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

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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

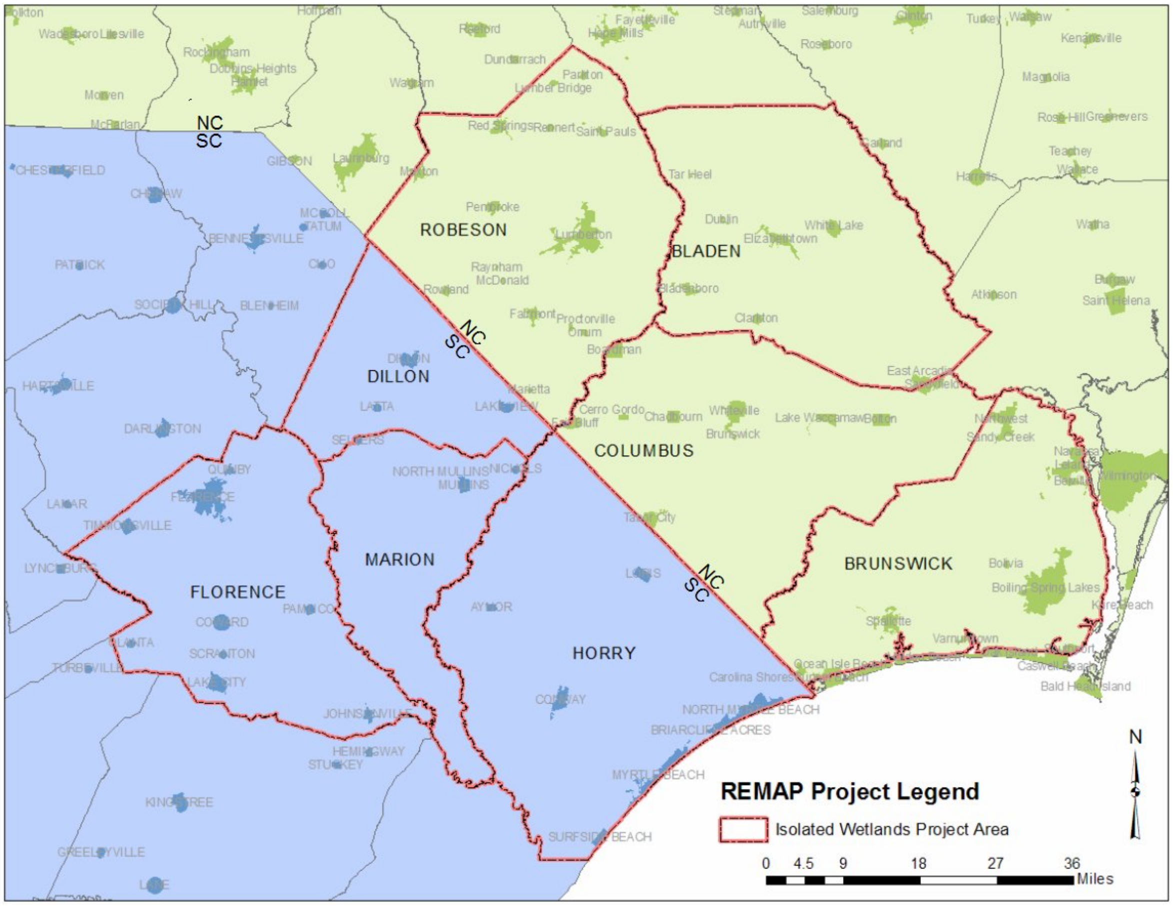

Figure 4-1. SEIWA study area, showing eight selected counties and population centers.

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.

[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

[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).

[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.

[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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