7 percent if that *Carex* was included. Additionally, 10 of the 28 *Carex* spp. had a C of C score that was considered sensitive at ≥7, so it is possible the FQAI score could have been higher as well. The Marion 2A site, which is similar to the Marion 2B site, was only surveyed intensively for one module rather than four so the FQAI value and other floristic quality metrics would likely have been different with a larger survey area. FQAI appears to be the best indicator of determining reference status for the L3 sites. These scores indicate that the Brunswick L3.1, L3.2, and Marion 2c sites are reference sites. The Marion 2a and 2b sites appear to be quality sites but FQAI scores indicate they are not reference standard. Marion 2a and 2b did have disturbed ground surface from past logging and a buffer that has had some silvicultural impacts in the last 15 years.

For the wetlands characteristic metrics, the FAQWet results indicate that the Marion 2B and Marion 2C sites have a higher percent of wetland species (OBL and FACW) in comparison to non-wetland species

(FAC and FACU). As noted earlier, the modules at the Brunswick sites overlapped with the edge of the surrounding upland and therefore picked up some upland species like bracken fern (*Pteridium aquilinum*), white oak (*Quercus alba*), and sassafras (*Sassafras albidum*). Additionally, a portion of the surveyed area at the Brunswick sites was standing water with some trees and shrubs but very few herbs, and there was a notable amount of standing water without any vegetation, especially at the Brunswick L3.1 site. Plants that did not have an indicator status were not included in the Relative Percent Wetland Plant Cover and Shrub Cover Metrics. It is very likely the unidentified *Carex* species at the Marion 2B site is a FACW or OBL wetland species since flooding has been observed at this site which would have made the Relative Percent Wetland Plant Cover metric result much higher at the Marion 2B site. The dominant presence of titi and fetterbush (both FACW species) resulted in a high value for wetland shrub cover at both the Brunswick sites. Fetterbush was also dominant at the Marion 2A and Marion 2C sites, but at the Marion 2B site, high bush blueberry, which is FAC, was more dominant than the FACW fetterbush and OBL southern spicebush resulting in the shrub stratum having only 34.6 percent coverage of wetland shrubs.

The functional guild metric results showed that the herb stratum was not highly diverse at any of the sites although the herb coverage was notably higher, 309.8 m^2, at the Marion 2B site because of the presence of 295 m^2 of the *Carex* spp. The Marion 2A site, also a Pond Cypress Savannah/Cypress Savannah, had higher herb coverage than the other three sites at 16.5m^2, but was dominated more with shrubs than the Marion 2A site. Due to the high coverage of the *Carex* spp., the Marion 2B site had a very high coverage for the Relative Percent Cyperaceae, Poaceae, and Juncaceae Cover Metric. Marion 2C, a shady site, with dense vegetative cover, only had 9m^2 of herb cover, of which the shady conditions supported ferns (58.1 percent) and moss (6.5 percent). The Brunswick sites had very low herb cover (<5 percent) which was composed of switch cane in the ecotone and a little Virginia chain fern in the wetland.

For the community structure metrics, the Marion 2C site had the highest surveyed coverage, 686.5 m^2, which was not surprising as this wetland pocosin had a dense shrub and canopy stratum. The Marion 2A site, which had only 114.3 m^2, would still have had the lowest coverage if multiplied by four to be comparable with the other four surveys. Marion 2A was a savannah and did have a very open canopy. The low coverage at the Brunswick L3.1 site, 515.5 m^2, in comparison to the Brunswick L3.2 site, 644.3 m^2, was probably due to the layout of the modules. The 2x4 array of modules that crossed the center of the wetland captured more of the deep water without vegetation at the Brunswick L3.1 site than did the U-shaped plot layout that avoided some of the open water sections and captured more vegetation. The Brunswick sites which had open canopies in the middle were still more diverse than the Marion sites and not surprisingly had more shade tolerant species, even though the Marion 2C site had a denser canopy. There were higher values for the Large Tree Density Metric at the Brunswick sites (0.27 at the Brunswick L3.1 site and 0.12 at the Brunswick L3.2 site) possibly due to the type of tree that was predominant at the Brunswick sites, Pond cypress. Pond cypress have buttressing bases and were often growing on tree islands or small compressed mounds of organic material comprised of old stumps, fallen logs, and organic debris which made getting the exact DBH difficult. Both the Brunswick and Marion sites have mature trees in the canopy, however both have been historically logged. Canopy importance was overrepresented at the Marion 2B site, with 2.3 due to only one module being surveyed. Shade shrubs were an important component of all of the sites as indicated by the Average Importance Shrub metric with scores ranging from 0.17 to 0.35. Standing snags also had an important occurrence, 0.19 to 0.25 at the four sites that had full eight-module vegetation surveys, which indicates the presence of good wildlife habitat.

3.6.5 Amphibian Monitoring Discussion

All four sites that were surveyed for the Level 3 phase of this study are intact isolated wetlands with minimal human disturbance (the presence of old stumps indicates some logging in the past) and appear to be high quality wetland sites (see Section 3.5.1 Site Description). The variable results for the amphibian survey between the Level 3 wetlands are probably related more to specific site conditions associated with the type of wetland than site conditions associated with human impact. Additionally, the survey method, survey effort, and the survey month affected which species were observed and the number of individuals that were counted.

The Brunswick sites, which are very similar ecologically, are lime sinks with year-round standing water that Schafale and Weakley (1990) define as Small Depression Ponds and Nelson (1986) defines as Pond Cypress Ponds. The Marion sites are more different ecologically from each other and from the Brunswick sites. Marion 2B is a Cypress Savannah according to Schafale and Weakley (1990) and a Pond Cypress Savannah according to Nelson (1986), while the shrubbier Marion 2C site is a Small Depression Pocosin according to Schafale and Weakley (1990) and a Pocosin according to Nelson (1986).

Both the Marion sites have ephemeral standing water conditions that provided habitat for amphibians in March 2010 but were completely dry by May 2010. It is likely that some years may provide better conditions for amphibians later in the year during May as standing water has been observed during summer months at the Marion sites. The Marion 2B site also had more and better habitat for amphibians than did the shrubbier Marion 2C site which in March only had enough standing water to allow for approximately half the placement of traps, 15, in comparison to the 32 that were deployed at the other three sites. This is probably why the abundance in March was 27 at the Marion 2B site and only 12 at the Marion 2C site. Also, during the May survey, wind levels made it more difficult to hear calling frogs at both the Marion sites and may have caused the lack of toad (*Bufo* sp.) observations. The year round standing water at the Brunswick sites also provided habitat for the broken striped newts and the lesser siren (both Caudata species) that were not observed at the Marion sites. The Brunswick sites have a closer proximity to other isolated and non-isolated wetlands in the landscape than did the Marion sites which allows for increased migration that likely improved the species richness and abundance at these sites.

The pH level is another notable site condition that could have affected the types of amphibians using these sites. All four wetlands have low pH readings (Brunswick L3.1-3.6, Brunswick L3.2-3.9, Marion 2B-3.7, Marion 2C-3.1), with Marion 2C being the lowest at a pH of 3.1. Many species of amphibians prefer a pH level of 4.5 or higher (Smith and Braswell, 1994). The wetlands in this study were forested wetlands with pine trees and cypress trees that lead to a lower pH than a more open wetland system. This feature would likely explain the absence of salamanders which were also not observed during the NCDWQ 2007 survey of amphibians in basin wetlands in Brunswick County (Savage et al., 2010). None of the more tolerant taxa in regards to pH that were observed in this study are considered listed at the state or federal level.

The survey results were also likely affected by the method used. The time survey yielded the best results overall but was the least quantitative (numbers of calling frogs are estimated) and was not as useful for catching broken striped newts or the lesser siren. The homemade mesh funnel traps resulted in the highest abundance, although this finding may have been due to placement rather than trap type. Many of the mesh traps were placed closer to the edge of the wetland where they were easier to deploy, which might have been better habitat for the broken striped newt. Also, plastic traps were only used in the May survey, due to lack of availability in March, and this type of trap had the least abundance and caught the one lesser siren (which are known to prefer plastic over metal traps; pers. Comm. Jeff Beane 2010). Bait (chicken liver) was used in the May survey traps and may also have helped catch the lesser siren. The coverboards were an ineffective method for this study possibly due to the lack of enough time for them to settle in the ground since there was flooding. Additionally, there were no migrating salamanders observed, which might have utilized the coverboards, going in or out of the wetlands to mate and lay eggs.

The predominance of southern cricket frogs and broken striped newts, both tolerant generalists with C of C scores of “1” and “2” respectively, at the Brunswick sites caused the higher percent tolerance and lower AQAI scores in comparison to the Marion sites. The Brunswick sites have better habitat for amphibians than did the Marion sites with year round fish-free standing water. The March survey resulted in higher abundance of individuals due to the number of southern cricket frogs at the Brunswick L3.1 site than the Brunswick L3.2 site. The only noticeable difference between the Brunswick sites was that Brunswick L3.2 had an abundance of bladderwort (*Utricularia* sp) in the shallower water although this probably did not affect the survey results. Only three species and two individuals in Marion County and 13-14 individuals in Brunswick that must have isolated wetlands for reproduction were heard (the pinewoods tree frog, Cope’s grey tree frog, and little grass frog), resulting in a fairly low IW-EW-SEEP-HW at all four sites.

Isolated predator-free wetlands that are void of pollutants are highly important for the survival and reproduction of numerous species of amphibians (EPA 2002a; Smith et. al. 1994; Willson et al. 2002). The lack of diversity (but not abundance) and the lack of reproductive amphibians that are associated with isolated wetlands in this study were probably not due to the qualities of the wetland sites other than their natural acidity. A more open-canopied site with pH levels above 4.5 and ephemeral standing water conditions that last into June would likely have a more diverse population of amphibians with the presence of terrestrial salamanders and other species often associated with isolated wetlands.

3.6.6. Aquatic Macroinvertebrate Discussion

The four wetlands surveyed for the Level 3 phase of this study are quality intact isolated wetlands that are different ecologically. Similarly to the amphibian survey results, these ecological differences probably caused variable aquatic macroinvertebrate results. One of the notable differences between the Brunswick and Marion sites is the difference in macroinvertebrate abundance. Abundance was more than 10 times as high at the Marion sites than the Brunswick sites. The year-round standing water at the Brunswick sites would suggest better habitat for aquatic macroinvertebrates, and therefore higher abundance levels, but this was not the case. There were slight differences in water quality between the sites in terms of pH and DO levels (Brunswick L3.1 had 3.6 pH and 4.9 mg/L DO, Brunswick L3.2 had 3.9 pH and 5.5 mg/L DO, Marion 2B had 3.7 pH and 6.1 DO, and Marion 2C had 3.1 pH and 6.3 DO). The higher DO levels at the Marion sites would suggest better conditions for aquatic macroinvertebrates.

The Brunswick sites also had a higher abundance of amphibians, including a population of broken striped newts and sirens, likely macroinvertebrate predators that were not present at the Marion sites. Additionally, the Brunswick sites a larger population of Anura species, primarily Southern Cricket Frogs which were also likely predators.

Marion 2B had a higher abundance of aquatic macroinvertebrates than Marion 2C at least in part due to sampling effort. Approximately two times as many funnel traps were deployed at the Marion 2B site in comparison with the Marion 2C site because of the lack of available standing water at the Marion 2C site. The Marion 2B combined funnel trap sample had nearly twice as many macroinvertebrates (66 taxa) as did the Marion 2C combined funnel trap sample (35 taxa). Marion 2B, which had the highest species richness (22) of the three sites also had the highest herbaceous coverage and probably the best microhabitats for macroinvertebrates.

The Marion 2C site, which was very shrubby, had a shorter hydroperiod, and had the least amount of standing water in comparison with the other three sites, had the lowest species richness (12), but also as already noted, did not have the same sampling effort. Additionally, Marion 2C, had the highest percentage of Diptera, primarily mosquito larvae, at 95 percent, which was notably higher than the other three sites (which were less than 25%). Diptera have a short life cycle and do not need a long hydroperiod to survive.

Results for the sensitivity and tolerance metrics indicate that these are low quality sites as evidenced by the high percentage of tolerant species (90.8 and 97.1 at the Marion 2B and 2C sites respectively and 42.9 and 65.5 at the Brunswick L3.1 and L3.2 sites respectively), low percentage of sensitive species (0.4 percent at Marion 2B and zero percent at the other sites), and fairly high biotic index scores which ranged from 7.7 to 9.3. The tolerance scores used in the three indices, derived from Merrit and Cummins (2008), DWQ (Lenat 1993), or a combination thereof, were mainly developed for streams and not wetlands, which typically have more stressful conditions (lower pH and DO) for aquatic macroinvertebrates. This was also indicated by the lack of mollusks at these sites which previous studies at DWQ (Baker et al., 2008; pers. comm. Eaton, 2010) indicate are deterred by the acidic conditions associated with wetlands.

The Brunswick sites, which had lower macroinvertebrate abundance than both of the Marion sites and a lower species richness than the Marion 2B site, did have a higher percentage of predators (Brunswick L3.1 – 38.6 percent, Brunswick L3.2-62.5%, Marion 2B-5.3 percent, Marion 2C – 4.1 percent) compared to the Marion sites. The higher percentage of taxa at the top of the food chain would suggest a healthy system exists in order for these predators to survive and prosper. The very high rate of collector-gatherers, 94.5 percent, at the Marion 2C site was due to the high abundance of *Aedes* sp., a collector-gatherer Diptera, at this site. The lack of year round standing water may have deterred the presence of predators and allowed for a higher percentage of other FFG types at the Marion sites.

The method used to capture the aquatic macroinvertebrates may have had some effect on which taxa, habit-wise, were collected. The sweep method is the most versatile and should have captured burrowers, climbers, sprawlers, and swimmers whereas the trap method was probably best at capturing swimmers (e.g., Coleopteran and Hemiptera taxa) but would have been less adept at capturing burrowers (e.g., Chironomidae).

The lack of abundance of Chironomidae (midges), often associated with wetlands, was surprising and may have been a result of the organic (Brunswick sites) and sandy (Marion sites) nature of the substrate at these sites. A stove-pipe method or Gerking box sampler might have yielded better results for Chironomidae abundance. It is also possible the depth of the samples may have affected the results, both species and abundance. The funnel traps were all deployed near the surface, but some were in as much as three feet of water at the Brunswick sites. The sweep nets were taken in 8-36 inches of water at the Brunswick sites, but most were taken in four inches or less at the Marion sites.

In this study, the variable nature of these wetland sites in regards to hydroperiod, amount of standing water, vegetated microhabitats, DO levels, and the presence of predators (amphibians) potentially affected the results of the composition and abundance of aquatic macroinvertebrates samples. Additionally, the sampling method (depth of sample and fewer funnel traps at the Marion 2C site) may also have had an effect on the results.

Other studies have shown aquatic macroinvertebrates are known to react to stress such as the presence of toxins and are therefore a useful indicator of wetland site quality (EPA 2002b). Aquatic macroinvertebrates have proven to be a useful bioindicator of health of an aquatic system due to their sensitivity to water quality and changes in their environment. While there are many works on using aquatic macroinvertebrates as health indicators in aquatic habitats such as streams, rivers, and lakes the body of work on the equivalent analyses of aquatic macroinvertebrates in wetlands, including isolated wetlands, is considerably less extensive (Rader et al. 2001). Further research to characterize aquatic macroinvertebrate communities in different ecological types of isolated wetlands, both reference standard and poor quality, is really needed fully understand the effect of human impacts on this sensitive community that has such an important role in maintaining a balanced food web and therefore healthy wetland system.

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Assessing Geographically Isolated Wetlands in North and South Carolina – Part 4: Summary, Discussion, and Conclusions

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4. Assessing Geographically Isolated Wetlands in North and South Carolina – Part 4: Summary, Discussion, and Conclusions

It is widely recognized that wetlands can provide significant environmental benefits, including assimilation of pollutants, flood water storage, ground water recharge, carbon sequestration, and fish and wildlife habitat, and that they are threatened with degradation and loss by various stressors including conversion to agriculture and silviculture as well as pressures from encroaching urban and suburban development. Geographically isolated wetlands (IWs) can provide the same benefits as wetlands in general and are particularly vulnerable to loss and degradation because they are geographically isolated and have varying amounts of regulatory protection.

Isolated wetlands have long been and continue to be a familiar part of the natural landscape of the North and South Carolina coastal plain. These ecosystems are made up of a variety of different wetland types of varying sizes and other ecological characteristics. The Southeastern Isolated Wetland Assessment (SEIWA) was conducted to develop a better understanding of this resource along with ways to further advance that understanding with science. The results of science can be used to inform policy makers in North and South Carolina about protection and management approaches for this type of wetland. The detailed results of the GIS-based mapping exercise (Part 1, Level 1 analysis), the statistically based random field evaluation and data collection (Part 2, Level 2 analysis) and the intensive, field evaluation (Part 3, Level 3 analysis) were presented earlier. This section of the report summarizes the results of these investigations and describes their possible relevance to management issues in North and South Carolina.

The southeast coastal plain has many types of IWs. Forested depression IWs present particular challenges for resource managers because they occur in large numbers, especially on the outer coastal plain. Forested depression IWs occur in hydrologic sinks in low spots of the landscape, have small watersheds, and are hydrologically isolated from surface flows. They may be seasonally or permanently ponded, depending on local conditions. Typically there is a shallow groundwater connection to other wetlands and streams and these wetlands can be sinks for nutrients; thus, alterations (e.g., ditching and drainage, silviculture) can have negative effects on downstream water quality (e.g., Amatya et al., 1998). With respect to drainage of natural wetlands, Riggs et al. (2005) provides a review of how historical drainage has impacted the wetland hydrology and water quality of the Waccamaw River basin (in the center of our study area), and Blann et al. (2009) provide an overview of drainage impacts on ecological systems, including “direct loss of habitat for wetland-dependent species, significant alteration of biogeochemical and hydrologic cycles, loss of flood storage and water quality functions of wetlands, and elimination of nutrient and sediment sinks and other buffering capacities of wetlands in relation to adjacent upland and riparian ecosystems”. Adjacent land management has important implications for the diversity and richness of sensitive taxa such as salamanders and frogs (Russell et al., 2002a; Russell et al., 2002b) and can have measurable effects on hydrology even in rural settings (Sun et al., 2000). Isolated forested depressions are frequently small (Tiner et al., 2002; and this study – Part 2, Level 2 report), making them difficult to detect and inventory, as mentioned above. Problems with detection and less scientific attention focused on these problems contribute to greater vulnerability to degradation and destruction through human activities in the wetland or on surrounding lands, and have led to inconsistent resource protection strategies for IWs in both natural resource management and regulatory agencies.

Recent reviews of the functioning of IWs, including those on the U.S. southeastern coastal plain, articulate a clear need for additional research to increase our understanding of these wetlands (e.g., Kirkman et al., 1999; Leibowitz, 2003). In other words, in spite of their vulnerability and potential importance, significant gaps in our understanding of key aspects of IW occurrence and ecological benefits make it difficult to manage IWs in both landscape and regulatory contexts (Leibowitz and Nadeau, 2003). This need is particularly urgent in the context of the rapid development and human migration that is transforming the coastal areas of North and South Carolina. SEIWA was designed and implemented to meet these needs by (1) developing, testing, and documenting methods that can be used to assess IW occurrence and ecological significance and (2) applying these methods to characterize IWs along the North and South Carolina coast.

4.1 SEIWA Project Summary

SEIWA developed and applied geographic information system (GIS) and field assessment methods in a probabilistic framework to identify and assess IWs in an eight-county study area in the coastal plain along the North and South Carolina coast (**Figure 4-1**). SEIWA employed a three-phase approach (**Figure 4-2**) that followed the three levels of wetland assessments recently described by the U.S. Environmental Protection Agency (U.S. EPA, 2006a). In the Level 1 phase, we developed a GIS mapping tool that used existing geospatial and remote sensing imagery to identify a population of candidate IW polygons in the study area and characterize this population in terms of likelihood to be IWs. Level 1 also used GIS data on historical extent of wetlands and IWs in the study area to estimate changes in wetland and IW extent over time.

In the Level 2 phase of the SEIWA project, we conducted field visits to randomly selected candidate IWs to determine if they were IWs and if so, collect information on their type, size, condition, and level of relative hydrologic, water quality, and habitat function. In addition to assessing the accuracy of the Level 1 method, the random selection of sites for Level 2 assessments enabled us to extend these results to all IWs in the study area. Finally, Level 3 detailed assessments were conducted on two clustered IWs to measure their hydrologic and water quality functions, including pollutant absorption capacity and

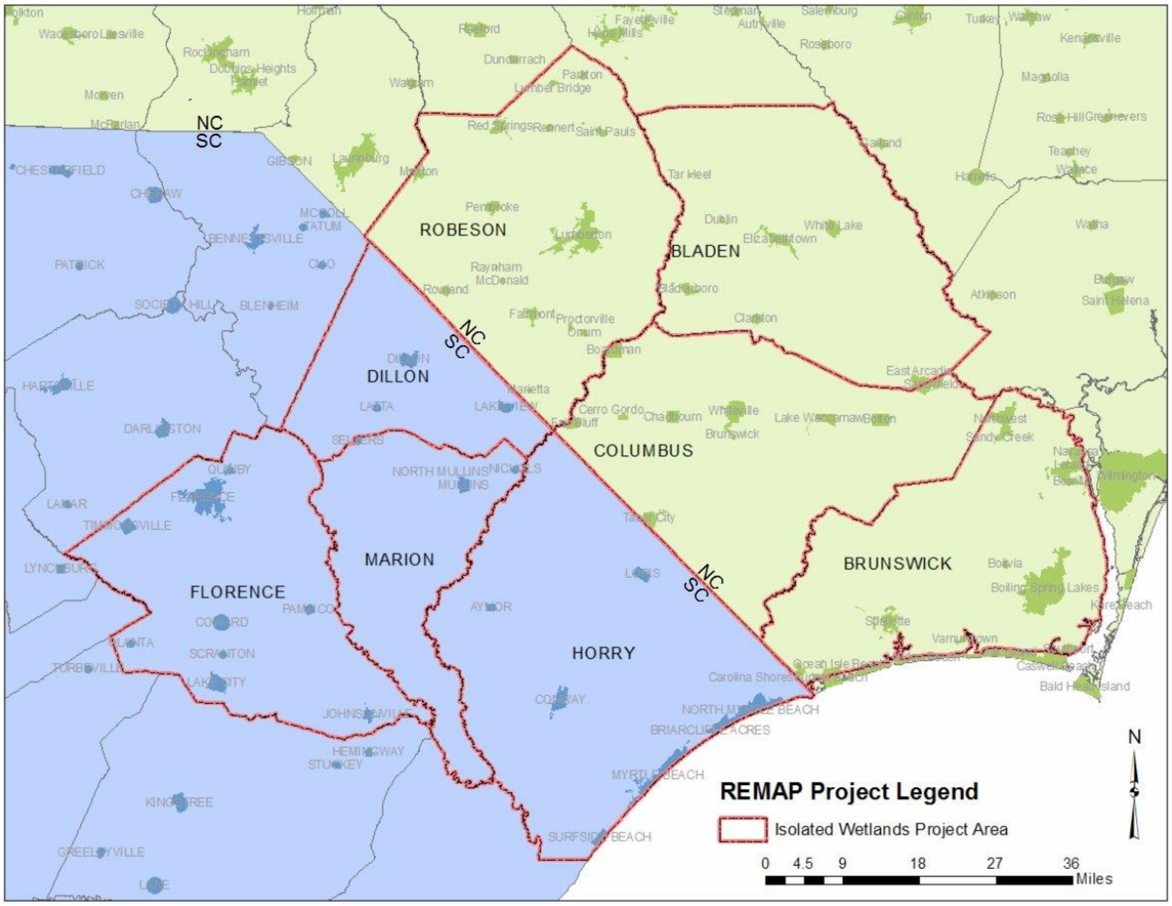

Figure 4-1. SEIWA study area, showing eight selected counties and population centers.

Level 1: Landscape Assessment

- Collect existing geospatial data and identify definitional criteria.
- Develop predictive mapping tool.
- Define sampling unit and construct sample frame for predictive mapping tool.

Level 2: Ground-truthing & Rapid Assessment

- Develop sampling design and randomly select sample sites
- Conduct site visits to determine accuracy of mapping tool (isolated. not isolated and why, historical isolation status).
- Evaluate the wetland's relative functioning and condition with rapid assessments (NCWAM and ORAM).
- Collect soil samples
- Evaluate the storage capacity and average and maximum depth

Level 3: Intensive Assessment

- Conduct quantitative field sampling to determine pollution absorption capacity and hydrological connectivity of clusters of isolated wetlands in the landscape.
- Characterize amphibians, aquatic macroinvertebrates and plant communities of typical examples of isolated wetlands in the study area

Figure 4-2. Three level SEIWA assessment methodology.

hydrologic connectivity, as well as the abundance of amphibians, macroinvertebrates, and plants that the IWs support. This information is a start towards quantifying the cumulative hydrologic effects of IW clusters as well as the broader ecological benefits of these systems.

4.2 SEIWA Methods

SEIWA developed and used geographic information system (GIS) mapping tools and probability based estimators to determine the number, size, spatial extent, and ecological characteristics of IWs in the eight-county study area. The Level 1, Level 2, and Level 3 wetland assessment methods developed were documented in Parts 1, 2, and 3 of this report, along with the overall results from each phase of the assessment. The methods assembled and used in this study can be applied in other areas of the southeastern coastal plain, or, because they use readily available spatial data and are based on established methods, they can be adapted for use in other areas around the country.

4.2.1 Level 1 GIS Methods

The Level 1 GIS methods developed for SEIWA drew on information from earlier studies as well as the expert knowledge on the study team about local conditions and criteria necessary to map the likelihood of geographically IWs in the project area. Because IWs in the portions of the southeast coastal plain examined during this project are almost always low spots in the landscape with no surface water connectivity, SEIWA employed available ground elevation data (LiDAR and hypsography) to identify topographic “sink” polygons as the candidate IW study population.

Sources of readily-available geospatial information (GIS layers for wetlands, soils, land cover, hydrography, floodplains, habitat, and infrared imagery) were then used to characterize the physical, hydrologic, and biological criteria that could be used to score the likelihood that a candidate IW polygon could be an IW[1]. A statistical sample was then taken of these polygons to identify a subset for field investigations to (1) determine the accuracy of the Level 1 method and (2) characterize the IW population using Level 2 methods.

4.2.1.1 Accuracy and Use of the Level 1 Assessment Method

Field verification of the Level 1 method found that 69% of the polygons predicted as IW by the GIS model in the study area were wetlands but only 22% were IWs. For NC, 55% of the polygons predicted as IWs by the GIS model were wetlands and 35% were IWs. For SC, 80% of the polygons predicted as IWs by the GIS model were wetlands but only 13% were wetlands. The significantly lower IW success rates for SC may reflect the lower resolution topographic data used for three of the four SC counties (as described below) combined with the small size of the IWs. The GIS method was better at identifying non-isolated wetlands, with the candidate IW polygons with medium and low likelihood of being IWs being non-IWs 75% of the time for the study area and 75% and 69% of the time for NC and SC.

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[1] This data layer, including the likelihood scores by polygon, can be obtained as a shape file from the study authors or can be viewed in the map viewer by logging in at http://sewwg.rti.org.

The main reason for the overall low rate of prediction of being an isolated wetland was the numerous, small ditches found in the field which connected these sites to downstream waters. These small ditches (often a foot or two deep) cannot be found on any available map and, because of their small size, do not show up always in the LiDAR data. Many of these ditches were constructed decades ago, are not depicted on current USGS topographic mapping or other maps, and are not maintained. However, their mere presence is enough to cause the wetlands connected by these ditches to be classified as connected wetlands that are subject to Clean Water Act jurisdiction rather than isolated wetlands that are not generally considered jurisdictional[2]. Any attempt to produce a more accurate map of isolated wetlands must address these small ditches by including a field mapping component to accurately estimate the extent of isolated wetlands in a particular landscape and to determine whether or not these features are connected through ditching.

4.2.1.2 LiDAR versus non-LiDAR Data

The high-resolution (4 to 5 m) LiDAR elevation data used to develop the initial topographic sinks for the candidate IW polygons using the Level 1 GIS model were only available for the four NC counties and Horry County in the SEIWA study area. For the remaining counties (Dillon, Florence, and Marion in SC), the sinks were derived using 30m topographic data from the USGS. As shown in Table 4-1 the number of candidate IW polygons generated varied greatly according to the elevation data used. Candidate IW polygons derived from the 4m to 5m resolution LiDAR data in NC and Horry County, SC, were much more numerous than those derived from the 30m USGS elevation data used in the non-LiDAR counties, with over an order of magnitude difference on a per square mile basis. The non-LiDAR and LiDAR counties also differed in mean individual IW area, with the non-LiDAR data producing on average larger IWs.

Table 4-1. Comparison of Isolated Wetland Counts and Areas for LiDAR and Non-LiDAR Counties

Parameter	Non-LiDAR Counties[1]	LiDAR Counties[2]
Area (mi^2)	1,694	4,749
Number of candidate IW polygons	6,552	208,967
Candidate IW polygons/mi^2	3.9	44
Number of IWs	1,806	32,507
IWs/mi^2	1.1	6.8
Mean IW size (acres)	2.4	0.68
Total IW acreage	4,373	22,111
IW acreage/mi^2	2.6	4.7

[1] Dillon, Florence, and Marion counties (SC)
[2] Bladen, Brunswick, Columbus, and Robeson counties (NC); Horry County (SC)

This elevation resolution discrepancy is perhaps the greatest source of potential bias in the Level 1 portion of the study and divides the study population of candidate IW polygons into two distinct

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[2] Note that new federal guidance is pending.

domains: LiDAR and non-LiDAR counties. It is clear from these results that any attempt to map isolated wetlands should use the most detailed elevation data available and should include the use of LiDAR data rather than the simple hypsography data derived from USGS topographic mapping.

4.2.1.3 Applicability of Level 1 Methods to Other Studies

The Level 2 field results suggest that while the SEIWA Level 1 method has a fairly good accuracy rate for identifying wetlands that might be isolated, even the high resolution LiDAR data had trouble identifying the small ditches and other drainage structures that can connect an isolated wetland to downstream navigable waters. This situation caused a high false positive rate for identifying actual IWs. Overall, the low true positive and high false positive rates indicate that Level 1 methods applied in this study require field verification on a random selection of sites to be useful in evaluating the extent and characteristics an IW resource. The higher precision for the true negative rates show that the GIS method is best at identifying the proportions of the sink polygons that are not isolated wetlands. The results also suggest that although mapping techniques can be useful in a regional context to help predict various attributes of isolated wetlands, the relatively low accuracy rate precludes their use on a site by site or property by property basis except as a tool to guide field investigative efforts to areas where IWs are more likely to be present. As discussed in Section 4.4, the candidate IW polygon GIS layer produced in this project, including individual scores of IW likelihood, provide a good starting point for finding IWs in any area of concern in the 8-county study area, and can be used other available data such as land cover and aerial photographs to assist with IW protection, restoration, and management.

Comparison of feature count and area results for the non-LiDAR and LiDAR counties in the study area showed that the lower resolution elevation data used for the non-LiDAR counties resulted in a significant undercount in the number of candidate IW polygons and IWs, an overestimate of individual IW acreage, and an underestimate in the total acreage of IWs. These results show that high resolution (4 to 5 m) LiDAR data is essential for accurate Level 1 identification of IWs in the southeast coastal plain. For the purposes of this study, the average feature or area per square mile in the LiDAR counties was used to adjust the estimates discussed below for number and total acreage of IWs in the non-LiDAR counties. However, this should be recognized as an uncertainty in the study results.

4.2.2 Statistical Methods

SEIWA probability based estimators and the Level 2 field results were used to determine the accuracy of the Level 1 GIS methods and to determine number, spatial extent, and ecological characteristics of IWs in the eight-county study area. The statistical estimates included uncertainty as standard error of each estimate. To ensure an even spatial coverage across the study area, the probability-based sample was stratified by county and 14-digit hydrologic unit (HUC). Results were totaled by state, by geologic unit, and for the overall study area as sample size was not adequate to extend the study results to some counties or to the HUC level.

The application of stratified random sampling techniques and field investigations to IWs in the SE coastal plain in this study demonstrate the power of these methods in extending field results from a relatively small number of sites (47 IWs in Level 2) to a much larger study population across a broad region (i.e., thousands of IWs across the NC/SC southeast coastal plain). Similar statistically based research methods can be used elsewhere in the country to analyze the occurrence, significance, and characteristics of geographically-isolated wetlands or other geographically dispersed ecological features of interest.

4.2.3 Level 2 Field Methods

The Level 2 methods employed in this study included characterization of the features according to state-level natural heritage classification systems, basic field measurements of size (area, depth, and volume), soil analyses, observations of vegetation class and structure, and rapid assessment methods for wetland condition (the Ohio Rapid Assessment Method, ORAM) and relative functioning (the North Carolina Wetland Assessment Method, NC WAM). The use of these quick methods (generally 4 to 8 hours for two staff members per site) in the context of a probability based survey demonstrate the applicability of such methods in providing useful information on numerous, broadly distributed features like isolated wetlands across the southeast coastal plain landscape.

4.2.3 Level 3 Field Methods

Although the Level 3 methods were only applied to two clusters of isolated wetlands in North and South Carolina, they serve as a compilation of the detailed, intensive methods that can be used to fully characterize an isolated wetland resource in terms of ecological functions and benefits – habitat, hydrology, water quality, and pollutant adsorption capacity. Follow-up studies on the same sites established during this study will continue to provide valuable detailed information on how these features interact in the surrounding landscape to provide ecological benefits. With quantification of their societal values, these benefits can be used as a basis for determining the ecological services of isolated wetlands in the southeast coastal plain.

4.3 SEIWA Results and Discussion

During the latter phases of the project, the project team and EPA project officer conferred to review the project objectives established in the project quality assurance project plan and adjust them in accordance with the project findings. The project results are discussed below in the context of each project objective.

4.3.1 Number and Spatial Extent of Isolated Wetlands in the SEIWA Study Area

The number of isolated wetlands identified in the study area was determined based on the mapped potential isolated wetlands corrected by field evaluations of randomly selected sites. The randomly chosen sites were (in general) readily accessible mainly due to the large number of smaller forestry roads across our study area that are accessible with four-wheel drive vehicles. Overall, 93% of the randomly chosen sites were accessible and only 7% were inaccessible and required use of an alternative, randomly chosen site for evaluation. As noted above, the availability (or lack thereof) of LiDAR data makes an important difference in these estimates, and IW counts and areas are adjusted to compensate for the non-LiDAR bias.

Five types of wetlands made up over 94% of the field-evaluated sites (small depression ponds [30%], wet pine flatwoods [24%], non-riverine wet hardwood forest [19%], small depression pocosins [14%] and non-riverine swamp forest [7%]) in North Carolina. In South Carolina, four types of wetlands made up 93% of the field-evaluted sites (pond cypress ponds [23%], pine flatwoods [19%], non-alluvial swamp forest [21%] and pocosins [8%]). Overall most isolated wetlands in our study area are small, forested depressions in the fairly level marine terraces that make up the southeastern coastal plain.

Our study area contained a large number of isolated wetlands widely spread across the landscape. Because the lack of LiDAR data in three of the South Carolina counties resulted in a serious underestimation of their true extent, we extended the IW density estimates from LiDAR counties to the non-LiDAR counties to estimate that there are 22,000 isolated wetlands in the South Carolina portion of our study area and 30,000 isolated wetlands in the North Carolina portion of our study area. Overall, the study area contained about 52,000 isolated wetlands at an average density of 8.1 isolated wetlands per square mile and a total area of 30,000 acres. Based on this estimate, isolated wetlands appear to be quite common in the southeastern coastal plain.

Isolated wetlands are generally small with a mean size of 0.77 acres and median size of 0.41 acres in the study area. They range in size from 0.002 acres to 21 acres. Large isolated wetlands appear to be rare because as size increases, it becomes more likely that the wetland will be connected to downstream waters through ditching or overland runoff to adjacent streams. In addition, there appears to be a real difference between coastal counties (Brunswick in North Carolina and Horry in South Carolina) versus non-coastal counties with respect to size; the coastal counties had a mean size of 0.38 acres and the non-coastal counties had a mean size of 1.5 acres using the LiDAR data.

In general, isolated wetlands make up a very small percentage of the overall wetlands in our study area, making up about 1.9% of the total wetland area. This number coincides with the percentage of wetland permits or certifications issued by the NC Division of Water Quality that are for impacts to isolated wetlands. Therefore we believe that this is an accurate estimate of the percentage of wetlands that are isolated in our study area.

4.3.2 Past Wetland Loss and Development Pressure

The percent loss of wetlands, defined as the mapped extent of all types of wetlands (isolated or connected) to the original extent of wetlands as estimated from hydric soil maps, varied across our study area. Overall about 9.2% of the original wetlands had been converted to another land use or land cover by the mid-1980's. This loss rate was highest in the most urban county (Horry County, SC) where the loss rate was about 20%. The other county with a high loss rate (Robeson County, NC at 16.3%) was primarily due to agricultural impact. These results can be transferred to IWs by assuming that the amount of loss of isolated wetlands is commensurate with the amount of loss of all wetland types.

A more detailed analysis of the loss rate of isolated wetlands was done for two counties (Horry, SC, and Brunswick, NC) where more detailed land cover data were available to compare 1992 to 2001 IW extent using the same mapping protocols developed for the large study. Loss rates of isolated wetlands were estimated at 2% annually from Brunswick County during this timeframe and at 0.5% per year in Horry County. Most of the change in Brunswick County was attributed to clearing of forest land for agriculture. However the acreage of agricultural land has not changed that much in Brunswick County so some of this agricultural impact may be isolated wetlands in areas cut-over for timber harvesting that were mapped as agricultural conversion in the 1992 to 2001 land cover change data. In any event, it is clear that pressures from agriculture, silviculture, and urban/resort development on isolated wetlands continue in these two rapidly growing counties.

4.3.3 Type and Occurrence of Isolated Wetlands in the SEIWA Study Area

The study area landscape is defined by a series of marine terraces formed from sediments laid down during past high stands of sea levels which increase in age and elevation away from the coast and towards the northwest. These flat terraces are dissected by stream valleys that were cut during lower sea levels (glacial maxima) and then filled with alluvium and marine sediments during the next period of sea level rise. The isolated wetlands we sampled and studied occur almost exclusively as depressions on these terrace surfaces and are vegetated with forest vegetation similar to other wetlands in the study area.

The SEIWA wetland vegetation and habitats are described by the wetland types defined by eight NC Third Approximation (NC) types and nine SC Natural Community types, which were assigned to each IW visited during the Level 2 field work. The NC and SC isolated wetland types can be grouped in three broad categories that comprise 99% of the IWs in the study area - forested flats (50%), forested ponds and pools (33%), and small pocosins (16%).

4.3.4 Environmental Significance of Isolated Wetlands in the SEIWA Study Area

The ecological condition and relative functions provided by IWs in the study area were assessed by the ORAM and NC WAM rapid assessment methods, respectively. Overall, the isolated wetlands in our study area are in fair to good ecological condition. About 98% of the isolated wetlands score in the top two thirds of the potential ORAM score. Also, the NC WAM assessments indicated that isolated wetlands tend to function at rates that are typical of other wetlands in the region that are in comparable condition.

4.3.4.1 Wetland Habitats and Flora

As described above, about 50% of the isolated wetlands in our study area were forested flats (mainly pine flatwoods), with 33% being forested ponds (mainly small depression ponds) and another 16% being small pocosins. The wet pine flatwoods were dominated by loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). The small depression ponds were more open communities and dominated by pond cypress (*Taxodium ascendens*), swamp tupelo (*Nyssa biflora*), sweet gum and red maple. The small depression pocosins had a fairly open canopy composed of loblolly pine, red maple and sweet bay (*Magnolia virginiana*). The pocosin community type generally had a very dense shrub layer made up of several species.

4.3.4.2 Wetland Soils

When the upland and wetland soils at our study sites were compared in the Level 2 study, there were a few significant differences. Soils in the wetlands were hydric and mainly consist of loams (40%), sands (33%), and muck (24%). In contrast, the upland soils adjacent to the wetlands were mostly loams (75%) and sands (21%). When the mucky sands and mucky sandy clay loams are added to the muck soils, this raises the percentage of soils with a dominant amount of muck to 43%. This pattern is consistent with our understanding that the longer hydroperiods would result in more mucky soils in the wetland sites.

In general, the wetland soils were acidic (mean pH of 4) but did not show pH differences between upland and wetland soils except for Florence County, where wetland soils were more acidic ($p = 0.001$[3]). For other soil parameters, only potassium and manganese showed significant differences between wetland and uplands. When evaluating these results, we noted that Columbus County showed significant upland to wetland differences for 10 of the 17 soil parameters measured, but in the opposite direction than would be expected from wetland science or from the results observed for the other counties. For example, although the mean loss on ignition (soil organic matter) estimates were 11 (SE 4.6) for wetland soils and 3.9 (SE 0.87) for upland soils, and statistically significant differences were observed for Florence ($p = 0.01$) and Horry ($p = 0.02$) counties, the difference across the study area was not statistically significant ($p = 0.12$), which could be due to the influence of the opposite significant trend observed in the Columbus County samples ($p = 0.001$). The SEIWA team is evaluating these discrepancies and the Columbus soil data to resolve this reverse trend.

In terms of the other counties and soil parameters, wetland soils were significantly higher than upland soils for humic matter (Horry County), cation exchange capacity (Bladen, Brunswick, Horry), exchangeable acidity (Bladen, Florence, Horry), sodium (Bladen, Horry), calcium (Robeson), magnesium (Robeson), nitrogen (Bladen, Robeson), phosphorous (Bladen, Marion, Horry), and zinc (Bladen). Wetland soils were lower than upland soils for dry bulk density (Bladen, Florence, Horry) and base saturation (Bladen). Though not consistent throughout the study area, these observations suggest that study area isolated wetland soils tend to be acidic and have higher organic matter, higher nutrients, and a higher capacity for nutrient and metal adsorption than corresponding upland soils. This is consistent with Level 3 work on phosphorous storage potential, which showed a higher PSI in wetland versus upland soils, and nitrate/nitrite, phosphate, and dissolved oxygen increases in groundwater as one moves away from the Level 3 IWs.

Significant amounts of organic matter are stored in the soils of these isolated wetlands. We estimate that the isolated wetlands in our study area store about 5.2 million metric tons of carbon. Based on the total IW acreage of 30,000 estimated in this project, IWs in the study area contain, on average, over 190 tons of soil carbon per acre. This is slightly above the upper end of the range of soil carbon content for natural wetlands of 175 tons per acre reported by Neely (2008) for North Carolina wetlands, well above the range (58 – 89 tons per acre) for wetland soils (gleysols) reported by Bridgham et al. (2006), and well below the typical value for peatlands (670 tons per acre for histosols) used in Bridgham et al. (2006).

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[3] Note that p-values < 0.05 are indicate significant differences in this study.

Finally most of the cation exchange capacity of the isolated wetland soils is associated with this organic matter rather than clay, which has implications for the pollutant removal ability of these wetlands.

4.3.4.3 Wetland Hydrology and Water Quality

The hydrologic system in the study area is a groundwater dominated system; because of the flat terrain and permeable (sandy) soil, surface water and groundwater are linked. For example, up to 62 percent of the flow in the Waccamaw River is from groundwater seepage (Harden et al., 2003), and Pyzoha et al. (2008) observed strong connections between surface water and shallow groundwater in a Carolina Bay wetland in the coastal plain of SC. SSURGO Soil descriptions for the hydric soils that are characteristic of IWs in the study area indicate that hydric soils are formed when the water table rises and stays near the surface during the wet months of the year. In other words, the isolated wetlands we studied in this project are filled by rainfall falling directly on the wetlands, runoff from the small surrounding watershed, and by water that infiltrates the surrounding land, raises the water table across the landscape, and wets the depressional wetlands from below.

In our Level 3 study sites we located transects of groundwater monitoring wells within and between wetlands and the nearest downgradient waterbody to measure and quantify this interconnectivity for two clusters of isolated wetlands in Brunswick (NC) and Marion (SC) counties. Long term monitoring will continue over the next several years through follow-up EPA grants, but preliminary results tend to confirm our hypothesis of the connected nature of these isolated wetlands through the shallow groundwater aquifers. From these preliminary data, the following conclusions can be made.

First, these wetlands appear to be perched water tables on top of clay or sandy clay lenses, similar to the Carolina Bay wetland studied by Pyzoha et al. (2008). This situation appears to constrain downward movement of water to deeper aquifers and may serve to retain water in the wetland during droughts or dry periods of the year (mainly the growing season). Second, the water levels in the wetlands respond quickly to significant local precipitation events. Third, there appears to be the potential for connectivity and groundwater movement between the isolated wetlands and the adjacent connected wetland at the Brunswick County site. In contrast at the Marion County site, any groundwater movement from the isolated wetlands to downstream waters appears to occur only during limited hydrologic conditions. Additional monitoring and simulation modeling will be pursued through the follow-up EPA grant to examine more precisely the connectivity of these isolated wetlands to connected wetlands and streams.

Preliminary water chemistry analyses have been conducted from the well transects in the isolated wetland clusters in Brunswick and Marion County, with four samples being taken from different seasons and analyzed for a variety of chemical constituents. As with the hydrology data, more work is planned to verify and extend these water quality results. Based on these preliminary data, pH levels are quite low in these wetlands (3.08 to 4.46) and the Marion sites appeared to have lower pH values than the Brunswick County sites. Levels of dissolved oxygen and nutrients (phosphorus and nitrogen compounds) are also generally low within the IWs, but increase in groundwater moving away from the IW. As expected, temperature showed an annual trend but the other constituents did not appear to have any annual trends associated with them.

4.3.4.4 Wetland Soil Phosphorous Adsorption Capacity

The phosphorus adsorption capacity of these isolated wetlands was estimated using a phosphorus adsorption index (PSI) from the soil samples collected in the Level 3 part of the study. PSI is a dimensionless index that rank soils based on their ability to adsorb and immobilize phosphorus. Overall the PSI was much higher in the wetland (median value of 16.0) than in the upland (median value of 5.5). Therefore it appears that these isolated wetlands have higher potential than the surrounding uplands to immobilize phosphorus introduced into the wetland via surface water. There was also a strong, positive correlation between PSI and aluminum concentrations in the soil which is a common occurrence in soil analyses, as well as an apparent increase in groundwater phosphorous levels as one moves away from the IW.

4.3.4.5 Wetland Habitat

The intensively studied isolated wetlands in the Level 3 part of this work generally had plant communities that were of high quality with 48 species of plants identified, including a federally endangered species, southern pond spicebush (*Lindera melissifolia*), found at one Marion County site. By comparing FQAI scores to a known natural heritage site we determined that the Brunsick L3.1, Brunswick L3.2, and Marion 2c sites are of reference quality. The Marion 2a and 2b sites, are high quality, but are not at the reference standard level. The two Brunswick County sites can be characterized as small depression ponds and two of the three Marion County sites are characterized as pond cypress savannahs; the other Marion County site was a pocosin. Detailed data were collected on the plant communities on these sites and various indices developed to describe the condition of the plant communities. In general, these indices confirm the fact that these communities are in good to excellent ecological condition and can be viewed as reference communities.

The amphibian communities of these five intensively studied sites were characterized by 12 different taxa mainly composed of nine species of frogs with no salamander species collected. In general, the Brunswick County sites had more amphibians than the Marion County sites. Most likely, the low diversity of species was probably due to the low pH (less than 4.0) of the water in these wetlands rather than anthropogenic disturbance.

With respect to aquatic macroinvertebrates, the intensively studied wetlands are high quality ecosystems. Most of the species found in these sites were tolerant of stressful conditions which are common in low pH and low DO systems. However, since these wetlands appear to be of reference quality, it can be concluded that this aquatic community is probably typical for isolated wetlands in good ecological condition in the study area.

4.4 Considerations for Wetland Protection and Management

Protection and management of isolated wetlands can be informed by the results produced by this collaborative research project. For example, the two states of North and South Carolina that encompass the project study area have each considered regulatory strategies for protecting isolated wetlands. North Carolina proceeded in 2006 to adopt statewide regulations for isolated wetlands. These regulations generally afford the same level of protection to isolated wetlands as to other wetlands of the State. Exemptions within the regulation focus on the size of the isolated wetland. For example, isolated wetlands that are less than 1/3 acre in size or 1/10 acre in size, east and west of Interstate Highway I-95 respectively, are exempt from permitting, so no permit review is required to impact isolated wetlands less than these sizes. Also, the requirement for the compensatory wetland mitigation of impacts to isolated wetlands is required only for impacts of greater than one acre of isolated wetland, which is higher than the general US Army Corps of Engineers threshold for non-isolated wetland mitigation.

South Carolina regulates isolated wetlands only in the coastal counties under the State's Coastal Zone Management Program. The regulation of isolated wetlands in the coastal counties was affirmed by a 2010 State Supreme Court ruling. In addition, legislation has been proposed within the South Carolina Legislature in recent years to expand the scope of protection of isolated wetlands to all parts of the State. A provision noted in the proposed legislation is to generally exempt isolated wetlands that are less than one acre in size (Heather Preston, SC DHSC, personal communication, January 6, 2011).

4.4.1 Utility of Study Results

The results of this research project may be used to help inform review of North Carolina's current regulations and South Carolina's consideration of possible future protection and conservation strategies. For example, both States consider the size of an isolated wetland as a key factor in making a determination about the level of protection given or that could be granted to this type of aquatic resource. Research results provide policy analysts and program managers with a new understanding of the size distribution and overall abundance of isolated wetlands in the Coastal Plain Region. For example, results show that most isolated wetlands are below the size thresholds for protection in use in each state, suggesting that the operable 1/3 acre threshold in NC could eliminate review about 46% of the isolated wetlands in the study area. Similarly, NC's one-acre impact threshold for mitigation could exempt about 93% of isolated wetlands

from mitigation requirements, while SC's policy trend to generally exempt isolated wetlands less than an acre to regulation would apply to over 90% of the isolated wetlands in our study area.

Results also provide information about the range in ecological conditions of isolated wetlands and the relative benefits that they provide within their environmental setting. Those benefits can include (1) storage of surface water, (2) storage of carbon, 3) capacity for nutrient storage and processing and (4) the conservation of bioversity, including plant and amphibian communities.

In addition, research results begin to point toward the additional benefit from isolated wetlands to buffer the hydrologic regime of a local catchment area. Isolated wetlands in the Coastal Plain Region may function to slow the downward percolation of water during drying periods and buffer stormwater flow during large rain events. Since stream flow in the region relies on groundwater, especially during dry periods, the occurrence of isolated wetlands may help mitigate the affect of stormwater in urbanizing areas. For example, streams may become less "flashy" because some isolated wetlands have the capacity to hold water across the landscape and release it slowly to surficial aquifers. In terms of “green-infrastucture,” isolated wetlands might be viewed as rain gardens or serve as other forms of best management practices used to control stormwater. As more Level 3 data are collected, they can be analyzed as to whether or not the functions of isolated wetlands are consistent with this particular water quality management scenario. If so, then future research results could provide the scientific information needed to develop protection strategies for isolated wetlands that integrate wetland regulation, water quality management and incentive-based wildlife conservation.

4.4.2 Utility of Study Methods

The methods used in this study to measure a wetland’s ecological conditions can be used by wetland regulators to assess wetlands to assist in their protection and day-to-day management. For example, forested wetlands have been considered for use in storm water and treated wastewater disposal in both North and South Carolina. In North Carolina, existing rules allow the use of natural wetlands for stormwater and wastewater assimilation (15A NCAC 2B .0201 (f)[4]). In addition, newly enacted rules in NC (15A NCAC 2U .1101 [Wetlands Augmentation rules]) provide explicit encouragement for the use of natural wetlands for wastewater assimilation with provisions for monitoring to make certain that wetland uses are not impacted. The PSI applied in Level 3 of this study can provide a relative measure of wetland phosphorous assimilation capacity to rank wetlands as to their treatment capacity, assess the likelihood that a particular wetland may be able to serve in this regard, or monitor impacts after implementation.

Finally, the candidate IW polygon layer produced in the Level 1 portion of this project also can be a resource to assist wetland managers in finding features that are likely to be wetlands, and possibly isolated wetlands. This data layer, which includes metadata on each polygon’s IW likelihood scores, is available as a shape file to wetland managers and has been posted for in a map viewer on the Southeast Wetlands Workgroup (SEWWG) website (http://sewwg.rti.org). The SEWWG map viewer allows users to visit the candidate IW polygons in the 8 county study area and view them against NLCD land cover for 1992 and 2001, land cover change from 1986 - 2009, soils, NC CREWS wetlands, NHD hydrography and catchments, and high resolution aerial photography from ESRI. This site (or the independent SEIWA GIS coverages) will enable wetland regulators and managers to review a particular area or watershed of interest see where IWs may be located and what sort of development pressures are they under, both currently and in the past. Some ideas for regulators and other wetland managers to consider for using the SEIWA isolated wetland GIS coverages:

- Any candidate IW polygon on the map can be considered to have around a 7 in 10 probability of being a wetland, or a 2 in 10 probability of being isolated, although individual likelihood scores as well as observations of surrounding land use can increase (or decrease) these probabilities.

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[4] http://ncrules.state.nc.us/ncac/title%2015a%20-%20environment%20and%20natural%20resources/chapter%2002%20-%20environmental%20management/subchapter%20b/15a%20ncac%2002b%20.0201.html

- As depressions in the landscape, candidate IW polygons that are obviously no longer wetlands or poor quality, impacted wetlands (i.e., those in highly developed areas) could be considered good restoration or mitigation candidates, especially those with hydric soils (indicating features that were once wetlands). Presently in NC, impacts to isolated wetlands do not require replacement with isolated wetlands (Ian McMillian, NC DWQ, personal communication, January 5, 2011). If the state decides to make that a requirement, then these maps will be a valuable tool to that end.

- As shown in Table 2-5 and Appendix 2A (Part 2), the Level 2 IW sites were predominantly (over 95%) forested, and at least partially surrounded by forest (about 93%). Almost 40% were surrounded by active silviculture. Recognizing that some types of IWs (e.g., forested flats) can be preserved and kept in fair condition within silviculture operations, regulators and other resource managers can use the website (or IW polygon GIS coverages) to review where IWs may be present within silviculture operations, and promote practices, such as harvesting in dry periods, avoiding ruts, and minimizing ditching and bedding, that can help preserve, protect, and improve the wetlands within them.

The map viewer and/or GIS coverages also serve as a record of the project, and particularly the Level 1 outputs, that can be reviewed along with this report to provide the geographical and landscape frame of reference for the study.

4.5 Conclusions and Recommendations

Overall, isolated wetlands in our study area are a common feature of the landscape, are relatively small features, and occupy a small percentage of the overall wetlands in the landscape. From the results of this study, isolated wetlands can store significant amounts of water, probably have connectivity through groundwater to downslope streams, seem to be acting as sinks for nutrients, metals, and carbon, and generally range in fair to good ecological condition. Isolated wetlands that are in good condition have relatively intact biological communities as compared to other least-disturbed wetlands of similar type. .Future results from intensive sampling at targeted isolated wetlands will help will confirm or otherwise corroborate the findings of this study. The wetland survey and assessment methods demonstrated in this research project provide some of the technical tools for advancing such further research, as well as for assessing the conditions of isolated wetlands or similar resources in other area. Finally, the maps of candidate IWs across the study are can serve as a guide to assist wetland regulators and managers in finding IWs and determining how they may be impacted by surrounding land use.

4.6 References

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