



U.S. Army Corps of Engineers
Charleston District

APPENDIX L

CHARLESTON HARBOR POST 45
CHARLESTON, SOUTH CAROLINA

Wetland Impact Assessment

03 October 2014

TABLE OF CONTENTS

List of Tables	iii
List of Figures	iii
Plant Species List.....	iv
1.0 Introduction	1
2.0 Technical Approach.....	2
2.1 Affected Environment: Wetlands	2
2.2 Wetland Assessment Context and Rationale.....	4
2.3 Methods.....	6
2.3.1 Wetland Delineation and Classification	6
2.3.2 Determination of Assessment Reaches	8
2.3.3 Determination of Length of River in Assessment Reaches	15
2.3.4 Calculation of “Wetlands per River-Foot” Ratios.....	15
2.3.5 Determination of Habitat Coverage Associated with Assessment Reaches.....	15
2.3.6 Interpolation of “Future-With-“ and “Future-Without-Project” Salinity Isopleths	17
2.3.7 Determination of Wetland Areas Affected by Alternatives.....	17
2.3.8. Assessment of Wetland Habitat Types Affected by Alternatives	18
3.0 Results.....	19
4.0 Conclusion.....	22
5.0 References	22

List of Tables

Table 1	Ashley River marsh zones	11
Table 2	Incremental wetland impacts for each alternative compared to the future without project condition in 2071 (50 year project life).	19
Table 3	Incremental wetland impacts for each alternative compared to the condition at the time of construction completion in 2022.....	21

List of Figures

Figure 1	Existing average annual surface salinity classifications within the project area	3
Figure 2	Cowardin classification system for estuarine systems.....	3
Figure 3	Wetlands within the Ashley River system connected to the river.....	10
Figure 4	Wetlands within the Cooper River system connected to the river.....	14
Figure 5	Wetlands within the Wando River system connected to the river.....	16
Figure 6	Wetland impacts resulting from the various project alternatives in the future-without-project condition (year 2071).....	21
Figure 7	Wetland impacts resulting from the project alternatives compared to the condition at the time of construction completion in 2022.....	22

Plant Species List

Scientific Name	Common Name
<i>Acer rubrum</i>	Red maple
<i>Juniperus virginiana</i>	Eastern red cedar
<i>Chamaecyparis thyoides</i>	Atlantic white cedar
<i>Magnolia virginiana</i>	Sweet bay
<i>Persea sp.</i>	Red bay
<i>Pinus serotina</i>	Pond Pine
<i>Magnolia grandiflora</i>	Magnolia
<i>Alternanthera philoxeroides</i>	Alligator weed
<i>Amaranthus cannabinus</i>	Salt marsh water hemp
<i>Amorpha sp.</i>	False indigo
<i>Andropogon sp.</i>	Beard grass
<i>Apios americana</i>	Groundnut
<i>Baccharis halimifolia</i>	Groundsel tree
<i>Bidens sp.</i>	Bur-marigold
<i>Bidens sp.</i>	Bur-marigold
<i>Bolboschoenus robustus</i>	Salt marsh bulrush
<i>Borrchia frutescens</i>	Sea oxeye
<i>Cicuta sp.</i>	Water hemlock
<i>Cladium jamaicense.</i>	Sawgrass
<i>Distichlis spicata</i>	Salt grass
<i>Egeria densa</i>	Brazilian elodea
<i>Eichhornia sp.</i>	Water hyacinth
<i>Eichornia sp</i>	Water Hyacinth
<i>Hydrilla verticillata</i>	Hydrilla
<i>Iva frutescens</i>	Salt marsh elder
<i>Juncus roemerianus</i>	Black needlerush
<i>Kosteletzkya pentacarpos</i>	Marsh mallow
<i>Leersia oryzoides</i>	Rice cutgrass
<i>Ludwigia sp.</i>	Water primrose
<i>Lycoris radiata</i>	Spider lily
<i>Myrica cerifera</i>	Wax myrtle
<i>Nyssa biflora</i>	Black gum

Scientific Name	Common Name
<i>Nyssa sp.</i>	Gum
<i>Onoclea sensibilis</i>	Sensitive fern
<i>Panicum hemitomon</i>	Maidencane
<i>Peltandra virginica</i>	Arrow arum
<i>Persicaria punctatum</i>	Dotted smartweed
<i>Physostegia virginiana</i>	Obedient plant
<i>Pluchea odorata</i>	Salt marsh fleabane
<i>Polygonum sp</i>	Smartweed
<i>Pontederia sp.</i>	Pickerelweed
<i>Potamogeton sp</i>	Pondweed
<i>Quercus sp.</i>	Oak
<i>Sagittaria lancifolia</i>	Bulltongue arrowhead
<i>Sagittaria sp.</i>	Arrowhead/duck potato
<i>Saururus cernuus</i>	Lizard's tail
<i>Schoenoplectus americanus</i>	Olney's three-square
<i>Scirpus sp.</i>	Bulrush
<i>Spartina alterniflora</i>	Smooth cordgrass
<i>Spartina cynosuroides</i>	Big cordgrass
<i>Spartina patens</i>	Salt meadow hay
<i>Spartina sp.</i>	Cordgrass
<i>Symphyotrichum sp.</i>	Salt marsh aster
<i>Taxodium distichum</i>	Bald cypress
<i>Typha angustifolia</i>	Narrow-leaved cattail
<i>Zizania aquatica</i>	Wild rice
<i>Zizaniopsis miliacea</i>	White marsh/cutgrass

1.0 Introduction

The Charleston Harbor Post 45 feasibility study analyzed and evaluated improvements to Charleston Harbor. Objectives of the study were to:

- 1) Reduce navigation transportation costs of import and export trade through Charleston Harbor and contribute to increases in national economic development (NED) over the period of analysis;
- 2) Reduce navigation constraints facing harbor pilots and their operating practices including limited one-way traffic in certain reaches; and
- 3) Develop an alternative that is environmentally sustainable for the period of analysis.

The third objective above takes into consideration both the short-term (i.e., resulting directly from construction itself) and long-term effects of the selected alternative on project area wetlands. To inform users of environmental impacts, a careful analysis of potential harbor improvements was conducted. Analyses included determining environmental effects of the Federal project (1) in its existing (45-foot channel depth) condition, (2) in a future-without-project (FWOP) condition, and (3) in the future condition given that the selected alternative is constructed. The USACE feasibility study analyzed, inventoried, and quantified environmental impacts related to construction incrementally based on potential dredge depths for the Entrance Channel, Lower Harbor, and Upper Harbor, in addition to combinations of deepening in certain areas of the Federal project and widening measures. The construction alternatives that were examined were determined based on anticipated vessel sizes/drafts and traffic/utilization over the expected “life of the project.” Future-with-project (FWP) evaluations were performed for proposed depths up to and including -54 feet MLLW (Entrance Channel); -52 feet (Lower Harbor) and -48 feet (Upper Harbor). The array of alternatives that were examined in the feasibility study included navigational improvements to some or all of the channels in Charleston Harbor, including (1) deepening channel(s), (2) widening channel(s), (3) adjusting existing channel alignments/bend easing, and (4) widening and/or lengthening turning basins. A detailed description of the alternatives can be found in the main report. Environmental impacts of the project were compared to environmental attributes that would be present in the FWOP condition. The discussion below addresses how wetland habitats were determined to be affected by the proposed project.

2.0 Technical Approach

2.1 Affected Environment: Wetlands

Charleston Harbor and watershed encompasses an area of 65 sq. miles, 40 sq. miles of which are marsh and lowlands. With the confluence of the Ashley, Cooper, and Wando Rivers, the harbor's contributing watersheds drain approximately 1,200 square miles (SCDHEC 2002). Historically, the Ashley, Wando, and Cooper Rivers were all tidal sloughs with limited freshwater inflow and extensive tidal marshes. Alterations, principally the construction of upstream reservoirs and canals, altered historic freshwater discharge on the Cooper River (which was very low). Also, in the 17th and 18th centuries, rice plantations were created in the upper Cooper and Ashley Rivers by extensive diking of intertidal wetlands. Remnants of these fields can be seen above the "Tee" where the Cooper River splits into the East and West Branches (see Figure 1 near top) and along the upper Ashley River. Notwithstanding the above, large tracts of tidal marsh remain throughout the project area, and these are extremely important for both resident and migratory fish and wildlife. Additional wetland functions and ecological services include the following: water purification, flood protection, shoreline stabilization, groundwater recharge, streamflow maintenance, retention of particles, surface water storage, subsurface storage, nutrient cycling, biodiversity, and aesthetics. Three broad types of marshes within the project area include tidal saltwater marsh (meso and poly-haline), brackish marsh (oligohaline), and tidal freshwater marsh (Figure 1). Since year to year variability makes a static delineation of these systems difficult to impossible, Figure 1 represents the modeled thresholds for an example low flow year using the hydrodynamic model for this study (Environmental Fluid Dynamics Code). Figure 2 indicates the distribution of these wetland types along a salinity gradient (defined by Cowardin et al., 1979).

Tidal meso- and polyhaline wetlands in Charleston Harbor include estuarine emergent marshes dominated by cordgrass species (*Spartina sp.*) and black needlerush (*Juncus roemerianus*). Higher emergent marsh areas contain sea oxeye (*Borrchia frutescens*), salt grass (*Distichlis spicata*), and salt meadow hay (*Spartina patens*). Estuarine scrub shrub wetlands are dominated by wax myrtle (*Myrica cerifera*), salt marsh elder (*Iva frutescens*), and groundsel tree (*Baccharis halimifolia*).

Tidal oligohaline wetlands are dominated by big cordgrass (*Spartina cynosuroides*) and black needlerush. Other species include smooth cordgrass (*Spartina alterniflora*), and salt-marsh bulrush (*Bolboschoenus robustus*). A number of freshwater species can occur within these marshes including including arrow-arum (*Peltandra virginica*), wild rice (*Zizania aquatica*), dotted smartweed (*Persicaria punctatum*), water primrose (*Ludwigia sp.*), bur-marigold (*Bidens sp.*), and salt-marsh aster (*Symphotrichum sp.*). Within the lower stretches of oligohaline marshes, freshwater species are sparsely distributed, and within the upper stretches of these marshes freshwater species appear with increasing regularity.

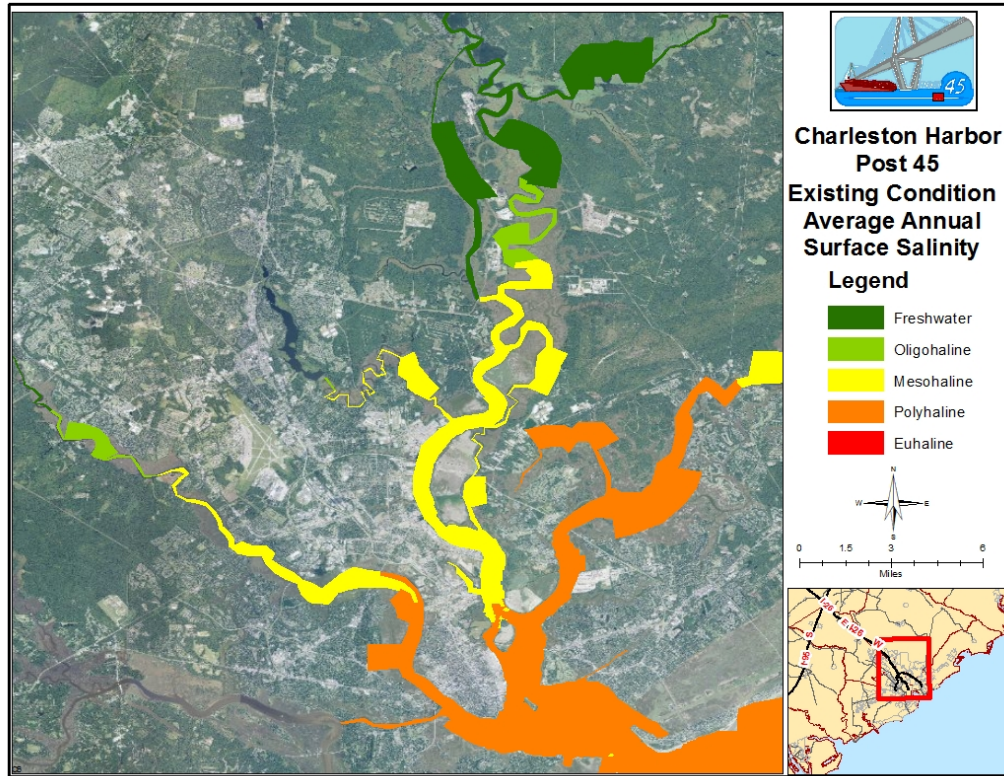


Figure 1 Existing average annual surface salinity classifications within the project area

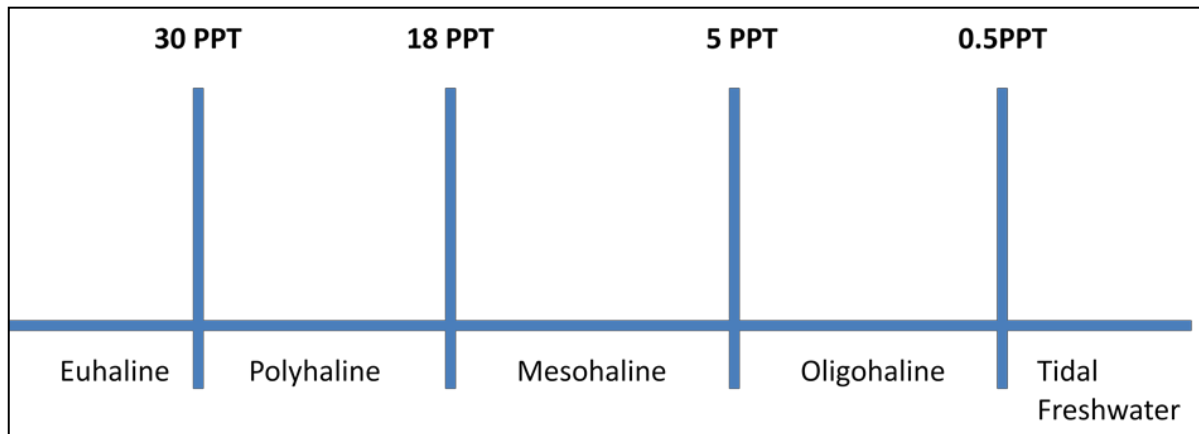


Figure 2 Cowardin classification system for estuarine systems

Tidal freshwater emergent wetlands in the upper portion of the Cooper and Ashley Rivers include intertidal emergent species, floating leaf vegetation, and submerged aquatic vegetation. The excerpt below from US Fish and Wildlife Service (1984) defines the major characteristics of tidal freshwater Wetlands. “Tidal freshwater wetlands are a distinctive type of ecosystem located upstream from tidal saline wetlands (salt marshes) and downstream from non-tidal freshwater wetlands. They are characterized by (1) near freshwater conditions (average salinity of 0.5ppt or below except during periods of extended drought, (2) plant and animal communities dominated by freshwater species and (3) a daily lunar tidal function.” Typically tidal freshwater wetlands/marshes are more species rich than

their brackish or saltwater counterparts. In the Cooper River, tidal freshwater marsh species include white marsh/cutgrass (*Zizaniopsis miliacea*), wild rice, sawgrass (*Cladium sp.*) and bulrush (*Scirpus sp.*). Also present and often mixed in with these common freshwater plants are big cordgrass, black needlerush, and salt-marsh bulrush. These wetlands frequently have an understory of green arrow arum (*Peltandra virginica*), water-primrose (*Ludwigia sp.*), water hyacinth (*Eichhornia sp.*), pickerelweed (*Pontederia sp.*), sensitive fern (*Onoclea sensibilis*), arrowhead/duck potato (*Sagittaria sp.*), water hemlock (*Cicuta sp.*), lizard's tail (*Saururus cernuus*), alligator weed (*Alternanthera philoxeroides*), obedient plant (*Physostegia virginiana*), spider lily (*Lycoris radiata*), smartweed (*Polygonum sp.*), beard grass (*Andropogon sp.*), false indigo (*Amorpha sp.*), and groundnut (*Apios americana*). Submerged aquatic vegetation primarily includes hydrilla (*Hydrilla verticillata*), Brazilian elodea (*Egeria densa*), pondweed (*potamogeton sp.*), and Carolina fanwort (*Cabomba sp.*). While floating leaf vegetation primarily included species such as water-primrose, water hyacinth, pickerelweed, and smartweed

Also present along the freshwater portion of these river systems are bottomland hardwood forests. These areas are similar to palustrine freshwater forested wetlands and occur at the interface of tidal aquatic and terrestrial ecosystems (James et al., 2012). Cowardin et al., (1979) define palustrine wetlands as, “all **nontidal** wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in **tidal** areas where salinity due to ocean-derived salts is below 0.5ppt.” James et al., (2012) indicated that palustrine freshwater forested wetlands exist at the landward extent of the head of tide and above the saltwater-freshwater interface, which theoretically occurs at the 0.5 ppt salinity boundary. Field et al., (1991) conservatively estimated that there are 40,000 hectares of tidal freshwater forested wetlands in South Carolina. EPA defines these systems as river swamps. “They are found along rivers and streams of the southeast and south central United States, generally in broad floodplains. These ecosystems are commonly found wherever streams or rivers at least occasionally cause flooding beyond their channel confines. They are deciduous forested wetlands, made up of different species of gum (*Nyssa sp.*) and oak (*Quercus sp.*) and bald cypress (*Taxodium distichum*), which have the ability to survive in areas that are either seasonally flooded or covered with water much of the year. Identifying features of these wetland systems are the fluted or flaring trunks that develop in several species, and the presence of knees, or aerial roots.” (<http://water.epa.gov/type/wetlands/bottomland.cfm>). Also observed in these areas are tupelo, red maple, eastern red cedar, Atlantic white cedar, wax myrtle, sweet bay, red bay, pine, magnolias, etc. These wetlands offer many ecosystem services including storm water runoff mitigation, storm surge protection, and structure and support for animal habitats (James et al., 2012). The Cooper, Ashley, and Wando Rivers all have palustrine wetlands (tidal and non-tidal) within their watersheds that are included within the impact assessment discussed below.

2.2 Wetland Assessment Context and Rationale

The proposed Charleston Harbor deepening will slightly alter salinity distribution in the Ashley, Cooper and Wando Rivers and thus may affect the distribution of salt tolerant wetland vegetation. Wetland distribution may also be influenced by water elevation, which fluctuates in response to daily tides, rainfall, freshwater discharges, and winds. The Charleston Harbor deepening will, however, have

only a negligible effect on water elevation, and therefore, salinity changes are the focus of this impact analysis.

For wetlands within the oligohaline, polyhaline and mesohaline areas, effects of moderate (one to three parts per thousand, for example) salinity increases would not typically have an effect on plant survival within the systems, as resident species are adapted for a range of salinities and the slight elevations in concentration would not likely be significant enough to cause a community-level change. Although some reductions in growth and nutrient uptake could occur with increased changes in salinity, species such as saltmarsh cordgrass are capable of surviving this scenario (Brown 2006). Most of the typical vegetation is halophytic and is adapted to tolerate higher salinity levels, but some effects may occur with elevated salinity levels in combination with extreme environmental circumstances such as drought.

Significant changes in salinity of certain wetlands can alter the vegetative composition, soils, and habitat function of the system. McKee and Mendelssohn (1989) conducted field and lab experiments to examine the impacts of salinity and elevation changes to freshwater marsh vegetation. Three dominant species (*P. hemitomon Schultes*, *Leersia oryzoides*, and *Sagittaria lancifolia*) succumbed to increases in salinity of 15%. The areas were quickly re-colonized by more salt-tolerant species. Flynn et. al., (1995) exposed freshwater marsh vegetation in a green house to a simulated saltwater intrusion event. Virtually all species present experienced a loss of above ground vegetation. Sharpe and Baldwin (2012) found that periodic saltwater intrusion did not reduce species richness, but consistent exposure reduced species richness of freshwater tidal marshes. It is anticipated that the loss of freshwater herbaceous wetland species would be replaced with salt tolerant species such as cordgrass, black needlerush, etc.

Most of the effects described above would occur within tidal and non-tidal palustrine freshwater forested systems, as these systems are not typically adapted to experience high salinity concentrations for increased frequencies or durations. James et al., (2012) found that the hydrology of tidal freshwater forested wetlands is regulated mainly by tidal fluctuations and that they “may be more alike coastal marsh systems than non-tidal bottomland upland habitats.” Within the marshes and the palustrine freshwater forested systems, plants that are not adapted to tolerate higher salinities will generally succumb and be replaced by those with higher tolerances. There is an abrupt change in vegetative communities between marsh and palustrine habitat which is primarily due to a salinity gradient (James et al., 2012). Higher salinities can increase the mineralization of nitrogen and phosphorous in soils, leading to “tree stress and senescence” as well as conversion to oligohaline marsh (Noe 2013). Increases in sulfate reduction can decrease organic matter content in the soil, reducing elevations and increasing flooding. Long-term increases in salinity resulting from sea level rise or other factors has shown to cause vegetation stress, mortality, and retreat of palustrine freshwater forested wetland communities which are then replaced by freshwater or brackish marsh vegetation (Doyle et al., 2010). Pezeshki et.al. (1989) conducted lab experiments to test the impacts of additional flooding and saltwater intrusion on seedling tupelo-gum seedlings. When salinity was increased, seedlings experienced declines in height and growth among other adverse impacts. Pezeshki et.al. (1990) found that “increased flooding and saltwater intrusion, a problem facing U.S. Gulf Coast

bottomland forests, can cause drastic reduction in net carbon assimilation, leaf burning and seedling mortality. The stress at sublethal levels can lead to weaker seedlings and, consequently, reduced survival rates, and the potential for long-term habitat changes thus limiting the existing natural range of these forests.” In North Carolina, following deepening of the Cape Fear River channel, Hackney (2013) monitored wetland vegetation, salinity, pore-water sulfate, and other parameters at riverine and estuarine sampling stations. Monitoring occurred over a ten-year period at a series of sites influenced by a variety of salinity and flooding regimes. The monitoring data suggested that wetland transition from tidal swamp (forested) to tidal marsh (nonforested) was caused by increasing sulfate in the soil as a result of inundation with sulfate-laden saline water. These changes can subsequently cause sediment accretion to be reduced, limiting the ability of a system to recover from land subsidence.

As discussed above, increased salinity has an adverse impact to cypress tupelo swamps and tidal freshwater wetlands. Both habitat types exhibit some tolerance to slight increases in salinity or brief exposures to salinity, but long-term or high levels of exposure to increased salinity are lethal. In summary, it is anticipated that if the proposed project is constructed in Charleston Harbor, salinity increases would have negligible impacts to tidal poly-, meso-, and oligohaline marshes. However, tidal freshwater marshes would experience a shift in the vegetative community toward species that are more salt-tolerant. Palustrine freshwater forested wetlands would experience some tree senescence and die-off as pore-water salinity increases. This could result in freshwater and brackish herbaceous species re-colonizing those areas. These assumptions, indicating that some adverse effect on existing wetlands could precipitate from the proposed harbor improvements, resulted in USACE’s need to identify general areas of effect (as practicable) and quantify the amount of impacts for the Post 45 project. The methods utilized to that end are detailed below.

2.3 Methods

The following methods describe details of the procedures used to predict salinity isopleths shifts and subsequent wetland impacts within the river systems. Modeled data necessarily predict information for certain conditions and environmental variables (i.e., wind, rain, temperature, etc.), which fluctuate annually, can affect salinity distribution in a river. The following method was developed to account for the annual variability that occurs in natural systems and was coordinated with the ICT. It takes into account the possibility that the isopleths could, *in situ*, be farther upstream or downstream than projected by the models. This is consistent with Cowardin et al.’s (1979) appreciation of the dynamic relative positions of salinity thresholds in open-water environments.

2.3.1 Wetland Delineation and Classification

Analysts used the sources listed below to prepare a wetland delineation of each of the three river basins within the project area:

- True-color aerial photography - National Agriculture Imagery Program (NAIP) 2011
- Color Infra-red (CIR) aerial photography - National Geospatial Center of Excellence (NCGC) 2009
- EFDC model output data (salinity isopleths)

- LiDAR (light detection and ranging) topographic/elevation data - 1 foot contours from 5-10 foot DEM grids
- ERDC marsh vegetation study (Reif, 2013)
- SC OCRM (Ocean and Coastal Resource Management) wetland study
- National Wetlands Inventory (NWI) maps
- Land (wetland) cover types from two SCDNR files: i.e.,
- SCDNR Alternative Energy Geodatabase Land Use/Cover

(the file including polygons named “Palustrine Forested Wetland”)

- SCDNR Landuse/Cover Wetlands (the file including polygons named simply “forested wetland”)

For the Cooper River basin, the ERDC survey map was considered to be the most up-to-date and accurate layer portraying wetland extents in that portion of the project area, with the exception of the forested wetlands. Because the ERDC maps comprised polygons that generalized forest cover (“woody mix” category; i.e., “Category 1” in dataset), they were corrected/updated based primarily on SCDNR and NWI data, which specified which forest areas comprised *wetland* forest cover; the remainder were designated as upland forests. Unfortunately, the SCDNR and NWI data sometimes had overlapping cover types that conflicted in designation or areas with no coverage type indicated whatsoever. This necessitated the comparison of LIDAR topographic data and landscape position to other “reliable” wetland polygons to determine the typical elevation of the boundary between wetland and upland. Using that typical elevation determined by analysts, i.e., approximately 5 feet above approximate mean sea level (specifically NAVD88 datum GEOID09), discontinuous and overlapping polygons representing forested-wetland habitats were repaired and replaced in the ERDC base map. The use of CIR aerial photography provided an additional method for verifying the inclusion or exclusion of habitats as wetlands.

The landward extent (from each river channel’s centerline) of wetlands associated with each assessment reach (as defined below) was then determined. The five-foot elevation contour provided a reasonable uphill limit (i.e., boundary) for wetlands in each assessment reach. Per convention (observed in SCDNR and ERDC data sets), open water areas (sloughs, creeks, canals, etc.) that were not part of the main river channel were not classified as wetland areas. Many of these forested wetland areas include both tidal and non-tidal systems but were determined to be connected to the river. The use of the 5 ft contour provides a conservative estimate of impacted area because not all of the delineated wetlands used in this impact assessment experience regular tidal inundation. These wetlands are defined as palustrine wetlands using the Cowardin (1979) system of wetland classification (defined above); however, some of these wetlands receive the majority of their water from precipitation, not riverine flooding. [*For future reference, this same delineation was performed to determine extent of wetlands within the mitigation/preservation tracts. Therefore, impacted wetlands are considered similar to the mitigation wetlands**]

Whereas the ERDC marsh vegetation study was the keystone for the Cooper River basin, for the Ashley and Wando River basins the OCRM wetland study provided the highest resolution and most accurate data from which to build on. SCDNR and NWI data layers were utilized as discussed above to

further determine wetland limits, along with the use of the five-foot topographic contour derived from the LiDAR data. These data were reconciled into a unified wetland delineation providing the optimum combination of comprehensive coverage and best available accuracy for estimating existing wetland type and acreage and subsequently, potential wetland impacts.

2.3.2 Determination of Assessment Reaches

Cowardin et al. (1979) stated, “Differences in salinity are reflected in the species composition of plants and animals. Many authors have suggested using biological changes as the basis for subdividing the salinity range between sea water and fresh water (Remane and Schlieper 1971)... Since the gradation between fresh and hypersaline or hyperhaline waters is continuous, any boundary is artificial, and few classification systems agree completely.” Though boundaries among salinity-differentiated habitats are artificial and constantly in flux in nature, the need to determine whether impacts may occur to these habitats has resulted in the necessary, compartmentalization of project-area river basins based on salinity. Given that wetland classifications based on dominant vegetation is a common practice, and that vegetation type is necessarily linked to water quality characteristics, an attempt was made to discern potential vegetation transitions *in situ*, and hence wetland type transitions, according to anticipated salinity affects in adjacent river channels.

Field observations from the Ashley River (by USACE during 2013) and the ERDC wetland characterization study (Reif, 2013) confirmed that certain wetland vegetation (assemblages) were associated with salinity levels in the adjacent river channel (in the existing condition from the EFDC model). Sections of river (referred to as “assessment reaches” here) associated with wetland vegetation with affinities for mesohaline (having salinities from 18 to 5 ppt), oligohaline (having salinities from 5.0 to 0.5 ppt), and freshwater (having salinities less than 0.5 ppt) habitats were determined. These three areas, as well as the transitional areas between each zone, for each the Ashley, Cooper, and Wando comprised the five assessment reaches (ARs) for the wetland impact analysis. Of particular importance were the vegetation community changes occurring upstream and downstream of estimated salinity boundaries, notably the 0.5 ppt boundary and the 5.0 ppt boundary, as (1) these were the thresholds where Cowardin et al (1979) determined that habitats differentiate, and (2) determination of potential impacts to freshwater marshes/swamps and low-salinity wetlands are a major consideration for this study. ARs were generally further divided into sub-reaches to facilitate a more detailed characterization of vegetation and physical conditions, particularly in areas where transitions occurred. The following sections define these reaches in the 3 river systems, and figures are provided for reference.

Ashley River Marsh Zone Characterization

Sub-Reach 1 - Salt-Marsh

The Ashley River salt-marsh community (see Figure 3) along Sub-reach 1 (downstream-most sub-reach) is characterized by sharply-defined, monospecific zones of smooth cordgrass and black needlerush. Smooth cordgrass comprises a relatively narrow approximately 100-ft-wide) low marsh zone along the edge of the Ashley River channel, and black needlerush dominates a wide, high-marsh zone that extends from the landward margin of the low marsh to the upland boundary. The principal changes in marsh structure and composition along the sub-reach include a gradual narrowing of the

smooth cordgrass zone and the establishment of big cordgrass as an important constituent of the marsh community. A few small patches of big cordgrass are associated with disturbed soils along the lower portion of the sub-reach. However, its occurrence as a natural component of the marsh begins at the approximate mid-point of the sub-reach, where it appears in small isolated patches along the landward margin of the smooth cordgrass zone. These patches appear with increasing regularity towards the upper boundary of the sub-reach.

Sub-Reach 2 - Salt to Brackish Marsh Transition

The lower (downstream) boundary of Sub-reach 2 (with Sub-reach 1) marks the beginning of a 1.7-mile transition from salt- to brackish-marsh dominance along the Ashley River. This transition is characterized by the decline of smooth cordgrass and the establishment of a continuous black needlerush-big cordgrass zone. The marsh community is characterized by three well-defined vegetation zones: 1) a narrow fringe of smooth cordgrass along the edge of the river channel, 2) a narrow (~50- to 100-ft-wide) zone dominated by black needlerush (90% cover) and big cordgrass (10% cover), and a broad interior marsh dominated by monospecific stands of black needlerush.

Sub-Reach 3 - Brackish Marsh

The brackish-marsh community along Sub-reach 3 (upstream of and adjoining Sub-reach 2) is characterized by four well-defined vegetation zones: 1) an irregular and discontinuous fringe of smooth cordgrass along the edge of the river channel; 2) a narrow (approximately 50-ft-wide) zone dominated by big cordgrass (95% cover) and salt-marsh bulrush (*Bolboschoenus robustus*) (5% cover); 3) a narrow (approximately 100- to 200-ft-wide) zone dominated by black needlerush (85% cover), big cordgrass (10% cover), and saltmarsh bulrush (5% cover); and 4) a broad, interior, black needlerush zone with scattered stems of big cordgrass and saltmarsh bulrush. A number of freshwater species occur sporadically along the edge of the river channel and in the adjacent fringing marsh; including arrow-arum (*Peltandra virginica*), wild rice, dotted smartweed, water primrose, bur-marigold, and salt-marsh aster. Freshwater species are sparsely distributed along the lower portion of the sub-reach, but appear with increasing regularity towards the upper boundary of the sub-reach.

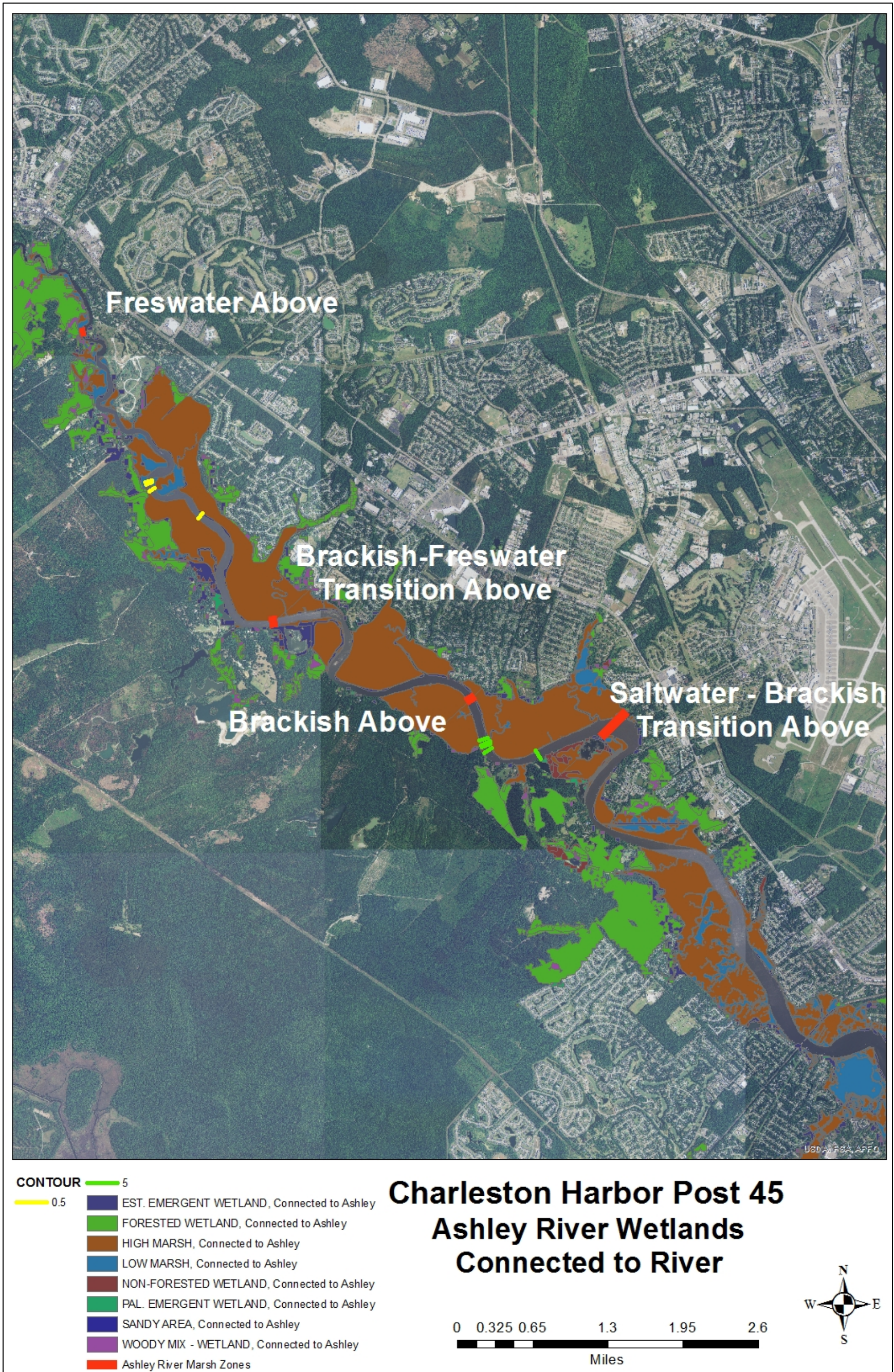


Figure 3 Wetlands within the Ashley River system connected to the river

Sub-Reach 4: Brackish to Freshwater Marsh Transition

The lower boundary of Sub-reach 4 (upstream of and adjoining Sub-reach 3) marks the beginning of a lengthy (approximately 4.0 river-miles) transition from brackish to freshwater marsh dominance along the Ashley River. This transition is characterized by the decline of black needlerush as the dominant interior marsh species and the establishment and proliferation of a diverse assemblage of freshwater species. Concurrently, the sharply-defined vegetation zones that characterize the lower marshes give way to a patchy mosaic of mixed brackish and freshwater vegetation.

Marshes associated with the lower portion of sub-reach are characterized by three poorly defined vegetation zones: 1) a discontinuous series of smooth cordgrass clumps along the edge of the river channel; 2) a narrow big cordgrass zone with a consistent series of wild rice clumps and a diverse assemblage of other low percent-cover freshwater species; and 3) a broad interior black needlerush zone with scattered big cordgrass and a diverse assemblage of low percent cover freshwater species.

Marshes associated with the central portion of Sub-reach 4 are characterized by high variability in terms of both composition and structure. Generally, marshes adjoining the river channel are dominated by variable combinations of big cordgrass, narrow-leaved cattail (*Typha angustifolia*), and black needlerush; with a diverse and variable assemblage of freshwater species. The interior marsh is generally dominated by black needlerush with large monospecific patches of narrow-leaved cattail, low to moderate densities of big cordgrass, and a diverse assemblage of low-percent cover freshwater species.

Marshes along the upper portion of the sub-reach generally lack distinguishable vegetation zones. The marsh community is generally dominated by variable combinations of big cordgrass, narrow-leaved cattail, and black needlerush; with scattered patches of sawgrass and a diverse assemblage of freshwater species; including bull-tongue arrowhead (*Sagittaria lancifolia*), pickerelweed, arrow-arum, wild rice, smooth sawgrass (*Cladium jamaicense*), Olney's three-square (*Schoenoplectus americanus*), dotted smartweed, marsh mallow (*Kosteletzkya pentacarpos*), salt-marsh fleabane (*Pluchea odorata*), salt-marsh water-hemp (*Amaranthus cannabinus*), water primrose, bur-marigold, and salt-marsh aster.

Table 1 Ashley River marsh zones

Ashley River Tidal Marsh Zones - 526 Bridge (0.0 rm) to Kings Grant (14.8 rm)		
Sub-Reach	Length (river miles)	Marsh Zone
1	0.0 – 5.5	Salt-marsh
2	5.5 – 7.2	Salt to Brackish Transition
3	7.2 – 9.6	Brackish Marsh
4	9.6 – 13.6	Brackish to Fresh Transition
5	13.6 – 14.8	Freshwater Marsh

Sub-Reach 5: Freshwater Marsh

The lower boundary of Sub-reach 5 (adjacent to Sub-reach 4) marks the transition to freshwater marsh dominance along the Ashley River. The final transition to freshwater marsh is relatively well-defined by the disappearance of black needlerush as a dominant constituent of the marsh and the

concurrent establishment of sawgrass as the principal, dominant species. Large, monospecific patches of sawgrass and narrow-leaved cattail are a prominent feature of the freshwater marsh. The intervening marsh areas are dominated by a variable assemblage of sawgrass, narrow-leaved cattail, big cordgrass, and a diverse array of freshwater species (see Sub-reach 4). At the upper boundary of the sub-reach, a number of severely stunted black gums (*Nyssa biflora*) are widely scattered throughout the marsh interior.

Cooper River Marsh Zone Characterization

The reaches in the Cooper River are similar to the Ashley River, but the ERDC classification study provided a greater level of detail regarding the wetland communities. These communities are described below and details on the communities can be found in Reif (2013).

Sub-Reach 1: Salt-Marsh

The salt-marsh community along Sub-reach 1 of the Cooper River (Figure 4) is strongly dominated by “Smooth Cordgrass Dominant” and “Black Needlerush Dominant” class types.

Sub-Reach 2: Salt to Brackish Marsh Transition

The salt- to brackish-marsh transition is characterized by the decline of the Smooth Cordgrass Dominant and Black Needlerush Dominant class types and the concurrent establishment of the Smooth Cordgrass Mix and Black Needlerush Mix class types as important constituents of the marsh. The “Mix” class types indicate the presence of brackish species that are not a regular component of the lower saltmarsh.

Sub-Reach 3: Brackish Marsh

The lower boundary of Sub-reach 3 (just upstream of Sub-reach 2) marks the beginning of a continuous Big Cordgrass Dominant zone along the river channel. The interior marsh is co-dominated by the Black Needlerush Dominant and Black Needlerush Mix class types. Freshwater class types appear as a minor constituent of the marsh near the upper boundary of the sub-reach.

Sub-Reach 4: Brackish to Freshwater Marsh Transition

The lower/downstream-most section of sub-reach 4 marks an abrupt decline of the Black Needlerush Dominant class type relative to that which was present in Sub-reach 3. Marsh is characterized by a narrow zone of the Big Cordgrass Dominant class type along the river channel and an interior marsh dominated by a combination of the Black Needlerush Mix and Freshwater Mix with Big Cordgrass/Cattail class types.

The marshes in Sub-reach 4 are characterized by a narrow zone of the Big Cordgrass Dominant class type along the river channel and an interior marsh co-dominated by Black Needlerush Mix, Freshwater Mix, and Freshwater Mix with Big Cordgrass/Cattail class types. Black Needlerush Mix declines abruptly at the upper boundary of the sub-reach adjacent to Sub-reach 5.

Sub-Reach 5: Freshwater Marsh

At the lower boundary of Sub-reach 5, the presence of black needlerush subsides as a dominant constituent of the marsh. Upstream of that boundary, the marsh is dominated by Freshwater Mix and Freshwater Mix with Big Cordgrass/Cattail class types.

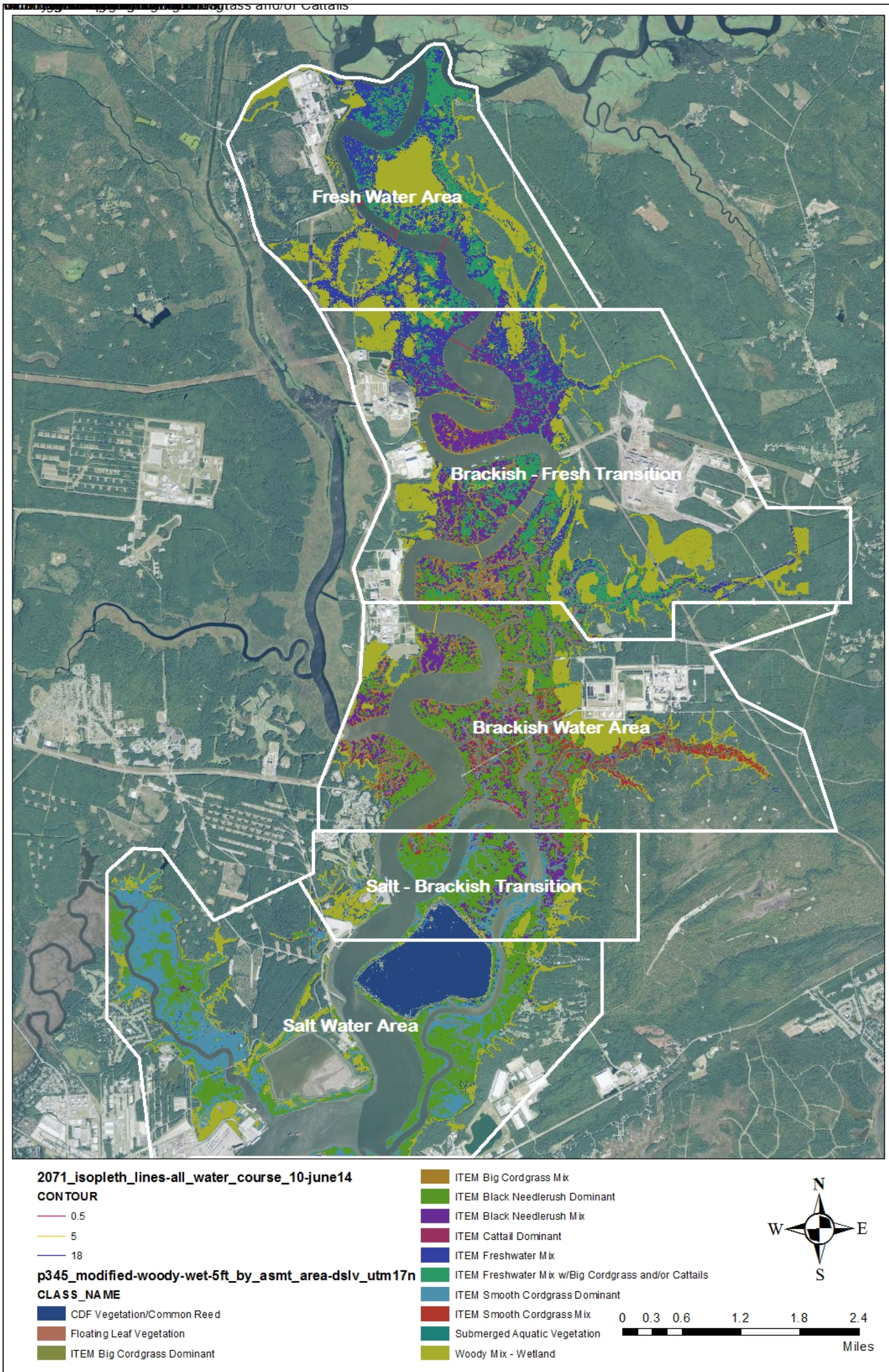


Figure 4 Wetlands within the Cooper River system connected to the river

Wando River Marsh Zone Characterization

The Wando River was not considered in the detailed analysis because project-related salinity changes in this mostly salt- and brackish-water system were not anticipated to appreciably change the biota. Currently the existing biota are associated with polyhaline and mesohaline communities—exhibiting salinities levels at which sensitive fresh and low-salinity plant species could not survive (Figure 5). Species in riparian Wando River wetlands are hardy species that would not suffer declines or sublethal effects if salinities increased a by a few parts per thousand. Therefore, no ARs were assigned in the Wando basin, and the area will not be monitored for project-related effects. Outside of the extent of the project related impacts, the extreme upper portion of the Wando River has palustrine freshwater forested wetlands associated with it.

2.3.3 Determination of Length of River in Assessment Reaches

Via standard GIS tools and the compartmentalization of river basins as outlined above, the extent (in linear feet along the centerline) of each river’s channel within each of the five Assessment Reaches was measured (Attachment L-1).

2.3.4 Calculation of “Wetlands per River-Foot” Ratios

For each AR, the acreage of wetlands associated with it was divided by the length (in feet, as previously measured) of the river channel contained therein. This yielded “Wetlands per River-Foot” for each AR (Attachment L-1).

2.3.5 Determination of Habitat Coverage Associated with Assessment Reaches.

Using GIS software, the area (acreage) of wetlands associated with each Assessment Reach (AR) was calculated, as were the acreages of all wetland habitat types (by acreage and percent-coverage) included therein (data found in tables in Attachment L-1). This analysis included the breakdown of the percent of forested palustrine wetlands and the percent of tidal herbaceous marsh wetlands. For the Ashley River wetlands, the 0.5ppt contour occurs within the brackish to freshwater transition AR, and the analysis determined that within this AR there was 70.6% tidal herbaceous marsh and 29.4% forested wetlands. For the Cooper River wetlands, the 0.5ppt contour occurs within the freshwater AR, and the analysis determined that within this AR there was 58.7% tidal herbaceous marsh and 41.3% forested wetlands. For the Wando River the analysis determined that within the saltwater AR there was 79.76% tidal herbaceous marsh and 20.24% forested wetlands.

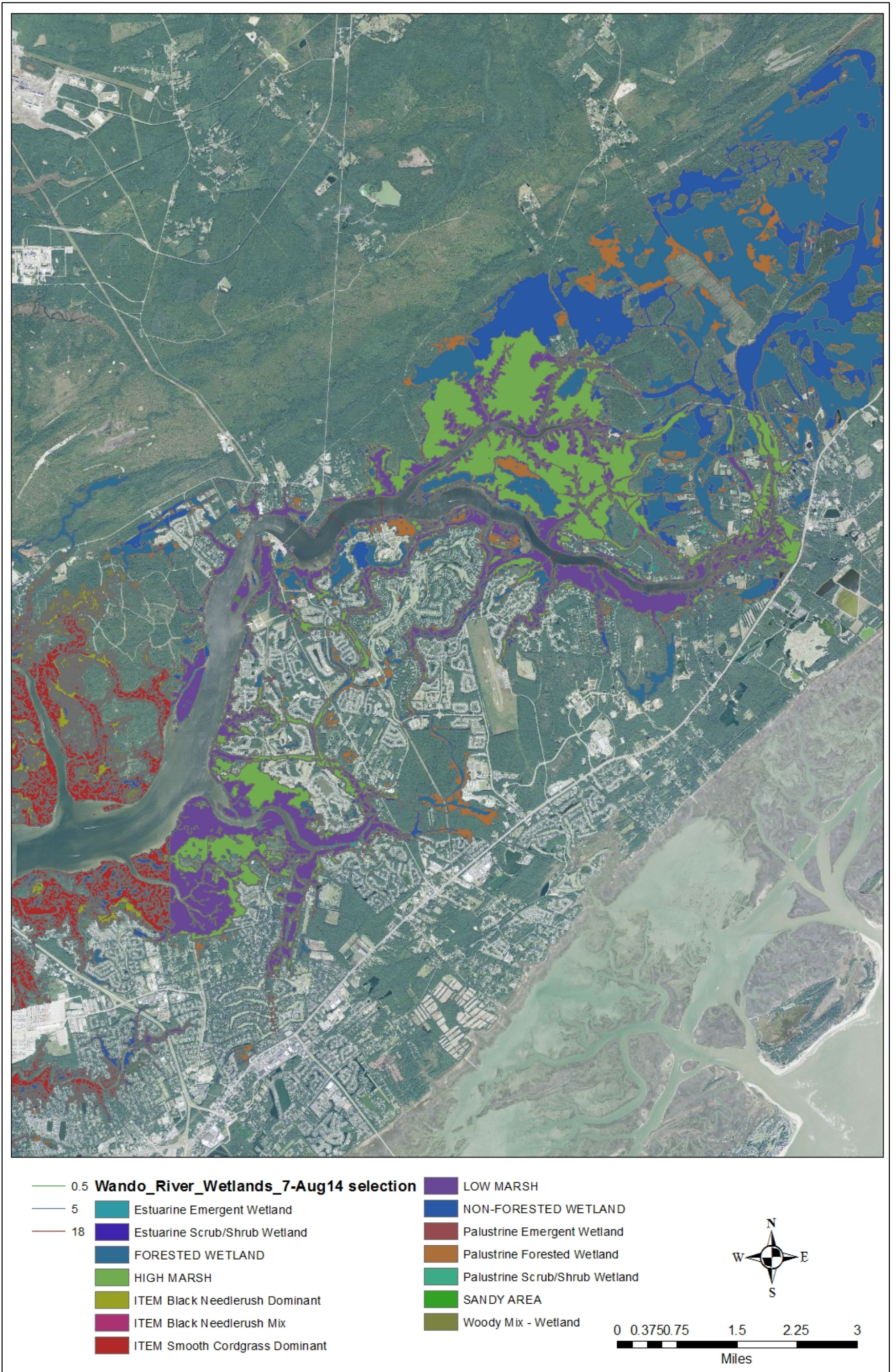


Figure 5 Wetlands within the Wando River system connected to the river

2.3.6 Interpolation of "Future-With-" and "Future-Without-Project" Salinity Isoleths

USACE used modeled flows and water quality parameters to estimate the positions of isopleths (a line on a map connecting points at which a given variable has a specified constant value) for average annual river-channel surface salinities of 0.5 ppt, 5.0, and 18.0 ppt for the three river basins in the study area. This was performed for the (1) existing condition, (2) the FWOP condition (assumes predicted salinity change resulting from *only* sea-level rise during next 50 years), (3) FWP conditions (assumed the influence of each alternative condition *in addition to* salinity change from 50 more years of sea-level rise), and (4) FWP conditions at the estimated completion of construction (2022) for each of six deepening alternatives for both low-flow and typical-flow conditions. Since these values are estimates based on the year in which data were collected (for an interval of a single year), they didn't represent the exact position of an isopleth for any subsequent year.

Because the accuracy of the positions of modeled isopleths could not be determined (although their relative positions could be), the above-discussed Assessment Reach method was adopted, as it takes into account the possibility that the isopleths could, *in situ*, be farther upstream or downstream than projected by the models. This is consistent with Cowardin et al.'s (1979) appreciation of the dynamic, relative positions of salinity thresholds in open-water environments.

Isoleths were determined by first performing an interpolation of the salinity point tables (the data from the centroids for each grid cell) for each alternative and depth. So as not to skew the analysis, this interpolation was masked to exclude points from the EFDC grid that were in the marsh areas and along the Back River area, because they would skew the results. An Inverse Distance Weighted raster interpolation technique was used to create a 30 meter output grid portraying the salinity levels throughout the study area; and it generated a raster (graphic) representing the salinity boundaries. For each isopleth, the upstream and downstream limits of the salinity boundary were determined, and polygons were generated from the interpolated raster in order to calculate the area represented by the two salinity classes at the boundary. The total distance from the up-river limit to the down-river limit was measured and the isopleth was placed at the location along the measured line that was appropriate to the proportion of the area that a salinity class occupied. An alternative set of isopleths were then drawn to better orient them perpendicular to the water flow and a center point was then created to give an isopleth centerline down the river.

2.3.7 Determination of Wetland Areas Affected by Alternatives

To determine the acreage of wetlands within an AR that is likely to be affected by a particular project alternative, the distance (measured in feet along the river centerline) from the isopleths/centroids of the FWP to the FWOP (for each alternative) was measured where changes in the 0.5 ppt and 5.0 ppt salinity thresholds were anticipated. That distance was multiplied by the calculated Wetlands per River-Foot (WRF) factor that was calculated for the respective AR. This analysis was performed for the "low-flow" conditions projected by the hydraulic/salinity models, because Cowardin et al. (1979) based wetland habitat type partly on low-flow conditions, and because the difference between FWP and FWOP conditions is magnified during low-flow conditions. The latter ensured that USACE did not underestimate impacts. Six depth combinations/ alternatives were analyzed. It was

assumed that forested wetlands within the 5 ft delineated boundary along those areas where the salinity shifts would occur, would similarly shift, and could then result in vegetation and other biotic changes. However, it is important to note in all three river systems that the delineated areas of freshwater forested wetlands occur within every salinity zone along the rivers.

2.3.8. Assessment of Wetland Habitat Types Affected by Alternatives

Pursuant to discussions by the Charleston Harbor Post 45 ICT (Interagency Coordination Team) on 17 April 2014, USACE determined which wetland community types would be subject to the effects of the proposed project (i.e., anticipated shifts in wetland substrate salinity and vegetation). This portion of the analysis was only used for the eventual compensatory mitigation calculations based on an April 17, 2014 decision by the ICT. For each affected wetland acreage calculated as described above, it was necessary to determine the maximum potential shift in wetland vegetation/community type. Each AR was examined relative to wetland community types present. The percent-change in community types between the downstream-most and upstream-most ERDC transects within the AR was determined and described. Specifically, the loss of any wetland-cover types comprising species intolerant of salinity increases were noted, quantified, and described. The percent-cover of those habitats was multiplied by the total acreage in the AR to determine the area considered for mitigation. This analysis was possible for only the impacts to the Cooper River's tidal herbaceous marshes because the wetland vegetation characterization study (Reif, 2013) was able to focus only on these species; woody wetland species were not quantified. Because of this, the impacts to woody wetlands were just determined by the affected number of acres per foot (determined as noted above) multiplied by the distance (ft) of the differences in the positions of the alternative and the FWOP isopleths movement. Since freshwater forested wetlands were determined within the 5 ft contour of every salinity zone of each river, the impacts to freshwater forested wetlands as a result of an isopleth shift is a conservative approach. The herbaceous wetland impacts were quantified by the affected number of acres per foot multiplied by the distance (in ft) of the isopleth difference in position and then multiplied by the percent change in dominant vegetation (i.e., shift in % freshwater wetland plants from one AR to another).

Isopleth shifts (aka position differences) were calculated for the 0.5, 5.0 and 18 ppt contours. However, wetland impacts were only assumed to occur as a result of the shift of the 0.5 ppt contour. As previously detailed, minor salinity changes to wetlands in the oligohaline, polyhaline and mesohaline portions of the rivers will not typically have an effect on plant survival or general assemblage type. The wetland plants ubiquitous to those wetlands are adapted for higher salinities and the slight increases in concentration would not cause a change to species such as *S. alterniflora*, *J. roemarianus*, etc. As documented by Brown (2006), although some reductions in growth and nutrient uptake could occur with increased levels of salinity, species such as saltmarsh cordgrass are capable of surviving these scenarios. It should be noted that the largest difference in any alternative vs. FWOP isopleth occurred for the 18 ppt contour in the Wando River, where the 52/48 alternative (recommended plan) causes an 18,292 ft shift upstream. Individual cells in the Wando River experience salinity increases between 0-2 ppt. Since the Wando River is saline along its whole length, these changes were not anticipated to result in wetland habitat changes to the system as a whole. It is likely that the majority of the salinity increase in the Wando may occur due to the channel widening measures associated with the Wando River Reach

and the Wando Turning Basin (see DEIS for the details on these widening measures). USACE has committed to performing ship simulation exercises during the Preconstruction, Engineering, and Design (PED) phase of the project in order to minimize and/or eliminate unnecessary wideners where allowable based on safety and efficiency factors. Any reduction in wideners will also reduce the overall wetland impacts to the system.

In summary, wetland impacts were calculated for all isopleths (0.5, 5.0 and 18ppt). However, the impacts related to the anticipated movement of the 0.5 ppt contour will be the only effects significant enough to warrant compensatory mitigation. The data for all contour shifts are presented in Attachment L-1.

3.0 Results

After completing the steps above, the following table (Table 2) was generated to compare impacts to wetlands resulting from each alternative. Impacts for each alternative were based on the differences between each alternative (involving *both* the influences of the project and 50 years of future sea level rise at the calculated historic rate) and the FWOP (due to only 50 years of future sea level rise at the calculated historic rate). This analysis helped guide the selection of a Tentatively Selected Plan (TSP). Alternative 52/48 was predicted to be associated with the greatest amount of wetland impacts. From an incremental perspective, there was a significant increase in the impacts between the 50/48 and the 52/48 alternatives (nearly 200 additional acres of wetland impact) (Figure 6). The difference between the 48 foot alternatives and the 50 foot alternatives was much smaller. It is uncertain exactly what hydrodynamic processes cause this increase, but it's likely attributable to the larger water prism resulting from factoring in 50 years of sea-level rise. The denser, more saline water propagates up the rivers more easily in the 52 foot alternatives.

Table 2 Incremental wetland impacts for each alternative compared to the future without project condition in 2071 (50-year project life), Ashley and Cooper River basins

Wetland Impacts	Alternative					
	48/47	48/48	50/47	50/48	52/47	52/48
Ashley River forested wetlands	4.88 acres	5.00 acres	5.46 acres	5.50 acres	6.80 acres	7.21 acres
Ashley River marsh wetlands	11.71 acres	11.99 acres	13.12 acres	13.20 acres	16.33 acres	17.30 acres
Cooper River forested wetlands	89.59 acres	97.46 acres	104.48 acres	111.28 acres	189.47 acres	193.52 acres
Cooper River marsh wetlands	127.49 acres	138.70 acres	148.69 acres	158.36 acres	269.62 acres	275.38 acres
Total	233.67 acres	253.15 acres	271.75 acres	288.34 acres	482.22 acres	493.41 acres

After further narrowing the list of alternatives (the /47 alternatives were eliminated based on relatively low differences in average annual costs and large differences in average annual net benefits in comparison to the /48 alternatives), the impacts were revised based on the time of construction. This analysis was performed because the ICT members indicated that the impacts and subsequent mitigation needs should be determined based on what the impacts would be shortly after construction, when the proportion of impacts related to construction (vs. sea level rise influence) is largest. For this analysis, the year 2022 was anticipated to be the year that project construction is completed. Since 2022 is 10 years after the existing-condition-modeled year of 2012, 10 years of sea level rise was added to represent what the sea level could be in 2022. Alternatives 48/48, 50/48, and 52/48 were then analyzed to determine their incremental wetland effects beyond the 2022 without project condition. The analysis was performed in the same manner as described in the methods presented above. Table 3 summarizes the wetland impacts on the Ashley and Cooper Rivers for each alternative. The results of this analysis found that the impacts were slightly smaller after only 10 years of sea level rise than with 50 years of sea level rise. Because most (as a proportion, relative to impacts from SLR) of the impacts (via changes in pore-water salinity and wetland vegetation) will occur nearer to construction than 50 years following it, these numbers were ultimately used to determine compensatory mitigation requirements.

Not only are wetland impacts smaller at the time of construction, but the incremental difference between alternatives are the same if the immediate post-construction temporal “snapshot” is used for calculating impacts. For instance, in the 2071 condition, the impacts resulting from the 50/48 alternative increase by 23.4 % from the 48/48 alternative, while the impacts resulting from the 52/48 alternative increase by 71.1% above the 50/48 alternative, a result that is significantly greater than the previous incremental increase. In contrast to the 2071 results, in the analysis for the time of construction (year 2022), the 50/48 impacts are 67.2% greater than the 48/48 impacts, and the 52/48 impacts are 39.2% greater than the 50/48 impacts. However, the incremental increase in the number of acres impacted is roughly the same at approximately 80 acres each (Figure 7). Since these numbers are attributable primarily to the outputs of the EFDC model, as described above, the assumptions in the EFDC model inform the salinity changes in these results. Since the only difference between the analyses of the 2022 impacts and the 2071 impacts is the amount of sea level rise factored into the EFDC model, sea level appears to be the significant driver in determining the potential for wetland impacts. The 2071 FWOP condition assumes roughly six inches more sea level rise than the 2022 condition. Hence, the baseline isopleth occurs in a different location of the river. Therefore, it is possible that the river bathymetry and longitudinal gradient plays a role in the difference in impacts between 2022 and 2071.

It should be noted that wetland impacts are predicted in the FWOP condition as a result of sea level rise causing salinity increases in the rivers. In the 2071 condition, the impacts on freshwater wetlands are 633.51 acres and 167.30 acres in the Cooper and Ashley Rivers, respectively (Attachment L-1). In the 2022 condition at the time of construction, the impacts on freshwater wetlands are 98.28 acres and 10.89 acres in the Cooper and Ashley Rivers, respectively (Attachment L-1). Project related impacts associated with salinity increase are incrementally evaluated from the FWOP condition. This analysis indicates that the salinity stress on freshwater wetland systems will occur regardless of the proposed project.

Table 3 Incremental wetland impacts for each alternative compared to the condition at the time of construction completion in 2022, Ashley and Cooper River basins.

Alternatives: Impacts at Time of Construction (Year 2022)			
Wetland Impacts	48/48	50/48	52/48
Ashley River forested wetlands	3.35 acres	4.88 acres	6.13 acres
Ashley River marsh wetlands	8.05 acres	11.71 acres	14.73 acres
Cooper River forested wetlands	45.09 acres	76.59 acres	107.34 acres
Cooper River marsh wetlands	64.17 acres	108.99 acres	152.76 acres
Total	120.66 acres	201.77 acres	280.96 acres

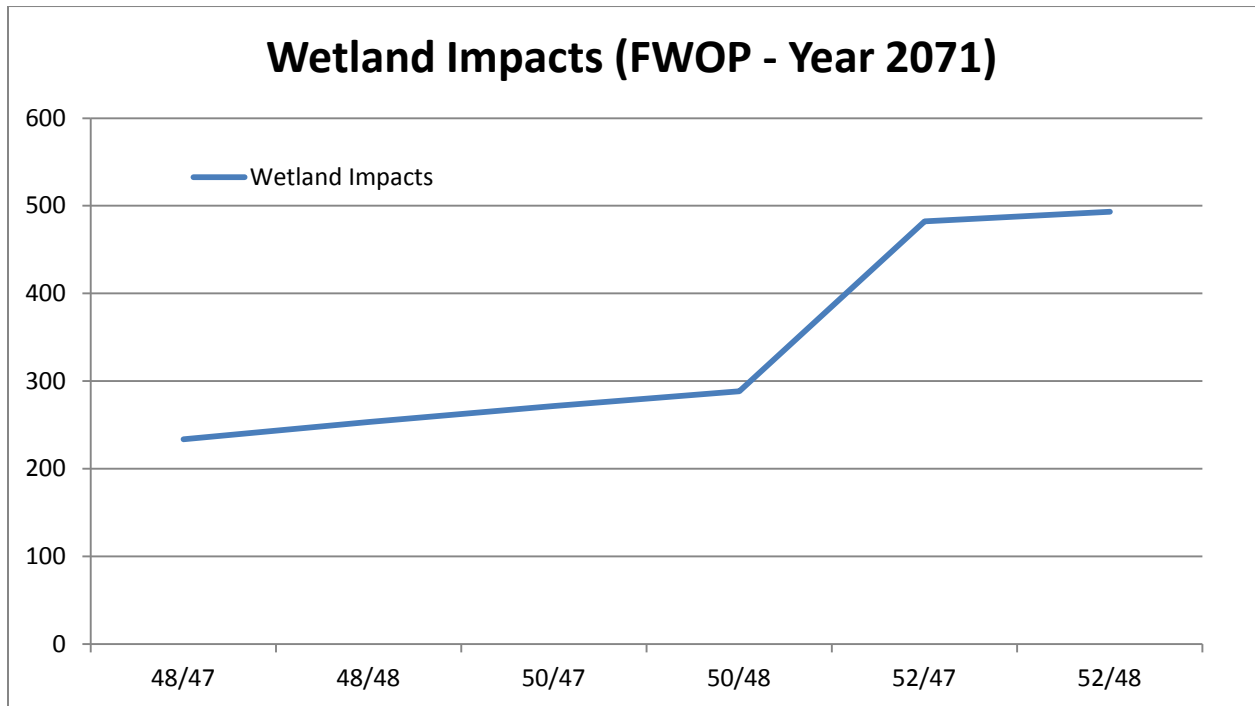


Figure 6 Wetland impacts resulting from the various project alternatives in the future-without-project condition (year 2071)

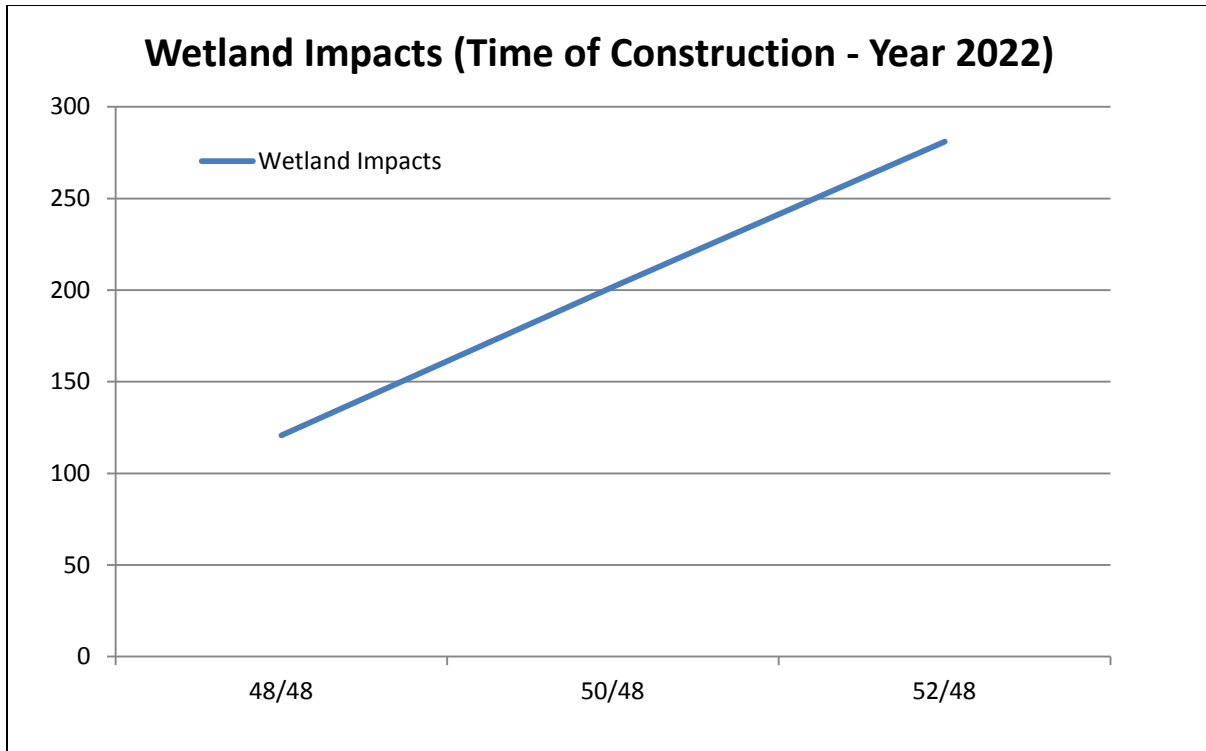


Figure 7 Wetland impacts resulting from the project alternatives compared to the condition at the time of construction completion in 2022.

4.0 Conclusion

The 52/48 alternative (the recommended plan) is anticipated to impact approximately 280.96 acres of wetlands along the Ashley and Cooper Rivers combined. These impacts would affect both palustrine forested wetlands and freshwater marshes and would likely occur just after construction of the project (the 2022 model year). The impacts would be indirect and would not occur immediately (but likely within a few years) because the salt stress will slowly change portions of the plant assemblage. The project, as presented, will have no direct impacts to wetlands resulting from dredging or disposal. Compensatory mitigation will be provided to offset these impacts, and is discussed in detail in the Appendix P (Mitigation Appendix) of the main report.

5.0 References

- Brown, C.E. (Brown) 2006. The effects of salinity and soil drying on nutrient uptake and growth of *Spartina alterniflora* in a simulated tidal system. C.E. Brown, S.R. Pezeshki, R.D. DeLaune. *Environmental and Experimental Botany* 58: 140–148. 2006
- Cowardin, LM, Carter, V, Golet, F.C. and LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats of the United States. US Fish and Wildlife Service FWS/OBS 79/31. 103pp.

- Doyle T.W., K.W. Krauss, W.H. Conner, A.S. 2010. Predicting the retreat and migration of tidal forests along the northern Gulf of Mexico under sea level rise. *Forest Ecology and Management*. 259: 770-777.
- Field D.W., A. Reyer, P. Genovese, B. Shearer. 1991. Coastal wetlands of the United States – an accounting of a valuable national resource. Strategic Assessment Branch, Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Ocean Service, National Oceanic and Atmospheric Administration, Rockville, MD.
- Flynn K.M., K.L. McKee, and I.A. Mendelssohn. 1995. Recovery of freshwater marsh vegetation after a saltwater intrusion event. *Oecologia* 103: 63-72.
- Hackney C.T., G.B. Avery, L.A. Leonard, M. Posey, and T. Alphin, 2007. Biological, chemical, and physical characteristics of tidal freshwater swamp forests of the Lower Cape Fear River/Estuary, North Carolina. 183-221.
- Hackney, C. T. 2013. Tidal wetland community response to varying levels of flooding by saline water. Unpublished report. University of North Florida, Jacksonville, FL.
- James, Brooke V., Carl C. Trettin, Timothy J. Callahan. 2012. Hydrologic influences within a tidal freshwater forested wetland. Proceedings of the 2012 South Carolina Water Resources Conference, held October 2012.
- McKee K.L. and I.A. Mendelssohn. 1989. Response of a freshwater marsh plant community to increased salinity and increased water level. *Aquatic Botany* 34: 301-316.
- Noe, G. B. (Noe) 2013. The effect of increasing salinity and forest mortality on soil nitrogen and phosphorus mineralization in tidal freshwater forested wetlands. Noe, Gregory B.; Krauss, Ken W.; Lockaby, B. Graeme; Conner, William H.; Hupp, Cliff R. *Biogeochemistry*, 114: 225 – 244. 2013
- Pezeshki, S.R., W.H. Patrick, Jr., R.D. DeLaune and E.D. Moser. 1989. Effects of waterlogging and salinity interactions on *Nyssa* aquatic seedlings. *For. Ecol. Manag.* 27:41--52.
- Pezeshki S.R., R.D. DeLaune and W.H. Patrick Jr. 1990. Flooding and saltwater intrusion: Potential effects on survival and productivity of wetland forests along the U.S. Gulf Coast. 33/34:287-301.
- Reif, Molly. 2013. Wetland Classification Study, Cooper River, South Carolina. Final Report to the US Army Corps of Engineers, Charleston District. Prepared by US Army Research and Development Center. Prepared for Charleston District, US Army Corps of Engineers.
- Sharpe P.J. and A.H. Baldwin. 2012. Tidal marsh plant community response to sea-level rise: A mesocosm study. *Aquatic Botany* 101: 34-40.
- Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC. Accessed March 2009. Available online at http://www.ncfisheries.net/habitat/chppdocs/F_Wetlands.pdf.

U.S. Fish and Wildlife Service. 1984. The ecology of tidal freshwater marshes of the United States east coast: a community profile. www.nwrc.usgs.gov/techrpt/83-17.pdf

ATTACHMENT L-1

DATA SPREADSHEETS

Cooper River Calculations

2071 Impacts (FWOP)									
Alternative	Flow	Contour	Length (river-feet)	Assessment Reach	Wetlands per River-Foot	Estimated total Impact acreage	Woody wetland impact (Est_impact_ac * % woody wetland in AR1)	Marsh Impact (Est_impact_ac * % herbaceous wetland in AR1)	% of impacts attributable to project vs. SLR
FWOP	Low Flow	0.5	7039	Fresh Water Area	0.090	633.51	261.45	372.06	
52_48	Low Flow	0.5	5210	Fresh Water Area	0.090	468.90	193.52	275.38	42.53
52_47	Low Flow	0.5	5101	Fresh Water Area	0.090	459.09	189.47	269.62	42.02
50_48	Low Flow	0.5	2996	Fresh Water Area	0.090	269.64	111.28	158.36	29.86
50_47	Low Flow	0.5	2813	Fresh Water Area	0.090	253.17	104.48	148.69	28.55
48_48	Low Flow	0.5	2624	Fresh Water Area	0.090	236.16	97.46	138.70	27.16
48_47	Low Flow	0.5	2412	Fresh Water Area	0.090	217.08	89.59	127.49	25.52
FWOP	Low Flow	5.0	8248	Brackish - Fresh Transition	0.086	710.98	191.47	519.51	52.88
52_48	Low Flow	5.0	4603	Brackish - Fresh Transition	0.086	396.78	106.85	289.93	38.51
52_47	Low Flow	5.0	4470	Brackish - Fresh Transition	0.086	385.31	103.77	281.55	37.82
50_48	Low Flow	5.0	3341	Brackish - Fresh Transition	0.086	287.99	77.56	210.44	31.25
50_47	Low Flow	5.0	3011	Brackish - Fresh Transition	0.086	259.55	69.90	189.65	29.06
48_48	Low Flow	5.0	2806	Brackish - Fresh Transition	0.086	241.88	65.14	176.74	27.63
48_47	Low Flow	5.0	1986	Brackish - Fresh Transition	0.086	171.19	46.10	125.09	21.27
FWOP	Low Flow	18.0	513	Saltwater		0.00	0.00	0.00	
52_48	Low Flow	18.0	1076	Saltwater		0.00	0.00	0.00	
52_47	Low Flow	18.0	1072	Saltwater		0.00	0.00	0.00	
50_48	Low Flow	18.0	735	Saltwater		0.00	0.00	0.00	
50_47	Low Flow	18.0	731	Saltwater		0.00	0.00	0.00	
48_48	Low Flow	18.0	607	Saltwater		0.00	0.00	0.00	
48_47	Low Flow	18.0	603	Saltwater		0.00	0.00	0.00	

Cooper River Calculations

2022 Condition Historical SLR									
Alternative	Flow	Contour	Length (river-feet)	Assessment Reach	Wetlands per River-Foot	Estimated total Impact acreage	Woody wetland impact (Est_impact_ac * % woody wetland in AR1)	Marsh Impact (Est_impact_ac * % herbaceous wetland in AR1)	% of impacts attributable to project vs. SLR
FWOP	Low Flow	0.5	1092	Fresh Water Area	0.090	98.28	40.56	57.72	
48-48	Low Flow	0.5	1214	Fresh Water Area	0.090	109.26	45.09	64.17	52.65
50-48	Low Flow	0.5	2062	Fresh Water Area	0.090	185.58	76.59	108.99	65.38
52-48	Low Flow	0.5	2890	Fresh Water Area	0.090	260.10	107.34	152.76	72.58
FWOP	Low Flow	5.0	864	Brackish - Fresh Transition	0.086	74.48	30.74	43.74	
48_48	Low Flow	5.0	2814	Brackish - Fresh Transition	0.086	242.57	100.11	142.46	76.51
50_48	Low Flow	5.0	4254	Brackish - Fresh Transition	0.086	366.69	151.33	215.36	83.12
52_48	Low Flow	5.0	5632	Brackish - Fresh Transition	0.086	485.48	200.36	285.12	86.70
FWOP	Low Flow	18.0	164	Saltwater	N/A	N/A	N/A	N/A	N/A
48_48	Low Flow	18.0	838	Saltwater	N/A	N/A	N/A	N/A	N/A
50_48	Low Flow	18.0	1004	Saltwater	N/A	N/A	N/A	N/A	N/A
52_48	Low Flow	18.0	1277	Saltwater	N/A	N/A	N/A	N/A	N/A

Ashley River Calculations

2071 SLR									
Alternative	Assessment Reach	Flow Condition	Contour	Length (River-Foot)	Wetland acres/River-Foot)	Estimated Impact Acreage	Marsh Impacts	Forested Impacts	% of impacts attributable to project vs. SLR
FWOP	Brackish - Fresh Transition	Low Flow	0.5	2935	0.057	167.30	118.11	49.18	
52_47	Brackish - Fresh Transition	Low Flow	0.5	430	0.057	24.51	17.30	7.21	12.78
52_48	Brackish - Fresh Transition	Low Flow	0.5	406	0.057	23.14	16.34	6.808	12.158
50_47	Brackish - Fresh Transition	Low Flow	0.5	328	0.057	18.70	13.20	5.50	10.05
50_48	Brackish - Fresh Transition	Low Flow	0.5	326	0.057	18.58	13.12	5.46	10.00
48_48	Brackish - Fresh Transition	Low Flow	0.5	298	0.057	16.99	11.99	4.99	9.22
48_47	Brackish - Fresh Transition	Low Flow	0.5	291	0.057	16.59	11.71	4.88	9.02
FWOP	Salt - Brackish Transition	Low Flow	5.0	2572	0.068	174.90	145.93	28.96	
52_48	Salt - Brackish Transition	Low Flow	5.0	558	0.068	37.94	31.66	6.28	17.83
48_47	Salt - Brackish Transition	Low Flow	5.0	235	0.068	15.98	13.33	2.65	8.37
48_48	Salt - Brackish Transition	Low Flow	5.0	242	0.068	16.46	13.73	2.73	8.60
50_47	Salt - Brackish Transition	Low Flow	5.0	329	0.068	22.37	18.67	3.70	11.34
50_48	Salt - Brackish Transition	Low Flow	5.0	336	0.068	22.85	19.06	3.78	11.55
52_47	Salt - Brackish Transition	Low Flow	5.0	1014	0.068	68.95	57.53	11.42	28.28
FWOP	Saltwater	Low Flow	18.0	3583					
52_48	Saltwater	Low Flow	18.0	2751					
48_47	Saltwater	Low Flow	18.0	2737					
48_48	Saltwater	Low Flow	18.0	1911					
50_47	Saltwater	Low Flow	18.0	1855					
50_48	Saltwater	Low Flow	18.0	1565					
52_47	Saltwater	Low Flow	18.0	1509					

Ashley River Calculations

2022 SLR									
Alternative	Assessment Reach	Flow Condition	Contour	Length (River-Feet)	Wetland acres/River-Foot	Estimated Impact Acreage	Marsh Impacts	Forested Impacts	% of impacts attributable to project vs. SLR
FWOP	Brackish - Fresh Transition	Low Flow	0.5	191	0.057	10.89	7.69	3.20	
48_48	Brackish - Fresh Transition	Low Flow	0.5	200	0.057	11.40	8.05	3.35	51.15
50_48	Brackish - Fresh Transition	Low Flow	0.5	291	0.057	16.59	11.71	4.88	60.37
52_48	Brackish - Fresh Transition	Low Flow	0.5	366	0.057	20.86	14.73	6.13	65.71
FWOP	Salt - Brackish Transition	Low Flow	5.0	313	0.068	21.28	17.76	3.52	
48_48	Salt - Brackish Transition	Low Flow	5.0	333	0.068	22.64	18.89	3.75	51.55
50_48	Salt - Brackish Transition	Low Flow	5.0	1211	0.068	82.35	68.71	13.64	79.46
52_48	Salt - Brackish Transition	Low Flow	5.0	1355	0.068	92.14	76.88	15.26	81.24
FWOP	Saltwater	Low Flow	18.0	593					
48_48	Saltwater	Low Flow	18.0	2529					
50_48	Saltwater	Low Flow	18.0	3194					
52_48	Saltwater	Low Flow	18.0	3867					

Wando River Calculations

2071 SLR									
Alternative	Assessment Reach	Flow Condition	Contour	Length (River-Feet)	Wetland acres/River-Foot	Estimated Impact Acreage	Marsh Impacts	Forested Impacts	% of impacts attributable to project vs. SLR
FWOP	saltwater	Low Flow	18	3071.00	0.17	515.93	411.50	104.42	
52_48	saltwater	Low Flow	18	16459.00	0.17	2765.11	2205.45	559.66	84.28
52_47	saltwater	Low Flow	18	16437.00	0.17	2761.42	2202.51	558.91	84.26
50_48	saltwater	Low Flow	18	15553.00	0.17	2612.90	2084.05	528.85	83.51
50_47	saltwater	Low Flow	18	15504.00	0.17	2604.67	2077.49	527.19	83.47
48_48	saltwater	Low Flow	18	13006.00	0.17	2185.01	1742.76	442.25	80.90
48_47	saltwater	Low Flow	18	11965.00	0.17	2010.12	1603.27	406.85	79.58

Wando River Calculations

	2022 SLR									
Alternative	Assessment Reach	Flow Condition	Contour	Length (River-Foot)	Wetland acres/River-Foot)	Estimated Impact Acreage	Marsh Impacts	Forested Impacts	% of impacts attributable to project vs. SLR	
FWOP	saltwater	Low Flow	18	588.00	0.17	98.78	78.79	20.0		
48_48	saltwater	Low Flow	18	12673.00	0.17	2129.06	1698.14	430.92	95.57	
50_48	saltwater	Low Flow	18	15890.00	0.17	2669.52	2129.21	540.31	96.43	
52_48	saltwater	Low Flow	18	18292.00	0.17	3073.06	2451.07	621.99	96.89	