Wilmington Harbor, North Carolina
Navigation Improvement Project

Integrated
Section 203 Study
&
Environmental Report

APPENDIX F

WETLAND IMPACT ASSESSMENT

February 2020

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List of Acronyms

%	Percent
DCA	Dial Cordy and Associates Inc.
DEM	Digital Elevation Model
EIS	Environmental Impact Statement
FT	Feet
FWOP	Future Without Project
FWP	Future With Project
GIS	Geographic Information System
NDVI	Normalized Difference Vegetation Index
PPT	Parts Per Thousand
RSLR	Relative Sea Level Rise
TSP	Tentatively Selected Plan
TWG	Technical Working Group
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

1 INTRODUCTION

Dial Cordy and Associates Inc. (DCA) conducted an assessment of potential tidal wetland impacts associated with proposed improvements to the Wilmington Harbor federal navigation channel. The wetland assessment was conducted as a component of the Wilmington Harbor Navigation Improvement Project Section 203 Feasibility Study & Environmental Report to evaluate the potential effects of proposed channel modifications on tidal wetlands within the Cape Fear River estuary. The composition of tidal wetlands along the Cape Fear River, Northeast Cape Fear River, and Black River is largely determined by their position along salinity gradients. Accordingly, a shift in the salinity gradient could potentially alter the composition, distribution, and relative extent of saltwater, brackish, and freshwater tidal wetlands within the Cape Fear River system. The wetland impact assessment included the development of an updated baseline tidal wetland classification for the study area and analyses of potential salinity driven changes in the composition and distribution of tidal wetland communities under Future Without Project (FWOP) and Future With Project (FWP) conditions. Potential salinity changes attributable to proposed harbor modifications and various sea level rise scenarios were evaluated under typical and low flow conditions using numerical hydrodynamic modeling. Projected future condition salinity isopleths were interpolated with the baseline wetland classification to predict potential changes in the composition and distribution of salt, brackish, and freshwater tidal wetland communities.

1.1 Technical Working Group

Resource agencies participated in this assessment through an interagency Wetland Technical Working Group (TWG) that was formed in December 2018. The Wetland TWG is an interagency team of representatives from state and federal resource agencies (Main Report, Appendix Q). The principal purpose of the TWG is to provide guidance and concurrence on the technical approach and procedures used to quantify potential wetlands effects. Wetland TWG meetings were held in Wilmington, North Carolina, on 20 December 2018 and 10 April 2019. This Draft Wetland Impact Assessment will be submitted to the TWG for review and comment. Ultimately, the goal is to reach agency concurrence on the final wetland impacts that will be incorporated into the Integrated Feasibility/Environmental Impact Statement (EIS) study document. Upon concurrence on the projected wetland effects, the TWG will participate in a functional assessment and evaluation of mitigation requirements. The results of this wetland assessment and the involvement of the Wetland TWG will be summarized in the Integrated Feasibility/EIS study document.

2 BASELINE TIDAL WETLAND CLASSIFICATION AND MAPPING

2.1 Background - Historical and Current Vegetation Change in the Cape Fear River Estuary

Human activities and sea level rise over the last two centuries have dramatically altered the composition and distribution of tidal wetland communities in the Cape Fear River estuary (Hackney and Yelverton 1990). The initial impact of European settlement, beginning in the late 1700s, was the conversion of essentially all tidal freshwater swamp forests in the lower to middle estuary to rice plantations. In the late 1800s, the United States Army Corps of Engineers (USACE) initiated major navigation dredging modifications of river channel for access to the Port of Wilmington. Incremental channel deepening and sea level rise since the late 1800s have increased the tidal range in the Cape Fear River, resulting in salinity intrusion and the conversion of tidal freshwater swamp forests to brackish marsh along the middle to upper reaches of the estuary. Hackney and Yelverton (1990) suggest that the distribution of former rice fields is a reliable indicator of the pre-settlement extent of tidal freshwater wetlands along the river, as rice is incapable of growing in fields that are flooded by saline water >1 parts per thousand (ppt). Based on this indicator, tidal freshwater wetlands would have been present at least as far downriver as Orton Plantation approximately (~) 12 miles above the river mouth. Changes are ongoing at the upper ends of the salinity gradients in the Cape Fear River, Northeast Cape Fear River, and tidal creeks. Hackney and Avery (2015) indicate that zones of active salinity-driven swamp forest to marsh conversion in the Cape Fear River estuary occur where 12 to 25 percent (%) of the flooding high tide events expose wetlands to saline waters >1 ppt. Wetlands above the conversion zone that are flooded by waters >1 ppt less than 12% of the time consist of relatively stable swamp forest; whereas, wetlands below the conversion zone that are flooded by >1 ppt waters more than 25% of the time consist of various forms of tidal marsh.

2.2 Wetland Classification Technical Approach

2.2.1 Delineation of the Tidal Wetland Assessment Area

The wetland assessment area encompasses the entire tidally affected estuarine/freshwater river-floodplain system of the lower Cape Fear River basin. As defined by the upper limits of tidal influence in the three main river channels, the assessment area includes the mainstem Cape Fear River up to Lock and Dam #1 (~60 river miles), the Northeast Cape Fear River from its confluence with the Cape Fear River to NC HWY 53 (~48 river miles), and the Black River from its confluence with the Cape Fear River to NC HWY 53 (~24 river miles). A 5-meter elevation contour derived from United States Geological Survey (USGS) digital elevation models (DEMs) was established as an initial assessment area boundary to capture all tidally affected tributaries and floodplains (Figure 1). The 5-meter boundary was subsequently refined to eliminate non-tidal areas through the classification process and associated groundtruthing efforts, as well as analyses of other resources such as soil and lidar data. The final assessment area encompasses a total area of 126,324 acres.

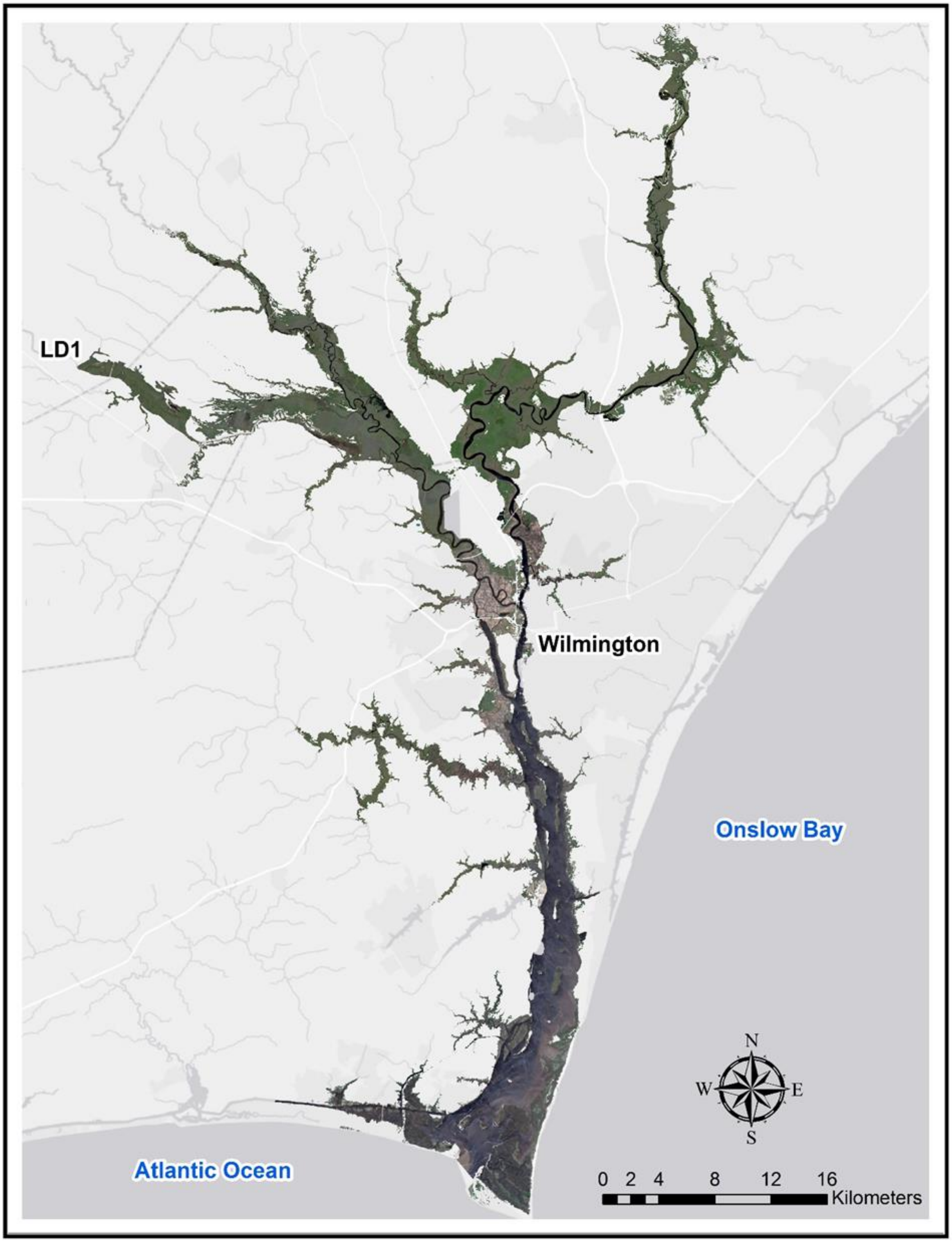

Figure 1
Study Area (Landsat 8 RGB Image Clipped to 5-meter USGS DEM Contour)

2.2.2 Classification and Field Survey Methodology

Dial Cordy and Associates Inc. used ENVI 5.4 image analysis software and moderate resolution satellite imagery (Landsat 8) to perform a geographic information system (GIS)-based (ArcGIS for Desktop 10) supervised classification of tidal wetlands within the Cape Fear River watershed. The ENVI supervised classification employs a maximum likelihood method to group pixels into spectral classes based on user defined training data. Early fall Landsat 8 imagery dated 22 October 2016 was selected to capture the color contrast associated with the early (late summer) senescence of monospecific cattail stands that dominant the upper mesohaline to oligohaline reaches of the estuary (Figure 2). Field surveys that included the use of a Phantom 4 Pro Quadcopter drone were used to collect training data for use in refining the classification (Figure 3).

As a precursor to the supervised classification, DCA performed a K-means unsupervised classification to gain a better understanding of spectral class variability. An unsupervised classification is an exploratory procedure based solely on software imagery analysis without the assistance of user-defined training data. The K-means algorithm calculates initial class means randomly in the data and then iteratively clusters all pixels into the most similar class using a minimum distance technique. The results of the unsupervised classification indicated a need to separate the vegetated and non-vegetated classes prior to the initial supervised classification. The Normalized Difference Vegetation Index (NDVI) was used to isolate the non-vegetated classes for subsequent removal via masking (Figure 4). The NDVI makes use of inherent properties found in plant leaf morphology and chlorophyll to isolate vegetation from non-vegetated cover types. After removing the non-vegetated classes, a supervised classification was run using the Maximum Likelihood Classifier method and a minimum of 100 training sites per class. The Maximum Likelihood Classification calculates the probabilities of a given pixel belonging to a set of user defined classes, and assigns the pixel to the highest probability class. Training site data were developed from field surveys and analysis of high resolution orthoimagery. In order to remove “noise” from the supervised classification, post classification processing was performed using the Majority Analysis Filter and a 3 x 3 kernel. The Majority Filter algorithm replaces the center pixel in the kernel with the majority class value of the kernel. An accuracy assessment of the initial supervised classification was performed to identify areas of confusion between the classes. The results of the initial accuracy assessment (accuracy of 72%) were used to refine training sites and select sites for field verification data collection. Additions of field verification data were used to improve the accuracy of the results in a series of iterative supervised classification reruns, resulting in a final classification accuracy of 84.33%. The process was completed by merging the excluded non-vegetated areas with the supervised classification in ArcMap.

Figure 2
Color Contrast between Early Senescent Cattail Marsh (right) and Fringing Smooth Cordgrass Marsh (left), Northeast Cape Fear River – 9 September 2017

Figure 3
Aerial Image Captured by Phantom 4 Pro Quadcopter

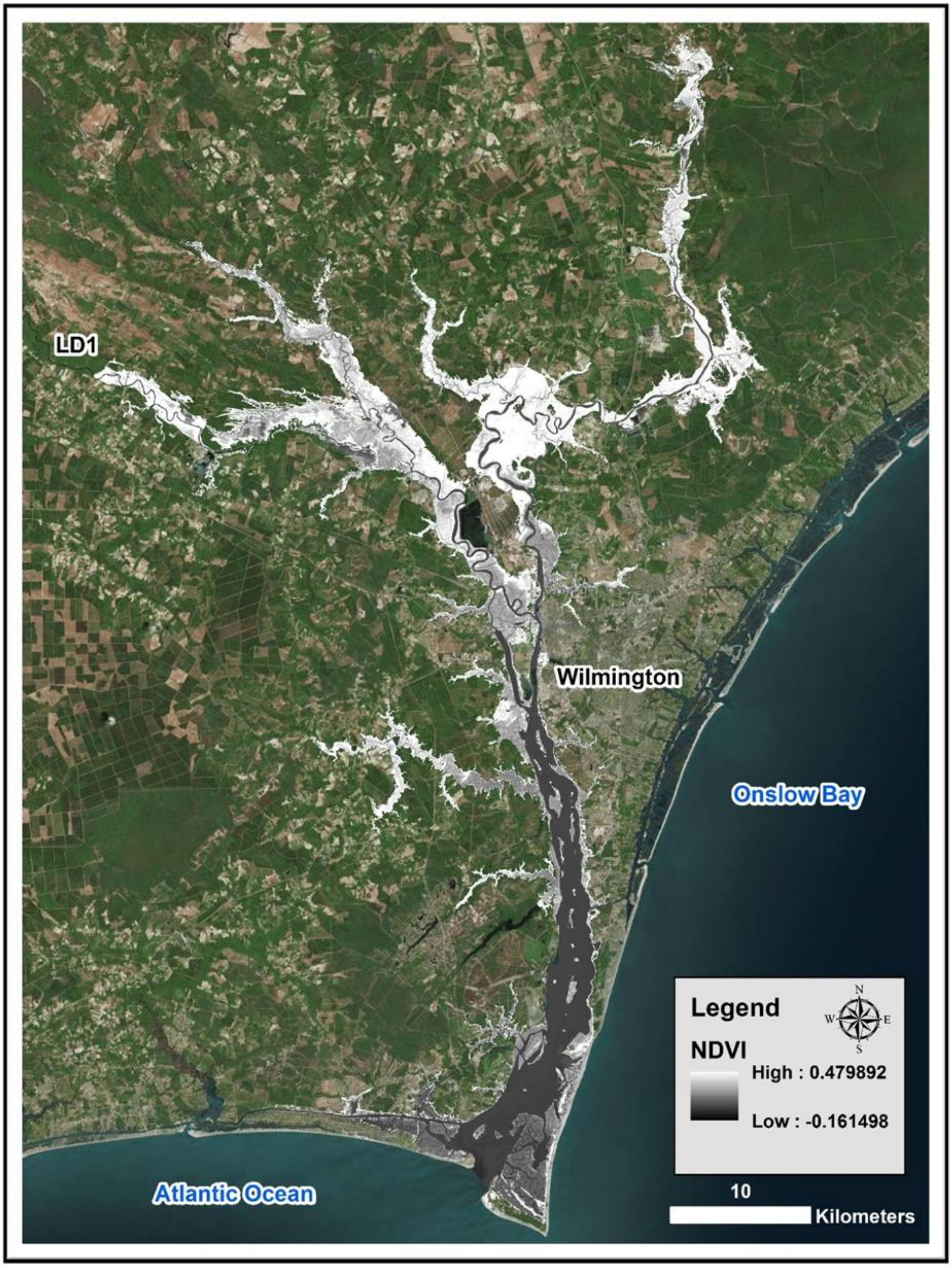

Figure 4
Normalized Difference Vegetation Index

Field surveys for purposes of collecting training and verification data were conducted on 31 August, 7-8 October, 14-15 October, and 24 November 2017. Field sites were accessed by boat and surveyed on foot. In the case of the most expansive tidal marshes, a Phantom 4 Pro Quadcopter drone was used as a supplemental field verification tool (Figure 3). Field surveys were used to define the species composition of vegetation classes at specific points along both river-parallel and river-perpendicular salinity gradients throughout the polyhaline, mesohaline, oligohaline, and freshwater tidal reaches of the river systems. Field surveys were also used to evaluate and document the general sequence of community-level compositional changes along the main river systems and their principal tributaries, including small-scale salinity driven changes that were below the resolution of the classification grid (30 x 30 meter pixel). The identification of transition points between broader scale saltmarsh, brackish marsh, and freshwater wetland salinity zones was a priority, and these areas were afforded the most intensive level of effort.

2.3 Results

The final supervised classification identified 66,671 acres of tidal wetlands distributed among six wetland classes (Table 1, Figure 5). An indexed set of baseline classification maps showing the distribution of tidal wetland classes within the study area is provided in Appendix A. The sections below describe the composition and distribution of the tidal wetland classes and the general sequence of community-level changes along salinity gradients in the mainstem Cape Fear River, Northeast Cape Fear River, and two of the tidal creeks (Town Creek and Smith Creek) that are representative of tributaries within the upper and lower estuary.

Table 1
Baseline Tidal Wetland Classification Results

Tidal Wetland Class	**Area (acres)**	**Percent**
Smooth Cordgrass Dominant	12,733	19.1
Brackish Mix	696	1.0
Cattail Dominant	6,066	9.1
Common Reed	2,403	3.6
Freshwater Marsh	1,379	2.1
Tidal Swamp Forest	43,394	65.1
Total	**66,671**	**100**

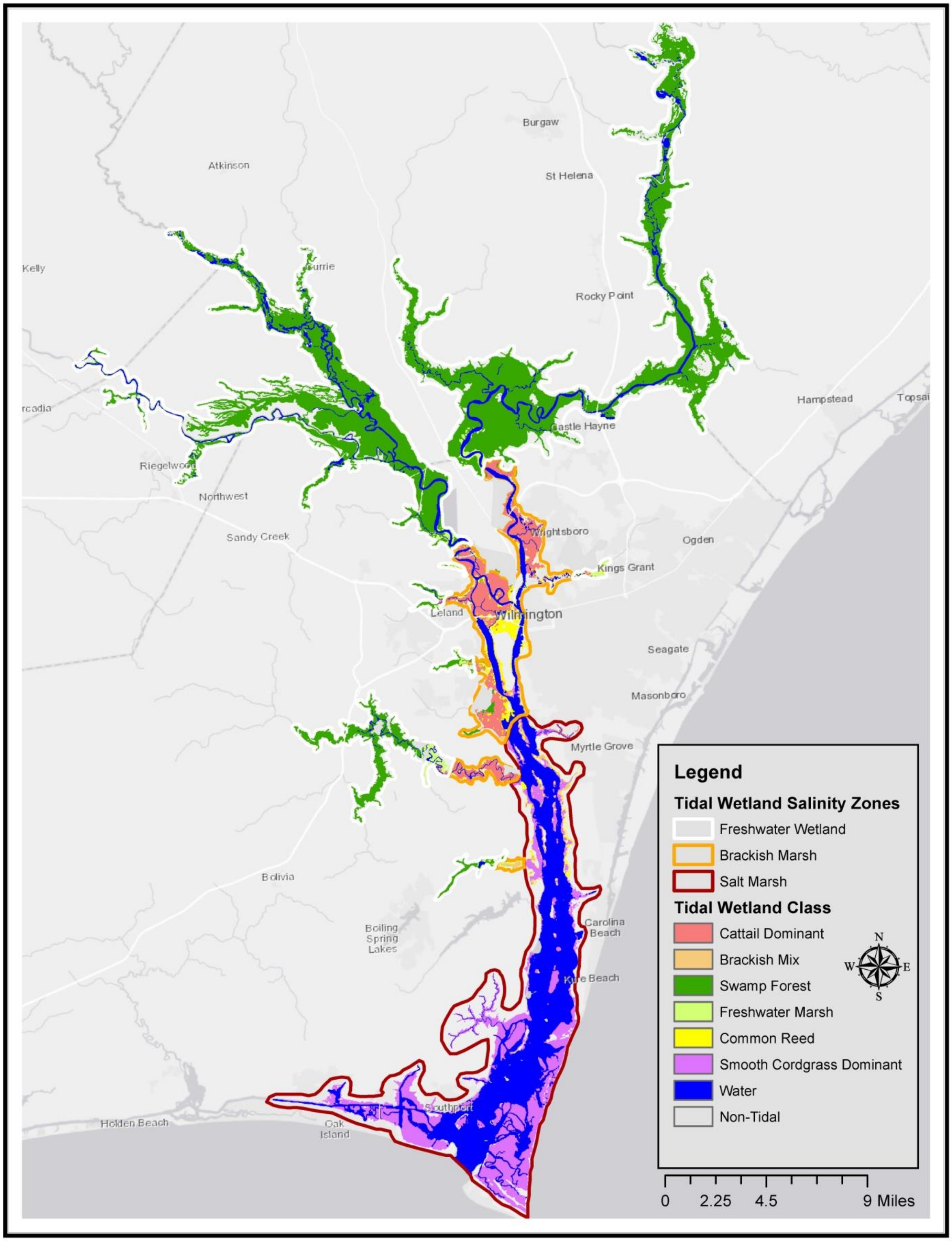

Figure 5
Baseline Wetland Classification

2.3.1 Cape Fear River Mainstem

2.3.1.1 Tidal Salt Marsh Zone

Salt marshes consisting of nearly monospecific stands of smooth cordgrass (*Spartina alterniflora*) dominate the contiguous tidal floodplains along the lower Cape Fear River mainstem from the river mouth up to Barnards Creek (~21 river miles) (Appendix A Figures A2 and A3). Dense patches of common reed (*Phragmites australis*) are interspersed among the smooth cordgrass marshes. Common reed is essentially restricted to deposits of dredged material and other fill that are higher than the natural tidal floodplain. Dredged material deposition in tidal marshes produces microtidal (i.e., tidally restricted) areas with reduced soil salinities that are susceptible to Phragmites invasion (Fell et al. 2002). . Well-defined high marsh zones are generally absent along the lower Cape Fear River mainstem. Typical high marsh species such as black needlerush (*Juncus roemerianus*) and saltmeadow cordgrass (*S. patens*) generally comprise only a narrow and discontinuous fringe along the upper edge of the salt marsh. Along the upper portion of the reach, small patches of black needlerush are interspersed among the smooth cordgrass marshes, and big cordgrass (*S. cynosuroides*) and salt-marsh bulrush (*Bolboschoenus robustus*) occur intermittently on the slightly elevated river banks immediately adjacent to the channel.

2.3.1.2 Tidal Brackish Marsh Zone

The transition from salt to brackish marsh along the Cape Fear River mainstem is marked by the decline of smooth cordgrass and the establishment of narrow-leaved cattail (*Typha angustifolia*) as the primary dominant species. This transition occurs abruptly in the vicinity of Barnards Creek (~2.5 river miles below the state port). The brackish marsh zone along the Cape Fear River mainstem extends approximately ten miles upriver to the I-140 Bridge (Appendix A Figure A7). The brackish reach is characterized by distinct vegetation zones; including a narrow fringing smooth cordgrass zone along the edge of the river channel; a narrow top-of-bank zone dominated by big cordgrass and salt-marsh bulrush; and a broad outer marsh zone dominated by narrow-leaved cattail. Cattail is a strong dominant of the brackish marshes along the Cape Fear River mainstem, forming vast monospecific stands across large sections of the tidal floodplain. The cattail-dominated marshes are interspersed with dense patches of common reed and areas of mixed brackish marsh that are dominated by variable combinations of cattail, common reed, black needlerush, big cordgrass, and salt-marsh bulrush. In relation to the lower salt marsh reach, there is a marked increase in the extent of common reed along the brackish reach that corresponds to an increase in dredged material deposits and other soil/topographical disturbance in the vicinity of downtown Wilmington. Along the upper portion of the Cape Fear River brackish reach (above the Northeast Cape Fear River confluence), species that are characteristic of diverse freshwater marsh communities begin to occur sporadically along the margins of the channel; including wild rice (*Zizania aquatica*), bull-tongue arrowhead (*Sagittaria lancifolia*), pickerelweed (*Pontederia cordata*), dotted smartweed (*Persicaria punctatum*), arrow-arum (*Peltandra virginica*), and water primrose (*Ludwigia bonariensis*). Freshwater species occur with increasing regularity toward the upper end of the brackish reach, eventually becoming a consistent component of the marsh fringe and gradually moving landward into the main body of the marsh.

2.3.1.3 Tidal Freshwater Wetland Zone

This transition from brackish to freshwater marsh is marked by the decline of cattail, big cordgrass, and black needlerush as dominant marsh constituents and the establishment of a diverse assemblage of freshwater species as the predominant marsh community. Species typical of the freshwater marsh community include wild rice, bull-tongue arrowhead, arrow-arum, pickerelweed, dotted smartweed, water primrose, sawgrass (*Cladium jamaicense*), Olney's three-square (*Schoenoplectus americanus*), tussock sedge (*Carex stricta*), water parsnip (*Sium suave*), marsh mallow (*Kosteletzkya pentacarpos*), salt-marsh fleabane (*Pluchea odorata*), salt-marsh aster (*Symphyotrichum tenuifolium*), and salt-marsh water-hemp (*Amaranthus cannabinus*). The transition to freshwater tidal marsh along the Cape Fear River mainstem occurs just above the I-140 Bridge (Appendix A Figure A7). The I-140 Bridge also marks the establishment of freshwater swamp forests as the dominant tidal floodplain community. Freshwater marshes are primarily confined to a narrow (≤100-feet-wide) zone along the edge of the channel, with freshwater swamp forests occupying the vast majority of tidal floodplain. Fringing tidal freshwater marshes occur intermittently along the ~4-mile river reach above the I-140 Bridge before being displaced entirely by tidal swamp forests. The overall extent of tidal freshwater marsh along the Cape Fear River mainstem is very limited. Although classified as freshwater marsh based on species composition, this community type appears to occur at the lowermost end of the oligohaline salinity range in the zone of active swamp forest to marsh conversion. At the uppermost end of the active conversion zone where changes are just beginning to occur, it is confined to a narrow fringing zone along the margins of the river channel. Towards the downstream end of the conversion zone where the effects of salinity changes have advanced further landward, tidal freshwater marshes are more extensive across the tidal floodplain.

River-contiguous tidal freshwater swamp forests dominate the Cape Fear River tidal floodplain from the I-140 Bridge to the Black River confluence (Appendix A Figure A9). The swamp forests along this ~10-mile reach receive tidal flow directly from the mainstem channel. The tidal swamp forest community is strongly dominated by bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), and swamp tupelo (*N. biflora*). The Cape Fear River floodplain above the Black River confluence has a complex depositional structure. In lieu of contiguous tidal floodplains, the areas directly bordering the river are composed of non-tidal mesic alluvial forests on natural levees. The levee forests grade downward and away from the river to cypress-gum dominated sloughs and complex ridge and swale systems. The initial series of wet sloughs and swales on Roan Island, although separated by levees from the majority of the Cape Fear River channel, is directly connected to both the Cape Fear River and Black River at their confluence. Above Roan Island, the floodplain sloughs and swales are isolated from the river and its tidal influence. Of the three main river systems that comprise the study area, these depositional features are unique to the brownwater floodplain of the Cape Fear River.

2.3.2 Northeast Cape Fear River and Black River

Brackish marshes dominate the tidal floodplains along the lower ~8-mile reach of the Northeast Cape Fear River from its confluence with the Cape Fear River (Appendix A Figure A7). Brackish marshes along the Northeast Cape Fear River are similar in composition to those of the Cape Fear River, with large monospecific cattail stands comprising the primary dominant assemblage. The cattail stands are interspersed with dense patches of common reed and areas of mixed brackish marsh that are dominated by variable combinations of cattail, common reed, black needlerush, big cordgrass, and salt-marsh bulrush. At the approximate mid-point of the brackish reach, species that are characteristic of freshwater marsh communities begin to occur along the margins of the channel. Freshwater species occur with increasing regularity along the upper 4-mile section of the brackish reach, eventually becoming a consistent component of the marsh fringe and gradually moving landward into the main body of the marsh. The assemblage of freshwater species that occurs along the Northeast Cape Fear River brackish reach is same as that described for the Cape Fear River.

The transition from brackish to freshwater marsh along the Northeast Cape Fear River (Appendix A Figure A10) is similar to that described for the Cape Fear River, with the principal brackish marsh dominants (cattail, big cordgrass, and black needlerush) giving way to a diverse assemblage of freshwater species. The transition to freshwater marsh occurs concurrently with the establishment of expansive tidal freshwater swamp forests along the Northeast Cape Fear River. The freshwater marshes are confined to a narrow zone along the edge of the channel, with freshwater swamp forests occupying the broad landward portion of the tidal floodplain. Fringing tidal freshwater marshes occur intermittently along the ~4-mile river reach above the brackish reach before being displaced entirely by tidal swamp forests. Tidal freshwater marshes along the Northeast Cape Fear River have a very limited distribution and are a relatively minor component of the overall tidal floodplain wetland system. The depositional features that characterize the brownwater floodplain of the Cape Fear River are absent from the blackwater floodplain of the Northeast Cape Fear River. In contrast to the Cape Fear River, contiguous tidal floodplains and associated tidal swamp forest communities occur along the entire upper tidal reach of the Northeast Cape Fear River.

The tidal floodplain of the Black River, from its confluence with the Cape Fear River to the upper limit of tidal influence, is dominated by tidal swamp forest communities (Appendix A Figure A9). The depositional features that characterize the Cape Fear River brownwater floodplain are absent from the blackwater floodplain of the Black River. Contiguous tidal floodplains and tidal swamp forest communities occur along the entire tidal reach of the Black River.

2.3.3 Town Creek and Smith Creek

Town Creek and its associated tidal floodplain extend ~20 miles beyond the contiguous mainstem Cape Fear River tidal floodplain. The tidal wetlands associated with Town Creek (Appendix A Figure A6) are characterized by compositional changes along salinity gradients that are similar to those of the wetlands along the mainstem Cape Fear River. The lower ~0.3-mile reach of Town Creek above the Cape Fear River confluence is dominated by smooth cordgrass salt marsh communities. Above the lower ~0.5-mile reach, the smooth cordgrass community is rapidly displaced by cattail-dominant brackish marshes. Monospecific cattail stands consistently dominant the majority of the tidal floodplain along the ~8-mile reach above the lower salt marsh zone. Along the lower section of the brackish reach, a continuous fringe of big cordgrass occurs on the slightly elevated banks immediately adjacent to the channel. At the approximate mid-point of the reach (just above the HWY 133 bridge), species that are characteristic of freshwater marsh communities begin to occur sporadically along the margins of the channel; including wild rice, bull-tongue arrowhead, arrow-arum, pickerelweed, Olney’s three-square, salt marsh aster, and salt-marsh fleabane. Concurrently, the narrow band of big cordgrass on the elevated banks is replaced by a broader and more diverse brackish assemblage of big cordgrass, salt-marsh bulrush, black needlerush, cattail, and common reed.

Freshwater species occur with increasing regularity along the reach above the HWY 133 bridge, eventually dominating the marsh fringe and the narrow top-of-bank zone. The transition from brackish to freshwater marsh along Town Creek occurs approximately four miles above the HWY 133 bridge. The transition is marked by the rapid displacement of the dominant cattail stands by a diverse freshwater marsh assemblage similar to those of the Cape Fear River and Northeast Cape Fear River. Freshwater marshes dominate the entire tidal floodplain along the ~5-mile reach above the brackish/freshwater transition. The freshwater marshes along Town Creek have a highly irregular overstory of snags and severely salt-stressed swamp forest trees, and it appears that the freshwater marshes may be expanding upstream as areas of swamp forest succumb to increased salinity levels. As a result, the transition from tidal freshwater marsh to tidal swamp forest along Town Creek is gradual and irregular, with tree densities varying widely along a relatively lengthy transitional reach.

Smith Creek and its associated tidal floodplain extend approximately eight miles beyond the contiguous mainstem Northeast Cape Fear River tidal floodplain. The lower ~5-mile reach of Smith Creek above its confluence with the Northeast Cape Fear River is dominated by brackish marsh communities (Appendix A Figure A8). Large monospecific cattail stands are interspersed with dense patches of common reed and small areas of mixed brackish marsh. A continuous narrow fringe of big cordgrass occurs on the slightly elevated banks immediately adjacent to the channel. At the approximate mid-point of the brackish reach, species that are characteristic of freshwater marsh communities begin to occur sporadically along the margins of the channel. Freshwater species occur with increasing regularity along the brackish reach above, eventually forming a consistent marsh fringe near the upper end of the reach. Above the ~5-mile brackish reach, the dominant large cattail stands are abruptly displaced by a diverse tidal freshwater marsh-swamp forest mosaic. The freshwater marsh-swamp forest assemblage dominates the remainder of the tidal reach above.

3 WETLAND IMPACT ANALYSIS

3.1 Impact Analysis Methodology

3.1.1 Salinity Modeling

The Delft 3D hydrodynamic model was used to simulate Existing Conditions (Baseline) estuarine salinity conditions and salinity changes under the No Action Alternative (FWOP) and Tentatively Selected Plan (TSP) (FWP). The main Delft 3D hydrodynamic salinity model was used to model salinity in the mainstem Cape Fear River and Northeast Cape Fear River channels, while a separate local model was developed for the tidal creeks to enable more accurate simulation of hydrological conditions within each of the smaller discrete watersheds. Year-long Existing Conditions model runs were developed for dry, typical, and high annual flow conditions. Year-long No Action and TSP model runs representing conditions at the end of the proposed project's design life in 2077 were developed for dry, typical, and high annual flow conditions and three relative sea level rise (RSLR) scenarios (low, intermediate, and high). The low RSLR scenario (RSLR1) represents sea level change at the measured historical rate of 2.3 millimeters per year at Wilmington based on tide gauge data from 1935-2017. Sea level change rates for the intermediate (RSLR2) and high (RSLR3) scenarios were derived from the extrapolation of rate curves developed by the National Research Council (1987). Projected future sea level increases through 2077 are 0.34 feet (ft) under the low scenario, 0.88 ft under the intermediate scenario, and 2.57 ft under the high scenario. No Action and TSP model runs were developed for all three annual flow conditions (dry, typical, and high) under RSLR1, while RSLR2 and RSLR3 model runs were limited to the typical annual flow scenario. The salinity modeling methods and results are described in detail in the Main Report Appendix A: Engineering.

3.1.2 Assessment of Wetland Impacts

Surface salinity data were extracted from the year-long model simulation results and averaged for each grid cell to produce average annual surface salinity GIS layers for the various Existing Conditions, No Action, and TSP flow and RSLR scenarios. Based on the grid cell average salinity values, salinity isopleths were added to define the boundaries or thresholds between the polyhaline, mesohaline, oligohaline, and tidal freshwater salinity zones in the various river and tidal creek channels (Figures 6 and 7). The model-projected Existing Conditions salinity isopleths [polyhaline-mesohaline (18 ppt), mesohaline-oligohaline (5 ppt), and oligohaline-tidal freshwater (0.5 ppt)] and the projected changes in the isopleths under the various No Action and TSP scenarios, in combination with the baseline wetland classification, comprise the basis for the analysis of wetland effects. This assessment is concerned only with the salinity of surface layer waters that would be expected to flood the adjoining tidal floodplains and wetlands during high tide events. All salinity data were extracted from the model results at a depth of three feet.

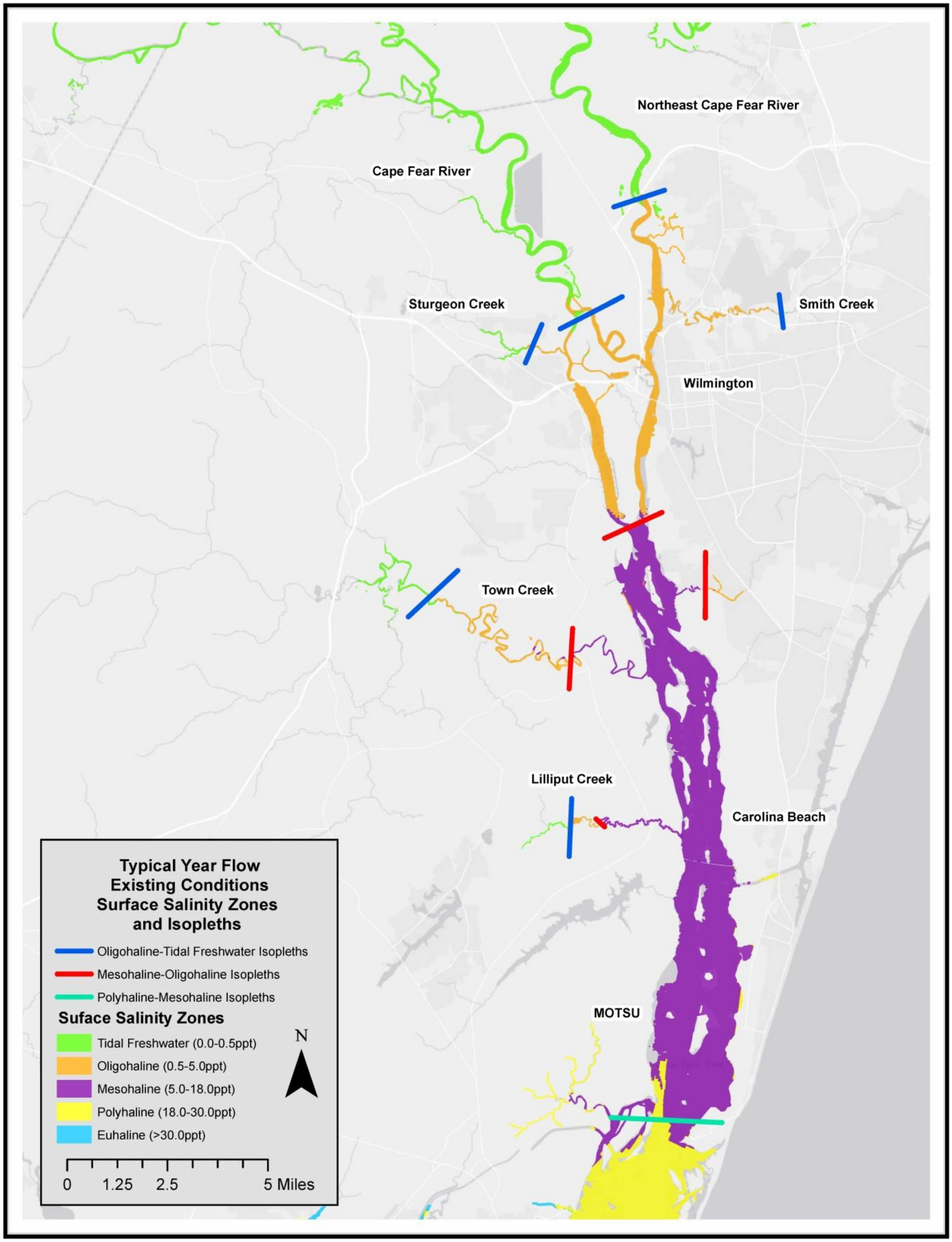

Figure 6
Existing Conditions Typical Year Flow Salinity Isopleths and Zones

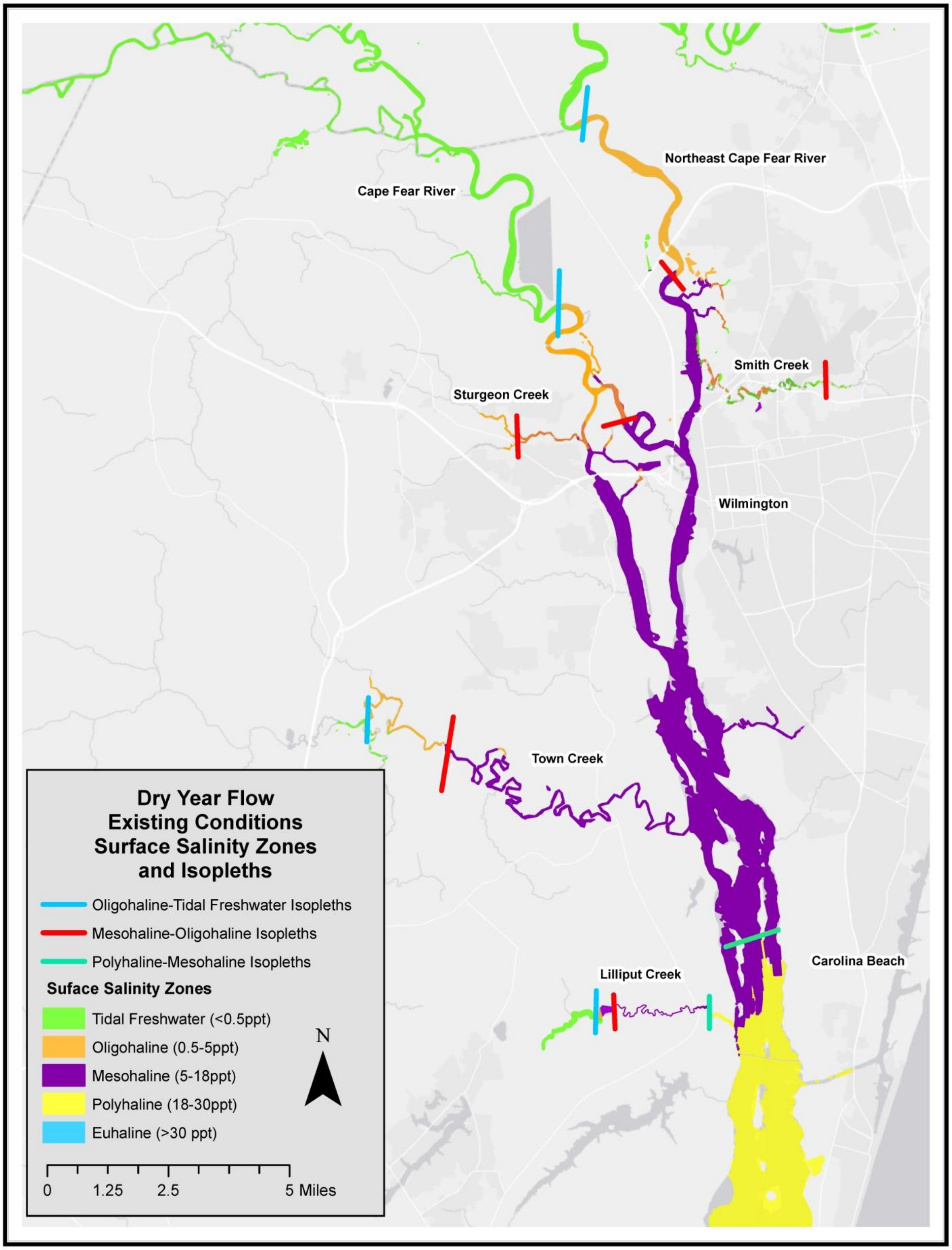

Figure 7
Existing Conditions Dry Year Flow Salinity Isopleths and Zones

The projected Existing Conditions salinity isopleths under the three flow scenarios (low, typical, and high flow) were evaluated for agreement with existing tidal wetland community thresholds, as defined by the baseline wetland classification. This assessment focused on agreement between the projected 0.5 ppt oligohaline-tidal freshwater isopleths and existing brackish marsh to tidal freshwater wetland thresholds. The active tidal swamp forest to tidal marsh conversion zone at the uppermost limit of the estuarine salinity gradient was defined as the optimal isopleth location for purposes of this analysis. Analyses of projected isopleths in the Cape Fear River, Northeast Cape Fear River, and tidal creeks were conducted independently in accordance with the use of the separate Delft 3D main and local salinity models. In the cases of the mainstem Cape Fear River and Northeast Cape Fear River, the projected typical flow year Existing Conditions oligohaline-freshwater isopleths fell ~3.0 miles below the active swamp forest to freshwater marsh transition zones on both rivers, whereas the dry flow year Existing Conditions oligohaline-freshwater isopleths fell approximately in the middle of the active transition zones (Figures 8 and 9). Thus, the typical flow Existing Conditions isopleths exhibited poor agreement with existing wetland community thresholds, whereas agreement between the dry year Existing Conditions isopleths and existing community thresholds was optimal. The high flow Existing Conditions isopleths were not evaluated in detail, as they fall well downstream of the typical year isopleths. Based on this initial assessment, the dry flow year model runs were determined to be the best indicator of vegetation change and thus, were selected for the analyses of No Action and TSP wetland effects along the mainstem Cape Fear River and Northeast Cape Fear River. Dry year model runs were only available for the low RSLR1 scenario, thus potential wetland effects along the mainstem Cape Fear River and Northeast Cape Fear River were not evaluated under the intermediate RSLR2 or high RSLR2 scenarios. However, the main Delft 3D hydrodynamic modeling results show that the relative effects of the TSP on tidal range and salinity are reduced at the higher sea level rise rates under the RSLR2 or high RSLR2 scenarios. Thus, the projected effects of the TSP under RSLR1 represent a liberal (high) estimate of potential wetland effects.

In the case of the tidal creeks, the typical flow Existing Conditions isopleths best defined the existing swamp forest to marsh conversion threshold; whereas, the dry year oligohaline-freshwater isopleths were either absent due to high projected salinities throughout the creeks (Sturgeon Creek, Smith Creek) or were located approximately three to six miles above the conversion zone (Town, Lilliput) (Figures 10-13). Therefore, the typical flow year model runs were selected for the analyses of No Action and TSP wetland effects along the tidal creeks. The typical flow existing oligohaline-freshwater isopleths in Sturgeon Creek and Smith Creek fell within the active swamp forest to marsh conversion zones; however, the isopleth positions in the remaining lower tidal creeks fell approximately one mile (Jackeys, Lilliput) to two miles (Town) above the conversion zone. As described below, impact analyses for the lower tidal creeks employed manual adjustments to the isopleths. Potential typical flow wetland effects along the tidal creeks were evaluated under the low RSLR1 sea level rise scenario. As described above, the relative effects of the TSP on tidal range and salinity are reduced under the RSLR2 and RSLR2 scenarios. Thus, the projected effects of the TSP under RSLR1 represent a liberal (high) estimate of potential wetland effects.

The Existing Conditions, No Action, and TSP river channel salinity isopleths for the selected flow and sea level rise scenarios were plotted on the baseline wetland classification layer and extrapolated across the tidal floodplain to define the potentially affected wetland areas. Due to the inability to predict tidal flow across the floodplain and the resulting effects on marsh soil

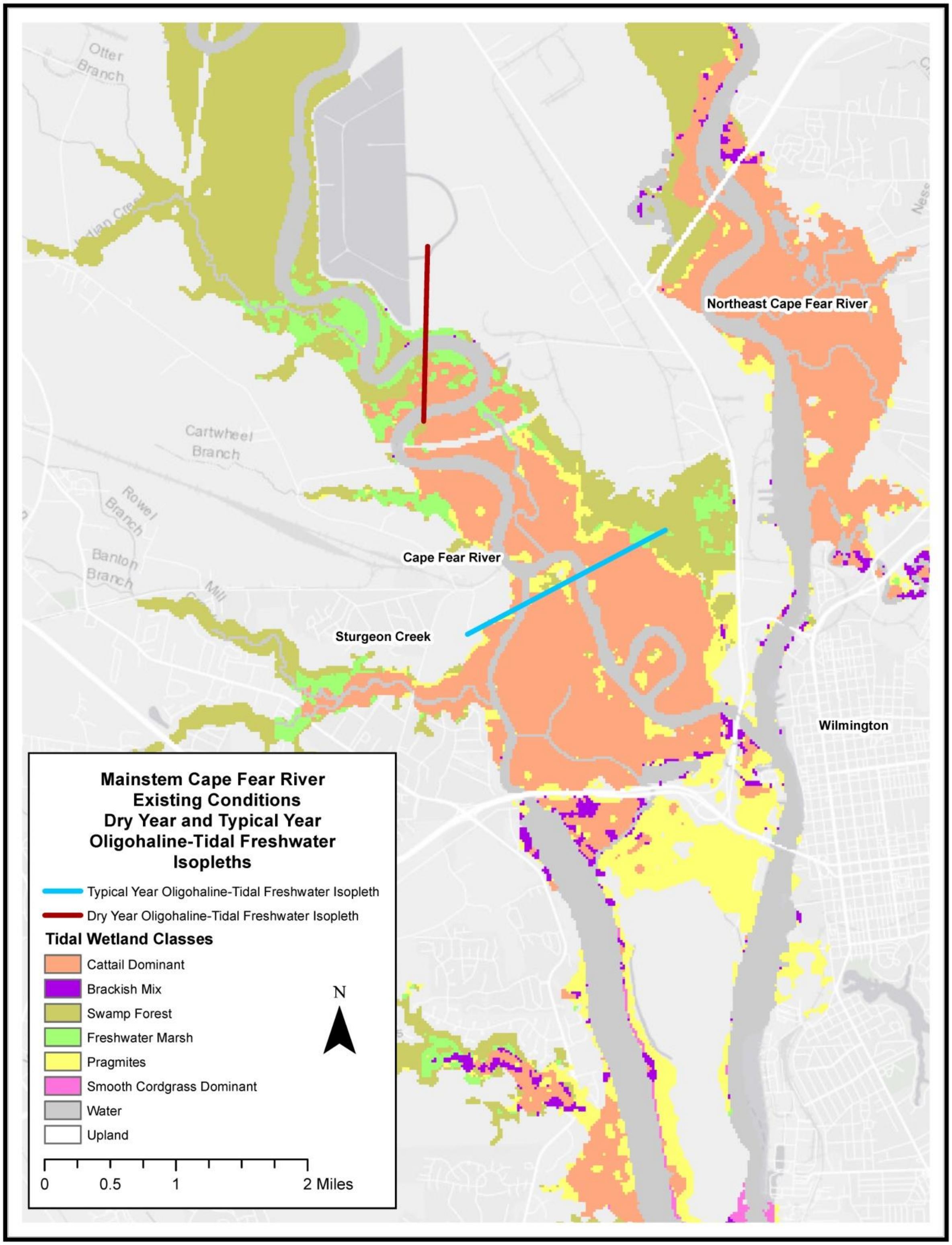

Figure 8
Mainstem Cape Fear River Existing Conditions Typical Year and Dry Year Oligohaline-Tidal Freshwater Salinity Isopleths

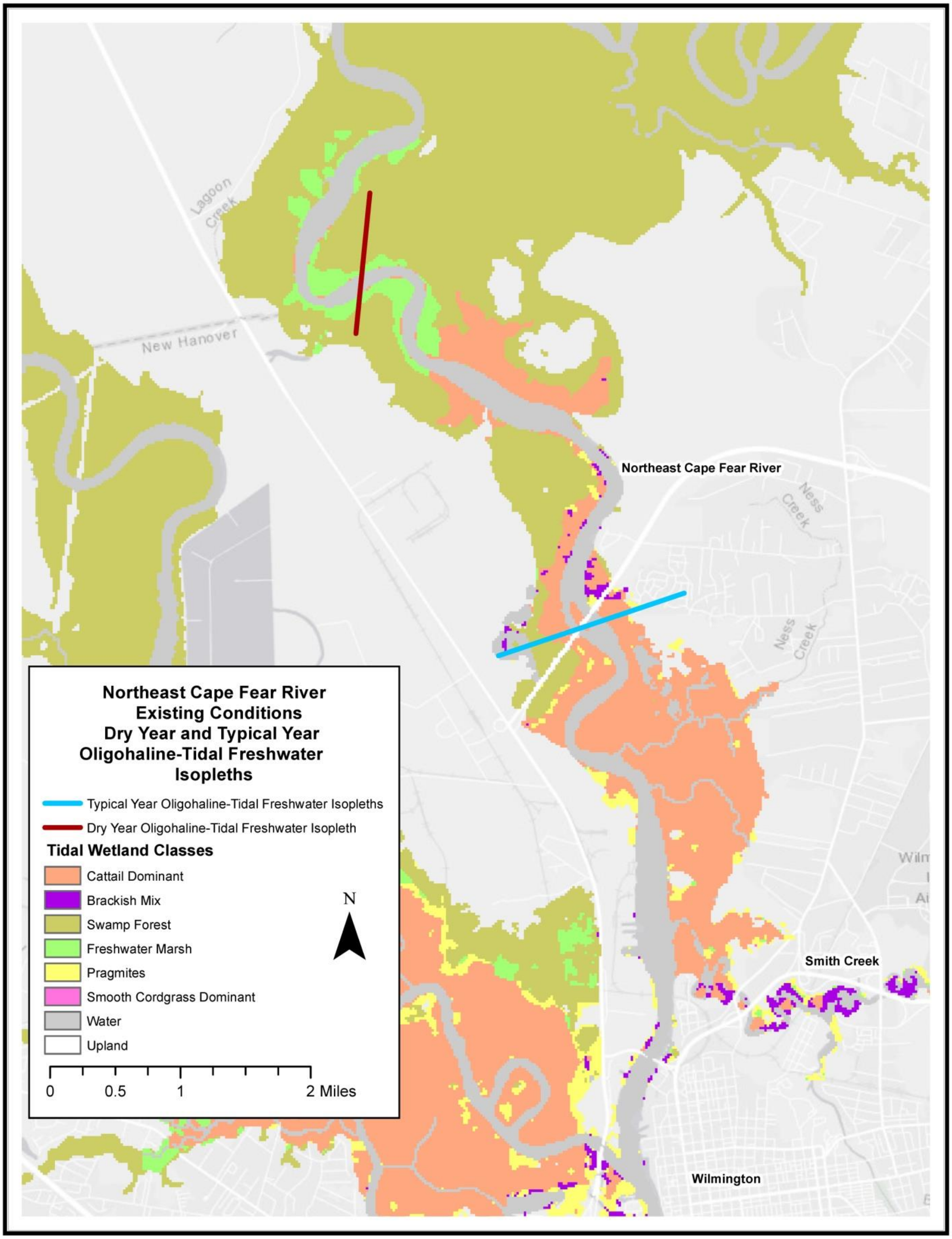

Figure 9
Northeast Cape Fear River Existing Conditions Typical Year and Dry Year Oligohaline-Tidal Freshwater Salinity Isopleths

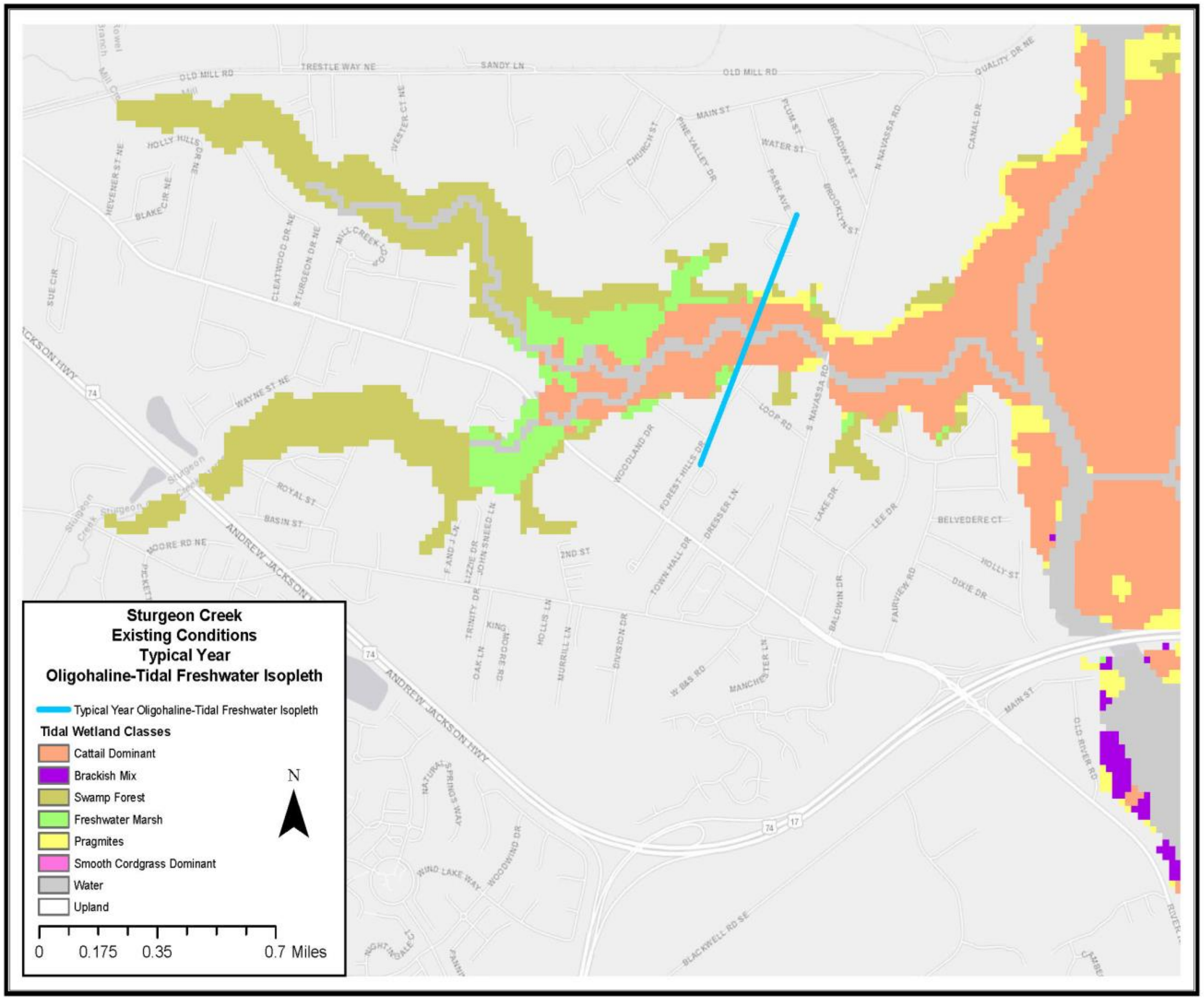

Figure 10
Sturgeon Creek Existing Conditions Typical Year Oligohaline-Tidal Freshwater Salinity Isopleth

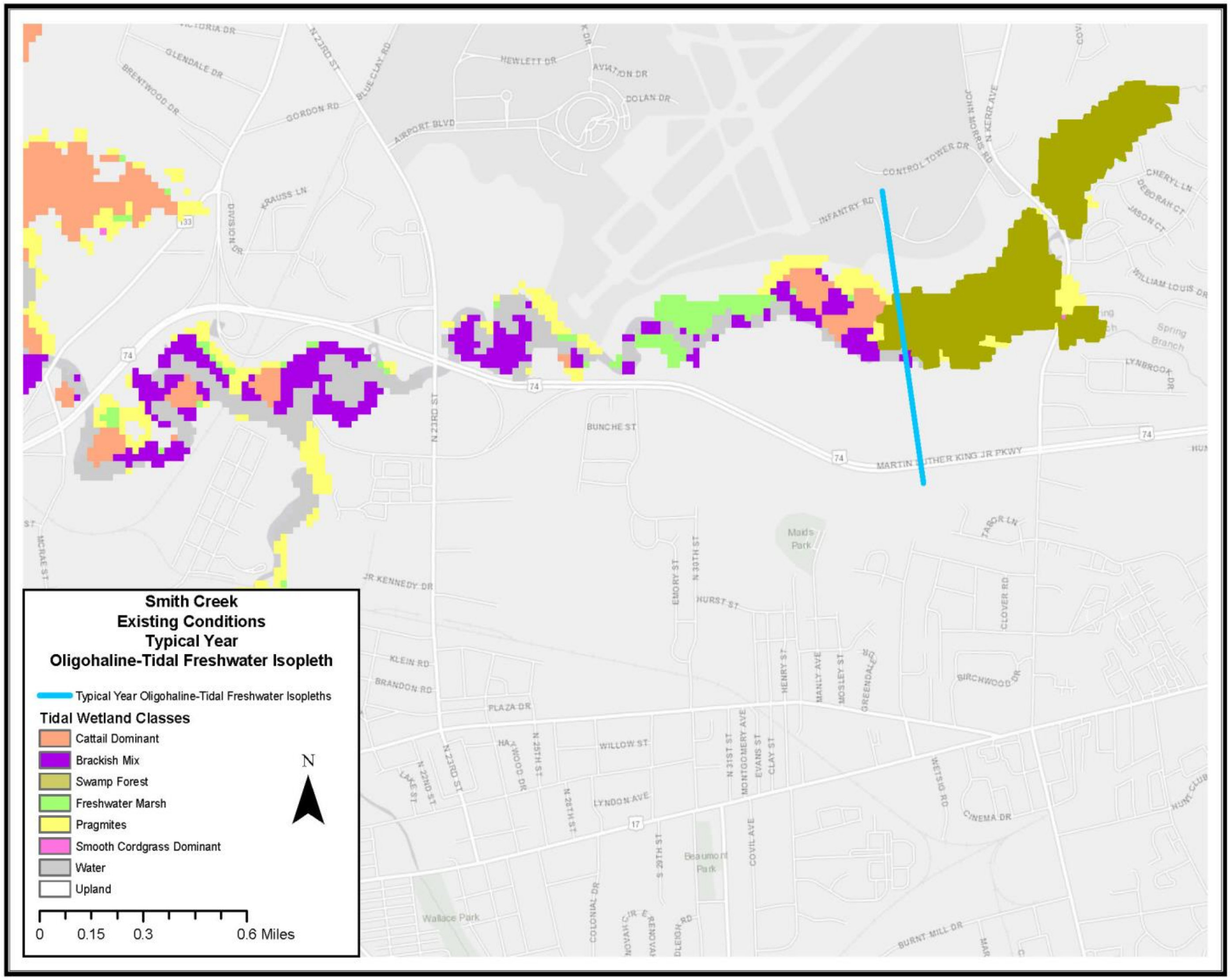

Figure 11
Smith Creek Existing Conditions Typical Year Oligohaline-Tidal Freshwater Salinity Isopleth

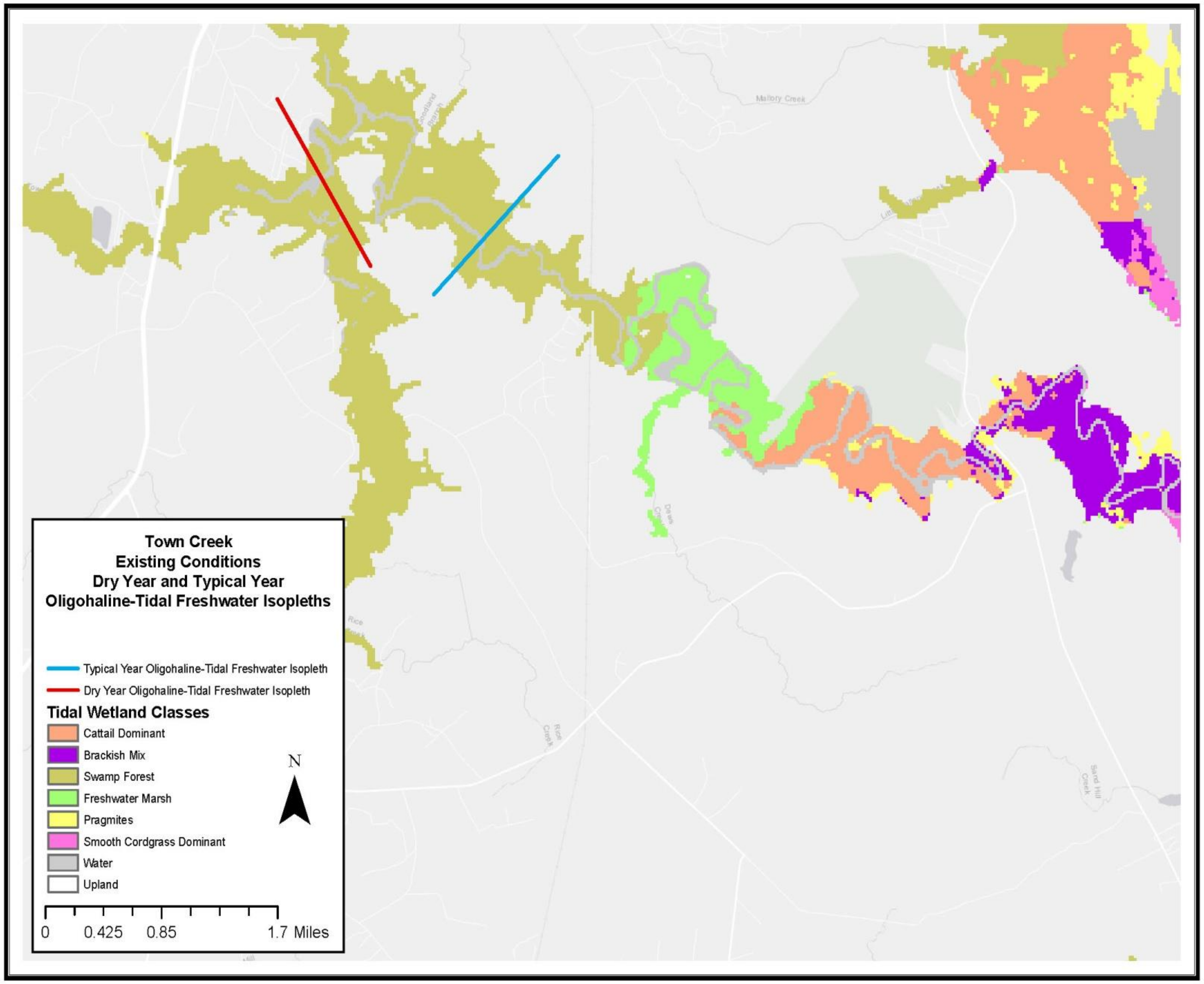

Figure 12
Town Creek Existing Conditions Typical Year and Dry Year Oligohaline-Freshwater Salinity Isopleths

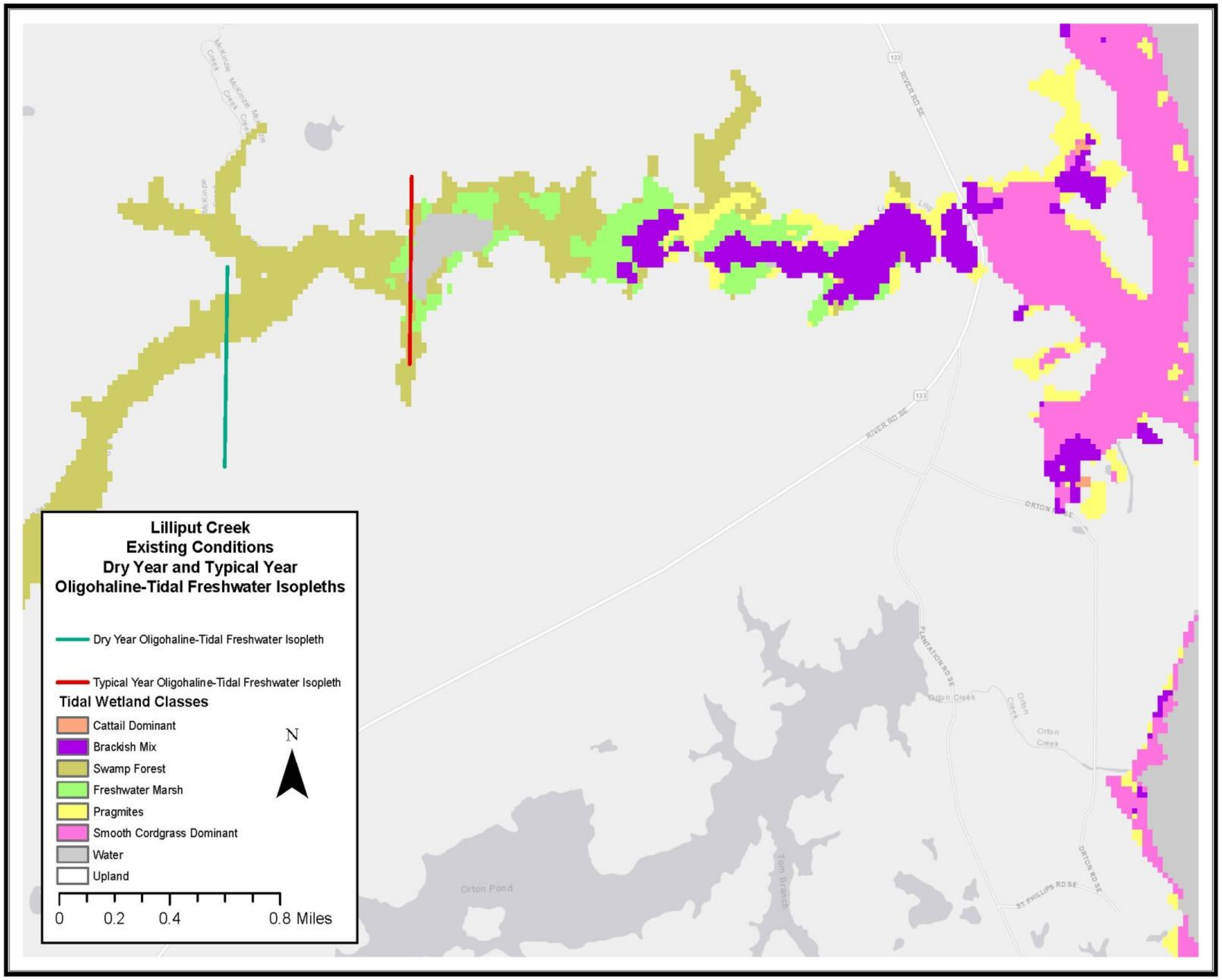

Figure 13
Lilliput Creek Existing Conditions Typical Year and Dry Year Oligohaline-Tidal Freshwater Salinity Isopleths

salinity and biochemistry, river salinity isopleths were extrapolated across the tidal floodplain as river-perpendicular, straight-line extensions from the edge of the channel to the landward non-tidal boundary. This procedure was applied consistently with the exception of a few isopleths along highly sinuous channel reaches, which required adjustments to avoid overlap with multiple channel bends. The potentially affected tidal floodplain areas between each set of Existing Conditions-No Action and No Action-TSP isopleths were delineated with polygons and the area of each wetland class within the polygons was calculated from the baseline wetland classification GIS layer.

As indicated above, projected Existing Conditions oligohaline-freshwater isopleths in the three lower tidal creeks (Jackeys Creek, Town Creek, and Lilliput Creek) exceeded the existing freshwater marsh-swamp forest transition zone by approximately one to two miles. In these cases, each set of Existing Conditions, No Action, and TSP isopleths was manually shifted downstream until the Existing Conditions isopleth was positioned at the upstream end of the active swamp forest to marsh conversion zone. In performing these downstream shifts, the original model-projected distances between the isopleths were maintained. This same procedure was used to shift the Lilliput Creek mesohaline-oligohaline isopleths downstream to the threshold between the cattail-dominant and smooth cordgrass wetland zones.

3.2 RESULTS

In accordance with the National Environmental Policy Act and the main Wilmington Harbor Navigation Improvement Project Feasibility Study/EIS document, the impacts of the No Action Alternative are defined as the difference between projected No Action conditions and Existing Conditions, whereas the impacts of the TSP are defined as the difference between TSP and No Action conditions. The projected impacts of the No Action Alternative represent the anticipated effects of RSLR without project implementation, while the projected impacts of the TSP represent the anticipated effects of harbor deepening in addition to the effects of RSLR.

Under the No Action Alternative, the salinity modeling results indicate that RSLR will cause upstream shifts in the oligohaline-freshwater (0.5 ppt) salinity isopleths ranging from ~0.08 to 0.75 mile (Table 2). Wetlands potentially affected by the projected upstream shifts in the 0.5 ppt isopleth under the No Action Alternative include ~278 acres of tidal freshwater wetlands and ~11 acres of tidal brackish wetlands (Table 2, Appendix B Figures B1-B9). The potentially affected freshwater wetlands include ~180 acres of tidal swamp forest and ~98 acres of tidal freshwater marsh. The potentially affected tidal brackish wetlands include approximately six acres of cattail marsh, approximately three acres of brackish marsh mix, and approximately two acres of Phragmites marsh. Projected shifts in the mesohaline-oligohaline (5.0 ppt) isopleths under the No Action Alternative are confined to the existing brackish marsh-dominated reaches of the estuary. The delineated tidal floodplain areas that are affected by the mesohaline-oligohaline isopleth shifts encompass ~267 acres of brackish cattail marsh, approximately two acres of Phragmites marsh, and approximately one acre of smooth cordgrass marsh (Table 2, Appendix B Figures B1-B9).

Table 2
No Action Alternative (Existing Conditions to FWOP) - Wetlands Potentially Affected by Projected Upstream Salinity Isopleth Shifts

Water Body	Model Scenario (Flow/RSLR)	Isopleth Shift (river miles)	Wetland Class[1] (acres)						Total
			SWF	FWM	CAT	BRM	PHR	SPA	
Oligohaline-Freshwater Isopleth Shifts									
Cape Fear River Mainstem	DY – RSLR1	0.08	6.0	3.6	2.4				**12.0**
Northeast Cape Fear River	DY – RSLR1	0.74	52.8	75.4					**128.2**
Smith Creek	TY – RSLR1	0.22	19.5	0.3		0.5	0.3		**20.6**
Sturgeon Creek	TY – RSLR1	0.11	1.2	0.5	3.6		2.1		**7.4**
Jackeys Creek[2]	TY – RSLR1	0.27	39.6	0					**39.6**
Town Creek[2]	TY – RSLR1	0.44	35.8	1.8					**37.6**
Lilliput Creek[2]	TY – RSLR1	0.75	25.4	16.0		2.4			**43.8**
Total Oligohaline-Freshwater (acres)			**180.3**	**97.6**	**6.0**	**2.9**	**2.4**	**0.0**	**289.2**
Mesohaline-Oligohaline Isopleth Shifts									
Cape Fear River Mainstem	DY – RSLR1	0.42			142.3		0.6		**142.9**
Northeast Cape Fear River	DY – RSLR1	0.06			15.0		0.7		**15.7**
Barnards Creek	TY – RSLR1	0.05			1.5			1.1	**2.6**
Lilliput Creek[3]	TY – RSLR1	0.67			42.7				**42.7**
Town Creek	TY – RSLR1	0.73			65.2		1.1		**66.3**
Total Mesohaline-Oligohaline (acres)			**0.0**	**0.0**	**266.7**	**0.0**	**2.4**	**1.1**	**270.2**

[1] SWF = Tidal Freshwater Swamp Forest; FWM = Tidal Freshwater Marsh; CAT = Cattail; BRM = Brackish Mix; PHR = *Phragmites australis*; SPA = *Spartina alterniflora*

[2] The model-projected series of Existing Conditions, No Action, and TSP salinity isopleths was manually shifted downstream until the Existing Conditions isopleth was positioned at the upper end of the active tidal swamp forest to freshwater marsh conversion zone. The model-projected distances between the isopleths were maintained.

[3] The model-projected series of Existing Conditions, No Action, and TSP salinity isopleths was manually shifted downstream until the Existing Conditions isopleth was positioned at the approximate threshold between the cattail dominant and *Spartina alterniflora* dominant tidal wetland zones. The model-projected distances between the isopleths were maintained.

Under the TSP, the salinity modeling results indicate that harbor deepening will cause additional upstream shifts in the oligohaline-freshwater 0.5 ppt salinity isopleths ranging from ~0.18 to 0.83 mile (Table 3). Wetlands potentially affected by the projected upstream shifts in the 0.5 ppt isopleths under the TSP include ~242 acres of tidal freshwater swamp forest, ~98 acres of tidal freshwater marsh, and ~62 acres of brackish cattail marsh (Table 3, Appendix B Figures B1-B9). Projected shifts in the mesohaline-oligohaline 5.0 ppt isopleths under the TSP are confined to the existing brackish marsh-dominated reaches of the estuary, with the exception of the Lilliput Creek isopleth, which extends ~200 ft into the transition zone where small patches of tidal freshwater marsh first begin to occur. The potentially affected freshwater marsh areas along Lilliput Creek total less than one acre. The remaining delineated tidal floodplain areas that are affected by the various mesohaline-oligohaline isopleth shifts under the TSP encompass ~470 acres of brackish cattail marsh, ~20 acres of Phragmites marsh, and approximately five acres of brackish marsh mix (Table 3, Appendix B Figures B1-B9).

The potentially affected brackish wetlands consist almost entirely of cattail marsh under both the No Action Alternative (97%) and TSP (96%), with the majority (~3.5%) of the remaining brackish wetlands consisting of marshes dominated by the non-native invasive species *Phragmites australis australis*. Cattail marshes dominate the estuarine tidal floodplain from approximately two miles below Eagle Island to the upper ends of the oligohaline reaches in the Cape Fear River and Northeast Cape Fear River, and thus are well adapted to a broad range of salinities.

Projected surface salinity changes within the mesohaline-oligohaline isopleth shift zones are limited to relatively small increases of ≤1.5 ppt. The potentially affected brackish wetlands consist almost entirely of cattail marsh under both the No Action Alternative (97%) and TSP (96%), with the majority (~3.5%) of the remaining brackish wetlands consisting of marshes dominated by the non-native invasive species Phragmites australis australis. Cattail marshes dominate the estuarine tidal floodplain from approximately two miles below Eagle Island to the upper ends of the oligohaline reaches in the Cape Fear River and Northeast Cape Fear River, and thus are well adapted to a broad range of salinities. Therefore, the relatively small increases in salinity that are projected under the No Action Alternative and TSP would not be expected to have any significant effect on cattail marshes. In the case of Phragmites marshes, any changes in community composition would be considered a beneficial effect. Therefore, the anticipated effects of the TSP on existing brackish marshes are considered to be insignificant and will not be considered in determining any wetland mitigation requirements for the TSP.

Projected surface salinity changes within the oligohaline-freshwater isopleth shift zones are limited to very small increases of ≤0.3 ppt. Freshwater tidal wetland communities at the oligohaline-freshwater boundary, including tidal freshwater marsh and tidal swamp forest, are most likely to be significantly affected by small increases in salinity. Conversely, the brackish marshes that occur below are dominated by a relatively small number of species that are adapted to a much broader range of salinities. Consequently, the brackish communities are not expected to be significantly affected by the relatively small increases in salinity (≤1.5 ppt) that are projected to occur within the isopleth shift zones. Although brackish wetlands potentially affected by the mesohaline-oligohaline isopleth shifts are quantified in this assessment, the potential effects of small salinity increases on brackish wetlands within the existing mesohaline and oligohaline zones are not considered to be significant.

Table 3
Tentatively Selected Plan - Wetlands Potentially Affected by Projected Upstream Salinity Isopleth Shifts

Water Body	Model Scenario (Flow/RSLR)	Isopleth Shift (river miles)	Wetland Class[1] (acres)						Total
			SWF	FWM	CAT	BRM	PHR	SPA	
Oligohaline-Freshwater Isopleth Shifts									
Cape Fear River Mainstem	DY – RSLR1	0.32	29.9	16.2					**46.1**
Northeast Cape Fear River	DY – RSLR1	0.44	75.8	16.7	8.0				**100.5**
Smith Creek	TY – RSLR1	0.32	27.4						**27.4**
Sturgeon Creek	TY – RSLR1	0.83	19.4	55.2	54.0				**128.6**
Jackeys Creek[2]	TY – RSLR1	0.66	58.0						**58.0**
Town Creek[2]	TY – RSLR1	0.18	13.9						**13.9**
Lilliput Creek[2]	TY – RSLR1	0.29	17.4	9.7					**27.1**
Total Oligohaline-Freshwater (acres)			**241.8**	**97.8**	**62.0**	**0.0**	**0.0**	**0.0**	**401.6**
Mesohaline-Oligohaline Isopleth Shifts									
Cape Fear River Mainstem	DY – RSLR1	0.32			69.3		9.7		**79.1**
Northeast Cape Fear River	DY – RSLR1	0.54			103.0		3.9		**106.9**
Barnards Creek	TY – RSLR1	0.69			66.2				**66.2**
Town Creek	TY – RSLR1	1.83			225.6	3.7	6.0		**235.3**
Lilliput Creek[3]	TY – RSLR1	0.15		0.9	6.0	1.2			**8.1**
Total Mesohaline-Oligohaline (acres)			**0.0**	**0.9**	**470.1**	**4.9**	**19.6**	**0.0**	**495.6**

[1] SWF = Tidal Freshwater Swamp Forest; FWM = Tidal Freshwater Marsh; CAT = Cattail; BRM = Brackish Mix; PHR = *Phragmites australis*; SPA = *Spartina alterniflora*

[2] The model-projected series of Existing Conditions, No Action, and TSP salinity isopleths was manually shifted downstream until the Existing Conditions isopleth was positioned at the upper end of the active tidal swamp forest to freshwater marsh conversion zone. The model-projected distances between the isopleths were maintained.

[3] The model-projected series of Existing Conditions, No Action, and TSP salinity isopleths was manually shifted downstream until the Existing Conditions isopleth was positioned at the approximate threshold between the cattail dominant and *Spartina alterniflora* dominant tidal wetland zones. The model-projected distances between the isopleths were maintained.

3.3 DISCUSSION

Projected surface salinity changes within the mesohaline-oligohaline isopleth shift zones are limited to relatively small increases of ≤1.5 ppt. The potentially affected brackish wetlands consist almost entirely of cattail marsh under both the No Action Alternative (97%) and TSP (96%), with the majority (~3.5%) of the remaining brackish wetlands consisting of marshes dominated by the non-native invasive species *Phragmites australis australis*. Cattail marshes dominate the estuarine tidal floodplain from approximately two miles below Eagle Island to the upper ends of the oligohaline reaches in the Cape Fear River and Northeast Cape Fear River, and thus are well adapted to a broad range of salinities. Therefore, the relatively small increases in salinity that are projected under the No Action Alternative and TSP would not be expected to have any significant effect on cattail marshes. In the case of Phragmites marshes, any changes in community composition would be considered a beneficial effect. Therefore, the anticipated effects of the TSP on existing brackish marshes are considered to be insignificant and will not be considered in determining any wetland mitigation requirements for the TSP.

The remaining tidal freshwater wetlands that were identified as potentially affected by oligohaline-freshwater isopleth shifts under the TSP include 241.8 acres of tidal freshwater swamp forest and 103.4 acres of tidal freshwater marsh (Table 4). Although in many cases the projected oligohaline-freshwater isopleth shifts cover substantial distances, the projected surface salinity changes within the isopleth shift zones are limited to very small increases of ≤0.3 ppt. Although tidal freshwater swamp forest communities are capable of tolerating or recovering from occasional pulses of saline water, they are generally not able to tolerate regular flooding by saline waters. Based on studies conducted in the Cape Fear River estuary, Hackney and Avery (2015) indicated that the location along the river salinity gradient where 12% to 25% of the high tide events flood the adjacent tidal wetlands with >1 ppt saline water is the active zone of tidal swamp to tidal marsh conversion. Tidal freshwater marshes, as defined by the baseline classification, are slightly more tolerant of very low oligohaline salinities; however, the restriction of freshwater marshes to relatively short reaches of the estuary in the immediate vicinity of the oligohaline-freshwater boundary indicates that overall salinity tolerance is very limited. Thus, tidal swamp forest and tidal freshwater marsh communities are potentially vulnerable to relatively small increases in salinity.

An analysis of potential effects based on the high tide salinity threshold described above was not possible, as the use of averaged flows in the Delft 3D model precluded an evaluation of individual tidal events. Given the very small projected increases in salinity, the exact nature and extent of effects are difficult to predict. Generally, it is anticipated that the projected salinity increases may have some effects on community composition, and that shifts in freshwater community composition towards the brackish marsh spectrum could reduce community diversity. However, it is considered unlikely that the projected increases would result in large-scale swamp forest to marsh conversions. A functional assessment would be performed in coordination with the Wetlands TWG to assess potential effects on wetland functions. The results of the functional assessment would be used to determine any compensatory wetland mitigation requirements for the TSP.

Table 4
Freshwater Tidal Wetlands Potentially Affected under the TSP

Water Body	Isopleth Shift	Model Scenario	Wetland Class (acres)		Total Freshwater Wetlands
			Tidal Swamp Forest	Tidal Freshwater Marsh	
Cape Fear Mainstem	Oligohaline-Freshwater	Dry Year RSLR1	29.9	16.2	**46.1**
Cape Fear Mainstem	Mesohaline-Oligohaline	Dry Year RSLR1	0.0	0.0	**0.0**
Northeast Cape Fear	Oligohaline-Freshwater	Dry Year RSLR1	75.8	16.7	**92.5**
Northeast Cape Fear	Mesohaline-Oligohaline	Dry Year RSLR1	0.0	0.0	**0.0**
Smith Creek	Oligohaline-Freshwater	Typical Year RSLR1	27.4	0.0	**27.4**
Sturgeon Creek	Oligohaline-Freshwater	Typical Year RSLR1	19.4	55.2	**74.6**
Jackeys Creek	Oligohaline-Freshwater	Typical Year RSLR1	58.0	0.0	**58.0**
Barnards Creek	Mesohaline-Oligohaline	Typical Year RSLR1	0.0	0.0	**0.0**
Town Creek	Oligohaline-Freshwater	Typical Year RSLR1	13.9	0.0	**13.9**
Town Creek	Mesohaline-Oligohaline	Typical Year RSLR1	0.0	0.0	**0.0**
Lilliput Creek	Oligohaline-Freshwater	Typical Year RSLR1	17.4	9.7	**27.1**
Lilliput Creek	Mesohaline-Oligohaline	Typical Year RSLR1	0.0	0.9	**0.9**
Total (acres)			**241.8**	**103.4**	**340.5**

4 REFERENCES

Fell, P.E., R.S. Warren, and W.A. Niering. 2002. Restoration of Salt and Brackish Tidelands in Southern New England *Angiosperms, Macroinvertebrates, Fish, and Birds.*

Hackney, CT and GB Avery. 2015. Tidal wetland community response to varying levels of flooding by saline water. Wetlands 35: 227.

Hackney, CT and GF Yelverton. 1990. Effects of human activities and sea level rise on wetland ecosystems in the Cape Fear River Estuary, North Carolina, USA. In: Kvet, Y; DF Whigham; and R Good (eds) Wetland ecology and management. Kluwer Academic Publishers, Dordrecht, pp 55–61.

APPENDIX A

INDEXED TIDAL WETLAND

CLASSIFICATION MAPS

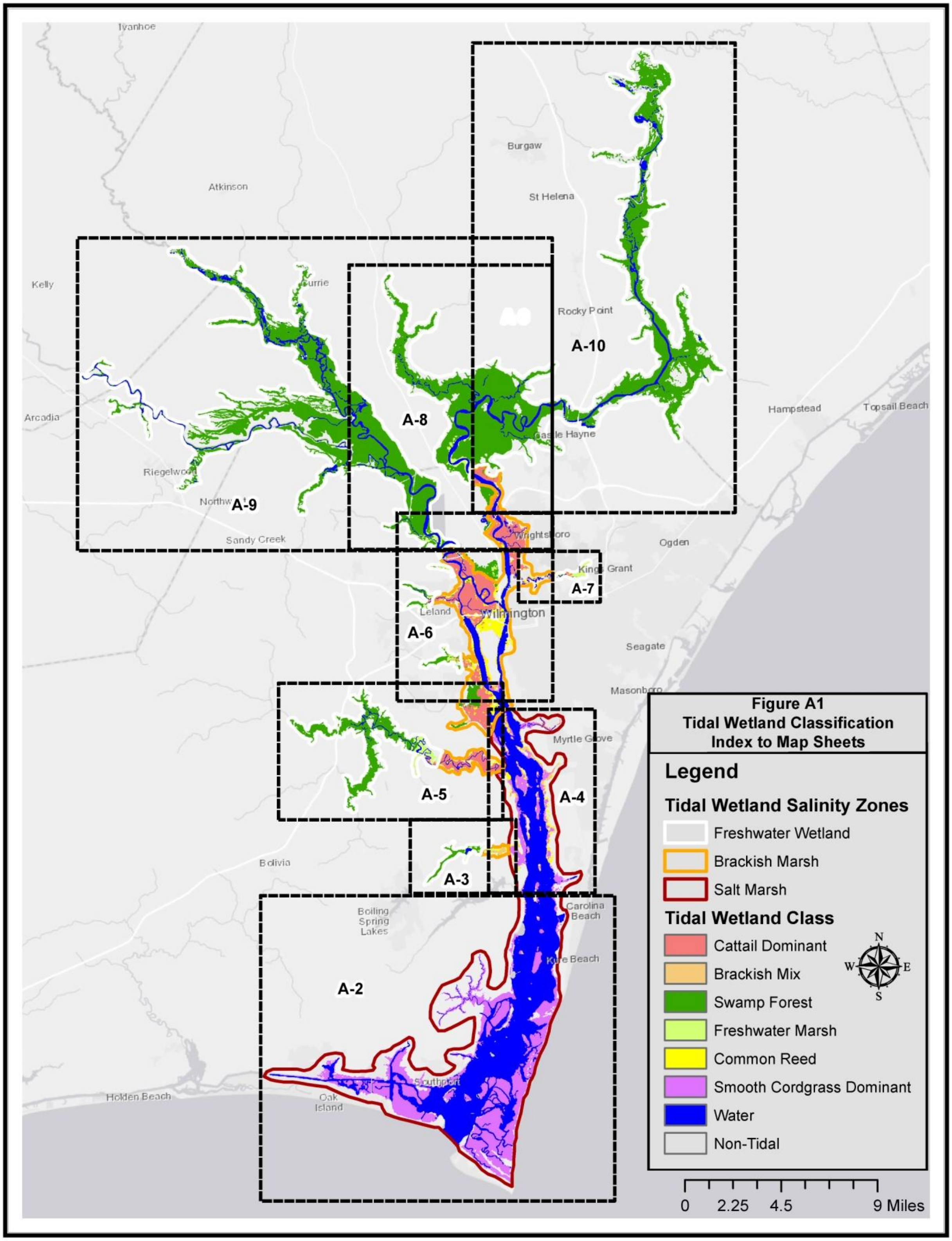
Figure A1
Tidal Wetland Classification
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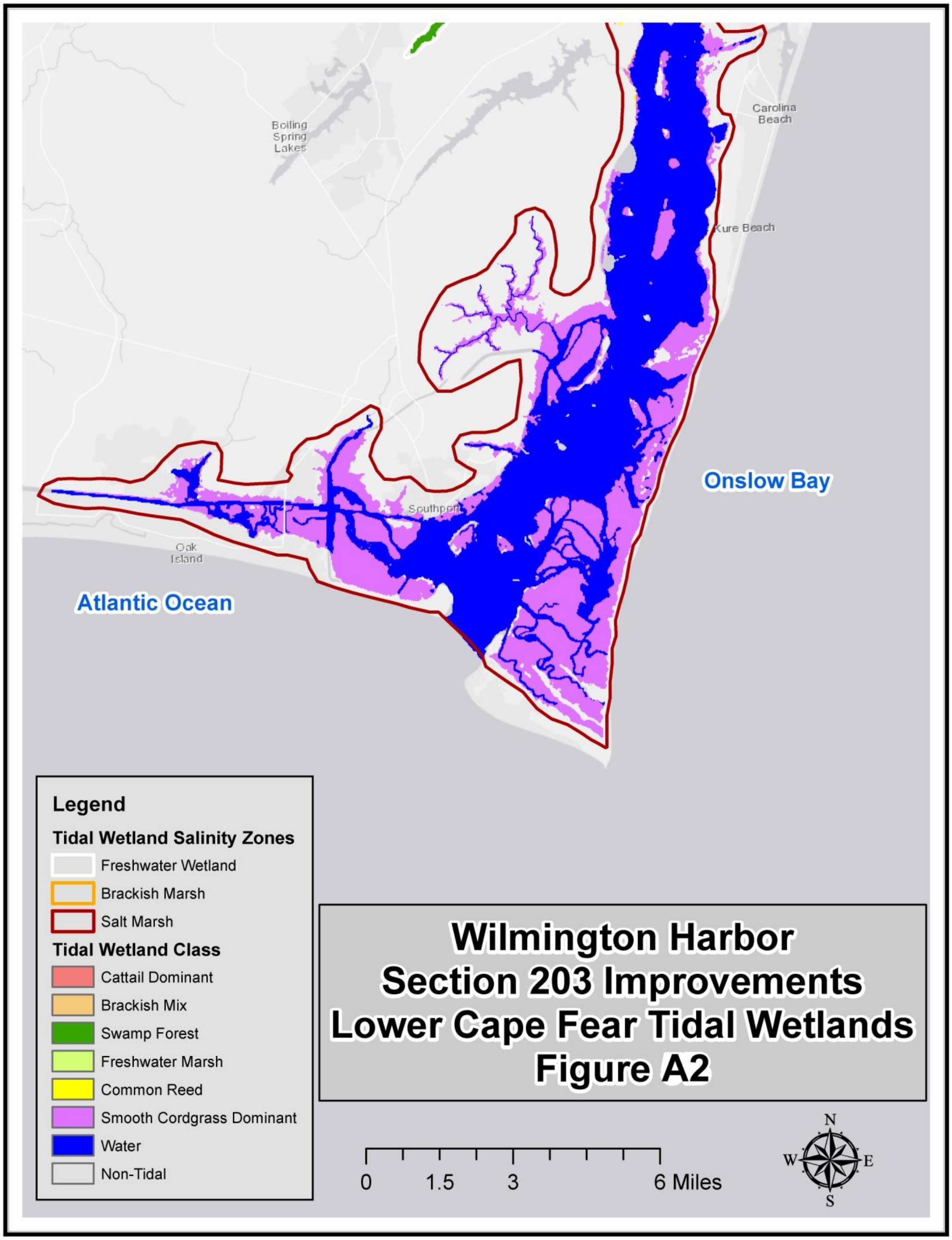
Legend
Tidal Wetland Salinity Zones
Freshwater Wetland
Brackish Marsh
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
0 2.25 4.5 9 Miles
N
S
E
W
A-2
A-3
A-4
A-5
A-6
A-7
A-8
A-9
A-10
Ivanhoe
Burgaw
Atkinson
St Helena
Kelly
Rocky Point
Arcadia
Hampstead
Topsail Beach
Riegelwood
Sandy Creek
Ogden
Leland
Wilmington
Seagate
Masonboro
Myrtle Grove
Bolivia
Boiling Spring Lakes
Carolina Beach
Kure Beach
Holden Beach
Oak Island
Southport


Boiling Spring Lakes
Carolina Beach
Kure Beach
Onslow Bay
Southport
Oak Island
Atlantic Ocean
Legend
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Freshwater Wetland
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Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
Wilmington Harbor
Section 203 Improvements
Lower Cape Fear Tidal Wetlands
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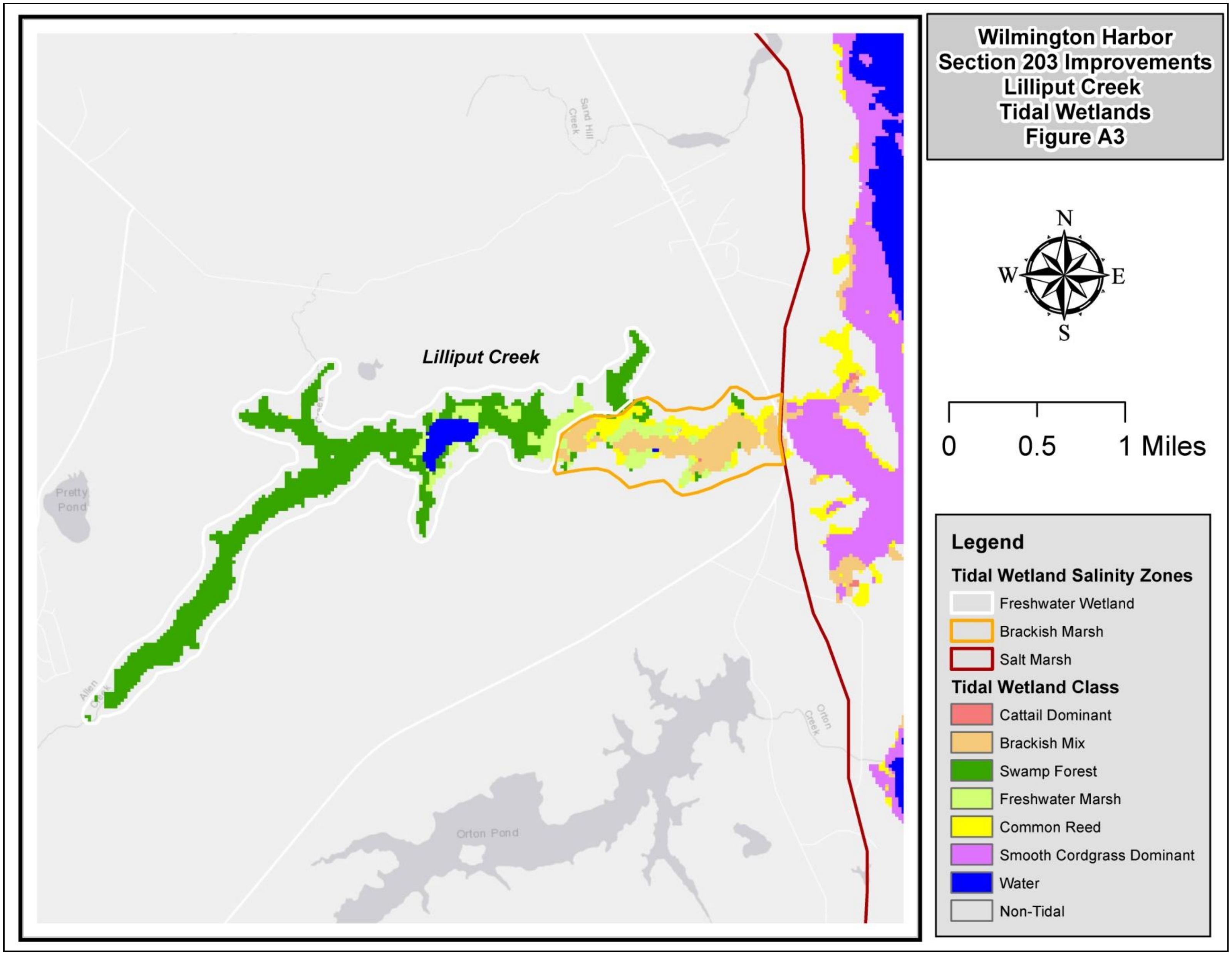
0 1.5 3 6 Miles
N
W
E
S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Section 203 Improvements
Lilliput Creek
Tidal Wetlands
Figure A3
N
W
E
S
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0.5
1 Miles
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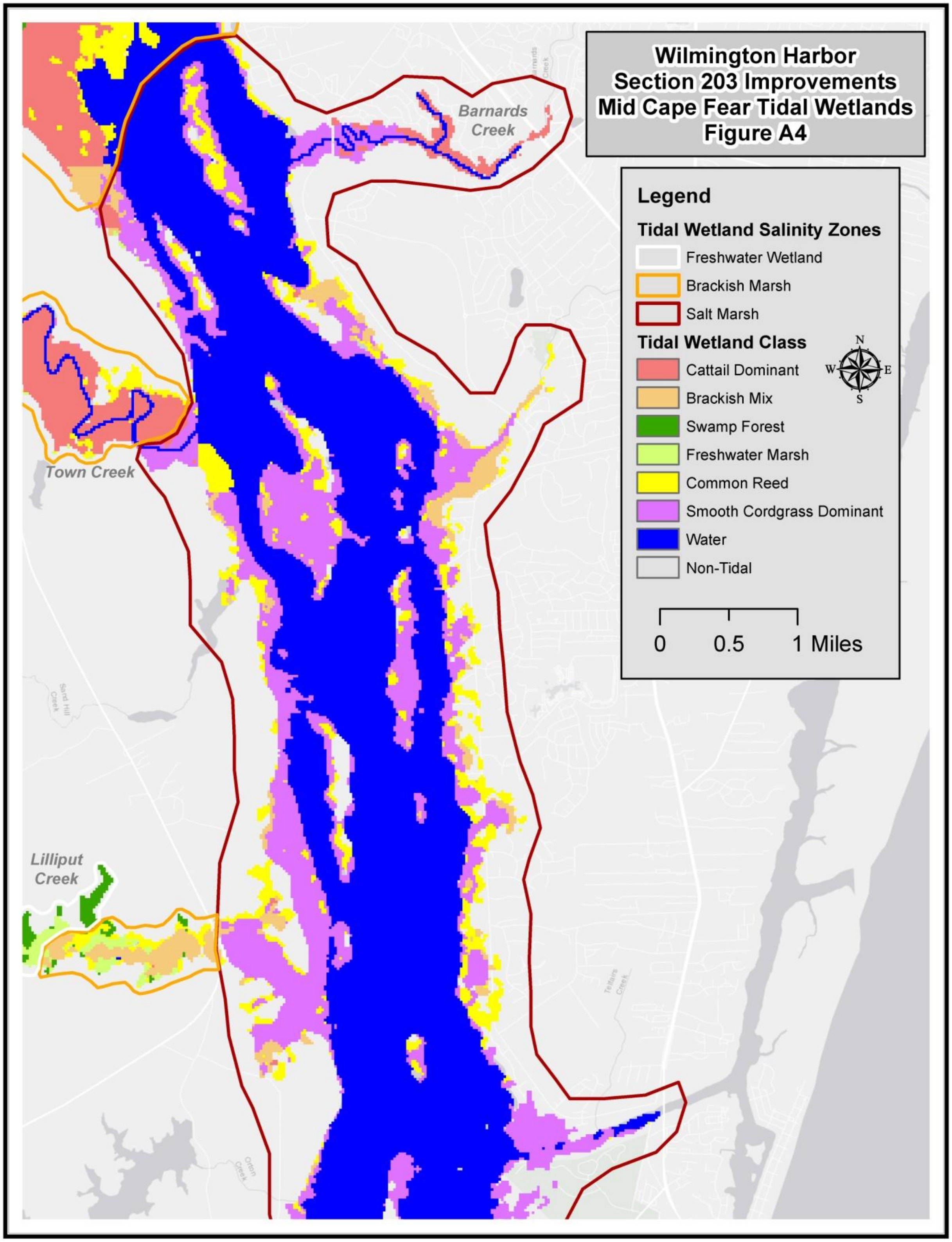
Sand Hill Creek
Pretty Pond
Allen Creek
Orton Creek
Orton Pond
Legend
Tidal Wetland Salinity Zones
Freshwater Wetland
Brackish Marsh
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal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Section 203 Improvements
Mid Cape Fear Tidal Wetlands
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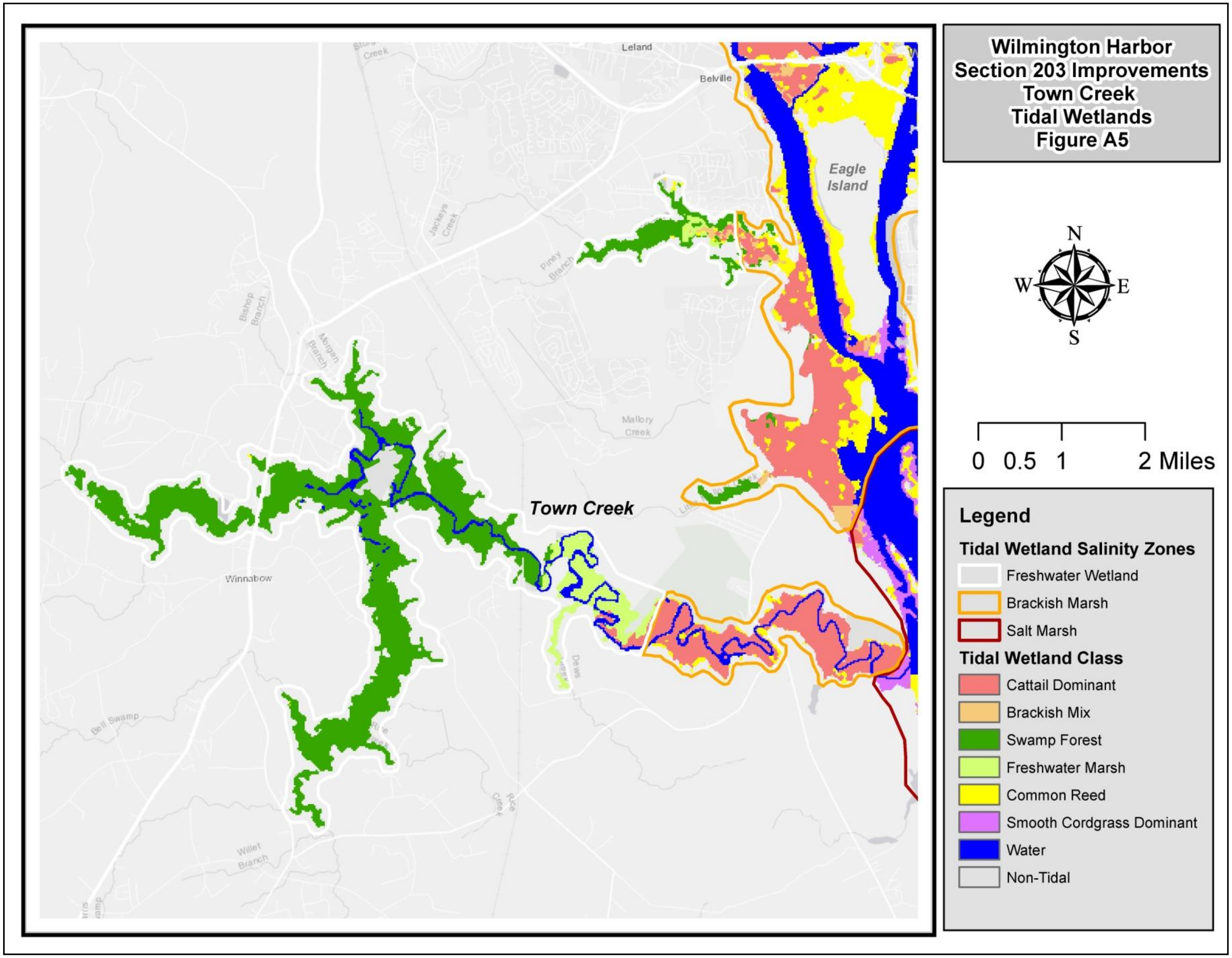
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
0
0.5
1 Miles
N
S
E
W
Barnards Creek
Town Creek
Lilliput Creek


Wilmington Harbor
Section 203 Improvements
Town Creek
Tidal Wetlands
Figure A5
N
S
E
W
0 0.5 1 2 Miles
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Brackish Marsh
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
Town Creek
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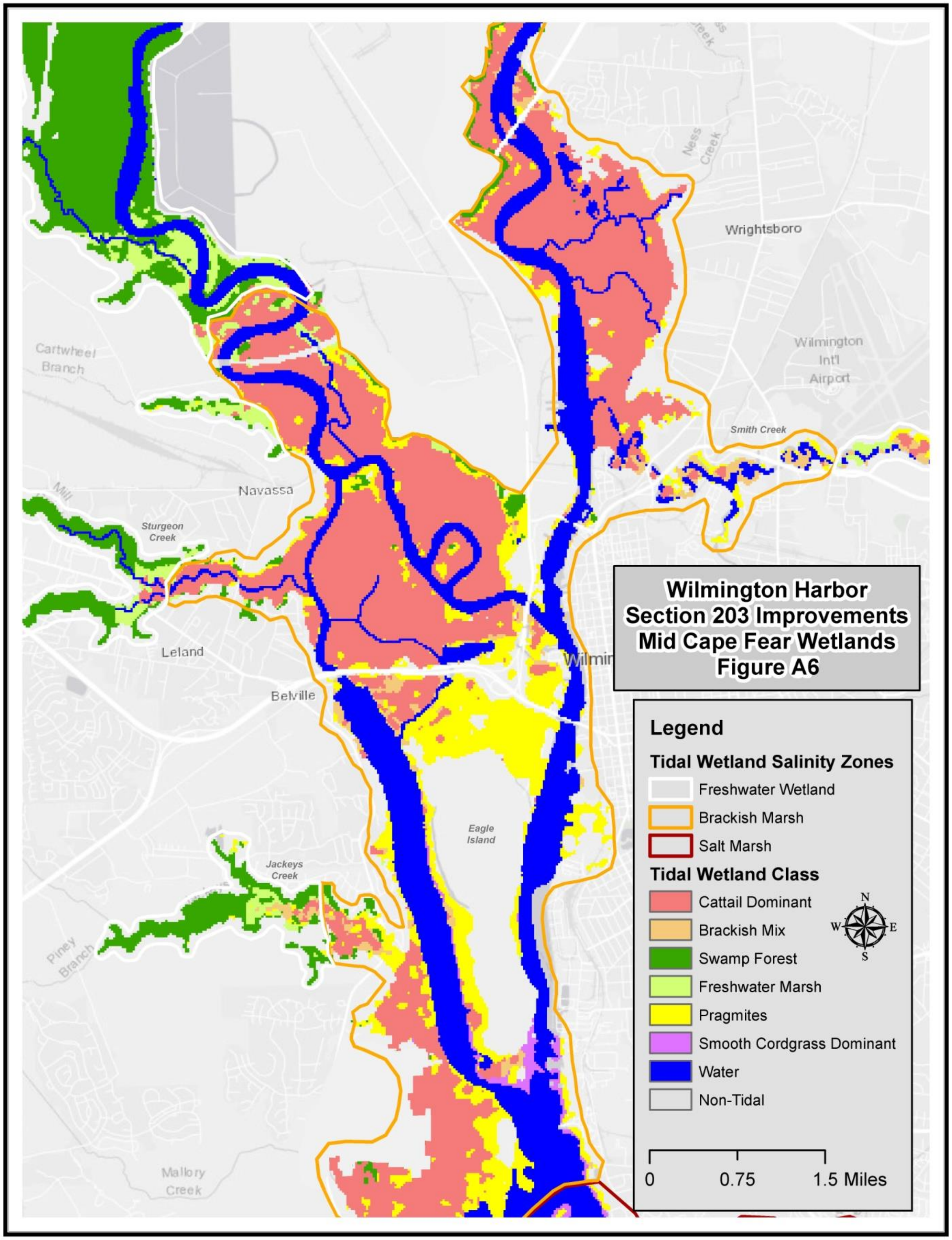
Leland
Belville
Winnabow
Mallory Creek
Piney Branch
Jackeys Creek
Morgan Branch
Bishop Branch
Bell Swamp
Willet Branch
Rice Creek


Wilmington Harbor
Section 203 Improvements
Mid Cape Fear Wetlands
Figure A6
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Tidal Wetland Salinity Zones
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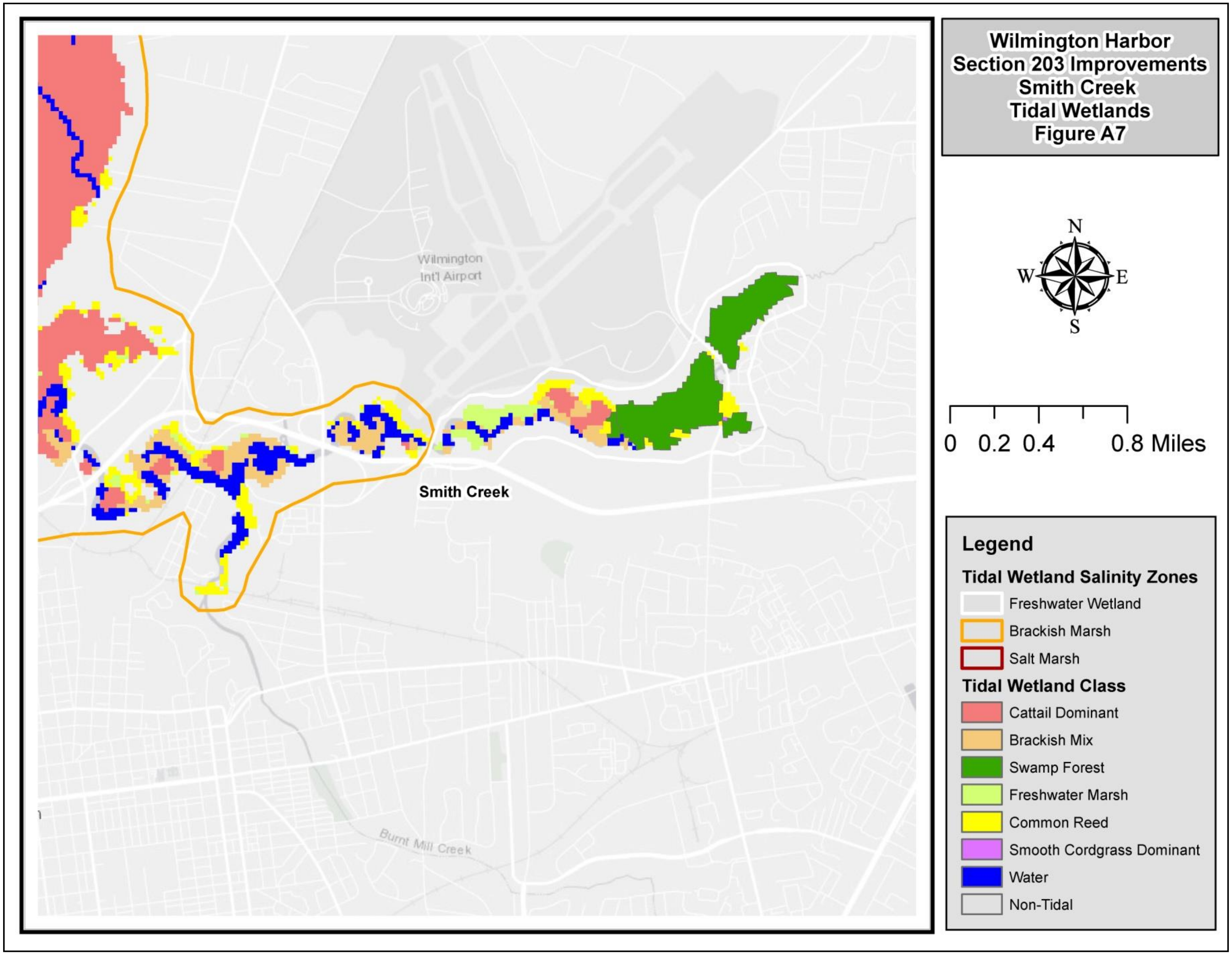
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Non-Tidal
0
0.75
1.5 Miles
N
S
E
W
Wrightsboro
Wilmington Int'l Airport
Smith Creek
Ness Creek
Cartwheel Branch
Navassa
Sturgeon Creek
Leland
Belville
Eagle Island
Jackeys Creek
Piney Branch
Mallory Creek


Wilmington Harbor
Section 203 Improvements
Smith Creek
Tidal Wetlands
Figure A7
N
W
E
S
0 0.2 0.4 0.8 Miles
Legend
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Brackish Marsh
Salt Marsh
Tidal Wetland Class
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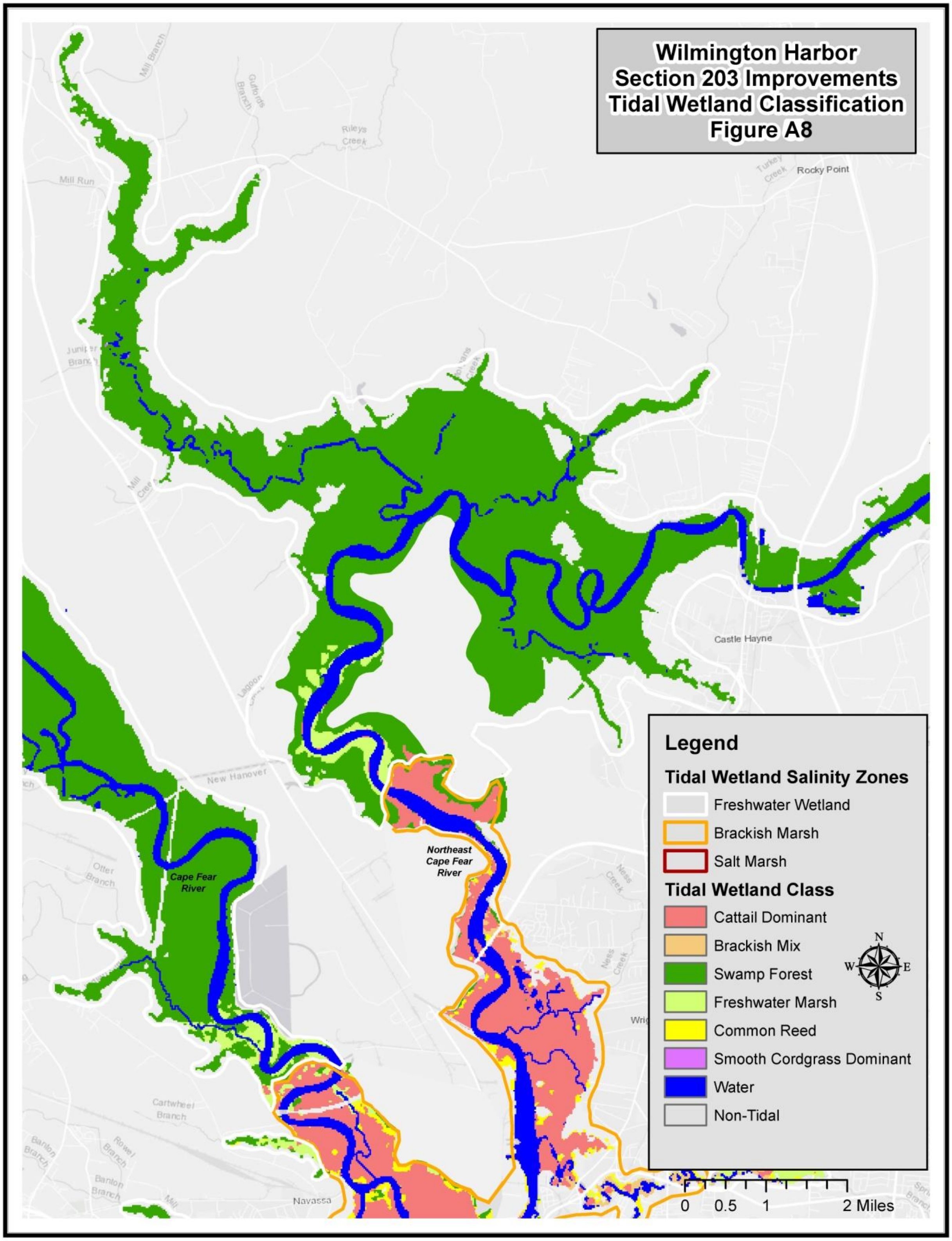
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
Wilmington Int'l Airport
Smith Creek
Burnt Mill Creek


Wilmington Harbor
Section 203 Improvements
Tidal Wetland Classification
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Tidal Wetland Salinity Zones
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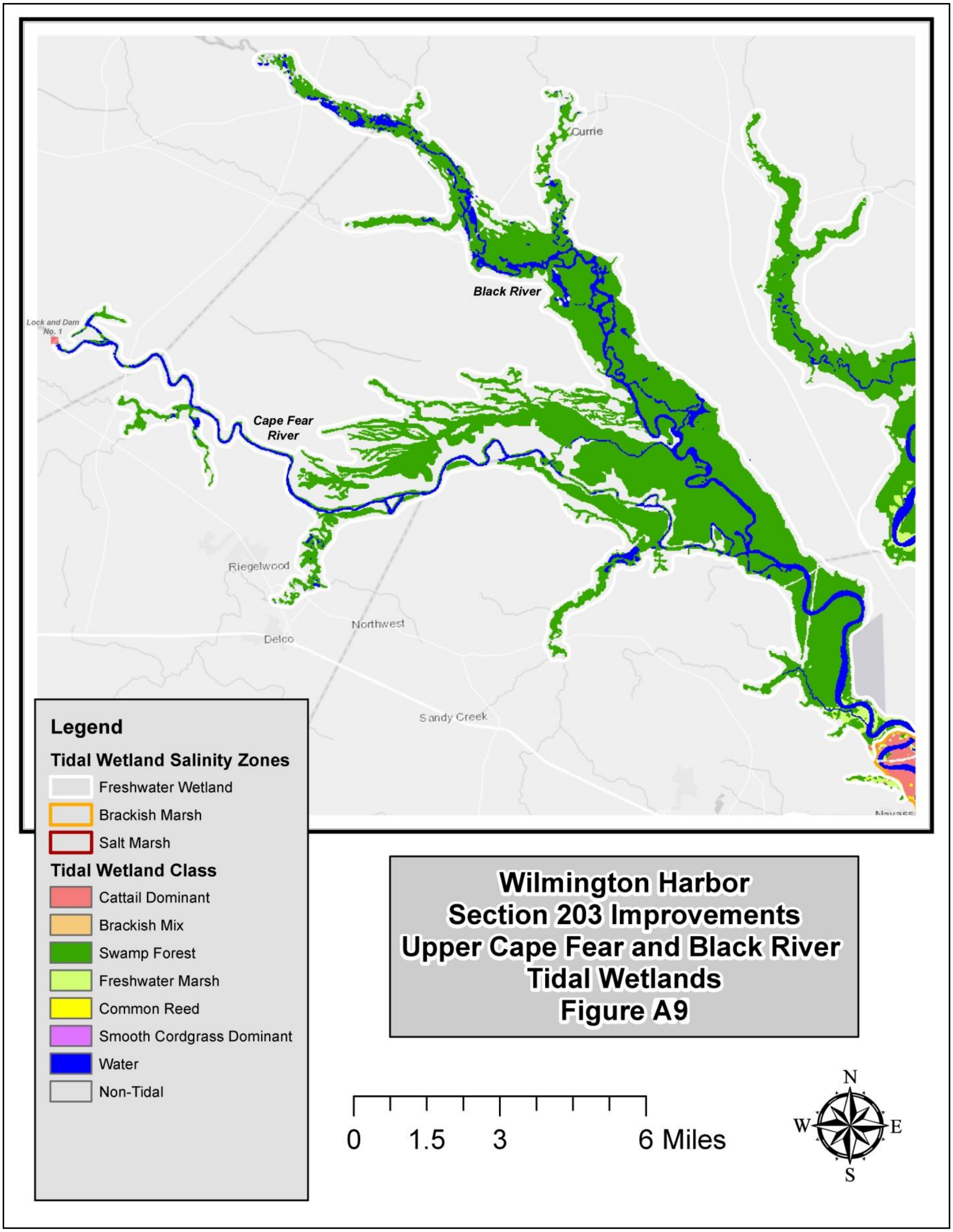
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
0 0.5 1 2 Miles
Cape Fear River
Northeast Cape Fear River
Rocky Point
Castle Hayne
Navassa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Lock and Dam No. 1
Cape Fear River
Riegelwood
Northwest
Delco
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Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
Wilmington Harbor
Section 203 Improvements
Upper Cape Fear and Black River
Tidal Wetlands
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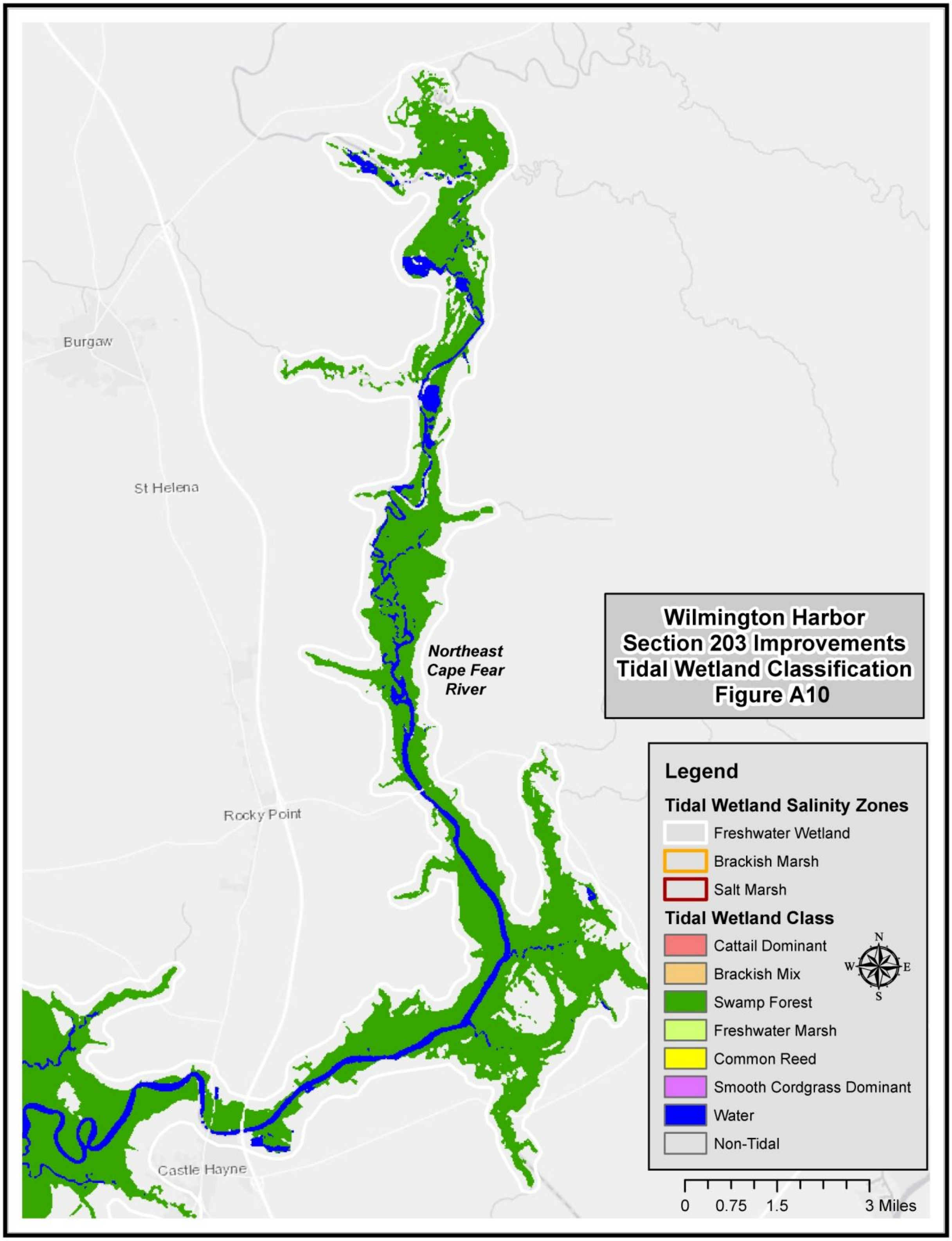
0 1.5 3 6 Miles
N
W
E
S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Section 203 Improvements
Tidal Wetland Classification
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Burgaw
St Helena
Rocky Point
Castle Hayne
Northeast Cape Fear River
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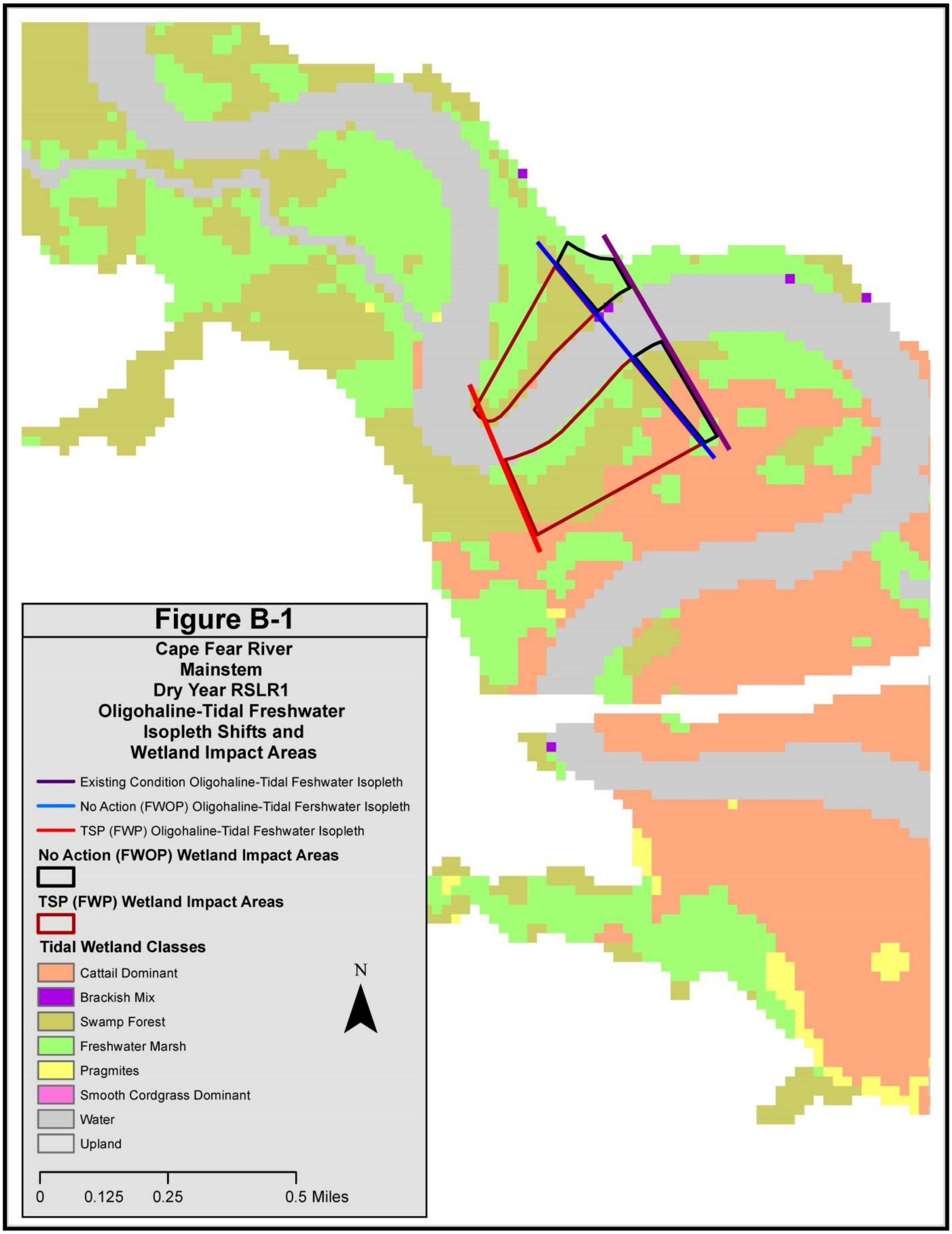
Brackish Marsh
Salt Marsh
Tidal Wetland Class
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Common Reed
Smooth Cordgrass Dominant
Water
Non-Tidal
N
S
E
W
0
0.75
1.5
3 Miles

APPENDIX B

PROJECTED SALINTY ISOPLETH SHIFTS

AND WETLAND IMPACT AREAS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Cape Fear River
Mainstem
Dry Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and
Wetland Impact Areas
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No Action (FWOP) Oligohaline-Tidal Fershwater Isopleth
TSP (FWP) Oligohaline-Tidal Feshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.125
0.25
0.5 Miles

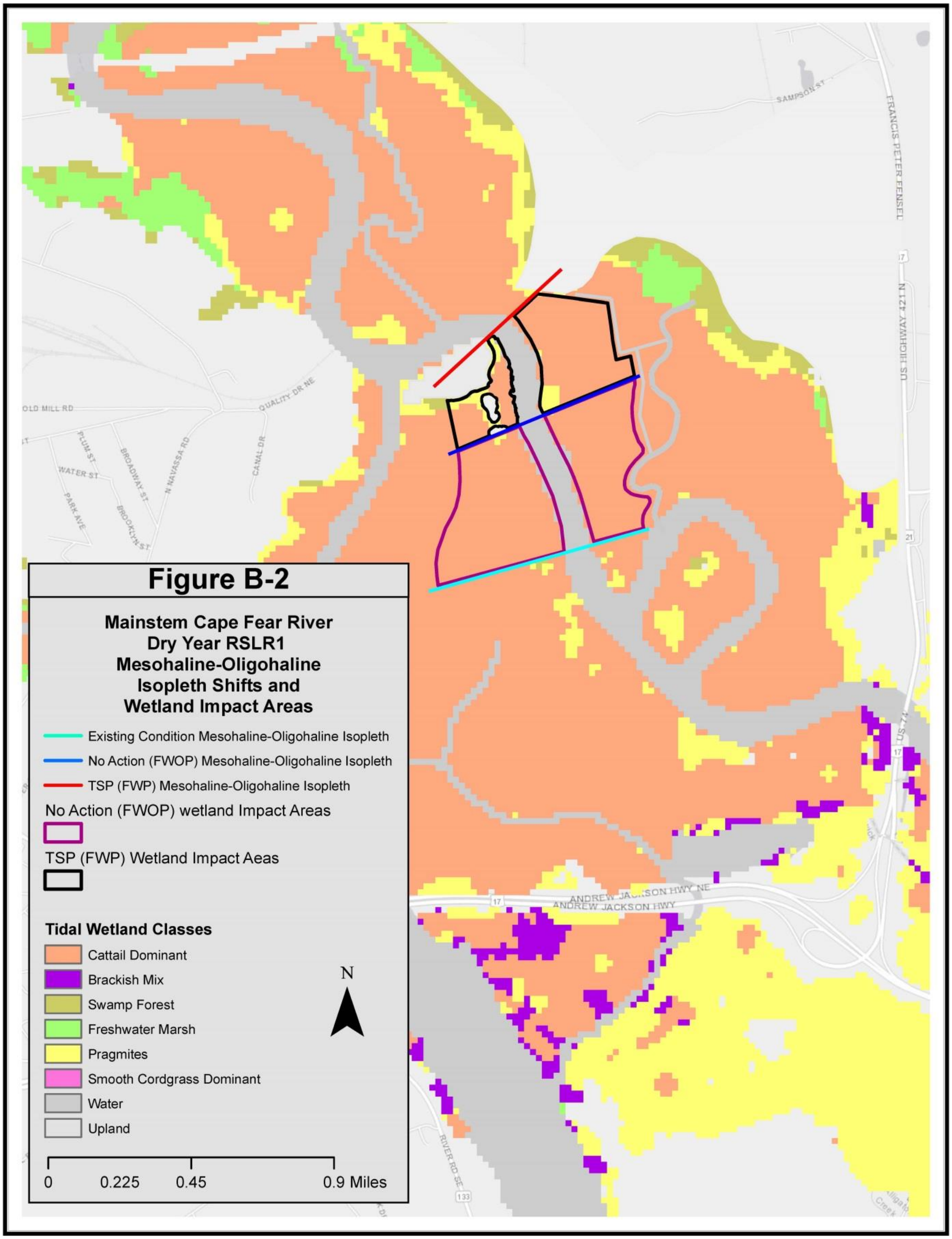
Figure B-2
Mainstem Cape Fear River
Dry Year RSLR1
Mesohaline-Oligohaline
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Mesohaline-Oligohaline Isopleth
No Action (FWOP) Mesohaline-Oligohaline Isopleth
TSP (FWP) Mesohaline-Oligohaline Isopleth
No Action (FWOP) wetland Impact Areas
TSP (FWP) Wetland Impact Aeas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.225
0.45
0.9 Miles
ANDREW JACKSON HWY
FRANCIS PETER FENSEL
US HIGHWAY 421 N
OLD MILL RD
QUALITY DR NE
SAMPSON ST
RIVER RD SE

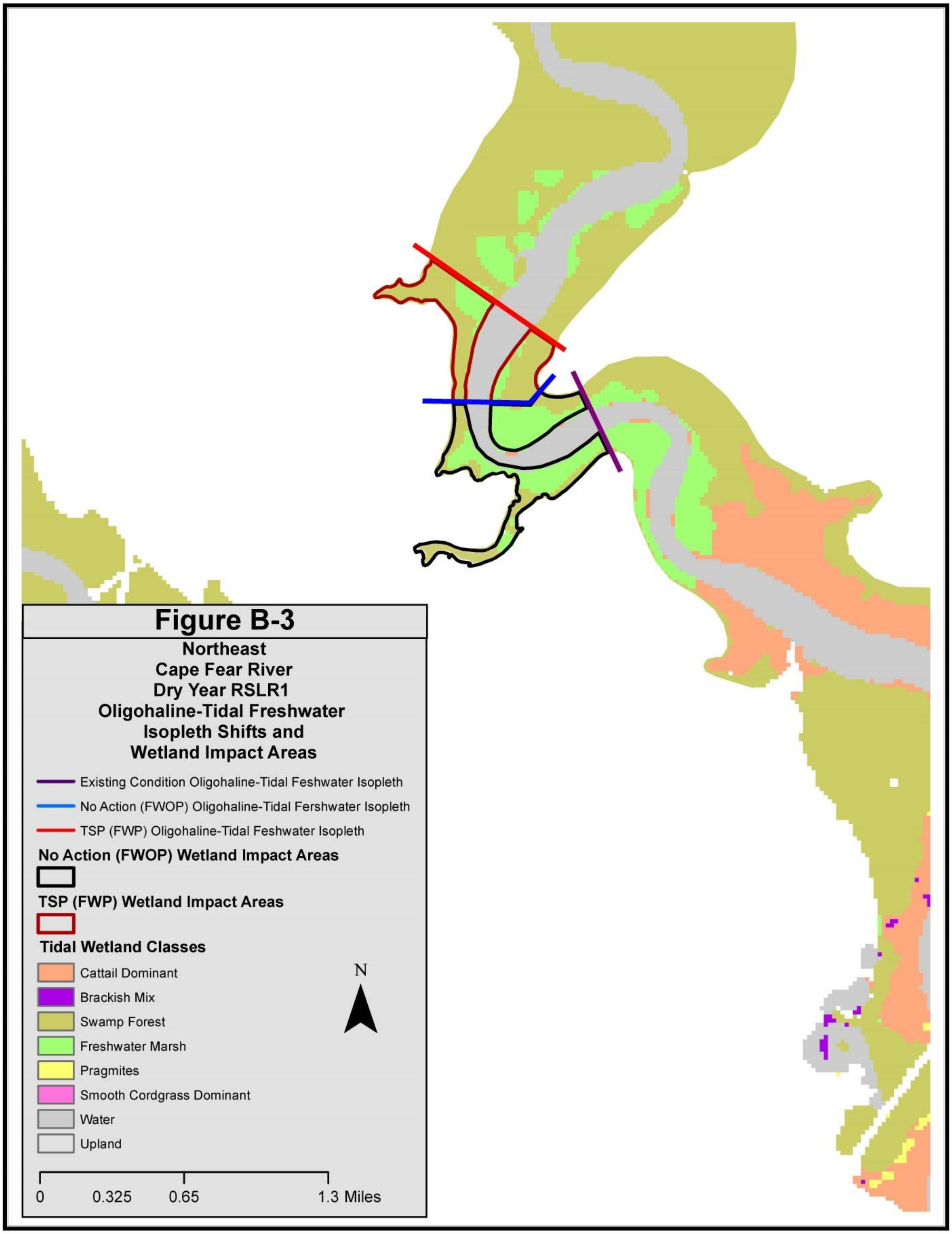
Figure B-3
Northeast
Cape Fear River
Dry Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Oligohaline-Tidal Feshwater Isopleth
No Action (FWOP) Oligohaline-Tidal Fershwater Isopleth
TSP (FWP) Oligohaline-Tidal Feshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.325
0.65
1.3 Miles

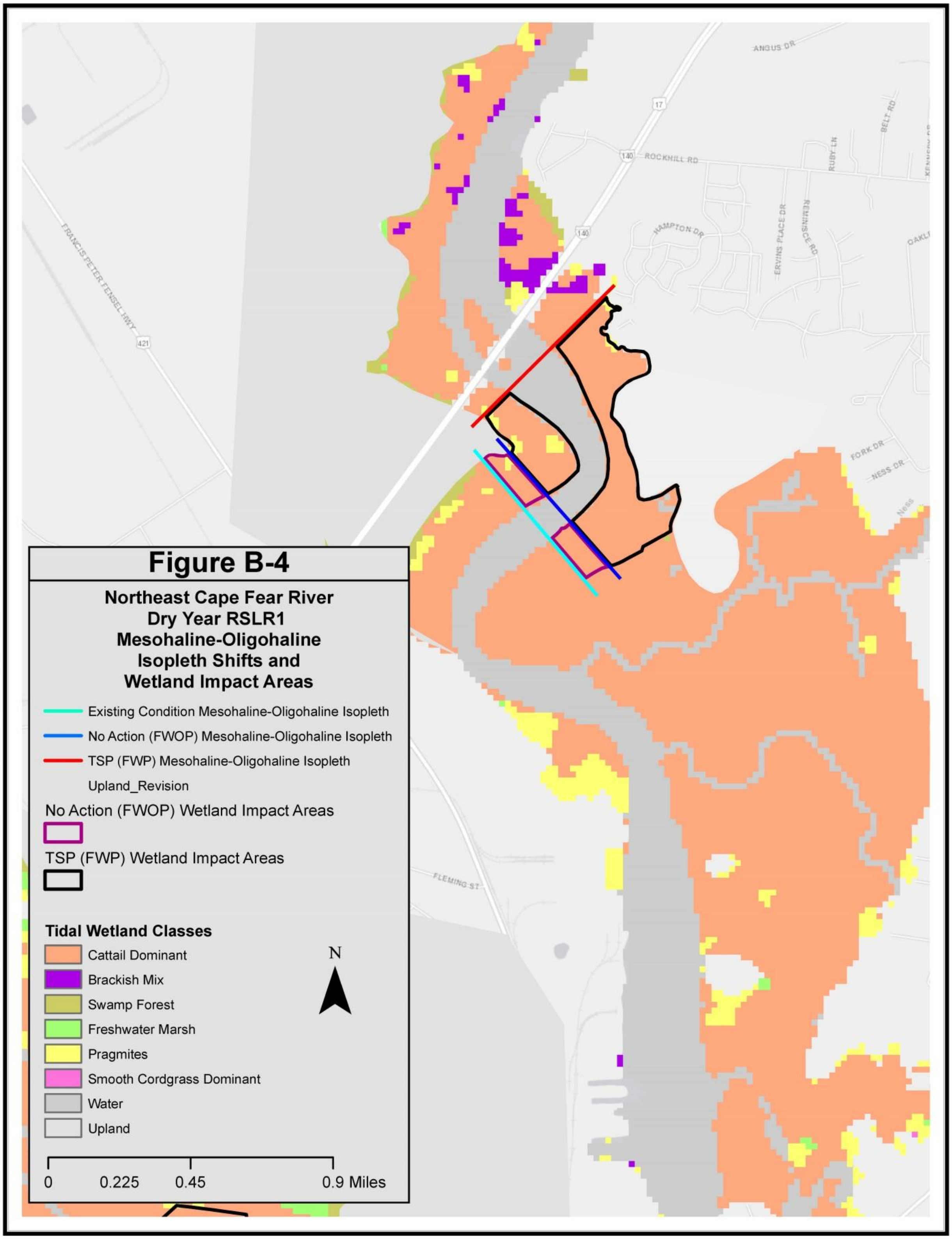
Figure B-4
Northeast Cape Fear River
Dry Year RSLR1
Mesohaline-Oligohaline
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Mesohaline-Oligohaline Isopleth
No Action (FWOP) Mesohaline-Oligohaline Isopleth
TSP (FWP) Mesohaline-Oligohaline Isopleth
Upland_Revision
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.225
0.45
0.9 Miles
ROCKHILL RD
HAMPTON DR
FRANCIS PETER FENSEL HWY
FLEMING ST
FORK DR
NESS DR
ANGUS DR

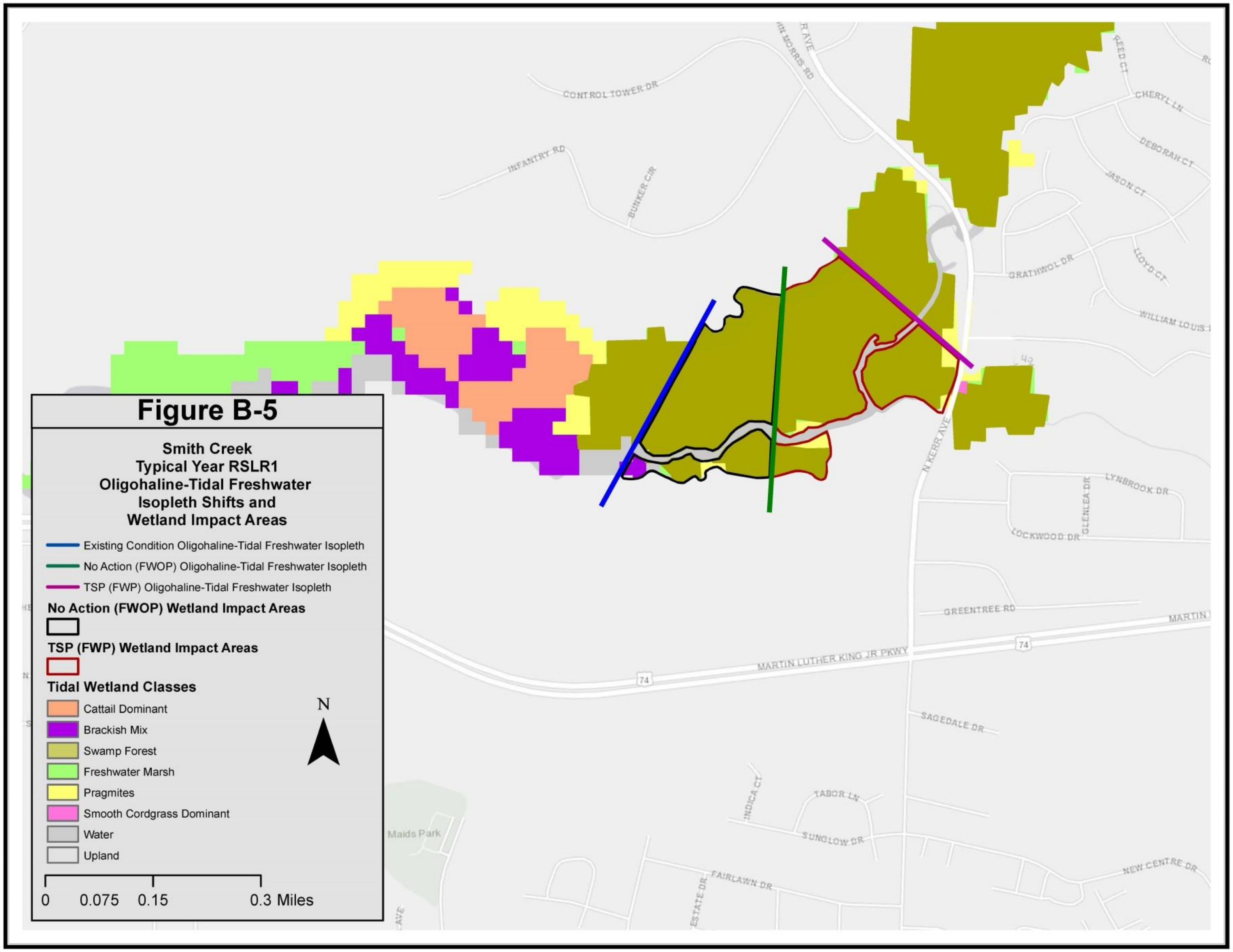
Figure B-5
Smith Creek
Typical Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Oligohaline-Tidal Freshwater Isopleth
TSP (FWP) Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.075
0.15
0.3 Miles
CONTROL TOWER DR
INFANTRY RD
BUNKER CIR
CHERYL LN
DEBORAH CT
JASON CT
GRATHWOL DR
LLOYD CT
WILLIAM LOUIS
N KERR AVE
LYNBROOK DR
GLENLEA DR
LOCKWOOD DR
GREENTREE RD
MARTIN LUTHER KING JR PKWY
74
SAGEDALE DR
INDICA CT
TABOR LN
SUNGLOW DR
FAIRLAWN DR
ESTATE DR
NEW CENTRE DR
Maids Park

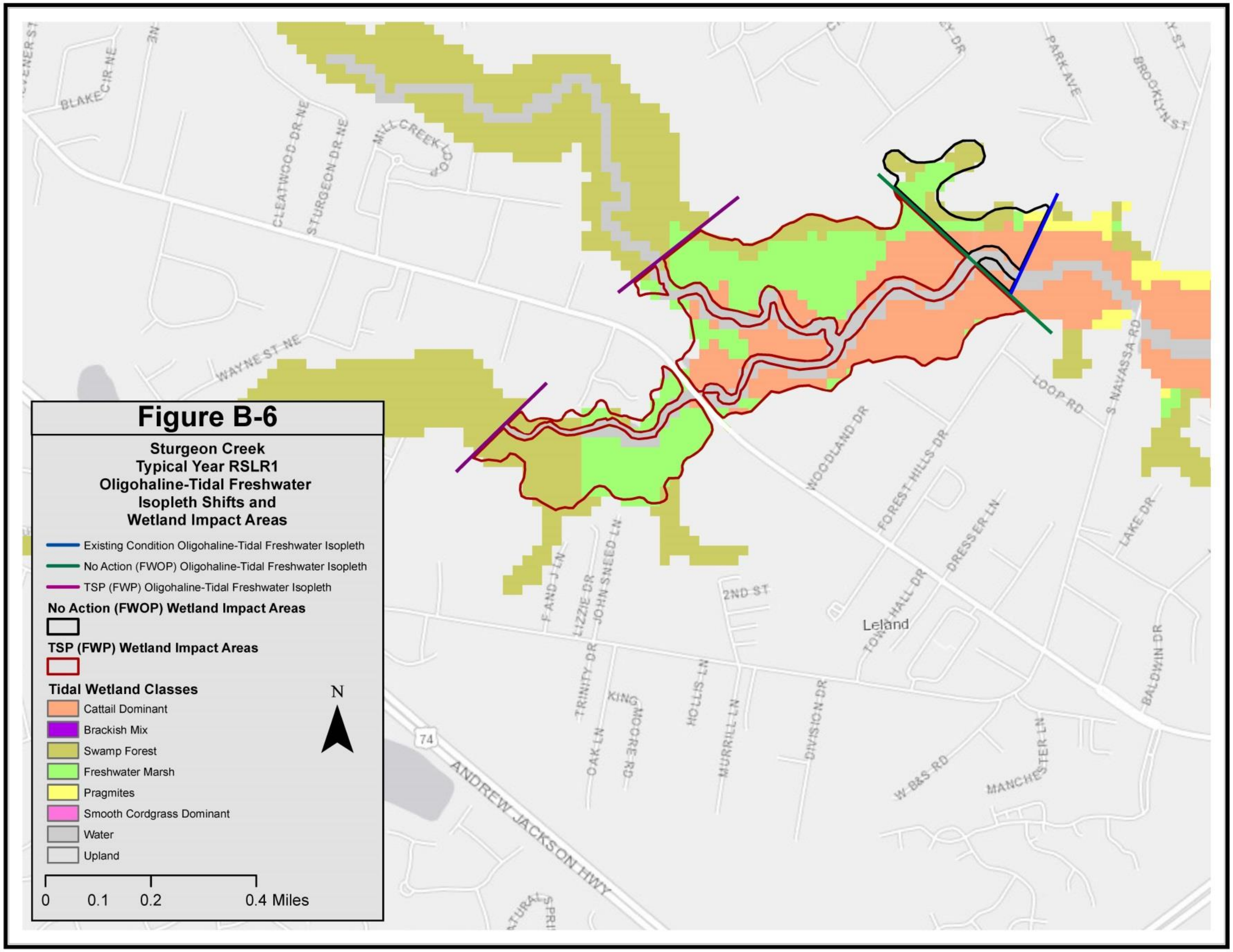
Figure B-6
Sturgeon Creek
Typical Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Oligohaline-Tidal Freshwater Isopleth
TSP (FWP) Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.1
0.2
0.4 Miles
Leland
ANDREW JACKSON HWY
WAYNE ST NE
BLAKE CIR NE
CLEATWOOD DR NE
STURGEON DR NE
MILL CREEK LOOP
PARK AVE
BROOKLYN ST
LOOP RD
S NAVASSA RD
WOODLAND DR
FOREST HILLS DR
DRESSER LN
LAKE DR
2ND ST
TOWN HALL DR
BALDWIN DR
TRINITY DR
LIZZIE DR
JOHN SNEED LN
KING
MOORE RD
OAK LN
HOLLIS LN
MURRILL LN
DIVISION DR
W B&S RD
MANCHESTER LN
74

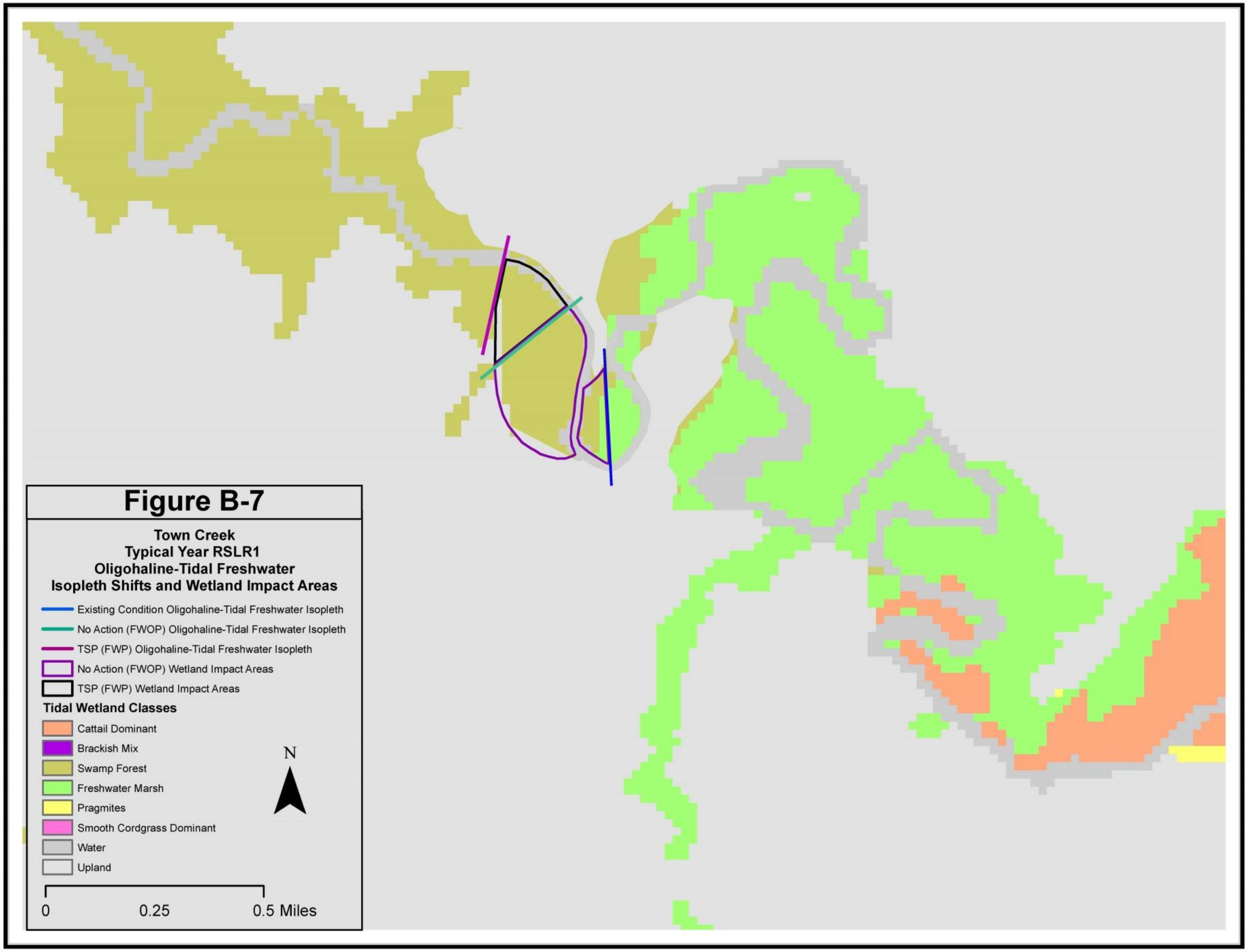
Figure B-7
Town Creek
Typical Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and Wetland Impact Areas
Existing Condition Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Oligohaline-Tidal Freshwater Isopleth
TSP (FWP) Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.25
0.5 Miles

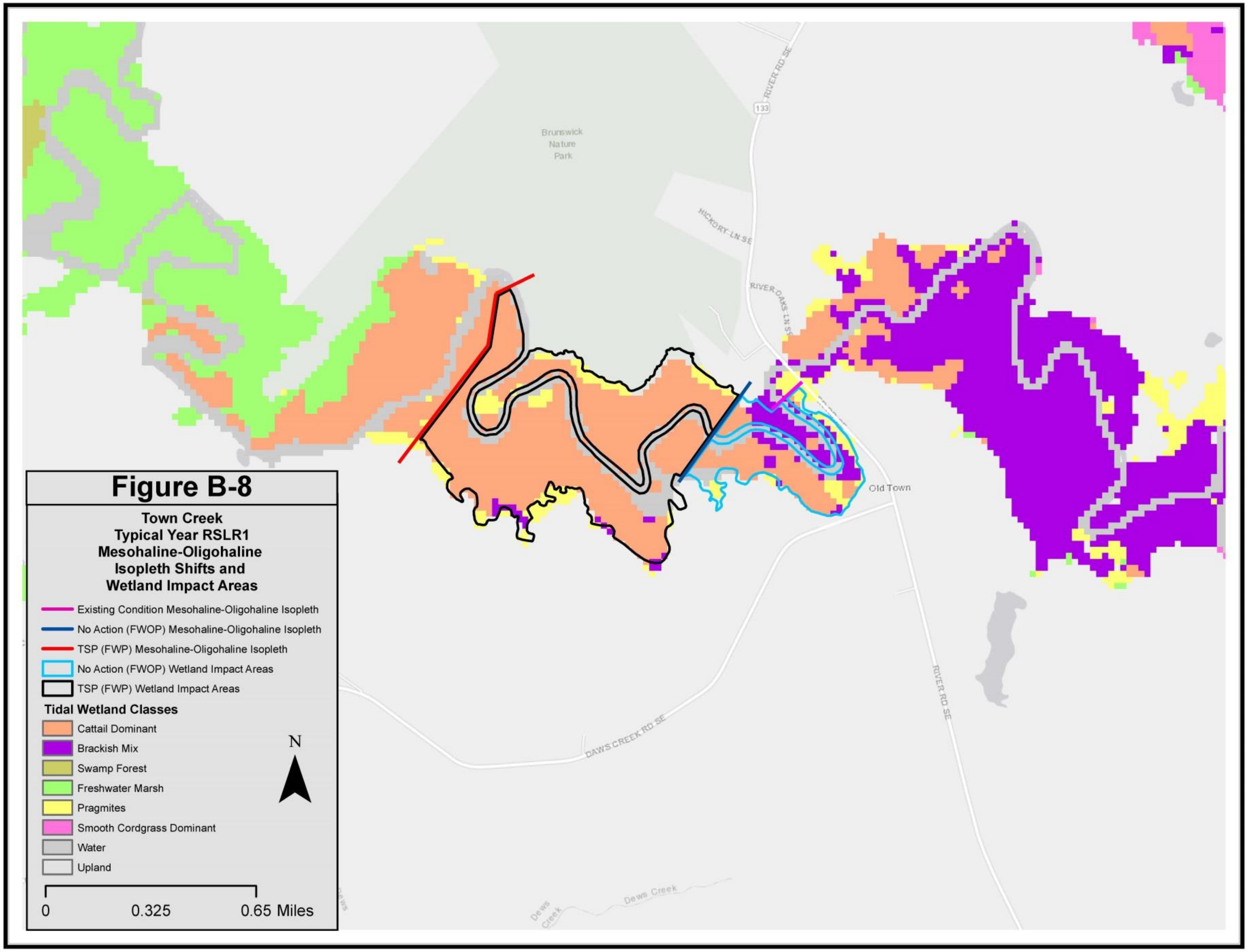
Figure B-8
Town Creek
Typical Year RSLR1
Mesohaline-Oligohaline
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Mesohaline-Oligohaline Isopleth
No Action (FWOP) Mesohaline-Oligohaline Isopleth
TSP (FWP) Mesohaline-Oligohaline Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0
0.325
0.65 Miles
Brunswick
Nature
Park
RIVER RD SE
133
HICKORY LN SE
RIVER OAKS LN SE
Old Town
DAWS CREEK RD SE
Daws Creek

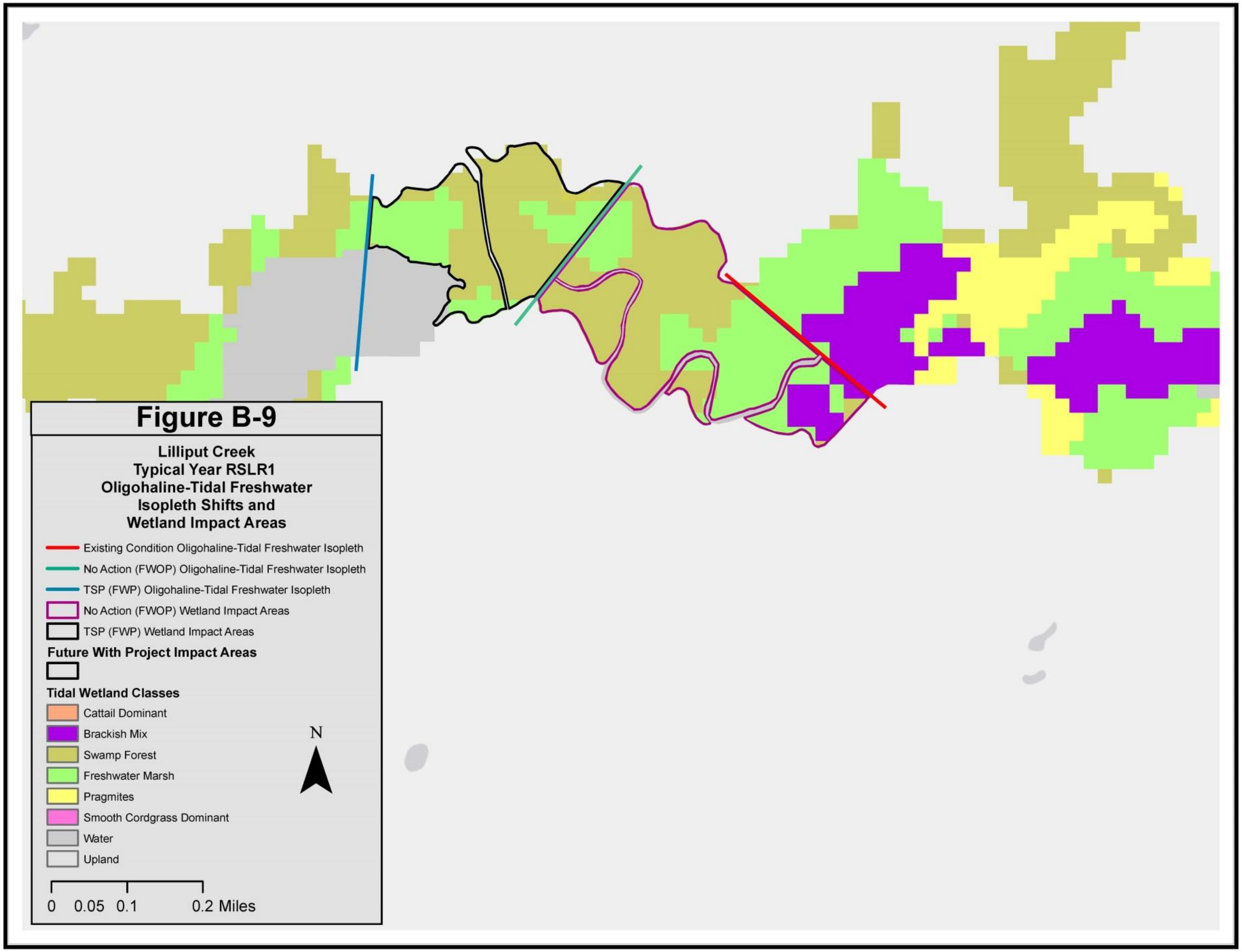
Figure B-9
Lilliput Creek
Typical Year RSLR1
Oligohaline-Tidal Freshwater
Isopleth Shifts and
Wetland Impact Areas
Existing Condition Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Oligohaline-Tidal Freshwater Isopleth
TSP (FWP) Oligohaline-Tidal Freshwater Isopleth
No Action (FWOP) Wetland Impact Areas
TSP (FWP) Wetland Impact Areas
Future With Project Impact Areas
Tidal Wetland Classes
Cattail Dominant
Brackish Mix
Swamp Forest
Freshwater Marsh
Pragmites
Smooth Cordgrass Dominant
Water
Upland
N
0 0.05 0.1 0.2 Miles